Assessing effects on biodiversity from wood pellet production in the Southeastern United States

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Applying an approach to assess effects of forest management practices on species of concern identifies mitigation activities that can reduce or avoid impacts of bioenergy pellet production on gopher tortoise (Gopherus polyphemus).

Figure 1: Bottomland forest in the Southeastern United States.

There is great concern about bioenergy wood pellet production effects on forest biodiversity in the southeastern United States (SE US). This article reviews the land-use history in the SE US, sets forth biodiversity concerns, gives a summary of pellet production activities in the SE US, and presents an approach for determining and reducing effects of forest management activities on biodiversity. An example of pellet production effects on gopher tortoise (Gopherus polyphemus) is provided.

History of Land Use in the SE US

The SE US has a long history of human activities that affected the natural landscape. For tens of thousands of years, more than two dozen native American groups actively managed the land for agriculture to grow crops such as maize (Zea mays subsp. mays), beans (Phaseolus spp.), and squash (Cucurbita spp.) and supplemented their diet with hunting, fishing, and foraging. Controlled burns were used to prepare farm plots, eliminate weeds, and manage wildlife habitat. As a result of occasional, managed fires, the SE US landscape consisted of a mosaic of grasslands and forests.

The arrival of European colonists greatly altered this intensively managed SE US landscape. As a result of rampant spread of smallpox and other diseases, many native people died, disrupting active management of the landscape. Furthermore, indigenous burning practices were suppressed by many of the colonists. Even so, the colonists often used controlled burns to clear their land or reduce the threat of wildfire, which resulted in fire patterns and ecological effects that were very different than those created by indigenous people. Two hundred years of land clearing, extensive forest conversion, and row crop cultivation resulted in high soil erosion rates. Fire suppression became official US federal policy by the early 20th century. Fire-dependent, native longleaf pine (Pinus palustris) forests that once covered large areas of the SE US were reduced to 3% of their original area as a result of settlement and fire suppression. Over the past 200 years, most bottomland forests have been converted to other land uses or managed for wood products. Even so, the bottomland forests seem to be maturing, as evidenced by the increase in area of large-diameter sized stands between 2002 and 2014 while that of medium- and small-diameter stands decreased.

> **Many forests in the SE US were cleared or degraded by human activity, but there is more forest cover on the landscape now than one hundred years ago.**

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During the 1900s much commercial agriculture moved from the SE US to the midwestern states, which have more suitable soils and climate for row crops. As a result, although many forests in the SE US were cleared or degraded by human activity, there is more forest cover on the SE US landscape now than there was one hundred years ago.

Biodiversity Concerns

Today the SE US supports a high diversity of plant and animal species, many of which occur nowhere else. An estimated 11% of the species in the region are currently at risk with the greatest threat to biodiversity in forest ecosystems being the spread of urban and suburban areas.

Most areas of special diversity including old-growth forests are under private or government protection. For example, some locations that support species listed as endangered or threatened by the Endangered Species Act are managed using a Safe Harbor Agreement, under which private or other non-federal property owners specify actions they employ to contribute to the recovery of those species Bottomland hardwood forests are of particular concern in the SE US, for they provide habitat for a variety of rare species. Major pressures on bottomland forest ecosystems today are not pellet production but rather conversion to urban areas; alterations in flooding patterns as a result of dikes, dredging, oil and gas extraction, and salt water intrusion; and intense grazing by high populations of white-tailed deer (Odocoileus virginianus).

Pellet Production Activities in the SE US

Commercial production of wood pellets in the SE US began in 2008 in response to European Union (EU) renewable energy targets to cut greenhouse gas emissions, the demise of pulp and paper operations in some SE US locations that resulted in stranded wood supplies, and the availability of residues from lumber and pulp mills in other places. Pellet production has helped to maintain some rural employment in the forest products industry. Approximately half of wood pellets in the SE US are produced using sawmill residues, which has no direct effect on forest habitat or biodiversity. Oceanic transport of the pellets is facilitated by carbon- and cost-efficient maritime shipping, direct shipping lanes, and ports located near productive timberlands with established forest product supply chains. Up to 2019 removals for pellet production constituted less than 5% of the total timberland removals per year in the SE US.

Studies that focused on the effects on biodiversity of pellet production in the SE US have found that local context and particular species must be considered when assessing effects. Management practices that are harmful for some species (e.g., thinning) are beneficial to other species. Responses of species to harvesting for wood-based pellets varies depending on the species' life-history characteristics, forest management practices, forest types, landscape conditions, and scale of analysis. Therefore, we developed an approach to assessing impacts and recommending management practices that considers these conditions.

An Approach for Determining Effects of Land Management Activities on Biodiversity

Our approach addresses effects of management actions on life-history conditions of species of concern within a given landscape. The approach entails 5 steps (Figure 2). (1) A species of concern is identified that is at risk of impact by specific management activities. (2) Key life-history conditions are determined for the species of concern. (3)

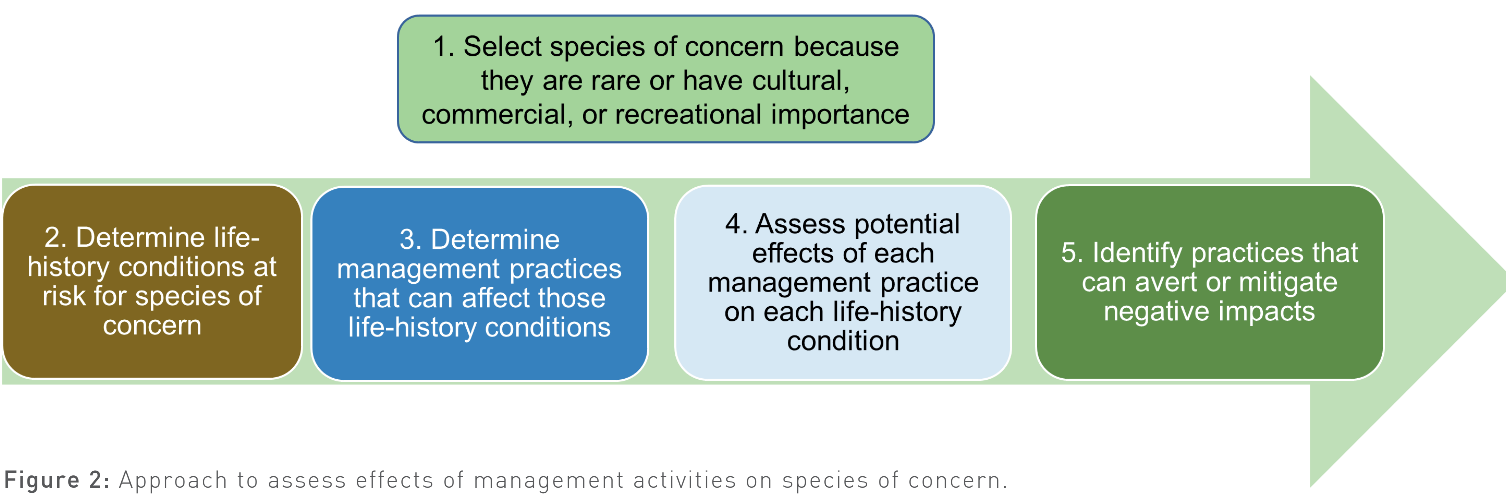

Figure 2: Approach to assess effects of management activities on species of concern.

Management practices associated with the activities under investigation are identified. (4) Potential effects of each management practice on each life-history condition for the focus species are assessed. And (5) mitigation practices are identified that can avert or minimize negative impacts on the species of concern. These 5 steps are accomplished by consulting the literature and experts in each topic area. This approach identifies life history conditions at risk, focuses the assessment, and identifies management practices that should be followed to reduce impacts on the species at risk.

Example Application of the Approach to Examine Effects of Pellet Production on Gopher Tortoise

Gopher tortoise (Gopherus Polyphemus) was selected as an example species for illustrating the approach. This large tortoise is a keystone species in the SE US, for it digs deep burrows upon which more than 360 other species depend (Figure 3). Gopher tortoise are of conservation concern in six SE US states that produce wood pellets for bioenergy and could potentially be affected by biomass harvesting for pellets throughout its range (Figure 4), which includes both naturally regenerating and planted pine forests. Tortoise prefer pine forest systems with well-drained sandy soils, herbaceous cover, and open canopy. Gopher tortoises have declined by about 80% in the past 100 years throughout the SE US due to loss of habitat, increased predation, and disease.

Five key life-history conditions of gopher tortoise that are affected by pellet production are burrowing, foraging, thermoregulation, reproduction, and survival. Conditions associated with dispersal, interactions (e.g., competition), and food consumption are not greatly affected by pellet production.

Figures 3a & 3b: Gopher tortoise grow up to 15 pounds (7 kg), and it's shovel-like front legs are specialized for digging. The species is endemic to the southeastern United States and prefers open pine forests. Historically understory of these forest was reduced by sporadic low-intensity burning.

Mitigation practices that can prevent or minimize negative impacts of pellet production on gopher tortoise include thinning, prescribed fire, and practices that deter vehicle activity within 4 meters of each burrow.

Sandy soils allow tortoise to dig deep, tunnel-like burrows, which maintain constant temperature and humidity conditions in spite of extreme weather and fire events. These burrows shelter not only the tortoises but also more than 360 other species, including several of conservation concern. These herbivorous tortoises graze on a variety of leaves and seeds as they forage on understory plants surrounding their burrows and beyond. On cool sunny days, these reptiles thermoregulate by basking in open areas. Reproduction is characterized by breeding from April to June and 100 days of egg incubation, but the eggs and young animals are often eaten by various predators. Survival is greater after the tortoise's shell hardens (at about 6-7 years). Canopy closure can entice the tortoises to relocate to more open edge habitats, such as open roadsides where injury from vehicles is more likely. Outbreaks of upper-respiratory-tract disease (URTD) are induced by physiological stress brought on by disruption of normal behavior patterns and habitat degradation. After maturity and without disease or injury, gopher tortoises may live for more than 60 years.

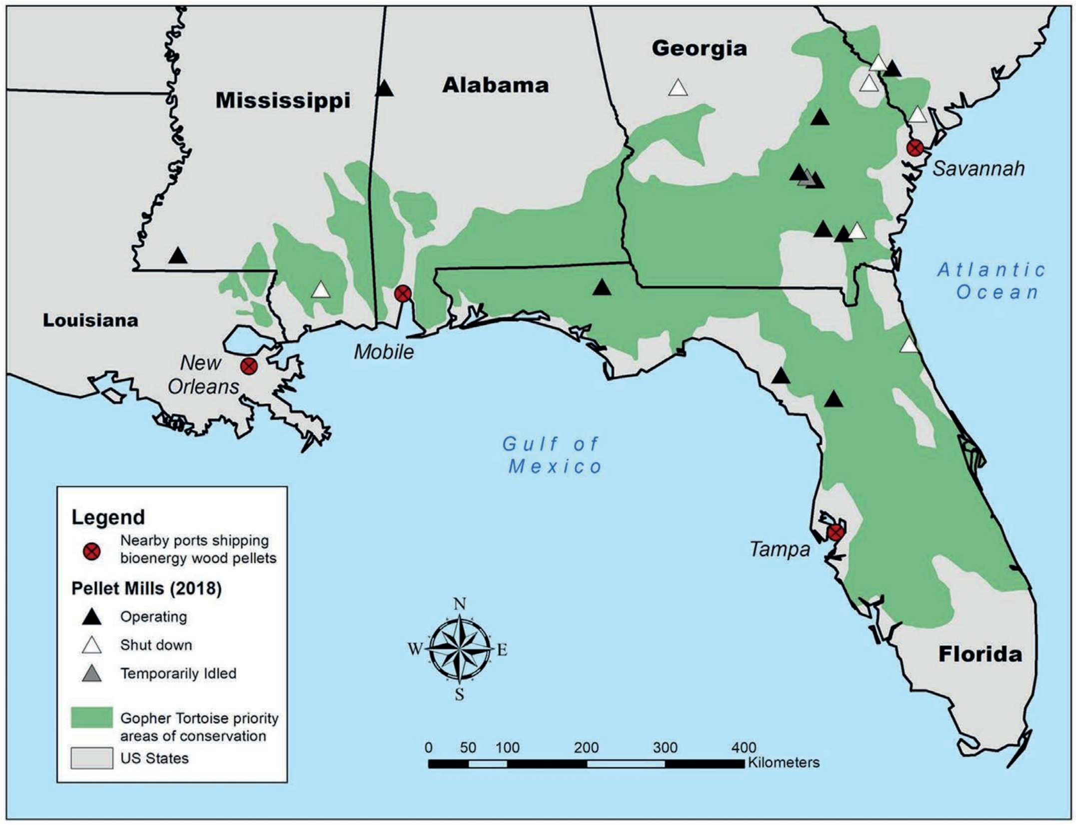

Figure 4: Gopher tortoise priority areas of conservation (shown in green) extend across six SE US states and overlap with timberland areas supplying export wood pellet mills. (Data sources: Databasin.org, Forisk, and the United States International Trade Commission).

Forest management practices associated with pellet production involve three practices that can impact gopher tortoise: logging, thinning, and dead wood removal. Logging practices common to timber and pulp and paper are also used for wood pellets and occur via uneven-aged management, two-aged management, and even-aged management through clearcuts. Thinning practices remove mid-story hardwood trees and small diameter or defective stem wood of low quality that is unsuitable for lumber or pulpwood. By reducing tree density, thinning can enhance forest health, biodiversity conservation, or fuel treatments. Removal of dead wood includes the branches and treetops often left in the forest during harvest to become downed woody debris that are typically burned or piled up and left to decompose.

Less than 5% per year of total SE US timberland removals up to 2019 have been used for bioenergy pellet production.

Intersecting the three types of forest removals for wood pellet production with the five key life-history conditions of gopher tortoise yields 15 interactions that constitute potential effects on the tortoise (Figure 5). These interactions are listed below as organized by each pellet production practice.

A. **Logging effects**

1. Burrowing can be negatively affected by burrow collapse and damage due to heavy machinery and abandonment due to loss of favorable habitat. Burrowing can be positively affected by an increase in open canopy sites suitable for burrowing and basking.
2. Foraging can decline due to loss of herbaceous vegetation as a result of equipment traffic and site preparation for logging operations.
3. Thermoregulation can be impeded because of habitat fragmentation, habitat islands, and reduced home range. Thermoregulation can be enhanced by creation of openings in the canopy.
4. Reproduction can be impacted by low quality forage that can decrease clutch sizes and/or egg quality or by reduced mating success associated with low density of burrows within the home range of a tortoise.

Forest practices that open the canopy and maintain habitat corridors may also benefit gopher tortoise.

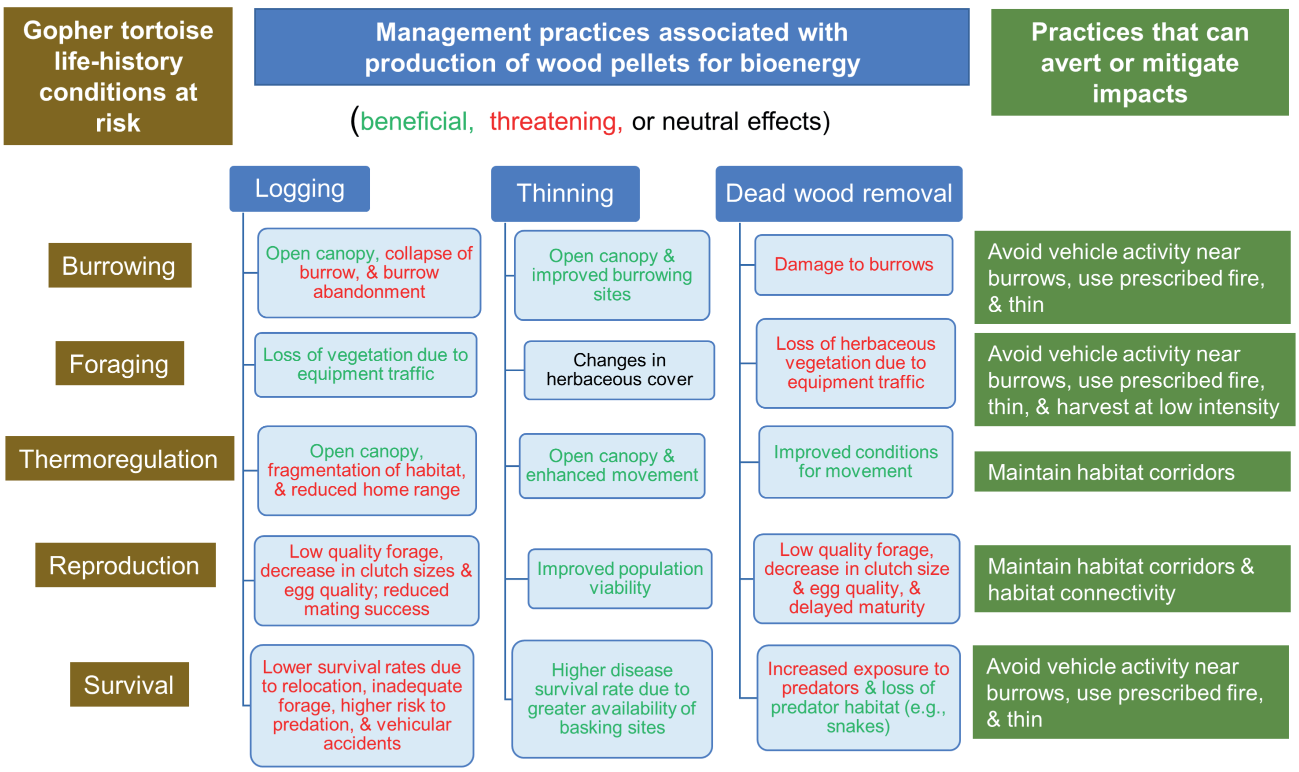

Figure 5: Applying the approach to gopher tortoise and production of wood pellets for bioenergy in the SE US.

5. Survival can be impaired as a result of inadequate forage and higher risk to predation and vehicles accidents or from relocated tortoises contracting URTD.

B. Thinning effects

1. Burrowing benefits from open canopy and better conditions for translocation.
2. Foraging is enhanced by changes in herbaceous cover due to more open canopy, but equipment traffic can induce vegetation loss.
3. Thermoregulation benefits from a more open canopy for movement and basking.
4. Reproduction is enhanced by improved chances of finding a mate under a more open canopy with habitat corridors.
5. Survival is enhanced, as thinning induces higher survival rates from URTD associated with more basking sites being available.

C. Dead wood removal effects

1. Burrowing is compromised, for burrows can collapse when dead trees are removed and may be damaged by heavy vehicle movement and vibrations.
2. Foraging is impaired, as equipment traffic causes loss of herbaceous vegetation.
3. Thermoregulation benefits from improved conditions for movement.
4. Reproduction is impacted with delayed maturity, decreased clutch sizes and/or egg quality associated with low quality forage.
5. Survival is diminished due to equipment collisions with tortoises and increased exposure to predators through loss of cover. But survival benefits from loss of habitat for predators (e.g., snakes).

Understanding these interactions leads to the identification of mitigation practices that can prevent or minimize negative impacts of pellet production on gopher tortoise. Tortoise burrowing, foraging, and survival can benefit from thinning, prescribed fire, and practices that deter vehicle activity within 4 meters of each burrow. Foraging can be enhanced by low-intensity harvesting. Thermoregulation can benefit from practices that open the canopy and maintain habitat corridors. Reproduction can be improved by harvesting practices that maintain habitat corridors and increase habitat connectivity.

This gopher tortoise example demonstrates that forest management practices for SE US pellet production management can be adjusted to protect habitat and life-history conditions for an at-risk species. Application of the approach reveals gaps in information, such as the optimal quantity of dead wood that should be left on the forest floor to protect gopher tortoise from predators. Protecting this keystone species can also benefit dozens of other species that depend on gopher tortoise and their burrows.

Conclusion

While many are concerned that increased pellet production may negatively impact biodiversity, SE US forest landscapes have experienced centuries of intensive management, and the major current pressure on them is urban and suburban expansion. Furthermore, timberland removals for pellet production currently constitute a very small proportion of the overall wood market. Even so, it is important to understand potential impacts on biodiversity and explore opportunities to minimize negative impacts. The example of intersecting key life-history conditions of the gopher tortoise with key forest management practices for pellet production shows that well designed management practices can minimize impacts on gopher tortoise and even enhance burrowing, foraging, thermoregulation, reproduction, and survival.

This straightforward approach can be applied to other species at risk from wood pellet production for bioenergy and other types of ecosystems. The approach is suitable for (1) ecosystems that support a species of special concern because it is rare, a keystone species, or has cultural, commercial, or recreational importance; (2) management activities that directly relate to life-history characteristics of that species; and (3) systems for which there is information available to identify mitigation practices that can avert or minimize negative effects on the species of concern.

NOTE: The article is based upon the paper by Parish et al. (2020), which should be consulted for further detail.

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SUGGESTED RESOURCES FOR FURTHER INFORMATION

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