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Indigenous People's Detection of Rapid Ecological Change

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Abstract: *When sudden catastrophic events occur, it becomes critical for coastal communities to detect and respond to environmental transformations because failure to do so may undermine overall ecosystem resilience and threaten people's livelihoods. We therefore asked how capable of detecting rapid ecological change following massive environmental disruptions local, indigenous people are. We assessed the direction and periodicity of experimental learning of people in the Western Solomon Islands after a tsunami in 2007. We compared the results of marine science surveys with local ecological knowledge of the benthos across 3 affected villages and 3 periods before and after the tsunami. We sought to determine how people recognize biophysical changes in the environment before and after catastrophic events such as earthquakes and tsunamis and whether people have the ability to detect ecological changes over short time scales or need longer time scales to recognize changes. Indigenous people were able to detect changes in the benthos over time. Detection levels differed between marine science surveys and local ecological knowledge sources over time, but overall patterns of statistically significant detection of change were evident for various habitats. Our findings have implications for marine conservation, coastal management policies, and disaster-relief efforts because when people are able to detect ecological changes, this, in turn, affects how they exploit and manage their marine resources.*

Keywords: benthos, ecological change, local knowledge, Solomon Islands, tsunami

Detección del Cambio Ecológico Rápido por la Población Indígena

Resumen: *Cuando ocurren eventos catastróficos repentinos, para las comunidades costeras se vuelve crítico detectar y responder a las transformaciones ambientales porque no hacerlo puede socavar la resiliencia general del ecosistema y amenazar el sustento de las personas. Por esto preguntamos qué tan capaz es la población indígena de detectar cambios ecológicos rápidos después de una disrupción ambiental masiva. Estudiamos la dirección y la periodicidad del aprendizaje experimental de las personas en las Islas Salomón occidentales después del tsunami de 2007. Comparamos los resultados de encuestas de ciencias marinas con el conocimiento ecológico local del bentos en tres aldeas afectadas y tres periodos antes y después del tsunami. Buscamos determinar cómo las personas reconocen cambios biofísicos en el ambiente antes y después de eventos catastróficos como los terremotos y los tsunamis y si las personas tienen la habilidad de detectar cambios ecológicos a lo largo de escalas cortas de tiempo o si necesitan una escala de tiempo mayor para reconocer los cambios. La población indígena pudo detectar cambios en el bentos a lo largo del tiempo. Los niveles de detección variaron entre las encuestas de ciencias marinas y las fuentes de conocimiento ecológico local en el tiempo, pero los patrones generales de la detección del cambio estadísticamente significativos fueron evidentes para varios hábitats. Nuestros hallazgos tienen implicaciones para la conservación marina, políticas de manejo de costas y esfuerzos de alivio de desastres pues la detección de cambios ecológicos afecta la forma en que las personas explotan y manejan los recursos marinos.*

Palabras Clave: bentos, cambio ecológico, conocimiento local, Islas Salomón, tsunami

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Introduction

Local and indigenous people's environmental knowledge can provide critical information about protracted climatic and ecological changes (Sagarin & Micheli 2001; Couzin 2007; Alexander et al. 2011; Huntington 2011). Little is known, however, about local and indigenous people's capacity to detect rapid ecological change following massive environmental disruption caused by extreme climatic or geological events. People's capacity to detect and respond to ecological change is fundamental to effective adaptation to the environment, and this ability is becoming increasingly important as Earth's climate and ecosystems undergo transformation (Burton et al. 1978; McClanahan & Cinner 2012). This capacity is also important for human exploitation of the environment (Winterhalder & Smith 2000) and fundamental for managing and conserving natural resources.

A number of authors, including ourselves (e.g., Aswani & Lauer 2006), advocate the use of local ecological knowledge (LEK) (also termed indigenous ecological knowledge) for assisting in the design of marine conservation programs (Johannes 1978; Hamilton & Walter 1999; Garcia-Qijano 2007), and case studies around the world have shown that LEK can be very helpful in this task (general reviews: Drew 2005; Cinner & Aswani 2007; Thornton & Scheer 2012). LEK has also proven valuable for detecting long-term ecological change (Laidler 2006; Lauer & Aswani 2010; Gearheard et al. 2011), albeit scant research has assessed the implications of rapid ecological transformations caused either by sudden climatic or geologically catastrophic events or direct human degradation on people's ability to understand and classify their surrounding environment subsequently. Naturally, the magnitude and periodicity of the disturbance will determine peoples capacity to detect change, and long-term changes, such as shifting baselines, are not always detected by all local residents, whereas acute and immediate disturbances are more likely to be noticed. In short, if local environmental knowledge is to be used successfully in the design of conservation programs, it is important to measure how local people account for environmental change. The use of knowledge that is no longer relevant or applicable due to undetected environmental permutations locally—while perhaps appropriate from the standpoint of participatory management and cultural sensitivity and equity—may lead to wrong conservation decisions (e.g., use of local knowledge to demarcate a locally recognized habitat that no longer exists).

The capacity to understand ecological change may also have implications for a society's ability to use resources sustainably, and therefore, possibly have an effect on social and ecological resilience. Current research suggests that social-ecological systems (SESs) are strongly coupled, highly complex, and evolving and that assessing variable levels of system resilience when under the stress—such as a tsunami—can help one understand change in human societies (Adger et al. 2005; Folke et al. 2005; Liu et al. 2007). Resilience emerges from social factors such as the sharing of knowledge, learning, cultural norms, economic strategies, regulatory enforcement, and ecological factors such as high biodiversity, greater abundance of key species, and a complete community structure (Hughes et al. 2003; Bellwood et al. 2004; Ostrom 2009). In fact, if the "ability to build and increase the capacity for learning and adaptation understanding" increases socio-ecological resilience (Resilience Alliance 2002), gauging how people perceive and adapt to ecological changes is fundamental. This is especially the case in localities susceptible to deteriorating coral reefs, rising sea levels, and increasingly unpredictable climatic and geological phenomena (Burton et al. 1978; Hughes et al. 2003).

We studied how an oceanic knowledge system accounts for rapid ecological change following a catastrophic event. We used a natural experiment to assess the periodicity of experimental learning (i.e., process of creating knowledge through experience and learning by doing [Berkes 2009]) when people face new or rapid transformations in their environment. We did not empirically assess the processes of knowledge building itself or sharing of information and learning for adapting by individuals in the affected communities. Rather, we measured whether people can detect across space and time environmental change following a catastrophic event. An earthquake measuring 8.1 struck 345 km northwest of the Solomon Islands' capital Honiara at 0740 local time on 2 April 2007. The earthquake created a tsunami that caused substantial damage in the Western Solomon Islands (Fig. 1) to both human and ecological communities. In addition to the tsunami effects, the earthquake caused substantial uplift of the landmass and adjacent marine areas, which caused a loss of habitat for species in productive fisheries—the basic source of household protein and income for the local communities (McAdoo et al. 2009).

Methods

We compared marine science surveys (MSSs) with LEK of the benthos across 3 affected villages and 3 periods. In a previous study, we asked indigenous people to identify marine abiotic and biotic substrates and related resident taxa in aerial photos. We then incorporated this information into a geographical information system (GIS) database, along with scuba survey data, to design a community-based marine protected area (Aswani & Lauer 2006). Given that we had pretsunami indigenous and scientific knowledge of marine abiotic and biotic substrates and related data on resident taxa in different areas in the Roviana and Vonavona lagoons, the sudden biological

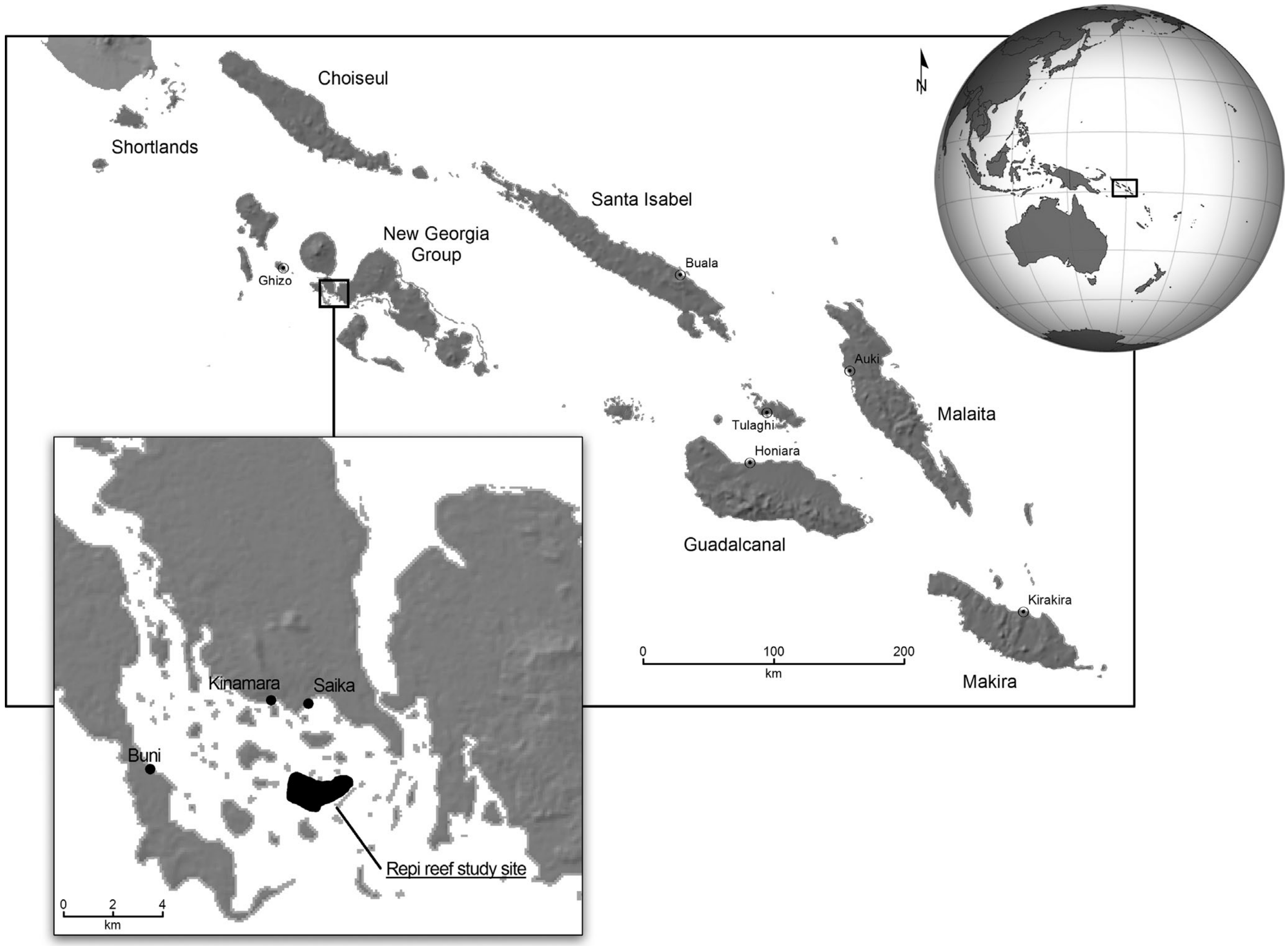

Figure 1. The Solomon Islands and study site in the Vonavona Lagoon.

and physical transformation of the seascape presented us with a unique natural experiment opportunity to examine the temporal dimensions of local peoples' change-detection skills.

We sought to determine how people recognize biophysical changes in the environment before and after catastrophic events such as earthquakes and tsunamis and whether people have the ability to detect ecological changes over short time scales or need longer time scales to recognize changes. We collected indigenous ecological knowledge and biophysical information from 3 affected villages (Buni, Kinamara, and Saika) in 2006 (before the tsunami), 2008 (after the tsunami), and 2010 in the Western Solomon Island (Fig. 1). The actual sampling for both data sets (MSS/LEK) took place in January 2006/January 2006, July 2008/January 2009, and March 2010/August 2010, respectively. The differences between target dates and actual sampling were a product of logistical difficulties, and this mismatch could have introduced error between local interpretation and the actual survey results. However, while there is some seasonal fluctuation in the abundance of seagrasses in the Western Solomon Islands (S. Albert, personal communication), the time gaps were unlikely to be adequate to alter which substrate was the dominant benthic surface due to local growth rates; therefore, these data can be useful for investigating ecological change from the tsunami and subsequent recovery.

To assess local understanding of rapid environmental change, we gathered current and retrospective ecological information through participatory image interpretation and compared it with MSSs. A digitally scanned and rectified color air photograph (1:25,000) taken over southern Vonavona lagoon on 2 September 1991 was used to create a map of the study site. This image was scanned at 600 dpi, and then georeferenced with ground control points. Control point data were taken with 2 Geoexplorer XT GPS receivers (rover and base data) to pinpoint rooftops, WWII wreckage, and other suitable features that could be identified on the image and on the ground. We performed differential correction on GPS data with Pathfinder Office version 2.9 to increase its spatial accuracy. The standard error associated with scanning, GPS measurements, and georeferencing was 5 m. All GIS analyses were conducted with ESRI ArcGIS 9.3. We created a poster-sized, laminated map so that local informants could visually interpret the image. The 253 ha study site was cropped from the georeferenced aerial photograph and printed on a large-format plotter, which produced a 61 × 122 cm hard-copy map at a scale of 1:3000 (1 cm on the map equaling about 50 m).

We used the large map as a visual tool to conduct participatory image interpretation exercises in each of the 3 study villages before the tsunami and twice after the tsunami. Ten seasoned fishers in each village, men and women (barring 1 village in which only 5 knowledgeable adults could participate), were selected via a purposive sample to be the photo interpreters. They were chosen on the basis of their knowledge of the marine environment and their overall fishing experience in the area. Although purposive selection of informants may have reduced variability and environmental uncertainty in responses, we decided to work with the most seasoned fishers available because we wanted to focus on the best available local expert knowledge and because of time constrains for sampling. We had the same seasoned fishers carry out the photo interpretation before and twice after the tsunami because they had paddled across or foraged in the area recurrently. During these focus-group exercises, we helped the seasoned fisher photo interpreters orient themselves to and gain the proper perspective of the aerial photo by encouraging them to recognize, identify, and name villages, islands, and other physical or cultural features on the map. Once the informants understood that the perspective of the image was from directly overhead, they were instructed to identify and discriminate particular marine areas (mangroves, seagrass, coral reefs, etc.) in the study area. We also asked them to provide information on habitat quality and resident marine species and their abundance (Aswani & Vaccaro 2008).

The same photo was used for all 3 periods because the map itself was used as a geospatial mnemonic devise. That is, it provided a canvas for people to demarcate benthic characteristics before and after the catastrophic event based on their recollection and ongoing experience of what was there. Informants therefore were not asked to identify possible changes visible in the image; rather, they were asked to use the image to recall benthic characteristics across different sites and spatial changes over time. Working as a group, the informants selected the most knowledgeable person and cooperatively drew the boundaries of abiotic and biotic substrates on the map with a felt-tip marker. The local informants spent 60–90 min performing their image interpretations. When their interpretations were completed, we photographed the map with a 5-megapixel digital camera set to its highest resolution. The digital photographs were georeferenced through image-to-image registration with the previously georeferenced air photograph, ensuring that the average RMS error was below 5 m. After georeferencing, the habitat boundaries drawn by the informants were traced using on-screen digitizing techniques that created polygons (shape files) of each of the benthic substrates.

Marine field surveys were conducted to test the correspondence between indigenous photo interpretation of major benthic features and the actual distribution of abiotic and biotic substrates before and after the tsunami. We selected sample sites by creating a sampling grid in the GIS that established points every 60 m. This resulted in 982 sampling points across the 253 ha study site. The geographic coordinates of each sample site were then loaded into a Trimble Geoexplorer XT GPS receiver. Using the GPS receiver, a researcher and 2 Roviana divers navigated to each of the predetermined field site locations and assessed the underwater habitats. At each site, a 1 × 1 m PVC frame was lowered onto the seabed and categories of substrate and dominant benthic characteristics defined by informants were recorded. If the sampled area had a mix of different attributes, the primary (dominant), secondary, or tertiary types were recorded. Depth soundings were also taken with a Speedtech 400-kHz, handheld depth sounder. Other observations included time of day, weather (sunny, partly cloudy, cloudy, or overcast, rainy), and vertical underwater visibility.

To compare the marine survey with the indigenous photo interpretations, we used GIS to spatially display the substrate data collected in the MSS as 1 layer (points and their attributes) and the layers (polygons and their attributes) created with the information provided by the indigenous photo interpreters as another layer. Then, we ran spatial queries that selected all the points from the MSS layer found within each polygon of the indigenously defined dominant benthic attributes. The queries allowed us to add an attribute column to the benthic data set indicating which indigenously defined benthic types were associated with each survey site. This served as the basis for measuring the correspondence between local aerial photo interpretations of benthic types and marine survey results.

Thereafter, data were tabulated and culled such that only sites with complete data from scientific surveys, Buni, Kinamara, and Saika sources were included for statistical analyses ($N = 982$). This culling fostered validity by ensuring that each comparison was made using the same sample size representing the exact same sites, with no unbalanced comparisons that might bias results and interpretation. Data were coded for the presence (1) or absence (0) of benthic substrates. Although multiple responses were given, only the first response was included, representing the more prevalent benthic surface at that location. Initially, responses were coded in the indigenous language (82 unique responses across villages), and then translated into 10 corresponding broader categories (branching coral, dead coral, submassive coral, short grass, long grass, microalgae, sand, silt, sand and silt, and new reef). These data were reduced to the following categories for statistical analyses: grasses, sand and silt, coral, and a miscellaneous category for sparse responses. Agreement between sources was determined by calculating percent agreement, chance-corrected percent agreement (Cohen's kappa), and by using the allocation and quantity disagreement statistics of Pontius (Pontius & Millones 2011). Grasses, sand and silt, and coral data were analyzed in parallel.

Measuring sensitivity of changes over time was assessed by comparing MSS and LEK data from 2006 with data from 2008, representing measures taken before and after the tsunami of April 2007. Then, the MSS and LEK 2008 data were compared with 2010 data to assess changes in benthic surface as the region recovered from the tsunami. Buni, Kinamara, and Saika data were combined for comparison with the marine survey data. Results are presented as the percent presence of grasses, sand and silt, and coral, change over time (delta), and statistical significance of the change (p). For these analyses, the McNemar's test for correlated proportions was used to detect significant changes over time within sources. The threshold for statistical significance was set at $p < 0.05$. No correction was made for multiple comparisons because the goal of the analysis was to assess 4 sources of data for similarities or differences in patterns of change from before the tsunami (2006) to after the tsunami (2008), and then to benthic recovery following the tsunami (2010). That is, no specific statistical comparison was used to directly test a specific hypothesis; rather, the systematic pattern of directional changes across sources was used to test the overall hypothesis that indigenous populations are sensitive to changes in benthic surfaces.

Results

Detection levels differed between MSSs and LEK sources over time, but overall patterns of statistically significant detection of change were evident for seagrass and for sand and silt. Coral data failed to support the hypothesis that indigenous populations are sensitive to changes in benthic surfaces, possibly due to the paucity of sites where coral was the predominant benthic substrate.

Nineteen percent of overall responses identified seagrass as the dominant benthic substrate. MSSs and LEK showed good agreement in the direction and magnitude of seagrass decline from 2006 to 2008 and subsequent increase from 2008 to 2010 (Table 1). Following the tsunami, MSS seagrass declined 18% (from 40% to 20%) and LEK seagrass declined 14% (from 19% to 5%) ($p < 0.001$). Then, during recovery from 2008 to 2010, MSS seagrass increased 16% (to 38%) and LEK seagrass increased 13% (to 18%) ($p < 0.001$).

Sand and silt was the most common benthic substrate (75% of responses) and identification of MSS and LEK sand and slit also showed good agreement in the direction and magnitude of change from 2006 to 2008 and subsequently 2008 to 2010 (Table 1). Following the tsunami, MSS sand and silt increased 20% (from 54% to 74%) and LEK sand and silt increased 12% (from 73% to 85%) ($p < 0.001$). During recovery from 2008 to 2010, MSS sand and silt decreased 20% (to 54%) and LEK sand and silt decreased 9% (to 76%) ($p < 0.001$).

At 6% of responses in the study, coral was the rarest of the benthic substrates and had no clear pattern over time (Table 1). The high agreement with MSS (>90% across years) reflected the paucity of coral. That is, the high agreement largely reflected frequent agreement that coral was not present.

Overall, quantity disagreement between MSS and LEK for seagrass and for sand and silt was similar in each period (approximately 20%). Regardless of source (MSS or LEK), the same pattern was visually evident: The tsunami brought sand and silt that covered seagrasses (2006–2008), and then seagrasses recovered (2008–2010) (Figs. 2a and b). Coral demonstrated no clear pattern over time (Fig. 2c).

Discussion

Our results suggest that indigenous people detect changes in benthic surfaces over time. The MSS and LEK sources showed good agreement in detecting the significant increase in sand and silt and the concomitant decrease in seagrass following the tsunami (2008 compared to 2006) and the increase of seagrass and the decrease of sand and silt as the benthic surface recovered following the tsunami (2010 compared to 2008). Coral data showed high agreement between sources but no clear pattern across time, possibly because coral were rarely the predominant benthic substrate.

Although the detections of tsunami-related change in grasses and sand and silt across time were identical in direction and similar in magnitude across MSS and LEK sources, there was a consistent systematic offset between data sources across the study that requires explanation and could be due to vantage differences in MSS and LEK measurement and coding techniques. The most likely explanation is that some light colored grasses are more easily detected by MSS divers who saw the surface up close, compared with LEK that largely comes from the vantage of the fishing canoe.

The MSS divers recorded seagrasses of all types as "seagrass" patches. In Roviana, seagrass beds are among the most widespread habitat and are distinguished locally by those occurring in very shallow waters ranging from 0.5 to 2 and those existing from 2 to 10 m in depth. The former are recognized as *kuli*, or beds dominated

Table 1. Changes in percent cover over time as detected by marine science survey (MSS) and local ecological knowledge (LEK) sources in seagrass, sand and silt, and coral.[a]

Source	*Unit of measure*	*2006*	*Year 2008*	*2010*
MSS seagrass	percent cover	40	21	38
	Delta (%)		−18	16
	McNemar		<0.001	<0.001
LEK seagrass	percent cover	19	5	18
	Delta (%)		−14	13
	McNemar		<0.001	<0.001
Agreement	percent	76	77	66
	allocation disagreement	4	7	14
	quantity disagreement	20	16	20
	Kappa	0.45	0.05	0.19
MSS sand or silt	percent cover	54	74	54
	Delta (%)		20	−20
	McNemar		<0.001	<0.001
LEK sand or silt	percent cover	73	85	76
	Delta (%)		12	−9%
	McNemar		<0.001	<0.001
Agreement	percent	72	67	59
	allocation disagreement	10	22	18
	quantity disagreement	19	11	22
	Kappa	0.41	0.00	0.15
MSS coral	percent cover	5	4	5
	Delta (%)		−1	2
	McNemar		0.148	0.077
LEK coral	percent cover	5	8	5
	Delta (%)		3	−3
	McNemar		<0.001	<0.001
Agreement	percent	92	91	94
	allocation disagreement	8	4	6
	quantity disagreement	0	4	0
	Kappa	0.14	0.21	0.36

[a] *Key: % delta, percent change from the previous time period; McNemar, statistical significance of a change over time; agreement, percentage of locations where both science and local knowledge sources agreed that a given feature was the predominant benthic substrate; quantity disagreement, disagreement between science and local knowledge in the percentage of sites where a benthic feature was the predominant substrate; allocation disagreement, disagreement between science and local knowledge sources in the location of benthic features; agreement + quantity disagreement + allocation disagreement = 100%; kappa (Cohen's Kappa), measured proportion of agreement above chance agreement.*

by *Enhalus acoroides*, which have long blades, occur predominantly in muddy substrates, and produce very dark patches as seen from the surface in the lagoon. Kuli ngongoto is a generic category that includes a number of Cymodoceaceae and Hydrocharitaceae seagrass species, which tend to have a smaller blade, co-occur with *Halimeda* spp. and other macroalgae, occupy areas of fine silt mixed with sand and coral rubble (with some dead and living massive and submassive coral colonies scattered throughout), and produce lighter patches as seen from the surface of the lagoon. It is possible that many areas recorded as seagrass by the scientific survey divers were categorized as sand and silt by the indigenous informants because most photo interpreters are not spearfishers who dive and the lighter patches formed by these seagrasses could easily be seen from the surface as sand and silt. This explanation could account for the consistent offset in the relative amounts of grass and sand and silt categorizations between sources and for the unmistakable parallelism in the changes over time measured from MSS and LEK. To avoid these types of potential problems, we suggest that future researchers standardize the categories of scientific monitors and local informants.

An alternative explanation is that the differences between target dates and actual sampling introduced some error between local interpretation and the survey results. However, this is unlikely because even if some seasonal fluctuations in the abundance of seagrasses in the Western Solomon Islands occur (S. Albert, personal communication), LEK sources (Kida Village local informants) said that the time gaps were not large enough to make much difference in local rates of ecological recovery and growth. Further, this explanation cannot account for the strong consistency in results of changes across time measured by MSS and LEK for grass and for sand and silt. That is, sampling error is an unlikely explanation because offset between data sources was consistent across 3 sampling years and the overall pattern of change over time was consistent for MSS and LEK.

Our results have several practical implications for future LEK studies and their use in environmental conservation. First, studies of the preservation and documentation

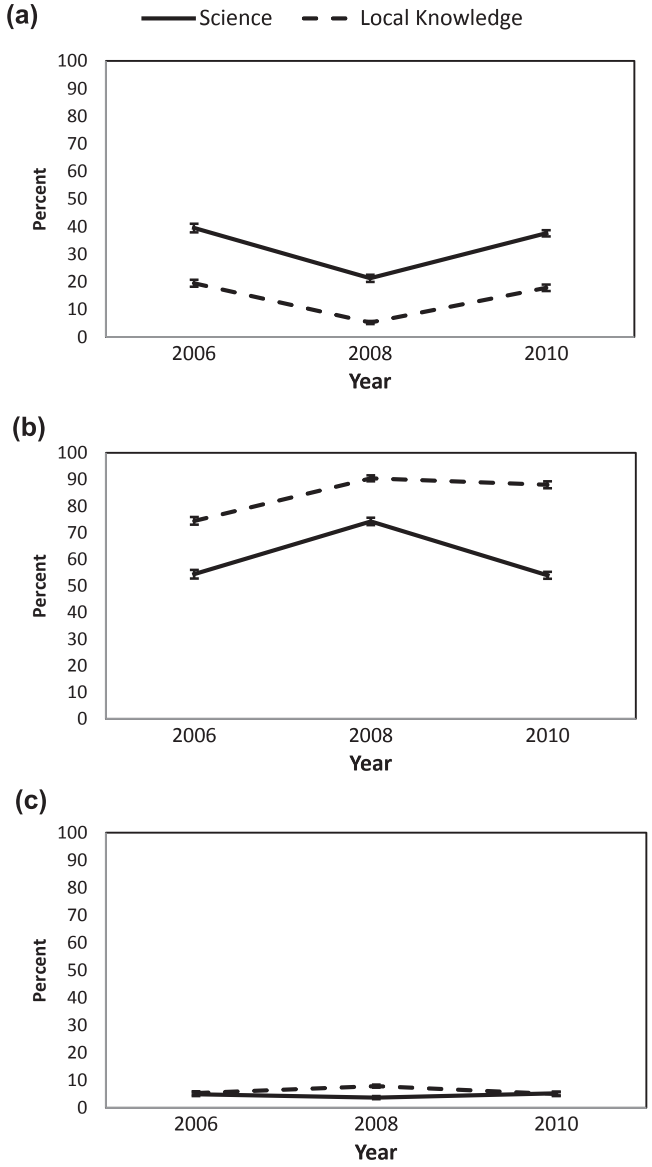

Figure 2. Mean (SE) percent change in (a) seagrasses, (b) sand or silt, and (c) coral over time on the basis of scientific survey and local knowledge. Values represent the percentage of sites (n = 982) cited as the predominant benthic substrate.

of indigenous ecological knowledge regarding resource characteristics, location, and use need to account for the capacity of local populations to detect and respond to environmental feedbacks. LEK is not only an intergenerational transfer of cognitive information that is set spatiotemporally, but is also one that is regenerated within the context of people's practical engagement with, experience of, and performance of productive activities in a dynamic and changing local environment (Ingold 1993; Lauer & Aswani 2009). In this process of regeneration, new knowledge and practices can emerge in response to specific ecological changes. Thus, to understand how knowledge systems change, future research will have to give more attention to the fine-grained processes involved in the practice-oriented acquisition and application of knowledge as people face a changing environment (Burton et al. 1978; Berkes 2008, 2009).

Second, conservation practitioners need to have a clear understanding of the variability in accuracy of local environmental knowledge of long-lasting or sudden changes (McClanahan et al. 2008). Local people were sensitive to change across time; therefore, use of local knowledge can be a suitable strategy for participatory and adaptive management decisions. For instance, not only are grassbeds important nursery sites (ecosystem function), but they are also a key habitat for endangered species. In the Roviana and Vonavona lagoons, seagrass beds are among the most widespread benthic cover and are dominated by a number of Cymodoceaceae and Hydrocharitaceae seagrass species and *Halimeda* spp. and other macroalgae are also common. Hawksbill (*Eretmochelys imbricata*) and green (*Chelonia mydas*) turtles are commonly speared during nocturnal high tides while feeding on seagrasses, and occasionally dugong (*Dugong dugon*) are seen foraging here (Aswani & Vaccaro 2008). Thus, seagrass beds are of prime conservation interest. In our case, relaying on local knowledge to demarcate seagrass beds following a transformative event resulted in good zonation and benthic cover representation choices (Aswani & Ruddle 2013). Nonetheless, caution should be exercised when using local environmental knowledge to design conservation programs because, unless empirically assessed, surveyed communities may be slow to detect the magnitude of change, and this time lag could influence efforts to map existing natural variability in the present and over time, which is a crucial consideration for designing successful resource management programs.

Third, there is increasing recognition of the role of LEK in disaster-risk reduction (McAdoo et al. 2009; Gelcich et al. 2010; Mercer et al. 2010), but little is known of LEK's role in postdisaster adaptation and the ensuing environmental use and management. Our results show that general environmental trends were understood locally following the tsunami. This potentially made people more resilient nutritionally and economically (because species assemblages are associated with specific sites and habitats during foraging) during the postdisaster adaptation period. This kind of knowledge needs to be considered in disaster relief programs that try to minimize vulnerability in coastal communities following a natural hazard.

Finally, our results may have some implications for resilience in coastal social and ecological communities. For instance, the large inner lagoon seagrass beds and the shallow coral reef are critical for protecting vulnerable life-history stages of many heavily exploited coral reef fishes. The larvae of these fish predominantly settle out of the plankton into shallow water biotopes of high structural complexity, such as mangroves and seagrass beds (Nagelkerken et al. 2000). The importance of the nursery function of the lagoon for coral reef fish species in this region can be deduced from the high densities of juveniles in the inner lagoon in contrast to the complete absence of juveniles on outer lagoon coral reefs. Hamilton (2003) documented this in the Roviana and Vonavona region for *Bolbometopon muricatum* and *Cheilinus undulatus*, and other authors have documented the importance of inner lagoon habitats such as grassbeds for various threatened coral reef fishes (Nagelkerken et al. 2000). If nursery areas were affected by the tsunami, which they seem to have been, it is not unreasonable to suggest that given the connectivity of inner lagoon habitats and coral reefs (A. Olds et al., in press), the tsunami could have had an effect on adjacent coral reef fisheries via decreased rates of juvenile recruitment, which would likely affect people's livelihoods.

Time allocation and creel survey data for this region suggest that seagrass beds and adjacent shallow coral reefs are very productive and heavily exploited by local fishers. A foraging analysis of Vonavona Lagoon communities conducted in 1995 and encompassing around 200 fishing trips (of which 67% were recorded for the inner lagoon) showed that the overall mean net return rate for fishing in inner lagoon reefs is around 1500 kcal per hour of fishing. When seagrass beds were sorted separately, the return rate is over 3000 kcal per hour (because of netting vs. line fishing) or twice the amount for all inner lagoon habitats put together (S. Aswani, unpublished data). Clearly, inner lagoon areas, including seagrass beds, were fundamental for the food security of Vonavona inhabitants at the time. Although we do not have catch data for the post-tsunami period (2007 onward), anecdotal evidence and current research on local perceptions regarding environmental change suggest the importance of these habitats and that one of the greatest changes noticed by people is a general decrease of fish. In the Kinda community, for instance, a large number of households believe the tsunami was one of the main causes of the general decrease in fish abundance (S.A. & K.A., unpublished data).

Having good rules of thumb regarding the actual location of prime fishing areas could result in fishing success and therefore livelihood security and overall socioecological resilience. Although the link between our data and a maintenance or increase in people's resilience is tenuous, it is not unreasonable to suggest that the success in detecting and responding to ecological changes caused by protracted or sudden events increases overall resilience and reduces vulnerability of coastal communities. Addressing perceptiveness of environmental change is important because the ways in which individuals detect and respond to ecological change shapes how information feeds back into the SES, and this feedback affects people's livelihoods and resource governance systems as they adapt to new circumstances. Building resilience in coastal SESs (traditional or otherwise) requires a capacity for learning, which, in turn, enhances adaptive responses and the capacity of communities to react to rapid ecological change.

We did not empirically assess the processes of knowledge building itself or sharing of information and learning for adapting by individuals in the affected communities, and hence can only make hypothetical connections between our data and vulnerability and resilience of Solomon Islands coastal communities. Nevertheless, what we did measure, directionality of change detection following a catastrophic event, can be reasonably used as a proxy to understand human responsiveness and adaptive capacity to environmental change. The capacity of people to perceive change has implications for how knowledge systems mediate between marine ecosystems and human communities, and this capacity may enhance resilience and reduce vulnerability following a catastrophic event.

The importance of learning as a component of adaptive capacity is known (e.g., Berkes et al. 2003; Hughes et al. 2003; Allenby & Fink 2005); thus, it is crucial for future socioecological research—regardless of the relative importance of other variables that affect human–environmental interactions (Ostrom 2009)—to measure empirically people's capacity to perceive and analyze abrupt environmental changes and to act upon their assessments. This understanding is fundamental for gauging how individuals and society cope with environmental challenges, whether these are self-inflicted or caused by random events (Kirch 2005). The failure to detect, understand, interpret, and respond to change undermines resilience and exacerbates vulnerability to ecological transformations because people need to identify and manage resources (for food and exchange) across space and time. Measuring this capacity in the future will be essential for building heuristic models of feedback loops in SESs. This theoretical and practical link needs further exploration in socioecological research if one is to build an understanding of how humans adapt to a changing environment. This knowledge is also critical for the design and implementation of conservation programs that build local resilience to climate and environmental change.

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