Mangroves mitigate tsunami damage: A further response

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Short Communication

Mangroves mitigate tsunami damage: A further response

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Abstract

This is a contribution to the discussion on the potential mitigating effect of mangroves to tsunami damage. Kathiresan and Rajendran (2005) were criticised by Kerr et al. (2006). We re-analysed of the original data with an ANOVA-model with covariates. We conclude: (a) the original conclusion of Kathiresan and Rajendran (2005) holds, mortality and property loss were less behind mangroves, and literature suggests that this can be generalised beyond the investigated area; (b) relocation of human settlements 1 km inland is not practical, instead a combination of societal preparedness with early warning and disaster response systems is to be preferred. Furthermore, we deduce that mortality was most strongly, and significantly reduced with increasing elevation above mean sea level, whereas property loss was governed by distance to the shore. This could improve coastal risk assessments.

Keywords: mangroves; tsunami; coastal protection; risk assessment; erosion; sea level rise

The recent paper by Kathiresan and Rajendran (2005) has received criticism by Kerr et al. (2006). We partly disagree with Kerr et al. (2006) and will explain so below. We similarly carried out a re-analysis of the original data provided by Kathiresan and Rajendran (2005) and then expand the discussion to address the following two questions: (a) does the conclusion of Kathiresan and Rajendran (2005) hold and is it generalisable? and (b) is their deduction for coastal zone management practical that ‘‘human inhabitation should be encouraged more than 1 km from the shoreline in elevated places, behind dense mangroves and or other coastal vegetation’’? We agree with all others that the findings of Kathiresan and Rajendran (2005) are potentially important and implementation could save future lives.

Kerr et al. (2006) had four points of criticism, summarised here as (1) ‘‘can a regression equation be used to assign functional dependency between large-scale physiographic variables such as topography … (and) human deaths?’’ (2) The data are not normally distributed. (3) The authors have failed to account for covariation among independent variables. (4) Spatial correlation among dependents and/or independents may have confounded the conclusions.

We are not sure whether we have interpreted the first point of criticism correctly, but the straightforward assignment of a functional relation ‘‘mitigating effect of mangroves on human lives’’ from a pattern with a probability in the observations presented may seem not formally correct in a Popperian sense, but may still be highly probable in a Bayesian sense. After all, coastal defence schemes across the world are based on estimates of risk (e.g. Nicholls and Klein, 2005). We also disagree with Kerr et al. (2006) on their second point. Their test on the deviation from normality has a significance of only $p = 0.089$. Transformation therefore does not appear crucial and may not even have affected the power of a test quite strongly. The fourth point is addressed by Kerr et al. (2006) themselves: spatial autocorrelation was weak at most and only so for wealth loss.

We fully concur with the third point of criticism. Potential covariance in multivariate data sets cannot be ignored, and, may well be used instructively and powerfully to distribute the observed variability over meaningful components. Here,

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Table 1
ANOVA of casualties per 1000 and per capita loss of wealth (2005 US$) in hamlets associated with three coastal types and using distance to the coast and elevation above mean sea level as covariates. Type III sums of squares were used. Data obtained from Table 1 in Kathiresan and Rajendran (2005). Coastal types were sandy beach, dune, and mangrove. Incorporation of dunes ($n = 2$) into sandy beach ($n = 10$) did not change levels of significance or explained variances

	d.f.	Casualties		Wealth loss	
		SS	*p*	SS	*p*
Distance from sea	1	642	0.233	517569	0.006
Elevation above mean sea level	1	5854	0.002	1188	0.879
Coastal type	2	31922	<0.001	1503823	0.001
Error	13	5346		637382	
Explained variance (%)		87		81	

however we disagree with Kerr et al. (2006) on the choice of a statistical approach. In our view, the question is whether loss of lives or property is affected by presence of mangroves or other coastal vegetation when correcting for the potential effects of distance from the shore or elevation above sea level. This to us suggests the use of an ANOVA with distance and elevation as covariates, instead of stepwise multiple regressions. We carried out such a series of ANOVAs for loss of lives and loss of wealth against type of coast (beach, dunes or mangroves, respectively $n = 10$, 2 and 6 hamlets). We could do so because Kathiresan and Rajendran (2005) report their data in full detail. Since the number of hamlets in a dune setting is limited, we also carried out an analysis where these were pooled into the type 'beach' but this did not alter the pattern. Clearly, the coastal setting had a significant effect on both loss of lives and loss of property (Table 1). Loss of lives and wealth was higher in the hamlets that had no mangroves, over and above the effect of distance from the sea or elevation above sea level. Another remarkable pattern emerges from this analysis: loss of lives was significantly affected by elevation above sea level but not distance, whereas loss of property correlated significantly with distance from the sea only. The latter is confirmed by the regressions of Kerr et al. (2006), but the former is not, probably because villages associated with mangroves also were farther from the sea (respectively 0.3 ± 0.1 km for beach villages and 1.7 ± 0.4 km for mangrove villages, *t*-test: $p = 0.014$), a feature better addressed by our analysis. Support for this apparent contrasting 6w?>pattern between loss of lives and loss of property comes from the observation that these two did not covary significantly ($p = 0.054$, $r^2 = 0.21$). We did not include the feature 'area of coastal vegetation' in our analysis, since it is confounded by distance to the coast and by being higher for mangrove coasts. Finally, we inspected whether a nonlinear transformation would improve the power of our analyses, as both casualties incurred and loss of property appear to decline exponentially with elevation and distance, respectively (Fig. 1). The explained variance of the nonlinear models was not significantly higher than that of linear models (*F*-ratio's of r^2 values respectively: property $0.59/0.41 = 1.4$, $p = 0.22$; and casualties $0.42/0.40 = 1.1$, $p = 0.48$).

We can only speculate why loss of lives is reduced so much with elevation but property loss with distance. Possibly, the risk of being drowned is associated with the depth of the incoming wave, whereas the destructive force of that wave to property reduced with increasing distance travelled inland.

We now return to our two main questions. Firstly, we do argue that the main conclusion of Kathiresan and Rajendran (2005) holds but these authors should have done a more careful analysis. Our present analysis suggests that indeed less lives and less property have been lost from hamlets in the shelter of mangrove stands, also when we correct for distance from the sea and elevation. We thus generalise that mangroves mitigate rare, incidental but major tsunami effects (see also Dahdou-Guebas et al., 2005; Danielsen et al., 2005) but clearly reduce continuous coastal erosion as well (Mazda et al., 1997; Winterwerp et al., 2005; Thampanya et al., in press). We do not agree with Kerr et al. (2006) that the pertinent question is how much protection can be expected from a particular type of coastal vegetation. That is a matter of specific local

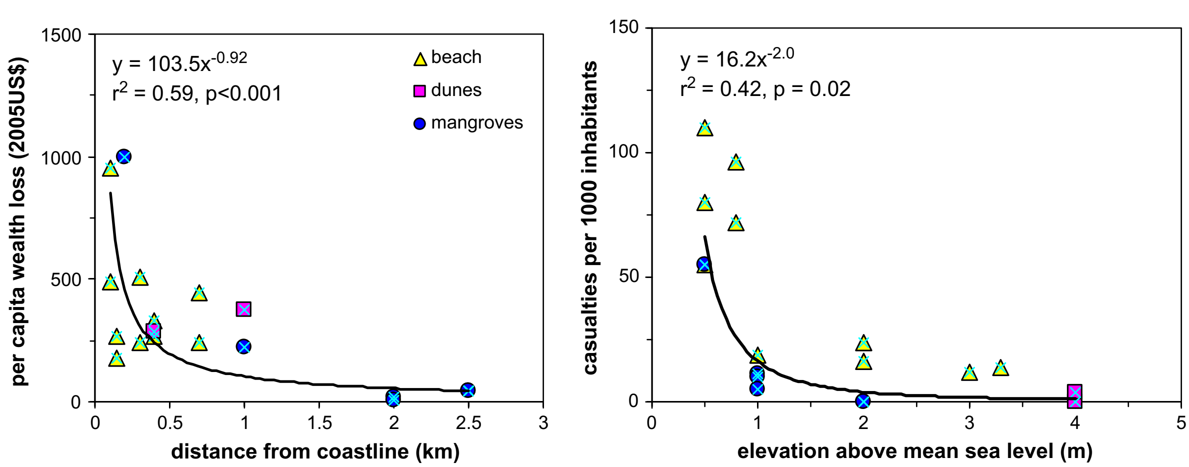

Fig. 1. Property loss (per capita 2005 US$, left) and mortality (lives lost per 1000, right) in 18 hamlets on the coast of Tamil Nadu as a function of distance from the shore (km) and elevation above mean sea level (m), respectively. Different symbols depict different coastal types. The fitted curve is to the pooled data set of 18 hamlets. Data from Kathiresan and Rajendran (2005).

conditions and practical guidelines (see, e.g. http://www.noaa.gov/tsunamis). This makes us turn to the second issue of the practicality of forcing coastal populations back 1 km from the shoreline. Firstly, also Danielsen et al. (2005) show that most coastal villages are very close to the coastline, which probably is a general pattern along the Indian Ocean and elsewhere since much of the coastal population is engaged in fisheries and related subsistence activities. Secondly, permanently settling more inland would mean a burden for coastal people by increasing travelling time to sea, and thirdly, it remains to be seen whether such land suitable for settlements is available. Rather, it seems useful to foster societal preparedness including early-warning and disaster response systems such as existing networks of typhoon refuges (cf. Thomalla et al., 2006). Finally, we would like to make a plea for the continued use of simple topographic features such as distance to sea and elevation because they are both understandable for the general public and readily applicable in vulnerability assessments (e.g. McFadden et al., in press).

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