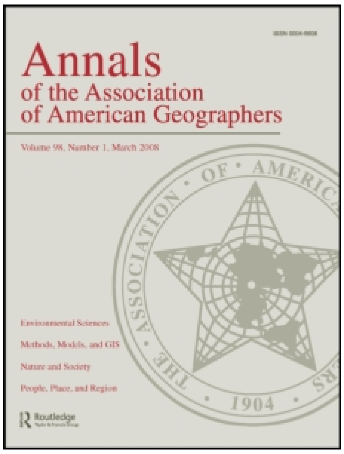

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The Hazards of Indicators: Insights from the Environmental Vulnerability Index

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Since the early 1990s a number of projects have developed indexes to measure vulnerability to environmental change. This article investigates the key conceptual and methodological problems associated with such indexes. It examines in detail an index that explicitly addresses environmental change as an issue of vulnerability, the Environmental Vulnerability Index (EVI) developed by the South Pacific Applied Geoscience Commission (SOPAC). This examination offers some broader lessons for indicator-based projects, all of which require a simple model of complex and uncertain social-ecological systems, and entail difficult choices about the selection, standardization, weighting, and aggregation of indicators selected to represent important aspects of those systems. We conclude that indexes of vulnerability to environmental change cannot hope to be meaningful when applied to large-scale systems, and so should focus on smaller scales of analysis. We argue that they should not be used as the basis for disbursing funds, comparing countries, or for measuring the performance of countries in environmental management. We also argue that vulnerability is a context-specific rather than a generic condition. Finally, we suggest that because vulnerability is about values at risk, there should be more input from a broader array of people when indexes are being developed and tested. *Key Words: environment, index, Pacific Islands, sustainability, vulnerability.*

自从1990年代初期以来，在一些研究项目中，已开发出多个指数来衡量因环境改变而造成的脆弱性。这篇文章考察了与这些指数相关的主要概念和方法论问题。它详细审查了由太平洋应用地球科学委员会所研发的，针对环境变化的，环境脆弱性指数。这项考察为基于指标的研究项目提供了一些更广泛的启示：基于指标的研究项目不止要具备一个能体现出复杂和不确定的社会生态系统的简易模型，也需要作出关于选择，标准化，所占的比重以及指标汇总的艰难抉择来代表制度重要的方面。我们的结论是，因环境改变而导致的易损性指标是不能够有意义地运用在大型系统上的。它们的运用范围应侧重于较小规模的分析。我们认为这些指标不应当被用来作为拨付款金的依据，国与国之间的比较或用于衡量一个国家管理环境的业绩。我们也认为易损性是因地而异，而不是一个普及的状况。最后，我们建议，由于易损性攸关着价值观的冲击程度，指标的研究与测试过程应包含更广大社群的建议。*关键词：环境，指数，太平洋岛屿，可持续性，易损性。*

Desde principios de la década de los 90, varios proyectos han desarrollado índices para medir la vulnerabilidad a los cambios ambientales. En este artículo se investigan los problemas conceptuales y metodológicos claves asociados con tales índices. Se examina con detalle un índice que explícitamente aborda el cambio ambiental como un problema de vulnerabilidad, el Índice de Vulnerabilidad Ambiental (Environmental Vulnerability Index, EVI) desarrollado por la South Pacific Applied Geoscience Commission (SOPAC). Este examen ofrece algunas lecciones más amplias para proyectos basados en indicadores, todos los cuales requieren un modelo simple de sistemas socioecológicos complejos e inciertos, e implica decisiones difíciles sobre la selección, estandarización, ponderación y agregación de los indicadores seleccionados para representar aspectos importantes de estos temas. Concluimos que los índices de vulnerabilidad hacia cambios ambientales no esperan ser significativos cuando se aplican a sistemas de gran escala, y se deben enfocar a escalas de análisis más pequeñas. Planteamos que no se deben usar como base para desembolsar fondos, comparar países ni medir el desempeño de los países respecto a administración ambiental. También planteamos que la vulnerabilidad es específica del contexto, no una condición genérica. Finalmente, sugerimos que, debido a que la vulnerabilidad implica valores en riesgo, debería haber más aportación de una variedad más amplia de personas cuando se desarrollan y prueban índices. *Palabras clave: ambiente, índice, Islas del Pacífico, sustentabilidad, vulnerabilidad.*

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The issue of vulnerability to environmental change has long been a central concern of geography. A key message from many geographic studies of these issues is that the causes and consequences of social and environmental change are complex and defy simple explanations. Since the 1990s a number of projects have developed indexes that measure vulnerability to social or environmental change. Vulnerability indexes have been developed to capture the susceptibility of the economies of small states to changing circumstances in the international economy (Briguglio 1995; Easter 1999), of coasts to sea-level rise (Gommes et al. 1998; Pethick and Crooks 2000), and of social systems to climate change (Adger et al. 2004; Vincent 2004). There have been indexes that seek to represent the ecological health or sustainable development of the United States (National Research Council 2000a; H. John Heinz III Center for Science, Economics, and the Environment 2002), Organization for Economic Co-Operation and Development (OECD) countries (OECD 2001), and a larger sample of 146 countries (Esty et al. 2005). Some indicators of environmental sustainability are constructed as part of, or as counterparts to, larger indexes of development or national well-being (Neumayer 2001; Prescott-Allen 2001; Millennium Change Corporation 2007). There is now an International Sustainability Indicators Network (ISIN), and in 2002 thirty representatives of government, business, academia, and nonprofits issued the Pocantino Statement on the need for national indicators of sustainability for the United States (ISIN 2007).

Indexes are signals that measure, simplify, and communicate the complex reality of a situation (Farell and Hart 1998). They are seen to be useful in that they help set targets and standards, allow for monitoring of change, allow for comparisons across different entities in space and time, help recognize alternative dimensions of well-being, and quickly convey complex issues (Easter 1999; Commonwealth Secretariat and the World Bank 2000; National Research Council 2000a; Niemeijer 2002; Villa and McLeod 2002; Briguglio 2003; Esty et al. 2005). Indexes can also be used as a basis for allocating resources. The Millennium Challenge Corporation, for example, determines country eligibility for assistance on the basis of sixteen indicators, and it seems likely that in the future they will utilize a Natural Resource Management Indicator (NRMI) as well (see Center for International Earth Science Information Network [CIESEN] 2006). The Global Environmental Facility (GEF) is also looking to develop an index of vulnerability to determine the allocation of funds toward countries in much the same way that country allocations under its Resource Allocation Framework are determined on the basis of a Global Benefits Index and GEF Performance Index.

The lure of policy relevance is therefore stimulating a number of efforts to develop indexes of vulnerability that are scientifically rigorous and useful to policy. Yet, as explained in the following section, the indexes and projects that have been developed thus far have conceptual and methodological problems, raising questions not just about the degree to which they reflect the complex reality of the causes and consequences of environmental change, but also about the extent to which they can be relied on as tools to inform policy. A systematic examination of indexes of vulnerability and the environment is therefore necessary and timely. This article offers such an examination. It reviews the literature on vulnerability, and indicators, drawing in particular on insights offered by geographers to identify the key conceptual and methodological problems associated with indexes. The insights from this discussion are then used to examine the conceptual, logical, and methodological bases of the only index that explicitly addresses environmental change as an issue of vulnerability, the Environmental Vulnerability Index (EVI) developed by the South Pacific Applied Geoscience Commission (SOPAC). This index and its particular approach to environmental vulnerability have yet to be independently examined. Conclusions of relevance to other indicator-based projects are then elicited.

Vulnerability

Vulnerability is an imprecise term with intuitive resonance, if no single definition. In general it refers to the potential for loss (Cutter 1996). Turner, Kasperson, et al.'s (2003) definition of vulnerability as " the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or a stress/stressor" (8074) is consistent with how social researchers working on hazards or environmental change define the term. There is no strong consensus on the best methods to assess vulnerability, but most assessments entail considering one or more of exposure to risks, susceptibility to damage, capacity to recover, and net outcomes (Cutter 1996; Alwang, Siegel, and Jorgensen 2001; Eakin and Luers 2006).

Vulnerability is widely considered to be the inverse of resilience, particularly in research on the vulnerability of ecological systems (see Holling 1973; DeAngelis

1980; Elmqvist et al. 2003; Folke et al. 2004), but also in many studies of the vulnerability of social systems (see Wildavsky 1988; Mortimore 1989; Adger 1999; Barnett 2001). Most definitions of resilience are variants of Holling's (1973) foundational definition of it as "the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist" (17). So, a resilient ecosystem is not one in which populations remain stable or where change is resisted, but rather where change is accommodated or absorbed in ways that do not fundamentally alter ecosystem structure (Folke et al. 2002). This is similar to some definitions of sustainability; for example, Dovers (1997) defines sustainability as "the ability of a natural, human, or mixed system to withstand or adapt to, over an indefinite time scale, endogenous or exogenous changes" (304).

Exactly what enables resilience so that ecological and social systems are not fundamentally altered is not well understood, and is contested. Indeed, the most common assumption that there is a positive relationship between resilience and biological diversity does not always hold true (Adger 2000). There does, however, appear to be common agreement that human-induced changes in the structure of ecosystems, including in biological diversity, decrease their resilience (Holling 1973; Elmqvist et al. 2003; Folke et al. 2004). Because there is no agreement about the properties of ecosystems that enable resilience, there tends to be no robust and widely accepted models on which indicators can then be developed (Villa and McLeod 2002).

Because vulnerability refers to the potential for loss, it is important that vulnerability studies and indicators identify benchmarks of unacceptable loss (Alwang, Siegel, and Jorgensen 2001). This entails clarifying what is normal, and which departures from it are important (Ellemor 2005). Determining what is an unacceptable loss is an inherently subjective process, as it is about determining what matters to an exposed group (Eakin and Luers 2006). Vulnerability is therefore about values at risk, and who holds those values. This implies at least five things. First, there can be elements of "external nature" (after Leiss 1972) whose potential change or loss might have no obvious material effects on people, yet are nevertheless considered to be vulnerable because of their intrinsic or known ecological value; for example, the concern associated with places of global significance such as Antarctica or the Amazon. Second, inhabited places at risk might be valued by a community far larger than that which resides within them; for example, the larger community of concern for World Heritage Areas (Bonyhady 1993). Third, it is possible for elements of external nature to be at risk of change or loss without this being a vulnerability issue; for example, there are tens of thousands of invertebrates and vascular plants that might become extinct due to climate change, but the risk of loss of any given one of these does not register as a vulnerability issue because its existence and particular function is effectively not known and so not valued (even though the larger issue of biodiversity is certainly valued for instrumental, ecological, and intrinsic reasons). Fourth, not all of the elements of external nature that are at risk will be valued equally, so there will be differing degrees of concern about their vulnerability (irrespective of the differing degrees of uncertainty about the processes that cause their vulnerability). Finally, it implies that there is a complex spatial politics to vulnerability: it cannot be meaningfully applied to large populations and places because what groups value varies enormously when the scale of analysis is large.

Almost all vulnerability studies share an explicit concern for losses that directly relate to human welfare, in terms of damage to property, damage to livelihoods, forced migration, morbidity, or mortality, for example. Integral to this research—in particular that of geographers—is the recognition that vulnerability is not equally distributed throughout a population exposed to risk. A raft of studies show that sensitivities to damage, capacities to respond, and the outcomes of environmental change are vastly differentiated according to class, gender, ethnicity, and location, and that there are winners and losers from environmental change (Bohle, Downing, and Watts 1994; Kasperson, Kasperson, and Turner 1995; O'Brien and Leichenko 2003). This recognition has grown since Burton, Kates, and White's (1978) influential book *The Environment as Hazard,* and it has been powerfully reinforced by research on land degradation (e.g., Blaikie and Brookfield 1987). White, Kates, and Burton (2001) have concluded that since their 1978 volume "much more responsibility is now laid at the door of human acts of omission and commission" (87).

Many recent reviews of vulnerability suggest that it must be understood as the product of changes in coupled social-ecological systems (Adger 2000; National Research Council 2000b; White, Kates, and Burton 2001; Folke et al. 2002; Cutter 2003; Parris and Kates 2003; Turner, Kasperson, et al. 2003; Kasperson et al. 2005; Eakin and Luers 2006). This is not to say, however, that the vulnerability of any given place is entirely the product of changes in the integrated social-ecological system of that place. Places can be rendered vulnerable by entirely social and largely exogenous processes. For example, violent conflict between 1975 and 1999 caused by armed invasion supported by arms trading has been a significant driver of poverty in East Timor. This poverty makes people more at risk from food insecurity arising through any or all of changes in markets, political instability, and climatic extremes, and their responses do not necessary result in ecosystem changes (they draw more on social capital than natural capital; Barnett 2006). In this case, the vulnerability of people is driven by exogenous social forces, and does not affect the vulnerability of the environment, although environmental change is a cause of people's vulnerability. It is also the case that people can be rendered vulnerable by the idea of environmental change irrespective of the material reality of that change. For example, Barnett and Adger (2003) argue that overstating the dangers of climate change in atolls might alter the calculations of return made by investors and aid donors, and, if internalized by local people, might lead to practices of unsustainable development such that the impacts of climate change materialize more through the idea of climate change than through material changes in ecosystems driven by climatic processes. In another island example, Campbell (1997) argues that discourses of island vulnerability downplay the resilience of communities, cast them as powerless, and risk reifying otherwise perceived relationships of inequality between the powerful and weak. Further, if the aforementioned understanding of vulnerability as values at risk has merit, then entities and systems in the natural world can be at risk of loss or change without any perceived risk to people's values.

So, social and ecological vulnerability are coupled (Turner, Kasperson, et al. 2003), and related (Adger 2000), but this does not mean that the human and ecological subsystems are always synergistically vulnerable: changes can occur in either without consequences for the other, and there are important intermediary variables concerning values and perceptions.

Vulnerability is the product of phenomena occurring at a range of interlinked spatiotemporal scales (Turner, Kasperson, et al. 2003). In terms of spatial scales, the three case studies compared in Turner, Matson, et al. (2003) show how globalized markets, trade liberalization processes, global climate change, exogenously derived pollutants, and national and local decisions about production interact with environmental systems to create vulnerability. This in turn implies that indicators of vulnerability that treat exposure units as discrete entities might grossly simplify the causes of and responsibility for vulnerability. In terms of the temporal scale, Kasperson, Kasperson, and Turner's (1995) *Regions at Risk* study has explained environmental criticality in key regions as the product of social-ecological changes over the past fifty to one hundred years, finding that the criticality is in part a function of the speed of these changes. A somewhat more salient example of the importance of considering history is the impact of Hurricane Katrina on New Orleans, which was the result of a long history of land use changes in the Mississippi Delta region such that there was a "disaster waiting to happen" (Fischetti 2001, 77).

The complex array of issues, scales, and processes associated with the manifestation of vulnerability make it increasingly difficult to speak of the vulnerability of large populations or places. Kasperson, Kasperson, and Turner (2005) argue that the selection of the unit of exposure is a critical issue in vulnerability studies, and that "a major pitfall lies in selecting the unit of exposure a priori, assuming that the social groups or ecosystems most at risk are known" (268). As a result, most vulnerability studies from geographers focus on discrete ecosystems, groups, or places where the risks are better understood, and can be more easily traced to pertinent processes. Thus Cutter (1996), the National Research Council (2000b), and Turner, Kasperson, et al. (2003) suggest that a place-based approach delivers a more accurate assessment of vulnerability than approaches that aggregate, and therefore homogenize, places for the purposes of comparison.

Many of the lessons emerging from the past thirty years of vulnerability assessment are summarized in Turner, Kasperson, et al. (2003). They identify a number of ways to maximize the utility of vulnerability analysis, including more recognition of vulnerability as a product of coupled human–environment systems; identifying the "complexity, interconnectedness, and iterative nature of the components" that generate vulnerability; situating the vulnerability of a particular place in a larger spatial and historical context; including both quantitative and qualitative data; recognizing that similar systems might not have the same vulnerabilities; and recognizing that not all parts of a system have the same vulnerabilities (Turner, Kasperson, et al. 2003, 8077–88). These are particularly geographic insights: place matters, scale matters, places, and people differ, and social systems and environmental systems are interconnected in complex ways. We offer two additions to these conclusions: first, because it is about values at risk, there is complex spatial politics to vulnerability that needs to be recognized, and second, the vulnerability of any given place is not necessarily the product of changes in the integrated social-ecological system of that place. These insights collectively suggest that there are many challenges to simplifying and conveying the complex reality of vulnerability in the form of an index.

Indicators of Vulnerability

The complex array of issues, scales, and processes associated with the manifestation of vulnerability suggests that attempts to express vulnerability in the form of a few indicators or a single index might be problematic. Yet, according to Parris and Kates (2003), there have been more than 500 attempts to develop indicators of environmental change, including some of the more prominent attempts referred to in the introduction to this article. That there have been so many attempts reflects the difficulty of the task, leading Parris and Kates (2003) and the National Research Council (2000b) to conclude that there is no consensus on their appropriateness, theoretical and scientific basis, and appropriate level of specificity or aggregation.

It is important that vulnerability and environmental change indexes offer a logically coherent model of vulnerability that is informed by the full gamut of studies of vulnerability, including those that do not use indicators. Without insights from these studies the model of vulnerability that informs the selection of indicators might be vastly divergent from the reality that it seeks to reflect (Villa and McLeod 2002). Such a model should include specification of the risks that are to be included, how exposure is determined, how systems function, which flows are important and what their effects on systems are, and what determines coping capacity. It need not be the case that such a model accurately represents the dynamics of ecosystems because this does not seem possible at present. The indicators selected should reflect either the outcomes of change or the causal relationships that drive change, although few indicator-based projects make this distinction and many inappropriately combine indicators of both (Parris and Kates 2003). In any event, it often seems to be the case that indicators are selected not because the data reflect important elements of a model of vulnerability, but because of the existence of data that are relatively easy to access and manipulate (King 2001; Niemeijer 2002; Parris and Kates 2003).

Indicator-based projects typically require large investments in data harvesting or collection and analysis (Villa and McLeod 2002). This constrains their utility for countries where there are fewer data and less technical capacity. The more intensive the process of data collection, the less likely it is to be repeated. Yet, if vulnerability indexes are to reflect differences between countries, it is important that their methods are reproducible across space and time (Bossel 1999; Briguglio 2003). The replicability of an index can be enhanced by minimizing the number of subindicators used, and by using widely available data (Bossel 1999; Vincent 2004). For example, the National Research Council (2000a) recommends thirteen subindicators to describe the condition of U.S. ecosystems. Esty et al.'s (2005) Environmental Sustainability Index (ESI) is based on twenty-one subindicators. The OECD (2001) uses a much larger number of indicators (fifty) to keep track of environmental progress in various countries, but these are not aggregated into a single index.

Indexes typically involve some aggregation of multiple subindicators to produce a single index. Aggregation can hide deficiencies in data, and so the mathematics of index development is very important (Bossel 1999). To produce a single index, diverse kinds of data and indicators need to be standardized into common units. This is most often done by reducing all components to a score on a scale between zero and one, or by scoring all components on a multiple-point scale (say a scale of between one and five; Briguglio 2003). The latter multiple-point approach is useful when data are qualitative. Briguglio (2003) suggests that multiple-point scales allow for comparisons of data on linear and nonlinear processes. However, given that this entails converting data on nonlinear processes to a common linear scale, it might fail to convey the severity of nonlinear risks (those with thresholds of irreversible change), particularly if these are compared to risks that are based on a linear scale. Furthermore, the threshold for hazards might be difficult to define on either a linear or nonlinear scale. For example, the sudden bleaching of a coral reef occurs once an otherwise linear change in sea-surface temperature has been crossed.

The total index is often calculated by taking the average of all subindicators, implying that subcomponents might be substitutable in some way (Sagar and Najam 1998). The multiplication of subindicators is most suited to systems where components interact (Villa and McLeod 2002). Multiplication might better reflect improvements in subindicators, depending on the criterion being used and the degree of comparability of data (Sagar and Najam 1998). Regardless of the approach used, standardization and aggregation of indicators is an inescapably subjective process (Vincent 2004). This tension between the scientific authority of an index and the somewhat subjective nature of their construction is something that decision makers might not always appreciate. The weighting of indicators is also a vexing problem in constructing vulnerability indexes.

Indexes cannot be truly tested given uncertainty about system dynamics, and this is even more the case with vulnerability indexes, given that they attempt to convey information about the risk of future events (Villa and McLeod 2002; Vincent 2004). However, indexes can be subject to reason by checking to see the extent to which their results broadly correspond to that which a community of knowledgeable people understands to be the relative degrees of vulnerability among places. So, to be credible, a vulnerability index should reflect in some way what people actually see, or at least have some intuitive resonance with experts (Sagar and Najam 1998, 252).

Perhaps the most influential indicator of social well-being that includes more than income is the United Nations Development Program's (UNDP) Human Development Index (HDI). This indicator measures well-being by aggregating indicators of income, education, and health status. The HDI does not explicitly include measures related to environmental change or vulnerability (Neumayer 2001), although it has been taken as a proxy for aspects of vulnerability to environmental change (Downing 2002; Barnett 2006). The HDI can be calculated for almost every country as it is based on three principal subindexes, two of which are calculated using simple and widely available indicators (life expectancy and gross domestic product [GDP]/capita), and one of which is a composite of two widely available indicators (adult literacy rate and combined gross enrollment ratio; UNDP 2003). Each subindicator is transformed into a standard scale (0.00–1.00), and in the case of the income subindex higher incomes are discounted through a log transformation that attempts to convey the decreasing utility of incomes as they rise above the world average. None of the three subindexes is weighted, effectively meaning that income is not seen to be more important than health or education in determining human development. The final HDI is the average of the three subindicators.

Despite being financially and intellectually very well supported, the EVI has been the subject of considerable criticism. Much of this has concerned the methods of its construction; for example, Desai (1991) and Sagar and Najam (1998) have argued that the method of aggregation implies that each of the three subcomponents is substitutable, and for this reason the latter propose instead that they be multiplied so that a poor performance in any indicator would be more directly reflected in the final HDI. Others argue that income is a more important variable and so should be weighted more heavily (Noorkbash 1998; Sagar and Najam 1998), although this would do little to overcome the criticism of McGilvray (1991) and Kelley (1991), who argue that the HDI does little more than reflect preexisting income-based rankings of national development. Sagar and Najam (1998) argue that the HDI does not reflect reality, Kelley (1991) argues that this is because its conceptual foundations are not firmly established, and for this and methodological reasons argues that policymakers should be more careful in how they act on the HDI. Given the conceptual and methodological problems with the HDI, Castles (1998) expresses concern about its heavy promotion by UNDP, and he, like almost all of the critics of the HDI, suggest that its influence on policy is not justified by its conceptual and methodological rigor.

So, there are some common problems that plague the development of indexes of vulnerability and environmental change (or at least this is the case when viewed from the geographic perspective). Indexes require a coherent model of vulnerability on which the selection of indicators can be based, but because vulnerability is a difficult concept, the processes that create it are complex, and the distinction between processes and outcomes is often blurred, underlying models of vulnerability are inevitably flawed. There are issues to do with the scale of the system to be measured: larger scales tend to be favored for their perceived policy relevance; yet the larger the scale, the less the specificity of risks and outcomes. The selection of indicators is another difficulty because the ideal data might not be available, the data that are available could be of questionable quality, and the model might lead to indicators that are redundant, implying that indexes should utilize fewer indicators based on widely available and robust data. The standardization of indicators can also be a problem, particularly as it entails converting nonlinear risks into linear scales. The weighting of indicators is often contentious; weighting can help reflect the judgments of experts and the values of groups of concern, yet determining the appropriate weighting of indicators is procedurally difficult. Methods of aggregation are also contentious. For these reasons all of the indexes currently available are imperfect and do not reflect the reality they seek to convey. Yet some are more imperfect than others because each index has its own approach to dealing with these problems of model, scale, standardization, weighting, aggregation, and testing.

It is notable that these problems arise regardless of the degree of support for the development of the index. In this respect our choice of index to examine—the EVI—is useful because it has yet to be examined in depth, and such an examination might help further understand the extent to which indexes of vulnerability and environmental change have common problems. The EVI is a useful example also because although there are many indicators that principally seek to measure either aspects of the environment or vulnerability, it attempts to measure both, making it somewhat unique.

The History of the EVI

The EVI is justified by an interpretation of The Programme of Action for the Sustainable Development of Small Island Developing States, more commonly referred to as the Barbados Programme of Action (BPOA; Fry 2005). Paragraph 113 (Chapter 15) of the BPOA created the impetus for the EVI:

> Small island developing States, in cooperation with national, regional and international organisations and research centres, should continue work on the development of vulnerability indices and other indicators that reflect the status of small island developing states and integrate ecological fragility and economic vulnerability. (United Nations 1994)

Ostensibly in response to Paragraph 113, in 1998 SOPAC began developing a method for quantifying environmental vulnerability at the scale of whole countries.

SOPAC is an intergovernmental organization with a mandate to contribute to sustainable development in the island countries of the South Pacific. The South Pacific is a region of great environmental and social diversity, containing twenty-two island states and territories and 8.6 million people speaking 20 percent of the world's languages (Secretariat of the Pacific Community 2004). Annual per capita incomes are generally low, ranging from U.S.$530 in Papua New Guinea to U.S.$6,820 in Palau (Asian Development Bank 2004). In general, most Pacific Islanders are income poor and heavily dependent on natural resources to meet their basic needs of fresh water, food, and shelter. The combined landmass of all countries is 550,000 km^2, but the region commands a vast combined exclusive economic zone of some 30 million km^2 (Overton 1999). The largest country is Papua New Guinea with a land area of 462,000 km^2, and the smallest is Tokelau with a land area of 12 km^2. There are large and mountainous islands with fertile soils and mineral resources, smaller volcanic islands, and low-lying coral atolls. There is also an array of environmental problems, including land degradation, deforestation, declining biodiversity, and coastal and marine degradation (United Nations Environment Program 1999). There is therefore considerable diversity in the environmental, economic, political, and cultural characteristics of the islands. It follows, then, that the ways in which environmental change will affect ecosystems, places, and people will differ.

This first phase of the EVI began in August 1998 and lasted until February 1999. It involved development of the method and its application to Australia, Fiji, and Tuvalu (Kaly et al. 1999a). The report from Phase I was considered at two meetings of experts in Fiji and Malta in 1999 (Kaly et al. 1999b, and Briguglio, Kaly, and Pratt 1999, respectively). The meeting of experts proposed three criteria for determining when the EVI would be "technically ready for use," namely that it include at least fifteen countries with widely ranging characteristics and there be no "redundant" indicators used (i.e., indicators with a high correlation with one or more other indicators); among those fifteen countries there is a spread of scores and countries with similar characteristics are clustered together; and the EVI be validated by independent experts (Kaly et al. 1999b, 22–23). The cost of Phase I, funded by the New Zealand government, was a very modest U.S.$75,000 (Pratt et al. 2002, Appendix).

Phase II of the EVI lasted from March 1999 to February 2000. Its aim was to subject the EVI to peer review, create a database for Pacific Small Island Developing States (SIDS), further develop the model, and test it on more Pacific SIDS. Phase II was also funded by the New Zealand government, and cost U.S.$85,000 (Pratt et al. 2002, Appendix). Phase III of the EVI began in March 2000 and is ongoing. The governments of New Zealand, Norway, Ireland, and Italy have principally funded it, with support from various global and regional agencies. Phase III has been a more expensive exercise, with annual costs ranging from U.S.$55,700 in 2003 (SOPAC 2003, 42) to U.S.$140,000 in 2004 (SOPAC 2004b, 56).

Phase III sought to "globalise the EVI, including the establishment of a global database," and further test the model and expose it further peer review (Kaly et al. 2003, 1). A meeting was held in Geneva in August 2001 to introduce and gain support for a "global" EVI to a larger group of countries and stakeholders beyond the SIDS community (see Kaly et al. 2001). It was noted at the meeting that getting the acceptance of the international community would be enhanced by stressing the links between the EVI and poverty. Thirty-two countries committed to collaborating in Phase III of the project (listed in Kaly et al. 2001). Phase III ended with the publication of the demonstration EVI report (Kaly et al. 2003). The finalization phase culminated in the 2004 Technical Report (Kaly, Pratt, and Mitchell 2004), and a shorter final report (SOPAC and UNEP 2005).

Overall, the EVI has been far from an expensive exercise. Indeed, as Pratt et al. (2002) show, insufficient funding has been a constraint, particularly given that some data needed to be purchased, or required further investments in collection in collaborating countries. The modest budget also constrained staff output given the time costs of attending regional and international meetings and satisfying reporting requirements. In that it has been extensively documented and these documents are easily accessed online (if not necessarily by many people in Pacific Island countries), the EVI is a notable example of an open access research project.

The Logic of the EVI

Paragraph 113 of the BPOA called for indicators that integrate ecological fragility and economic vulnerability, yet the EVI measures only the vulnerability of "the natural environments of states" (SOPAC and UNEP 2005). This article examines the extent to which the EVI achieves this narrower aim, but it also considers the social relevance of the EVI, which its authors claim arises because "it is the natural environment that is the foundation for the economic and social structures of nations" (Kaly et al. 2003, 5).

The EVI estimates the "vulnerability of the environment of a country to future shocks" using fifty indicators (Kaly, Pratt, and Mitchell 2004, Executive Summary). The indicators are combined by averaging, and then reported as a single index as well as a range of subindexes. These subindexes seek to summarize a wide range of environmental conditions and processes thought to be relevant to countries. The diverse kinds of data for each indicator are rendered comparable by conversion into a seven-point scale (i.e., a scale of one to seven).

The environment is defined for the purposes of the EVI as "those biophysical systems that can be sustained without human support" (Kaly, Pratt, and Mitchell 2004, 35). The EVI therefore excludes environments significantly affected by human activities such as urban areas and farmland (SOPAC and UNEP 2005). This was a contentious issue at the first think tank in 1999, where it was recommended that human systems be included (Kaly et al. 1999b, 18). SOPAC offers three reasons why human environments have not been included in the EVI: first, the brief given to SOPAC by the New Zealand government explicitly referred to the natural environment; second, incorporating human environments "may lead to internal conflicts in the model"; and third, it is assumed that "any damage to the environment would lead to reduced human welfare" (Kaly et al. 1999b, 25–26). However, in many Pacific Island communities (the original countries of concern to the EVI project), the distinct division between society and nature that is assumed in the EVI does not exist. Pacific Islanders tend not to see the kinds of wild landscapes unaffected by human activity that the EVI sees. Further, in very small countries such as Tuvalu, Kiribati, the Maldives, and Niue it is arguably impossible to locate non-human-affected terrestrial areas.

In narrowly focusing on "the natural environments of states" the EVI makes an overly simple assumption about the relationship between the well-being of places and the environment. The territory of countries is often not the only foundation for their environmental, economic, and social well-being. Most developed countries are nowhere near as dependent on natural resources as developing countries, and as has been made patently clear through dependency theory (Frank 1969), and in environmental terms through the study of ecological footprints (Chambers, Simmons, and Wackernagel 2000), many countries sustain themselves through the use of other countries' resources. Because not all countries are equally dependent on their own resource base, the significance of environmental vulnerability to social welfare varies enormously from country to country. For countries such as Singapore with developed industrial and service sectors, high GDP, and diverse trading relationships, the vulnerability of its endogenous ecosystems is a relatively far less important issue for economic and social well-being than for countries such as Tuvalu that have low GDP and where people's livelihoods largely depend on access to resources.

The EVI study also fails to grasp the significance of larger contexts that shape vulnerability. Environmental change in places exposes associated groups to risk, but the causes of environmental change, and the drivers of the susceptibility of groups to damage from that risk and their capacity to recover from it are determined by processes that are often regional and global in scope. The drivers of deforestation, for example, include unequal exchanges associated with colonization and trade dependence, strategies for export-led growth that promote land clearing, and interventions by multinational logging companies seeking to maintain unequal forms of exchange (Skole et al. 1994; Dauvergne 1997). Indeed, globalization now means that very few of the processes that drive environmental change, or that determine a community's sensitivity to and capacity to adapt to environmental change, can be said to be entirely local in origin (Leichenko and O'Brien 2008).

So, in that it treats countries as discrete units, the EVI ignores the ways a country's activities can create vulnerability in another. Like the ESI, this can make dirty countries look clean (see Morse and Fraser 2005). Further, by not considering the larger political economy of vulnerability, the EVI implies that the cause of a country's environmental vulnerability is only its population. This makes the proposal that the EVI be used by donors as an indicator of a recipient country's environmental performance deeply ironic given that in most cases the consumption and pollution that occurs in donor countries will be a significant cause of the vulnerability of its client.

The EVI's underlying nature–society dualism means that processes associated with economic development such as population growth (indicator 46), fertilizers (indicator 31), coastal settlements (indicator 48), and tourism (indicator 47) are all cast as risks to natural systems, irrespective of the qualitative nature of these processes, which may not be equally damaging to the environment. In this sense the EVI is an antidevelopment index that, when applied to developing and least developed countries, has the unfortunate effect of seeing as negative processes that often have positive social outcomes. The EVI does not only avoid directly considering social losses, it could indeed be seen as rewarding situations of low economic development. Indeed, because the EVI rewards conservation and penalizes development, it risks becoming a policy instrument that justifies the kind of global environmental managerialism or eco-imperialism that worries the developing world (see Adams 1990; Shiva 1993; Dietz 1999).

The EVI's definitions of vulnerability and resilience are important. Vulnerability is "the extent to which the environment is prone to damage and degradation" (Kaly et al. 2003, 6). Sources of damage are identified as being "natural and human events and processes, such as the weather and pollution," although in practice the EVI is most concerned with "larger and more intense" meteorological events such as droughts, geological events such as tsunamis, and anthropogenic impacts such as mining (Kaly et al. 2003, 7). Resilience is defined as "the extent to which the responder is able to *resist* damage/degradation by hazards" (Kaly, Pratt, and Mitchell 2004, 35, emphasis in original). This emphasis on resistance differs from the understanding of resilience used by ecologists such as Holling (1973) and Gunderson (2000), who emphasize absorption of changes, which is seen to be a function of attributes such as biological diversity, response diversity, and redundancy (see also Peterson, Allen, and Holling 1998; Elmqvist et al. 2003; Walker et al. 2004).

The EVI does not clearly delineate what it considers to be the unacceptable losses that would constitute the realization of vulnerability. It calls the outcome of realized vulnerability "damage," which it sees as "the loss of diversity, extent, quality and function of environments" (Kaly et al. 2003, 6). However, it does not specify how much loss would constitute a bad outcome, perhaps because to do so entails engaging with the diverse values of the environment to people. By not including measures of social loss the EVI does not offer any common basis on which decision makers can compare information about their environment with information about their development. Yet it is the balance between these environmental and development considerations that is central to the idea of sustainable development, including as it informs the BPOA.

On the basis of these conceptualizations of environment, vulnerability, resilience, and damage, the EVI has a model of vulnerability with three "distinct aspects," namely "the risks associated with hazards, resistance, and acquired vulnerability (damage)" (Kaly, Pratt, and Mitchell 2004, 6–7). The first of these refers to the "frequency and intensity of hazardous events," resistance refers to "the inherent characteristics of a country that would tend to make it more or less able to cope with natural and anthropogenic hazards," and acquired vulnerability means "the vulnerability that has been acquired through the loss of ecological integrity or increasing levels of degradation of ecosystems" (Kaly, Pratt, and Mitchell 2004, 6).

The Method of the EVI

The EVI is the average of fifty smart indicators, so called because of their ability to summarize environmental conditions and processes that are considered important. They are selected on the basis of their global applicability, ease of collection, ease of comprehension, and their ability to measure or be a proxy for a change with adverse consequences (Kaly, Pratt, and

Mitchell 2004). The indicators are categorized according to the three aspects in the EVI's model of vulnerability (see Table 1). These categorizations enable the compilation of subindexes. The subindexes assume that hazards (thirty-two indicators) are more important in the vulnerability of country than both resistance (eight indicators) and acquired vulnerability (ten indicators) combined.

The hazards subindex is composed of a variety of factors that vary, from hydrometeorological through to geological, biological, and industrial sources. None of these are weighted, so the EVI is ambiguous about the significance of these various sources of risk. These indicators of hazard also mean that processes such as volcanos, earthquakes, tsunamis, dry spells, and high winds are seen as being risks to the environmental integrity of countries. Within this schema, a volcano is a risk to a country's mountains rather than a phenomenon that makes mountains (given that the EVI does not consider its impacts on people), and a flood is a risk to country's flood-dependent riparian species. In the EVI, then, the environment is a risk to itself. Throughout the documentation of the EVI project, the words "ecological" and "ecosystem" are used interchangeably with "environment." This perhaps reveals that what the EVI really means by environment is biota, which explains how it can consider nonbiological processes such as volcanos and earthquakes to be risks to the environment (remembering that the risks they pose to people are not considered).

Table 1. The EVI's 50 smart indicators arranged by aspects of vulnerability (numbers assigned by the South Pacific Applied Geoscience Commission [SOPAC])

Hazards	Resistance	Damage
1. Wind	11. Land	17. Imbalance
2. Dry	12. Dispersion	21. Introductions
3. Wet	13. Isolation	22. Endangered
4. Hot	14. Relief	23. Extinctions
5. Cold	15. Lowlands	24. Vegetation
6. Sea-surface temperatures	16. Borders	26. Fragmentation
7. Volcanos	19. Migratory species	27. Degradation
8. Earthquakes	20. Endemics	45. Density
9. Tsunamis		48. Coastal
10. Slides		50. Conflicts
18. Openness		
25. Loss of vegetation		
28 Reserves		
29. Marine protected areas		
30. Farming		
31. Fertilizers		
32. Pesticides		
33. Biotechnology		
34. Productivity overfishing		
35. Fishing effort		
36. Water		
37. SO_2		
38. Waste		
39. Treatment		
40. Industry		
41. Spills		
42. Mining		
43. Sanitation		
44. Vehicles		
46. Growth		
47. Tourists		
49. Agreements		

Most of the eight factors that comprise the resistance aspect (such as land area, isolation, relief, lowlands, and shared borders) are more about a country's exposure to risk events rather than its ability to cope with them. They also seek to measure factors that are not clearly associated with vulnerability. For example, relief (indicator 14) is seen to be good for mountainous Fiji, and its absence is seen to be good for low-lying atoll-country Kiribati, but not equally so for low-lying Tuvalu (Kaly et al. 2003).

Because the data for each indicator come in diverse forms, they are converted (mapped) into a multipoint scale to allow for aggregation. There are seven points on the scale (i.e., a scale of one to seven). The fact that all indicators are reduced to a common scale implies that they are all—including linear and nonlinear processes—comparable. For example, in the EVI the indicator Environmental Agreements (indicator 49) uses a linear scale based on the number of environmental treaties in force in a country, whereas "Waste Production" (indicator 38) is a nonlinear scale based on "average annual net amount of generated and imported toxic, hazardous and municipal wastes per square kilometre of area over the last 5 years" (Kaly, Pratt, and Mitchell 2004, 239). Commensuration of linear and nonlinear parameters in this way can lead to underestimation of the severity of those risks that are measured on logarithmic scales. Some of the conversion of raw data for each indicator into the multipoint scale occurred at the meeting of experts in Suva in 1999, and the rest was done on the basis of "the technical literature" or consultations with both "generalists" and "specialists" in each field (Kaly et al. 2003, 10).

The ways in which data are mapped into indicators is also questionable. For the indicator of dry periods, for example, the scaling is based on the number of months in the past five years in which rainfall was at least 20 percent lower than the thirty-year average for that month. The use of limits such as these creates artificial delineations; for example, for the indicator for dry periods, seven months of 20 percent less rainfall over the past five years will rate a score of two, whereas sixty months of 19 percent variation will rate the lowest score of one (Lambert 2001). The selection of a time horizon of five years does not capture either the El Niño Southern Oscillation events that typically occur every four to six years (An and Wang 2000), or in the case of the Pacific Ocean, the Interdecadal Pacific Oscillation, which causes shifts in climate every twenty years or so (Salinger, Renwick, and Mullan 2001).

There remain persistent problems in getting data for thirteen of the indicators, including indicators critical for islands such as sea temperature, high winds, dry periods, wet periods, heat spells, lowlands, and coastal vulnerability. There are data for 80 percent of the indicators for 142 countries (although not for the vast majority of SIDS; Kaly et al. 2004). Nevertheless, this 80 percent requirement is arbitrary (Villa and McLeod 2002). In comparison, Esty et al.'s (2005) Sustainability Index requires only 60 percent of its twenty-one indicators. This 80 percent requirement is not only without significant reason, it also ignores issues of the quality of the data used, and it ignores the possibility that the 20 percent of indicators that matter most might be missing and an EVI score will still be considered to be valid. Indeed, in the Demonstration EVI (Kaly et al. 2003) data on sea temperature, high winds, dry periods, and wet periods were missing for the atoll countries (Kiribati, Maldives, the Marshall Islands, Tokelau, and Tuvalu), even though these factors are critical determinants in their principal environmental problems of coral bleaching, storms, droughts, and flooding. However, in the period between the Demonstration EVI (April 2003) and the December 2004 technical report (Kaly, Pratt, and Mitchell 2004) data for each of these indicators for all of these countries were produced.

Where the indicator is seen to be of little importance to environmental vulnerability, a low score (toward one) on the scale is assigned, and where it is seen to be important a high score (toward seven) is assigned. In the 2003 Demonstration EVI, when the indicator in question was seen to be nonapplicable (for example, coastal degradation in a land-locked country) a score of one was assigned because although the factor might not be at all present in the particular country, "it was considered at least potentially possible that it might occur in the future" (Kaly et al. 2003, 19). However in the 2004 Technical Report this apparently changed so that "countries for which an indicator is considered non applicable attract no EVI score for that indicator" (Kaly, Pratt, and Mitchell 2004, 23). This change does not seem to have been fully implemented in the calculation of EVI scores; for example, low-lying Tuvalu still has a score of one for slides, and Bhutan has a score of one for coastal settlements (SOPAC 2005). In other cases, not only do some indicators that seem not applicable receive a score, they make a positive contribution to a country's EVI score; for example, Tuvalu has no heavy industry at all, yet the indicator for sulphur dioxide emissions is scored as two (making a positive contribution to Tuvalu's EVI score); and Kiribati has had no violent conflict in the last fifty years, yet receives a score of five for this factor (SOPAC 2005).

Where data are not available, no value (zero) is given for the indicator and the denominator for the average is adjusted down accordingly. Therefore where there are no data, that risk factor makes no contribution to the EVI for that country. In Niue's case, for example, there are no data for indicators of the risks that are known to be important such as high winds, pesticides, fisheries effort, and water resources. Yet the supply and quality of fresh water and sustainable yields from fisheries are critical issues for Niue, as are winds, given that Cyclone Heta, which struck in 2004, caused damages equal to three times GDP, excluding the cost of timber and biodiversity losses from its large native forest (Government of Niue 2004). Therefore, although by any commonsense measure Niue has high social and ecological vulnerability, it is ranked as being less vulnerable than Italy or Korea because the risk factors that matter most are not included in its final EVI score.

The EVI does not assign different weights to indicators, effectively meaning all are of equal importance for any given country. For example, although a tsunami in Papua New Guinea in 1998 killed more than 2,000 people and carried uprooted trees for over a kilometer (McSaveney et al. 2000), the EVI sees tsunamis as being a risk equal to land area (both scored two), and a lesser risk than isolation (scored four) or borders (scored three). In calculating the EVI score for Papua New Guinea, then, isolation is effectively twice as important as tsunami, an outcome that might not arise were experts in Papua New Guinea consulted in the selection, weighting, and scoring of indicators. Weighting can also help overcome some of the difficulties of comparing countries, for example by assigning a high weight to sea temperature for atoll countries at risk of coral bleaching, or a high weight to slides for mountainous countries. Kaly et al (2003) report that when experts at the 1999 think tank were asked to assign weights, the net result was that all weights applied cancelled each other out. That the experts that provided much of the input into the mapping of data into the one-to-seven range could disagree so much further underlines that the EVI should be seen as a numerical expression of multiple subjective judgments.

The EVI's model includes risks to environmental integrity that are not well supported by cognate areas of research. For example, indicator 13, isolation, is intended to convey the risks that arise from the distance of a country from refugia, sites of recolonization, and biodiversity. The more distant a country is from a continent the higher the score it receives for this indicator. This is a highly questionable factor and not well founded in the scientific literature, and the EVI makes no reference to any theory that suggests that isolation is a positive or negative factor in the risk of ecosystem disturbance.

Despite some efforts of the EVI team to eliminate redundant indicators, many indicators have been included despite their apparent redundancy. There is, for example, an indicator called coastal settlements that correlates with fifteen other indicators, including tourists, introductions, fragmentation, and vehicles (Kaly et al. 2003, 25). Others understate offsetting factors, for example the diverse ways institutions manage environmental change are captured in relatively few indicators such as agreements, marine protected areas, and (terrestrial) reserves (itself a very Eurocentric construct that fails to acknowledge the importance of customary conservation practices [McDowell 1998]). The EVI team states that if all redundant indicators were eliminated the EVI would be based on only five or six indicators (Kaly et al. 2003, 25). There is no reason to suggest why this is not acceptable.

The Results of the EVI

The EVI assumes that it is possible to compare environmental vulnerability across countries, regardless of how diverse their ecological and social systems. This is not justified in the case of the South Pacific region given the diversity of social-ecological systems, let alone in that the EVI seeks to compare nearly all countries in the world, from Singapore (score 428) to Suriname (score 211), from China (score 360) to Chad (score 217; SOPAC 2005).

The EVI gives scores for 235 countries and territories. In the Demonstration EVI (Kaly et al. 2003) countries were explicitly ranked by score, but after criticism from some countries at the SOPAC Governing Council meeting in 2004, countries are now listed in alphabetical order (see SOPAC 2004a). Nevertheless, the fact that each country's score is readily comparable makes comparisons inevitable. Indeed SOPAC offers a partial ranking in as much as countries are grouped into categories of extremely vulnerable, highly vulnerable, vulnerable, at risk, and resilient (Kaly, Pratt, and Mitchell 2004). Table 2 shows a selection of these scores.

The EVI's results clearly reveal its conceptual and methodological problems. The rankings can be examined in two ways: as indicating the vulnerability of natural systems as is the intention of the EVI (the vulnerability of the environment), and as indicating the vulnerability of social systems to environmental hazards (the vulnerability of people), as is intuitively conveyed by the idea of environmental vulnerability.

In terms of the vulnerability of the environment, the country rankings produce some seemingly illogical results. Singapore, for example, is ranked as the second most environmentally vulnerable country in the world (92 percent of indicators), and Nauru (76 percent of indicators) is ranked as the third most vulnerable. Yet there are arguably no unaffected natural systems in ei-

Table 2. Environmental Vulnerability Index (EVI) scores, ranking, and data availability for a selection of countries

Country	EVI score	Rank	% of indicators
American Samoa	436	1	50
Singapore	428	2	92
Nauru	421	3	76
Japan	389	14	94
Netherlands	388	15	98
Italy	386	18	98
Korea	373	30	96
Tuvalu	367	35	78
United Kingdom	373	39	96
China	360	41	94
Germany	357	44	98
Spain	352	52	96
Marshall Islands	348	56	80
Denmark	345	59	98
Fiji	333	74	92
Samoa	328	81	78
Sweden	311	105	94
Niue	309	108	68
Solomon Islands	281	152	86
Honduras	273	165	90
Ethiopia	260	182	80
Papua New Guinea	251	193	94
Australia	238	208	96
Niger	208	228	80

ther country. In terms of the vulnerability of people, neither country is particularly badly affected by environmental perturbations. American Samoa (50 percent of indicators) is ranked as the most vulnerable country in the world, whereas neighboring Samoa (78 percent of indicators), which is in most respects highly similar, is ranked eighty-first. Papua New Guinea (94 percent of indicators) is ranked as the 193rd most environmentally vulnerable country, yet in terms of the vulnerability of the environment Papua New Guinea has large-scale deforestation of tropical forests and significant impacts on biodiversity and rivers from mining, which seem far more environmentally significant than those that occur in Singapore.

In terms of people's vulnerability to environmental perturbations, in the past ten years Papua New Guinea has experienced a tsunami, volcanic eruptions, and a drought-induced famine, which have created significant social disruption and caused more than 2,000 deaths. New Zealand, on the other hand, is seen as being more environmentally vulnerable (rank 134, 98 percent of indicators), despite having far fewer risks to natural systems (and more national parks), and far less social disruption due to environmental hazards. People in Singapore (EVI score 428, 92 percent of indicators) are almost twice as environmentally vulnerable as people in war-torn and hunger-ridden Congo (EVI score 219, 94 percent of indicators).

It is difficult to argue that the results of the EVI are close to reflecting reality. They are also discordant with the results of other indexes. Esty et al. (2005) find that there is only a weak relationship between their ESI and the EVI, noting that they are based on different conceptual foundations. Nor is there much correlation between the Natural Resource Management Indicator and the EVI (CIESEN 2006). There are indeed some striking differences between the EVI on the one hand, and the ESI and the NRMI on the other. For example, taking the ranking of countries in quartiles, the EVI ranks Japan as being in the most vulnerable quartile, whereas the ESI ranks it as being in the most sustainable quartile, and the NRMI as being in the best for resource management quartile. The EVI ranks Ethiopia as being in the least vulnerable quartile, whereas the ESI ranks it as being in the least sustainable quartile, and the NRMI has it in the worst for resource management quartile.

One of the more ironic outcomes of the EVI is that its results do not clearly show that Pacific SIDS are particularly vulnerable (arguably due to the absence of critical hydrometeorological data). This is contrary to the belief of most Pacific Island leaders, most people who study environment and development issues in the region, and many environmental agreements such as the United Nations Framework Convention on Climate Change, which recognizes the special vulnerability of SIDS, a point stressed by Tuvalu at the SOPAC Governing Council meeting in 2004 (SOPAC 2004a). It is also somewhat at odds with the EVI team's own recommendation that this special vulnerability be taken "into account in regional and international processes, including adjustments and assistance as necessary" (Kaly, Pratt. and Howorth 2002a, 38).

The final technical report of the EVI project argues that the EVI is *inter alia* "an essential aspect of understanding the environment" and the way social and economic processes affect sustainability; assists with environmental reporting; and gives users a rapid insight into "how vulnerable countries are overall, and in terms of particular aspects of their risk to hazards" (Kaly, Pratt, and Mitchell 2004, 6). Elsewhere they claim the EVI has predictive value, can help with national and regional planning including signaling to donors places in need of assistance, can serve as a performance indicator for donor funding, and can help determine the least developed country status of countries (by allowing for non-GDP-based measures of development; Kaly et al. 2001; Kaly, Pratt, and Howorth 2002b; Kaly et al. 2003). These claims considerably overstate the achievements of the EVI, and its flaws suggest that it should not be used as a basis for disbursing funds or measuring the performance of countries in environmental management.

Parris and Kates (2003) propose that an indicator system be assessed on three broad criteria: its relevance to decision makers (salience); its scientific and technical adequacy (credibility); and the degree to which it is respectful of stakeholders' divergent values and beliefs, unbiased, and fair (legitimacy). On these grounds the EVI does not fare well. Its lack of salience can be discerned from the criticism of Pacific Island leaders at the SOPAC Governing Council meeting in 2004, and in its nonendorsement from the leaders of SIDS at the ten-year review of the BPOA at Mauritius in January 2005. As this article has shown, the EVI is neither scientifically nor technically credible. It is based on a simplistic model of environmental vulnerability, and sees vulnerability as a generic national condition rather than a temporally and spatially specific phenomenon. These core problems perhaps explain why a detailed discussion of the EVI project has not been published in a peer-reviewed journal despite repeated recommendations that its scientific rigor be tested in this way. Its presentation as science implicitly claims objectivity and authority, which is not justified by its model and method. The legitimacy of the EVI is also highly questionable. Its finding that countries such as Ethiopia and Papua New Guinea are not particularly vulnerable is at odds with the evidence of the impact of environmental hazards on social and ecological systems in those countries. Further, its rewarding of situations of low economic development works against the development rights of people, and diverges from its mandate in the BPOA.

In their explanation of the concept of environmental criticality—a concept perhaps most like environmental vulnerability—Kasperson, Kasperson, and Turner (1995) demonstrate the need for an integrative perspective "that must recognize the essential role of the environment in sustaining human life but recognise at the same time that not all elements of the environment are essential or equally important. It must also appreciate the central role of human management and response . . . and place regions in their global context" (7–8). In contrast, the EVI treats all elements of a country's environment as equally important, largely ignores the role of human management and responses, and fails to capture the larger contexts that shape and give meaning to environmental vulnerability in any given country.

Conclusions

This article offers lessons for both the construction of indexes of vulnerability and environmental change, and for the broader study of these phenomena. It offers three broad lessons for those seeking to develop indexes of vulnerability and environmental change. First, constructing a country-scale index to appeal to national decision makers and to facilitate intercountry comparisons creates levels of abstraction that dilute the meaningfulness of the index as a reflection of reality. At such large scales of analysis the diverse values and risk perceptions of communities become so aggregated that vulnerability becomes a generic condition that has little relevance or meaning to anyone. The number of processes that determine generic vulnerability also become so numerous that the availability and quality of data on which to base indicators become significant constraints, and the tasks of standardizing, weighting, and aggregating data also become more difficult. Further, at large scales the underlying model of social–ecological interactions needs to be so complex that uncertainties compound to the point that the resulting index is excessively erroneous.

The geographic literature on vulnerability reviewed earlier in this article advocates smaller scale and place-based assessments of coupled social–ecological interactions on the grounds that these produce more meaningful, detailed, and policy-relevant insights. We have noted that this is not the *sine qua non* for vulnerability assessment, but nevertheless strongly suggest that it offers the best approach to constructing a meaningful index, noting that this does not preclude the aggregation of the results of many such studies. So, if it is ecological change per se that an index is seeking to represent, the scale of analysis is perhaps best kept to the scale of relatively distinct ecosystems. If it is environmental changes of social relevance to be measured and monitored, the scale of analysis is probably best determined in the first instance by the scale of the proximate communities of concern (the groups most obviously likely to be affected by environmental change). Nevertheless, although indexes based on smaller scales of analysis are more likely to reflect reality than indexes that apply to larger scales, they are unlikely to capture the complex spatial politics to vulnerability or the complexity of drivers of vulnerability.

The second lesson of this article's analysis for the development of indexes is that indexes should not be promoted as policy tools. Indeed, we question the very possibility of reducing complex social–ecological processes to numbers, or a number, given the diversity of spatiotemporal processes involved. As Kasperson, Kasperson, and Turner (2005) argue, studies of the environment and vulnerability "cannot be expected to result in a quantitative understanding equivalent to that of the forcing functions in the scientific arena of global environmental change" (249). The development of indexes has some ontological and epistemological value, but we reject their use for measuring the performance of countries, for intercountry comparisons, or for the allocation of resources.

The third lesson for the development of indexes is the need for input into their design and assessment from experts in the study of the exposure unit in question as well as from experts in the design of indicators and indexes per se. Input from those most knowledgeable about—or who have the greatest stake in—the exposure unit could at least come in the form of their involvement in the weighting of various subcomponents of an index. This is a minimal way to ensure some inclusion of the knowledge and values of those people who otherwise implicitly populate indexes, and to increase the legitimacy of the index to the people who are responsible for and bear the consequences of environmental management. This will require more consultation and participation in the design and testing of indexes, and might best be done along the lines of the expert elicitation method developed by Morgan and Keith (1995; see also Morgan and Dowlatabadi 1996).

There are four lessons of this article's analysis for the study of vulnerability and environmental change. First, if such studies are to be socially relevant they need to understand why and to whom these problems matter. Vulnerability is about values at risk, and identification of vulnerable environments cannot purport to be meaningful if it does not recognize the relative values of environments at risk to diverse groups. This is not to say that attempts to understand environmental change independent of social impacts are not useful, but it is to say that the significance of those changes only arises through consideration of their impacts on the values of social groups. Studies of environmental change and vulnerability that seek to reflect reality cannot therefore be based on an imaginary nature–society dualism. Second, vulnerability is not a generic national condition, but is a phenomenon that is specific in space and time and arises out of specific social and ecological processes. Third, cross-site comparisons of vulnerability are largely meaningless because of the complexities and nuances of the material and symbolic processes that give rise to vulnerability. Finally, research on vulnerability and environmental change is best advanced through detailed empirical investigations rather than through the construction of indexes.

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References

Adams, W. 1990. *Green development: Environment and sustainability in the third world*. London: Routledge.

Adger, W. 1999. Social vulnerability to climate change and extremes in coastal Vietnam. *World Development* 27:249–69.

———. 2000. Social and ecological resilience: Are they related? *Progress in Human Geography* 24:347–64.

Adger, W., N. Brooks, G. Bentham, M. Agnew, and S. Eriksen. 2004. *New indicators of vulnerability and adaptive capacity*. Tech. Rep. 7. Norwich, U.K.: Tyndall Centre for Climate Change Research.

Alwang, J., P. Siegel, and S. Jorgensen. 2001. *Vulnerability: A view from different disciplines*. Social protection discussion paper No. 0115. Washington, DC: The World Bank.

An, S.-I., and B. Wang. 2000. Interdecadal change of the structure of the ENSO mode and its impact on the ENSO frequency. *Journal of Climate* 13: 2044–55.

Asian Development Bank. 2004. *Key indicators 2004: Poverty in Asia: Measurement, estimates, and prospects*. Manila, Philippines: Asian Development Bank.

Barnett, J. 2001. Adapting to climate change in Pacific Island countries: The problem of uncertainty. *World Development* 29:977–93.

———. 2006. Climate change, insecurity and justice. In *Fairness in adaptation to climate change*, ed. W. Adger, J. Paavola, M. Mace, and S. Huq, 115–29. Cambridge, MA: MIT Press.

Barnett, J., and N. Adger. 2003. Climate dangers and atoll countries. *Climatic Change* 61:321–37.

Blaikie, P., and H. Brookfield. 1987. *Land degradation and society*. London: Methuen.

Bohle, H., T. Downing, and M. Watts. 1994. Climate change and social vulnerability: Toward a sociology and geography of food insecurity. *Global Environmental Change* 4:37–48.

Bonyhady, T. 1993. *Places worth keeping: Conservationists, politics and law*. St Leonards, U.K.: Allen & Unwin.

Bossel, H. 1999. *Indicators for sustainable development: Theory, method, applications*. Winnipeg, Canada: International Institute for Sustainable Development.

Briguglio, L. 1995. Small island states and their vulnerable economies. *World Development* 23:1615–32.

———. 2003. *The vulnerability index and small island developing states: A review of conceptual and methodological issues*. Malta: Islands and Small States Institute. http://home.um.edu.mt/islands/research.html (last accessed 18 December 2007).

Briguglio, L., U. Kaly, and C. Pratt, eds. 1999. *Report of the meeting of experts on the environmental vulnerability index*. Suva, Fiji: South Pacific Applied Geoscience Commission.

Burton, I., R. Kates, and G. White. 1978. *The environment as hazard*. New York: Oxford University Press.

Campbell, J. 1997. Examining Pacific Island vulnerability to natural hazards. In *Proceedings, VIII Pacific science intercongress*, ed. A. Planitz and J. Chung, 53–62. Suva, Fiji: United Nations Department for Humanitarian Affairs, South Pacific Programme Office.

Castles, I. 1998. The mismeasure of nations: A review essay on the Human Development Report 1998. *Population and Development Review* 24:831–45.

Center for International Earth Science Information Network (CIESEN). 2006. Millennium Challenge Corporation: Natural Resource Management Index. http://sedac.ciesin.columbia.edu/es/mcc.html (last accessed 6 February 2007).

Chambers, N., C. Simmons, and M. Wackernagel. 2000. *Sharing nature's interest: Ecological footprints as an indicator of sustainability*. London: Earthscan.

Commonwealth Secretariat and the World Bank. 2000. *Small states: Meeting challenges in the global economy*. London/Washington, DC: Commonwealth Secretariat and the World Bank.

Cutter, S. 1996. Vulnerability to environmental hazards. *Progress in Human Geography* 20:529–39.

———. 2003. The vulnerability of science and the science of vulnerability. *Annals of the Association of American Geographers* 93:1–12.

Dauvergne, P. 1997. *Shadows in the forest: Japan and the politics of timber in Southeast Asia*. Cambridge, MA: MIT Press.

DeAngelis, D. 1980. Energy flow, nutrient cycling, and ecosystem resilience. *Ecology* 61:764–71.

Desai, M. 1991. Human development concepts and measurement. *European Economic Review* 35:350–57.

Dietz, T. 1999. Political environmental geography of the tropics. *Development* 42:13–19.

Dovers, S. 1997. Sustainability: Demands on policy. *Journal of Public Policy* 16:303–18.

Downing, T. 2002. Linking sustainable livelihoods and global climate change in vulnerable food systems. *Die Erde* 133:363–78.

Eakin, H., and A. Luers. 2006. Assessing the vulnerability of social-ecological systems. *Annual Review of Environment and Resources* 31:365–94.

Easter, C. 1999. Small states development: A commonwealth vulnerability index. *The Round Table* 351:403–22.

Ellemor, H. 2005. Reconsidering emergency management and indigenous communities in Australia. *Environmental Hazards* 6:1–7.

Elmqvist, T., C. Folke, M. Nystrom, G. Peterson, J. Bengtsson, B. Walker, and J. Norberg. 2003. Response diversity, ecosystem change, and resilience. *Frontiers in Ecology and the Environment* 1:488–94.

Esty, D., M. Levy, T. Srebotnjak, and A. de Sherbinin. 2005. *Environmental Sustainability Index: Benchmarking national environmental stewardship*. New Haven, CT: Yale Center for Environmental Policy and Law.

Farell, A., and M. Hart. 1998. What does sustainability really mean? The search for useful indicators. *Environment* 40:4–9, 26–31.

Fischetti, M. 2001. Drowning New Orleans. *Scientific American* 285:77–85.

Folke, C., S. Carpenter, T. Elmqvist, L. Gunderson, C. Holling, B. Walker, et al. 2002. *Resilience and sustainable development: Building adaptive capacity in a world of transformations*. Scientific background paper on resilience for the process of the World Summit on Sustainable Development. www.sou.gov.se/mvb/pdf/resiliens.pdf (last accessed 18 December 2007).

Folke, C., S. Carpenter, B. Walker, M. Scheffer, T. Elmqvist, L. Gunderson, and C. Holling. 2004. Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review of Ecology Evolution and Systematics* 35:557–81.

Frank, A. 1969. *Capitalism and underdevelopment in Latin America: Historical studies of Chile and Brazil*. New York: Monthly Review Press.

Fry, I. 2005. Small island developing states: Becalmed in a sea of soft law. *RECIEL* 14:89–99.

Gommes, R., J. Du Guerny, F. Nachtergaele, and R. Brinkman. 1998. *Potential impacts of sea-level rise on populations and agriculture*. Rome: Food and Agriculture Organisation of the United Nations.

Government of Niue. 2004. *National impact assessment report of cyclone Heta*. Alofi, Niue: Department of Economic Planning, Development and Statistics.

Gunderson, L. 2000. Ecological resilience—In theory and application. *Annual Review of Ecology and Systematics* 31:425–39.

H. John Heinz III Center for Science, Economics and the Environment. 2002. *The state of the nation's ecosystems: Measuring the lands, waters, and living resources of the United States*. New York: Cambridge University Press.

Holling, C. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* 4:1–23.

International Sustainability Indicators Network (ISIN). 2007. Welcome to ISIN. http://www.sustainability-indicators.org/ (last accessed 30 January 2007).

Kaly, U., L. Briguglio, H. McLeod, S. Schmall, C. Pratt, and R. Pal. 1999a. *Environmental vulnerability index (EVI) to summarise national environmental vulnerability profiles*. SOPAC Tech. Rep. 275. Suva, Fiji: South Pacific Applied Geoscience Commission.

———. 1999b. *Report on the environmental vulnerability index (EVI) think tank 7–10 September 1999, Pacific Harbour, Fiji*. SOPAC Tech. Rep. 299. Suva, Fiji: South Pacific Applied Geoscience Commission.

Kaly, U., C. Pratt, E. Khaha, A. Dahl, L. Briguglio, and E. Sale-Mario. 2001. *Globalising the Environmental Vulnerability Index (EVI): Proceedings of the EVI globalisation meeting, 27–29 August 2001, Geneva, Switzerland*. SOPAC Tech. Rep. 345. Suva, Fiji: South Pacific Applied Geoscience Commission.

Kaly, U., C. Pratt, and R. Howorth. 2002a. A framework for managing environmental vulnerability in small island developing states. *Development Bulletin* 58:22–38.

———. 2002b. *Towards managing environmental vulnerability in small island developing states (SIDS)*. SOPAC Miscellaneous Rep. 461. Suva, Fiji: South Pacific Applied Geoscience Commission.

Kaly, U., C. Pratt, and J. Mitchell. 2004. *The Environmental Vulnerability Index (EVI) 2004*. SOPAC Tech. Rep. 384. Suva, Fiji: South Pacific Applied Geoscience Commission.

Kaly, U., C. Pratt, J. Mitchell, and R. Howorth. 2003. *The demonstration environmental vulnerability index (EVI)*. SOPAC Tech. Rep. 356. Suva, Fiji: South Pacific Applied Geoscience Commission.

Kasperson, J., R. Kasperson, and B. Turner. 1995. *Regions at risk: Comparisons of threatened environments*. Tokyo: United Nations University Press.

Kasperson, J., R. Kasperson, B. Turner, W. Hsieh, and A. Schiller. 2005. Vulnerability to global environmental change. In *Social contours of risk*, Vol. II, ed. J. Kasperson and R. Kasperson, 245–85. London: Earthscan.

Kelley, A. 1991. The Human Development Index: "Handle with care." *Population and Development Review* 17:315–24.

King, D. 2001. Uses and limitations of socio-economic indicators of community vulnerability to natural hazards: Data and disasters in Northern Australia. *Natural Hazards* 24:147–56.

Lambert, S. 2001. *The assessment of Pacific Island environmental vulnerability: A critical study of an environmental vulnerability index by the South Pacific Geoscience Commission*. Master of Arts of Geography thesis, Department of Geography, The University of Canterbury.

Leichenko, R., and K. O'Brien. 2008. *Double exposure: Global environmental change in an era of globalization*. New York: Oxford University Press.
Leiss, W. 1972. *The domination of nature*. New York: George Braziller.
Millennium Challenge Corporation (MCC). 2007. "Indicators." http://www.mcc.gov/selection/indicators/index.php (last accessed 11 January 2007).
McDowell, T. 1998. Slow-motion explosion: The global threat of exotic species and the international response to the problem in the South Pacific. *Colorado Journal of International Environmental Law and Policy* 9:187–220.
McGilvray, M. 1991. The human development index: Yet another redundant composite development indicator? *World Development* 19:1461–8.
McSaveney, M., J. Goff, D. Darby, P. Goldsmith, A. Barnett, S. Elliott, and M. Nongkas. 2000. The 17 July tsunami, Papua New Guinea: Evidence and initial interpretation. *Marine Geology* 170:81–92.
Morgan, M., and H. Dowlatabadi. 1996. Learning from integrated assessment of climate change. *Climatic Change* 34:337–368.
Morgan, M., and D. Keith. 1995. Subjective judgements by climate experts. *Environmental Science and Technology* 29:468A–76A.
Morse, S., and E. Fraser. 2005. Making "dirty" nations look clean? The nation state and the problem of selecting and weighting indices as tools for measuring progress towards sustainability. *Geoforum* 36:625–40.
Mortimore, M. 1989. *Adapting to drought: Farmers, famines and desertification in West Africa*. Cambridge, U.K.: Cambridge University Press.
National Research Council. 2000a. *Ecological indicators for the nation*. Washington, DC: National Academy Press.
———. 2000b. *Our common tourney: A transition toward sustainability*. Washington, DC: National Academy Press.
Neumayer, E. 2001. The human development index and sustainability: A constructive proposal. *Ecological Economics* 39:101–14.
Niemeijer, D. 2002. Developing indicators for environmental policy: Data-driven and theory-driven approaches examined by example. *Environmental Science and Policy* 5:91–103.
Noorkbash, F. 1998. A modified human development index. *World Development* 26:517–28.
O'Brien, K., and R. Leichenko. 2003. Winners and losers in the context of global change. *Annals of the Association of American Geographers* 93:89–103.
Organization for Economic Co-Operation and Development (OECD). 2001. *OECD environmental indicators 2001*. Paris: OECD.
Overton, J. 1999. Sustainable development and the Pacific Islands. In *Strategies for sustainable development: Experiences from the Pacific*, ed. J. Overton and R. Scheyvens, 1–18. Sydney: University of New South Wales Press.
Parris, T., and R. Kates. 2003. Characterizing and measuring sustainable development. *Annual Review of Environment and Resources* 28:559–86.
Peterson, G., C. Allen, and C. Holling. 1998. Ecological resilience, biodiversity, and scale. *Ecosystems* 1:6–18.
Pethick, J., and S. Crooks. 2000. Development of a coastal vulnerability index: A geomorphological perspective. *Environmental Conservation* 27:359–67.
Pratt, C., U. Kaly, E. Sale-Mario, and J. Seddon. 2002. *Towards a global Environmental Vulnerability Index (EVI): Update on progress March–June 2002 and Revised Funding Proposal 2002–2003*. SOPAC Misc. Rep. 465. Suva, Fiji: South Pacific Applied Geoscience Commission.
Prescott-Allen, R. 2001. *The wellbeing of nations: A country-by-country index of quality of life and the environment*. Washington, DC: Island Press.
Sagar, A., and A. Najam. 1998. The human development index: A critical review. *Ecological Economics* 25:249–64.
Salinger, J., J, Renwick, and A. Mullan. 2001. Interdecadal Pacific Oscillation and South Pacific climate. *International Journal of Climatology* 21:1705–21.
Secretariat of the Pacific Community. 2004. *Pacific Island populations 2004*. Noumea, New Caledonia: SPC Demography/Population Programme.
Shiva, V. 1993. The greening of the global reach. In *Global ecology: A new arena of political conflict*, ed. W. Sachs, 149–56. London: Zed.
Skole, D., H. Chomentowski. W. Salas, and A. Nobre. 1994. Physical and human dimensions of deforestation in Amazonia. *BioScience* 44:314–22.
South Pacific Applied Geoscience Commission. 2003. *SOPAC 2003 approved work programme and budget*. Suva, Fiji: South Pacific Applied Geoscience Commission.
South Pacific Applied Geoscience Commission. 2004a. *Proceedings of the thirty-third session hosted by the Government of Papua New Guinea in the Coral Coast, Fiji Islands 17–24 September 2004*. Suva, Fiji: South Pacific Applied Geoscience Commission.
South Pacific Applied Geoscience Commission. 2004b. *SOPAC 2004 approved work programme and budget*. Suva, Fiji: South Pacific Applied Geoscience Commission.
South Pacific Applied Geoscience Commission. 2005. EVI country profiles. http://www.vulnerabilityindex.net/EVI_Country_Profiles.htm (last accessed 25 January 2006).
South Pacific Applied Geoscience Commission and United Nations Environment Programme. 2005. *Building resilience in SIDS: The Environmental Vulnerability Index*. Suva, Fiji: South Pacific Applied Geoscience Commission.
Turner, B., R. Kasperson, P. Matson, J. McCarthy, R. Corell, L. Christensen, et al. 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences* 100:8074–79.
Turner, B., P. Matson, J. McCarthy, R. Corell, L. Christensen, N. Eckley, et al. 2003. Illustrating the coupled human–environment system for vulnerability analysis: Three case studies. *Proceedings of the National Academy of Sciences* 100:8080–85.
United Nations. 1994. *Report of the global conference on the sustainable development of small island developing states. Bridgetown, Barbados, 25 April–6 May 1994*. New York: United Nations Department of Public Information.

United Nations Development Program (UNDP). 2003. *Human development report 2003*. New York: Oxford University Press.

United Nations Environment Program. 1999. *Pacific Islands environmental outlook*. Samoa: UNEP and the South Pacific Regional Environment Programme.

Villa, F., and H. McLeod. 2002. Environmental vulnerability indicators for environmental planning and decision-making: Guidelines and applications. *Environmental Management* 29:335–48.

Vincent, K. 2004. *Creating an index of social vulnerability to climate change for Africa*. Tyndall Centre for Climate Change Research Working Paper 56. Norwich, CT: Tyndall Centre for Climate Change Research.

Walker, B., C. Holling, S. Carpenter, and A. Kinzig. 2004. Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society* 9: article 5. [online] http://www.ecologyandsociety.org/vol9/iss2/art5/ (last accessed 18 December 2007).

White, G., R. Kates, and I. Burton. 2001. Knowing better and losing more: The use of knowledge in hazards management. *Environmental Hazards* 3:81–92.

Wildavsky, A. 1988. *Searching for safety*. New Brunswick, NJ: Transaction Books.

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