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Coastal sediments and the darkness at noon

David R Schiel[1], Christopher N Battershill[2], Rahera Ohia[3]

First, we recognise and respect the territories of the iwi and hapū who are kaitiaki of the coasts of Aotearoa New Zealand. We further acknowledge the strong connections the diverse communities of Aotearoa New Zealand have with the lands, waters and people that surround them. The inter-dependence of lands, waters and people enables us to create a more complete picture of what is happening on our coasts and why. It also highlights where potential solutions might be found and who needs to be engaged to implement them successfully.

In asking advanced university students to provide a ranked list of threats to the marine environment, the top choices were overfishing, invasive species and climate change. Only one student in the class, who clearly paid attention to one of our lectures last year, mentioned run-off from the terrestrial environment. Their perceptions were no doubt influenced by the emphasis that years of teaching and the media have had on these issues. In Aotearoa New Zealand, the main marine spatial management tool is protected areas, which lessens overfishing, but does not deal with diffuse and sometimes catastrophic pouring of sediments and contaminants from land into the sea across catchments and regions. These often accumulate in the nearshore coastal zone only to be resuspended during increasingly frequent storm events. This affects the very infrastructure of rocky reef ecosystems, as water-column light, on which thriving kelp forests depend, is obstructed or diffused. We now see persistent states where kelp habitat, biodiversity, and productivity are lost. In fact, the rapidly accelerating degradation of kelp forest communities and their associated ecosystem services have been highlighted by iwi and agencies throughout New Zealand over at least the past 10 years (e.g. Donald & Battershill 2023, McCormack et al. 2024, Schiel 2013, Schiel & Howard-Williams 2015).

However, detailed assessments of the rate of decline and the consequences of kelp forest demise have not until very recently been reflected in scientific publications or in specific New Zealand science policy designed to mitigate further deterioration. This lends urgency to the need for lessening the 'manageable' stressors that are accumulating to push kelp forest ecosystems beyond critical 'tipping points' as they increasingly interact with warming seas.

Coastal sedimentation from terrestrial run-off affects much, if not most, of the coastline of New Zealand. Increases in land use intensification and forestry have added to the coastal stressors around the country. This was seen in dramatic fashion last year when Cyclone Gabrielle devastated the coastal environment from East Cape southwards. Slash from harvested forestry blocks cascaded down the steep slopes along with torrents of water, mud and debris that inevitably made their way onto the coastal plain and into the marine environment.

Catastrophic as these types of events can be, there are more pernicious and less visible impacts on the marine environment from such activities. Nearshore kelp forests and their resident organisms are often smothered in the rain of sediments cascading to the sea floor. Resuspension during storms is a decadal (if not longer) legacy along our coasts because of occluding the transfer of light through the water column. Anyone who has flown over the country during periods after intense rain will have seen the vast sediment plumes coursing out of rivers and coastal waterways. Younger generations now sadly see this as normal, and the shifting baseline for triggering concern is an insidious barrier to realising fully the potentially catastrophic, non-reversible consequences of coastal sedimentary inundation. The water column beneath these sediment plumes is seriously compromised, not only with the amount of light reaching benthic habitats, but the frequency or wavelengths of light in the photosynthetic spectrum, on which kelp growth and reproduction rely, is also filtered out and reduced in murky waters. Therefore, there is shallowing or recession of kelp forests from the combined effect of mortality due to smothering, and poor recovery in the altered light environment.

'Coastal darkening' is becoming a worldwide problem in temperate coastal environments where the vast majority of kelp forests occur in waters less than 20 m in depth. In combination with other stressors such as more frequent and intense marine heat waves (Tait et al. 2021, Thoral et al. 2022, Montie et al. 2023, Xu et al. 2022) and generally warming seas, coastal sedimentation can affect the very infrastructure of unobstructed rocky reef and water-column light on which thriving

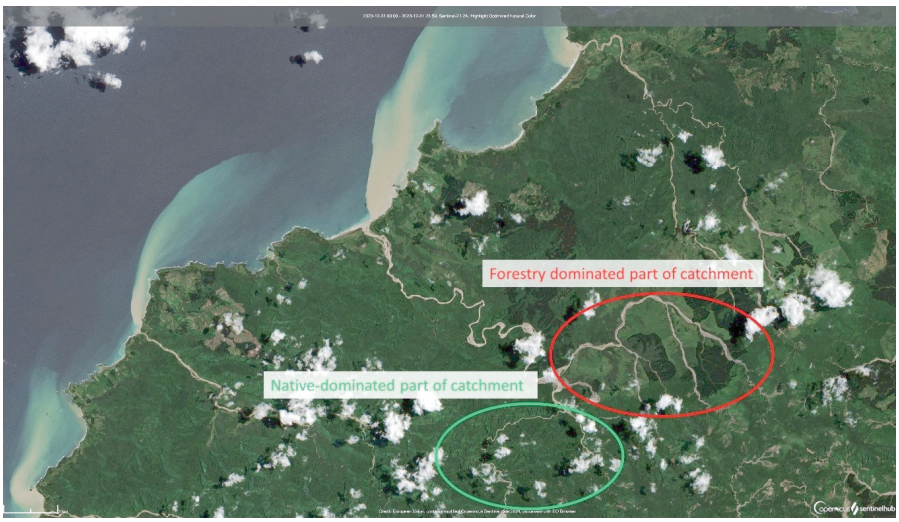

Figure 1: Coastal sediment plume after rain event in January 2024. This dumped a large load of sediment on coastal reefs along the coast near Raukokore.

1 David Schiel, Distinguished Professor, Canterbury University.

2 Chris Battershill, Professor, Coastal Science, Waikato University.

3 Rahera Ohia, Ngāti Pūkenga, Ngāi Te Rangi, Waitaha.

Figure 2: The rain of coastal sediments smother kelp and subcanopy encrusting fauna and flora also diminishing light further affecting seaweed regeneration.

kelp forests depend, resulting in other persistent states where kelp habitat, biodiversity, and productivity are lost.

Our five-year, multi-institutional, MBIE-funded programme entitled *Toka Ākau Toitū Kaitiakitanga – building a sustainable future for coastal reef ecosystems*, aims to provide the necessary scientific and cultural underpinnings that will lead to more effective coastal management. This is a recognition that there is currently no cohesive understanding of these degradative drivers that allow informed and effective management strategies. Equally, there is inadequate understanding of scale-dependent biophysical interactions that result in observed patterns of effects. Historical baselines remain poorly parameterised despite being essential for gauging improvements – a problem exacerbated by limited surveillance tools for quantifying the status of these ecosystems and their associated values. This programme responds to piecemeal and often single-stressor research done in disparate locations. To date, there has been no co-designed programme of targeted biophysical coastal reef science, combined with traditional Māori knowledge, squarely aimed at the expressed needs of Māori, resource managers, and stakeholders, to achieve practical management outputs for reversing degradation. New management models and tools for sustaining healthy and resilient kelp forests are urgently needed. In recognition that no single entity can solve these pernicious problems, this programme was developed over a several years with key rangatira/mana wahine across the Mātauranga Māori-Science-Management-Stakeholder domain in response to that need, and to provide a clear pathway to knowledge uptake by whanau and communities.

Our approach is to use the most up-to-date technical advances in remote sensing, molecular and environmental chemistry, and participatory management models to gain a spatially-scaled understanding of stressor reduction and apply this new knowledge to achieve thriving kelp forest communities.

The research aims are:

1 **Understanding and establishing historical baselines:** Informed by Māori knowledge and experience, oral histories and previous data-sets, baselines of past ecological kelp forest structure, habitats and taonga species of particular significance are being identified and mapped. This helps resolve historical context, sources and gradients of stressors, and gauges ecosystem restorative targets.

2 **Measuring stressor effects:** Fit-for-purpose high-tech and environmental chemistry tools are being optimised and used for gauging kelp forest community composition and impact gradients. These include remote sensing tools for measuring within-habitat to wide-scale kelp forest structure. Environmental chemistry and e-DNA will help reveal sources and flows of contaminants and organic matter, trophic linkages, and hidden diversity of kelp forests.

3 **Developing new management models:** Engagement and Integration and scenario testing. The purpose here is to develop and transfer methodology that empowers iwi/hapū and provides regional managers with the means to monitor, gauge, report on, and react to changes in kelp forests. Environmental health indicators are being developed to provide meaningful metrics of kelp forest condition and gauge improvements over time. We are exploring co-management models that can be tested and put into practice to underpin adaptive/effective management.

This is an ambitious programme that involves researchers from many organisations, institutes and agencies, including key people from Ngāti Pūkenga, Ngāi Te Rangi, Ngāti Ranginui, and Te Whānau-ā-Apanui, the Universities of Canterbury, Waikato and Otago, NIWA, the Bay of Plenty Regional Council, and other regional and district councils. With the aid of this research programme it is hoped that some of the very hard issues of cross-ecosystem management can be increasingly resolved. Not all stressors are 'manageable', but it is clear that we as a country need to adopt a more holistic approach to cross-ecosystem management. The sea has always been the downstream accumulator of terrestrial-sourced contaminants. Without improvements and more effective management, the 'darkness at noon' will only get worse, to the further detriment of our iconic kelp forests.

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