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A DESIRABLE ENVIRONMENTAL MODEL

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ABSTRACT

A long-term ecological model is presented for man's use of the environment. A definition of Desirable Environmental Use is formulated in terms of Actual Environmental Use and two limits on Actual Environmental Use. One limit, the Impact Share, is the amount of negative impact allowed on each species in the environment. The other limit, the Resource Share, is the amount of each non-living resource that may be acquired. Desirable Environmental Use is related directly to maximum desirable human population size and maximum desirable individual consumption.

Introduction

The purpose of this article is to present an ecological model, or program, for man's use of the environment. This model employs several perspectives. First, man is treated as one of many interdependent species utilizing the environment. Second, it is recognized that man and other species require long-term use of an environment with a full complement of resources. Third, man's actions are seen to have long-term consequences both for the environment and for himself.

A distinction is made in the model between species whose adaptation to the environment over time occurs primarily through technological innovation, and species whose adaptation occurs primarily through biological, or non-technological, innovation. For the sake of brevity, the two types will be labeled simply technological species and non-technological species. At the present time man is the only known technological species. Technological innovations

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produced by man include agriculture, writing, science, etc. All other species on earth are classified as non-technological. Unlike non-technological species, a technological species can determine the nature and degree of the impact it has on the environment.

This model defines the range of Desirable Environmental Use by a technological species. Desirable Environmental Use is defined in terms of Actual Environmental Use, and two limits on Actual Environmental Use. Actual Environmental Use is the aggregate of all uses of the environment by a technological species, and includes every contact it makes with its environment. This model allows the technological species complete freedom in Actual Environmental Use provided neither of the two limits is exceeded.

The two limits on Actual Environmental Use are termed the Impact Share and the Resource Share. The Impact Share is the amount of negative impact which a technological species is allowed to have on each non-technological species. The other limit, the Resource Share, is the amount that a technological species is allowed to acquire of each naturally-occurring non-living resource. The Resource Share applies only to naturally-occurring non-living resources.

This model is presented piecemeal. The constituents of Desirable Environmental Use—the Impact Share, the Resource Share, and Actual Environmental Use—will each be considered in turn. Subsequently, Desirable Environmental Use will be related directly to maximum population size and maximum individual consumption of Desirable Environmental Use.

Impact Share

Initially, we will define the Impact Share, which limits Actual Environmental Use by a technological species. The Impact Share (IS) is the aggregate of all specific impact shares.

$$IS = i_1 s, i_2 s, \ldots, i_n s$$

A specific impact share (is) is the maximum amount of negative impact that a technological species is allowed to have on a particular non-technological species. Therefore, the Impact Share is the maximum amount of negative impact a technological species is allowed to have on all non-technological species.

In its use of the environment, a technological species has considerable negative impact on many non-technological species. Negative impact occurs both through killing members of non-technological species and through causing a decrease in numbers by limiting their resources. They are killed through efforts at extermination, use for food and materials, and unintended injury. Their resources are limited when technological species employ the resources themselves, restrict access by means of barriers, and otherwise render areas less habitable. As resources are increasingly limited, the environment supports fewer members of the affected species. Negative impact by a technological species includes a) negative impact by members of non-technological species which the technological species intentionally or unintentionally supports, calculated for the period they are supported, and b) negative impact by members of non-technological species which the technological species intentionally or unintentionally introduces into new sections of the environment, calculated from the time of introduction until the time their impact resembles that of comparable species fully integrated into the environment.

The specific impact share is obtained by

$$i_1 s = \frac{K + A}{NTS}$$

where K is the number of members of the given non-technological species that are killed by other non-technological species, A is the number of individuals of the given species which would be supported by the environment, but are absent because of the limitation of their resources by other non-technological species, and NTS is the number of other non-technological species which have negative impact on the given species. There are several qualifications to be incorporated into the previous statement. First, only non-technological species which have negative impact totaling at least one death or absence are included in determining the specific impact share. Second, negative impact by a technological species on a given non-technological species is to occur at the same rate as the average negative impact by other non-technological species on that species. Third, the negative impact on the particular species by members of non-technological species which are supported or introduced by a technological species is counted as negative impact by the technological species, and is not included in determining the average amount of negative impact that non-technological species have on the particular species. In defining specific impact shares, killings and absences are combined, in order that in the interest of flexibility, the technological species can choose any combination of the two it wishes. Also, we are not concerned with the negative impact which members of a species have on other members of the same species.

Although a technological species may utilize as little of a specific impact share as it desires, in terms of Desirable Environmental Use it is not to exceed any specific impact share.

Resource Share

Next, we will define the Resource Share, or the maximum amount of all naturally-occurring non-living resources that a technological species is allocated during a given period of time. All other uses of the environment, such as using technological products or other species, are not subject to limitation by the Resource Share. The subscript $_{nn}$ will be used to identify naturally-occurring non-living resources. The Resource Share (RS) is the aggregate of all specific $_{nn}$resource shares (rs).

$$RS = r_1 s, r_2 s, \ldots, r_n s$$

A specific $_{nn}$resource share is the maximum amount of a $_{nn}$resource that a technological species is allowed to acquire during a given period of time. A $_{nn}$resource will be defined in terms of a) the technological level at which it can be exploited, and b) the fact it is singled out for use. $_{nn}$Resources will be allocated in terms of a) the length of time $_{nn}$resources may be needed, and b) the number of technological species using a given section of the environment.

The availability of $_{nn}$resources is related to the technological ability of the species. As a technological species acquires additional technological ability it is able to make use of an increasing number of $_{nn}$resources, and to use these $_{nn}$resources for further technological development. If, however, specific $_{nn}$resources are exhausted or missing, the progress of the technological species is likely to be slowed and in some cases may even be halted. Thus the lack of available coal and gasoline would seriously hinder the transition from a domesticated-animal technology to an atomic technology. If particular $_{nn}$resources become unavailable, then it may prove difficult or even impossible for a) a technological species to remain at a particular technological level, recover from a technological decline, or advance to further technological levels, and for b) subsequent technological species to advance to the levels achieved by previous technological species. Consequently, this model does not permit exhaustion of any $_{nn}$resource. In other words, through the conservation of each specific $_{nn}$resource this model a) enables a technological species to maintain its present technological level, advance to further technological levels, and recover from a technological decline, and b) enables subsequent technological species to advance to the levels achieved by previous technological species. In order to accomplish this, ${}_{nn}$resources are defined and conserved in terms of the technology necessary to exploit them.

A ${}_{nn}$resource is any portion of the natural (non-technological) environment which a) is singled out by a technological species for use, and b) is available for exploitation at a particular level of technological ability. A portion of the environment is recognized as a separate ${}_{nn}$resource on the basis of the level of technology at which it can be exploited. Thus we may recognize many portions, or ${}_{nn}$resources, of a substance, where each portion requires additional technological sophistication before exploitation can take place. In some cases a portion is available at a null level of technology. In others the portion becomes available only after a certain level of technology—knowledge, tools, and organization—has been reached.

We are concerned with the level of technology at which a given portion can *first* be exploited, and not with later developments in technology which exploit the same portion, even if more effectively. A separate ${}_{nn}$resource is acknowledged only when a technological advance enables the species to exploit a new portion which it could not otherwise exploit.

Exploitation is used here to mean "exceed the ${}_{nn}$resource share." Thus we recognize a new ${}_{nn}$resource only when the technology is sufficiently advanced to exceed the share that a technological species is allowed to have of a new portion of the environment.

In determining the Resource Share, it is necessary to consider the length of time ${}_{nn}$resources may be needed. This will be set at the length of time remaining during which the environment can support technological species. In the case of the earth, the existence of technological species does not appear likely to be threatened by the increasing luminosity of the sun for several billion years. Although one cannot predict how long man, his descendants, and other technological species will require earth's resources, conservation can ensure that ${}_{nn}$resources will not be exhausted as long as the earth can support technological species. Areas which cannot independently support technological species, such as the moon, are treated as segments of the neighboring environment which can support technological species, and their ${}_{nn}$resources are distributed according to the same principles.

In determining specific ${}_{nn}$resource shares, we are concerned with the existing quantity of each specific ${}_{nn}$resource, together with the various increases and decreases in quantity which will occur between the present time and the time when the environment can no longer support technological species. In accordance with the specific $_{nn}$resource share, technological species may acquire as much of the specific $_{nn}$resource as desired during a period of time, provided that this does not result in there being less than equal amounts of the $_{nn}$resource to acquire during equal periods of time. Specific $_{nn}$resources are subject to various increases and decreases, which occur for a variety of reasons, including geological erosion and construction, radioactive decay, and recycling due to natural (non-technological) causes. Technological species must take these increases and decreases into account in determining how much of a specific $_{nn}$resource may be acquired during the current time period. For example, when the amount a $_{nn}$resource is renewed depends upon the amount of the $_{nn}$resource currently available, technological species must determine what combination of the original amount and the renewed amount will ensure equal amounts available in equal time periods. The amount acquired by technological species must be adjusted to prevent there being less than equal amounts during equal time periods until the time the environment can no longer independently support technological species. However, when there is nothing technological species can do to prevent there being less than equal amounts during certain equal periods of time, technological species are entitled to any surpluses which may occur.

Apportionment of a specific $_{nn}$resource is based on the amount of time remaining during which the environment can independently support technological species. The $_{nn}$resource is not apportioned retroactively in terms of previous periods in which a technological species lacked either the desire or the technology to exploit the $_{nn}$resource. However, as will be seen below, once a technological species is capable of exploiting the $_{nn}$resource, it may save current shares for future use.

At this time man is the only technological species present in man's environment. However, we cannot take for granted that this will always be the case. Other technological species may appear as a result of further evolution of Homo sapiens, continuing evolution of other species on earth, genetic engineering, and origin in alien environments. While none of these may seem likely to happen at the present time, the possibility of one or more occurring increases markedly given a time span of several billion years.

It is necessary to recognize those sections of the environment which a technological species uses in common with one or more other technological species. In this model, each $_{nn}$resource within these sections is divided evenly between all the technological species which a) use a section, b) want the $_{nn}$resource, and c) are technologically able to obtain it. Although at any point in time one would expect various technological species to have different requirements for specific $_{nn}$resources, over time such requirements are likely to change. A strict division permits continued access to all $_{nn}$resources within the common section, and does not preclude the possibility of trade between species.

In summary, the specific $_{nn}$resource share of a technological species during a time period is given by

$$r_1 s = \frac{q_1}{TS}$$

where q_1 is the quantity of the $_{nn}$resource allowed to all technological species during the time period and TS is the number of technological species using that section of the environment which want the $_{nn}$resource and are technologically able to acquire it. The quantity allowed to all technological species during the time period is

$$q_1 = Q_1 - Q_x$$

where Q_1 is the amount of the $_{nn}$resource available during that time period and Q_x is the amount of the $_{nn}$resource needed to make the quantity allowed to technological species in each future time period of equal duration equal to q_1 in as far as this is possible. Future time periods include all time periods between the present time period and the time technological species can no longer be independently supported by the environment.

The specific $_{nn}$resource share is the maximum amount of a specific $_{nn}$resource that a technological species is allowed to acquire during a specified period of time. Although during this time the technological species may use as little of each specific $_{nn}$resource as it desires, from the standpoint of Desirable Environmental Use, it may not exceed any specific $_{nn}$resource share. In this model specific $_{nn}$resource shares cannot be increased and decreased in terms of each other. They are not interchangeable and cannot be traded off. If the technological species were to attempt to balance overuse of some $_{nn}$resources with underuse of others, all $_{nn}$resources would not be conserved for future use.

Actual Environmental Use

The aggregate of all uses a technological species makes of the environment constitutes Actual Environmental Use. Actual

Environmental Use is composed of new Environmental Use and residual Environmental Use. New Environmental Use involves environmental uses by a technological species which are not already in effect. Residual Environmental Use involves the continuation of environmental uses which are already in effect, i.e., uses previously implemented as new Environmental Use. Residual Environmental Use includes a) ongoing uses, such as using cars and buildings constructed in the past and recycling for repeated use, as well as b) remainders of use, such as pollution and discarded products. Residual Environmental Use continues until phenomena are no longer qualitatively and quantitatively distinct from their occurrence in nature. Once reintegrated into the natural environment, phenomena are again available for new Environmental Use.

Both new Environmental Use and residual Environmental Use produce negative impact. In terms of Desirable Environmental Use, the negative impact produced by the combined effects of new Environmental Use and residual Environmental Use must remain equal to or less than the Impact Share. If residual Environmental Use causes enough negative impact, a technological species must restrict or even forego new Environmental Use in order to remain within the limits of the Impact Share. The technological species has maximum control over new Environmental Use only when the amount of negative impact from residual Environmental Use is negligible.

From the standpoint of Desirable Environmental Use, we are concerned with the current Impact Share. At no time may a technological species exceed the current Impact Share. This is to say that past Impact Shares may not be saved up for later use, nor may a technological species encroach into future Impact Shares.

It is also necessary to distinguish between current, past, and future Resource Shares. The current Resource Share is the present amount which a technological species is allowed to acquire of each and every specific $_{nn}$resource. Past Resource Shares are the Resource Shares which were available to a technological species in the past as current Resource Shares. Future Resource Shares are those Resource Shares which will be available to a technological species in the future as current Resource Shares. A technological species can either use all of the current Resource Share or it can save all or part of the current Resource Share to supplement one or more future Resource Shares. Consequently, at any time a technological species may have portions of past Resource Shares saved to supplement its current or future Resource Shares. However, in order that all $_{nn}$resources be conserved for the future, a technological species is not to utilize future Resource Shares before the time they become current Resource Shares.

New Environmental Use of $_{nn}$resources may use both the current Resource Share and saved portions of past Resource Shares. In accordance with Desirable Environmental Use, new Environmental Use of $_{nn}$resources must employ no more than the combination of both types of Resource Shares.

In summary,

$$cDEU = [(reEU + nEU) \rightarrow cNI \leqslant cIS], \text{ where } nEU_r \text{ utilizes} \leqslant (cRS + saRS)$$

in which cDEU is current Desirable Environmental Use, reEU is residual Environmental Use, nEU is new Environmental Use, cNI is the current negative impact, cIS is the current Impact Share, nEU_r is new Environmental Use of $_{nn}$resources, cRS is the current Resource Share, and saRS is the saved portions of past Resource Shares.

Actual Environmental Use must be controlled and modified when necessary in order that neither the Resource Share nor the Impact Share is exceeded. It may prove necessary for a technological species to use less than the entire Resource Share—composed of the current Resource Share and saved portions of past Resource Shares—in order not to exceed the Impact Share; and it may prove necessary to use less than the entire Impact Share in order not to exceed the Resource Share. Aside from the limits of the Resource Share and the Impact Share, a technological species is unrestricted as to the nature and extent of its use of the environment.

Population and Consumption

Desirable Environmental Use provides the range of desirable environmental use by a technological species. When we consider that Desirable Environmental Use is distributed among all members of a technological species, we have a means of determining the maximum desirable population size and the maximum desirable individual consumption of Desirable Environmental Use for that species. Specifically,

$$\max DEU = \max P \cdot \max \bar{c}$$

where max DEU is maximum Desirable Environmental Use, max P is the maximum desirable population size, and max $\bar{c}$ is the maximum desirable average individual consumption of Desirable Environmental Use. Consequently, an increase in population size necessitates a proportional decrease in average individual consumption, and conversely, an increase in average individual consumption requires a proportional decrease in population size. Therefore, a technological species has considerable leeway to determine its own balance between population size and individual consumption of Desirable Environmental Use.

Discussion

The advantages of this model are that a) technological and non-technological species would be able to coexist and develop in their own ways, and b) both technological and non-technological species would retain long-term use of an environment in which resources would not be depleted. The disadvantages of this model are that a) current patterns of environmental use by man would have to be markedly altered, b) human population would have to be sizably reduced, and c) application of the model would necessitate considerable research, planning, and monitoring.

Application of the model could be facilitated in a variety of ways. For example, the amount of attention given to governing environmental use could be lessened by sampling environmental use and by keeping well within the bounds of Desirable Environmental Use so that relatively coarse measures of use would suffice. Also, holding environmental use within the limits of the model would be made easier by pricing every good and service in terms of the fraction of Desirable Environmental Use that it exhausts. Thus man could apply the same ingenuity he uses to exploit the environment to achieving his goals within the limits of the model.

Finally, it is not necessary to have jurisdiction over the entire environment to put the model into effect. The model can be initiated in one or more sections of the environment at a time, regardless of the size of the sections.

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