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REPORT

I-C-SEA Change: A participatory tool for rapid assessment of vulnerability of tropical coastal communities to climate change impacts

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Abstract We present a synoptic, participatory vulnerability assessment tool to help identify the likely impacts of climate change and human activity in coastal areas and begin discussions among stakeholders on the coping and adaptation measures necessary to minimize these impacts. Vulnerability assessment tools are most needed in the tropical Indo-Pacific, where burgeoning populations and inequitable economic growth place even greater burdens on natural resources and support ecosystems. The Integrated Coastal Sensitivity, Exposure, and Adaptive Capacity for Climate Change (I-C-SEA Change) tool is built around a series of scoring rubrics to guide non-specialists in assigning scores to the sensitivity and adaptive capacity components of vulnerability, particularly for coral reef, seagrass, and mangrove habitats, along with fisheries and coastal integrity. These scores are then weighed against threat or exposure to climate-related impacts such as marine flooding and erosion. The tool provides opportunities for learning by engaging more stakeholders in participatory planning and group decision-making. It also allows for information to be collated and processed during a "town-hall" meeting, facilitating further discussion, data validation, and even interactive scenario building.

Keywords Climate change impacts · Vulnerability · Coastal habitats · Tropical ecosystems

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INTRODUCTION

Most tropical coastal habitats are threatened by human impact and climate change (Scavia et al. 2002; Hoegh-Guldberg et al. 2007; Carpenter et al. 2008). More than half of the world's coral reefs have been lost or will be lost in the next 40 years (Wilkinson 2008). The area covered by seagrasses decline at an estimated rate of 2–5 % per year, whereas the area covered by mangroves decline at 1–3 % per year (Duarte et al. 2008). The sources, levels, and future impact of the threats driving these losses and declines in coastal habitats must be identified, measured, and projected as bases for planning in order to avert further losses. Threats to human settlements must also be evaluated against the capability to prepare for and adapt to these threats (Walsh et al. 2004). Vulnerability, which is defined as "…the degree to which a system is likely to experience harm due to exposure to a hazard" (Turner et al. 2003) must be measured. Vulnerability assessments (VAs) allow for better planning, improvements in policy and law, and investments in structures and institutions in order for settlements to better respond to human environmental impact and climate change.

The application of VA tools is particularly important in tropical Indo-Pacific where burgeoning populations and inequitable economic growth place even greater burdens on natural resources and support ecosystems. For example, the Philippines has a significant agricultural and fisheries economy driven by a climate system dominated by reversing monsoons and frequent storms. The country is prone to climate impacts because of its small, densely populated islands that depend on their threatened coastal habitats. In spite of being known for their outstanding biodiversity, there are equally high risks for their destruction and loss (Duarte et al. 1997; Polidoro et al. 2010;

Burke et al. 2011; Primavera et al. 2012; Sanciangco et al. 2013). Moreover, the Philippines' climate system and its location in the Pacific Ring of Fire make it one of the most disaster-prone and climate-vulnerable countries in the region (Yusuf and Francisco 2009) and the world (Dilley et al. 2005).

Governance mechanisms in the Philippines emphasize the role of local governments and participatory processes in coastal and fisheries management, and disaster response. However, like many governments in the Indo-Pacific, technical expertise at this level is often limited. VA, decision support, scenario building, and communication tools are needed to provide the bases for consensus building, participatory decision making, and concerted action among various stakeholders and local governments. Stakeholder involvement is critical given the limited enforcement capability and financial resources of local governments. Hay and Mimura (2013) found that the needs and capacities for vulnerability assessment in Pacific Island countries could not be addressed by a single approach but recommend that the special circumstances of the Pacific be considered to develop tools that can be applied using the available knowledge and expertise while generating "…information, empowerment and action at the local scale, where most adaptation decisions are made." While other participatory VA tools exist (e.g., WWF-SPP 2009, Maynard et al. 2010), they either do not fully utilize scientific information accessible at the community level, or require information and expertise that are not yet available at that level.

In this paper, we present a participatory, rapid assessment VA tool to help identify the impacts of climate change. The tool also serves as basis for discussions among stakeholders on coping and adaptation measures to prepare for climate impacts, especially acute, short-term events (i.e., within 1–3 years). The Integrated Coastal Sensitivity, Exposure, and Adaptive Capacity for Climate Change (or I-C-SEA Change) was designed as a prelude to two other thematic VA tools: the Coastal Integrity Vulnerability Assessment Tool and the Tool for Understanding Resilience in Fisheries (MERF 2013; Mamauag et al. 2013). These tools, which are more technical and detailed, were designed to address long-term vulnerability of coastal integrity and fisheries, respectively. On the other hand, the I-C-SEA Change identifies sources of vulnerability especially to immediate, acute impacts of climate change (e.g., storm surges, ocean warming), which are easier to perceive. This is done in an integrated, non-sectoral fashion that emphasizes the stakeholders' shared "fates" and responsibilities to each other. In this manner, I-C-SEA Change is a rapid assessment tool that provides the basis and prepares the audience for more comprehensive and broader assessments on which the planning for coastal adaptation responses is best based.

I-C-SEA Change is built around a series of scoring rubrics to guide non-specialists in assigning scores to the three basic elements of vulnerability, namely *sensitivity*, *exposure*, and lack of *adaptive capacity* (LAC), following a framework revised from IPCC (2001) and Allison et al. (2009)

We operationally define these terms as the following:

- *Sensitivity* of a bio-physical system refers to characteristics that describe the present state of the system and the degree to which this state will respond to changes in climate. The sensitivity criteria in I-C-SEA Change are divided into three subgroups relating to (1) the health of coastal habitats, (2) coastal integrity vis-a-vis flooding and erosion, and (3) fisheries.
- *Exposure* quantifies the intensity or severity of the conditions (or threat thereof) of the physical environment that drives changes in the state or condition of systems.
- *Adaptive capacity* of the natural system involves measures of its ability to cope with impacts of the changes in climate. These measures are proxies that quantify processes that renew, replenish, or replace the state variables described by the sensitivity measures.

Vulnerability in I-C-SEA Change is the intersection of sensitivity, exposure, and LAC, as represented by circles in a Venn diagram (Fig. 1). As these three parameters increase in magnitude, the area of overlap increases leading to greater vulnerability. I-C-SEA Change introduces explicit consideration of the role of coral reefs, seagrass, and

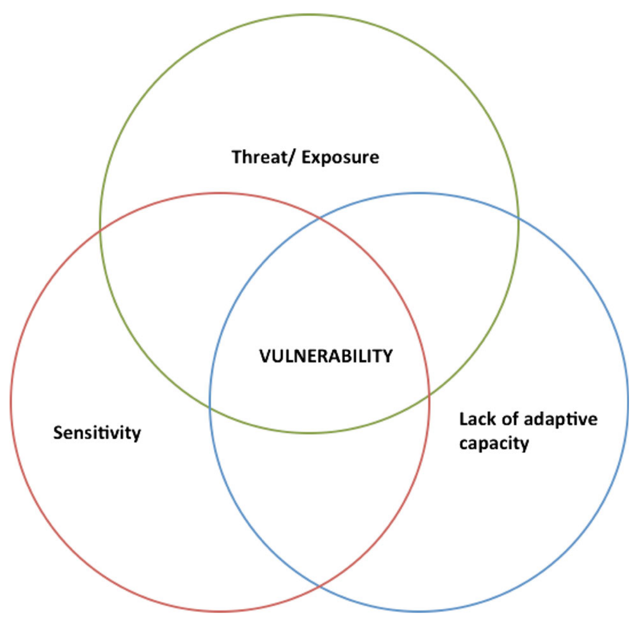

Fig. 1 Venn diagram used to define a framework for assessing vulnerability from the sensitivity, exposure, and lack of adaptive capacity components

mangrove habitats. The scoring rubrics make this VA tool accessible to more stakeholders, allowing them to participate in decision making on community affairs. Hence, the tool provides bases for more objective identification of necessary coping and adaptation responses.

MATERIALS AND METHODS

The I-C-SEA Change tool

Scope of assessment

The "barangay" is the smallest political unit in the Philippines and serves as the primary planning and implementing unit of government. It is used in this paper to represent a coastal community in the tropical Indo-Pacific with at least 2000 inhabitants and a land area of about 5 km^2. Criteria presented in the scoring rubrics in Tables 1 and 2 were selected to be relevant to this scale of assessment. Exposure scores have also been computed to the barangay level and are now readily available in the Internet (e.g., Savant survey tool in the Google Play Store).

To allow for a greatly simplified set of sensitivity and LAC criteria, I-C-SEA Change is focused on acute, immediate impacts such as strong waves and flooding associated with typhoons and extreme weather events. Less emphasis was placed on the impact of gradual, long-term shifts in climate, sea-level rise, and changes in human infrastructure and activities along the coast. Fewer and simpler criteria make I-C-SEA Change more accessible to groups of nonspecialists working together and explaining matters to each from the perspective of the stakeholders they represent. The outcome of the VA exercise is also easier to use in short-term planning for disaster risk reduction, annual budget allocation, and goal setting of local officials.

Scoring and scoring rubrics

Rubrics of I-C-SEA Change are designed to guide nonspecialists in the assignment of scores for sensitivity and LAC. These, together with the framework to integrate the scores, enable users to rank coastal sites according to their vulnerability. In most cases, the information needed to score I-C-SEA Change sensitivity and LAC scoring are available from participatory coastal resource assessments (PCRA; Deguit et al. 2004). For the case study on Lian, Batangas, information from quantitative coastal habitat and fisheries surveys (e.g., coral photo transects, fish visual census, seagrass quadrats, mangrove plots, etc.) led by trained resource persons were complemented with community knowledge and broad-scale observations (MERF 2013).

I-C-SEA Change assessment rubrics use a five-point, three-level scoring for sensitivity and LAC, requiring that distinction be made for scores within the "low" (1 or 2 points) and "moderate" (3 or 4 points) levels, whereas only one score (5 points) is allowed for "high." The lowest score allowed per LAC criterion is two (2) points following the assumption that a low LAC cannot completely negate a high sensitivity or exposure score. Such a scoring system aims to deter the assignment of "fence sitting" middle scores.

If there is no information to base a sensitivity or LAC score on, it is recommended that a high score (i.e., 5 points) is used as the default score. This recommendation is meant to encourage the local governments concerned to collect the information needed to provide the bases for these scores to produce more accurate assessments in the future.

Threshold values (e.g., width of the reef flat or coastal platform, the steepness of the coast) used in the rubrics are based on studies that are deemed most appropriate to conditions and situations prevailing in the Philippines. Others are based on local statistics (e.g., the population density) or regulations (e.g., the percentage of coastal waters reserved for an MPA). These thresholds should be adjusted as needed if the tool is to be used in other countries, although the criteria themselves, how final scores are grouped and averaged, must be kept standard for synoptic and broader level comparisons. I-C-SEA Change quantifies the relative contributions of sensitivity, exposure, and LAC to generate a ranking of the communities in a given assessment. The final scores of a single community are most meaningful when compared to those of adjacent communities.

Assessing exposure in I-C-SEA Change

Scoring for exposure in I-C-SEA Change is based on a typology of climate-related coastal parameters in the Philippines (David, unpubl.) that considers past (30 year) trends in sea level, sea surface temperature, and model-based relative exposure to waves (see Villanoy et al. 2013). I-C-SEA Change, which is designed to consider immediate to short-term time scales, emphasizes that certain stressors such as storm surges may influence a community's vulnerability more profoundly than others. I-C-SEA Change exposure, like sensitivity and LAC, is determined using thresholds (Table 3). Sea level height and sea surface temperature trends are cross-tabulated, the composite of which is subsequently cross-tabulated with a relative exposure index to waves (see the electronic supplementary material). Thus, the weight of the wave exposure scores is double that of surface temperature and sea level height trends. Since these stressors often operate at spatial scales that are far larger than the towns and barangays, it was

Table 1 Scoring rubric used for assigning sensitivity scores, including the bases for criteria and thresholds that were defined. Note that a high default score is used when the information needed to assign a score is not available

	Criteria	Low 1–2 Points	Moderate 3–4 Points	High 5 Points	Remarks: basis and reference(s) for criterion	Basis and reference(s) for the scoring rubric
Coastal habitat						
Is there a coral reef in your area (with a defined profile)?						
1	How much of the coastline is lined by coral reefs?	More than 50 % is lined by coral reefs?	Between 25 and 50 % is lined by coral reefs?	Less than 25 % is lined by coral reefs?	Reef areas with a defined reef flat and reef slope (as opposed to non-reefal habitats; see Reigl et al. 1995) attenuate waves and reduce coastal erosion (Villanoy et al. 2012), and provide habitats (along with mangroves, seagrass) to support reef fisheries (Mumby et al. 2004)	The use of a quartile scale is suggested to simplify estimation from maps
2	What is the highest hard coral cover (%)?	Over 50 %	Between 25 and 50 %	Less than 25 %	Same as above. The highest cover is used to represent the best reef in the area of assessment rather than the average condition. The latter is harder to estimate and requires more data than is typically available	The scale is consistent with the widely used quartile scale of Gomez et al. (2004). Average coral cover in the Philippines is less than 20 % (Bruno and Selig 2007) which means many reefs will get a sensitivity score of 5
Are there large seagrass meadows?						
3	How much of the shallow areas are covered by seagrass?	Seagrasses cover more than half of the reef flat	Seagrasses cover more than 1/8 to 1/2 of the reef flat	Seagrasses cover less than 1/8 of the reef flat	Seagrass meadows with high percent cover help in stabilizing sediments and filtering upland runoff and provide habitats for marine organisms	The use of fractions is suggested to simplify estimation from available satellite and topographical maps
4	What is the maximum number of seagrass species?	Mixed bed with over 5 species	2–4 Species	Monospecific bed	Species of seagrasses have varied responses to sediment burial stress, hypersalinity, and storm blow out (Björk et al. 2008; Terrados 1998, 1999). Thus, the more species, the less sensitive the community is to disturbances	Seagrass meadow with high species diversity is also an indication of the number of zones that a meadow has thereby the extent of the remaining meadow
Are the mangrove areas widespread?						
5	How much of the natural mangrove areas are left?	over 50 % of the natural mangrove areas are left	Between 25 and 50 % of the natural mangrove areas are left	Less than 25 % of natural mangrove areas are left	The percentage of remaining natural mangrove forest is an indication of the present extent of the forest that may help in protecting the coast from strong waves, filter upland runoff, and serve as habitat and nursery for marine organisms (Alongi 2008; McLeod and Salm 2006)	The natural mangrove areas in the Philippines is less than 40% at present, with more than 60% converted to aquaculture ponds and other uses. The use of percent natural mangrove areas remaining is suggested to simplify estimation using available satellite images and topographic maps
6	What kind of mangrove forest is left?	Riverine-basin-fringing type	Riverine-fringing type	Scrub-fringing type	As in criterion #5, the type of mangrove forest left is a proxy for the extent of the remaining mangrove forest. Mangrove areas that receive large amount of sediment from adjoining areas are considered highly productive due to high concentrations of nutrients due to sediment trapping (as cited in McLeod and Salm 2006)	In the Philippines, widest mangrove forests are those of the riverine-basin-fringing type, while fringing type alone is the narrowest. Riverine mangroves are considered to be the most productive type of forest

Table 1 continued

Criteria		Low 1–2 Points	Moderate 3–4 Points	High 5 Points	Remarks: basis and reference(s) for criterion	Basis and reference(s) for the scoring rubric
Coastal habitats average						
Fish and fisheries						
What kind of fishery operates in your barangay/area?						
7	What is the dominant catch?	The catch is predominantly made up of pelagic fishes (e.g., tuna, mackerel, etc.)	The catch is a mix of demersal and pelagic species	The catch is predominantly made up of demersal fish (e.g., groupers)	It is reported that 25 % of all fish species are strongly associated with coral reefs (Spalding et al. 2001) and will be affected by ongoing degradation of coral reef habitats caused or aggravated by climate-induced coral bleaching events (Jones et al. 2004; Munday 2004; Pratchett et al. 2008). Demersal fish that mainly constitute catch of nearshore fisheries (Mamauag et al. 2009), including coral reefs, are thus highly vulnerable to climate change impacts (e.g., destructive waves, rising sea surface temperatures or SST)	The categories (predominantly demersal, mix of demersal and pelagic, and predominantly pelagic) are presented in a way that it is simple and easy for the local stakeholders to score. It is more qualitative than quantitative, hence scoring is based mainly on majority or minority in the catch composition
8	What is the average catch rate per fisher?	>8 kg per day (or equivalent catch per unit effort or CPUE)	3–8 kg per day (or equivalent cpue)	<3 kg per day (or equivalent CPUE)	Catch rate (e.g., catch per unit effort) is a metric that provides an indication of fishing effort, which is a good indicator of fishing pressure	The values for the categories (L, M, and H) are derived from the database of catch rate information from forty (40) municipality sites in the Philippines (e.g., Mamauag et al. 2009; Muallil et al. 2014). The dataset has a wide range of mean artisanal catches subjected by varying levels of fishing effort
9	Are the fishing gears used restricted to shallow water (coral, mangrove, seagrass) habitats?	Mostly mobile fishing gear	Presence of both types	Mostly habitat-associated gear (e.g., fixed gear on seagrass beds)	Given that the shallow water habitats are vulnerable to climate change such as increasing SST (e.g., coral bleaching events) (Pratchett et al. 2008) with concomitant deleterious effects on target species found in these habitats, fishing gears that are highly associated with these habitats (e.g., Cinner et al. 2009) therefore have the same vulnerability	Basis is mainly taken from Cinner et al. (2009) which showed the vulnerability of reef fish species to coral mortality and loss of habitat structure and consequently reflected similar vulnerability for gears targeting reef or demersal fishes. Hence, gears that are fixed on the substratum for longer periods of time (e.g., fish corral) are considered the most vulnerable, whereas those that target mobile semi-pelagic and pelagic fishes are the least vulnerable
How important is the fisheries to the community?						
10	What is the population density (in the population center of interest)?	200 Persons or less per square kilometer (1 household per 2.5 ha)	Between 200 and 500 persons per square kilometers (1 household per 1.25 ha)	More than 500 persons per square kilometer (1 household per 1 ha)	High densities of population will drive increasing pressure on the resources and environment exceeding the human carrying capacity. This also holds true for fishery resources (Garcia and Rosenberg 2010) given its open access nature	The categories for population density are primarily based on national census data of the Philippines. In 2010, the National Statistics Office reported an average density of 308 people per square kilometre which we put in the moderate category

Table 1 continued

Criteria		Low 1–2 Points	Moderate 3–4 Points	High 5 Points	Remarks: basis and reference(s) for criterion	Basis and reference(s) for the scoring rubric
11	How dependent is the community on fishing?	35 % or less of the population are fishers	36–60% of the population are fishers	More than 60 % of the population are fishers	Many coastal communities of the developing countries in the tropics depend largely on the fishery resources for food and livelihood (Allison et al. 2009; Muallil et al. 2011). This reflects the vulnerability of social and ecological systems of the fisheries subjected to climate change	The basis for the categories is the range of fisher density estimate of fishing communities (*barangay*) from the 40 municipalities in the fisheries database of COMECO (Muallil et al. 2014). The average density in coastal areas in the Philippines is around 300 per sq. km. NSO (2010)
Fish and fisheries average						
Coastal integrity						
Is the coastline prone to erosion and marine flooding?						
12	Has the beach changed much in the last 12 months?	Land gain/accretion	Stable	Eroding	The use of a 12 month window accounts for an annual cycle as basis for deciding whether a coastal segment is eroding, stable, or accreting overall	
13	Is the coastline prone to erosion?	Rocky, cliffed coast; beach rock	Low cliff (<5 m high); cobble, gravel beaches; alluvial plains	Sandy beaches; delta; mud- or sandflat	The potential for erosion is dependent on lithology for hard rock and grain size for loose sediments (Gornitz et al. 1994; Thieler and Hammer-Klose 1999). The presence of biological features (e.g., mangrove shorelines) may dampen the effects of waves	Modified from Gornitz et al. (1994) to incorporate the presence of natural biological wave buffers
14	How wide is the shore platform (m)?	>100	[50, 100]	<50	This factor considers wave attenuation provided by the fringing reefs and similar geomorphic features such as wave-cut platform (Brander et al. 2004)	Random measurement using Google Earth® yielded common widths within 100 m
15	How steep is the coast?	<1:50	1:50–1:200	>1:200	This factor considers the landward penetration of waves (Thieler and Hammer-Klose 2000)	The cut-off is still arbitrary
Coastal integrity average						
Sensitivity—general average						

Table 2 Scoring rubric used assigning the lack of adaptive capacity scores, including the bases for the criteria and thresholds that were defined. Note that a high default score is used when the information needed to assign a score is not available

Lack of adaptive capacity criteria	Scoring 2 (Low)	3 (Moderate)	4 (Moderate)	5 (High)	Remarks: Basis and reference(s) for criterion
Coastal habitat					
Health of coral habitats					
1 If there are corals, are there more hemispherical corals compared to branching ones?	Three times more branching than hemispherical corals	Two times more branching than hemispherical corals	As many branching as hemispherical corals	More hemispherical than branching; or no corals	Coral community patterns and zonation (Done 1982, Licuanan 2002); hemispherical corals are more tolerant to wave action and sedimentation; hemispherical corals are less susceptible to coral bleaching compared to branching corals
2 If there are corals, are there more large colonies compared to small colonies for the dominant species?	Number of adult and large colonies is 1/3 that of juvenile and small colonies of the species	Number of adult and large colonies is 1/2 that of juvenile and small colonies of the same species	As many large colonies as small ones of the same species	More large adults than juveniles and small colonies of the same species; or no corals	The size-structure is used to infer regenerative capacity of the dominant coral species
3 Is the coral diversity much reduced?	The coral community is a mix of four growth forms (e.g., branching, hemispherical, encrusting, and foliose) of corals	The coral community is mostly made of a mix of three growth forms of coral	The coral community is mostly made of a mix of two growth forms of coral	The coral community is mostly made up of hemispherical or encrusting forms of coral	The variety of coral growth forms is used a proxy for the species diversity
Health of seagrass meadows					
4 If there are seagrasses, is *Enhalus acoroides* density highest among the seagrasses?	*Halophila–Halodule* dominated meadow	*Thalassia–Cymodocea–Halodule* dominated meadow	*Enhalus acoroides–Thalassia hemprichii* dominated meadow	*Enhalus acoroides* dominated meadow; or no seagrass	Climax species such as *Enhalus acoroides, Thalassia hemprichii,* and *Cymodocea serrulata* are slow growing plants that need more time and a more stable environment to anchor in the sediment (Bjork et al. 2008). Pioneer species (*Halodule uninervis, Halophila ovalis, Cymodocea rotundata*) can colonize an area rapidly
5 Are there more barren areas within the seagrass meadow?	Meadow is continuous and barren area is less than 20 %	Barren area is between 20 and 40 % of the meadow	Barren area is between 40 and 60 % of the meadow	Barren area is more than 60 % of the meadow; or there are no meadows	A seagrass meadow with more barren areas indicates that it is disturbed area and it has poor meadow integrity (low density and abundance, poor cover) and hence has low potential for recovery

Table 2 continued

Lack of adaptive capacity criteria	Scoring				Remarks: Basis and reference(s) for criterion
	2 (Low)	3 (Moderate)	4 (Moderate)	5 (High)	
Health of mangrove forests					
6 If there are mangroves, are the slow growing, slow colonizing species most common in the area?	Presence of more than five mangrove species capable of colonizing newly available habitat at a rate that keeps pace with the rate of relative sea-level rise	Presence of three to four mangrove species capable of colonizing newly available habitat at a rate that keeps pace with the rate of relative sea-level rise	Presence of one to two mangrove species capable of colonizing newly available habitat at a rate that keeps pace with the rate of relative sea-level rise	Yes, all species are slow growing, slow colonizing	The presence of pioneer species (*Avicennia marina, Sonneratia alba, Rhizophora* spp, *Ceriops* spp.) is a good indication of the recruitment potential of an area after a disturbance (McLeod and Salm, 2006)
7 Are there more large trees than small propagules (in terms of density) in natural stands?	Seedlings and propagules observed between 8 and 12 months every year	Seedlings and propagules observed between 4 and 8 months every year	Seedlings and propagules observed between 1 and 4 months every year	Yes, all trees are large, seedlings and propagules are absent	Access to abundant supply of propagules internally is an indication of the recovery potential of an area (McLeod and Salm 2006, Alongi 2008)
Water quality					
8 Is the water murky, silty in most of the year?	Water is clear all year round	Water is observed to be murky for one to two quarters of a year	Water is observed to be murky, silty for three quarters a year	Water is murky, silty all year round	High turbidity and sedimentation can cause partial or whole coral colony mortality
9 Does the area experience warm, still- water in a year?	No	Short periods of warm, still-water prevails and is related to tides	Periods of warm, still- water prevails for several days or weeks at a time	Periods of warm, still- water prevails for several months	
10 Does solid waste accumulate in this coastal area?	No	Solid waste is observed in this coastal area between one and four months every year	Solid waste is observed in this coastal area between four and eight months every year	Solid waste accumulates in this coastal area all year round	Bad water quality will affect the viability of the early life stages of marine organisms. Presence of garbage can also affect tourism and fisheries
Habitat restoration efforts					
11 How much of the degraded mangrove area remains to be rehabilitated?	Less than 50 % of the degraded mangrove area remains to be re-habilitated	Between 50 and 70 % of the mangrove area remains to be re-habilitated	Between 70 and 90 % of the mangrove area remains to be re-habilitated	More than 90 % of the mangrove area remains to be rehabilitated	
Marine protected area (MPA)					
12 How much is the need to expand the marine protected area (MPA)?	Almost none; MPAs are 15 % or more of municipal waters	Total MPA areas are 7.5–15 % of the municipal waters	Total MPA areas are between 1 and 7.5 % of the municipal waters	Total MPA areas are less than 1 % of the municipal waters	Based on the 15 % protected area requirement as per Republic Act 8550 (Philippine Fisheries Code)
13 Was the MPA design and management focused on fishery enhancement alone?	No, biodiversity and tourism aims also considered	Fisheries and tourism were considerations	Tourism was the only consideration	Yes	Ideally MPAs should address multiple objectives. However, in practice, most MPAs were established mainly to address fisheries objectives

Table 2 continued

	Lack of adaptive capacity criteria	Scoring				Remarks: Basis and reference(s) for criterion
		2 (Low)	3 (Moderate)	4 (Moderate)	5 (High)	
14	To what extent do protected areas focus on single habitats (mangrove, seagrass, coral) alone?	All habitats represented in the MPA	Only two habitats were included in the MPA	Only one habitat was included in the MPA	No habitats were included in the MPA	Ontogenetic connectivity of marine organisms (Sale et al. 2010); larger areas enhance population persistence by increasing the protection of larger populations of more species (see Green et al. 2014)
Fish and fisheries						
15	What is the contribution of fisheries to the per capita consumption of the area?	Less than 20 %	Between 20 and 40 %	Between 40 and 60 %	More than 60 %	Per capita food consumption is an important metric in ensuring food security (e.g., Kent 1997). Fish is considered as one of the critical and cheap sources of dietary protein especially for people dependent on this industry (Garcia and Rosenberg 2010)
16	What is the average fish catch (in kilograms) per day per fisher?	More than 5 kilos per day per fisher	Between 2.5 and 5 kilos per day per fisher	Between 1 and 2.5 kilos per day per fisher	Less than 1 kilo per day per fisher	This catch rate differs from the one in the sensitivity part which signifies a present state of the fishery subjected to climate stressor, whereas this one represents a metric that allows a mechanism (i.e., enhanced fisheries production) to adapt to changes in climate (Cinner et al. 2012)
17	Are fishery resource management plans effective?	Yes the fishery resource management plans effective	Somewhat effective	Mostly ineffective	No; Or there are no management plans	This represents the governance aspect of the fisheries (e.g., Garcia and Rosenberg 2010) and therefore a good indicator of adaptive capacity
18	What is the average fishing experience per fisher?	Less than 5 years per fisher	Between 5 and 10 years	Between 10 and 20 years	More than 20 years	The number of years a fisher spends on fishing is a major factor that influences exit from fishery (Muallil et al. 2011)
19	Is fishing the only source of livelihood?	No, more than three other sources of livelihood	Fishing plus two other sources of livelihood	Fishing plus another source of livelihood	Yes	Fishing dependence or the presence of other livelihoods is also key socio-economic indicator to represent adaptive capacity (Allison et al. 2009, Muallil et al. 2011)
Coastal integrity						
20	How much has the land eroded in the last 30 years?	0, Accretion	Between 0 and 15 m land loss	Between 15 and 30 m land loss	More than 30 m of land loss	The use of 30 years is to be consistent with climate change definition

Table 2 continued

Lack of adaptive capacity criteria	Scoring				Remarks: Basis and reference(s) for criterion
	2 (Low)	3 (Moderate)	4 (Moderate)	5 (High)	
Human activity					
Human settlements					
21 How much does the present land-use pattern deviate from the approved comprehensive land-use plan (CLUP)?	No deviation from the CLUP	Between 1 and 25 %	Between 25 and 50 %	More than 50%, or there is no use land-use plan	
22 To what extent do coastal modifications (e.g., pier, wharf, and seawall construction, reclamation, foreshore use) deviate from CLUP and similar regulations?	No deviation from the CLUP	Between 1 and 25 %	Between 25 and 50 %	More than 50 %, or there is no land-use plan	
Economy					
23 How extensive is the conversion of the coastal lands from rural-agricultural to residential to commercial and industrial use?	Industrial	Commercial	Residential	Rural, fishing, agricultural	
Education					
24 How much of the adult population has less than 10 years of schooling?	Less than 10 % of the population has less than 10 years of schooling	Between 20 and 40 %	Between 40 and 60 %	More than 60 %	Educational attainment is a major factor that influences fishers to exit the fisheries (Muallil et al. 2011)

Table 3 Criteria and data sources used to compute the exposure scores. Exposure data were binned to represent low, moderate, and high levels using Jenks natural breaks optimization to define the thresholds at the Philippine level using linear rates of sea surface temperature and sea surface height increase, and the relative wave exposure index

Parameter	Method of calculation	Metrics of comparison	Exposure score thresholds
Sea surface temperature	Slope (AVHRR 1982–2008)	Global average per decade (0.133 °C ± 0.047) northern ocean average (0.19 °C)	Low < 0.086; 0.086 ≤ Moderate ≤ 0.19; High > 0.19
Sea surface height	Slope (Topex Poseidon/JASON 1992–2008)	Global average per decade (3.1 cm ± 0.7).	Low < 2.4; 2.4 ≤ Moderate ≤ 3.8; High > 3.8
Relative wave exposure index	Wave exposure model (WEMO) developed by Malhotra and Fonseca (2007) in REI mode[a] applied using Philippine coastline, bathymetry and wind data	No metrics of comparison used. Thresholds were based on relative wave exposure values along the country's coastlines	Low < 815; 815 ≤ Moderate ≤ 6030; High > 6030

[a] WEMO's REI (relative exposure index) mode uses an empirical approach to calculate exposure as a function of wind, fetch and bottom depth with depth variations controlled by an inverse weighting function to account for the greater damping effect of shallow water at a nearer distance than farther off

decided that the final exposure score should not be rescaled relative to the other communities being evaluated within a given analysis. Consequently, if the climate vulnerability of five communities belonging to the same town is to be evaluated, the exposure scores for all five will likely be the same. If the scores are rescaled, then the least exposed of the aforementioned five communities gets a low score and the most exposed gets a high score.

RESULTS

An application of the I-C-SEA Change tool: Lian, Batangas, Philippines

A sample application of I-C-SEA Change in the five coastal barangays of Lian, Batangas in western Luzon Island is presented in Table 4 and Fig. 2. The town of Lian is primarily an agricultural town relying on sugarcane farming, fishing, and small-scale mass tourism. Of the six coastal barangays in Lian, Barangays San Diego, Lumaniag, and Balibago are primarily fishing villages, while Barangays Binubusan and Matabungkay rely on a mix of fishing and tourism. The vulnerability assessment using the I-C-SEA Change tool in Lian was conducted during a one-day workshop involving key town and barangay officials concerned with planning and development, fisheries, disaster response, health, and the environment, along with representatives of people's organizations such as those for fisheries and agriculture. Participants were encouraged to bring the relevant data and documentation needed such as the municipal profile and PCRA reports. Scores for each criterion were assigned in plenary by presenting each criterion and the relevant information for each, as collated from the data provided by the participants. The participants were then asked to agree on a score per criterion per barangay. The agreed scores were then tabulated on a separate screen.

Results of the I-C-SEA Change workshop showed different results for each of the barangays (Table 4). Barangay San Diego had the highest aggregate sensitivity score, whereas Barangays Lumaniag and Balibago had the lowest sensitivity scores. The coastal habitat sensitivity scores of Barangays Lumaniag and Binubusan benefited from their being mostly inside Talim Bay, which has better developed reef, seagrass, and mangrove habitats. The larger numbers of fishers in San Diego and Lumaniag resulted in their higher fisheries sensitivity. Binubusan has fewer fishers and most of them target pelagic fishes in distant islands. Thus, they are less dependent on the condition of the nearby coastal habitats. San Diego registered high sensitivity scores for coastal habitats and coastal integrity indicators. Compared to other barangays, the coastline of San Diego has no natural buffers to protect from the onslaught of waves, making the area more prone to coastal erosion.

All barangays scored moderately for waves and temperature anomalies and had high scores for sea surface height. The latter is the case for the country as a whole because the North Equatorial Current pushes the thermally expanded waters of the Pacific toward the Philippines.

In terms of LAC indicators, the scores for the seagrass, mangrove, water quality, and fisheries criteria for the five barangays did not differ much from each other (Table 4). Yet the scores were poorest for San Diego and Balibago. San Diego's location in an alluvial plain, as well as the current lack of marine protected area (MPA) management in Balibago contributed to the poor rating. Default scores (5 points) for the health of coral habitats were also given to San Diego and Balibago since information on these were not available.

When the sensitivity, exposure, and LAC scores were combined, all five barangays showed moderate

Table 4 The sensitivity and lack of adaptive capacity scores assigned to the five barangays of the town of Lian in western Luzon Island, the Philippines. The table cells were colored red, yellow, and green for high, moderate, and low levels, respectively, for sensitivity and lack of adaptive capacitycapacity

SENSITIVITY CRITERIA				San Diego	Lumaniag	Binubusan	Matabungkay	Balibago
COASTAL HABITAT	Is there a coral reef in your area (with a defined profile)?	1	How much of the coastline is lined by coral reefs?	5	1	2	1	1
		2	What is the highest hard coral cover (%)?	5	4	4	5	5
	Are there large seagrass meadows?	3	How much of the shallow areas are covered by seagrass?	5	1	2	2	1
		4	What is the maximum number of seagrass species?	3	1	1	1	3
	Are the mangrove areas widespread?	5	How much of the natural mangrove areas are left?	2	2	3	5	3
		6	What kind of mangrove forest is left?	3	4	4	5	3
	COASTAL HABITATS | AVERAGE			3.8	2.2	2.7	3.2	2.7
FISH AND FISHERIES	What kind of fishery operates in your barangay/area?	7	What is the dominant catch?	3	3	3	3	3
		8	What is the average catch rate per fisher?	4	3	4	3	3
		9	Are the fishing gears used restricted on shallow water (coral, mangrove, seagrass) habitats?	4	3	2	3	3
	How important is the fisheries to the community?	10	What is the population density (in the population center of interest)	1	1	1	2	1
		11	How dependent is the community on fishing?	5	5	1	2	1
	FISH AND FISHERIES | AVERAGE			3.4	3.0	2.2	2.6	2.2
COASTAL INTEGRITY	Is the coastline prone to erosion and marine flooding?	12	Has the beach changed much in the last 12 months?	4	2	3	4	2
		13	Is the coastline prone to erosion?	5	3	4	4	4
		14	How wide is the shore platform (m)	4	1	1	1	1
		15	How steep Is the coast?	5	1	3	5	1
	COASTAL INTEGRITY | AVERAGE			4.5	1.8	2.8	3.5	2.0
	SENSITIVITY: GENERAL AVERAGES			3.9	2.3	2.5	3.1	2.3
				MODERATE	MODERATE	MODERATE	MODERATE	MODERATE

Table 4 continued

LACK OF ADAPTIVE CAPACITY CRITERIA				San Diego	Lumaniag	Binubusan	Mata-bungkay	Balibago
COASTAL HABITAT	Health of coral communities	1	If there are corals, are there more massive corals compared to branching ones?	5	5	5	5	5
		2	If there are corals, are there more large colonies compared to small colonies for the dominant species?	5	4	4	4	5
		3	Is the coral diversity much reduced?	5	2	2	2	5
	Average for corals			**5.0**	**3.7**	**3.7**	**3.7**	**5.0**
	Health of seagrass meadows	4	If there are seagrasses, is *Enhalus acoroides* density highest among the seagrasses?	4	4	3	3	4
		5	Are there more barren areas within the seagrass meadow?	5	4	4	4	4
	Average for seagrass			**4.5**	**4.0**	**3.5**	**3.5**	**4.0**
	Health of mangrove forests	6	If there are mangroves, are the slow growing, slow colonizing species most common in the area?	2	2	3	2	2
		7	Are there more large trees than small propagules (in terms of density) in natural stands?	2	2	2	2	2
	Average for mangroves			**2.0**	**2.0**	**2.5**	**2.0**	**2.0**
	Water quality	8	Is the water murky, silty in most of the year?	3	2	3	3	3
		9	Does the area experience warm still-water?	3	3	3	3	3
		10	Does solid waste accumulate in this coastal area?	4	3	3	3	3
	Average for Water Quality			**3.3**	**2.7**	**3.0**	**3.0**	**3.0**
	Level of biodiversity management							
	Habitat restoration efforts	11	How much of the degraded mangrove area remain to be rehabilitated?	3	2	3	2	2
	Marine protected area	12	How much is the need to expand the marine protected area (MPA)?	3	3	3	3	3
		13	Was the MPA design and management focused on fishery enhancement alone?	2	2	2	4	5
		14	To what extent do protected areas focus on single habitats (mangrove, seagrass, coral) alone?	2	2	2	4	5
	Average for Marine Protected Area			**2.5**	**2.3**	**2.3**	**3.7**	**4.3**
	COASTAL HABITATS - AVERAGE (Remember: Include Item #11)			**3.5**	**2.9**	**3.0**	**3.2**	**3.7**
FISH AND FISHERIES		15	What is the contribution of fisheries to the per capita consumption of the area?	4	4	3	3	4
		16	What is the average fish catch (in kilograms) per day per person?	3	3	4	4	4
		17	Are fishery resource management plans effective?	5	5	5	5	5
		18	What is the average fishing experience per fisher?	3	3	3	5	3
		19	Is fishing the only source of livelihood?	3	3	2	3	3
			FISH AND FISHERIES - AVERAGE	**3.6**	**3.6**	**3.4**	**4.0**	**3.8**

Table 4 continued

COASTAL INTEGRITY		20	How much has the land eroded in the last 30 years?	5	2	3	4	5
HUMAN ACTIVITY	Human settlements	21	How much does the present land use pattern deviate from the approved comprehensive land use plan (CLUP)?	2	2	2	2	2
		22	To what extent do coastal modifications (pier, wharf, and seawall construction, reclamation, foreshore use) deviate from CLUP and similar regulations?	2	3	5	3	2
	Economy	23	How extensive is the conversion of the coastal lands from rural-agricultural to residential to commercial and industrial use?	4	4	3	3	3
	Education	24	How much of the adult population has less than 10 years of schooling?	4	4	4	2	4
	HUMAN ACTIVITY - AVERAGE			3.0	3.3	3.5	2.5	2.8
	LACK OF ADAPTIVE CAPACITY: GENERAL AVERAGES			3.8	2.9	3.2	3.4	3.8
				MODERATE	LOW	MODERATE	MODERATE	MODERATE

vulnerability. Of the five, San Diego was the most sensitive due to its degraded coastal habitats, erosion-prone coasts, and dependence on fisheries. Lumaniag, one of the least sensitive barangays, was also dependent on fisheries but it had better coastal habitats, steeper coasts that made it less prone to coastal erosion and wave damage. Lumaniag also had the best adaptive capacity scores, affirming efforts of barangay officials and fisher organizations here in MPA management and mangrove rehabilitation.

As the results of the vulnerability assessment in Lian became evident during the workshop, so did the pride of some community representatives (e.g., those from Lumaniag) for their achievements. Because the sources of climate vulnerability were made more obvious, the town's environment officer then used the situation to encourage the under-performing barangays to take advantage of the relevant programs of the town, and encourage the other town offices represented to realign their programs. The scoring rubrics also clarified to the participants the role of coastal habitats in enhancing coastal integrity and fisheries and the need to improve the implementation of MPAs in Barangays Lumaniag and Binubusan. The results also provided the needed bases for conservation, fisheries, and infrastructure planning sectors to work together. When used in a participatory, consensus-building workshop, I-C-SEA Change was especially useful as a communications tool, and this is evidenced by subsequent requests by the Lian participants to have the tools presented to their barangay constituents. The workshop also led to subsequent efforts to update the town's climate change adaptation plan.

DISCUSSION

VA tools make projections about future states (vulnerability) from current states (sensitivity), threats to these states (exposure), and processes (adaptive capacity). These tools serve as integrative models with explicit assumptions and interrelationships. As a synoptic, participatory tool for non-specialists, I-C-SEA Change enables the use of semi-quantitative rubrics applicable to a wide variety of coastal settings, one of which is presented here.

I-C-SEA Change enables non-specialists to conduct rapid, participatory assessments of vulnerability of coastal settlements to the immediate impacts of climate change. However, the I-C-SEA Change's use of semi-quantitative rubrics affects the accuracy and the resolution of the resulting vulnerability scores. Compromises have to be made when the boundaries of the ecosystem components considered do not match the site boundaries and the spatial extent of relevant human activities, and when the information needed for scoring are not uniformly available and up-to-date. For example, one community may be fishing near other communities with whom they share the same contiguous reef and seagrass habitats. Consequently, scores may not differ much between adjacent communities. On the other hand, data gaps and data collected at different

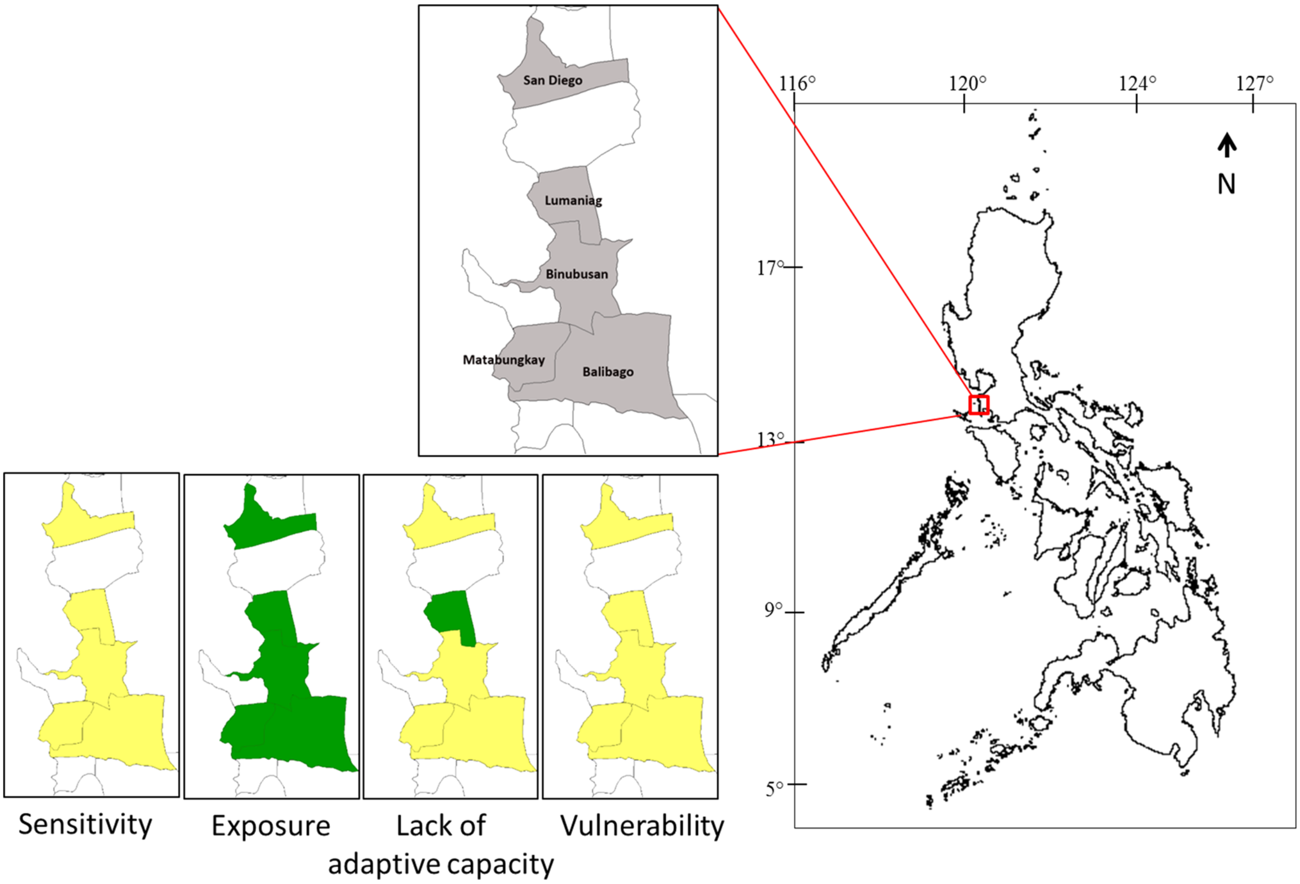

Fig. 2 Map of the five barangays of the town of Lian in western Luzon Island, Philippines showing their sensitivity, exposure, lack of adaptive capacity, and final I-C-SEA-Change vulnerability levels. *Red*, *yellow*, and *green* shadings represent high, moderate, and low levels, respectively

times may result in different sensitivity and LAC scores being assigned to very similar barangays. Thus, caveats must be considered and documented when interpreting and reporting results, and when applying more detailed VA tools that I-C-SEA Change serves as a prelude to.

The simplified rubrics and scoring system allow for a more objective, transparent process as well as a synoptic, semi-quantitative scoping, or rapid assessment tool. This combination of traits makes I-C-SEA Change unique among similar tools developed for the Indo-Pacific. But like similar tools (e.g., Maynard et al. 2010), I-C-SEA Change cannot be expected to produce precise, "knife-edge" vulnerability scores from such rubrics. It was designed to educate stakeholders by helping them identify, evaluate, and inter-relate the elements of the socio-ecological system they belong to. The I-C-SEA Change tool is hereby presented as a public education and communications tool that helps stakeholders achieve a better understanding of their vulnerability. It sets the basis for a discussion among the stakeholders using a shared vocabulary. The tool also empowers the stakeholders by providing them semi-quantitative measures of their contribution to common problems and, more importantly, helping them see their role in addressing these in a shared, concerted fashion. The conversation that the tool fosters thus seems more objective and collaborative, and less confrontational and fault-finding. Furthermore, since information is collated and processed in the same meeting, feedback of the findings is immediate, which facilitates data validation and discussion on topics such as improvements in data collection and monitoring.

I-C-SEA Change also encourages"what-if" scenario building since participants are able to explore the best, most balanced means to reduce their barangay's vulnerability scores. In the process, they learn to recognize which components of vulnerability are shared and require coordinated action among neighboring barangays. Participants are also able to discern vulnerability components that are intrinsic to the environment or climate-driven. Thus, they are able to identify components that are urgent and must be addressed immediately from those they can only prepare for through a more long-term effort. Participants can also discern their own personal roles in contributing to, and addressing the vulnerabilities. Johnson and Marshall (1997) see such personal connection as crucial in effecting behavioral change.

In the I-C-SEA Change framework, sensitivity and exposure are not combined as "potential impact" (Allison et al. 2009), but are taken separately and given equal weight to LAC, which de-emphasizes the importance of adaptive capacity. Like the scoring system, this is consistent with the assumption that adaptive capacity cannot completely negate a high sensitivity or exposure score especially for immediate, short-term impacts of climate change. It also distinguishes sensitivity, which is essentially *the lack of resistance*, from LAC, which is the *lack of resilience*. Such a framework enables the tool to be particularly effective in identifying options for coping. Coping is short-term and immediate, motivated by crisis, and is oriented toward survival, while adaptation is more long-term and targets sustainable alternatives (Daze et al. 2009). Both are necessary to plan for, since the range of adaptation options is narrowed considerably when coping measures are not in place (see Engle et al. 2014). For example, acute impacts of climate change such as storm surges can result in many casualties and inflict considerable damage to structures such as coral reefs and sea walls whose rehabilitation will be costly and time consuming. However, a sequential coping-to-adaptation strategy could include the social preparation to facilitate pre-emptive evacuations (the coping measure), while roads and utilities are established in a safer location where the community may be permanently relocated (the adaptation measure). Such a strategy takes advantage of the opportunity to use a disaster or threat thereof to overcome social resistance in relocating human settlements since a designated evacuation area is already prepared as a potential permanent relocation site for a community. Rehabilitation is thus made less urgent and expensive.

I-C-SEA Change also aids stakeholders in realizing and understanding that coral, mangrove, and seagrass habitats sustain nearshore fisheries and ensure long-term coastal integrity and are thus valuable to livelihood and human settlements. Hence, the implicit value of these habitats and the ecosystem services they provide can be explicitly incorporated in the planning process vis-a-vis more typical responses involving infrastructure (e.g., seawalls and groynes) and rehabilitation over space and time. Ideally, costs of these are also built into decision-support tools following application of I-C-SEA Change and other VA tools in community settings.

The value of biodiversity conservation and habitat management can also be incorporated into the monitoring and evaluation process, when I-C-SEA-Change vulnerability is used as an appraisal of performance or effectiveness in implementing coping and adaptation strategies. I-C-SEA-Change can be a very versatile educational, communications, and evaluation tool when used in participatory settings. Organizations that use I-C-SEA Change with communities are encouraged to compile scores and outcomes of these meetings into case studies. These could then serve as bases for development of "rules of thumb" for assessments or best practices for other communities to adopt and emulate.

I-C-SEA Change satisfies most of the five criteria of Schröter et al. (2005) to guide VAs to help achieve the objective of informed decision making on adaptation options. First, I-C-SEA Change is based on varied knowledge incorporating indigenous, local knowledge, and experiences. Second, the approach used in I-C-SEA Change is place based, recognizing the boundaries of management without ignoring the multiple spatial and temporal scales of operation of natural processes. Third, I-C-SEA Change considers multiple and interacting drivers of climate change as well as local hazards such as tsunami risk. Fourth, the differential adaptive capacity of stakeholders is recognized in I-C-SEA Change and enhanced by having a common, participatory framework and collaborative discussions among stakeholders. However, the exposure scores of I-C-SEA Change are based on historical trends and not on prospective models. Thus, I-C-SEA Change does not completely satisfy the fifth criterion that recommends the use of both past trends and future projections. This shortcoming can be partially offset when I-C-SEA Change is used in well-planned "what-if" scenario-building. It should be reemphasized that I-C-SEA Change scores are meant to produce rankings and not knife-edge estimates of vulnerabilities of sites and their sources. Over interpretation of small differences in vulnerability scores should be avoided. Nonetheless, I-C-SEA Change can yield a good synoptic overview of patterns of vulnerability and their sources when the tool is applied consistently over several communities.

Exposure, sensitivity, and adaptive capacity are scale-dependent (Lioubimtseva 2015). However, downscaled, locally specific projections on future climate stressors are not yet available in most local settings (Romieu et al. 2010). Even if these projections were available, they cannot be fully utilized without adjustments to account for local, non-climate stressors associated with human activities (e.g., degradation of coastal habitats, land use and land-cover changes) that can magnify climate impacts (Fussel 2007; Romieu et al. 2010). The lack of adjustments, coupled with the limited data, expertise, time, and financial resources at the local level increases the long-term uncertainty of these projections. Thus, this situation favors stakeholder involvement from the onset and vulnerability-based approaches focused on short-term responses (Fussel 2007). I-C-SEA Change could serve as the preliminary adaptation assessment for the identification and prioritization of adaptation options (Fussel 2007). At the same time, I-C-SEA Change could be used in adaptation planning and disaster risk reduction since there are shared sensitivity and adaptive capacity measures for hazards such as tsunamis and storm surges, and marine flooding during storms and sea-level rise (see Romieu et al. 2010).

I-C-SEA Change will have limited impact though if its use is not embedded in a broader system that provides more detailed information and ensures that assessments are utilized in operational planning in disaster preparedness, resource management, economic development, and social programs of local and national governments, and relevant international agencies. I-C-SEA Change is one of the "Philippine Vulnerability Assessment Tools for Coastal Ecosystems" (see MERF 2013) mentioned on page 20 of the Local Early Adaptation Planning (LEAP) tool (U.S. Coral Triangle Initiative Support Program 2013) as an evolving case study.

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