MAXIMUM POWER

The Ideas and Applications of H. T. Odum

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Chapter 21

STRUGGLING WITH AN EMERGY ANALYSIS: SHRIMP MARICULTURE IN ECUADOR

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Resource Management Strategies for Coastal Ecosystems

About three-quarters of the current human population lives along the coastlines of this planet. If, as predicted, the human population doubles by 2030, then the great majority of these additional people will attempt to make their livelihood along the coasts of developing tropical nations, most of them in sprawling cities (Merrick 1989). This is a grim prospect, because it appears unavoidable that the vast majority of these people will live in abject poverty.

I have worked in developing countries for several years, attempting to promote a process whereby resource management strategies for coastal environments can be formulated and implemented. I have had to conclude that in an increasing number of situations, the carrying capacity of these ecosystems to support people at an acceptable quality of life, with the technologies available to them, has already been exceeded. The result is a spiral towards increased poverty, greater environmental degradation, and all too often, greater community violence. Resource managers attempt to formulate strategies by which a workable truce between man and nature can be thought through and implemented. While there are examples of balanced, sustainable relationships between people and nature from the past, they seem to be disappearing in the tropics as fast as the rain forests. The current problems are widely recognized, and there are plenty of plans for action. The majority of these plans address only a few aspects of the closely interrelated issues of human dependence upon environment. Very few of them are being translated into meaningful action. As a result, grounds for hope for sustainable levels of utilization of these ecosystems are diminishing.

In coastal ecosystems, the evidence of environmental overuse and degradation typically include:

- Declining water quality in rivers, estuaries, groundwater, and even the nearshore ocean;
- Destruction of habitats important for the production of food, fiber, and fuel and for maintaining ecosystem integrity and of habitats with important roles in maintaining the physical stability of the coastline;
- Declines in nearshore fishery resources;
- Mounting user conflicts;
- Increasing inability of governmental organizations to cope by either mitigating adverse effects or mediating among conflicting groups.

Scott Nixon invited H. T. Odum to give a series of lectures at my university in 1988, and this was my first introduction to H. T.'s concepts. I was both impressed and mystified. I wanted to see what an emergy analysis of a problem I know something about might produce. H. T. agreed and, at the modest cost of some graduate student time and a lot more of his time pro bono, he undertook an emergy analysis of shrimp mariculture in Ecuador (Odum and Arding 1991). In this chapter, I attempt to sort through some initial reactions, as a resource manager, to what he has told us.

Ecuador, a Country Losing Ground

I know as a practicing resource manager, and emergy analysis reaffirms, that you must always look one scale bigger than the problem at hand. So before we consider shrimp mariculture, let us consider Ecuador. It is a small country, about the size of West Virginia, that straddles the equator on the west coast of South America. An emergy analysis of Ecuador suggests that a confluence of natural endowments gives Ecuador a particularly high potential for generating wealth for human societies. Its position on the planet and its topography provide it with a rich resource base with abundant rainfall, fertile volcanic soils, large rivers, and abundant fisheries. This rich natural endowment has been recognized by people for millennia and helps explain why the oldest human settlements in the Americas are found along the Ecuadorian coast. The Guayas estuary, the largest on the west coast of South America, was a

hub for maritime trade borne on sophisticated balsa rafts when the first European conquerors arrived in the 15th century. The estuaries are rich in fish, shellfish, and mangroves. Until recently, there were magnificent forests both along the coast and in the Amazon. In the past 40 yr, the coastal forests have been replaced by cropland and vast expanses of low-yield pastures. The Amazonian forest is also disappearing, but somewhat less rapidly. In the highlands, soil erosion due to poor agricultural practices is occurring on a massive scale, and many areas that supported crops a generation ago are now bare rock. In this century, the coastal region, which encompasses four provinces that coincide roughly with the lowlands between the base of the Andes and the ocean, has become a center for industrial agriculture export crops. Historically, export crops have followed boom–bust cycles that have made a few people very rich but, when the boom is over, do not leave much in the way of a wealth-producing system for the bulk of the population. The population itself is doubling every 30 yr, but the density, compared to that of many tropical nations, is low at 33/km^2 (World Resources Institute 1986). Population growth is most rapid in the coastal region. Oil was discovered in the Amazonian region in the 1970s and has fueled the biggest boom in exports in this century.

The best of everything, including the majority of the oil, the bananas, the coffee, the fish, and the shrimp, is exported. The gross national product (GNP) in 1965, before oil was discovered, was $1.1 billion. It was $11.5 billion in 1986. This is a respectable rate of growth, and that, supposedly, is good. But in 1986, 34% of the income from the exports so urgently promoted by the International Monetary Fund and the unilateral foreign assistance programs was required merely to pay the interest on the national debt, which in that year almost equaled the GNP ($11.2 billion). For many, the standard of living has fallen precipitously in the last decade. For example, a professor at the coastal polytechnic university (ESPOL) made $1,000 a month in U.S. dollar equivalents in the mid-1970s but is making less than $400 a month this year. And a dollar, however you value it, buys far less today than it did 15 yr ago. For the poor, the cost of basic necessities keeps spiraling upward while the national social support system has been depleted. A resident of Guayaquil can no longer walk to the market and purchase shrimp, mangrove oysters, or crabs for a pittance. The fish that as recently as 20 yr ago were big and abundant are now small and scarce. Even the mangrove poles required to build a simple house are scarce. Last year there were riots over modest increases in the price of a bus fare. Malnutrition is on the increase, as is malaria. The poor are pouring into shantytown suburbs around the cities, but the rural population is growing too.

Population growth is obviously a primary cause of many of today's problems, but an examination of economic trends suggests it is not the only problem causing a growing sense that the current order is not solving, or even addressing, the root problems. Why is it that a country so richly endowed with natural resources and that produces so much remains so poor? There are two major schools of thought. Both have been around for a long time. The first is to hope that some new natural resource bonanza will be discovered that can be exported in large enough volumes to bring wealth to some and a trickle down to the majority. The second is to conclude that the existing system for making decisions and allocating wealth is fatally flawed and must be replaced by some other system. Communism has been the only alternative on the table, but the recent history of Eastern Bloc societies demonstrates that this system is hardly worth copying.

Ecuador's Shrimp Mariculture Industry

A little over 20 yr ago, the owner of a banana plantation noticed that floodwater from the Guayas estuary trapped behind a dike produced a large population of sizable shrimp. By the early 1970s, shrimp mariculture was growing in a gold rush-like atmosphere. Early investors could make back the entire costs of bulldozing ponds, building dikes, installing pumps, and building a packing plant in 1 or 2 yr. A few Ecuadorians and foreign investors became very wealthy. The great majority of the ponds have been built in publicly owned salt flats and mangroves, with the necessary permits often obtained after a farm was built and in operation. The permit procedure is complex and involves several agencies, but there have been no discernable policies directing the growth of the industry. There has been concern for the rapid destruction of mangrove wetlands. Several governmental Executive Decrees have been promulgated and regulations adopted to halt the destruction of these wetlands. The impact of these decrees and regulations, however, has been negligible. In fact, the annual rate of destruction was more rapid between 1984 and 1987 than it was between 1969 and 1984 (Olsen and Arriaga 1989).

In 20 yr, shrimp mariculture has radically altered Ecuador's coastal ecosystems. Large areas of every estuary and every lagoon along all but the northernmost stretch of the 950 km shoreline have been subdivided into ponds (Figure 21.1). The water flow through every estuary has been reduced to an often narrow channel, and formerly wide fringes of mangroves are gone. In Bahia de Caraquez, a large bay until recently famous for its seafood and its beauty, 90% of the mangroves that were present 15 yr ago are gone. The once-productive artisanal fisheries of this estuary have collapsed, and the formerly large community of fishermen has scattered up and down the coast.

In 1983, Ecuador temporarily surpassed Taiwan as the world's largest producer of farm grown shrimp (Olsen and Arriaga 1989). In 1988, some 50,000 m.t. worth $387 million

Figure 21.1 Extensive shrimp pond development in coastal Ecuador. (Photo by Jon Boothroyd.)

were exported (Table 21.1), almost all to the United States, making shrimp the second largest earner of foreign exchange, following oil. Currently, 120,000 ha of ponds have been authorized, and some 100 hatcheries have been licensed. The industry has brought economic benefits to coastal communities from employment on the farms and from the shrimp postlarvae fishery. As many as 90,000 people engage in this fishery (McPadden 1989), where it is possible in a few days during moon tides, working a push net in waste-deep water, to make more than a month's salary as a laborer. A major concern is whether the shrimp stocks can sustain the combined pressures of a trawler fishery for adults, a specialized fishery for the egg-bearing females required by the hatcheries, a massive postlarvae fishery, and wholesale alterations to the estuarine habitat of this "river" shrimp (Olsen and Maugle 1986). The sustained prosperity of the farms is also not to be taken for granted. Disease is becoming an increasing problem. Many other countries are rushing to join in the shrimp bonanza, and prices, at least in Southeast Asia, have fallen. Ecuadorian growers are still making money, but not as fast as 10 yr ago. Will shrimp mariculture follow the traditional Ecuadorian cycle of boom followed by bust? Will it leave behind a degraded ecosystem less capable of producing wealth for a rapidly growing human population?

The Urgent Need for New Unifying Concepts

It is clear to me that those of us working in countries like Ecuador on environmental issues in ecosystems where man dominates can hope to succeed only if we become armed with powerful ideas that can unify us and inspire us to take the radical actions that are required. In the past many months, I have begun to suspect that H. T. Odum may be offering us such a set of ideas. Although I, like others, have some problems with specifics of emergy analysis, it is clear that comprehensive assessment of both the human and natural aspects of economic systems is urgently needed. There may be fatal flaws in the manner in which he models systems and calculates the flow of emergy. So far, I haven't heard anyone point them out. I have seen a lot of hand wringing and finger pointing, but that should be expected when a new idea with some very painful implications to the powerful emerges.

I am often impressed that so much of the research that is done, and undertaken presumably because it will help understand a resource management problem, produces results with little policy content. This occurs because people have not bothered to map out the context or cannot see, even when they try, what connects with what. An emergy analysis does not suffer from this drawback. The connections are all there if one can wade through the spaghetti in the diagrams and believe the transformity calculations (Figure 21.2 and Table 21.2). The implications of alternative courses of policy action are clear enough to send most politicians who are trying to survive in today's madly unsustainable world diving for cover.

Table 21.1 Shrimp produced in ponds and total value of shrimp exported

Year	Exports, in Metric Tons[1]	In Thousands of Dollars U.S.[2]	Cummulative Hectares of Authorized Shrimp Ponds[1]
1977			1,655
1978	5,000		3,177
1979	6,200		5,416
1980	9,200	56,884	12,351
1981	11,200	77,525	34,468
1982	16,400	122,348	46,879
1983	23,300	175,073	59,013
1984	21,700	159,840	80,895
1985	18,700	156,486	93,042
1986	23,300	187,882	108,370
1987	48,912	383,136	114,205
1988	56,210	387,000	121,740
1989	46,280		124,922
1990	52,770		128,071
1991	79,030		131,961
1992	36,800		133,336
1993	71,410		

[1]Subsecretaria de Pesca, Ecuador, and Ecuadorian Federation of Shrimp Explorers.
[2]Total m.t. exported, Banco Central, Ecuador.

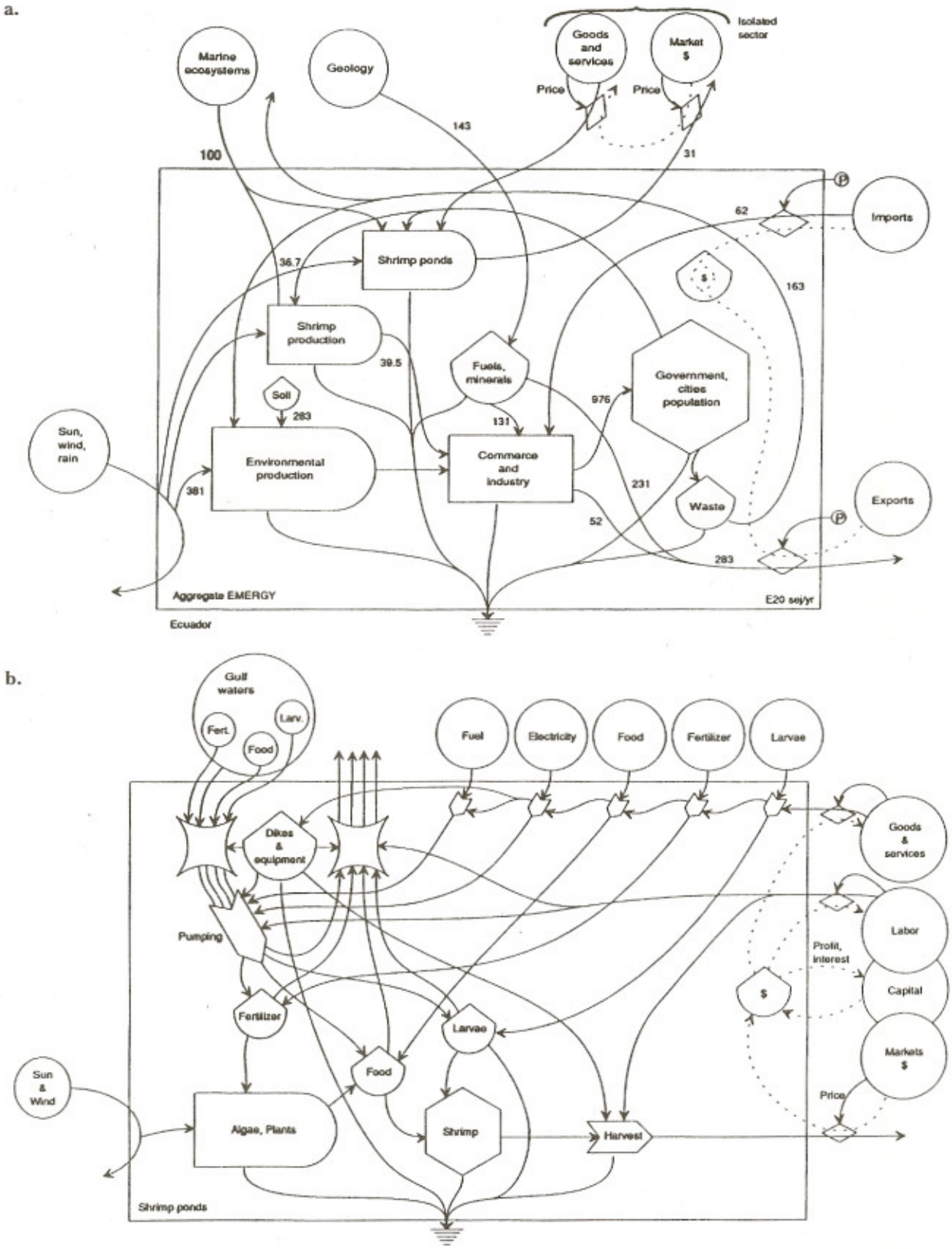

Figure 21.2 (a) Overview systems diagram of Ecuador and its foreign trade; (b) overview systems diagram of shrimp culture ponds and their inputs. From Odum and Arding 1991.

Table 21.2 Annual emergy* flows of the coastal system of Ecuador

Item	Raw Units J, g, $	Transformity sej/unit	Solar Emergy E20	Macroeconomic U.S. $E6
Offshore: continental shelf and coast area: 18,500 E6 m²				
Sun	6.88E+19 J	1	0.688	34.40
Wind	6.69E+15 J	663	0.044	2.22
Rainfall	1.46E+17 J	6,380	9.315	465.74
Current energy	1.07E+14 J	8.0E+06	8.560	428.00
Deepwater nutrient, N(g)	3.70E+11 g	9.00E+08	3.330	166.50
Deepwater nutrient, P(g)	1.02E+11 g	8.10E+09	8.262	413.10
Tide	1.06E+17 J	23,564	24.978	1,248.89
Pelagic trawl, fuel used	3.17E+13 J	53,000	0.017	0.84
Pelagic trawl, goods/services	1.13E+06 $	8.80E+12	0.099	4.97
Pelagic fishery landings	4.15E+15 J	1.31E+05	5.437	271.83
Shrimp trawl, fuel used	5.48E+14 J	53,000	0.290	14.52
Shrimp trawl, goods/services	3.58E+06 $	8.80E+12	0.315	15.75
Shrimp fishery landings	2.08E+13 J	4.0E+06	0.832	41.60
Inshore: estuaries and beaches area: 6,330 E6 m²				
Sun	2.36E+19 J	1	0.236	11.80
Wind	2.29E+15 J	663	0.015	0.76
Waves	7.76E+16 J	25,889	20.090	1,004.49
Rainfall	5.00E+16 J	15,444	7.722	386.10
River, chemical potential	5.13E+17 J	41,068	210.679	10,533.94
River, total N (g)	1.29E+11 g	9.00E+08	1.1573	57.87
River, total P (g)	1.42E+10 g	8.10E+09	1.1522	57.59
River, organic load (COD)	2.77E+16 J	62,400	172.536	8,626.80
Tide	7.27E+16 J	23,564	17.131	856.55
Inputs to Shrimp Ponds	—	—	21.84	1,092.00
Shrimp pond yield				
Minimum efficient value	1.68E+14 J	4.00E+06	6.720	336.00
Resource used in ponds	1.68E+14 J	1.30E+07	21.84	1,092.00

*Solar emergy divided by 2E+12 sej/$ for U.S.A.
Some of these emergy values are included in others.
COD = chemical oxygen demand.

Does an emergy analysis help us understand reality? Is such an analysis useful? So far, my reaction has to be a resounding yes, even though I feel like someone who after a 3 wk crash course in a new language is let loose in a country where people speak only that language. I stumble along, but I often miss the point and have to take a lot on faith.

Emergy Concepts

The keystone of emergy analysis is embodied in the assertion that "money is paid only to people and values only what people do; money is not paid to nature and does not measure the work of nature" (Odum and Arding 1991). Emergy analysis is a method for calculating the value of a resource or product by summing the investment made in each step of its production process. At first this may

appear to be a bizarre notion. But, is it any more bizarre than asserting that a forest or a fishery or an estuary is worth what people through "the marketplace" think it is worth? H. T. contends that human free choices, given enough time and sometimes after social turmoil and much wasteful destruction of natural resources, will through trial and error find the means for maximizing public wealth. Emergy evaluation tells us the value by providing a means for predicting what actions will maximize public wealth and produce sustainable economies; emergy evaluation provides policymakers with a means for short-circuiting the process and avoiding an otherwise slow and wasteful evolutionary process. Odum argues that the market value of products and services is of obvious importance to individuals and businesses but is largely irrelevant as a measure of the "true wealth" of a society or a geographic area. From Odum and Arding (1991):

> A tank of gasoline drives a car the same distance regardless of what people are willing to pay for it. A day of summer sunlight generates so much corn growth regardless of whether a human thinks it's free or not. A nugget of copper concentrated by geological work will make so much electric wire regardless of its price.
>
> When resources are abundant, wealth is great, standard of living is high, and money buys more. But when resources are abundant, market values and prices are small. Prices are not a measure of resource contribution to wealth.
>
> When resources are scarce, prices are high not only because shortages affect demand, but because more human services are required to mine, transport, or concentrate scarce resources. By the time the resources have been collected and used, the net contributions of the resource have been diminished by the extra efforts to process the resources.
>
> In other words, prices are not only a measure of the contribution of resources and commodities to an economy, they are inverse, being lowest when contributions are greatest. EMERGY provides another measure for evaluating contributions to public wealth.

Emergy analysis does not propose to replace the free market as the system for setting prices for human transactions. The price of lipstick, an art work, a piece of real estate, or a commodity on the future's market should continue to be set by what society is willing and able to pay and what those who produce it are willing and able to make it for.

Emergy analysis is offered as a tool for those charged with setting policy and attempting to balance between short-term gains and long-term stability for a society. This is, after all, one of the primary roles of government. If emergy analysis is based on sound perceptions of how ecosystems—including their human component—function and respond, then it can provide powerful insights when considering such questions as: How much is a natural resource worth? How great is the contribution of the unpaid environment to a commodity? What is the wealth-generating potential of the natural resources of a region or a country? What substitutions can be made to the process of generating a product without changing the productivity of a system? How can taxes be used to effectively reinforce those levels and types of consumption that benefit society without threatening the productivity of the economy? Emergy analysis applies the principles of system ecology to such questions and brings to bear observations on how ecosystems function, and why, in competitive settings, certain systems prevail.

When H. T. applies his emergy methodologies and principles to an analysis of shrimp mariculture in Ecuador, the results are sometimes startling and lead to a number of specific recommendations. What follows is an attempt by a neophyte to make an initial digestion.

Emergy Equity and Foreign Trade

According to emergy accounting, Ecuador has an abundance of "free" environmental emergy compared to most "developed" nations. Thus the ratio of purchased emergy to free environmental emergy is only two Ecuador compared to seven in its principle trading partner, the United States of America. This ratio is a measure of intensity of development and estimates the high degree of environmental energies available for human investments to exploit in Ecuadorian ecosystems. When environmental emergy is abundant, the market price for the resources and services provided by nature is low. But quality of life, at least in terms of ready access to food, clean water, living space, and the like, is high.

Neoclassical economics suggests that a growing national GNP measures "progress," is "good," and presumably indicates improvements in the wealth and well-being of the nation. It is now being recognized (see, for example, Repetto 1989) that destruction of such natural resources as the forests of Indonesia is "bad" for that country even though it produces an increase in Indonesia's GNP. Shrimp mariculture development in coastal Ecuador is currently giving the GNP a major boost, but how much is it strengthening the economy of the country? This form of mariculture channels substantial environmental emergy into shrimp for export and away from people who formerly enjoyed the "free" benefits of abundant mangrove timber for building and charcoal production and abundant fish and shellfish to eat. Ecuador's mangroves even provided abundant living space if one chose to be a mangrove dweller as many Ecuadorians did before the shrimp boom. The market price of fish, shellfish, charcoal, and mangrove poles and pilings are now all much higher than they were 20 yr ago, at least in part because shrimp mariculture has made them less abundant.

In questions of foreign trade, H. T. sees the equity issue as the dominant one. The current economic order, in conformance with the maximum power principle in a successional system, is sucking emergy into the dominant systems at the expense of the smaller, poorer ones. If the goal is to maximize wealth in developing nations and to improve quality of life for the people of individual nations, then this inequitable flow must be checked. The solution, as H. T. Odum sees it, is to consider emergy equity when formulating a trade policy. In his view, Ecuador will never prosper if it continues to trade its natural wealth at such inequitable rates of exchange.

Selection of Development Strategies to Benefit Local Economics

The same principles of public policy hold when H. T. considers the impacts of an economic activity on the local economy, in this case Ecuador's coastal region. If shrimp mariculture is to benefit the regional economy, then the emergy per dollar ratio of the product must be close to the average emergy per dollar ratio of the regional economy. If the ratio is substantially higher, the product will be too expensive for the local populace to buy. For cultured shrimp, the cost of the product is far greater than the regional mean. The prevailing view in Ecuador is that export crops are the national priority, and the fact that locals can't buy cultured shrimp is irrelevant. H. T. argues that in effect those benefiting the most from shrimp mariculture in Ecuador are an enclave of the First World economy. They are deflecting Ecuador's coastal emergy into the U.S. economy, and the net effect in the absence of emergy equality in trade is to channel wealth out of Ecuador to benefit societies in the First World at the expense of local societies. Ecuador badly needs to import machinery, medicine, and other goods from the United States, but according to H. T., it must pay three times more for such goods, in emergy equivalents, than the United States pays for Ecuador's products.

Use of Fuels to Build Local Economies

A third application of these principles applies to a fuel source like petroleum. Ecuador has, by world standards, modest reserves of petroleum. So far, the policy has been to export this resource as crude and to tax petroleum-derived fuels for national consumption. Both of these policies are bad mistakes, according to H. T. An emergy-rich resource such as petroleum should be used to build the national economy, not exported to benefit economies elsewhere. If the goal is to build a national economy, then fuel should be taxed only to discourage profligate use and luxuries. This final application of emergy principles to export policy is somewhat less radical than the preceding two. Thailand, another country in which I have been working, discovered gas reserves a few years ago. The policy adopted there, on the advice of neoclassical economists, is that this fuel will not be exported but used to generate finished products and build up the Thai economy.

Identification of Priority Resource Management Issues in the Coastal Region

The farther we move away from the application of emergy analysis to foreign trade toward more localized issues in how resources are allocated and managed, the less radical H. T.'s recommendations appear. Here the same diagrams and tables provide an internally consistent series of insights into the integrated ecological–economic systems of Ecuador's coastal region. Emergy analysis offers conceptual models that, like any model, can be adjusted and refined to accommodate new data and an appreciation of new linkages. When I turn from applying the emergy principles to foreign trade, where the conclusions as drawn by H. T. are nothing less than revolutionary, and look toward the smaller-scale regional ecological–economic system, then the conclusions appear both reasonable and very much to the point.

For example, river waters contain a considerable amount of emergy. The dams that are now being built and planned on the rivers that flow into Ecuador's magnificent estuaries should be viewed with great concern. They will deflect emergy away from the estuaries and redirect it to irrigated farmland and other uses. To date, the assumption, based on the telephone book-size studies by many expert teams, is that the negative impacts on fisheries, mangrove systems, and mariculture will be inconsequential. But an emergy analysis shows that emergy now flowing into estuaries will be reallocated and that there will be unavoidable trade-offs that must be evaluated carefully. Such an analysis has not yet been done, but an emergy analysis of the redirection of emergy to new uses would produce an estimate of the trade-offs. A major issue, from H. T. Odum's point of view, is whether the benefits accruing from irrigated agriculture will be shipped overseas as export crops or will directly benefit the people of Ecuador. If the answer is the former, then H. T. Odum concludes that we will see yet another example of exporting wealth to benefit the First World at the expense of the Third World.

At an even smaller scale, the same emergy analysis when applied to shrimp ponds quickly shows what critical pieces of information are required for a better understanding and therefore a better management of these systems. H. T. developed an emergy diagram on a laptop computer in Ecuador; the diagram suggested that shrimp ponds are releasing a lot of organic matter back into the estuaries and therefore may be producing localized eutrophication problems. The recommendation? Find something to take up the excess before it enters the estuary, such as the *Grassilaria,* or favor extensive culture without supplemental feeds rather than intensive culture. Replanting mangroves may also help, as would increasing the water

exchange in the channels that bring water from the estuary to the shrimp farms. I find it interesting that these and other issues identified by H. T. on the basis of emergy analysis, but without his knowing very much at all about the practice of shrimp mariculture, are in most cases identical to the key issues recently identified by shrimp mariculture experts from Southeast Asia fully conversant with the far more intensive shrimp culture practices that are well established in that part of the world.

Emergy Analysis and Sustainable Development

When emergy analysis is applied to the issue of sustainable levels and patterns of development, the insights that emerge also appear to be useful. Here any concern for how radical the prescription is does not concern me because the "radical" nature of any thinking that addresses limits to growth is unavoidable in a society that has until now opted to ignore the impossibility of endless growth. So far I have gleaned three major ideas on this topic. The first and most obvious is that an emergy analysis attempts to quantify *all* the resources, in terms of emergy, that are available. The available emergy can be divided readily into emergy per unit area or emergy per person, which in turn can provide a sense of the quality of life that can be generated for populations of various sizes following defined development strategies. If the emergy available is indeed correlated to quality of life, this will be useful. It could provide yet another set of arguments for making population control the top priority in many nations. Another idea is that of transformity matching, which gets at the question of efficiency. In essence, the principle is that a small quantity of something with a high emergy content should not be used directly but, rather, should be used to extract the maximum wealth-producing benefits from a large amount of something with a low emergy content. For example, a small amount of high-emergy phosphate will multiply the benefits from a lower-emergy field of wheat. In practice, someone trained in emergy analysis should be able to predict what matchings are appropriate and will most benefit the system. Conversely, products that cost more in emergy terms to produce than they can yield are doomed to failure. This has gotten H. T. into a lot of trouble. He asserts that many of the energy-producing technologies offered as replacements to oil and coal are not economic in emergy terms. Advocates of solar power and shale oil find this highly upsetting, but the disappointing experience of the last 15 yr with these fuels is consistent with H. T.'s perspective.

For me, the most appealing result of applying emergy analysis to sustainability issues is the reaffirmation that feedback loops are essential. Complex but sustainable systems, such as rain forests and coral reefs, are characterized by a complexity of interrelationships that recycle the available emergy to maximize its benefit to the overall system. The principle here is that a pattern of use either reinforces production processes or is replaced by other uses that do. This contrasts with the traditional neoclassical view that any expenditure of money is good because it increases the GNP, whether it is for unnecessary products and services or not. When one applies the principle to framing policy for the utilization of estuaries, farmland, or forests, the emphasis switches from production and profits with little consideration given to nurturing the production process itself to selecting patterns of use that reinvest in the system itself. The necessity of maintaining and nurturing the source of production appears obvious. But the current world order yields policies that frequently take us in the opposite direction, and degraded farmland, destroyed forests, and overexploited fisheries are the result.

Likely Reactions to Emergy Analysis

Like many significant figures in the history of human thought, H. T. Odum finds himself in the difficult position of seeing widespread acceptance of concepts and techniques he developed decades ago—but very little acceptance of or even interest in the ideas to which he has dedicated the majority of his recent life, ideas he views as the logical outgrowth of the concepts formulated 30 yr ago. As I think about all this, I see two possible conclusions. The first is that there may be something fundamentally wrong with emergy analysis. The big stumbling block appears to be the notion of transformities. The alternative conclusion is that the problem does not lie in the concepts but in the disagreeable nature of the consequences of emergy analysis. Let us consider these consequences briefly.

If H. T. is correct, then we must conclude that neoclassical economics cannot address the pressing problem of how to ascribe values to natural resources and the work of nature. The underlying concepts of neoclassical economics simply don't apply. This of course makes economists unhappy, if not angry. Economists have enjoyed great power and prestige in this century, and like any group of people, they will not want to give it up. The resistance from economists, however, is dwarfed by the resistance of the classes, institutions, and societies that benefit most directly from the current world order. I have no doubt that the community of bankers, business people, and all of us who enjoy the benefits of the current world order will not like the immediate implications of a world economy based on trading on emergy equity terms. The resistance will be enormous. On the other hand, those who are, according to emergy analysis, losing through the current world order might be expected to embrace these ideas. The arguments, confrontations, and realignments could quickly become complex and, from a world order and balance of power perspective, quite dangerous. For institutions and individuals with power and prestige, emergy analysis, if it is

not flawed, is very bad news. A time honored reaction is to shoot the messenger or at least ignore him.

Is there a middle ground here? I suspect that there may be. The world cannot and probably should not switch to emergy-based trade systems overnight. If emergy analysis provides a rationale for forgiving the crippling debts of many developing nations, that may be all to the good. Some economists have argued it is in the interest of the world economy (traditionally perceived) to do so. If national policymakers become conscious of the need for feedback loops that reinvest in the ecosystems that produce wealth for their people, trade with partners at similar levels of development, and adopt policies that increase the quality of life for their people, then this is all to the good.

These are powerful ideas. The priority, in my view, is to present them in ways that encourage thoughtful examination and debate. Where there are flaws, let us discover them quickly and assess their implications. I see nothing but major benefits accruing from the application of emergy analysis from the national and regional levels downwards. Nor do I see much disagreement in the prescriptions that flow from emergy analysis from any of those concerned with the condition of the planet as a place where human societies can flourish and be sustained. The problem is the consternation that will be heard when emergy principles are applied to world trade. Perhaps on careful examination we will see that the results of applying emergy principles to foreign trade policy are no more draconian then any other measures that will be required if the awesome collision between uncontrolled growth and a finite planetary ecosystem is to be avoided. I end therefore with a plea that we examine these concepts and principles with care and respect. They may contain some of the essence of the unifying new ideas that we all desperately need.

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