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Endangered Species and Timber Harvesting: The Case of Red-Cockaded Woodpeckers

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Abstract

This paper 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. Timber harvesting probability and methods in a large number of mature private forests are assessed using a forest production model based on the conventional theory of capital. The empirical results indicate that landowners whose forests are close to a known RCW habitat have a high propensity to cut timber and use a clear-cut method. All these behaviors may be to achieve one apparent objective: destruction or foreclosure of potential RCW habitat quickly and before the Endangered Species Act (ESA) comes into force. This means that ESA has given landowners perverse economic incentives and induced actions that they would otherwise not have and that are detrimental to the full recovery of endangered species. The results have implications for future reforms in environmental regulations.

I. Introduction

The issue of differentiating legitimate public regulation of private property from regulatory takings has become important and controversial in the U.S. (Pilon 1988; Flick et al. 1995). The Endangered Species Act (ESA), probably the most powerful environmental regulation ever enacted in the U.S., is in the center of this controversy. First enacted in 1973 and amended several times since, the ESA is intended to protect species from becoming extinct (Tobin 1990). The ESA creates two main processes: the *designation* of species and their critical habitat through listing, and *protection*. 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 (Souder 1995).

Under ESA, no person may take endangered or threatened species. Taking is defined very broadly—far beyond merely killing an animal or plant. 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 [ESA section 3(19)]." Furthermore, U.S. Fish and Wildlife Service guidelines define harm to include "an act which actually kills or injures wildlife by significant habitat modification or degradation where it actually kills or injuries by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering." This regulatory definition and its application to private lands have recently been upheld by the U.S. Supreme Court (*Sweet Home v. Babbitt*, 11 S.Ct. 714, 1995).

More than 80 percent of listed endangered species have some habitats on private lands, most of which are private forest and agricultural lands (GAO 1994). There are no publicly-provided incentives for private landowners to protect endangered species. Federal tax incentives and cost sharing programs used to encourage private landowners to behave so as to advance public objectives, such as soil conservation and tree planting, have not been used to protect endangered species until very recently (Eisner et al. 1995).

The usual presumption is that, other things being equal, landowners would avoid management activities that would attract endangered species onto their lands. 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 some environmental groups, especially the Environmental Defense Funds, designed and implemented the “Safe Harbor Program,” “No Surprise Policy,” and “No Take Regulation” (EDF 1995, Zhang 1999). Except for some isolated case studies (e.g., Mann and Plummer 1995), the view that weakness in the current endangered species related regulations impedes good management and stewardship of forest resources is rarely supported by quantitative evidence.

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 on private rights and landowner behavior and performance (e.g., Posner 1992; Cotter and Ulen 1988; Zhang and Pearse 1996, 1997). However, despite its importance to public policy, the quantitative influence of endangered species related regulatory uncertainty on landowner behavior has not received much attention, partly due to its controversial nature and the requirements of strict confidentiality of many landowners that have endangered species on their lands.

This paper 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 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 of this paper is that regulatory uncertainty and lack of positive economic incentive alter landowner timber harvesting behavior and hinder endangered species conservation on private lands. This paper 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, conclusions, and policy implications.

II. Analytical Framework

The Birds and the Regulation

The RCW was listed as an endangered species in 1970. Unlike other woodpeckers, the RCW chooses to chisel 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 fungus, which tends to weaken the heartwood and make the birds' excavation somewhat easier. Furthermore, the RCW prefers open park-like stands containing little understory and usually forages for insects on trees over 45 years in age. In much of the vast southern pinery, hardwood forms a substantial component of the forest, to the detriment of the RCW. 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 significance of the RCW is that it needs medium to large size tracts of mature southern pine forests for its habitat. Southern pines are the most important commercial species in the South. Since the South accounts for nearly half of the timber harvests and one-third of forest inventory in the country (Powell *et al.* 1992) and more than 70 percent of southern forests are privately owned, protecting the RCW will likely alter some private forest management activities. Therefore, the RCW probably has the most significant economic impacts on private and public landowners in the U.S. of all endangered species except the Northern Spotted Owls (Souder 1995).

The U.S. Fish and Wildlife Service has specific rules that apply to private landowners with RCW (U.S. Fish and Wildlife Service 1992). This manual contains definite restrictions on private landowners' forest management options. In the cluster area, a 200-foot radius (2.9 acres) surrounding a cavity tree, no trees greater than 10 inch in dbh (diameter at breast height or at 1.3 meters height) should be cut, no pesticide should be used, and no road should be built without permission. In addition, a minimum of 60 acres of foraging habitat within a half mile of the cavity tree, and a minimum of 3,000 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. Since a half-mile radius covers 502 acres, landowners can do some timber harvesting if they or other landowners maintain enough foraging habitats within a half mile of the cavity tree.

Unlike the Northern Spotted Owls, RCW is a territorial bird, meaning that it usually does not fly far away from its primary habitats. The biological attributes of RCW, its significant economic impacts, and the presence of a government guideline for managing private forests where RCW resides all provide a unique opportunity to study the impact of ESA-related regulatory uncertainty on landowner behavior.

Will forest landowners have an economic incentive to harvest early before the RCW comes to their lands and otherwise manage in a way that minimizes the suitability of their forests for RCW habitat? Previous studies are primarily focused on national forests (e.g., Hyde 1989) or numerical calculation of the impacts of the guidelines on timber harvesting revenue (Cleaves et al. 1994; Meyers et al. 1995) or forest conditions and timber production possibilities when RCW is present (Rosie et al. 1990). We adopt an analytical and econometric approach to answer this question.

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

A landowner who faces regulatory uncertainty or possible invasion of an endangered species may behave differently from other landowners in terms of timber harvesting. This behavior can be shown in a simple forest production model. To illustrate the main point of the analysis, we take the perspective of stand-level optimization. We assume the following:

(i) Capital markets are perfect so that timber producers can borrow and lend at a known real interest, r.

(ii) Stumpage prices, P, are constant;

(iii) Timber yield, Q(t, I) is a function of age t and silvicultural investment I, where $Q_i=\partial_q/\partial_i>0$; $Q_{ii}<0$ for i=t, I.

(iv) If no endangered species are on the land, the landowner has a secure property right to his forest, and the probability of losing a portion of the forest is zero. There is a non-zero (δ) probability of losing a portion (α, $0<\alpha<1$) of the forest if an endangered species moves into the forest and ESA applies. This is a case of 'partial regulatory taking' where regulations only restrict landowner's management activity, take away part of their property rights, and reduce the value of their property partially, and landowners do not get any compensation.

(v) The probability of losing a portion of his forest (δ) is an increasing function of time. This reflects that the longer the landowner waits before harvesting, the more likely he will lose a portion of the forest because RCW prefers to reside in old growth forests.

The analysis is considerably clearer and more intuitive if we simply consider 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. 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 problem 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 forests (α=0), the expected value of the forest can be expressed as:

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

If he does lose a portion (α) of their forests (δ=1), the expected value of the forest can be expressed as:

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

The objective is then to maximize:

$$V(t, E) = (1 - \delta)\ [P\ Q(t, I)\ e^{-rt} - I] + \delta\ [(1- \alpha)\ P\ Q(t, I)\ e^{-rt} - I] \qquad (3)$$

This is the well-known Faustmann formula with the addition of a stochastic uncertainty factor (Gane 1968). It is the same as 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 contains the weakness that it is 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

$$V(t, E) = (1 - \alpha\, \delta)\, P\, Q(t, I)\, e^{-rt} - I \quad (4)$$

First order condition for a maximum requires that

$$\partial V/\partial t = [(1 - \alpha\, \delta)\, (P\, Q_t - r\, P\, Q) - \alpha\, \delta_t\, P\, Q]\, e^{-rt} = 0 \quad (5)$$

Which can be simplified as

$$Qt - \alpha\, \delta_t\, Q\, /\, (1 - \alpha\, \delta) = r\, Q \quad (6)$$

or

$$Qt/Q = r + \alpha\, \delta_t\, /\, (1 - \alpha\, \delta) \quad (7)$$

The optimal condition (6) can be interpreted easily. On the right is the interest foregone by postponing harvesting the forest 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 harvest due to ESA during the period. Obviously, for optimality the marginal gain from postponing the harvest one period must equal the marginal loss of postponement.

Since δ_t and $(1 - \alpha\, \delta)$ are great than zero, the second term in equation (7) is positive. In the absence of policy uncertainty, $\delta = 0$, equation (7) simply reduces to the well-known result that a forest should be harvested when its rate of growth equals the discount rate. With regulatory uncertainty, the forest should be harvested when the rate of growth is more than the discount rate. In other words, the effect of policy uncertainty has the same impact as the increasing discount rate in the Faustmann formula. A review of literature shows that, in general, an increase in discount rates leads to earlier harvesting (Hyde 1980, Chang 1983, Hyde and Newman 1991). Therefore, everything else being equal, landowners who face possible invasions of endangered species to their forests will cut timber earlier than those who do not have to face the regulation.

The possibility of RCW invasion is higher when a forest stand is close to an RCW habitat. Figure 1 illustrates the location relationship among landowners who have an endangered species (say, the RCW) on their lands and those who face possible invasions of the endangered species on their lands. Lands in zone one are active endangered species habitats and therefore are subject to the ESA. Lands in zone two are adjacent to or very close (say, within 1 mile) to the active RCW habitats, and there is a high possibility of the endangered species moving to these lands in the near future if suitable habitats are provided. These lands will be subject to the ESA if RCW does come. Lands in zone three are farther away from the active RCW habitats and relatively safe from possible RCW invasion.

Everything else being equal, we hypothesize that landowners close to an active RCW habitat will harvest their forests earlier and use a harvesting method that forecloses potential RCW habitats. There are, of course, other factors that will influence landowners' timber harvesting behaviors in particular circumstances—the marginal revenue and characteristics of the forest stand and the landowners' characteristics. Thus,

$$\text{HARVEST} = f\,(\text{ZONE, MR, } C_f\text{, USE, } C_o) \qquad (8a)$$

$$\text{METHOD} = f\,(\text{ZONE, MR, } C_f\text{, USE, } C_o) \qquad (8b)$$

where HARVEST is harvest or not (discretionary dependent variable);

METHOD is the harvesting method (discretionary dependent variable);

ZONE is a measurement of closeness of a forest stand to a known RCW habitat;

MR is the marginal revenue of the stand;

C_f is the characteristics of the forest stand, including basal area (a measure of density and tree size, species composition, and size of the forest stand;

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

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

The results of a regression of the above logistic equation can reveal the influence on landowner timber harvesting and harvesting method decision of each of the independent variables. Clear-cutting, the most destructive method to a potential RCW habitat, is hypothesized to be more often used when the possibility of the RCW's coming to the stand is high.

III. Data

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

The study area covers 32 counties in the sandhills and coastal South Carolina and North Carolina (Figure 3). All of these counties currently have active RCW. A mail survey designed according to the total design method (Dillman 1978) was conducted in the Fall of 1998. The survey contained 56 questions, focusing on timber harvesting activities (and the lack of them) in the past 10 years. If timber harvests had been done, the landowners were asked to provide location (the closeness to a known RCW habitat), harvesting method used and forest stand characteristics for a maximum of three stands they cut in the last 10 years. They were then asked to provide the same information for one oldest forest stand that had not been cut and was older than 35 years (All known RCW cavity trees are older than 35 years). These who had not cut any timber were asked to provide information for the oldest forest stand. And those who had not cut any timber in the last 10 years and did not have any forest stands old than 35 years were only asked to respond to questions related to landowner characteristics.

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

The sampling procedure was designed to achieve a representative and unbiased sample of relatively large non-industrial private forest landowners in these counties. Industrial forest landowners were excluded from this study because they have the time, space, and financial flexibility that non-industrial forest landowners rarely have. In addition, many forest landowners have signed "no take agreements" with the U.S. Fish and Wildlife Service so that they can conduct forest practices approved by the Service, and the Service will not challenge their management activities under the ESA.

The names and addresses of all forest landowners who owned more than 100 acres of forest lands (large tract is more likely to attract RCW) in these counties were collected from individual county tax assessors. Seven of these counties only provide a list of owners of farm and forestlands over 100 acres. After deleting all known forest industry landowners, a sample of one out of 10 landowners (and one out of every 15 for the seven counties with combined lists of forest and agricultural landowners) in each county was then selected for the survey. The final mailing list comprised 1,742 randomly selected landowners.

The final survey sample had 1,696 landowners since 48 surveys (3%) were returned unopened. Five hundred and eight of the surveys were completed and returned, representing a response rate of 30 percent. A follow-up telephone survey of a randomly selected sample of 50 (3%) of the non-respondents reveals that non-respondents are not correlated to the size of ownership, income, education, age, and county origins. The overall estimated error for the survey results is plus or minus 4 percent at the 95 percent confidence level. Some 190 respondents that did not cut any timber in the last 10 years and have no forest stands older than 35 years were excluded from this study, leaving 318 respondents. Excluding stands that are predominantly hardwood (66), which is not a good habitat for RCW and is not relevant to this study and another 18 stands where (18) pre-mature thinning method (thinning of stands less than 30 years' old) was applied leaves 522 timber stands (and 252 respondents as some respondents reported more than one timber harvesting). However, information on characteristics of 206 stands are not available as some landowners did not respond to the questions and do not have or did not provide the name of assistance forester or timber buyers. The final useful timber stands used in this study are 316, of which 230 were harvested in the last 10 years and 86 are still standing. Of the 230 harvested stands, clear-cutting was used in 164 stands and other methods, including seed-tree, shelterwood, selection, and thinning, were used in the rest of the 66 stands.

Table 1 describes the variable definitions used in the statistical analysis, their mean values, and standard deviation. The mean values and standard deviations of these variables used in the harvesting method model are not much different from these in the timber harvesting model and are not reported here. Tables 2 and 3 present the corresponding information for each zone.

HARVEST and METHOD are two qualitative dependent variables that were estimated by means of logistic regression. HARVEST took the value of one when the stand was harvested in the last 10 years and zero otherwise. Similarly, METHOD took the value of one when the stand was harvested using clear-cutting and zero otherwise.

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 is adjacent to or within one mile of a known RCW habitat and zero otherwise (i.e., if the stand is 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). Since closeness to an RCW habitat may attract RCW to the tract and bring the ESA that affects the management options for landowners, the coefficient for this variable is expected to have a positive sign in both harvesting and harvesting method models.

Landowners' timber harvest decisions are often based on the marginal revenue of cutting the timber and the marginal cost of letting the timber grow one more period. They cut their timber when the marginal revenue equals marginal cost. Therefore, a variable MR, the marginal revenue per acre, is included in equations 8a and 8b. It is calculated as

$$MR = \sum(\text{Pine Product} * \text{Stumpage}) * \text{Interest rate} / \text{CPI} \quad (9)$$

The pine products cover pole, sawtimber, chip-n-saw, and pulpwood. The first part of equation 9 is the total revenue per acre. Multiplying it by the interest rate gives the marginal revenue of the stand. CPI is the consumer producer index (1997=100), which standardizes the MR in the 1997 constant dollar. Since the interest rates of individual landowners are unknown, we used the prime loan rate—the interest rate that banks charge their best customers, as an instrumental variable to reflect the general conditions of the money market.

Equation 9 is valid because change in marginal revenue as a result of price change and biological growth equals interest rates. When the stand is not cut, the marginal revenue is calculated as of the fourth quarter of 1998. The coefficient of MR is expected to be positive for the harvesting model. However, its sign in the harvesting method model is less clear. One on hand, large marginal revenue may mean that landowners can afford to use harvesting methods other than clear-cutting. But there are no theoretical base and empirical studies that show marginal revenue influencing landowners' choices of any specific harvesting methods.

The stand characteristics include BA (basal area), SPECIES, and SIZE. The coefficient of BA is 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. However, its sign is difficult to predict in the harvesting method model since no empirical study on the relationship between basal area and landowner's choice of harvesting method exists.

The variable SPECIES took the value of 1 when the predominant species in the stand was Longleaf pine, and zero otherwise. Longleaf pine is known to be a preferred species for RCW. However, longleaf typically matures later than other pine species, and, everything else being equal, landowners will cut it later than other species. Since we have controlled for factors related to the possibility of the RCW's coming to the stand, the coefficient of SPECIES is expected to be negative. The variable, SIZE, is expected to have a negative sign in both models because cutting too much timber within a year could make landowners jump to a high tax bracket and pay more income taxes.

The variable USE is a dummy variable that represents the primary management objective of landowners. It took the value of one if the primary objective was anything other than timber production (hunting and other recreation, hunting lease, pine straw harvesting, farm or domestic use, and land investment). It is expected to be negative for the harvesting model and positive for the method model. If landowners have a primary objective other than timber production, they will postpone timber harvesting and use other aethestically appealing harvesting methods if they decide to cut some timber.

A variable FIRE was used in the method model to control the cleanness of forest stands on harvesting method. It took the value of 1 if landowners used prescribed fire in every 7 years or less and zero otherwise. It is expected to have a negative sign for two reasons. First, the forest stands will be cleaner if fire is frequently used, making other harvesting method such as seed-tree, shelterwood, thinning applicable. Second, fire promotes natural regeneration. Harvesting methods other than clear-cutting protect young tree seedlings better.

Finally, three variables were used to control the characteristics of landowners. FINCOME took the value of one if a landowner had more than 10 percent of his family income from his forests in the last 5 years and zero otherwise. It is expected to be positive in both models, as landowners with a high portion of their income from forests tend to cut more timber. LENGTH is the number of years since owning the first tract of forest. It is expected to be negative for both models since landowners who have owned forestlands for a long time have probably developed a better land stewardship ethic. The variable EDUCATION took the value of one if the landowner had a college degree or post-graduate degree. It is expected to be negative in both models as they are more knowledgeable and probably more appreciative of forest uses other than timber production.

IV. Empirical Findings

Equations 8a and 8b were run using linear logistic regression. Both models fit relatively well as the –2log L (-2*the logarithm of likelihood ratio) and Score test are all significant at the 0.1 percent level or better. Models in which the continuous independent variables took logarithms were run as well. In both cases, the simple linear model performed better. None of the variables used has correlation coefficients exceeding "0.40.

The results of the regression for equations 8a and 8b are presented in Tables 4 and 5, respectively. Of the 10 parameters estimated in each equation, 6 are significant at the 10 percent level or better in the timber harvesting model and 5 are significant in the harvesting method model. Most of the signs and values appear reasonable. Indeed, all signs in estimated models confirm our expectation.

The variable for closeness to a known RCW habitat, ZONE, is positive and significant in both models at the 1 percent level. Therefore, possible regulatory intervention induced by proximity to a known endangered species habitat has a significant positive impact on landowners' decisions to harvest timber and to use the clear-cut method. These results indicate that after allowing for other influences, the possibility of timber harvesting and using the clear-cut method are higher when the stand is close to a known RCW habitat.

Figures 3 presents the effect of ZONE on the probability of timber harvesting and harvesting method, respectively. These relationships are based on the results in Tables 4 and 5. To produce these figures, the continuous variables were fixed at their mean values, and the others based on the assumption that the stand is predominantly longleaf pine and is used primarily for timber production, prescribed burning is used for every 7 years or less, the owner's income from forestry is greater than 10 percent of his family income, and the owner has a college degree.

The coefficient for marginal revenue is positive and significant at the 1 percent level, confirming the expectation that a high marginal revenue increases the possibility of the stand's being cut (Table 4). Among other significant influences on timber harvesting probability, the positive coefficient for basal area suggests that highly dense stands tend to be harvested earlier, as expected. The variables for size and primary use show that these, too, are significant influences on timber harvesting probability, both in a negative way. Education influences the timber harvesting possibility in the same fashion. Other variables for species composition, income from forestry, and length of ownership are not significant.

The coefficients for variables in the harvesting method model are similar to those in the timber harvesting model. The other significant variables include size, use of prescribed fire, forestry income, and length of forest ownership. In this model, coefficients for the marginal revenue and basal area are not significant at any reasonable significant level, indicating that both variables do not influence a landowner's choices of harvesting method.

V. Conclusion 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 the landowner's decision to cut timber quickly and to use a harvesting method that forecloses the potential endangered species habitats. The logic of this convention is clear enough: Without any financial compensation for providing habitats for endangered species but more governmental regulatory limitation on their land use and management options, landowners do not have any incentive to voluntarily provide any additional habitats for endangered species. Thus, landowners will do things that they might not do otherwise—to cut the timber and eliminate suitable habitats and to do so before the endangered species come onto their lands.

The findings of this study support this general argument. To this extent, they are broadly consistent with the conclusion of other studies on property rights (Feder et al. 1988; Luckert 1988; Zhang and Pearse 1996, 1997) and on the Endangered Species Act in popular articles and books (Mann and Plummer 1995; Stroup 1996). More uniquely, the empirical findings indicate that the magnitude of disincentive-induced foreclosure of potential endangered species habitat is large.

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, their future to stay there and to survive well is not bright if the current policy is not changed. A full recovery of these species, as mandated in the Endangered Species Act, is even more remote as private landowners have little incentive to provide additional habitats to endangered species, but to much incentive to preclude them from coming onto their lands. Facing isolation, many groups of endangered species could eventually die out. Moving all of these species onto public lands seems to be an unpractical solution for most endangered or threatened species.

Having realized this situation, many environmental groups started to lobby for more flexible regulations and more programs that provide positive incentives for landowners. Safe Harbor is invented for this purpose. Safe Harbor is a voluntary agreement between landowners and the U.S. Fish and Wildlife Service. Under these agreements, landowners are committed to doing something that is expected to benefit endangered species. In return, landowners receive assurances that they can "undo" the thing that they carry out under the agreements in the future. The agreements apply to landowners with or without an endangered species on their lands. In either case, a pre-agreement 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. Others have called for cost-share programs and tax breaks for landowners who provided habitats for endangered species (e.g., EDF 1996).

A more dramatic solution is to provide for compensation or rental payments for landowners who provide endangered species habitats on their land (e.g., Epstein 1985; Bourland and Stroup 1996). If implemented, a compensation policy will provide all incentives that landowners need to provide habitats for endangered species. However, the political feasibility of this policy is unknown, and the transaction costs for implementing this policy need to be studied.

The results of this study have broad policy implications. First, the ESA is not working on private lands because it does not provide much incentive to landowners. Any attempt to make ESA more effective will have to accommodate the need of private landowners and provide them positive incentives for endangered species conservation. More flexibility in the application of the ESA, such as Safe Harbor, is a step towards the right direction. However, it is not enough to attract small, non-industrial landowners who do not have the necessary time, space and financial resources that large and industrial landowners possess. Second, many environmental regulations designed to protect the environment have unintended consequences on producer and consumer behavior, which in turn, harm the very environment that the regulation is intended to protect. Future reforms to these regulations need to eliminate the regulation-induced behaviors by providing positive incentives to producers and consumers. In other words, regulations can work or work better only when private incentives are built in.

It is widely known to foresters and many forest landowners that the RCW will go away if no prescribed burning is used for a period of 7 to 10 years so that understory hardwood grows high enough to reach the RCW cavity holes. We have found a negative but statistically insignificant relationship between prescribed burning and closeness to a known RCW habitat. We understand that several key variables such as closeness of the site to a city or township and the attitude and experience of landowners with fire were missing from the models. Further research could be done in this area.

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Table 1. Variable definitions and sample statistics

Variable	Definition	Mean	Standard deviation
HARVEST	Occurrence of timber harvesting (dummy: 1 if timber harvesting occurred in the last 10 years, 0 otherwise)	0.7278	0.4458
METHOD	Harvesting method (dummy: 1 if clear-cut, 0 otherwise)	0.7130	0.4533
ZONE	Closeness to a know RCW habitat (dummy: 1 if adjacent or within one mile of a known RCW habitat, 0 otherwise)	0.4051	0.4917
MR	Marginal revenue of pine products per acre, in constant 1997 dollar	196.3412	90.0782
BA	Basal area in square feet	79.4873	22.7041
SPECIES	Predominant species (dummy variable: 1 if longleaf pine, 0 otherwise)	0.2848	0.4520
SIZE	Number of acres of the stand	172.1772	427.4596
USE	Primary use (dummy: 1 if primarily used for anything other than timber production, 0 if for timber production)	0.4905	0.5007
FIRE	Use of prescribed burning (dummy: 1 if prescribed burning is used for every 7 years or less, 0 otherwise)	0.3956	0.4897
FINCOME	Percent of forestry income in the family's total annual income in the last 5 years (dummy: 1 if more than 10 percent, 0 otherwise)	0.4462	0.4979
LENGTH	Years of forest land ownership	34.4430	30.3485
EDUCATION	Owner's level of education (dummy: 1 if college or post graduate degree, 0 otherwise)	0.8259	0.3798

Table 2. Sample Statistics of the explanatory variables by zones for timber harvesting

	ZONE =1		ZONE = 0	
Variable	Mean	Stand deviation	Mean	Stand deviation
HARVEST	0.8047	0.3980	0.6755	0.4694
MR (in 1997 dollar)	193.9880	81.5384	197.9434	95.6371
BA	78.8125	21.5417	79.9468	23.5083
SPECIES	0.4219	0.4958	0.1915	0.3945
SIZE	228.5547	565.8152	133.7926	294.4664
USE	0.5547	0.4990	0.4468	0.4985
FINCOME	0.4531	0.4998	0.4415	0.4979
LENGTH	39.9844	38.8832	30.6702	22.1209
EDUCATION	0.8125	0.3918	0.8351	0.3721
No. of observations	128		188	

Table 3. Sample Statistics of the explanatory variables by zones for timber harvesting method

	ZONE=1		ZONE =0	
Variable	Mean	Standard deviation	Mean	Standard deviation
METHOD	0.7864	0.4118	0.6535	0.4777
MR (in 1997 dollar)	211.0242	77.3784	213.2681	101.5531
BA	82.9417	19.2246	84.3543	22.1927
SIZE	140.8350	168.3852	97.7244	144.6842
USE	0.4660	0.5013	0.3858	0.4887
FIRE	0.3495	0.4791	0.3858	0.4887
FNCOME	0.4660	0.5013	0.4882	0.5018
LENGTH	40.9515	41.1657	30.4646	22.3162
EDUCATION	0.8058	0.3975	0.8346	0.3730
No. of observations	103		127	

Table 4. Value for the explanatory variables for timber harvesting

Variable	Coefficient	Wald χ^2 ratio
ZONE	1.1996	11.7109***
MR	0.0065	7.8354***
BA	0.0212	7.4099***
SPECIES	-0.1280	0.1341
SIZE	-0.0014	4.2985**
USE	-1.0721	11.2374***
FINCOME	0.1860	0.3584
LENGTH	-0.0010	0.0278
EDUCATION	-0.6114	2.1917*
INTERCPT	-0.9362	1.7706
–2 log L (df=9)	72.8700	
Score (df=9)	67.7260	
No. of observations	316	

* Significant at the 10 percent level.
** Significant at the 5 percent level.
*** Significant at the 1 percent level.

Table 5. Value for the explanatory variables for timber harvesting method

Variable	Coefficient	Wald χ^2 ratio
RCW	1.0836	9.3377***
MR	-0.0001	0.0056
BA	0.0004	0.0021
SIZE	-0.0025	5.4396**
USE	0.1329	0.1524
FIRE	-0.5203	2.5792*
FINCOME	1.2798	12.4277***
LENGTH	-0.0130	6.7190***
EDUCATION	-0.2579	0.3407
INTERCPT	1.0618	1.9564
–2 log L (df=9)	31.3990	
Score (df=9)	29.3700	
No. of observations	252	

* Significant at the 10 percent level.
** Significant at the 5 percent level.
*** Significant at the 1 percent level.

Figure 1. Endangered species habitat zone and its surrounding areas

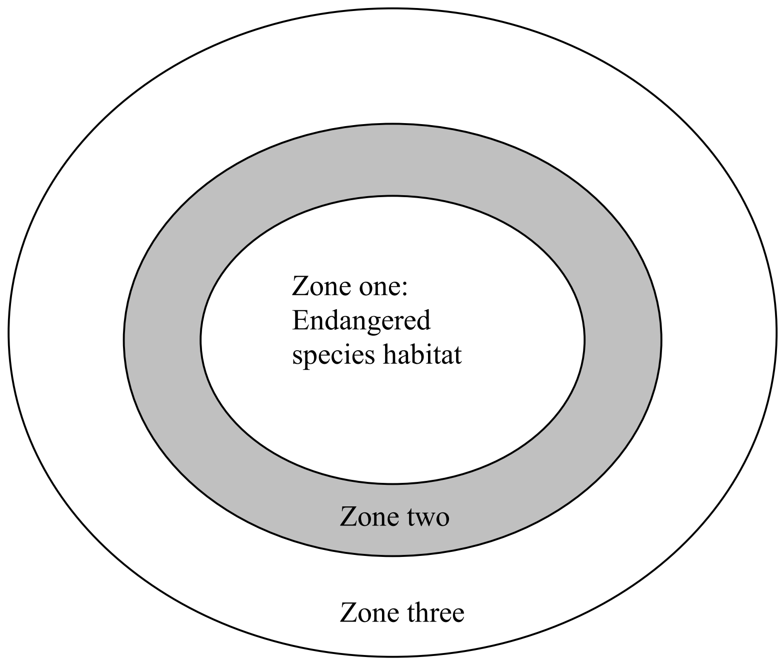

Figure 2. Geographical regions of North and South Carolina included in the timber harvesting survey

Figure 3. Probability of timber harvesting and using clear-cut method