School of Earth Sciences
McCoy Building
The University of Melbourne,
Victoria 3010, Australia

9 Feb. 20

Dear Editor,

<u>Re: Reid et al. : A new method for calibrating marine biota living-depth using the 2016 Kaikōura Earthquake uplift</u>

Thank you for the opportunity to comment on this manuscript. The authors have developed a method of using tide tables and ecological understanding of tidal biozones to determine coseismic surface uplift from the elevation of stranded algal anchors. They present these results alongside biological estimates underpinned by a tide gauge calibration, and compare the results of all with the vertical component of differential lidar and locally a strong motion sensor. Their short discussion summarizes the results and discusses the systematic deviation from the Lidar measurements.

The method is novel and but the paper unfortunately lacks punch in the discussion, which goes nowhere really. The first two paragraphs are basically a summary and the third paragraph discussion of systematic deviation from Lidar measurements of uplift (figure 5b) and what they mean for the calibration is limited to invoking fluctuations. If the fluctuations are on the order of minutes, and the tide level was measured repeatedly at a site, can the consistent high estimates be put down to fluctuations? At line 427 (While the influence…) they say that fluctuations in the tide are mitigated by using tide gauge, but surely the estimates there were obtained using the various correction factors and local sea level measurements. My reading is that the tide gauge was only used to establish the correction, and not thereafter.

Intuitively, one would expect the RTK-tide gauge correction to be the most robust. That is borne out by the RTK-tide gauge correction around the tide gauge, which was within plus/minus 7 cm of correct while tide table corrected results varied more widely. At other sites (e.g. Paia point) each group of individual assessments are within 5% of each other but there can be 20% discrepancy from one group to the next, and with respect to the Lidar estimate. It seems to me as though the correction is reasonably precise (suggesting that the underlying concept is robust) but also quite inaccurate.

If I was a coastal ecologist I would be interested in that. Obviously local wave climate or tidal fluctuations can be a factor, as they discuss, but it may also be more interesting than that. The X-factor is a positive elevation value and is subtracted, so if the uplift is too high (most places), then not enough has been subtracted and the organism is actually shallower dwelling relative to MLWS. If the uplift value is too low, then too much has been subtracted and the organism is deeper dwelling relative to MLWS (Kaikoura harbour). Both the tide gauge and the harbour are presumably very sheltered and also areas of boat traffic, which must have some impact on marine algae distribution. The only site that yielded a too-low estimate was Kaikoura Harbour, where boat traffic and maybe sheltering is greatest. Given that in most cases the correction is too small, it may be that the organisms actually range further above MLWS than expected, while still remaining below MLWN. At Paia Point, it seems that the algae attached to rocks furthest to seaward are the most undercorrected, suggesting that those rocks (in an area where they will be bathed regularly by swell and wave action, even at the lowest tides) have the shallowest depth range.

Another thing that would be informative is to know what timescale this technique is available over. The authors carried out their work after a few months, but how much longer could they have realistically applied the technique. Also, is the 20 holdfasts that seems to be their lower limit statistically valid. If the authors take their first five, ten, twenty measurements at a site, does the result change significantly. Would it improve if they used fifty? Maybe start by showing the number of measurements of each type on Figure 5. Maybe somehow on Figure 6 too.

One strategy for the discussion is already present in the introduction. The authors provide an extensive list of coastal uplifts and biological assessments thereof in the introduction. I have always thought that the discussion should revisit the key points of the introduction. So, please revisit that list and discuss the advantages and limitations of this technique. How many historic earthquakes have caused coastal uplift, what magnitudes of coastal uplift have been documented, using what biological indicators. Which of them could have been targeted with this technique, and over what timescale. Maybe put together a useful chart/table showing the preservation potential, accuracy, precision, ease of deployment, best vertical resolution (critical if you want to document uplifts of half a meter or less), speed of survey, skill requirements, etc of the various techniques and illustrating why this one is important – I am thinking something like Table 2B in Quigley et al. (2016), in which the lead author was responsible for another biological assessment of vertical displacement. Or maybe a McCalpin style graphic. Whatever you do, please re-read your introduction and use it to put some spice into the discussion.

These are just a few ideas, but I really think the author team is uniquely qualified to lead this discussion towards a useful earthquake-ecology viewpoint, especially given the lead author's established expertise in biological zonation (Reid et al., 2011 - their fig 2 deserves a citation here) and earthquake effects on that in New Zealand (Quigley et al., 2016). One way or another the discussion needs to be beefed up. A brief discussion of some of these points, possibly using these results to think further about some previous Reid et al work, would probably find favour with coastal ecologists and increase the citability of the paper. A table or graphic of the kind I suggest above would surely contribute to the quantitative coastal ecological impact assessments that will follow future earthquakes, in New Zealand and elsewhere.

Enough long-winded discussion of the discussion (eek). Another key criticism relates to the description of the methods. I found this opaque, with many ambiguities. The opacity is largely because the paper dives straight into formulae without really explaining the strategy. This is not helped by a major discrepancy between the formula shown in text and that shown in Figure 3. After some careful checking I am happy that the methods are valid but they need to be clarified and subscripts used consistently. I also see little indication of the uncertainties in the figures. They are covered to a certain extent in the text, but there are no error bars on major figures (e.g. Fig 6).

Below I provide detailed comments and corrections, mostly regarding the methods and description thereof. There may be some errors of understanding on my part and I apologise for any such errors contained here.

Once again, thank you for this opportunity and good luck to the authors. I look forward to seeing this published.

Sincerely,

Brendan

LINE	COMMENT
25	Satellite data is ubiquitous, Lidar replacement is the real target here.
31	Surely Darwin could get a mention here?
78	Not convinced this is the right reference. What about Williams et al. (2013)?
83	An earthquake network comprises several faults. An earthquake is a process that ruptures a fault or a network of faults. An earthquake does not comprise a network of faults.
97	Vaguely and unintentionally implies that the mapped surface faults and coastal uplift, as well as the tsunami, extended 250 km south of Kaikoura.
102	Here and elsewhere (e.g., line 103, 105, 114…), the word ‘exposed’ and derivatives of that word are used in two different senses of the word – Exposed coastlines and exposed holdfasts. Sometimes it is clear from context and sometimes it requires a double read to figure it out. Please consider using expos… in one sense only and replacing the other meaning with a different word. Line 114 is particularly bad – controlled by exposure above the tide? Lack of shelter? It is not an easy issue to address but maybe keep exposed for ‘unsheltered’ and use qualifications such as subaerially-exposed, terrestrially-exposed, outcropping, etc for stuff that is above sea level.
106	It is not diurnal, it is semi-diurnal, with two full cycles daily.
188	It seems to me that you never explicitly state the tide gauge uplift except in Table 1. Why not?
189	Change to "Biological data collection" and then add a new section title at line 220 - "Data processing"
211	Were the wave effects given a plus-minus value?
213	Was sea-level remeasured after each group of twenty?
215	215-218 – As somebody with building experience I would have forgotten about the tape and used either 1) a builder’s laser level and a reflective staff. Measure the height of the laser level mount with a tape, then measure the height of holdfasts in all positions using a reflective staff. Laser levels are small, portable, and cheap as chips and the staff could be a stick with a high vis jacket. Any holdfast accessible with RTK could be done with a laser level, especially in the late evening, and would yield similar accuracy to RTK. 2) Even cheaper, a homemade water level, with the reservoir placed on a local high point. Engineers used commercial versions widely after the Chch earthquake to survey floor levels. (https://en.wikipedia.org/wiki/Water_level_(device))
220	New section title here - maybe "3.3 Data Processing".
221	These field measurements of apparent uplift… [No. they are field measurements of exposure above a reference tide level. Nobody would consider that to be apparent uplift because it is a time-dependent measurement] were then further processed to determine the total uplift [No. uplift is either of rock or surface – in this case both are equivalent at this moment in time, so just say surface uplift], taking into account the time of data measurement and the pre-earthquake living position of the algal holdfasts which is the difference between pre- and post-earthquake elevation of algal holdfasts [Note that position is a 3D thing and we are only interested in z, not x or y].
222	Just say “Three different corrections were used to derive surface uplift from elevation above sea level at a point in time. These were a) tide gauge calibration; b) interpolation of NIWA tide forecaster and c) interpolation of LINZ tide forecaster. Method a) calculated a correction using direct measurement of stranded algae relative to the

	known uplift of the Kaikoura tide gauge, whereas b) and c) combined the tide forecaster interpolation with local knowledge of biological living zones. Although more subjective, corrections b and c are applicable to sites where no tide gauge is available.
229	A factor is a number that is multiplied by another to yield a product. This is not a factor, it is a constant. There is also more than one constant.
229	I suggest that you change title to “Correction a) Deriving living depth constants for target species using the Kaikoura tide gauge.”
230	230-250 – Try and be a little kinder to those who want to reproduce this. I found it very hard to follow until I figured out what you were doing. Maybe describe in words what you are doing, rather than diving straight into the derivation of your constant. I recommend: “Surface uplift is the difference between the present, post-uplift elevation and the pre-uplift elevation (the living elevation) of the organisms holdfasts. The target species occupy slightly different living positions in the inter-tidal zone, so this new method first derives a constant living elevation (X, in m) for each target species (XC – Carpophyllum; XD – Durvillaea; Combined XG), by calculating the pre-earthquake elevation of the stranded holdfasts relative to the spring-tide mean low water level (MLWS). The constant XC/D/G is calculated in three stages, using holdfasts at sheltered sites close to the Kaikoura tide gauge. First the height of the stranded holdfast above the uplifted tide gauge mount is calculated from the sum of the tide gauge height and the observed elevation of the stranded holdfast relative to sea level (both at measurement time). Secondly, the tide gauge uplift is subtracted obtain the elevation relative to the pre-quake tide gauge. Finally, MLWS is further subtracted to obtain elevation relative to MLWS, which is a key reference level for the biological zonation. This procedure is given by the equation: ... where
231	Depth implies below sea level. At least one species lived above MLW_S, so depth would be negative. Just use elevation, since you are differencing with elevation.
235	Bit of a mess here. Outer parentheses are redundant. The MLWS subtraction is not shown in the equation on Figure 3. Figure 3 uses H_{TG} instead of H, so please be consistent.
240	subscripts rather than indices?
241	… average **post-uplift** tide gauge reading…
244	You have already said they occupy different levels, especially if you adopt the text above, so just leave out the first sentence of this paragraph.
247	“Further, only ….” – This should appear within the derivation of the formula. See comment for line 230 above.
256	You introduce a parameter without defining it (UB(TG)). Sure I can work out what it is but I shouldn't need to. Also H in eqn 2 looks a lot like H in eqn 1. Hence the need to use HTG in eqn 1. Each time you use H it refers to a specific time and place. I wonder if you need to have HTG and HSS (survey site). One way or another your subscripts need to be unique, informative and consistent, because at the moment they are not. I recommend that you include a glossary of the terms used in your equations
265	Please clarify this process. Maybe change text beginning line 265 to read... "where OMCDG is the observed elevation of the holdfasts relative to locally measured sea level, HNIWA/LINZ is the difference between the predicted tide height at survey time and the MLWS based on one year of predictive tables, and XC/D relies on expert assessment as follows: Carpophyllum..." Note here, please be consistent with subscripts. I cant see any reason why OM here would be different to OMC/D/G in equation 1. Also, how would you get an expert assessment of tidal zonation in Timor for instance?

272	What is a regional height
274	Replace height with holdfast elevation (height is a vague term)
285	Why are NIWA and LINZ different? Can you illustrate the difference in a figure, or summarize it somehow?
292	The absolute accuracy of RTK may be 5 cm vertical if you put your base station on a suitable order trig. The internal relative accuracy is better than that (2 cm) with favourable GPS environment (see e.g table 1 in Duffy et al. 2013). On that note, where was your base station set up? Maybe it doesn't matter, if all of your RTK measurements were differenced with a local sea level measurement every 10 minutes or so but you should still mention it. Personally, I would have opened and closed the survey at the tide gauge, so that I could see how well my sea level measurements replicated the tide gauge.
314	Please check figure order. I haven't checked super carefully, but Fig 7 seems to come before 5 and 6. Please make sure they are numbered in order.
320	The problem with the lidar at Kaikoura harbour should be mentioned here, not in the results. And really, I want to know how inconsistent they were. If you do a histogram over a couple of roads around the harbour, what do you get? Is it consistent with the strong motion instrument or not?
336	New heading - 4.1 Tide gauge locality
339	Delete sentence - "Uplift estimates derived…"
344	… tide gauge (Figure 5) and compared with uplift of the Kaikoura tide gauge (calculated in section 3.1)
370	New section title here - maybe "4.2 Paia Point and Omihi Point".
392	How inconsistent? And why? Differential beach gravel compaction? Something else? Does this inconsistentcy affect have any effect over the distance from strong motion sensor to measurement sites?
432	Basically repeats something you have said in 360 and in 226. Just say it once, with maximum impact.
FIGURE 2	In the caption, mention green ulva (from line 120)
FIGURE 3	Fix the missing bit of the formula. Shift the Rtk data panel somewhere else or at least change the background colour, because as drawn it looks like part of the conceptual panel.
FIGURE 4	Not really correct. Why is an equation shown on Figure 3 but not on Figure 4? Surely X_{C/D_NIWA_LINZ} is measured from MLWS??
FIGURE 6	Caption - note that no lidar comparison was produced for Kaikoura harbour. Even better, show the real picture with appropriate error bars.
FIGURE 7	part b - No Rainbow, not now, not ever. Use a proper colour stretch, and stretch it over the elevation range from sea to just above the road. I don't particularly care about the hill.

Quigley, M. C., Hughes, M. W., Bradley, B. A., Ballegooy, S. v., Reid, C., Morgenroth, J., Horton, T., Duffy, B., and Pettinga, J. R.: The 2010-2012 Canterbury earthquake sequence: Environmental effects, seismic triggering thresholds and geologic legacy, Tectonophysics, 672-673, 228-274, 2016.
Reid, C. M., James, N. P., and Bone, Y.: Carbonate sediments in a cool-water macroalgal environment, Kaikoura, New Zealand, Sedimentology, 58, 1935-1952, 2011.