Project Baseline Wellington: Monitoring Giant Kelp in Wellington Harbor

by Nicole Miller, Ph.D.

Seaweeds, like giant kelp, play a critical role in coastal marine ecosystems.

DIVING in healthy kelp forests is an amazing experience, and we are lucky to have giant kelp (*Macrocystis pyrifera*) in New Zealand's capital, Wellington, which serves as the species' northernmost limit. Divers and snorkelers are privileged to experience the beauty and bounty of life in seaweed beds in the harbor and along the coast, but in doing so, they become aware of human impacts on the coastal and marine environment. To raise awareness about the importance of, and threats to, the area's coastal marine ecosystems, Wellington Underwater Club started Project Baseline Wellington. Volunteer snorkelers and divers monitor the extent of giant kelp at Kau Bay Point in Wellington Harbor every six months and then share other observations related to biodiversity and seaweed ecosystems around Wellington with the wider public.

Within sight of Wellington's Central Business District, popular dive sites dot the Miramar Peninsula, which stretches north into the harbor. Many of the bays have been spared urban development and extensive shore modification. Native flora and fauna flourish, and these areas provide refuge and habitat for native wildlife like the little blue penguins. Seaweeds grow on the rocky substrate in the shallows and are the basis for this highly diverse and productive coastal ecosystem.

Seaweeds are photosynthetic macroalgae that are grouped based on their photosynthetic pigments into green, brown, and red algae. They differ from one another profoundly and vary enormously even within each group in their size, shape, texture, life cycle, and habitat. Along Wellington Harbor, large brown seaweeds of the order Laminariales (true kelps like *Macrocystis pyrifera* and the invasive *Undaria pinnatifida*) and fucoids (order Fucales, which includes *Carpophyllum flexuosum* and *C. maschalocarpum*) form extensive underwater gardens and forests.[1] A range of hard encrusting, or upright-growing, calcified red coralline algae as well as soft, filamentous red algae are common in the harbor. The diversity of seaweeds across all of New Zealand is staggering; a recent publication by the Department of Conservation reported the presence of 938 macroalgae taxa.[2]

Large brown seaweeds have an important function as ecosystem engineers, similar to tall canopy-building trees in rainforests.[1] They influence the physical environment (for example, light penetration and water movement), provide shelter and habitat, food and nutrients, and act as natural shore protection. **Read more about seaweed functions in the insert *Seaweed – A Cornerstone of Life* (pg. 42).** Local kelp beds and seaweeds are under threat by a range of stressors, including increased water temperature[3] and wave action (storms), reduced water quality caused by sedimentation or pollution, sand inundation of rocky substrate, land reclamation, and coast modification.

Worldwide, a range of indices based on macroalgae have been used to assess ecosystem health, as loss or extinction of habitat-forming species can result in fundamental ecosystem shifts and profound impacts on the associated biota (i.e., shift from canopy-forming species to turfing algae[4]). A recent report by R. D'Archino et al. (2019)[4] covers monitoring programs and methods used for mapping coastal macroalgae internationally and provides a comprehensive update on New Zealand's research into large brown seaweeds. In New Zealand, large brown seaweeds could be used as ecological indicators due to their susceptibility to specific stressors or to guide overall ecosystem management, acknowledging the critical role of kelp forests in increasing biodiversity or ecosystem resilience. The report notes, however, that there is a need for better baseline data, understanding of natural variability and linkages, and standardized approaches to monitoring.[4,5] On a local scale, giant kelp is a distinctive large brown seaweed species known to be susceptible to environmental change, including increasing water temperature.

A map of giant kelp beds in the Wellington area was published by Cameron H. Hay[6] based on surveys in November 1988 and April 1990. Oral accounts from local divers suggested that the extent of giant kelp fluctuated considerably over time and space. An initial qualitative comparison of Hay's map indicated there was a smaller area of giant kelp around the eastern side of the harbor and the northern tip of the Miramar Peninsula in June 2016. Giant kelp was present at Kau Bay Point, and we decided to establish a Project Baseline project at this popular dive site to monitor the extent of surface area covered by floating giant kelp biannually. Monitoring in New Zealand winter and spring accounts for seasonal changes in growth rates.

GPS data obtained by snorkelers swimming offshore around the floating kelp fronds at low tide is used to delimit the extent of the giant kelp bed in the core project area (dark green square, Figure 1) and to map and calculate the area covered for each monitoring date.

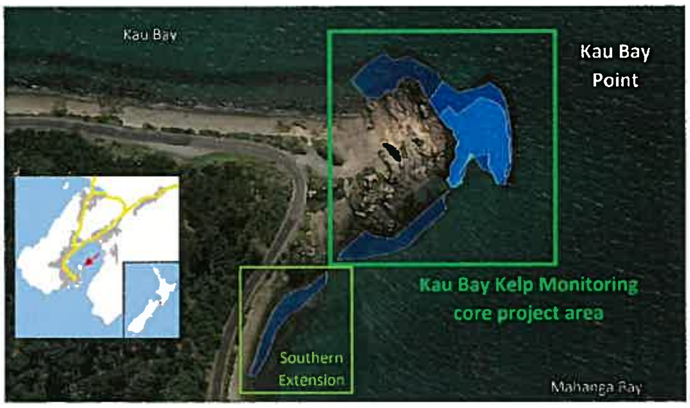


Figure 1: Project area with smallest and largest extent of giant kelp-covered surface recorded between June 2016 and June 2019. Smallest: December 2016 (green bottom layer, appears as light blue - 1,377 m), largest: November 2017 (darker blue - 3,619 m, plus southern extension - 553 m). Equals a ratio of minimum-to-maximum area covered (1,377 m/4,172 m) of 1:3.

The smallest extent of giant kelp was recorded in December 2016 in a small area around Kau Bay Point (Figure 1, light blue/green). In November 2017, giant kelp was productive close to shore on both sides outside the core project area and the largest area covered was recorded (Figure 1, dark blue). We also observed an area covered

[1] The two types of large brown seaweed, true kelp and fucoids, vary in their life history. True kelps alternate between a conspicuous (kelp or sporophyte) phase and a microscopic (gametophyte) phase. The fucoids have a direct life history in which egg and sperm are produced and fuse to form a zygote. Refer to *Beautiful Browns*, a guide to the large brown seaweeds of New Zealand, Kate Neill, Wendy Nelson, NIWA, v1 2016 and *An Illustrated Guide to New Zealand Seaweeds*, Wendy Nelson, Te Papa Press, 2013.

[2] *Conservation status of New Zealand macroalgae*, Wendy A. Nelson, Kate Neill, Roberta D'Archino and Jeremy R. Rolfe, Department of Conservation, 2019, ISSN 2324-1713 (online).

[3] Radio New Zealand National, Marine heatwaves to get stronger and more common (published 05 Mar 2019, retrieved 08 Sep 2019): https://www.rnz.co.nz/news/national/383999/marine-heatwaves-to-get-stronger-and-more-common.

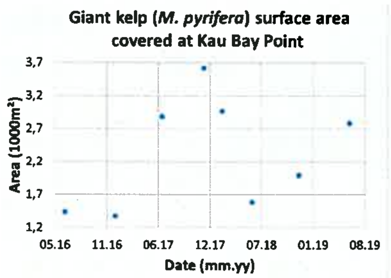
[4] *New Zealand Macroalgae: Distribution and Potential as National Scale Ecological Indicators*, R. D'Archino, K. F. Neill, W. A. Nelson, E. Fachon, C. Peat, New Zealand Aquatic Environment and Biodiversity Report No. 207, Fisheries New Zealand, 2019, ISSN 1179-6480 (online).

[5] Methods to inventory and monitoring of marine species and habitats have been published by the Department of Conservation. The module is updated as more methods and guides become available: https://www.doc.govt.nz/our-work/biodiversity-inventory-and-monitoring/marine/ (retrieved 14 Sep 2019).

[6] Cameron H. Hay, Journal of the Royal Society of New Zealand, 1990, 20:4, 313-336.

by giant kelp stretching into Mahanga Bay (shown on the map as "southern extension"). Figure 2 shows a graph and table of the observed surface area covered from June 2016 to June 2019 in the core project area.

Hay[6] reports that "in New Zealand *M. pyrifera* is confined to open coasts where the highest monthly mean temperature is cooler than 16°C to 17°C (61°F to 63°F), and there is little likelihood of summer maxima exceeding 18°C to 19°C (64°F to 66°F)." The author also refers to "the summer deterioration of some inner harbor beds" and that "the inner embayments of Wellington Harbor are clearly at the very limits of growth" of giant kelp.[6] Greater Wellington Regional Council (GWRC) records and publishes water temperature and bacteria load within 500 m (1,640 ft) of the project site over the summer season (November to March).[7] Figure 3 shows the available water temperature from November 2015 to March 2019, including the 2015–2016 summer before the project's start.



Date	Area (m²)
06.06.2016	1439
17.12.2016	1377
17.06.2017	2886
26.11.2017	3619
06.02.2018	2968
02.06.2018	1590
30.11.2018	1996
15.06.2019	2788

Figure 2: Surface area covered by giant kelp between June 2016 and June 2019 in the core project area

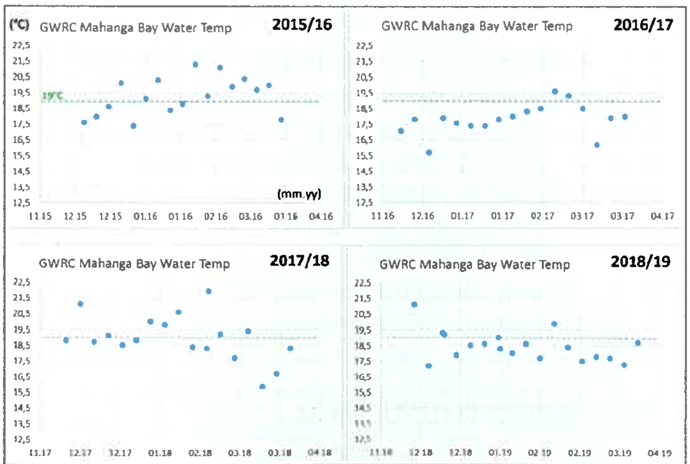


Figure 3: Water temperature (°C) between November and March (dd.mm.yy) recorded by the Greater Wellington Regional Council (GWRC) at the Mahanga Bay monitoring site (within 500 m/1,640 ft of the project area)

Season	Date	Max. Water Temp (°C)
2015/16	08.02.2016	**21.3**
2016/17	20.02.2017	19.6
2017/18	13.02.2018	**21.9**
2018/19	03.12.2018	21.1

Table 1: *Maximum water temperatures recorded by Greater Wellington Regional Council at Mahanga Bay for summer seasons (November to March) since 2015/16. Summer seasons with relatively warm water highlighted in bold, relatively cool seasons in grey.*

Over the 2015–2016 summer season, temperatures in Mahanga Bay frequently reached 20°C to 21°C (68°F to 70°F) (Figure 3), and the area covered by giant kelp observed in June 2016 was relatively small. In the 2017–2018 summer season, the water temperature in Mahanga Bay reached nearly 22°C (72°F), and a significant decrease of the size of the kelp bed was observed in June 2018, while the kelp bed size was observed to increase after summers with lower water temperatures (Figure 4).

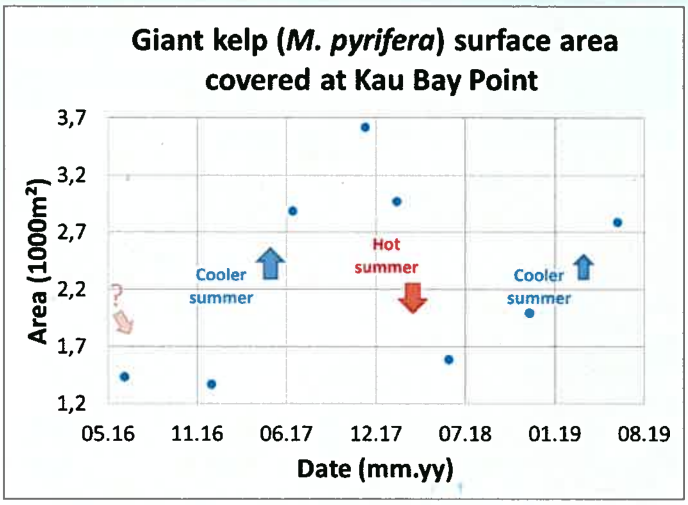


Figure 4: Surface area covered by floating giant kelp fronds and potential corelation with summer water temperatures

Our project monitoring data is consistent with the report by Hay[6] that giant kelp is less likely to occur in areas where summer water temperatures exceed 18°C to 19°C (64°F to 66°F) and his observation of summer deterioration of giant kelp beds in the harbor. To conclude if the reduction in kelp bed size is a result from shorter spikes of "hot" water or from the cumulative effect of exposure to warm temperatures above a critical temperature and time of exposure, more frequent monitoring data would be required.

The impact of sedimentation, sand inundation, and pollution could be variables to investigate in a more detailed study. No extraordinary events like harbor dredging or significant and prolonged pollution events were noted over the project time to date. Investigating the potential impact of strong storms and resulting nearshore swells on giant kelp beds, and research into wave height and wind directions might provide further insights into possible impacts over the project duration. The flow of Hutt River, nutrient levels in the harbor, and patterns of kelp recruitment are other variables that might impact the growth and health of giant kelp at the project site.

[7] Greater Wellington Regional Council GIS Viewer & Environmental Monitoring Database (retrieved 08 Sep 19): https://mapping.gw.govt.nz/GW/GWpublicMap_Mobile/ Monitoring Data Mahanga Bay: http://graphs.gw.govt.nz/?siteName=Mahanga%20Bay&dataSource=Water%20 Temperature%20(X).

AERIAL MONITORING OF GIANT KELP

The surface area as measured by GPS is a good indication of the surface coverage, but it doesn't provide information about the density of growth or the thickness of the *M. pyrifera* strands. Methods for monitoring seaweed on a larger spatial scale are developing rapidly with advancements in acoustic and optical remote sensing technologies and the ability to process and analyze large amounts of data.[4,8] Satellite images and drones are now commonly used tools for monitoring terrestrial and marine ecosystems[9] and provide more detailed observations. In addition, consumer grade drones are readily available with sophisticated image technology.

In March 2018, we started investigating the use of a drone (DJI Mavic Pro) to support the giant kelp monitoring project at Kau Bay Point. Our initial trials were promising,[10] and subsequent use of flight planning and mapping software (Drone Deploy) allowed us to create photomosaics of the Kau Bay Point kelp bed in June 2018 and June 2019 (Figure 5).

With the monitoring of giant kelp well underway, we decided to look at other possible stressors impacting kelp beds.

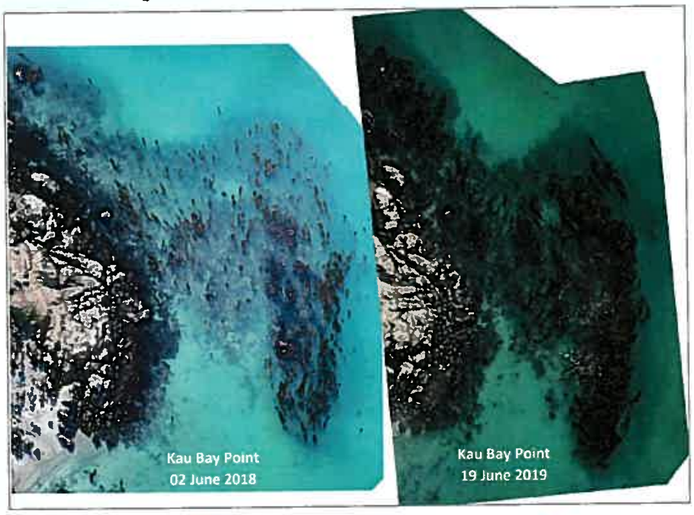


Figure 5: Photomosaics from drone images (DJI Mavic Pro) at 30 m (100 ft) flight height at low tide (June 2018 and June 2019)

KINA BARRENS AND INVASIVE UNDARIA SEAWEED

One of the biggest threats to seaweed is exploding numbers of sea urchins. Kina, *Evechinus chloroticus*, is the most common species of sea urchin in New Zealand. In the absence of predators, the numbers of kina can get out of control, resulting in kelp beds being grazed off completely and left as only barren rock, or so called "kina barrens."[11] During the initial site survey in June 2016, scuba divers noted an area of kina barren along the margin of the kelp bed with an estimated size of 30 m x 15 m (98 ft x 49 ft).

We undertook a GPS-tracked video dive in June 2019 (97 m/318 ft transect length) and observed kina barrens, areas only thinly covered by seaweed (see video screenshots in Figure 6), and patches with dense kina populations on the edge of the giant kelp bed. We are now planning to map kina barrens and areas thinly covered by seaweed in more detail to monitor changes in extent and type of coverage over time.

Figure 6: Screenshots of the Kau Bay Point kina video survey (August 4, 2019). An example of invasive Undaria pinnatifida *is circled in the top row of images.*

The invasive seaweed *Undaria pinnatifida* is well established in Wellington Harbor, and we recorded both the juvenile and reproductive stage of Undaria on recent monitoring dives. Research suggests that in areas with moderate grazing pressure, kina could exclude native seaweed species, resulting in coastal areas with lower biodiversity.[12]

EDUCATION AND OUTREACH

Coastal marine ecosystems are under threat, particularly in densely populated areas where potential negative impacts of coastal and harbor developments exacerbate other stressors. Raising awareness about the importance of healthy seaweed gardens and forests and providing opportunities for residents to experience seaweed ecosystems is crucial to gain support for mitigating urban pressures.

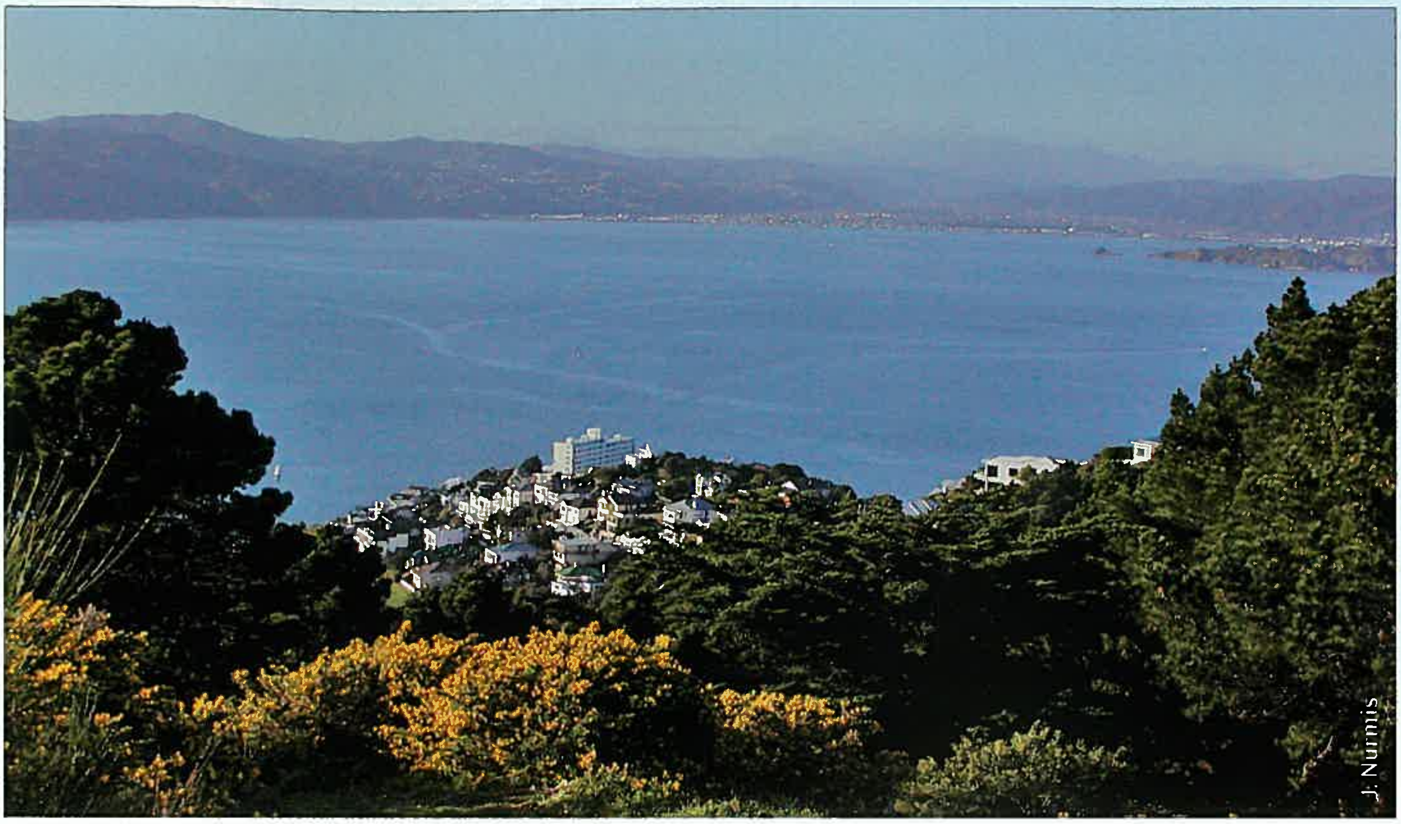
[8] R. D'Archino et al.,[4] for example, developed and applied machine learning algorithms to identify and map dominant seaweed species on Wellington's South Coast from video data. The research team report strong initial results, discuss limitations, and provide recommendations for further development of the method.

[9] Sustainable Seas National Science Challenge Webinar: Using drones to monitor marine ecosystems. Dr. Leigh Tait from the National Institute of Water and Atmospheric Research (NIWA) describes his research on monitoring kelp and seaweed biodiversity of coastal marine ecosystems using drones (recorded 06 Jun 2019, retrieved 08 Sep 19): https://youtu.be/-A83VI2xWk4.

[10] Our initial test on the use of drones is one of three examples mentioned by R. D'Archino et al.[4] For a detailed discussion, refer to chapter 4.3.2 "Mapping by Drone and UAV (Unmanned Aerial Vehicle)" of the report.

[11] Booth, J. D. 2017. Characterising fisheries and other marine harvesting in the Bay of Islands, with ecological consequences, from first human settlement to the present. *New Zealand Aquatic Environment and Biodiversity Report No. 186*; Booth, J. 2015. Flagging kelp: potent symbol of loss of mauri in the Bay of Islands.

[12] Review of research on *Undaria pinnatifida* in New Zealand and its potential impacts on the eastern coast of the South Island, Mike D. Stuart, Department of Conservation Science Internal Series 166, 2004, ISSN 1175–6519 (online).



Project Baseline Wellington continues to monitor the extent of giant kelp while raising public awareness of this important aquatic species.

In 2018, Project Baseline Wellington supported the Year 9 and Year 10 Seaweed Action Projects run by Mountains to Sea Wellington Trust. As part of the program, students experience what a kelp forest looks like above and beneath the ocean's surface and learn how new technologies can be applied to seaweed monitoring and conservation. We continue to support Mountains to Sea Wellington Trust with education and outreach as part of the LoveRimurimu campaign.[13]

Warmer summer water temperatures, grazing pressure by sea urchins, and compounding impacts of other stressors could profoundly change the makeup and biodiversity of Wellington's coastal marine ecosystem. Our observations of the fluctuating extent of giant kelp at Kau Bay align with the expected impacts of varying summer water temperatures over the project duration. We are now looking at mapping kina barrens and assessing the biodiversity at our project site in more detail. Our baseline data and observations are publicly available, and we will continue with other marine education and conservation projects. Regeneration of our extremely important coastal seaweed ecosystems needs to be a priority for organizations charged with maintaining the health of the region's biodiversity.

ACKNOWLEDGEMENTS

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[13] Mountains to Sea Wellington Trust Seaweed Action Project: http://mountainstoseawellington.org/seaweed-project/ (retrieved 08 Sep 19); LoveRimurimu, restoring seaweed forests (retrieved 02 Feb 2020): http://mountainstoseawellington.org/love-rimurimu/

Seaweed – A Cornerstone of Life *(by Katrin Mager)*

Far from being the obnoxious, unwanted plants the poorly chosen name suggests, the "weeds" of the sea play an essential role in the coastal marine ecosystem. Seaweeds are marine macroalgae that live attached to rock and other structures in coastal areas. They are one of the foundations of abundant underwater life and contribute a great deal to our wellbeing as well.

Habitat. Anchored to reefs with amazing holdfasts, seaweeds form three-dimensional structures in shallow waters close to shore and provide habitat in which a myriad of life forms settle. Large kelp can even grow so long that it builds underwater forests. Like their terrestrial counterpart, these subtidal forests are complex systems that consist of a community of aquatic organisms interacting with their physical surrounding.

Shelter. Algal beds and turfs provide refuge for invertebrates and many different fishes. Breeding nurseries rely on seaweed gardens and forests for protection. Some fishes are so adapted to seaweeds, they look like fronds themselves.

Food source. Seaweeds are an important primary source of nutrients for aquatic food webs. Fishes and invertebrates eat the seaweed when it is still attached to hard substrate, and when pieces break off and are carried away by currents, other aquatic critters feed upon it. In addition, seaweeds produce mucilage, which is an important food source for small organisms that are themselves vital to coastal food webs. The slime dissolves in the water and provides food for bacteria, fungi, and protozoans, which sustain filter feeders. Eventually, drifting plant matter not consumed by aquatic animals washes up onto the beach where insects enjoy a seaweed feast before they are in turn consumed by birds like seagulls.

Protection from erosion. A strong growth of macroalgae can absorb wave energy, which helps protect the coast from the elements. Some seaweed species can withstand prolonged burial under sand, enduring the ever-changing conditions of coastlines.

Carbon sinks. Kelps are productive in the amount of carbon they fix by photosynthesis, known as Blue Carbon.[1] This process also helps to reduce ocean acidification, a serious problem we face in this time of climate change. Seaweeds and seagrass (which is similarly productive in our estuaries) play a vital role for the global atmosphere.

Oxygen production. As part of the carbon cycle, ocean plants produce a huge amount of oxygen. Some estimate more than 70% of the oxygen we breathe comes from the sea, the blue lungs of our planet. Most of the oxygen is produced on the vast surface of the open ocean by phytoplankton, a microscopic algae. But on sunny days divers can observe oxygen bubbles being released in coastal seaweed gardens.[2]

Human consumption, fertilizer, biofuels, and other uses. From seaweed crackers to growth stimulants for vineyards, there is ample opportunity to explore and discover a wide range of possible uses for seaweed. Seaweed farming can provide important nutrients, help combat climate change, and provide for underwater ecosystems all at once. Further, invasive *Undaria* (in Japanese, "wakame"), a popular food item for humans, is harvested from mussel lines for export.[3]

[1] Substantial role of macroalgae in marine carbon sequestration, D. Krause-Jensen, C. M. Duarte, Nature Geoscience, 9, 737–742 (2016).
[2] Seaweed – Oxygen Producer Galore: (retrieved 08 Sep 19).
[3] From pest seaweed to future food, published 02 September 2019 (retrieved 05 Sep 19): https://www.mbie.govt.nz/about/news/from-pest-seaweed-to-future-food/.

Dr. Nicole Miller is Chair of the Friends of Taputeranga Marine Reserve Trust, Wellington Underwater Club President, a certified cave and GUE Tech 1 diver, and an active member of the New Zealand Speleological Society. Nicole has established marine citizen science projects in the marine reserve and Wellington Harbor and is passionate about environmental education and public engagement. Check out her immersive 360^0 underwater tour of Taputeranga Marine Reserve at www.adventure360.co.nz/360tmr and search for #CrittersOfWellington and #LoveSeaweed on Facebook for more details about Wellington's marine environment.