Investments in Biodiversity Prospecting and Incentives for Conservation

R. David Simpson
Roger A. Sedjo

Discussion Paper 96-14

April 1996

Resources for the Future
1616 P Street, NW
Washington, DC 20036
Telephone 202-328-5000
Fax 202-939-3460

Investments in Biodiversity Prospecting and Incentives for Conservation

R. David Simpson, and Roger A. Sedjo

Abstract

There is considerable interest in biodiversity prospecting (the search for valuable new products from natural sources) as a conservation strategy. In an earlier paper, we have argued that the value of the marginal species (and, by extension, the incentives for the conservation of the habitat on which it is found) is small. In this paper, we show that investments in biodiversity prospecting are unlikely to increase incentives for conservation by much. If the value of the marginal species were appreciable, researchers ought already to have made investments to exploit it. If it is not, it is doubtful that additional investments will generate any substantial increase. It is important to be clear about our findings: we are *not* saying that none of the myriad uses of biodiversity is important. Quite to the contrary, we are saying that if biodiversity is important, more effective strategies for its conservation must be found.

Keywords: biodiversity; biodiversity prospecting; investment; conservation policy.

JEL Classification Nos.: O13, Q29

Table of Contents

Investments in Biodiversity Prospecting and Incentives for Conservation

R. David Simpson, and Roger A. Sedjo[1]

I. INTRODUCTION

A number of authors have recently argued that biodiversity prospecting might be employed as a mechanism for financing conservation of biological diversity [see, e.g., Eisner, 1992; Wilson, 1992; Rubin and Fish, 1995; Mendelsohn and Balick, 1995]. Biodiversity prospecting is the search among naturally occurring organisms for new products of industrial, agricultural, and, particularly, pharmaceutical value. If payments received for biodiversity prospecting were dedicated to the maintenance of the natural habitats in which endangered species are found, further incentives for the preservation of such endangered species would be generated.

In recent work we have argued that the value of the "marginal species" with respect to its potential use for new product research is likely to be low [Simpson, Sedjo, and Reid, 1996a]. This result is an example of the diamonds and water paradox. No one could reasonably argue that biodiversity is not of great importance as a source of leads in the development of new products. Nature displays an inventiveness unlikely to be matched by synthetic chemists [Reid, *et al*., 1993]. But the important consideration for determining economic value–and for

---

[1] The authors are, respectively, Fellow and Senior Fellow, Energy and Natural Resources Division, Resources for the Future. This work has been supported in part by subcontract number DE-FG02-95ER62113 from the United States Department of Energy Office of Energy Research's Global Change Integrated Assessment Research Program. All opinions expressed are those of the authors only.

evaluating the conservation incentives generated by biodiversity prospecting–is not *total* value, but, rather, value at the margin. In our earlier work we have argued that if biologists are correct in their estimates of the numbers of untested–and, in many instances, undiscovered–species, the marginal species simply cannot command much willingness to pay. When numbers of species to be tested are large, the probability of discovery must either be so high as to make it likely that the marginal species will prove redundant or so low that no species tested is likely to yield the product being sought. If the marginal species is of little value, the marginal hectare of endangered habitat on which it is supported must also be of little value.[2] A country faced with a decision as to whether or not to convert habitat rich in biodiversity to another use will, then, have little incentive to preserve the marginal hectare of endangered habitat for its biodiversity prospecting potential.

The analysis of our earlier paper–and, indeed, the strategies of some conservation donors–begs another question, however: are there steps that may be taken to increase the conservation incentives afforded by biodiversity prospecting? Some authors have suggested that greater investments in biodiversity-prospecting-related assets might be helpful in the achievement of conservation objectives [see, e.g., Eisner, 1992; Mendelsohn and Balick, 1995]. In other work, we have made informal criticisms of such suggestions [Simpson, Sedjo, and

---

[2] In our earlier paper we noted that biogeographical models [e. g., MacArthur and Wilson, 1967] predict that species loss per unit of area loss are likely to be relatively small, so small estimates of the value of the marginal species should translate into correspondingly small estimates of the value of the marginal hectare of endangered habitat [Simpson, Sedjo, and Reid, 1996a]. It is worth noting in passing also that common biogeographical models support the notion that there is such a thing as a "marginal species:" species loss may reasonably be modeled as a smooth function of habitat conversion.

Reid, 1996b]. Our argument there can be summarized in two rhetorical questions. First, if more investment in biodiversity-prospecting-related capital is financially justified, why is the private sector not making such investments? Second, if more investment is not financially justified, would not conservation incentives be more efficiently provided by making direct payments for the conservation of imperiled biological diversity?

We are willing to entertain doubts about these matters. Perhaps private investors are confronted with certain market imperfections that dissuade them from investing as much as they otherwise might in biodiversity-prospecting-related assets. Perhaps difficulties in monitoring compliance and assuring performance would reduce the efficacy of more direct conservation-related payments.[3] We ought, then, to think about how increased investment (i. e., investment over and above the privately profit-maximizing level) would affect the value of the marginal species and consequent conservation incentives. Even if such investment might not be an ideal strategy in a world of perfect markets and information, might it be a useful second-best strategy for generating stronger conservation incentives?

The answer we derive is "probably not." We construct a simple model in which the speed with which natural samples can be tested is increased (in this context, this is approximately equivalent to an increase in testing capacity). The first-order condition characterizing the private profit-maximizing level of investment relates the value of the

[3] We must note in passing, however, that it is by no means obvious to us that these same market imperfections and information asymmetries would be any less problematic with respect to biodiversity prospecting investments than with respect to more direct payment mechanisms [for an informal analysis of these issues in a somewhat more general context, see Simpson and Sedjo, 1996b].

marginal species to the overall return on investment and the increase in technical efficiency afforded by additional investment. We find that the satisfaction of the first-order condition must imply one or more of the following: (1) the value of the marginal species is infinitesimal (in which case further investment would make it a somewhat larger, but still infinitesimal, quantity); (2) the biodiversity prospecting operation as a whole is on the verge of losing money (in which case the argument that additional funds devoted to it might be better spent on more direct conservation incentives gains force, even with the possibility of market imperfections); and/or (3) further investment would have only negligible impact on the value of the marginal species, as costs of further improvements are increasing rapidly.

In the next section we specify and develop our model, and elaborate the three cases reviewed above. Any tractable model of a phenomenon as complex as biodiversity prospecting must make a number of simplifying assumptions, and we cannot claim that the model we employ here has any close resemblance to reality. We do, however, argue in a final section that we have captured the essence of the phenomenon we are studying, and that elaboration of the model would not change the basic implications of our results. A final section briefly concludes.

In reporting work with potential for controversy it is always wise to be clear on what one is saying. We want explicitly to note that we are not making any judgments concerning the value–either in total or at the margin–of biodiversity in all its aspects. There are virtually innumerable ethical, esthetic, and ecological reasons for which conserving biological diversity may be extremely important. The model developed here is, in fact, motivated by the view that the value of biodiversity exceeds (and may vastly exceed) that which can be realized from biodiversity prospecting alone. The issue at present is not whether biodiversity prospecting motivates the preservation of biodiversity, but rather, whether there are better mechanisms to employ in pursuing that goal.

II. SPECIFICATION AND DEVELOPMENT OF THE MODEL

We will extend a model adopted from an earlier paper [Simpson, Sedjo, and Reid, 1996a]. In that model we presumed that a new product researcher may search among n species for a product useful in a particular application (a cure for a disease, or a new food crop, for example). We treat each species available for testing as an independent Bernoulli trial with an equal probability, p, of success. While the Bernoulli trial assumption is adopted to keep the mathematics tractable, it does not seem a bad approximation to reality: in pharmaceutical research there is a very high probability of failure in the testing of any one lead, and the payoff to success is relatively concentrated. If the product is found, a payoff of R is realized. We will abstract from costs of sample evaluation here.

The model of this paper differs from our earlier work in that the speed with which a researcher can evaluate samples can be reduced by fixed investment. Let τ be the time required to determine the efficacy of a species in a particular application. Let r be the interest rate. A dollar to be received at time τ from the present is, then, worth $\delta = e^{-r\tau}$ now. Let R be the payoff in the event that the result of a test is a "success," and let p be the probability of success in any given test. Then the value of a collection of species of size n from which sampling can take place is

$$V(n, \delta) = pR + \delta(1-p)pR + \delta^2(1-p)^2 pR + \ldots + \delta^{n-1}(1-p)^{n-1} pR$$

$$= pR\frac{1 - \delta^n(1-p)^n}{1 - \delta(1-p)}. \qquad (1)$$

Note that the value of the marginal species–the increment in the expected net present value of revenue as a result of having another species from which to sample–is

$$v(n, \delta) = V(n+1, \delta) - V(n, \delta) = pR\frac{1 - \delta^{n+1}(1-p)^{n+1}}{1 - \delta(1-p)} - pR\frac{1 - \delta^n(1-p)^n}{1 - \delta(1-p)}$$

$$= pR\delta^n(1-p)^n \qquad (2)$$

The intuition underlying (2) is straightforward. What is it worth to have an *n*+1*st* species to test for the development of a new product? It is the probability that the product is not developed from any of the first *n* species tested, $(1\text{-}p)^n$, times *p*, the probability that it is developed from the *n*+1*st* species tested, times *R*, the payoff if it is developed from the *n*+1*st* species tested, all discounted back to the present by multiplying by δ^n. Note that v(*n*, δ) is increasing in δ: by reducing processing time, the date at which the marginal species is tested is moved forward, and its expected net present value increased.

Suppose now that the researcher can make an investment *K* by which she can reduce the time required to evaluate samples. Recalling that the net present value of a dollar at the end of the time required to conduct a test is $\delta = e^{-r\tau}$, let us suppose that $\tau = \tau(K)$, $\tau'(K) < 0$. Then the researcher's profit net of investment will be $\Pi(n, \delta(K), K) = \Pi(n, K) = V(n, \delta(K)) - K$. Investment will be chosen so as to maximize the expected net present value of profit. Differentiating $\Pi(n, K)$ with respect to *K* we have

$$\frac{\partial \Pi(n,\, K)}{\partial K} \;=\; pR\frac{-n[1-\delta(1-p)]1\delta^{n-1}(1-p)^n \;+\; (1-p)[1-\delta^n(1-p)^n]}{[1-\delta(1-p)]^2}\frac{\partial \delta}{\partial K} \;-\; 1 \;=\; 0\,,$$

with the second equality holding when *K* is chosen optimally.

Using (1) and (2), we can rearrange this first-order condition as follows

$$\left[(1-p)V(n) - \frac{n}{\delta}v(n)\right]\frac{\partial \delta}{\partial K} \;=\; 1-\delta(1-p)\,. \tag{3}$$

Since $v(n, \delta) = V(n+1, \delta) - V(n, \delta)$, we can interpret $nv(n, \delta)/V(n, \delta)$ as the elasticity of the value function with respect to *n*. Denote this elasticity as $\phi(n, \delta)$. As $V(n, \delta)$ is a concave function in *n* that passes through zero, $\phi(n, \delta)$ is necessarily less than one (and, we might suppose in a large number of instances, would be considerably less than one--it must vanish as *n* grows large). Rearranging terms again, we can rewrite (3) as

$$[\delta(1-p) - \phi(n,\delta)]\frac{V(n,\delta)}{\delta}\frac{\partial \delta}{\partial K} \;=\; 1-\delta(1-p)\,.$$

After one more rearrangement we find that, when the investment in processing-time-reducing capital is optimal

$$\frac{\partial \delta}{\partial K}\frac{K}{\delta}\frac{V(n,\,\delta)-K}{K} \;=\; \frac{1-\delta(1-p)}{1-\phi(n,\,\delta)+\delta(1-p)}\,. \tag{4}$$

We now consider three possibilities.

1. *The right-hand side of (4) is not near zero.*

If this were true, we must have $\delta << 1$ and/or $p >> 0$. If either were the case, and maintaining the assumption that *n* is large, the value of the marginal species is necessarily negligible. If δ were substantially less than one, the marginal species would not be tested until some point in the distant future. Discounting expected returns from that date to the present would imply that the returns would be negligible. If p were substantially greater than zero, it would be vanishingly unlikely that the marginal species would ever be tested, as the product sought would, with high probability, be found in earlier testing.

2. *The right-hand side of (4) is small and* $[V(n, \delta) - K]/K$ *is near zero.*

If this were the case, further investment would not be justified by expected project returns. That investment in excess of the level that would maximum expected profit would result in lower expected profit is a tautology. That further investment might dissipate *all* rents accruing from a biodiversity prospecting operation is a considerably stronger, and potentially more troubling, result. If increased investment results in greater losses, surely it would be wiser to devote funds to more effective conservation programs.

3. *The right-hand side of (4) is small and the elasticity of required testing time with respect to capital expenditure,* $(\partial\delta/\partial K)(K/\delta)$*, is near zero.*

The elasticity $(\partial\delta/\partial K)(K/\delta)$ is near zero if $(\partial\delta/\partial K)$ and/or K are near zero. We reject the latter possibility on the basis of casual empiricism, and concentrate on the former (recall also from the first of the possibilities considered above δ must be near one if we are to have an interesting problem). When $\partial\delta/\partial K$ is small (and assuming decreasing returns), further capital expenditures will accomplish little to speed up the research process and, consequently, augment the value of the marginal species. Since the right-hand side of (4) is assumed to be small in this scenario, we must have $\delta \approx 1$; hence there is an inherent limit as to how much more processing speed can be purchased with additional capital investment.

It may be useful to be more explicit in the modeling of δ to illustrate this scenario. One reasonable way to motivate the model we are using here is as an approximation to one in which capital investment determines the number of samples that can be processed simultaneously.[4] Greater speed in processing then corresponds to greater capacity for simultaneous sample evaluation. Suppose, then, that the researcher decides how many samples, m, to process simultaneously. Then m may be interpreted as the number of test facilities available (which could be determined by, for example, numbers of laboratory technicians hired, numbers of assaying machines purchased, etc.). Suppose that the acquisition of each test facility requires a capital expenditure k, and choose units so as to make $k = 1$. Then total capital expenditure is $K = m$.

Under these assumptions, it seems more reasonable to suppose that what we identified above as τ, the time required to perform a test is a constant, rather than a function of total expenditure, K. The *average time* required per sample evaluation, however, is a function of K: $\bar{t} = \tau/K$. Then for τ relatively short and m not too large, we can consider an "average discount factor" $\bar{\delta} = e^{-r\bar{t}} = e^{-r\tau/K}$. Computing the elasticity in this case,

---

[4] These assumptions generate *approximately* the model with which we are working so long as the time required to conduct tests is relatively short and the probability with which more than one species sampled at any one time yields the desired product is relatively small. The violation of either assumption would mean that the value of the marginal species would necessarily be negligible. We have worked with a more complex model in which simultaneous product discoveries were possible, but the algebra becomes substantially more complex without yielding many new insights. In a related paper [Simpson and Sedjo, 1996a] we have developed a model in which a supplier of biodiversity chooses the optimal number of species to test in any given time period.

$$\frac{\partial\bar{\delta}}{\partial K}\frac{K}{\bar{\delta}} = \frac{r\tau}{K}.$$

In short, the incremental contribution of further investment in reducing testing time is inversely proportional to the level of investment.

III. DISCUSSION AND CONCLUSION

The model we have developed is far from realistic. New product researchers do not treat the leads available to them as independent Bernoulli trials. Rather, they conduct their searches sequentially and adaptively. The most promising leads are those explored first, and findings from early investigations are applied in later sampling and testing. Testing is not a simple process of finding out whether one species will or will not provide a lead to the product sought, but rather, a multistage process in which samples may pass some tests but not others. Test evaluation is not always so simple as being a matter of "passing" or "failing."

We doubt, however, that any of these more realistic embellishments would change the outcome of our model much. The basic point is that, if the marginal species were of much value to the pharmaceutical researcher, she would already have made the investments required to advance the date on which she would test it. Since one cannot do any better than (almost) instantaneous testing, further investments would not enhance the value of the marginal species much. On the other hand, if the marginal species were *not* of much value to the pharmaceutical researcher, there is little to be done to make her appreciate it more. Either the discount factor would have to be reduced dramatically (i. e., testing speed would have to be increased dramatically, which is an expensive proposition); or additional investment would dissipate all rents, in which case other uses of money ought to be more efficient, at least as conservation strategies.

In closing, we want to emphasize again that what we have to say hear has no bearing on the overall value of the myriad benefits of biological diversity.[5] Our point is much simpler and narrower. Our earlier work suggests that the value of the marginal species (and, by extension, the value of the marginal hectare of threatened habitat) *for use in new product research* is negligible. This paper suggests that attempting to increase incentives for habitat conservation by increasing investment in biodiversity prospecting ventures is unlikely to be successful.

[5] In fact, it is worth mentioning that this analysis is not complete even with respect to the social benefits arising from biodiversity prospecting: the development of new products generates consumer surplus that cannot be fully appropriated by the new product developers themselves. The issue we are investigating, however, is not whether the social benefits of biodiversity preservation are great–they may well be–but rather, whether the subsidization of commercial biodiversity prospecting efforts is an effective conservation strategy.

REFERENCES

Eisner, Thomas. 1989. "Prospecting for Nature's Chemical Riches," *Issues in Science and Technology*, 6, pp. 31-34.

MacArthur, Robert H., and Edward O. Wilson. 1967. *The Theory of Island Biogeography* (Princeton, N.J., Princeton University Press).

Mendelsohn, Robert, and Michael J. Balick. 1995. "The Value of Undiscovered Pharmaceuticals in Tropical Forests," *Economic Botany*, 49 (June), pp. 223-228.

Reid, Walter V., Sarah A. Laird, Carrie A. Meyer, Rodrigo Gamez, Ana Sittenfeld, Daniel H. Janzen, Michael A. Gollin, and Calestous Juma. 1993. "A New Lease on Life," Chapter 1 in Walter V. Reid, Sarah A. Laird, Carrie A. Meyer, Rodrigo Gamez, Ana Sittenfeld, Daniel H. Janzen, Michael A. Gollin, and Calestous Juma, eds., *Biodiversity Prospecting: Using Genetic Resources for Sustainable Development* (Washington, D.C., World Resources Institute).

Rubin, Steven M., and Stanwood C. Fish. 1994. "Biodiversity Prospecting: Using Innovative Contractual Provisions to Foster Ethnobotanical Knowledge, Technology, and Conservation," *Colorado Journal of International Environmental Law and Policy*, 5, pp. 23-58.

Simpson, R. David, and Roger A. Sedjo. 1996a. "A Model of Simultaneous Search in Sequential Batches: The Valuation of Biodiversity Prospecting Opportunities," draft discussion paper, Resources for the Future, Washington, D.C., March.

Simpson, R. David, and Roger A. Sedjo. 1996b. "R. David Simpson and Roger A. Sedjo, "Paying for the Conservation of Endangered Ecosystems: A Comparison of Direct and Indirect Approaches," *Environment and Development Economics 1*, in press.

Simpson, R. David, Roger A. Sedjo, and John W. Reid. 1996a. "Valuing Biodiversity for Use in Pharmaceutical Research," *Journal of Political Economy*, 104 (February), pp. 163-185.

Simpson, R. David, Roger A. Sedjo, and John W. Reid. 1996b. "The Commercialization of Indigenous Genetic Resources as Conservation and Development Strategy," in Lakshman Guruswamy and Jeffrey McNeely, eds., *Their Seed Preserve: Strategies for Protecting Global Biodiversity* (Durham, N.C., Duke University Press), forthcoming.

Wilson, Edward O. 1992. *The Diversity of Life* (Cambridge, Belknap).