Arbitrage, Options and Endangered Species

Geoffrey Heal*
Columbia Business School

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Abstract

I model the impact of mitigation banking accompanied by Safe Harbor provisions on a land-owner's choices about supporting a population of an endangered species. The Safe Harbor provision is equivalent to a free call option on a population with market value, and mitigation banking can allow a land-owner with an endangered species to arbitrage between land without and with permission to develop. A land-owner whose land is not zoned for development may therefore stand to benefit from the discovery of an endangered species on his land.

Key Words: Endangered Species, Arbitrage, Options, Habitat, Mitigation Banking.

JEL classification: G 19, Q 20.

1 The ESA and Mitigation Banking

One of the most important pillars of environmental conservation in the United States, the Endangered Species Act (ESA) is also arguably one of the most controversial. The operation of the Act has evolved substantially since its inception in 1973. Originally administered in a fashion that was economically inefficient, a failing that was bad economics and bad politics, the last two decades have seen more imaginative and flexible approaches to its implementation, with the introduction of habitat conservation plans, natural community conservation plans, mitigation banking and safe harbor provisions amongst others.[1] These have undoubtedly made the attainment of the Act's goals less costly and have softened its impact on land owners, particularly private landowners (see Bean [2] and Polasky and Doremus [9]). But have they compromised the effectiveness of the Act from a strict conservation perspective? Where

*Author's address: gmh1@columbia.edu, 616 Uris Hall, Columbia University, New York NY 10025. www.gsb.columbia.edu/faculty/gheal/ I am grateful to Michael Bean, Kai Chan, Raymond Dacey, Frank Davis, Dale Goble and Mike Scott for helpful comments.

[1] See Brown and Shogren [5], Noss et al [8], Czech and Krausman [6].

will such developments lead if pursued to their fullest extents? Do they represent a good model for the evolution of species and habitat conservation? This paper focuses on one of these developments, mitigation banking, which, although widely used and growing in acceptance, has rarely been the subject of a thorough analytical study that melds together economic and ecological concepts. We develop an analytical model of mitigation banking and Safe Harbor provisions[2] in the context of the ESA and use this as a vehicle to study the impact of such measures on the conservation of species and the economic cost of this conservation.

Mitigation banking (MB) was introduced in the Clean Water Act of 1977. Its essence is that developers are allowed to use habitat that is threatened and protected provided that they mitigate by ensuring the conservation in perpetuity of a compensating amount of equivalent habitat elsewhere, with the choice of what is a compensating amount, and what is equivalent habitat, determined by the appropriate conservation authority. In particular, compensation may be at a rate of more than one for one, so that more than one acre of land must be set aside elsewhere to compensate for the use of one of the original acres. A developer may in addition conserve more equivalent land than required and hold this excess to sell to others who wish to develop and yet not be involved in finding and conserving equivalent space. This process of creating equivalent conserved land in excess of immediate requirements, to hold for future sale to others who need to mitigate, is known as mitigation banking, and is now a well-developed practice in some areas.[3] It was first introduced in connection with wetlands under the Clean Drinking Water Act, and has now spread to other types of habitat.

A more complex version of this practice has developed in the application of the ESA. A good illustration is an agreement reached between International Paper (IP) and the U.S. Fish and Wildlife Service concerning the red-cockaded woodpecker, *Picoides borealis*. This bird is endangered[4] and nests in forests owned by International Paper. IP and the Fish and Wildlife Service agreed on a target number of breeding woodpecker pairs, and provided that this number is attained or exceeded, IP will be regarded as complying with the ESA, whatever use they make of the land (Bayon [1], Bonnie [3], Bonnie and Bean [4]). Further, the agreement also provides that any surplus breeding on the land can be "banked,"— that is, used by the company to offset ESA requirements with respect to red-cockaded woodpeckers elsewhere. It is also possible that title to surplus could be sold to other landowners and used by them to gain some measure of exemption. This ability to store or sell the surplus over the amount required by regulations is mitigation banking. As the excess of nesting pairs over a target is salable, IP now actually has an economic incentive to encourage the

[2] The first Safe Harbor Agreement was approved in 1995, and the policy was codified in 1999.

[3] See for example www.wildlandsinc.com as an illustration of a company in the mitigation banking business.

[4] It was listed as an endangered species in 1973, one of the first species listed under the ESA (see Rosenzweig [10]).

endangered species, something it never had with a strict interpretation of the ESA. IP currently believes that it can sell banked breeding pairs for about $100,000 per pair, implying a value of the value of land for breeding woodpeckers greatly in excess of its value as a source of timber.[5][6]

This seems to be an interesting extension of mitigation banking to species conservation, with several potential advantages: it reduces the cost of compliance with the ESA to land-owners, and provides the latter with a clear financial incentive to encourage conservation. But to date there seems to have been no formal modelling of this, and no moves to check rigorously whether the promise is in fact likely to be fulfilled if there is extensive use of this scheme. Our aim here is to begin this process. Our conclusion is that mitigation banking with species and a Safe Harbor provision can radically change the ESA's impact on land-owners, to the point where under certain conditions it may be in their interests to discover endangered species on their land, quite the opposite of the current situation. Through promoting the growth of a population of endangered species on land that is not zoned for development and banking the population increase, the owner of this land may allow the release for development of land otherwise encumbered by the ESA, and effectively arbitrage between land with and without permission to develop.

2 A Model of Mitigation Banking

We begin our analysis with the simplest possible case, that of pure mitigation banking in land. We assume that there is an extant area of habitat that is valuable and should ideally be protected: this area is H_0. The management authority, the U.S. Fish and Wildlife Service in the case of the ESA, determines in response to pressure for development that an amount $\underline{H}$ must be conserved and that the difference $[H_0 - \underline{H}]$ can be sold for development. In addition, more of the initial area H_0 can be sold if an equivalent amount of currently unpreserved similar habitat is put irreversibly into preservation: this is the mitigation provision. We take it that a unit of similar habitat elsewhere is deemed equivalent if it is F times the area of the amount to be developed. The factor F is set by the management authority on the basis of ecological considerations. It need not be constant - it could depend on how far the new land is from the initial habitat, how similar or dissimilar it is in terms of soil characteristics, vegetation and species supported, and other relevant factors. As we are not explicitly modelling these, we take F to be a constant without any great loss of generality. And to make matters even simpler we take it to be one.

[5] The IP case is unusual in that the Mitigation Bank is performance -based, in that the credits given to IP depend on its success in managing the endangered species. This is not typical of earlier species mitigation banks. I am grateful to Michael Bean for this point.

[6] Some timber harvest can occur on land inhabited by the red cockaded woodpecker, provided it does not reduce the density of old tress too much: the opportunity cost of maintaing cover suitable for the woodpeckers has been estimated at $25,000 per pair (Michael Bean, personal communication).

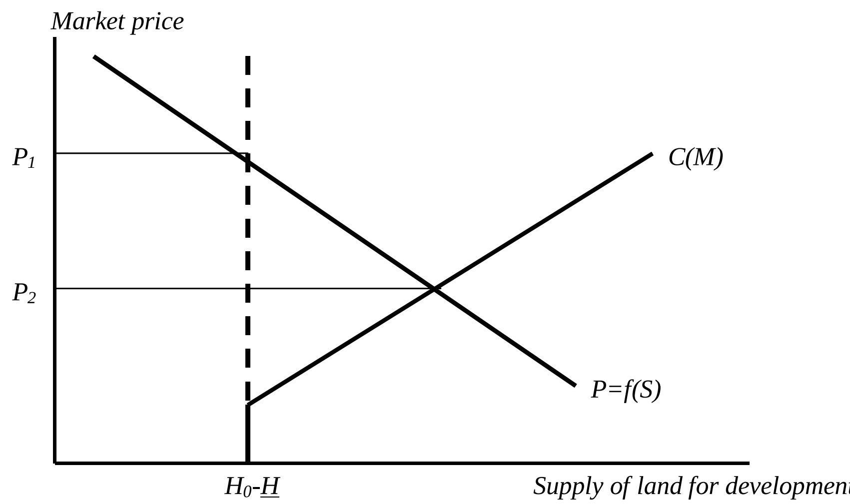

Figure 1: Equilibrium in the market for land without (P_1) and with (P_2) mitigation.

There is a demand for land for development in the original area. The demand curve is described by $P = f(S)$ where S is the amount supplied and P is what developers are willing to pay for an extra unit area: clearly P is decreasing in S. Absent any mitigation, the supply of land for development would be just $[H_0 - \underline{H}]$ and so the market price would be $P = f(H_0 - \underline{H})$. Mitigation allows the supply of land for development to be increased by the amount of land available for mitigation. But mitigation has a cost: the land to be banked has to be purchased and then set aside. As more equivalent land is purchased and set aside the cost of finding such land will rise: we assume the cost curve of land for mitigation is $C(M)$ where C is the cost of an extra unit and M is the amount used for mitigation. So at a market price of P per unit of land the total supply is the amount of the initial area allowed to be used for development $[H_0 - \underline{H}]$ plus the amount supplied for mitigation at a market price of P, which is the value of M given by $C(M) = P$. Hence we have a market equilibrium with mitigation when the price is such that demand and supply are equal, so that

$$f(H_0 - \underline{H} + M) = C(M)$$

Figure 1 shows this diagrammatically. $[H_0 - \underline{H}]$ is the amount of the original space made available for development, which constitutes a supply that is made available inelastically: to this supply is added the supply from mitigation banking, denoted $C(M)$. This supply curve intersects the demand curve at price P_2, which is lower than the price P_1 at which the market would clear in the absence of mitigation banking. So the impact of the banking provision is to lower the cost of development and to increase the supply of land for development, without the target habitat falling below $\underline{H}$. The precise amount by which these changes occur will depend on the slope of the curve $C(M)$, which in turn depends on the amount of equivalent land available, its cost, and the factor F that we took to be unity: a higher value for this will increase the cost of mitigation and raise the slope of $C(M)$. So ecological factors will affect the equilibrium price and the amount of development that occurs, and the final equilibrium is a function of both economic and ecological considerations. Whether the final equilibrium attains the conservation goals underlying the exercise depends on the mitigation factor F, which sets the terms on which developers have to compensate for protected land use.

3 Mitigation Banking with Species

Next we extend the model of the previous section to the application to endangered species illustrated above by the case of the red-cockaded woodpecker. For this extension we need to consider the factors that contribute to the size of the population of an endangered species. This clearly depends on the area of habitat available to it, which we denote by H. It also presumably depends on the resources put into supporting the species. In the case of the red-cockaded woodpecker, IP devoted resources to establishing nesting sites in places where these did not naturally occur. (It can take a red cockaded woodpecker a year to bore a nesting cavity - employees of international paper can do this in an hour.) In other cases endangered species may be protected from predators,[7] or some aspect of the physical environment may be controlled or modified for their benefit - stream flow may be modified to help fish or wild fowl,[8] or a wetland may be restored. We shall use the symbol R to denote the monetary value of the resources used to support the endangered species, understanding that across species the nature of the support may be very different. So the current population, denoted B, is a function of H and $R : B = f(H, R)$. B is clearly an increasing function of both H and R: it might be linear in H, so that if H is doubled with no change in R then the population will double in equilibrium. In this case, as a function of both variables B shows increasing returns. And if B is increasing in both inputs then this means that we can support the same population with less land if we use more resources, so there is a land-resource trade-off that is formalized in the function $f(H, R)$. This is illustrated by the isoquants of this function, curves in the $H - B$ plane that join alternative combinations of H and B that can support a given population. Figure 2 illustrates a possible form for these. Habitat is measured horizontally and resources vertically. The slope up and to the left shows that as we supply more resources a given population needs less habitat. There is, we assume, a minimum area of habitat needed by any population and this is the vertical asymptote of the

[7] As in the case of the Australian company Earth Sancturaies Ltd protecting native Autralian animals from introduced predators, see [7].

[8] This has occured with some dams in the Pacific Norrthwest.

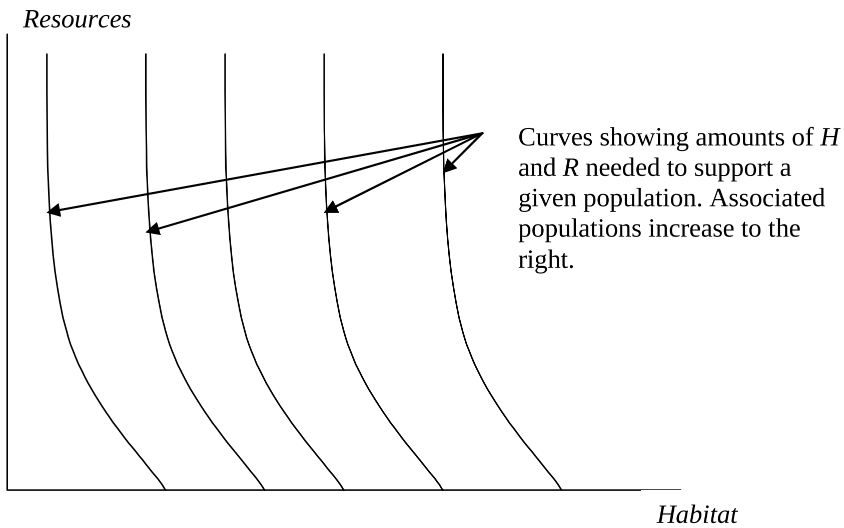

Figure 2: Isoquants of the population support function $B = f(H, R)$

corresponding isoquant.

Now we suppose that in this context we introduce a mitigation banking system of the type used for woodpeckers, and outlined above. Specifically, there is a current population B_0 and this must be preserved. Any land use is possible provided that the population remains intact. Initially no resources are devoted to supporting this population and the habitat used is H_0. Figure 3 shows us that some land can be released if we move up and to the left along the isoquant corresponding to the initial population, so that a possible response for the landowner is to do just this, investing in supporting the population and reducing the amount of land that it needs, so that land can be released for development. The landowner will invest in support until the marginal cost of releasing land this way just equals its market price.

An additional feature of the examples of species mitigation banking mentioned above is that if the population rises above B_0 then the excess over B_0 entitles the landowner to release more land for development, or to transfer to another landowner the right to use previously-restricted land for development. If land is used for development on the basis of a population increase then the higher population has to be maintained, but otherwise there is no obligation on the landowner to maintain the larger population. This feature of the agreements is known as a Safe Harbor provision: it assures the landowner that he cannot be made worse off by promoting the growth of an endangered species. As we shall see in more detail below, this provision gives an option-like structure to the landowner. In this aspect of the species mitigation banking arrangements an important parameter is the rate at which the

Figure 3: Red-cockades woodpeckers at nesting site (from US FWS web site)

Figure 4: Building a nest for a red cockaded woodpecker (from USFWS web site).

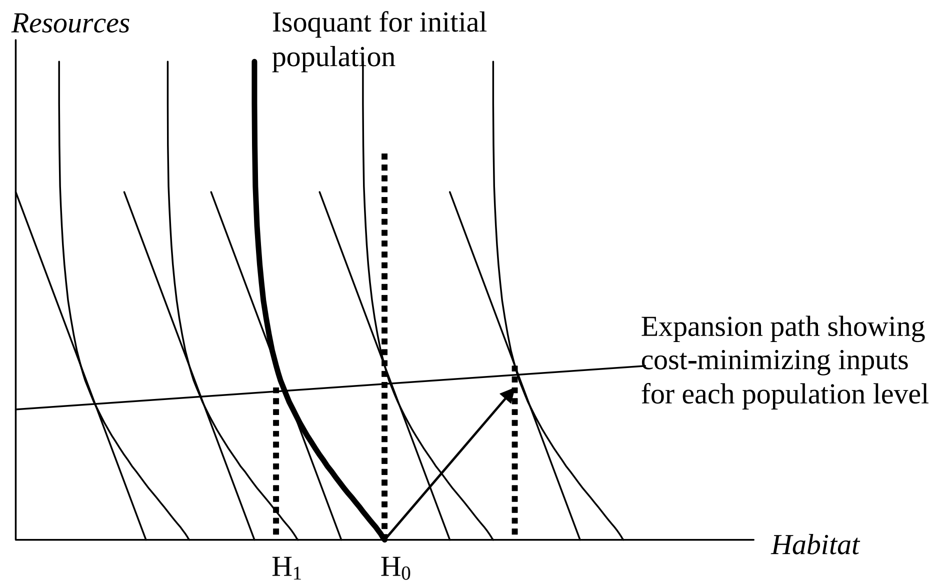

Figure 5: A land-owner's choice under mitigation banking and Safe Harbor

landowner is allowed to release land for development, or to entitle others to do this, as the population of the endangered species increases.

Figure 5 allows us to see geometrically the options facing a landowner who takes part in a system of mitigation banking with Safe Harbor provisions. The axes, as before, are the amounts of habitat and resources devoted to the support of an endangered population, with larger populations corresponding to curves further to the right. Initially the landowner allocates habitat H_0 to the species, and no resources, so that the population is that corresponding to the curve that cuts the horizontal axis at H_0 : call this population B_0. The straight lines that are tangents to the isoquants are budget lines - they show alternative combinations of resources and habitat that can be purchased for a fixed cost, and their slopes are all equal to the price ratio of resources to land. The least cost combination of land and resources that will support a given population is that where a budget line is tangent to the isoquant, and the line that connects all such tangencies is the expansion path shown in the diagram. The least cost way of supporting the population B_0 is therefore to reduce land input from H_0 and raise resource input until the point of tangency between the H_0-isoquant and a budget line is reached: this isoquant is shown in bold in the figure. This leads to a drop in the amount of habitat used from H_0 to H_1, and this much could then be sold for development purposes, consistent with maintaining the population intact. Alternatively the landowner could increase the population supported and then bank the increase, hoping to sell it to others. By maintaining the amount of habitat constant and raising the allocation of resources to a point on the expansion path he could generate a bankable population increase, and indeed he could generate an even larger population increase by moving in the direction of the arrow from H_0 and allocating more habitat and resources to produce a larger bankable surplus. Which of these would he choose, in order to maximize his profits?

We use L to represent the area of land that can be released from ESA restrictions in exchange for a one unit population increase. L is clearly a variable that is very central to this analysis, yet seems not to have been the subject of much discussion. Profits are given by

$$\pi = LP\left[B\left(H,R\right)-B_0\right]-R-P\left[H-H_0\right] \tag{1}$$

In this expression the term $\left[B\left(H,R\right)-B_0\right]$ gives the excess of the population after allocation of habitat and resources, $B\left(H,R\right)$, over the initial level B_0, and so is the amount available for banking. LP is the market value of the land that can be released as a result of this banking and so what the banked population is worth. To get profit we subtract from this the resources allocated R and also the market value of the habitat used (which could be negative if habitat is released and $H < H_0$). Choosing H and R to maximize profits gives as first order conditions

$$\frac{\partial B}{\partial H}L = 1 \text{ and } \frac{\partial B}{\partial R}LP = 1 \tag{2}$$

From these results we can perform elementary comparative static analysis to see how the allocation of land and resources to the endangered species changes as the parameters L and P are altered.

Suppose that L, the amount of land released when the population increases, is raised. How will the profit-maximizing value of H change? In other words, what is $\partial H/\partial L$ when the landowner is a profit-maximizer? Under the assumption that the marginal product of habitat decreases as habitat increases, this is positive: an increase in L will raise the amount of habitat allocated to supporting the endangered species. The same is true of the effect of an increase in L on the choice of resources R: assuming diminishing returns to resources alone, a higher L leads to more resources allocated to the endangered species. An increase in the price of land P acts in the same way, increasing the resources allocated to the species.

In the above analysis we assumed that there was a single price of land in equation (1), meaning that the price at which land can be sold as a result of mitigation banking is the same as the cost to the land-owner of using his own land. There will be cases in which this is true, but it was not in the red-cockaded woodpecker case. Here IP owned land zoned for forestry, whereas other neighboring landowners owned land zoned for development. The ESA applied equally to all, prohibiting activities that threatened woodpeckers on either type of land, but the value of releasing land zoned for development from ESA restrictions was obviously much greater than that of releasing land whose only permitted use was forestry. In a case like this there are two land prices, one P for land for development and another P_0 the opportunity cost to the land-owner of using his own land, with $P > P_0$. In this case profits are given by

$$\pi = LP\left[B(H,R) - B_0\right] - R - P_0\left[H - H_0\right] \tag{3}$$

and the first order conditions for a maximum are

$$\frac{\partial B}{\partial H}LP = P_0 \text{ and } \frac{\partial B}{\partial R}LP = P_0 \tag{4}$$

In this case both the amount of land and of resources allocated to supporting the population will increase with an increase in the ratio P/P_0 of the market price of land for development to the opportunity cost of land to the land-owner (assuming that the land-owner's land is not zoned for development). This reflects the fact that by using land of low market value to breed the endangered species and thus release high-value land to the market, the owner of the low-value land can appropriate some of the value of land zoned for development. The banking of the endangered species becomes a vehicle for arbitrage between two different land markets.

Now assume that there is a spontaneous increase in the population of the endangered species, from B_0 to B_1. The growth in population means that some land can be released for development, but to offset this the higher population requires more land and resources to support it. The landowner will presumably support the extra population if the value of the land released exceeds the cost of land and resources needed to support the population increase. The amount of land released when one new population unit is released is L. We use $H_0(B)$ to stand for the amount of land needed to support a population of B when no additional resources are provided, so that

$$B = f(H_0, 0)$$

There is a cost to supporting a higher population because more resources and land are needed. The minimum cost of supporting a population of B when the market price of land is P is given by the cost function

$$C(B,P) = \min_{f(H,R)\geq B}\left[PH + R\right]$$

which corresponds to the locus of points of tangency between a budget line and and isoquant in figure 3. The profit that a landowner makes from the sale of land when the population rises by one unit is therefore

$$\pi = PL - \frac{\partial C(B,P)}{\partial B} \tag{5}$$

where $\frac{\partial C}{\partial B}$ is the marginal cost of a population increase. Because the landowner does not have to support the population increase unless it is in his interest to do so under the Safe Harbor provisions, his profit from the increase is in fact the maximum of (5) and zero:

$$\pi = \max\left(PL - \frac{\partial C}{\partial B}, 0\right) \tag{6}$$

This makes it clear that the Safe Harbor provisions act to give the landowner a call option[9] on the profits from population growth.

There is an important irreversibility associated with releasing land for development, as developed land can rarely be returned to is original condition, and in particular to a condition where it can support the endangered species. This implies an asymmetry: resources that can substitute for land in supporting an endangered population can be withdrawn easily whereas the land that they replace cannot be returned to a state in which it can replace them. Policy-makers therefore need to ensure that resources that replace land are committed in perpetuity if the land is developed.

3.1 Expansion of Habitat

To date the focus of mitigation banking has been the preservation of existing habitat. Could the same methods be applied to adding new habitat to what currently remains for an endangered species?[10] This is an important issue in conservation terms as the habitat that remains when a species is endangered is often, indeed almost by definition, inadequate for that species to thrive. Merely to conserve the existing habitat is therefore to condemn the species to a shadow existence on the margins of extinction. Figure 5 provides an insight into the possibility of providing new habitat: it shows that the profit-maximizing policy for the landowner could indeed be to increase the total habitat available to the species, following the rightwards arrow from H_0. Under what conditions will he choose to do this?

Equations (2) and (4) indicate an answer. Focus on (4), which is the more general: this shows that an increase in L or in the ratio P/P_0 will increase the amount of habitat allocated to the species. So raising the amount of land that can be released as the population grows, or raising the ratio of the price of released land to the price of habitat, will raise the amount of habitat available. One way of raising the ratio P/P_0 is to lower the effective value of P_0, the opportunity cost to the landowner of putting land into use for supporting the endangered species. A natural policy instrument for achieving this would be a tax deduction on for the value of the land so allocated, in effect treating it as if a conservation easement were placed on the land. I noted above that resources committed to supporting a species in place of land could be withdrawn, whereas the land used for development as a result of the

[9] A call option on a good conveys the right but not the obligation to purchase the good at a pre-specified price, the exercise price. It has value if the market price exceeds the exercise prices and not otherwise.

[10] I am grateful to Kai Chan for posing this question.

commitment of those resources could not be undeveloped, implying that an important part of any agreement that results in the release of land for development must be a long-term commitment to the provision of the substituting resources. The same is true of committing habitat to the support of a species in exchange for the release of land for development elsewhere: the commitment of the habitat must be for the long-run, as would be the case if the commitment were made through a conservation easement, so that this is perhaps the appropriate way to manage this process.

3.2 Equivalence of Habitats

In section 2 an important variable was F, the amount of land that has to be banked to offset the use of a unit of valued habitat. I noted there that F certainly does not have to be a constant: the amount of land to be banked to offset one unit could naturally depend on its proximity to the land being used and also on its ecological characteristics, so that F is a formula or table rather than a single number. Nothing in the analysis of section 2 would change in this case.

The astute reader may have noticed that in section 3, on mitigation banking with species, there is nothing equivalent to the constant F. In a context where mitigation is in terms of species rather than land, there is no need to choose an equivalence rate for land, as there is a clear unit of measurement, the number of members of the threatened species. This suggests that when banking with land rather than species the rate of equivalence should be determined by capacity to support one or more threatened or endangered species. In the species banking case there is a parameter to be chosen, L, but this plays a rather different role, that of controlling in part the incentive that landowners have to invest in the species.

4 Conclusions

Mitigation banking with land alone appears to be capable of attaining its principle economic and political goals - reducing the impact of species conservation on land markets and providing some mechanism for compensating in part for the removal of land from the development market. It can reduce the impact of habitat conservation on market prices while still maintaining intact the amount of land targeted by conservationists. Any reservations must come from the ecological rather than economic aspects of this practice. Here the critical issue is whether the correct terms are set for compensation: these are the terms that set what type of land, where, and how much, will mitigate the loss of one unit of the designated habitat. This choice affects the economic outcome in the obvious ways - a more restrictive choice will raise the market price and vice versa. But whatever the choice the economic aspects of this system will operate correctly. However the wrong choice can nullify the ecological aspects of mitigation banking by leading to the conservation of areas and patterns of habitat that are not sufficient to support the threatened population.

Mitigation banking with species is more complex. Figure 3 and equations (1) and (2) show that in certain cases this can not only release land for development while preserving the initial population intact but may also provide an incentive for an affected land-owner to invest in increasing the population, as exemplified by the red-cockaded woodpecker case. This incentive is particularly strong in the case in which the opportunity cost to the land-owner of allocating land to the endangered species is below the market price of land zoned for development: mitigation banking effectively allows the land-owner to arbitrage between these markets via the endangered species bank, and provides him with an economic opportunity that is otherwise completely absent. Finding an endangered species on his land may in this case be in the land-owner's interest: if none of his land is zoned for development then he can nevertheless access some of the premium from development by facilitating development by others.

One more point that we noted above is the option value conveyed by the Safe Harbor provisions introduced under the ESA: these provisions allow a land-owner to support and bank an increased population only if it is to his advantage to do so, so he effectively has a free call option on the increased population. Obviously this has some economic value, though this might be difficult to quantify. This is another aspect of species mitigation banking that acts to the advantage of land-owners. The ESA, together with the mitigation banking provision, acts to redistribute wealth away from owners of land that can be developed and whose development is restricted by the ESA, towards owners of land not so zoned, who by supporting and banking the endangered species can sell to the others the key that unlocks their development potential, and take a fraction of that potential in exchange. Landowners as a group probably neither gain nor lose, but there is a redistribution within the group.

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