4. COMPLEMENTARY PAPERS

4.1 The Underlying Causes of Biodiversity Decline: An Economic Analysis

by Timothy Swanson

Overview. *This paper opens with the premise that all of the various examples of biodiversity loss are consequences of human and societal choices and that humans should be seen as being fundamentally responsible for all of the various forms of biodiversity decline by reason of their choices regarding the allocation of resources. The paper commences by setting forth the original economic framework utilised to explain over exploitation-based resource depletion, and then goes on to demonstrate how this "irresponsible" behaviour may be incorporated within a more fundamental theory of human choice regarding resource allocation and biodiversity depletion. This theory is then developed in order to demonstrate how each of the various phenomena associated with biodiversity loss is a proximate cause of biodiversity decline resulting from fundamental human choices concerning the allocation of the resources required for continued survival. The paper argues that economic forces drive biodiversity losses which implies the conclusion that the assessment of biodiversity decline requires an understanding and assessment of these economic forces. In order to redress the decline of diversity it will be necessary to reshape the economic incentives that cause human societies to choose systematically to reshape the living world in the way that they do.*

4.1.1 Introduction: Human Responsibility for Biodiversity Depletion

The popular conception of biodiversity decline is that human rapaciousness and overexploitation are the primary causes of extinctions and hence biodiversity's decline. This is attributable to the fact that when most people consider the causes of known species' extinctions, they usually address them within the context of a few high-profile cases, such as the decline of the great whales or the African elephant. In these contexts, the focus is usually on human overexploitation of the usefulness of the species (for ivory production, for example) as the cause of the species' endangerment. Alternatively the focus is on the general decline of entire systems, such as erosion of the tropical rainforests. These well-publicised case studies give rise to the general impression that it is *human irresponsibility* that lies at the core of biodiversity endangerment.

However, when a broader range of species is considered, it is apparent that there are other forces at work as well: exotic incursions and land conversions are two other well-documented forces in biodiversity's decline (WCMC, 1992). Both of these forces are sourced in human choices regarding the introduction of new species and new methods into frontier

environments. Humans *choose* to expand their domain by means of converting lands to new uses and to new species, and this continues to result in the contraction of the domain previously available to other uses and other species. When the focus on biodiversity decline shifts to the more abstract level of varietal loss and the decline of agricultural genetic diversity, it becomes even more apparent that the forces at work are sourced in explicit human choices. In the context of the erosion of genetic resources for agriculture, it is underuse of a wider range of resources rather than their overuse which results in the loss of biological diversity (Swanson, Pearce and Cervigni, 1993). Human societies now make the choices concerning the allocation of lands, water and other resources which determine which of the diversity of life forms will continue to exist. Human *responsibility*, not irresponsibility, should be seen as the underlying cause of the decline of biological diversity.

In order to explain the underlying causes of biodiversity decline, we need to develop a general framework that is capable of explaining all of these various examples of biodiversity losses: well-publicised overexploitation and "mining", conversions of lands and agricultural-based changes. The framework developed here will explain all of these various phenomena as consequences of human and societal choices. Human societies should be seen as being fundamentally responsible for all of these various forms of biodiversity decline by reason of their choices regarding the allocation of resources (land based, and financial).

The paper commences by setting forth the original economic framework utilised to explain overexploitation-based resource depletion, and then goes on to demonstrate how this "irresponsible" behaviour may be incorporated within a more fundamental theory of human choice regarding resource allocation and biodiversity depletion. This theory is then developed in order to demonstrate how each of the various phenomena associated with biodiversity losses (overexploitation, mining and land use conversion) is a proximate cause of biodiversity decline resulting from fundamental human choices concerning the allocation of the resources required for continued survival.

The inevitable conclusion of this theory is that human societies are fundamentally responsible for the decline of biodiversity by virtue of the choices that they make regarding the allocation of resources. This is important because it is based on the idea that economic forces that drive biodiversity losses, and it implies the conclusion that the assessment of biodiversity decline requires an understanding and assessment of these economic forces. In order to redress the decline of diversity, it will be

necessary to reshape the economic incentives that cause human societies to choose systematically to reshape the living world in the way that they do.

4.1.2 Extinction in the Context of Marine Resources

The economic analysis of extinction was initially developed in regard to marine resources. This was the case because many of the earliest examples of modern species' threats occurred within that context. The Pacific fur seals suffered near extinction in the late nineteenth century due to overexploitation. The blue whale experienced a severe decline in the same period. During the twentieth century the analysis focused on the decline of various fisheries, as the advance of technology made it possible to overfish entire stocks of various oceanic species. As will become apparent later, much of the initial analysis of species endangerment was focused on the marine context precisely because endangerment so often occurred in that environment.

Overexploitation and Extinction

In the case of marine resources *overexploitation* was perceived to be the cause of the resource's decline. That is, fishing and hunting pressures were occurring, with regard to many oceanic species, at levels that were unsustainable. Therefore the initial focus of the economic study of extinctions concerned the deleterious impacts of human hunting and fishing on various resources (Gordon, 1954).

The study of overexploitation was the first attempt at an economic analysis of the interface between human society and the remainder of the biological world. This resulted in the development of so-called *bio-economic models*: models analysing the interaction between human harvesting pressures and biological resource regeneration. The questions addressed in these models concerned the characteristics of a resource and resource management system that rendered them incompatible, i.e. made the resource incapable of sustaining the systemic pressures placed upon it by human society.
Economic analysis gave a short and simple answer to these questions. In the context of marine resources, exploitation of an open access resource was likely to be unsustainable if:

(a) the price/cost ratio of harvesting the resource was “high”; and

(b) the natural growth rate of the resource was “low” (Clark, 1976).

These two conditions determined the ultimate impact of human harvesting pressures on a freely available species. Condition (a) determines the incentives for human harvesting when only the immediate costs of

harvesting are taken into account. Condition (a) states that a species with a high price relative to the cost of harvest is potentially very profitable, and therefore attracts substantial harvesting pressure. Condition (b) determines the capability of a species to sustain these pressures; that is, a species with a low natural growth rate cannot regenerate itself at a rate sufficient to withstand substantial harvesting pressure.

Therefore, the economic analysis of extinction in the context of marine resources is quite straightforward: the existence of financial incentives for significant harvesting pressures applied to freely available and slow growing resources implies unsustainability. This explains the decline of such species as the great whales. Their high values as the providers of important oil products (in the nineteenth century) combined with their naturally slow growth rates and free availability meant that population declines were the likely result of the uncontrolled harvest, and this is the pattern that was in fact observed.

Open Access as a Fundamental Cause of Overexploitation

The emphasis however must be placed on the relatively *unmanaged* nature of marine exploitation activity. Overexploitation has often occurred in the context of the oceans precisely because the harvesting activities in this environment have been so poorly controlled historically. Until very recently, the oceans have been non-sovereign territory (beyond a ten mile zone), and their resources have been subject to appropriation on a first come – first served basis. This form of "resource management" is known in economics as an *open access regime*. Such a regime installs a system of incentives based solely upon first appropriation, and this implies that no individual harvester has any incentive to discontinue harvesting the resource, because any of the resources that one harvester leaves behind will simply be captured by another.

Then, in the context of an open access regime, extinction is a possibility if there are incentives to harvest the resource which exceed its capacity to replace itself. This is precisely what the bio-economic models of extinction (in the context of marine resources) have demonstrated: open access regimes are a primary contributory force to extinctions. The question remains: why are open access regimes employed by human societies? In the context of oceanic resources, the problem clearly was one of costly cooperation and conflict between human societies. All societies would benefit from joint management of the common resource, but each would do better individually if others engaged in restraint while they pursued exploitation unconstrained. This so-called "prisoners' dilemma" situation requires the development of enforceable joint management institutions for its resolution. In the context of oceanic resources, the costliness of management failures resulted in part

in the adoption of a new management institution: the 200 mile exclusive economic zone (Swanson, 1991). This is an instance in which the institution known as "private (national) property rights" might be seen as evolving at the international level in response to the costliness of joint management failures. Human societies chose not to utilise the institution of open access as its costliness became apparent.

Therefore open access management cannot be a fundamental explanation of biodiversity decline in any context, even though it is often a contributing proximate cause. This is because open access management is itself chosen as the management system applied by the relevant societies to the respective resources. The question remains: why would human societies choose to apply such an obviously inefficient institution to the management of a valuable resource?

4.1.3 Extinction in the Context of Terrestrial Resources

The questions raised in the context of marine resources will continue to be examined in the context of terrestrial ones. The economic analysis of extinction in the context of terrestrial resources is very different from the analysis of marine resources. This is attributable to two fundamental differences, one on the biological and one on the societal side of the bio-economic model.

Choosing to Use Open Access Management

First, it is even more apparent that there is no reason why the assumption of open access management should be carried over from the marine context to be applied to terrestrial resources, even wildlife species. With regard to oceanic resources, the choice of the management system was not an option for national governments for many years, because these resources lay in the international domain; it necessitated long international negotiations to subject more of these resources to national choices regarding management techniques. However, on land there has long been one nation with the designated responsibility for making management decisions with regard to the resources associated with any piece of territory. This is the economic meaning to be given to the legal concept of national territorial sovereignty, i.e. that there are "owner-states" with responsibility for management decisions within their boundaries.

Once it is accepted that national governments are responsible for resource management decisions within their boundaries, then the continuing existence of open access regimes for terrestrial resources becomes a matter of national choice. That is, if a terrestrial resource is managed by an open access form of regime, this is because that owner-state has chosen to apply

this manner of management to this resource in this situation. An owner-state may in fact choose to apply a management regime selected from a wide range of different forms of institutions to terrestrial resource management. For example, there are various forms of common resource management (such as communally managed pastures and forests), private property rights (exclusive to a single individual) and national ownership (such as national parks and forests). Any one of these resource management regimes may be best in a given context and locality. The choice of the best management regime will depend upon the perspective of the state concerned and the nature of the resource involved.

Paradoxically, even an open access regime could be a best choice from a particular owner-state's perspective, even though it will always result in the inefficient overexploitation of the resources subjected to it. This is because there are two potentially conflicting objectives at issue: the objective of maximising the efficiency of the management of a particular resource (or group of resources) versus the objective of maximising the efficiency of the management of the totality of a society's resources (natural, human and human-made). The efficient pursuit of the latter objective will imply the necessity of some trade-offs in regard to the pursuit of the former; then, inefficient forms of resource management may be "optimal" from the owner-state's perspective.

In order to explain this concept clearly, it is necessary to understand that all state-level decisions concerning the regulation of natural resources are *investment decisions*, i.e. the state is deciding implicitly whether the particular resource or region is worthy of an allocation of scarce societal investment funds. Efficient management of a given biological resource will require the regulation of harvesting activities with regard to a biological resource, in order to allow some amount of the existing stock of a species to remain for the purpose of generating future growth. This capacity for growth is the reason that economists refer to a natural resource as *natural capital*. A natural resource is capable of generating a return just as with investments in any other form of asset (Solow, 1974).

Investing in management regimes for a particular natural resource is the state's means for inducing individual investments in that resource. That is, the crucial difference between the different forms of management regimes listed above is the aggregate amount of societal investment (by the group of all individuals using it) that results. For example, as described above, an open access regime creates incentives *not* to invest in the resources subjected to it; the users of the resource will not view the resources as being worthy of investment because others will capture most of the benefits of their investments. On the other hand, if the state were to institute another

institution (such as a property rights regime), then the harvesters would see some individual benefit to investing in the resources. In either case, the owner-state determines the ground-level investment incentives by its choice of management institutions for a particular region or resource.

Despite the fact that it has the power to choose the "efficient" management regime, it is sometimes optimal from the owner-state's perspective to allow open access regimes to continue in place. This is because another important difference between these various management regimes (open access, common property, private property, national property) is the differential amounts of state resources that they require for their implementation. In general, the creation and implementation of state institutions for protecting rights and monitoring production are costly affairs. The one exception is that the institution of an open access regime costs the owner-state nothing (in the form of state spending requirements); other forms of state management regimes will require more significant commitments of state funding.

A zero level of state spending with regard to the management of a particular resource or habitat may be optimal from a state's more general perspective because of the competing claims for national investments within a developing state. In short, it cannot be assumed that full and effective institutions will be warranted for the protection and production of all existing natural resources. The state must select its investments carefully, and allocate its scarce funds to those resources and regions that it believes will make use of them most productively.

Therefore, although an open access regime is the embodiment of an inefficient resource management regime, it will be the choice made by many states from their own individual perspective in the context of severe scarcities of investment funds for institutional development. This implies that the fundamental cause of many land-based extinctions, especially those resulting from overexploitation, is not the existence of open access institutions. Instead, the fundamental cause is the existence of incentives in these developing states to not invest in the necessary management institutions in some regions of the country or in regard to some resources. It is the choice of human societies not to invest in a species that results in its depletion.

Competition for "Niches"

The second important difference between oceanic and terrestrial resources is the nature of the forces determining the size of the niche available to the species. In this instance the term “niche” is being used advisedly in order to describe the set of *base resources* (land, sunlight) that are necessary to

foster the continued survival and propagation of a particular species or variety. With regard to oceanic species, the size of the niche is for the most part determined exogenously; that is, the niche available to a marine species is determined by the carrying capacity of its natural environment. The species will be able to expand to the limits of its niche, as determined by its capacity to compete with other species (other fish, sea mammals, etc.) for the base resources within that environment.

For terrestrial species, the extent to which base resources are made available to sustain a given species is no longer determined by a "natural" equilibrium of this sort but by human choice. That is, one very important difference between marine and terrestrial resources is the number of competing uses that humans have for their respective habitats. The almost exclusive avenue by which humans interact with ocean-going species is via direct overexploitation (and, increasingly, pollution); however, with regard to terrestrial species, the nature of the interaction is much more multi-faceted. A terrestrial species will compete with humans (for the use of its habitat) in a multitude of different ways. Humans may consider making use of the habitat for purposes of agricultural production, and therefore the naturally-occurring species will have to be competitive with these in order to retain their lands. Alternatively, humans may consider using the land for purposes completely unrelated to the biosphere (e.g. residences or factories), and then the species must compete with these land uses as well.

Once again the decline of the species is best viewed as the result of a fundamental investment decision. In the case of land use conversions, the choice concerns human allocation of base resources between various species. Humans have a wide range of goods and services which they wish to derive from the use of lands under their control, and they allocate these lands between these various uses in accordance with the flows that they will produce. Human societies now control land uses over most of the globe, and they continue to re-allocate their use toward certain specific activities (domesticated species, cultivated crops, human settlements). It is the failure of humans to invest these lands in a wider variety of uses that results in the decline of biological diversity from land use conversions.

With regard to this form of the problem, the danger to the species is that they will be undercut rather than overexploited. That is, these are resources that will lose their capacity to survive not because humans place too much pressure on their stocks but rather because humans convert their habitats to other uses. It is the same fundamental decision problem concerning human resource allocation that is driving biodiversity decline, but the resource concerned has shifted from management funding to land use. Once again it is under-investment that is the underlying cause of biodiversity loss.

Three Routes to Extinction: One Fundamental Cause

In sum, there are three alternative routes to extinction for terrestrial species (as opposed to the single route that is usually relevant for marine species). These three routes are all proximate causes of extinctions, but there is only the one fundamental cause: under-investment. Human societies now control the resources required for continued survival of most species on earth, and it is their choices on how to allocate those resources that determines which species will proliferate and which will perish. It is the investment decisions of human societies that determines the rate and form of biodiversity decline.

How does this investment decision actually work biodiversity decline? The fundamental nature of the investment problem facing human societies in the allocation of these resources concerns how to allocate various forms of societal capital (lands, stocks of living resources, management resources) to the generation of a flow of human-desired goods and services from the biosphere (food, clothing, housing materials etc.). When these stocks of societal capital are invested in support of other living resources, the pre-existing ones lose the support that they rely upon and decline. Biodiversity decline in the fundamental sense is lack of investment of one of three types: diversion of supporting capital, divestment of capital, and/or conversion of capital.

Three Forms of Diversity Disinvestment

(1) ***Stock Disinvestment***

Stock disinvestment occurs when the subject resources have high price/cost ratios but low growth rates. In that case, there are incentives to harvest the entirety of the resource (for its high net value) in order to invest the funds in other assets (for their greater growth rates) (Clark, 1973). In short, stocks of natural resources represent natural capital which may be retained in its current form or transformed into cash for investment in other, preferred forms of assets.

An example of this force in action is the deforestation of the tropical hardwood forests. These trees represent substantial amounts of standing value, but they have very low growth potential. It is then perceived to be socially beneficial from the owner-state's perspective to “cash in” the slow-growing hardwoods in order to invest the returns in other, more productive assets (such as education or health).

2) ***Management-based Divestment***

Divestment occurs when the resource is of relatively low growth but the net value of a managed harvest is also low. Since these are once again slow growing resources, they make little sense as assets from the perspective of the owner-state i.e. society has no incentive to invest in their growth capacity. In addition, on account of the relatively high cost of a managed

harvest, they do not justify a commitment of substantial amounts of national resources for the management of the exploitation process. Under these circumstances the owner-state will allow these resources to be depleted through unmanaged exploitation.

Examples of this process include the depletion of many of the large land mammals, such as the African elephant. During the decade of the 1980s, sub-Saharan Africa lost half of its elephant population (from 1.3 to 0.6 million). However, on closer inspection of the national population statistics, it appears that four countries alone (Sudan, CAR, Tanzania and Zambia) lost 600,000 thousand elephants between them. It is also clear how these elephants were lost. These four countries fell at the bottom of the tables of African park and protection spending (averaging about $15 per square kilometre) (Swanson, 1993). The decline of the African elephant in the 1980s was the result of these tacit "open access" regimes.

3) ***Base Resource Conversions***
Conversion occurs when the subject resources are of little or no known value to humans on an individual basis. They are lost because humans find alternative uses for the lands on which they rely; the base resources are converted to the use of other biological resources. The diverse biological resources are then undercut rather than overexploited. An example of this process is the depletion of many types of virtually unknown life forms (e.g. plants and insects) when land is deforested and converted to other forms of use, such as cattle ranching.

Investment Patterns and the Specialised Species

Once a species is determined to be unworthy of investment by human society, there is this multiplicity of routes available for it to move to its extinction; however, the question remains: why is it that so many species are now being determined to be unworthy of investment? One very important reason is the bias towards investment in the *specialised species*. Diverse species may be viewed simply as all of those species on earth which suffer from the handicap of not being one of the few species for which a positive investment bias exists; then they suffer from under-investment on a relative basis. The specialised species are the domesticated (animal) and cultivated (plant) species that have been selected by humans to receive the vast majority of investment for purposes of meeting human consumption needs. They represent a minute proportion of the world's diversity, but they constitute the vast majority of the food consumed by humans. Only twenty species produce the vast majority of the world's food. The four carbohydrate crops (wheat, rice, maize and potatoes) feed more people than the next 26 crops combined (Wilson, 1988).

The specialised species are of particular importance because their mere existence indicates the nature of the underlying problem. These species are so prevalent because they are monopolising the investments of human societies in biological production. In a world where human investments are now necessary for species survival, these *natural monopolies* in a handful of species imply non-investment in literally millions of others, and non-investment equates with extinction.

The extent to which this *process of conversion* underlies the process of extinction is indicated by the rates and locations of recent land-use conversions. During the twenty years 1960-1980, the whole of the developing world saw the proportion of its land area dedicated to the specialised species increase by 37.5%, while that same proportion remained constant in the developed world (where the conversion process is complete) (Repetto and Gillis, 1988). At the "forested frontier" these rates of conversion are even greater than the average, and are continuing to the present. For example, during the 1980s, Paraguay (72%), Niger (32%), Mongolia (32%) and Brazil (23%) have all experienced significant rates of conversion of lands to specialised crops; Ecuador (62%), Costa Rica (34%), Thailand (32%) and the Philippines (26%) have all experienced significant conversions of lands to specialised livestock (World Resources Institute, 1990).

Why is this conversion to the specialised species continuing across the world? One reason is that there are increasing returns to scale from the adoption of a common technology that is in use world-wide; it is cheaper to adopt agriculture than it is to adapt it. However, this cost-based explanation is not complete, as there is the demand for diversity to counter-balance it. Another part of the problem may be perceptual. Another reason is that, to a large extent, the conversion frontier is perceived to be synonymous with the development frontier. That is, many developing countries do not wish to be seen to build their development strategies upon diversity; diversity is often seen to be a sign of backwardness. The problem is then one of demonstrating the importance of selecting the most appropriate path to development rather than automatically following the same used earlier.

Regulating Extinction: Correcting Investment Incentives

This framework focuses on the perceived investment-worthiness of the resource as the fundamental source of biodiversity losses. In the context of owner-states (where the allocation is determined by the sovereign state), all questions of extinctions and species declines are based on the incentives for under-investment. That is, the fundamental problem is that the owner-states do not invest in their diverse species (in terms of stocks, management and

habitat). It is the failure of a state to provide these requirements for a terrestrial species that inevitably results in its decline.

The decision to withhold these investments in regard to a given area of habitat implicitly derives from a determination that the naturally existing resources do not warrant the required investments. In regard to the developing tropical countries (where most diversity now exists), these are usually decisions not to invest in managing the forested frontier, thereby allowing wholesale overexploitation of the diverse resources and encouraging widespread conversion to the traditional agricultural commodities (which are perceived as more productive).

For example, in the Amazon region, it is often the case that the owner-state refuses to engage in resource management on the frontier region before the conversions occur. Usually, the first vestiges of a management institution (e.g. private property rights with some state enforcement) are put into place when the land is deforested, enclosed and converted to agriculture. This indicates the unwillingness of the state to invest in management regimes for the slate of diverse resources that naturally exist there, (and the willingness to introduce these regimes with the introduction of different assets in those regions). Therefore, the fundamental basis for any land-based species' decline is a state's determination, implicit or explicit, not to invest in that particular species (or, equivalently, its habitat). In order to regulate extinction, it will be necessary to operate through the perceptions of these states, affecting the determination of which resources are investment-worthy. Once again this points to the importance of demonstrating and supporting the belief in alternative paths to development.

4.1.4 Conclusion: Human Responsibility for Biodiversity Decline

This paper has described a general economic framework that demonstrates how human societies are responsible for the decline of biodiversity. It is based on the idea that humans now have control over the biosphere, and make decisions regarding its constitution both explicitly and implicitly by means of resource allocations. It is the perception of relative investment-unworthiness by a managing owner-state that destines a diverse resource to oblivion. After this fundamental determination has been made, the only issue that remains is the route through which this divestment/conversion will work itself. Human societies are responsible for all forms of biodiversity losses by virtue of the investments they undertake and the perceptions that they hold. These are the fundamental determinants of biodiversity's decline.

References

Albon, S. and Leader-Williams, N. 1988. Allocation of resources for conservation. *Nature* 336, 533-5.

Barbier, E., Burgess, J., Swanson, T. and Pearce, D. 1990. *Elephants, Economics and Ivory.* Earthscan, London, UK.

Clark, C. 1976. *Mathematical Bioeconomics: The Optimal Management of Renewable Resources.* John Wiley, New York, USA.

Clark, C. 1973. Profit Maximisation and the Extinction of Animal Species. *Journal of Political Economy* **81(4)**: 950-61.

Conrad, J. and Clark, C. 1987. *Natural Resource Economics.* Cambridge University Press, Cambridge, UK.

Dasgupta, P. 1982. *The Control of Resources.* Blackwell, Oxford, UK.

Dasgupta, P. and Heal, G. 1979. *Economic Theory and Exhaustible Resources.* Cambridge University Press, Cambridge, UK.

Douglas-Hamilton, I. 1989. Overview of Status and Trends of the African Elephant. In Cobb, S. (ed.), *The Ivory Trade and the Future of the African Elephant.* Report of the Ivory Trade Review Group to the CITES Secretariat.

Gordon, H.S. 1954. The economic theory of a common-property resource: the fishery. *Journal of Political Economy* **62**:124-42.

Hardin, G. 1968. The tragedy of the common. *Science* 162, 1243-48.

Hotelling, H. 1931. The economics of exhaustible resources. *Journal of Political Economy* **39**:137-75.

IUCN Environmental Law Centre, 1985. *African Wildlife Laws.* IUCN, Gland, Switzerland.

IUCN Environmental Law Centre, 1986. *Latin American Wildlife Laws.* IUCN, Gland, Switzerland.

Ivory Trade Review Group (ITRG), 1989. *The Ivory Trade and the Future of the African Elephant.* Report to the Conference of the Parties to CITES, Lausanne, Switzerland.

Lyster, S. 1985. *International Wildlife Law* Grotius, London, UK.

Marks, S. 1985. *The Imperial Lion: Human Dimensions of Wildlife Management in Africa.* Westview Press, Colorado, USA.

McNeely, J., Miller, K., Reid, W., Mittermeier, R. and Werner, T. 1990. *Conserving the World's Biological Diversity*. IUCN, Gland, Switzerland.

Repetto, R. and Gillis, M. 1988. *Public Policies and the Misuse of Forest Resources*. Cambridge University Press, Cambridge, UK.

Solow, R. 1974. The Economics of Resources or the Resources of Economics. *American Economic Review* **64**.

Spence, M. 1975. Blue Whales and Applied Control Theory. In Gottinger, H. (ed.), *System Approaches and Environmental Problems.* Vandenhoeck, Göttingen, Germany.

Swanson, T. 1989. Policy Options for the Regulation of the Ivory Trade. In *The Ivory Trade and the Future of the African Elephant.* ITRG, Lausanne, Switzerland.

Swanson, T. 1990a. Conserving Biological Diversity. In Pearce, D. (ed.), *Blueprint 2: Greening the World Economy*. Earthscan, London, UK.

Swanson, T. 1993. The Economics of Extinction Revisited and Revised. *Oxford Economic Papers*.

Swanson, T. 1993. *The International Regulation of Extinction.* MacMillan, London, UK.

Swanson, T. and Barbier, E. (eds.) 1992. *Economics for the Wilds: Wildlands, Wildlife, Diversity and Development.* Earthscan, London, UK.

Wilson, E. 1988. *Biodiversity*. National Academy Press, Washington, USA.

World Conservation Monitoring Centre (WCMC), 1992. *Global Biodiversity.* Chapman & Hall, London, UK.

World Resources Institute, 1990. *World Resources 1990-1991*. Oxford University Press, Oxford, UK.