INTEGRATING INDIGENOUS AND SCIENTIFIC KNOWLEDGE BASES FOR DISASTER RISK REDUCTION IN PAPUA NEW GUINEA

by

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ABSTRACT. In investigating ways to reduce community vulnerability to environmental hazards it is essential to recognize the interaction between indigenous and scientific knowledge bases. Indigenous and scientific knowledge bases are dynamic entities. Using a Process Framework to identify how indigenous and scientific knowledge bases may be integrated, three communities impacted upon by environmental hazards in Papua New Guinea, a Small Island Developing State, have established how their vulnerability to environmental hazards may be reduced. This article explores the application of the framework within the communities of Kumalu, Singas and Baliau, and how this could impact upon the future management of environmental hazards within indigenous communities in Small Island Developing States.

Key words: disaster risk reduction, indigenous knowledge, scientific knowledge, Small Island Developing States, Papua New Guinea

Introduction

Changes in people’s social, economic, cultural, political and environmental contexts have resulted in increased risk and vulnerability to environmental hazards (Lewis 1999; Wisner et al. 2004; Hewitt 2007). When disasters happen, they are rarely, if ever, ‘natural’, instead being the result of poorly managed interactions between environmental hazards and human society that have placed people in harm’s way without adequate coping mechanisms – and in many cases society has exacerbated the impact of such hazards through development activities (e.g. Hewitt 1983, 2007; Lewis 1999; Wisner et al. 2004). As noted in the Hyogo Framework for Action 2005–2015 (UN 2005), disaster-prone developing countries, especially least developed countries and Small Island Developing States (SIDS), warrant particular attention in light of their higher vulnerability and risk levels which often greatly exceed their capacity to mitigate, prepare for, respond to and recover from disasters.

Increasingly, indigenous communities in SIDS are severely disadvantaged in their ability to deal with environmental hazards. In part, this can be attributed to a loss of indigenous knowledge, as many of these communities have adapted to and coped with environmental hazards for centuries, yet are only now becoming rapidly more vulnerable (Campbell 2006). However, it can also be attributable to the generally resource-poor nature of SIDS which affects their disaster risk reduction and response capacities, leaving indigenous communities to address their vulnerability in isolation.

That creates much of the inherent vulnerability of SIDS to environmental hazards, but other vulnerability aspects emerge from the interaction with external pressures such as climate change, including associated sea-level rise, and globalization (Pelling and Uitto 2001; UN 2003). As a direct result of their inherent vulnerabilities, the effects of environmental hazards are more pronounced and cause greater damage when affecting SIDS, with a resulting adverse effect upon the sustainable development of SIDS (Lewis 1999; Kaly et al. 2002).

One consequence is increased interest and the application of holistic approaches to disaster risk reduction, incorporating linkages between development and disasters (Lewis 1999; McEntire 2004). Despite these endeavours, environmental hazards continue to contribute to increased disruption within indigenous communities in SIDS (Lewis 1999; Pelling and Uitto 2001), suggesting that new policies and practical applications for better linking development and disasters are urgently required (Tran and Shaw 2007). It is therefore timely and appropriate to establish community-level approaches for disaster risk reduction in SIDS where communities are able to identify and implement appropriate and effective strategies to reduce their risk.

Recently, an important shift in disaster risk reduction has led to recognition of the potential of in-
Using both scientific and indigenous knowledge to their environment and having adapted to change, centuries, indigenous communities have responded to societal and environmental changes. For this, developing and adapting as communities respond to these changes, the failure to use or highlight the value of indigenous knowledge for disaster risk reduction has been a problem. As stated by Agrawal (1995), this neglect in using indigenous knowledge is not new. However, in many cases the interaction has exacerbated the vulnerability of indigenous communities to environmental hazards and inadequate consideration has been given to how both knowledge bases may be integrated effectively for disaster risk reduction (Dekens 2007a; Mercer et al. 2007). Identifying the specific strengths of each knowledge base, and integrating these strengths, would further empower indigenous communities to prepare for and mitigate environmental hazards.

This article examines how indigenous and scientific knowledge was integrated to establish disaster risk reduction strategies for three indigenous communities affected by environmental hazards in Morobe and Madang Provinces, Papua New Guinea (PNG), which is officially a Small Island Developing State. The choice of a SIDS for case studies, irrespective of the diversity of SIDS, is important because past work demonstrates not only the exacerbated challenges and vulnerabilities that these places face from environmental hazards, but also the creative, locally based solutions that are often developed and tested in SIDS – which then become useful for other locations (Dolman 1985; Lewis 1999; Pelling and Uitto 2001; Howorth 2005; Méheux et al. 2006; Kelman et al. 2006; Kelman, 2007; 2008; Mercer et al. 2007). This study uses a Process Framework developed by Mercer et al. (forthcoming). The Process Framework is a step-by-step approach enabling communities to identify their existing knowledge, both scientific and indigenous, in order to discover how this knowledge can be integrated in a culturally compatible and sustainable manner to reduce their vulnerability to environmental hazards. This article discusses the use, implementation and application of the Process Framework but does not evaluate the use of the integrated strategy developed as a result.

**Process Framework utilizing participatory techniques**

In an effort to engage both indigenous and scientific knowledge within disaster risk reduction, the Process Framework (Fig. 1) aims at building a sustainable relationship between the two knowledge bases to reduce indigenous communities' vulnerability to environmental hazards (for further information, see Mercer et al. forthcoming). While the concept of community is in itself highly contested and quite
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complex (Brint 2001; Marsh 2001; Cannon 2007), it provides the building blocks in many political jurisdic-tions for development (Buckle et al. 2003). Based on such discussions, community is defined here as ‘a group of people sharing common ideals, resources, environment, aspirations etc. whilst living in the same geographical location’ (Mercer et al. forthcoming).

Within international disaster risk reduction, there has been a noticeable movement away from top-down directives and towards bottom-up planning (e.g. Wisner et al. 2004; Louis 2007). In order to initiate bottom-up planning, participatory techniques have been increasingly used to initiate community engagement and involvement in decision-making (e.g. Comfort et al. 1999).

Building upon this strong theoretical foundation, especially in the context of disaster-related geography studies (see in particular O’Keefe et al. 1976; Hewitt 1983, 1997; Campbell 1984, 2006; White et al. 2001; Wisner et al. 2004), the Process Framework used here follows a participatory approach through guided discovery (Bruner 1961; Chambers 1994a, 1994b; Pain and Francis 2003), designed to be an interactive and collaborative experience (see Mercer et al. (2008) for more details on and background to the methodology). Communities were able to draw on past experiences and existing knowledge to discover facts, relationships and new ‘truths’ (Bruner 1961; Mercer et al. 2008) through techniques such as mapping, timelines, cartoons, matrix ranking and seasonal calendars (Kumar 2002). This enabled the identification of indigenous and scientific knowledge used by communities to deal with environmental hazards, with an ultimate aim of establishing how this knowledge could be integrated to further reduce vulnerability (Mercer et al. forthcoming). As discussed in Mercer et al. (forthcoming), the Process Framework involved a series of steps. These are briefly outlined below:

(1) Step One: engaging the community in discussions surrounding their vulnerability to environmental hazards and the benefits of indigenous and scientific knowledge.

(2) Step Two: identification of underlying vulnerability factors and the contribution of each factor to a community’s current vulnerability to environmental hazards.

(3) Step Three: identifying indigenous and scientific strategies used both past and present for disaster risk reduction.

Fig. 1. Process Framework integrating indigenous and scientific knowledge.
Source: adapted from Mercer et al. (forthcoming).
Fig. 2. Map of PNG showing village location. Source: adapted from UN (2004).
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(4) Step Four draws together the information from the previous three steps to develop an integrated strategy for disaster risk reduction. The expected impact upon vulnerability levels can then be considered in relation to previous exposure, thereby determining the likely impact of an integrated strategy.

Study area
This study was set within the context of PNG’s ‘National Disaster Risk Reduction and Disaster Management Framework for Action 2005–2015’ (NDC 2005) within which the need to incorporate indigenous knowledge into disaster risk reduction strategies was identified. The study was carried out within three rural communities in Morobe and Madang Provinces, PNG (Fig. 2) to determine the viability of such an approach and how, if at all, such an approach could be incorporated into disaster risk reduction strategies for indigenous communities.

Communities were accessed through consultation with the National Disaster Centre, non-governmental organizations (NGOs) and Provincial Disaster Offices. Selection criteria included hazard prevalence, good internal community organization, being representative of other hazard-prone communities in the province, use of indigenous strategies in dealing with environmental hazards and some degree of openness to outsiders. A local research assistant experienced in participatory techniques and an interpreter were used to facilitate work with the communities. Where possible, work was undertaken in PNG’s official languages of English and Tok Pisin. However, PNG is linguistically complex country with over 800 languages (Gordon 2005). This meant that in some circumstances villagers translated from their own language (called in PNG Tok Ples, ‘talk place’) to Tok Pisin or English. For Baliau village, Tok Ples was the main medium of communication.

Kumalu village is located in Bulolo District of Morobe Province and situated along the Snake River. The community is mainly based on subsistence living although it has connections with a nearby gold-mining site in Bulolo, the district centre. The village itself has approximately 565 people scattered throughout a number of small hamlets alongside the river bank and further up the mountains. The village amenities include a pre-school, a church and an aid post with the nearest primary school a one- to two-hour walk away. The community is badly affected by flooding and landslides.

Singas village is located along the banks of the Markham River in Markham District of Morobe Province. The village, like Kumalu, consists of a number of small hamlets scattered along the river bank, although it is situated in a flat valley with hills rising up behind the community. The population is approximately 296 people who are all regularly affected by flooding. The people are subsistence dwellers, occasionally selling vegetable goods to fund school fees. There are no amenities such as shops or markets within the village. Although the centre of Markham District is situated on the opposite bank of the Markham River to Singas, access involves a one- to two-hour walk to cross the river where passable.

Baliau village is located on the Northwestern Shore of Manam Island in Bogia District of Madang Province and is affected by the nearby Manam volcano. The whole island was evacuated to the mainland in 2004, with villagers residing in care centres in Bogia District. The population of Baliau is currently 297 people living on the island permanently with approximately a further 100 living in care centres on the mainland. Villagers are scattered in a linear pattern above the shoreline, surviving through gardening and cash-cropping of copra. Villagers are slowly returning to their island despite warnings from the government to the contrary. As a result of the 2004 eruption, all amenities on the island are closed. There were previously several pre-schools, a primary school, a church, a convent, an aid post and an ambulance.

Process Framework implementation: Kumalu, Singas and Baliau
The study was completed over a total period of nine weeks. Three weeks were spent within each of the three communities, during which time a representative sample of both men and women took part in activities. The whole community was invited to join the group exercises and, in many cases over the three-week period, the whole community participated whether in one or several groups. In general, each village was ethnically and culturally homogenous. However, there were those who had married into the village from outside clans and extended friends/family members who were staying for short periods who also partook in the research.

To prevent sample bias, all information given by outsiders was cross-referenced with that given by the main village group to ensure its legitimacy (see Mercer et al. (2008) for more methodological de-
Disagreements among the villagers were discussed and resolved within group exercises. Participating villagers ranged in age from primary school students to community elders.

As a result of recent hazard experience within each of the three villages, the disaster focus was one of experience rather than of possibilities. Concentration was placed upon the particular hazard and/or associated hazards such as landslides and flooding rather than what may or may not occur in the future. In each village, the same steps of the Process Framework were followed, the results of which are outlined below, demonstrating the use, implementation and application of the Process Framework. However, to further ensure the efficacy of the Process Framework, and to continue improving it, follow-up evaluation within the communities would be required. To establish a clear understanding of terms within the communities, indigenous and scientific as defined earlier were referred to as traditional and non-traditional respectively.

2006 – (1) Two houses washed away by flooding. (2) Major relocation of hamlet as a result of floods, relief aid provided by government.
2005 – Bus and passengers washed away by flood.
2004–2005 – Munnung Station (nearest town with government buildings, school and police station), downstream from village completely destroyed by floods.
2003 – Patrol officer from Munnung station visits Kumalu to report on floods – no feedback received.
2001 – Major relocation of hamlet as a result of landslide.
2000 – (3) Government official visits Kumalu to assess flooding. (1) Massive destruction experienced as a result of flooding.
1999/2000 – (1) Old and new Munnung Bridge destroyed by flooding. (2) Dam built to try and mitigate against flooding destroyed by floods.
1997 – Drought impacted slightly upon crops.
1996 – Road closure due to flooding. Villagers still have to walk to the main road, a journey of one to two hours.
1996 – Beginning of huge landslide with flood. Start of big disaster, first coffee gardens washed away.
1981 – Massive destruction caused by flood to village gardens and coffee plantations.
1962 – Two people killed by flood.
1953 – Landslide accompanied by flooding, two children died.
1952 – Landslide experienced at river source in mountains.
1951 – First major landslide experienced according to the villagers’ memory.

Fig. 3. Hazard timelines for Kumalu, Singas and Baliau. Source: developed by the villagers.
Step One: community engagement

To ensure the sustainability of any strategy identified as a result of using the Process Framework, it was important for the activities within the Process Framework to be community owned and managed. To achieve this, it was necessary for each community and the researcher to develop a good rapport and to work in partnership together to identify community goals and objectives. This was achieved through several working group sessions establishing general background information. These sessions included establishing a community history, mapping exercises to determine vulnerable aspects of the community and their perception of hazard(s), hazard(s) history, livelihood analysis determining the impact of the hazard(s) upon their livelihoods, buildings and construction, and seasonal and daily activities alongside an assessment of their assets and linkages to other institutions (for more details, see Mercer et al. forthcoming). Each working group session was attended by community representatives, young and old, and then presented to the community as a whole to triangulate information.

Baliau community had direct experience interacting with government and NGOs. In their case, there had been three evacuations of the island to care centres on the mainland as a result of volcanic eruptions. In an additional working group session, the changes in the environmental landscape of each

Hazard timeline and environmental trends. A hazard timeline was established by all three communities (Figs 3 and 4). While the focus was on the major hazard experienced, there were commonalities among all three hazard timelines with the identification of the El Niño phenomenon and reference to the subsequent drought in 1997 (Glantz 2001). Kumalu and Singas, while regularly impacted upon by environmental hazards, had received next to no interaction with either NGOs or the Provincial Disaster Office. Despite this, the communities held very different views concerning the role of the government in disaster risk reduction. Kumalu community felt that ‘the government should look after them’ and therefore they should not be doing anything, while Singas community recognized that help may not be forthcoming and so were much more proactive in reducing their risk. This difference is perhaps explained by the fact that, for Singas, the river was first and foremost their livelihood and, second, a hazard (Mercer and Kelman 2008), presenting Singas community with a reason to be proactive in reducing their risk. In contrast, for Kumalu, the river was first and foremost a hazard.

Fig. 3. Continued.
community over the years were discussed in light of the hazard timelines previously identified.

Kumalu community felt that the main changes in their surrounding landscape from 1940 through to the present day (decades and within living memory) had occurred as a result of changes in their agricultural practices. Community elders remembered ‘times of plenty’ when land was abundant and the river flowed gently along a narrow river bed. There were no recollections of flooding events during these times. The villagers felt that the present-day situation of heavy erosion and resulting destruction caused by floods and landslides resulted from loss of indigenous practices, the influence of the modern world and a hunger for money and material goods. The drive for a cash economy contributed to a change in agricultural practices from subsistence farming to cash-cropping and an associated lack of respect for the land, as it was no longer seen as of primary importance.

As a result, more bush was cleared for gardens which removed stabilizing vegetation, previously left under indigenous law to ensure protection for the land. Erosive activity therefore increased, contributing to land degradation and loss. Population increases have also led to the uncontrolled expansion of gardens where, previously, this was controlled under indigenous strategies designed to conserve vegetation identified as necessary for stabilizing land. Increased interaction with the outside community also led to higher expectations, especially in terms of material goods and the need for education. Therefore, cash-cropping was seen as essential.

In Singas, a similar situation was described with the argument that ‘before they had lots of land’ whereas today ‘the situation is different with less land’. The regular movements of Singas village, as shown on the hazard timeline in Fig. 3, are all within their land boundaries and are therefore fairly close to each other. Loss of land has been equated to the loss of indigenous practices, the influence of the modern world and a hunger for money and material goods. The drive for a cash economy contributed to a change in agricultural practices from subsistence farming to cash-cropping and an associated lack of respect for the land, as it was no longer seen as of primary importance.

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In Baliau, the situation was slightly different. While there were similar changes in the land experienced as a result of the introduction of cash-cropping, the changes here were greatly influenced by the 1957 volcanic eruption and evacuation, resulting in the subsequent interaction of the islanders with the mainland. This resulted in population levels increasing, in many cases through intermarriage
with mainlanders and subsequently returning to the island. Education levels, previously high on the island due to the presence of the Catholic Mission and their compulsory education system, were also impacted upon by the volcanic eruption along with changes to the schooling system in 1973 when a select quota system for high school was introduced. This left many Manam students no option but to stay at home having not been selected for school.

Step Two: identification of vulnerability factors

As outlined in Mercer *et al.* (forthcoming), the identification of vulnerability factors was essentially split into two parts. The two parts consisted of those factors extrinsic to a community; that is, anthropogenic and non-anthropogenic factors outside of community control, and the direct results of these within a community (i.e. intrinsic factors), which to some extent a community could address (see Table 1, taken from Mercer *et al.* 2007). The baseline data established in Step One was analysed to determine those extrinsic and intrinsic factors impacting upon vulnerability.

In PNG, extrinsic factors were identified as causes (those which communities felt they had no control over) and linked to intrinsic factors or effects (those which communities felt to some extent they could address) on a ‘cause–effect’ tree (see Fig. 5). Villagers felt that all the ‘causes’ and ‘effects’ identified on cause–effect trees contributed in some way to the specific hazard(s) they faced (see Fig. 5). This approach could be adjusted depending on the preferred community method of identifying extrinsic and intrinsic factors.

While some such effects could be considered causes, the diagrams represent community interpretation of cause and effect. The communities established intrinsic factors (effects) which were exacerbating their vulnerability to hazard(s) and which, if addressed, could significantly ameliorate the impact of environmental hazards. The communities often identified large numbers of intrinsic factors, so it was important to prioritize those that contribute most to vulnerability. To assist the community in identifying their priority intrinsic impacts, pair-wise ranking was used. This is a method of comparison between each of the intrinsic factors identified by the communities (Kumar 2002). For more details on the step-by-step method of pair-wise ranking see Mercer *et al.* (forthcoming).

The use of the pair-wise ranking technique enabled all intrinsic factors to be labelled in terms of their contribution to vulnerability (e.g. see Table 2). The grid provided the basis for further discussions, enabling the community to clarify and conceptualize their vulnerability in more detail, making changes as they saw fit. While this method provided a brief overview, it was necessary to establish more detail for determining the effectiveness of an integrated strategy at a later date.

The intrinsic factors having the largest impact on community vulnerability were identified through the grid scores and further discussions. For example, all three villages in PNG focused upon the top five factors and scored these on a scale of 1–10 regarding their contribution to vulnerability levels and the subsequent impact of an environmental hazard (see Table 3). A decision to concentrate upon the top five was made in consul-
### Table 2. Example of pair-wise ranking for Kumalu village, PNG.

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<tr>
<th>SIGNS</th>
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<td>Z</td>
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</table>

**TOTAL**: 4 16 6 4 16 4 18 22 12 6 14 10

**Key:**
- Limited knowledge: 1. Vulnerable housing
- Construction of houses in dangerous places: 2. Land loss
- Lack of diversification of income sources: 3. Land clearance
- Minimal outside support: 4. Construction of houses in dangerous places
- Land clearance (loss of bush/trees): 5. Garden accessibility
- No community planning: 6. Hunger
- Land loss (gardens and coffee due to hazards): 7. Market access
- Vulnerable housing: 8. Changes in farming practices
- Hunger: 9. Lack of diversification of income sources
- Changes in farming practices (coffee, vegetables etc): 10. No community planning
- Garden accessibility: 11. Lack of knowledge
- Market access: 12. Minimal outside support

**Note:** the symbol N/A (not applicable) is used throughout the centre of a grid to avoid two of the same factors being compared against each other.
tation with villagers, drawing conclusions that the top five factors were essential to address in reducing vulnerability with each of these having a potential effect upon reducing the impact of further factors. The scores identified are returned to at a later stage of the Process Framework to determine the effectiveness of an integrated strategy (Mercer et al. forthcoming).

Interestingly, despite the different environmental hazards faced amongst the communities, the top five factors identified were similar. All three communities identified vulnerable housing and lack of knowledge as major contributory factors to their vulnerability to environmental hazards, while two communities identified a loss in traditional practices as contributing to their current vulnerability levels. Kumalu identified not only vulnerable housing but also the construction of housing in vulnerable places as a result of the limited land area available to them. However, after much discussion, housing was found to be less vulnerable if not constructed in dangerous places (see Table 3).
Step Three: identification of indigenous and scientific strategies

Step Three involved communities identifying past and present, indigenous and scientific strategies used to cope with intrinsic effects and ultimately hazard(s). Communities divided themselves into working groups with each identifying a topic incorporating disaster risk reduction strategies such as land use planning or housing construction. Villagers ensured that community elders were included within each group to guarantee the inclusion of past strategies.

Disaster risk reduction strategies are often embedded within community life, becoming a normal part of the daily or seasonal routine, so this step involved intense discussion to ensure that all strategies were determined. Upon establishing strategies, information was triangulated with the whole community to ensure that no single strategy was excluded. It was noted that, while the community was able to identify those strategies already in existence within the community, further elaboration upon the framework and more time available would have allowed for the incorporation of additional stakeholders and ultimately further knowledge available from outside of the community.
Table 4 gives some examples of indigenous and scientific strategies identified by the communities for the common vulnerability factors identified as 'lack of knowledge' and 'vulnerable housing' (strategies were identified for all the priority vulnerability factors identified). As outlined in the introduction, the scientific strategies consisted of knowledge which originated outside of the community which the community were able to access. This enabled communities to move ahead with an integrated strategy using existing knowledge in a more effective manner to reduce their risk to hazards.

**Step Four: develop integrated strategy**

Further to identifying indigenous and scientific strategies, there was a need to determine their effectiveness in mitigating against intrinsic components. This activity should be directed by the communities. In PNG, the communities selected the use of four variables in assessing strategy viability. These were (1) sustainability, (i.e. whether the option could be maintained or could continue to be useful in a changing environment); (2) cost (i.e. does the proposed strategy make effective use of available resources?); (3) equitability (i.e. will the option be accessible to all community members or
will some members benefit more?); and (4) stability (i.e. will the option bring change in an incremental and systematic way that causes a minimum level of disruption in the ecology, social structure and livelihoods of the community?) (Mercer et al. forthcoming).

As outlined in Mercer et al. (forthcoming), communities scored each strategy out of 5 in the above-mentioned criteria with 5 meaning ‘strongly agree’ and 1 meaning ‘disagree’, plus there was a ‘no impact’ option. This enabled communities to identify the most beneficial strategies whether past or present, indigenous or scientific in dealing with each individual intrinsic component. The most effective strategies should then be integrated to mitigate against intrinsic factors and ultimately the hazard(s). In some cases conflict or incompatibility between some strategies may arise, in which case integration may not be feasible.

The approach addresses strategies that have fallen into disrepair but which may still be useful. Environmental trend analyses completed at the beginning of the framework, while painting a picture of social, environmental and economic changes within a community, also identified how these changes may have contributed to vulnerability, as shown below in the integrated strategy for each community. Once a decision has been reached for a strategy to mitigate against intrinsic components, the combination of this approach should contribute to reduced vulnerability to environmental hazards.

<table>
<thead>
<tr>
<th>No.</th>
<th>Kumalu priority list</th>
<th>Score /10</th>
<th>Singas priority list</th>
<th>Score /10</th>
<th>Baliau priority list</th>
<th>Score /10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vulnerable housing</td>
<td>6</td>
<td>Decreased education/ lack of knowledge</td>
<td>9</td>
<td>No community planning</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>Land loss</td>
<td>8</td>
<td>Sickness</td>
<td>6</td>
<td>Changes in traditional practices</td>
<td>6</td>
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<tr>
<td>3</td>
<td>Land clearance</td>
<td>10</td>
<td>House vulnerability</td>
<td>5</td>
<td>No disaster plan</td>
<td>6</td>
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<tr>
<td>4</td>
<td>Construction of house in dangerous places</td>
<td>10</td>
<td>Changes in traditional values/structure</td>
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<td>Lack of knowledge</td>
<td>8</td>
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<tr>
<td>5</td>
<td>Lack of knowledge</td>
<td>8</td>
<td>Hunger</td>
<td>8</td>
<td>Vulnerable housing</td>
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<td>6</td>
<td>Garden accessibility</td>
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<td>Erosion</td>
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<td>Loss of cash-crops</td>
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<td>8</td>
<td>Market access</td>
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<td>Increased land clearance</td>
<td></td>
<td>Loss of fertile soil</td>
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<td>9</td>
<td>Changes in farming practices</td>
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<td>House location</td>
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<td>Business breakdown</td>
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<td>No community planning</td>
<td></td>
<td>Competition</td>
<td></td>
<td>Construction of house in dangerous places</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td>Loss of wildlife</td>
<td></td>
<td>Changes in farming practices</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No community planning</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Changes in traditional practices</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Priority lists for communities resulting from pair-wise ranking and top five factors scored on a scale of 1–10 as to their contribution to vulnerability levels (1 = low contribution to vulnerability and 10 = high contribution to vulnerability).

<table>
<thead>
<tr>
<th>Vulnerability factor</th>
<th>Past and present indigenous strategies</th>
<th>Past and present scientific strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vulnerable housing</td>
<td>Semi permanent buildings</td>
<td>Wooden doors and locks</td>
</tr>
<tr>
<td></td>
<td>Level ground using traditional method</td>
<td>Use of stone walls and flowers to stabilise ground</td>
</tr>
<tr>
<td></td>
<td>Use of bush materials – easy access and movable</td>
<td>Use of nails</td>
</tr>
<tr>
<td></td>
<td>Houses on stilts</td>
<td>Glass and fly grates on windows</td>
</tr>
<tr>
<td></td>
<td>Building planning</td>
<td>Use of iron roofing</td>
</tr>
<tr>
<td></td>
<td>Houses constructed using rope – easy to move quickly</td>
<td>Use of factory timber for floors and walls</td>
</tr>
<tr>
<td></td>
<td>Fire places/kitchens on floor</td>
<td>Adaptation of house frames to use nails</td>
</tr>
<tr>
<td>Lack of knowledge</td>
<td>Cohesive community</td>
<td>Community planning</td>
</tr>
<tr>
<td></td>
<td>Sharing of resources and experiences</td>
<td>Interaction with NGOs/government</td>
</tr>
<tr>
<td></td>
<td>Knowledge passed down by ancestors</td>
<td>Awareness of importance of education</td>
</tr>
<tr>
<td></td>
<td>(forgotten/not listened to)</td>
<td>Use of outside knowledge sources</td>
</tr>
</tbody>
</table>

Table 4. Examples of past and present, indigenous and scientific strategies identified by the three communities for two common vulnerability factors.
Integrated strategy for Kumalu. Figure 6 shows the integrated strategy determined by Kumalu community for each of the five key intrinsic components identified. For example, in analysing Kumalu’s effectiveness rankings for strategies addressing the intrinsic factor of ‘land clearance’, the selected strategy includes previous indigenous approaches along with some scientific approaches. In referring back to their environmental trend analysis, they believe that land mismanagement and a loss of indigenous practices have led to increased vulnerability. From this, they established their ability to revert back to previous indigenous strategies and integrate these with scientific knowledge to improve their ability to mitigate against intrinsic factors and subsequently the hazard(s). A clear pattern also emerged in mitigating against land loss and vulnerable housing, with a noticeable link back to the environmental trend analysis.
To address housing construction in dangerous places, the community decided to use a variety of strategies to reduce their vulnerability overall. These included building some houses on the ground such as kitchens or fireplaces as these were easily replaceable and therefore the risk of building them on the ground was acceptable, whereas the main living structures were of more importance and were built on stilts and were of sturdier construction. This often meant that one family would have two structures – one for living and one for cooking. They felt it was important to ensure that houses were built either high up in the mountains or lower down the mountainside, in both cases away from unstable ground and in more stable areas. Houses should also be close to water sources rather than on the sloping hillsides, which has been the recent practice in order to avoid lengthy hikes to gardens.

Lack of knowledge could be addressed both through a return to a sharing of knowledge and experiences, and through inclusion of non-indigenous practices which had been introduced to them and could serve to assist in the transfer of knowledge. Such methods included use of mothers’ groups and youth groups along with the revival of traditional community activities such as sing-sings which are events with traditional community dance and interaction. Overall, the community identified that addressing each of the intrinsic components through an integration of indigenous and scientific knowledge, or a return to indigenous practices still considered viable but not utilized, could significantly reduce their vulnerability to landslides and flooding (see Table 5).

**Integrated strategy for Singas.** Figure 7 shows the integrated strategy determined by Singas for each of the five key intrinsic components they identified as contributing to their vulnerability to environmental hazards. As with Kumalu, there are links...
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Singas community considered a loss in traditional values and structures as an important factor in their increased vulnerability to environmental hazards. To address this, the community considered it important to incorporate village activities used in the past as well as those introduced to the community. Church gatherings, for example, enabled knowledge to be transferred from the older to the younger generation to maintain traditional practices and respect for the land which sustains them. While recognizing the impact and importance of scientific input and non-traditional strategies, such as money, it was felt that these could be integrated with indigenous practices in order to reduce the impact of changes in traditional values upon their vulnerability to environmental hazards.

Addressing the factors of hunger, vulnerable housing, sickness and lack of knowledge, the community identified priority intrinsic components and developed an integrated strategy as shown in Fig. 7.

![Fig. 7. An integrated strategy addressing priority intrinsic components identified by Singas community.](image-url)
Community were able to identify a way forward through integrating the most effective strategies incorporating past and present, indigenous and scientific knowledge. The approach also enabled the community to realize how much resources were actually available to them immediately in reducing their vulnerability to flooding.

Integrated strategy for Baliau. Figure 8 shows the integrated strategy determined by Baliau for each of the five key intrinsic components they identified as contributing to their vulnerability to environmental hazards. As mentioned previously, Baliau was in a slightly different position from the other two communities, since they had already experienced interaction with NGOs and governmental bodies. This enabled the community to have access to scientific strategies which they may not otherwise have had, such as evacuation route maps, hazard maps and an early warning system provided by the volcano observatory in Rabaul.

Yet despite the early warning system, the villagers reported that for the 2004 eruption, they identified that the volcano was going to erupt prior to the warning issued by the volcano observatory. This was determined through using indigenous warning signs which included an appearance of blue smoke and smoke rings, the death of grass around the top of the volcano and a continuous low tide coupled with what had been a very hot dry season. While these are factors which could be considered coincidental to a volcanic eruption, past community history states otherwise. Hence, in discussing the integration of knowledge bases to address the intrinsic component of ‘no community planning’ and ‘no disaster plan’, it was felt it was important to integrate the indigenous warning system and the scientific warning system to ensure that the community was forewarned of a potential eruption.

In mitigating against vulnerable housing, it was deemed important to return to their traditional type of house rather than to the iron roofing which they have recently started using. While the iron...
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 roofing is seen as a status symbol of wealth within the community, the traditional roofing is considered far more practical and efficient in coping with light tephra fall and strong winds. However, it was felt that elements of scientific strategies, such as guttering to collect rainwater, considering the shortage of fresh water on Manam Island, could greatly enhance indigenous strategies. Similarly, it was felt that the lack of knowledge could be addressed through an integration of both knowledge bases, using information available to them from outside the community as well as building up their indigenous knowledge through a sharing of resources and knowledge, a practice that had occurred in the past and which could be reintroduced.

Step Five: reduce vulnerability to environmental hazards

The extent of this study was to determine how, if at all, a Process Framework would enable indigenous and scientific knowledge to be integrated to reduce vulnerability to environmental hazards. For Step Five, following up the work reported here would be essential to determine the success of such a strategy when implemented by a community.

In Step Two of the Framework, each community estimated their vulnerability levels for each of the top five intrinsic factors identified as contributing most to vulnerability. Following the use of the Process Framework, communities determined that their vulnerability to environmental hazards would be reduced as a result (Table 5). The communities felt that the approach enabled them to identify disaster risk reduction strategies using existing resources. In addition, it enabled them to link the environmental trend analysis and the subsequent identification of vulnerability factors so that they could see changes to vulnerability. In summary, they felt that they were able to identify how much potential they had in reducing the impact of the hazard(s) upon themselves with the resources currently available to them.

Nevertheless, an essential part of this approach is continuous revision and monitoring, since communities are frequently beset by new challenges and social and environmental changes (e.g. Lewis 1999; Nunn et al. 2007). Despite the suggested benefits of the framework in these circumstances, its effectiveness could be further evaluated and, perhaps, enhanced. This could be achieved through collaboration among relevant stakeholders such as NGOs, government bodies and indigenous communities, who could provide access to relevant and up-to-date scientific and indigenous knowledge. Facilitating information exchange between relevant stakeholders could assist in learning and applying lessons while identifying the applicability of the approach elsewhere.

Discussion: promotion of an integrated strategy for disaster risk reduction

This research applied a Process Framework developed by Mercer et al. (forthcoming) to establish how indigenous and scientific knowledge bases could be integrated for disaster risk reduction in three indigenous communities in PNG, a SIDS. The Process Framework assisted communities in identifying past and present disaster risk reduction strategies and how, in some cases, a loss of indigenous knowledge has contributed to increased vulnerability to environmental hazards.

This approach did not generate new knowledge, but rather a way of identifying how existing knowledge could be integrated and applied for reducing vulnerability to intrinsic factors and subsequently to environmental hazards. This is especially important within a SIDS, such as PNG with limited disaster risk reduction and response capacity particularly with regard to inadequate external assistance for both pre-disaster vulnerability and post-disaster response. As a result of the inherent vulnerabilities of SIDS and the reduced effectiveness of provincial and national assistance, it is essential to build upon community-level approaches to disaster risk reduction in SIDS.

Despite numerous disaster risk reduction measures in the literature, these are sometimes far removed from realities faced by indigenous communities in SIDS, as discussed earlier, that lead to SIDS communities often being unable to access timely and adequate disaster risk reduction and response capacity. In light of this and the increased impact of environmental hazards upon SIDS due to their inherent vulnerabilities, it is necessary to build upon existing indigenous knowledge within communities. This then needs to be integrated with accessible scientific knowledge to further reduce indigenous community vulnerability in SIDS to environmental hazards. In the past, disaster risk reduction strategies have often been top-down and led by outsiders, leading to rejection by indigenous populations as a result of lack of communication,
conflicting ideas with their own ideologies, or poor facilitation with scientific applications (Campbell 1984, 1990; Dekens 2007a).

Instead, the approach presented here builds on the increased realization within international disaster risk reduction that a wealth of knowledge exists within communities. The approach reinforces the view that communities have the power to deal with environmental hazards (Wisner et al. 2004; Haque and Etkin 2007). Moving away from the frequent view of disasters as products of geophysical and biophysical processes, this approach

Fig. 8. An integrated strategy addressing priority intrinsic components identified by Baliau community.

The impacts of environmental hazards are more pronounced in SIDS as a direct result of their inherent vulnerabilities. A holistic approach to vulnerability is needed, rather than tackling only the hazard(s) (Wisner et al. 2004). The underlying vulnerabilities need to be addressed in order to reduce the impacts of environmental hazards and to contribute to long-term sustainable development within SIDS (e.g., Lewis 1999; Pelling and Uitto 2001; Wisner et al. 2004). Enabling a community to identify with their situation and to compile indigenous and scientific disaster risk reduction strategies creates a culture of reflection upon which communities are able to identify links that might otherwise be overlooked.

For example, Kumalu community identified a link between clearing their land on slopes for agriculture and the increased incidence of landslides. This was a connection they had not previously established, due in part to an overly technocratic approach to disaster risk reduction which addressed the hazard rather than the underlying vulnerabilities. The practice of engaging people in identifying solutions to their own problems provided an opportunity for community empowerment (Fraser et al. 2006) that conventional disaster risk reduction approaches often do not provide.

During the past decade, a shift has occurred away from the technocratic approach to disasters towards a more human and societal basis (White et al. 2001; Wisner et al. 2004). Increasingly, it is recognized that for any disaster risk reduction strategy to be sustainable, it needs to be owned and developed by those most at risk who are best placed to identify solutions (Wisner et al. 2004). It
ess Framework integrating both knowledge bases communication (Bala and Joseph 2007). A Proc-

turing and adapting through exchange and mental impacts (Campbell 2006). Knowledge sys-

tems are dynamic entities that are continually modernization have in many cases had detri-

mental impacts (Campbell 2006). Knowledge sys-

tems are dynamic entities that are continually changing and adapting through exchange and communication (Bala and Joseph 2007). A Proc-

ess Framework integrating both knowledge bases could potentially enable indigenous communities in SIDS to move forward with more effective disaster risk reduction strategies addressing vulnerabilities rather than focusing on the hazard(s) per se. It also helps identify those practices that were beneficial in the past and, if adapted to contemporary contexts, could reduce community vulnerability to environmental hazards in SIDS.

Focusing on vulnerability rather than specific hazards ensures that disaster risk reduction is not isolated from other relevant processes, namely those associated with sustainable development (Lewis 1999; Jigyasu 2002; Wisner et al. 2004). It highlights the value of indigenous knowledge and the use of existing resources, as opposed to introducing new technology or techniques which may not be applicable to or effective for the community concerned.

It is necessary to clearly frame vulnerability within the existing context of indigenous communities in SIDS rather than focusing solely on the hazard through technocratic approaches. To contribute to sustainable development and to reduce the inherent vulnerability of indigenous communities in SIDS to environmental hazards, the richness of both knowledge bases needs to be incorporated into any disaster risk reduction strategy. Focusing solely on scientific strategies or more technocratic approaches is to the detriment of indigenous communities in SIDS and neglects the consideration of wider environmental, social and political changes.

The Process Framework should be considered as an ongoing and evolving process in which there is continual adjustment and integration of both indigenous and scientific knowledge to the benefit of indigenous communities, to a large degree on their

<table>
<thead>
<tr>
<th>Kumalu priority list</th>
<th>Before application /10</th>
<th>After potential application /10</th>
<th>Singas priority list</th>
<th>Before application /10</th>
<th>After potential application /10</th>
<th>Balau priority list</th>
<th>Before application /10</th>
<th>After potential application /10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vulnerable housing</td>
<td>6</td>
<td>4</td>
<td>Decreased education/ lack of knowledge</td>
<td>9</td>
<td>7</td>
<td>No community planning</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Land loss</td>
<td>8</td>
<td>5</td>
<td>Sickness</td>
<td>6</td>
<td>5</td>
<td>Changes in traditional practices</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Land clearance</td>
<td>10</td>
<td>7</td>
<td>House vulnerability</td>
<td>5</td>
<td>3</td>
<td>No disaster plan</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Construction of house in dangerous places</td>
<td>10</td>
<td>7</td>
<td>Changes in traditional values/structure</td>
<td>10</td>
<td>5</td>
<td>Lack of knowledge</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Lack of knowledge</td>
<td>8</td>
<td>4</td>
<td>Hunger</td>
<td>8</td>
<td>5</td>
<td>Vulnerable housing</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

is necessary to consider the value of both indigenous and scientific knowledge, rather than solely scientific knowledge as has frequently occurred beforehand.

In line with current thinking, the approach presented here recognizes the value of both scientific and indigenous knowledge in reducing the increased risk of environmental hazards upon indigenous communities in SIDS. It also recognizes the resource limitations and limited access to knowledge experienced by many indigenous communities in SIDS. Hence, this approach seeks to integrate the existing knowledge available and address underlying vulnerabilities. This in turn contributes to reducing the impact of environmental hazards upon indigenous communities. A holistic approach to vulnerability reduction is needed in order to create a sustainable solution, open to constant adjustment, feedback and revision, and able to incorporate future developments from indigenous and scientific knowledge.

As the strategies were suggested and integrated by the communities, they are context-specific. The strategies apply to the locally identified vulnerability factors and the community situation for which they were developed. This approach enabled communities to identify with their situation and to establish linkages between their practices and vulnerability (Tran and Shaw 2007).

This approach is necessary in SIDS where the loss of indigenous practices and the encroachment of modernization have in many cases had detrimental impacts (Campbell 2006). Knowledge systems are dynamic entities that are continually changing and adapting through exchange and communication (Bala and Joseph 2007). A Process Framework integrating both knowledge bases could potentially enable indigenous communities in SIDS to move forward with more effective disaster risk reduction strategies addressing vulnerabilities rather than focusing on the hazard(s) per se. It also helps identify those practices that were beneficial in the past and, if adapted to contemporary contexts, could reduce community vulnerability to environmental hazards in SIDS.
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own terms. The steps within the Process Framework enable a clear and thoughtful analysis in which communities in SIDS are able to visualize their situation and identify appropriate strategies with both knowledge bases. Rather than focusing on what is not available, and therefore what a community must acquire, the Process Framework consolidates knowledge available within a community. It identifies how it may be better utilized and how the two knowledge bases may be integrated to reduce vulnerability to environmental hazards in SIDS.

Given the rapid and often externally forced environmental, political and social changes faced by indigenous communities in SIDS, many indigenous disaster risk reduction strategies are often criticized as being no longer relevant. Despite these changes, indigenous knowledge is constantly adapting and has successfully assisted indigenous populations in dealing with environmental hazards over millennia (Campbell 1984, 2006).

The Process Framework reported in this article has the potential for delivering disaster risk reduction strategies which successfully reduce vulnerability to environmental hazards. In addition, no individual or community could have developed it in isolation, due to its being an integration of two knowledge bases. While a divide frequently exists in sharing knowledge between scientists and indigenous communities, this Process Framework presents an approach whereby dialogue may be initiated in determining how the two knowledge bases may assist the other. It demonstrates a defined need to consider both indigenous and scientific knowledge for disaster risk reduction in SIDS, rather than solely the latter.

While this research has identified how the Process Framework may be used, implemented and applied for indigenous communities in SIDS, it is subsequently necessary to evaluate the approach and undertake follow-up with the communities to identify the efficacy of the integrated strategy developed as a result. The positive benefits of such a strategy are recognized and accepted by the indigenous populations used as case studies here. Yet a culture of hand-outs and expectation of assistance within such populations, rather than wanting to assist themselves, could hinder the use of the Process Framework (Campbell 1990; Tuiloma-Palesoo 2004).

The tendency has previously been to concentrate upon scientific solutions addressing the hazard directly rather than considering the wider issue of vulnerability. This, alongside the propensity of more affluent countries to provide relief aid in times of disaster has supported a complacency attitude (Campbell 1990, 2006). It is vital to rebuild local capacity within indigenous communities in SIDS for disaster risk reduction. The Process Framework needs to be situated within the local institutional, social and political contexts, thereby encouraging communities to address their vulnerabilities first and foremost by themselves (see also Petal et al. 2008). The Process Framework should be considered as a step forward in building the capacity of indigenous communities in SIDS for disaster risk reduction.

Conclusion

While many communities globally are impacted upon by environmental hazards, the effects upon indigenous communities in SIDS are far more pronounced. This is due to the inherent vulnerabilities of SIDS, loss of indigenous knowledge and the inability of SIDS authorities to provide adequate disaster risk reduction capabilities (Pelling and Uitto 2001; Campbell 2006). This article describes a guided discovery learning activity by which indigenous communities in SIDS can use a Process Framework for integrating indigenous and scientific knowledge to reduce their vulnerability to environmental hazards.

Too often in the past, top-down disaster risk reduction strategies have failed due to their inability to fit the context within which they are placed. The Process Framework enables indigenous communities in SIDS to develop context-specific disaster risk reduction strategies using existing knowledge available to the community. The research findings here emphasize the value of both indigenous and scientific knowledge bases for disaster risk reduction, indicating that the sole use of indigenous or scientific strategies is unlikely to be as effective as the two combined.

Rather than one knowledge base overpowering the other (Shaw et al. 2006), the Process Framework utilizes and gives credit to both indigenous and scientific knowledge. Each knowledge base is assessed upon its own merits in determining its efficacy in reducing vulnerability. Rather than neglecting indigenous knowledge as has previously been the case (Dekens 2007a), the Process Framework learns that lesson and applies it, empowering communities to identify the most applicable and effective indigenous knowledge and integrate...
this with the most applicable and effective scientific knowledge to reduce vulnerability. It responds to the need identified by Tran and Shaw (2007) to develop new practical approaches to disaster risk reduction at a local level.

Increasingly, indigenous strategies have fallen into disrepair or are no longer considered viable whereas scientific strategies may be more applicable to some level, given that indigenous communities in SIDS are faced with a rapid rate of change as a result of global pressures (Pelling and Uitto 2001). However, as shown by the analysis and the links that communities made within their environmental trend analyses, indigenous strategies used in the past can have relevance today.

In particular, those indigenous strategies, when also used with scientific knowledge, support the need for tackling root causes of vulnerability, as shown by the case studies. As noted, despite differences in hazards faced by the communities, vulnerabilities identified and methods of reducing vulnerabilities showed significant similarities, placing these case studies within theoretical foundations of disaster risk reduction studies (O’Keefe et al. 1976; Hewitt 1983, 1997; Lewis 1999; Wisner et al. 2004). Such outcomes, though, are only the first step in determining the efficacy of the Process Framework.

While this article has outlined the application and use of the Process Framework, it is now necessary to undertake further follow-up work for evaluating the outcomes of the pre-identified strategy. This is in order to further validate the use of the Process Framework among indigenous communities in SIDS. In addition, for such an approach to be sustainable, an open dialogue needs to be initiated among relevant stakeholders including indigenous communities. As White et al. (2001) note, conflicting interests within and between different groups has often led to the failure to use or recognize indigenous knowledge. The Process Framework assists in overcoming this challenge by providing an opportunity to generate dialogue and respect within and between communities and others. Without such a dialogue and the institutional support, the successful application of an integrated strategy could be compromised.

Strengthening the disaster risk reduction capabilities of indigenous communities through an integration of the two knowledge bases using participatory approaches should be seen as critical for sustainable disaster risk reduction. Through the use of guided discovery within such a Process Framework, a dialogue based on respect between indigenous communities and others can be built. Furthermore, the communities develop a more empowered attitude through the identification of their own capabilities, rather than creating an expectation of external assistance (see also Lewis 1999; Wisner et al. 2004). This builds upon and adds further evidence to support the increasing recognition that, in order to reduce disaster risk and to address vulnerability among indigenous communities in SIDS, new, sustainable relationships developed from the strengths of both knowledge bases are vital (Agrawal 1995; Larsen 2006; Mercer et al. 2008).

As outlined in the introduction, the interaction between scientific and indigenous knowledge is not new (Dekens 2007a). However, in many cases this interaction has contributed to an increased vulnerability of indigenous communities in SIDS, with inadequate consideration given to the effective integration of both knowledge bases (Mercer et al. 2007). Recognizing this, the Process Framework provides a method in which communities are empowered to assess the specific strengths and capabilities of each knowledge base for potentially addressing their community vulnerability, thereby moving forward from past work and beginning to resolve the previously identified challenges.

The application here of the Process Framework developed by Mercer et al. (forthcoming) within three communities in PNG has demonstrated an innovative approach to disaster risk reduction for indigenous communities in SIDS. The roots of the approach lie at the community level, but value is given to both indigenous and scientific knowledge and how the two knowledge bases may be integrated to reduce environmental hazard vulnerability. With further development and validation, the Process Framework could provide a tool for indigenous communities in SIDS and further afield to identify how the two knowledge bases may be integrated to develop stronger capacity for reducing vulnerability to environmental hazards.

Acknowledgements

Many thanks to three anonymous reviewers and the editors for their comments and helpful discussion on earlier drafts, and to Macquarie University for an International Macquarie University Research Scholarship under which this work has been completed.
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