



Exotic Caulerpa and the Hauraki Gulf

Assessing the ecosystem services at risk

NZIER final report to Hauraki Gulf Forum

July 2024

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Authorship

This paper was prepared at NZIER by Michael Bealing.

The assistance of Sarah Spring is gratefully acknowledged.

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Registered office: Level 13, Public Trust Tower, 22–28 Willeston St | PO Box 3479, Wellington 6140

Auckland office: Level 4, 70 Shortland St, Auckland

Tel 0800 220 090 or +64 4 472 1880 | econ@nzier.org.nz | www.nzier.org.nz

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Key points

This report aims to assess the value put at risk by exotic Caulerpa and evaluate what's at stake based on the limited evidence available.

- The purpose of this brief report is to assess the value of risks to the ecosystem services in the Hauraki Gulf posed by invasive exotic Caulerpa.
- The quantitative evidence of the effect of an invasion of Caulerpa is limited to a small number of studies globally.
- In New Zealand, field research into the environmental impacts of exotic Caulerpa is still in its preliminary stages.
- The evidence of the effects of exotic Caulerpa on the Hauraki Gulf ecosystems will continue to improve as field research is completed.

This report draws on NZIER's research into the value of ecosystem services in the Hauraki Gulf and international evidence of the effects of exotic Caulerpa to evaluate the potential social and economic value of ecosystem services vulnerable to exotic Caulerpa. However, it is not a forecast of the losses because more information is needed to complete a robust assessment.

The worst case scenario for quantifiable value from ecosystem services in the Hauraki Gulf at risk due to exotic Caulerpa is from \$73m to \$154m annually.

- The worst case scenario for quantifiable value from ecosystem services in the Hauraki Gulf at risk due to exotic Caulerpa is from \$73m to \$154m annually, and the unquantified risk to services would increase this estimate.
- Exotic Caulerpa is a hardy organism capable of surviving in colder and deeper water than its competitors.
- International evidence indicates that exotic Caulerpa will outperform seagrass, decreasing the diversity and volume of aquatic life.
- Loss of spawning and nursery habitat could risk half the commercial catch in the Hauraki Gulf or three out of five of the top species caught, including blue mackerel, snapper and trevally.
- The risks to aquaculture in the Gulf have proven too hard to quantify due to a lack of evidence. However, the results of an NIWA field study found exotic Caulerpa crowding out wild shellfish.
- There is local evidence that exotic Caulerpa affects kina and scallop populations, and an investigation is ongoing. This means the Caulerpa could negatively impact both cultural and provisioning services.
- Recreational fishing will be impacted alongside commercial fishing, and some recreational activities like scuba diving will be negatively affected. However, we found

no evidence of direct effects on boating and swimming beyond the requirements for eradication activities or restrictions.

- Internationally, an invasion of *Caulerpa* has been found to decrease biodiversity and biomass in the food chain.

The findings in this report are a starting point based on the available evidence. However, there is uncertainty involved, and therefore, the conclusions should be seen as something that will evolve as more New Zealand-based field research is completed.

- NZIER's analysis has not assessed the impacts of exotic *Caulerpa* on Te Tiriti settlements, Marine and Coastal Area Act claims, and Iwi Fisheries. NZIER recommends that this assessment be completed to inform the discourse and decision making.
- NZIER also recommends that there is greater investment in economic research that captures the Māori perspective.

This report should be used to inform decision-making about the benefits of further research to improve the evidence base on the effects of exotic *Caulerpa* in the Hauraki Gulf and to motivate actions to limit the spread of the invasive species until the effects are better understood.



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1 Purpose and approach

1.1 The context of the report

Since 2021, two exotic invasive species of *Caulerpa* algae have been discovered in the Hauraki Gulf, New Zealand. These species are *Caulerpa brachypus* and *parvifolia*. They are known for their colonising abilities and negative effects on local biodiversity and economic contributions of marine environments. The two species showed similar characteristics to the highly invasive *Caulerpa taxifolia* that has been problematic overseas. *Caulerpa taxifolia* has been listed as a Notifiable Species under New Zealand's Biosecurity Act since 2001. In September 2021, *Caulerpa brachypus* and *parvifolia* were given the status of Unwanted Organisms under the Biosecurity Act.¹

Henceforth in, exotic *Caulerpa* is used to refer to the invasive *Caulerpa brachypus* and *parvifolia* in this report.

1.2 Purpose

This report provides an indicative assessment of the potential impact of exotic *Caulerpa* on ecosystem services in the Hauraki Gulf environment. This assessment is a rough-order estimation of the effects of the invasive species on the Hauraki Gulf and is not intended to be interpreted as an in-depth assessment or the final word on the matter. The aim of the assessment is to rapidly provide an assessment of what could be a risk based on a quick desktop assessment using publicly available research findings and other information from New Zealand and overseas.

1.3 Our approach

The assessment utilises the previous research on valuing the ecosystem services of the Hauraki Gulf as the basis for the value of the services that could be at risk due to the incursion of exotic *Caulerpa*.

The contribution of the natural environment can be defined using the ecosystem services framework, which links ecosystem conditions to natural functions and services of value to people. It focuses on four kinds of ecosystem services that nature provides for humans:

- **Provisioning services** such as the supply of wild food, timber, sources of energy and water.
- **Regulating services** such as flood mitigation, erosion control, and water quality.
- **Cultural services** such as providing settings for recreation and non-use or passive nature appreciation.
- **Supporting services** include basic processes like nutrient cycling or pollination on which all other services depend, but supporting services are rarely subject to separate estimation because of their interconnection with other services and the risk of double counting.

¹ <https://niwa.co.nz/news/marine-invader-caulerpa-triggers-biosecurity-response>

2 What is Caulerpa?

Caulerpa is a green alga that is widely distributed globally. Caulerpa is a genus of algae, of which there are 106 species globally,² and several are native to New Zealand³. Caulerpa has several traits that make it effective at colonising coastal marine environments rapidly in a way that supplants existing species, which negatively impacts the existing biodiversity. Caulerpa's biological traits include:

- Its hardiness and ability to survive in a range of marine environments, including brackish areas.
- Surviving in lower light conditions, deeper water, and colder water than other species makes it harder and increases its range compared with other species.
- In New Zealand, exotic Caulerpa has been found growing on shellfish and climbing over natural rock barriers.⁴
- A high reproduction rate and an asexual reproduction system that allow it to invade new areas quickly.

The ecological impacts include:

- Some species of Caulerpa are toxic to marine life, and a subset is toxic to humans.⁵
- The number of cases of death and illness associated with seaweed broadly is low, with a total of 14 deaths and 73 cases of illness.
- Toxic organic compounds contribute to protecting it from grazers.⁶
- However, the diversity of Caulerpa is wide, and some species are suitable for human consumption.⁷
- Caulerpa covers the sea floor, crowding out other species, such as scallops, mussels, and sponges, which may be already under pressure from sedimentation and overfishing.
- The density and toxicity of Caulerpa exclude fish from feeding on worms, crabs and shellfish, which can lead to a decrease in the population of some fish species in response to less accessible feedstocks.
- The density and toxicity (in some cases) of Caulerpa also impact existing marine nurseries such as seagrass, which negatively affects reproduction rates.

The biodiversity of marine ecosystems is negatively affected by *Caulerpa prolifera* as its presence has been shown to be associated with fewer species and a decline in the

² AlgaeBase. 2024. 'AlgaeBase'. 2024. <https://www.algaebase.org/>.

³ National Institute of Water and Atmospheric Research. 2024. 'Marine Invader Caulerpa Triggers Biosecurity Response'. 2024. <https://niwa.co.nz/news/marine-invader-caulerpa-triggers-biosecurity-response>.

⁴ <https://www.nzgeo.com/stories/killer-algae/>

⁵ Cheney, D. 2016. 'Chapter 13 - Toxic and Harmful Seaweeds'. In *Seaweed in Health and Disease Prevention*, edited by Joël Fleurence and Ira Levine, 407–21. San Diego: Academic Press. <https://doi.org/10.1016/B978-0-12-802772-1.00013-0>.

⁶ <https://www.fisheries.noaa.gov/west-coast/habitat-conservation/caulerpa-species-west-coast#about-caulerpa>

⁷ Mahadevan, Kritika. 2015. 'Chapter 13 - Seaweeds: A Sustainable Food Source'. In *Seaweed Sustainability*, edited by Brijesh K. Tiwari and Declan J. Troy, 347–64. San Diego: Academic Press. <https://doi.org/10.1016/B978-0-12-418697-2.00013-1>.



populations of existing species because of its combined impact on habitat, the reproductive success of other species and the food chain.

3 Assessment of the effects of exotic *Caulerpa*

3.1 The effects of *Caulerpa* on provisioning services

The Hauraki Gulf provides a range of provisioning services used for consumption and trade activities in the economy.⁸

In general, the effect of controlled area notices (CAN) can include restrictions on fishing, fishing activities that contact the seafloor and anchoring. In the instance of Aotea, such restrictions have now been in place for some time, which has an immediate impact on the local ability to gather kai moana and a knock-on effect on the local Aotea economy through a reduction in trade.

There are several tourist-dependent islands in the Hauraki Gulf – Aotea, Waiheke, Rakino, Tiritiri Matangi, Rangitoto and so on. There can be knock-on impacts to tourism operators, such as ferry services.

Commercial and recreational fishing

International evidence indicates that exotic *Caulerpa* has the potential for significant adverse effects on commercial and recreational fishing.⁹ There are few detailed studies on the effect of *Caulerpa*. Parreira et al. (2021) showed the loss of seagrass due to invasive *Caulerpa prolifera* was associated with the loss of nursery areas for commercial fish species. Seagrass was a habitat for 68% of commercial species, while no juveniles of commercial species were observed in areas where it had invaded and supplanted seagrass. That study also reported that it had colonised unvegetated areas, which no longer meant those areas were suitable habitats for commercial shellfish species. The commercial fish species adversely affected were flat fish and sparidae. Sparidae is a family group that includes snapper.

Research is underway in New Zealand to understand the effects of exotic *Caulerpa* on the ecology of the Hauraki Gulf. Early findings show that exotic *Caulerpa* has supplanted seagrass and colonised unvegetated areas in New Zealand.¹⁰ The effect of exotic *Caulerpa* on commercial species in New Zealand is subject to ongoing research by NIWA. This study may also shed light on the impacts of customary fishing. It could be impacted by changes in the ecosystem and biodiversity.

Caulerpa gets caught in netting, anchor chains and other equipment, which has a small negative effect on productivity and maintenance activities, including additional cleaning costs, especially under an eradication mandate.

Aquaculture

Exotic *Caulerpa* has the potential to grow on aquaculture equipment that may interfere with the productivity of aquaculture farming and affect boat movement.

⁸ <https://www.nzier.org.nz/hubfs/Valuing%20the%20Hauraki%20Gulf%20-%20NZIER%20final%20report.pdf>

⁹ Parreira, Filipe, et al. "Biodiversity consequences of *Caulerpa prolifera* takeover of a coastal lagoon." *Estuarine, Coastal and Shelf Science* 255 (2021): 107344.

¹⁰ NIWA (2023). *Caulerpa 2023- Impact of exotic *Caulerpa* on native species at Aotea/Great Barrier Island – Phase 1.*

Sand extraction

It's unclear whether exotic *Caulerpa* will majorly affect commercial sand extraction. Additional costs might be associated with pest management and initial vegetation removal from the extraction site.

Shipping, ports and cruise industry effects

Like aquaculture and commercial fishing, there is potential for exotic *Caulerpa* to increase equipment cleaning and biosecurity costs, but the extent of these costs is unclear.

3.2 The effects of exotic *Caulerpa* on cultural services

Effects on recreation benefits

Recreational activities such as swimming and boating in areas colonised by *Caulerpa Taxifolia* have been shown to increase the risk of spreading to other areas.¹¹ Even if recreational activities are not deterred in colonised areas, there is a case for restricting recreational activities in colonised areas to control the spread of invasive species.

Depending on the extent of such restrictions on recreational activities, they could have the following range of effects including:

- discourage recreational activities
- relocate recreational activities
- change the nature of recreational activities.

Currently, there are no restrictions on swimming in controlled areas.¹²

Swimming is not negatively affected by the presence of *Caulerpa*. Where *Caulerpa* variants have been cultivated for human consumption, the risk associated with toxicity of those variants has been found to be low.¹³

Scuba diving is more affected than other recreational activities because an invasion of *Caulerpa* leads to dense monoculture vegetation, lower biodiversity, and lower capacity to support marine populations. Therefore, an area invaded by exotic *Caulerpa* will become less attractive to scuba drivers.

Effects on property amenity values

Caulerpa is algae that looks like green seaweed and is often used to beautify private and public aquarium displays. It is not an unattractive slime like other aquatic invasive species. In this assessment, we have assumed that exotic *Caulerpa* is unlikely to negatively affect property and amenity values. Therefore, the estimates of the loss of property amenity values in the context of the ecosystem services assessment are low or zero. However, in the short term, there may be temporary negative effects, particularly in the event of a storm that causes debris. The image below shows *Caulerpa* washing up after Cyclone Gabriel on

¹¹ West, Elizabeth J., Andrew R. Davis, Peter B. Barnes, and Jeffrey T. Wright. 2009. 'The Role of Recreational Activities in Creating Fragments of Invasive *Caulerpa Taxifolia*'. *Journal of Experimental Marine Biology and Ecology* 376 (1): 17–25. <https://doi.org/10.1016/j.jembe.2009.05.015>.

¹² <https://www.mpi.govt.nz/dmsdocument/46390-Caulerpa-brachyopus-in-Blind-Bay-Aotea-Fact-sheet>

¹³ Parent-Massin, D. 1996. 'Evaluation of the Toxicological Risk to Humans of Caulerpenyne Using Human Hematopoietic Progenitors, Melanocytes, and Keratinocytes in Culture'. *Journal of Toxicology and Environmental Health* 47 (1): 47–59. <https://doi.org/10.1080/009841096161924>.

Okupe Bay on Aotea Great Barrier Island. We understand the community conducted a clean-up exercise to remove the material.

Figure 1 Caulerpa washing up on Okupe Bay after Cyclone Gabriel



Source: photograph by Noel Nancekivell

Special consideration of the Māori perspective of the cultural services

The value of the Hauraki Gulf Māori perspective of the cultural services was not quantified due to insufficient information to do it justice. However, there is concern that exotic Caulerpa will alter the biodiversity of the Gulf in a way that negatively impacts the cultural connection to the marine environment, depleting the mauri and negatively affecting the availability of kia moana and other cultural practices.¹⁴

In August 2023, Ngāti Rehua/Ngāti wai ki Aotea filed a Waitangi Tribunal Claim on the matter. There have also been several letters from iwi leaders that mention a breach of Te Tiriti article two. NZIER's analysis has not assessed the impacts of exotic Caulerpa on Te Tiriti settlements, Marine and Coastal Area Act claims, and Iwi Fisheries. It was out of scope. NZIER recommends that this assessment be completed. We would also recommend that there is greater investment in the assessment of the Māori perspective of the cultural services of the environment. Such research would be tremendously value for strengthening economic and policy analysis.

3.3 The effects of exotic Caulerpa on the regulating and supporting services

Regulating and supporting ecosystem services in a marine environment is fundamental to the ecosystem's health and existence and its benefits for human society. Regulating services include waste management, climate control and flood management. Supporting

¹⁴ <https://www.nzgeo.com/stories/killer-algae/>

services include the overall habitat, biodiversity level, photosynthesis and soil formation. In practice, separating the value of regulating and supporting services is difficult. As a result, they are often combined into a single category of ecosystem services. The three regulating and supporting services were valued in the NZIER report of the value of the Hauraki Gulf's ecosystem services were: biodiversity, water quality and carbon sequestration.

Effects of Caulerpa on biodiversity

The international evidence indicates that an exotic Caulerpa invasion is associated with a decrease in biodiversity. The effects of exotic Caulerpa on biodiversity include:

- crowding out other species
- disrupting the food chain
- forming a dense monoculture on the sea floor
- colonising nursery areas and inhibiting nursery functions

International evidence indicates that when Caulerpa replaces seagrass, the observed level of biodiversity decreases from high to medium diversity.¹⁵ This suggests a risk to the biodiversity of the Hauraki Gulf, but further local research is needed to quantify the risk in New Zealand. One international study found the exotic Caulerpa taxifolia was associated with the following effects:

- 23–31% decrease in species richness
- 31–36% loss in mean density
- 42–57% decrease in fish biomass over a six-year period.¹⁶

Effects of Caulerpa on carbon sequestration

As a plant, Caulerpa contributes to carbon sequestration. However, the effects of Caulerpa are both positive and negative. The positive contribution of Caulerpa to biodiversity includes its own sequestration and its ability to colonise unvegetated areas, which will increase the sequestration in those areas. However, Caulerpa could also decrease the level of carbon sequestration due to the loss of biodiversity (a loss of biodiversity is expected to result in lower carbon sequestration). In addition, Caulerpa has been found to sequester less carbon than the species it replaces. Overall, the effect of exotic Caulerpa on carbon sequestration is likely to be negative.

Effect of exotic Caulerpa on water quality

Field research by NIWA at Great Barrier Island found that exotic Caulerpa's presence had negligible impact on water velocity, pH, dissolved oxygen, and water column dissolved organic matter concentrations. It was also suggested that cost savings could be made by discounting these tests in future field studies, which indicates that there is no expectation of material changes in these water quality measures.¹⁷ Based on this field evidence, it is assumed that exotic Caulerpa will not affect the value of water quality as an ecosystem service.

¹⁵ Parreira, Filipe, Begoña Martínez-Crego, Carlos Manuel Lourenço Afonso, Margarida Machado, Frederico Oliveira, Jorge Manuel dos Santos Gonçalves, and Rui Santos. "Biodiversity consequences of Caulerpa prolifera takeover of a coastal lagoon." *Estuarine, Coastal and Shelf Science* 255 (2021): 107344.

¹⁶ Harmelin, Mireille, et al. Impact of Caulerpa taxifolia on Mediterranean fish assemblages: a six year study Proceedings of the workshop on Invasive Caulerpa species in the Mediterranean. UNEP, January 1999.

¹⁷ [NIWA \(2023\). Impact of exotic Caulerpa on native species at Aotea/Great Barrier Island – Field report \(Trip 2\)](#)



4 Conclusion

The effect of exotic Caulerpa on the value of Hauraki Gulf's ecosystem services

Table 1 shows the assessment of the value of the ecosystem services that are vulnerable to the impact of exotic Caulerpa in the Hauraki Gulf. The estimated effect is intended to indicate the worst-case scenario because it implicitly assumes the widespread uncontrolled invasion of Caulerpa rather than adjusting for the distribution of the exotic invasive algae.

Table 1 Estimated ecosystem services vulnerable to exotic Caulerpa

\$m annually

Ecosystem service	Service	2023 estimated value ¹⁸	Effect of exotic Caulerpa	Share of value lost to Caulerpa	Cost of exotic Caulerpa	Level of confidence
Provisioning	Commercial fishing	\$29.8	Crowds out nurseries and feeding opportunities	25–50% of species at risk due to effects on spawning and feeding 3 of the top 5 commercial species are at risk (blue mackerel, snapper, trevally)	\$8-\$15	Medium based on evidence from an international field study. Local field studies are ongoing.
	Recreational fishing	\$187.8	Crowds out nurseries and feeding opportunities	25–50% at risk due to effects on spawning and feeding	\$47-\$94	Medium based on evidence from an international field study. Local field studies are ongoing.
	Aquaculture	\$83.3	Crowds out shellfish and clogs equipment	Unquantifiable	Unquantifiable	Low
	Ports and shipping	\$1,340	Extra cleaning maintenance	Unquantifiable	Unquantifiable	Low
	Cruise tourism	\$292.0	Extra cleaning maintenance	Unquantifiable	Unquantifiable	Low
	Sand extraction	\$5.0	Negligible	0%	None	Medium
Cultural	Recreation	\$2,493.0	Negative effects on the scuba diving experience	Unquantifiable	Unquantifiable	Low – no data on how much scuba diving occurs
	Property value uplift	\$526.1	None	None	None	High
Regulating and supporting	Water quality	\$96.0	None	None	None	Medium
	Biodiversity	\$89.8	Habitat loss, increased competition and lower biomass in the food chain	20–50%	\$18-\$45	Medium-high academic publication
	Carbon Sequestration	\$2.5	Decrease	Unquantifiable	Unquantifiable	Low

Source: NZIER

¹⁸ Estimated annual of ecosystem service value from NZIER (2023) Valuing the Hauraki Gulf: An ecosystem services and natural capital approach. <https://www.nzier.org.nz/publications/valuing-the-hauraki-gulf-an-ecosystem-services-and-natural-capital-approach>

The worst case scenario for quantifiable value from ecosystem services in the Hauraki Gulf at risk due to exotic *Caulerpa* is from \$73m to \$154m annually. The unquantified risk to services would increase this estimate.

The findings in this report are a starting point based on the available evidence. However, there is uncertainty involved, and therefore, the conclusions should be seen as something that will evolve as more New Zealand-based field research is completed.

This report should be used to inform decision-making about the benefits of further research to improve the evidence base on the effects of exotic *Caulerpa* in the Hauraki Gulf and to motivate actions to limit the spread of the invasive species until the effects are better understood.

