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Dean Lueck
University of Arizona

Jeffrey A. Michael
Towson University

Department of Agricultural and Resource Economics
College of Agriculture and Life Sciences
The University of Arizona

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FOREST MANAGEMENT UNDER THE ENDANGERED SPECIES ACT

DEAN LUECK & JEFFREY A. MICHAEL

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ABSTRACT: The regulations imposed by the Endangered Species Act (ESA) have altered the incentives to manage forestland, for both private and public forests. This paper examines the economic incentives for forest management that are created by the ESA and examines some of the implications for forest practices. On private land, the ESA effectively limits the property rights a forest owner has to timber value and thus can create incentives for the owner to preemptively alter suitable habitat for endangered species in order to avoid potentially costly regulations. On public forests, the situation is different because bureaucratic managers and commercial timber companies do not have sufficient property rights to allow preemptive land management. Instead land use is expected to be shifted away from timber production when ESA regulations are binding. This paper examines the forest management incentives for the two types of landowner and examines forest management for two important endangered species – the red cockaded woodpecker and the northern spotted owl. Data from North Carolina landowners are used to examine the effects of potential ESA regulations on the age of timber when it is harvested. The evidence from the 1980s indicates that the greater the likelihood of ESA restrictions the younger the stands will be at harvest, while the evidence from the 1990s finds little evidence of such preemptive activity. Data from National Forest in the Pacific Northwest, however, indicates that ESA regulations lead to a decrease in timber harvest rather than an increase. These differential incentives on private and public land are used to explain the political opposition to amending the ESA.

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I. Introduction

In 1973 the Endangered Species Act (ESA) was passed with the near unanimous approval of Congress.[1] Within a few years the ESA had become perhaps the most contentious of all the various pieces of federal environmental legislation passed during the early 1970s. Battles over land use and development between landowners and the Fish and Wildlife Service (FWS)[2] became hostile and costly.

Within this context, some of the important battles have centered on the management of forestlands. Table 1 summarizes the most important endangered species that inhabit forestlands in the United States. Though there are many forest species involved, most of the U.S. debate regarding the ESA and forest management has revolved around two species -- the red-cockaded woodpecker (RCW) and the northern spotted owl[3] – because these species have impacted millions of acres of productive timberland. In this paper, we focus on these two species, examining the extent to which private forest owners have acted to preemptively harvest timber in order to avoid ESA regulations and environmental groups have altered land use on public forestlands by using ESA regulations to limit timber harvests.

Economists have noted that under the ESA, the incentives of both private and public forest managers are altered [Brown and Shogren 1998]. On private land, the ESA effectively limits the property rights a forest owner has to timber value and thus can create incentives for the owner to alter the habitat [Epstein 1997, Polasky and Doremus 1998,

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[1] The vote was 92-0 in the Senate and 390-12 in the House [Yaffee 1982].
[2] The FWS is the prime federal agency charged with administering the ESA, although on federal lands other agencies can also be involved and marine endangered species administered by the National Marine Fisheries Service.

Stroup1997]. In some cases, landowners have been known to secretly kill endangered species, behavior now known as “shoot, shovel, and shut up” [Dolan 1992, Lambert and Smith 1994]. In other cases, landowners take action to destroy habitat that may prove suitable to endangered species. In these ways, landowners can avoid costly regulations that can severely limit their ability to earn income on their forest assets. Environmentalists have also recognized that ESA regulations intended to protect endangered species habitat may actually provide incentives for private landowners to reduce the available habitat [Wilcove et. al. 1996]. On public forests, the situation is different because bureaucratic land managers do not have the control over forest uses or incentives of a private land owner. Similarly, commercial lumber companies who use these forests for their source of raw timber do not have direct control of landuse. In this paper we examine the economic incentives for forest management that are created by the ESA and then examine some the implications for actual forest practices. We also present some evidence of the impacts of the ESA on forest management in the United States on both private and public lands.

II. Economics of forest management under the ESA

A. Management of private forests under the ESA

Consider the economics of forest use under private ownership of a forest, by first assuming that the forest is valued only for timber production and that the forest owner starts with a plot of bare land. In this model, the owner of a private forest must choose the optimal rotation period for each successive stand of timber. We assume that the

[3] See Chase [1995] for a detailed study of forest management in the face of the ESA with a focus on the Pacific

forest is an even-aged stand, that the forest site only has value for its harvested timber, and that there are no costs of replanting once the forest is harvested.

To begin, assume there are no ESA regulations and hence no uncertainty about the ability to harvest. Assuming the value of the forest grows over time and is given by $V(t)$, where $V'(t) > 0$ and $V''(t) < 0$, the problem for the forest owner is to maximize the present value of the forest, or

$$(1) \qquad \max_t \left[\frac{V(t)e^{-rt}}{1-e^{-rt}}\right].$$

The optimal rotation age, $t^*(r)$, solves the following first-order necessary condition:

$$(2) \qquad V'(t^*(r)) \equiv rV(t^*(r)) + \left(\frac{rV(t^*(r))}{e^{rt^*(r)}-1}\right).$$

This well-known formulation has a simple interpretation. The left-hand side is simply the marginal benefit of allowing the forest to grow another period; the right-hand side is the total marginal cost of such growth and is comprised of two parts. The first term is the marginal cost of the current forest stand and the second term is the marginal cost of all future stands (or the forest's "site value").

The ESA and forest management incentives.

Although many of the high profile conflicts over the ESA have involved public land management, such as the snail darter in Tennessee and the northern spotted owl, the majority of endangered and candidate species reside on private land (U.S. General Accounting Office 1994). For private land, sections 9 and 3 of the ESA are the most

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Northwest.

important. Section 9 made it unlawful to take any endangered species[4] within the jurisdiction of the United States, and section 3 defined "take" to mean "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect." In 1975, the Secretary of Interior went on to define "harm" as:

> *An act or omission which actually injures or kills wildlife, including acts which annoy it to such an extent as to significantly disrupt essential behavioral patterns, which include, but are not limited to, breeding, feeding, or sheltering; significant environmental modification or degradation which has such effects is included within the meaning of "harm."*[5]

By the mid-1980s, a combination of administrative and court rulings combined to make habitat modification a violation of the ESA's section 9.[6] This policy was further solidified in 1995 in *Babbitt v. Sweet Home*, where the Supreme Court overturned a lower court's decision and upheld the broad definition of "take" that includes habitat alteration.[7] Thus, under Section 9 of the ESA, it is not only illegal to destroy an endangered species, but it is also illegal to damage their habitat.

The legal linkage from take to harm to habitat modification, clearly settled in *Babbitt*, is only the first of two steps in understanding how the ESA can generate private

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[4] The lesser category of "threatened" species are not strictly protected by section 9 but the FWS typically regulates its take so that in practice they are treated the same as "endangered" (Bean and Rowland 1997).

[5] 40 Fed. Reg. 44412, 44416 (1975). Initially, however, the ESA gave no protection against taking for listed plants. The 1988 amendments did apply section 9 to plants on federal land (Rohlf 1989).

[6] This began to change with several federal decisions, starting with *Palila I* in 1979, where the court sided with the Sierra Club and other environmental groups who charged the state of Hawaii was "taking" an endangered bird (the palila) by maintaining populations of feral sheep and goats (for sport hunting) that adversely impacted the palila's nesting sites. The court ordered the state to remove the animals after considering the ESA's definition of take and harm. In the *Palila II* decision in 1986, the court held that harm applies to a species not just individual animals, strengthening the connection between habitat modification and "harm." See 1986 *Palila v. Hawaii Department of Land and Natural Resources* 471 F. Supp 985 (D. Hawaii 1979) *aff'd* 639 F2d 495 (1981) and *Palila v. Hawaii Department of Land and Natural Resources* 649 F. Supp 1070 (D. Hawaii 1986) *aff'd* 852 F2d 1106 (9th cir.1988).

[7] *Babbitt v. Sweet Home Communities for a Greater Oregon* 515 U.S. 687 (1995). The exact boundaries of "harm" and "take" are unknown (Bean and Rowland 1997, pp.213-25 and Nagle 1998). For example, while timber harvesting constitutes a take, bulldozing and livestock grazing may or may not. This ambiguity stems from such

land use restrictions. The second step is an explicit definition of habitat for each listed species. In practice, the FWS develops habitat protection guidelines as part of "recovery plans" for all listed species.[8] Recovery plans typically discuss the species' distribution and history, target recovery populations, and outline actions necessary to promote species recovery, including habitat requirements. Most important, a recovery plan will define "critical habitat" -- specific habitat requirements (e.g., grass of a certain height, water of a certain quality, or trees of a certain age) -- that limits the range of compatible land uses.[9]

By linking take to harm and by linking harm to specific habitat recovery plans, the ESA becomes a land use regulation.[10] Even so, the ESA is not like a typical zoning statute because its application is contingent on the presence of a listed species, rather than an explicit geographical zone. If a listed species inhabits a plot of land the landowner is clearly subject to the habitat recovery plan and its guidelines so that habitat modification would violate the ESA under section 9.[11] Still, if a landowner has habitat suitable for the species -- perhaps even identical to land inhabiting the species -- but presently the species

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unresolved issues as causation, intent, knowledge, and omission.

[8] Although section 4 of the 1978 ESA amendments requires plans (Rohlf 1989, p.87), many listed species do not have them.

[9] For federal land critical habitat must be designated under section 4 and it is protected under section 7 (Rohlf 189, pp. 48-52).

[10] This aspect of the ESA makes it unique among species conservation law. No other country has such landuse restrictions. See "Issues in International Conservation" ed. Justina Ray, *Conservation Biology* 13 (1999):956-969. States also tend not to have ESA-like land use restrictions in their species protection legislation. Rohlf (1989, p.67) also agrees with our claim that Congress did not intend for the ESA to generate "sweeping controls on non-federal land use."

[11] Landowners, of course, might still choose to damage habitat and face the expected penalties. Section 11 provides for fines up to $50,000 and one year in prison for each violation, civil damages up to $25,000 for each violation and litigation costs, and forfeiture of property used in a violation (Rohlf 1989, Bean and Rowland 1997). Under the 1982 Amendments to the ESA, a landowner may acquire an incidental take permit (where the taking of species or habitat is incidental to and not the primary purpose of the activity) provided they develop a habitat conservation plan designed to mitigate the taking through appropriate conservation measures and habitat enhancement. Landowners also may simply ignore the law and eliminate any endangered species currently residing on their land before government officials can react. The well-know acronym for this behavior -- SSS -- stands for "shoot, shovel and shut up." See Dolan (1992) for some cases.

does not inhabit his land he is not subject to the habitat modification restriction of the recovery plan. Such habitat could potentially attract individuals from a mobile, nearby population of the endangered species and thus may ultimately be subject to landuse restrictions intended to prohibit harm. Because of this possibility of land use restrictions, landowners with potential endangered species habitat may have the incentive to "preempt" the ESA by destroying those characteristics of the land that would attract the species. Such preemptive activity would be a completely legal land use decision spurred by the potential for costly regulations.

Optimal forest rotation under the ESA

The possibility of endangered species inhabitation and attendant ESA land-use regulation can be examined by considering potential ESA regulations as a possible "catastrophe" that destroys the value of current and future timber stands.[12] Under ESA habitat guidelines for forest species the existing timber stand must often be preserved (e.g., red cockaded woodpeckers, spotted owls) thus preventing future stands from being established. Because forests are long-lived, this prohibition sufficiently rules out future rotations after the endangered species leave the area. Let $\lambda \in (0,1)$ be a constant probability (each period) that the ESA will be invoked (because of inhabitance by an endangered species and detection by FWS), thus eliminating all current and future timber value. To simplify we assume that λ does not depend on the age of the forest so that the probability of no ESA regulation during the first period is $(1-\lambda)$ and the probability of no

[12] Our model is an adaptation of Reed's (1984) fire model. Preemption can also be studied in a framework similar to

ESA regulation after t periods is $(1-\lambda)^t$. Because of the permanent nature of ESA regulation, a second timber rotation will only occur with probability $(1-\lambda)^t$, the chance that endangered species were not discovered during the first rotation. Thus, the probability of no ESA regulation after the initial rotation and the first period of the second rotation is $(1-\lambda)^t(1-\lambda) = (1-\lambda)^{t+1}$, and the probability of no ESA regulation at the end of two rotation periods is $(1-\lambda)^{2t}$, and so on.

Because the ESA only allows the entire stand to be harvested if there are no endangered species present, the expected market value of the timber at the end of the first rotation is $V(t)e^{-\lambda t}$, and the expected value of the n^{th} rotation is $V(t)e^{-\lambda nt}$.

The forest owner will now maximize the expected present value of the forest, which is given by

$$(3) \qquad \max_t \left[\frac{V(t)]e^{-(r+\lambda)t}}{1-e^{-(r+\lambda)t}}\right]$$

The optimal time to harvest the forest, $t^{ESA}(\lambda,r)$, must satisfy the following first-order necessary condition:

$$(4) \qquad V'(t^{ESA}(\lambda,r)) \equiv (r+\lambda)V(t^{ESA}(\lambda,r)) + \left(\frac{(r+\lambda)V(t^{ESA}(\lambda,r))}{e^{(r+\lambda)t^{ESA}(\lambda,r)}-1}\right).$$

The optimality condition in (4) has a simple interpretation that is best seen when it is compared to equation (2) and is different only by the addition of the ESA regulation

industrial organization models of preemption and entry deterrence (e.g., Lueck and Michael 2003).

probability, λ, essentially as an additional discounting term. This effectively increases the marginal cost of letting a stand grow in terms of foregone value derived from both current and future stands. It is clear from inspection of (2) and (4) that optimal rotation decreases with the potential for endangered species inhabitation; that is, $t^{ESA} < t^*$. More important, however, is the result that as the probability of endangered species colonization increases, the shorter will be the optimal forest rotation; that is, $\partial t^{ESA}/\partial\lambda < 0$.[13]

It is a straightforward extension to incorporate the a species' proclivity for older trees (e.g., both red cockaded woodpeckers and spotted owls prefer old growth forests) by assuming that the probability of the regulatory "catastrophe" is increasing in the age of the stand (i.e., $\lambda=\lambda(t)$, $\lambda'(t) > 0$). Thus, as stand age increases, the probability of endangered species inhabitation and ESA regulation increases, causing a decrease in the optimal rotation period. Figure 1 illustrates the effect by showing how the presence of potential ESA regulations shifts the MC curve to the left, thus leading to a shorter rotation period.

B. Management of public forests under the ESA

On public land such as national or state forests, the ESA creates different incentives because land managers and land users do not have effective control over land use like a private landowner [Deacon and Johnson 1985, Nelson 1995]. Property rights to public lands can take the form of long term leases (e.g., cabins, ski areas), shorter term use

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[13] This simply extends the well-known result of the effect of discount rate on optimal rotation (Bowes and Krutilla

permits (e.g., timber harvest contracts), or simply long term historical practice. For example, in the Pacific Northwest timber companies have been purchasing and cutting public timber for nearly a century and likely had (prior to the ESA) the expectation that this practice would continue. So, while property rights to public lands do exist, they are much less clearly defined compared to private forests and subject to changes through political and administrative processes.

On public forests the ESA creates a mechanism by which rights can be claimed for species preservation without compensation to the prior users of the land. The presence or the possibility of an endangered species on public land weakens and possibly dissolves other property claims to public lands such as timber harvest rights or other actions that might alter the habitat for the listed species (e.g., road development. mineral extraction, grazing). If, for example, an endangered species is found in an area where public timber is harvested, the ESA may be used to place a moratorium on timber harvest and essentially transferring property rights over this land to the FWS or environmental groups pushing for the implementation of the ESA. Claiming public land can also occur when a known species becomes listed under the ESA as a "threatened" or "endangered" species and invokes ESA protections.[14] Because the ESA allows third parties to nominate species for protection and because the ESA allows third parties to sue the FWS (and other federal agencies) for improperly administering the ESA, environmentalists can use the ESA to claim forest habitat and limit timber harvest. Because the precise incentives are difficult to determine in public forest management it is

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1989, Hartman 1976).

accordingly difficult to develop a precise economic model with clear predictions. Yet, the following outcomes are plausible predictions about public forest management under the ESA. First, we expect that timber harvest rates will decline in the presence of ESA regulations. Second, we expect the public forest agencies will divert their budgets and employees from timber management (and other extractive land uses) toward wildlife management and recreational uses that do not adversely impact wildlife.

III. The red-cockaded woodpecker and the southeast pine forest

The red-cockaded woodpecker (*Piocoides borealis*) was one of the original species listed under the ESA, having been listed in 1970 under the ESA's precursor, the Endangered Species Conservation Act of 1969. The RCW is a non-migratory, territorial woodpecker that resides primarily in southern pine ecosystems ranging from Texas to Florida to Virginia. RCWs live in social units called clans or colonies, which consist of a single breeding pair, the current year's offspring and a several "helpers." Costa and Walker [1995] estimate that there were 4,582 surviving RCW colonies, 3,639 clans on public lands and 893 clans on privately owned lands.

The North Carolina Sandhills region -- part of our study area -- is home to the second largest RCW population with 371 colonies and is the only large population with a significant amount of habitat on private land. From the early 1980s to 1990 the estimated number of colonies in the Sandhills declined by over a third. Declining RCW populations are directly related to the loss of suitable habitat, from timbering, the encroachment of hardwoods into mature pine stands, and the demographic isolation of

[14] Claiming could and does take place through arguing over the definition of what is the minimum required habitat.

individual groups.[15] Timber harvesting directly reduces RCW habitat by eliminating the pine trees necessary for nesting and foraging habitat.

For our purposes, the most important ecological characteristics of RCWs are their dependence on mature forests for nesting and foraging habitat and their limited mobility. Although RCWs are considered "non-migratory," they are known to travel up to 15 miles to find new habitat or a mate.[16] RCWs typically excavate nesting cavities in pines greater than 70 years old, but have been known to nest in 40-70 year old trees when older trees are not readily available [Jackson et. al. 1979, Lennartz et. al. 1983, Hooper 1988]. While older pines are preferred for nesting cavities, trees as young as 30 years can provide RCW foraging habitat. Depending on the age structure and density of the trees, between 60 and 200 hundred acres of pine forest are required for the nesting and foraging habitat of a single colony of RCWs.

A. The history of RCW policy

Changes in FWS habitat guidelines, and the events that led to these changes, are the most important aspect of RCW management for our study. Table 2 summarizes the major events during the 30 years of RCW management under the ESA [Environmental Defense Fund 1995, McFarlane 1992, Michael 1999, U.S. Fish and Wildlife Service 2003]. Throughout most of the 1970s, there was no formal recovery plan in place for the RCW. U.S. Forest Service policy was to leave an undisturbed 200-foot buffer around cavity trees,

[15] Cely and Ferral (1995) study declining RCW populations in South Carolina between 1977 and 1989, finding hardwood encroachment (32.6%), Hurricane Hugo (27.4%), and timbering (21.0%) were important causes of loss. Hugo did not affect North Carolina forests and is not relevant for this study. Development is not always harmful; golf courses are often compatible with RCWs.

[16] Costa and Walker (1995) estimate movement of 5 to 10 miles, while Winkler, Christie, and Nurney (1995) estimate up to 15 miles for males.

while the forest industry standard was simply to not harvest RCW cavity trees. In 1979, the FWS finally approved the first RCW Recovery Plan. The primary habitat requirements were a 200-foot buffer protecting cavity trees and providing 100-250 acres of adjacent foraging habitat consisting of trees at least twenty years old.

Disappointed in the recovery plan and its implementation on public lands, the National Wildlife Federation filed a notice of violation of the Endangered Species Act with the FWS and the Forest Service in 1983.[17] In response, the two agencies agreed to resolve their differences and develop a revised recovery plan that was issued in 1985. The 1985 RCW Recovery Plan significantly strengthened the habitat requirements of its predecessor [Lennartz and Henry 1985]. The new plan increased the minimum age for foraging habitat from twenty to thirty years, and required that forty percent of foraging habitat be maintained in trees of at least sixty years of age. An alternative specification allowed owners of particularly well-stocked foraging habitat to meet their requirements on somewhat less land than the previously required 125 acres, perhaps as little as 60 acres.[18] Increasing the required age of foraging habitat increases the cost of providing habitat and reduces the management flexibility of rotating the available foraging habitat between different forest stands. Bonnie [1995] uses the 1985 guidelines to estimate the cost of foregone timber harvests from providing habitat for a single RCW colony at $196,107 ($981 per acre) of foregone timber revenue. If the forest owner is able to harvest pine straw (needles) while maintaining the old growth pine forest these costs fall to $101,694

[17] The intense lobbying over the details of FWS guidelines are consistent with Ando's [1999] study of listing politics.
[18] The plan also allowed a timber volume-based habitat requirement in which a colony could be provided with 6,350 pine stems greater than 10 inches in diameter (at breast height) and 8,490 square feet of basal area within a half mile

($508 per acre). These estimates indicate that under the 1985 guidelines there was a large financial incentive for landowners to preemptively harvest timber if there is a chance that RCWs may locate on their land.[19]

In addition to the stricter guidelines, there appeared to be an increase in ESA enforcement following 1985, perhaps because of the threat of third party lawsuits such as the complaint filed by the National Wildlife Federation. For example, in 1987 a development company was found guilty of killing two RCWs and cutting and burying 200 cavity trees to prepare a site for a 4,500 home residential development near Ocala, Florida.[20] In 1989, the FWS issued the "Blue Book Guidelines"[21] to clear up some confusing areas of the 1985 Recovery Plan. The Blue Book specifically stated that if a landowner took action that reduced habitat below the levels specified in the guidelines, and colony abandonment followed, there would be "strong evidence" of a taking violation. In 1991, the regulation of private landowners for RCW habitat made national headlines with the case of North Carolina landowner Ben Cone. To protect 12 colonies of RCWs, the FWS restricted Cone from harvesting timber on 1,500 of his 7,200 acres. After a consultant estimated the timber value of the regulated acres at $2 million, Cone became an

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of colony sites.

[19] A typical one-acre stand of 70-year old pine holds around 12-13 thousand board feet of saw timber, valued at roughly $200 per thousand board feet. This generates a timber value approximating $2,500 per acre. For other similar estimates see Cleaves et.al. [1994] and Lancia et.al. [1995]. Some selective cutting of trees is allowed under FWS guidelines as long as a minimum standards are met, and foraging habitat does not have to be totally provided by old growth stands, only nesting habitat. Thus, the cost estimates of about $1,000 acres are less than the total old growth timber value assuming landowners manage their property as efficiently as possible.

[20] The two top officials of the company were fined a total of $400,000 and each received 2-year probationary sentences for this violation of the ESA [McFarlane 1992]. For a summary see Bryanna Latoof, "Two Accused of Killing Rare Birds: Indictment Charges Woodpeckers Shots, Nesting Trees Removed." *St. Petersburg Times* August 3, 1987,p.3B, and "Men Fined for Killing Woodpeckers." *St. Petersburg Times* September 16, 1987,p.1B. In total the company incurred over one million dollars in penalties including court costs and habitat mitigation expenses.

[21] The publication was officially titled, "Guidelines for Preparation of Biological Assesments and Evaluations for the Red-Cockaded Woodpecker." Because the Guidelines were distributed in a blue binder, this became commonly

outspoken critic of the ESA and proceeded to clearcut potential RCW habitat on his unregulated acres. Cone's behavior clearly demonstrates how the incentives of the ESA can drive some landowners to destroy more habitat than they protect [Stroup 1997].

Since the Cone case in 1991, FWS enforcement has been characterized by greater flexibility [Environmental Defense Fund 1995]. In 1992, the FWS prepared a draft private lands manual that effectively cut in half the required acreage of old growth pine per RCW colony. Habitat Conservation Plans with private landowners became more common in the mid to late 1990s.[22] In 1995, the FWS implemented the first "Safe Harbor" program in the North Carolina Sandhills region, which allows a landowner with RCWs to establish and protect a base population in return for no future land use restrictions. By 2001, the FWS had authorized 12 "incidental takes" of RCW habitat by private landowners in return for some mitigation actions, and had implemented statewide Safe Harbor programs in South Carolina, Texas and Georgia. The most recent revision of the RCW recovery plan, approved in January 2003, emphasizes voluntary participation of landowners in RCW management, and places HCPs, Safe Harbor and mitigation for incidental takes at the center of its private lands strategy. Clearly, the FWS has changed the regulations and enforcement of RCW habitat several times over the past 30 years. Enforcement was strongest between 1985 and 1992, but has become increasingly cooperative and flexible since that time. Thus we expect the probability of preemptive forest harvest to be greatest during from late 1980s and early

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known as the "Bluebook Guidelines."

[22] Ben Cone dropped his lawsuit against the FWS in 1996 after signing an HCP that released him from any future responsibilities under the ESA in return for paying approximately $40,000 to relocate the 12 RCW colonies from his

1990s.

B. Evidence of preemptive habitat destruction

The anecdotal stories of habitat destruction in the previous section are informative, but are insufficient to determine whether the ESA has induced habitat destruction on a larger, more significant scale. To explicitly test for the presence to preemptive timber harvesting requires examination of a large sample of landowners that face varying possibilities of being regulated under the ESA. We use two different data sets covering different time periods to explore preemptive timber harvest in North Carolina. First, we use the U.S. Forest Service's Forest Inventory and Analysis (FIA) data to examine timber harvesting between 1984 and 1990, a period of strict FWS enforcement of RCW regulations. Second, we use a survey of forest landowners conducted by North Carolina State University (NCSU) to examine timber harvesting in the mid 1990's, a period of increasing flexibility and cooperation by the FWS when regulating private landowners with RCWs.

Our theoretical analysis predicts that an increase in the probability that inhabitation of endangered RCWs and subsequent timber harvest restrictions will decrease the age at which forest stands are harvested.[23] To test this prediction, we combine data on timber harvest and other characteristics of randomly selected forest plots with the location of RCW colonies. The forest plot characteristics in each data set are different, and are described separately in the following sections. In both data sets,

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property to a nearby National Forest.

[23] Lueck and Michael [2003] use probit models to estimate the impact of potential ESA regulations on the probability of timber harvest.

we measure the RCW inhabitation probability with data on the density of known populations of woodpeckers in the proximity a particular forest plot.

Our measures of RCW density use GIS to map the location of forest plots and RCW colonies and then calculate the number of RCW colonies within a given radius of each forest plot. The data on RCW colonies is from the North Carolina Natural Heritage Foundation which maintains the most comprehensive database on the location of known RCW colonies. There are 1,194 colonies in their database, which is consistent with the biological literature indicating the North Carolina population to be around 1,000 colonies. Since RCWs may travel up to 15 miles, we calculate the number of RCW colonies within 5, 10 and 15-mile radius of each forest plot. The descriptive and summary statistics are shown in Tables 3A-3B.

The FIA data: 1984-1990.

The FIA data is a detailed inventory of timber and other forest characteristics for approximately 5,000 randomly selected, forest plots in North Carolina. The forest plots were surveyed first in 1984-85 and again in 1989-90, providing information on timber harvest, forest characteristics, and forest growth for each plot during the period between the surveys that coincides with the period when FWS policy for RCW protection was most onerous to private landowners. Because we limit our analysis to privately owned plots of southern pine within the RCWs historical range, our data consists of 1,199 forest plots.

Table 3A shows the descriptive and summary statistics for the FIA data. It shows, for example, that the average age at harvest (*HARVESTAGE*) was 47.9 years. The age of the stands at the beginning of our study period (*STANDAGE*) has a mean value of 31.5 years but ranges from 1 year to 130 years. The data contain information on the dominant species and distinguish between four species of southern pine (longleaf, loblolly, pond, and slash) and a mixed pine-oak forest. Loblolly pine is the most common species, found on 55 percent of the plots, and longleaf is the least common, found on just 4 percent of the plots.[24] The data also include a measure of timber site productivity (*SITEINDEX*), which measures the height (in feet) of a fifty-year old stand of pine grown on a specific plot. The data also identify plots by ownership type (private forest industry and private non-industrial) using the dummy variable *INDUSTRY* which shows 29 percent of the plots are owned by industrial firms.

We use timber prices and FIA data on timber volume and growth for each plots to create variables controlling for timber market considerations in the harvest decision. Our data allow us to create two such variables: the total value of the timber at the beginning of the survey period (*TIMBERVALUE*) and a measure of the net marginal benefit of an additional year of forest growth (*NMB*). From the harvest age model the marginal benefit (*MB*) is $V'(t)$ and the marginal cost (*MC*) is $rV(t) + rV(t)/(e^{rt}-1)$. By combining information on timber volume with information on prices we are able to calculate *MB* and *MC* for each plot by computing the market value of the sampled timber stands at the time of each survey. Each tree is valued for different products as it grows, and each of these products has a different price per unit (for example, board foot) of timber. As a result, the value of a timber stand is not directly proportional to

[24] Loblolly is the fastest growing species and is thus preferred for the establishment of timber plantations.

the total timber volume, but is increasing in volume (and age), and typically increases with the age and size of the trees.[25] Thus the stand's value must be calculated by classifying each tree in the sample plot into one of five product classes[26], each with a different price.

The NCSU data: 1993-1997.

Data from North Carolina forest landowners was collected from a Fall 1997 survey conducted by the School of Forestry and the College of Agriculture and Life Sciences at North Carolina State University. The survey generated a sample of 530 non-industrial forest landowners. Compared to the FIA data, these data contain less information on such variables as species composition and timber value[27] but do contain information on non-timbers land uses such as quail hunting, residential sites, and pine straw collection, which are often important for non-industrial forest owners in this region. The presence of these land use characteristics add value to standing timber and are likely to increase the optimal rotation age, and possibly decrease or mitigate the incentive to preemptively destroy potential RCW habitat.[28]

Table 3B shows the descriptive and summary statistics for the NCSU data. It shows, for example, that the average age at harvest (*HARVESTAGE*) was 44 years and that the average size of forest holding (*ACRES*) was 184 acres. *RESIDE*, *QUAIL*, and *STRAW* are

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Accordingly, loblolly stands tend to be younger than stands comprising other pine species.

[25] Let $V(t) = p(t)f(t)$ where $f(t)$ is the volume of timber at time t with $f'(t) > 0$ and $f''(t) < 0$; and $p(t)$ is the competitive price per unit of harvested timber, which depends on the age of the timber, so that $p'(t) > 0$.

[26] Three of these classes are the ones noted above and two are for hardwoods that are occasionally present in southern pine forests.

[27] Because of the collaborate agreement that guided the survey, there were constraints on the survey questionnaire that prevented us from obtaining more detailed information.

[28] Models with valuable standing timber do not generate clear predictions about optimal rotation age.

dummy variables that indicate whether the landowner has their principal residence, hunts quail or gathers pine straw[29] for income on the forest tract. The table shows that 27% of the owners used the forest as a residence, that 27% hunted quail on the forest property, and that 6% collected pine straw for revenue.[30] The survey did not have enough detail on timber volume to allow a calculation of FIA variables like *NMB* or *TIMBER VALUE*, but we did construct an index (*TIMBER IMPORTANCE*) based on self-reported information on the value of timber compared to recreational uses. The index is positive if landowners place a higher priority on timber production than recreation, and negative if recreation is a higher priority. The mean value of 1.68 for *TIMBER IMPORTANCE* shows that timber production is more important than recreation for most survey respondents.

Harvest age and preemption estimates.

To test the prediction that increases in the probability of ESA regulations will reduce the age of harvest we estimate the age of a forest stand at the time of harvest. For both the FIA from the 1980s and the NCSU data from the 1990s we use both OLS and censored regression estimation methods. For both data sets, only a fraction of the forest plots are harvested: 385 out of 1199 for the FIA data and 204 out of 530 for the NCSU data). This means the information on the age at harvest is thus censored and OLS estimation of age using this censored data would yield inconsistent parameter estimates. Thus, in addition to OLS estimation, we also use the following empirical specification.

[29] Pine straw is a popular mulch for landscaping in this region.
[30] The correlation coefficient for *QUAIL* and *RESIDE* is just 0.055 despite the nearly identical means.

(5) $$A_i^* = X_i\beta + ESA_i\theta + \varepsilon_i \quad \varepsilon_i \big| X_i, A_i^0 \sim Normal(0,\sigma^2)$$

(6) $$A_i = \min\{A_i^*, A_i^0\}$$

In this specification i indicates a specific plot; X_i is a row vector of exogenous timber market and timber stand variables plus a constant; β is a column vector of unknown coefficients; ESA_i is the measured probability that the ESA will be enforced for plot i; θ is an unknown coefficient; and ε_i is a plot specific error term. A_i is the observable age of the stand but, as implied by (6), it takes on different values because of data censoring. A_i^* is the age of a stand that is harvested and A_i^0 is the age of the unharvested plots at the end of the study period (1990 for FIA data and 1997 for the NCSU survey data).[31] Our prediction is that the age of a forest at harvest will be lower as nearby RCW populations become more dense; that is, $\theta < 0$. We use censored normal regression to generate maximum likelihood estimates of the model given by (5) and (6). For comparison we also estimate A_i^* using OLS. Our dependent variable, *HARVESTAGE*, equals the age at harvest for uncensored observations and the age of the unharvested stand for censored observations.

Table 4A presents the parameter estimates from eight (four OLS and four censored regressions) different specifications using the 1980s FIA data. For both OLS and censored regressions, two equations include *NMB* and two include *TIMBERVALUE*.[32] All equations include timber stand variables that control for the ownership category, site

[31] This is right censoring or what is sometimes called "top coding" (Wooldridge 2002, p.571).

productivity, and species composition. All of the coefficient estimates for the *RCW* variables have a negative sign as predicted. The estimates are not statistically significant in the OLS specifications but are in the censored regression specifications. These estimates indicate that proximity to larger populations of a listed endangered species decreases the age at which a forest stand will be harvested. As predicted the estimated coefficients from *NMB* are negative, and statistically significant, in all three equations. The specifications that use *TIMBERVALUE* as a timber market variable (instead of *NMB*) show as predicted, positive estimated coefficients.

The estimated coefficients can be directly interpreted. For example, using the coefficient in specification (6) -- *RCW-15* -- an additional colony of RCWs will reduce the harvest age by 0.012 years, or 4.4 days. Using the 10-mile RCW density (specification 5) the age is reduction is 0.039 years, or 14.2 days. A more relevant measure these effects is seen by examining a movement from low to high-density RCW areas. For the 10-mile density, this means a change from 3 colonies to 66 colonies, or a reduction in harvest age of 2.5 years. For the 15-mile density, this means a change from 7 colonies to 171 colonies, or a reduction in harvest age of 2.0 years. These effects should probably not be interpreted as inducing every forest owner to make a small adjustment in harvest age. A more plausible interpretation is that a small number of owners make large adjustments in optimal harvest age. A switch from 70 to 40 year rotations by just 10% of the landowners would be consistent with a 3-year decrease in average harvest age. Ben Cone, who shortened his timber rotations from 80 years to 40

[32] Lueck and Michael [2003] find this evidence to be robust to various specifications and methods.

years to protect himself from increases in his RCW population, is such an example.

The estimated coefficients for site productivity (*SITEINDEX*) are always negative in the censored regressions, but only statistically significant in those specifications that include *TIMBERVALUE*. These findings are intuitive; more productive timberland will be harvested at a younger age. The estimated effect of ownership (*INDUSTRY*) shows that industry timber tends to be harvested at a younger age (from 2_ to 6 years) than non-industrial private forests. The effects of species mix vary among the species. Again, the pine species dummies are used and the oak-pine mix is the left out category. The estimates consistently show that longleaf pine forests are harvested at an older age. Loblolly pine is harvested at a younger age but these estimates are only statistically significant when *TIMBERVALUE* is included. The estimated effects for pond and slash pine are never statistically significant.

Table 4B presents the parameter estimates from eight (four OLS and four censored regressions) different specifications using the 1990s NCSU data. All equations include variables that control for pine straw production, residential home use, the size of the forest tract, and the relative importance of timber production to the landowner.[33] For some models, we also included an interaction variable between the *RCW* variables and *STRAW*. Pine straw production is one income producing use of land that is compatible with the presence of RCWs, in fact the open understory forests preferred by RCWs are ideal for pine straw raking because there are fewer contaminants (e.g., leaves) and obstacles (e.g., brush) to interfere with collecting pine straw from the

[33] We also used *QUAIL* in other specifications, but the coefficient estimates were always statistically significant, of

forest floor. We expect a positive coefficient for *RCW*STRAW* variables, because landowners who produce pine straw have lower costs from RCW regulation and are therefore less like to preemptively harvest timber.

The estimated coefficients for the timber stand variables do not give as clear a picture as with the FIA data. The *RESIDE* variable has the expected positive coefficient and is statistically significant in all specifications indicating that landowners who live on the forest tract harvest their timber about 9 years later than landowners who do not reside on the tract. The *STRAW* variable is consistently positive when the interaction term is not present, and is statistically significant in the censored regressions. In the specifications with *STRAW*RCW*, the coefficient on *STRAW* is not statistically significant indicating that pine straw raking does not lead to longer forest rotations in areas with few RCWs. The negative coefficient on *ACRES* indicates that forest rotations are slightly shorter for larger tracts, but the magnitude of this effect is very small.

The estimated coefficients for the *RCW* variables have the expected negative effect and are statistically significant in the OLS specifications, but are of varying sign and insignificant in the censored regressions. When the interaction term is included, the point estimates on the RCW variables are smaller than with the FIA data. For example, using *RCW-15*, a move from an area of low RCW density to high density would decrease harvest age by .72 years compared to 2 years for the FIA data. The coefficient on the *RCW*STRAW* variables are of the expected positive sign and statistically

inconsistent sign and very close to zero.

significant for both the OLS and censored regressions. This indicates that pine straw producers do not preemptively harvest their timber and may actually increase their forest rotation age near RCWs.

Compared to the 1984-1990 FIA data, the *RCW* coefficient estimates for the 1993-1997 NCSU data do not strongly support the prediction that the possibility of ESA regulations leads to preemptive timber harvesting. At least two reasons for this finding are plausible. First, the 1990 NCSU data contain less information on stand composition and timber value than do the FIA data, and thus may suffer from omitted variable bias. Second, as we noted in section II, the FWS's enforcement policy change for habitat modification changed substantially from the late 1980s until the mid 1990s, so that the incentive to preemptively harvest timber may simply have largely diminished for the RCW.[34]

C. RCWs on public land

In section II we argued that the incentive for preemptive harvest will be absent from public lands because public land managers will have little incentive to push for earlier harvests since they do not gain directly from the timber revenues. For public lands with prospective RCW habitat then, the ESA is expected to alter land use from timber harvest to non-timber management compatible with RCW conservation. Though we have not done a comprehensive survey of public land management in the RCWs

[34] In fact, the high RCW density area for the landowner survey is the five-county Sandhills region where the FWS launched the first Safe Harbor program in 1995.

southeastern pine forest, there is some case study evidence that indicates this has been the case.

In the South, the most important public land use conflict over the RCW has been on military bases. In particular, Eglin Air Force Base in Florida and Fort Bragg Army Base in North Carolina are both home to over 200 active RCW colonies. Approximately 22 percent of the 3,500 remaining active colonies are on Army installations. Large expanses of these bases are now off limits to many training exercises. Training realism and scope has been reduced, as infantry cannot train all of its wartime missions on base because of the restrictions of the use of armor and aviation near protected RCW habitat. In addition, training costs have increased substantially as units must be relocated to other bases for many exercises. For example, required gunnery qualifications cost an additional $42,000 to conduct because it is necessary to transport an attack helicopter battalion from Fort Bragg, NC to Fort Stewart, GA due to restrictions on training near RCW habitat on Fort Bragg [Sneddon 1993]. Military administrative resources have also been diverted into RCW management developing management guidelines, conducting research, and ensuring compliance with the ESA.[35]

Our prediction that preemption is not likely to occur on public lands ultimately depends on the political and bureaucratic constraints faced by the public land managers. It is possible that if the agency were sufficiently captured by a commercial timber interest group that the public land managers might pursue a policy of preemption. Indeed, something like this may have happened on the national forests in east Texas in

[35] Since the war in Iraq, however, the Department of Defense has put pressure on FWS and Congress to relax these

the late 1980s. In 1988 a federal court explicitly ruled that timber harvest could be a taking of RCWs under section 9 of the ESA. The decision, in *Sierra Club v. Lyng*,[36] came after a group of environmental groups led by the Sierra Club and Wilderness Society filed suit against the Forest Service charging that the agency was failing to obey and enforce federal laws regarding the RCW in Texas. The court concluded that Forest Service timber management, by adversely modifying RCW habitat, constituted a taking of RCWs, and ordered the Forest Service to immediately change its practices in Texas. The Forest Service responded by developing a new management policy throughout the southeast that included halting all active timber sales within three-quarters of a mile of RCW colonies.[37]

IV. The spotted owl and the ancient northwest forests

Although the red-cockaded woodpecker has led to considerable conflict over forestland use, the conflict over the northern spotted owl has been even more contentious and perhaps more costly. The northern spotted owl (*Strix occidentalis caurina*), named for the white spots on its head and nape and it mottled belly, is a medium-size owl that inhabits the old-growth conifers of the Pacific Northwest (including British Columbia) and California [Forsman and Meslow 1986].[38] Its numbers have been dwindling as old growth is harvested and converted into managed second growth forests. Although it is not clear why the owls prefer old growth the likely

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restrictions.

[36] *Sierra Club v. Lyng*, 694 F. Supp 1260 (E.D. Tex. 1988) aff'd in part, vacated in part, *Sierra Club v. Yuetter*, 926 F. 2d. 429,439 (5th Cir. 1991). Also see *Friends of Endangered Species v. Jantzen*, 760 F. 2d 976 (9th Cir. 1985).

[37] This exceeds 1,000 acres, more than the standard guidelines.

[38] The northern spotted owl is one of three subspecies of the spotted owl. The other two are the California spotted owl and the Mexican spotted owl [Forsman and Meslow 1986].

reasons are that the old growth forests provide desirable prey, suitable perches, or protection from extreme weather. Adult owls tend to mate for life and occupy the same territory year after year; in the Northwest they nest if cavities or platforms in trees. The home range for adult owls can vary from 1,000 acres to 8,000 but because a mating pair does not always travel together the combined home range for such a pair is much larger.

A. The history of spotted owl policy

Though interest in spotted owl conservation actually began in the 1970s with a graduate students' thesis at Oregon State University [Forsman and Meslow 1986], it was not until the early 1980s environmentalists became concerned and began to pressure federal forest managers (U.S. Forest Service or USFS and the Bureau of Land Management or BLM) to limit harvest of old growth forests. The owl was not even listed under the ESA as a threatened species until 1990. Table 5 summarizes the major events during the past three decades in which the spotted owl policy has developed in the courts and administrative agencies. During the 1980s there were several spotted owl management plans designed to protect certain areas from logging but new information about declining owl numbers and their rather large home ranges ultimately spurred litigation against federal land managers [Chase 1995, Yaffee 1994]. In two lawsuits filed during the late 1980s, environmentalists challenged both the BLM and the USFS under a variety of federal environmental laws for failing to consider how proposed timber sales would affect the spotted owl.[39] The first bite from this litigation took place in May

[39] The two key cases are *Portland Audubon Society v. Hodel* (the BLM case) and *Seattle Audubon Society v. Robertson* (the USFS case). The key laws are the Federal Land Policy and Management Act, the National Forest Management Act of 1976, and the National Environmental Policy Act.

1988 when the 9th U.S. Circuit Court of Appeals, in *Portland Audubon Society v. Hodel*, temporarily enjoined the BLM from selling old growth timber. Although, this particular case was temporarily overturned upon appeal, the general trend of the litigation had been established. Federal land managers would have to prohibit the harvest of old growth timber in order to provide habitat for the spotted owl [Chase 1995, Yaffee 1994]. Once the spotted owl was listed as a threatened species throughout its range in 1990, litigation focused on the ESA rather than other, more general environmental laws.

B. Changing land use in the northwest forests

As a result of these lawsuits and the settlements that followed millions of acres of public lands in California, Oregon, and Washington were set aside as critical habitat for spotted owls and thus removed from the stock of potentially harvestable timber.[40] Table 6 shows the amount of acres devoted to spotted owl protection on federal lands in these three states.[41] The table shows that by 1996 nearly 11 million acres of federal land in California, Oregon and Washington were considered as critical habitat and off limits from timbering operations. This acreage represents a substantial fraction of public forests in these three states, as much as 50% in Oregon and Washington.[42] These data do not include millions of acres of public land in national parks and wilderness areas where logging is already prohibited and therefore already committed to preserving old

[40] This dispute culminated with the "forest summit" held by in Portland by President Clinton in April 1993 which led to the policy recommend by the Forest Ecosystem Management Team (FEMAT). See Chase [1995] and Yaffee [1994].

[41] These acreages are designated as either "congressionally withdrawn" or "administratively withdrawn" depending on the origin of the action and indicate areas for which timber harvest is prohibited [Forest Ecosystem Management 1993].

[42] This fraction depends on how one defines federal forest lands. If only USFS and forested BLM lands are included (so that national park lands are excluded) the fraction is about one-half for Oregon and Washington combined.

growth forests. Although the data are highly aggregated and do not show how owl lands differ from other forest lands, the evidence is clear that by invoking the ESA (and related environmental legislation) environmentalists have substantially altered land uses on public forest land in the Pacific Coast states.

Given that a substantial proportion of public forests have been designated as spotted owl habitat under the ESA, it is not surprising that timber harvests from public lands dramatically declined in the 1990s.[43] Figure 2 and Table 7 show annual timber harvest in the Pacific Northwest from 1965 to 1996. The decline in harvest begins around 1988, when *Portland Audubon Society v. Hodel* was decided in a federal court. As Figure 2 shows, the harvest decline is greatest for federal lands (labeled "national forest" and "other federal" in the figure) and almost non-existent for private and state lands. Table 7 summarizes the data in Figure 2 by showing the mean annual harvest for two periods by various forest ownership classes. We use 1978-88 as our pre-ESA period and 1989-1996 as our post-ESA period and find that annual harvest rates decline substantially on public forests but do not change appreciably on private industrial forests.[44]

Our examination of the effects of the ESA on forests of the Pacific Northwest is limited by the highly aggregated nature of the data and our inability to control for other economic forces such as timber prices. At the same time, the data on spotted owl

[43] Chase [1995, p.374-78, 396-99] examines other economic impacts, including timber price increases and regional mill closures.

[44] 1988 is, of course, not the only possible date to use but this seems to be the beginning of major policy changes for spotted owl management. Murray and Wear [1998] also find that 1988 is a useful cut-off in their study of timber market integration. Figure 2 also shows that harvest rates on private forestlands seem to rise from 1982-88, perhaps because firms were anticipating stringent owl regulations to limit future old growth harvests.

habitat preservation acreage and the time series for regional timber harvest suggest a relatively large impact on land use allocation after the ESA. These effects are roughly consistent with our idea that environmentalists can gain control over public forest management by invoking the ESA. Of course, there are many other possible issues to examine to more fully understand the effect of spotted owl protection on land use and timber markets in the Pacific Northwest.[45] Simple supply and demand analysis suggests that timber prices should have increased as owl acreage increased. This analysis also suggests that forest owners with few old growth stocks may have benefited substantially from the reduction in the supply of old growth timber. Indeed, the apparent lack of change in timber harvest in industrial forests (see Table 7 and Figure 2) suggests that private forest owners (likely to have less old growth) may have been such beneficiaries as also might be the case for forest owners in other parts of the country.[46]

V. Other forest management issues

The red-cockaded woodpecker and the northern spotted owl are the most important (in terms of acreage and timber values) involved endangered species inhabiting forests. Yet, as Table 1 shows, there are many other endangered species on forestland. Some species like the spruce fir moss spider are found in extremely limited locations and their protection under the ESA appears to have had little impact. Other species, such as the golden-cheeked warbler and the marbled murrelet, have had significant impacts. The

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[45] Montgomery and Brown (1992) and Montgomery, Brown and Adams (1994) examine the costs of spotted owl conservation policies.

[46] This is consistent with Murray and Wear [1998] who find that after the ESA-based owl restrictions were in place the U.S. timber market became more integrated, indicating that southern timber producers entered the northwest timber market. Montgomery, Brown & Adams [1994] estimate the cost of increasing the probability of spotted owl survival

marbled murrelet is a small seabird, a bit larger than a robin, which lives along the Pacific Coast, from Alaska to central California. Even though its natural history is much different, its recent economic history is tied closely to that of the spotted owl. Like the owl it inhabits old growth forest, including the giant redwoods of northern California. Along with the spotted owl, the marbled murrelet was enlisted in the litigation effort to preserve old growth (spruce-fir) forest along the Pacific Coast, ultimately leading, among other things, to the acquisition of 44,000 acres for Redwood National Park.[47]

The golden-cheeked warbler is a small song bird (4 or 5 inches long) that inhabits the central Texas woodlands during the spring and the summer, returning to Mexico and Central America for the remainder of the year.[48] It was listed as an endangered species in 1990, although the FWS had listed it as a "Category 2" species in 1982 indicating that it might need attention in the near future. Not only does the warbler inhabit a relatively small region of Texas but also this area has been the sight of rapid development around the city of Austin.[49]

In the late 1980s the city of Austin and Travis County were already in the process of addressing the protection of the black-capped vireo, another small and endangered bird (listed under the ESA in 1986) that also inhabits the Hill Country around Austin. The city of Austin formed a committee to study the issue and develop a

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[47] Chase [1995] documents the highly contentious, and sometimes dangerous, battles between logger and environmentalists in the northern California redwood forests.

[48] See Mann and Plummer [1995, pp.190-210] for a detailed discussion of the conflicts surrounding the golden-cheeked warbler in central Texas.

[49] Warblers make their nests from strips of ashe juniper (native to central Texas), the bark from which cannot be stripped until the tree is at least 20 years old.

plan to (the Balcones Canyonlands Conservation Plan or BCCP) in order to be prepared for what seemed to be the inevitable listing of the golden-cheeked warbler. The idea was to develop the BCCP and get the approval of FWS so that development in the area could proceed according to some predetermined ground rules for species preservation.

The plan never came to fruition however. In 1989, a biological study indicated that 123,000 acres in the Austin area, where land prices hovered at roughly $1,000 per acre, would be required to protect a viable population of warblers. It was clear that the stakes were much higher than anyone had imagined. Shortly thereafter, the FWS announced its decision to list the warbler as "endangered" and the decisions of landowners reverted to those discussed in our preemptive harvest model. As Mann and Plummer (1995) note, landowners began destroying ash juniper forests in order to thwart ESA regulations.[50] Hundreds of landowners had their lands surveyed for warblers and warbler habitat; if a parcel was clean a landowner could receive a "bird letter" from the FWS indicating the land was not suitable for the warbler preserve and thus not subject to ESA regulations that might limit development. Mann and Plummer report that the value of such a letter was as much as a 25% increase in the value of a parcel. The complex and contentious negotiations between locals (developers, environmentalists, and voters) and the FWS broke down and the BCCP, at least in it grandest form, was never enacted. While politicians and bureaucrats negotiated, individual developers began cutting deals (via habitat conservation plans and incidental

[50] The evidence, though not systematic, is fairly clear here because some landowners were caught and because members of the environmental group Earth First! began collecting information by trespassing on private land [Mann and Plummer 1995].

take permits) with the FWS, which jeopardized the grand BCCP. Travis County voters rejected the plan trumpeted by Interior Secretary Bruce Babbitt in 1993. Ultimately, a preserve – the Balcones Canyonlands National Wildlife Refuge – was established well beyond the city limits and scattered parcels are protected under individual habitat conservation plans. Meanwhile, landowners near the new refuge "mismanage" their land in order to limit the possibility of settlement by warblers and regulation by the ESA.[51] The lesson of the golden-cheeked warbler is that the ESA can have significant impacts on forest land even when timber considerations are not important.

VI. Summary and conclusions

The enactment of the 1973 ESA was a major shift in wildlife law in the United States [Lueck 1998]. Prior to the 1973 act preservation of endangered populations was limited to season closures or explicit compensation to those providing habitat (by either lease or purchase). The 1973 Act also extensively broadened the scope of federal action at the expense of state authority. By introducing strict landuse controls on both public and private landowners the ESA has altered the property rights to habitat that sustains endangered species. In this paper we have focused on how the ESA has impacted the use of forests in the United States.

Our framework indicates that the effects of the ESA will be different on private and public lands. On private land, there are incentives for landowners to kill species and preemptively destroy habitat in order to avoid costly regulation.[52] Our evidence for the

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[51] In 1992 Austin voters approved a $22 million bond to fund its share of the preserve designed in the BCCP.

[52] The economic theory of crime suggests that to eliminate this behavior penalties for violating the ESA will have to be quite high because of the high costs of detecting violations.

red-cockaded woodpecker indicates that this has, indeed, occurred in some southeastern pine forests, at least during the 1980s when FWS enforcement was strongest and before the Safe Harbor policy was implemented. On public land, there is an incentive for environmentalists and others supporting wildlife preservation to use political and legal methods under the ESA to get species listed and put habitat conservation plans in place in order to effectively claim control over land use. Because these groups do not face the opportunity costs of these actions and because they cannot easily compensate previous land users, battles can be contentious and costly. Aggregate evidence from the Pacific Northwest indicated that since the late 1980s environmentalists have been successful in claiming public forest from commercial timber users by using the ESA's protection of the northern spotted owl.[53]

The current dissatisfaction with the ESA, among both environmentalists and property owners, suggests that the relevant interest groups recognize some of the incentive problems with the current ESA examined in this paper. While property owners tend to be uniformly opposed to the ESA (unless they can be sure they will avoid its force), the ESA has been a double-edged sword for environmental groups. On one hand the ESA has allowed environmentalists to have great sway in the use and management of public lands. On the other hand, habitat is being destroyed and species are losing ground on private land, because of the ESA. These combined forces seem to be generating pressure to change the ESA, especially as it affects private landowners. Indeed the rapidly increasing use of HCPs, Safe Harbor, and some landowner assistance

[53] We should emphasize that without a detailed study it is hard to determine the net economic effects of this change in

grants shows movement in this direction, although it appears to be change within the framework of the existing ESA rather than taking on the more difficult challenge of changing the law.

land use. In some cases, using the ESA to alter land use could limit "pork barrel" projects, thus leading to a net gain.

DATA APPENDIX

Forest Inventory and Analysis (FIA) Data

The plot level FIA is available at http://www.srsfia.usfs.msstate.edu/ewdata/ewrec.htm. The data include timber volume for each plot at each survey date, 1984 and 1990. All harvested plots were clearcut, and the data give an estimate of the plot's harvest date and timber volume at harvest for plots that were harvested during the period between the two surveys. Confidentiality agreements with the landowners prevent the identification of the owner of any sampled plot or any of the owner's characteristics. Because of the confidentiality agreements the data on the latitude and longitude of each FIA sample plot are only available to the nearest one hundred seconds (about 1.9 miles).

Timber Market Data

Price data is taken from Timber Mart South's monthly survey of timber prices in the North Carolina coastal plain. The calculations use stumpage prices, the price paid to the timber owner are net of harvesting and transportation costs. All prices are expressed in real 1987 dollars. There are five product classes: three for pine (pulpwood, chip and saw, sawtimber) and two for the small amount of hardwoods in these pine stands, classified as pulpwood and sawtimber.

TIMBERVALUE and NMB are calculated the following way. For the i^{th} plot, let Q_{ijt} be the timber volume by product class j at time t and P_j be the price for class j in 1984, the beginning of the sample period. Let V_{it}, be the value of i^{th} stand at time t is

(A-2) $$V_{it} = \sum_{j=1}^{5} \left[Q_{ijt} P_j \right].$$

TIMBERVALUE is simply the formula given by (A-2) calculated using the initial survey parameters. Using (A-2) it is straightforward to calculate MB and MC. We let t^* be the year of harvest (or

1990, the year of the second survey for unharvested stands), so the marginal benefit of waiting to harvest for the ith stand, MB_i, is

(A-3) $$MB_i = \frac{V_{i,t^*} - V_{i,t=1984}}{t^* - 1984}.$$

The formula in (A-3) replicates the left-hand side of the optimality condition for the optimal age at harvest. In a similar way, the marginal cost of not cutting a stand this year, MC_i, -- the foregone return on the present value of the existing stand and its site value -- is calculated as

(A-4) $$MC_i = r\left(V_{i,t^*} + \frac{V_{i,t^*}}{e^{rt^*} - 1}\right),$$

where r is the market interest rate [As is the common practice in the forestry literature we use an interest rate of 4%] The formula in (A- 4) replicates the right-hand side of the optimality condition for the optimal age at harvest. Our variable NMB, the net marginal benefit of additional growth, is simply $NMB_i = MB_i - MC_i$.

North Carolina State University (NCSU) Data

The School of Forestry and the College of Agriculture and Life Sciences at North Carolina State University conducted the survey in the fall of 1997. Eleven counties were selected in the Coastal Plain and Sandhills that have similar distributions of forest cover but different concentrations of RCWs. The five Sandhills counties (Cumberland, Hoke, Moore, Richmond, and Scotland) have high numbers of RCWs and are home to public lands that support large populations (Fort Bragg and the Sandhills Game Lands). The six selected counties in the coastal plain (Bladen, Brunswick, Columbus, Jones, Onslow, and Pender) have relatively low numbers of RCWs. Two hundred non-industrial landowners within each county were randomly selected from property tax records. Using the tax map for each county, we were able to locate each of the 2,200 survey recipients' properties within a one to two square mile area and estimate a latitude and longitude for each sample point. The survey's random sample of property owners contrasts with the FIA data's random sample of points in the forest. Thus, small property owners are likely to be more represented in the survey data than in the FIA data. Non-response bias is an important concern in a survey of this type, but is difficult to detect given the limited information about non-respondents. Response rates in the Sandhills counties, where RCWs occur in greater numbers, were about 3% higher than the Coastal Plain. However, a probit analysis of respondents and non-respondents shows no statistically significant relationship between response rate and RCW proximity.

Red-Cockaded Woodpecker Colony Location Data

The North Carolina Natural Heritage Foundation is a cooperative effort between the Nature Conservancy and the State of North Carolina. The U.S. Fish and Wildlife Service does not maintain a comprehensive database of all locations. In the Natural Heritage data, the latitude and longitude of each colony is recorded along with the most recent date of observation. The latitude and longitude in the Natural Heritage data are to the nearest second, much more precise than the approximate locations determined for the FIA (nearest 100 seconds) and survey (within 1-2 square miles from tax maps, similar in precision to the FIA data) sample points. The data is compiled from all known sources of RCW location data, including academic, private and public agency biologists who share information collected through their own work and research. (The Natural Heritage Program is described at http:/ils.unc.edu/parkproject/nhp/index.html.)

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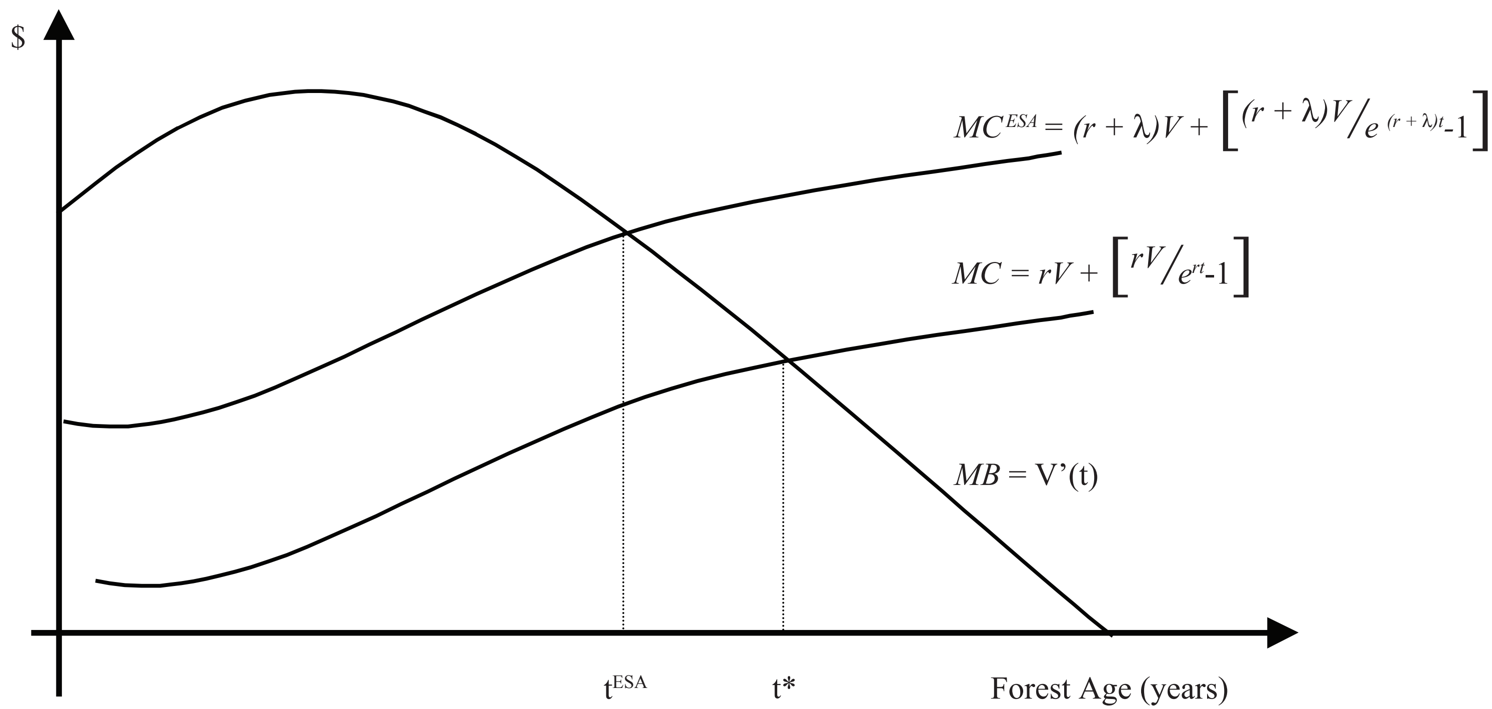

FIGURE 1. OPTIMAL HARVEST AGE WITH AND WITHOUT ESA REGULATIONS

Figure 2: Washington and Oregon Timber Harvests by Owner Class 1965-1996

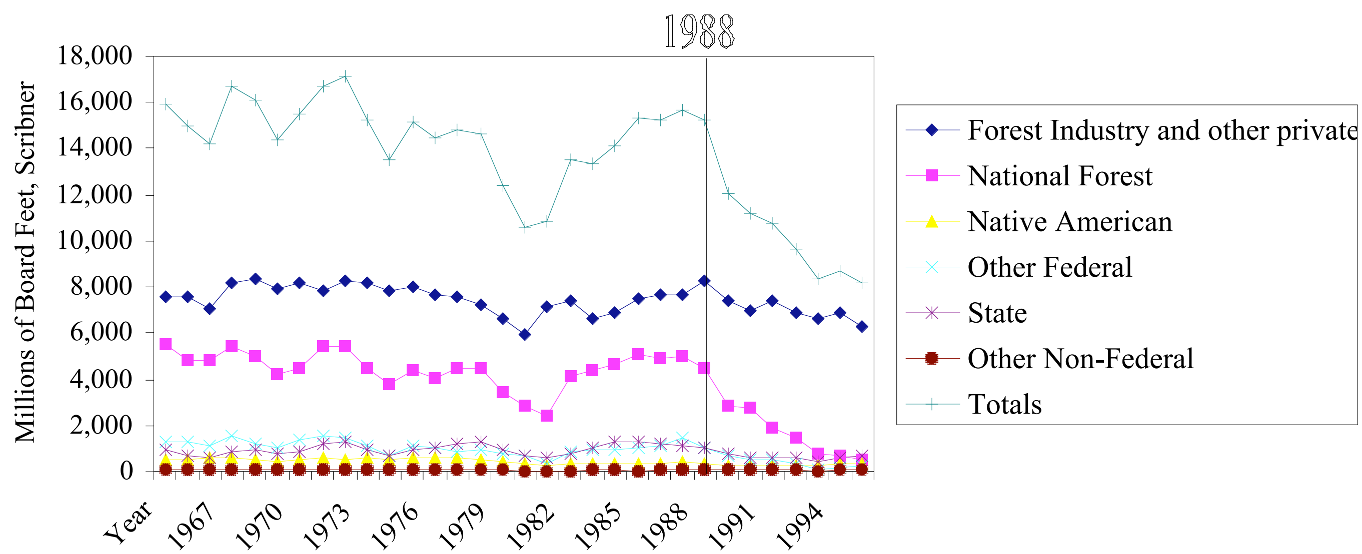

TABLE 2. TIMELINE OF SIGNIFICANT EVENTS IN RCW MANAGEMENT POLICY.

YEAR	EVENT
1968	The RCW is identified by the FWS as rare and endangered
1970	The RCW is listed as an endangered species under the Endangered Species Conservation Act of 1969
1971	The first RCW symposium is attended by forty people. The 18 papers form the basis of future RCW management.
1973	The Endangered Species Act is passed and the RCW is one of the original listed species.
1975	A five-member team is appointed to draft the first RCW recovery plan.
1979	After four years of contentious negotiations with environmentalists, the timber industry, and the U.S. Forest Service, the FWS approves the first RCW recovery plan.
1983	The second RCW symposium attracts 150 participants and 32 papers. The research shows RCW numbers continuing to decline on both public and private lands.
1985	The RCW recovery plan is revised with a substantial strengthening of the habitat guidelines.
1987	Florida construction company CEO receives 2 years probation and $1 million in fines, court costs, and mitigation expenses for killing 2 RCWs and cutting 200 cavity trees that interfered with a proposed 4,500 home residential development.
1988	Environmental groups in Texas (Sierra Club, Wilderness Society and others) sue the Forest Service over RCW management practices in Texas. Environmental groups secure major victory, forcing the Forest Service to revise its management plans throughout the Southeast.
1989	"Blue Book Guidelines" issued by FWS which are a more detailed version of the 1985 recovery plan. First formal statement that failing to follow foraging habitat recommendations and subsequent loss of a colony would be evidence of a "take" violation.
1991	Ben Cone incident draws media attention to the cost and incentives of the ESA for private landowners.
1992	FWS prepares a draft RCW manual for private lands with large reductions in the habitat requirements for private landowners. The draft is widely circulated and eventually becomes the new standard for RCW management on private lands.
1993	The third RCW symposium attracts 310 participants and 65 papers. RCW numbers appear to have stabilized on public lands, but continue to decline on private lands.
1995	FWS begins the first "Safe Harbor" program in the NC Sandhills.
1995	In *Babbit vs. Sweet Home*, the Supreme Court accepts habitat alteration as a "take" violation, thus preserving the basis for the FWS habitat guidelines for the RCW.
2001	Safe Harbor plans increase greatly. Statewide plans exist in Texas, South Carolina, and Georgia, and draft plans are being negotiated in many other areas.
2003	Fourth RCW symposium held in Savannah, GA.
2003	Second revision of RCW Recovery Plan is approved and released. Reaffirms commitment to private landowner flexibility (in place since 1992), with little change to minimum habitat requirements. Notes that nearly 50% of known RCWs on private lands are now under Safe Harbor or other HCP agreements, and that private land populations are showing signs of stabilizing.

Information from Meier (1995), Jackson (1995), Environmental Defense Fund (1995), McFarlane (1992), and Costa (1997).

TABLE 5. TIMELINE OF SIGNIFICANT EVENTS IN SPOTTED OWL MANAGEMENT POLICY.

Date	*Event*
1972	Eric Forsman began his study on the spotted owl at Oregon State and made the first recommendation to the FS and BLM to proceed cautiously in harvesting over-mature Douglas fir.
1973	The FS and the BLM reject the Task Force's recommendations including temporary protection for the NSO.
1981	A final Environmental Impact Statement (EIS) for the BLM's proposed Coos Bay district plan, the proposed old growth set-asides would result in a 7% reduction in the allowable cut in the Coos Bay district.
1982	The FWS published a list of "Sensitive Species" in which the spotted owl was included.
1986	The two-volume Draft SEIS was released for public review and a final SEIS was issued in April 1988 which recommended a 5% reduction in timber supplied from the national forests.
1987	Green World sent a petition to list the spotted owl as endangered to the FWS. The FWS denied the petition. Acting on behalf of 25 environmental organizations, Sierra Club Legal Defense Fund filed suit on May 6, 1988 contesting the FWS's action of not listing the owl. *Northern Spotted Owl v. Hodel* was filed and decided on November 17, 1988.
1987	The FWS and the FS sign an Interagency Agreement. It included the BLM and National Park Service in August 1988.
1987	*Portland Audubon Society, et al v. Lujan* was filed and resulted in an injunction against timber harvesting in NSO habitat because the BLM had not completed an EIS as required by NEPA.[6]
1988	The Washington Wildlife Commission declared the northern spotted owl as a state-listed endangered species.
1988	The Washington Wildlife Commission filed an administrative appeal of the Loner Elk timber sale in the Olympic National Forest. In August they requested that the Mt. Baker-Snoqualmie National Forest defer sales in owl habitat until additional surveying could take place. The FS denied this request.
1989	A timber industry coalition and a coalition of sixteen environmental groups filed separate appeals of the Chief's decision on the final EIS to increase the amount of habitat to be protected in a spotted owl habitat area on the Olympic Peninsula to 3000 acres within 2.1 miles of a nest. On February 3, Assistant Secretary of Agriculture John Dunlop denied the appeals.
1989	The Seattle Audubon Society and five other environmental groups filed suit in Seattle, *Seattle Audubon Society v. Robertson*. At the same time, the Western Washington Commercial Forest Action Committee filed in Portland against the FS decision, and on March 2 the Washington Contract Loggers Association filed in Seattle.
1989	*Seattle Audubon Society v. Robertson*. In mid-March, Seattle District Court Judge William Dwyer granted a temporary restraining order on 139 planned FS timber sales and in May he extended the injunction indefinitely.
1989	The FWS decides to propose that the owl be listed as a threatened species under the Endangered Species Act.
1990	The FWS listed the Northern spotted owl as threatened under the Endangered Species Act.
1991	*Northern Spotted Owl v. Lujan.* The court ordered the FS to designated critical habitat for the spotted owl.
1993	President Clinton hosts forest conference in Portland, Oregon, the "forest summit" and later directs the USFS and BLM to develop a management plan for the 19.4 million acres of National Forest and 2.7 million acres of BLM land in the region that will be "scientifically sound, ecologically credible, and legally responsible."
1993	*Portland Audubon Society v. Babbitt* results in an injunction against timber sales on BLM lands until the BLM prepared an EIS which considered the impacts of logging on the spotted owl.[6]
1994	The FS and BLM adopt a joint management plan for old growth forests in western WA and OR and northern CA. The plan was challenged but the court upheld it in *Seattle Audubon Society v. Lyons*.
1994	*Lane County Audubon v. Dombeck* was decided and resulted in an injunction against further timber sales in northern spotted owl territory.
1994	Montgomery, Brown and Adams study published in the *Journal of Environmental Economics and Management*.

Sources: Bean, Michael J. and Rowland Melanie J. The Evolution of Natural Wildlife Law, Westport, CT: Praeger, 1997. Yaffee, Steven Lewis. The Wisdom of the Spotted Owl, Washington D.C.: Island Press, 1994. See Appendix B for further details.

TABLE 6: ALLOCATION OF FEDERAL LAND FOR SPOTTED OWL HABITAT

Acres by Ownership	U.S. Forest Service	BLM	National Park Service	Other Federal	Non-Federal
Washington	6,914,000	0	1,788,500	136,600	12,494,900
Oregon	7,059,800	2,329,000	164,300	11,000	11,830,400
California	5,426,800	331,900	77,500	20,600	8,416,700
Three State Total	19,400,600	2,660,900	2,030,300	168,200	32,742,000

Federal Land Acres	Total	Congressionally Withdrawn Areas	Administratively Withdrawn Areas
Washington	8,839,200	4,201,600	1,261,800
Oregon	9,564,200	1,428,200	1,273,000
California	5,857,300	1,353,300	1,510,600
Three State Total	24,260,700	6,983,100	4,045,400

Federal Forest Acres	Total	Congressionally Withdrawn Areas	Administratively Withdrawn Areas
Washington	7,023,200	3,326,500	984,100
Oregon	8,950,500	1,285,800	1,152,200
California	4,484,300	1,064,200	1,147,700
Three State Total	20,458,000	5,676,500	3,284,000

TABLE 1: MAJOR ENDANGERED SPECIES ON FOREST LAND IN THE UNITED STATES

SPECIES	FIRST LISTING	LOCATION IN U.S.	HABITAT; AREA REQUIREMENT	LAND USE CONFLICTS, THREATS TO THE SPECIES	POPULATION ESTIMATE
Kirtland's Warbler (E)	1967	MI	Large stands of young jack pine	Development and fire suppression	1,050 singing male warblers counted in the 2002 census
Delmarva Peninsula Fox Squirrel (E)	1967	DE, MD, VA	Mature loblolly pine and oak open forests	Timber harvest, short-rotation pine forestry, and conversion to agriculture	Not available
Indiana bat (E)	1967	AL,AR,GA, IO, IL, IA, KA, KT, MD, MI, MO, MS, NC, NJ, NY, OH, OK, PN, SC, TNVA, VT, WV	River corridors with well developed riparian woods; Foraging areas average 11.2 acres per animal	Commercialization, destruction and vandalism of caves	500,000 individuals
Gray Wolf (E, T in MN)	1967	CO, ID, MI, MT, ND, SD, WA, WI, WY, MN	Northern forested areas	Intensive settlement, conflict with domestic livestock	3,000 wolves
Grizzly Bear (T)	1967	ID, MT, WA, WY	Forest	Habitat loss and conflicts with humans	Not available
Red-Cockaded Woodpecker (E)	1970	S-Cen. & SE. U.S.	Open stands of pine and pine hardwood stands; 80-125 acres per pair	Intense logging for lumber and agriculture, and fire suppression	10,000-12,000 birds
Ozark big-eared bat (E)	1979	AR, MO, OK	Caves in mature hardwood forests	Habitat loss and disturbance and vandalism of their caves	1,800 individuals
Woodland Caribou (E)	1983	ID, WA	Old-growth spruce and hemlock forests	Timber management and recreation	50 caribou
Carolina Northern Flying Squirrel (E)	1985	NC, TN	Transition zones between coniferous and northern hardwood forests; 2-7 ha	Clearing of forests, logging, mineral extraction, and development	No estimates are available, the species seems to be very rare
Virginia Northern Flying Squirrel (E)	1985	VA, WV	Northern hardwood forests	Habitat destruction from forest clearing, development and mineral extraction	No estimates are available
Least Bell's Vireo (E)	1986	CA	Willow dominated riparian habitats	Destruction of riparian woodlands	291 breeding males
Mount Graham Red Squirrel (E)	1987	AZ	Spruce-fir and old growth Douglas-fir forests	Logging, recreational development	380-400 individuals
Golden-cheeked Warbler (E)	1990	TX	Mature Ashe juniper and deciduous hardwoods	Clearing for agriculture, urbanization, development	4,822-16,016 pairs
Northern Spotted Owl (T)	1990	CA, OR, WA, Canada (B.C)	Old-growth Douglas Fir forests; 2,500-5,000 acres per pair	Logging and natural disasters	3,000-6,000 pairs and declining at 5% per year
Louisiana Black Bear (T)	1992	LA, MS, TX	Hardwood forests found in river basin habitats	Habitat destruction, fragmentation, and conversion to cropland	780 bears
Marbled Murrelet (T)	1992	AK, CA, OR, WA	Coastal coniferous forests including Douglas-firs	Commercial timber harvest, forest management practices, and development	Not available
Mexican Spotted Owl (T)	1993	AZ, CO, NM, TX,UT	Mature old-growth stands, mixed conifer forests, forested mountains, rocky canyons	Habitat alteration from timber management practices, especially even-aged silviculture	Not available
Southwestern Willow Flycatcher (E)	1995	AZ, CA, CO, NM, NV, TX, UT; Central America	Woodlands along streams and rivers	Urban, recreational, and agricultural development	300-500 pairs
Canada Lynx (T)	2000	CO, ID, ME, MI, MN, MT, NH, NY, OR, UT, VT, WA, WI, WY	An interspersion of young and mature deep-snow, high elevation evergreen forests; home ranges vary from 16-20 km^2	Lack of guidance to conserve the species in current Federal land management plans	Not available

E = endangered species. T = threatened species. Source: The United States Fish and Wildlife Service, http://endangered.fws.gov/wildlife.html#Species , the species' Recovery Plans, Habitat Conservation Plans, and the petitions to list a species. For more detailed species information see Appendix A: A Detailed Species' Account.

TABLE 7: MEAN ANNUAL TIMBER HARVEST IN THE PACIFIC NORTHWEST BEFORE AND AFTER SPOTTED OWL PRESERVATION

PLACE/PERIOD	INDUSTRY	USFS	BIA	BLM	STATE	OTHER PUBLIC	TOTAL
OREGON							
1978-88	3,259	2,982	112	889	228	30	7,500
1989-96	3,393	1,426	91	448	129	33	5,519
% change	+3.9	-52.2	-18.8	-50.4	-43.4	+10.0	-26.4
WASHINGTON							
1978-88	3,865	1,175	276	22	811	27	6,176
1989-96	3,716	485	212	10	549	25	4,996
% change	-3.9	-58.7	-23.2	-54.5	-32.3	-7.4	-19.1
NORTHWEST							
1978-88	7,124	4,157	389	910	1,038	57	13,675
1989-96	7,109	1,911	302	457	678	58	10,515
% change	-0.01	-54.0	-22.4	-49.8	-34.7	+1.8	-23.1

* All timber harvest numbers are mean annual harvest rates by owner class are in millions of board feet, Scribner. (For Washington, BLM means "other federal" lands besides USFS).

TABLE 3A. DESCRIPTIVE AND SUMMARY STATISTICS, FIA DATA 1984-1990

VARIABLE NAME	DEFINITION	Minimum	Maximum	Mean	Standard Deviation	Observations
Dependent Variables:						
HARVESTAGE	Age of forest at the time of harvest.	7	136	47.9	19.8	385
Exogenous Variables:						
Timber Market Variables						
NMB	Net marginal benefit of additional year of growth.	-196.91	581.43	-6.43	38.47	1199
TIMBERVALUE	Value of timber on plot in 1984.	1.05	5513.43	676.76	801.43	1199
ESA Variables						
RCW-10	Number of RCW colonies within 10 miles of a plot.	0	326	12.5	40.2	1199
RCW-15	Number of RCW colonies within 15 miles of a plot.	0	526	28.0	77.6	1199
Timber Stand Variables						
INDUSTRY	= 1 if landowner is industrial firm; = 0 if a non-industrial private firm.	0	1	0.29	0.46	1199
SITEINDEX	Timber site productivity (height of a 50-year old stand in feet).	30	120	70.1	13.3	1199
STANDAGE	Age of forest stand in 1984.	1	130	31.5	20.2	1199
LONGLEAF	= 1 if longleaf pine is the dominant species; = 0 if not.	0	1	0.04	0.20	1199
LOBLOLLY	= 1 if loblolly pine is the dominant species; = 0 if not.	0	1	0.55	0.50	1199
POND PINE	= 1 if pond pine is the dominant species; = 0 if not.	0	1	0.13	0.33	1199
OAKPINE	= 1 if pine with oak under-story is the dominant forest; = 0 if not.	0	1	0.23	0.42	1199
SLASH	= 1 if slash pine is the dominant species; = 0 if not.	0	1	0.043	0.20	1199

TABLE 3B. DESCRIPTIVE AND SUMMARY STATISTICS, NCSU DATA 1993-1997

VARIABLE NAME	DEFINITION	Minimum	Maximum	Mean	Standard Deviation	Observations
Dependent Variables:						
HARVESTAGE	Age of forest at the time of harvest in years.	12	200	43.97	22.44	204
Exogenous Variables:						
Timber Market Variables						
TIMBER IMPORTANCE	Index of timber versus recreation importance to landowner.*	-6	6	1.68	2.55	379
ESA Variables						
RCW-10	Number of RCW colonies within 10 miles of a plot.	0	330	34.95	65.43	520
RCW-15	Number of RCW colonies within 15 miles of a plot.	0	530	86.31	130.49	520
Timber Stand Variables						
ACRES	= number of acres of softwood (pine) forest owned.	26	12000	183.59	606.84	530
RESIDE	= 1 if owner resides on the tract; = 0 if not.	0	1	0.27	0.44	517
QUAIL	= 1 if owner hunts quail on the tract; = 0 if not.	0	1	0.27	0.44	520
STRAW	= 1 owner generates income from pine straw; = 0 if not.	0	1	0.06	0.24	530

* Respondents were asked to rate the importance of timber production and recreation on a 7 point scale where 1 represents "low priority" and 7 represents "high priority." This variable is the difference between the rating for timber production and recreation. For example, the maximum value of 6 means a landowner rated timber production as a 7, and recreation as a 1.

TABLE 4A: OLS & CENSORED REGRESSION ESTIMATES OF THE AGE AT HARVEST, 1984-1990

Dependent variable = *HARVESTAGE*

	OLS REGRESSION				CENSORED REGRESSION			
Exogenous Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CONSTANT	36.46***	36.46***	53.10***	53.01***	66.109	66.156	79.379	79.339
	(5.67)	(5.67)	(5.59)	(5.58)	(5.458)***	(5.460)***	(5.253)***	(5.253)***
Timber Market Variables:								
NMB	-0.174***	-0.174***			-0.046	-0.460		
	(0.024)	(0.024)			(0.183)**	(.0183)**		
TIMBER VALUE			0.013***	0.013***			0.0094	0.0094
			(0.0011)	(0.0012)			(.0011)***	(.0011)***
ESA Variables:								
RCW-10	-0.021		-0.0084		-0.039		-0.029	
	(0.021)		(0.019)		(.0204)**		(0.182)*	
RCW-15		-0.011		-0.0032		-0.0120		-0.0140
		(0.011)		(0.010)		(.0107)**		(.0096)*
Timber Stand Variables:								
INDUSTRY	-5.218***	-5.27***	-2.921	-2.906	-5.634	-5.711	-2.544	-2.591
	(2.308)	(2.315)	(2.15)	(2.16)	(2.074)***	(2.078)***	(1.878)	(1.803)
SITEINDEX	1.79***	1.80***	-1.63***	-1.62***	-0.718	-0.713	-3.651	-3.638
	(0.750)	(0.749)	(0.797)	(0.796)	(.7103)	(.7100)	(.0745)***	(.0745)***
LOBLOLLY PINE	-7.66***	-7.65***	-12.17***	-12.17***	-0.522	-0.505	-4.199	-4.182
	(2.11)	(2.11)	(2.00)	(2.00)	(2.091)	(2.090)	(1.899)**	(1.899)**
LONGLEAF PINE	9.67**	9.38**	5.22	4.95	14.042	13.721	8.824	8.499
	(4.94)	(4.85)	(4.60)	(4.51)	(4.663)***	(4.612)***	(4.218)**	(4.177)*
PONDPINE	-0.340	-0.326	-3.914	-3.901	3.129	3.108	-0.551	-0.554
	(3.07)	(3.06)	(2.87)	(2.87)	(2.964)	(2.964)	(2.690)	(2.690)
SLASH PINE	-14.322***	-14.368***	-15.816***	-15.94***	-4.914	-4.884	-6.127	-6.164
	(6.283)	(6.278)	(5.80)	(5.79)	(5.143)	(5.144)	(4.601)	(4.603)
Observations	385	385	385	385	1199	1199	1199	1199
R^2	.2399	.2399	.3509	.3507				
Log-likelihood					-1963.08	-1963.17	-1936.51	-1936.71

Note: Standard errors in parentheses. ***, **, * statistically significant at the 1%, 5%, & 10% levels respectively, 1-tailed test for predicted coefficients (ESA variables).
Lueck & Michael [2003] is the source for the censored regression estimates.

TABLE 4B: OLS & CENSORED REGRESSION ESTIMATES OF THE AGE AT HARVEST, 1993-1997

Dependent variable = *HARVESTAGE*

	OLS REGRESSION				CENSORED REGRESSION			
Exogenous Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CONSTANT	51.62***	50.269***	54.030***	53.421***	78.974***	77.889***	78.834***	78.514***
	(5.80)	(5.925)	(5.632)	(5.757)	(4.963)	(5.022)	(4.748)	(4.832)
Timber Market Variables:								
TIMBER IMPORTANCE	-2.211*	-1.841	-2.732**	-2.331*	-3.730***	-3.752***	-3.974***	-3.966***
	(1.688)	(1.695)	(1.629)	(1.624)	(1.161)	(1.158)	(1.109)	(1.103)
ESA Variables:								
RCW-10	-0.101**		-0.105**		0.0107		-0.0190	
	(0.0535)		(.0513)		(0.0408)		(0.0389)	
RCW-15		-0.0337		-0.0451**		0.0167		-0.00438
		(0.0277)		(0.0267)		(0.0208)		(0.0201)
*RCW-10*STRAW*			4.616***				2.714*	
			(1.766)				(1.742)	
*RCW-15*STRAW*				0.438***				0.297**
				(0.158)				(0.130)
Timber Stand Variables:								
ACRES	0.000124	-0.000035	0.000204	0.0000512	-0.00359*	-0.00346*	-0.00275	-0.00267
	(0.00218)	(0.00222)	(0.00209)	(0.00211)	(0.00240)	(0.00240)	(0.00225)	(0.00225)
RESIDE	19.221***	19.049***	15.510**	15.314**	9.411*	9.245*	9.481**	9.120*
	(6.944)	(7.081)	(6.802)	(6.878)	(5.956)	(5.938)	(5.693)	(5.645)
STRAW	7.414	9.733	-23.345	-16.678	24.003**	23.168**	-3.754	-3.412
	(13.777)	(13.902)	(17.684)	(16.327)	(10.749)	(10.796)	(13.368)	(12.461)
Observations	71	71	71	71	320	320	320	320
R^2	0.153	0.127	0.235	0.220				
Log-likelihood					-394.169	-393.875	-388.471	-388.215

Note: Standard errors in parentheses. ***, **, * statistically significant at the 1%, 5%, & 10% levels respectively, 1-tailed test for predicted coefficients.