EVI Technical Report

Report on the Environmental Vulnerability Index (EVI) Think Tank

7 – 10 September 1999

Pacific Harbour, Fiji

SOPAC

South Pacific Applied Geoscience Commission

SOPAC Technical Report 299

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1. Vulnerability index – environment

Abstract

These proceedings describe the debates, developments and progress made on the Environmental Vulnerability Index (EVI) during an international think tank which was run 7-10 September 1999 at Pacific Harbour, Fiji. The EVI was initially developed in early 1999 by SOPAC to provide an index that could be calculated on the scale of entire states for the purpose of ranking them and providing a single-figure expression of their relative environmental vulnerabilities. The work was done in response to a call made in the Barbados Plan of Action, the Alliance of Small Island States (AOSIS) and an increasing awareness that small island developing states face disadvantages to their development associated with their remoteness, small size, dispersion, economic conditions and limited natural resources. Most vulnerability indices developed in the past describe the vulnerability of human systems. There have been very limited attempts to describe effects on the environment. Because human systems and the environment are dependent on one another, risks to the environment of a state will eventually translate into risks to humans. A full description of the EVI that was developed is available in the first report of this series.

The purpose of the think tank was to assemble a group of experts from a range of disciplines central to the index to subject the EVI to critical peer review. A list of discussion topics was developed to provide a focus for debates on all aspects of the EVI, including the structure of the model, the indicators used, mathematical testing, a finishing line for deciding on when the index would be considered operational, its strengths and weaknesses and future directions for development.

The assembled group of experts generally accepted the approach taken to the development of the EVI and made improvements to the framework and changes to most of the indicators. The changes to the framework can be incorporated immediately. The indicators, in contrast, will require much effort, including mathematical testing, before they can be completed. The final list of indicators included 47 questions which was 10 less that the original EVI. Testing of the EVI model and correlations amongst indicators will require data from 15 countries.

Participants at the meeting were in disagreement on whether the EVI should be focused on the natural environment of states, or whether it should encompass human and natural environments. The EVI as it stands has been designed for natural environments, in accordance with the initial brief for this work. If human environments are to be incorporated, the indicators will need to change extensively. Some participants called for the separate or composite development of an EVI that includes both types of environment. Written submissions from participants are largely concerned with this question.

The main recommendations made by the group were that the EVI should be thoroughly tested using a range of countries of widely differing characteristics and global extremes. The EVI should also be independently assessed on a small number of countries (5) using a team of vulnerability assessors against which the EVI could be compared for reliability. It was also recommended that peer and user reviews be continued and that the think tank meeting be reconvened at a later date.

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We wish to express our thanks to all of the participants of the think tank. We acknowledge that they fully engaged themselves in the discussions during the meeting and undertook to develop parts of the EVI relevant to their areas of expertise. We look forward to on-going discussions on issues still to be addressed.

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1 Introduction

1.1 Background and Rationale

Vulnerability is the potential for the attributes of a system to be damaged by the action of hazards, while resilience is the potential for that system to minimise or absorb the effects of damaging hazards. It has become increasingly recognised that studies on, and successful characterisations of the vulnerability to harm of human and natural systems at the level of entire states would provide valuable information for international processes and management actions. However, to undertake such studies on an *ad hoc* basis would be prohibitively expensive and/or lead to results which, for international processes, might be difficult to compare. The solution to this problem has been the attempt over the past decade to construct vulnerability indices that could be calculated for states on a common basis. The aim of vulnerability indices, then, is to describe and summarise the relative vulnerability of states.

Different forms of vulnerability of states have been identified, including economic, social / human quality of life and environmental. For example, economic vulnerability is concerned with external forces which act on the welfare of the economy, while social vulnerability occurs when natural or other disasters force massive upheavals of residence, traditions and society. Initial attempts at constructing a vulnerability index focused on the economic aspects of a state and followed a proposal by the Maltese Ambassador during a 1990 UNCTAD expert meeting on the problems of small island developing states.

Vulnerability indices designed to characterise states, need necessarily to be global. It is only within the global context of extremes that the vulnerability of any state can be derived. The initial drive to develop vulnerability indices has come in recognition that Small Island Developing States (SIDS) face serious disadvantages to their development associated with an interplay of factors such as remoteness, geographical dispersion, vulnerability to natural disasters, a high degree of economic openness, small internal markets, limited natural resources and fragile ecosystems. These issues have been recognised and increasingly highlighted in international fora during the last decade.

Vulnerability indices have been developed for the hazards associated with climate change and sea-level rise, the El Nino-Southern Oscillation (ENSO) phenomenon, anthropogenic impacts and natural disasters. Most of these indices describe the vulnerability of human systems (i.e. the responders are economies, development, social systems) to these risks. Only a few studies have attempted to measure the vulnerability of the environment itself to anthropogenic and natural hazards.

Human systems and the environment are dependent on one another. Risks to the environment of a state will eventually translate into risks to humans because of their dependence on the natural environment for resources. In turn, the environment is susceptible to natural events, the actions of humans and their management strategies. This means that overall vulnerability of a state should include measures of both human and natural systems and the risks which affect them. The completion of an Environmental Vulnerability Index (EVI) will be an important step towards characterising the overall vulnerabilities of states, regardless of whether the information is presented separately or merged with other vulnerability indices to develop a Composite Vulnerability Index (CVI).

1.2 Purpose of the Think Tank

The Think Tank was run between the dates of 7-10 September 1999 at Pacific Harbour Fiji. The purpose of this meeting was to assemble a group of internationally recognised scientists who were experts in fields relevant to the EVI. This group was asked to examine all aspects of the model designed by SOPAC (Kaly et al, 1999); to provide inputs on improving its design and function, to make recommendations on how to test the model and the criteria it should pass before it could be introduced to the international arena. The overall aims of the Think Tank were therefore to:

1. Obtain peer-review and commentary from experts in a range of fields relevant to the development of the EVI;
2. Obtain sufficient inputs to make the EVI acceptable and/or operational in the international community;
3. Assemble information necessary to ensure that the EVI will be internationally applicable to all regions of the world; and
4. Identify directions for future work.

The scientists invited to the Think Tank were experts in the following fields:

- Statistical methods, particularly multivariate techniques;
- Biodiversity, biogeography and protected areas
- Other types of indices which summarise very complex data of an ecological or environmental nature
- Weather and climate
- Disaster research
- Ecosystem management, impacts
- Fisheries
- Forestry and agriculture
- Productivity and energy flows
- Environmental economics.

1.3 Opening Speeches

1.3.1 Address by Mr Nicholas Kiddle, Acting High Commissioner for New Zealand

"New Zealand has long been supportive of work on an Environmental Vulnerability Index (EVI).

Our geographical location in the Pacific means we are closer, and therefore more exposed, to the effects of environmental impacts on Pacific neighbouring states than many other development partners.

We are called upon every year to respond to natural disasters.

And, of course, we have developed systems to help islands states respond - contact networks and funds and logistical support systems which operate at both national and regional levels.

But disaster response and mitigation are only part of a more complex picture of the full impact of the environment on some countries. Small island developing states, for example, are much less resilient to physical damage than larger, more diverse economies with large land masses. Small island states can find that their limited capacities to repair or restore not only affects their immediate standard of living, but also affects their long term development prospects.

It seems unfair therefore for these states to be judged on their ability to adapt and grow in line global economic forces without taking into account this particular fact of life.

This has become what we all know now to be the concept of vulnerability and how (and whether) it should be factored into thinking and planning at the international political level - thinking and planning that contributes to life chances and opportunities for many of the Pacific peoples.

My government for one has therefore seen merit in taking a much closer look at how vulnerability can be measured and whether, once measured, it could be used as a tool in development planning.

It was that interest that underpinned our stance at Committee on Development Planning and UN ECOSOC sessions where the graduation of some small island states had risen close to the top of the agenda.

In that context we said, "hang on a minute, let's postpone graduation while we take a closer look at this issue".

And to help speed things along, we dug deep into our pockets and found some capital to assist SOPAC to develop a model to measure environmental vulnerability.

We hoped that if SOPAC was successful then this work could add to work in the Commonwealth, the CDP, and elsewhere which may (or may not) head toward the compilation of a composite index.

We saw SOPAC's contribution as especially valuable. It was stand alone - even though it would be designed to fit as a integral component to others' work. And it was focussed on an area that we thought was not being adequately targeted elsewhere.

Earlier this year I was among the first to be briefed by SOPAC on the preliminary results of research it had done on a framework. As a lay person I was fascinated by the depth and breadth of the model that was taking shape. And although I am not an expert in these matters, it seemed to me that the model could lend itself to genuine applicability in the fields for which it is being designed.

So after some further discussion with Wellington it was finally agreed that the framework deserved wider distribution. And this was done. In various guises and in different ways, its existence was made plain to audiences in New York, London, Australia, the Pacific, and recently in Norway.

I think it is fair to say that those presentations have been well received.

But at the same time we are all cognisant of the work that remains to be done. And there is plenty of it. Wellington is keen for SOPAC to now concentrate on gathering data for five countries (Fiji, Australia, Tuvalu, Samoa and Vanuatu), to see how the five stack up against 80 percent of the 57 indicators of vulnerability that have been identified as relevant to the PICs. It is our hope that those country EVI profiles would then be useful to the work of the Committee on Development Planning, and to UNGASS.

But, as you all know very well, we have here somewhat of a chicken and egg situation. Which is why this workshop has been convened. The gist is this: in order to be useful the framework of assumptions and principles that underpin the model should be robust enough in the opinion of the international scientific community to be pretty much beyond question. And that is where you come in.

Peer review of the framework is critical to the success of further work. And peer review needs first hand live input from experts such as yourselves, with the freedom to debate and criticise unhindered by political considerations, so that when you are done, we can all sit back and be fairly confident that the model is about as useful and realistic as we can make it.

Only once that process has been completed (and it may well be an ongoing process) will others, such as myself, pick up the matter again and contemplate its political utility.

And although we cannot forecast where that particular debate might end, we can say that in Wellington there is a good deal of expectation that the model will be very useful in helping governments and the donor community plan environmental projects to tackle *newly identified vulnerabilities, as well as making a possible contribution to policy planning at the international level.*

With those few words it is indeed my great pleasure to wish all the participants here the best of luck, and to declare the conference open."

1.3.2 Address by Alfred Simpson, Director of SOPAC

The Director welcomed all participants on behalf of SOPAC to the EVI Expert Group Meeting. He thanked them for coming and taking time out of their very busy schedules to participate in the meeting. He also thanked the United Nations Committee on Development Policy (UN CDP), United Nations Environment Programme (UNEP), World Meteorological Organisation (WMO), the Governments of Australia, Vanuatu and Samoa, regional CROP agencies including Secretariat for the Pacific Community (SPC), Forum Secretariat and South Pacific Regional Environment Programme (SPREP) for supporting participants to attend this very important meeting.

The Director encouraged all participants to be actively involved and to contribute to constructive debate on the technical development of such an important international tool – the environmental vulnerability index. He highlighted that SOPAC did not have a predefined agenda for developing the EVI and hoped that they would contribute freely as their participation is considered essential for advancing the EVI into a universally defendable, internationally applicable, robust tool.

The Director also expressed his appreciation on behalf of SOPAC for the continued support of the New Zealand Government in the development of the environmental vulnerability index. He also expressed particular appreciation for the efforts of the local High Commission in promoting this important work.

2 Approach to the Think Tank

A list of eight topics was compiled to provide a focus for discussions. These topics were purely technical in nature and were not concerned with the political applications of the EVI. Seven of the topics were designed for discussion during the Think Tank, and one to prompt written submissions for aspects which needed research or specific inputs from an expert. The following is a list of the topics presented to the group to guide discussions and submissions.

Topic 1: General discussion and definitions

1.1 Definition of environmental vulnerability on the scale of countries

1.2 If the "Environment" is vulnerable to "natural" events (e.g. cyclones) then the EVI is essentially concerned with the environment from the inevitable human perspective. We judge change as "negative". The EVI is thus an index of environmental vulnerability from the point of view of humans and can never be separated from their view of it. It is not some "pure" index concerned with the welfare of the environment in itself, unless we separated all natural risks out. Comments?

1.3 Working definition of the EVI: A dimension-less relative measure that provides a snapshot assessment of the level of exposure and ability to cope with human and natural hazards to the environment at the scale of countries…?

Topic 2: Sub-indices of the EVI

2.1 What are the most important risks / hazards to the environment? Or: which could be immediately excluded?

2.2 What are the responders to those risks and hazards? (list)

2.3 We defined that there were three aspects of vulnerability and that these aspects would lead to three sub-indices. Are there others that should be considered?

- Exposure to natural or human risks / hazards (= Risk exposure index = REI)
- Intrinsic resilience (=Intrinsic resilience index = IRI)
- Present status of the 'health' of the environment (= Environmental Degradation Index = EDI) (Assumption: Impacts in the past affect the ability of the environment to tolerate new impacts).

2.4 Can these three sub-indices be put together into a dimension-less measure?

2.5 What would the index mean? (Revise 1.2)

Topic 3: The indicators of vulnerability

3.1 How many indicators do we need? We suggested 57.
- 3-6 Indicators used for human systems (economic, social)
- 12-15 Indicators when more emphasis on effects of natural disasters and ecological variables on humans
- 60 When anthropogenic pressures on environment
- Does having more indicators make it harder to interpret? Do we need more to ensure generality?

3.2 Should we have an equal number of indicators in each sub-index category?
3.3 We are short on indicators of intrinsic resilience – any additional ones?
3.4 Any of the indicators redundant? Any new ones that should be in?
3.5 Max and min levels for each indicator? World range or regional? (affects written submissions for individual indicators)
3.6 Scoring linear or otherwise on the 1-7 scale? What kinds of indicators should be linear, what kinds non-linear? Any general rules?
3.7 Should some indicators be weighted? How?
- Do we need to weight some questions?
- We did 6 we thought were more important than others - given value of 5
- Delete weighting?

3.8 Any other weighting required?

Topic 4: Mathematics

4.1 Mapping of the data on the 1-7 scale as a way to standardise heterogeneous data
4.2 The values of 0 or NA: Nett and gross Vulnerability
- Is this an issue?
- Better terminology?
- Report both? Report one? Which one?

4.3 How should the values of the indices be accumulated? Averages or other approaches?
4.4 Should the final EVI be an average of the three sub-indices (giving them equal value regardless of the number of indicators in each?)
4.5 What is the cut-off for data availability for a credible EVI: 80% of questions answered?

Topic 5: Strengths and weaknesses of the new EVI

5.1 Assumptions
5.2 Strengths
5.3 Weaknesses -consider both meanings of "weakness":
- Inherent weaknesses that cannot be removed but must be stated or understood
- Weaknesses we could improve

5.4 Any conditions for people using the indices to keep in mind?

Topic 6: The future

6.1 Should the EVI be stand-alone or composite with economic or other human indicators?
6.2 How should the EVI be extended to other regions (climatic, biogeographic) of the world?
6.3 What testing should this EVI be put under exactly?
6.4 When do we decide it is operational?

Topic 7: Recommendations

List of specific recommendations made by the group for future uses and development of the EVI.

Topic 8: Written submissions

A report on the proceedings of this Think Tank will be produced by the SOPAC team (this document). This will include a description of the proceedings and summary of the decisions taken in the discussions above, followed by written submissions received from participants. The latter will be included under your authorship. We need these submissions before you leave the meeting as we are under very tight deadlines for the report. If these are in draft form because you need access to your office to obtain references, examples etc., we will be happy to receive your final version by e-mail later. We would like to receive all final submissions within 2 weeks of the end of this meeting.

8.1 Are there any other concerns or issues you wish to raise or think we need to address?
8.2 We need help with writing the indicator questions. Please provide any changes, new maxima or minima and mapping for indicators in your area of expertise. If you have additional indicators, please provide these complete with all details of scaling and weighting and possible sources of the data within a country.
8.3 Any comments on the mathematical approach?
8.4 We have built into the index data of different qualities. Responses to the indicators can be given based on “best guess” or as information based on real data. These do not change the value of the index, but the proportion of responses based on each is reported with the index value giving the user a chance to evaluate their confidence in the index (much like a mean reported with its variance). Do you wish to comment on this?
8.5 Comments on the strengths and weaknesses of the index as it stands now.

3 Results

All of the discussion topics designed for the Think Tank were covered during the discussions, with resolution reached for most. For some of the topics, however, agreement could not be reached within the four days and a longer discussion will be carried out between participants and the EVI team over the months that follow. It is expected that during that time definitional issues will be resolved and the indicators list will be finalised.

3.1 Changes to the EVI in brief

The EVI model can be divided into two parts:

- **The framework** which consists of the logical approach and mathematical model for calculating the index describing vulnerability of the environment; and
- **The indicators** including their specific mapping on the 1-7 scoring scale and their weighting (importance) in relation to the overall model.

3.1.1 Changes to the framework

The framework originally designed by SOPAC was generally accepted by the group during the Think Tank. There were, however, several changes or areas in which additional work would be required that were suggested by the group. These were relatively minor changes to the model and can be incorporated in the updated EVI immediately:

1. The definition of “environment” to which this EVI pertains needs careful consideration. Several of the experts felt that the EVI should not just describe the vulnerability of the natural environment, but that it should also capture vulnerability of the human environments of states (note that this suggestion would work against SOPAC’s initial brief for constructing the EVI);
2. Scoring of indicators should be on a scale of 1-7, not 0-7;
3. For yes/no answers, scoring should be less extreme than suggested by SOPAC. Instead of selecting the extremes of 1 and 7 for yes and no, the scale should be moderated to 2 and 6;
4. The idea of nett and gross vulnerability should be dropped, with only gross being calculated (note that two participants disagreed with this);
5. Indicators which are not applicable should be scored as a 1 on the mapping scale;
6. Although it is useful to continue to refer to all indicators as being either a measure of risk (REI), intrinsic resilience (IRI) or extrinsic resilience (EDI), the group decided that only two sub-indices should be calculated. These would be the REI and RI which would be termed the Risk Exposure sub-Index and the Resilience sub-Index, respectively. The RI would be composed of the old Intrinsic Resilience Index and the Environmental Degradation Index from the original EVI study;
7. The overall EVI should be calculated across all indicators irrespective of which sub-index they belong to;

8. Mathematical testing of the model was recommended by the group. This would include several considerations: (i) at least two methods for aggregating the scores obtained for each indicator into an index should be examined using the data from at least 15 countries (averaging as in the original EVI and the Villa modification of the Storie Index (Villa, 1995)); (ii) an independent test of the usefulness of the EVI should be made by deploying a group of uninitiated experts who would rank the test countries in terms of environmental vulnerability. Their rankings would then be compared with the EVI scores. For the EVI to pass this test, the difference between the EVI score and the mean of the group of experts should be no more than the difference among the experts themselves; (iii) a sensitivity analysis; and (iv) The states used for testing should represent the extremes across the globe, including for example, Greenland and Switzerland to contrast against SIDS.

3.1.2 Changes to the indicators

The largest and most important changes to the EVI occurred, as expected, in relation to the indicators. These were:

1. Indicators should be global to provide a context for the EVI value obtained for any single country;
2. Many of the original indicators were replaced with new indicators by the experts relevant to the field;
3. The total number of indicators was reduced from 57 to 47 though this figure is not final and may move up or down with further refinement;
4. The list of criteria for selecting indicators was revised;
5. The mapping of the indicators on the 1-7 scale will be done by the appropriate individual experts;
6. When data from 15 countries are available, indicators will be examined for redundancy using correlation techniques. It may be possible at that stage to eliminate further indicators from the model;
7. It was decided that the indicators needed a better weighting system than initially suggested by SOPAC. The weighting of indicators will be examined when data for 15 countries are available. One of two methods suggested by two of the participants will be used to apply weightings after experts assign relative importance values to each indicator. This has to be done in the context of information on correlations between indicators obtained from the 15 test countries.

It should be noted here that the changes in the indicator questions suggested by the group must remain provisional until it can be ascertained whether data will be available for each and whether there are still redundancies.

3.2 Detailed description of the up-dated EVI

3.2.1 What is environmental vulnerability?

Vulnerability is the potential for attributes of a system to be damaged by exogenous impacts and resilience is the potential to minimise or absorb the effects of these damaging impacts. The aim of vulnerability indices is to describe the relative vulnerability of states. Different forms of vulnerability of states have been identified. For example, economic vulnerability is concerned with external forces which act on the economy, while social vulnerability occurs when natural or other disasters force massive upheavals of residence, traditions and society.

The focus of the EVI is on vulnerability of the environment itself to both human and natural hazards. This includes effects on the physical and biological aspects of ecosystems, diversity, populations or organisms, communities and species. Unlike previously-developed vulnerability indices, human impact is considered an exogenous factor, and human systems not the recipients of the impact.

Environmental vulnerability differs from vulnerability of human systems because the environment is complex with different levels of organisation from species to interdependent ecosystems and the complex linkages between them. Data are often not available and indicators for health and vulnerability of the environment have to be physically measured. Indicators may be heterogeneous in nature and not expressible in common units. This means that developing an index for the environment needed a new approach which relies largely on proxy indicators that may have different units of measurement and which would have to be mapped onto an artificial scale to allow for comparisons.

3.2.2 Purposes of the EVI

The purposes to which the EVI could be put include:

- Determination of Least Developed Country (LDC) status;
- State of the Environment (SOE) reporting (though the EVI is not an expression of the SOE, but an expression of its vulnerability to future hazards, it would be useful in the context of SOE because it would identify mechanisms which tend to degrade the state of the environment);
- Has predictive value for identifying the types of hazards and approaches to stewardship of the environment of a state;
- Would be a useful sustainable development tool;
- Could provide a performance indicator for aid;
- Provides a tool for identifying problem areas for internal intervention and external assistance.

3.2.3 Definitions

The EVI is a numerical indicator that reflects the status of a country's environmental vulnerability, where:

- "Environment" includes those biophysical systems that can be sustained without human support (note that the Think Tank participants were divided on the question of whether the "environment" of interest for the EVI included only natural systems or whether the definition should be broadened to include human systems. Although a slight majority of participants voted that human systems should be included, we have excluded them here because the brief was for an EVI of natural systems and the indicators incorporated so far do not attempt to measure vulnerability of human systems);
- "Vulnerability" is the extent to which the environment is prone to damage and degradation; and
- "Damage" is the loss of diversity, extent, quality and function of environments.

The definitions given here are pragmatic and only to be used for the purposes of the EVI.

3.2.4 Theoretical framework for the EVI

The maintenance of ecosystem or ecological integrity is at the heart of the development of a vulnerability index for the environment, because it is ecosystem integrity that is threatened by natural and anthropogenic hazards. The notion of ecosystem integrity is so complex that it cannot be expressed through a single indicator, but rather requires a set of indicators at different spatial and temporal scales and hierarchical levels of the ecosystem. Ecosystem integrity depends on biodiversity, ecosystem functioning and resilience, all of which are such interrelated variables, that factors which affect just one of these can have far-reaching ecosystem-wide consequences.

The risks to the environment are any events or processes that can cause damage to ecosystem integrity. These include natural and human events and processes such as 'the weather' and 'pollution'. Some researchers have identified natural hazards as those in which natural environmental conditions depart from 'normal' to such an extent that systems of interest (human, environmental) may be adversely affected. The problem with this definition is that unless we identify certain natural events as being anthropogenically altered (e.g. anthropogenically-accelerated sea-level rise), all events are 'normal'. The implication from this line of reasoning is that the changes we see to the natural world as a result of natural hazards are deemed 'unacceptable' from a human perspective. This means that except in the case of anthropogenic risks, in an assessment of environmental vulnerability, what we really are examining is unacceptable departures from our (human) view of how the environment should change. For the purposes of this study, we will accept that risk events should include those which cause sudden and seemingly-negative impacts on natural systems as a way to evaluate vulnerability.

Although most identifiable risk events are capable of causing damage, it is only the larger and more intense events that are likely to cause wholesale changes in the environment, at least in the short to mid-term. Some of the more important risks which can impact on the environment include meteorological events (e.g. cyclones, droughts, heatwaves, floods, tornadoes), geological events (earthquakes, tsunamis, volcanoes), anthropogenic impacts (mining, habitat destruction, pollution), biological events (plagues, blooms), climate change and sea-level rise.

The entities at risk, termed the 'responders' include ecosystems, habitats, populations and communities of organisms, physical and biological processes (e.g. beach building, reproduction), energy flows, diversity, ecological resilience and ecological redundancy.

Three aspects of environmental vulnerability were identified which would need to be incorporated into an EVI. These are:

1. The level of risk to hazards which act on the environment within a state This relates to the frequency and where possible, the intensity of hazardous events which may affect the environment. These are based on levels observed over the past 5-10 years for most hazards, but may include data for much longer periods for geological events. These indicators measure potential risk only: There is no logical expectation that patterns of risk expression during the immediate history of a state will necessarily result in similar risk levels today or in the future;
2. Intrinsic resilience of the environment to risks refers to characteristics of a country which would tend to make it less/more able to cope with natural and anthropogenic hazards; and
3. Extrinsic resilience results from external forces acting on the environment and describes the ecological integrity or level of degradation of ecosystems. The more degraded the ecosystems of a country (as a result of past natural and anthropogenic hazards), the more vulnerable it is likely to be to future risks.

These three aspects of vulnerability form two sub-indices for the EVI as follows:
REI = Risk Exposure sub-Index incorporates measures of the level of risk to hazards; and
RI = Resilience sub-Index incorporates measures of intrinsic resilience + extrinsic resilience which describe how the environments of a country might be able to resist damage from hazards.

3.2.5 Methodology: sub-indices and the indicators

Because the risks are many and ecosystem resilience and integrity are complex in character, it was necessary to use a set of indicators to characterise them. This means that not all aspects were covered, but that a subset of variables was selected which describes frequency and intensity of risks, intrinsic resilience, and the health of ecosystems, organisms, physical features of the environment and mitigators of effects.

For the purposes of the EVI the following definitions relating to indicators and indices were used:

- An **indicator** was defined as any variable which characterises the level of risk, resilience or environmental degradation in a state;
- The **sub-indices** (the REI, RI) were defined as an aggregated average of the scores for indicators which relate separately to risk, and intrinsic resilience / degradation; and
- An **index** (the EVI) was defined as an aggregated average of all indicators regardless of the sub-index to which they belong, to give an overall measure of the environmental vulnerability of a state.

The criteria for the selection of indicators were that they:

- Should be applicable globally;
- Would have data that were available or easily obtainable;
- Should be likely to measure change or be a proxy for change which would do significant harm to the environment;
- Should be independent of the source of change;
- Could not be selected on any political criteria but relate only to environmental vulnerability;
- Could be weighted to reflect the probability of change to the environment and the amount of damage which might be done;
- Should be relatively easy for users to understand;
- Be well-defined;
- Be as uncorrelated with each other as possible to limit redundancy.

A total of 47 indicators of environmental vulnerability were finally selected for inclusion in the index. This included 27 indicators of risk (REI), 7 indicators of intrinsic resilience and 13 indicators of environmental integrity or degradation (the latter two forming the RI). Many of the indicators were expressed as a fraction of area of land rather than absolute numbers because it is risk density or proportion of area degraded that is of interest from an environmental perspective. A summary table of the indicators selected is provided in Table 1 below, with a more detailed description of the purpose for selecting it in Appendix 6.2.

Table 1: List of the indicators selected by the Think Tank group for inclusion in the EVI.

The indicators are classified into 5 categories (M = Meteorological, G = Geological, B = Biological, CC = Country Characteristics and A = Anthropogenic). Provided with each indicator is a new reference number; the old indicator number referring to its reference number either in Kaly et al (1999) or during development at the Think Tank; and the sub-index to which the indicator belongs. The final list of indicators were categorised by the Think Tank participants in terms of their perceived importance so that preliminary weightings could be assigned. Participants were asked to score each indicator with a value of between 0 and 4, where 0 showed the lowest level of importance (to be discarded) and 4 the highest. The results of this weighting exercise are shown in the 4 last columns of the table; as suggested weighting (L = low, M = Medium, H = High); Mean and Standard Deviation (SD) of weighting values assigned, and the frequency of 0 values assigned, f(0). Data were collected from 21 participants.

New Indicator #	Old Indicator #	Sub-Index	Category	Indicator	WT Proposed	Mean WT	SD	f(0)
1	1	REI	M	Greatest average annual deviation in Surface Sea Temperature in last 5 years from long term mean (30 years) (more work required to finalise form) (Centralised database)	M	2.48	1.12	1
2	4	REI	M	% of reference climatological stations experiencing >= 1/100 yr. 3 second wind gusts in a 5 year period / land area	M	2.48	1.25	1
3	3	REI	M	% of reference climatological stations experiencing <= 1/100 yr. minimum annual rainfall in a 5 year period / land area	M	2.35	1.18	1
4	2	REI	M	Cum # of 24 hr periods over all Reference Climate Stations over last 5 years during which rainfall is >= 1/100 yr. (1/50, 1/20 ?? Less?) event / stations	M	2.14	1.15	1
5	6	REI	M	% of reference climatological stations experiencing >= 1/100n yr. daily max temp in a 5 year period	M	2.10	1.18	1
6	5	REI	M	% of reference climatological stations experiencing <= 1/100 daily min temp in a 5 year period / land area	M	2.05	1.16	1
7	10	REI	G	Number of volcanoes with potential for eruption >= VEI 4 (Volcano explosivity Index) within 100km of country land boundary / area of land	M	2.10	1.18	1
8	8	REI	G	Earthquake energy within 100km of country land boundaries / land area with ML >=6.0 and <=15km depth per 5 years	L	1.95	1.32	2
9	9	REI	G	Number of tsunamis or storm surges with run-up >2m above MHWS / 100km coastline since 1900	L	1.95	1.24	2
10	40	IRI	CC	Total land area (sq. km)	H	2.71	1.45	2
11	41	IRI	CC	Ratio of length of ocean shoreline : total land area	H	2.62	1.32	1
12	69	IRI	CC	Distance to nearest continent (km)	L	1.90	1.09	0
13	70	IRI	CC	Altitude range (Highest point – lowest point in country)	M	2.19	1.08	1
14	43	IRI	CC	Percent of land area <10m above sea-level	H	2.57	1.16	0
15	44	IRI	CC	Land area below 10m elevation with unimpeded access to the coast composed of unconsolidated sediments (excluding coral reefs and ice) / land area (%)	M	2.00	1.22	2
16	42	IRI	CC	Number of known endemic species / 10,000 sq. km land area	H	2.52	1.17	1
17	53	REI	B	Number of catastrophic organism outbreaks over the last 5 years / land area (pathogens, blooms, plagues etc)	M	2.29	1.10	0
18	59	REI	B	Total tonnage of freight imported / year	M	2.05	1.20	1
19	57	EDI	B	Number of all introduced species / 10,000 sq. km land area since 1900	M	2.14	1.42	3
20	56	EDI	B	Number of endangered & threatened species / 10,000 sq. km of land area (IUCN definitions)	H	2.76	1.18	1
21	55	EDI	B	Number species which have become extinct since 1900 / 10,000 sq. km land area (IUCN definitions)	H	2.71	0.85	0

22	48	EDI	B	Percentage of natural & regrowth vegetation remaining (e.g. forests, mangroves, saltmarshes, prairies, savannah, desert, tundra)	H	2.67	1.43	2
23	51	EDI	B	Tonnage of intensively-farmed animal products / yr. / land area	L	1.81	1.08	2
24	49	EDI	B	Percent of fisheries stocks overfished (FAO)	H	2.57	1.03	0
25	47	EDI	A	Density of people living in coastal settlements (define area)	H	2.57	1.12	1
26	38	REI	A	Total human population density (per sq. km land area)	H	3.57	0.75	0
27	37	REI	A	Annual human population growth rate (average over last 5 years)	H	2.90	0.94	0
28	62	REI	A	Net percentage of land area changed by the removal of natural vegetation over last 5 years	H	3.00	1.14	1
29	39	REI	A	Annual number of international tourists * average days stay / 365 / 100 sq. km (last 5 years)	M	2.05	1.16	1
30	65	REI	A	Megalitres of untreated industrial and domestic wastewater discharged to aquatic system / 1,000 km aquatic ecosystems (length coast + length rivers)	H	2.62	1.28	1
31	29	REI	A	Total tonnage of generated and net imported toxic, hazardous & municipal wastes/ 10,000 sq. km land area / year (average last 10 years)	M	2.00	1.14	0
32	67	REI	A	Mean percent of industrial and municipal waste managed or treated / yr.	L	1.95	1.16	2
33	32	REI	A	Number spills of oil and hazardous substances >1,000 litres during last 5 years within territorial waters	L	1.71	0.85	0
34	31	REI	A	Number of nuclear, chemical and other major industrial facilities that could cause significant damage / 10,000 sq. km land area	L	1.71	0.96	0
35	34	REI	A	Number of cars / land area	M	2.38	0.97	0
36	30	REI	A	Max 24 hour SO_2 concentration (micro g /cubic m) (average over last 5 years)	M	2.33	0.86	0
37	14	REI	A	Tonnes of N,P,K fertilisers used / 10,000 sq. km agricultural land area / year (average last 5 yr.)	L	1.90	0.82	0
38	13	REI	A	Tonnes of pesticides used / 10,000 sq. km of agricultural land / year (average last 5 years)	L	1.86	0.84	0
39	66	REI	A	Number of new fisheries species added to country over last 5 years (within territory)	L	1.62	1.02	2
40	64	EDI	A	% Land area degraded since 1950	H	3.10	1.14	1
41	71	EDI	A	Question on importance of water…?	H	2.60	1.35	1
42	28	REI	A	Kilotonnes of mining material (ore + tailings) extracted / 10,000 sq. km land area / year (average last 5 years)	L	1.29	0.64	1
43	54	EDI	A	Land and sea area affected by mining & quarrying / land area	L	1.71	1.10	2
44	25	EDI	A	Percent of terrestrial zone set aside as reserves	M	2.29	1.10	0
45	22	EDI	A	Percent of marine zone set aside as reserves (mean high tide to continental shelf)	L	1.90	1.22	2
46	58	EDI	A	Number of war or civil strife years over the last 50 years within the territory	M	2.05	1.20	3
47	23	REI	A	Environmentally related legislation with regulations				

Several indicators initially selected were discarded because they either did not have data available and data were unlikely to be procured in the near future, they were ambiguous or bimodal in their responses; or were redundant and the information they intended to capture was present in another indicator. A list of discarded indicators is provided in Appendix 6.3.

Some of the data required for calculating the EVI, to set the response levels of each indicator and to test the model have already been collected for several countries: Vanuatu, Samoa, Fiji, Tuvalu and Australia. These data were obtained by visiting the some of the countries to work with local authorities and from country reports, UN, WHO, SOPAC, SPREP, FAO and other publications from international agencies, centres for risk assessment and management (e.g. Tsunami Centre, NOAA), local experts and government officers. Additional data are now required to provide the information necessary for new indicators added to the model by participants to the Think Tank.

For full testing of the EVI model, it will be necessary to obtain data for 15 countries from around the globe. These countries should represent the extremes of environmental conditions and are required to globalise the EVI. Even if the EVI is initially only to be applied to SIDS, it is necessary to globalise it from the start, since it is only in the context of the entire world that the vulnerability of any state can be assessed.

3.2.6 Quantifying vulnerability

The overriding principle in constructing the EVI was not to introduce complexities into the model unless there was a justifiable reason to do so.

Environmental indicators are of a heterogeneous nature, that is they include variables for which the responses are numerical, qualitative and on different scales (linear, non-linear, or with different ranges). To deal with the heterogeneity, it was necessary to map the possible responses to the indicators onto a 1-7 scale. Where data were not available, no value was given for the indicator and the denominator of the average adjusted down by 1 value. Where an indicator was considered 'non-applicable' in a state (such as volcanic eruptions in Tuvalu which has no volcanoes), the lowest vulnerability score of 1 is attributed to that indicator.

Mapping on the 1-7 scale for each of the indicators is to be set wherever possible using the experts who attended the Think Tank. The remainder will be set using the technical literature or by consultation with other generalists and specialists in each field. At the conclusion of the Think Tank only some of the indicators had been assigned values on the 1-7 scale, the remainder will be defined fully over the next few months.

Appropriate weighting of the EVI indicators was considered important by the participants at the Think Tank. The purpose of this weighting was to identify those indicators which were most important to the measurement of vulnerability and ensure that the signals they contributed to the EVI were larger than less important indicators. In the original EVI, six of the 57 indicators were assigned an intrinsic weighting factor of 5, while the remaining indicators were given the default weighting of 1. At the Think Tank, the 47 indicators were rated in terms of relative importance by participants and a simple weighting scale involving 5 weighting categories suggested. However, it will be necessary to repeat the process of assigning weightings (and therefore relative importance of indicators) once correlations between indicators have been identified.

The EVI and sub-indices will be calculated using an EXCEL workbook. The workbook (Version 8-EVI-calculator.xls) is comprised of seven linked worksheets, each dealing with a different aspect of calculation and reporting. Report Level 1 is the highest, and gives the value of the EVI and sub-indices for each country and measures of confidence in the data. Report Level 2 gives a breakdown of the REI and RI sub-indices showing the relative contribution of meteorological, geological, biological, and anthropogenic signals as well as country characteristics. Report

Level 3 gives the scores for each individual indicator. A separate copy of the calculator is required to evaluate the vulnerability indices for each country.

After adjustment for weighting (which does not vary by country), the scores for each indicator within a sub-index are averaged to produce a sub-index value of between 1 and 7. Where data are unavailable for an indicator, that indicator is to be omitted from the average, so that it makes no contribution to the mean. At least 80% of the indicator questions have to be answered for a valid EVI to be calculated for a state.

In parallel with scoring each indicator against the 1-7 scale, the EVI model incorporates a way of assessing the reliability of data. These reliability values are reported alongside each index and should be read with them. The data reliability scores give the number indicators for which data are not currently available, the number of responses which are based on real data; and the number of responses based on 'best guess' or estimated by the operator and/or authorities.

Although some initial testing of the EVI was carried out by SOPAC on Tuvalu, Fiji and Australia (Kaly et al, 1999), it will now be necessary to extend data collection to 15 countries before full testing can be completed. The initial results from the three countries tested so far (see Kaly et al. 1999) show that the EVI model gives single-figure measures of environmental vulnerability that appear to be able to distinguish countries and can identify sources of vulnerability within a country.

3.2.7 Strengths and weaknesses of the EVI

As for all methods of summarising and modelling data, the EVI developed here is associated with a number of strengths and weaknesses which must be understood for its proper application and use. The Think Tank participants identified a set of strengths and weaknesses that have been added to those compiled by the SOPAC team.

The strengths of the EVI have been identified as follows:

- It is the first comprehensive and convenient measurement of environmental vulnerability;
- Permits comparisons among countries;
- Identifies a number of indicators which describe the features of risk and resilience for a country;
- Can be used as a measure of change in environmental vulnerability;
- Can be used to identify in-country vulnerability and therefore areas of major concern;
- Stimulates debate at the science / policy interface at national and international levels and amongst disciplines;
- It is able to incorporate quantitative and qualitative data on different response scales and non-linearities;
- Is globally applicable;
- Could be used for awareness-raising;
- Indicators and weightings chosen by a panel of international experts;
- Differences in interpretation of users can be minimised by training;

- Has been designed with a set of validation tests to be performed and criteria to be met before it is passed over to be used by decision-makers;
- Is based on a theoretical framework that prompted the EVI team and expert panel to find indicators for all identified aspects of vulnerability;
- Identifies areas of environmental concern which could provide a focus for new or improved data collection.

The weaknesses of the EVI were identified as follows:

- There is subjectivity in assigning weights to indicators and non-linearities to the scores (as in other indices);
- Some complex environmental factors have been represented by proxy indicators because they could not be measured directly;
- The EVI is affected by the indicators chosen and the results obtained may differ if different variables were chosen;
- The method of aggregating the indicator scores does not allow for the contribution of a variable to be conditional on, or amplified by another variable (e.g. feedback, multiplicative or inhibitory effects). That is, it assumes a non-interactive system;
- The EVI is subject to problems with differences in the interpretation of users, although this could be minimised with training;
- Some of the data may be difficult to obtain.

In addition to the above lists of strengths and weaknesses, users of the EVI will need to be aware of the following conditions whilst using the index:

1. The EVI emphasises short term environmental change, rather than longer term trends;
2. It does not address climate change and sea-level rise because it is an ‘instantaneous’ expression of vulnerability, describing the risks to and resilience of the environment of a state now, rather than attempting to predict impacts expected in the future (it is not a state of the environment statement or an impact assessment);
3. Some local variations, short and long term effects and other details could not be incorporated into the model without making it too complex.

4 Future Directions and Recommendations

4.1 Testing and procedures required for making the EVI operational

The Think Tank group identified a range of tasks that need to be completed in order to operationalise the EVI. These include improvements in the model and refinement of the indicators (including mathematical testing), peer and user reviews and logistic arrangements.

4.1.1 Improving the model

The main procedures for improving the EVI model or framework suggested by the Think Tank participants were to:

1. Calculate the EVI for a range of countries so that tests of its ability to summarise the environmental vulnerability of states can be undertaken;
2. Ensure that countries used in testing represent the global extremes so that testing covers all of the expected spread among countries;
3. Undertake independent ranking of countries by experts to demonstrate that the EVI is concordant with the aims, is useful for the purposes for which it was designed and provides the information required in an efficient manner;
4. Carry out a sensitivity analysis;
5. Ensure that the vulnerability breakdown (sub-indices and groupings into Meteorological, Geological, Biological, Country Characteristics and Anthropogenic signals) and profiles are logical and accompanied by diagrams to assist users in their interpretation;
6. Test alternative methods for accumulating indicator scores into the final EVI value.

By the end of the Think Tank, two methods of accumulating scores into the EVI had been considered. The first was *status quo*, where scores for individual indicators were accumulated as averages to produce the final index. A second method was suggested by F. Villa which is a modification of the Storie Index (Villa, 1995). This is a non-linear aggregation method which will tend to highlight differences among countries at the high end of the vulnerability scale (EVI scores close to 7). This could provide a useful way of more closely examining relative differences among highly vulnerable countries while tending to be less sensitive at distinguishing countries which are not very vulnerable. This makes operational sense since it is the more vulnerable countries that we are most concerned about at the single figure level. Using this technique would not affect profiles, so that internal identification of problem areas would still be effective for all countries. Both of these methods of accumulation could be tested as part of the process of improving the EVI model.

4.1.2 Refining the indicators

The list of indicators as it stands now requires a lot of work. Many of the original indicators were discarded, and the new ones suggested by the participants of the Think Tank are incomplete because of limited time available at the meeting. It is now necessary to refine the indicators before the EVI can once again become functional and testable. This is expected to occur over the next few months through consultation with the experts who attended the Think Tank and others. The main tasks which will be required are:

1. Complete the operational definitions for those new indicators that have not been fully defined;
2. Locate sources of data for each indicator;
3. Identify data which will need to be collected in the future and determine whether any of these can be taken up by global data-collection organisations;
4. Set the scaling for each indicator in the global context (this will require collecting data for countries at the global extremes);
5. Test indicators for redundancy (i.e. correlations among them);
6. Finalise the weightings for indicators in the context of their degree of correlation with other indicators in the model.

No data exist which can be used to weight indicators using ecological criteria. That is, we do not know which hazards and effects are most important in determining the vulnerability from an environmental perspective. As is common practice, it was therefore agreed at the Think Tank that indicators would be weighted in terms of their perceived importance by the experts assembled at the meeting. Two methods of weighting indicators were suggested.

The first of these, suggested by L. Briguglio, consisted of simultaneously ranking all 47 indicators with an importance rating of between 0 and 4. Indicators receiving a score of 4 were considered by a participant to be of top importance in measuring vulnerability. Indicators which were considered unimportant were given a score of 1, and so on. The score 0 was reserved for indicators thought by a participant to be irrelevant or redundant and which should be removed. This method of weighting was used during the Think Tank, and the preliminary results reported in Table 1.

The second method, suggested by F. Villa, consisted of pair-wise ranking of each indicator against all other indicators. This method requires the ranker only to assess whether one indicator is more important than another at any one time. It is not necessary to remember the ranking given to any other indicator whilst carrying out this procedure. The resultant pair-wise ranking matrix is then analysed simultaneously for all rankers (experts), and clusters of indicators of more and less relative importance identified. Each of the clusters would then be assigned a weighting to be applied to the indicators it contains.

Either of these two techniques for weighting could be used for refining the indicators once the question of correlations has been addressed.

4.1.3 Peer and user reviews

It was considered important that the EVI remain under constant review during its development. The main mechanisms for review include publication of the EVI and presentation at international meetings. The main outcomes of review would be the:

- Development of a stable list of indicators in association with experts and within the context of data availability;
- Acceptance of the indicators by nationals as useful and non-threatening mechanisms for describing the environmental vulnerability of states; and
- Acceptance of the EVI by donors.

4.1.4 Logistics

The main logistic considerations for the continued development of the EVI are in locating funds for data collection and testing, training and testing operators, identifying sources of data to simplify the task of calculating the index and dealing with pragmatic problems associated with the global nature of the index.

It is likely that the development of the EVI will take about two years to complete. During that time it will be necessary to collect data for 15 test countries and send experts out to 5 countries for validation information. It is also expected that the Think Tank participants would need to reconvene to discuss the results of testing and adjust the model if necessary. These procedures require sources of funding to ensure that the EVI is efficiently and successfully completed and suitable for the task for which it is being developed.

The EVI will need to be calculated in-country before it is reported to the international community. To ensure that it is comparable across countries, it will be necessary to undertake capacity-building, including the training (and testing) of operators. The sources of data for each indicator will need to be identified, and where possible, international data-collection authorities (e.g. GEF) mobilised to simplify the task.

In order to simplify the calculation of the EVI, practical considerations such as translation of the documentation and model need to be considered. It will be important to ensure that the model is presented in a user-friendly computerised interface with graphical outputs and help screens so that the task can be streamlined.

4.2 Criteria for deciding on when the EVI is operational

A list of three criteria was developed to provide guidance to experts, funding agencies and the international community on when the EVI would be technically ready for use. This list is important because it provides an independent 'finishing line' for the procedures described in Section 4.1 above. It ensures that appropriate milestones can be developed and a completed EVI identified in relation to the funding that will be required to complete the work.

4.2.1 Criterion 1: Redundancy among indicators

The data for 15 states need to be collected so that redundancy among indicators can be identified if they exist. It was agreed during the Think Tank that at least 15 countries with widely ranging characteristics would need to be included in this test. Any indicator with a high correlation with one or more other indicators would at this stage be dropped or merged. The final list of indicators would then only consist of those which bring significantly new information into the EVI value. The final weighting of indicators can only occur after redundancies in the model have been limited.

Test: When the correlation coefficient among two indicators is non-significant in a standard statistical test.

4.2.2 Criterion 2: EVI scores for a range of country types

The EVI scores need to be evaluated for at least 15 countries with widely ranging characteristics to examine how well the model provides the spread required to distinguish them. The countries included in this test (same as for criterion 1) should include small islands, large continental masses, highly-fragmented countries, land-locked states, tropical and cold climate countries and deserts. The EVI should be able to cluster similar countries together and provide spread among countries which are very different. The response scales for each of the indicators (which is the mechanism in the EVI which provides the spread) can be finalised when data for these 15 test countries are available.

Test: When the spread in EVI values among the 15 test countries occupies much of the 1-7 range expected and countries considered *a priori* to be 'similar' cluster closer together than 'dissimilar' countries.

4.2.3 Criterion 3: Validation

The purpose of constructing an EVI is to simplify the task of categorising countries according to their relative environmental vulnerabilities. If personnel, funding and time were unlimited, this could be done by sending several independent teams of scientists to each country and commissioning them to carry out a vulnerability assessment for each. The replicate assessments for each country could then be used to classify countries in terms of their vulnerability. This exercise would of course be extremely expensive and it is one of the purposes of the EVI to simplify this process.

However, the only independent means of assessing the effectiveness of the EVI in carrying out this task in a simplified way, is to compare the results of the EVI with a full assessment for a small number of, say 5, countries. Several teams of experts would have to be mobilised in each of the test countries to provide a 'mean assessment' for each. The consultants involved should be unaware of the mechanics of the EVI to ensure that they do not unintentionally bring bias into the results. These assessments could then be compared with the EVI scores obtained.

Test: When the difference between the value obtained by the EVI and the mean of the assessment provided for a country by several experts (who are unaware of the workings of the EVI) is about the same, or less than, the spread found among the assessments of the experts. This test should be performed for about 5 countries.

4.3 Issues requiring resolution

Two main issues arose during the Think Tank that will require on-going discussions before they can be resolved. The first of these, concerning the issue of whether the EVI should only be concerned with the natural environment, or whether it should also include the human environment of states, was unexpected. The EVI described in this document and in Kaly et al (1999) has been designed only for the natural environment of states, and as such, our operational definition of 'environment' for the EVI has not been expanded at the time of this report to include human systems. This decision is in keeping with the original brief given to SOPAC by NZODA to construct an EVI for the natural environment. It is expected that this debate will continue and several of the written submissions in Appendix 6.4 are concerned with this question.

The second issue not resolved during the EVI was entirely expected. This concerns the precise definition, scaling, weighting and testing of indicators for the EVI model. Insufficient time and access to resources were available during the Think Tank, and the process of stabilising the list of indicators is expected to take some months of discussion and consultation with Think Tank participants and other experts.

4.4 Recommendations

1. The Think Tank participants considered the question of whether the EVI should be a stand-alone figure or a composite one with economic or other human indicators, but did not take a strong stand in either direction. They did suggest, however, that the EVI would be *useful* as a stand-alone index.
2. The EVI needs to be entirely global. Even developing it for SIDS (small island developing states) has to be done in the global context, because it is only in contrast to the global environments that vulnerability of any single state can be assessed.
3. The EVI should be considered at the next CDP session (Commonwealth Secretariat, Commission for Development Planning) when indicators for classification of Least Developed Countries (LDC's) come under review.
4. There was expressed a need to develop an index which incorporates the human environment. This would be a vulnerability of human quality of life index and its content would be focused on direct impact of hazards on humans.
5. The EVI model should now be published in an international peer-reviewed journal.

6. The EVI should retain its ability to describe country profiles at the same time that it summarises them into a single figure index. The Think Tank participants felt that a written assessment should accompany the three levels of reporting already incorporated into the EVI (index, sub-indices and responses for individual indicators).
7. The process of peer review begun during the Think Tank should be continued in the future.
8. The EVI Think Tank should be reconvened at a later date to critically review the work done and direct refinements.

4.5 Conclusions

The overall outcomes of the Think Tank were that the EVI as being developed by SOPAC is a viable tool for characterising the vulnerabilities of states. The approach taken so far has merit, and with some changes suggested by the Think Tank participants and mathematical testing, the EVI can become a globally-applicable tool.

The biggest concern expressed by the group at the Think Tank was on whether the EVI should be limited to natural environments, or whether it should be expanded to include human environments of a country. This issue is still unresolved. SOPAC's initial mandate was to construct an EVI for natural systems and it appears that incorporating human systems may lead to internal conflicts in the model. In any case, the EVI for natural systems can function as an effective proxy for human systems. The original premise was that the reason for calculating the EVI was because human systems are ultimately dependent on natural ones for goods, services and support. The arguments raised for and against including human systems require further debate.

5 Literature Cited

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6 Appendices

6.1 Summary record of discussions at the Think Tank

DAY 1 Tuesday 7th September

Chair: Alfred Simpson

Alfred Simpson, Director of SOPAC, welcomed everyone and introduced Nik Kiddle, Acting NZ High Commissioner. The meeting was then officially opened by Nik Kiddle. The opening was attended by HE Mr Enele Sopoaga, Tuvalu Ambassador, HE Mr Gadaro Gallen, Federated States of Micronesia Ambassador and HE Mr Babani Maraga, Papua New Guinea Ambassador.

After morning tea, the session was chaired by Alfred Simpson. Participants introduced themselves and their areas of expertise for the think tank. This was followed by a brief background presentation by Professor Lino Briguglio introducing the issue of vulnerability, the work done in other fields (such as economic vulnerability) and the international call to create a vulnerability index for the environment. Dr Ursula Kaly presented the work carried out to date on the Environmental Vulnerability Index developed by SOPAC.

After a short break, the objectives of the think tank were presented by Dr Kaly. During this time, she emphasised that the meeting should focus clearly on solving technical issues relating to the EVI and not concern itself with the political processes.

Topic 1: General discussion and definitions
Definition of "Environment"

The following interim definition was agreed upon by the group. This was to be revised during later discussions when other issues had been examined: The "environment" of concern for the EVI included those "Biophysical systems that sustain all living organisms and that can be sustained without direct human support, but which may be affected by contemporary human activity".

A main part of this discussion revolved around the question of whether humans can be removed from the environment and be considered as an external risk factor. Several experts considered the removal of people from the system to be rather arbitrary. It was decided that clear boundaries would need to be set for the purposes of the EVI. It was accepted that human welfare is dependent upon environmental health. This meant that environmental vulnerability is ultimately of interest to humans, because any damage to the environment would lead to reduced human welfare. It was therefore considered logical to focus on measuring risks to the environment and health of the environment and not the direct effects on humans.

The EVI is intended to complement other indices and not to repeat the information within those indices already in existence. This was one of the arguments for excluding humans as responders. It was also pointed out that human value is implicit in the EVI, therefore although humans are excluded as responders, indicators have been selected taking into account the value that humans place on the environment.

<u>1.1 Definition of "Environmental Vulnerability at the National Level ":</u>

During the discussion, the following three definitions were proposed. These were to be revised following more detailed discussion on the indicators (Topic 3):

1. "Vulnerability at the national level is the potential for those attributes of a state's environment which are valued by humans to be reduced by hazardous events or processes of degradation."
2. "Vulnerability at the national level is the extent to which the environment is prone to damage."
3. "Vulnerability at the national level is defined as the potential for attributes of the country's environment to respond adversely, as valued by humans, to the occurrence of hazardous events and/or processes" (modified from Kaly et al. 1999, page 12).

<u>1.2 Definition of "Environmental Vulnerability Index"</u>

The provisional definition proposed during this discussion was: "Numerical indicator that reflects the status of the country's environmental vulnerability (and resilience)." The group had still to agree on the final version of this definition.

<u>Discussion Topic 2: Sub-indices</u>
<u>2.1 What are the most important risks to the environment? Which can be immediately excluded?</u>

Risks relating to biotic invasion, split into disease and pathogenic organisms and other species should be included. Reference was made for SOPAC to contact Mick Clout (Auckland University) from the IUCN project and Greg Shirley with SPREP working on an invasive species strategy.

A question was raised on the possibility of designing the EVI with the flexibility to allow for major impacts of vulnerability to be captured through the assignment of a core list of 8 major risks for each country (geological risk in particular). This issue was debated and difficulties relating to comparability expressed.

There was a philosophical concern that the EVI should not be used for comparing the vulnerability of countries. It was suggested that because politicians will compare countries anyway (e.g. GDP, human development index), the group should try to produce the best, most workable a tool for comparison that was possible.

Ecosystem services were suggested as an alternative conceptual basis for an EVI. It was agreed that if an example could be found then discussion would continue on this.

It was suggested that a future test for the EVI could be the following: countries would be ranked in terms of environmental vulnerability by the EVI and compared with rankings determined by a group of experts who had no framework to start from. If the results obtained by each were found to be similar, then the EVI would be seen as a useful tool because it would simplify the arduous task of determining vulnerability for many countries. By this reasoning, the EVI does not necessarily require a watertight scientific basis. It is not intended to be a strict scientific model, but a pragmatic tool.

2.2 What are the responders to those risks?

The group was aware that theoretically, the EVI should include indicators for all of the following responders, but acknowledged that this would not be practically possible:

- Ecosystem services
- Ecosystems
- Populations / communities / biodiversity
- Physical & biological resources
- Physical & biological processes (energy, reproduction, productivity)

2.3 The Sub-indices

It was suggested that the IRI and EDI be merged together as a single Resilience Sub-Index. The EVI would then divide into two (rather than the original 3) sub-indices, the RI (Resilience Index) and the REI (Risk Exposure Index).

It was agreed that the weightings for the original sub-indices and the revised sub-indices would need to be compared. A request was made for information on (i) weighting assigned to each indicator (1 or 5) and (ii) the overall resultant weighting of that indicator within the EVI. [Editor's note: These were not really used, as alternative weighting methods were tried later on during discussions].

Points To Be Discussed Later

- The purpose of EVI (to be discussed as Topic 6)
- Should the `country' include EEZs?
- Discussion of time frame for the selection of indicators?
- Decision on the definition for environment to be confirmed.
- Decision on the definition for "environmental vulnerability" (after topic 3 discussion)
- Group needs to agree on EVI-definition (after topic 3 discussion)

While winding up this session, it was pointed out that there should be some explanation for policy makers on the connection between the State of Environment (SOE) reporting and vulnerability or the EVI.

DAY 2: Wednesday, 8th of September, 1999

Chairs: Patrick Nunn and John Campbell

<u>Topic 3: The indicators of vulnerability</u>

<u>3.1 How many indicators do we need?</u>

It was pointed out the smaller the number of indicators in the EVI, the easier it would be to operationalise. At the same time, sufficient indicators would be needed to adequately describe the environment in a state. There was no *a priori* preferred number of indicators.

To avoid bias, one recommendation was that there should be the same amount of indicators for each possible category, ideally only 1, which would be easier for weighting. The experts suggested that the indicators should be globally oriented and not be restricted to the Pacific Region. For the EVI to be applied globally there might be the need for more indicators. It was, however, suggested that a greater number of indicators would increase the complexity of the EVI and may reduce the chance of applying it internationally. Testing of real data is required.

The SOPAC team clarified the island bias of the indicators in Kaly et al. (1999). This occurred because the initial brief was for a SIDS EVI and because most of the experts were from the Pacific Region. It was pointed out that the EVI has the capacity to utilise any choice of indicators. This would not involve any major changes to the EVI model.

<u>3.2 Should we have an equal number of indicators in each sub-index category?</u>

It was agreed that the indicators would first need to be revised before the number of them could be considered. It was proposed, that the indicators should meet the following criteria:

- Global
- Data and literature available
- If it is likely to change or to be a proxy for change to the environment and may do significant harm to humans or other species
- Independent source of change
- Weight should reflect probability that it will change the environment and the amount of damage it can do.

These criteria were not conclusively accepted. A further concern was that the selection of indicators should not be influenced by whether they favour or disfavour islands.

The index was divided into 5 groups of indicators. These included:

- Meteorological indicators
- Geological indicators
- Country characteristics
- Biological indicators
- Anthropogenic indicators

Country characteristics indicators were to be discussed in plenary. Experts were assigned to the following 3 subgroups (according to their areas of expertise) to discuss the indicators during the morning and afternoon sessions:

- *Meteorological and Geological indicators*: Tom Clarkson, Russell Blong, Patrick Nunn, Henry Taiki, Violet Wulf, Jackson Lum, Susanna Schmall
- *Biological indicators*: Brian McArdle, Terry Done, Geoff P. Jones, Jerry Vanclay, Wren Green, Ferdinando Villa, Ursula Kaly
- *Anthropogenic indicators*: Peter Waterman, Peter Abelson, Crispin d'Auvergne, John Campbell, David Osborn, James Toa, Craig Pratt, Helena McLeod

The results of these deliberations were presented to plenary and discussed. The subgroups then reconvened to further discuss and revise their indicators.

Topic 4: Mathematics

4.1 Mapping of data on the 1-7 scale as a way to standardise heterogeneous data?

The experts did not object to the use of the 1-7 scale for use of mapping in the EVI. For questions with yes/no answers extremes should be limited by using the numbers 2 and 6 (instead of 1 and 7). It was thought that weighting on 1 and 7 was too extreme.

4.2 The values of 0 and NA: Nett and Gross Vulnerability?

The decision was made to give an indicator which could not be applied to a country the score of 1 (instead of 0). The concept of nett vulnerability was dropped and decsision was made that the EVI would only measure gross vulnerability.

4.3 How should the values of the indices be accumulated? Averages or other approaches?

Given that simplicity and transparency are important, and that the EVI is not a precise tool, the use of averaging was considered a reasonable approach to the EVI. It may be possible to introduce weighting through measured relationships between indicators (for non-linearity), but this much information rarely exists for any environmental responders. The discussion about the pros and cons of averaging and further ideas on the mathematical approach should be further discussed and reported by the experts on statistics.

4.4 Should the final EVI be an average of the three sub-indices (giving them equal value regardless of the number of indicators in each?

The EVI values can be calculated either by averaging the values for the RI and the REI or by expressing the RI and REI as a ratio. An opinion was that due to the difficulty in measuring resilience and finding suitable indicators for the RI, weighting the REI and RI equally would reduces the credibility of the EVI. To get around this problem, it was suggested that the EVI could be calculated by averaging all indicators, regardless of sub-index. This would avoid the problems of arbitrary weighting and the risk of doubling up if some indicators might have applicability as either risks or resilience.

4.5 What is the cut off for data availability for a credible EVI: 80 % of questions answered?

Answer postponed after the discussion of indicators. [During later sessions, this figure of 80% came into common usage and was accepted without further discussion].

Points to be discussed at a later time:

- The discussion about the pros and cons of averaging and further ideas for the mathematical approach should be further discussed and written down by the experts on statistics.
- How the REI and the RI are weighted will be decided after the indicator discussion.
- The decision on a reasonable cut off for data availability was postponed after the discussion of indicators.

DAY 3: Thursday, 9th of September, 1999

Chair: Terry Done and Patrick Nunn

The sub-groups presented the revised list of indicators and presented a summary of their rationale from the Wednesday session. All indicators were discussed in plenary by the experts.

Indicators were reviewed and divided into groups; either dropped completely, dropped and replaced by other indicators or revised. Following the discussion, some indicators were given to individual participants to develop further. Some new indicators were also introduced to capture issues that were considered to have been omitted from the original list. Whilst identifying indicators the international applicability of the EVI was carefully considered.

The actual risk or measure of environmental health that the group desired to capture could often not be found due to limitations in the availability of data. Proxies were therefore used. These proxies often represented a number of risks or resilience factors. Key words, which indicated the main factors that the proxy indicators captured, were added. This would facilitate understanding for future assessors of indicators.

It was sometimes difficult, particularly for anthropogenic factors, for indicators to be assigned to a particular sub-index. Although the REI and RI were now the only real sub-indices, the original categorisation into REI, IRI or EDI would be retained for. The group decided to allocate each indicator to a sub-index at a later stage when the list was complete.

It was suggested that to approach the weighting of indicators objectively, experts would rank the revised indicators into four groups. The ranking on a 0-4 scale would be assigned by each participant to indicate the relative importance of each indicator from the expert's point of view. Weighting could then be based on this expert ranking. An alternate, and less subjective, system of assigning weights was also suggested at the session. This second method was not attempted during the meeting due to time constraints. Either of the two methods will be used at a later date once indicators have been tested for correlations and hence redundancy.

During the discussion of the meteorological data, it was proposed that local data instead of internationally available information should be used to promote capacity building. It was also stated that local personnel could be trained in the procurement via internet, libraries etc. of international data. In addition there are anthropogenic indicators, which have to be answered at the local level. These were considered arguably, to be more useful for capacity building as the countries then have a chance to reduce anthropogenic risks.

It was stressed that indicators should be chosen for which data could be collected. If an indicator could be used for which data collection was cheap, easy and incorporated similar information into the model, it should be preferred over a more complex or difficult indicator.

A concern was raised that the number of indicators at the present time might not allow countries' environmental vulnerabilities to be easily distinguished from one another. Clustering of countries might also be present. Testing will be needed to examine this possibility. A suggestion was made that it might be wise to reduce the number of indicators in the index. The idea of selecting core indicators was suggested.

It was felt that the revised list of indicators would have to be revised to ensure that a comprehensive list of generic indicators was used to form a truly international index.

A concern was raised that it was tautological to include total land area as an indicator. This argument assumes, wrongly, that the EVI is being created to identify small island states or to identify SIS as particularly vulnerable. This led to the fear that including total land area would create a bias towards small states. It was argued during the session that land area is an important indicator of ecosystem diversity, and was being selected solely on the basis that it provides information on environmental vulnerability. This argument was accepted by the group.

Almost all of the indicators are deflated by size, that is, their effect is divided by the available land area to give a density measure rather than an absolute total. It was agreed that this was necessary to eliminate the effect of size of the state in the action of the indicators. There was concern that some indicators might not be linear with respect to size. Modelling of the data will be carried out when information has been collected for at least 10 countries (currently underway).

The issue of good governance was thought to be very relevant as a modifier of risk and resilience. It was thought that it would be difficult to formulate objective indicators which would be useful in this context.

It was agreed that a technical glossary in the final report would be very useful for readers.

Topic 5: Strengths and weaknesses of the new EVI

5.1 Assumptions

The discussion was postponed, and most of the points appear under strengths and weaknesses.

5.2 Strengths

1. It is the first comprehensive and convenient measurement of environmental vulnerability;
2. Permits comparisons across countries;
3. Identifies a number of indicators which describe the features of risk and resilience for a country;
4. Can be used as a measure of change in environmental vulnerability;
5. It can be used to identify in country vulnerability and areas of major concern;
6. Stimulates debate at the science policy interface at national and international levels and amongst disciplines;
7. Able to incorporate quantitative and qualitative data on different response scales and non-linearity;
8. Is potentially globally-applicable;
9. Could be used for awareness raising;
10. Indicators and weightings were chosen by a panel of international experts;
11. Differences in interpretation of users will be minimised by training;
12. (Has been validated)
13. (Robust)

The last two points are conditional on the results of testing which will occur when the data from 15 countries has been collected.

5.3 Weaknesses

1. Subjectivity in assigning weights to indicators and non-linearity to the scores as in other indices
2. Some complex environmental factors have been represented by proxy indicators rather than measured directly
3. EVI is affected by the indicators chosen and the results obtained may differ if different variables were chosen
4. The method of aggregating the indicator scores did not allow for a variable contribution to be conditional on, or amplified by another variable (e.g. feedback, multiplicative effects, inhibitory effects) i.e. it assumes a non-interactive system
5. Subject to problems with differences in interpretation of users, although this could be minimised with training
6. Some of the data may be difficult to obtain

5.4 Any conditions for people using the indices to keep in mind?

- Emphasises short term environmental change
- Does not address climate change / SL rise
- Some local variations, short and long term effects and other details could not be incorporated into the model without making it too complex

Points to be discussed at a later time:

Assumptions of the EVI

DAY 4: Friday 10th of September, 1999

Chair: Paddy Nunn

Topic 1:Definitions (topic picked up from earlier postponement)

The question of a definition for “Environment” was tabled for the second time. There was a discussion of the original purpose of the EVI and an urging that that the definition should be chosen to reflect this original purpose. The participants were divided on the final definition. One group thought that human as well as natural systems should be included in the EVI, while the remainder thought that human systems should be excluded from the index. A vote cast in the room gave a slight majority win to including human systems in the EVI. [Despite this, the EVI described in this volume specifically excludes human systems because (i) the original brief was for natural environments, and (ii) the indicators selected so far meet that initial brief. The question of including human systems will require further debate].

The definition of vulnerability was next discussed and defined as follows;

- *Vulnerability is the extent to which the environment is prone to damage and degradation;* and
- *Damage is the loss of diversity, extent, quality and function of environments.*

The issue of weighting of the indicators was discussed further. It was suggested that a number of indicators may be redundant due to correlation with others. To assess which indicators are correlated, it will be necessary to collect data from a number of countries and calculate correlation coefficients. This procedure will form part of the mathematical testing of the EVI model.

The list of indicators had been ranked over night by the experts into five categories showing the relative importance the experts assigned to the indicators (0-4). These values were summarised as means, standard deviations and frequency of zero values (the latter implying that the indicator should be removed). The indicators were then organised into 3 groups of High, Medium and Low ranking (see Table 1). Discussions centred around the results of the ranking exercise. An alternative method for ranking was suggested by F. Villa. His method involved the systematic pair-wise ranking of every indicator against every other. Although more involved to analyse, it was pointed out at the meeting that this binary ranking technique would be less confusing for the rankers (experts) because only two indicators needed to be compared at any one time, and it was not necessary for the experts to recall any rankings they had given previously. Either of these two techniques could be used after indicators have been examined for correlations.

Topic 6: The Future

The Future of the EVI was discussed. It was agreed that the EVI could be useful either as a stand-alone or a composite index. The index needs to be entirely global, even if it is initially only to be used to for Pacific SIDS. The criteria for deciding when the index would be operational were discussed and agreed on. These included the processes that need to be included in the mathematical testing stage.

Alfred Simpson, the Director of SOPAC, formally closed the meeting after thanking the support that had been given by New Zealand, UNEP and SPREP.

6.2 Indicators (and explanatory text) included in the EVI by the end of the Think Tank

The think tank participants were divided into three subgroups to work through the indicatiors proposed by the SOPAC Team. The indicators were divided into 5 categories: Meterological, Geological, Biological, Country Characteristics and Anthropogenic indicators. The subgroups were assigned categories according to the expertise of participants so that the indicators would tend to be examined by those most experienced in a field.

The final indicators selected by the think tank participants are presented in the form shown in the box below. With each indicator is provided a short text which describes why the question was selected and what it indicates. There are, at present, no scaling levels set for any of the new indicators. These will be completed by the relevant experts and the EVI team over the following months.

Final Indicator Number, (Old indicator number) REI/IRI/EDI [category]
Indicator question
Explanatory notes

Indicator 1, (1) REI [Meteorological]
Greatest average annual deviation in Surface Sea Temperature in last 5 years from long term mean (30 years)

Changes of surface sea temperature impact on wind patterns, coral bleaching, fishes and cause environmental stress. The question was raised of whether this indicator could also be applied to landlocked countries, which feel the impact of a surface sea temperature change. Such impacts were, however, considered too indirect in comparison with the direct impacts of coral bleaching etc. This means that the indicator will only apply to countries with a coastline. It was agreed that more work is required to finalise the form of this question.

Indicator 2, (4) REI [Meteorological]
Percent of reference climatological stations experiencing >= 1/100 yr. 3 second wind gusts in a 5 year period / land area

Two indicators 4 and 7 of the original EVI study were combined in this new indicator. These were the “number of category 1-5 cyclones (<994 hPa central pressure) / decade / 10,000 sq. km land area (last decade only)” and the “number of severe storms and tornadoes / 10.000 sq. km / decade (last 10 years)”. This merger simplifies the EVI model and makes the indicator general enough to be applicable over the globe.

Indicator 3, (3) REI [Meteorological]
Percent of reference climatological stations experiencing <= 1/100 yr. minimum annual rainfall in a 5 year period / land area

This question indicates the risks from droughts. The old EVI study indicator 3: “number of months over last 5 years during which rainfall is more than 20 % below 30yr average for that month” was changed by the same reasoning as indicator 4, below.

Indicator 4, (2) REI [Meteorological]
Cumulative number of 24 hr periods over all Reference Climate Stations over last 5 years during which rainfall is >= 1/100 yr. (1/50, 1/20 ?? Less?) event / stations

This question is intended as an indicator for the risk of floods and other effects associated with periods of high rainfall (e.g. turbidity of coastal waters). Floods themselves depend on many factors other than rainfall. This indicator attempts to focus on the proximal cause of environmental effects (the rainfall) rather than its downstream effects (floods, turbidity, run-off). Some of the specific effects which could arise by interaction with rainfall are incorporated into other indicators (e.g. effects of deforestation).

The subgroup discussed whether flood has a significant impact on biophysical systems. The assumption was made that nature is adapted to a 20 % increase in rainfall and that the indicator should only focus on extreme deviations like one in a hundred year events. For these events, seasonal variations are not relevant. Indicator 2 of (Kaly et al. 1999) “Number of months over last 5 years during which rainfall is more than 20 % above 30yr average for that month (average for all major weather stations in the country)” was discarded and an interim indicator was brought up: “Number of reference climatological stations divided by total land area which experience >= 1/100 year 24 hour rainfall events in 5 year periods”.

In the plenary it was decided that a division of stations by land area results in unpredictable and very small figures. Some experts also commented that climatological stations were proxy indicators of proxy indicators and more direct measures of high rainfall should be used. The division by stations standardises the data so that small and large countries can be compared (i.e. those with few versus many climate stations), and the question “Percent of Reference Climatological Stations (WMO definition) experiencing >= 1/100 yr. 24 hour rainfall events in a 5 year period” was suggested.

An indicator counting the number of stations (or expressing them as percentage) does not reflect the case of two events experienced by one station. Therefore the indicator was changed into the new indicator (see above), which considers the cumulative 24hr periods.

There was no final agreement on the indicator and the other meteorological indicators. There was a concern that the indicators based on 100 year events measure the recent distribution of events for which the ultimate frequency is known (i.e. by definition). For some experts, almost all the meteorological indicators were considered too complex and would be expected to result in problems of understanding and data collection for operators calculating the indicator values. It was suggested that data available from centralised databases should be used, but this led to a concern that this would harm the capacity building aspect of the EVI (see minutes from Wednesday).

All the meteorological questions need revision and further development. Tom Clarkson volunteered to assist with this work (see his submission in Appendix 6.4).

The question of whether natural hazards can cause ecological damage arose repeatedly throughout the think tank, and again in relation to this indicator. In Kaly et al. (1999) the original form of this question was identified as examining the risk of flooding and other effects associated with high rainfall from the perspective of ecological systems. That is, greater than average rainfall can affect reef areas by freshwater and silt inputs, cause damage to rivers and deltas and flood inland areas. Some of the participants in the plenary stated that all natural hazards also have positive effects on nature, especially floods. They destroy habitats but create others. This was discussed in the session and in Kaly et al. (1999) where it was identified that any kind of rapid change in the environment which resulted in changes in ecological characters and/or the way that people used the environment would constitute “harm” to the environment for the purposes of the EVI.

Indicator 5, (6) REI [Meteorological]
Percent of reference climatological stations experiencing >= 1/100n yr. daily max temp in a 5 year period

This indicator was reformulated from Kaly et al. (1999), indicator 5: “mean number of days per year (last five years) in which the maximum temperature was >5oC above the mean monthly maximum (calculated over last 30 years) / land area” by the subgroup in order to emphasis extreme events. No agreement was reached on the final form this indicator should take.

Indicator 6, (5) REI {Metrological]
Percent of reference climatological stations experiencing <= 1/100 daily min temp in a 5 year period / land area

This indicator was reformulated by the subgroup from (Kaly et al, 1999, indicator 6: “Mean number of days per year (last five years) in which the minimum temperature was >5oC below the mean monthly minimum (calculated over last 30 years”) to emphasis extreme events. No agreement was reached on the final form for this indicator.

Indicator 7, (10) REI [Geological]
Number of volcanoes with potential for eruption >= VEI 4 (Volcano explosivity Index) within 100km of country land boundary / area of land

The original indicator 10: “number of volcanoes with potential for explosive eruptions / 10,000 sq. km land area” was slightly modified by using the Volcano Explosivity Index.

Indicator 8, (8) REI [Geological]
Earthquake energy within 100km of country land boundaries / land area with ML >=6.0 and <=15km depth per 5 years

The original indicator 8: “Number of earthquakes over the last 50 years / 10,000 sq. km land area with intensity of >6.0 Richter” was too vague because it did not consider depth. Deeper earthquakes present significantly less risk to the environment. After a long discussion, the subgroup decided that the measure "earthquake energy" would provide a better combination of the number of earthquakes and their strength in one indicator. The question was also raised on whether the earthquake energy should be divided by the EEZ instead of the land area. After discussion, the subgroup agreed on the inclusion of underwater earthquakes within 100km of country boundaries, but to relate them only to the land area, where the most obvious and significant environmental changes are thought to take place.

Indicator 9, (9) REI [Geological]
Number of tsunamis or storm surges with run-up >2m above MHWS / 100km coastline since 1900

The original indicator 9 "Number of tsunamis with run up 2m+ over last 50 years / 10,000 sq. km coastal area" was discarded due to expected problems of data availability relating to problems of defining and measuring the extent of the "coastal area". As a result of this discussion, all indicators referring to the coastal zone would be related to the length of coastline. The inclusion of storm surges improves global applicability of this indicator.

Indicator 10, (40) IRI [Country characteristics]
Total land area (square kilometres)

This indicator was retained from the original list of Kaly et al. (1999). The discussion surrounding this indicator focussed mainly on the opinion of some experts that it would be politically unwise to include this indicator because it would appear to bias small countries as being more vulnerable. It was clearly pointed out at the meeting, however, that the EVI had to be technically consistent and that this indicator was being included only for ecological reasons. Size of the country is related to ecosystem diversity, extent, and persistence.

A further concern of some experts was the misunderstanding that this indicator is redundant because size of the country is a denominator in many indicators (indicators divided by total land area). The argument was made that those indicators which were divided by total land area were actually treated in this way to remove the effect of size of the country from their signals. That is, that only the density of hazards was left in the signal and not overall country size.

Indicator 11, (41) IRI [Country characteristics]
Ratio of length of ocean shoreline : total land area

This indicator (the same as original indicator 41) shows the "islandness" and fragmentation of a country. The more fragmented a country is the more vulnerable it is to risk impacting on the coastline. This indicator could be generalised further to include all states by taking the perimeter length of those which are land-locked.

Indicator 12, (69) IRI [Country characteristics]
Distance to nearest continent (km)

This new question is a proxy indicator for isolation. In isolated countries the risk of loss of species is higher than for countries in close proximity to a source of recolonisers of a species which has become locally extinct. It was acknowledged that large islands can have the same function as species refugia for remote islands as continents, but that continents would be used as the indicator to ensure a simple and globally-applicable measure.

Indicator 13, (70) IRI [Country characteristics]
Altitude range (Highest point - lowest point in country)

This is a new indicator which is a proxy for ecosystem diversity. It is a global measure for which data are easily available.

Indicator 14, (43) IRI [Country characteristics]
Percent of land area <10m above sea-level

This indicator describes resilience to tsunamis, sea-level rise, flooding, etc. and is a proxy for ecosystem diversity.

Indicator 15, (44) IRI [Country characteristics]
Land area below 10m elevation with unimpeded access to the coast composed of unconsolidated sediments (excluding coral reefs and ice) / land area (%)

The basis for this indicator was the Kaly et al. (1999) indicator number 44 “Percent of coastal land area composed of unconsolidated sediments (i.e. not native rock base)”. The subgroup discussed whether the focus on unconsolidated sediment appropriately proxies the impacts resulting from hazards. The indicator shows the vulnerability of a country to sea-level rise, tsunamis and storm surges. The critical height of 20 m in indicator 43 of the original model was changed to 10 m.

Indicator 16, (42) IRI [Country characteristics]
Number of known endemic species / 10,000 sq. km land area

The word “known” was added to the original indicator number 42. The basis for this indicator is that the more endemic species a country has the more vulnerable it is (to their extinction), because localised extinction cannot be re-supplied from elsewhere by natural or augmented recolonisation. The indicator encompasses all species.

Indicator 17, (53) REI [Biological]
Number of catastrophic organism outbreaks over the last 5 years / land area (pathogens, blooms, plagues etc)

Catastrophic organism outbreaks include plant diseases, viruses, pathogens, blooms, plagues etc. This would include, but not be restricted to rats, mice, locusts, fruitfly, hyacinths, cane toads, chicken ‘flu, red tides, paralytic shellfish poisoning, ciguatera and many others. The original indicator number 53 “Number of harmful algae blooms including ciguatera, red tides etc over last 5 years / 10,000 sq. km coastal area" was generalised to this globally-applicable indicator.

Indicator 18, (59) REI [Biological]
Total tonnage of freight imported / year

This is an indicator for the risk of species invasion. The risk of invasion is seen as proportional to the imported freight. The question of passenger movements into the country / year was considered, but freight was considered more risky for introductions because the volume is large and species may stowaway not just in the freight, but also in the vessel (e.g. ballast of ships, on trains etc.). A further indicator of invasion was considered: "Border control legislation regarding biological introductions", but the presence of legislation does not necessarily correlate with effective implementation.

Indicator 19, (57) EDI [Biological]
Number of all introduced species / 10,000 sq. km land area since 1900

Indicator 20, (56) EDI [Biological]
Number of endangered & threatened species or habitats / 10,000 sq. km of land area (IUCN definitions)

This indicator, number 56 of Kaly et al. (1999) was agreed to by participants without changes.

Indicator 21, (55) EDI [Biological]
Number species which have become extinct since 1900 / 10,000 sq. km land area (IUCN definitions)

This indicator is based on the original indicator 55: "Number of species, which have become extinct this century / 10,000 sq. km land (and coastal area *0.5)".

Indicator 22, (48) EDI [Biological]
Percentage of natural & regrowth vegetation remaining (e.g. forests, mangroves, saltmarshes, prairies, savannah, desert, tundra)

The greater the percentage of natural and regrowth vegetation that exists in a state, the more intact is its terrestrial and coastal ecosystems, and the more resilient the natural environments of the country. Indicator number 48 of Kaly et al. (1999): "Percentage of primary or old growth forests or vegetation remaining (e.g. prairies, savannah, desert, tundra)" was modified to "Percentage of land cover, which has changed significantly over past 200 years" by the subgroup before being finalised as this new indicator. There were problems with the interpretation of the term "changed significantly" in the interim indicator. This new question will specify what is understood by "natural" and "regrowth" vegetation. However there may be problems with data availability. The timeframe referring to the remaining vegetation is not yet given. The old indicators 50 "Percentage of land under agriculture including plantation / forestry (now)" and 52 "Percentage of original mangrove / saltmarsh area remaining" were discarded, because they are included in this new indicator.

Indicator 23, (51) EDI [Biological]
Tonnage of intensively-farmed animal products / yr. / land area

This indicator refers to farming, the effluents of which, cannot largely be attenuated within the area the farms occupy. The subgroup replaced original indicator 51: “Number of mariculture farms / 10,000 sq. km” by “Percent of land and sea area under factory animal farming (mariculture, chickens, pigs etc) (x km from coast)” in order to globalise the application of the indicator. This was further modified during the plenary session to the new indicator above, which guarantees a better availability of data.

Indicator 24, (49) EDI [Biological]
Percent of fisheries stocks overfished (FAO)

This indicator, number 49 from the original list, is a proxy indicator for marine degradation. The data and definition for “overfished” will be taken from FAO.

Indicator 25, (47) EDI [Biological]
Density of people living in coastal settlements (define area)

This question is a proxy indicator for the degradation of coastal and marine habitats. Indicator 47 of Kaly et al. (1999): “% degraded coral reef area (ICRI Reef Check)” was discarded due to problems of data availability and definition of “degraded”. The old indicator also focussed on coral reefs which were considered too limited in their application on the global scale. The term “coastal settlements” might be definable in terms of settlements with their centres within 50km of the coast.

Indicator 26, (38) REI [Anthropogenic]
Total human population density (per sq. km land area)

This is a proxy for the pressure on the environment resulting from the numbers of humans being supported per unit of land. This includes all of the goods and services provided by the natural environment to humans including natural resources and the assimilation of wastes.

Indicator 27, (37) REI [Anthropogenic]
Annual human population growth rate (average over last 5 years)

This is another measure of risk expressed as the rate of change of the human population. It is risk complement to the EDI Indicator 26, and focuses on increasing (or decreasing) rates of natural resource exploitation and the waste that will need to be assimilated into the environment.

Indicator 28, (62) REI [Anthropogenic]
Net percentage of land area changed by the removal of natural vegetation over last 5 years

This is a measure of risk to further losses of natural vegetation and includes deforestation of primary rainforests, loss of wetlands and other natural ecosystems. It is a rate of change and complements the information gathered in Indicator 21, above, which is an expression of standing condition. It incorporates losses of biodiversity, soils, and floodwater protection.

Indicator 29, (39) REI [Anthropogenic]
*Annual number of international tourists * average days stay / 365 / 100 sq. km (last 5 years)*

Pressure on the environment through increased population at peak times can be severe, this is captured in this indicator.

Indicator 30, (65) REI [Anthropogenic]
Megalitres of untreated industrial and domestic wastewater discharged to aquatic systems / 1,000 km aquatic ecosystems (length coast + length rivers)

This captures risk to water quality, but there are likely to be problems with the data. This indicator will need to be revised.

Indicator 31, (29) REI [Anthropogenic]
Total tonnage of generated and net imported toxic, hazardous & municipal wastes/ 10,000 sq. km land area / year (average last 10 years)

The focus for this indicator is on amount of wastes being generated or brought into the country. Captures risk to groundwater pollution, waterways coastal pollution and litter.

Indicator 32, (67) REI [Anthropogenic]
Mean percent of industrial and municipal waste managed or treated / yr.

The focus here is on management of the wastes and is a different indicator to number 32,below. This captures risk to groundwater pollution, waterways and coastal pollution and litter. The relative contribution of municipal waste is likely to swamp the other types of waste, but taken together, this indicator is expected to yield useful information on how well the human population of a state is managing its waste.

Indicator 33, (32) REI [Anthropogenic]
Number of spills of oil and other hazardous substances >1,000 litres during last 5 years within territorial waters

Captures the contamination of marine and bird life.

Indicator 34, (31) REI [Anthropogenic]
Number of nuclear, chemical and other major industrial facilities that could cause significant damage / 10,000 sq. km land area

Used to take into account accidents such as the Bhopal chemical explosion in India, as well as incidents such as the Chernobyl and more recently, the Japanese nuclear disasters.

Indicator 35, (34) REI [Anthropogenic]
Number of cars / land area

This is a proxy for many human impacts, including loss of biodiversity and fragmentation of the countryside. Air pollution and lead pollution on land and in waterways would also be implicated. It is a restated form of Indicator 34 which was concerned with the number of cars per 1,000 people.

Indicator 36, (30) REI [Anthropogenic]
Max 24 hour SO_2 concentration (micro g /cubic m) (average over last 5 years)

Used as a proxy for air pollution in general, which impacts on many aspects of ecosystem health, such as water quality and biodiversity. This indicator was chosen because it is likely that data will be generally available.

Indicator 37, (14) REI [Anthropogenic]
Tonnes of N,P,K fertilisers used / 10,000 sq. km agricultural land area / year (average last 5 yrs)

This indicator represents the damage from fertilisers on ecosystems, water quality, coral reefs and soil quality.

Indicator 38, (13) REI [Anthropogenic]
Tonnes of pesticides used / 10,000 sq. km of agricultural land / year (average last 5 years)

This indicator represent the damage from pesticides on ecosystems, water quality, coral reefs and soil quality.

Indicator 39, (66) REI [Anthropogenic]
Number of new fisheries stocks exploited by the country over last 5 years (within territory)

Attempts to capture the pressure on fishing stocks. The logic is that new species and ecosystems are coming under risk and that the addition of new stocks might be occurring in response to losses of previously and current fished stocks.

Indicator 40, (64) EDI [Anthropogenic]
Percent land area degraded since 1950

Indicator 64: “Percentage area of land desertified since 1950” was generalised in order to apply the indicator world-wide. The question indicates the status of land degradation. The term “degraded” has to be defined, but it is likely that a standard definition arising from IUCN or other international environmental bodies exists. There might also be problems with data availability and only “best guesses” possible. The indicator is also representative of the level of biodiversity remaining, as well as the quality of soil, resilience against floods and assimilative capacity of the environment to pollution.

Indicator 41, (70) EDI [Anthropogenic]
Question on importance of water…..?

Water pollution, quality and availability was thought to be a key factor for the integrity of ecosystems. A suitable indicator was not formulated during think tank. Further work will be undertaken on this indicator.

Indicator 42, (28) REI [Anthropogenic]
Kilotons of mining material (ore + tailings) extracted / 10,000 sq. km land area / year (average last 5 years)

Represents risk of large-scale disturbances to the land and seabed, effects of tailings leakages or pollution in waterways or in the deep-sea. Although this measure is dependent to some extent on the standard of environmental management, even in the best case scenarios, we are not sure that site rehabilitation does restore original or close to original ecosystem values.

Indicator 43, (54) EDI [Anthropogenic]
Land and sea area affected by mining & quarrying / land area

Proxy for the level of environmental degradation which has accumulated over a long period due to mining practices.

Indicator 44, (25) EDI [Anthropogenic]
Percent of terrestrial zone set aside as reserves

Captures the intactness of the terrestrial environment, the presence of refugia and the level of environmental management. Changed from an REI to EDI question.

Indicator 45, (22) EDI [Anthropogenic]
Percent of marine zone set aside as reserves (mean high tide to continental shelf)

This indicator is a proxy for intactness of the marine environment, the presence of refugia and level of environmental management. For marine environments, and due to a dispersive larval phase in the life cycle of many organisms, the presence of a breeding population in one area is expected to lead to seeding of larvae and migrations of adults over a large area. This would tend to build resilience in the marine environments.

Indicator 46, (58) EDI [Anthropogenic]
Number of war or civil strife years over the last 50 years within the territory

Captures degradation through bombing, land mines, chemicals left in the environment, temporary camps and vehicle disturbances. This indicator is also a proxy for the lack of environmental management during those years.

Indicator 47, (23) REI [Anthropogenic]
Environmentally related legislation

Looks at the level of environmental management and its operation in the country.

6.3 Discarded Indicators

1, REI [Meteorological]
Deviation in average sea temperatures during moderate or greater El Nino (NOAA) ^{o}C

The meteorological and geological indicators subgroup discarded the indicator 1 from the EVI study because El Nino is mainly a Pacific phenomenon and therefore the question could not be applied globally.

2, REI [Meteorological]
Percent of Reference Climatological Stations (WMO definition) experiencing >= 1/100 yr. 24 hour rainfall events in a 5 year period

3, REI [Meteorological]
Number of months over last 5 years during which rainfall is more than 20% below 30yr average for that month (drought risk)

4, REI [Meteorological]
Number of category 1-5 cyclones (<994 hPa central pressure) / decade / 10,000 sq. km land area (last decade only)

5, REI [Meteorological]
Mean number of days per year (last five years) in which the maximum temperature was >5oC above the mean monthly maximum (calculated over last 30 years) / land area

6, REI [Meteorological]
Mean number of days per year (last five years) in which the minimum temperature was >5oC below the mean monthly minimum (calculated over last 30 years)

7, REI [Geological]
Number of severe storms and tornadoes / 10,000 sq. km land area / decade (last decade)

8, REI [Geological]
Number earthquakes over the last 50 years / 10,000 sq. km land area with intensity of >6.0 Richter

An indicator for avalanches was also considered but then thought to be not significant for the vulnerability of a country due to the limited impact area of avalanches.

9, REI [Geological]
Number tsunamis with run up 2m+ over last 50 years / 10,000 sq. km coastal area

9, REI [Geological]
Number of volcanoes with potential for explosive eruptions / 10,000 sq. km land area

44, IRI [Country characteristics]
Percent of coastal land area composed of unconsolidated sediments (i.e. not native rock base)

60, REI [Biological]
Passenger movements into the country / year

61, REI [Biological]
Border control legislation regarding biological introductions

47, EDI [Biological]
Percent degraded coral reef area (ICRI Reef Check)

48, EDI [Biological]
Percentage of land cover which has changed significantly over past 200 years

50, EDI [Biological]
Percentage of land under agriculture including plantation / forestry (now)

51, EDI [Biological]
Percent of land and sea area under factory animal farming (mariculture, chickens, pigs etc) (x km from coast) (farming the effluents of which cannot be largely attenuated within the area it covers)

52, EDI [Biological]
Percentage of original mangrove / saltmarsh area remaining

53, EDI [Biological]
Number of harmful algal blooms including ciguatera, red tides etc over last 5 years / 10,000 sq. km coastal area

15, REI [Anthropogenic]
Rate of deforestation of primary forest (% of remaining forest lost per year) (average of last 5 years)
Replaced by the more generic indicator 46 referring to loss of natural vegetation which takes into account wetlands, prairies and other natural ecosystems as well as forests.

12, REI [Anthropogenic]
Percentage of agriculture land under subsistence / organic agriculture
Discarded as redundant. It was felt that indicators 11,12 and 46 took the environmental factors associated with these into account. The remaining indicators represent intensive use of pesticides, fertilisers and loss of natural vegetation (in this case it could be from land conversion to agriculture).

16, REI [Anthropogenic]
Percentage of agricultural land which is mechanised, monoculture and/or commercial

Discarded as redundant. It was felt that indicators 11,12 and 46 took the environmental factors associated with these into account. The remaining indicators represent intensive use of pesticides, fertilisers and loss of natural vegetation (in this case it could be from land conversion to agriculture).

17, REI [Anthropogenic]
Number of commercial inshore fishing vessels / 10,000 sq. km coastal area / year (average of last 5 years)
Dropped because `number of' was thought not to be related closely enough to mass of catch or sustainable yield. A vessel could be huge or tiny. They were replaced by the indicator 49 Number of new fisheries species added to country over last 5 years.

18, REI [Anthropogenic]
Number of commercial offshore fishing vessels / 10,000 sq. km of EEZ / year (average of last 5 years)
Dropped because `number of' was thought not to be related closely enough to mass of catch or sustainable yield. A vessel could be huge or tiny. They were replaced by the indicator 49 Number of new fisheries species added to country over last 5 years.

19, REI [Anthropogenic]
Destructive fishing methods used? (dynamite, cyanide, muro ami, rotenone)
This was felt to be too specific to the Pacific and not suitable for a generic, global index.

20, REI [Anthropogenic]
Number patrols run (boat or plane) / 10,000 sq. km EEZ / year (average of last 5 years)
This indicator was aimed at the level of enforcement and regulation in the fisheries sector. It was discarded because experts thought that more general measures of environmental enforcement and regulation could be found.

21, REI [Anthropogenic]
Fisheries observer programmes?
This indicator was aimed at the level of enforcement and regulation in the fisheries sector. It was discarded because experts thought that more general measures of environmental enforcement and regulation could be found.

24, REI [Anthropogenic]
Percent of development projects accompanied by EIA in last 5 years
Dropped as it was felt there wasn't a close link between EIAs being undertaken and a high level of environmental management or enforcement. In many instances they are rubber stamps.

26, REI [Anthropogenic]
Tonnes of coral extracted / year / 10,000 sq. km of coastal area (average of last 5 years)
Dropped due to coral being too specific to the Pacific replaced by a more generic indicator EDI 40 Land and sea area affected by mining and quarrying.

27, REI [Anthropogenic]

Kilotonnes of sand / gravel extracted / year / 10,000 sq. km coastal area (average of last 5 years)
Represented by indicator 40 Land and sea area affected by mining and quarrying.

30, REI [Anthropogenic]
Tonnes of carbon burned per 1,000 people / year (Greenhouse Gas Inventory)
Dropped in favour of indicator 20 Max 24 hour SO_2 concentration. As we are looking at country environmental vulnerability we do not consider their emissions of CO_2 as this is a global pollutant. The SO_2 indicator represents air pollution in general.

32, REI [Anthropogenic]
Number of shipping ports which maintain and/or produce ships / 10,000 sq. km of coastal zone
Dropped in favour of 22 Number of oil and hazardous waste spills. However, it was noted that this indicator captured the pollution from tributyl tin a major coastal polluter.

33, REI [Anthropogenic]
Electricity consumption kilowatt hours / capita / year
Replaced by indicator 20 max 24 hour SO2 concentration. This is to capture air pollution in general. Again carbon emissions are not included in this index as they are a global pollutant and not country specific.

35, REI [Anthropogenic]
Percent of toxic wastes disposed of by high temperature incineration (average last 5 years)
Discarded as too specific.

36, REI [Anthropogenic]
Percent of population with at least secondary sewage treatment

39, REI [Anthropogenic]
Standing stock of international tourists / 100 sq. km land area (Standing stock = # tourists x average # days stay / 365) (average for last 5 years)

45, EDI [Anthropogenic]
Has nuclear testing occurred?

63, EDI [Anthropogenic]
Percentage marine habitat destroyed within 12 nautical miles of land
Suggested in subgroup but discarded in plenary as it was felt data would be lacking.

10 REI [Anthropogenic]
Percent land area burned by forest fires per year (worst year of last 5 years)
This question was dropped in the subgroup work as it was suggested fires are often a natural part of rejuvenation or used in traditional management practices and not necessarily detrimental. However the plenary session decided it should be included as for instance, the huge forest fires in Indonesia shouldn't be ignored.

14 (23,24) REI [Anthropogenic]
Environmentally-related Legislation with regulations
Proxy for level of enforcement of environmental protection. Dropped because enforcement is difficult to gauge.

15 (23,24) REI [Anthropogenic]
Implementation of environmental and natural resource management procedures
Again this attempts to capture the level of environmental management and will be further refined.

Table 2: Summary list of indicators considered for the EVI but later discarded.

Indicators are recorded here with old reference number, sub-index allocation and category (M = meteorological, G = G Geological, B = biological, CC = country characteristics, A = anthropogenic.

Index #	sub-Index	Category	Indicator
2	REI	M	Percent of Reference Climatological Stations (WMO definition) experiencing >= 1/100 yr. 24 hour rainfall events in a 5 year period
3	REI	M	Number of months over last 5 years during which rainfall is more than 20% below 30yr average for that month (drought risk)
4	REI	M	Number of category 1-5 cyclones (<994 hPa central pressure) / decade / 10,000 sq. km land area (last decade only)
5	REI	M	Mean number of days per year (last five years) in which the maximum temperature was >5oC above the mean monthly maximum (calculated over last 30 years) / land area
6	REI	M	Mean number of days per year (last five years) in which the minimum temperature was >5oC below the mean monthly minimum (calculated over last 30 years)
7	REI	G	Number of severe storms and tornadoes / 10,000 sq. km land area / decade (last decade)
8	REI	G	Number earthquakes over the last 50 years / 10,000 sq. km land area with intensity of >6.0 Richter
9	REI	G	Number tsunamis with run up 2m+ over last 50 years / 10,000 sq. km coastal area
10	REI	G	Number of volcanoes with potential for explosive eruptions / 10,000 sq. km land area
44	IRI	CC	Percent of coastal land area composed of unconsolidated sediments (i.e. not native rock base)
60	REI	B	Passenger movements into the country / year
61	REI	B	Border control legislation regarding biological introductions
47	EDI	B	% degraded coral reef area (ICRI Reef Check)
48	EDI	B	Percentage of land cover which has changed significantly over past 200 years
50	EDI	B	Percentage of land under agriculture including plantation / forestry (now)
51	EDI	B	Percent of land and sea area under factory animal farming (mariculture, chickens, pigs etc) (x km from coast) (farming the effluents of which cannot be largely attenuated within the area it covers)
52	EDI	B	Percentage of original mangrove / saltmarsh area remaining
53	EDI	B	Number of harmful algal blooms including ciguatera, red tides etc over last 5 years / 10,000 sq. km coastal area
12	REI	A	Percentage of agriculture land under subsistence / organic agriculture
15	REI	A	Rate of deforestation of primary forest (% of remaining forest lost per year) (average of last 5 years)
16	REI	A	Percentage of agriculture land which is mechanised, monoculture and/or commercial

17	REI	A	Number of commercial inshore fishing vessels / 10,000 sq. km coastal area / year (average of last 5 years)
18	REI	A	Number of commercial offshore fishing vessels / 10,000 sq. km of EEZ / year (average of last 5 years)
19	REI	A	Destructive fishing methods used? (dynamite, cyanide, muro ami, rotenone)
20	REI	A	Number patrols run (boat or plane) / 10,000 sq. km EEZ / year (average of last 5 years)
21	REI	A	Fisheries observer programmes?
24	REI	A	Percent of development projects accompanied by EIA in last 5 years
26	REI	A	Tonnes of coral extracted / year / 10,000 sq. km of coastal area (average of last 5 years)
27	REI	A	Kilotonnes of sand / gravel extracted / year / 10,000 sq. km coastal area (average of last 5 years)
30	REI	A	Tonnes of carbon burned per 1,000 people / year (Greenhouse Gas Inventory)
32	REI	A	Number of shipping ports which maintain and/or produce ships / 10,000 sq. km of coastal zone
33	REI	A	Electricity consumption kilowatt hours / capita / year
35	REI	A	Percent of toxic wastes disposed of by high temperature incineration (average last 5 years)
36	REI	A	Percent of population with at least secondary sewage treatment
39	REI	A	Standing stock of international tourists / 100 sq. km land area (Standing stock = # tourists x average # days stay / 365) (average for last 5 years)
45	EDI	A	Has nuclear testing occurred?
63	EDI	A	% Marine habitat destroyed within 12 nm of land
10	REI	A	& land area burned by forest fires per year (worst of last 5 years)
14	REI	A	Environmentally-related legislation with regulations
15	REI	A	Implementation of environmental and natural resource management procedures

6.4 Written Submissions by participants

The written submissions which follow were collected during the Think Tank and up to 2 weeks after its conclusion. They are arranged in alphabetical order of authors.

6.4.1 Anonymous, Submission 1: Why natural events should have zero weight in the EVI (10/9/99)

In what way do natural events do harm to the natural environment?

(1) It has been argued that people do not like changes to the natural environment. Now suppose that:
- Natural event (A) kills 100 people
- Natural event (B) reduces the pleasure of scuba diving for 1000 people.

It would be absurd to say that society preferred (A) to event (B). Embodying any such social preference in an EVI would condemn it to new universal derision. Therefore, since (A) does not matter (by definition of this workshop), nor can (B).

(2) Natural events may harm other species. This seems a reasonable criterion. However, as many participants have observed, it is essentially changes in the natural variability of nature that harms species. Natural variability includes extreme events. No evidence has been presented to this workshop that the natural variability of nature is changing in any country. Moreover, none of the proposed measures of changes in the variability of nature are reliable indicators that the natural variability of nature is changing.

The logical conclusion is that natural events should have zero weight in the EVI.

6.4.2 Abelson, P., Submission 1: Developing an EVI: A note (25/9/99)

“In order to be useful the framework of assumptions and principles that underpin the model should be robust enough in the opinion of the international scientific community to be pretty much beyond question.” Opening address by Nicholas Kiddle, Acting High Commissioner, New Zealand.

I suspect that most of us agree that we have some way go to meet the goal set by the NZ Acting High Commissioner. Like Jerry, and probably most workshop participants, I think the method for developing the EVI must be presentable in defined and formal terms. I attempt below to do this and raise some basic related issues.

The general model

The model appears to run something like this. Following Jerry's note,

$$EV = f(B, C) \quad (1)$$

where EV = environmental worth,

B = biomass (total productivity)
C = complexity of the food web

And broadly following the workshop,

$$f(B,C) = f(ECE, BI, EHP, FHP, CC) \quad (2)$$

where:
ECE = extreme climatic events
BI = biological indicators
EHP = existing human pollution
FHP = future human pollution
CC = country characteristics

The unit of study is a country but standardised for differences in land area. In order to estimate environmental vulnerability, a model of negative changes in EV (-ΔEV) is needed. For any country, this requires estimates of:

- the partial derivatives ΔEV / ΔECE, etc. and
- the probability of occurrence of each determining variable π(ΔECE) etc.

The expected total change in environmental value (ΔEV) would be

$$\underline{\Delta EV = = \sum_{I} (\Delta EV / \Delta I) * \pi(\Delta I)} \quad (3)$$

where I stands for indicators.

This assumes (heroically) that the indicators have an independent impact on EV. It may be noted that, in this formulation, positive events can offset negative ones.

Because Equation (3) is difficult to measure directly, an environmental vulnerability index (EVI) is needed as a proxy for ΔEV.

$$\underline{EVI = \sum_{I} W_I * CS_I} \quad (4)$$

Where the W are weights (1 to 4 at present) and CS are country scores (1 to 7) for each indicator.

However, the EVI should retain the basic concepts embodied in Equations (1 to 3) as far as possible. Thus the weights (W_I) should reflect both the expected damage and the probability of an indicator occurring averaged over all countries.

$$W_I = avr\ [\Delta EV / \Delta I * \pi(\Delta I)] \qquad (5)$$

The country scores would also reflect expected damages:

$$S_I = \Delta EV / \Delta I * \pi(\Delta I) \qquad (6)$$

Of course, country ranking for EVI may be quite different from country ranking for EV. Indeed this is likely as the more EV that a country has, the more it has to lose. This does not invalidate the search for an EVI, but may lead to such questions as: which country deserves more support – one with a low EV or one with a high EVI? (See for example Figure 1 below).

The definition and measure of environmental value

How is EV defined and measured? If definition and measurement are not possible, the project will surely fail. Is Jerry's preferred measure of environmental worth (a) acceptable in principle and (b) roughly estimable? Jerry's measure seems to be the front runner at this stage (gaining some support from Geoff Jones' email), but doubtless warrants and will get much more discussion. For example, is all productivity of equal value? Can complexity be measured?

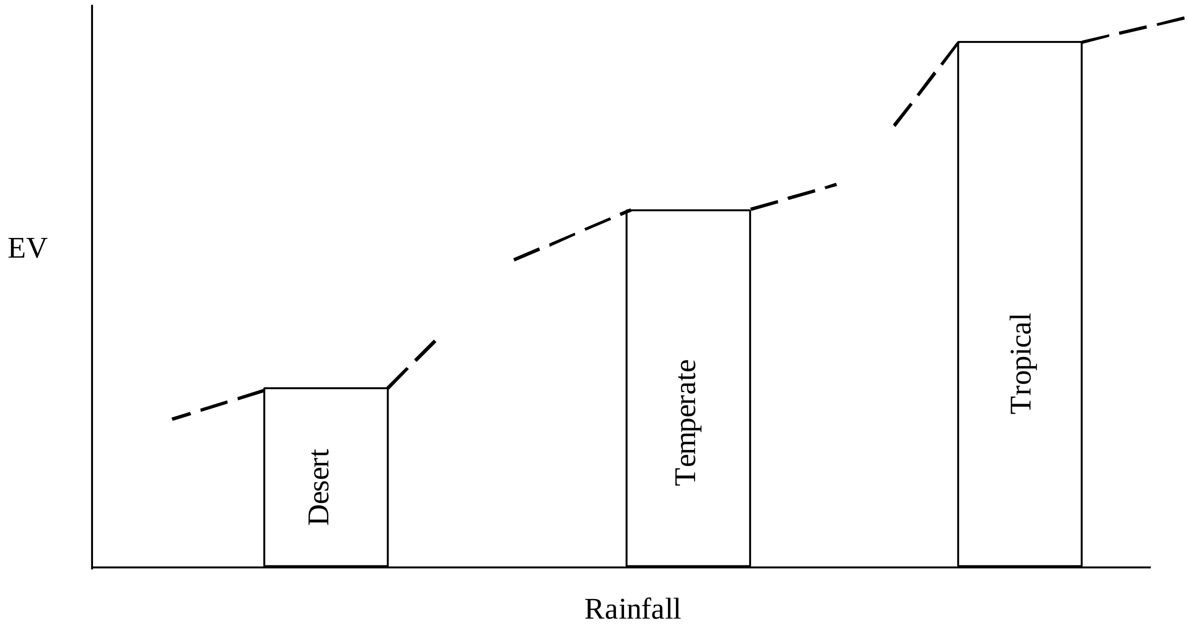
Jerry seems to suggest that EV might include some human products, like crops. This contains a risk. If some things that humans value are in EV and others are not, perverse results will occur such as a concern for coral reefs degradation being more important that the loss of many lives. In my view, human welfare should be all out of, or all in, the model. A half-way position could create major anomalies. Whether it is possible to completely remove human preferences from measures of EV remains to be seen.

The indicators

I remain a little sceptical of the impacts of **extreme climatic or geological events** (unless these are proxies for expected long-term change), and I am not sure that Tom's proposed new version is easy to interpret (what is a 'modified' ecosystem on a time-scale beyond one season?). As discussed at the workshop, many extreme events are part of the normal variation and some extreme events may be good for EV (especially as defined above). For example, I suppose that a sharp increase in temperature in the short or long run could increase EV in cold climate countries.

Figure 1 shows three countries: desertified, temperate and tropical along with their typical EV on the vertical axis. Rain is shown in the horizontal axis. In all three cases EV is invariant over a normal rainfall range, increases with increased rainfall (even in the tropics), and falls with reduced rainfall. Is this unreasonable?

Figure 1 Environmental Value and Extreme Rainfall



However the likely long-term change of global warming will damage EV in some countries and the omission of this indicator may be considered strange.

There is also a problem with **biological indicators** in that they are correlated with EV but they are not causes of ∆EV. Thus, biological indicators should also be correlated with the other indicators that are damaging EV, not independent indicators. If this is correct, the EVI should include either the biological indicators or the other indicators, but not both.

Existing anthropogenic pollution indicators can be included on the ground that EV is not fully adjusted to these sources of pollution, which may cause further loss of EV. Alternatively, these indicators may represent likely future pollution.

In the latter case, it would be double counting to include also likely **future anthropogenic pollution indicators**. The more general issue is that human caused pollution is very largely a matter of governance. Most forms of pollution have fallen in developed economies in recent years. One governance indicator could replace most of the anthropogenic indicators. For such an indicator and a perspective on human-sourced pollution see *The Economist*, 11-17 September, pp.24-7.

Including **country characteristics** in the index also runs the risk of double counting because country risks are embodied in all the scores. Thus country characteristics should be included only when they represent a risk that is not adequately covered by other indicators.

Concluding comments

The arguments above point to (a) the need for a clear definition of EV and (b) a substantial reduction in indicators. In the workshop pilot weighting exercise, most participants included all, or nearly all, 57 indicators – and so I suppose that most will not agree with (b). However, if the EVI proceeds with such a long list of indicators, I think it will be necessary to justify them against the kinds of points made here.

Doubtless participants are experiencing some correspondence fatigue. To those who made it to the end of this note and wish to comment on it, I should welcome your observations.

6.4.3 Blong, R., Submission 1: Edits and suggestions (10/9/99)

Indicator (new number)*	Words with definitional / operational problems
1	"agricultural"
6	"major" industrial facilities
16	"managed" or "treated"
17	"catastrophic"
21	"potential"
12	"removal of natural vegetation"
34	Does honest point incl. Death Valley < Dead Sea
35 + 36	"reserve"
39	"degraded"
41	"coastal settlement"
42	"natural" and "regrowth"
43	"overfished"
44	"intensively farmed"

* Note, numbering system may have changed since this submission received.

6.4.4 Campbell, J., Submission 1: Simplicity, the HEVI and smallness (10/9/99)

Simplicity
It is important that the entire "system" that is the EVI be kept simple. This includes all components. This include

- Questions
- Descriptors of units used in the scoring scale
- The system of weighting among questions
- Definitions of terms used in indicators.

The axiom for all levels of refinement of the EVI in the weeks/years ahead should be “can this component” be achieved, worded or calculated in a more simple way without loss of integrity of the EVI.

To be included as a recommendation:
That consideration be given to the development of a “Human Environment Vulnerability Index” (HEVI). This index would seek to include environments that impinge directly on human wellbeing. These include such parts of the biophysical environment as agricultural, forestry and built environments, for example.

There could be two approaches to the development of the HEVI.

1. An index that could stand alongside, but separate from, the EVI (although there would be considerable overlap in the indices used.
2. Integrated into an overall environmental vulnerability. In this case redundant indicators would have to be identified.

A useful way of doing an overall index could be to have three subsets of indicators:

a. Natural Environmental Vulnerability Indicators
b. Common Environmental Vulnerability Indicators
c. Human Environmental Vulnerability Indicators

a + b =	Natural Environmental Vulnerability Index (NEVI)
b + c =	Human Environmental Vulnerability Index (HEVI)
a+ b + c =	Overall Environmental Vulnerability Index (EVI)

A note on smallness and vulnerability
(This is just an observation)
The development of the EVI is part of a process in which small island countries are increasingly characterised as vulnerable. This is reflected, for example, in the UNFCC, the Yokohama Message on the Reduction of Natural Disasters, and in work carried out by the Commonwealth Secretariat and work done in conjunction with the Lomé convention. Indeed, the Barbados Declaration, which provided the impetus for the development of the EVI, has several references to the high levels of vulnerability of Small Island Developing States.

The outcome is the creation of a “discourse of vulnerability”. From almost all perspectives SIDS are characterised as vulnerable (e.g. trade, economics, environment, disaster, etc.). Yet, despite this, one finds vibrant and resilient communities on islands. At least in PICs, at the village level, there is little evidence of human vulnerability. Indeed, there is ample evidence of considerable resilience among island communities in the face of enormous disruptions in the past one or two hundred years.

6.4.5 Clarkson, T., Submission 1: Climatic indicators (20/9/99)

I undertook to refine and score the questions on Sea Surface Temperature (20), the five other climate questions (23-27) and the air pollution question (5).

The sea surface temperature question:
This can stay as it is:

Greatest average annual deviation in Surface Sea Temperature in last 5 years from long term mean (30 years)

This information is assembled globally as weekly and monthly averages and is archived. The greatest annual average deviations are about +/-3 degrees in El Niño /La Niña events.

Suggestion for scoring.

7 for >3 degrees
6 for 2.5 to 3 degrees
5 for 2 to 2.5 degrees
4 for 1.5 to 2 degrees
3 for 1 to 1.5 degrees
2 for 0.5 to 1 degrees
1 for 0 to 0.5 degrees
0 for countries without a marine zone

Suggestion for weighting 2.

This index will be correlated with others, especially climate (drought), ecosystem changes (fishery redistribution) and should not be weighted too highly because of this.

The climate questions:

I circulated some ideas on improving and simplifying the five climate questions. The only full response I received (Susana) was encouraging – towards a single climate question.

I tend to agree with Uschi's submission on climate questions that the proposals with the 100yr return periods will not work very well. I keep coming back to the problem of virtually everything climatic being "normal" from an environmental viewpoint, while recognising that climate events can devastate a country's environment on a human time scale.

We had five climate questions (hot, cold, wet, dry and windy) which I think can be replaced by a single highly-weighted question. Try this:

What is the maximum percentage of the country's environment that has been significantly affected by a single climatic event during the past decade.

“Significantly affected” means ecosystems were modified on a time scale beyond one season.

100% more than once = score of 7
81 -100% = score of 6
31-80% = score of 5
11-30 % = score of 4
6-10% = score of 3
1-5% = score of 2
0% = score of 1

Suggestion for weighting: 10.

Climatic events include :
Flood
Drought
Heat wave
Cold snap
Wind storm including cyclones.

Small island states that experience cyclones will score 6 or 7. Only events that have environmental effects will be considered. Events difficult to count otherwise may be considered e.g. a modest rain event causing floods after high antecedent rainfall. This question will cover the case of downstream flood Obvious correlations with smallness, but countries are what we are considering. Scoring is non-linear and rates anything over 30% as high vulnerability (score of 5 or more). Susana suggested that a combination of the countries largest events may give a more complete idea of its vulnerability to climate, but I have stayed with the idea of a single past event as a first guess at the future.

Estimates:
Tuvalu 6 or 7 (cyclone or drought?)
Fiji 5 (cyclone)
Australia 2 (abnormal drought?)
New Zealand 2 or 3 (drought)
US 2 or 3 (big freeze)

The air pollution question:

The question still looks OK as a single general indicator of air quality.

Max 24 hour SO2 concentration (micro g /cubic m) over the last 5 years

This peak value is only going to occur close to a city or industrial area.

Scoring suggestion
7 >300
6 200-300
5 100-200
4 50-100
3 10 - 50
2 1-10
1 <1

Some non-industrial countries will probably have no monitoring station. A zero (not applicable) score would be OK, otherwise 1.

Suggestion for weighting 3.

6.4.6 d'Auvergne, C., – Submission 1: General comments (10/9/99)

Conditions of use:
Due to the size?, location and other specific conditions some indicators may not be applicable to a particular country

Weakness:
Non-applicability of some indicators. One or more indicators may not be applicable to a specific country.

Strength:
The method attempts to ensure inter-country comparable by identifying a range of indicators, which address specific issues, which may not be applicable to all countries.

Definition:
The Environment: The sum of biophysical systems, which in the absence of human interference would be self-sustaining.
Or
The Environment: The sum of biophysical systems which, under natural conditions, could be sustained without human intervention.

6.4.7 Done, T., Submission 1: The Environment

The Environmental Vulnerability Index (EVI) is a number intended to describe the present vulnerability of a country's natural environment to damage from anthropogenic and natural causes, relative to other countries.

It seeks to represent the degree to which a country's location, natural geographic and biophysical attributes, and state of development, expose it to detrimental environmental effects, and to natural hazards referred to as 'acts of God'.

Definitions and Assumptions

The 'natural' environment (c.f. the 'built' environment and the 'production' environment) comprises that portion of the biosphere whose structure, processes and variability are not intentionally modified or used for consumptive purposes by humans.

The 'natural environment' consists of atmosphere, landscapes, lakes, seascapes and linear systems (i.e. rivers, coasts). Current understanding of the natural environment and is biophysical systems leads us to assume that their vulnerability is increased by human actions that:-

- decrease its net extent
- decrease its connectivity among its parts
- interrupt its linear systems
- disrupt its process

The natural environment is decreased in net extent and connectivity among its parts when humans bring areas into consumptive use (e.g. clearing; cropping; wild harvest; pastures; ranging) or transform areas into 'built environment'.

Linear systems such as coasts and rivers are interrupted by dams on rivers, groins, ports and walls on coasts that disrupt processes of sediment and water transport

Processes are disrupted by :

- human use and/or diversion of natural resources such as minerals and water
- pollution
- nutrification
- introductions and invasions of pest species

To derive the <u>Index</u>, we have defined 57 <u>Indicators</u>, each of which is a score on a seven point scale indicating relative <u>vulnerability</u> to the types of decreases, interruptions and disruptions mentioned above.

6.4.8 Green, W., Submission 1: Notes and suggestions for indicators (10/9/99)

Indicator 23: Environmentally-related legislation

Scale	Descriptor
1	Legislation and regulations cover conservation, natural resource management and environmental impacts of development and is widely implemented
2	
3	Environmentally-related legislation is limited in scope and effectiveness but other (social) controls regulate use of natural resources
4	
5	Environmentally-related legislation exists or in draft, but is largely ineffective in controlling use of natural resources
6	
7	No environmentally-related legislation; no regulation of use of natural resources

Basis for determining indicator (with ranking numbers):

	No “controls”	“controls”
“no”/little legislation	7	3
legislation	5	1

State of types of indicators:

Type of indicator	Pre meeting	Current
Meteorological	6	6
Geological	4	4
Habitat	1	4
Agriculture	5	2
Fisheries	5	3
Government	4	3
Mining	3	2
Pollution	8	9
Country Details		5
Water		1
Population (Human)	2	3
Species		3
Invasions		3

6.4.9 Jones, G.P., Submission 1: Debate on whether human environments should be included in the EVI (17/9/99)

I agree with Uschi’s submission that the human environment should not be directly incorporated into the EVI. If we include the human environment under the definition of environment, then the EVI as it stands is a tautology. Human activities cannot simultaneous be a threatening process and a response variable. The factors affecting the vulnerability of natural and human environments may be fundamentally different, so they could not be easily combined into one index. It is an underlying assumption of the EVI, as it stands, that human population growth and development represent a major factor increasing the vulnerability of the environment. Thus as the human environment expands, the natural environment contracts and becomes more vulnerable. This is the fundamental basis of many of the indicators in the current index and it is not without foundation. There is plenty of evidence that human activities (e.g. habitat destruction, introduction of exotic species) have been the major cause of the animal and plant extinctions that have occurred in the last 200 years (Soule 1991, Science 253:744-749). There is also increasing evidence that loss of biodiversity will impair the function of ecosystems (Johnson et al. 1996, TREE 11:372-377). If we are interested in the maintenance of a country's biodiversity, then pastures cannot be considered equivalent to natural habitats and buildings cannot be considered equivalent to the natural physical environment. They are not equivalent. One group can persist in the absence of humans and one cannot. We need not worry that focusing on the natural environment is too narrow. As we come to end of the twentieth century there will be plenty of use for an index that focuses strictly on the natural environment.

I agree with Jerry Vanclay that it would be excellent to measure vulnerability in more biologically rigorous terms. For example, the likelihood of species being extinguished from a country within a specified period. Unfortunately, conservation biology theory is probably not precise enough for us to be able to make these predictions. For example, does a 20% increase in population size result in a X% increase in the predicted number of species going extinct in the next five years? For each indicator (e.g. population growth rate) we would have to model the effects on the probability of extinction of all indicator species. This is a tall order. Deviations in productivity and food web complexity may also be good indicators of the vulnerability of ecosystems. However, as with population viability, ecological theory is probably still inadequate to predict changes in productivity in response to our 50 indicator variables.

If we decide to include the human environment in the index, the indicators we have chosen will have to be reconstructed. We would have to identify some ideal balance between human development and undisturbed environments, and any deviation in either direction would lead to increased vulnerability. Countries with extremely low population densities would be just as vulnerable as those at high densities, but for different reasons. The index would have to be able to respond to changes in the make up of the human environment, which the current index does not do. For example, a shift from monoculture human environments into diversification in cropping would have to reduce the vulnerability of the environment. As we would have to go back to the drawing board to construct a new model to measure such things, I suggest that it be discussed only as an option for the future.

6.4.10 Kaly, U.L., Submission 1: How the SOPAC Environmental Vulnerability Index can be used for human environments (13/9/99)

The SOPAC EVI was developed specifically to measure the vulnerability of the natural environments of states to both natural and human hazards. There was some concern raised at the Think Tank that the usefulness of the EVI would be less than expected because it did not address the vulnerability of human environments such as agricultural lands and urban areas.

This submission is being made to the Think Tank proceedings to show (i) why the human environment might not be directly included in the EVI; (ii) how this EVI can be used as a *proxy* for the vulnerability of human environments; and (iii) how this EVI can be adapted to form a new index which *specifically* deals with human environments.

(i) The human environment should not be directly included in the EVI

The SOPAC EVI is comprised of three categories of indicators. These are the:

- Risk Exposure sub-Index (REI) – Indicators measure the amount of risk to the environment from both natural and human hazards;
- Intrinsic Resilience sub-Index (IRI) – these measure the innate ability of the state to resist or absorb the impacts of hazards; and
- Environmental Degradation sub-Index (EDI) – the present 'health' of the environment under the assumption that the less degraded the environment is, the more likely it will be able to withstand the effects of hazards in the future.

All of these sub-indices provide proxy measures of vulnerability by providing information on the level of exposure and the expected resilience of natural environments to hazards. The REI and many of the IRI indicators would be common for both natural and human environments. That is, both natural and human environments are at risk of harm from the same types of hazards. For example, cyclones and pollution are risks to natural ecosystems as well as human systems such as croplands and urban areas.

The EDI proxy is, however, a measure only for natural systems and should not be mixed with measures relating to human systems. This is because:

1. SOPAC's brief was to create an EVI for natural environments.
2. Direct damage to crops and urban areas from natural and human hazards can be assessed directly in dollar terms and need not be proxies. Further, the damage to human systems may often be assessed in direct association with the hazard (human or natural) which caused it. For natural environments, direct associations between damage sustained and any one hazard are often difficult to make and poorly understood.
3. The degradation of an urban environment does not necessarily predispose it to further damage by hazards. Humans can repair the damage sustained and the human environment can be completely restored given sufficient natural resources, money etc.
4. Once a natural area becomes degraded, it can change category to a human modified or supported system (forests are cut down to make way for agriculture, mining and cities). Often, a hazard which causes degradation of the natural environment, is used as support for human systems (e.g. pesticides). These considerations mean that there is likely to be a strong connection between the loss of the natural systems and changes in the human ones leading to indicators which are highly correlated.
5. It is worth keeping the vulnerability of natural and human systems separated because they are under such different forms of control and damages to them can have such different consequences that combining them may not give us a *useful* picture of the vulnerability of a state.
6. By keeping measures for natural and human systems separate, we could attribute different weightings to hazards which are likely to impact differently in each type of system.

(ii) The SOPAC EVI can be used as a proxy for human environments

Human environments are subject to the same natural and human risks as natural environments. In addition, some of the measures of intrinsic resilience used in the EVI also describe the intrinsic resilience of human systems (e.g. proportion of land below 10m elevation which is therefore subject to cyclones, storm surges, tsunamis and coastal flooding).

Human environments such as croplands and urban areas are open systems which include natural elements, but more importantly are dependent on natural environments for goods and services. Further, most of the anthropogenic hazards to the entire environment of a state are introduced through its human systems. It can therefore be logically assumed that the health of human systems is largely dependent on the continued health and function of natural ecosystems (even if these are located outside the borders of the state) which provide the support of goods and services to human systems (attenuation of pollution, creation of soils, provision of natural resources).

If the EVI provides a measure of the vulnerability of natural environments to damage, it is also providing a proxy measure of the vulnerability of human environments. If natural environments are at risk or are damaged, human environments will follow suit. This is one of the meanings of the EVI being a measure of the vulnerability of the natural environment from a human perspective.

(iii) How this EVI can be adapted to form a new vulnerability index which *specifically* deals with human environments.

The SOPAC EVI could be adapted to specifically deal with human environments under a separate index. Such an index, which we will term the $HEVI_1$ (human environmental vulnerability index), could incorporate the same REI and many of the IRI indicators because, as argued above, both human and natural environments are subject to the same kinds of hazards. It may be therefore be sufficient to construct only a risk index which may or may not be supplemented with the intrinsic resilience information.

An alternative and more useful index, $HEVI_2$ could be constructed which incorporates information on actual damage sustained in the past as a measure of how vulnerable the specific human systems created in a state are to hazards. Humans build systems with widely differing resilience to hazards which would become the focus of the index. This assumes that cultures in different countries create different types of croplands, urban areas etc. which may be differentially susceptible to hazards. For example, typical city structures in Australia may be more or less susceptible to cyclones than cities in the Philippines.

In contrast to the EVI, for the HEVI it is not the way that people have managed their natural environments that matters, but the way in which they specifically choose to create their human ones.

In the $HEVI_2$ case, a proxy which describes the potential to be *degraded* further because of damage already sustained would be difficult or impossible to construct. A direct measure of *damage* as dollars lost due to cyclones, or pollution, or volcanoes would be more appropriate. These new indicators could be worded as a measure of damage sustained in the immediate past (e.g. 5 years) as a way of anticipating the likely vulnerability in the immediate future. Some examples could be:

- Mean annual $ loss (over the last 5 years) due to crop loss from pests and disease as a % of GDP
- Mean annual $ cost of lost infrastructure to cyclones and earthquakes (over last 5 years) as a % of GDP

Or, more simply, the $HEVI_2$ could be just the following measure:

- Mean annual loss as % of GDP (over last 5 years) as a result of natural and human hazards.

For the $HEVI_2$, these direct measures of loss are not proxies and do not need to be accompanied by measures of risk exposure or intrinsic resilience. They are losses which have actually occurred in the preceding 5 years and which are then being used as a proxy for the vulnerability of the human environment in the next 5 years (say). The risks are automatically incorporated in these measures as observed effects of hazards. This was partially done by Pantin (1997), who however ignored human hazards.

Literature

Pantin, D.A., 1997. Alternative ecological vulnerability indices for developing countries with special reference to small island developing states (SIDS). Report to UN Department of Economic and Social Affairs, 22pp.

6.4.11 Kaly, U.L., Submission 2: Why using a 1/100 year climatic event does not measure risk for the EVI (14/9/99)

The purpose of the REI is to obtain a signal of the amount of risk to the environment from natural and human hazards. That is, frequency, and wherever possible intensity, are taken into account. Using a 1/100 yr. event as a measure does not provide this information.

A 1/100 yr. event occurs, by definition, once every 100 years (+/-). That means that for a country, the 5 year previous assessment period has a 1/20 chance of containing one. The same would occur for all countries in the comparison and the REI indicators pertaining to the 1/100 yr. events would only show which countries had their event in the previous 5 years. Eventually, after 20 EVI assessments, we would expect every country to have had the event turn up once (+/-). This does not measure risk of the event, but merely reports in which assessment bracket of 5 years it occurred. The measure would suggest, however, that if you've just had a 1/100 yr. event that your chances of having another within the foreseeable future is low, but for the purposes of the EVI, this is not what we need.

I suggest we need climatic measures that are expressed in terms of some % deviation from the norm, where norm might be a 30 year period. We need the events to be defined independently of any time period, except where they refer to specifying a period over which we describe 'baseline' conditions.

6.4.12 Osborn, D., Submission 1: Comments on definitions (10/9/99)

Assumption (square peg in round hole):
EVI values are not an indication of the vulnerability of specific ecosystems, communities or populations partly or completely within the boundaries or adjacent waters of individual states.

Weakness:
The EVI does not consider unilateral, bilateral and multilateral legislative or regulatory frameworks and/or management regimes that may have a mitigating effect on anthropogenic pressures (risks) on the environment. NB – consistently low scores on anthropogenic issues may be an indication that legislative, regulatory or management regimes are effective.

Definition of Environment:
- The concept of excluding humans and human managed systems has been misunderstood.
- The mandate is: to not consider human or economic values of the environment when determining its fragility, e.g.
1. a building has the same ecological value as a rock
2. humans are just another species and have no greater value than spiders
3. a field of barley is simply a monoculture of grass

- This is fundamentally different to excluding humans and biophysical systems requiring human support from the definition of environment.
- The mandate calls for an index that expresses the vulnerability of the entire State and not only the biophysical systems sustained without human support.
4. If we define environment to exclude systems requiring human support, why the do we collect data for areas outside this definition, e.g. Total land area would have to be rewritten "total land area not sustained by human support".

Suggested wording under definitions:
Environment: the collective biophysical systems of the area to which the index is being applied.

Suggested wording under assumptions
For the purpose of this index, humans, their infrastructure and biophysical systems requiring human support, irrespective of their perceived monetary or other value, have no inherent value and are given no preference in the determination of environmental impact.

6.4.13 Osborn, D., Submission 2: Environment Australia Submission

Environment Australia (EA) views the Environmental Vulnerability Index (EVI) as addressing a real issue in a difficult field. The efforts to date of the Government of New Zealand and the South Pacific Applied Geoscience Commission (SOPAC) in developing the EVI are commendable.

Australia strongly supports the Barbados Program of Action for the Sustainable Development of Small Island Developing States. Australia is committed to its implementation and supports the consideration of vulnerability as a factor in decision making on access of small island states to concessionary treatment in a range of international fora.

The information collected to calculate a State's EVI will undoubtedly provide a useful initial guide to the relative need for technology, advice, capacity building and/or development assistance.

Australia's Minister for the Environment, Senator Robert Hill, has approved his Department's continued support of the SOPAC initiative and acceptance of the invitation to act as Australia's principal point of contact for the EVI project, to assist in co-ordinating the peer review process within Australia, and to facilitate the completion of data collection for Australia.

Sustainable Development

The EVI report, as it currently stands, states "Human systems and the environment are dependent on one another …". This is not entirely correct. While the environment is impacted by the existence and integrity of human systems, it is not dependent on human systems. The report could therefore be amended to read:

"Human systems are dependent on the health and integrity of the natural environment and risks to the environment of a State will translate, either immediately or progressively, into risks to humans."

This important principle needs to be established as an underlying theme for the EVI, remembering that the EVI is envisaged as a tool for the sustainable development of small island developing states. The EVI should aim to measure a states ecological integrity, thereby providing a numerical indicator of the risk and resilience of States as human habitats.

Definitions

To avoid confusion the term 'environment' needs to be defined in the context of the EVI and clearly articulated. In the current model the EVI focuses solely on the natural environment of a state, and not the social, political or economic environment. That is, the EVI is a measure of ecosystem integrity, irrespective of the any economic and/or social values that humans might place on that ecosystem. Using the metaphor suggested by SOPAC, the EVI measures the patients 'proneness' to a long and healthy life, taking into account the patients current health, family history and personal care practices (resilience) and the patients surroundings and lifestyle choices (risks). In doing this, the EVI does not consider the value society places on the patient or the patients earning potential.

The EVI also needs to distinguish between the natural environment and a natural environment. The natural environment of a state is all encompassing and includes its air; its ground-water, rivers, lakes and oceans; its soil (sediments) and bedrock; its plant and animal life; and the systems which link each of these elements together. Phrased in another way, the environment of a state its biophysical systems. The environment of any particular place is three dimensional, incorporating the air above it, the ground and water below it, the life on it, and all the systems which contribute to it. The natural environment is dynamic by definition and changes can occur with or without human intervention.

On the other hand, a natural environment refers to subsets of the natural environment where there is little evidence of human modification and/or management. These areas are increasingly difficult to define (particularly in the terrestrial zone) as the impact of humans spread across the globe. In most states humans have significantly modified large areas of the natural environment. Modifications include, inter alia, cities and roads, large areas of cleared native vegetation, dammed rivers and irrigation systems, and pollutants in the air, sea and land. In other areas human modifications may be far more subtle. They may take the form of an introduced species or pathogen, the removal of species, or activities far removed that directly impact the area being considered, i.e. activities up-river or up-wind. Along the ‘spectrum of naturalness’, determining the threshold point when an environment is no longer considered natural is extremely difficult and value-laden.

The EVI should aim to assess the vulnerability of a states entire environment and not be limited to those remaining areas of a state that might be labelled ‘natural’ such as virgin forests, wilderness areas, etc. Repeating the metaphor used earlier, the EVI must consider the whole patient and not exclude the mouth because the patient already has dentures, or the skin because the patient already has tattoos.

Indicators that reflect risk and intrinsic resilience are not effected under this broad definition. However, the task of identifying the sub-set of indicators that reflect degradation becomes extremely difficult, as these indicators essentially measure changes along the ‘spectrum of naturalness’. For example, it may be simple to assume that a field of sugarcane is more degraded than the endemic rainforest that was cleared to plant the sugarcane, but is a subsequent field of corn more degraded than the field of sugarcane? For this reason it is necessary to identify a threshold along the spectrum and accept indicators that measure change across the threshold, making an assumption that such change increases vulnerability. These indicators then serve as a proxy for all forms of degradation. The degradation indicators drafted during the think-tank do this.

Application of the EVI
As a tool for sustainable development the EVI has limited applicability as an absolute measure.

From a socio-political perspective, the potential use of the EVI, either alone or in combination with an economic vulnerability index, in a simplistic way, has wide reaching implications. If the EVI is used in this simplistic fashion, developing countries should perceive benefit from being rated as ‘highly vulnerable.’

From a scientific perspective, it is doubtful that a single quantifier can be used to compare relative environmental vulnerability meaningfully, and certainly not comprehensively. This is especially the case when the data available for the model calculations are inadequate, of poor quality, or inaccurate, and the index does not include a 'confidence rating'. It also means that for different purposes or different 'pressure scenarios' the aggregated average index may need to be disaggregated, and one (or two) component(s) used in a comparative assessment – for instance in a scenario where risk and intrinsic resilience were considered important, but condition (degradation) much less so.

For these reasons, Environment Australia supports efforts to present the EVI as an environmental vulnerability profile, where index and sub-index figures are supported with quantitative and qualitative summaries.

Subjectivity of Indicators and Weightings
A major issue still to be addressed with the EVI is its subjectivity. The criteria used to choose the indicators currently included are valid but are still very broad. In an attempt to address this the scientific rationale for choosing each indicator should be a part of the final EVI.

As was discussed at length during the think-tank, weightings can and do skew the final index value appreciably. A single index figure will be counterproductive if it guides policy on the basis of weightings that are not transparent and which may not accurately reflect current scientific understanding or the current values of the local or global community. Considerable effort should be expended to review the weightings.

Stand Alone or Composite
Finally, the EVI should be viewed as a tool, not an end. Stemming from the Barbados Program of Action, the purpose of generating an EVI is to provide a tool which, when considered along side any number of other tools, will ensure informed and appropriate decisions regarding the sustainable development of small island developing states.

Whether the EVI is used to form a composite with other indicators, in isolation or to complement other indicators, is not a decision that needs to be made in this forum. The question should be "How can the EVI be best presented as a tool for the decision making process?"

6.4.14 Persaud, B., Submission 1: Comments on the EVI (26/9/99)

A basic problem is the meaning of the Index ---- the conception it is capturing. For instance it was not entirely clear what the EVI relative values for Australia, Fiji and Tuvalu really signified. Since vulnerability is not a technical term in economics or ecology, a precise meaning must be given in any use, so that when an index throws up values for individual countries, the meaning of these values must be clear, or at least fairly so at the beginning.

The emergence of a clear meaning would be difficult, if there are many components. At present the EVI incorporates many characteristics ---- risks, resilience, degradation and human and natural factors. Besides, while some of the indicators are measurable, others require proxy data because information is not available and some must rely on judgement. In some cases actual values were used, in others a weighting scale. Where weighting was difficult to apply, as between risk and resilience components, it was abolished. And with each indicator usually being given a weighting of one, dropping and adding indicators all affected the overall weightings.

A serious problem which scarcely arises in the case of many widely used economic indices, such as stock market prices, wages, retail prices etc is that it is not required to add apples and oranges. While in the case of the Criteria for classifying Least Developed Countries, this happens to some extent at the level of sub-components, and even more widely in the case of the Human Development Index (HDI), it happens to a larger extent in the EVI, and because of the large number of indicators involve, this fudges meaning and precision.

Many countries are now developing environmental indicators covering areas of major environmental impact, thus providing information on the state of the environment or extent of deterioration in the particular area concerned e.g.: air quality, water quality, forest degradation etc. The difficulty arises when attempts are made to combine these to provide composite indices to indicate overall state of the environment, vulnerability or degradation. In the case of composite economic indices, common money values or weightings suggested by the data themselves, avoid the need to add apples and oranges, or to resort to judgement to arrive at weightings. Thus if a composite index has many components each measured imprecisely, or by judgmental measures, and each weighted judgementally when being combined, overall meaning or conception becomes severely compromised.

These considerations lead me to the view that developing a composite index for countries which could be used for international comparisons would have to proceed with great care. The best approach would be to use a small number of indicators covering crucial and representative aspects. Where differences in country characteristics necessitate widening the list of indicators, difficulties arise which compromise the development of meaningful comparative values. An alternative might be to develop EVIs which could be used for groups of countries rather than for all countries e.g. island developing countries, other developing countries, island developed countries, other developed countries, etc.

A basic difference between the EVI and the economic vulnerability index that others have been trying to construct is that the latter is concerned with threats and impacts from exogenous factors acting on a community e.g. the state, whereas the EVI is concerned with the ecosystem, and one source of impact is from the community itself.

If SOPAC succeeds in developing a useful EVI, the CDP could consider it as a sub-component for its new economic vulnerability component. This might help to strengthen the environmental component of our economic vulnerability sub-index. However, conceptual and data problems would seem to put such inclusion some way off. We need to see how refined the Index would become after influence from the Fiji Meeting.

As an ecosystem index, the EVI will not be suitable as a replacement for our economic vulnerability sub-index. It is too distant from economic impact.

6.4.15 Vanclay, J., Submission 1: Adding rigour to the EVI (13/9/99)

The journey home gave me time to reflect on our EVI collaboration, and I found my thoughts returning to our definitions. It's critical that we get these right to clear up misunderstanding between ourselves and amongst potential users.

I subscribe to David's views on "environment". If we retain "without human intervention" we face a contradiction relating to agricultural land. An organism within a national park is not independent of the cultivated land (or water) outside the park, because some link in the food chain, whether predator or prey, may depend in part on that land. Thus I like the definition about "land, water and air" that was proposed earlier. Perhaps "The natural environment includes the land and water within the defined area, the air above it, and all that lives in or on it". To this, we should add that humans (and their crops and livestock) are treated as any other species; they have no greater and no less value than any other species, and our roads, buildings and other infrastructure have no more or less value than mole tunnels, termite mounds and spider webs.

I think that a definition of vulnerability as "proneness to change or damage" is too subjective. If it encompasses a change in appearance, it is too subjective - beauty is in the eye of the beholder. Does a resort make a beach more or less beautiful? Unless we propose a more rigorous definition of vulnerability, experts will have a hard time ranking countries consistently for comparison with our index - and we will have a hard time agreeing on the weights contributing to our index.

I like the idea of measuring vulnerability in terms of the risk that a species will be extinguished from its natural habitat within a nominated period (perhaps the next 100 years). This has a number of interesting properties. It is species that matter; the loss of individuals doesn't matter except if it erodes genetic diversity or increases risk of extinction. Existing models can be used to compute specific extinction likelihoods (given present populations, fecundity and mortality rates), so we can get an independent estimate of vulnerability. But this defines vulnerability in terms of species, not countries. We could arrive at country estimates by combining specific estimates for all species involved, weighted by the inverse of the number of countries in which a species occurs. Migratory animals pose a challenge, as they may be totally dependent on more than one country, so a different weighting may be required for these. Crop plants also pose a problem, as many of these are vulnerable in their natural habitats (e.g. Pinus radiata; I guess that a GM crop, artificial cultivar/variety or hybrid doesn't have a natural habitat). On balance, I don't like this approach, because it doesn't extrapolate well to countries, and may be too slow to respond to degradation.

Perhaps a better way to measure change is by monitoring productivity. A pristine environment should be quite productive, any loss of that productivity may be viewed as environmental damage. Several formulae exist to compute expected primary productivity anywhere in the world, and comparison with observed productivity could give a measure of productivity - but this is not really what we want: algal blooms are pretty productive. We want total productivity, not primary productivity, and we want it appropriately weighted for the expected 10-fold reduction in biomass at each tier in the food chain. Since we're interested in the whole food web and its complexity, and since we need to weight the high-order consumers heavily, we could just look at those high-order organisms, such as raptors, big cats, etc - that would be much easier to measure. If a site is productive and its food web is in good shape, then it should be reflected in the biomass and diversity of raptors, etc. And it is a bonus that they're long-lived and slow to breed, so that individuals have time to accumulate toxins, etc and manifest symptoms. And the biomass and diversity of raptors etc should be relatively easy to monitor, at least for selected sites.

So I suggest that we define vulnerability in terms of the likelihood of losing productivity and complexity from the food web. I suspect that this will correlate pretty well with more anthropocentric measures such as "loss of natural beauty". It will provide a firm basis for experts to rank countries, and allows the possibility that we could compute the biomass and diversity of raptors etc for selected countries to provide a rigorous benchmark to compare with the expert ranking. It also allows the possibility that we collate this data for some nations at a nominated reference date (e.g. 1970). This would allow two possibilities: (1) that we empirically "validate" our EVI for selected countries to see if a 1970-EVI helps predict changes in raptors etc since 1970;
or (2) that we empirically calibrate the weights assigned to our questions rather than relying on "expert knowledge".

6.4.16 Vanclay, J., Submission 2: The definition of Environment (16/9/99)

Uschi's submission is a good one, and helps explain the rationale behind SOPAC's EVI. However, I fear that we are at cross purposes, and that some of us are attempting to communicate on different wavelengths.

At the end of the workshop, I had the feeling that we did not share an unambiguous vision of the scope and purpose of the indicator. Despite that, I think that we came up with a good product that will help further the debate. However, our failure to share a common vision suggests that users (both those estimating the EVI, and those applying the EVI) will have the same difficulty, and that is a weakness that will cause a problem sooner or later. I think that it is essential to be able to define the scope and purpose of the indicator to all parties.

So where do we draw the line? We can draw it logically or geographically. I like David Osborn's logical line - that humans equal other species, our crops are no different to other species (cf. ants farming fungi), our structures are just objects (cf. ants nests), and thus we can deal with the entire land surface of a nation.

A geographic line is somewhat more arbitrary. We can agree that cities are human systems, and national parks are natural systems. But what of crop lands, Pinus radiata plantations, plantations of indigenous tree species, selectively-logged forests? What of national parks in the UK, where the park area includes farmland and other human modifications? How do we account for the fact that an animal found on one side of the line, may depend substantially on food obtained from the other side of the line? As you can see, I have some difficulties with a geographically-based separation into human and natural systems.

I do not disagree with Uschi's thesis (i) that "the human environment should not be directly included in the EVI", but for me the question is how best to separate it out? I think that David's suggestion offers an objective approach that is not easily misinterpreted.

I'll not comment on Uschi's points (ii) and (iii). I don't dispute that the SOPAC EVI can be used as a proxy for human environments, or that there are lots of ways to do it. However, I don't have any particular expertise in that area, so I'll leave that for others.

I would like to return to another source of ambiguity in the EVI as it stands. We all have notions of "environmental quality", "vulnerability", etc, but we don't necessarily all share the same notion. This came out during the workshop - e.g., is a flood good, bad, or just a phenomenon? Given these different notions, how can we produce an unambiguous index unless we can relate it to something quantitative or "universally agreed" - hence my earlier suggestion about relating it to the likelihood of extinguishing a species or of reducing the diversity and complexity of a food web.

I fear that unless we add some rigour by better defining the scope and by tying the index to something that can be measured, the index will have short life.

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