An Index to Determine Vulnerability of Communities in a Coastal Zone: A Case Study of Baler, Aurora, Philippines

Pedcris M. Orencio, Masahiko Fujii

Received: 18 January 2012/Revised: 28 March 2012/Accepted: 14 June 2012/Published online: 14 July 2012

Abstract A coastal community vulnerability index (CCVI) was constructed to evaluate the vulnerability of coastal communities (Buhangin, Pingit, Reserva, Sabang, and Zabali) in the municipality of Baler, Aurora, Philippines. This index was composed of weighted averages of seven vulnerability factors namely geographical, economic and livelihood, food security, environmental, policy and institutional, demographic, and capital good. Factor values were computed based on scores that described range of conditions that influence communities' susceptibility to hazard effects. Among the factors evaluated, economic and livelihood, policy and institutional and food security contributed to CCVI across communities. Only small variations on CCVI values (i.e., 0.47–0.53) were observed as factor values cancelled out one another during combination process. Overall, Sabang received the highest CCVI, which was contributed mainly by geographical and demographic factors. This technique to determine factors that influenced communities' vulnerability can provide information for local governments in enhancing policies on risk mitigation and adaptation.

Keywords Vulnerability indicators · Coastal communities · Philippines · Social survey · Geographic information system (GIS)

INTRODUCTION

Many of the causal systems and interrelationships that are relevant in the coastal areas can be described as complex (Nicholls et al. 2007). This complexity stems from the fact

that these areas are in the forefront of change and development (Selman 2000), and are influenced by various factors in global environmental (Boesch et al. 2000; McCarthy et al. 2001) and social systems (Creel 2003). Meteorological events such as hurricanes and tropical cyclones that result in damages from flooding, and shore-line erosion (Sharples 2006), or social events like economic development, population growth and human-induced vulnerabilities have increased the risks that threaten the well-being of coastal communities (USIOTWSP 2007).

In the environmental system, the interaction of these factors result in a vulnerable condition (Cutter et al. 2003; Brooks et al. 2005) that adversely affects the quality of ecosystem services (Grant et al. 2008). In the coastal areas, these include food, livelihood and good health (Marshall et al. 2010), which when made insufficient results to dramatic social changes (Adger et al. 2005), such as communities with high dependence become vulnerable (Grant et al. 2008). These conditions and processes that increase the susceptibility of a community to the impact of hazards that result from physical, social, economical, and environmental factors is regarded as vulnerability within the social systems (UNISDR 2004).

However, despite consequences of any perturbation, communities generally have inherent characteristics, and this uniqueness had permitted them to either counter or intensify any hazard effects. Most characteristics are moderated or enhanced by filters such as experiences and response capacities (Cutter et al. 2003), and the locus is an individual person. When individual characteristics are aggregated, this could provide a distinct vulnerability character for a community (UNEP 2002). A community with people having more capability to cope with extreme events is considered less vulnerable (Buckle et al. 2001). Vulnerability, in this case, can be more described as a

Electronic supplementary material The online version of this article (doi:10.1007/s13280-012-0331-0) contains supplementary material, which is available to authorized users.

potential condition that is expected depending on the character of an element at risk (individual) with respect to a natural or social hazard (Varnes 1984; Hufschmidt 2011).

To determine this assumption, different social and environmental conditions influencing communities were examined with a composite index for coastal community vulnerability. This index aspired to measure communities' inherent vulnerable characteristics by putting values that quantify individual experiences and trade-offs on different attributes of potential disaster scenarios and societal processes that enhance their susceptibility to hazards. The analysis aims to provide information, which may help local governments to better understand communities' vulnerabilities in order to establish their resilience.

ASSESSING VULNERABILITY

Previous studies discussed that to determine vulnerability in a system is oftentimes difficult and intricate (Cutter et al. 2003; Eakin and Luers 2006) and no single approach is yet established (UNEP 2002). Approaches vary according to natures of risk and hazards (Mitchell et al. 1989; Cutter 1996) and systems (Eakin and Luers 2006; Fussel and Klein 2006) being analyzed. These are oftentimes bogged by lack of information about stressors in an appropriate scale (O'Brien et al. 2004; Brooks et al. 2005) which result in a tendency of biased evaluation (Birkmann 2006), or issues of inconsistent variables that influence proper conceptualization (Fekete et al. 2009).

One approach for assessing vulnerability is through the indicator method, which is based on the systematic combination of indicators to assess the levels of vulnerability (Fussel 2009). Index levels may be global (Brooks et al. 2005) or national (O'Brien et al. 2004) in scale, and their simplification may vary to the kind of spatial analysis they provide (McLaughlin and Cooper 2010). However, indices are limited in their application due to considerable subjectivity in selecting variables and their relative weights, availability of data at various scales and difficulty of testing or validating different metrics (Luers et al. 2003; Fussel 2009).

These concerns, as well as nuances on application of vulnerability in the realm of human–environmental systems (Kumpulainen 2006; Cutter and Finch 2008) were considered in constructing the index for coastal community vulnerability in this study. This index was designed to manage incommensurability associated with different types of data and applicability of approaches (Sullivan and Meigh 2005; Cutter and Finch 2008) and followed a starting point appraisal perspective (Kelly and Adger 2000; O'Brien et al. 2004; Eakin and Luers 2006).

In the starting point appraisal, different environmental, socio-economic and political processes and their potential levels in the communities were considered to determine the

state of the human dimension—one that is made vulnerable by multiple factors and mechanisms generated in social systems, with some occurring within the system (Turner et al. 2003). Based on an underlying theoretical vulnerability framework, a composite metric of these processes was developed to provide a single measurement of compounded events (Hiete and Merz 2009), and these measurement were used to categorize and rank overall community vulnerability (UNEP 2002).

THE COASTAL COMMUNITY VULNERABILITY INDEX (CCVI)

Coastal communities' vulnerability was assessed based on a composite index, termed in this study as CCVI. This index was derived from combination of seven major factors namely geographical, environmental, economic and livelihood, food security, demographic, policy and institutional, and capital good (Fig. 1). These factors were modified from an indicative framework of factors affecting vulnerability of communities (Buckle et al. 2001) and were described by a set of different indicators and variables (see Table 1 in Electronic Supplementary Material).

Indicators and variables that described the seven major factors were sourced from related researches encompassing disaster and epidemic, human security, environmental change (UNEP 2002), and sustainable livelihoods (DFID 2000). Variables like technology, infrastructure, institutions, and political systems (Kelly and Adger 2000; McCarthy et al. 2001), as well as, age, income, gender, employment, residence type, household type, health insurance, house insurance, car ownership, disability, and debt and savings (Dwyer et al. 2004) were also considered. As a major resource, fisheries was considered as indicator for environmental, food security, and economic and livelihood factors. In environmental factor, communities' perception on importance and capacity for access of this resource was assessed, while communities' dependence for food and livelihood were assessed in food security and economic and livelihood factors, respectively.

All community characteristics were evaluated in relation with their experience on natural disasters such as flood events, or social incidents, like theft, wherein people that are access deprived, elderly or in poor health are more vulnerable (Birkmann 2006). In describing experiences on hazards, basic information such as location, time, intensity and frequency are given importance (Gravley 2001). A mix of natural and anthropogenic incidents described as socio-natural events (Garatwa and Bolin 2002) were used to define these hazards, as classified from geophysical to human induced with respect to a hazard spectrum (Smith 2000). Human-induced hazards that include pollution and illegal environmental practices were considered as variable components of human environmental destruction, an indicator for social hazards.

Fig. 1 Indicative framework of major factors, and their respective sub-factor indicators that comprised the composite index used for analysis of coastal community vulnerability

The methods undertaken to construct the composite index, which included quantification of these factors and their respective indicators are discussed in the following sections. Indicators were scored based on responses of individuals in a social survey that was conducted in a coastal municipality in the Philippines, where use of the index was piloted. The results were then analyzed and used to craft recommendations that may address sources of vulnerability of a coastal community that was ranked most vulnerable.

MATERIALS AND METHODS

Index Construction

To establish the index, each indicator and variable was quantified using values from scores generated in a social survey. The survey was conducted face-to-face and in

random with household heads, and with use of a questionnaire that was scaled and designed at the level of a barangay (a term for village and is the smallest administrative division in Philippines). The determination of this scale was based on considerations gathered from pre-survey assessment activities. This technique to use surveyed information in generating values for indicators made CCVI somewhat different from how other composite indices were constructed.

The pilot study area was Baler, a coastal municipality in province of Aurora, Philippines. The municipality is situated in northern mid-eastern part of Luzon Island, and has a total land area of 9255 ha divided into 13 barangays, of which five constitutes the coastal barangays of Buhangin, Pingit, Reserva, Sabang, and Zabali (Fig. 2). A grave threat of potential natural hazards that affected the coastal areas underscored the relative importance in selecting this as study site, and was reinforced by evidences of equally interesting social factors that influenced communities' vulnerabilities.

These conditions are demonstrated by competition on access to important terrestrial and marine priorities (Provincial Land Use Committee 2004), and low community regard on resource management and poor disaster response (Mohanty 2005). These are expected to complicate, as actual proofs of geographic and climatic conditions have increased the occurrence of natural hazards (Technical Working Group 2005).

Index Computations

The process adopted to compute the composite index followed a balanced weighted average approach (Sullivan 2002; Hahn et al. 2009), where major factor values equally contributed to the CCVI value. In this approach, major factors were maintained evenhanded despite difference in quantity of sub-factor indicators for each major factor. The values of sub-factor indicator that determined the major factor values were quantified from the aggregation of their respective variable component values.

A total of 82 variable component values were computed from scored responses of individuals in each community. Responses were treated as individual scores taken from a set of scales ranging from minimum to maximum (see Table 2 in Electronic Supplementary Material), which were described by level of difficulties that communities have experienced to contribute to their susceptibility to hazard effects. All individual scores from the same community were used for computing the variable component values for that community. Prior to this, scores were checked with their respective mean values, and were all found significant at $p < 0.05$ using the three standard deviation rule, and only a standard error of 0.2.

The computation for each variable component values $\text{Index}_{V_{\text{com}}}$ followed a process of standardization adopted from computation of life expectancy index of human development index (Hahn et al. 2009). This computation is shown in Eq. (1):

$$\text{Index}_{V_{\text{com}}} = \frac{V_{\text{ave}} - V_{\text{min}}}{V_{\text{max}} - V_{\text{min}}}, \quad (1)$$

Fig. 2 Map of the north-eastern Philippines showing Baler, Aurora with inset map showing the five coastal communities

where V_{ave} is the computed mean average of all scores collected corresponding to a variable component V_{com} , while V_{max} and V_{min} are maximum and minimum scores of respondents, respectively, based on the scales set for each V_{com} .

For example, to get $Index_{V_{com}}$ of a frequency of a social hazard, all scores of respondents in a community refer to the set of scales: 1 = Never; 2 = Seldom; 3 = Occasional; 4 = Often; 5 = Very often (see Table 2 in Electronic Supplementary Material). The mean value of all scored responses gathered, which ranges from 1 to 5 will be the V_{ave} . Meanwhile, all resulting $Index_{V_{com}}$ were, respectively, combined to determine the values of 23 sub-factor variables, 21 sub-factor indicators, and 7 major factors, with adopted and modified equations from previous studies (e.g., Hahn et al. 2009).

The computation for sub-factor variable values S_{fv} followed Eq. (2):

$$S_{fv}i = \frac{\sum_{i=1}^n Index_{V_{com}}}{n_{V_{com}}}, \quad (2)$$

where S_{fv} is determined based on the average of all variable component values $Index_{V_{com}}$ of a S_{fv} , divided by the total number of variable components $n_{V_{com}}$ that contribute to S_{fv} . All computed sub-factor variable values S_{fv} were then computed to obtain the sub-factor indicator values S_f with Eq. (3):

$$S_fi = \frac{\sum_{i=1}^n S_{fv}i}{n_{S_{fv}}}, \quad (3)$$

where S_f is determined based on the average of all sub-factor variables S_{fv} of a S_f , divided by the total number of sub-factor variables $n_{S_{fv}}$ that contribute to that S_f .

Every major factor value F_b for each barangay b, on the other hand, was obtained with Eq. (4):

$$F_b i = \frac{\sum_{i=1}^n S_f i}{n_{S_f}}, \quad (4)$$

where F_b is determined based on the average of all sub-factor indicator values S_f of a F_b divided by the number of sub-factor indicators n_{S_f} that contribute to that F_b .

The seven F_b that were assessed for their respective contribution to vulnerability of coastal communities included geographical (GF), environmental (EF), food security (FF), economic and livelihood (ELF), demographic (DF), policy and institutional (PIF), and capital good (CGF). All levels of contribution of F_b were scaled from 0 (low contribution) to 1 (high contribution).

All F_b for each barangay b were averaged to establish the $CCVI_b$ for that b using Eq. (5):

$$CCVI_b i = \frac{\sum_{i=1}^7 W_{F_b i} F_b i}{\sum_{i=1}^7 W_{F_b i}}, \quad (5)$$

where $CCVI_b$ is equal to the weighted average value of seven major factors F_b , and their weight W_{F_b} is determined by the number of sub-factor indicator S_f that made up each F_b . $CCVI_b$ was measured from a scale of 0 (least vulnerable) to 1 (most vulnerable).

Social Survey

With the intention to facilitate first-hand information, the authors designed and developed the survey questionnaires and encouraged local institutions' participation in a social survey. Municipal and barangay governments, local academe and research institutions such as the Aurora State College of Technology (ASCOT) and Aurora Marine Research Development Institute (AMRDI) participated in pre-selection of enumerators from the academe's senior-level forestry students. These students underwent a brief course on data gathering techniques, which included a practicum on the use of questionnaires. These exercises were useful for students in the conduct of actual field data collection.

The survey was conducted on two consecutive Saturdays and Sundays in September 2010, when most household heads were available. A total of 182 households participated or about 35–40 persons in each barangay, and their identities were undisclosed in ways to preserve anonymity. The bulk of information collected for each household meant most respondents spent an average duration time of 45 min to complete a questionnaire. Household respondents interviewed were predominantly male (67 %) and middle-aged, from 35- to 50-year old (50 %).

The questionnaire comprised four major sections: household characteristics and tenure, resource use and access, social and environmental trends and livelihood and economic activities (Orencio 2011). To quantify intensity and frequency of both social and environmental hazards in a community, three questions were asked to respondents, and their responses were used to measure the geographical factor (see Table 3 in Electronic Supplementary Material).

RESULTS

Vulnerability Factors

Major factors that appeared in high values in all communities were considered highly contributing to their respective vulnerability measurements. These factors were observed to be considerably influenced by their respective high sub-factor indicator values. This direct attribution between sub-factor indicator's contributions resulted in variations in major factor values in all communities. For instance, Sabang's geographical factor, which scored the

highest value of 0.58 among communities were contributed primarily by its sub-factor indicators, frequency of social hazards at 0.25 and intensity and frequency of natural hazards at 0.90 and 0.54, respectively (see Table 4 in Electronic Supplementary Material).

Meanwhile, other communities like Reserva received the highest environmental factor values of 0.58, contributed mainly by inaccessibility to ecosystem services by highly dependent communities with values at 0.55. Buhangin's high values on policy and institutional factor at 0.72, on the other hand, was contributed by values that described the community's lack of knowledge on environmental management activities of institutions at 0.50, which have influenced a low level of community participation on resource management at 0.94.

In terms of economic and livelihood, and food security factors, Zabali had the highest values of 0.70 and 0.80, respectively, contributed by values that described communities' dependency on fisheries for income and food at 0.44 and 0.62, and lack of other income and food sources at 0.96 and 0.97. On the demographic factor, Zabali had the lowest value of 0.46 when compared with other communities, as Buhangin and Sabang had the same value at 0.51, while Pingit and Reserva were the same at 0.50.

Whilst, sub-factor indicators that contributed to the demographic factor values among communities were found to vary substantially from one to another. In Buhangin, the quantity of aged people and household members to support, valued at 0.58 and 0.60, respectively, influenced its demographic factor values. In Sabang, values that described individuals with the least security in current occupation (0.84) were its highest contributing sub-factor.

On the other hand, Reserva had different contributing sources from Pingit, as this was influenced by high values that described individuals in a least secured tenure with current residence (0.24). Pingit had no specific highest sub-factor indicator values but it exhibited similarity with Reserva because its values that described the number of aged people to support (0.52), and the number of individuals with least security in current occupation at (0.83), were not far from highest values, respectively, received by Buhangin and Sabang.

Despite these notable variations on major factor values across communities, there were no large variations on CCVI values because of the cancelling effect between factors with low values and factors with high values during the process of combination. For example, Sabang's low values on capital good factor at 0.37 cancelled out its high values on geographical factor at 0.58, and demographic factor at 0.51, which resulted in a CCVI value of 0.53, the highest among communities. In Zabali, its low geographic factor values of 0.24 cancelled out its high values on food security factor at 0.80, economic and livelihood factor at

0.70 and capital good factor at 0.41. It received the lowest CCVI value of 0.47 despite the high factor values being surprisingly higher than other communities.

DISCUSSION

Factors and CCVI Relationships

Observations on variations in major factors with high values that directly contributed to CCVI measurements for coastal communities supported the idea that inherent conditions exist between communities, and their variations distinctively contributed to their level of vulnerability (see Table 4 in Electronic Supplementary Material). To illustrate major factors' relationships to CCVI, the Pearson's correlation coefficient of determination (R^2), which expressed the percent of CCVI explained, was computed.

Factors that exhibited significant R^2 with CCVI at $p < 0.05$ included geographical and demographic at 0.93 and 0.83, respectively. This relationship was considered probable as in both major factors and CCVI, Sabang was evaluated highest among communities, despite most of its factors being evaluated as low. It can be assumed therefore that considerable negative effects experienced by communities on occurring hazards, and the quantity of socially disadvantaged individuals, could likely influence a vulnerable coastal community.

On the other hand, when mean values of similar major factors of communities were computed, food security, policy and institutional, and economic and livelihood factors were evaluated highest at 0.68, 0.63, and 0.61, respectively (Fig. 3). This suggests that vulnerabilities of most communities were caused by their high level of dependency on fisheries for food and income, as well as their poor knowledge and participation on environmental management activities of institutions.

Mapping CCVI and Factor Values

Further analysis of all major factor and CCVI values of all communities was undertaken with Geographic Information System (GIS) software, ArcGIS 9.3.1. The procedure followed a normalized raster computation to produce maps with a minimum–maximum method based on a range of 0 (least vulnerable) to 1 (most vulnerable) for CCVI, and 0 (least contributing factor) and 1 (most contributing factor) for major factor values. These maps showed that communities were distinctively affected by various factors that make them vulnerable (i.e., geographical and demographic factors in Sabang). Most communities, however, were observed as vulnerable due to food security, policy and institutional, and economic and livelihood factors (Fig. 4).

Fig. 3 Major factor values and their level of contribution to overall vulnerability scaled from 0 (least contribution) to 1 (most contribution) as aggregated from their respective sub-factor indicator values for each community

Spatial Assessment

A resource mapping activity in March 2011 was conducted with selected communities, following the method that assesses risks using qualitative and field based information on livelihood and food economy zones (Save the Children Fund 1997). In this workshop, participants plotted in a topographic map the location of environmental resources and major livelihood activities, and these were then digitized spatially using ArcGIS 9.3.1 (Fig. 5).

The analysis made in this activity was entirely independent and did not in any way influence the survey results. Rather, this was used to explain some significant factor's results. For instance, proximity to ecosystems could be a reason for Buhangin and Reserva's limited knowledge and participation on resource management, as nearer communities like Sabang and Zabali have higher participation rates. However, this proximity also encouraged high dependence rates on coastal resources for food and livelihood. In Zabali, this rate was considered higher because of having the least difficult access on resources. Meanwhile, Buhangin, Pingit, and Reserva were found less dependent

on coastal resources because of availability of land for agriculture-related activities.

Sabang's Vulnerability

Among the communities assessed, Sabang was observed to be most vulnerable given its highest CCVI values. Major factors that contributed highly to this value included geographical and demographic values at 0.58 and 0.51, respectively. Conditions that triggered occurrence of these factors should be identified to address them effectively and to establish resilient communities in Sabang.

For example, Sabang's vulnerability due to demographic factors was caused by a large population density of resource-dependent individuals despite its small shoreline (Technical Working Group 2005). This limited availability of resources for a population that consisted mostly of socially disadvantaged groups requires the implementation of equity- and economic-based measures. Securing quality standard of living by provision of basic services (e.g., easy access to systems for health, information and transportation) and enhancing a network of

Fig. 4 Normalized major factor and CCVI maps prepared with minimum–maximum method, scaled from 0 (least) and 1 (highest). All major factor maps show their relative contribution to vulnerability

across communities, while CCVI map show the overall vulnerability for each community

individuals to act as quasi-support mechanisms may also assist.

As argued by Mohanty (2005), with its geographic condition, Sabang must take into account potential risks from impending natural hazards by establishing an early warning system, recognized and monitored by communities, based on indicators of an imminent disaster. When designed based on timing, degree of effects and preparedness of communities, they may benefit from this especially when embodied in a larger community-based emergency response system within available and accessible technologies, knowledge, and manpower.

Further worth noticing was the unique social problem in Sabang brought by the influx of local and foreign immigrants due to tourism development. Tourism led to incidences of intermittent urban sprawl that have had considerable impact on the patterns and demands on food and livelihoods (Provincial Land Use Committee 2004). The local government could consider facilitating zonal activities in order to minimize overdevelopment. Although this has been recognized in the Baler Comprehensive Land Use Plan (Technical Working Group 2005), which anticipated that such approaches might also address overexploitation, there were no significant improvements made. Communities were even made vulnerable due to social inequities promoted by competitive and over-exploitative situations that damage important ecosystems.

Limitations in Index Design

The development of any index is in itself vulnerable to constraints from techniques and data sources used. As social survey was used in this respect, concerns on the development of scales posed some limitations in this study. One of this is the use of a five-point scale versus a three-point scale in measuring variables. Although scores were not affected as these were standardized regardless of the scale's ranges, the five-point scale might have provided better graduated choices for respondents.

Other concerns also included scales that were set in the lowest measure, which could have defeated the determination of presumed inherent vulnerability. While scales that measure variables from lowest to highest, such as in assessing frequency of hazards, where “Never” instead of “Very Seldom” to counter “Very Often” was used, might have created misrepresentations on variable scales that could likewise lead to a tendency to skew responses to higher scales.

In this case, the scaling system for variables may be established to provide an effective categorization of factors that contributed to their vulnerability. This and the cancelling out of values during aggregation of sub-factor indicators and major factors can be made effective with an indicator specific weighting system—an important step,

Fig. 5 Map of important livelihood and food sources and environmental resources in the coastal barangays of Baler, Aurora, Philippines, estimated based on research validation activities conducted in this study

that could further distinguish the character and contributions of each individual component in the process of measuring vulnerability.

To practically address some limitations on data gathering techniques and assumptions used in the context of rapid appraisal, some measures were undertaken. For instance, pre-survey assessment for a site that is evidently vulnerable based on social conditions was found helpful before administering survey to the wider communities. These provided the presumptions on communities' potential vulnerability that assisted survey design, which include questionnaires for assessing chosen indicators and variables.

Without pre-survey activities, data gathering might not be purposive, to the extent that reliability of collected data may be compromised. Moreover, participation of local institutions during training and data gathering were observed to encourage informed decision making that likewise enhanced local ownership of research activity. On the other hand, post activities like feedback sessions with local representatives on survey results, and cross-assessment activities with communities may be conducted to counter evaluate results that might be prone to biased approaches.

Research Contributions

Managing vulnerability is part and parcel of the precautionary approach that allows policy makers to make discretionary decisions in situations where there is possibility of harm, especially to general public, based on their capacity to apply the approach. However, when there is limited information such as on sources of vulnerability, this may compromise the ability of governments to take proactive measures. In the local setting, it poses great problems because of threats that communities might face in times of extreme or uncertain change.

The starting point interpretation for vulnerability analysis has contributed to this aspect by providing significant understanding of how various components and mechanisms influence a social system. In the context of complex environment, this has led to observable levels of vulnerability that can be described by indicators, disaggregated by variables and measured in metrics. In a social survey, these indicators and variables were explained in various events and conditions that were recognized by individuals based on their experiences and perceptions.

While a pragmatic application of the index at hand was found useful in local-scale analysis, calibration is still recommended prior to its use in other communities. Different sets of variables may be required for each factor that is constructed based on specific community-level scenarios. Nevertheless, results of the assessments can be considered more as baseline rather than a measure of cumulative effects of events, as causation and net impact were not part of the design. This, however, may be considered in future studies.

CONCLUSION

Vulnerability is difficult to determine because it involves the analysis of complex systems. The CCVI provides a way to reduce this complexity by undertaking a simplified measurement of plausible conditions using the social survey. The results, however, should not be treated as an outcome but rather a state of being, wherein changes in social equities, resource distribution and access, opportunities in human security, livelihood patterns, and institutional management structures have influenced the conditions that make communities susceptible to any potential hazard effects.

As observed, there were slight differences in the CCVI values among communities due to the cancelling out of factor values during the process of aggregation. Among seven factors assessed, food security, economic and livelihood, and policy and institutional were found dominant as attributed to their highly rated indicator values. These results explain that communities were made vulnerable by their high dependence on fisheries resources for food and income, and poor knowledge and participation on environmental management activities of institutions. Overall, Sabang ranked as most vulnerable barangay in Baler, Aurora, Philippines with its highest CCVI, influenced by communities' negative experiences on occurring hazards, coupled with an increase of socially disadvantaged individuals.

This site-specific assessment of local vulnerable conditions was achieved based on quantified views of individuals. This process helped not only to integrate relevant critical factors and depict theoretical coherences but also to present results in a transparent and traceable way, which is particularly important for decision making towards managing sources of vulnerabilities. Whilst the distinct vulnerability character of a community was determined, the process can be improved by standardizing the scales used for scoring the variables, and by adopting an indicator-weighting system. With this, factors and indicator variables' distinct effects to a communities' potential vulnerability will be more relatively evaluated.

Acknowledgments This research was funded by a Japanese Government (Monbukagakusho) Scholarship. The authors would like to acknowledge Professors Michio Kishi and Noriyuki Tanaka for their valuable insights and suggestions, and Hokkaido University's Sustainable Low Carbon Society Project, Aurora State College of Technology and Aurora Marine Research Development Institute for logistics and manpower support.

REFERENCES

- Adger, W.N., T. Hughes, C. Folke, S.R. Carpenter, and J. Rockstrom. 2005. Social-ecological resilience to coastal disasters. *Science* 309: 1036–1039.
- Birkmann, J. (ed.). 2006. *Measuring vulnerability to natural hazards: Towards disaster resilient societies*. Tokyo: United Nations University Press.
- Boesch, D.F., J.C. Field, and D. Scavia, eds. 2000. The potential consequences of climate variability and change on coastal areas and marine resources: Report of the Coastal Areas and Marine Resources Sector Team, US National Assessment of the Potential Consequences of Climate Variability and Change, US Global Change Research Program. NOAA Coastal Ocean Program Decision Analysis Series No. # 21. NOAA Coastal Ocean Program, Silver Spring, MD, 163 pp.
- Brooks, N., W.N. Adger, and P.M. Kelly. 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change* 15: 151–163.
- Buckle, P., G. Marsh, and S. Smale. 2001. Assessing resilience and vulnerability: Principles, strategies and actions. Emergency Management Australia: Project 15/2000.
- Creel, L. 2003. Ripple effects: Population and coastal regions. Making the link. Population Reference Bureau. Washington, DC 20009 USA, 8 pp.
- Cutter, S.L. 1996. Societal vulnerability to environmental hazards. *International Social Science Journal* 47: 525–536.
- Cutter, S.L., and C. Finch. 2008. Temporal and spatial changes in social vulnerability to natural hazards. *Proceedings of the National Academy of Sciences of the United States of America* 105: 2301–2306.
- Cutter, S.L., B.J. Boruff, and W.L. Shirley. 2003. Social vulnerability to environmental hazards. *Social Science* 84: 242–261.
- DFID. 2000. *Sustainable livelihoods—current thinking and practice*. London: Department for International Development.
- Dwyer, A., C. Zoppou, O. Nielsen, S. Day, and S. Roberts. 2004. Quantifying social vulnerability: A methodology for identifying those at risk to natural hazards. *Geoscience Australia Record* 2004/14.
- Eakin, H., and A.L. Luers. 2006. Assessing the vulnerability of social–environmental systems. *Annual Review of Environment and Resources* 31: 365–394.
- Fekete, A., M. Damm, and J. Birkmann. 2009. Scales as a challenge for vulnerability assessment. *Natural Hazards* 55: 729–747.
- Fussel, H.-M. 2009. Review and quantitative analysis of indices of climate change exposure, adaptive capacity and impacts. Development and climate change: Background Note to the World Development Report 2010, 35 pp.
- Fussel, H.-M., and R.J.T. Klein. 2006. Climate change vulnerability assessments: An evolution of conceptual thinking. *Climatic Change* 75: 301–329.
- Garatwa, W., and C. Bolin. 2002. Disaster risk management: Working concept. Eschborn: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). Retrieved April 2012 from <http://www2.gtz.de/dokumente/bib/02-5001.pdf>.

- Grant, F., J. Young, P. Harrison, M. Sykes, M. Skourtos, M. Rounsevell, T. Kľuvánková-Oravská, J. Settele et al. 2008. Ecosystem services and drivers of biodiversity change. Report of the RUBICODE E-Conference, April 2008.
- Gravley, D. 2001. Risk, hazard and disaster, University of Canterbury. Retrieved April 2012 from http://homepages.uc.edu/~huffwd/Volcanic_HazardRisk/Gravley.pdf.
- Hahn, M., A. Reiderer, and S. Foster. 2009. The livelihood vulnerability index: A pragmatic approach to assessing risks from climate variability and change—a case study in Mozambique. *Global Environmental Change* 19: 74–88.
- Hiete, M., and M. Merz. 2009. An indicator framework to assess the vulnerability of industrial sectors against indirect disaster losses. In Proceedings of the 6th International ISCRAM Conference—Gothenburg, Sweden.
- Hufschmidt, G. 2011. A comparative analysis of several vulnerability concepts. *Natural Hazards* 58: 621–643.
- Kelly, P.M., and W.N. Adger. 2000. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Climatic Change* 47: 325–352.
- Kumpulainen, S. 2006. Vulnerability concepts in hazard and risk assessment. Natural and technological hazards and risks affecting the spatial development of European Regions. *Geological Survey of Finland, Special Paper* 42: 65–74.
- Luers, A.L., D.B. Lobell, L.S. Skar, C.L. Addams, and P.A. Matson. 2003. A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. *Global Environmental Change* 13: 255–267.
- Marshall, N.A., P.A. Marshall, J. Tamelander, D. Obura, D. Malleret-King, and J.E. Cinner. 2010. A framework for social adaptation to climate change: Sustaining tropical coastal communities and industries. Gland, Switzerland, IUCN, v + 36 pp.
- McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken, and K.S. White, eds. 2001. Climate change 2001: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, USA, 1032 pp.
- McLaughlin, S., and J.A.G. Cooper. 2010. A multi-scale coastal vulnerability index: A tool for coastal managers? In *Coastal hazards and vulnerability*. *Environmental hazards* 9, ed. McFadden, L., 233–248 (3-Special Issue).
- Mitchell, J.K., N. Devine, and K. Jagger. 1989. A contextual model of natural hazard. *Geographical Review* 79: 391–409.
- Mohanty, S. 2005. Multi-sector contributions in reducing vulnerability to natural disaster: A case study of Baler, Aurora Province, Philippines. Master's Thesis. Diliman, Quezon City: University of the Philippines.
- Nicholls, R.J., P.P. Wong, V.R. Burkett, J.O. Codignotto, J.E. Hay, R.F. McLean, S. Ragoonaden, and C.D. Woodroffe. 2007. Coastal systems and low-lying areas. In *Climate change 2007: Impacts, adaptation and vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, ed. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, 315–357. Cambridge: Cambridge University Press.
- O'Brien, K., S. Eriksen, A. Schjolden, and L. Nygaard. 2004. What's in word? Conflicting interpretations of vulnerability in climate change research, CICERO Working Paper 2004:04, Oslo, Norway.
- Orencio, P. 2011. Developing a composite index for vulnerability of coastal communities in Baler, Aurora, Philippines. Master's Thesis. Sapporo, Japan: Hokkaido University.
- Provincial Land Use Committee. 2004. Provincial physical framework plan/comprehensive provincial land use plan of Aurora (2005–2015). Provincial Planning and Development Office. Aurora, Philippines.
- Save the Children Fund (UK). 1997. User's Guide: Risk Map, Version 1.2.
- Selman, P.H. 2000. *Environmental planning: The conservation and development of biophysical resources*, 2nd ed. London: SAGE. xii, 308 pp.
- Sharples, C. 2006. Indicative mapping of Tasmanian coastal vulnerability to climate change and sea-level rise: Explanatory report, 2nd ed. Consultant Report to Department of Primary Industries & Water, Tasmania, 173 pp, plus accompanying electronic (GIS) maps.
- Smith, K. 2000. *Environmental hazards: Assessing risk and reducing disaster*, 3rd ed, 381. London: Routledge.
- Sullivan, C.A. 2002. Calculating a water poverty index. *World Development* 30: 1195–1210.
- Sullivan, C.A., and J.R. Meigh. 2005. Targeting attention on local vulnerabilities using an integrated index approach: The example of the climate vulnerability index. *Water Science and Technology* 51: 69–78.
- Technical Working Group. 2005. Comprehensive land use plan of Baler, Aurora (2005–2015). Municipal Planning and Development Office. Baler, Aurora, Philippines.
- Turner, B., R. Kaspersen, P. Matson, J. McCarthy, R. Corell, L. Christensen, N. Eckley, J. Kaspersen, et al. 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences of the United States of America* 100: 8074–8079.
- United Nations Environmental Programme. 2002. *Assessing human vulnerability due to environmental change: Concepts, issues, methods and case studies*, 55. Nairobi: UNEP.
- United Nations International Strategy for Disaster Reduction (UNISDR). 2004. *Living with risk: A global review of disaster reduction activities*, 429. Geneva: United Nations Publications.
- US Indian Ocean Tsunami Warning System Program. 2007. How resilient is your coastal community? A guide for evaluating coastal community resilience to Tsunamis and other coastal hazards. US Indian Ocean Tsunami Warning System Program supported by the United States Agency for International Development, Bangkok, Thailand, 144 pp.
- Varnes, D.J. 1984. *Landslides hazard zonation: A review of principles and practice*, 63. Paris: UNESCO.

AUTHOR BIOGRAPHIES

Pedcris M. Orencio (✉) is a coastal resources management and development planner by profession in the Philippines. He is currently a doctoral student at the Graduate School of Environmental Science in Hokkaido University. His research interests span from assessing vulnerability and disaster resilience of coastal communities, to local government planning and governance of coastal resources. Address: Graduate School of Environmental Science, Hokkaido University, North 10 West 5, Sapporo, Hokkaido 060-0810, Japan. e-mail: p.orencio@frontier.hokudai.ac.jp

Masahiko Fujii is an associate professor at the Graduate School of Environmental Science, Hokkaido University where he achieved his PhD in Environmental Earth Science in 2001. He worked as a postdoc at the National Institute of Environmental Studies (Japan) and at the University of Maine (USA), studying marine ecosystem modeling for several years. His current activities are more relevant to education and research for sustainable development, especially focusing on: (1) achieving low carbon society and (2) balancing marine ecosystem and human activities such as fisheries and marine tourism in coastal regions including coral reefs in Asia. Address: Faculty of Environmental Earth Science, Hokkaido University, North 10 West 5, Sapporo, Hokkaido 060-0810, Japan. e-mail: mfujii@ees.hokudai.ac.jp