ENDANGERED SPECIES AND TIMBER HARVESTING: THE CASE OF RED-COCKADED WOODPECKERS

DAOWEI ZHANG*

This article presents a theoretical framework and empirical evidence on the relationship between regulatory uncertainty induced by the possible invasion of an endangered species—the red-cockaded woodpecker (RCW)—and timber harvesting. The results indicate that landowners whose forests are close to a known or perceived RCW habitat have a high propensity to cut timber and use a clear-cut method. These preemptive actions are apparently aimed at destroying potential RCW habitat so that the existing values of their property could be protected from the Endangered Species Act (ESA)–related land use limitations. (*JEL* D23, K32, Q23, Q28)

I. INTRODUCTION

The issue of differentiating legitimate public regulation of private property from regulatory takings has become important and controversial in the United States. The Endangered Species Act (ESA), probably the most powerful environmental regulation ever enacted in the United States, is in the center of this controversy. The modern version of the ESA was enacted in 1973, and it has been amended several times since. The ESA is intended to protect species from becoming extinct. The ESA creates two main processes: the *designation* of species and their critical habitats through listing, and *protection*. Souder (1995) shows that listing is important because it triggers the four major provisions of the ESA, which are to *conserve* listed species, avoid *jeopardizing* them, avoid destruction of *critical habitat*, and avoid *taking* them.

Under the ESA, no person may take endangered or threatened species. In the ESA, "the term 'take' means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt to engage in any such conduct" (16 USC Section 1532 [19]). Furthermore, the U.S. Department of the Interior has defined the statutory term *harm* as "an act which actually kills or injures wildlife, including significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering" (50 CFR Section 17.3 [1995]). This regulatory definition has been upheld by the U.S. Supreme Court (*Sweet Home v. Babbitt*, II S.Ct. 714 [1995]), and it is the fulcrum on which the government levers regulation of private land. Because habitat modification may be a "take," Flick et al. (1996) indicate that the normal forestry activities of landowners fall within the purview of the U.S. Fish and Wildlife Service on lands with endangered or threatened species.

U.S. Government Accounting Office (1995) shows that more than 80% of listed endangered species have some habitat on private lands that are mostly used for forestry or agricultural purposes. Furthermore, the list of endangered or threatened species is growing continually with no limit in sight. Because the ESA prescribes behavior and extracts use rights from the bundle purchased or inherited by private landowners, its potential reach over private

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Zhang: Professor, School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL 36849-5418. Phone 1-334-844-1067, Fax 1-334-826-0374, E-mail zhangdw@auburn.edu

ABBREVIATIONS

ESA: Endangered Species Act
RCW: Red-Cockaded Woodpecker

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land is very large yet uncertain. Few publicly provided incentive programs have been offered to private landowners for protection and enhancement of endangered species until very recently.[1]

Because of this "stick" approach to public policy regarding endangered species, the usual presumption is that, other things being equal, landowners will avoid management activities that might attract endangered species onto their lands and possibly develop their lands early.[2] This belief continues to produce advocates for protection of private property rights, not only from private landowner organizations but also from public agencies and some environmental groups. Recently, the U.S. Fish and Wildlife Service, with the support of the Environmental Defense Fund, designed and implemented the Safe Harbor Program, No Surprise Policy, and No Take Regulation, as noted by Zhang (1999). These policies were in part designed to mitigate the existing incentives to manage against endangered species on private lands. On the other hand, individuals and groups who want to stop development, construction, or logging may latch onto the ESA as a tool to do so, with little or no concern in fact for listed species. "Not in my back yard" and other motives are served well by the strong ESA as currently formulated. As such, these individuals and groups who can be labeled as bootleggers are no doubt supportive of the current ESA.[3]

However, with the exception of Lueck and Michael (2003), there is little empirical evidence in support of the view that weakness in the current endangered species–related regulations impedes good management and stewardship of forest resources. That is, the influence of endangered species induced regulatory uncertainty or weakening of private property rights on landowner behavior has been a subject of much speculation but very little empirical study. There have been a number of theoretical and policy studies of the relationship between private right security and landowner behavior and performance, such as Zhang and Pearse (1996; 1997), Innes (1997), and Polasky and Doremus (1998); some isolated case studies of the ESA, such as Mann and Plummer (1995); and studies on the impacts of endangered species on public lands, as in Hyde (1989). Lacking quantitative studies on the influence of endangered species–related regulation on landowner behavior is partly due to its controversial nature and the requirements of strict confidentiality of many landowners who have endangered species on their lands.

This article presents the results of an initial attempt to measure directly the influence of endangered species induced regulatory uncertainty on landowner timber harvesting behavior. The study differs from other investigations of this question insofar as it is based on the classical Faustmann model and an econometric analysis of recorded timber harvesting activities under two different regulatory conditions, utilizing a large sample of data on an important endangered species, the red-cockaded woodpecker (RCW). The primary finding is that regulatory uncertainty and lack of positive economic incentives alter landowner timber harvesting behavior and hinder endangered species conservation on private lands. This article begins in the next section by describing the RCW and the theoretical framework and econometric methods adopted. This is followed by a discussion of the data used in this study. The remaining sections present empirical findings and conclusions and policy implications.

II. ANALYTICAL FRAMEWORK

The Birds and the Regulation

The RCW was listed as an endangered species in 1970. The RCW chisels out its den cavity in live mature pine trees, a task that may take as long as four years. The RCW prefers mature pine trees that have been infected with red heart

1. See Eisner et al. (1995) and Zhang and Flick (2001) for habitat creation with positive incentive. However, it might take giant incentives to overcome the threat of large and direct losses with the current command-and-control powers inherent in the current ESA programs. On the other hand, absent of those draconian (potential rather than inevitable) penalties, small positive incentives might bring forth much habitat protection now being preemptively reduced or destroyed and habitat creation.

2. See Innes (1997) and Polasky and Doremus (1998). Both articles use game theoretic models and show that private landowners have incentive to develop their property early when facing potential ESA regulation. Although this study can be thought of as an empirical test of these models, I use the traditional Faustmann forest rotation model to study timber harvesting.

3. Yandle (1989) labels "Baptists" as those who promote any public or private interest by attaching it to other issues that have broad public support (such as protecting the environment), while "bootleggers" are characterized as those who would support the same interest without attaching it to any public issue.

fungus, which tends to weaken the heartwood and make the birds' excavation somewhat easier. In addition, the RCW prefers open, park-like stands containing little understory and usually forages for insects on mature pine trees near its den. If the pine stands are open and hardwood competition grows up in the understory, the birds will abandon the site. Intentionally controlled (prescribed) burning can control the undergrowth, preventing this cause of nest abandonment.

The RCW is one of the most controversial endangered species in the country. The economic significance of the RCW is that without human assistance (such as an artificial nest box) and under currently available habitat alternatives, it prefers to use medium to large-size tracts of mature southern pine forests as its habitat. Southern pines are the most important commercial species in the South. Because the South accounts for approximately 65% of timber harvests in the country and because 90% of Southern timberlands are privately owned (Smith et al. [2001]), protecting the RCW likely will alter some private forest management activities. Therefore, protecting the RCW may have larger economic impacts among landowners than any other currently listed species, except the northern spotted owls.

The U.S. Fish and Wildlife Service (1992) specifies regulations applicable to private forest with RCW, restricting private landowners' forest management activities. For example, the manual specifies that no trees greater than 10 inch in dbh (diameter at breast height or at 1.3 m height) should be cut, no pesticide should be used, and no road should be built without permission within a 200-foot radius (2.9 acres) surrounding a cavity tree. In addition, a minimum of 60 acres of foraging habitat within a half mile of the cavity tree, and a minimum of 3000 square feet of pine basal area (a cross-section area of all trees measured at dbh) in trees 10 inches dbh or larger should be maintained. A half-mile radius covers 502 acres, so landowners can do some timber harvesting if they or other landowners maintain enough foraging habitats within one half-mile of the cavity tree.

Unlike the northern spotted owls, the RCW is a territorial bird, meaning that it usually only has a few mile migratory range and does not move far away from its primary habitat in search for food. The biological attributes of the RCW, its significant economic impacts on private forest management, and the presence of a government guideline for managing private forests where the RCW resides all provide a unique opportunity to study the impact of ESA-related regulatory uncertainty on landowner behavior.

In theory, forest landowners have an economic incentive (to protect or enhance the existing value of their property) to harvest early, before the RCW comes to their lands and otherwise manage in ways that minimize the suitability of their forests for RCW habitat, analogous to anticipatory buying before a hurricane or anticipatory production before a labor strike, as in Warren-Boulton (1977). With the exception of Lueck and Michael (2003), previous analyses of this predicted behavioral impact are focused primarily on numerical calculation of the impacts of the guideline on timber harvesting revenue and cost, as in Cleaves et al. (1994) and Meyers et al. (1996), or forest conditions and timber production possibilities when the RCW is present (Roise et al. [1990]). This study adopts an analytical and econometric approach to explore the impact of ESA-induced regulatory uncertainty on private landowner behavior.

A Model of Forest Landowners Facing Regulatory Uncertainty Induced by an Endangered Species

Similar to Innes (1997) and Polasky and Doremus (1998), Zhang (2001) shows landowners facing the prospect of an endangered species on their lands and ESA regulation may behave differently from other landowners in terms of their timber harvesting behavior. These behavioral implications are derived from a simple forest production model. To illustrate the main point of the analysis, I take the perspective of stand-level optimization. I assume the following:

1. A landowner can borrow and lend at a known real interest, r.
2. Stumpage prices, P, are constant;
3. Timber yield, $Q(t, I)$ is a function of stand age, t, and silvicultural investment, I, where $Q_i = \partial Q/\partial_i > 0$; $Q_{ii} < 0$ for $i = t, I$.
4. If no endangered species are present, the landowner has a secure property right to his forest, and the probability of losing any portion of the forest is zero. There is a nonzero (δ) probability of losing a portion (α, $0 < \alpha < 1$)

of the forest if an endangered species moves into the forest and ESA applies. The value of α depends on the characteristics of the landowner's own as well as surrounding forests. For simplicity, I assume α is exogenous (as I do not know the characteristics of forest other than the landowner's own in the empirical study).[4] This is a case of "partial regulatory taking" where regulations restrict a landowner's management activity without any compensation.

5. The probability of losing a portion of his forest (δ) is an increasing function of time (i.e., the stand age).[5] This is because the longer the landowner waits before harvesting, the more likely he will lose a portion of the forest because an RCW prefers to reside in old pine forests.

The analysis is considerably clearer and more intuitive if one simply considers a model in which the planning horizon runs through one rotation. The landowner maximizes net return, V, to the fixed factor, land, over time t. Zhang (2001) demonstrates that restating the problem to allow either land purchase at the beginning of the timber rotation and land sale at harvest time or continuous replacement of timber harvests leaves the relevant predictions unchanged.

In the case of simply focusing on one rotation, the objective is to maximize the expected present value of future cash flow considering regulatory uncertainty. If the landowner does not lose any portion of his forest to regulation (i.e., $\alpha = 0$), the expected value of the forest can be expressed as

$$V_1 = P\,Q(t, I)e^{-rt} - I. \tag{1}$$

If the landowner does lose a portion (α) of his forest to regulation (i.e., $\delta = 1$), the expected value of the forest can be expressed as

$$V_2 = (1 - \alpha)P\,Q(t, I)e^{-rt} - I. \tag{2}$$

4. The value of α varies according to the landowner's own stand size and characteristics as well as those of his neighbor's and the number of RCW clusters. When α varies, the predicted result in equation (7) changes only in magnitude, not in direction.

5. More precisely in this study, $\delta(t)$ is an increasing function of time after pine trees reach 35 years because all known RCW cavity trees are more than 35 years old. I excluded less than 35 years old stands in the empirical analysis (see data section).

Thus the expected value of the forest under regulatory uncertainty is

$$V(t, I) = [1 - \delta(t)][PQ(t, I)e^{-rt} - I] + \delta(t)[(1 - \alpha)PQ(t, I)e^{-rt} - I]. \tag{3}$$

The landowner's objective is to maximize $V(t, I)$. This is the well-known one-rotation Faustmann formula, as in Gane (1968), with the addition of a stochastic uncertainty factor. It is equivalent to maximizing the difference between gross revenues and total costs, where revenues are harvest receipts and costs are the annual opportunity costs of forest land use and silvicultural investment under regulatory uncertainty. The model has a weakness in that it treats the landowner as risk-neutral. However, if the result shows that a risk-neutral landowner responds negatively to policy uncertainty, risk-averse landowners will respond negatively to policy uncertainty as well.

Equation (3) can be simplified as

$$V(t, E) = [1 - \alpha\,\delta(t)]PQ(t, I)e^{-rt} - I. \tag{4}$$

First-order conditions for a maximum require that

$$\partial V/\partial t = \{[1 - \alpha\,\delta(t)](PQ_t - rPQ) - \alpha\,\delta_t PQ\}e^{-rt} = 0, \tag{5}$$

which can be simplified as

$$Qt - \alpha\,\delta_t Q\,/\,[1 - \alpha\,\delta(t)] = rQ \tag{6}$$

or

$$Qt/Q = r + \alpha\delta_t/[1 - \alpha\delta(t)]. \tag{7}$$

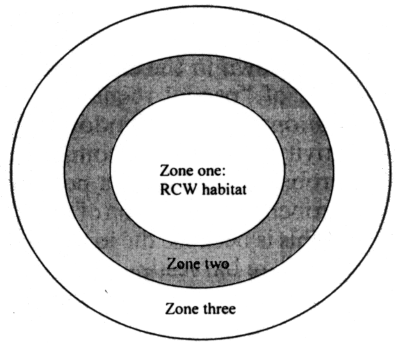
The optimal condition (6) can be interpreted easily. On the right is the interest forgone by postponing harvesting the timber stand for one period. On the left is the gain from postponing the harvest one period, consisting of the value of timber growth over the period minus the portion of timber that the landowner might not be able to harvest due to the ESA during the period. For optimality, the marginal gain from postponing the harvest one period must equal the marginal loss of postponement.[6]

Because δ_t and $[1 - \alpha\, \delta(t)]$ are greater than zero, the second term in equation (7) is positive. In the absence of regulatory uncertainty, $\delta(t) = 0$, equation (7) simply reduces to the well-known result that a forest stand should be harvested when its rate of growth equals the discount rate if stumpage price is assumed to be constant and opportunity cost of the land is ignored (single rotation). With regulatory uncertainty, the forest should be harvested when the rate of growth is greater than the discount rate. In other words, the policy uncertainty has the same impact as an increase in discount rate in the Faustmann formula. Hyde (1980) and Chang (1983) show that in general an increase in the discount rate leads to earlier harvesting. Therefore, everything else being equal, landowners who face possible invasions of endangered species to their forests (and thus ESA regulation) will cut timber earlier than those who do not have to face such regulation.

Although the analytical model is continuous (age at harvest), the dependent variables (probability of timber harvesting and harvesting method) used in this empirical analysis are dichotomous. The connection between them lies in the fact that the probability of observing harvest during a given period of time (ten years in this study) is negatively related to the optimal harvesting age. In other words, landowners who cut timber at a shorter rotation age—whether it is due to regulatory uncertainty or to other factors—have a correspondingly higher probability of harvest in the given period of time.

Other things equal, stands near existing RCW clusters are more likely to be colonized than stands far away. Figure 1 illustrates the location relationship among stands that have RCW habitats and that face possible occupation of the RCW. Lands in zone one are active RCW habitats and therefore are subject to the ESA. Lands in zone two are adjacent to or very close (say, within one mile) to the active RCW habitats, and there is a higher possibility of the RCW moving to these lands if suitable habitats

FIGURE 1
RCW Habitat Zone and Its Surrounding Areas



are provided. These lands will be subject to the ESA if the RCW does come. Lands in zone three are farther away from the active RCW habitats and relatively safe from RCW occupation.

The closer a mature stand is to an active RCW cluster, the more likely the RCW will come if the stand is not harvested. Everything else being equal, I hypothesize that landowners who have stands close to an active RCW habitat will be more likely to harvest their forests than landowners whose forests are distant from the RCW. Furthermore, landowners' decisions to harvest or not to harvest in a given period of time are influenced by the expected total stumpage revenue of the timber stand (which is determined by price and timber volume in various products categories). Third, the biological characteristics (especially those that influence growth rate) of the timber stand affect landowners' harvesting decisions, as shown in Dennis (1989). Finally, landowners' management objectives and characteristics, such as their financial need, attitude, and knowledge about forest management, play a role in their timber harvesting decisions (Binkley [1981]). Thus,

$$(8) \quad HARVEST = f(ZONE, TR, C_f, USE, C_o),$$

where

HARVEST is harvest or not (discretionary dependent variable);

6. Zhang and Flick (2001) show that optimal silvicultural investment varies dependent whether or not the ESA applies. Because this article is focused on timber harvesting, the optimal condition of the investment variable is not derived.

ZONE is a measurement of proximity of a forest stand to a known or perceived RCW habitat;

TR is the expected total stumpage revenue of the forest stand per acre, which is determined by stumpage price and timber volume in each products class;

C_f is a vector of characteristics of the forest stand, including basal area (a measure of density and tree size), species composition, and size of the forest stand that influence its suitability as RCW habitat;

USE is the landowner's primary use of the forest stand;

C_o is a vector of characteristics of the landowner, especially his education, income and length of forestland ownership.

Therefore, the primary linkage between the theoretic model and empirical analysis is a measure of closeness of a forest stand (*ZONE*) to a known or perceived RCW habitat. The other linkages include stumpage price (which is assumed to be constant in the theoretic model), timber volume (Q), and factors (biological characteristics of the stand) influencing the growth rate (Q_t) of timber volume. The landowner's management objective and characteristics are factors ignored in the theoretic model but need to be controlled for in empirical analysis because they vary significantly.

The model only predicts when the forest should be harvested and does not indicate which harvesting method should be chosen. The frequently used harvesting methods include clear-cut, seed-tree, shelterwood, and selection. Using harvesting methods other than clear-cut will result in some large trees being left on the ground. Because the RCW prefers open, park-like stands containing little understory, using nonclear-cut harvesting methods may improve the suitability of the forest stand as RCW habitat. Although not all nonclear-cut methods are equally desirable to the RCW, they are all preferable to the RCW comparing to clear-cut method, and thus their use or nonuse might be affected by the possible application of the ESA and RCW regulations. Because clear-cut destroys or forecloses potential RCW habitat quickly, I hypothesize that it will be more often used when the possibility of the RCW's coming to the stand is high.

In the absence of regulatory uncertainty, landowners choose among harvesting methods to maximize stumpage revenue (net of reforestation cost, if any) subject to constraints such as forest stand characteristics (some stands are suitable for certain harvesting methods), aesthetics, management objective, and tax liability. Landowners can maximize revenue by using the clear-cut method, but they usually have to make some reforestation investment shortly after harvesting to ensure the productivity of the land and forest succession. In addition, clear-cut lands usually lack aesthetic appeal, and large clear-cut stands attract less wildlife, such as deer and turkey, limiting landowners' opportunities for recreational use (hunting or leasing for hunting rights) and potentially subjecting them to a higher tax bracket. The other harvesting methods have the opposite effect (relatively less revenue, but the resulting cutover lands have more aesthetic appeal, attract more wildlife, and can ensure forest succession based on natural regeneration). Thus, closeness to an RCW habitat, stand characteristics, and landowners' management objectives and characteristics are determinants of harvesting method:

$$(9)\quad METHOD = f(ZONE,\ C_f,\ USE,\ C_o),$$

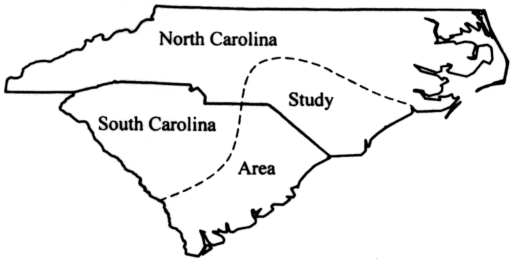
where *METHOD* is the harvesting method (discretionary dependent variable).[7]

III. DATA

The unit of observation for this study is the forest or timber stand, which is a tract of forest with similar age, species composition, location, and belonging to a single ownership. Here each stand is treated as a homogeneous unit with respect to its stand characteristics, location,

7. It is widely known to foresters and some landowners that the RCW will go away if no prescribed burning is used for a period of seven to ten years and the understory hardwood grows high enough to reach the RCW cavity holes. I have run a model similar to equation (9) and found a negative but statistically insignificant relationship between prescribed burning and closeness to a known or perceived RCW habitat. I understand that several key variables (such as closeness of a stand to a city or township and the attitude and experience of landowners with fire) are missing in the model. Further research could be done in this area.

FIGURE 2
Geographical Regions Included in Timber Harvesting Survey



and species composition.[8] Ideally, we would like to have a random sample of timber stands in different zones. Such a forest stand database was not available, so I had to rely on a survey of landowners. The sampling strategy was to randomly select a group of landowners and reveal their timber harvesting decisions in various stands for a given period of time.

The study area covers 32 counties in the sandhills and coastal areas of South Carolina and North Carolina (Figure 2). All of these counties currently have active RCW populations. A mail survey designed according to the total design method by Dillman (1978) and Salant and Dillman (1994) was conducted in fall 1998. The survey contained 56 questions, focusing on timber harvesting activities (and the lack of them) in the previous ten years. If timber harvests had been conducted, the landowners were asked to provide location (the closeness to a known or perceived RCW habitat), harvesting method used, and forest stand characteristics for a maximum of (the last) three stands cut in the past ten years.[9] They were then asked to provide the same information for the oldest forest stand that had not been cut and was older than 35 years (because all known RCW cavity trees are older than 35 years and the RCW prefers to reside in older pine forests). Those who had not cut any timber were asked to provide information for the oldest forest stand. Those who had not cut any timber in the past ten years and did not have any forest stands old than 35 years were only asked to respond to questions related to landowner characteristics. In other words, landowners who cut trees less than 35 years old and who did not have stands that are more than 35 years old were excluded from this study; therefore, the heterogeneity of tree ages were controlled for.

There are no current and comprehensive databases with information on the location of known RCW habitat on private lands. The database maintained by the National Heritage Foundation is based on historical occurrence records, not periodic and systemic surveys. As such, the quality of the database is questionable. For example, the South Carolina database only has 51 known RCW occurrence records on private forestlands, far less than the estimates by the U.S. Fish and Wildlife Service. Furthermore, the RCW records on public forests in the database do not match up well with those in the database maintained by the U.S. Fish and Wildlife Service, which is based on periodic surveys. Thus the U.S. Fish and Wildlife Service do not use the National Heritage Foundation database even without an RCW location map of its own on private land (not to mention a list of surrounding landowners). Note that even if my measure of RCW proximity is not factually accurate, it may give a better measure of landowners' perception of RCW proximity than would a perfect GIS database. Harvesting decisions will be influenced by what landowners know and think, not necessarily by what is true.

Because some questions concerning the forest stand characteristics were fairly detailed and technical, landowners who could not answer them were asked to provide the names, addresses, and phone numbers of assistance foresters they used or their timber buyers. Then a follow-up telephone interview with these foresters or timber buyers was conducted to recover this information.

8. It is possible that one large stand could become two stands if the landowner conducts two separate timber harvesting or harvests a portion of it and leaves the rest intact.

9. I wanted to take a *snapshot* at timber harvesting behavior of random-selected landowners using a window of ten years. All landowners we surveyed had the opportunity of providing information on their *last* timber harvest. If they cut more than one stand, they were asked to provide information on the second and third last timber stands harvested. I did not include other timber stands harvested in the survey for two reasons—landowners might not have the information on these harvests and, more important, putting too many questions in one survey questionnaire would reduce response rate. I only asked the oldest standing timber stand. The logic for not asking more standing timber stands is simple—everything else being equal, the oldest stand should get cut first. Therefore, if a landowner cuts a 45-year-old timber stand but keeps a 55-year-old timber stand, there must be a reason. In searching for the reason, we do not need to ask information on another 40- or 50-year old stand.

The sampling procedure was designed to achieve a representative and unbiased sample of relatively large nonindustrial private forest landowners, as the chance of small landowners having RCW on their lands is relatively remote. Industrial forest landowners were excluded from this study primarily because they have the time (the marginal utility that can be generated from a particular stand at a given time is small), space (planning can be done on large land base), and financial flexibility that nonindustrial forest landowners rarely have. In addition, some industrial forest landowners have signed "No Take Agreements" with the U.S. Fish and Wildlife Service, which give them assurance that they would not be challenged under the ESA since 1994. Finally, nonindustrial private owners own approximately 70% of forest lands in the U.S. South, whereas industrial forest owners own some 20%. Nonindustrial private forests are more important to various endangered species, including the RCW. Nonetheless, excluding industrial owners from this study does not mean that the ESA does not impact their behavior, but that their behavior could be different from that of nonindustrial private landowners.

The names and addresses of all forest landowners who owned more than 100 acres of forestland in these counties were collected from individual county tax assessors. Seven counties only provided a list of owners of farm and forestlands over 100 acres. After deleting all known industrial forest landowners, a sample of 1 out of 10 landowners (and 1 out of every 15 for the seven counties with combined lists of landowners) in each county was then selected for the survey. The final mailing list comprised 1742 randomly selected landowners.

The final survey sample had 1696 landowners because 48 surveys (3%) were returned unopened. Five hundred eight of the surveys were completed and returned, representing a response rate of 30%.[10] A follow-up telephone survey of a randomly selected sample of 50 (3%) of the nonrespondents reveals that nonresponding is not correlated to the size of ownership, income, education, age, and state origins. Some 190 respondents that did not cut any timber in the past 10 years and had no forest stands older than 35 years were excluded from this study, leaving 318 respondents. Excluding respondents who reported hardwood stands, which is not a good habitat for the RCW and is not relevant to this study, leaves 252 respondents and 522 timber stands (as some respondents reported more than one stand). However, information on characteristics of 206 stands was not available because some landowners did not respond to the questions and did not provide the name of their assistance foresters or timber buyers. The final number of timber stands useful for this study is 316, of which 230 were harvested in the last 10 years and 86 remain standing. Clearcutting was used in 164 of the 230 harvested stands, and other methods, including seed-tree, shelterwood, selection, and thinning, were used on the remaining 66 stands. Sixty-seven landowners provided information on both stand(s) they cut and their oldest remaining stands. These 134 stands comprise the sample used in the timber harvesting model.[11]

Table 1 provides the definitions of variables used in the statistical analysis, their mean values, and standard deviation. The mean values and standard deviations of the variables used in the harvesting method model are not much different from these in the harvesting model and are not reported here. Tables 2 and 3 present the corresponding information for each zone. Though the means for *HARVEST* and *METHOD* are 0.50 and 0.71, respectively, for all observations (Table 1), they differ between zones (Tables 2 and 3). However, any conclusions regarding the effect of *ZONE* on harvesting decisions can only be firmly drawn after additional econometric analysis is conducted, because other factors differ between zones as well.

10. The primary appeals for landowners to respond to our survey are the importance of the issue under this study and the promise of sending them papers coming out of the research.

11. The reason for using this partitioned data in timber harvesting model is to control for the possible nonrandomness of the survey as landowners might have cut more than three stands and have more than one remaining stands. In this case, all 67 landowners having two (or more) stands chose to cut one and leave the other(s) intact. This approach is similar to a controlled experiment on the same landowners who harvest one mature stand and leave the other(s) intact. Another approach is to augment the sample by including landowners who only cut one or more stands but do not have any remaining stand and who only have one or more remaining stands but did not cut any. The results using this augmented sample (227 observations) are similar to those reported in Table 4, although the coefficient (1.272) and marginal effect (0.287) of the *ZONE* variable (both are significant at the 1% level) using the augmented sample are slightly larger.

TABLE 1
Variable Definitions and Sample Statistics

Variable	Definition	Mean	SD
HARVEST	Whether or not harvest occurred (dummy: 1 if timber harvesting occurred in the last 10 years, 0 otherwise)	0.500	0.502
METHOD	Harvesting method (dummy: 1 if clear-cut, 0 otherwise)	0.713	0.453
ZONE	Proximity to a known or perceived RCW habitat (dummy: 1 if adjacent or within 1 mile of a known RCW habitat, 0 otherwise)	0.306	0.463
TR	Expected or potential total stumpage revenue of mature forest products per acre, in constant 1997 $ (100)	23.668	10.591
BA	Basal area in square feet	75.097	24.479
SPECIES	Predominant species (dummy variable: 1 if longleaf pine, 0 otherwise)	0.269	0.445
SIZE	Number of acres of the stand	200.246	550.615
USE	Primary use (dummy: 1 if primarily used for anything other than timber production, 0 if for timber production)	0.515	0.502
FIRE	Use of prescribed burning (dummy: 1 if prescribed burning is used for every 7 years or less, 0 otherwise)	0.410	0.493
FINCOME	Percent of forestry income in the family's total annual income in the last 5 years (dummy: 1 if more than 10%, 0 otherwise)	0.418	0.495
LENGTH	Years of forest land ownership	29.119	22.102
EDUCATION	Owner's level of education (dummy: 1 if college or post graduate degree, 0 otherwise)	0.821	0.385

Of the independent variables in the two regressions, that for the location, *ZONE*, is of special interest in this study. *ZONE* was assigned a value of one if the stand was (or was perceived to be) adjacent to or within one mile of a known or perceived RCW habitat and zero otherwise (i.e., if the stand was more than one mile away from a known RCW habitat or the owner did not know or was not sure how far the stand was from an RCW habitat).[12] Because proximity to existing habitat increases the odds of colonization, which would bring the ESA regulation into force, the coefficient for this variable was expected to have a positive sign in both harvesting and harvesting method models.

The expected or potential total revenue (per acre) variable, *TR*, is included in equation (8) to capture variations among stands in the amount of money an owner could get from each stand at some given set of prices. It is calculated as

$$TR = \sum (P_i * V_i)/CPI \tag{10}$$

where P_i and V_i are stumpage prices and harvested volume of product i (i includes pine products—pole, sawtimber, chip-n-saw, and pulpwood—and hardwood sawtimber and hardwood pulpwood), and *CPI* is the Consumer Price Index (1997 = 100). Stumpage price data were from Timber-Mart South (1999) and were tied to the date (quarter of the year) of harvesting. When the stand is not cut, the total

12. The choices for this distance question (how far is the stand from the closest RCW habitat) are within the habitat, adjacent to the habitat, not adjacent to but within 1 mile of the habitat, 1–5 miles from the habitat, 6–18 miles from the habitat, more than 18 miles from the habitat, and do not know or is not sure. Scientific evidence shows that the RCW rarely goes beyond 1–5 miles from its habitat in search for food, and no RCW has been found more than 18 miles from its cavity trees under normal conditions. See Kulhavy et al. (1995). My preliminary analysis indicates that landowners change their behavior when they know or perceive that RCW is within one mile of their timber stand. About 26% of respondents indicated that they did not know or were not sure how far their stands were from an RCW habitat. Excluding these landowners generates results similar to those reported here.

TABLE 2
Sample Statistics of the Explanatory Variables by Zones for Timber harvesting

Variable	*ZONE* = 1 Mean	*ZONE* = 1 SD	*ZONE* = 0 Mean	*ZONE* = 0 SD
HARVEST	0.707	0.461	0.409	0.494
TR (100 in 1997$)	26.965	12.070	22.214	9.583
BA	83.829	23.091	71.247	24.196
SPECIES	0.195	0.401	0.301	0.461
SIZE	196.829	771.190	201.753	423.912
USE	0.488	0.506	0.527	0.502
FINCOME	0.439	0.502	0.409	0.494
LENGTH	28.073	17.338	29.581	23.974
EDUCATION	0.829	0.381	0.817	0.389
No. of observations	41		93	

TABLE 3
Sample Statistics of the Explanatory Variables by Zones for Timber Harvesting Method

Variable	*ZONE* = 1 Mean	*ZONE* = 1 SD	*ZONE* = 0 Mean	*ZONE* = 0 SD
METHOD	0.786	0.412	0.654	0.478
TR (100 in 1997$)	27.722	9.606	29.014	13.268
BA	82.942	19.225	84.354	22.193
SIZE	140.835	168.385	97.724	144.684
USE	0.466	0.501	0.386	0.489
FIRE	0.350	0.479	0.386	0.489
FINCOME	0.466	0.501	0.488	0.502
LENGTH	40.952	41.166	30.465	22.316
EDUCATION	0.806	0.398	0.835	0.373
No. of observations	103		127	

revenue is calculated as of the fourth quarter of 1998. The coefficient of *TR* was expected to be positive for the harvesting model as landowners harvest when the expected total revenue is high.

The stand characteristics include *BA* (basal area), *SPECIES*, and *SIZE*. The coefficient of *BA* was expected to be positive in the harvesting model because high basal area means that the stand is dense and that doing nothing to the stand will reduce its biological growth rate. Its sign was also predicted to be positive in the harvesting method model because dense forests make selective cutting more difficult to conduct without damaging trees intended to be left. The variable *SPECIES* was used to control for the predominant species in the stand. Longleaf pine is known to be a preferred species for the RCW. However, longleaf typically matures later than other pine species, and, everything else being equal, landowners will cut it later than other species. Therefore, the sign of the *SPECIES* variable could only be determined empirically. The variable *SIZE* was expected to have a negative sign in both models because, everything else being equal, cutting too much timber within a year could make landowners jump to a higher tax bracket and pay more income taxes.[13]

The variable *USE* represents the primary management objective of landowners. It was expected to be negative for the harvesting model and positive for the method model. If landowners have a primary objective other than timber production (such as hunting and other recreation, hunting lease, pine straw harvesting, farm or domestic use, and land investment), they will delay timber harvesting, making the *USE* variable have a negative sign in the harvesting model and use other aesthetically appealing harvesting methods if they decide to cut some timber (which will make the *USE* variable have a positive sign in the harvesting method model).

A variable *FIRE* was used in the harvesting method model to control for the "cleanness" of forest stands on harvesting method. It was expected to have a negative sign for three reasons. First, the forest stands will be clean if fire is frequently used, making nonclear-cut harvesting methods applicable. Second, fire promotes natural regeneration, and harvesting methods other than clear-cutting protect young tree seedlings better. Finally, fire promotes park-like stands with little understory, which is preferred by the RCW. Thus, those who use clear-cut method to reduce the likelihood of regulatory taking due to the RCW would tend not to burn. Since *FIRE* and *SPECIES* are highly correlated ($r = 0.79$), the variable *SPECIES* was dropped from equation (9) to avoid multicollinearity. The high level of correlation between these two variables reflects the fact that longleaf pine forests are fire-dependent. In other words, longleaf pine forests could easily be converted to other forests in a few years without natural or controlled fires.

13. Landowners can cut a portion of a large stand to avoid paying high tax. In this case, the stand size will be smaller than the whole stand. See note 8.

TABLE 4
Results of Logistic Regression on Timber Harvesting Model

Variable	Coefficient	*t*-Ratio	Marginal Effect	*t*-Ratio
ZONE (proximity to an RCW habitat)	1.002	2.189*	0.250	2.183*
TR (potential total stumpage revenue)	0.040	1.689*	0.010	1.688*
BA (basal area)	0.019	1.785*	0.005	1.784*
SPECIES (predominant species)	0.184	0.388	0.046	0.388
SIZE (acreage of the stand)	−0.001	−0.859	0.000	−0.863
USE (primary use)	−1.266	−2.788*	−0.316	−2.787*
FINCOME (share of forestry income)	0.016	0.036	0.004	0.036
LENGTH (years of ownership)	−0.010	−1.014	−0.002	−1.014
EDUCATION (level of education)	−0.979	−1.747*	−0.244	−1.747*
INTERCEPT	−0.786	−0.820	−0.196	−0.820
Log-likelihood function	−73.913			
Restricted log-likelihood function	−92.882			
Chi-squared (df = 8)	37.938			
No. of observations	134			

*Significant at the 10% level.

Finally, three variables were used to control for characteristics of landowners. *FINCOME* was expected to be positive in both models, as landowners with a high portion of their income from forests tend to cut more timber, either through timber harvesting or using clear-cut methods. The variables *LENGTH* and *EDUCATION* were expected to be negative in both models because highly educated and knowledgeable landowners with longtime land ownership might be more appreciative of multiple forest uses and have a longer-term perspective on forest management.

IV. EMPIRICAL FINDINGS

Equations (8) and (9) were run using linear logistic regression. Both models fit relatively well as the chi-squared statistics are significant at the 0.01% level or better. Models in which the continuous independent variables took logs were run as well. In both cases, the simple linear model performed better. None of the variables used has pair-wise correlation coefficients exceeding ±0.35.

The results of the regression for equation (8) are presented in Table 4, using only 134 observations (the last stands harvested in the last ten years and the oldest timber stands that had not been cut, as reported by the 67 landowners). Of the nine parameters estimated, five are significant at the 10% level or better. All signs in estimated models confirm my expectation, and most of the values, as indicated by the marginal effect, appear reasonable. What is critical about this analysis is that each landowner had at least two stands that were more than 35 years old, of which one was harvested. The question is, did proximity to RCW influence the landowner's choice of which one was cut?

The variable for closeness to a known or perceived RCW habitat, *ZONE*, is positive and significant at the 5% level. This is consistent with the hypothesis that possible regulatory intervention induced by proximity to a known or perceived RCW habitat has a significant positive impact on landowners' decisions to harvest timber. These results indicate that after allowing for other influences, the likelihood of timber harvesting is higher when the stand is close to a known RCW habitat. The marginal effect, as shown in Table 4, is quite large (about 25%). In other words, a landowner is 25% more likely to cut forests when he or she knows or perceives that a RCW cluster is within a mile of the land than otherwise.

The coefficient for total revenue per acre is positive and significant at the 10% level, confirming the expectation that high revenue increases the possibility of the stand being cut. Among other significant influences on timber harvesting probability, the positive coefficient for basal area suggests that dense stands tend to be harvested earlier, as expected. The coefficients for the primary use and education

TABLE 5
Results of Logistic Regression on Timber Harvesting Method Model

Variable	Coefficient	*t*-Ratio	Marginal Effect	*t*-Ratio
ZONE (proximity to a RCW habitat)	1.084	3.058***	0.207	3.156***
BA (basal area)	0.001	0.016	0.001	0.016
FIRE (use of prescribed fire)	−0.521	−1.610*	−0.099	−1.620*
SIZE (acreage of the stand)	−0.002	−2.353**	−0.001	−2.340**
USE (primary use)	0.135	0.398	0.026	0.398
FINCOME (share of forestry income)	1.280	3.525***	0.244	3.659***
LENGTH (years of ownership)	−0.013	−2.605***	−0.002	−2.646***
EDUCATION (level of education)	−0.259	−0.586	−0.049	−0.586
INTERCEPT	1.056	1.398*	0.201	1.428*
Log-likelihood function	−122.166			
Restricted log-likelihood function	−137.863			
Chi-squared (df = 8)	31.393			
No. of observations	230			

*Significant at the 20% level.
**Significant at the 5% level.
***Significant at the 1% level.

TABLE 6
Predicted versus Actual Outcomes of Timber Harvesting and Harvesting Method Models

Actual	Predicted 0	Predicted 1	Total	% Correct	Random Assignment (%)
Timber harvesting model					
0	48	19	67	72	50
1	20	47	67	70	50
Total	68	66	134		
Harvesting method model					
0	24	42	66	36	29
1	7	157	164	87	71
Total	31	199	230		

variables show that they, too, have significant impacts on timber harvesting probability, both in a negative way. Other variables for species composition, income from forestry, and length of ownership are not significant. The marginal effects of all significant variables are also significant.

The results of the regression for harvesting method equation (9) are reported in Table 5. The variable *ZONE* is significant at 1%, confirming that possible regulatory intervention has a positive impact on landowners' decision to employ clear-cutting as their harvesting method. The marginal effect of this variable is about 21%. The other significant variables include use of prescribed fire, stand size, percent of forestry income, and length of forest ownership. In this model, the coefficient for the basal area is not significant at normal levels. Dropping this variable did not have much impact on the estimates of other variables.

Table 6 compares the predicted and actual outcomes for the two models. This measures the performance of the models in predicting landowners' timber harvesting behaviors. For example, in case of the timber harvesting model, the model correctly predicts 95 (48 + 47) of the 134 outcomes, an overall success rate of 71%. Comparing the two specific outcomes, the model correctly predicts 72% of the "0 (no harvesting)" and 70% of the "1 (harvesting)." However, the model performs well in predicting the usage of clear-cut method but not the usage of other harvesting methods. To demonstrate the explanatory power of the model, another measure is presented in the rightmost column of Table 6. The numbers in this column show the randomly assigned ratios of 1 and 0 to the dependent variables. That is, if there were no explanatory variables and outcomes were assigned according to their ratios, 50% (67/134) will be correctly predicted as 0 and 1 in the timber harvesting model. Comparing these numbers to those in the percent correct column demonstrates an increase in the explanatory power of the model due to the inclusion of the independent variables.

A Comparison with a Similar Study

The results of this article are similar to those presented in Lueck and Michael (2003), who use quite similar logic and techniques. It is striking that two similar studies were initiated independently at roughly the same time and that the results reached support each other.

Nonetheless, there are differences in these studies. Data used in these two studies are different. Lueck and Michael use secondary data (U.S. Forest Service Forest Inventory Survey data and a North Carolina State University survey data) in North Carolina alone. As such, they do not control for landowner characteristics. In contrast, this study uses primary data based on a survey of landowners in both North and South Carolina. More important, the proximity to RCW is measured as actual *number* of colonies within various (5, 10, 15, and 25 miles) distances to a forest property in their study but as known or perceived *existence* of RCW habitat (as defined by U.S. Fish and Wildlife Service, an RCW cluster area, which is the 200-foot-area surrounding a cavity tree, and foraging habitat is a minimum of 60 acres within half a mile of the cluster) within 1 mile to a forest property in this study. Consequently, the magnitude of the marginal effect of this proximity variable in these two studies is somewhat different and may not be directly compared. Third, this study is able to control for forest characteristics, such as basal area and tract size, whereas the other study has done better in controlling for landowner objectives. Finally, this study is able to cover another dimension of timber harvesting—harvesting method (and to a much lesser degree, the use of controlled burning), and the other study covers actual rotation age and industrial landowners.

Despite the use of different data, the basic conclusions reached in these two studies are similar: the ESA regulations actually lead landowners cut their timber sooner, to the detriment of the RCW, than they otherwise would do. As a consequence, RCW habitats have been reduced on private lands because of the ESA. In this case the ESA imposes costs but does not generate conservation benefits. These findings add substance to anecdotal claims of preemption and are consistent with concerns of those who have noted that RCW populations have been declining since it has been listed as an endangered species.

V. CONCLUSIONS AND POLICY IMPLICATIONS

The purpose of this study was to assess quantitatively the popular notion that regulatory uncertainty induced by possible invasion of an endangered species influences landowners' decisions to cut timber quickly and to use a harvesting method that forecloses potential endangered species habitat. The conventional logic is clear: without any financial compensation for providing endangered species habitat but facing more governmental regulatory limitation on their land use and management if an endangered species comes onto their property, landowners have no incentive to voluntarily provide additional habitat for endangered species. Instead, landowners will act in ways that they might not otherwise act—to cut timber and eliminate suitable habitat and to do so before endangered species come onto their lands to protect or enhance the existing value of their property. Furthermore, they have an incentive to urge their neighbors to do the same, because the RCW on neighboring land increases the vulnerability of them and other neighbors as well.

The findings of this study support this general argument. To this extent, they are broadly consistent with the conclusion of other studies on property right security such as Epstein (1985), Feder et al. (1988), and Zhang and Pearse (1996; 1997) and on the ESA in popular magazines and books such as Mann and Plummer (1995) and Stroup (1995) and in academic journals such as Stroup (1996) and Innes (1997). The results of this article help verify with independent evidence the point made earlier by others but supported empirically primarily by Lueck and Michael (2003), that at least for the RCW, the ESA has a strong and negative effect on habitat. More uniquely, the empirical findings indicate that the magnitude of disincentive-induced destruction or foreclosure of potential endangered species habitat may be substantial.

The implications of these findings are significant. Of the vast majority of endangered species that have some or all of their habitats on private lands, the likelihood of them thriving is not great if the current policy is not changed. A full recovery of these species, as mandated in the ESA, is even more remote because private landowners have little incentive to provide additional habitat to endangered species but much incentive to preclude them from coming onto their lands. Facing isolation, some endangered species could eventually become extinct. Moving all of these species onto public lands seems to be an impractical solution for most endangered or threatened species.

Having realized that perverse incentive could lead to undesirable harvesting behavior, some environmental groups have started to lobby for more flexible regulations and more programs that provide positive incentives for landowners.[14] The Environmental Defense Fund (1995) recommends cost-share programs and tax breaks for landowners who provide habitat for endangered species. Stroup (1996) and Bourland and Stroup (1996) call for compensation or rental payments to landowners who provide endangered species habitat on their land. If implemented, a compensation policy would provide economic incentives that induce landowners to supply more endangered species habitat. However, Czech and Krausman (1999) show that the political feasibility of this policy is questionable. Furthermore, the transaction costs for implementing it need to be studied.

Some individuals and groups do not want to make any changes to the ESA, and that's why the ESA has been mired in congressional gridlock since its authorization expired in 1992. Those who want to use the ESA as a tool to stop development, construction, and logging certainly do not want to weaken the ESA provisions on private or public lands. "Not in my back yard" motives are also served by the strong ESA as currently formulated, while listed species seems to be quite badly served. When considering ESA reauthorization, it would be wonderful if policy makers can identify the noise made from these bootleggers and look at hard empirical evidences.

Public lands can be affected in the same way by the ESA as private lands. For example, if U.S. Department of Defense uses land (such as Fort Benning, GA, and Fort Bragg, NC, which both have RCW colonies) for military exercises and such land use is threatened if listed species are found thereon, their commanders may, to protect their military missions, engage in habitat modifications to the same end as private landowners and with the same negative results for habitat. At another extreme, four firefighters lost their lives in Okanogan National Forest in Winthrop, Washington, in July 2001 because delays in granting permission for fire-fighting helicopters to use water from nearby streams and rivers protected by the ESA (Fox News [2001]). More likely, because the managers of public lands have a weak ownership of the land, they are not expected to alter land use to preempt the ESA. Thus the ESA will be more successful in preserving habitat on public land. But the current ESA could still provide incentives to public land managers to either act like private landowners or stick to the ESA overzealously.

The problem with the ESA is not an artifact of private property or market operation as difficulty with implementing it exists in private as well as public lands. Rather, it reflects the tunnel vision by those seeking to serve their own mission—whether it is saving species or other goals—at unlimited expense of other missions. Why else would land use restrictions emanating from the ESA not be considered as in the case of public lands or be paid for as in the case of private lands, regardless of their cost?

The broad policy implications of this study are twofold. First, the ESA is not working well on private lands because it does not provide adequate incentive for landowners to conserve endangered species and enhance habitat. Any attempt to make ESA more effective will have to accommodate the need of private landowners and provide them with positive incentives for endangered species conservation. More flexibility in the application of the ESA, such as the Safe Harbor Program, is a step toward correcting misguided incentives. However, it is not enough to attract many small, nonindustrial landowners who do not have the necessary time, space, and financial resources that large and industrial landowners possess. Second, many environmental

14. The Safe Harbor Program is invented for this purpose. Safe Harbor is a voluntary agreement between landowners and U.S. Fish and Wildlife Service. Under the agreement, landowners commit actions that are expected to benefit endangered species. In return, they receive assurances that they can "undo" these actions in the future. The agreement applies to landowners with or without an endangered species on their lands. In either case, a preagreement baseline population of endangered species (which may be zero) is established, and landowners are required to maintain this population unless unforeseeable natural events destroy endangered species habitats.

regulations have unintended consequences with respect to producer and consumer behavior, such as creating additional harm to the environment that the regulations were intended to protect. Future reforms to these regulations need to eliminate or reduce the regulation-induced behavior by providing positive incentives to producers and consumers. In other words, regulations can work or work better only when there is incentive compatibility.

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