Legacies of the Kaikōura earthquake on the coastal marine ecosystem

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Introduction

Natural ecosystems have many buffers that ameliorate the effects of disturbances. High species diversity, robust food web linkages, and redundancies of functions such as primary production and provision of seafood, are intimately linked. They are also bound to the physical elements of the environment to which they are adapted. When cataclysmic disturbances occur, such as the magnitude 7.8 Kaikōura earthquake, many of these linkages are broken, the usual buffers to change are greatly affected, and 'recovery' is unlikely to be a return to the pre-disturbance state.

The immediate impacts of the Kaikōura earthquake on the coastal marine ecosystem have been well-described (Alestra et al. 2019, 2020, Schiel et al. 2018, 2019, Thomsen et al. 2020). In summary, nearshore rocky habitats were lifted by up to 6.4 m above their former tidal heights along c 130 km of the coast, entire algal communities were lost because they were no longer immersed by tides, tens of thousands of mobile species such as banded wrasse, lobsters and pāua were stranded, and the pāua fishery was (and remains) closed to commercial and recreational fishers. Three and a half years later, the ecosystem is still in flux. Here we briefly describe the state of recovery along the coast.

Summary of what was done

After the November 2016 earthquake, thorough monitoring of rocky reef communities in the intertidal and shallow subtidal zones was done six-monthly for the first two years and then annually at 16 sites that encompassed the full range of uplift. All species and their abundances were recorded in random quadrats along set transect lines from the newly configured high intertidal zone to around 10 m depth subtidally.

Sampling for the sizes and abundances of juvenile pāua (*Haliotis iris*) was done separately because much of their obligate small-boulder habitat in the lowest tidal zone was permanently lifted by the earthquake. Because of the patchiness of this habitat, the research team walked c 20 km of the heterogeneous coastline to locate and measure juvenile pāua. Experimental work on algal recovery was initiated, pāua population enhancement from hatchery-reared juveniles is being monitored in conjunction with the fishing industry and Kaikōura community, and innovative aerial drone techniques are being developed and used to judge the scale of habitat changes and recovery along the coastline. As well, temperature and light sensors are arrayed at critical habitats to gauge the altered and fluctuating physical environment.

Summary of recovery trajectory

Algal loss

Bull kelp (*Durvillaea* spp) was one of the hardest hit groups. The low intertidal species (*D. antarctica* and *D. poha*) died off almost completely at many sites, regardless of the degree of uplift, and have not recovered well, if at all, in most places. This undoubtedly reduced the primary productivity of these areas, as there has been no functional replacement of bull kelp by any other species. In fact, few of these large brown fucoid algae have functional replacements, so the loss of any of them greatly affects community composition and recovery after disturbances (Schiel 2006). Bull kelps considerably enhance species diversity within their habitats, and their loss has consequences lasting at least eight years (Schiel 2019). Large bull kelps also buffer the coast from wave action, and their loss may be contributing to the severe erosion of soft sedimentary rocky habitats (see cover photo). The slow recovery time of *Durvillaea* is related to their life history. They have a limited reproductive season of around three months during winter, are dioecious so male and female gametes must come from different individuals, and their propagules normally travel only a matter of tens of meters (Schiel et al. 2019). Recruitment of formerly occupied areas will therefore most likely come from detached drifting adults of distant populations.

Overall, the recovery of algae has been highly variable along the coast. There is virtually no recovery of the formerly dense mid-intertidal beds of the beaded fucoid alga Neptune's Necklace (*Hormosira banksii*). This species died off from the very large, high-diversity platforms around Kaikōura and has returned only in small patches on the lower tidal fringes. Across the coastline, there is little algal recovery in the mid and high intertidal zone. Where algal cover has returned, it is mostly tough calcareous coralline species and fleshy red algae in the low tidal zone. The recovery is related to the degree of coastal uplift (Figure 1). Sites with little uplift (< 0.2 m) have mostly returned to their former algal cover of 75%-80% in the low zone. At these sites the fucoid *Carpophyllum maschalocarpum* is now abundant rather than much larger bull kelp.

At sites lifted by around 2 m, algae cover around 30% of rocky surfaces, and beyond 4 m uplift there is only sparse algal cover. This compares to cover of at least 70% in the low zone of most sites before the earthquake. Subtidally the loss of algae has been less dramatic, but the high uplift sites are demonstrating poor recovery, most likely because of continued disturbance from shifting gravel and sediments, poor light quality, and a paucity of reproductive adult algae to seed new areas.

Changed infrastructure

The niche space of species is defined not only by interactions with the myriad other species present but also by the topography, tidal regime, temperature, wave forces and light environment of habitats. All of these were greatly altered by the earthquake. Unfortunately, as rocky habitats pushed upwards, there was little replacement by

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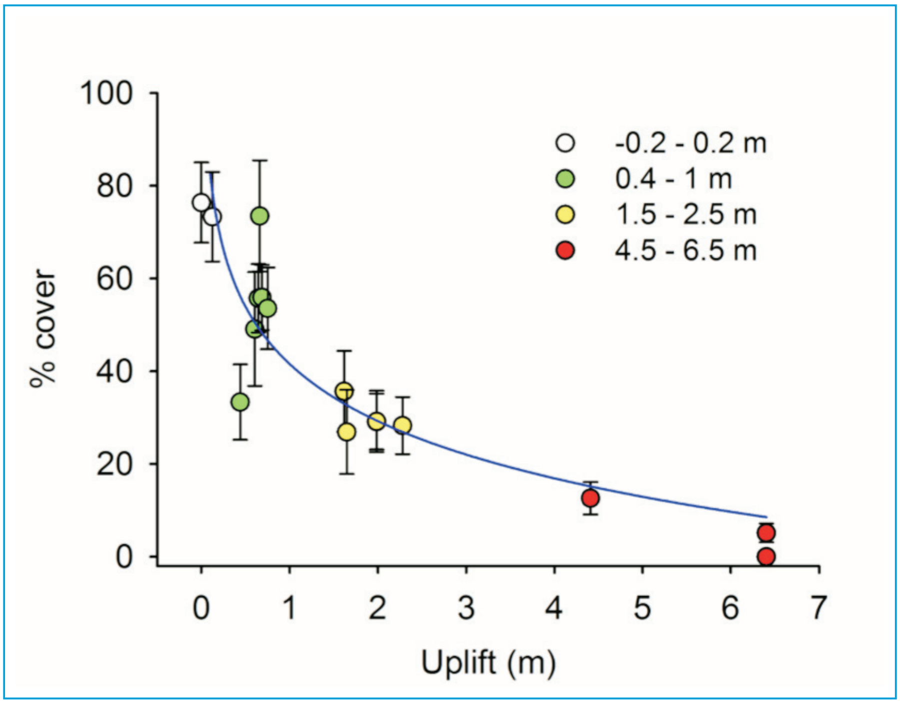

Figure 1: The percentage cover of large brown algae in the low intertidal zone at sites across degrees of uplift. The pre-earthquake cover of algae averaged around 75%-80% at these sites. This work is coordinated by post-doctoral researcher Tommaso Alestra.

rocks below them. The earthquake coast is mostly sand, gravel and boulders. The large reef platforms around Kaikōura, extending >100 m in width, once supported some of the greatest per-area diversity in New Zealand but now are almost barren. The tide still covers the reefs, but at a much shallower depth and for shorter periods. It is now common to see substratum temperatures >40 °C for several hours during low tides, which are lethal to most species. The increased erosion of reefs, after losing coralline algae that helped consolidate the friable surfaces, also slows the recovery (Schiel et al. 2019). The width of the intertidal zone is now usually only a few meters in most places and is near-vertical. This also is inhospitable to algal attachment because of direct pounding by waves.

Rain and storm events have continued to produce a large influx of sediments from coastal cliffs and catchments into the nearshore zone. This often smothers algae, invertebrates and their habitats, but also diminishes the light environment in coastal waters, with potential flow-on effects on algal productivity. For now, this is the new infrastructure within which recovery must occur. We have seen many instances where species have begun to come back, only to be lost because of inhospitable conditions or marine heat waves (Thomsen et al. 2019).

Pāua recovery

Pāua population recovery has been one of the more heartening stories of coastal improvement. Extensive patches of juvenile habitat were found along the coastline and there has been very strong recruitment of pāua in the years following the earthquake. Tagging studies of natural pāua and hatchery-raised juveniles placed into some sites show very good growth rates of 30-40 mm per year and good survival. This project has had great interest with the Kaikōura community and the pāua fishing industry (Figure 2).

Aerial drones

A major problem in assessing change in natural ecosystems is the large spatial scale that must be accommodated. To increase spatial coverage and provide a quantitative baseline against which to assess change, we have used multi-spectral drone imagery for rocky reef topography and algal cover. With machine learning, individual species can be identified and their spatial coverage determined accurately (Tait et al. 2019, Figure 3). This technology has also been useful for tracking dune formation, erosion and formation of gravel beaches, and for mapping habitats of coastal plants and birds. It is quite an exciting development of this research programme, which shows great promise for future uses in research and management.

Conclusion

Change to the earthquake-affected coast will continue because the algal communities and species that rely on them are still in flux (Figure 4). This is only a brief overview of 'recovery' so far. There continue to be natural impacts on the coastal infrastructure. These can be exacerbated by increased human usages and impacts from greatly increased access to the coastline around formerly isolated headlands. Time will tell how well we manage this collectively.

Figure 2: Ongoing work with pāua seeding of sites around Kaikōura, to augment natural recovery of pāua populations after the earthquake. Seed pāua from the hatchery are bright blue-green in shell colour. Top right: tagged hatchery pāua in experimental habitat, caged to keep out predators. Lower right: school pupils help find seed pāua, which shelter beneath rocks for around 3 years. Lower right: the blue-green shell cap is still visible on pāua that have grown for around 15 months in field sites. This work is part of PhD studies by Shawn Gerrity.

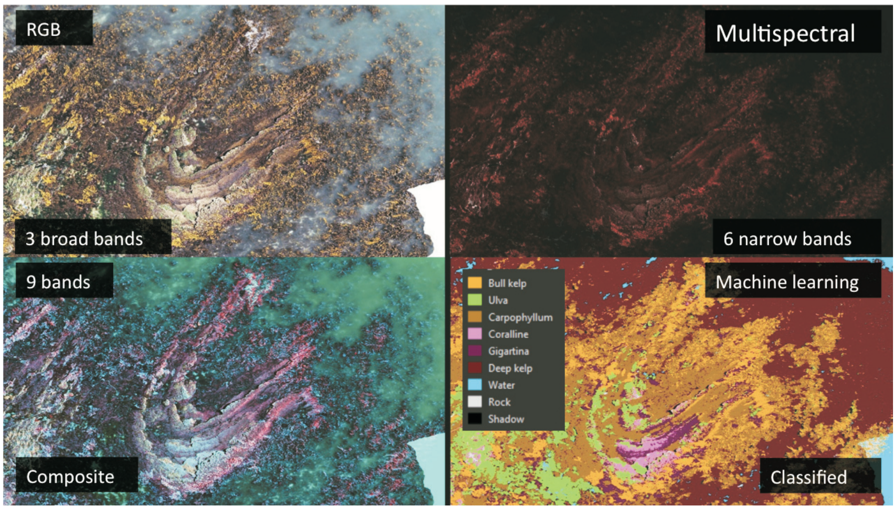

Figure 3: Different depictions of the same algal covered reef, in visible and non-visible light. Training machine learning programmes with greater spectral information ('bands') can greatly improve automated mapping over large areas, such as in lower right where the cover of different algae is shown (work from Leigh Tait, NIWA).

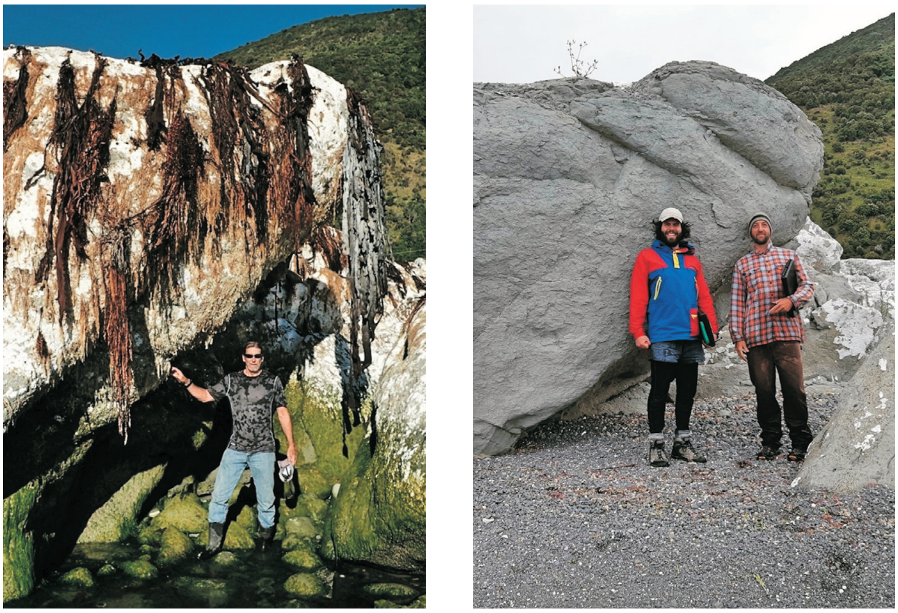

Figure 4: Left: Newly exposed subtidal reef two weeks after the earthquake, showing subtidal fucoid algae at Waipapa, where uplift was 6.4 m. Right: The same rock in 2019, showing infill of eroded sedimentary rock and movement of gravel (Photos: S Gerrity).

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References

Alestra, T, Gerrity, S, Dunmore, RA, and Schiel, DR (2020). *Rocky reef impacts of the Kaikōura earthquake: extended monitoring of nearshore habitats and communities – Year 1 results*. Prepared for the Ministry for Primary Industries. New Zealand Fisheries Assessment Report 2020/01, 40 pp.

Alestra, T, Gerrity, S, Dunmore, RA, Marsden, ID, Pirker, JG, and Schiel, DR (2019). *Rocky reef impacts of the Kaikōura earthquake: quantification and monitoring of nearshore habitats and communities*. Prepared for the Ministry for Primary Industries. New Zealand Aquatic Environment and Biodiversity Report 212, 120 pp.

Schiel, DR (2006). Rivets or bolts? When single species count in the function of temperate rocky reef communities. *Journal of Experimental Marine Biology and Ecology*, 338: 233-252.

Schiel, DR (2019). Experimental analyses of diversity partitioning in southern hemisphere algal communities. *Oecologia*, 190(1), pp.179-193.

Schiel, DR, Alestra, T, Gerrity, S, Orchard, S, Dunmore, RA, Pirker, JG, Lilley, SA, Tait, LW, and Thomsen, MS (2019). The Kaikōura earthquake in southern New Zealand: loss of connectivity of marine communities and the necessity of a cross-ecosystems perspective. *Aquatic Conservation* 29: 1520-1534.

Schiel, DR, Gerrity, S, Alestra, T, Pirker, JG, Marsden, ID, Dunmore, RA, Tait, LW, South, PM, Taylor, DI, and Thomsen, MS (2018). Kaikōura earthquake: Summary of impacts and changes in nearshore marine communities. pp. 25-28 in: *Shaky Shores – Coastal impacts & responses to the 2016 Kaikōura earthquakes*. New Zealand Coastal Society, Special Publication 3. 44pp.

Thomsen, MS, Mondardini, L, Alestra, T, Gerrity, S, Tait, L, South, PM, Lilley, SA and Schiel, DR (2019). Local extinction of bull kelp (*Durvillaea* spp.) due to a marine heatwave. *Frontiers in Marine Science*, 6, p.84.

Tait, L, Bind, J, Charan-Dixon, H, Hawes, I, Pirker, J, and Schiel, DR (2019). Unmanned Aerial Vehicles (UAVs) for Monitoring Macroalgal Biodiversity: Comparison of RGB and Multispectral Imaging Sensors for Biodiversity Assessments. *Remote Sensing*, 11: 2332.

Thomsen, MS, Metcalfe, I, Siciliano, A, South, PM, Gerrity, S, Alestra, T, and Schiel, DR (2020). Earthquake-driven destruction of an intertidal habitat cascade. *Aquatic Botany* 164: 103217.

In 2018, NZCS published 'Shaky shores: Coastal impacts & responses to the 2016 Kaikōura earthquakes', which looked specifically at the coastal impacts and response to the November 2016 earthquakes. Included in this was an article summarising the impacts and changes in nearshore marine communities, which provides a 'then' context to the current article's 'now' perspective. A copy of 'Shaky Shores' can be downloaded from the NZCS website (under the Media/Publications tab at www.coastalsociety.org.nz).