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Economics and Ecology: The Need for Detente in Conservation Ecology

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INTRODUCTION

The most important problem facing our species in the next century is how to reconcile our insatiable drive for development with the limited resources of our planet. Attempts at resolution, which should involve collaboration between economists and ecologists, have often deteriorated into adolescent debates between "traditional ecologists" and "traditional economists." The former have donned sackcloth and ashes and haunted the halls of our social and political institutions screeching doom in a reedy voice. The latter have donned dark suits and red neckties, proclaiming, with reassuring bass voices, that the rosy glasses of technology will cancel the oil slick covering our shoes. The caricatures may seem exaggerated, but don't protest overmuch before checking the back of your closet (and lecture notes) for traces of sackcloth or red ties.

To solve the problem, the ecologist must realize that telling the human species to stop economic development is like telling koalas to stop eating eucalyptus leaves. Just consider Genesis I:28ff: "Be fruitful, multiply, fill the earth and conquer it." Development is what this species does. You won't stop it from the outside with laws and regulations. Likewise, economists must realize that environmental changes are not just irritating externalities. We have accumulated hundreds of examples of ecosystem feedbacks on the economic system. The environment is not an externality, it is the system within which we operate.

The solution to THE problem of the 21st century requires interdisciplinary detente. The premise of this article is that synthesis can be founded on the realization that economic theory predicts how this particular species responds to its resource environment, and ecological theory predicts how the system reacts. The two sides of the controversy are simply two aspects of the same integral feedback process. It has long been apparent to a few visionaries (Daly 1968, Odum 1971, Isard 1972) that man and nature form a single dynamic system.

FALLACY − It's a War: It's Economics vs. Ecology

It is shortsighted to consider ecology and economics as diametrically and irreconcilably opposed on issues of economics and environmental quality. It has long been understood that neoclassical economic theory does not incorporate all relevant human values. Concepts of "market failure" and "externalities" are well developed in the economics literature and can be found in any principles of economics textbook (e.g., Baumol and Blinder 1994). Much economic research focuses on finding remedies, such as taxes and incentives, that will correct for market failure (Tietenberg 1988). The interconnectedness of economics and ecology has long been recognized by economists in the fields of agriculture and forestry (Gregory 1972, Bowes and Krutilla 1989) and by resource economists in general (Kahn 1995).

The intimate relationship between economic activity and the ecosystem is particularly clear in the management of renewable resources (Hamilton 1948, Watt 1968). One of the best examples is provided by the fishery industry (e.g., Paulik and Greenough 1966). As the rate of harvest approaches the reproductive potential of a population, the catch per unit effort decreases. Fisheries management has learned to build the population dynamics into the economic model and to explicitly include the feedbacks. Forestry and whaling have also recognized the need to integrate population dynamics into the economic models (Walters 1986).

FALLACY − Boxing Up the Other Guy

One impediment to integrating economics and ecology is the manner in which each field abstracts the human−environment system. Abstractions isolate the dynamic behavior of interest. The economic model isolates the intricate interactions of the market, abstracting the environment into a box labeled "resources" on the input side and a box labeled "effects" on the output side. As such, the environment becomes external to the economic activity. We have been guilty of this ourselves (e.g., Spofford et al. 1976).

The ecological model isolates the intricate interactions of the natural system and abstracts human activity into a box labeled "disturbances." The abstractions are successful as long as the assumption holds that human activity occurs on a relatively small scale. That assumption is clearly violated when economic activity reaches the scales we have experienced in the latter half of the 20th century. The reality is that human society is another interactive component of the ecosystem: we are part of a single, integrated system (McDonnell and Pickett 1993).

FALLACY − Give Me Your Numbers and Go Away

The goal of integration is also impeded by the sweeping assumption that the role of ecologists is "valuation." The hypothesis sounds reasonable on the surface. Ecologists should find a way to place a monetary value on the environmental effects of economic activity. Values for these "externalities" can then be inserted into the economic model. However, the strategy is limited because the environment is still not a dynamic entity within the economic model. The feedback loop between the human species and its ecosystem is still not complete.

FALLACY − Nah! Nah! My Theory is Bigger than Your Theory

The global ecosystem and its dominant, *Homo sapiens,* are extremely complex. Neither economic nor ecological theory has been exceptionally successful in predicting large−scale events. The approach in each field has been to narrow the range of topics down to something it can predict, and then report success. At the moment, the range of topics that we can predict is narrow indeed. Neither body of understanding is superior, and both have serious limiting assumptions (see Russell 1995). We will need an integrated theory that uses each in the areas where it is best, but uses both and develops innovative approaches that lift the most serious limiting assumptions.

FALLACY − Ecologists Should Concentrate on the Study and Preservation of the Natural World

This logic goes back to a key concept of science: the controlled experiment. Mechanisms underlying a complex system can be investigated by systematically isolating individual parts to understand how they function in isolation. The pieces and their interactions then can be reassembled into an understanding of the complex, connected system. The ecologist endeavors to understand system dynamics by isolating the "natural" ecosystem, i.e., the system "undisturbed" by man. However, the desire to isolate can become counterproductive when humans become the dominant species in the ecosystem. It might be possible to study some aspects of forest ecosystems while ignoring the trees, but our mechanistic understanding would be seriously limited.

The simple fact is that there is no longer any natural ecosystem unaffected by man. At some point in the recent past, point−source pollution could be considered a local phenomenon and an external disturbance to the ecosystem. More than 4,000,000 chemicals are now registered with the American Chemical Society, 43,000 of which, excluding pesticides, are listed by the Environmental Protection Agency as subject to the Toxic Substance Control Act (Council on Environmental Quality 1979). Any persistent chemical with low vapor pressure that is released as fine particles can be transported worldwide in days to weeks (Woodwell 1981). The result is an impressive inventory of chemicals in the atmosphere. Global CO_2 increases, acid precipitation, loss of global biodiversity, the impact of chlorofluorocarbons on the ozone layer, and the rapid transport of chestnut blight, Dutch elm disease, and HIV throw serious doubt on the assumption that ecological systems can be studied in isolation from economic activity.

A MATTER OF SCALE

Many fallacies suggested in the previous section have a common root: an assumption of small scale. As long as human economic activity remains small and local, the assumptions of isolated economic and ecological theory are reasonable. The argument is simple and intuitively appealing. If a single miner attacks a mountain with a hammer and chisel, the dynamics of the mountain can be ignored because they are orders of magnitude different in scale. You can study dynamics of the mountain, such as erosion, and ignore the miner. You can study the activity of the miner and assume that the dynamics of the mountain are so slow that no feedback occurs. However, when the scale of the mining activity approaches the scale of the mountain, the systems become dynamically connected. The mining activity can no longer ignore the dynamics of the mountain, such as landslides and sloughing. The feedbacks become an integral part of the economic activity.

A similar small−scale assumption underlies the neoclassical market model. Price tends to increase with scarcity.

In response to the price increase, the quantity demanded decreases. On a graph of price as a function of quantity, the supply and demand curves cross and a price is set. The price is stable in a mathematical sense, in that any effort to move the price away from this point will shift market forces, e.g., increasing price will decrease the quantity demanded, so that the price returns to this stable "equilibrium" point. This model assumes small−scale dynamics, i.e., that the supply and demand curves can be characterized as well behaved in the vicinity of the equilibrium point. A change in the supply will not destabilize the underlying environmental system. The assumption is valid as long as the scale of the dynamics is small in both space and time. When the scale of the economic system approximates the scale of the ecosystem, the assumption is violated. The simple fact is that the scale of resource utilization by society is now approaching the scale of dynamics of the ecosystem. It is no longer reasonable to assume that environmental feedbacks are not a dynamic component of the economic system.

A SIMPLE EXAMPLE

A simple example may help us to think about linkages between two separate systems. Figure 1 represents an arbitrary economic system, E, interacting with an arbitrary natural system, N. One component of the economic system, E_1, extracts resources from the natural system at N_2. Another component, E_2, deposits a decomposable waste product into N_4. Equations for the system and parameter values are given in Table 1.

FIG. 1: Linkage between an economic system, E, and a natural system, N. The component E_1 extracts natural resources at N_2, and the component E_2 deposits decomposable waste at N_4. See Table 1 for equations and parameter values.

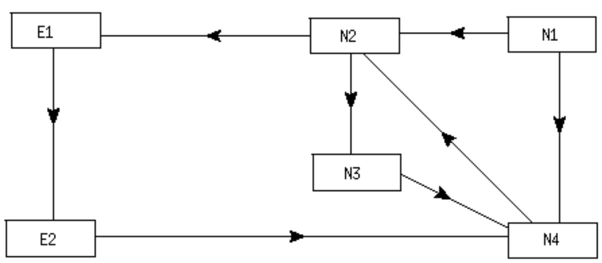

TABLE 1: Example model of an economic system, E, interacting with a natural system, N. The combined system is diagrammed in Fig. 1. [See erratum.]

$dE_1/dt = I - b_1E_1 + eE_1N_2$,	$E_1(.) = 10$
$dE_2/dt = b_1E_1 - b_2E_2 - eE_2$,	$E_2(.) = 10$
$dN_1/dt = P - a_1N_1N_2 - a_2N_1$,	$N_1(.) = 315.23$
$dN_2/dt = a_1N_1N_2 - eE_1 - a_3N_2N_3 + a_4N_4N_2$,	$N_2(.) = 316.23$
$dN_3/dt = a_3N_2N_3 - a_5N_3N_4$,	$N_3(.) = 631.46$
$dN_4/dt = a_2N_1 + a_5N_3N_4 + eE_2 - a_4N_4N_2 - a_6N_4^2$,	$N_4(.) = 316.23$

$I = 1.0$

$b_1 = 0.1 = b_2$

$e = 0.0$

$P = 1000$

$a_1 = 0.01 = a_2 = a_3 = a_4 = a_5 = a_6$

The point of the example is to illustrate what happens as the scale of the economic activity begins to increase, i.e., as we increase the parameter *e*. Note that e determines both the rate of resource extraction and the rate of waste deposition. Simulations are begun with all components at equilibrium and then the value of *e* is increased (Table 2). As our metric of the impact of the economic activity on the natural system, we use the value of N_2 at 500 time steps after the increased activity begins. The table indicates that low levels of resource extraction have only a minor impact on the natural system. Even extracting 10% of N_2 per unit time only alters N_2 by 1.3%, surely a sustainable level of resource use.

TABLE 2: Values of N_2 (Fig. 1) at $t = 500$, with increased economic activity represented by parameter *e*.

e	*N2*
0.00	316.23
0.01	316.23
0.02	316.22
0.03	316.21
0.04	316.20
0.05	316.18
0.06	316.14
0.07	316.08
0.08	315.95
0.09	315.56
0.10	312.13

The surprise comes when we consider not the direct impact of resource extraction, but how closely the systems *E* and *N* are linked. At what point do the dynamics of the two systems become so closely linked through the parameter *e* that they are no longer two separate systems? We examine this question by considering the stability properties of *N*. As a surrogate for the eigenvalue of *N*, we consider the time required for N_2 to recover from a perturbation (Table 3). For these simulations, we start the system at equilibrium, increase *e*, and simultaneously disturb N_4 by setting it to $N_4(0) = 310$, i.e., a decrease in the initial value of ~2%. We then record the number of time steps until N_2 reaches the final values given in Table 2.

TABLE 3: Time intervals required for N_2 to recover (to two significant digits) from a perturbation ($N_4(0) = 310$) given increases in economic activity, *e*.

e	Time
0	7
0.01	7
0.02	7
0.03	8
0.04	9
0.05	11
0.06	35
0.07	69
0.08	156
0.09	383
0.10	> 5000

What is clear from Table 3 is that, somewhere around $e = 0.05$, the dynamics of the two systems become linked. At higher values of e, the intrinsic stability properties of N are affected. Somewhere around $e = 0.1$, a threshold is crossed and N becomes unstable. Over the range $e = 0.05$ to 0.1, the scale of the economic activity has increased such that the two systems have become a single dynamic system. It no longer makes sense for the economic model to consider the natural system as external to the economic system. It no longer makes sense for the ecologist to consider the economic system as an external perturbation. The scale of activity has reached a point where the two have become a single, interacting dynamic system.

The point of this example has been made far more elegantly by a number of theoretical economists (Ijiri 1968, 1971, Chipman 1976) and ecologists (Schaeffer 1981, Luckyanov et al. 1983, Luckyanov 1984, 1995, Iwasa et al. 1987), who have considered the complementary issue: when can a dynamic system be dissected into several subsystems that can be analyzed separately? Results are similar: at some point, the interactions between subsystems reach a scale at which dynamics depend on the total system. The internal dynamics of one subsystem cannot be analyzed in isolation from the internal dynamics of the other system.

The simplest way to make the point is to consider a linear model of two interacting components, X and Y:

$$dX/dt = -aX + bY$$

$$dY/dt = cX - dY$$

Each component has its own intrinsic turnover rate, represented by a and d, and there are interactions with magnitude determined by b and c. The dynamics of the combined system are represented by the eigenvalues, lambda $_i$, of the interaction matrix:

$$\begin{bmatrix} -a & b \\ c & -d \end{bmatrix}$$

where lambda $_i = -\frac{1}{2}(a + d) \pm \frac{1}{2}((a + d)^2 - 4(ad - bc))$

Now assume that $a = d$ and $b = c$, and the equation for lambda $_i$ becomes

$$\text{lambda}_i = -a \pm b\,.$$

If the interaction coefficients ($b = c$) equal zero, each of the two components shows dynamics governed by its intrinsic rate $a = d$. As the interaction coefficients become larger, neither component is governed by its intrinsic dynamics. As b approaches c, each component becomes dominated by the interaction. For b greater than or equal to a, the system becomes unstable. Whether the two components behave like separate systems or a single entity depends on the magnitude of the interaction coefficients, i.e., the scale of the feedbacks.

SYNTHESIS

The key to synthesizing economic and ecological theory may be the simple observation that, as the scale of development increases, economic activity becomes connected to more and more of the environmental dynamics. Many phenomena can still be studied in isolation. There is still room for an isolated economic theory and for controlled ecological experiments. At some scale, however, connectivity increases to the extent that externalities must be internalized into the dynamics of the economic activity.

There are already many papers in the literature that consider economic and ecological systems as a dynamic unit. Daly (1968) proposes a macroeconomic model similar to Fig. 1 and suggests that economics might be considered a life science. Odum (1971) proposes power as a limiting factor that links society and the ecosystem. Kahn (1995) discusses the conservation of ecological services as the key determinant of sustainable economic development. Jones and O'Neill (1992*a*,*b*) studied tropical deforestation with explicit feedbacks between labor−intensive soil conservation and agricultural productivity. If conservation is effective and increased cultivation is limited to good soils, decreased or modified deforestation can result. Jones and O'Neill (1993) have also linked tropical agriculture with the population dynamics of malaria−bearing mosquitoes. Their study seeks to balance the farmer's activities between agricultural production and labor−intensive activities to destroy mosquito breeding habitat.

Despite these examples, the concept of conservation ecology is often limited to a protectionist agenda: buy, fence, and lock up as much as possible of the natural world. But fences rot and locks rust. Arbitrary lines drawn on a map have always faded in time; just ask a Cherokee. The critical challenge for science, and our species, demands that we abolish intellectual barriers, crush limited paradigms, and take the broadest possible view of the problem.

IMPEDIMENTS TO DETENTE

There are few, if any, technical barriers to synthesis. Both fields describe their systems with linked, ordinary differential equations. Regrettably, both adopt the same "myth of simplification" and analyze the equations near a fictional equilibrium. Both revel in providing precise answers to trivial questions, rather than approximate answers to critical questions. Both ignore uncertainty and fantasize a deterministic universe. Not a pretty picture, but no impediments to integration. Clearly, both fields would benefit from a good swift kick in the paradigm!

The primary problem appears to be myopia. Each views its internal challenges as daunting and requiring several more lifetimes of research. Unfortunately, both systems may be extinct before the disciplinary goals are reached. Each defends its borders with the impenetrable barbed wire of jargon. What the economist calls "marginal analysis" is known as sensitivity analysis in the rest of the civilized world. Most importantly, neither field has developed social institutions that encourage novelty and interdisciplinary boldness. Like some secret Masonic handshake, you still have to grind out single−authored papers before the Masters will let you into the Lodge and grant tenure! The social dilemma can be profound for the student or young investigator. One is forced to memorize the chemistry of pigments, instead of being encouraged to paint. It gets harder and harder to master the myopic core of the discipline, so there is no incentive to pile on course work from across campus. Interdisciplinary explorations are greatly undervalued in the tenure process. The "Magnificent Poobahs," with their thick glasses, still evaluate every research proposal. We cannot condemn those who choose the safe, well−marked highway to tweed jackets, oak desks, and a nice view of the quadrangle.

However, myopia and cynicism must not force the rest of us to abandon the quest. Professional societies can encourage joint meetings and interdisciplinary symposia. Funding agencies can reserve a fraction of their resources for interdisciplinary exploration. Individual scientists can support the nascent infrastructure, such as the International Society for Ecological Economics. Individual students can seek postdoctoral experiences in the other discipline. Graduate students can lobby for exploratory curricula. The risks undertaken are justified by the clear potential for breakthroughs. We hope that *Conservation Ecology* will provide a forum for such exploration. Let us strive to keep the contents as visionary as the format.

RESPONSES TO THIS ARTICLE

Responses to this article are invited. If accepted for publication, your response will be hyperlinked to the article. To submit a comment, follow this link. To read comments already accepted, follow this link.

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