EVI Phase II Report

Environmental Vulnerability Index: Development and provisional indices and profiles for Fiji, Samoa, Tuvalu and Vanuatu

SOPAC

South Pacific Applied Geoscience Commission

SOPAC Technical Report 306

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1. Vulnerability index – environment

Abstract

The SOPAC Environmental Vulnerability Index has now been developed to the stage that the model and indicators have become stable enough that further technical review yields little change. This means that data can be collected and provisional EVI results calculated for countries seeking to examine their environmental vulnerabilities. This report describes the progress made during Phase II of the EVI project which focused on (1) obtaining rigorous peer review, (2) refining the model and indicators, (3) developing a mechanism for the collection of data, (4) calculating provisional results for Fiji, Samoa, Tuvalu and Vanuatu, (5) introducing and discussing the EVI in a range of international fora, and (6) developing criteria and a workplan for testing and refining the index to a stage where it could be internationally acceptable.

The results obtained for the four countries examined in this report demonstrates the potential of the EVI for identifying countries which are environmentally vulnerable in a general sense, while also providing a list of focal issues that could be used by the countries themselves and donors to improve their status. We recommend that a third and final phase of the EVI project is needed to test the model and indicators using a larger set of countries. It will also be necessary to continue the process of peer review, set the scoring and weighting factors, improve the capacity of countries to work with the EVI, collect EVI data and operationalise the index. It is strongly recommended that the EVI be fully globalised in Phase III, rather than remain focused on the Pacific Region.

Summary

The Environmental Vulnerability Index (EVI) was developed in early 1999 by SOPAC to provide a measure of vulnerability for the environment which could be calculated on the scale of entire states. The EVI was initially developed for the purpose of ranking countries and providing a single-figure expression of their relative environmental vulnerabilities. The work was done in response to a call made in the Barbados Programme 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. Although other types of indices which describe vulnerability of humans in relation to a range of stressors have been developed in the past, there have been few attempts to describe effects on the environment. Because human systems and the natural environment are dependent on one another, risks to the environment of a state will eventually translate into risks to humans. The EVI is a shortcut method of measuring and characterising the potential of harm to the natural environment arising from a range of risks.

Phase II of the EVI Project focused on developing and refining the draft index presented in Phase I and on calculating provisional indices for several Pacific Island countries. The specific aims were to:

1. Obtain international peer review on the model and indicators of the EVI to determine whether the approach was sound, indicators appropriate and the index acceptable to the international community;
2. Improve the draft EVI developed in Phase I to a stage where it could be used to collect data, provide provisional results for a small number of countries and allow for testing of the model when sufficient data are available;
3. Develop a procedure for data collection;
4. Calculate provisional EVI values for Fiji, Samoa, Tuvalu and Vanuatu to demonstrate the viability and uses of the EVI;
5. Introduce the EVI to international agencies, donors, governments, scientists and environmental managers to facilitate collaboration, the exchange of data and increase the profile and understanding of the EVI; and
6. Develop criteria for when the EVI could be considered operational and a work plan for testing and refining it to a stage where it could be internationally acceptable.

Technical review of the EVI was obtained through the running of a Think Tank in Fiji, a meeting in Malta, attendance at several key meetings, discussions with experts and publication of papers in the proceedings of meetings. The most significant progress was made during the Think Tank. The purpose of the think tank was to assemble a group of international experts from a range of disciplines central to the index, to subject it 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 recommended changes to the framework were incorporated immediately. The indicators, in contrast, were developed more slowly, in the context of additional inputs from other experts, potential users, recommendations from the Malta Meeting and the data collected from 4 Pacific countries.

The EVI model and indicators were modified during Phase II, particularly during the Think Tank, and have now stabilised. Participants at meetings after the Think Tank were less likely to be able to suggest improvements to the model that had not been previously suggested or make suggestions for upgrading or adding indicators. This means that the EVI model is now at a stage where although further improvements are likely, the basic form is sufficiently accepted to allow us to begin the process of larger scale data collection and testing. The list of indicators now numbers 47 (10 less that the original EVI in Phase I) and provisional scaling has been set for each indicator. Testing of the model and correlation amongst indicators will require data from at least 15 different types of countries from all geographic regions of the world.

It was necessary during Phase II to develop a protocol for the collection of data from participating countries. This involved a visit to each country, briefings of the nature, importance and need for the EVI, methods for obtaining and recording the data required and follow-up contact. Because the EVI is still in provisional form, and scoring levels for the indicators have not been finalised, it was necessary to circulate data sheets to the ministries and departments most likely to have access to the data required. This approach was successful in three of the four countries trialled, resulting in sufficient data to calculate a valid EVI (Fiji 81%, Samoa 83%, Tuvalu 85%). For Vanuatu this approach was less successful with only 70% of data obtained, rendering its EVI values strictly invalid. The results for Vanuatu are nevertheless presented in this report for information. Further work will be required to collect the missing data for this country.

The provisional results obtained for Fiji, Samoa, Tuvalu and Vanuatu demonstrated the great potential of the EVI as an international and national management tool. The overall unweighted EVI values for the four countries identified Tuvalu as the most vulnerable with a value of 4.5. Fiji, Samoa and Vanuatu returned similar scores in the range of 3.1-3.4. The application of weighting to the indicators made little difference to the EVIs for all countries except Vanuatu. It was difficult to separate biases caused by insufficient data from the real effects of weighting in this trial. The sub-indices calculated for risk exposure (REI), intrinsic resilience (IRI) and extrinsic resilience / environmental degradation (EDI) and the categorised indicators (meteorological, geological, biological and anthropogenic) revealed that although Tuvalu was generally the most vulnerable, the different countries were vulnerable in different ways. The most notable patterns were that the countries differed greatly in terms of their IRIs (intrinsic characteristics), and geological and biological hazards, but did not differ as much in their REIs, EDIs, meteorological and anthropogenic hazards. Again, because the EVI has not been sufficiently tested, these are provisional results. Vulnerability profiles were used to identify those indicators for which high EVI scores were obtained (the value 7 or 6, indicating high vulnerability). This was a successful procedure that resulted in a report card for each country that identified the most important vulnerability issues.

The EVI was presented to international agencies, donors, governments, scientists and environmental managers to facilitate collaboration, the exchange of data and increase the profile and an understanding of the EVI. We represented the EVI at a total of 24 meetings during Phase II, two of which we hosted. We were also able to gain the support for future data collection from participants from a range of countries.

The EVI has now been developed to the stage that it clearly demonstrates its potential power for identifying countries which are environmentally vulnerable in a general sense, while also providing a list of focal issues that could be used by the countries themselves and donors to improve their status. The problem now is that the EVI presented here is still in provisional form. Although there is general agreement on the indicators and the way that the model has been constructed, there remain issues related to testing and scaling which have not been attempted here. These will have to be addressed in a third and final phase of the project.

At the end of Phase II there is now a choice to either create a global EVI or one crafted specifically for the Pacific Region (original brief). For the EVI to have its widest range of uses, it has to be globalised. This requirement was raised at every meeting we attended to introduce and discuss the EVI, and was a major recommendation of the Think Tank. A global focus is highly recommended because it seeks to develop the EVI on a world scale, providing an appropriate context for Pacific and other SIS. That is, the indicators selected and scaling set for each will encompass vulnerability issues and the range of conditions found world-wide. This is important if the SIDS wish to be identified as a group with special issues to consider. By contrasting them with all other countries, minor differences between them will be de-emphasised and the differences between the Pacific Region and others will become the focus of international procedures.

What is the EVI ?

A shortcut. A relatively quick and inexpensive way of characterising the vulnerability of natural systems (at the level of a region, state, province or island). By doing this as an index, the characterisation can be comparative because there is a common basis for the measurements

What is the alternative ?

Ad hoc assessments done on a case-by-case basis for each country - very costly in terms of resources & time

What are its uses ?

- Determination of LDC status (if globalised)
- Getting a comprehensive general sense of the environmental vulnerability of a country
- Predictive value for identifying vulnerability issues, types of hazards and approaches to stewardship of the environment of a state
- Identify problem areas for external assistance to a country
- Provides performance indicator for donor funding
- Can be used as a measure of change in environmental vulnerability if repeated assessment are made (5 years)
- Tool for raising awareness of environmental vulnerability and the actions that increase or decrease it
- Tool for monitoring sustainable development
- Useful for SOE reporting by identifying mechanisms that would tend to degrade the state of the environment

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The views expressed in this document are those of the authors and SOPAC, but are not necessarily shared by the New Zealand Government or any of the people consulted during the project. The work and results described in this document are often the consensus views of participants of meetings and discussions. Not all participants agreed with all of the decisions made throughout each meeting. We have tried to record alternative views along with the mainstream ones, and any omissions of these are accidental and are our responsibility.

Contents

Figures and Tables

1 Introduction

1.1 Background

Concern regarding the issue of vulnerability of Small Island Developing States (SIDS) was first brought to international attention during the Global Summit on Small Island States held in Barbados in 1994. At this conference, SIDS, with the support of the United Nations, expressed the desire for the development of a vulnerability index that reflects the status of SIDS and integrates ecological fragility and economic vulnerability. This desire was included in the Barbados Programme of Action with additional support from the Alliance of Small Island States (AOSIS). As a result of these events, the South Pacific Applied Geoscience Commission (SOPAC) was approached to develop an Environmental Vulnerability Index (EVI) for the natural environment with a focus on the Pacific Region. Its purpose was primarily to highlight an increasing awareness that SIDS face disadvantages to their sustainable development as a result of their remoteness, small size, dispersion, economic conditions, natural disasters and limited natural resources.

The impacts of natural hazards and human activities on the environment can potentially affect all countries and their ecosystems. Their impacts can influence countries both large and small, developed and developing, or land-locked and fragmented. Further, hazards may be operating under a number of guises, each with different operational definitions. An example of this are storm force winds which occur throughout the world and are known by several different names including cyclones, hurricanes or typhoons depending on which part of the world in which they occur. This means that any methodology developed for determining environmental vulnerability should be applicable to all countries on a common basis if any meaningful comparisons are to be made and if we are to determine which countries are more vulnerable than others in the world context.

Vulnerability indices have been developed in the past which describe the risks associated with economic and social conditions, climate change, sea-level rise, natural disasters, anthropogenic impacts and more recently, sustainability. Most of these indices describe the vulnerability of human systems with only limited attempts having been made to describe effects on the environment. Human systems and the environment are dependent on one another so that risks to the environment of a state will eventually translate into risks to humans and their welfare. The index described here has been the first attempt to construct an index that focuses on the vulnerability of the environment.

The environmental vulnerability index (EVI) is being developed as a robust, flexible tool aimed at providing a simple, short cut measure of the vulnerability of the environment of countries. The index will be intuitively and easily comprehensible to allow for wide usage in international processes (such as determination of LDC status) in addition to being a powerful tool for identifying vulnerability issues. That is, the main strength of the EVI will be that it can provide not only simplified summary information, but also the detailed data required to highlight specific areas of concern for environmental managers and scientists. Vigorous testing of the EVI will ensure that it is as much as possible an impartial measure which will differentiate among countries and allow comparisons and determination of which countries are more vulnerable than others on the world scale.

1.2 Aims for Phase II

The SOPAC EVI project has passed through two phases of development to date. The first phase of this study begun in August 1998 and culminated in a report outlining a conceptual framework for determining environmental vulnerability and initial EVI calculations for Fiji, Australia and Tuvalu. This approach allowed us to test our draft model using three countries selected for their range in size, climatic and geological characteristics and level of economic development. The outcomes of that study were described in "*Environmental Vulnerability Index (EVI) to summarise national environmental vulnerability profiles"* (Kaly et al, 1999a SOPAC Technical Report 275).

This report describes the development of the EVI during Phase II (but see also Kaly et al, 1999b). Phase II of the project was carried out between February 1999 and February 2000 with the following objectives:

1. To obtain international scientific peer review of the model and indicators to determine whether the approach was sound and to refine the way that the model was defined and the indicators which drive it. This work includes the running of the Fiji Think tank, a UNEP meeting in Malta, attendance at several other meetings to which we were invited, and the publication of two papers in the proceedings of meetings. The results of this work are described in Sections 2, 5, 9.3 and 9.4 of this report.
2. To develop the EVI model and indicators to a stage that it could be used to collect data and produce provisional results. The results of this work are described in Section 3.
3. To develop a streamlined procedure for the collection of environmental vulnerability data from participating countries (Sections 4.1 and 9.3).
4. To compile provisional EVI values and vulnerability profiles for Fiji, Samoa, Tuvalu and Vanuatu[3]. The results of this work are described in Section 4, with the data and sources being included in Sections 9.1 and 9.2.
5. To introduce the EVI in a range of fora to facilitate collaboration, data exchange and increase understanding of the need for and nature of the index (Section 5).
6. To develop criteria and a plan of the work required to test and refine the EVI to a stage where it could be internationally accepted (Section 6).

[3] Although it was intended during Phase II to include Australia in the trial, we were unable to obtain their data.

2 Update on the EVI model during Phase II

The EVI model and indicators were refined during Phase II via the following mechanisms and activities.

1. The EVI Think Tank (September 1999)
2. The Malta Meeting (Nov/Dec 1999)
3. Data collection from Fiji, Samoa, Tuvalu and Vanuatu
4. On-going development carried out by the SOPAC EVI Team, including discussions with experts and inputs from other meetings.

Of these mechanisms, the most important were the Think Tank, country data collection and development by the EVI Team. Changes resulting from the Think Tank are described in detail in the report Kaly et al (1999b) and are summarised in Section 2.1 below. Results of the Malta Meeting are summarised in Section 2.2 and the details will be available soon in a report by Briguglio et al (2000). Changes to the indicators made by the EVI Team resulting from our own work, expert commentary and the collection of country data are concerned largely with the setting of the response scale (i.e. the data values that correspond to the 1-7 vulnerability mapping scale used in calculating the index) and are summarised in Section 3.2. Changes in the way that indicators are worded and the data they are intended to capture were made in a similar manner and are summarised in the same section.

2.1 Changes resulting from the Fiji September 99 Think Tank

2.1.1 Purpose and approach

The Think Tank was run between the dates of 7-10 September 1999 at Pacific Harbour Fiji. The purpose of that meeting was to assemble a group of internationally recognised scientists who were experts in fields relevant to the EVI to obtain their opinions and assistance with developing the index. The group was asked to examine all aspects of the original model designed by SOPAC (Kaly et al, 1999a); 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 and impacts; fisheries; forestry and agriculture; productivity and energy flows; and environmental economics.

A range of topics designed to stimulate debate and solve technical problems was developed for the Think Tank (see Kaly et al 1999b). These 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 has been on-going between participants, other experts and the EVI team.

The EVI model can be divided into two parts and it is of value here to discuss changes to these parts separately:

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

2.1.2 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 were largely immediately incorporated in the updated EVI:

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 and was not adopted);
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 was dropped, with only gross vulnerability being calculated and the terminology being omitted altogether;
5. Indicators which were considered not applicable to a country 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 (this has not been adopted to date because it reduces the usefulness of the EVI sub-index information by unnecessarily pooling intrinsic and extrinsic risk);
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; (iv) The states used for testing should represent the extremes across the globe, including for example, Greenland and Switzerland to contrast against SIDS.

2.1.3 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 in addition to the EVI Team;
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 fully when data for 15 countries are available, though for the purposes of this report, the weightings suggested at the Think Tank were trialled (see Sections 3 and 4). 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 remain provisional until it can be ascertained whether data will be available for each and whether there are still redundancies.

2.2 *Changes resulting from the Malta November 99 Meeting*

The participants at the Malta Meeting represented Caribbean, Mediterranean and Indian Ocean small island states (Malta, Mauritius, Jamaica, St Lucia and Trinidad & Tobago). Participants fully supported the approach taken by the SOPAC EVI Team for describing and measuring environmental vulnerability at the scale of states. There was, as expected, some discussion regarding the various definitions being used for the EVI and in particular that for "environment". As a result of that discussion, it was agreed that the EVI should focus purely on attempting to describe the vulnerability of the *natural environment*. The term "environment" itself has been used to describe different parts of the world's systems, including the "natural environment", the "human environment" and others. It was therefore suggested, that to avoid confusion, the name of the EVI could be changed to the "Vulnerability Index for the Natural Environment" (VINE).

Further discussions focussed on the choice of indicators and ensuring that indicators captured all environmental vulnerability issues relevant to those states. Several general recommendations regarding the indicators included:

- There was a need for an additional column of keywords with every indicator to help the respondent understand better what the indicator is measuring and to highlight the linkages between the different indicators (adopted, see Table 1);
- Some of the environmental data that is derived from national sources is not properly audited and standardised for international comparisons, and additional care should be taken to reduce the dangers of comparing like with unlike;
- The indicators should be accompanied by some coefficient indicating the level of confidence in the data (this was included in the model during Phase I);
- The EVI needs to be further cross-examined through publication in an international peer-reviewed journal;
- In the narrative describing the index, more emphasis should be made on the association between environmental vulnerability and costs and benefits to human systems and welfare;
- That in the same narrative, the policy implications associated with anthropogenic indicators be given importance;
- That the indicators be calculated over a span of time, so that rates of change can be calculated and thus be used as a dynamic tool towards natural environmental assessment and management (this was incorporated during Phase I); and
- That clear definitions be developed for several indicators e.g. "continent" (partially addressed in this report).

2.2.1 Suggested Changes to the Indicators

Several changes were suggested by the Malta Meeting participants for several indicators as follows:

- Indicator 15 relating to the percent of land area composed of unconsolidated sediments - It was suggested that the wording be changed to the following: "Percentage of land area less than 10m elevation within 2km of coast composed of unconsolidated sediments (exclude coral reefs and ice)" (It was noted that this indicator may be somewhat difficult to measure);

- Indicator 17 relating to the number of reported organism outbreaks - It was suggested that the word "catastrophic" be replaced by "reported and verified by appropriate authorities". (It was noted that this indicator may still be open to interpretation especially regarding the terms "outbreak" and "appropriate authorities");
- Indicator 23 relating to tonnage of intensively-farmed animal products - It was suggested that the question should clearly indicate that intensive farming should include aquaculture;
- Indicator 31 relating to generated toxic, hazardous and municipal wastes - There was some discussion relating to the difference of toxicity between domestic and industrial waste. It was agreed that this difference could be incorporated into the model by having two separate indicators instead of one. It was also agreed that given data constraints that at the very least the indicator should include imported toxic and hazardous materials;
- Indicator 32 relating to mean percent of waste effectively managed or treated - There was discussion relating to the meaning of managed and treated waste. It was suggested that the term "effective management" would be more appropriate referring to the following strategies: composting; reusing; recycling; controlled incineration (including temperature control, retention time control and control of emissions), controlled landfill (involving treatment of leachate, containment, gas management, aftercare and rehabilitation i.e. recovery, planting, and post management);
- Indicator 33 relating to number spills of oil and hazardous substances - It was noted that spills of oil and hazardous substances are not confined to the coastal areas. It was therefore suggested that the indicator be changed to refer to the number of spills of oil and hazardous substances greater than 1,000 litres during the last 5 years on land, in rivers or in territorial waters;
- Indicator 34 relating to industrial facilities that could cause significant damage - Following discussion it was agreed that the denominator should include territorial waters as well as land area. With this new denominator, industrial facilities would therefore include such structures as oil rigs (our comment: we would include oil rigs but not necessarily need to divide the count by an area larger than that occupied by the land in a state);
- Indicator 35 relating to number of cars / land area - It was agreed that the term "vehicles" should be used instead of cars, as per World Bank Definition. There was some discussion on whether to use density of vehicles on roads rather than total land area. It was noted, however, that this may not be appropriate, since the former is used as a measure of congestion, rather than of the ability of land to attenuate pollution emitted by vehicles;
- Indicator 39 relating to the number of new fisheries stocks added - There was discussion regarding the term "new fisheries species added". It was pointed out that (a) new fisheries does not take into account added effort or new technology, (b) a threshold of at least 20% in increase in catches should be set, and (c) the way the question was formulated could be misleading because it focuses on species rather than on stocks. It was suggested that the wording of this indicator be changed as follows: "Number of new fisheries stocks and added effort exploited by countries over the last 5 years". It was also agreed to develop this indicator further to incorporate points (a) - (c);

- Indicator 40 relating to percentage of land area degraded since 1950 - It was noted that data for this indicator could be difficult to obtain. It was agreed that there needs to be a clear rationale to show that the indicator captures erosion, salination and desertification and that this indicator should exclude urban areas;
- Indicator 41 relating to annual internal renewable water resources per capita - A properly specified indicator was required to capture quantity and quality of freshwater separately. It was suggested that an indicator to capture quantity could be the following: "Annual internal renewable water resources per capita." This would be measured by average annual runoff and recharge of groundwater from endogenous precipitation. The rationale for measuring the renewable water supply per capita was that lower availability per head would create higher pressures on natural ecosystems (i.e. water for people is considered to have a higher priority than for ecosystem conservation). It was noted that the issue of water quality has been covered by indicators 30, 33, 37 and 38;
- Indicator 43 relating to land, rivers and coastal zone affected by mining & quarrying - It was suggested that sea area should not be included in this indicator. The indicator should therefore read as follows: "Percentage of land, rivers and coastal zone affected by mining and quarrying". It was noted that "coastal zone" needs to be defined more precisely; and
- Indicator 47 relating to environmental legislation - There was considerable discussion regarding this indicator and its usefulness. It was suggested that this indicator be dropped (this was also suggested by a number of Think Tank participants), because the information might be considered sensitive, would be difficult to measure and because aspects of environmental management would be covered by other indicators.

Many, but not all, of the suggestions made by the participants at the Malta Meeting for refining indicators were adopted by the EVI Team and appear in the indicators lists included in this report (Table 1 and Table 2).

2.2.2 Suggested possible New Indicators

Participants at the Malta Meeting agreed to suggest the following indicators for possible inclusion in the EVI following further consideration by SOPAC's EVI Team.

- Reported mass *mortalities* of organisms, including strandings - this indicator is related to Indicator 17, but focuses on losses of organisms and is a proxy for the outcome of pollution and other imbalances in the environment;
- The number of ships/tonnage of hazardous substances carried/transiting within 100km of a country per year (averaged over the last 5 years) - this was considered to be significantly different from Indicator 18 which focuses on possible introductions of pests and disease. The purpose of this indicator would be to focus on the risk of spills, wrecks and ballast introductions caused by ships which might not register as having entered a port in the country; and
- Pollution coming in currents of air or sea or rivers from outside the territory - this would require a yes/no response when a country is or is not downstream by air or water from a major pollution source, within 1,000 km. It was noted that this indicator would require

further development and refinement. It was also noted that this indicator may be captured by indicators 26, 33 and 34.

2.2.3 Possible Indicators for a Subsidiary List

Participants at the Malta Meeting also identified an additional group of environmental issues for which indicators might be developed in the future. These would be indicators for which data are probably not presently available, but which could provide important insights into the risks to and resilience of a country. These were:

- marine and forest productivity;
- salination of groundwater, though it was pointed out that this may be captured by indicator 40; and
- the effects of hail and glacial melt.

3 Description of the EVI by the end of Phase II

3.1 The approach, framework and model

3.1.1 Purposes of the EVI

The purposes to which the EVI could be put include:

- Determination of Least Developed Country (LDC) status (if globalised);
- 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);
- In sub-index and profile format, the EVI has predictive value for identifying the main vulnerability issues, 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 donor funding;
- Provides a tool for identifying problem areas for internal intervention and external assistance;
- Could be used to detect trends in vulnerability – it is intended that the EVI would be recalculated every 5 years.

3.1.2 Definitions

The EVI is a dimensionless 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.

3.1.3 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 relating to ecosystems. Ecosystem integrity depends on biodiversity, ecosystem function 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 have been identified and are 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 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 basis for an 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 three sub-indices for the EVI as follows:
REI = Risk Exposure sub-Index incorporates measures of the level of risk to hazards;
IRI = Intrinsic Resilience sub-Index which examines that natural resilience of a state based on its innate characteristics (intrinsic resilience); and
EDI = Environmental Degradation sub-Index which measures the degree of damage sustained by natural systems as a signal for how well those systems might be able to resist damage from future hazards (extrinsic resilience).

3.1.4 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 of vulnerability are 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, IRI, EDI) were defined as an aggregated average of the scores for indicators which relate separately to risk, intrinsic resilience and 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 relatively easily obtainable;
- Should be likely to measure change or be a proxy for change which would do significant harm to the environment;
- 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; and
- Be as uncorrelated as possible to limit redundancy.

47 indicators of environmental vulnerability have been selected for inclusion in the index. This includes 27 indicators of risk (REI), 7 indicators of intrinsic resilience (IRI) and 13 indicators of environmental integrity or degradation (EDI). The indicators were also divided into 5 subject categories, independently of which sub-index they belonged to: Meteorological events (6 indicators), Geological events (3 indicators), Country characteristics (7 indicators, and is the same as the IRI), Biological factors (8 indicators) and Anthropogenic factors (23 indicators).

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 describing the main features of each of the indicators selected and their rationale is provided in Section 3.2 (Table 1).

Several indicators initially selected were discarded because they either did not have data available or 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 Kaly et al 1999b and is not reproduced here.

Some of the data required for setting the response levels of each indicator were collected during Phase II for Fiji, Samoa, Tuvalu and Vanuatu. Some these data sets are not complete, a valid provisional EVI was calculated for 3 of these 4 countries (that is, 80% of indicator questions were answered). An EVI was calculated for Vanuatu, but this would not be considered valid because only 70% of the required data were made available to us.

Australia was invited to contribute a fifth set of data because of its potential to define the higher or lower values for indicators. Unfortunately our contacts there declined the invitation because of the incomplete status of the EVI and the daunting task of collecting the data required for such a large country. Australia has agreed to contribute data at a later stage when the EVI is more complete and has been tested more fully.

The data for Fiji, Samoa, Tuvalu and Vanuatu were obtained by visiting the countries to work with local authorities, from country reports, UN, WHO, SOPAC, SPREP, FAO and other publications from international agencies (e.g. WRI), centres for risk assessment and management (e.g. Tsunami Centre, NOAA), local experts and from government officers.

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 fully assessed and in particular if it is to be used for LDC purposes.

3.1.5 How vulnerability is quantified in the EVI

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, or if weighted by the value of the indicator’s weighting. 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 was attributed to that indicator.

Mapping on the 1-7 scale for each of the indicators was provisionally set during Phase II using the data collected, the technical literature, and the inputs of experts, particularly those who attended the Think Tank.

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 any measurement of vulnerability and to 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 in the opinion of participants and a simple weighting scale involving 3 weighting categories (high, medium and low) suggested. These weights were provisionally applied to the data collected for Fiji, Samoa, Tuvalu and Vanuatu in three strengths:

0 = No weighting - despite the weightings applied by the Think Tank participants, each indicator was given an equal weighting value of 1;

Weak = Indicators considered of low importance were assigned the weighting value of 1, Medium a weighting of 2 and High a weighting of 3; and

Strong = Indicators considered of low importance were assigned the weighting value of 1, Medium a weighting of 5 and High a weighting of 10.

The weighting category of each indicator is given in Table 1 and the results of applying these weightings are given in Section 4. Note, 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 during further development of the index.

The EVI and sub-indices were calculated using an EXCEL workbook. Normally, our 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 IRI and EDI 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. In that workbook, a separate copy of the calculator is required to evaluate the vulnerability indices for each country. For the purposes of evaluating the data in Phase II, however, we constructed a single workbook for our own use which was not given out to the responding countries because the scoring scale could not be set before obtaining their data. Data for Phase II was therefore collected by issuing questionnaires which were filled out by the countries manually (see Section 4.1).

After adjustment for weighting (which does not vary by country), the scores for each indicator within a sub-index were averaged to produce a sub-index value of between 1 and 7. Where data are unavailable for an indicator, that indicator was omitted from the average, so that it made no contribution to the mean. At least 80% of the indicator questions had 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. In the future, these reliability values are to be reported with each index and should be read with them. In this report, the data reliability scores give the number indicators for which data are not currently available. In the future we will incorporate information on 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.

3.1.6 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 that must be understood for its proper application and use. After discussions held at the Think Tank and Malta Meeting as well as with expert representatives a set of strengths and weaknesses were identified and 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 potentially globally applicable;
- Could be used for awareness-raising;
- Indicators and weightings were 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 made available for use 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, for simplicity 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. This is appropriate as it allows responses to identified areas of vulnerability to be monitored;
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.

3.2 *Status of the EVI indicators*

By the end of Phase II the EVI indicators have stabilised to 47 questions covering exposure to risks, intrinsic characteristics of a country, level of environmental degradation and meteorological, geological, biological and anthropogenic factors (Table 1). Most of the changes from the original (Phase I) indicators occurred as a result of the Think Tank meeting. There were a few changes resulting thereafter from our own investigations, the Malta Meeting, or other interactions at meetings or with experts.

The indicators shown in Table 1 differ from those issued to the countries with respect to Indicator 47. The additional indicator shown here was a modification from the Malta Meeting which occurred after the process of data collection was underway. The results that follow in Section 4 are therefore in relation to an Indicator 47 which asks about the status of environmental legislation in each country. In the future this indicator will be dropped and the new indicator on safe sanitation incorporated.

Table 1: Summary table of the indicators selected throughout Phase II, including the Think Tank and Malta meetings.

Each indicator is accompanied by a short form key name, detailed definition, list of key words which describe the main factors for which it is a proxy and the weighting category (WC) applied by the Think Tank participants (H=high; M=Medium; L=Low). Cat = categorisation where: REI = Risk exposure sub-index; IRI = Intrinsic resilience sub-index; EDI = Environmental degradation sub-index; Met = Meteorological; G = Geological; CC = Intrinsic country characteristics; B = biological and A = Anthropogenic indicators.

#	Cat	Key name	Indicator text	Main proxy factors	WC
1	REI Met	Sea Surface Temperature	Greatest average annual deviation in Surface Sea Temperature in last 5 years from long term mean (30 years) (Centralised database)	Coral bleaching; fisheries; currents; eddies; ENSO; cyclones	M
2	REI Met	High winds	Number of days over the last 5 years during which the max recorded wind speed (3 second gusts) >20% higher than the average maximum for that month (use 30yr average for each month as reference) (Data accumulated over all reference climate stations / # stations)	Cyclones; tornadoes; storms; erosion	M
3	REI Met	Dry periods	Number of months over the last 5 years during which rainfall >20% lower than the 30yr average for that month. (Data accumulated over all reference climate stations / # stations)	Droughts; dry spells; water resources	M
4	REI Met	Wet periods	Number of months over the last 5 years during which rainfall >20% higher than the 30yr average for that month (Data accumulated over all reference climate stations / # stations)	Floods; wet spells; coral reefs; pollution; erosion	M
5	REI Met	Heat waves	Number of days over the last 5 years during which the max temperature >5 C higher than the mean monthly maximum for that month (use 30yr average for each month as reference) (Data accumulated over all reference climate stations / # stations)	Heat waves; desertification; water resources; temperature stress	M
6	REI Met	Cold snaps	Number of days over the last 5 years during which the max temperature >5 C lower than the mean monthly minimum for that month (use 30yr average for each month as reference) (Data accumulated over all reference climate stations / # stations)	Cold snaps; temperature stress	M
7	REI G	Volcanic eruptions	Number of volcanoes with potential for eruption >= VEI 4 (Volcano explosivity Index) within 100km of country land boundary / area of land	Eruptions; landslides; geysers; gas; fires; ash; dust; marine kills	M
8	REI G	Earthquakes	Earthquakes within 100km of country land boundaries / land area with ML >=6.0 and <=15km depth over last 5 years	Earthquakes; landslides	L

9	REI G	Tsunamis	Number of tsunamis or storm surges with run-up >2m above MHWS / 100km coastline since 1900	Tidal waves; erosion; habitat disturbance and organism kills	L
10	IRI CC	Land area	Total land area (sq km)	Richness of habitat types; refugia; species redundancy and richness	H
11	IRI CC	Fragmentation or "islandness"	Length of ocean shoreline or land border divided by total land area	Fragmentation; erosion; exposure at borders or coasts	H
12	IRI CC	Isolation	Distance to nearest continent within 10 degrees latitude (km) (Australia is smallest continent)	Proximity to refugia; recolonisation; biodiversity	L
13	IRI CC	Vertical relief	Altitude range (Highest point - lowest point in country)	Biodiversity of habitats and species	M
14	IRI CC	Lowlands	Percent of land area <10m above sea-level	Floods, areas of accumulation of pollution, sensitive habitats	H
15	IRI CC	Coastal vulnerability	Percentage of land area <10m elevation within 2km of coast composed of unconsolidated sediments (excluding coral reefs and ice)	Storm surges; cyclones, erosion	M
16	IRI CC	Endemic species	Number of known endemic species / sq km land area (multiply result by 1,000)	Biodiversity; unique species	H
17	REI B	Pathogens and plagues	Number of reported (and verified) organism outbreaks over the last 5 years / land area (competitors, pathogens, blooms, plagues etc) (multiply result by 1,000)	Ecosystem stress; eutrophication; pollution; introductions; disturbance	M
18	REI B	Potential for introductions	Total tonnage of freight imported / year / sq km land area	Potential for Introductions	M
19	EDI B	Introductions	Number of all introduced species / sq km land area since 1900 (multiply result by 1,000)	Past introductions; biodiversity	M
20	EDI B	Endangered species	Number of endangered and threatened species / sq km of land area (IUCN definitions) (multiply result by 1,000)	Biodiversity; Keystone species	H
21	EDI B	Extinctions	Number species which have become extinct since 1900 / 10,000 sq km land area (IUCN definitions) (multiply result by 1,000)	Biodiversity; Ecosystem structure and function	H
22	EDI B	Natural vegetation	Percentage of natural and regrowth vegetation remaining (e.g. forests, mangroves, saltmarshes, prairies, savannah, desert, tundra)	Ecological redundancy; Biodiversity; Ecosystem services and goods	H
23	EDI B	Intensive farming	Tonnage of intensively-farmed animal products / yr / sq km land area (includes acquaculture, pigs, chickens, etc)	Pollution; Eutrophication	L
24	EDI B	Fisheries	Percent of fisheries stocks overfished (FAO)	Resource depletion	H
25	EDI A	Coastal settlements	Density of people living in coastal settlements with city centre within 20km of coast (people per sq km land area)	Stress on coastal ecosystems; pollution; eutrophication; resource depletion	H
26	REI A	Human population density	Total human population density (per sq km land area)	All incidental damage caused by human activities	H
27	REI A	Human population growth rate	Annual human population growth rate (percent) (average over last 5 years)	Potential for future incidental damage caused by human activities	H
28	REI A	Rate of loss of natural vegetation	Net percentage of land area changed by the removal of natural vegetation over last 5 years	Pollution attenuation; biodiversity; soil formation; natural resources; groundwater regeneration; CO_2 fixing	H
29	REI A	Tourists	Annual number of international tourists * average days stay / 365 / sq km (last 5 years)	Additional load of all human impacts not reported in population statistics	M
30	REI A	Wastewaters	Litres / sq km / day of untreated industrial and domestic wastewater discharged	Eutrophication; water pollution	H
31	REI A	Production of hazardous and municipal wastes	Total tonnage of generated and net imported toxic, hazardous and municipal wastes / sq km land area / year (average last 5 years)	Pollution; habitat destruction; groundwater damage	M
32	REI A	Waste treatment	Mean percent of hazardous, toxic and municipal waste effectively managed or treated / year	Proportion of wastes rendered less harmful	L
33	REI A	Oil spills	Number spills of oil and hazardous substances >1,000 litres during last 5 years on land, in rivers or within territorial waters / land area (multiply results by 1,000)	Pollution	L
34	REI A	Toxic industries	Number of nuclear, chemical and other major industrial facilities that could cause significant damage / 10,000 sq km land area	Pollution; acid rain	L
35	REI A	Vehicles	Number of vehicles (World Bank definition) / land area	Habitat damage; habitat fragmentation; pollution; mining; hazardous wastes	M
36	REI A	SO_2 concentration	Max 24 hour SO_2 concentration (micro g /cubic m) (average over last 5 years)	Pollution; attenuation rates; acid rain	M
37	REI A	Fertilisers	Tonnes of N,P,K fertilisers used / sq km agricultural land area / year (average last 5 yrs) (multiply result by 1,000)	Eutrophication; pollution; soil damage; loss of arable land	L
38	REI A	Pesticides	Tonnes of pesticides used / sq km of agricultural land / year (average last 5 years) (multiply result by 1,000)	Pollution; soil damage; damage to reproductive systems of organisms	L
39	REI A	Fisheries stocks	Number of new fisheries stocks or expanded fisheries efforts (>20% increase in catches) added to country over last 5 years (within territory)	Rate of resource depletion	L
40	EDI	Degradation	%Land area degraded since 1950 (includes salinisation,	Rate of habitat loss	H

	A		desertification etc.)		
41	EDI A	Water resources	Mean rate of water usage per capita per day	Use of surface free water and groundwater; groundwater, river and habitat damage	H
42	REI A	Sub-surface mining	Tonnes of mining material (ore + tailings) extracted / sq km land area / year (average last 5 years)	Pollution; habitat disturbance; heavy industry	L
43	EDI A	Surface mining	%Land, rivers and coastal zone affected by mining and quarrying	Habitat disturbance	L
44	EDI A	Terrestrial reserves	Percent of terrestrial zone set aside as reserves	Increases resilience, pollution attenuation, limits loss of biodiversity	M
45	EDI A	Marine Reserves	Percent of marine zone set aside as reserves (mean high tide to continental shelf)	Increases resilience, pollution attenuation, limits loss of biodiversity	L
46	EDI A	War / civil strife	Number of war or civil strife years over the last 50 years within the territory	Habitat disturbance; pollution; habitat degradation	M
47	EDI A	Legislation (discarded)	Environmental legislation with regulations	Controls; management of goods and services	M
47	EDI A	Sanitation	Percentage of population with access to safe sanitation (WHO)	Eutrophication; pollution	

Draft scoring levels for the indicators were set using the data collected from the four Pacific countries and additional information from international data sources (Table 2). For some indicators no data were available and no levels were set (e.g. 36). These indicators will be scaled at a later time when the required information can be obtained.

The scaling applied here is necessarily in draft form. It has been applied largely using the data returned by the four test countries (Fiji, Samoa, Tuvalu and Vanuatu). Where possible, the scaling levels were set using known ranges from international data sources and may therefore be (appropriately) outside the range indicated by the 4 test countries. In some cases (e.g. 44 & 45) the scales were set based on ecological criteria (actually the most appropriate for EVI, but not often available). For scaling to be completed, we will need access to data from a larger range of Pacific countries and a range of very different countries from other regions of the world (see discussion in Kaly et al. 1999b).

Table 2: The draft scoring levels set for each of the EVI indicators during Phase II. These levels were used for calculating the draft EVI scores in Section 4 below.

#	Cat	Key name	1	2	3	4	5	6	7	Units
1	REI / Met	Sea Surface Temperature	0				>0-1	>1	>2	Degrees
2	REI / Met	High winds	0	1-10	11-20	21-30	31-40	41-50	>50	Days
3	REI / Met	Dry periods	0-5	6-10	11-15	16-20	21-25	26-30	>30	Months
4	REI / Met	Wet periods	0-5	6-10	11-15	16-20	21-25	26-30	>30	Months
5	REI / Met	Heat waves	0-10	11-20	21-30	31-50	51-70	71-80	81-100	Days
6	REI / Met	Cold snaps	0-10	11-20	21-30	31-50	51-70	71-80	81-100	Days
7	REI / G	Volcanic eruptions	0			1-2	3-4	5	>5	Volc / sq km
8	REI / G	Earthquakes	0			1-2	3-4	5	>5	Eqk / sq km
9	REI / G	Tsunamis	0			1-2	3-4	5	>5	Ts / 100 km
10	IRI / CC	Land area	>1,000,000	100,001-1,000,000	10,001-100,000	5,001-10,000	1,001-5,000	100-1,000	<100	Sq km
11	IRI / CC	Fragmentation or "islandness"	0	>0-0.1	0.1-0.5	0.6-1	1.1-1.5	1.6-2	>2	km / sq km
12	IRI / CC	Isolation	0	>0 - 500	501-1000	1001-1500	1501-2000	2001-3000	>3000	km
13	IRI / CC	Vertical relief	>3000		2001-3000	1001-2,000	101-1000	11-100	<10	m
14	IRI / CC	Lowlands	0	>0-2	2.1-4	4.1-5	5.1-10	10.1-20	>20	%
15	IRI / CC	Coastal vulnerability	0	>0-2	2.1-4	4.1-5	5.1-10	10.1-20	>20	%

16	IRI / CC	Endemic species	0	>0-10	11-30	31-50	51-70	71-100	>100	spp / sq km
17	REI / B	Pathogens and plagues	0	>0-10	11-30	31-50	51-70	71-100	>100	outbr / sq km
18	REI / B	Potential for introductions	0	>0-100	101-200	201-300	301-400	401-500	>500	t / sq km / yr
19	EDI / B	Introductions	0	>0-100	101-200	201-300	301-400	401-500	>500	spp / sq km
20	EDI / B	Endangered species	0	>0-100	101-200	201-300	301-400	401-500	>500	spp / ' sq km
21	EDI / B	Extinctions	0	>0-1	1.1-2	2.1-5	5.1-8	8.1-10	>10	spp / sq km
22	EDI / B	Natural vegetation	>80	61-80	41-60	31-40	21-30	11-20	0-10	%
23	EDI / B	Intensive farming	0	>0-1	1.1-2	2.1-5	5.1-8	8.1-10	>10	t / sq km / yr
24	EDI / B	Fisheries	0		>0-20	21-40	41-60	61-80	81-100	%
25	EDI / A	Coastal settlements	0-20	21-40	41-60	61-80	81-100	101-200	>200	People / sq km
26	REI / A	Human population density	0-20	21-40	41-60	61-80	81-100	101-200	>200	People / sq km
27	REI / A	Human population growth rate	0		>0-0.5	0.51-1	1.1-1.5	1.6-2	>2	%
28	REI / A	Rate of loss of natural vegetation				0	>0-2.5	2.6-5	>5	%
29	REI / A	Tourists	0-10	11-20	21-30	31-40	41-60	61-80	>80	People / sq km / day
30	REI / A	Wastewaters	0-1,000	1,001-2,000	2,001-3,000	3,001-4,000	4,001-6,000	6,001-9,000	>9,000	L / sq km / day
31	REI / A	Production of hazardous and municipal wastes	0-10	11-20	21-30	31-40	41-50	51-60	>60	t / sq km / yr
32	REI / A	Waste treatment	81-100	61-80	41-60	21-40	11-20	5-10	<5	%
33	REI / A	Oil spills	0		>0-0.5	.51-1	1.1-1.5	1.6-2	>2	Spills / sq km
34	REI / A	Toxic industries	0		>0-0.5	.51-1	1.1-1.5	1.6-2	>2	Facilities / sq km
35	REI / A	Vehicles	0-5	6-10	11-15	16-20	21-25	26-30	>30	Vehicles / sq km
36	REI / A	SO_2 concentration								Micro g / m^3
37	REI / A	Fertilisers	0-20	21-40	41-60	61-80	81-100	101-200	>200	t / sq km / yr
38	REI / A	Pesticides	0-20	21-40	41-60	61-80	81-100	101-200	>200	t / sq km / yr
39	REI / A	Fisheries stocks	0	>0-1	1.1-2	2.1-5	5.1-8	8.1-10	>10	Stocks
40	EDI / A	Degradation	0	>0-1	1.1-2	2.1-5	5.1-8	8.1-10	>10	%
41	EDI / A	Water resources	0-20	21-40	41-60	61-80	81-100	101-200	>200	L / capita / day
42	REI / A	Sub-surface mining	0-20	21-40	41-60	61-80	81-100	101-200	>200	t / sq km / yr
43	EDI / A	Surface mining	0	>0-1	1.1-2	2.1-5	5.1-8	8.1-10	>10	%
44	EDI / A	Terrestrial reserves	>20%	11-20%	6-10%	1-5%			0	%
45	EDI / A	Marine Reserves	>20%	11-20%	6-10%	1-5%			0	%
46	EDI / A	War / civil strife	0	>0-1	1.1-2	2.1-5	5.1-8	8.1-10	>10	Years
47	EDI / A	Legislation (discarded)	With legislation , No controls		No legislation , With social controls		With legislation , No controls		No legislation , No controls	No units
47	EDI / A	Sanitation	No	levels	set					

4 Environmental Vulnerabilities of Fiji, Samoa, Tuvalu and Vanuatu

4.1 Approach and methods for the collection of country data

4.1.1 Approach

The EVI has been designed to summarise a wide range of environmental vulnerability information for a country. Much of the required environmental data are at present only being collected and compiled at the national level. The international reporting and publication of environmental data is not as yet well established as the reporting of country economic data. As a result of this, we have had to rely on the often complex process of asking officers in each country to collate the data we required from diffuse, fragmented and uncomputerised databases located in a range of different government departments or ministries. This has meant that not all of the data required for the EVI could always be collected.

Several international initiatives have begun to address the problem of acquiring environmental data for a range of purposes, given the internationally recognised need for the publication and auditing of national environmental data. This includes the Global Environment Outlook (GEO) and the World Resources Institute (WRI). To date, however, none of these sources has been able to collect all of the data needed for the Pacific. Part of the aim of this project will be to work with these initiatives to identify additional types of environmental data required to assess environmental vulnerability.

The data needed for the EVI includes meteorological and geological data, information on resources available and their rate of usage, information on area of land and sea under different uses and its quality, natural hazards, and the way in which populations manage their ecosystems. The diverse and wide-ranging nature of these data means that their sources are widely dispersed and require some effort by a country to identify, collect and compile the information. Some of the indicators require information that could only be provided by the authorities or by experts in the respective country. It is therefore essential to have full government co-operation in the data gathering process to ensure success. This has largely been the case in the Pacific SIDS.

Several difficulties were experienced in the initial stages of data gathering in the four participating Pacific Island countries Fiji, Samoa, Tuvalu and Vanuatu. These included difficulties with understanding the data requirements for providing responses to EVI indicator questions, and in many cases, a lack of capacity to compile the necessary data. Overcoming these initial problems required the importation of assistance, in-country, to identify the major problems and to try to provide possible solutions so that country environmental vulnerability data files could be compiled.

The in-country approach to data gathering, while beneficial to the countries and rewarding in terms of data collection, is not a sustainable method of data gathering in the long term and would be impossible to extend globally. It became obvious that a more simple and directed approach would need to be developed to assist governments in the gathering of country data. The development of an alternative approach to data gathering that is simple and which could be easily adopted by countries both large and small is critical to the overall development of the EVI. In this study, a questionnaire approach was developed and adopted to facilitate gathering. This was found to be relatively successful in the four countries approached for this study.

The approach used involved the compilation of a questionnaire which presented each EVI indicator question accompanied by an explanation of what it was trying to measure. Each indicator was also complemented with a clear indication of what the data might look like, how to step through the calculations required and guidance on which agency or sources might hold the required information.

To ensure that the data gathering process is sustainable in the future and can be applied internationally, it has been suggested that a supplementary handbook be developed to be distributed with the questionnaires. This help guide could be used to provide an in depth background to the EVI, its mechanics, and specific instructions on how to identify and gather the required information. This could reduce or eliminate the need for continued assistance and support in the data gathering process.

4.1.2 Problems encountered during data collecting

We encountered several problems during the data collection process which limited the amount and reliability of the data required. The most important of these were:

- A complete lack of data of the type required. This included Indicator 36 on SO_2 concentrations and Indicator 45 which required information on the size of the continental shelf. Both of these indicators are important and should not be omitted from the EVI. It is recommended that mechanisms be sought for collecting these data in the Pacific SIDS;
- Inaccuracies because the data available could only be provided in units unlikely to be internationally applicable and had to be converted. This refers to Indicator 23 on intensive farming. The data from the four participating countries could only be supplied as head of animals and not as tonnages and had to be converted using an estimated weight per animal. For most countries, these data are in tonnes; and
- Omission of data that should have been available for unknown reasons. Vanuatu was unable to supply meteorological data that would undoubtedly have been available.

These problems account for the ND (no data) entries in the EVI data table for each country (Appendix 9.1).

4.2 Provisional comparative results for Fiji, Samoa, Tuvalu and Vanuatu

4.2.1 EVI scores

Valid EVI scores, with greater than 80% of indicator questions being answered were obtained for Fiji, Samoa and Tuvalu, but not for Vanuatu.

Tuvalu returned the highest and most different EVI score of the four countries examined. With an EVI of 4.5, it was more than 1.1 index units higher than Samoa at 3.4. This result means that in an overall sense, using the EVI, Tuvalu would be considered the most vulnerable country of those examined.

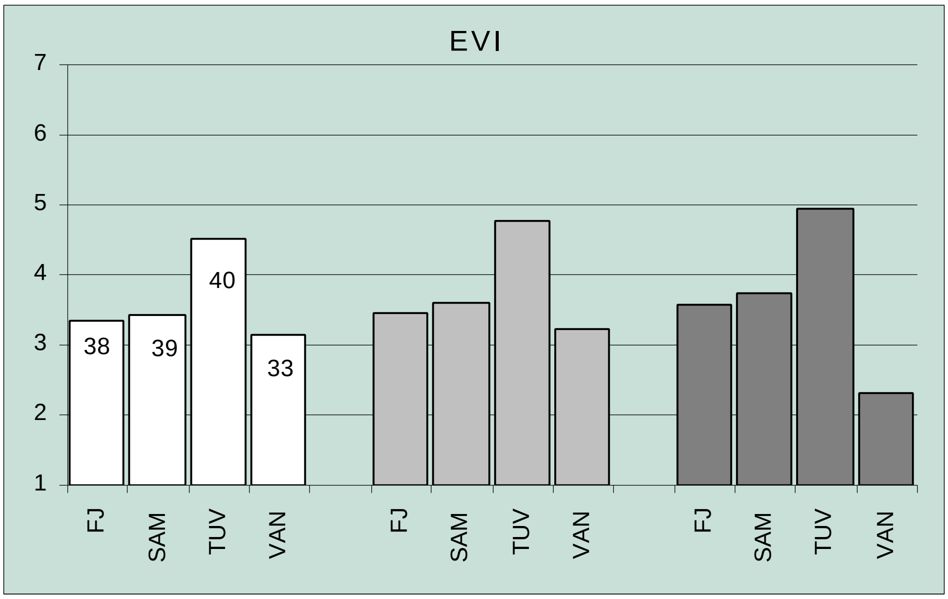
The overall EVI scores obtained for Fiji, Samoa and Vanuatu were similar and in the range of 3.1-3.4 when no weighting was applied (Figure 1). Weak weighting applied to the model resulted in little change to the results obtained for these three countries. When strong weighting was applied, however, the results for Vanuatu changed dramatically.

Because many data were missing for Vanuatu, it is unclear whether this change is a real reshuffling of results based on relative importance of indicators (as set by the Think Tank and which would be the purpose of weighting) or whether it results merely from the combination of data that were missing. Comprehensive testing of the EVI, as planned in Phase III is required to differentiate between these possibilities. Almost all of the missing data for Vanuatu were of medium or high weighting. This appears to have pulled its EVI score downwards (compared with the value calculated without weighting) when strong weighting was applied to the model. The EVI obtained for Vanuatu was *a priori* determined to be invalid because less than 80% of the data were returned. With the completion of its data table in the future, this country will be able to obtain a better estimate of its environmental vulnerability.

These results suggest that the four countries may fall into two vulnerability groups. A moderate vulnerability group comprising Fiji, Samoa and perhaps Vanuatu and a higher vulnerability group consisting only of Tuvalu. This result is very preliminary because the ranges and levels set for the indicators are limited by the availability of only a very small group of test countries (4) which do not encompass the conditions possible in the Pacific, let alone the globe. These results strongly support the need for more test countries from within the Pacific and from other regions before reliable EVIs can be calculated.

Figure 1: EVI results for Fiji, Samoa, Tuvalu and Vanuatu.

For this and the following figures, the graphs show EVI index values in the range of 1 (least vulnerable) to 7 (most vulnerable). White bars are results without weighting (i.e. all indicators of equal value), pale grey bars are results with weak weighting, and dark bars with strong weighting. Numbers shown in the white bars are numbers of indicators answered of a possible 47.



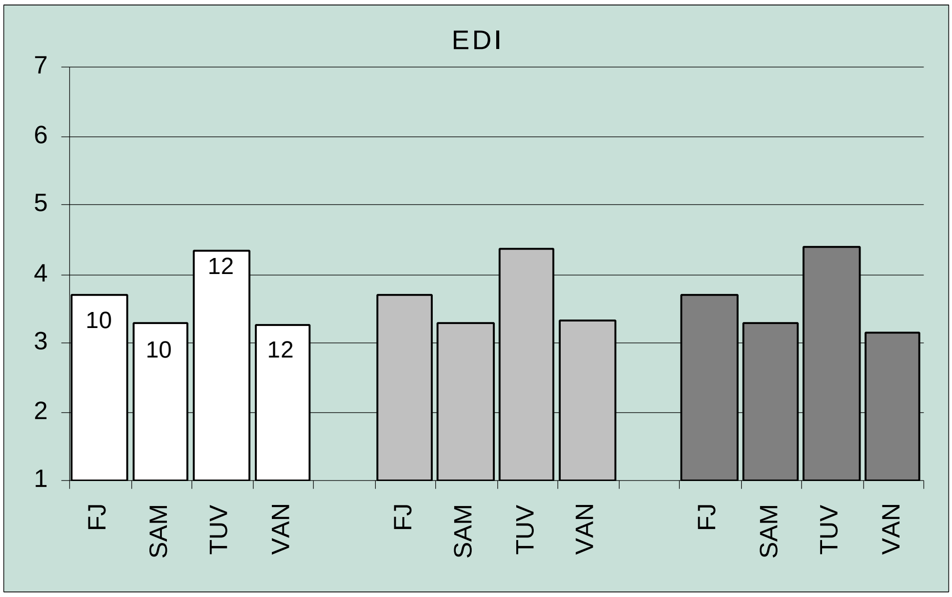
4.2.2 Sub-indices (REI, IRI and EDI)

The Risk Exposure sub-indices (REI) show a similar pattern to the results shown for the EVI in Section 4.2.1 above. Fiji, Samoa and Vanuatu cluster together with REIs of around 3, while Tuvalu returned a score of almost 4 (Figure 2). The arguments concerning the lack of data for Vanuatu's EVI also apply for its REI score. In terms of risk to hazards Tuvalu appears to be the more vulnerable, with little difference among the remaining three countries.

The Intrinsic Resilience sub-index (IRI) separated the countries more markedly (Figure 2). In terms of intrinsic resilience, or country characteristics (the sub-index IRI and the category CC are the same measure), Vanuatu appears to be the most resilient (3.4), followed by Fiji (4.2) and Samoa (5.1). Tuvalu is the least resilient country in terms of natural characteristics (6.6). The large differences between the values suggest that the indicators and levels set might be good at differentiating the countries, though a larger context is required through collecting data from a wider range of country types.

In terms of environmental damage already sustained (EDI), the differences among countries are lower and the data returns better. Samoa and Vanuatu have EDI scores of around 3.3, Fiji a score of 3.7 and Tuvalu of 4.3 (Figure 2). These results may suggest that differences in the environmental damage sustained by the countries in the past do not differ markedly. Most of the differences in environmental vulnerability may be related more to risks and intrinsic resilience than to extrinsic resilience.

Figure 2: Sub-index scores (REI, IRI and EDI) for Fiji, Samoa, Tuvalu and Vanuatu.



4.2.3 Categories (Meteorological, Geological, Country Characters, Biological and Anthropogenic)

Meteorological index scores could not be calculated for Vanuatu because none of the 6 meteorological indicators were answered by the country. For the remaining three countries, unweighted scores were similar, ranging only between 2.6 (Fiji) and 3.25 (Samoa) (Figure 3). These results suggest that Samoa is the most vulnerable in terms of weather and Fiji the least. Without a wider context for comparison of the data, it is unclear whether the values obtained here indicate that the countries are indeed similar in terms of their meteorological variables as this graph suggests, or whether the levels for the indicators have been set with insufficient sensitivity.

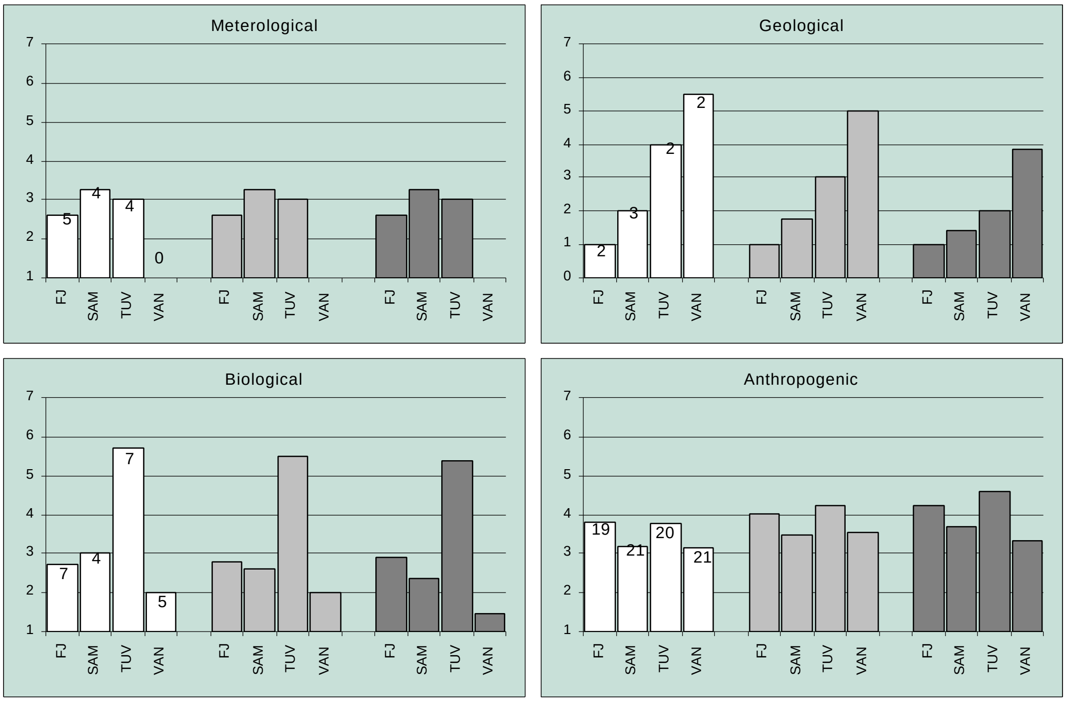
There were marked differences among countries in terms of geological hazards (Figure 3) with a range of index values from 1 to 5.5 (unweighted). Fiji appeared generally not to be susceptible to geological phenomena, while Vanuatu recorded the highest vulnerability score. The relatively high score recorded for Tuvalu was largely carried by the number of tsunamis recorded. However, this result may require further investigation because the so-called “pencil effect” may systematically render any tsunamis that approach that country harmless. A high score under those conditions would be spurious.

The biological index scores resulted in marked differences among the countries (Figure 3). Vanuatu (score of 2) showed the least vulnerability in relation to biological phenomena such as species and disease introductions, organism outbreaks, resource utilisation and extinctions. Tuvalu returned a high score of 5.7, while Fiji and Samoa returned values of 2.7 and 3 respectively.

The categorical scores for anthropogenic factors were relatively similar for all of the countries, varying between 3.14 and 3.79 (Figure 3). The higher scores were obtained by Fiji and Tuvalu, and the relatively lower scores by Samoa and Vanuatu.

Figure 3: Categories index scores for Fiji, Samoa, Tuvalu and Vanuatu.

Categorised scores have been calculated for meteorological (6 indicators) and geological (3 indicators) events, biological phenomena (8 indicators) and anthropogenic effects (23 indicators). Note that the category Country characteristics relates to the same indicators as the IRI and is not repeated here.



4.3 *Detailed results for Fiji*

4.3.1 General features of Fiji

Fiji is an archipelago made up of over 300 islands located between latitudes 15 and 22^{o} South and longitudes 177^{o} West and 175^{o} East. The Fiji islands have a combined land area of approximately 18,272 square kilometres of which 87 percent comprises the two main islands of Viti Levu and Vanua Levu. These two larger volcanic islands are characterised by steep, mountainous country, deeply incised by rivers and streams.

The islands of Fiji support a wide variety of ecosystems including significant areas of natural forest. Also present are a range of coastal and marine ecosystems including mangrove forests and coral formations. The climate is tropical with an average annual temperature of around 26^{o}C and relatively heavy annual rainfall, especially on the windward sides of the larger islands. The average annual rainfall ranges from 1800 to 2600 mm. Fiji is potentially subject to natural hazardous events including earthquakes, landslides, cyclones, flooding and storm surges.

Fiji has a population in excess of 750,000 with increasing urban drift and concentration in coastal regions. Escalating population growth together with *ad hoc* development and a lack of a co-ordinated approach to environmental management has had serious detrimental implications for the environment.

4.3.2 Persons met and data returned

Data gathering within Fiji was greatly facilitated by the location of SOPAC headquarters in that country. Helena McLeod and Reginald Pal of the EVI team met with several government representatives to provide a briefing and discussion of the EVI. Follow-up meetings were arranged to collect data from the following Fiji Government representatives:

- Sadeesh Chang (Senior Health Inspector);
- Sakiusa Qereqeretabua (Fiji Visitors Bureau);
- Ifereimi Dau (Mineral Resources Department);
- Sulana T. Nuison (Ministry of Lands and Mineral Resources);
- Yauka Soro (Hydrographic Cartographer - Marine Department);
- Pumale Reddy (Senior Surveyor – Lands Department);
- Subodh Sharma (Acting Senior Fisheries Officer – Fisheries Department);
- Elizabeth Erasito (Acting Director – National Trust for Fiji);
- Nazmin Bi (Acting Senior Scientific Officer – Fiji Meteorological Service);
- Epeli Nasome (Director – Environment Department);
- Jone Feresi (Agricultural Officer – Land & Water Resources Management).

Most of the follow-up effort for compiling the Fiji environmental vulnerability data file has involved repeated requests to the contacts in the listed departments that they provide the necessary data. To date this process has been relatively successful with 81% of all required data being compiled.

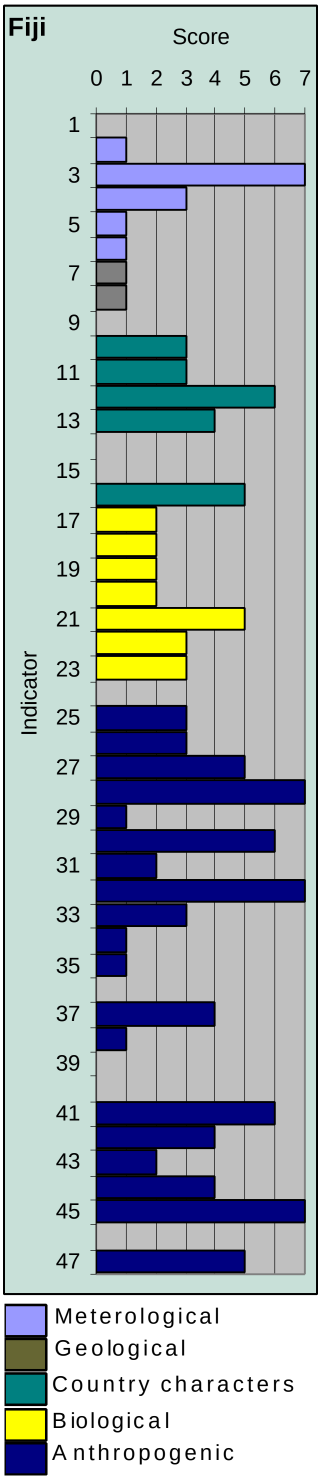


Figure 4: Vulnerability profile for Fiji. Individual vulnerability scores are shown for each indicator of the EVI. Missing bars mean no data were available.

4.3.3 Vulnerability issues for Fiji

Figure 4 is a graphical representation of the scores obtained by Fiji for each indicator in the EVI. An examination of the results in this detail rapidly allows the identification of areas of particular vulnerability for the country – information that could lead to better management and possibly better vulnerability scores in the future.

The most important vulnerability issues for Fiji (those scoring a 7 on the EVI scale) and identified using the EVI relate to:

- Dry spells;
- Loss of natural vegetation cover;

- Lack of effective management of wastes; and
- Lack of marine protected areas to build resilience.

Several other issues arose for Fiji that scored a 6 on the EVI scale and would represent its next most vulnerable aspects. These were:

- Isolation from nearby sources of recolonisation should its natural environments become damaged;
- A high discharge rate of untreated waste waters; and
- A high rate of water usage by its industries and population.

4.4 Detailed results for Samoa

4.4.1 General features of Samoa

Samoa is situated between latitudes 13^o and 15^o South and 168^o and 173^o West close to the International Date Line. The country consists of two main islands Savai'i and Upolu and several smaller islands. The islands are mostly of volcanic origin with steep mountain ranges rising from narrow coastal plains. The greater part of the territory is covered by lush vegetation.

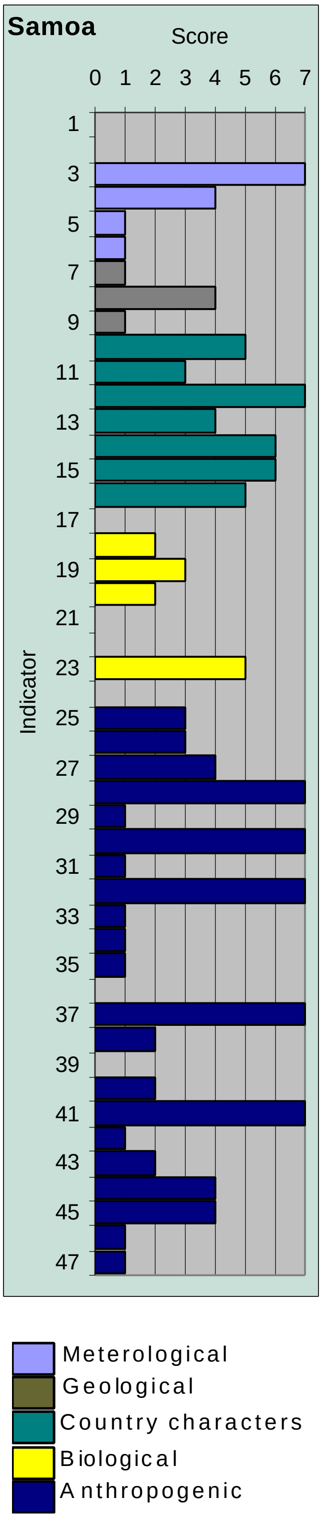
The climate is tropical with generally hot and humid conditions. The average annual temperature is about 26.5^{o}C with an annual rainfall of around 3000mm. Samoa is positioned within the cyclone belt and storm patterns regularly affect the island group from November to January. Two strong cyclones struck the country in the early 1990 and 1991 causing extensive damage.

4.4.2 Persons met and data returned

Members of the EVI Team visited Samoa between 9th and 14th August 1999. This visit was made by Craig Pratt and Reginald Pal to provide assistance and training in the identification, gathering and collation of the environmental information required for the calculation of Samoa's EVI.

Experience with data collection in Vanuatu highlighted the need to provide a more detailed briefing and discussion prior to more intensive meetings. This ensured that the purpose and approach for the EVI had been fully clarified and that data identification and collection could proceed more efficiently. Follow-up meetings with the appropriate government staff were required at their places of work so that data returns were maximised during the visit. The representatives of the Samoa Government consulted included the following:

- Mose Sua (Secretary for Foreign Affairs)
- Sailimalo Pati Liu (Assistant Director DEC/DCSE)
- Anne Trevor (Fisheries Division)
- Silia Kilepoa-Ualesi (Treasury - Energy)
- Siuli Tuailemafua (Samoa Visitors Bureau)
- Teleiai Sapa Saufaleupolu (National University of Samoa (NUS))



- Sami Lemalu (Forestry)
- Faatoia Malele (Climatology)
- Faefia Taliaoa (Climatology)
- Violet Wulf (DEC/DCSE)
- Sagato Tuiafiso (Scientific Officer - Meteorology)
- Malaki Iakopo (Assistant Director Forestry)
- Pau Ioane (Senior Draughtsman - Forestry)

Follow-up work upon return to the SOPAC Secretariat included corresponding with the identified focal point in the Department of Environment and Conservation as well as with specific representatives met during the team's visit. Most of the follow-up effort was put into maintaining a continual link with the Samoan co-ordinating focal group in an effort to assemble the most complete data file possible for Samoa. To date this process has yielded a data collection rate of 83% for that country.

Figure 5: Vulnerability profile for Samoa. Individual vulnerability scores are shown for each indicator of the EVI. Missing bars mean no data were available.

4.4.3 Vulnerability issues for Samoa

Samoa's areas of greatest vulnerability (producing EVI scores of 7) include indicators 3, 12, 28, 30, 32, 37 and 41 (Figure 5). This means that if we use the EVI as a tool for identifying areas of environmental vulnerability, Samoa's most vulnerable attributes would be:

- Dry periods;
- Isolation from other land masses;
- Rate of loss of natural vegetation;
- Untreated wastewaters;
- Poor management of wastes;
- Use of agricultural fertilisers; and
- High usage of water resources.

4.5 Detailed results for Tuvalu

4.5.1 General features of Tuvalu

Tuvalu is a small fragmented atoll country comprised of nine islands and atolls spread over some 1.3 million square kilometres of ocean. The total land area is among the smallest in the world at only 25.9 km^2. The country is isolated, located approximately 1,100 km north of Suva, Fiji and serviced by two flights per week and a monthly freight ship. Tuvalu is subject to a number of natural risks such as cyclones and storm surges. The islands are low-lying with most of their area below 3m above sea-level and no point higher than 4.5 metres. This feature potentially makes the country highly susceptible to erosion and inundation from ocean surges.

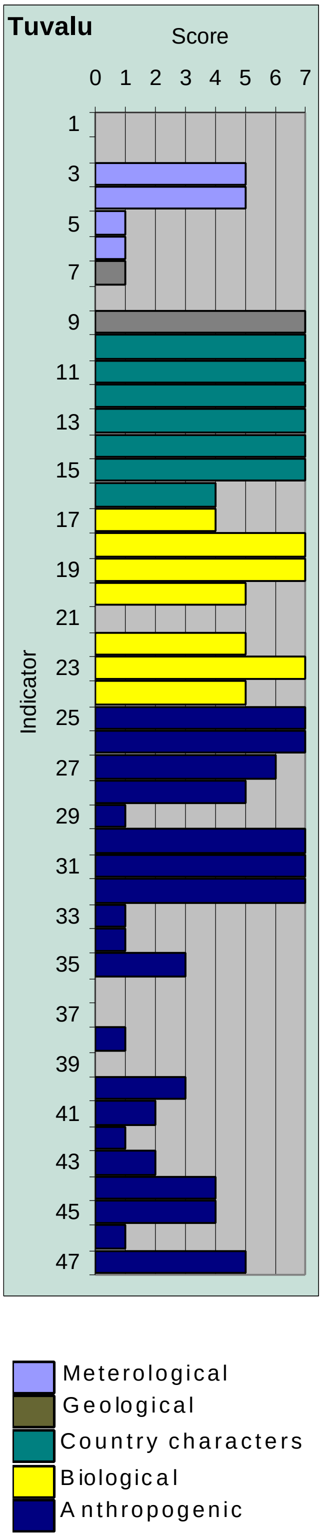
Because of its tiny landmass, limitations in the carrying capacity of the environment are immediately apparent. There is little land available to assimilate waste, and as population increases, risks to the environment from human pressure and poor management will continue to increase. On the main islet of Fogafale on the atoll of Funafuti, about 4,600 people are crowded together in less than 2.8 square kilometres. A third of the land is uninhabitable due to its use as an airfield and the presence of excavated borrow pits.

4.5.2 Persons met and data returned

Helena McLeod visited Tuvalu between 4th and 9th October 1999 where she teamed with Ursula Kaly to facilitate the process of identification, collection and collation of environmental vulnerability data for Tuvalu. A briefing session was held with government representatives to discuss the EVI and the data requirements. Follow-up meetings were made with the following government officers to ensure that as much of the data required could be collected:

- Seluka Seluka (PICCAP)
- Mataio Tekinene (Environment)
- Claudia Ludescher (Funafuti Conservation Area)
- Tesimita Ailesi (Lands and Survey)
- Fanoanoaga Patoro (Lands & Survey)
- Hilia Vavae (Meteorological Service)
- Itaia Lausaveve (Agriculture)
- Sautia Maluofenua (Fisheries)
- Mataliki Christopher (Central Statistics Division)
- Uatimani Maloo (Tourism, Trade & Commerce)
- Julia Heiloa (Funafuti Town Council)
- Christopher I Kae (Customs)

Tuvalu was an easy country from which to collect data for the EVI. This was because of its small size, concentration of government departments in a small area for easy access and the fact that one of our team is resident in the country and was able to increase the profile of the project. The small size of the country meant that information was usually readily accessible, easy to sift through, or could be collected as required. For example, the number of cars present on Fogafale was hand counted from the original registration records, an approach that would have been too laborious in larger countries. The most significant



problem encountered was that information was generally lacking for some sectors, particularly fisheries and for standard environmental data. This necessitated the return of some data based on best guess estimates made by government officers.

Follow-up work on return to the SOPAC Secretariat involved ensuring acquisition of the data for the few indicators still to be collected. 85% of data required for the EVI was collected for Tuvalu.

Figure 6: Vulnerability profile for Tuvalu. Individual vulnerability scores are shown for each indicator of the EVI. Missing bars mean no data were available.

4.5.3 Vulnerability issues for Tuvalu

The results obtained from the EVI identified Tuvalu as the most vulnerable country tested. 15 of the 40 indicators for which data could be obtained resulted in an EVI score of 7, with a further single indicator scoring an EVI value of 6. Issues of high vulnerability occurred in all categories of data except meteorological phenomena. The main issues that country might consider examining in relation to its environmental vulnerability are:

- Tsunamis (though this is provisional since the “pencil effect” may systematically render them harmless);
- Small land area, high fragmentation and isolation;
- Low relief and 100% of land area susceptible to coastal inundation and erosion;
- A history of past and large potential for new introductions of new species, pests and diseases;
- Pollution effects from intensive farming of pigs over a small land area;
- High human population density and growth rate; and
- Poor management of wastes.

4.6 Detailed results for Vanuatu

4.6.1 General features of Vanuatu

Vanuatu is an archipelago of over 80 islands with a combined land area of some 12,190 square kilometres. The country is relatively mountainous with about a quarter of the land forming rugged or steep ranges characteristically in the inland areas of the larger islands. About a third of the forest resources of the country are found in these rugged, erosion-prone inaccessible areas.

The population of Vanuatu is around 189,000 people distributed over 70 of the islands in the archipelago. The Exclusive Economic Zone (EEZ) covers an area of sea of about 710,000 square kilometres of ocean with a rich diversity of inter-tidal mangrove communities, seagrasses, lagoons, coral reefs and pelagic areas.

Vanuatu generally has a hot, wet climate with a marked difference in climate through the archipelago from tropical in the northern areas to sub-tropical in the south. Rainfall is variable with an average annual rainfall at around 1500mm and with an average temperature of about 24^{o}C. Vanuatu is considered uncommonly prone to natural disasters such as volcanic activity, earthquakes, cyclones and the associated problems of landslides and tidal waves.

4.6.2 Persons met and data returned

A trip to collect EVI data was undertaken from 22 – 29 June 1999 to Vanuatu by Craig Pratt of the SOPAC EVI team. While there he trained technical personnel in the identification, gathering and collation of environmental information required for the calculation of Vanuatu's EVI.

Meetings were held with government representatives in several departments and ministries. Meetings involved briefings on the EVI together with discussions to clarify the purpose of the work and the required data clearly identified. Follow-up work for the completion of data collection was co-ordinated by the Department of Environment.

Government representatives with whom meetings were held included:
- Stanley Temakon (Director General – Ministry of Natural Resources);
- Chris Ioan (Acting Director – Geology);
- Jean Michelle (Seismology);
- Jean-Phillippe (Seismology);
- Ericson (Water);
- Leo Moli (Principal Energy Officer – Energy Department);
- Tatsuo Honda (JICA Expert);
- Ernest Bani (Principal Environment Officer – Environment Department);
- Emil Mael (Vanuatu Land Use Planning Office);
- Peter Morris Jimmy (Statistician – Bureau of Statistics);

- Jacqui Caine (Deputy High Commissioner – NZ High Commission);
- Ario Niki Roberts (Director - National Tourism Development Office);
- Patricia Mawa (Meteorological Officer – Meteorology);
- Benuel Tarilongi (Director - Vanuatu Quarantine & Inspection Service);
- Moses Amos (Director - Fisheries Division);
- Wesley Obed (Fisheries Licensing Officer); and
- Norris Hamish (Director Ports & Marine Department).

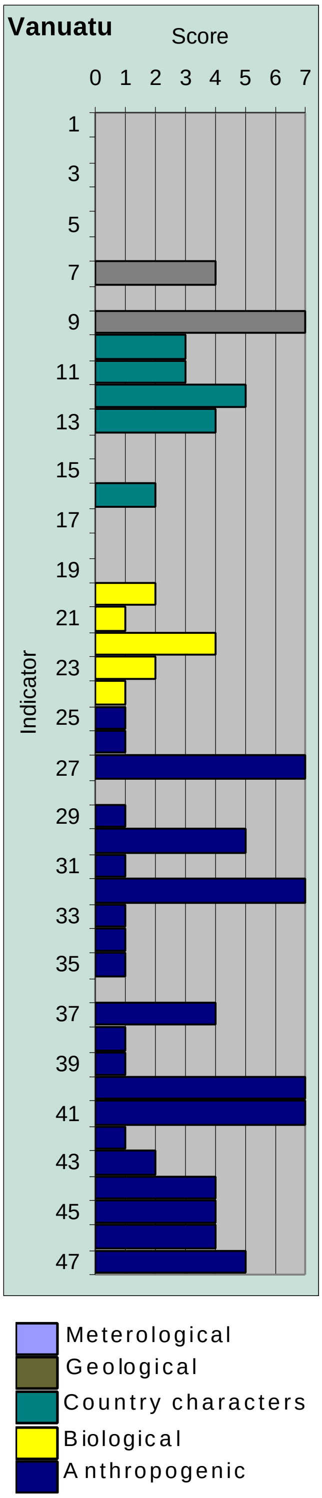


Figure 7: Vulnerability profile for Vanuatu. Individual vulnerability scores are shown for each indicator of the EVI. Missing bars mean no data were available.

Data collection in Vanuatu was less successful than in the remaining 3 countries included in this study, with a total of only 70% of the required data being collected. This meant that the EVI values calculated Section 4.2 fell short of the 80% data requirement for a valid EVI. The profiles discussed below which provide individual scores for indicators that were answered, however, could still provide useful information for in-country identification of vulnerability issues. The questionnaire and meetings approach, though used in the same manner as in Fiji, Samoa and Tuvalu resulted in relatively little data being collected in-country in Vanuatu. We conclude that additional emphasis would need to be placed in the future on a discussion of the importance of the EVI, its uses and outcomes and the critical need for data.

After leaving Vanuatu, the EVI Team continued its efforts in trying to generate urgency and sufficient understanding of the EVI and the critical need for environmental vulnerability data. Problems with correspondence and several changes in staffing and co-ordinating focal people added to the low data returns. A follow-up visit made by Helena McLeod on 22nd November 1999 yielded little improvement. Despite efforts by both the SOPAC EVI team and the Vanuatu Government, data targets could not be met by the time of writing this report and will need to be addressed in future to create a valid EVI for this country.

4.6.3 Vulnerability issues for Vanuatu

Of the indicators for which data were obtained, 5 scored a value of 7 on the EVI scale. There were no indicators with a score of 6 EVI units. The main environmental vulnerability issues identified for Vanuatu were:

- Tsunamis;
- Human population growth rate;

- Management of wastes;
- Land degradation; and
- Water usage.

Other issues may come to light when all of the required data can be collected for this country.

4.7 Discussion and conclusions

The results obtained for the overall EVI scores for the four countries examined here (Figure 1) demonstrate the potential of the EVI as a tool for international processes such as the determination of LDC status. The EVI is able to summarise environmental vulnerability information collected for a range of indicators in a form that is comprehensible, visual, and which could be used to identify countries which have high environmental vulnerability. In addition, the vulnerability profiles provided by the sub-indices and scores for the individual indicators (Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7) demonstrate the powerful potential of the EVI for identifying issues of vulnerability that could be used to prioritise efforts for environmental management within countries.

The results presented here are necessarily provisional. The scoring levels set by the EVI team are based on data derived from only four countries, all of which are Pacific SIDS which share characteristics of small size, isolation, developing economies, climate, biodiversity and other factors. For the EVI to be able to provide a reliable mechanism for international comparisons and a context for how well any individual country might be faring in terms of risks and intrinsic and extrinsic resilience, it is necessary that the scaling for the model be set within a much broader range of country types. Ultimately, this means that the EVI needs to be globalised so that the full range of vulnerability issues facing states can be incorporated into the model.

The results presented here are also provisional because the EVI has not been mathematically tested (see Kaly et al, 1999b for description of tests needed). The weighting of indicators is in draft form and the biases of types and strengths of weightings need to be modelled against independent assessments of vulnerability made by independent experts. It is also necessary that the effects of missing data on the outcome of the EVI be investigated. All of these issues can be addressed when data from a larger number of countries of a range of types can be collected.

Problems with a lack of data, resulting in an invalid EVI for Vanuatu, and less than complete returns for the remaining countries need to be addressed. Public awareness, political will, capacity building and the establishment of permanent data collection mechanisms are all required to address this issue in the future.

5 Meetings attended

5.1 Technical meetings focused on the EVI

A range of meetings were attended by the EVI team during Phase II to introduce the EVI methodology to its potential users, a range of SIDS, SOPAC member countries and potential donors. SOPAC also hosted a meeting in Fiji (Think Tank) and assisted the Foundation for International Studies (FIS) of the University of Malta to host a meeting in Malta. Both of these meetings were for the purpose of developing the EVI. The latter was also designed to introduce the EVI to the Caribbean, Indian, Mediterranean and Atlantic small island states (SIS).

Committee for Development Policy (UNCDP / UNDESA) Technical Group's Meeting on the Vulnerability Index, London, March 1999

This meeting was hosted by CDP at Marlborough House, 1-3 March 1999. The purpose of the meeting was to explore the potential for using indices of vulnerability in the criteria for identifying LDCs. The indices discussed included the Economic Vulnerability Index being developed by the Commonwealth Secretariat, the EVI and a composite index made of these and other types of vulnerability measures.

This meeting was attended by Drs Russell Howarth and Ursula Kaly who introduced the EVI to participants, gave a seminar and held discussions on the potential role of the EVI in determining LDC status.

EVI Think Tank, Fiji, September 1999

This meeting was hosted by SOPAC and held at Pacific Harbour in Fiji, 7-10 September 1999. The purpose of the meeting was to assemble an international group of experts from a range of technical disciplines relevant to the development of the EVI and to use their expertise to rapidly and efficiently review all of the most important defining conditions for the model and its indicators. The participants invited were experts in statistics, biodiversity, biogeography, protected areas, other types of indices, weather & climate, disaster research, ecosystem management, environmental impacts, fisheries, forestry & agriculture, productivity & energy flows, and environmental economics.

The meeting was attended by the entire SOPAC EVI team, and was opened by New Zealand and the Director of SOPAC. It gave the EVI the critical peer review and development boost required to confirm that the team had basically been taking an appropriate approach as well as provided constructive criticism and suggested improvements to the selection of indicators. Almost all of the changes suggested were adopted as part of the new EVI.

SOPAC Annual Session Donors Presentation, Nadi, October 1999

A special seminar and discussion forum within the SOPAC Annual Session was conducted on 27th October 1999. The EVI was introduced to representatives of SOPAC's member countries and to Regional Donors with a view to informing them of the status, progress made and requirements for the completion of the EVI. The seminar was given by Dr Ursula Kaly and Mr Craig Pratt.

UNEP Global Workshop on Vulnerability and Adaptation 4 – 5 October 1999, Nairobi, Kenya

The meeting was hosted by the United Nations Environment Programme (UNEP) in Nairobi, Kenya at UNEP headquarters. The goal of the meeting was to develop a framework for comparing vulnerability and adaptability to climate change impacts. The meeting was held over two days and divided into 5 sessions focussed on: Global vulnerability framework research and experiences of similar indices; Vulnerability framework; Sectoral issues; Adaptation to climate change; and Future directions.

The meeting was attended by international experts from all over the world. Representatives included government officials, international, university and technical institution experts from Bangladesh, Kenya, Denmark, Switzerland, England, Morocco, Tanzania, Mauritius, Zimbabwe, USA, Cuba, Uganda, Togo, Canada, Costa Rica, Brazil, Haiti and Mauritania.

Mr Craig Pratt presented an abstract and gave a seminar on the EVI. He also fielded discussion on the development of the index and how it could be of value in the development of a climate change vulnerability index. He also circulated copies of previous EVI reports.

The primary output from the meeting was a discussion paper: Climate Change Vulnerability: Toward a framework for comparing adaptability to climate change impacts. Other outcomes of the meeting included the preparation of a brief to be tabled at the Conference of the Parties (COP6) with more time and effort being put into preparing a more complete discussion paper on the development of a vulnerability index for climate change to be presented at the next COP.

UNEP / FIS University of Malta Meeting, Valetta, November/December 1999

This meeting was funded by UNEP and hosted by the Foundation for International Studies at the University of Malta with assistance by SOPAC, 29 November – 3 December 1999. The purpose of the meeting was to introduce the EVI to small island states in the Caribbean, Indian, Mediterranean and Atlantic Regions, to review and further develop the indicators selected so far and to gain support from countries in these regions in the process of data collection. Of particular concern was the question of whether the indicators developed so far were applicable to countries outside of the Pacific Region.

The meeting was hosted by Professor Lino Briguglio and attended by Dr Ursula Kaly and Mr Craig Pratt. Representatives of Malta, St Lucia, Trinidad & Tobago, Jamaica and Mauritius were present at the meeting.

The outcomes of the meeting were that the EVI and indicators were generally suitable for those countries and that few further changes were suggested by the participants. All of the representatives of the countries listed agreed to assist with the future development of the EVI by providing data for their countries.

UNEP / Australian Institute of Science (AIMS) Meeting on Information Management and decision support for marine biodiversity protection and human welfare: Coral Reefs, Townsville, December 1999

This meeting, hosted by UNEP and AIMS was run at AIMS headquarters in Townsville, Australia, 6 – 10 December 1999. Its purpose was to develop a programme relevant to coral reefs for GEF funding: 1) to describe elements of the process by which resource use practice is modified with a view to improved outcomes for humans and for aquatic ecosystems; 2) to identify key indicators that accurately reflect both current status and progress towards those outcomes; 3) to define the information needs necessary to develop the indicators; 4) to identify and, if necessary, specify improvements to infrastructure to: a) effectively manage information and indicators, and b) assist decision makers in scenario-testing for various policy options.

Dr Ursula Kaly attended this meeting to describe the EVI and the lessons it could provide in the development of indicators for the health of coral reefs. She supplied an abstract to the meeting, gave a seminar and produced a paper that is at present under peer review before it will be published in the proceedings (see Appendix 9.5).

5.2 Meetings at which SOPAC represented the EVI

1. SIDS Meeting in New York, US, February 1999
2. CSD 7, New York, March 1999
3. Commonwealth Secretariat/UN Task Force on Vulnerability of SIDS, London, April 1999
4. AOSIS Clean Development Mechanisms for Climate Change Meeting, Majuro, Marshall Islands, June 1999
5. Forum Economic Ministers Meeting, Apia, Samoa, July 1999
6. Pacific Science Congress, Sydney, Australia, July 1999
7. IPCC Meeting of Lead Authors of Chapter 17 on SIS, Malta, July 1999
8. IOC General Assembly Meeting, Paris, France, July 1999
9. IDNDR Meeting, Geneva, Switzerland, July 1999
10. CROP Meeting, Nadi, August 1999
11. Pacific Island Climate Change Assistance Programme (PICAPP) Meeting on Climate Change Integrated Model (PACCLIM), Auckland, New Zealand, August, 1999
12. International Workshop on Sustainable Development in SIDS, Loften, Norway, August 1999

13. UN General Assembly on Special Session on SIDS, New York, September, 1999
14. South Pacific Tourism Organisation (SPTO) Governing Council Annual Session, Apia, Samoa, October, 1999
15. Pacific Island Forum, Palau, October 1999
16. SOPAC Governing Council Annual Session, Nadi, Fiji, October 1999
17. Diplomatic Training Workshop for Forum Island Countries, Suva, Fiji, November 1999
18. UNEP Meeting of Experts on the Environmental Vulnerability Index (EVI), Valetta, Malta, November 1999

5.3 Upcoming meetings at which SOPAC will present the EVI

- Bermuda Workshop on Vulnerability and Risk, International Ocean Institute, Bermuda, February 2000
- Global Conference on Development Agenda for Small States (Commonwealth Secretariat/World Bank Joint Task Force on Small States), London, February 2000
- Leaders Summit, Tokyo, Japan, April 2000

6 Future directions and steps to the functional completion of the EVI: Phase III

The EVI has now been developed to the stage that it clearly demonstrates its potential power for identifying countries which are environmentally vulnerable in a general sense, while also providing a list of focal issues that could be used by the countries themselves and donors to improve their status. The problem now is that the EVI presented here is still in provisional form. Although there is general agreement on the indicators and the way that the model has been constructed, there remain issues related to testing and scaling which have not been attempted here. These will have to be addressed in a third and final phase of the project.

In this section we describe the main EVI development issues for Phase III. Many of these criteria and tests were determined during the Think Tank meeting and have therefore resulted from international peer consensus. This means that we are confident that the procedures described below are both necessary and sufficient to render the EVI functional and internationally acceptable. In Section 6.1 we describe what these procedures are, and in Section 6.2 the tasks we would need to undertake to accomplish them.

6.1 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.

6.1.1 Improving the model and indicators

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 that 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.

The list of indicators as it stands now requires additional work. Many of the original indicators (Phase I) were discarded, and the new ones suggested by the participants of the Think Tank and Malta meetings require refinement of definitions and scaling. The main tasks which will be required are:

1. Complete the operational definitions for those 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);
6. Test the effects of data omissions on the final EVI scores;
7. 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. The average of all of these scores were then calculated separately for each indicator and a simple weighting of High, Medium or Low applied to each indicator. We used this system of weighting in this study for Fiji, Samoa, Tuvalu and Vanuatu with zero, weak and strong weighting multipliers (see Section 3). We have not assumed, however, that this system of weighting is the best one to use for the EVI and will carry out mathematical modelling to find the best system in Phase III.

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.

6.1.2 The importance of 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 international organisations, such as the UN, and donors.

6.1.3 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 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.

Criterion 1: Redundant indicators

The data for at least 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 that 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.

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 (the mechanism in the EVI that 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.

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.

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.

6.2 Proposed work plan for making the EVI functional: Phase III

At the end of Phase II there is now a choice to either create a global EVI or one crafted specifically for the Pacific Region (original brief). For the EVI to have its widest range of uses, it has to be globalised. This requirement was raised at every meeting we attended to introduce and discuss the EVI, and was a major recommendation of the Think Tank. In Figure 8 we provide a logical framework for the full development of the EVI. The two options available for development are represented in Figure 8 as Option 1 - Global Focus and Option 2 – Pacific Focus.

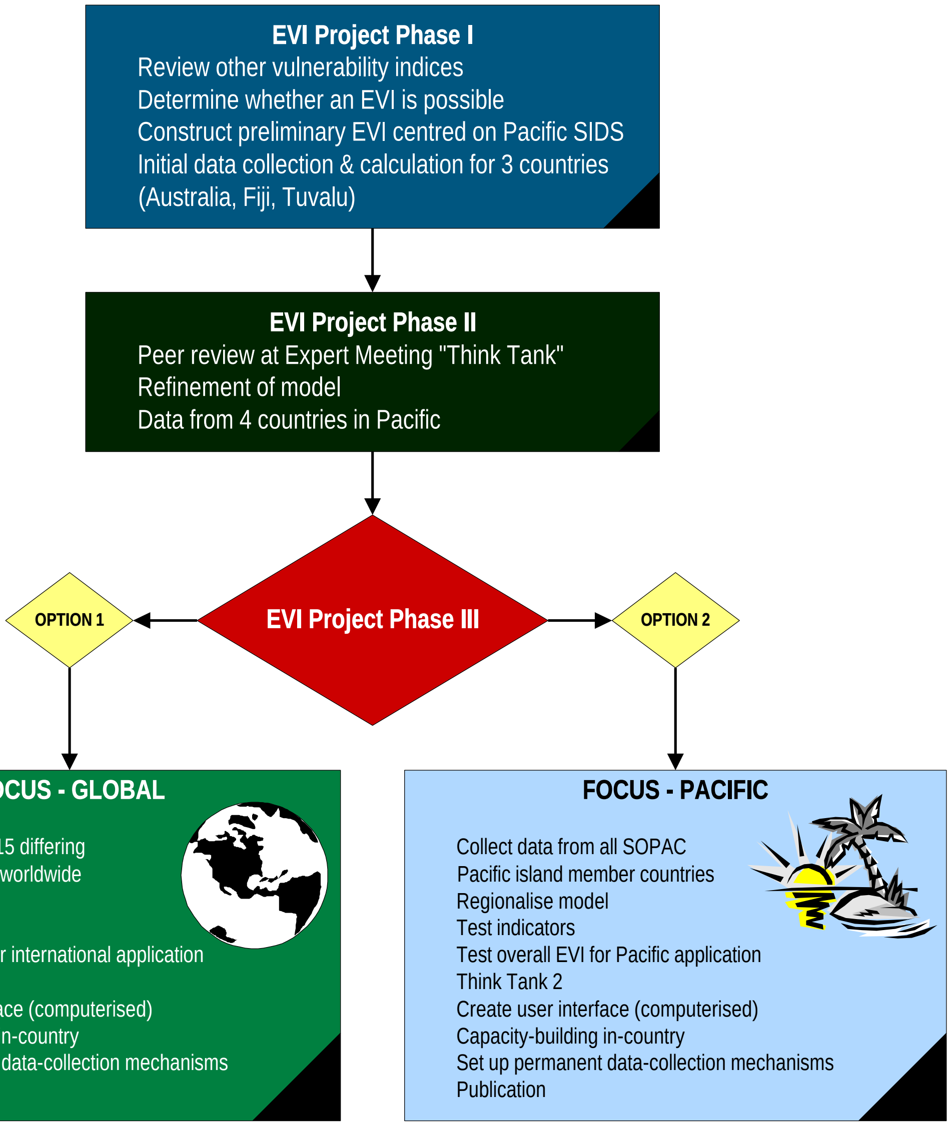
Option 1 – Global Focus is highly recommended because it seeks to develop the EVI on a world scale, providing an appropriate context for Pacific and other SIDS and SIS. That is, the indicators selected and scaling set for each will encompass vulnerability issues and the range of conditions found world-wide. This is important if the SIDS wish to be identified as a group with special issues to consider. By contrasting them with all other countries, minor differences between them will be de-emphasised and the differences between the Pacific Region and others will become the focus of international procedures.

Option 2 – Pacific Focus is not recommended here. It would be the development path taken if the original scope of the study, to develop an EVI for Pacific SIDS, were followed. This work would necessarily require most of the same steps as Option 1, but would result in an EVI with narrower focus and applicability. By restricting the EVI to the Pacific Region, index values will not provide a global context for the conditions and issues found in Pacific SIDS and will instead emphasise the differences found among Pacific Island countries. A Pacific EVI will result only in one Pacific Island Country being compared with another.

A full description of the aims, tasks to be undertaken and outputs for Phase III is provided in Section 9.5. Only Option 1 is detailed because of the strong pressure from the international technical community to globalise the EVI. Details for Option 2 can be provided on request.

Figure 8: Logical framework for the development and completion of the EVI.

This framework describes the tasks completed in Phases I and II and those that will be required to complete the index in a third and final phase. Two options are provided here for completion: Global and Pacific Focus which correspond to Options 1 (recommended) and 2, respectively.



7 Recommendations and conclusions

7.1 *Recommendations*

1. The EVI needs support for further development during a third phase before it could be considered functional and acceptable to the international community.
2. The EVI should be globalised. Restricting the index to the Pacific SIDS will result in a lack of context for the conditions found in those countries. It will result in a less powerful EVI because the scaling of indicators will be limited to a narrow range of conditions found in this region. The failure to globalise the EVI is likely to result in an index that will compare one Pacific State with another, rather than identifying them as a group in the world context. 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 (UN Committee for Development Planning) when indicators for classification of Least Developed Countries (LDC's) come under review.
4. 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 (similar to that provided for each country in this report) should accompany the three levels of reporting already incorporated into the EVI (index, sub-indices and responses for individual indicators).
5. The EVI model should be published in an international peer-reviewed journal. Although some publications were produced during Phase II, this process should be on-going and a paper describing the full model and its indicators published.
6. The EVI Think Tank should be reconvened at a later date to critically review the work done and direct refinements.

7.2 *Conclusions*

The outcomes of the Think Tank and other inputs from peer review during Phase II revealed that the SOPAC EVI was generally appropriately approached and constructed. Suggested changes to the model and indicators resulting from these reviews were incorporated into the EVI during this phase of the work. This resulted in a provisional EVI that has met with the approval of a range of international experts and potential users.

The provisional EVI is now a viable tool for characterising the vulnerabilities of states. In conjunction with the Think Tank, other meetings and our own work, the EVI is now at a stage that it could be used to collect data from a larger range of countries from the Pacific and other regions for testing.

Although a procedure for the collection of data from Pacific SIDS was developed, it met with mixed success. For three of the four countries trialled in Phase II, sufficient data were collected using a single visit to the country, capacity building and questionnaires for the indicators. This was not true for Vanuatu, for which sufficient data for a valid EVI could not be collected during this study. Our approach to the task of data collection will need to be reviewed during Phase III of the project.

EVI values, sub-indices and vulnerability profiles were calculated for four Pacific Island test countries with exciting results. The overall EVI scores demonstrate the potential of the EVI as a tool for international processes such as the determination of LDC status. The EVI is able to summarise environmental vulnerability information collected for a range of indicators in a form that is comprehensible, visual, and which could be used to identify countries that have high environmental vulnerability. In addition, the vulnerability profiles provided by the sub-indices and scores for the individual indicators demonstrate the powerful potential of the EVI for identifying issues of vulnerability within countries that could be used to prioritise efforts for environmental management.

The EVI was successfully introduced to a range of international bodies, donors, states, environmental managers and experts during Phase II through publication, discussions and attendance at meetings. Support for the project was widespread and opportunities for collaboration and the procurement of data for a larger range of countries were secured. We now expect to be able to collect data from Jamaica, St Lucia, Trinidad & Tobago, Malta and Mauritius in addition to the remaining Pacific Island States.

A work plan for the completion of the EVI was developed during Phase II largely in association the participants at the Think Tank. This plan calls for the globalisation of the EVI, data collection for a wide range of country types, formal testing and the setting of criteria for deciding when the EVI could be considered operational.

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9 Appendices

9.1 Summary of EVI data for Fiji, Samoa, Tuvalu and Vanuatu

Indicator	Fiji	Samoa	Tuvalu	Vanuatu
1	ND	ND	ND	ND
2	0	ND	ND	ND
3	35	35	21	ND
4	12.5	18	22	ND
5	0.5	0	0	ND
6	2.5	0	0	ND
7	0	0	0	1
8	0	1.418439716	ND	ND
9	ND	0	9	13
10	18272	2820	25.9	12190
11	0.274	0.183	3.142	0.207
12	2650	3800	3300	1800
13	1324	1848	4.58	1877
14	ND	20	100	ND
15	ND	20	100	ND
16	64.9	63.5	38.6	1.07
17	0.547	ND	38.6	ND
18	70.71316769	50.28687943	521.24	ND
19	52.9	186	10039	ND
20	21.7	61.3	309	0.82
21	7.77	ND	ND	0
22	44	ND	29	40
23	1.03707	6.58865	51.27413	0.54471
24	ND	ND	50-60	0
25	44.49	57.2	438.2	14.93
26	44.49	57.2	438.2	14.93027071
27	1.2	0.68	1.66	2.45
28	7.18	16.6	1	ND
29	0.434	0.544	1.743	0.074
30	7265.21	31458.83	13146.72	4105.82
31	14.13	5.028	65.946	3.542
32	0	0	0	0
33	0.109	0	0	0
34	0	0	0	0
35	1.315	2.061	12.9	0.328
36	ND	ND	ND	ND
37	78.7	375	ND	69.4
38	6.5	22.6	negligible	6.94
39	ND	ND	ND	0
40	ND	1.06	1-2	34
41	171.27	550	30	275
42	71.682	0	0	0
43	0.1	0.00284	0.0097	0.00656
44	0.31	1.06	0.24	0.595
45	0	0.0008	0.0037	0.0000211
46	ND	0	0	3
47	Draft	Legislation (option 1)	Draft	Draft

9.2 Sources of EVI data for Fiji, Samoa, Tuvalu and Vanuatu

Indicator	Fiji	Samoa	Tuvalu	Vanuatu
1	ND	ND	ND	ND
2	C	ND	ND	ND
3	C	C	C	ND
4	C	C	C	ND
5	C	C	C	ND
6	C	C	C	ND
7	C	C	C	C
8	C	C	ND	ND
9	ND	C	C	C
10	C	SOE	C	SPC
11	C	C	C	CIA
12	C	C	C	WA
13	CIA	C	C	CIA
14	ND	C	C	ND
15	ND	C	C	ND
16	C	C	C	C
17	C	ND	C	ND
18	C	C	C	ND
19	C	C	C	ND
20	C	SOE	C	C
21	C	ND	ND	C
22	SOE	ND	C	C
23	FAOSTAT	FAOSTAT	FAOSTAT	FAOSTAT
24	C	ND	C	C
25	C	C	C	C
26	C	C	C	FAOSTAT
27	C	C	C	FAOSTAT
28	C	C	C	ND
29	C	C	C	C
30	C	C	C	C
31	C	SOE	C	C
32	SOE	SOE	C	C
33	C	C	C	C
34	C	C	C	C
35	C	C	C	ESCAP
36	ND	ND	ND	ND
37	C	C	ND	C
38	C	C	C	C
39	ND	ND	ND	C
40	ND	C	C	C
41	C	C	C	C
42	C	C	C	C
43	C	C	C	C
44	C	IUCN	C	C
45	C	IUCN	C	C
46	ND	C	C	C
47	C	C	C	C

LEGEND

C	Returned by country on EVI Data Sheets
SOE	State of the Environment Country Report
FAO	Food and Agricultural Organisation
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific (Asia Pacific In figures 1997)
IUCN	International Union for Conservation of Nature and Natural Resources
CIA	CIA Factbook
WA	World Atlas 2000

9.3 Publication (Pratt 1999): Data Collection for the Environmental Vulnerability Index (EVI) – Discussion paper

Craig Pratt

1. Introduction

The SOPAC environmental vulnerability index (EVI) is still in development and has been designed as a multi-level model to describe the vulnerability of the natural environment of countries to a range of natural and anthropogenic hazards. The index is being developed in such a way that it can be broken down into sub-indices that describe levels of risk and resilience and the effects of these influences on the health or integrity of a country's environment. Due to the variety of risks and complexities of ecosystem resilience and integrity, an indicator approach was taken to characterise them.

There are currently a total of 47 indicators in the EVI. Although the SOPAC EVI team has selected a set of indicators with extensive inputs from international reviewers, details are still being finalised on the basis of inputs by experts from different countries and regions.

The formulation and choice of indicators are based on the following criteria:

- The indicators should be applicable globally;
- They should be based on data already available or easily obtainable;
- They should measure change or be a proxy for change which would do significant harm to the environment;
- They must not be selected on any political criteria but relate only to environmental vulnerability;
- They could be weighted to reflect the probability of change to the environment and the amount of damage which might be done;
- They should be relatively easy for users to understand;
- They should be well-defined;
- They should be as uncorrelated with each other as possible to limit redundancy.

The most vital criterion used in the choice of indicators is that relating to the data and its availability. The availability of appropriate environmental vulnerability data is fundamental to both the development of the EVI and ultimately the final calculation of a country's EVI value. The success of the EVI as a measure of vulnerability is therefore wholly dependent on accessing and obtaining relevant country environmental data for calculation of EVI values.

In light of the key role that data play in the development of the EVI, this discussion paper has been prepared to provide insight into some of the issues that have been faced in the identification and collection of data for the EVI in the Pacific, some of the lessons learnt and to provide some suggestions as to how we may progress this important process of data collection for the EVI internationally.

2. Approach to the Data Gathering Process

The EVI by its very essence attempts to summarise a wide variety of environmental vulnerability data for a country. Much of this environmental data is now only collected and compiled at the national level and reporting and publication of this data internationally is not as yet well-established as the frequent reporting of country economic data. Several international initiatives have been instituted to address this need for international publication of national environmental data and these include such initiatives as the Global Environment Outlook and various others.

The data needed for the EVI includes meteorological data, fisheries data, land area, natural hazard data and so on. The very diverse and wide-ranging nature of these data means that their sources are widely dispersed and require some effort by a country to identify, collect and compile the information. Some of the indicators require information that could only be provided by the authorities or by experts in the respective country. It is therefore essential to have full government co-operation in the data gathering process to ensure success, as has been the case in the Pacific.

The first major issue that arose in the initial stages of trying to gather data for the EVI in the Pacific was the difficulty in creating an understanding of the data required to provide responses to EVI indicators, and the lack of capacity to compile the necessary data. Overcoming these initial problems required the importation of assistance, in-country, to identify the major problems and to try to provide possible solutions so that country environmental vulnerability data files could be compiled.

The in-country approach to data gathering, while beneficial to the country and rewarding in terms of data collection, is not a sustainable method of data gathering in the long term and would be impossible to extend globally. It was therefore decided that a more simple and directed approach should be developed to assist the governments in the gathering of country data. This approach involved the use of detailed questionnaires for each of the EVI indicators.

Each indicator is presented with its detailed indicator question and is accompanied by an explanation of what the proxy indicator is trying to measure. All indicators require a response and guidance is provided towards the possible agency or agencies that may be sources for the information required. Each indicator is also complemented with a clear indication of what data is needed for a complete response to the indicator question.

3. Issues Relating to Data Gathering in the Pacific

During the process of data gathering in the Pacific, several important issues arose. These include difficulties in the following areas:

- Data source identification
- Accessibility
- Availability
- Quality

- Capacity

3.1 Data Source Identification

The identification of possible data sources and appropriate agencies to approach for the required data has been difficult. This is due to the major differences in bureaucratic structures of the various governments throughout the Pacific. Although agencies may have similar titles they can be given quite different responsibilities and hold different data sets compared with other countries. This has made the identification of appropriate sources and collection of information difficult.

Another issue is the identification of data that may be held by agencies but which may not be known to its officers or which has not be recognised by its officers as relevant to the EVI. This has largely been due to an inability to fully understand an indicator and its data requirements, the changing of staff or just a lack of knowledge of the databases held by the agency.

3.2 Accessibility

Collection, analysis and storage of data is without doubt an expensive exercise. As a result there is increasing recognition of the importance and true value of data which has had a significant impact on access to information. As many government agencies are asked to carry out these tasks on ever-reducing budgets, many are looking to recover their costs through charges for both primary data and time taken by personnel to access and compile required data.

Also in many cases, certain data may be considered sensitive by a country resulting in limited access. Although most data required for EVI indicators would not be considered sensitive, there have been several instances where access to information has required special authorisation. The support of government for the EVI and the data gathering process has therefore been essential in overcoming these problems in the Pacific.

3.3 Availability

Despite international recognition of the value and importance of environmental data in decision-making, collection and the maintenance of these data sets in Pacific Island countries have not always been given priority. In many countries there is either no data collection or it is inconsistent, or when data is collected regularly, there is no proper handling or storage of the data sets leading to incomplete databases and loss of, or poor access to the information.

3.4 Quality

The issue of data quality is not peculiar to the Pacific. In the course of data gathering, several inconsistencies between local data and international data sets have arisen. The use of different standards or methods of data collection or the use of general assessments based on small-sample-biased data may have contributed to these differences. There is also the potential of inaccurate equipment, lack of proper training in measurement procedures, lack of quality control procedures and many other reasons which could all lead to inaccuracies in data reported.

3.5 Capacity

The issue of the lack of capacity is a common one throughout SIDS. In Pacific countries this has been one of the main difficulties in the facilitation of EVI data gathering. The lack of capacity is two-fold in that it involves both institutional as well as personnel capacity problems.

In the Pacific, data gathering exercises like the EVI have placed an added burden on existing institutions' responsibilities to provide data and information. With limited resources and few trained personnel this task can often be an impossible expectation. The only way to assist these countries facilitate their country collection of environmental data has been to provide in-country input and assistance. This is extremely costly and it is imperative that alternative approaches are found to provide the assistance needed.

Another issue that has arisen is that it has been difficult to create an adequate understanding in personnel on the specific data and information requirements needed for a response to indicator questions. This is due in part to a lack of understanding of the purpose of the EVI, its mechanics and, more generally, the inadequate training of personnel in the identification, collection, analysis and manipulation of data.

4. The Future

The development of an approach to data gathering that is simple and can be easily adopted by countries both large and small is critical to the overall development of the EVI. Currently, SOPAC is attempting to develop an alternative questionnaire approach to facilitate country environmental data gathering. It still requires a lot of improvement and refinement to ensure that users of the EVI are able to get a better understanding of the purpose of the EVI, the data requirements and answers to frequently asked questions to the questionnaires.

A help handbook would prove useful as a possible way to provide a detailed background to the EVI, its mechanics and specific instructions and assistance in how to identify and gather the required information so as to reduce the need for continued assistance and support in the data gathering process.

9.4 *Publication (Kaly 2000): Lessons from the EVI and smart indicators for coral reefs*

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Abstract

This paper describes lessons learned from the development of the SOPAC Environmental Vulnerability Index (EVI) that could be used in the development of indicators of the status or 'health' of coral reefs. The EVI was developed to describe the vulnerability of natural environments at the scale of entire states to a range of natural and human hazards and uses an indicators and index approach. It embodies three methodological aspects that are relevant to providing information for the management of coral reefs. The first of these is the explicit definition of 'pristine' conditions as the direction that all management actions should take, acknowledging that different uses of reefs will keep their health at other than pristine levels. The indicators developed for coral reefs would act not only to identify the current status of reefs, but could be used to define thresholds for management. The second insight is that humans are part of the human-coral reef greater system. This means that human choices and behaviours are an integral part of the structure and function of reefs and should be included as indicators of reef health. Finally, I discuss the need for smart indicators for coral reefs. This means that indicators need to be developed that summarise the structure and function of a large number of transactions occurring on coral reefs, without our necessarily knowing how each works or what condition it is in. Smart indicators also have built in them some expression of how well a reef is faring in relation to optimum conditions and other reefs elsewhere.

Introduction

If humans are to be truly able to manage coral reefs they are going to need a reliable, simple, relatively inexpensive way of checking on 'health' of the reefs and being able to make some assessment of how they are going in their attempts to manage them in relation to some ideal. This would form part of an iterative system of management with the ability to constantly adjust management options in relation to real outcomes and unpredictable behaviour on the part of reefs. Problems with this adaptive management approach were highlighted recently in a special feature in Conservation Ecology (Gunderson 1999; Johnson 1999). Problems include difficulties in developing acceptable predictive models, conflicts between ecological values and management goals, inattention to non-scientific information, and unwillingness to implement long-term risky or costly programmes. By suggesting that human behaviour be incorporated into the information collected for a coral reef management model, Done and Diop (1999) have in this workshop attempted to take adaptive management a step further. They suggest the incorporation of human systems (socio-economic, use/conservation and policy/management) as part of the overall coral reef complex to be managed. That is, measures of the health and viability of coral reefs includes in its greater context the way that people choose to use and manage them and the socio-economic context from which they make their choices.

The concept of health in relation to reefs is a slippery one. We have no way of indicating the ideal number of species, community characteristics, energy flows or ecosystem services for even a single reef, let alone arrive at some guidelines for the range of complex systems we are concerned with across the globe. Despite not really being ready for the challenge, we are forced by necessity to start taking action (Daily 1999) and learning as we go (Walters and Holling 1990). In the past we have not as a group of scientists, planners and managers looked into coral reef ecosystems to try and find simple measures that would indicate health and provide some way of easily measuring changes through time. We have not looked hard enough for those measures that would provide a proxy or summary for the millions of processes that must be going on within human and coral reef systems and on all kinds of time scales.

In this paper, I wish to focus on how we might go about obtaining the kinds of information we might need through indicators as a basis for management of corals reefs. The information would have to be collected in relation to defined ideal conditions for human and ecosystem measures. I will describe the approach taken for some related work done for assessing the vulnerability of natural environments at the scale of entire states. I will then suggest ways of constructing indicators in relation to targets for the health of coral reefs and the healthy behaviour of humans in relation to them. Finally, I will deal with what I will term ‘smart indicators’ which might be an approach to providing relatively simple measures of how well reefs and their humans are faring in terms of coexistence.

The EVI approach

The Environmental Vulnerability Index (EVI) was developed by the South Pacific Applied Geoscience Commission (SOPAC, Fiji) as a response to calls for measures of the vulnerability of states from the Alliance of Small Island States (AOSIS) and the Barbados Programme of Action (Kaly et al. 1999a). The EVI was designed to provide a relatively quick and inexpensive mechanism for characterising states in terms of the vulnerability of their natural environments to natural and anthropogenic hazards. The alternative would be ad hoc assessments for each state which would be costly in terms of time and resources and which would not provide a common basis for comparison.

The EVI uses 47 indicators of exposure of the natural environments of a state to hazards and their intrinsic and extrinsic resilience to hazards (table 1). The table of indicators is included here because it shows the range and complexity of indicator questions considered necessary to measure vulnerability of natural environments. The measures include both natural and human components, forming three types of sub-index: The REI (Risk Exposure Index) provides information on the types and intensity of risk to natural and anthropogenic hazards. The IRI (Intrinsic Resilience Index) measures signals relating to the innate characteristics of a state which tend to make it resilient to hazards, while the EDI (Environmental Degradation Index) provides an assessment of the present condition of the natural environments assuming that those in the best condition will be most resilient to future shocks. Information collected for a state for each of the indicators is compared with ideal conditions and/or those conditions found world-wide so that data may be mapped onto a 1-7 scale. That is, the conditions for any state with respect to a single indicator will be represented somewhere on that 1-7 scale. The scale itself may be linear, non-linear or discontinuous and was developed to accommodate heterogeneous types of information (yes/no, percentage or numerical). The scores derived from this mapping are then averaged to produce an overall EVI and sub-indices. Because data are mapped on the 1-7 scale, for which a high score is considered more vulnerable, it is possible to use the individual scores as a way of identifying problem areas in terms of risk or environmental degradation (see Kaly et al. 1999a,b).

The EVI relies on four assumptions of importance to this discussion. At its basis, the EVI assumes that (i) the more pristine environments are, the better will be their resilience to natural and anthropogenic shocks. It also assumes that (ii) natural environments in good condition generally serve the needs of humans better than damaged ones. The EVI assumes that (iii) human behaviours, choices and socio-economic conditions are part of environmental vulnerability and seeks to measure these as part of the index. Finally, it assumes that (iv) indicators may be found which describe and summarise a host of complex processes which must be operating and which vary in terms of their final values in a way that relates to (the largely immeasurable) details of interest in the system being measured.

In many ways, the needs to be met by the EVI are similar to those for managing the world's coral reefs. Although not directly applicable in its present form, the approach taken for the EVI could be adapted to the task of providing information for the protection of aquatic biodiversity, ecosystem management and identifying areas for action.

Table 1. Indicators used for calculating the Environmental Vulnerability Index (EVI). Indicators fall into three sub-indices (S-I) as follows: The REI = Risk exposure sub-index; IRI = Intrinsic Resilience Sub-index; and EDI = Environmental Degradation sub-index. Categories refer to risks to the natural environment as follows: Met = meteorological, G = geological, CC = country characteristics, B = biological, A = anthropogenic. Response levels for the indicators are not provided here.

#	S-I	Category	Indicator
1	REI	Met	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)
2	REI	Met	Number of days over the last 5 years during which the max recorded wind speed (3 sec gusts) >20% higher than the average max for that month (use 30yr average for each month as reference) (Data accumulated over all reference climate stations / # stations)
3	REI	Met	Number of months over the last 5 years during which rainfall >20% lower than the 30yr average for that month (Data accumulated over all reference climate stations / # stations)
4	REI	Met	Number of months over the last 5 years during which rainfall >20% higher than the 30yr average for that month (Data accumulated over all reference climate stations / # stations)
5	REI	Met	Number of days over the last 5 years during which the max temperature >5 C higher than the mean monthly maximum for that month (use 30yr average for each month as reference) (Data accumulated over all reference climate stations / # stations)
6	REI	Met	Number of days over the last 5 years during which the max temperature >5 C lower than the mean monthly minimum for that month (use 30yr average for each month as reference) (Data accumulated over all reference climate stations / # stations)
7	REI	G	Number of volcanoes with potential for eruption >= VEI 4 (Volcano explosivity Index) within 100km of country land boundary / area of land

8	REI	G	Earthquake energy within 100km of country land boundaries / land area with ML >=6.0 and <=15km depth per 5 years
9	REI	G	Number of tsunamis or storm surges with run-up >2m above MHWS / 100km coastline since 1900
10	IRI	CC	Total land area (sq km)
11	IRI	CC	Ratio of length of ocean shoreline : total land area
12	IRI	CC	Distance to nearest continent (km) (*define continent)
13	IRI	CC	Altitude range (Highest point - lowest point in country)
14	IRI	CC	Percent of land area <10m above sea-level
15	IRI	CC	Percentage of land area <10m elevation within 2km of coast composed of unconsolidated sediments (excluding coral reefs)
16	IRI	CC	Number of known endemic species / 10,000 sq km land area
17	REI	B	Number of reported (and verified) organism outbreaks over the last 5 years / land area (pathogens, blooms, plagues etc)
18	REI	B	Total tonnage of freight imported / year
19	EDI	B	Number of all introduced species / 10,000 sq km land area since 1900
20	EDI	B	Number of endangered and threatened species / 10,000 sq km of land area (IUCN definitions)
21	EDI	B	Number species which have become extinct since 1900 / 10,000 sq km land area (IUCN definitions)
22	EDI	B	Percentage of natural and regrowth vegetation remaining (e.g. forests, mangroves, saltmarshes, prairies, savannah, desert, tundra)
23	EDI	B	Tonnage of intensively-farmed animal products / yr / land area (includes acquaculture, pigs, chickens, etc)
24	EDI	B	Percent of fisheries stocks overfished (FAO)
25	EDI	A	Density of people living in coastal settlements (define area)
26	REI	A	Total human population density (per sq km land area)
27	REI	A	Annual human population growth rate (average over last 5 years)
28	REI	A	Net percentage of land area changed by the removal of natural vegetation over last 5 years
29	REI	A	Annual number of international tourists * average days stay / 365 / 100 sq km (last 5 years)
30	REI	A	Megalitres of untreated industrial and domestic wastewater discharged to aquatic system / 1,000 km aquatic ecosystems (length coast+length rivers)
31	REI	A	Total tonnage of generated and net imported toxic, hazardous and municipal wastes/ 10,000 sq km land area / year (average last 10 years)
32	REI	A	Mean percent of hazardous, toxic and municipal waste effectively managed or treated / yr
33	REI	A	Number spills of oil and hazardous substances >1,000 litres during last 5 years on land, in rivers or within territorial waters / land area
34	REI	A	Number of nuclear, chemical and other major industrial facilities that could cause significant damage / 10,000 sq km land area (*Denominator should be territorial area?)
35	REI	A	Number of vehicles (World Bank definition) / land area (*Denominator could be length roading or length roads / land area)
36	REI	A	Max 24 hour SO2 concentration (micro g /cubic m) (average over last 5 years)
37	REI	A	Tonnes of N,P,K fertilisers used / 10,000 sq km agricultural land area / year (average last 5 yrs)
38	REI	A	Tonnes of pesticides used / 10,000 sq km of agricultural land / year (average last 5 years)
39	REI	A	Number of new fisheries stocks or expanded fisheries efforts (>20% increase in catches) added to country over last 5 years (within territory)
40	EDI	A	% Land area degraded since 1950 (includes salinisation, desertification etc.)
41	EDI	A	Annual internal renewable water resources per capita (average annual runoff plus recharge of groundwater from endogenous precipitation)
42	REI	A	Kilotonnes of mining material (ore + tailings) extracted / 10,000 sq km land area / year (average last 5 years)
43	EDI	A	% Land, rivers and coastal zone affected by mining and quarrying
44	EDI	A	Percent of terrestrial zone set aside as reserves
45	EDI	A	Percent of marine zone set aside as reserves (mean high tide to continental shelf)
46	EDI	A	Number of war or civil strife years over the last 50 years within the territory
47	EDI	A	Percentage of population with access to safe sanitation (WHO)

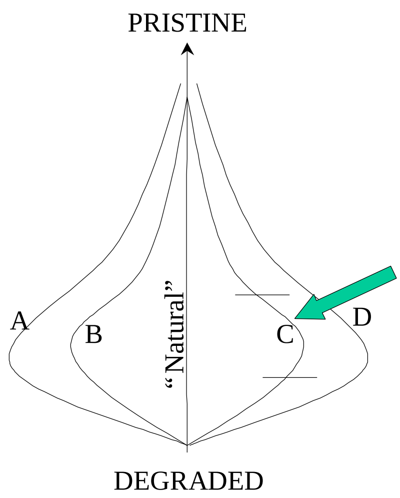
Setting targets for indices

There are three aspects of ecosystem condition of concern to us if we are to provide information and decision support for coral reefs. These are: (1) The ideal condition we would like our system to be in; (2) The present state of a reef in relation to this ideal and defined management thresholds; and in order for our management to work in the long run: (3) The total viability and health of coral reefs made up from a composite picture at a range of spatial scales.

The first two assumptions of the EVI relate to explicitly setting targets for the condition of natural environments against which the performance of a particular state could be measured. This applies also to coral reefs in the present discussion. It needs to be explicitly-stated that ‘pristine’ or ‘natural’ conditions of a reef are the direction in which all management should aim, and that thresholds along that arrow may mark certain management choices (figure 1). The purpose of indicators and indices would then be to locate a particular reef or group of reefs in terms of their health along the axis from “degraded’ to ‘pristine’.

These above points relate specifically to not setting management arrows so that they point towards a particular usage type or management zone (e.g. open access fishing area). Doing so would make it difficult to assess damage sustained through human pressures because the new management target could become an artificial reef community which might not best serve our aims at preserving biodiversity and human welfare. There is also a question of being able to accumulate coral reef data over larger scales to examine overall viability and status of the world’s reefs. To do this, we need a common basis for comparison – I suggest this common basis should be some measure of ‘pristineness’ of reefs. The health of the world’s coral reefs depends on the overall picture made up of its many pixels, highlighting the value of GIS.

Figure 1. Management arrow which explicitly states that ‘natural’ or ‘pristine’ conditions are the direction of management strategies because these conditions ultimately support all coral reef processes and human welfare. Also shown are management options (A-D) as deformations of the line running from pristine to degraded. This reinforces the idea that certain uses of a reef can deform the way it is structured and functions. The solid arrow is an expression of the current state of the reef. A particular reef may be being managed along deviation line C. Along line C are some management thresholds showing the lower acceptable limit for health and an upper limit which could lead to the decision for more exploitation (horizontal lines).



Humans as part of the reef system

Humans are explicitly incorporated as indicators in the EVI, and in the categories identified by Done and Diop (1999). A total of 38% of the EVI's indicators are direct measures of human choices and behaviour in relation to environmental vulnerability. There are socio-economic indicators: 25, 26, 27, 46, 47; those dealing with use/conservation: 18, 23, 29, 30, 32, 33, 34, 35, 37, 38, 39; and policy/management: 44, 45 (table 1). In addition to these, indirect human measures are implicit in some of the remaining indicators (e.g. indicators 17, 19, 20, 21). By incorporating humans directly into the model and indicators, it is expected that we will be better able to observe interactions between humans and their natural environments and alert institutions when any part of the system starts to slide backwards along the management arrow. Clearly, the search for indicators for the management of the world's coral reefs will need to incorporate humans as an explicit and fully integrated part of the information and decision-support system.

'Smart indicators' for checking the health of reefs

'Smart indicators' could be defined as those which capture a large number of elements in a complex interactive system while at the same time showing how the value obtained relates to some ideal or agreed-upon condition. The central aim of the EVI was to populate it with only smart indicators, and the search for appropriate smart indicators is on-going. The basic assumption of smart indicators is that the value of a chosen indicator is a culmination of perhaps millions of transactions that must have been operating appropriately to result in the value obtained. Thankfully, this does not require our full knowledge of every transaction because if this were a requirement, we would never be able to use indicators at all. Further, to some extent all indicators are 'smart' – this is essentially a search for the smartest and most efficient for our purposes. In the EVI for example, indicator 36 deals with the maximum SO2 concentration in the largest city of a state. This indicator is obviously intended to capture industrial discharges, but has within it the density of those discharges, choices people make about the form that discharge takes and the ability of the environment to attenuate them. In turn, the ability of the environment to attenuate discharges captures other features of the system such as forest cover, wind patterns etc.

In the case of coral reefs, a similar search for smart indicators will be required. Some possible avenues for development were identified during the workshop and possible smart indicators were examined for corals, other invertebrates, fishes, recruitment and physical features. Humans and other reef categories will need to be incorporated in the future.

Central to the concept of smart indicators is the idea that good and bad performance is inherent in the way the indicator is expressed. For the EVI this was achieved by mapping the value of an indicator on a scale ranging from 1 (relatively resilient) to 7 (very vulnerable). This approach serves two important functions. Firstly, for the managers and scientists it forces us to decide on actual values for the indicator that are 'good' or 'bad'. This has not been an easy task because information on the vulnerability and limits to viability of ecosystems is generally lacking (Daily 1999). Further, for the EVI it was necessary to make the index globally-applicable. This means that the range of values for an indicator not only has to indicate vulnerability, but also be applicable across all conditions found on the planet !

The second function of inherently expressing the value of an indicator is of greatest interest to the users of the EVI. Irrespective of whether the final EVI is calculated or not, any single indicator gives us a performance rating for that measure that contains within it our best understanding of how ecosystems respond to hazards. This means that the user need not be an expert to read the results - the work has already been done in the selection of the indicators and the setting of response levels. For users, smart indicators mean near-instant results, making them amenable to use by non-scientists, until now one of the weaknesses of adaptive methods of management (Shindler and Cheek 1999).

For coral reefs it may be sufficient to provide cut-off levels for each indicator, rather than mapping them onto a graded scale. One promising smart indicator suggested by Cliff Hearn at this workshop took the form of measuring the amount of incident wave energy translated across a reef. For a healthy reef, the amount of energy passing the reef should be no more than 10% of the incident energy. This smart indicator has built into it the idea of a limit so that users can understand whether their reef is healthy or not, and incorporates information on hundreds of measures and processes that must be operating well to pass the test. These processes might include good recruitment of corals and fishes, high rugosity of the reef, good cover by corals and algae, a good upwards growth rate and all of the minor and major transactions that would be going on within a healthy reef ecosystem to result in the translation of only 10% of incident wave energy. It is a range of indicators such as this that is urgently needed for better management of coral reefs.

Conclusions

Providing information and decision support for the urgent task of pulling the world's coral reefs back from the brink requires, in part, the development of rapid methods for assessing their health. The approach taken during the development of the Environmental Vulnerability Index provides us with some direction for coral reefs. The first lesson derived from the EVI is that the indices require the explicit statement of ideal conditions that reefs should be in, and that this ideal should be on a continuum that points towards natural or pristine conditions. The second lesson is that humans are part of the coral reef system and that their choices and behaviours need to be monitored as part of a reef's health just as importantly as any measure of diversity or ecosystem structure or function. This suggests that measures of coral reef health need to include human indicators. Finally, I have introduced the concept of smart indicators in the context of coral reefs. For indicators to provide the information necessary and to bridge the distance between science and users, it is necessary that they be end-point indicators. This requires that they be crafted so that they embody details of which we might not be aware and that they convey in their expression an immediate understanding of the status of coral reefs.

Acknowledgements

The development of the EVI has been generously supported by New Zealand ODA. Additional support was given by the United Nations Environment Programme (UNEP), the governments of Fiji, Samoa, Tuvalu, Vanuatu and Australia, the South Pacific Regional Environment Programme (SPREP), the Pacific Island Forum Secretariat, the Secretariat for the Pacific Community, the University of Malta and the World Meteorological Organisation (WMO). Thanks to Claudia Ludescher and Craig Pratt for comments on this manuscript.

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9.5 SOPAC funding proposal for Phase III – Option 1 globalising and testing the EVI

NAME OF PROJECT	Environmental Vulnerability Index (EVI) Project Phase III
TYPE OF PROJECT	Development of a robust global environmental vulnerability index
AUTHORITY SUBMITTING THE PROJECT	South Pacific Applied Geoscience Commission (SOPAC) [4]
IMPLEMENTING ORGANISATION	South Pacific Applied Geoscience Commission (SOPAC)
RECIPIENT STATES	Pacific Countries
COMMITMENT PROPOSED AS A GRANT	USD $604,307
DURATION OF PROJECT	2 YEARS

The project proposal has been endorsed by the SOPAC Governing Council during its 28th Annual Session for submittal for funding.

Keywords: *Pacific Regional initiative, Environmental Vulnerability, National level, Pacific Island Countries, Global issues, LDC status.*

1. Background

In July 1998, the United Nations Economic and Social Council (ECOSOC) in its resolution 1998/39 requested the Committee for Development Planning to report on the usefulness of a vulnerability index as a criterion to designate least developed countries (LDC).

In CDP's recent report to ECOSOC 26 – 30 April 1999, the CDP stated that the best approach to take explicit account of economic vulnerability in the designation of LDCs would be to utilise a composite Economic Vulnerability Index. CDP also stressed that this economic vulnerability index will give only a partial and appropriate measure of vulnerability for a country. CDP also emphasised that the vulnerability of developing countries is a much broader issue which also has **ecological** and social aspects which should be a priority for international research activities and work for the Committee. The CDP also noted the important work and related debates relating to the development and use of vulnerability indicates being undertaken by SOPAC, the Caribbean Development and the Commonwealth Secretariat.

[4] SOPAC Member Countries: Australia, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia (Associate), Guam, Kiribati, Marshall Islands, Nauru, New Caledonia (Associate), New Zealand, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu.

Currently, it is our understanding that ECOSOC has deferred decision on the CDP recommendations. SOPAC is currently seeking clarification on this and implications for Pacific SIDS. It is also our understanding that both the EU and the United States have expressed concerns about the issue of vulnerability and the CDP report. The EU position recognises vulnerability as an issue but clearly states that the EU has concerns over proposed mechanisms for its use and measurement.

It is possible that the deferral of the ECOSOC decision on the inclusion of vulnerability indices as a criterion for assessing least developing country status could be tabled at ECOSOC 2001 but a decision is not expected to be delayed any further. It is therefore essential that all development work on the EVI be completed before March 2001.

2. Project Aim

The EVI is a Pacific Regional initiative. Its purpose is to provide a measure that will simplify the otherwise expensive and difficult task of carrying out detailed assessments of countries to provide a statement of the likely vulnerability of the environment to natural and human hazards. It also provides a common basis for comparison among countries.

The overall aim of this project is to complete the development of a fully functional and tested EVI, so that it is capable of serving these functions. To achieve this aim, it will be necessary to complete the following tasks:

1. Fully define, set upper and lower limits to, and set scoring scales for the indicators of environmental vulnerability identified to date, and any new ones which might be required;
2. Collect data from a total of 15 countries with a range of characters and conditions (deserts, rainforests, tropical, temperate, large, small, etc) for testing the EVI model;
3. Test indicators for redundancy using the data from 15 widely different types of countries and from there adjust them and determine appropriate weightings;
4. Test the EVI model against *a priori* criteria for determining when it would be acceptable for use as an international tool. This includes an independent test of the index to be made by sending professionals to 5 countries to make independent assessments of vulnerability against which the usefulness of the EVI could be examined;
5. To develop a simple robust computer user interface for the environmental vulnerability index model to facilitate data entry and streamline calculation;
6. To build capacity within the South Pacific region to identify, analyse and collect data for the environmental vulnerability index;
7. To develop a sustainable data collection mechanism for the EVI using in-country and international resources.

3. Introduction

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. A range of these indices has been developed to describe vulnerability of human systems to harm from other human influences or natural ones.

Economic and quality of life indices are well on the road to completion. For natural environments, SOPAC's work is the first of its kind. The first two phases of the environmental vulnerability index project were funded by the New Zealand Government in support of a Commission on Sustainable Development initiative as part of the implementation of the Barbados Programme of Action. The Barbados Programme of Action called for the development of a composite vulnerability index that reflects the risks and resilience of Small Island Developing States (SIDS) and integrates ecological fragility and economic vulnerability.

The SOPAC environmental vulnerability index is still in development and has been designed as a multi-level model to describe the vulnerability of the natural environment of countries to a range of natural and anthropogenic hazards. The work includes the development of an overall environmental vulnerability index, which is broken down into sub-indices that describe levels of risk and resilience and the effects of these influences on the health or integrity of a country's environment. This information can be presented as an individual index or as sub-indices which can all be detailed into a full country environmental vulnerability profile to highlight specific areas of concern. It is important that all of these aspects of environmental vulnerability be developed simultaneously so that the final product can be widely applicable to different aspects of decision-making both among and within countries. It is also envisaged that the index would be recalculated periodically (every 5 years) to provide information on the effectiveness of actions taken by countries that have altered their relative vulnerabilities.

The SOPAC-developed environmental vulnerability index and methodology selected for its computation (SOPAC Technical Report 275), recently underwent critical peer review at an International Expert Group Meeting held in Fiji, 7–10 September 1999. At this meeting, the index and its methodology were exposed to peer review and debate to determine whether the approach taken was technically acceptable and that the index could be refined into a robust and internationally applicable measure.

The Expert Group supported the conceptual approach to determining environmental vulnerability as developed by SOPAC and supported its development into a global tool. They also made several recommendations including that:

I. The EVI be considered by the United Nations Committee on Development Policy (UN CDP) at its next meeting that considers vulnerability indices as criteria for classifying countries and assigning Least Developed Country (LDC) status;
II. The environmental vulnerability index is considered a useful tool not just as a single number defining environmental vulnerability of a country but also in providing detailed

country profiles on the hazards, intrinsic features and environmental health likely to affect environmental vulnerability;

III. There is a need to look further into the development of a separate vulnerability index which examines the human environment (more content on direct impacts on human systems – vulnerability of human quality of life index);

IV. The EVI should be tested using data from no less than 15 widely differing countries; and

V. Should be published in an international peer-reviewed journal

The index itself was modified during the Expert Group Meeting (SOPAC Technical Report 299). Changes were made to the structure of the model (framework) and to the indicators which 'capture' or 'measure' vulnerability. Most of the structural changes can be incorporated immediately, while changes to the indicators will require work to redefine them, set their scaling within the global context and remove redundancies. The first part of this refinement will be completed during Phase II of the project using data from 5 countries centred in the Pacific Region (Australia, Fiji, Samoa, Tuvalu and Vanuatu). This third report is expected to be available in March 2000 (Table 1).

The EVI being developed by SOPAC requires further development and testing against criteria set by the expert group during the think tank before it can become fully operational (Table 1). This will involve testing of the environmental vulnerability index mathematically and with real international country data to refine the model and its indicators and to ensure its global applicability, workability and robustness. This work will also include in-country capacity-building where required, the development of a computer interface to simplify data collection and calculation of the EVI and the establishment of a permanent, international system for collection of the data. Through the process of capacity building, consultation and involvement by Pacific Island Countries, the formulation and design of an environmental vulnerability index, as a useful environmental management and policy decision-making tool that meets the needs of region will be developed. To be effective, the EVI needs to be global since it is in the global context that PIC's can benefit the most from the index.

Several major tasks have been identified for the successful full development of the EVI as a tool for measuring and managing the vulnerability of countries (see also Table 1). These are presented in the format of modules, some of which must be run in parallel with others for the work to be undertaken efficiently.

Table 3: Summary of phases and tasks undertaken since September 1998 and plans for future work

Phase	Description	Accompanying report
Phase I	1. Review other vulnerability indices 2. Determine whether an EVI is possible 3. Construct preliminary EVI centred on Pacific SIDS 4. Initial data collection & calculation for 3 countries (Australia, Fiji, Tuvalu)	SOPAC Technical Report 275 (January 99)
Phase II	1. Peer review at Expert Meeting "Think Tank 1" 2. Refinement of model 3. Data from 5 countries in Pacific	SOPAC Technical Report 299 (October 1999) Technical Report due March 2000
Phase III	1. Collect data from 15 differing types of countries worldwide 2. Globalise model 3. Test indicators 4. Test overall EVI 5. Think tank 2 6. Create user interface (computerised) 7. Capacity-building in-country 8. Set up permanent data-collection mechanisms 9. Publication	Work to begin in March 2000

SOPAC is now seeking funding to take the project into Phase III and to complete the work. The funding is envisaged primarily as being assembled as a single package through co-funding from donors (though some of the modules may be identified separately for funding).

It is important to highlight the need to secure funding for all modules to ensure the complete development and refinement of the EVI. SOPAC is currently seeking immediate funding for Module 1 that will guarantee the continued development and refinement of the EVI. The acquisition of funding for other modules will enhance and expand the development and refinement process during Phase III.

The basic modules include:

Module 1: Refinement and Comprehensive Testing of the Environmental Vulnerability Index (Collecting data from 15 countries and profiles from 5, Globalising the model, testing indicators, testing the overall index, Think Tank 2, publication)

Module 2: Pacific EVI Country Capacity-Building

Module 3: Sustainable Data Collection Process for the Environmental Vulnerability Index (through in-country and international agencies)

Module 4: Computer Environmental Vulnerability Index Interface Development

Module 5: Validation of the EVI

The modules are currently presented in concept with estimated budgets and timeframes. Detailed proposals for each module can be provided as required.

All tasks will be carried out in consultation and partnership with all Committee for Regional Organisations in the Pacific (CROP) members including: South Pacific Regional Environment Programme, Forum Secretariat, Secretariat of the Pacific Community, University of the South Pacific, Forum Fisheries Agency, Pacific Island Development Program, Tourism Council of the South Pacific, non-government organisations and other regional agencies. Particular inputs will be sought from all Pacific island governments and the international agencies with a mandate for international affairs and particularly SIDS.

4. Modules Required for EVI Development and their Justification

Module 1: Refinement and Comprehensive Testing of the EVI

Aim: To operationalise the EVI through extensive testing with real environmental vulnerability data from at least 15 countries that represent the vast variety of different environments found globally

Tasks: Collecting data from 15 countries, Profiles from 5 countries for validation, Globalising the model, Testing indicators, Testing the overall index, Think Tank 2, Publication.

Technical development of the environmental vulnerability index will require that the model and its indicators be extensively tested with environmental data from at least 15 countries with widely differing characteristics. These countries have to represent the variety of environmental and risk conditions found on the globe so that the EVI can be set within a world-wide context. The real data obtained from these countries will be used to define the parameters within which the conditions of any single country can be identified.

Examples of countries could include high mountainous countries like Nepal or Bolivia, small land-locked countries like Lesotho and Switzerland, countries with a large size embracing numerous ecosystems like the United States of America, highly industrialised countries constituted mainly of man-made environments like Germany, or countries with cold climates like Greenland or Russia. Data collection from these countries would be additional to any country information collected within the Pacific.

It is expected that the selection of 15 countries will include several developed countries whose voluntary participation and provision of data is essential to the process of data collection. It is also envisaged that the participation of several developing countries may require technical assistance to facilitate the collection of environmental vulnerability data files and this will need to be co-ordinated by the project.

The environmental vulnerability index will also need to undergo extensive mathematical and statistical analysis to fully refine and operationalise it. The testing will include correlation analyses to identify and discard redundant indicators, weighting of indicators and sensitivity analyses.

Outputs/Benefits:

- An index which is globally applicable while at the same time providing context for its application in the Pacific Region
- Environmental vulnerability data for 15 international countries which show their relative vulnerabilities for a range of variables which affect or characterise their environments
- A fully mathematically and statistically tested model using real data from a diverse range of countries leading to a refined and robust EVI

Module 2: Pacific Environmental Vulnerability Index Country Capacity-Building

Aim: To provide training to SIDS country representatives in the use, data collection and computation of the environmental vulnerability index.

For some countries, data may be obtainable by contacting the relevant departments and asking for assistance with data acquisition. For most SIDS, this approach is unlikely to yield adequate results. It will therefore be necessary for the EVI Team to carry out a capacity building workshop with representatives from at least 10 member countries to introduce them to the environmental vulnerability index concept, its workings and information required for its computation. Also included in this capacity-building exercise is follow-up work for the 10 countries.

The workshop will be held over 5 days at the SOPAC Secretariat which is located in Suva, Fiji and is centrally situated in the South Pacific. The SOPAC Secretariat has all the necessary computer, training and workshop facilities required to facilitate such a workshop thus reducing the need to secure outside facilities at additional cost.

The workshop participants would be provided with an introduction to the environmental vulnerability index, the underlying concepts, benefits and uses of the model in environmental management and decision-making, and an introduction into the mechanics and computation of the EVI. The aim of the introduction would be to provide participants with the basic skills needed to determine information needs for the EVI together with the identification of possible sources of information in their respective countries and how to collect appropriate data. The knowledge gained through the workshop would allow participants to provide their countries with detailed explanations on the need for environmental management information, the conceptual mechanics and overall benefits of the environmental vulnerability index and its application in environmental management.

To ensure the effectiveness of the workshop in providing country representatives with the appropriate skills for data manipulation, it will be necessary to undertake follow-up work. This will entail visits by the EVI Team to countries to facilitate and assist in the collation of environmental vulnerability data for all participating countries.

Outputs/Benefits:

- Trained country personnel in all aspects of EVI calculation
- Strengthening of country capacity to identify, collect and compile environmental information
- Improved understanding of the environmental vulnerability index, its uses, mechanics and applications in environmental management and policy making
- Environmental vulnerability data for at least 10 Pacific countries
- Pacific ownership of the EVI and the work that has been carried out in the region

Module 3: Development of a computerised EVI Interface

Aim: To develop a user interface in Microsoft Access for the EVI

The model developed for calculating the EVI during Phase I was built into EXCEL spreadsheets. This makes calculating the EVI cumbersome for the endpoint users and was not intended for use by them because files may be easily damaged or altered, making calculations inaccurate.

During Phase III, the EVI model will be built into a user-friendly ACCESS application with on-line help to allow for easy and streamlined input of data. The computer interface will also make the mathematical calculations robust to damage by users and secure the generation of final reports into quick and simple formats with graphical outputs.

Output/Benefits:

- The development of a robust and simple user-friendly Microsoft Access interface for the environmental vulnerability index model
- Simplified and streamlined entry of environmental vulnerability index data with enhanced generation of final environmental vulnerability index values and reports

Module 4: Sustainable Data Collection Process for EVI

Aim: To develop a sustainable mechanism for EVI data collection and computation every 5 years

When the EVI is internationally accepted and set in place as a regular tool to assess the environmental vulnerability of countries world-wide, a sustainable strategy is needed to establish data collection and analysis.

Sustainable data collection has to be institutionalised, transparent and as effective and economic as possible. A suitable mechanism has to be identified which will ensure the co-ordination and collection of country environmental vulnerability data. This should also be a world-wide initiative and be accepted as such.

Potential mechanisms for data collection by country institutions and reporting mechanisms to international organisations responsible for international data collation and analysis will need to be investigated for applicability possible use. For example, one possible mechanism could be the collection of national environmental data through the Global Environment Outlook (GEO) process. This mechanism may be able to provide a suitable platform through which data is collected nationally and then collated internationally. Countries may then also utilise the information at the national level for their own purposes.

Outputs/Benefits:

- Identification of an appropriate international mechanism for the continual collection of environmental vulnerability data by all countries
- Identification of an appropriate approach to the collection of country environmental vulnerability data for use both within country and internationally
- The continual collection of environmental vulnerability data by countries which will allow EVI values to be calculated at repeated intervals by all countries

Module 5: Validation of the EVI

Aim: To independently peer review and validate the EVI

Peer review is essential throughout the development of the EVI to ensure international applicability and robustness. Because the task is multi-disciplinary and breaks new ground, it will be necessary to obtain rigorous technical inputs through a second think tank and through publication in an international academic journal. International experts from the fields of climate, geology, ecology, statistical methods, modelling, environmental assessment and management, economics and indexing will need to be consulted in a forum which allows their areas of expertise to be integrated.

An important part of this validation exercise of the EVI involves the independent assessment of 5 countries by consultants not initiated in the workings of the EVI. These detailed country vulnerability assessments will be compared against environmental vulnerability index values to ascertain their correlation. This was considered by think tank participants to be the ‘acid test’ for determining when the EVI could be considered operational.

Outputs:

- A globally applicable scientifically sound, robust, fully tested and validated EVI

5. Overall Expected benefits from the project

All of the above modules are required to fully develop an internationally recognised and acceptable EVI. By ensuring that the model has been fully tested and that consultation has occurred at all levels (technical and political) the EVI can become an important tool for examining relative vulnerabilities of states, whether they be small islands or continental. Consultation and involvement of Pacific Island Countries throughout the project will ensure that the initiative remains with the region and that the needs and expectations of those countries are incorporated into the development of the EVI. It will also mean that the capacity of Pacific Island Countries for environmental management using tools like the environmental vulnerability index are secured.

6. Overall Project Outputs

The major outputs from Phase III will be:

- Pacific ownership of the EVI and the work that has been carried out in the region
- An internationally tested, robust, validated and operational EVI which is transparent in its strengths, biases and functions as a way of summarising the environmental vulnerability of states
- Capacity-building within the region in the use, mechanics and applications of the EVI in environmental management and policy making
- Strengthened capacity in Pacific Island Countries in the identification, collection and analysis of environmental management data
- Environmental vulnerability data for at least 10 Pacific island countries and 15 international countries which show their relative vulnerability's of a range of variables which affect or characterise their environments
- A user-friendly computer programme which can be sent to all countries wishing to calculate their EVIs (some with assistance)
- An EVI that can be combined with other vulnerability indices into a composite vulnerability index
- Identification of an international mechanism for the continual collection of environmental vulnerability data by all countries

10. Acronyms & definitions for indicators

AIMS	Australian Institute of Marine Science
AOSIS	Alliance of Small Island States
CDP	United Nations Committee for Development Policy
COP	Conference of the Parties (to the Convention on Climate Change)
CROP	Committee for Regional Organisations in the Pacific
CSD	Commission on Sustainable Development
ECOSOC	United Nations Economic and Social Council
EVI	Environmental Vulnerability Index
GEF	Global Environment facility
GEO	Global Environment Outlook
IDNDR	International Decade for Natural Disaster Reduction
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental panel on Climate Change
LDC	Least Developed Country
PACCLIM	Pacific Island Climate and Sea Level Change Model
PICCAP	Pacific Islands Climate Change Assistance Programme
SIDS	Small Island Developing States
SIS	Small Island States
SOPAC	South Pacific Applied Geoscience Commission
SPTO	South Pacific Tourism Organisation
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDESA	United Nations Department of Economic and Social Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WRI	World Resources Institute

Degraded	(Indicator 40) Reduction or loss in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: soil erosion caused by wind and/or water; deterioration of the physical, chemical and biological or economic properties of soil; and long-term loss of natural vegetation. This definition is the standard for Agenda 21 and the Convention to Combat Desertification (Kadomura, 1997).
Endangered	(Indicator 20) A taxon is endangered when it is not critically endangered (see below) but is facing a very high risk of extinction in the wild in the near future, as defined by any of the criteria for “endangered” in Table 4. In our indicator, we are including the IUCN category of “*Critically*

	endangered" which includes species which are facing an extremely high risk of extinction in the wild in the immediate future, as defined by any of the criteria for "critically endangered" in Table 4. IUCN Red List category 1994.
Endemic	(Indicator 16) Species which occur exclusively in the country and not elsewhere.
Extinct in the wild	(Indicator 21) A taxon is extinct in the wild when it is known only to survive in cultivation, in captivity or as a naturalised population (or populations) well outside the past range. A taxon is presumed extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Extinct	(Indicator 21) A species is extinct when there is no reasonable doubt that the last individual has died. IUCN Red List category1994.
Intensive farming	(Indicator 23) For the EVI, intensive animal farming includes all farming practices for which the waste products produced cannot be largely attenuated over the land on which they are conducted. This includes, but may not be limited to most poultry farming, pig farming and intensive aquaculture. For the countries we examined, data on poultry and pigs was often returned as head of animals produced per year, rather than tonnage. We used the following conversion rates for this study: chickens and ducks each weighing 2kg and pigs each weighing 100kg.
ML-6	(Indicator 8) Earthquake energy units. The ML or Magnitude Local scale is equivalent to the Richter Scale. It measures the magnitude of an earthquake as the logarithm of the amplitude of waves recorded by seismographs, adjusted for variation in the distance between seismographs and the epicentre of earthquakes. For our indicator, the earthquakes of interest must be 6.0 or stronger and must occur within 15km of the earth's surface.
Vehicle	(Indicator 35) This uses the World Bank definition as follows: *****
VEI-4	(Indicator 7) Expression of potential for volcanic eruption based on plume height, volume of eruption, classification of the volcano and frequency of eruption. VEI-4 is a cataclysmic volcano with a plume height of 10-25km, lava/ash volumes of 100,000,000s of m^3, of vulcanian / plinian classifications, and erupting on a time scale of 10's of years.
Vulnerable	(Indicator 20) A taxon is vulnerable when it is not Critically endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future, as defined by any of the criteria for "vulnerable" in Table 4. IUCN Red List category 1994.

Table 4: IUCN Criteria for the categories Endangered and Vulnerable, 1994

IUCN Category	Criteria	Details	
CRITICALLY ENDANGERED	A. Population reduction in the form of either of the following:	1. An observed, estimated, inferred or suspected reduction of at least 80% over the last 10 years or three generations, whichever is the longer, based on (and specifying) and of the following:	a) direct observation b) an index of abundance appropriate for the taxon c) a decline in area of occupancy, extent of occurrence and/or quality of habitat d) actual or potential levels of exploitation e) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.
		2. A reduction of at least 80%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer, based on (and specifying) any of b), c), d) or e) above.	
	B. Extent of occurrence estimated to be less than 100km2 or area of occupancy estimated to be less than 10km2, and estimates indicating any two of the following:	1. Severely fragmented or known to exist only at a single location	
		2. Continuing to decline, observed, inferred or projected, in any of the following:	a) extent of occurrence b) area of occupancy c) area, extent and/or quality of habitat d) number of locations or sub-populations e) number of mature individuals
		3. Extreme fluctuations in any of the following:	a) extent of occurrence b) area of occupancy c) number of locations or sub-populations d) number of mature individuals.
	C. Population estimated to number less than 250 mature individuals and either:	1. An estimated continuing decline of at least 25% within three years or one generation, whichever is longer or	
		2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals and population structure in the form of either:	a) severely fragmented (i.e. no sub-population estimated to contain more then 50 mature individuals) b) all individuals are in a single sub-population.
	D. Population estimated to number less than 50 mature individuals		
	E. Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or 3 generations, whichever is the longer.		
ENDANGERED	A. Population reduction in the form of either of the following:	1. An observed, estimated, inferred or suspected reduction of at least 50% over the last 10 years or three generations, whichever is the longer, based on (and specifying) and of the following:	a) direct observation b) an index of abundance appropriate for the taxon c) a decline in area of occupancy, extent of occurrence and/or quality of habitat d) actual or potential levels of exploitation e) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.
		2. A reduction of at least 50%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer, based on (and specifying) any of b), c), d) or e) above.	
	B. Extent of occurrence	1. Severely fragmented or known to exist at no	

	estimated to be less than 5000km2 or area of occupancy estimated to be less than 500km2, and estimates indicating any two of the following:	more than 5 locations	
		2. Continuing to decline, observed, inferred or projected, in any of the following:	a) extent of occurrence b) area of occupancy c) area, extent and/or quality of habitat d) number of locations or sub-populations e) number of mature individuals
		3. Extreme fluctuations in any of the following:	a) extent of occurrence b) area of occupancy c) number of locations or sub-populations d) number of mature individuals.
	C. Population estimated to number less than 2500 mature individuals and either:	1. An estimated continuing decline of at least 20% within 5 years or 2 generations, whichever is longer, or	
		2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals and population structure in the form of either:	a) severely fragmented (i.e. no sub-population estimated to contain more then 250 mature individuals) b) all individuals are in a single sub-population.
	D. Population estimated to number less than 250 mature individuals		
	E. Quantitative analysis showing the probability of extinction in the wild is at least 10% within 100 years.		
VULNERABLE	A. Population reduction in the form of either of the following:	1. An observed, estimated, inferred or suspected reduction of at least 20% over the last 10 years or three generations, whichever is the longer, based on (and specifying) and of the following:	a) direct observation b) an index of abundance appropriate for the taxon c) a decline in area of occupancy, extent of occurrence and/or quality of habitat d) actual or potential levels of exploitation e) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.
		2. A reduction of at least 20%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer, based on (and specifying) any of b), c), d) or e) above.	
	B. Extent of occurrence estimated to be less than 20,000km2 or area of occupancy estimated to be less than 2000km2, and estimates indicating any two of the following:	1. Severely fragmented or known to exist at no more than 10 locations	
		2. Continuing to decline, observed, inferred or projected, in any of the following:	a) extent of occurrence b) area of occupancy c) area, extent and/or quality of habitat d) number of locations or sub-populations e) number of mature individuals
		3. Extreme fluctuations in any of the following:	a) extent of occurrence b) area of occupancy c) number of locations or sub-populations d) number of mature individuals.
	C. Population estimated to number less than 10,000 mature individuals and either:	1. An estimated continuing decline of at least 10% within 10 years or 3 generations, whichever is longer or	
		2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals and	a) severely fragmented (i.e. no sub-population estimated to

		population structure in the form of either:	contain more then 1000 mature individuals) b) all individuals are in a single sub-population.
	D. Population very small or restricted in the form of either of the following:	1. Population estimated to number less than 1000 mature individuals	
		2. Populations is characterised by an acute restriction in its area of occupancy (typically less than 100km2) or in the number of locations (typically less than 5). Such a taxon would thus be prone to the effects of human activities (or stochastic events whose impact is increased by human activities) within a very short period of time in an unforeseeable future, and is thus capable of becoming critically endangered or even extinct in a very short period.	
	E. Quantitative analysis showing the probability of extinction in the wild is at least 10% within 100 years.	1. Population estimated to number less than 1000 mature individuals	
		2. Populations is characterised by an acute restriction in its area of occupancy (typically less than 100km2) or in the number of locations (typically less than 5). Such a taxon would thus be prone to the effects of human activities (or stochastic events whose impact is increased by human activities) within a very short period of time in an unforeseeable future, and is thus capable of becoming critically endangered or even extinct in a very short period.	