CONSERVATION RECONSIDERED

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> "It is the clear duty of Government, which is the trustee for unborn generations as well as for its present citizens, to watch over, and if need be, by legislative enactment, to defend, the exhaustible natural resources of the country from rash and reckless spoliation. How far it should itself, either out of taxes, or out of State loans, or by the device of guaranteed interest, press resources into undertakings from which the business community, if left to itself, would hold aloof, is a more difficult problem. Plainly, if we assume adequate competence on the part of governments, there is a valid case for *some* artificial encouragement to investment, particularly to investments the return from which will only begin to appear after the lapse of many years."
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> A. C. PIGOU

Conservation of natural resources has meant different things to different people. But to the economist from the time of Pigou, who first took notice of the economics of conservation [10, p. 27ff], until quite recently, the central concerns have been associated with the question of the optimal intertemporal utilization of the fixed natural resource stocks. The gnawing anxiety provoked by the Malthusian thesis of natural resource scarcity was in no way allayed by the rates of consumption of natural resource stocks during two world wars occurring between the first and fourth editions of Pigou's famous work. In the United States, a presidential commission, reviewing the materials situation following World War II, concluded that an end had come to the historic decline in the cost of natural resource commodities [12, pp. 13-14]. This conclusion reinforced the concern of many that the resource base ultimately would be depleted.

More recently, on the other hand, a systematic analysis of the trends in prices of natural resource commodities did not reveal any permanent interruption in the decline relative to commodities and services in general [11]. Moreover, a rather ambitious attempt to test rigorously the thesis of natural resource scarcity suggested instead that technological progress had compensated quite adequately for the depletion of the higher quality natural resource stocks [1]. Further, given the present state of the arts, future advances need not be fortuitous occurrences;

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rather the rate of advance can be influenced by investment in research and development. Indeed, those who take an optimistic view would hold that the modern industrial economy is winning its independence from the traditional natural resources sector to a remarkable degree. Ultimately, the raw material inputs to industrial production may be only mass and energy [1, p. 238].[1]

While such optimistic conclusions were being reached, they were nevertheless accompanied by a caveat that, while we may expect production of goods and services to increase without interruption, the level of living may not necessarily be improved. More specifically, Barnett and Morse concluded that the quality of the physical environment—the landscape, water, and atmospheric quality—was deteriorating.

These conclusions suggest that on the one hand the traditional concerns of conservation economics—the husbanding of natural resource stocks for the use of future generations—may now be outmoded by advances in technology. On the other hand, the central issue seems to be the problem of providing for the present and future the amenities associated with unspoiled natural environments, for which the market fails to make adequate provision. While this appears to be the implication of recent research,[2] and is certainly consistent with recent public policy in regard to preserving natural environments, the traditional economic rationale for conservation does not address itself to this issue directly.[3] The use of Pigou's social time preference may serve only to hasten the conversion of natural environments into low-yield capital investments.[4] On what basis, then, can we make decisions when we confront a choice entailing action which will have an irreversible adverse consequence for rare phenomena of nature? I investigate this question below.

Let us consider an area with some unique attribute of nature—a geomorphologic feature such as the Grand Canyon, a threatened species, or an entire ecosystem or biotic community essential to the survival of the threatened species.[5] Let us assume further that the area can be used

[1] The conclusions were based on data relevant to the U.S. economy. While they may be pertinent to Western Europe also, all of my subsequent observations are restricted to the United States.

[2] For example, see [7].

[3] It must be acknowledged that with sufficient patience and perception nearly all of the argument for preserving unique phenomena of nature can be found in the classic on conservation economics by Ciriacy-Wantrup [3].

[4] An example of this was the recent threat to the Grand Canyon by the proposed Bridge and Marble Canyon dams. Scott makes a similar point with reference to natural resource commodities [13].

[5] Uniqueness need not be absolute for the following arguments to hold. It may be, like Dupuit's bridge, a good with no adequate substitutes in the "natural" market area of its

for certain recreation and/or scientific research activities which would be compatible with the preservation of the natural environment, or for extractive activities such as logging or hydraulic mining, which would have adverse consequences for scenic landscapes and wildlife habitat.

A private resource owner would consider the discounted net income stream from the alternative uses and select the use which would hold prospects for the highest present net value. If the use which promises the highest present net value is incompatible with preserving the environment in its natural state, does it necessarily follow that the market will allocate the resources efficiently? There are several reasons why private and social returns in this case are likely to diverge significantly.

Consider the problem first in its static aspects. By assumption, the resources used in a manner compatible with preserving the natural environment have no close substitutes; on the other hand, alternative sources of supply of natural resource commodities are available.[6] Under the circumstances and given the practical obstacles to perfectly discriminating pricing, the private resource owner would not be able to appropriate in gate receipts the entire social value of the resources when used in a manner compatible with preserving the natural state. Thus the present values of his expected net revenues are not comparable as between the competing uses in evaluating the effciency of the resource allocation.

Aside from the practical problem of implementing a perfectly discriminating pricing policy, it is not clear even on theoretic grounds that a comparison of the total area under the demand curve on the one hand and market receipts on the other will yield an unambiguous answer to the allocative question. When the existence of a grand scenic wonder or a unique and fragile ecosystem is involved, its preservation and continued availability are a significant part of the real income of many individuals.[7] Under the conditions postulated, the area under the demand curve, which represents a maximum willingness to pay, may be significantly less than the minimum which would be required to compensate such individuals were they to be deprived in perpetuity of the opportunity

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principal clientele, while possibly being replicated in other market areas to which the clientele in question has no access for all practical purposes.

[6] The asymmetry in the relation posited is realistic. The historic decline in cost of natural resource commodities relative to comomdities in general suggests that the production and exchange of the former occur under fairly competitive conditions. On the other hand, increasing congestion at parks, such as Yellowstone, Yosemite, and Grand Canyon, suggests there are no adequate substitutes for these rare natural environments.

[7] These would be the spiritual descendants of John Muir, the present members of the Sierra Club, the Wilderness Society, National Wildlife Federation, Audubon Society and others to whom the loss of a species or the disfigurement of a scenic area causes acute distress and a sense of genuine relative impoverishment.

to continue enjoying the natural phenomenon in question. Accordingly, it is conceivable that the potential losers cannot influence the decision in their favor by their aggregate willingness to pay, yet the resource owner may not be able to compensate the losers out of the receipts from the alternative use of the resource. In such cases—and they are more likely encountered in this area—it is impossible to determine whether the market allocation is efficient or inefficient.

Another reason for questioning the allocative efficiency of the market for the case in hand has been recognized only more recently. This involves the notion of *option demand* [14]. This demand is characterized as a willingness to pay for retaining an option to use an area or facility that would be difficult or impossible to replace and for which no close substitute is available. Moreover, such a demand may exist even though there is no current intention to use the area or facility in question and the option may never be exercised. If an option value exists for rare or unique occurrences of nature, but there is no means by which a private resource owner can appropriate this value, the resulting resource allocation may be questioned.

Because options are traded on the market in connection with other economic values, one may ask why no market has developed where option value exists for the preservation of natural environments.[8] We need to consider briefly the nature of the value in question and the marketability of the option.

From a purely scientific viewpoint, much is yet to be learned in the earth and life sciences; preservation of the objects of study may be defended on these grounds, given the serendipity value of basic research. We know also that the natural biota represents our reservoir of germ plasm, which has economic value. For example, modern agriculture in advanced countries represents cultivation figuratively in a hot-house environment in which crops are protected against disease, pests, and drought by a variety of agricultural practices. The energy released from some of the genetic characteristics no longer required for survival under cultivated conditions is redirected toward greater productivity. Yet because of the instability introduced with progressive reduction of biological diversity, a need occasionally arises for the reintroduction of some genetic characteristics lost in the past from domestic strains. It is from the natural biota that these can be obtained.

The value of botanical specimens for medicinal purposes also has been long, if not widely, recognized. Approximately half of the new drugs currently being developed are obtained from botanical specimens.[9] There is a traffic in medicinal plants which approximates a third

[8] For a somewhat differently developed argument, see [6].

[9] For an interesting account of the use of plants for medicinal purposes, see [8].

of a billion dollars annually. Cortisone, digitalis, and heparin are among the better known of the myriad drugs which are derived from natural vegetation or zoological sources. Since only a relatively small part of the potential medicinal value of biological specimens has yet been realized, preserving the opportunity to examine all species among the natural biota for this purpose is a matter of considerable importance.

The option value may have only a sentimental basis in some instances. Consider the rallying to preserve the historical relic, "Old Ironsides."[10] There are many persons who obtain satisfaction from mere knowledge that part of wilderness North America remains even though they would be appalled by the prospect of being exposed to it. Subscriptions to World Wildlife Fund are of the same character. The funds are employed predominantly in an effort to save exotic species in remote areas of the world which few subscribers to the Fund ever hope to see. An option demand may exist therefore not only among persons currently and prospectively active in the market for the object of the demand, but among others who place a value on the mere existence of biological and/or geomorphological variety and its widespread distribution.[11]

If a genuine value for retaining an option in these respects exists, why has not a market developed? To some extent, and for certain purposes, it has. Where a small natural area in some locality in the United States is threatened, the property is often purchased by Nature Conservancy,[12] a private organization which raises funds through voluntary subscriptions.[13] But this market is grossly imperfect. First, the risk for private investors associated with absence of knowledge as to whether a particular ecosystem has special characteristics not widely shared by others is enormous.[14] Moreover, to the extent that the natural environment will support basic scientific research which often has unanticipated practical results, the serendipity value may not be appropriable by those paying to preserve the options. But perhaps of greatest significance is that the preservation of the grand scenic wonders, threatened species, and the like involves comparatively large land tracts which are not of merely

[10] The presumption in favor of option value is applicable also to historic and cultural features; rare works of art, perhaps, being the most prominent of this class.

[11] The phenomenon discussed may have an exclusive sentimental basis, but if we consider the "bequest motivation" in economic behavior, discussed below, it may be explained by an interest in preserving an option for one's heirs to view or use the object in question.

[12] Not to be confused with a public agency of the same name in the United Kingdom.

[13] Subscriptions to World Wildlife Fund, the Wilderness Society, National Parks Association, etc. may be similar, but, of course, much of the effect these organizations have on the preservation of natural areas stems not from purchasing options, but from influencing public programs.

[14] The problem here is in part like a national lottery in which there exists a very small chance for a very large gain. Unlike a lottery, rather large sums at very large risk typically would be required.

local interest. Thus, all of the problems of organizing a market for public goods arise. Potential purchasers of options may be expected to bide time in the expectation that others will meet the necessary cost, thus eliminating cost to themselves. Since the mere existence or preservation of the natural environment in question satisfies the demand, those who do not subscribe cannot be excluded except by the failure to enroll sufficient subscribers for its preservation.

Perhaps of equal significance to the presumption of market failure are some dynamic characteristics of the problem suggested by recent research. First, consider the consumption aspects of the problem. Davidson, Adams, and Seneca have recently advanced some interesting notions regarding the formation of demand that may be particularly relevant to our problem [5, p. 186].

> When facilities are not readily available, skills will not be developed and, consequently, there may be little desire to participate in these activities. If facilities are made available, opportunities to acquire skill increase, and user demand tends to rise rapidly over time as individuals learn to enjoy these activities. Thus, participation in and enjoyment of water recreational activities by the present generation will stimulate future demand without diminishing the supply presently available. Learning-by-doing, to the extent it increases future demand, suggests an interaction between present and future demand functions, which will result in a public good externality, as present demand enters into the utility function of future users.

While this quotation refers to water-based recreation, it is likely to be more persuasive in connection with some other resource-based recreation activity. Its relevance for wilderness preservation is obvious. When we consider the remote backcountry landscape, or the wilderness scene as the object of experience and enjoyment, we recognize that utility from the experience depends predominantly upon the prior acquisition of technical skill and specialized knowledge. This, of course, must come from experience initially with less arduous or demanding activities. The more the present population is initiated into activities requiring similar but less advanced skills (e.g., car camping), the better prepared the future population will be to participate in the more exacting activities. Given the phenomenal rise of car camping, if this activity will spawn a disproportionate number of future back-packers, canoe cruisers, cross-country skiers, etc., the greater will be the induced demand for wild, primitive, and wilderness-related opportunities for indulging such interest. Admittedly, we know little about the demand for outdoor experiences which depend on unique phenomena of nature—its formation, stability, and probable course of development. These are important questions for research, results of which will have significant policy implications.

In regard to the production aspects of the "new conservation," we need to examine the implications of technological progress a little further. Earlier I suggested that the advances of technology have compensated for the depletion of the richer mineral deposits and, in a sense, for the superior stands of timber and tracts of arable land. On the other hand, there is likely to be an asymmetry in the implications of technological progress for the production of goods and services from the natural resource base, and the production of natural phenomena which give rise to utility without undergoing fabrication or other processing.[15] In fact, it is improbable that technology will advance to the point at which the grand geomorphologic wonders could be replicated, or extinct species resurrected. Nor is it obvious that fabricated replicas, were they even possible, would have a value equivalent to that of the originals. To a lesser extent, the landscape can be manufactured in a pleasing way with artistry and the larger earth-moving equipment of today's construction technology. Open pit mines may be refilled and the surroundings rehabilitated in a way to approximate the original conditions. But even here the undertaking cannot be acccomplished without the cooperation of nature over a substantial period of time depending on the growth rate of the vegetal cover and the requirements of the native habitat.[16] Accordingly, while the supply of fabricated goods and commercial services may be capable of continuous expansion from a given resource base by reason of scientific discovery and mastery of technique, the supply of natural phenomena is virtually inelastic. That is, we may preserve the natural environment which remains to provide amenities of this sort for the future, but there are significant limitations on reproducing it in the future should we fail to preserve it.

If we consider the asymmetric implications of technology, we can conceive of a transformation function having along its vertical axis amenities derived directly from association with the natural environment and fabricated goods along the horizontal axis. Advances in technology would stretch the transformation function's terminus along the horizontal axis but not appreciably along the vertical. Accordingly, if we simply take the effect of technological progress over time, considering tastes as constant, the marginal trade-off between manufactured and natural amenities will progressively favor the latter. Natural environments will represent irreplaceable assets of appreciating value with the passage of time.

If we consider technology as constant, but consider a change in tastes progressively favoring amenities of the natural environment due to the learn-by-doing phenomenon, natural environments will similarly for this

[15] I owe this point to a related observation, to my knowledge first made by Ciriacy-Wantrup [3, p. 47].

[16] That is, giving rise to option value for members of the present population.

reason represent assets of appreciating value. If both influences are operative (changes in technology with asymmetric implications, and tastes), the appreciating value of natural environments will be compounded.

This leads to a final point which, while a static consideration, tends to have its real significance in conjunction with the effects of parametric shifts in tastes and technology. We are coming to realize that consumption-saving behavior is motivated by a desire to leave one's heirs an estate as well as by the utility to be obtained from consumption.[17] A bequest of maximum value would require an appropriate mix of public and private assets, and, equally, the appropriate mix of opportunities to enjoy amenities experienced directly from association with the natural environment along with readily producible goods. But the option to enjoy the grand scenic wonders for the bulk of the population depends upon their provision as public goods.

Several observations have been made which may now be summarized. The first is that, unlike resource allocation questions dealt with in conventional economic problems, there is a family of problems associated with the natural environment which involves the irreproducibility of unique phenomena of nature—or the irreversibility of some consequence inimical to human welfare. Second, it appears that the utility to individuals of direct association with natural environments may be increasing while the supply is not readily subject to enlargement by man. Third, the real cost of refraining from converting our remaining rare natural environments may not be very great. Moreover, with the continued advance in technology, more substitutes for conventional natural resources will be found for the industrial and agricultural sectors, liberating production from dependence on conventional sources of raw materials. Finally, if consumption-saving behavior is motivated also by the desire to leave an estate, some portion of the estate would need to be in assets which yield collective consumption goods of appreciating future value. For all of these reasons we are confronted with a problem not conventionally met in resource economics. The problem is of the following nature.

At any point in time characterized by a level of technology which is less advanced than at some future date, the conversion of the natural environment into industrially produced private goods has proceeded further than it would have with the more advanced future technology. Moreover, with the apparent increasing appreciation of direct contact with natural environments, the conversion will have proceeded further, for this reason as well, than it would have were the future composition of tastes to have prevailed. Given the irreversibility of converted natural

[17] See [2]; also [9].

environments, however, it will not be possible to achieve a level of well-being in the future that would have been possible had the conversion of natural environments been retarded. That this should be of concern to members of the present generation may be attributable to the bequest motivation in private economic behavior as much as to a sense of public responsibility.[18]

Accordingly, our problem is akin to the dynamic programming problem which requires a present action (which may violate conventional benefit-cost criteria) to be compatible with the attainment of future states of affairs. But we know little about the value that the instrumental variables may take. We have virtually no knowledge about the possible magnitude of the option demand. And we still have much to learn about the determinants of the growth in demand for outdoor recreation and about the quantitative significance of the asymmetry in the implications of technological advances for producing industrial goods on the one hand and natural environments on the other. Obviously, a great deal of research in these areas is necessary before we can hope to apply formal decision criteria comparable to current benefit-cost criteria. Fully useful results may be very long in coming; what then is a sensible way to proceed in the interim?

First, we need to consider what we need as a minimum reserve to avoid potentially grossly adverse consequences for human welfare. We may regard this as our scientific preserve of research materials required for advances in the life and earth sciences. While no careful evaluation of the size of this reserve has been undertaken by scientists, an educated guess has put the need in connection with terrestrial communities at about ten million acres for North America [4, p. 128]. Reservation of this amount of land—but a small fraction of one per cent of the total relevant area—is not likely to affect appreciably the supply or costs of material inputs to the manufacturing or agricultural sectors.

The size of the scientific preserve required for aquatic environments is still unknown. Only after there is developed an adequate system of classification of aquatic communities will it be possible to identify distinct environments, recognize the needed reservations, and, then, estimate the opportunity costs. Classification and identification of aquatic environments demand early research attention by natural scientists.

Finally, one might hope that the reservations for scientific purposes would also support the bulk of the outdoor recreation demands, or that substantial additional reservations for recreational purposes could be

[18] The rationale above differs from that of Stephen Marglin which is perhaps the most rigorous one relying on a sense of public responsibility and externalities to justify explicit provision for future generations. In this case also, my concern is with providing *collective consumption goods for the present and future,* whereas the traditional concern in conservation economics has been with provision of *private intermediate goods for the future.*

justified by the demand and implicit opportunity costs. Reservations for recreation, as well as for biotic communities, should include special or rare environments which can support esoteric tastes as well as the more common ones. This is a matter of some importance because outdoor recreation opportunities will be provided in large part by public bodies, and within the public sector there is a tendency to provide a homogenized recreation commodity oriented toward a common denominator. There is need to recognize, and make provision for, the widest range of outdoor recreation tastes, just as a well-functioning market would do. We need a policy and a mechanism to ensure that all natural areas peculiarly suited for specialized recreation uses receive consideration for such uses. A policy of this kind would be consistent both with maintaining the greatest biological diversity for scientific research and educational purposes and with providing the widest choice for consumers of outdoor recreation.

References

1. H. J. Barnett and C. Morse, *Scarcity and Growth: The Economics of Natural Resource Availability*. Baltimore 1963.
2. S. B. Chase, Jr., *Asset Prices in Economic Analysis*. Berkeley 1963.
3. S. V. Ciriacy-Wantrup, *Resources Conservation*. Berkeley 1952.
4. F. Darling and J. P. Milton, ed., *Future Environments of North America, Transformation of a Continent*. Garden City, N.Y. 1966.
5. P. Davidson, F. G. Adams, and J. Seneca, "The Social Value of Water Recreation Facilities Resulting from an Improvement in Water Quality: The Delaware Estuary," in A. V. Kneese and S. C. Smith, ed., *Water Research*, Baltimore 1966.
6. A. E. Kahn, "The Tyranny of Small Decisions: Market Failures, Imperfections, and the Limits of Economics," *Kyklos*, 1966, 19 (1), 23-47.
7. A. V. Kneese, *The Economics of Regional Water Quality Management*. Baltimore 1964.
8. M. B. Kreig, *Green Medicine: The Search for Plants that Heal*. New York 1964.
9. F. Modigliani and R. Brumberg, "Utility Analysis and the Consumption Function: An Interpretation of Cross-Section Data," in K. K. Kurihara, ed., *Post-Keynesian Economics*, New Brunswick 1954.
10. A. C. Pigou, *The Economics of Welfare*. 4th ed., London 1952.
11. N. Potter and F. T. Christy, Jr., *Trends in Natural Resources Commodities: Statistics of Prices, Output, Consumption, Foreign Trade, and Employment in the United States, 1870-1957*. Baltimore 1962.
12. The President's Materials Policy Commission, *Resources for Freedom, Foundation for Growth and Security*, Vol. I. Washington 1952.
13. A. D. Scott, *Natural Resources: The Economics of Conservation*. Toronto 1955.
14. B. A. Weisbrod, "Collective Consumption Services of Individual Consumption Goods," *Quart. Jour. Econ.*, Aug. 1964, *77*, 71-77.