9.5 Kelp forest extent and quality

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State of Knowledge of the "Kelp forest extent and quality" attribute: Medium / unresolved – some studies/data but conclusions do not agree

Kelp forests are well studied in some regions with some consistent monitoring occurring, however, in other regions there are few observations or studies, and most regions lack consistent monitoring. For example, some marine reserves (e.g., Goat Island, Poor Knights, Fiordland) are regularly monitored, but few consistent monitoring programmes exist nationally. Furthermore, the focus of many monitoring studies has been the relative occurrence of *Ecklonia radiata* and urchin barrens (Wing et al 2022). However, satellite remote sensing has been successfully used to monitor giant kelp (*Macrocystis pyrifera*) across its geographic range in Aotearoa, New Zealand (Tait et al. 2021). These products, while covering large spatio-temporal scales, have limitations and caveats. In particular, they do not resolve populations unless they reach the sea-surface, and only provide broad metrics of total coverage, and do not provide estimates of density or biomass.

Kelp forests in Wellington region have been mapped testing whether machine learning and computer vision techniques approaches could be used to identify dominant macroalgal species. The trial of machine learning approaches produced very compelling results and indicated great future potential for monitoring subtidal kelp forests and ground truth remote sensing data (D'Archino et al 2021). *Macrocystis pyrifera* in Wellington harbour was mapped in 2017 and its distribution compared with historical data (Hay, 1990). Several areas of decline, absence or persistence were identified (D'Archino et al. 2019). The citizen science Project baseline Wellington (https://projectbaseline.org/wellington/) has been providing data (underwater videos, photos and mapping) of kelp forests at Kau Point (Wellington harbour) since 2016. These data provide a snapshot of *Macrocystis pyrifera* and *Carpophyllum* spp. bed fluctuations over the years and the large invertebrates associated with, including number of sea urchins.

Part A—Attribute and method

A1. How does the attribute relate to ecological integrity or human health?

Kelp forests are a vital indicator of marine ecosystem health in temperate ecosystems (D'Archino & Piazzi 2021). Loss of kelp forests leads to a cascading shift in ecological assemblages which are often associated with a loss of key ecosystem functions and biodiversity (Filbee-Dexter & Scheibling 2014). Large macroalgae (e.g., kelp) are capable of altering the biophysical environment of rocky reef ecosystems through physical (e.g., wave dampening; Dubi & Tørum 1995) and physiological processes (e.g., oxygen production, carbon fixation; Pfister et al 2019). These processes support a rich variety of species, including many commercially important species such as paua, kina, koura and finfish. The health and integrity of temperate rocky reef ecosystems is directly linked to the presence and abundance of kelp forests.

Healthy functioning kelp forests provide numerous ecological services that can benefit human health, directly or indirectly. For example, kelp and seaweeds are photosynthetic, they produce oxygen and absorb CO_2. Furthermore, because they are at the base of the food web, they provide energy for other organisms and are themselves a notable source of food. Combined the provision of sustenance from kelp forests is potentially high, and in some cases important pharmaceutical products are extracted from seaweeds (Lomartire & Gonçalves 2022).

Additionally, the ability to absorb and integrate nutrients (particularly nitrogen) is another service that can improve water quality, thereby reducing risks to human health. Kelp and fucoid algae provide coastal protection from erosion, dampening the wave's energy (Morris et al 2020) and they mitigate ocean acidification by up taking CO2 (Hepburn et al. 2011).

A2. What is the evidence of impact on (a) ecological integrity or (b) human health? What is the spatial extent and magnitude of degradation?

There is a large body of literature that details the decline of kelp forests under a range of scenarios and environments. Loss of kelp forests is frequently associated with dramatic shifts in ecological states and a loss of functioning and integrity (Filbee-Dexter & Scheibling 2014).

Evidence suggests that up to 30% of fished reef habitats in northeastern New Zealand are likely degraded and dominated by Urchin barrens (Kerr et al. 2024). Although Tait et al. (2021a) identified declines in giant kelp (*Macrocystis pyrifera*) in southern New Zealand following marine heat-waves, many beds recovered 6-12 months after the event. Localised loss of other kelp forests (e.g., Durvillaea spp) following marine heat waves appears to be more catastrophic (Thomsen et al. 2019; 2021).

Population of giant kelp (*Macrocystis pyrifera*) at their northern limit (Wellington region) are particularly at risk for increased temperature.

A3. What has been the pace and trajectory of change in this attribute, and what do we expect in the future 10 - 30 years under the status quo? Are impacts reversible or irreversible (within a generation)?

At the scale of individual reef systems, the pace of change has been rapid. For example, urchin barrens can form quickly (i.e., months), and the impacts of marine heat-wave events can be almost immediate (Thomsen et al. 2019; Tait et al. 2021a). These events have decreased dramatically in the past 10 years (Thoral et al 2022). Urchin barrens can be reversed through active harvesting or culling of urchins (Miller et al. 2024), however, the impacts of marine heat-waves may be harder to reverse, and active restoration of kelp can be challenging (Thomsen et al. 2019).

Ocean warming and increase in frequency and duration of marine heat waves will negatively affect cold water species e.g., *Durvillaea poha*, *D. willana*, *Macrocystis pyrifera*, particularly populations at their northern limit, with consequent loss of associated species. Increasing temperature might not affect directly population of *Ecklonia radiata* in the Northern New Zealand but could promote an expansion in the distribution of the subtropical sea urchin *Centrostephanus rodgersii* leading to urchin barrens (Cornwall et al.2023, Shear et al. 2024).

A4-(i) What monitoring is currently done and how is it reported? (e.g., is there a standard, and how consistently is it used, who is monitoring for what purpose)? Is there a consensus on the most appropriate measurement method?

There is no standardisation of monitoring methodology or responsible agencies. In most cases monitoring is completed for different reasons and with different tools or methods. However, ultimately each monitoring method can be converted to one of two metrics that can be compared and standardised at a national level. These metrics are density (e.g., number of plants per m^2) or cover (percentage cover per m^2). Ensuring consistent collection of metadata (e.g., depth, location, fetch, exposure) will be vital to nation-wide comparisons and standardisation for temporal comparisons.

A4-(ii) Are there any implementation issues such as accessing privately owned land to collect repeat samples for regulatory informing purposes?

While there are typically few access barriers to implementing monitoring, there are a range of practical limitations that have historically affected the application of monitoring. For example, marine habitats with high levels of wave and wind exposure are difficult to safely monitor and access. Furthermore, some regions of Aotearoa are remote and difficult to access from the sea. Such areas have typically been accessed by land or not at all. Increasingly, aerial imagery from satellites (Tait et al. 2021a) and drones (Tait et al. 2019; Tait et al. 2021b) can be used to monitor kelp and seaweed populations that occur in exposed and hard to reach areas.

A4-(iii) What are the costs associated with monitoring the attribute? This includes up-front costs to set up for monitoring (e.g., purchase of equipment) and on-going operational costs (e.g., analysis of samples). [Costs to measure/monitor this attribute].

Costs for monitoring kelp ecosystems are highly context specific, as kelp forests come in a variety of types in a range of settings. For example, giant kelp (*Macrocystis pyrifera*) can be observed from freely available satellites, while subtidal *Ecklonia radiata* forests require in water monitoring by divers, or possibly remote operated or towed cameras. Intertidal kelp forests can be monitored in situ using cheaper equipment. However, subtidal kelp monitoring requires a reasonable investment in diving equipment or camera systems. The use of vessels for any method greatly adds to the overall costs of monitoring.

Georeferenced underwater videos can be acquired with small boats, able to access shallow water (2-20 m) and automated video analysis can significantly reduce the cost (D'Archino et al 2021). Algorithms could be developed to estimate percentage coverage and biomass of subtidal species.

A5. Are there examples of this being monitored by Iwi/Māori? If so, by who and how?

Mana whenua are holders of a wealth of information on the status of kelp beds over time due to historical and present day uses of bull kelp and other kelp and seaweeds for various purposes. There are likely many examples of iwi and hapū monitoring kelp forest attributes, particularly in intertidal and shallow subtidal habitats. One example known to us is in the Wellington region, where Taranaki Whānui is actively involved in seaweed monitoring (intertidal surveys) and restoration. To complement this, they are testing the use of harakeke and pingao for growing seaweed as an alternative biodegradable substrate in laboratory settings at NIWA.

A6. Are there known correlations or relationships between this attribute and other attribute(s), and what are the nature of these relationships?

Kelp forests are indicative of overall ecosystem health and are a key ecological indicator in temperate reef ecosystems (D'Archino & Piazzi 2021). Poor kelp forest health is often associated with degradation of a range of fisheries species, particularly paua, kina and koura. Abundance of kelp can be considered an excellent indicator of whole ecosystem health.

Part B—Current state and allocation options

B1. What is the current state of the attribute?

While there are in some cases clear signs of decline of kelp beds (Thomsen et al. 2019; Thomsen et al 2021), not all kelp forests from all regions are well represented at a national level. Other kelp forests (e.g., *Macrocystis pyrifera*) show concerning trends under elevated sea surface temperatures (Tait et al. 2021a) but also bounce back quickly during cooler years. In some regions, particularly Northland and Bay of Plenty, *Ecklonia radiata* beds are grazed by kina (*Evechinus chloroticus*), but increasingly the black-spinned urchin (*Centrostephanus rodgersii*) (Balemi & Shears 2023).

Baseline data are needed to benchmark the state and condition of the system being managed, for trends to be identified. This lack of sound baseline information constrains the ability to evaluate the effectiveness of management methods. This lack of critical information impedes the detection of range shifts in response to local or global stressors, as well as the occurrence of local extinctions and the introduction of non-native species.

B2. Are there known natural reference states described for New Zealand that could inform management or allocation options?

There are reports and resources that have attempted to describe natural reference states for kelp in New Zealand. In 2015 MPI funded a project to understand the role of macroalgae as ecological indicators and their distribution at national scale (D'Archino et al. 2019). This study summarised international and national literature about decline of kelp and monitoring techniques, tested different approaches for mapping, including machine learning and tested stressors (e.g., temperature, light, sediment) on different species. In addition, distribution data gathered from scientists and members of the Local Government Coastal Special Interest Group (C-SIG) involved in ecological research and environmental monitoring, were used to identifying gaps or areas where monitoring work could be repeated.

Kelp forest in Cook Strait and the Marlborough Sounds have been documented by tow-video surveys (Anderson et al 2019) and their role, as biogenic habitat assessed (Anderson et al. 2018).

B3. Are there any existing numeric or narrative bands described for this attribute? Are there any levels used in other jurisdictions that could inform bands? (e.g., US EPA, Biodiversity Convention, ANZECC, Regional Council set limit)

Giant kelp (*Macrocystis pyrifera*) and bull kelp (*Durvillaea spp.*) are native New Zealand seaweed and classified as 'Threatened - At Risk – Declining' (Nelson et al 2019). Due to its decline in Victoria, South Australia and Tasmania the giant kelp is protected under Australia's national environmental law, the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) as a threatened ecological community. However, to our knowledge, there are no known numeric or narrative bands describing the state of this attribute (apart from "barrens" vs not).

B4. Are there any known thresholds or tipping points that relate to specific effects on ecological integrity or human health?

Known tipping points exist for some key parameters. For example, urchin densities above 2 urchins/m2 are often sufficient to turn kelp forests into urchin barrens, yet fewer urchins are required to maintain barrens (Ling et al 2015). Light intensities less than 1 $mol/m^2/d$ is also a key limit for healthy and productive kelp forest ecosystems (Tait 2019).

B5. Are there lag times and legacy effects? What are the nature of these and how do they impact state and trend assessment? Furthermore, are there any naturally occurring processes, including long-term cycles, that may influence the state and trend assessments?

There may be time-lags related to reversing poor water clarity (especially if it is the result of resuspension of legacy sediment), and it may take time following marine reserve establishment for the typical kelp-urchin-predator cascades to re-establish.

B6. What tikanga Māori and mātauranga Māori could inform bands or allocation options? How? For example, by contributing to defining minimally disturbed conditions, or unacceptable degradation.

Māori are intimately familiar with their moana, especially with kina being a kaimoana resource. They hold significant knowledge on what constitutes the "natural state" or minimally disturbed conditions.

Part C—Management levers and context

C1. What is the relationship between the state of the environment and stresses on that state? Can this relationship be quantified?

The general relationship is that high kelp cover on rocky reefs is associated with high ecosystem health (high diversity and trophic transfer), whereas key stressors such as overfishing (reducing keystone predators) and sediment loading (reducing light and increasing deposition) can reduce lush canopies of macroalgae to practically unvegetated barrens. There is evidence for key thresholds of light and temperature, e.g., giant kelp (*Macrocystis pyrifera*) appears to be somewhat limited to sea water temperatures less than 19°C (Hayes 1990). Furthermore, many kelp species require light intensities greater than 1 mol/m^2/d (Tait 2019). Sites with light intensities below this threshold show compromised health attributes in kelp forests (Tait et al. 2019). Likewise, more than two exposed urchins per m^2 is associated with excess grazing and loss of kelp (Kerr et al. 2024). All of these relationships are quantified, however, not every species that form kelp forests are equally studied.

C2. Are there interventions/mechanisms being used to affect this attribute? What evidence is there to show that they are/are not being implemented and being effective?

Interventions around the culling and harvesting of urchins have been shown to be highly effective for restoring kelp forests (Miller et al. 2024). While it is expected that improving water quality attributes (e.g., sedimentation) would lead to improved kelp forest health, there are no examples where land-based restoration has been of sufficient scale to examine potential recovery.

C2-(i). Local government driven

Some regional councils have rocky reef monitoring and water quality monitoring programmes, but there are few-to-no examples of management interventions designed to maintain or restore coastal rocky reef kelp forests.

C2-(ii). Central government driven

The main intervention/mechanism that has helped reverse urchin barrens in some locations is the establishment of Marine Protected Areas.

C2-(iii). Iwi/hapū driven

There have been partnerships with Māori designed to eliminate urchin barrens in places (e.g., Little Barrier Island), and rāhui and temporary closures are used to stop overfishing (which could indirectly help improve kelp forest cover and health).

C2-(iv). NGO, community driven

The community project Love Rimurimu with the assistance of NIWA and Victoria University of Wellington is aiming to restore kelp bed in Wellington harbour and identify the drivers for giant kelp (*Macrocystis pyrifera*) decline.

C2-(v). Internationally driven

Kina barrens and kelp loss are global problems and there are examples of kelp restoration projects involving the provisioning of artificial hard substrate in Southern California that have shown signs of success.

Part D—Impact analysis

D1. What would be the environmental/human health impacts of not managing this attribute?

Degradation of kelp forests will impact key environmental health metrics and compromise critical ecosystem functions. This could influence human health through a lack of suitable food resources (e.g., related fisheries). Allowing kelp forests to continue to degrade will impact the environment and to a lesser degree human health.

D2. Where and on who would the economic impacts likely be felt? (e.g., Horticulture in Hawke's Bay, Electricity generation, Housing availability and supply in Auckland)

Fisheries in particular would feel the economic impacts of degradation of kelp forests. Many key fisheries (e.g., paua, kina, koura and many finfish) rely on healthy and functioning kelp forests. Loss of kelp forests would quickly lead to declining fish stocks. These impacts may be greatest felt in southern New Zealand, however, areas of northern New Zealand where barrens occur may also experience loss of economic value in associated fisheries.

D3. How will this attribute be affected by climate change? What will that require in terms of management response to mitigate this?

Evidence already shows that climate change, particularly extreme events like marine heat-waves, greatly impact kelp forests (Thomsen et al, 2019; Tait et al. 2021a; Thomsen et al. 2021). There is also evidence that poor water quality (particularly turbidity), compromises ecological resilience of giant kelp forests (Tait et al. 2021a). Management interventions that focus on improving water clarity will likely improve the resilience of kelp forests to climate change stressors.

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