

Response to Reviewer Comments

Natural Hazards and Earth System Sciences (NHESS)

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Human-Centred Design approaches to Tsunami Mitigation under Sea Level Rise in Kesennuma, Japan

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We thank the reviewer for their continued engagement with the manuscript, and we have addressed each remaining point carefully in the revisions below.

Comment 1: Relative Risk Framing and Figure 12

"In the first reviewer comment, I strongly suggested to remove absolute estimates of fatalities, and this is still my position. On the other hand, I the changes and clarifications performed in the revision has helped, but the changes are not sufficient yet. First, the authors should also clarify that they use of relative risk measures in their analysis in the introduction section to conclude on the effect of their countermeasures. Second, the assumptions and uncertainties related to the fatality model should be emphasized more. I.e. assumptions behind table 2 should be elaborated in the text. Moreover, the relationship to the derivation of the fatality models to the exposure data should be described in detail (i.e. what exposure are used to derive the fatality ratios in the empirical data, the people present during impact or the people living in the area). Third, and most importantly, since the results should focus on the relative differences before and after the countermeasures, only the results in relative measures should be presented (compared to no countermeasure) in Figure 12 (i.e. relative change in fatalities), in this way the results could be interpreted as more neutral to the fatality model assumptions. In other words, Figure 12 needs to be changed to present relative measures."

Response to Comment 1:

We thank the reviewer for these further points. We have added a sentence to the objectives paragraph of the introduction stating explicitly that we use fatality, inundation, and economic loss results throughout as relative measures of protective performance and draw our conclusions on countermeasure effect from these relative comparisons rather than from absolute predictions of real-world outcomes.

We have also elaborated on the assumptions underlying Table 2 in Section 3.4.2, stating that the depth thresholds assume a uniform fatality probability within each depth band and do not account for velocity, debris loading, or building type. We have clarified the exposure basis of the empirical fatality ratios, stating that they were derived using residential population counts, that is, people living in the area rather than people present at the moment of impact, consistent with the census-based population data used in this study.

Figure 12 has been redrawn to present the percentage reduction in fatality rate relative to the no-defence baseline, for both Kesennuma and Karakuwa. The revised figure shows that Defence 2 and Defence 3's performance against the no-defence baseline continues to improve as SLR increases, while Defence 1's performance falls sharply under late-century, high-emission scenarios. We have updated the corresponding text in Section 4.3 and the figure caption to reflect this change.

Comment 3: No Countermeasure Baseline

"Thanks for including this, I believe it greatly improves the paper! On the other hand, I could not find any discussion related to this comparison. In fact, for some risk measures (economic loss) the barriers seem to reduce significantly the risk, whereas the risk reduction towards fatalities are much less pronounced. This difference was not so visible when the benchmark was only the present coastal protection. I believe that this could be discussed more and might an important for discussing how effective these physical protection measures are for saving lives in acute situations."

Response to Comment 3:

We agree this contrast warranted discussion. We have added a paragraph to Section 5 explaining that the reduction in fatalities relative to the no-defence baseline is comparatively small because fatality estimation is population-weighted, whereas economic loss is not. Defences 2 and 3 achieve their largest decrease in inundation extent in the port district and industrial areas, where resident population is minimal, in contrast to the substantial fall in economic loss achieved in the same areas. We note that fatality ratios are inherently a function of the population present within an area, and that residential fatalities during the 2011 GEJE were concentrated within populated inland areas rather than in commercial or industrial zones, citing Latcharote et al. (2018) and Suppasri et al. (2016b) in support of this explanation.

We have also added discussion directly addressing the reviewer's point on life-safety effectiveness, noting that physical defences alone provide a less direct route to improving life safety than to reducing economic loss, consistent with existing evidence that hard structural measures are less effective at reducing loss of life than at reducing physical damage (Takabatake et al., 2020). We state that this study cannot determine whether closing this gap would be better achieved through further structural investment or through non-structural measures such as evacuation planning and early warning, since the fatality model used here does not capture evacuation, warning status, or behavioural factors known to significantly influence real-world outcomes (Suppasri et al., 2016b; Latcharote et al., 2018).

Comment 4: Scope

"I would like to thank the authors for greatly improving the introduction and also for deleting section 2.3. However, in this paper (contrary to the preceding paper by Leggett et al., 2025), the objectives of the paper is still relatively classical in the sense that the authors mainly explore how physical protection mechanisms reduces physical risk (economic, mortality), rather than

exploring community response and HCD. The focus on HCD is partly misleading to this end as this paper is mostly exploring a numerical exercise on reducing losses, so I still think this is not clear enough from reading the introduction, and I would suggest that the authors elaborate a little more on the technical scope in the introduction."

Response to Comment 4:

We agree that the technical scope of the study needed to be stated more directly. We have added a sentence to the end of the objectives paragraph in the introduction clarifying that this study is fundamentally a numerical performance assessment, that HCD is used to generate the design inputs for the three defence configurations, and that the evaluation itself is conducted entirely through hydrodynamic modelling of their physical and economic outcomes.

Comment 5: Laboratory Testing

"Thanks for reading including a short discussion on this. However, it would be great if the authors could also cite possible existing work on this topic, if available."

Response to Comment 5:

We thank the reviewer for this suggestion. We have added a sentence to our existing discussion of laboratory testing, citing physical testing of comparable hybrid tsunami defence configurations, including flume experiments on embankment-vegetation systems (Zaha et al., 2019) and tsunami overflow tests on reinforced mound breakwaters (Sajan et al., 2025), noting that these findings support the feasibility of empirical validation for the defences proposed in this study.

Line by line comments

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"Please add references to SRL studies such as Li et al. (2018), Dura et al. (2021), Sepúlveda et al., (2021). I could not find that these papers, that I believe are central in the tsunami literature for SRL hazard, were cited. Please include citations to them."

Response

We apologise for this oversight in the previous revision. Li et al. (2018), Dura et al. (2021), and Sepúlveda et al. (2021) have now been added to the citation cluster in the introduction alongside Koyano et al. (2022) and Chua et al. (2024), and the corresponding references have been added to the bibliography.

We hope the revised manuscript and responses above adequately address the reviewer's remaining concerns, and that the manuscript is now suitable for publication in NHESS.

Kind regards,
Hayley Leggett, on behalf of all authors.