PREEMPTIVE HABITAT DESTRUCTION UNDER THE ENDANGERED SPECIES ACT*

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Abstract

This paper examines the extent to which landowners have preemptively destroyed habitat for the endangered red-cockaded woodpeckers (RCWs) in the forests of North Carolina in order to avoid potential land-use regulations prescribed under the Endangered Species Act (ESA). Under the ESA, it is illegal to kill an endangered species and it is also illegal to damage its habitat. By preventing the establishment of an old-growth pine stand, landowners can ensure that RCWs do not inhabit their land and avoid ESA regulations that limit or prohibit timber harvest activity. Data from 1984–90 on over 1,000 individual forest plots are used to test predictions about the probability of harvest and the age of timber when it is harvested. We find that increases in the proximity of a plot to RCWs increases the probability that the plot will be harvested and decreases the age at which the forest is harvested.

> [T]he highest level of assurance that a property owner will not face an ESA issue is to maintain the property in a condition such that protected species cannot occupy the property. . . . This is referred to as the "scorched earth" technique. [National Association of Home Builders, Developer's Guide to Endangered Species Regulation (1996)]

I. Introduction

IT is no secret that firms will take action, both legal and illegal, to avoid costly laws and regulations. When regulations or their implementation are

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anticipated, firms can avoid them by "preempting" the implementation and enforcement of agencies. In this paper, we study the efforts of landowners to avoid potentially costly land-use regulations implemented under the Endangered Species Act of 1973 (ESA). We do this by examining how forest harvest practices in North Carolina are affected by the possibility that the endangered red-cockaded woodpecker might inhabit a parcel stocked with valuable timber. The objective of this paper is to estimate the extent to which landowners have preemptively destroyed woodpecker habitat in order to avoid potential regulation under the ESA.

Although many of the high-profile conflicts over the ESA have involved public land management (for example, the snail darter in Tennessee and the northern spotted owl in the Pacific Northwest), the majority of endangered and candidate species reside on private land.[1] For private land, Sections 9 and 3 of the ESA are the most important. Section 9 makes it unlawful to take any endangered species of fish and wildlife within the jurisdiction of the United States, and Section 3 defines "take" to mean "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect." The Interior Secretary further defines "harm"[2] as that "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." In a crucial case, *Babbitt v. Sweet Home*, the Supreme Court upheld the view that "take" includes habitat alteration.[3] Thus, under the ESA, through a combination of administrative decisions and court rulings,[4] not only is it illegal to destroy an endangered species, but it is also illegal to damage their habitat.

By linking "take" to "harm" and by defining "harm" to include habitat alteration, the ESA becomes a land-use regulation. Even so, the ESA is not like a typical zoning statute because its application is contingent on the presence of a listed species and does not simply apply to an explicit geographical zone. If a listed species inhabits a plot of land, the landowner is clearly subject to the ESA such that habitat modification would violate the ESA under Section 9.[5] Still, if a landowner has habitat suitable for the

[1] General Accounting Office, Endangered Species Act: Information on Species Protection on Nonfederal Lands (1994).

[2] 40 Fed. Reg. 44412, 44416 (1975).

[3] Babbitt v. Sweet Home Communities, 515 U.S. 687 (1995).

[4] This legal and administrative history is discussed in Dean Lueck, The Law and Politics of Federal Wildlife Preservation, in The Politics of Environmentalism: Going behind the Green Curtain 61 (Terry L. Anderson ed. 2000); and Jason Shogren, Private Property and the Endangered Species Act: Saving Habitats, Protecting Homes (1998).

[5] Landowners, of course, might still choose to damage habitat and face the expected penalties. Section 11 provides for fines up to $50,000 and 1 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. See Michael J. Bean & Melanie J. Rowland, The Evolution of National Wildlife

species—perhaps even identical to land inhabited by the species—but presently the species does not inhabit his land, he is not subject to the habitat modification restriction. Such habitat could potentially attract individuals of the species from a mobile, nearby population and thus may ultimately be subject to land-use 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.

The possibility of preemptive habitat destruction has been noted by many students of the ESA, including biologists, bureaucrats, economists, environmentalists, and lawyers.[6] There have been a number of theoretical studies of the ESA by economists[7] and legal scholars.[8] These studies typically derive optimal compensation systems under a variety of conditions, and nearly all discuss preemption to some degree. There are a few published empirical studies of the ESA, but none of these examine preemption.[9]

Systematic studies of the occurrence and extent of preemption may be

Law (2d ed. 1997); and Daniel J. Rohlf, The Endangered Species Act: A Guide to Its Protections and Implementation (1989). Landowners also may simply ignore the law and eliminate any endangered species currently residing on their land before government officials can react. The well-known acronym for this behavior—SSS—stands for "shoot, shovel, and shut up." For some cases see Maura Dolan, Nature at Risk in a Quiet War, L.A. Times, December 20, 1992, at 1A.

[6] For example, Dolan *supra* note 5; Richard Epstein, Babbitt v. Sweet Home: The Law and Economics of Habitat Preservation, 5 Sup. Ct. Econ. Rev. 1 (1997); Elizabeth T. Kennedy, Ralph Costa, & Webb M. Smathers, Jr., New Directions for Red-Cockaded Woodpecker Habitat Conservation: Economic Incentives, 94 J. Forestry 22 (1996); Charles I. Mann & Mark L. Plummer, Noah's Choice: The Future of Endangered Species (1995); Timothy J. Riddiough, The Economic Consequences of Regulatory Taking Risk on Land Value and Development Activity, 41 J. Urban Econ. 56 (1997); J. B. Ruhl, The Endangered Species Act and Private Property: A Matter of Timing and Location, 8 Cornell J. L. & Pub. Pol'y 37 (1998); Shogren, *supra* note 4; Richard L. Stroup, The Economics of Compensating Property Owners, 15 Contemp. Econ. Pol'y 55 (1997); Barton H. Thompson, Jr., The Endangered Species Act: A Case Study in Takings and Incentives, 49 Stan. L. Rev. 305 (1997); and David S. Wilcove *et al.*, Rebuilding the Ark: Toward a More Effective Endangered Species Act for Private Land (1996).

[7] See, for example, Robert Innes, Stephen Polasky, & John Tschirhart, Takings, Compensation and Endangered Species Protection on Private Lands, 12 J. Econ. Persp. 35 (1998); Stephen Polasky & Holly Doremus, When the Truth Hurts: Endangered Species Policy on Private Land with Incomplete Information, 35 J. Envtl. Econ. & Mgmt. 22 (1998); and Shogren, *supra* note 4.

[8] Epstein, *supra* note 6; and Thompson, *supra* note 6.

[9] See, for example, Amy Whritenour Ando, Waiting to Be Protected under the Endangered Species Act: The Political Economy of Regulatory Delay, 42 J. Law & Econ 29 (1999); Jeffrey J. Rachlinski, Noah by the Numbers: An Empirical Evaluation of the Endangered Species Act, 82 Cornell L. Rev. 326 (1997); and Jeffrey J. Rachlinski, Protecting Endangered Species without Regulating Private Landowners: The Case of Endangered Plants, 8 Cornell J. L. & Pub. Pol'y 1 (1998). Daowei Zhang, Endangered Species and Timber Harvesting: The Case of Red Cockaded Woodpeckers (unpublished manuscript, Auburn Univ., Sch. Forestry & Wildlife Sci. 2002) is similar to our study.

rare, but anecdotes abound. Michael Bean[10] and Lee Ann Welch[11] note how some forest landowners have harvested mature southern pine[12] in order to avoid inhabitation of their land by the red-cockaded woodpecker. A notable case is that of North Carolina landowner Ben Cone, who dramatically increased his harvest of old-growth pine in response to potential ESA regulations and who became famous for his confrontations with Fish and Wildlife Service (FWS) and for his lawsuit that settled out of court.[13] In Texas, Charles Mann and Mark Plummer report habitat destruction for the golden-cheeked warbler, and J. B. Ruhl reports the same for the black-capped vireo.[14] Albert Gidari finds evidence of clear-cutting in the Pacific Northwest in order to avoid logging restrictions designed to protect the northern spotted owl.[15] In California, and other areas where land development values are high, Maura Dolan finds similar cases.[16] As the epigraph shows, the National Association of Home Builders actually advises preemption, or what it calls "scorched earth" management. Bean and Brian Seasholes document other cases of preemptive habitat destruction.[17]

With the possibility of preemptive habitat destruction, the ESA might actually cause a long-run reduction in the habitat and population of a listed species.[18] This possibility has led many, including economists, environmentalists, landowners, and lawyers to criticize the so-called perverse incentives inherent in the ESA. Economic and legal scholars, in particular, have pointed out that these preemption incentives arise because the ESA does not provide compensation to landowners whose land uses are restricted.[19] Others, however, dismiss preemption as prevailing in only a few isolated, and even

[10] Michael J. Bean, The Endangered Species Act and Private Land: Four Lessons Learned from the Past Quarter Century, 28 Envtl. L. Rep. 10701 (1998).

[11] Lee Ann Welch, Property Rights Conflicts under the Endangered Species Act: Protection of the Red-Cockaded Woodpecker, in Land Rights: The 1990s Property Rights Rebellion, chap. 5 (Bruce Yandle ed. 1995).

[12] "Southern pine" refers to pine species native to the South including longleaf pine, loblolly pine, pond pine, and slash pine.

[13] See Robert Innes, The Economics of Takings and Compensation When Land and Its Public Use Value Are in Private Hands, 76 Land Econ. 195 (2000); Stroup, *supra* note 6; and Welch, *supra* note 11.

[14] Mann & Plummer, *supra* note 6; and Ruhl, *supra* note 6.

[15] Albert Gidari, The Endangered Species Act: Impact of Section 9 on Private Landowners, 24 Envtl. L. 419 (1994).

[16] Dolan, *supra* note 5.

[17] Bean, *supra* note 10; Brian Seasholes, Anecdotes on Perverse Incentives under the Endangered Species Act (1997).

[18] Preemption might also occur during the administrative process of considering a species for listing. See Ando, *supra* note 9; and Ruhl, *supra* note 6. Since the RCW was listed long before our data were collected, we do not examine this behavior.

[19] See, for example, David A. Dana, Natural Preservation and the Race to Develop, 143 U. Penn. L. Rev. 655 (1995); Epstein, *supra* note 6; Robert Innes, Takings, Compensation and Equal Treatment for Owners of Developed and Undeveloped Property, 40 J. Law & Econ. 403 (1997); Innes, *supra* note 13; Polasky & Doremus, *supra* note 7; and Stroup, *supra* note 6.

celebrated, cases, and they do not contend that it is a widespread phenomenon that suggests a rethinking of the ESA.[20]

Our purpose is to systematically examine preemptive behavior for a single endangered species that has a wide geographic dispersion and whose protection directly conflicts with commercial land uses. The case of the red-cockaded woodpecker (RCW) in North Carolina offers a test bed for such an analysis. First, the RCW has been a listed species for over 25 years, and its management has been one of the most contentious ESA conflicts involving private landowners. Second, RCWs require a specific habitat type—mature stands of southern pine—so habitat modification can successfully rid a landowner of potential ESA regulations. Our study area is comprised only of land that is potentially suitable habitat for RCWs so that we need not control for habitat quality. Third, RCW habitat is highly valued for timber, so ESA land-use restrictions can be quite costly. Finally, in our study area there are no other endangered species policies to confound the effects of the ESA on land-use decisions. This final point is especially important because many areas, especially in the western United States, have several endangered species sharing the same habitat (for example, marbled murrelets, salmon, and spotted owls share Pacific Coast forest habitat), so sorting out the effects attributed to a single cause would be difficult.

Our paper begins with an overview of RCW policy under the ESA. We then develop an economic model of forest harvest under regulatory uncertainty. Next we test the predictions of our model with microdata on forest landowners. In general, we find that increases in the probability of ESA land-use restrictions, as measured by a landowner's proximity to existing RCW colonies, increase the probability of forest harvest and decrease the age at which timber is harvested. The strength of our study lies in our ability to link forest landowner behavior to credible measures of the probability of ESA regulations that vary across landowners. We conclude the study by discussing the implications of our estimates for endangered species conservation policy.

II. The Endangered Species Act and the Red-Cockaded Woodpecker

The RCW (*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 nonmigratory, territorial woodpecker that resides primarily in southern pine ecosystems ranging from Texas to Florida to Virginia. Red-cockaded woodpeckers live in social units called clans or colonies, which consist of a single breeding pair,

[20] Robert W. McFarlane, A Stillness in the Pines: The Ecology of the Red-Cockaded Woodpecker (1992); and Rachlinksi, Protecting Endangered Species, *supra* note 9.

the current year's offspring, and several "helpers." Ralph Costa and Joan Walker estimate that in 1995 there were 4,694 surviving RCW colonies, 3,725 clans on public lands, and 969 clans on privately owned lands.[21] The basic features of RCW ecology and the ESA as enforced by the FWS create the potential for preemptive habitat destruction in North Carolina.[22]

With 371 colonies, the North Carolina Sandhills region—part of our study area—is home to the second largest RCW population 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 one-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 individual groups.[23] Timber harvesting directly reduces RCW habitat by eliminating the pine trees necessary for nesting and foraging habitat.

For our study, 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 nonmigratory, they are known to travel up to 15 miles to find new habitat or a mate.[24] Red-cockaded woodpeckers typically excavate nesting cavities in pines greater than 70 years old but have been known to nest in 40- to 70-year-old trees when older trees are not readily available.[25] 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 acres of

[21] Ralph Costa & Joan L. Walker, Red-Cockaded Woodpecker, in Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals and Ecosystems (Edward T. LaRoe *et al.* eds. 1995).

[22] Our information on RCWs and ESA policy draws from Environmental Defense Fund, Incentives for Endangered Species Conservation: Opportunities in the Sandhills of North Carolina (1995); McFarlane, *supra* note 20; Jeffrey A. Michael, The Endangered Species Act and Private Landowner Incentives (unpublished Ph.D. dissertation, N.C. State Univ. 1999); Welch, *supra* note 11; and a personal interview with the FWS's RCW coordinator, Ralph Costa (conversation with one author, September 9, 1997).

[23] Declining RCW populations in South Carolina between 1977 and 1989 result from hardwood encroachment (32.6 percent), Hurricane Hugo (27.4 percent), and timbering (21.0 percent), according to John Emmit Cely & D. Patrick Ferral, Status and Distribution of the Red-Cockaded Woodpecker in South Carolina, in Red-Cockaded Woodpecker: Recovery, Ecology and Management 470 (D. L. Kulhavy, R. G. Hooper, & R. Costa eds. 1995). Hugo did not affect North Carolina forests and is not relevant for this study. Development is not always harmful; golf courses, for instance, are often compatible with RCWs.

[24] Costa & Walker, *supra* note 21, estimates movement of 5–10 miles, while Hans Winkler, David A. Christie, & David Nurney, Woodpeckers: A Guide to the Woodpeckers of the World (1995), estimates up to 15 miles for males.

[25] Jerome A. Jackson, Michael R. Lennartz, & Robert G. Hooper, Tree Age and Cavity Initiation by Red-Cockaded Woodpeckers, 77 J. Forestry 102 (1979); Robert G. Hooper, Longleaf Pines Used for Cavities by Red-Cockaded Woodpeckers, 52 J. Wildlife Mngmt. 392 (1988); and Michael R. Lennartz *et al.*, Status of Red-Cockaded Woodpecker Nesting Habitat in the South, in Red-Cockaded Woodpecker Symposium II: Proceedings 13 (Don Wood ed. 1983).

pine forest are required for the nesting and foraging habitat of a single colony of RCWs.

The 1985 RCW Recovery Plan is the most important ESA policy guideline for the RCW. It required private landowners to protect between 60 and 300 acres per colony.[26] Using prices from the mid-1990s, cost estimates of forgone timber harvests from providing habitat for a single RCW colony (using 200 acres of mature pine forest) range from $30,000 to $200,000.[27] These estimates indicate that under the 1985 guidelines there was a potentially large financial incentive to preemptively harvest timber if there was a chance that RCWs may inhabit the land. 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. And in 1995, the FWS implemented its Safe Harbor program, which allows a landowner with RCWs to establish and protect a base population in return for no future land-use restrictions. The 1985 guidelines, with the largest habitat requirements, govern the period we study.

III. The Economics of Preemption under the Endangered Species Act

To analyze preemption under the ESA, we model the decision of a forest owner to harvest a stand of trees in a given period. The model leads to testable predictions concerning the behavior of forest owners when faced with potential land-use restrictions under Section 9 of the ESA. Our model is not a comprehensive model of the ESA; rather, it focuses on the basic incentives facing a landowner whose land is potential habitat for a currently listed species such as the RCW. The government agency simply enforces the regulations under the ESA. The model does not consider other landowner choices such as preemption during the listing process, the illegal taking/killing once the ESA is in force (for example, SSS), or land-use behavior that slowly deteriorates habitat and might thus be called passive preemption.

For our purposes, consider a two-period model with nature (N) and two agents—a forest landowner (L) and a government agency enforcing the ESA

[26] Michael R. Lennartz, & V. G. Henry, Red-Cockaded Woodpecker Recovery Plan (1985).

[27] See Robert Bonnie, An Analysis to Determine Opportunity Costs of Red-Cockaded Woodpecker Habitat Protection on Private Lands in the Sandhills of North Carolina, in Incentives for Endangered Species Conservation: Opportunities in the Sandhills of North Carolina (Environmental Defense Fund ed. 1995); D. R. Cleaves *et al.*, Costs of Protecting Red-Cockaded Woodpecker Habitat: Interaction of Parcel and Cluster Size (unpublished manuscript, U.S.D.A. Forest Service, Southern Region, New Orleans, 1994); and Richard A. Lancia *et al.*, Opportunity Costs of Red-Cockaded Woodpecker Foraging Habitat, 13 South. J. Applied Forestry 81 (1989). These studies of opportunity costs assume that a landowner maintains only the minimum habitat requirements. According to the guidelines, only the nesting habitat has to be old growth. The majority of acres are foraging habitat, which can be harvested to some extent, does not require old-growth trees, and can be used for lower-income products such as pine straw.

(the FWS).[28] Initially, the land harbors no endangered species, but it is potential habitat for an endangered species. The land's value as habitat (to the species) depends on the landowner's behavior. The landowner can choose to maintain (m) or destroy (d) potential habitat in period 1. The landowner has private information about the habitat value and has a clear first-mover advantage over the FWS because of this information and because of his ownership incentives as a landowner. In fact, the FWS cannot move before the landowner because a landowner without an endangered species is not subject to land-use restrictions. Destroying habitat has a one-time cost (C_D) and generates benefits (B_D) from development such as timber harvest. The term C_D is the cost of developing early, for example, harvesting timber before it has reached the optimal harvest age.

N moves after L and determines the population levels of an endangered species, which depend on the land-use choice made in period 1. If the habitat is destroyed, the probability that the endangered species inhabits the land is zero. If the habitat is maintained, there is a probability, $\gamma \in (0, 1)$, that a population of the species will inhabit the land because of migration from nearby populations.

The FWS moves in period 2 and will detect the presence of an existing endangered species with probability $\delta \in (0, 1)$. If FWS detects an endangered species, the ESA is invoked; FWS regulates land use (under Section 9) so that habitat cannot be altered and can perfectly enforce this regulation. Because FWS detection depends on the probability that an endangered species inhabits the land, the probability of the ESA being invoked is, assuming independent events, $\gamma\delta < 1$, and the probability that the ESA will not be invoked is $(1 - \gamma\delta) < 1$. If the ESA is invoked, the firm loses all benefits from development in period 2 ($B_D = 0$ in period 2) but may earn a smaller amount of benefits from an alternative land use ($B_A < B_D$).[29] If, however, L waits until period 2 to develop, he faces no costs of development ($C_D = 0$). In the absence of the ESA, it is clear that the optimal time to develop is in period 2 in order to avoid the extra costs of developing in period 1. L takes as given market prices (which determine the magnitudes of the various ben-

[28] Industrial organization models of preemption and entry deterrence are similar but tend to focus on commitment, such as Robert Wilson, Strategic Models of Entry Deterrence, in 1 Handbook of Game Theory with Economic Applications, chap. 10 (Robert J. Aumann & Sergiu Hart eds. 1992); John W. Maxwell, Thomas P. Lyon, & Steven C. Hackett, Self-Regulation and Social Welfare: The Political Economy of Corporate Environmentalism, 43 J. Law & Econ. 583 (2000), has a regulatory model that generates "political preemption" but not the perverse-incentive outcome as in our case. Thomas J. Miceli & Kathleen Segerson, Compensation for Regulatory Takings: An Economic Analysis with Applications 152 (1996), presents a model of development with irreversible investment that is closest to our approach and generates premature development without compensation. Polasky & Doremus, *supra* note 7; and Innes, Polasky, & Tschirhart, *supra* note 7, study other incentive issues surrounding the ESA.

[29] Examples of such use would include pine straw raking (pine straw is widely used as garden mulch) and quail hunting, which are compatible with maintaining pine habitat for RCWs.

efits and costs) and the probability of FWS detecting an existing endangered species in period 2. The decision tree in Figure 1 illustrates the problem and the payoffs from L's choices. The lowest branch shows the case in which L maintains habitat and is later subject to ESA land-use restrictions.

We assume that L chooses its action in period 1—destroy or maintain habitat—in order to maximize the expected value of the land. Thus L will choose to destroy the habitat as long as the expected value of early development exceeds that of waiting, or

$$[B_{\mathrm{D}} - C_{\mathrm{D}}] > (1 - \gamma\delta)B_{\mathrm{D}} + (\gamma\delta)B_{\mathrm{A}}. \tag{1}$$

The decision to destroy or maintain habitat will depend on the value of these parameters and leads to several straightforward comparative statics predictions. First, increases in the probability that an endangered species will inhabit the land (γ) will increase the probability of preemptive habitat destruction. Second, increases in the probability that the FWS will detect a listed species (δ) will lead to more habitat destruction. This probability could increase because of conditions that reduce detection costs or because of increases in detection and enforcement resources for FWS. Third, as the net value of development ($B_{\mathrm{D}} - B_{\mathrm{A}}$) increases, habitat destruction is more likely. Fourth, as the opportunity cost of early development increases (C_{D}), it is less likely that habitat destruction will occur.[30]

IV. Empirical Analysis

In this section, we test the model's implications regarding how increases in the probability of ESA regulation either increase the probability of harvest or decrease the optimal age of harvest. For the case of the RCW, these predictions can be further clarified in terms of the probability of RCWs inhabiting potential forest habitat. Thus, our two ESA predictions are as follows:

Prediction 1. An increase in the probability that RCWs will inhabit a forest stand increases the probability that the stand will be harvested.

Prediction 2. An increase in the probability that RCWs will inhabit a forest stand decreases the age at which a forest stand is harvested.

Prediction 1 comes directly from the model. Prediction 2 is a corollary: if harvest is more likely during a given period because of RCWs, then it also means that RCW proximity will lead to harvesting timber at an early

[30] The predictions are easily seen by rewriting equation (1) as $\gamma\delta(B_{\mathrm{D}} - B_{\mathrm{A}}) > C_{\mathrm{D}}$. Other predictions can be derived with minor adjustments to the model. For example, landowner compensation for endandered species will increase the payoff from maintaining habitat or waiting to develop. Also, development permits that make endangered species detection and enforcement easier will reduce preemption (by increasing C_{D}). And, of course, risk-averse landowners (perhaps smaller, less wealthy landowners) will preempt more often than risk-neutral landowners. We ignore the unlikely possibility that illegal avoidance (for example, SSS) is so cheap that the destroy option is never chosen.

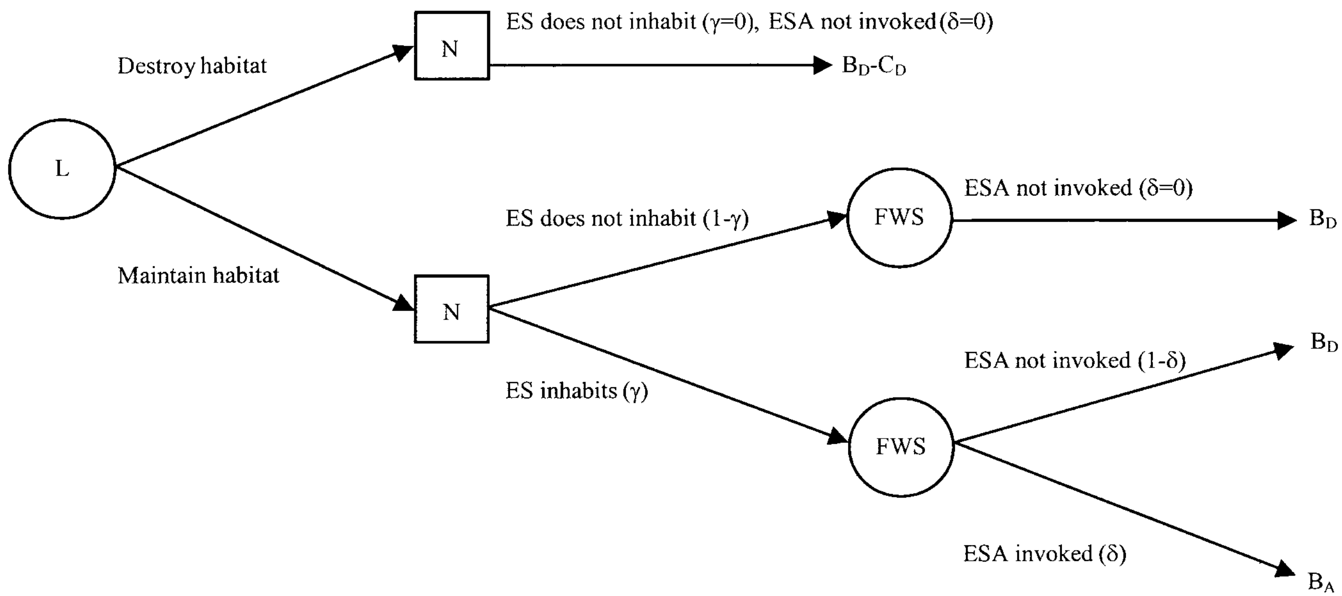

FIGURE 1.—Decision tree for landowner under the Endangered Species Act (ESA)

age.[31] To test these predictions, we use data on management actions and the characteristics of randomly selected forest plots, the location of RCW colonies, and timber prices. Below we summarize the main features of the data, while details are left to the Appendix. Table 1 shows descriptive and summary statistics for these data.

A. The Data

Forest Plot Data. Forest plot data come from the U.S. Forest Service's Forest Inventory and Analysis (FIA) Data, a detailed survey of timber and other forest characteristics for approximately 5,000 randomly selected forest plots in North Carolina. This study utilizes plots that were surveyed first in 1984–85 and again in 1989–90, which provides information on timber harvest, forest characteristics, and forest growth for each plot during the period between the surveys. This period also coincides with the period when FWS policy for RCW protection was most onerous to private landowners under the guidelines of the 1985 recovery plan. Our analysis examines only privately owned plots in the Coastal Plain and Sandhills regions of North Carolina, which consist of southern pine or mixed forest of both hardwoods and pines. A total of 1,199 forest plots meet these criteria, which limits the analysis to forest stands with the potential to be future RCW habitat that are within the RCW's historical range.

Table 1 shows that 32 percent of the plots (385 out of 1,199) were harvested (Harvest) during the 1984–90 period and 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 to 130 years. The data contain information on the dominant species and distinguish among four species of southern pine (longleaf, loblolly, pond, and slash) and a mixed pine-oak forest. As Table 1 shows, loblolly 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.[32] The data also include a measure of timber site productivity (Siteindex), which measures the height (in feet) of a 50-year-old stand of pine grown on a specific plot. Higher-productivity sites will have higher values of this variable, and Table 1 shows a mean value of 70.1 feet and a standard deviation of 13.3 feet. The data also identify plots by ownership type (private forest industry and private

[31] Prediction 2 can also be derived from a Faustmann model of optimal harvest age, treating ESA regulation as a "catastrophic" event. See William J. Reed, The Effects of the Risk of Fire on the Optimal Rotation of a Forest, 11 J. Envtl. Econ. & Mgmt. 180 (1984); Dean Lueck & Jeffrey A. Michael, Forest Management under the Endangered Species Act (unpublished manuscript, Montana State Univ. 2003).

[32] Loblolly is the fastest growing species and is thus preferred for the establishment of timber plantations. Accordingly, loblolly stands tend to be younger than stands comprising other pine species.

TABLE 1

Descriptive and Summary Statistics

Variable Name	Definition	Minimum	Maximum	Mean	Standard Deviation	*N*
Dependent variables:						
Harvest	1 if plot was harvested; 0 otherwise	0	1	.32	.47	1,199
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 ($)	−196.91	581.43	−6.43	38.47	1,199
Timbervalue	Value of timber on plot in 1984 ($)	1.05	5,513.43	676.76	801.43	1,199
Endangered Species Act variables:						
RCW-5	Number of RCW colonies within 5 miles of a plot	0	113	3.0	11.4	1,199
RCW-10	Number of RCW colonies within 10 miles of a plot	0	326	12.5	40.2	1,199
RCW-15	Number of RCW colonies within 15 miles of a plot	0	526	28.0	77.6	1,199
Timber stand variables:						
Industry	1 if landowner is industrial firm; 0 if a nonindustrial private firm	0	1	.29	.46	1,199
Siteindex	Timber site productivity (height of a 50-year-old stand in feet)	30	120	70.1	13.3	1,199
Standage	Age of forest stand in 1984	1	130	31.5	20.2	1,199
Longleaf	1 if longleaf pine is the dominant species; 0 otherwise	0	1	.04	.20	1,199
Loblolly	1 if loblolly pine is the dominant species; 0 otherwise	0	1	.55	.50	1,199
Pond pine	1 if pond pine is the dominant species; 0 otherwise	0	1	.13	.33	1,199
Oakpine	1 if pine with oak understory is the dominant forest; 0 otherwise	0	1	.23	.42	1,199
Slash	1 if slash pine is the dominant species; 0 otherwise	0	1	.043	.20	1,199

Note.—RCW = red-cockaded woodpecker.

nonindustrial).[33] We use the dummy variable Industry to identify forest ownership, and Table 1 shows that industrial firms owned 29 percent of the plots.

Red-Cockaded Woodpecker and Endangered Species Act Data. Our theoretical analysis predicts that the probability of preemptive habitat destruction will increase with the probability of RCW inhabitation and subsequent ESA regulation.[34] To measure this inhabitation probability we use data on the density of known populations of woodpeckers in the proximity of a particular forest plot. We develop our measures of RCW density using data from the North Carolina Natural Heritage Foundation. This group 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 that indicates that the North Carolina population is around 1,000 colonies.

Other than the recognition that RCWs may travel 10 or 15 miles, the biological literature offers no guidance on measuring the probability of inhabitancy from surrounding populations.[35] As a result, we calculate the number of RCW colonies within a 5-, 10-, and 15-mile radius of each forest plot. This procedure is described in the Data Appendix. Table 1 shows the summary statistics for these RCW density variables, respectively denoted RCW-5, RCW-10, and RCW-15. They show increasingly larger means and standard deviations as the distance increases from a plot. For example, there are an average of 28 colonies within a 15-mile radius of plot, although the numbers range from no RCWs to 526 colonies. Many plots did not have any nearby colonies; for example, 17 percent of the plots had no colonies within 15 miles.

Timber Market Data. We use timber prices and FIA data on timber volume and growth for each plot 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

[33] Many studies by forest economists note the behavioral distinctions between owners of industrial forests and private nonindustrial forest (commonly called NIPF) owners. See, for example, David H. Newman & David N. Wear, Production Economics of Private Forestry: A Comparison of Industrial and Nonindustrial Forest Owners, 75 Am. J. Agric. Econ. 674 (1993). The variable Industry measures the type of owner, not the type of forest, and refers to land controlled (through ownership or long-term lease) by companies or individuals who also operate wood-using plants. Owners of NIPFs may be corporations or individuals.

[34] As the model indicated, the probability of ESA regulations is the joint probability of RCW inhabitation (γ) and FWS detection and enforcement (δ). Ideally, we would like data on both of these probabilities for each landowner. There is no reason, however, to believe that FWS enforcement varies spatially, and, in fact, there are no data on the probability of FWS enforcement across landowners. As a result, we assume that FWS detection and enforcement probability is a constant normalized to one and focus on the probability of RCW inhabitation.

[35] A thorough review of the literature and discussions with leading RCW biologists Ralph Costa, FWS's RCW coordinator (conversation with one author, September 9, 1997); and Phil Doerr at North Carolina State University (conversation with one author, November 1, 1997) reveal no model that predicts where RCWs will nest.

survey period (Timbervalue) and a measure of the net marginal benefit of an additional year of forest growth (NMB). Standard forest economics shows that the forest harvest decision is made when the marginal benefits of timber growth are equal to the marginal costs in terms of forgone return on the timber investment. Assuming the value of the forest grows over time and is given by $V(t)$, where $V'(t) > 0$ and $V''(t) < 0$, the marginal benefit (MB) is $V'(t)$ and the marginal cost (MC) is $rV(t) + rV(t)/(e^{rt} - 1)$.[36] 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.

We calculate the market value of each timber stand using the FIA's tree-level data. 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. A stand with a given timber volume may be a young, densely stocked stand of low-value pulpwood or a mature and less dense stand of high-value sawtimber. As a result, the value of a timber stand is not directly proportional to the total timber volume but is increasing in volume (and age) and typically increases with the age and size of the trees.[37] For example, southern pine 5–9 inches in diameter are used for pulpwood, those 9–11 inches are used for chip-and-saw, and trees greater than 11 inches in diameter are used for sawtimber, the most highly valued product.[38] Thus the stand's value must be calculated by classifying each tree in the sample plot into one of five product classes,[39] each with a different price. For the ith 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.[40] This means that V_{it}, the value of ith stand at time t, is

$$V_{it} = \sum_{j=1}^{5} [Q_{ijt} P_j]. \tag{2}$$

The variable Timbervalue is simply the formula given by equation (2) cal-

[36] This optimality condition comes from a standard Faustmann model in which the forest owner maximizes the present value of the forest, or

$$\max_t \frac{V(t)e^{-rt}}{1 - e^{-rt}},$$

where r is the relevant interest rate and t is the rotation period.

[37] This simply means that $V(t) = p(t)f(t)$ 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 $p'(t) > 0$.

[38] The relationship between timber prices and timber volume is described in *Timber Mart-South,* a timber market publication for the southern states that can be accessed at http://www.tmart-south.com/tmart/.

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

[40] In lieu of data on expected timber prices, we use constant prices from 1984.

culated using the initial survey parameters. Table 1 shows that this variable has a mean value of \$677 and ranges from \$1 to \$5,513.

Using equation (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 *i*th stand, MB_i, is

$$\mathrm{MB}_i = \frac{V_{i,t^*} - V_{i,t=1984}}{t^* - 1984}. \tag{3}$$

Equation (3) replicates the left-hand side of the optimality condition for the optimal age at harvest.[41] In a similar way, the marginal cost of not cutting a stand this year, MC_i—the forgone return on the present value of the existing stand and its site value—is calculated as

$$\mathrm{MC}_i = r\left(V_{i,t^*} + \frac{V_{i,t^*}}{e^{rt^*} - 1}\right), \tag{4}$$

where r is the market interest rate.[42] Equation (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 $\mathrm{NMB}_i = \mathrm{MB}_i - \mathrm{MC}_i$. Table 1 shows the summary statistics for NMB; it has a mean value of $-$\$6 and a standard deviation of \$38. Optimal forest rotation theory predicts that a stand should be harvested when NMB $= 0$ and that the probability of forest harvest increases as NMB decreases. A stand with a negative value for NMB would be past the optimal time of harvest in a standard forest harvest model.

B. Empirical Estimates of Preemption

We use two estimation approaches to test for the presence of ESA-induced preemptive harvest. First, we estimate the probability that a plot is harvested during the survey period. Second, we estimate the age at which a plot is harvested.

1. Harvest Decision Estimates

To test prediction 1, we estimate the probability that a specific forest plot is harvested during the 1984–90 interval using the following empirical speci-

[41] The only difference from the theory is that since each plot is surveyed just twice over a 6-year period, the values of MB and MC are the averages over the period. This approach also assumes a linear timber growth curve over the 6 years.

[42] As is the common practice in the forestry literature, we use an interest rate of 4 percent; see Frederick C. Zinkhan, Forestry Projects, Modern Portfolio Theory and Discount Rate Selection, 12 S. J. Applied Forestry 132 (1988).

fication:

$$\hat{H}_i = X_i\delta + \mathrm{ESA}_i\chi + \mu_i, \tag{5}$$

$$H_i = \begin{cases} 1 & \text{if } \hat{H}_i > 0, \\ 0 & \text{if } \hat{H}_i \le 0. \end{cases} \tag{6}$$

In this specification, i indicates a specific plot, $\hat{H}_i$ is an unobserved timber harvest response variable; H_i is the observed dichotomous choice of harvest for forest plot i, which is equal to one if the timber was harvested during the sample period and zero if the timber was not harvested; X_i is a row vector of exogenous timber market and timber stand variables plus a constant; δ is an unknown coefficient; ESA_i is the measured probability that woodpeckers will inhabit plot i and the FWS will enforce the ESA; χ is an unknown coefficient; and μ_i is a plot-specific error term. Prediction 1 states that the probability a plot will be harvested increases as the probability of woodpecker inhabitation increases, or $\chi > 0$.

We use a probit model to generate maximum-likelihood estimates of the model given by equations (5) and (6).[43] Our dependent variable, Harvest, equals one if a forest plot is harvested during the 1984–90 interval and zero if it is not harvested. The parameter estimates from nine different specifications are presented in Table 2 and support the theoretical predictions of the model. The specifications vary in their inclusion and choice of timber market variables and in their measures of RCW colonies. Three equations do not include a timber market variable, three equations include NMB, and three include Timbervalue. All equations include timber stand variables that control for the age of the stand in 1984 (Standage), the ownership category (Industry), site productivity (Siteindex), and species composition.

The number of RCW colonies at 5-, 10-, and 15-mile radii from each plot are used as the ESA variables (RCW-5, RCW-10, RCW-15). All of the coefficient estimates for these variables have a positive sign consistent with prediction 1. The parameters for the 10- and 15-mile measures are statistically significant. The values of the estimated coefficients themselves vary little across the specifications. These estimates indicate that proximity to larger populations of a listed endangered species increases the probability that a forest plot will be harvested. We are unable to identify plots where the ESA

[43] Our approach is consistent with an established literature in forest economics in which harvest probability is estimated using probit models, and our specifications are similar to other empirical studies of the forest harvest decision using cross-sectional data. See, for example, Clark S. Binkley, Timber Supply from Private Nonindustrial Forests: A Microeconomic Analysis of Landowner Behavior (Yale University School of Forestry and Environmental Studies Bulletin No. 92, 1981); Roy Boyd, Government Support of Nonindustrial Production: The Case of Private Forests, 51 S. J. Econ. 89 (1984); and Donald Dennis, A Probit Analysis of the Harvest Decision Using Pooled Time-Series and Cross-Sectional Data, 18 J. Envtl. Econ. & Mgmt. 176 (1990).

currently prohibits timber harvest. If there are currently regulated plots in the sample, our models may underestimate the true preemption effect because such plots would not be harvested even with high numbers of proximate RCWs. This effect is most likely for the RCW-5 variable and may be a partial explanation for why it is not statistically significant. The central preemption results are robust to many alternative measures of RCWs, which are not presented here, including using the natural logarithm of the number of RCW colonies, using RCWs within a 25-mile radius, and using distance to nearest RCW colony rather than a density-based measure.[44]

Specifications (1)–(3) in Table 2 do not include a timber market variable, but specifications (4)–(6) use NMB as a timber market variable. As predicted, the estimated coefficients from NMB are negative, and statistically significant, in all three equations.[45] These estimates indicate that as the net marginal benefit of an additional year of forest growth declines, the probability of harvest will accordingly increase. Specifications (7)–(9) replace NMB with Timbervalue as a timber market variable. As predicted, the estimated coefficients are positive, and statistically significant, in all three equations. These estimates indicate that as the total value of a timber stand increases, the probability of harvest will accordingly increase. The coefficient estimates for both NMB and Timbervalue are consistent across the specifications and support basic forest economics models.

The estimated coefficients for the timber stand variables are quite stable and sensible. First, the estimates for the age of the stand (Standage) are always positive and statistically significant. While we use this variable as a control, it might be considered a timber market variable because an older stand will be a more valuable stand and thus is expected to be more likely to be harvested. Second, the estimated coefficients for site productivity (Siteindex) are always positive and statistically significant. These findings are also intuitive; more productive timberland will be more likely to be harvested during a given period. Third, the value and sign of the estimated effect of ownership (Industry) depends on the inclusion of the timber market variables, but in no case are the estimates statistically significant. This finding indicates that the type of ownership has no effect on the probability of harvest. Fourth, the effects of species mix vary among the species. The pine species dummies are used, and the oak-pine mix is the omitted category. The estimates consistently show that loblolly forests are less likely to be harvested. Similar findings are found for longleaf and slash pine, but these estimates

[44] These findings are also robust to using various combinations of timber market and timber stand variables, besides those shown in Table 2.

[45] As a reviewer noted, using equation (3) to calculate NMB for harvested stands with fewer years than nonharvested stands creates the possibility that NMB is endogenous. Our data do not allow us to correct for this, but we present several model specifications without NMB, which show little effect.

TABLE 2

PROBIT ESTIMATES OF FOREST HARVEST DECISION, 1984–90, USING HARVEST AS THE DEPENDENT VARIABLE

Exogenous Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Constant	−2.389	−2.426	−2.422	−2.316	−2.353	−2.349	−1.584	−1.626	−1.612
	(.264)**	(.2649)**	(.2650)**	(.2674)**	(.2680)**	(.2685)**	(.3107)**	(.3113)**	(.311)2**
Timber market variables:									
NMB				−.0033	−.0033	−.0033			
				(.0011)**	(.0011)**	(.0011)**			
Timber value							.00039	.00039	.00040
							(.00008)**	(.00008)**	(.00008)**
Endangered Species Act variables:									
RCW-5	.0035			.0033			.0036		
	(.0035)			(.0035)			(.0035)		
RCW-10		.0020			.0020			.0021	
		(.0010)*			(.0010)*			(.0010)**	
RCW-15			.0009			.00089			.0010
			(.0005)*			(.00053)*			(.0005)*
Timber stand variables:									
Age of stand	.0210	.0210	.0210	.019	.019	.0194	.0125	.0123	.0124
	(.0022)**	(.0022)**	(.0022)**	(.0023)**	(.0023)**	(.0023)**	(.0028)**	(.0028)**	(.0028)**
Industry	−.0161	−.0047	−.028	.0071	.018	.0203	.0667	.080	.829
	(.0970)	(.0974)	(.0976)	(.0976)	(.0108)	(.0982)	(.0994)	(.0998)	(.1000)

Siteindex	.210	.213	.212	.2045	.207	.207	.1078	.1099	.109
	(.0356)**	(.0356)**	(.0356)**	(.0359)**	(.0360)**	(.0360)**	(.0415)**	(.0415)**	(.0414)**
Loblolly pine	−.432	−.433	−.433	−.443	−.444	−.444	−.595	−.598	−.599
	(.1014)**	(.1015)**	(.1014)**	(.1017)*	(.1017)*	(.1017)**	(.107)**	(.1074)**	(.1074)**
Longleaf pine	−.309	−.369	−.345	−.330	−.390	−.367	−.395	−.466	−.443
	(.2231)	(.2238)+	(.2220)	(.2237)	(.224)+	(.2226)*	(.2241)*	(.2253)*	(.2234)*
Pond pine	−.0839	−.079	−.078	−.104	−.099	−.099	−.189	−.185	−.185
	(.1444)	(.1445)	(.1445)	(.1448)	(.1449)	(.1449)	(.1464)	(.1466)	(.1465)
Slash pine	−.337	−.380	−.374	−.325	−.368	−.362	−.429	−.478	−.474
	(.2356)	(.2378)	(.2378)	(.2351)	(.2373)	(.2373)	(.2353)*	(.2378)*	(.2379)*
Log likelihood	−648.15	−646.65	−647.17	−643.29	−641.81	−642.32	−636.45	−634.71	−635.19

NOTE.—Standard errors are in parentheses. N = 1,199.

+ Statistically significant at the 10 percent level, one-tailed test for predicted coefficients (Endangered Species Act and timber market variables).

* Statistically significant at the 5 percent level, one-tailed test for predicted coefficients (Endangered Species Act and timber market variables).

** Statistically significant at the 1 percent level, one-tailed test for predicted coefficients (Endangered Species Act and timber market variables).

TABLE 3

PREDICTED PROBABILITIES OF HARVEST BY AGE OF STAND AND THE DENSITY OF RED-COCKADED WOODPECKER (RCW) COLONIES

Density of RCW colonies	5-mile density (RCW-5)	10-mile density (RCW-10)	15-mile density (RCW-15)
30-year-old timber stand:			
No RCWs	.2840	.2780	.2777
Low RCW density	.2852	.2802	.2800
High RCW density	.3024	.3275	.3376
50-year-old timber stand:			
No RCWs	.4474	.4409	.4407
Low RCW density	.4488	.4435	.4434
High RCW density	.4686	.4973	.5086
70-year-old timber stand:			
No RCWs	.6204	.6146	.6146
Low RCW density	.6218	.6171	.6172
High RCW density	.6406	.6676	.6779

NOTE.—Low density: RCW-5 = 1; RCW-10 = 3; RCW-15 = 7. High density: RCW-5 = 15; RCW-10 = 66; RCW-15 = 171. Uses specifications in Table 2 for Age of stand, Timber value, and timber stand variables.

are less precise. The estimated effects for pond pine are never statistically significant.

Predicted Probabilities of Harvest. To gain a better understanding of the effects of potential ESA regulations on land-use decisions, we use the probit estimates in Table 2 to calculate the predicted probability of harvest for different values of the RCW variables. In particular, we use specifications (7)–(9) in Table 2—which use Timbervalue as a market variable—but the predictions derived from the other probit specifications are nearly identical.[46] Table 3 shows how the predicted probability of harvest varies according to RCW density. More specifically, Table 3 shows the probabilities for 30-, 50-, and 70-year-old stands with no RCWs and with "low" and "high" densities of RCWs within 5, 10, and 15 miles. Low-density sites are defined as having the same number of colonies as the average for the sample points located in the Coastal Plain counties where RCWs are found in the smallest number. High-density sites are defined as having the same number of colonies as the average for the sample points located in the five Sandhills counties where RCWs are found in the greatest number. For example, using the 15-mile density measure (RCW-15), a low-density site means seven colonies of RCWs within 15 miles, while a high-density site means 171 colonies within 15 miles.

Several findings emerge from Table 3. First, the probabilities of harvest do not depend on whether a 5-, 10-, or 15-mile density measure is used.

[46] For these calculations, timber stand variables were set at their mean values, except for NMB and Timbervalue, which were set at their predicted values.

Second, the probability of harvest increases with the age of the stand. For instance, the harvest probabilities range from 28 percent to 34 percent for 30-year-old stands, from 44 percent to 51 percent for 50-year-old stands, and from 61 percent to 68 percent for 70-year-old stands. Third, the table also shows how increases in the RCW population alter the probability of harvest, holding constant the age of the timber stand. For example, using the 15-mile RCW densities (far right column of Table 3), the probability of harvest for 50-year-old timbers with no RCWs is 44.1 percent, the probability of harvest for the same stand with a low density of RCWs is 44.3 percent, and the probability of harvest with a high RCW density is 50.9 percent. Comparing these probabilities allows us to calculate a marginal effect of potential ESA regulations. In this case, going from no RCWs to high RCW density increases harvest probability by 6.8 percent.

2. Age of Harvest Estimates

To test prediction 2, we estimate the age of a forest stand at the time of harvest. Because plots are only sampled in 1984 and 1990, only 385 of the 1,199 sample plots were harvested. Information on the age at harvest is thus censored, and ordinary least-squares estimation of age using this censored data would yield inconsistent parameter estimates. As a result of the data censoring we use the following empirical specification:

$$A_i^* = X_i\beta + \mathrm{ESA}_i\theta + \varepsilon_i, \tag{7}$$

$$\varepsilon_i | X_i,\ A_i^0 \sim \mathrm{Normal}(0,\ \sigma^2),$$

$$A_i = \min\{A_i^*,\ A_i^0\}. \tag{8}$$

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. The observable age of the stand is A_i, but, as implied by equation (8), it takes on different values because of data censoring. The age of a stand that is harvested is A_i^*, and A_i^0 is the age of the unharvested plots at the time of the second survey in 1990.[47] Prediction 2 states that the age of a forest at harvest will be lower as nearby RCW populations become more dense; that is, $\theta < 0$.

We use a censored normal regression to generate maximum-likelihood estimates of the model given by equations (7) and (8). Our dependent variable,

[47] This is right censoring or what is sometimes called “top coding” (for example, Jeffrey M. Wooldridge, Econometrics of Cross Section and Panel Data 517, 518 (2002)). Our case, however, is slightly different because the data are censored differently for each observation.

TABLE 4

CENSORED REGRESSION ESTIMATES OF THE AGE AT HARVEST, 1984–90 (Dependent Variable Is Harvestage)

Exogenous Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Constant	64.884	65.777	65.825	65.237	66.109	66.156	78.826	79.379	79.339
	(5.513)**	(5.536)**	(5.538)**	(5.435)**	(5.458)**	(5.460)**	(5.238)**	(5.253)**	(5.253)**
Timber market variables:									
NMB				−.046	−.046	−.460			
				(.0183)*	(.183)*	(.0183)*			
Timber value							.0094	.0094	.0094
							(.0011)**	(.0011)**	(.0011)**
Endangered Species Act variables:									
RCW-5	−.060			−.0603			−.0453		
	(.0732)			(.0722)			(.0646)		
RCW-10		−.040			−.039			−.029	
		(.0207)*			(.0204)*			(.182)$^{+}$	
RCW-15			−.0203			−.0120			−.0140
			(.0109)			(.0107)*			(.0096)$^{+}$
Timber stand variables:									
Industry	−5.869	−6.140	−6.218	−5.368	−5.634	−5.711	−2.327	−2.544	−2.591
	(2.094)**	(2.098)**	(2.101)**	(2.070)**	(2.074)**	(2.078)**	(1.871)	(1.878)	(1.803)
Siteindex	−.493	−.570	−.564	−.644	−.718	−.713	−3.617	−3.651	−3.638
	(.7174)	(.7184)	(.7177)	(.709)	(.7103)	(.7100)	(.0745)**	(.0745)**	(.0745)**
Loblolly pine	−.289	−.328	−.311	−.483	−.522	−.505	−4.198	−4.199	−4.182
	(2.124)	(2.121)	(2.120)	(2.093)	(2.091)	(2.090)	(1.899)*	(1.899)*	(1.899)*

Longleaf pine	13.310	14.827	14.502	12.573	14.042	13.721	7.729	8.824	8.499
	(4.724)**	(4.726)**	(4.673)**	(2.093)**	(4.663)**	(4.612)**	(4.212)*	(4.218)*	(4.177)+
Pond pine	3.777	3.639	3.616	3.266	3.129	3.108	−.474	−.551	−.554
	(3.004)	(3.002)	(3.002)	(2.966)	(2.964)	(2.964)	(2.689)	(2.690)	(2.690)
Slash pine	−6.226	−5.258	−5.224	−5.855	−4.914	−4.884	−6.808	−6.127	−6.164
	(5.166)	(3.208)	(5.209)	(5.103)	(5.143)	(5.144)	(4.567)	(4.601)	(4.603)
Log likelihood	−1,967.59	−1,966.17	−1,966.20	−1,964.54	−1,963.08	−1,963.17	−1,937.52	−1,936.51	−1,936.71

NOTE.—Standard errors are in parentheses. $N = 1,199$.

+ Statistically significant at the 10 percent level, one-tailed test for predicted coefficients (Endangered Species Act variables).

* Statistically significant at the 5 percent level, one-tailed test for predicted coefficients (Endangered Species Act variables).

** Statistically significant at the 1 percent level, one-tailed test for predicted coefficients (Endangered Species Act variables).

Harvestage, equals the age at harvest for uncensored observations and the age of the stand in 1990 for censored observations. The parameter estimates from nine different specifications are presented in Table 4 and also support the model. Except for the exclusion of Standage, we use essentially the same specifications as in the Table 2 probit estimates. Three equations do not include a timber market variable, three equations include NMB, and three include Timbervalue. All equations include timber stand variables that control for the ownership category, site productivity, and species composition.

As in Table 2, the number of RCW colonies at 5-, 10-, and 15-mile radii from each plot are used as the ESA variables. All of the coefficient estimates for these variables have a negative sign consistent with Prediction 2. The parameters for the 10- and 15-mile measures are statistically significant. The values of the estimated coefficients themselves vary little across the 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 with the probit estimates, the central results are robust to specifications that use alternative measures of RCWs and various combinations of timber market and timber stand variables.

Like Table 2, specifications (4)–(6) use NMB as a timber market variable.[48] As predicted, the estimated coefficients from NMB are negative, and statistically significant, in all three equations. Specifications (7)–(9) replace NMB with Timbervalue as a timber market variable. As predicted, the estimated coefficients are positive, and statistically significant, in all three equations.

Unlike the probit estimates, the estimated coefficients in a censored regression model can be directly interpreted. The coefficients for the RCW variables are largest in magnitude for the 5-mile density and smallest for the 15-mile density. For example, using the coefficient in specification (3)—RCW-15—an additional colony of RCWs will reduce the harvest age by .0203 years, or 7.4 days. With the 10-mile RCW density (specification (2)), the age is reduced to .040 years, or 14.6 days. A more relevant measure of 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 three colonies to 66 colonies, or a reduction in harvest age of 2.5 years. For the 15-mile density, this means a change from seven colonies to 171 colonies, or a reduction in harvest age of 3.3 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 percent of the landowners would be consistent with

[48] Theoretically, one can argue that only site characteristics that are not a function of the stand's age should be included in this model. This would suggest not including NETMB and Timbervalue because they are a function of age. Because of this, we focus on specifications (1)–(3), but we present specifications (4)–(9) including these variables to maintain consistency between probit and censored regression models.

a 3-year decrease in average harvest age. Ben Cone, who shortened his timber rotations from 80 years to 40 years to protect himself from increases in his RCW population, is such an example.

The estimates for the timber stand variables are less robust than in the probit model. The estimated coefficients for site productivity (Siteindex) are always negative 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 2.5 to 6 years) than nonindustrial 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.

V. Discussion and Conclusion

Regulations such as the ESA often redefine property rights to the disadvantage of firms. Firms can often reclaim these rights because they have private information and a first-mover advantage over regulatory agencies and legislatures. In the process, they can preempt regulations and may do so in ways that counter the intended goals of the regulations. Land preservation restrictions are perhaps the classic case, although preemptions have been noted for many types of environmental regulations as well.[49] While regulators consider restrictions to preserve land, developers race to beat the regulations, resulting in more rapid development than would have otherwise occurred. For example, in the spring of 1999, after state regulators in North Carolina proposed stiffer rules on wetlands drainage, landowners went on a drainage and ditching spree, leading to 15–20 times the annual wetland development in the state in just a few months.[50] This study demonstrates that the ESA itself has induced habitat destruction.

For the endangered RCW in North Carolina, our empirical results indicate that the ESA has led some forest landowners to preemptively harvest timber in order to avoid costly land-use restrictions. Landowners in North Carolina who are closer to populations of RCWs, and are thus more likely to be restricted by the ESA, are more likely to prematurely harvest their forest and

[49] Dana, *supra* note 20, discusses land-use regulations; and Mark A. Cohen, Monitoring and Enforcement of Environmental Policy, in 3 International Yearbook of Environmental and Resource Economics 44 (Tom Tietenberg & Henk Folmer eds. 1999), discusses environmental regulations.

[50] James Eli Shiffer, Landowners Saw Opportunity in Government's Delay, News & Observer (Raleigh, N.C.), March 7, 1999, at B1.

choose shorter forest rotations. This evidence indicates that some RCW habitat has been reduced on private land because of the ESA. Our findings add substance to anecdotal claims of preemption and are consistent with the concerns of those environmentalists who have noted that RCW populations have been declining on private land during the 30 years in which the RCW has been protected by the ESA. Because private land provides the habitat for most listed species, these incentives are of general importance to the conservation of many endangered species.

Although we find evidence of preemptive habitat destruction for the RCW, questions remain about how important preemption is, both in the North Carolina RCW case we examine and for the ESA generally. Two difficult questions dominate, and our study cannot offer complete answers. First, how costly is preemption in terms of land-use misallocation? Second, how large is the impact on endangered species habitat and populations?

In the case of the RCW, the cost of premature commercial timber harvest may not be large. For landowners managing only for commercial timber, the optimal time to cut southern pine in the absence of the ESA varies little between 30 and 35 years.[51] This means that preemptive harvest is not likely to diminish the net present value of the timber by much.[52] Many landowners, however, use longer rotations because of their multiple-use objectives. This means that landowners who maintain relatively old pine stands for nontimber benefits (for example, amenities, hunting) are less likely to do so because of the ESA. With preemption, these landowners actually increase their commercial timber returns at the expense of a reduction in the standing value of the forest.[53] Thus, for our study, the primary cost of preemption seems to be the reduction in the conservation benefits from RCW protection. This cost not only includes the public benefits of species protection but also includes the private environmental benefits to landowners of maintaining old-growth pine forests for recreation and for other reasons.

The question of the extent of the preemption effect on RCWs is also difficult to answer because it requires information about the long-term extent of preemption and the dynamics of habitat loss and RCW populations. We can, however, use our harvest estimates to roughly calculate the short-term reduction in pine forest acreage suitable for RCWs that results from preemptive timber cutting. Using the estimates in Table 3, we calculate the marginal increase in harvest probability when moving from no RCWs to low and high RCW densities. From this we are able to calculate the additional

[51] Lancia, *supra* note 28.

[52] Regulatory costs of the ESA, of course, are large if landowners get regulated and are, in fact, prohibited from harvesting.

[53] For example, Ben Cone's reduction in timber harvest age increased his timber receipts but diminished the quality of his hunting retreat.

TABLE 5

ESTIMATED REDUCTION IN RED-COCKADED WOODPECKER (RCW) HABITAT AND POPULATIONS FROM PREEMPTIVE HARVESTING, 1984–90, NORTH CAROLINA

RCW DENSITY MEASURE AND TIMBER AGE CLASS	REDUCTION IN ACREAGE OF PINE FOREST HABITAT (in Acres) SUITABLE FOR RCWS	
	Southern Coastal Plain	Sandhills Subregion
5-mile density (RCW-5):		
30–50 years	3,027	2,463
50–70 years	1,642	1,333
70+ years	421	329
Total (over 30-year-old stands)	5,090	4,125
Potential RCW colony reduction (200 acres/colony)	25 colonies	21 colonies
10-mile density (RCW-10):		
30–50 years	7,659	6,625
50–70 years	4,121	3,546
70+ years	1,007	864
Total (over 30-year-old stands)	12,787	11,035
Potential RCW colony reduction (200 acres/colony)	64 colonies	55 colonies
15-mile density (RCW-15):		
30–50 years	9,098	8,017
50–70 years	4,866	4,270
70+ years	1,180	1,031
Total (over 30-year-old stands)	15,144	13,318
Potential RCW colony reduction (200 acres/colony)	76 colonies	67 colonies

NOTE.—Estimated probability of harvest comes from Table 3. See the Data Appendix for details.

harvested acreage due to preemption.[54] Table 5 shows the results of these calculations for North Carolina during the 1984–90 period using these marginal preemption effects for the 5-mile, 10-mile, and 15-mile RCW density measures. In 1984, the year the plots are first sampled, the southern Coastal Plains region of North Carolina had 961,000 acres of pine forest old enough to provide nesting and foraging habitat for RCWs. Table 5 shows that between 5,090 and 15,145 additional acres of mature pine were, by our estimates, harvested in order to avoid potential ESA regulations. In the Sandhills subregion alone, where RCWs are the most populous, the preemption acreage ranges from 4,125 to 13,318 acres, about 5 percent of the subregion's potential habitat.

To put this into perspective, consider how this acreage calculation might be converted into potential RCW colonies under ideal conditions. Making the assumptions that the "extra" forest is in large enough parcels, that a nearby population is available to populate that stand, and that an RCW colony

[54] See the Data Appendix for a detailed description of these calculations.

requires 200 acres under the 1985 guidelines, this acreage might have provided habitat for between 25 and 76 colonies within the state of North Carolina. In the Sandhills alone, between 21 and 67 colonies might have been provided with habitat. To add further perspective, consider these estimates relative to current populations and FWS goals. As of 1990, biologists estimated that 371 colonies were active in the Sandhills, down from 590 in the early 1980s.[55] In the early 1980s, only 84 of the colonies were located on privately owned land. The recovery plans for the RCW and biological research[56] estimate that the minimum viable population size is approximately 500 colonies, and the FWS adopted this as its recovery goal for a dozen RCW populations in the 1985 plan. Our estimates of between 21 and 67 "lost" colonies would make a significant contribution to the 500-colony goal and are very close to the estimated 84 private-land colonies protected by the ESA during the study period.

Even with these preemption calculations, the total impact of the ESA on RCWs is difficult to assess. Undoubtedly the ESA has preserved some RCW habitat by preventing private landowners with existing populations from harvesting mature pines, and there is no way, given available data, to estimate how much of this protected habitat would have been destroyed in the absence of the ESA. Thus, we cannot determine whether this positive effect of locking in habitat is larger than the negative effect of preemption, and we cannot calculate the net effect of the ESA on the supply of RCW habitat on private lands during the study period. Also, our study estimates only a single negative effect, preemptive timber harvesting, but landowners may also harm RCWs directly (for example, SSS)[57] or passively degrade RCW habitat by allowing hardwood intrusion into their forests that provide habitat for predators (for example, snakes) and nesting site competitors (for example, flying squirrels).

Our study uses forest management data from the period in which RCW policy enforced by the FWS was the most onerous for private landowners, and our results suggest that the ESA did little to increase RCW habitat during this period. Since 1992, the FWS has relaxed acreage requirements for RCW protection and has introduced polices such as Safe Harbor that reduce the uncertainty of a landowner's burden under the ESA. While these policy changes do not completely remove preemption incentives, they are likely to reduce them.

This paper is an empirical study of the highly controversial, perverse

[55] Francis James, The Status of the Red-Cockaded Woodpecker in 1990 and the Prospect for Recovery, in Kulhavy, Hooper, & Costa eds., *supra* note 23, at 439.

[56] For example, see Ernst Steven, Population Viability Considerations for Red-Cockaded Woodpecker Recovery, in *id.* at 227.

[57] We know of two cases of landowners being prosecuted for intentionally killing RCWs in Florida, and it is quite possible that others have avoided arrest for similar actions. See Bryanna Latoof, Men Fined for Killing Woodpeckers, St. Petersburg Times, September 16, 1987, at 1B.

incentives of the ESA on private lands, and the results must be interpreted carefully. Finding evidence of RCW habitat destruction does not imply that there are similar effects for all endangered species. For species for which there is less information, where habitat is more difficult to destroy, or where habitat is widely dispersed, preemptive habitat destruction is less likely. However, our study can also be seen as an underestimate of the total perverse impacts since we consider only preemptive timber harvesting and do not measure direct harm to RCWs or more indirect, passive approaches to reducing habitat. A complete assessment of ESA effects on private lands will require studies on more species and more methods landowners may utilize to harm them and their habitat as they attempt to avoid the ESA's regulatory costs.

DATA APPENDIX

I. Forest Inventory and Analysis (FIA) Data

The plot-level FIA data are available at http://www.ncrs.fs.fed.us/4801/FIADB/fiadb_dump/fiadb_dump.htm. The data include timber volume for each plot at each survey date, 1984 and 1990. Owner confidentiality agreements prevent a more precise location from being released in the public data, but the survey crews have detailed locations so that they visit the exact same 1/5-acre plots each survey. All harvested plots were clear-cut, 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 also 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 available only to the nearest 100 seconds (about 1.9 miles). This means the location of each sample plot can be determined with no more than a 1.4-mile margin of error. Each data point can be located within a nearly square quadrilateral with sides roughly 1.92 miles long. Using the Pythagorean theorem, the corners of the quadrilateral are about 1.36 miles from its midpoint, the furthest an actual sample plot could be from the coordinates given in the FIA data.

II. Timber Market Data

Price data are taken from Timber Mart South's monthly survey of timber prices in the North Carolina coastal plain. The calculations use stumpage prices, which are the prices paid to the timber owner net of harvesting and transportation costs. Using an average stumpage price over the entire region implicitly assumes that harvesting and transportation costs are identical over all the sites. Given that all the FIA sample plots are softwood stands in the flat coastal plain region, it is reasonable to assume that the plots would have similar harvesting costs. Data on the road distance to processing facilities and other factors affecting transportation costs were not readily available, and no adjustments were made. Stumpage prices for each year are calculated as the average price over the 12 months of that year. The calculations use 1984 prices. As equation (2) shows, 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.

III. 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. FWS 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 are 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) Using ArcView GIS software, the number of RCW colonies within a 5-, 10-, 15-, and 25-mile radius were counted for each FIA sample point. In addition, the distance to the nearest colony was measured for each sample point.

IV. Calculations of Preemptive Harvest for North Carolina, 1984–90

The 1984 FIA data show that North Carolina's southern coastal plain had 961,000 acres of privately owned pine forest 30 years or older. This represents the base acreage of suitable privately owned RCW habitat for our calculations. Of this, 213,009 acres were in the Sandhills subregion where RCW densities are "high," and 748,414 acres were in the non-Sandhills southern coastal plain where RCW densities are "low." The FIA data show an age class distribution for pines over 30 years as follows: 62.83 percent are 30–50 years old, 29.52 percent are 50–70 years old, and 7.65 percent are 70 years old and older. From Table 4 we calculate the differential harvest probability for each age and region in order to calculate the additional acreage harvested. For example, there are 62,880 acres of pine between 50 and 70 years old in the Sandhills (213,009 × 29.52 percent). Since the no-RCW harvest probability is 44.1 percent for the RCW-15 measure on a 50-year-old stand and the harvest probability is 50.9 percent for a similar stand in an area with high densities of RCWs (the Sandhills is the high-density subregion), the marginal increase in harvest probability is 6.8 percent (50.9 − 44.1). The additional acreage harvested because of the preemption, for 50- to 70-year-old stands in the Sandhills, is 4,270 acres (6.8 percent of 62,880 total acres). A similar calculation is made for each age class in each region and summed to get the totals shown in Table 5. These estimates do not include pine forests in the northern coastal plains region where very small populations of RCWs currently live.

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