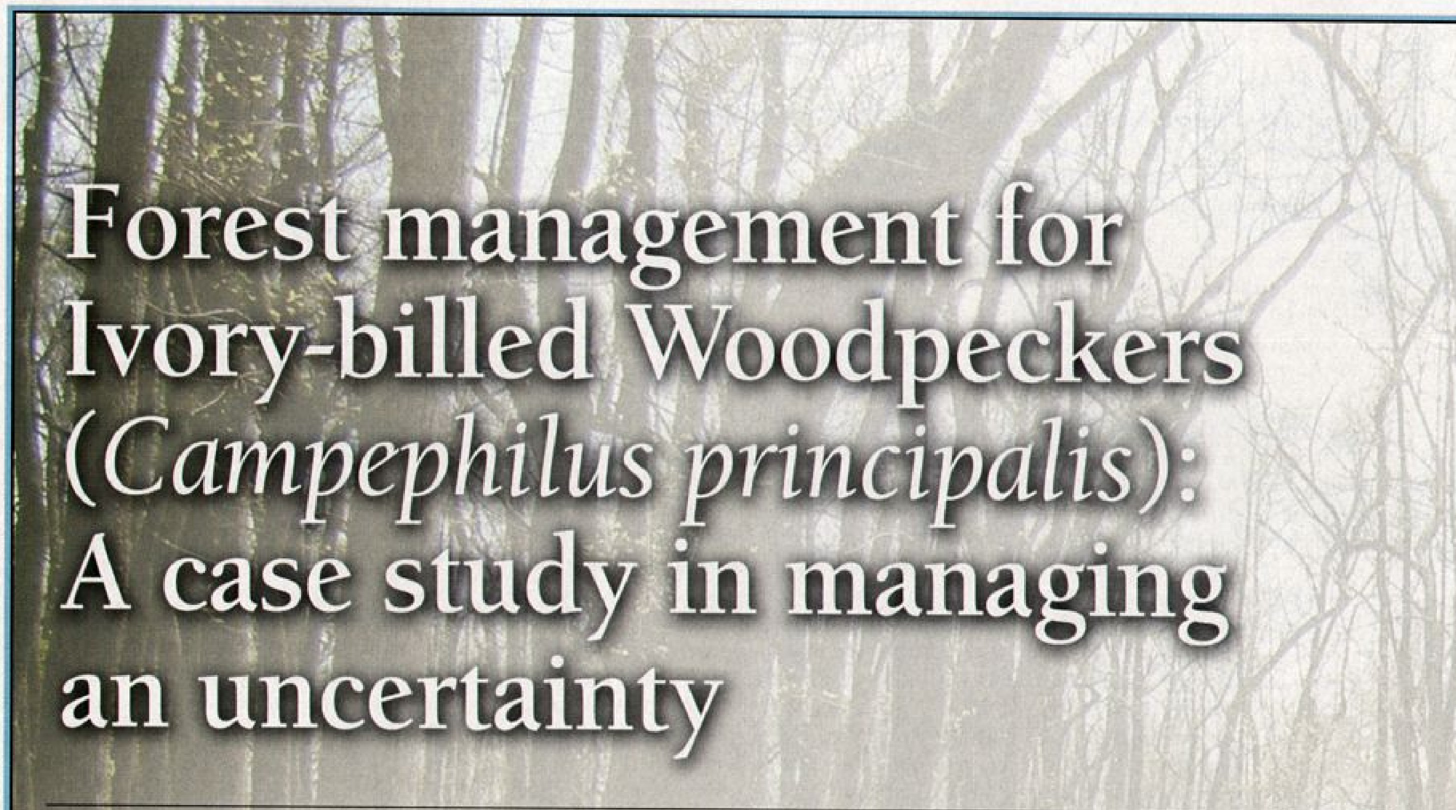

Forest management for Ivory-billed Woodpeckers (*Campephilus principalis*): A case study in managing an uncertainty

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ABSTRACT

The near extinction of Ivory-billed Woodpecker (*Campephilus principalis*) has been attributed to the elimination of old-growth forests in the Southeast. Notwithstanding, forest management regimes could be adapted to approximate the natural disturbances with which this species is apparently associated. Uneven-aged management could ensure enough post-harvest structure to support Ivory-billeds and allow stands to generate standing dead wood throughout a cutting cycle. Management regimes would require minimum rotation lengths and variable retention practices sufficient to generate and retain large (>60-cm dbh) stems. A model is advanced to set appropriate standing dead wood stock guidelines, accounting for dead wood stem density, stem dimensions, and stand area. Prescriptions for achieving stock objectives via artificial inputs to standing dead wood, either through selective girdling or prescribed fire, are calculated as a function of existing stocks, observed natural mortality, and decay rate of dead wood. Although focused on a species nearly extinct, these guidelines offer an approach to deriving practical management applications from incomplete information, a situation with which land managers continue to be confronted.

Background

Ivory-billed Woodpecker (*Campephilus principalis*) has apparently been on the verge of extinction for over a century. Not since 1944, the last year in which an individual was reported from the Singer Tract in Louisiana, had this species been documented in any area of its former North American range—until 2004 (Fitzpatrick et al. 2005). Understandably, relatively few efforts have been made to formulate conservation practices from the existing, albeit limited, literature on the species. Most research efforts have been focused on searching for surviving individuals, with the implicit understanding that no concerted management actions would be taken without definitive proof of the species' existence.

The limited nature of existing knowledge, from which prescriptions might have been developed, has further stymied the impetus to carry out pro-active management on behalf of this species. The conservation of a potentially wide-ranging species such as this one calls for considerations beyond protected areas. Adaptive silviculture is required, such that forest management can be made to contribute to, or at least not to hinder, broader conservation plans, similar to what has been advanced for the management of Red-cockaded Woodpecker (*Picoides borealis*) (e.g., Seagle et al. 1987, Hedrick et al. 1998). One fundamental difference between management of Red-cockadeds and Ivory-billeds is that numerous extant populations of Red-cockaded Woodpeckers have been accessible for repeated and detailed studies, whereas information on Ivory-billeds must be gleaned from a single quantitative study (Tanner 1942) and scattered natural history narratives.

This paper was originally written as a hypothetical case study in managing forest dead wood stocks with uncertain objectives—uncertain, that is, until the announcement of the species' recent rediscovery in eastern Arkansas (Fitzpatrick et al. 2005). Although recovery of Ivory-billed Woodpecker is still far from certain, this paper offers one approach to deriving practical management applications from incomplete information, a situation with which land managers continue to be confronted in the case of many species. Despite the fact that explicit causal relationships between the birds and their habitat may not be established, circumstantial evidence can be used to guide initial characterizations of their habitat "preferences." Taking action need not wait until the presence of Ivory-billeds can be confirmed beyond reasonable doubt. Informed management interventions could in fact serve to facilitate their discovery—by drawing individuals to areas where they are likely to be detected, as well as potentially benefiting other species at the same time.

Ivory-billeds and Timber Harvest

The disappearance of Ivory-billed Woodpecker signaled a fundamental change in forest structure, dynamics, or composition at some scale over the period of its decline. In North America, the disappearance of the Ivory-billed coincided with the advance of harvests of old-growth forests in the Southeast. Tanner (1942) reported the disappearance of the Ivory-billed over the period 1885 to 1915, which correlates closely with the peak period of activity of the southern logging industry, between 1890 and 1930 (Williams 1992). Logging, with its associated infrastructure, may have further facilitated access by collectors, and indeed the bulk of Ivory-billed skins were collected during this same time period (Jackson 2004). Even so, in areas where the forest was not converted to agriculture and the species was not subject to collecting pressure, some post-logging conditions may have been adequate for Ivory-billeds. For example, Herbert Stoddard noted a pair of Ivory-billeds collected in Florida in 1924 in a stand "heavily cut over" 20 years before (Dennis 1979).

Observations from Cuba offer insight into the use of young regenerating forests by the species as well. Ivory-billeds occupied the Sierra de Moa region more or less continuously from the 1940s through the 1980s, following and during extensive logging. In the Moa area, some 40,000 hectares were logged between 1938 and 1946 (Lamb 1957), and extensive logging took place again between 1956 and 1959 (Short 1985). Ivory-billeds were encountered where habitat was described as young, small-diameter stands of Cuban Pine (*Pinus cubensis*). Dennis (1948) and Short (1985) referred to seven- and 20-year-old stands. Dennis even described a pair occupying a site only two years after logging had taken place. Mean tree diameter at breast height (dbh) in these areas was estimated at around 13–15 cm (Dennis 1948, Lamb 1957). Still, given the apparent low productivity of these ultramafic sites (Smith 1954; ultramafic = soils known for inducing physiological stress in plants and consequent low productivity), size could be a misleading indicator of age. In fact, trees of this size cored by Smith in this same area in 1952 revealed ages of around 60 years. A key component of the structure of these documented stands was the scattered larger dead and cull trees remaining following logging (Dennis 1948, Short and Horne 1986). These stems provided critical opportunities for the excavation of nest and roost cavities, which were often in short supply following logging. Although these second-growth pine forests may have been sub-optimal habitat (home range sizes in the Sierra de Moa were estimated at three to four times those in the Singer Tract in Louisiana [Lamb 1957]), the Ivory-billed's tenacity in this area demonstrates its resilience to large scale disturbances such as logging and its ability to nest and feed in sub-old growth conditions, though this conclusion should be qualified with the understanding that Ivory-billeds in Cuba were likely more versatile in their habitat use than their North American counterparts due to the lack of interspecific competition with other large woodpeckers (i.e. Pileated Woodpecker (*Dryocopus pileatus*)).

The persistence of scattered large cull trees in regenerating stands could presumably offer some of the same foraging and roosting opportunities as did old growth. In the Singer Tract, an old-growth, mixed-age hardwood stand, Ivory-billeds, while foraging over a wide range of tree size classes, favored large trees relative to their abundance in the forest (Tanner 1942). Tanner found that 38% of feeding took place on trees greater than 61 cm dbh, which made up only 7% of total stems. These trees were, on average, 60 years old and older, based on study of radial increment of Delta bottomland hardwoods (Figure 1). The threshold for nesting and roosting trees was similar. Allen and Kellogg (1937) measured breast high circumferences of 7.5 and 10 feet for two cavity trees in the Singer Tract, corresponding to equivalent diameters at breast height of 73 cm and 97 cm. Estimated diameter at breast height of three cavity trees—calculated from data on diameter at cavity height in Tanner (1942)

Relict cull tree from mixed age bottomland hardwood stand, Delta National Forest, Mississippi. October 2001. ***Photograph by David Shoch.***

and assuming 1.1 cm taper heights per meter height—ranged from 51 to 56 cm (n=3). A larger dataset of cavity heights summarized by Tanner ranged from closely 7.6 to 21.3 meters (n=17), averaging around 15 m, incidentally comparing closely with the range of 9.1–18.3 m reported by Lamb (1957) for cavity heights in old growth Cuban Pines. Applying a dbh:total height relationship derived from measurements of Delta bottomland hardwoods (Figure 2), these were trees averaging approximately 54 centimeters dbh, assuming cavities were located at approximately one-half of total tree height.

Ivory-billeds and Forest Disturbance

Discrete patches of dead trees, created by disturbance events, are a defining element in the distribution of dead wood across a landscape. In the absence of sufficient endemic rates of dead wood generation, large-scale disturbances would be critical in providing feeding opportunities for Ivory-billeds, and Ivory-billeds were presumably uniquely adapted to seek them out. Although Ivory-billeds were noted for their specialized means of feeding, knocking chunks of bark off recently killed trees to expose wood-boring insects, this same reliance on newly dead trees may have dictated a transitory and opportunistic lifestyle over the life of an individual. Tanner (1942) notes: "...the Ivory-billed is well adapted to traveling long distances. It is a strong flier with a fast flight for a woodpecker ... they usually travel in pairs ... which would be important for wandering birds of few numbers in order that mates may keep together."

The abundance of shade-intolerant species such as Sweet Gum (*Liquidambar styraciflua*) in Singer Tract is an indication that the forest there initially regenerated in response to extensive disturbance. Even within the Singer Tract, which Ivory-billeds occupied continuously from at least 1934 to 1944, Ivory-billed ranges shifted in response to localized tree death events. For instance, Ivory-billeds colonized an area through which a cyclone that killed many trees had passed two years previously, and then moved out two years later (Tanner 1942). Tanner believed that Ivory-billed territories within the Singer Tract were steadily becoming less suitable as mortality rates decreased after the loss of weakened stems from the previous disturbance, a fire 14 years earlier. Annual rates of tree mortality in the Singer Tract sites at the time of Tanner's research, expressed as percent of existing stems, ranged from 1.5% to 2.4% (calculated from Tanner, 1942), which are typical of low "background" mortality rates in southeastern bottomland hardwood forests, rather than those resulting from disturbance events such as extended flooding and wind throw, which may result in annual mortality rates, again as percent of pre-existing stems, of up to 16%, and to over 50%, respectively (Conner et al. 2002).

Ivory-billeds foraged in a wide range of forest types. Tanner's (1942) chapter on habitats frequented by the Ivory-billed reads like a nearly comprehensive description of southeastern forest types, not only including bottomland hardwoods, but also cypress swamps, hammocks, bays, and pine flatwoods. Although by the time of Tanner's study, Ivory-billeds used pines to a lesser degree than hardwoods, the use of pines, which were logged before hardwoods in the Southeast, may have been historically more prevalent (Jackson 2002, 2004). Likewise, Cuban Ivory-billeds, which most recent observations link closely with pine forests, formerly occupied both tropical hardwood and pine forests (Lamb 1957). More than any particular forest type, then, Ivory-billeds seemed to be dependent instead on the conditions and events that generated an abundance of dead trees. While other species of woodpeckers continued to mine snags throughout the process of wood decay, Ivory-billeds moved on to maintain themselves at the vanguard of forest turnover. The Ivory-billed was thus a unique indicator species, occupying a niche position in the process of forest decline, a species whose abundance was more dependent on rates of tree death than on accumulating stocks of standing dead wood.

A variety of disturbances were attractive to Ivory-billeds, including beetle outbreaks, wind throw, and even logging. Outbreaks of Southern Pine Beetle (*Dendroctonus frontalis*) are often initiated in response to large-scale disturbance events such as fire or wind throw, and during epidemics spread their attacks to healthy trees, creating discrete "spots" of infestation. Herbert Stoddard observed two female Ivory-billeds feeding in beetle-killed pines in southern Georgia in the 1950s (Leon Neel, pers. comm., Greenwood Plantation, November 2002). Ivory-billeds were recorded feeding for extended periods in storm-produced blowdowns in the Singer Tract and at Wakulla Beach, Florida, and among post-harvest logging slash in the Singer Tract (Tanner 1942). Periodic extended

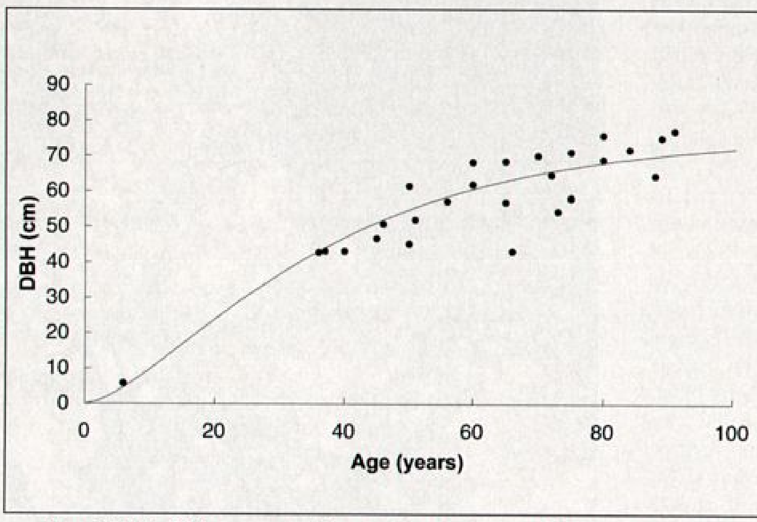

Figure 1. Relationship between age and diameter at breast height for bottomland hardwoods sampled from uneven-aged stands in the Mississippi alluvial valley in Tennessee, Arkansas, and Mississippi (Environmental Synergy, Inc., unpublished). Modeled DBH (cm) = $76 * (1 - e^{-0.035 \times AGE})^{1.67}$.

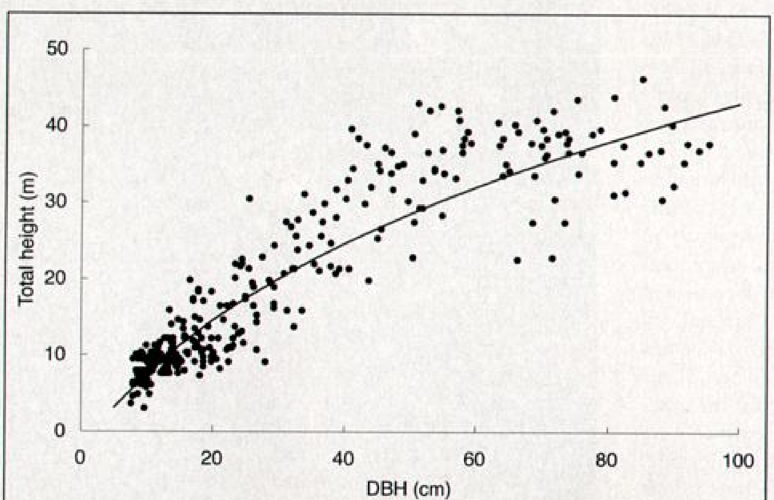

Figure 2. Relationship between diameter at breast height and total height for bottomland hardwoods sampled from uneven-aged stands in the Mississippi alluvial valley in Tennessee, Mississippi, and Louisiana (Environmental Synergy, Inc., unpublished). Modeled Height (m) = $0.9093 * (\mathrm{LN\ DBH\ (cm)}^{2.5271})$.

flooding events may have been another source of trees kills from which Ivory-billeds profited.

Perhaps the disturbance with which Ivory-billeds were most commonly associated was fire. Historically, fire was a dominant force in shaping the structure and composition of the forests of the southeastern United States. For the Ivory-billed, fire provided not only an abundance of newly-killed trees but left a legacy of weakened trees and delayed mortality that would steadily supply foraging sites over subsequent years. Wayne (1893) remarked on Ivory-billeds feeding on fire-killed trees in the Suwanee River region. Allen and Kellogg (1937) described Ivory-billeds feeding in "small and medium-sized pines that had been killed by fire" in Florida. Herbert Stoddard (1969, p. 39) described areas attracting Ivory-billeds in central Florida around the turn of the century: "…isolated stands of pines on 'islands' surrounded by wet swamp or on high ground between the forks of creeks … [that] might escape burning for many years … when at length … were burned out, the pines became infested with beetles and died … it was also there that Ivory-billeds, which love the sawyers, could also be seen in late summer and fall." Tanner (1942) includes a report of Ivory-billeds from Highlands Hammock, Florida, occupying an area of recently fire-killed Baldcypress (*Taxodium distichum*) for several months, and then leaving the area after the cypress snags had "dried out." In Louisiana, fires burned over the Singer Tract in 1917 and 1924, at which time, presumably in response to the fires, Ivory-billeds were reported as more numerous according to Tanner's informants (Tanner 1942). Dennis (1948) remarked on the frequent fires in the forests of the Sierra de Moa in Cuba, where Ivory-billeds were seen: "a view of the mountains always revealed columns of smoke rising from a dozen or more points." Although it is not clear that fire-killed trees were what drew Ivory-billeds to the area, Dennis did postulate on the benefits of fire in producing quantities of recently killed trees for foraging Ivory-billeds.

Where the frequency and intensity of these disturbances is diminished (e.g., through fire suppression or flood control), regenerating shade-tolerant cohorts begin to become established in the understory and midstory. The progressive recruitment over time of volunteer stems will increase competition for resources and may reduce the growth rate of the dominant tree cohort, as well as substantially alter the character of the habitat. Open-forest structure, associated with recurrent disturbance, may well have facilitated movements of this large species (Jackson 2002, 2004) and is evident in photographs (Allen and Kellogg 1937) and descriptions of occupied Ivory-billed habitat, for example the telling account of J. J. Kuhn driving his car through the Singer Tract forest (Gallagher 2005). Wider spacings also favor development of large branches and tend to increase the complexity of the canopy architecture. Though the correlation between Ivory-billeds and natural disturbance is clear, the exact nature of the relationship and detailed characterization of the disturbance regimes that favored Ivory-billeds—information that would serve to prescribe management—is lacking.

Forest Management for Ivory-billeds

Harvest regimes on managed forests could potentially serve to mimic the disturbances with which Ivory-billeds were associated. Forest management practices can be divided into even-age and uneven-age management systems, each of which generates distinctive stand structures. Even-aged management, and the stand-replacing disturbances which they simulate, often result in bell-shaped age distributions suggesting a single dominant cohort regenerating from disturbance. Uneven-aged management (e.g., single tree or group selection), with long-term application, results in a negative exponential age distribution, made up of multiple cohorts regenerating from disturbances of limited areal extent (i.e., death or removal of single trees or clusters of trees) recurring at relatively uniform rates. Although even-aged management may best replicate the scale of the natural disturbance detailed above, clearcutting essentially eliminates a stand for use by Ivory-billeds and would require decades to replace. Over time and across a landscape, an even-aged harvest regime, even staggered across annual cutting blocks, would result in significant areas of unsuitable habitat.

A single tree or group selection harvest regime could presumably retain enough structure post-harvest to continue to support Ivory-billeds, and most importantly, stands would retain potential to generate standing dead wood throughout the period of the cutting cycle. Uneven-aged management potentially yields a further benefit in producing more uniform stand conditions across the landscape that could potentially reduce risk of predation associated with transit across open, non-forested tracts. In fact, forest harvest practices in the region have changed significantly since the initial logging of old growth and contemporaneous disappearance of the Ivory-billed. At that time, clearcuts were the dominant practice, and "left a land surface completely bare of … mature trees" (Williams 1992), likely precluding the use of newly regenerating stands by Ivory-billeds. Conditions in residual stands improved with the widespread replacement of clearcutting with selective cutting practices after 1930 (Williams 1992), and consequent accumulation of non-merchantable "wolf," or cull, trees in successive stands, which made up over 40% of existing stocks on some 1.1 million acres of Mississippi delta forests by 1984 (Rudis and Birdsey 1986).

Regardless of management regime employed, election of appropriate rotation age is

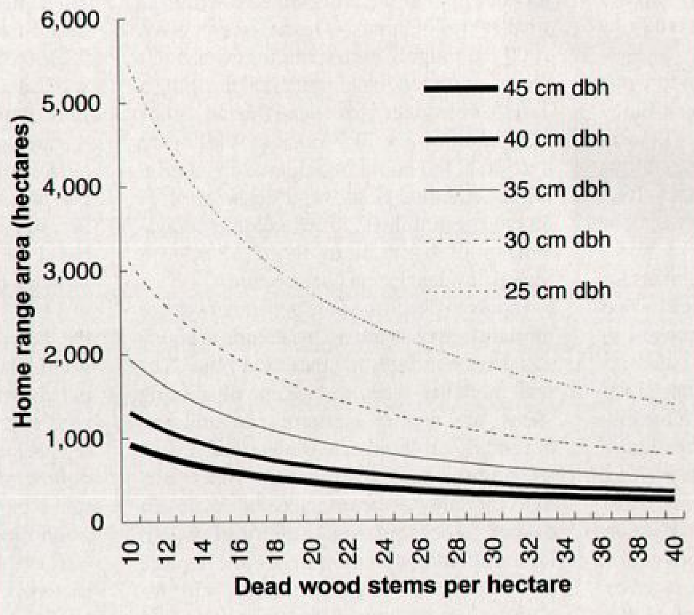

Figure 3. Relationship of standing dead wood stem density, standing dead wood stem dimensions, and Ivory-billed pair home range size. Stem volume calculated using Smalian's formula. Dead wood dimensions use 2/3 total height (Height (m) = 0.9093 * (LN DBH (cm) $^{2.5271}$), derived previously) and taper (assuming 1.1 cm/m length). 2.54 cm bark thickness was discounted from end diameters.

essential to ensure the continued presence of trees of suitable dimensions, here proposed as 60 centimeters mean dbh minimum for Ivory-billeds, reflecting the size of stems used for cavity construction and preferred for foraging. A minimum rotation of 60 years is required to maintain 60-cm dbh stems. Given the different growth rates associated with the distinct stand structures and light environments produced by even-aged versus uneven-aged management, rotation age required to generate 60-cm dbh stems would potentially differ with management regime (i.e., slightly less for even-aged management). With uneven-aged management, habitat could be further improved by lengthening cutting cycles within the rotation to increase the abundance and residency of stems exceeding 60 cm dbh.

With the long-term application of fixed rotations, however, large trees (i.e., exceeding the maximum dbh permitted by the rotation) will be progressively phased out of the forests as the existing stock of large cull trees steadily deteriorates and succeeding cohorts are not permitted to reach comparable ages and dimensions. Retention of some mature *live* stems following harvest, or variable retention (*sensu* Franklin et al. 1996), offers the potential to ensure the growth of stems beyond the size classes permitted by the rotation for the eventual generation of large-dimension snags and dead limbs on live stems within the stand. Selection of stems for retention should take place at the end of a rotation, at which point vigorous individuals with the greatest likelihood to succeed into larger size classes and resist windthrow can be identified.

Adequate stocks of dead wood for foraging and cavity construction must be ensured within an occupied home range. Tanner's (1942) survey of dead wood volumes in two recently logged acres of the Singer Tract resulted in an estimate of 208 ft^3 per acre, or 14.39 m^3/ha, which is used here as a surrogate for standing dead wood requirements for Ivory-billeds. The surface area of dead wood under bark, which is of particular interest in quantifying foraging sites for Ivory-billeds, is assumed to be proportional to volume. Total dead wood volume thus serves as a more easily quantifiable index for surface area under bark. Using a pair's range in the Singer Tract in the breeding season of 4 mi^2, or 1036 hectares, and assuming uniform distribution of standing dead wood across this area equivalent to the nearby harvested site surveyed by Tanner, this yields a requirement of 14,908 m^3 of standing dead wood per pair for adequate foraging. Figure 3 illustrates a proposed relationship between standing dead wood stem density, standing dead wood stem dimensions, and Ivory-billed home range size, and serves to generate tentative predictions of mean stocks of standing dead wood required across a landscape and maintained over time. For example, a pair of Ivory-billeds would require 31,058 30-cm dbh (0.48 m^3 volume equivalent) stems of dead wood. Across 1036 ha (home range in the Singer Tract), 13 40-cm mean dbh (1.15 m^3 volume equivalent) or 30 30-cm mean dbh stems per hectare are required. The latter value agrees with the mean reported by Tanner of 31 dead stems per hectare, though Tanner did not record mean dead wood stem volume or dbh on the Singer Tract. Although it is unlikely that small-dimension snags alone could support this species, as suggested by the upper line in Figure 3, density of foraging substrates and home ranges of individual woodpeckers have been shown to be inversely correlated (Renken and Wiggers 1989, Fitzpatrick et al. 2005), and it is likely that Ivory-billeds compensate for scarcity by expanding their home ranges.

Where management objectives seek to concentrate presently wide-ranging birds in a specific area (e.g., where they could be better monitored), and ultimately to increase population size and density, dead wood volume per unit area objectives could be set appropriately. For example, the Big Woods in Arkansas where an Ivory-billed was recently reported comprises a large area of some 220,000 ha (Fitzpatrick et al. 2005), a size that presents severe logistical challenges where the management of a few roaming individuals is concerned. If the objective were to provide sufficient dead wood stocks for two pairs of Ivory-billeds within a smaller area of intensive management, of say 2000 ha, roughly corresponding with home ranges reported by Tanner in the Singer Tract, objectives for dead wood stock (29,816 m^3 = 2 × 14,908 m^3 or 14.9 m^3/ha over 2000 ha) could be achieved by managing for standing dead wood densities of 31 30-cm mean dbh (0.48 m^3 volume equivalent) or 13 40-cm mean dbh (1.15 m3 volume equivalent) stems per hectare.

Inputs to dead wood are generated via tree mortality. Tree death is by nature a highly variable event both in space and time. Natural mortality rates, as percent of existing stems, are neither constant nor uniform, depending on stand age, stem size and density, and stochastic disturbances. Where natural mortality is insufficient to maintain desired stocks of standing dead wood, killing additional stems is necessary. In place of traditional thinning operations, selective girdling or prescribed fire, which would leave dead stems standing, could be used. Targeted interventions such as this would be of particular importance both in young forests (regenerating from past stand-level disturbance such as logging) and also in intensively managed forests, where less vigorous stems are systematically thinned from stands, conditions in which old weakened individuals are absent and incidence of tree mortality is low (Lorimer 1989).

Live trees may house a considerable fraction of dead wood in hardwood forests (Welsh and Capen 1992), and total dead wood requirements of Ivory-billeds were only partly satisfied by dead stems. Aside from labor-intensive interventions such as girdling large limbs, these stand characteristics can only be managed for by extending rotation ages and/or designating some stems for post-harvest retention to allow natural senescence and gradual crown die-back of large stems to take place.

The role of forest management in Ivory-billed conservation would be to maintain desired stocks and inputs of standing dead wood over time across a landscape. For steady state desired stock, ***annual inputs = desired stock * decay rate.***

The annual decay rate of dead wood, expressed as fractional mass loss (k), calculated for southeastern U.S. forests, is ~0.08 (Mattson et al. 1987, Onega and Eickmeier 1991), which translates to a mean residence time ($1/k$) of 12.5 years. Although specific gravity of dead wood decreases over the decomposition process, mass per *solid* volume can be considered as a constant and the mass loss rate applied to decay *volume* stocks in the above equation. Assuming that dead wood provides no useful foraging opportunities to Ivory-billeds beyond 25% mass loss, given the species' preference for recently killed stems, the lifetime of dead wood utilization by Ivory-billeds is 3.6 years (t=ln 0.75/-0.08). Thus, a new decay rate of 0.28 was calculated based on a mean residence time of utilization of 3.6 years,

annual inputs = desired stock × 0.28.

Desired stock, whether in units of volume per hectare or stems of a specific size per hectare, can be determined as in Figure 3, based on inferred dead wood requirements of Ivory-billed pairs. For example, if a tract of 14,183 hectares—for instance, the area of the Pearl River Wildlife Management Area near Slidell, Louisiana, where a pair of Ivory-billeds was reported in 1999—were managed to provide adequate foraging sites for ten pairs of Ivory-billeds (1418 ha per pair), desired stocks must equal 22 30-cm dbh stems per hectare equivalent. Annual dead wood inputs must equal 2.9 m^3 per hectare (= ((14,908 m^3 × 10 pairs) × 0.28) / 14,183 hectares) or 6 30-cm dbh (0.48 m^3) stems equivalent per hectare.

Desired annual inputs can be alternatively quantified by subtracting existing stock from desired stock. Existing dead wood stock and/or annual natural mortality can be estimated through periodic forest inventories, which should be designed to estimate dead wood volumes associated both with snags and live stems. The balance of the total required, whether as stock or input, can be met by killing stems within the managed landscape and leaving them standing. These interventions need not be additional to an established regiment of management activities but could rather be scheduled as part of programmed thinning operations.

The availability of dead wood for cavity excavation and as a foraging substrate should be a critical management concern; however, other, as yet unidentified, factors may be influential in limiting woodpecker abundance (Welsh and Capen 1992), particularly where snag density is, apparently, no longer limiting (Morrison et al. 1987, Bunnell et al. 2002). While invertebrates associated with dead wood were clearly the most important food source, Ivory-billeds further supplemented their diet with seasonal fruits (Tanner 1942). Guidelines for minimum dead wood stocks and rotation ages should be only one component of a more comprehensive management program, which can evolve and be developed progressively with modern data on Ivory-billed Woodpecker ecology.

Clearly, more information is required to design reliable and effective management protocols. Further refinement of forest management prescriptions would require detailed site-specific information on the stand structures required by Ivory-billeds and the disturbance regimes which maintain them, especially at a landscape scale, given the characteristic heterogeneity of dead wood in forests. Where future research opportunities become possible, priority should be given to deriving guidelines for management. Outstanding considerations include comparative benefits of aggregated versus dispersed foraging to optimize the spacing of management-generated dead wood, quantitative recommendations for post-harvest retention of large-dimension live trees sufficient to maintain desired levels of natural mortality, and how to mesh Ivory-billed recovery and conservation with other forest management goals. However, given the anticipated unlikelihood of acquiring new and comprehensive information in a timely manner, the limited management-relevant existing knowledge can serve to develop and implement tentative prescriptions for adaptive management.

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