# Regulatory reform for environmentally responsible management of beach wrack and estuarine seaweed growth

The conventional approach to managing wild seaweed in Australia has been based around concerns there should be minimal disturbance to marine ecology. Seaweeds have properties that contribute to water quality, including combatting the adverse impacts of climate change through absorbing carbon, reducing ocean acidification and temperature, and maintaining habitat for vulnerable marine species. The Australian hands-off approach to seaweed management is reflected in regulatory regimes that constrain harvesting seaweed from where it is growing, as well as restricting collection of beach-cast seaweed (beach wrack).

The hands-off approach was justifiable in the past when there was limited knowledge about the ecological interactions and sustainable uses of seaweeds. However, with recent improved understanding and high-quality information available, it is appropriate to review this approach. There are various unintended consequences from minimal interventions. In particular, there is evidence that benthic marine ecologies are suffering from increased growth of macroalgae (seaweeds) in response to changing environmental conditions. Different management regimes are emerging in various parts of the world that seek to restore ecological balance while also directing the excess seaweed towards productive use, including agricultural inputs.

## Ecological impacts of seaweed

Macroalgae species have distinctive properties but there are common ecological functions and impacts on their environments. The major ecological function of Australian brown seaweeds is forming canopies that protect other benthic organisms from harmful solar radiation. In rocky benthic ecosystems, seaweeds may provide habitat and nutrients for the other organisms. Their growth is stimulated by the presence of nutrients, and they are effective in absorbing nitrogen and phosphorus quickly, with an additional slower but effective uptake of carbon. While absorbing nutrients from their habitat, seaweeds also release chemicals that provide ecological and geochemical benefits. However, they also contain a number of halocarbons, notably including bromoform, which can contribute to ozone depletion and coral degradation if the ecological balance is disturbed.

Pollution of waterways as a result or urban or agricultural land uses (sewage, livestock effluent, fertiliser runoff) is leading to massive increases in seaweed growth within estuaries, exacerbated by increased marine temperatures. The initial take-up of nutrients by seaweeds can be a benefit to water quality, but this may be reversed if the seaweed growth is unchecked. Estuaries may be choked, reducing water circulation and oxygen levels. Decaying seaweeds may release nutrients back into the water.

If the seaweed is subsequently washed onto beaches, the decaying materials will release a number of harmful emissions:

- Hydrogen sulphide, which not only creates an unpleasant smell but is also harmful to health
- Greenhouse gases, including carbon dioxide, methane and nitrous oxide
- Ozone-depleting gases, such as halogenated hydrocarbons.

The level of emissions from beach wrack in some environments has been estimated to be 1 tonne $CO_2$-e from 2 tonnes dried beach cast material, with 1-3 tonnes per day per km being deposited. Increased seaweed growth appears to be resulting in even greater deposition of seaweed beach wrack in many areas.

## New approaches to seaweed management

Recent approaches to seaweed management take the ecological and biological behaviour of seaweeds into account. The ability of seaweed to rapidly uptake nutrients means it can be used in the bioremediation of eutrophication in coastal water sheds, including estuarine environments. In European environments, it has been estimated that 1,000 tonnes of wet seaweed can remove 8 tonnes of nitrogen and 200 kg of phosphorus from the surrounding waters. Chinese seaweed aquaculture is targeted to remove 100% of Chinese coastal phosphorus pollution by 2026. Seaweed can be used as a small-scale biofilter to treat aquaculture effluents in coastal areas, as seen in South Korea and eastern Australia. Unlike natural seaweed biomasses, the seaweed used for bioremediation is cultivated in ways that minimise the decay and release of harmful gases. The nitrogen and phosphorus re-absorbed from aquaculture effluents can be re-used as an aquaculture feed, and have the additional potential to be used as fertilisers and biostimulants in agriculture.

The excessive eutrophication of coastal waters results in seaweed blooming in benthic ecosystems and coastal water sheds. These are sometimes called 'green tides', when green seaweeds are the dominant species occupying an entire region of sea surface, or 'red tides', when red species are dominant. Regular but low levels of eutrophication incrementally increase seaweed biomass over time, with consequent beach wrack deposits. This material is either swept back into the sea, enabling reabsorption of nutrients, or left on land where it releases harmful emissions. These gases are released most rapidly in the early stages of decomposition, so any mitigation would require collection of fresh material as soon as possible after it is washed up.

In a natural ecological system, seaweed management is achieved through grazing by marine fauna, promoting new growth and reducing the drift of detached fronds. In the absence of natural marine grazing, harvesting by humans may be a beneficial intervention. Wild harvesting of seaweed and collection of beach wrack has been a tradition of many Indigenous communities, practised at a small and sustainable level. Contemporary changes to estuarine ecology suggest a different response may be appropriate.

Some regulatory regimes have permitted contemporary harvesting activities at selected localities, but have restricted the scale and timing of operations. Within Australia, regulations differ between states, but all are highly restrictive. Regulatory regimes are now being questioned in some overseas jurisdictions, with potential reforms proposed to enable more proactive management of excessive seaweed growth, including deposits of beach wrack.

## Use of wild-harvested seaweeds

There are considerable challenges in the use of wild-harvested seaweeds:

- Seaweed biomass is highly perishable and deteriorates rapidly, so it needs to be collected and processed regularly and without delay.
- Seaweed biomass has a high moisture content in this fresh state (typically 80-90%), adding to transport costs.
- Natural epiphytes (other seaweed species) and material attached to seaweeds (e.g. sand, molluscs) increase the difficulty of processing, with some uses requiring pre-cleaning and pre-washing.
- The seasonality or otherwise intermittent and variable nature of seaweed growth and beach deposition prevents a continuous throughput for processing, with some uses requiring frequent analytical testing.

In circumstances where different seaweed species can be separated during collection, it may be cost effective to wash and shred the fronds, and then preserve the material in oil. There is a good market for this wild-harvested produce if it is directed to pharmaceutical or nutraceutical uses. A few licensed collectors of beach wrack in Australia are able to tap into this market.

Where species separation is not feasible, which is the case with much of the available beach wrack, the cost effectiveness of processing can be improved by creating economies of scale. In Europe, collection of beach wrack is being promoted as a basis for regional manufacturing hubs producing biogas or biochar. Both the digestate from biogas production and the seaweed biochar product retain much of the nutrient content of the seaweed feedstock, and are potentially valuable as agricultural inputs.

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## Trialling silage production from seaweed

If the necessary economies of scale are not achieved, there are additional possibilities for collection and processing. Making silage from seaweed is one possibility, and was recently trialled using beach wrack collected from Warrnambool beaches in south-west Victoria. Warrnambool beaches are known for 'red tides', where predominantly red-coloured seaweed deposits accumulate on beaches, together with a mix of seaweeds species. Substantial amounts of brown kelp are found within this mix.

In this trial, bull kelp species were separated and hung to dry, then brushed and blow-dried to remove sand, with some further washing. All these measures, however, only removed a limited amount of sand. Shredding was then necessary for the kelp component of the seaweed that had been collected, and it became apparent a fairly powerful shredder not normally available on individual farms was required for this purpose. A second sample involved finer red seaweed, with the less-bulky mass not requiring shredding. Whey was applied as a final wash before packing with conventional silage inoculant and mixing with hay as a helpful fermenting adjunct.

Unfortunately, the resulting quantities of silage after processing were not sufficient for rigorous analysis. Additionally, practical challenges associated with the preparation process mean producing silage from seaweed is unlikely to appeal to individual farmers. There has been limited laboratory research conducted on seaweed silage indicating its potential use as animal fodder, but with mixed results in terms of nutritional quality and palatability for livestock; more time appears to be needed for the required fermentation to take place compared with conventional silage making. While mixing seaweed with hay may assist the process, this is still likely to be slower than ensiling hay alone.

A less-complicated use for harvested seaweed and beach wrack is compost manufacture. This would require mixing semi-dried seaweed with an explicit quantity of dry high-cellulose materials (such as straw or sawdust) to achieve the optimal carbon:nitrogen (C:N) ratio for aerobic composting, i.e. promoting decomposition without excessive greenhouse gas emissions. Research elsewhere (Paul, 2020) has indicated there is no need to wash seaweed before using it as a compost feedstock, with the levels of salt and sand being too low for any adverse impact. Empirical evidence suggests the resulting compost is a highly effective soil amendment, with immediate improvements seen in plant growth and productivity.

**Figure 1.** A red tide at a Warrnambool beach.

**Figure 2.** Shredded bull kelp collected from the red tide.

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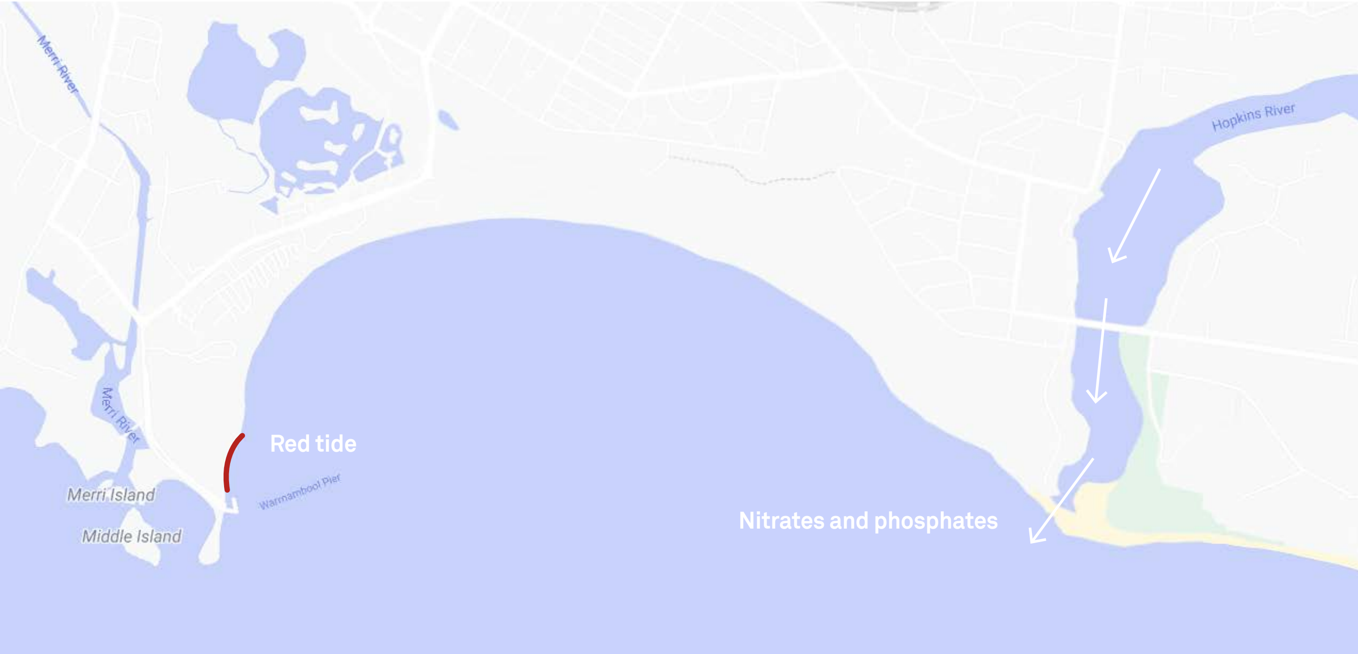


**Figure 3.** Agricultural eutrophication of nitrogen and phosphorus contributing to the red tide at Warrnambool.

## Curdies River catchment as a case study

The Curdies River catchment in south-west Victoria provides a useful case study for potential regulatory and operational reforms to seaweed management. The estuary is wide and shallow, with limited flushing to the ocean. There have been longstanding concerns about the excessive nutrient content of the waterways flowing into the estuary, arising primarily from agricultural uses such as dairy farming. The frequency of toxic algae blooms appears to be increasing, with evidence of devastating impacts on fish and livestock. While land management strategies being promoted may ultimately reduce nutrient discharge into the catchment waterways, the level of nutrients contained within river and estuary sediments is such that their release will be an ongoing cause of poor water quality for several decades.

Several past studies have been carried out to identify the impacts of high nutrient levels on water quality and aquatic ecology. Curiously, these make scant reference to the presence and potential role of macroalgae. It is evident from observation that the estuary is currently supporting substantial growth of seaweed, particularly kelp species, but this may be a very recent phenomenon. This macroalgal bloom is likely a potential benefit in terms of absorbing phosphorus and nitrogen, which are the main pollutants. However, if the seaweed growth is unchecked, as much as 25% of annual growth could be cast off into the surrounding water. Decaying seaweed that sinks to the estuary floor smothers the seagrasses that are integral to the natural ecology of the estuary, and this decaying material will release the absorbed nutrients back into the estuarine waters. Unchecked growth could also lead to choking the estuary, reducing the benefits of ocean flushing, lowering oxygen levels and exacerbating toxic algal blooms.

When the estuary is periodically open to ocean flushing (sometimes requiring human intervention), detached seaweed fronds are likely being carried out to sea, contributing to increased quantities of beach wrack being deposited on the nearby beaches. This creates a significant nuisance for residents and visitors, as well as giving rise to harmful emissions. If the nutrients are absorbed into ocean waters, this may amplify the effects of ocean acidification, which is already leading to erosion of the limestone coastal landscape, including the famous Twelve Apostles.

The properties of seaweeds can be monetised if the cost of bioremediation is assessed together with the value of carbon sequestration. Based on an estimated area of 1.5 km$^2$ for the Curdies River estuary, the combined amount of seagrass and seaweed sequestration in a managed system could be at least 2,000 tonnes of $CO_2$-e per year, which could be worth more than $100,000 in carbon credits at the present price. This suggests budgeting $100,000 per year for seaweed management is financially worthwhile, and a greater amount may be justifiable in terms of nutrient removal as well as the potential for economic benefits derived from processing the removed seaweed.


**Figure 4.** Agricultural eutrophication of nitrogen and phosphorus polluting the marine water.

Given the prevalence of dairying in the catchment, it is appropriate to consider a circular model for recycling the nutrients being discharged into the catchment waterways. Harvesting seaweed from the estuary and collecting beach wrack could provide feedstock for composting, with the compost used as a partial replacement for synthetic fertiliser applications in pastures and cropping areas. This could be pursued through a commercial composting enterprise or as an individual on-farm activity.

Reform of regulations around such activities might involve development of a marine ecosystem-based management (EBM) framework such as is proposed in New Zealand, balancing environmental benefits and risks from management interventions. This could be a valuable contribution to the development of other blue economy initiatives, mobilising marine resources for reducing or offsetting greenhouse gas emissions in ways that provide socioeconomic co-benefits.

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