ASSESSING THE POTENTIAL FOR SEAWEED AQUACULTURE IN GIPPSLAND

Guidance in selecting species and locations

Summary Report
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ACKNOWLEDGEMENTS

We acknowledge Aboriginal people as Australia’s First Peoples and as the Traditional Owners and custodians of the land and water on which we rely. In particular, the Gunaikurnai and Bunurong people, custodians of the land and waters of the Gippsland region, and pay respect to their Elders past, present, and emerging. We acknowledge that Aboriginal and Torres Strait Islander peoples hold extensive traditional knowledge about seaweeds and their use, which has been practiced for thousands of generations.

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Cover Image: *Ecklonia radiata*, John Turnbull, 2017

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EXECUTIVE SUMMARY

Global seaweed aquaculture has expanded rapidly over recent decades, reaching a US$16.5 billion industry in 2020, with more than 35 Mt wet weight of seaweeds produced annually for a range of commercial applications including food production, pharma/nutraceuticals, biofuels, fertilisers, and animal feeds. The industry is currently dominated by Asian countries (65% of total production) and cultivation of five northern hemisphere species (92% of total production).

With global demand for seaweed biomass continuing to increase, it is timely for countries like Australia – which has an abundance of coastline and many endemic seaweed species – to investigate seaweed market opportunities. Seaweed aquaculture in Australia is in its infancy, with considerable knowledge gaps around the distribution, abundance, chemical composition, and commercial applications of seaweed species endemic to the region.

The aim of this project, funded by Food & Fibre Gippsland in collaboration with Deakin University, was to investigate the potential to develop seaweed aquaculture in Gippsland, a coastal region in southeastern Australia. More specifically, this project investigated: a) what species with potential commercial value are present in the region; and b) what areas are available to cultivate them.

These investigations were led by leading seaweed scientists, with expertise spanning ecology, physiology, and environmental economics.

The approach involved diver surveys of the Gippsland embayments (Western Port, Corner Inlet and Gippsland Lakes) and examination of historical records for seaweed presence and abundance data in the Gippsland region. Water quality data were also collated and collected to understand the environmental conditions in the region and how they align with known growth requirements to support aquaculture for a variety of species.

Additional to assessing the ecological potential for seaweed aquaculture in Gippsland, we have also begun consultation with key stakeholders (e.g., Victorian Fisheries Authority and VRFish) around governance, approvals, and community support. Questions put to stakeholders included: What processes and approvals are required to establish new aquaculture reserves for seaweed cultivation, and what impacts might this have on existing users (e.g., Traditional Owners, recreational fishers) of Gippsland waters?

This Summary Report is a condensed version of the key findings and overall recommendations detailed comprehensively in the Technical Report.
KEY FINDINGS

We selected 10 priority seaweed species (see images below) to investigate further for aquaculture potential in Gippsland. Our findings indicate that the priority species identified, as well as other naturally occurring species, have potential commercial applications and value across a range of industries including; food and nutrition, pharma/nutraceuticals, aquaculture, agriculture, manufacturing, and bioremediation.

Top five species for embayments:
- *Caulocystis cephalornithos*
- *Gracilaria* spp.
- *Laurencia* spp.
- *Ulva* spp. (Sea Lettuces)
- *Cladophora* spp.

Top five species for the coast:
- *Phyllospora comosa* (Crayweed)
- *Ecklonia radiata* (Golden Kelp)
- *Plocamium angustum*
- *Plocamium dilatatum*
- *Phacelocarpus peperocarpos*

We estimated there are up to 413,770 hectares available for seaweed aquaculture in Gippsland, indicating space is not a limiting factor (see Figure A below). Within the embayments there are potentially up to 21,782 hectares available, with Western Port having the largest area available and the most conducive environmental conditions for seaweed aquaculture. Along the coast there are potentially up to 391,988 hectares available, however, high wave exposure is likely to make coastal areas logistically and operationally more challenging than sheltered embayments. It is worth noting that whilst this area is potentially feasible for seaweed aquaculture, it is recommended only a fraction of the potential area be occupied by seaweed aquaculture sites.

![Figure A. Map showing results of spatial analysis with potential area available for seaweed aquaculture in Gippsland. Black triangles mark boat access points, with distance from boat access points also shown. The grey line represents Victorian coastal waters boundary.](image-url)
RECOMMENDATIONS

The priority seaweed species and possible areas for seaweed aquaculture recommended herein have the potential to deliver valuable seaweed products to supply the growing seaweed industry in Australia and the global market.

Our summarised recommendations for progressing seaweed aquaculture in Gippsland are:

- Conduct an economic feasibility study to determine costs and benefits of potential seaweed aquaculture ventures at various scales for a range of products

- Conduct fine-scale, species-specific site selection to determine most appropriate sites within the areas suggested in this report, considering the whole process from seaweed cultivation through to product processing

- Carefully plan and conduct detailed research to optimise cultivation techniques specific to seaweed species in Gippsland

- Pursue further research and development (R&D) into production capability, scale, and product innovation (e.g., biochemical analysis of little-known local seaweed species)

- Consider land-based opportunities for seaweed aquaculture such as modular nursery facilities for seedling cultivation, product processing facilities, and analytical laboratory facilities for further research
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BACKGROUND

Seaweed aquaculture is growing worldwide with global production valued at USD$16.5 billion (AUD$23.4 billion) (FAO, 2022). Aside from human food and nutrition products, seaweeds are used across multiple industries including pharma/nutraceuticals, aquaculture feeds, biofuels, fibre manufacturing, fertilisers, and bioremediation (Kelly, 2020). The current Australian seaweed industry is limited, relying mostly on imports with AUD$40 million worth of seaweed products imported in 2017/18 (Kelly, 2020). This shows there already exists a significant market for seaweed, which could be transitioned towards locally cultivated products.

Given the unique diversity of seaweed species in southern Australia, there is substantial potential for Australia to capitalise on the demand for sustainably cultivated seaweed, introducing novel, high-value seaweed products to the market. A barrier to implementing new seaweed aquaculture ventures in Australia is a lack of information about endemic seaweeds, such as the distribution and abundance, seasonality, biology, biochemical composition and potential end uses. Research is emerging on cultivation techniques, biochemical composition, and potential applications of native Australian species, but research and production are still limited to only several species. This means there are hundreds of untapped species for which we know little about. For Australia to realise the potential of seaweed aquaculture, we urgently need greater investment in research.

Investment in Australian seaweed aquaculture, with the potential for a $1.5 billion industry by 2040, creating 9,000 jobs (Kelly, 2020), will have widespread economic benefits, including financial gain and local job creation. This will help boost local economies and communities transitioning into new, sustainable industries. The Gippsland region, spanning ~680 km of coastline, could provide a unique opportunity to pursue seaweed aquaculture in Australia. However, at this stage, there are no designated aquaculture reserves in Gippsland. Which means the locations and area potentially available for seaweed farms in the region are undefined. Establishing seaweed aquaculture reserves is not a simple procedure, and necessary actions to ensure minimal impact on the surrounding environment need to be considered. Environmental conditions and sociocultural factors will also need to be thoroughly assessed as part of the process.

This project aimed to provide a preliminary assessment of the potential for seaweed aquaculture in Gippsland. It is fundamental to understand what seaweed species grow and where in Gippsland waters due to the diversity of seaweed species biology and commercial applications. This will inform further research on cultivation techniques and product development, and help to realise the full economic, societal, and environmental potential of seaweed aquaculture for the Gippsland region.
Project Objectives:

Specifically, this project included four main objectives:

1. **Seaweed distribution and abundance**
   Collate existing data and collect new data on seaweed species and their abundance across Gippsland.

2. **Environmental conditions**
   Collate and collect environmental data to guide selection of suitable locations for seaweed aquaculture in Gippsland.

3. **Spatial limitations**
   Assess spatial limitations on seaweed aquaculture in Gippsland.

4. **Synthesis**
   Synthesise all relevant information to clearly outline the potential areas available and priority species to consider for seaweed aquaculture in Gippsland.

To meet these objectives, existing data were collated and new data collected within the Gippsland embayments of Western Port, Corner Inlet, and Gippsland Lakes to close gaps in existing seaweed knowledge. Synthesising new and available data resulted in the spatial maps of potential areas available for seaweed aquaculture in Gippsland and a list of 10 seaweed species with commercial potential.

Detailed methods and results of the study can be found in the Technical Report. This Summary Report provides a condensed overview of the main results.
SEAWEED DISTRIBUTION AND ABUNDANCE GIPPSLAND

To determine what species grow and where in Gippsland, we collated existing seaweed distribution and abundance data for the coastal regions from various sources (Parks Victoria Subtidal Reef Monitoring Program (SRMP), Reef Life Survey (RLS), Atlas of Living Australia (ALA)). These data were localised to Phillip Island, Wilsons Promontory, and the Twofold Shelf region (Point Hicks to Cape Howe). We also conducted field surveys of the embayment regions to fill in the gaps of seaweed distribution and abundance across Gippsland; these data were focused on the eastern side of Western Port, Corner Inlet, and Gippsland Lakes. See Figure 1 for SRMP and Deakin survey site locations.

Figure 1. Map showing survey sites within Gippsland embayments that were included in the seaweed survey in red. Each individual survey area contained 15 sites (see inset for example). Coastal SRMP survey sites conducted by Parks Victoria are shown in yellow. Local Government Areas (LGAs) are coloured in the top panel: Bass Coast LGA shown in pink, South Gippsland LGA in blue, Wellington LGA in yellow, and East Gippsland LGA in green.
SEAWEED DISTRIBUTION AND ABUNDANCE GIPPSLAND

A total of 269 unique seaweed species were found in Gippsland (see Figure 2 for a breakdown of these species by type and location). Red seaweeds were the most diverse, followed by brown seaweeds, then green seaweeds. The coastal regions of South Gippsland and East Gippsland had greater species diversity compared to their embayment counterparts, whereas Bass Coast had similar seaweed diversity across both coastal and embayment regions.

The coastal regions of Gippsland support a substantially different seaweed community to the embayment regions, with mainly large brown and red seaweeds most abundant along the coast, and smaller reds and greens more common in the embayments. These differences are driven by environmental variation between coastal and embayment systems such as wave exposure, depth, nutrient availability, temperature, and salinity.

The 10 most common seaweeds (coloured by seaweed type) for embayment and coastal regions were:

**EMBAYMENTS**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gracilaria spp.</td>
</tr>
<tr>
<td>2</td>
<td>Lobosira bicuspidata</td>
</tr>
<tr>
<td>3</td>
<td>Cladophora spp.</td>
</tr>
<tr>
<td>4</td>
<td>Dictyomenia harveyana</td>
</tr>
<tr>
<td>5</td>
<td>Ulva spp.</td>
</tr>
<tr>
<td>6</td>
<td>Caulerpa trifaria</td>
</tr>
<tr>
<td>7</td>
<td>Laurencia spp.</td>
</tr>
<tr>
<td>8</td>
<td>Caulocystis cephalornithos</td>
</tr>
<tr>
<td>9</td>
<td>Areschougia congesta</td>
</tr>
<tr>
<td>10</td>
<td>Ulva lactuca</td>
</tr>
</tbody>
</table>

**COASTAL**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Phyllospora comosa</td>
</tr>
<tr>
<td>2</td>
<td>Ecklonia radiata</td>
</tr>
<tr>
<td>3</td>
<td>Jania rosea</td>
</tr>
<tr>
<td>4</td>
<td>Acrocarpia paniculata</td>
</tr>
<tr>
<td>5</td>
<td>Plocamium angustum</td>
</tr>
<tr>
<td>6</td>
<td>Phacelocarpus peperocarpos</td>
</tr>
<tr>
<td>7</td>
<td>Ballia callitricha</td>
</tr>
<tr>
<td>8</td>
<td>Zonaria turneriana</td>
</tr>
<tr>
<td>9</td>
<td>Plocamium dilatatum</td>
</tr>
<tr>
<td>10</td>
<td>Amphiroa anceps</td>
</tr>
</tbody>
</table>

Figure 2. Bar graph displaying the total number of seaweed species identified per seaweed type within the embayments and coastal regions of each LGA in Gippsland.
ENVIRONMENTAL CONDITIONS

EMBAYMENTS

To assess environmental conditions for seaweed aquaculture in the Gippsland embayments, we collated existing water quality data for variables that are important drivers of seaweed growth including salinity, nutrients (nitrogen and phosphorus), and productivity (Chlorophyll a). Existing data were collected by EPA Victoria between 1990 and 2021; and new water quality data were collected during our field surveys (see Figure 3 for salinity data and survey sites). For detailed water quality results see the Technical Report.

Western Port

Western Port displays suitable conditions for seaweed aquaculture with high salinity (>36 psu) at all the sites sampled and healthy productivity levels, although nutrient levels have historically been elevated. Nitrogen, a key requirement for seaweed growth, is therefore unlikely to be limiting in the eastern section of Western Port.

Corner Inlet

Long-term water quality data are lacking for Corner Inlet, making it difficult to assess conditions. Available information suggests salinity is suitable (~33-37 psu) with a history of elevated nutrient availability from catchment inputs. Species with high nutrient tolerance are best suited here. These species may actually help reduce nitrogen which will have a positive impact on the sensitive seagrass beds unique to Corner Inlet.

Gippsland Lakes

Gippsland Lakes experience large variations in water quality through time and between locations. Salinity is highly variable ranging from 10 psu to almost 40 psu due to the influence of both fresh and salt water inputs. Productivity and nutrients are also variable with higher levels at the western end near the catchments and lower levels at the eastern end near the entrance. These conditions mean fewer but well-adapted seaweed species are supported in Gippsland Lakes with wide tolerance ranges for salinity and nutrients.

Figure 3. Map showing location of salinity measurements of Deakin surveys and EPA Victoria water quality monitoring sites. Coloured circles represent mean (average) salinity in psu, measured during Deakin seaweed surveys in 2022 for three Gippsland embayments. Coloured squares represent EPA average salinity data in psu over time, some monitoring sites (such as in Gippsland Lakes) include data dating back to 1990.
ENVIRONMENTAL CONDITIONS

COASTAL

The coastal waters of Gippsland are less influenced by freshwater river inputs compared to the embayment regions. Consequently, coastal waters display relatively uniform salinity ~33-37 psu and high water clarity, although salinity along the Gippsland coast is consistently ~0.5-1 psu higher than waters elsewhere in Victoria. Nearshore coastal water quality is, therefore, generally suitable for seaweed aquaculture, with the major limiting factor being wave exposure.

Wave height (see Figure 4) is quite high along the Gippsland coast with heights of up to 6 m. These conditions limit what species could be grown as certain species thrive in rough waters (such as *E. radiata* /Golden Kelp), and others unable to withstand wave forces so better suited to less exposed regions. For potential coastal seaweed aquaculture sites, consideration of required infrastructure is recommended based on the high levels of wave exposure experienced.

Planning should consider ways to minimise damage to infrastructure and the potential impacts of dislodged infrastructure on the marine environment, and include regular maintenance. Optimising infrastructure and substrate type for the selected species in this environment will also reduce loss of yield. High wave exposure can also interfere with accessibility, deployment, maintenance, and harvesting compared to low swell conditions. Investment to address challenges associated with high wave exposure may be worthwhile though, due to the high commercial potential of seaweed species that thrive in such conditions (e.g., *P. comosa* /Crayweed, *E. radiata* /Golden Kelp).

![Image: Squeaky Beach](Image: Squeaky Beach)

**Figure 4.** Wave height recorded by offshore wave buoys in the Gippsland region, measurements recorded half-hourly between January 2020 and May 2020. Within the box-plot, the solid black horizontal line = median value. Above and below this within the box is 25-75% of the data, with the lines and individual points representing some of the rarer measures. Average wave height for each location shown as a red asterisk.
Given the large expanse of coastline in Gippsland and high diversity of seaweed species, there is great potential for seaweed aquaculture in Gippsland. The available area (see table below) was calculated by deducting the areas that are unsuitable or unavailable for aquaculture within 40 km of the Gippsland coast (including the eastern end of Western Port, Corner Inlet, and Gippsland Lakes) from the total available area of water. Unsuitable or unavailable areas included; close proximity to shore, too shallow, too deep, areas with existing ecosystems to avoid, marine protected areas, and shipping channels. For more information, see the Technical Report.

The total available area (413,770 hectares) is the area that has potential for seaweed aquaculture, as it does not interfere with any existing industry or ecosystems. It should be noted though that this is a first-pass overview, and localised site-specific assessments are recommended for fine-scale site selection. The results indicate that space is not a limiting factor for the establishment of seaweed aquaculture in Gippsland.

### EMBAYMENTS

<table>
<thead>
<tr>
<th>LGA</th>
<th>EMBAYMENT</th>
<th>COAST</th>
<th>TOTAL AREA AVAILABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bass Coast</td>
<td>12,471 ha</td>
<td>20,281 ha</td>
<td>32,752 ha</td>
</tr>
<tr>
<td>South Gippsland</td>
<td>6,688 ha</td>
<td>56,579 ha</td>
<td>63,267 ha</td>
</tr>
<tr>
<td>Wellington</td>
<td>N/A</td>
<td>223,994 ha</td>
<td>223,994 ha</td>
</tr>
<tr>
<td>East Gippsland</td>
<td>2,623 ha</td>
<td>91,134 ha</td>
<td>93,757 ha</td>
</tr>
<tr>
<td>Total Gippsland</td>
<td>21,782 ha</td>
<td>391,989 ha</td>
<td>413,770 ha</td>
</tr>
</tbody>
</table>

*Blue areas represent potential area available for seaweed aquaculture

**Western Port**

Our results indicate there are large areas in Western Port that have potential for seaweed aquaculture (blue areas above) with good accessibility, although, existing seagrass maps are outdated. For site selection, it is recommended to visit sites to minimise interference with existing ecosystems.

**Corner Inlet**

Available area in Corner Inlet is limited to the deeper channels due to shallow depth elsewhere. These channels are heavily influenced by tidal flows and currents, which could increase difficulty. Accessibility is from Port Welshpool or Port Albert. Water quality testing, environmental impact assessments and trials are recommended prior to cultivation.

**Gippsland Lakes**

Due to the complex nature of the lakes and existing water users, space here is most limited compared to other embayments. Water quality, mainly salinity, is the primary limiting factor, which is not included in this spatial modelling. Low salinity can cause issues for seaweed growth, however, there are species here with commercial applications that are well adapted to their environment.
Given the large expanse of coastline and limited current uses (no existing aquaculture reserves, limited existing habitat beyond sparse rocky reefs) there are vast potential areas of coast available for seaweed aquaculture (see Figure 5).

The main limiting factors here are accessibility and exposure. Available data suggests that wave heights can reach up to 6 m along the Gippsland coast, thus making coastal areas logistically and operationally more difficult. Costs associated with addressing these difficulties may, however, be outweighed by the commercial potential of seaweeds that thrive in exposed environments (e.g., *P. comosa*/Crayweed, *E. radiata*/Golden Kelp).

Site selection should be focused on access, with infrastructure requirements tailored to the local area. Water quality parameters are less likely to be an issue in nearshore waters, where salinity levels are stable, and nutrients are likely to be sufficient for seaweed growth. Areas near large river mouths and sewage outfalls should be assessed with caution, as they are likely to have more contaminants - given the vast area available it is advisable to simply avoid these areas.

The most promising coastal areas are nearshore waters, in areas that are slightly less exposed, and within reasonable proximity to suitable boat access points. Coastal areas with good accessibility include nearshore waters from Phillip Island to Port Albert, near Lakes Entrance, and near Mallacoota. Further analyses at a fine scale are recommended going forward to determine site locations.

Figure 5. Map showing potential areas available for seaweed aquaculture along the Gippsland coast and distance from suitable boat access points, insets showing each LGA. Black triangles mark appropriate boat access points. Grey line represents Victorian coastal waters boundary.
To prioritise the selection of seaweed species for further research and investigation, we analysed the distributions and abundances of seaweed species across the Gippsland region, incorporating spatial factors, limitations, and water quality parameters, along with expert knowledge on seaweed cultivation and commercial applications.

Considering all results shown in the Technical Report, the priority species were selected based on the following criteria, in order of importance:

**Species that are native to the area**
- Not allowing cultivation of invasive species reduces impact to local ecosystems, and is a requirement of VFA.

**Species that are common and abundant**
- This indicates that the environmental conditions are suitable, and ensures ease of seed stock collection with high levels of genetic diversity.

**Species that have known or potential commercial applications**
- R&D for commercial uses of seaweed requires significant time and money, therefore, selecting species with known uses and compounds will fast track the process of industry establishment.

**Species with previous research or existing cultivation methods**
- R&D for cultivation methods requires substantial time and money, with no guarantee of success, therefore, selecting species with known cultivation methods, at least within the same taxonomic category, will save considerable time and cost.

**Species that can be efficiently included with other fisheries**
- Combining seaweed aquaculture with other aquaculture, such as finfish, molluscs or crustaceans, has the potential to reduce environmental impact and create opportunities to diversify aquaculture in the region beyond seaweed.

Given that environmental conditions and species populations are different in exposed coastal waters versus sheltered embayments, we have selected 5 species each for the embayments and coastal regions. See the following pages for the priority species selected for further research for seaweed aquaculture in Gippsland.
# TOP 5 SEAWEED SPECIES FOR EMBAYMENTS

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<tbody>
<tr>
<td>phycocolloids*</td>
<td>alginate</td>
<td>agar</td>
<td>agar</td>
<td>ulvan</td>
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<tr>
<td>food &amp; nutrition</td>
<td>high in Vitamin E</td>
<td>fibre carbohydrate</td>
<td>Omega-3 fatty acids</td>
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<td>fish feed supplement</td>
<td>abalone, sea urchin feed</td>
<td>fishmeal protein</td>
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<td>bioremediation</td>
<td>IMTA** high N uptake</td>
<td>pigments anti-ageing</td>
<td>wastewater bioremediation</td>
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<tr>
<td>cosmetics</td>
<td>gelling properties</td>
<td>anti-ageing</td>
<td>pigments anti-ageing</td>
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*phycocolloids are polysaccharides derived from seaweeds with various commercial applications, predominantly in food manufacturing

**IMTA: integrated multi-trophic aquaculture

NB: spp. indicates multiple different species within the same genus

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## COMMERCIAL APPLICATIONS

- **Food & nutrition**
- **Pharma/nutraceuticals**
- **Agriculture**

## CULTIVATION METHODS

No existing cultivation methods, however techniques for cultivating other fucoid species can be trialled and adapted for this species. Research is underway by DeakinSeaweed to facilitate potential cultivation of *Caulocystis cephalornithos* and product development.

## PROPOSED METHODS

Artificial spawning and fertilisation followed by seeding of zygotes either directly onto twine or onto small blocks attached to twine, tank cultivation in nursery (required period yet unknown), out-plantation at 1-3 m depth. Winter or early spring harvest likely to be optimal

## PROPOSED LOCATION

Western Port

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## GIPPSLAND DISTRIBUTION

Relatively widespread throughout Bass Coast and South Gippsland LGAs. More common in sheltered embayments, less abundant in coastal waters.
**Gracilaria spp.**

**CULTIVATION METHODS**
Spores cultivated in nursery then out-planted on ropes in open water, pond cultures, or on land in tanks. Asexual reproduction with vegetative propagation is the most common cultivation technique for *Gracilaria* spp., currently used for ease and efficiency.

**PROPOSED METHODS**
Nursery based tank culture, with fragments transplanted onto lines in embayment sites, cultivated at 1 m depth.

**PROPOSED LOCATION**
Western Port, Corner Inlet, Gippsland Lakes

**GIPPSLAND DISTRIBUTION**
Widespread across Bass Coast, South Gippsland, and East Gippsland LGAs. Common in sheltered embayments, less common in coastal waters. This seaweed has tolerance for wide range of salinities and temperatures.

**COMMERCIAL POTENTIAL**
Contains compounds with antimicrobial, antibacterial, antioxidant, anti-cancer, and cytotoxic properties. Good source of essential omega-3 fatty acids (EPA and DHA).

**COMMERCIAL APPLICATIONS**
Food & nutrition | Pharma/nutraceuticals | Agriculture Aquaculture feeds | Bioremediation | Cosmetics

**Laurencia spp.**

**CULTIVATION METHODS**
Current methods include indoor tank cultivation

**PROPOSED METHODS**
Indoor tank tumbling cultivation (recommended), or open water

**PROPOSED LOCATION**
Corner Inlet, Western Port, land-based

**GIPPSLAND DISTRIBUTION**
Relatively widespread across Bass Coast and South Gippsland LGAs and to a lesser extent in East Gippsland LGA. Grows in various habitats depending on species, species found during field surveys were seagrass epiphytes

**COMMERCIAL POTENTIAL**
Approx. 208 species worldwide, complex and highly variable. Genomic profiling recommended.

**COMMERCIAL APPLICATIONS**
Food & nutrition | Pharma/nutraceuticals | Aquaculture feeds | Cosmetics

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Markers indicate currently known presence of this species. Data from field surveys, Parks Victoria and Atlas of Living Australia.

Phylum Rhodophyta – Class Florideophyceae – Order Gracilariales – Family Gracilariaceae

Phylum Rhodophyta – Class Florideophyceae – Order Ceramiales – Family Rhodomelaceae
**Ulva spp.**

*Sea Lettuces*

**COMMERCIAL APPLICATIONS**

Food & nutrition | Pharma/nutraceuticals | Agriculture
Aquaculture feeds | Bioremediation | Cosmetics

**CULTIVATION METHODS**

Land-based cultivation in tanks and raceways the current method in Australia and elsewhere in the world. Research is underway into upscaling for open water cultivation of *Ulva* spp. in Europe.

**PROPOSED METHODS**

Land-based cultivation using tanks and/or raceways (recommended), other opportunities include open water cultivation, integration with wastewater facilities and integration with aquaculture facilities.

**PROPOSED LOCATION**

Gippsland Lakes, Corner Inlet, land-based

**GIPPSLAND DISTRIBUTION**

At least two species of *Ulva* were found during field surveys and were widespread across South Gippsland, and East Gippsland LGAs. Several other species of *Ulva* are relatively widespread across Gippsland. Wide range of environmental tolerances, with an affinity for high nutrients.

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**Phylum Chlorophyta – Class Ulvophyceae – Order Ulvales – Family Ulvaceae**

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**Cladophora spp.**

**COMMERCIAL APPLICATIONS**

Food & nutrition | Pharma/nutraceuticals | Agriculture
Aquaculture feeds | Bioremediation | Cosmetics

**COMMERCIAL POTENTIAL**

Despite substantial research into bioactive and pharmaceutically valuable compounds derived from *Cladophora* spp., there has been limited commercialisation to date.

**CULTIVATION METHODS**

Open cultures with nutrient-enriched water and closed systems under lab conditions. Grows well in culture systems for biomass production.

**PROPOSED METHODS**

Open culture in ponds or raceways.

**PROPOSED LOCATION**

Land-based

**GIPPSLAND DISTRIBUTION**

Widespread across Bass Coast, South Gippsland, and East Gippsland LGAs. Approx. 31 known species in Australia. Wide range of environmental tolerances.

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**Phylum Chlorophyta – Class Ulvophyceae – Order Cladophorales – Family Cladophoraceae**

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### COMMERCIAL POTENTIAL

No existing commercial applications, however, research has been conducted in Australia. Highly abundant and common with wide range of potential products.

### CULTIVATION METHODS

Nursery phase cultivation has been defined whilst at-sea culture requires further research.

### PROPOSED METHODS

Nursery cultivation on seeded twine and deployment on horizontal long lines in open water at 2–5 m depth.

### PROPOSED LOCATION

Exposed coastal areas along Bass Coast, South Gippsland, or East Gippsland.

### COMMERCIAL APPLICATIONS

- **Food & nutrition**
  - Phycocolloids*
  - Alginate
- **Pharma/nutraceuticals**
  - Anti-cancer
  - Antimicrobial
- **Agriculture**
  - Animal feed
  - Fertiliser animal feed
- **Aquaculture feeds**
  - Abalone feed
  - Abalone feed
  - IMTA** high N uptake
- **Bioremediation**
  - Commercial IMTA in TAS
  - IMTA**
- **Cosmetics**
  - Carrageenan
  - Drug discovery
  - Antimicrobial
  - Biostimulant
  - Abalone feed
  - IMTA**

*Phycocolloids are polysaccharides derived from seaweeds with various commercial applications, predominantly in food manufacturing.

**IMTA: integrated multi-trophic aquaculture

### Phyllospora comosa

**Crayweed**

- Highly important species for marine ecosystems.
- Sensitive to high nutrients and high temperatures.

### GIPPSLAND DISTRIBUTION

Common and abundant throughout coastal areas of Bass Coast, South Gippsland, and East Gippsland LGAs. Prefers cold waters with high to medium exposure. Not found in Bunurong Marine National Park or in embayments.
**Collection of reproductive material, gametophyte cultures can be kept in continuous culture, gametophytes seeded onto twine and cultured in nursery, with deployment on longline ropes in coastal waters (Nursery and at-sea cultivation research underway, see link)**

**CULTIVATION METHODS**
Collection of reproductive material, gametophyte cultures can be kept in continuous culture, gametophytes seeded onto twine and cultured in nursery, with deployment on longline ropes in coastal waters (Nursery and at-sea cultivation research underway, see link)

**PROPOSED METHODS**
Further optimisation of existing methods may improve production. Likely to thrive in areas with high nutrients and capacity for longline culture systems at 2 m

**PROPOSED LOCATION**
Moderately exposed to sheltered coastal areas along Bass Coast, South Gippsland, or East Gippsland

**GIPPSLAND DISTRIBUTION**
Baseline species for Great Southern Reef. Common and abundant on rocky reefs throughout Bass Coast, South Gippsland, Wellington, and East Gippsland LGAs. Has wide environmental tolerances but is vulnerable to sustained high temperatures

**COMMERCIAL APPLICATIONS**
Food & nutrition | Pharma/nutraceuticals | Agriculture
Aquaculture feeds | Bioremediation | Cosmetics

**POTENTIAL**
- Anti-cancer
- Antioxidants
- Antimicrobial
- Insecticide
- Abalone feed

**COMMERCIAL POTENTIAL**
Currently no commercial applications for *P. angustum*, however, related species are harvested by hand in the US and France for agar. Extensive research in NZ shows this species has potential in a variety of industries

**CULTIVATION METHODS**
Currently no existing cultivation. Trials of other species within the *Plocamium* genus have been conducted in other parts of the world e.g., land-based cultivation of *P. cartilagineum* in tanks

**PROPOSED METHODS**
Land-based cultivation in tanks or trials in water

**PROPOSED LOCATION**
Land-based or moderately exposed coastal areas along Bass Coast, South Gippsland, or East Gippsland

**GIPPSLAND DISTRIBUTION**
Common on exposed coasts up to 50 m deep and in shaded shallower waters. Widespread across Bass Coast, South Gippsland, and East Gippsland LGAs. Not found in embayments
**COMMERCIAL POTENTIAL**
Research indicates *P. dilatatum* has potential as abalone feed. Other species in *Plocamium* genus exhibit various compounds which may be useful in anti-cancer treatment and also have potential as an insecticide.

**CULTIVATION METHODS**
Currently no existing cultivation of *P. dilatatum*. Trials of other species within the *Plocamium* genus have been conducted in other parts of the world e.g., land-based cultivation of *P. cartilagineum* in tanks.

**PROPOSED METHODS**
Land-based cultivation in tanks.

**PROPOSED LOCATION**
Land-based or exposed coastal areas along Bass Coast, South Gippsland, or East Gippsland.

**GIPPSLAND DISTRIBUTION**
Common on moderately to rough exposed coasts throughout Bass Coast, South Gippsland, and East Gippsland LGAs. Growing from 3-22 m deep.

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**COMMERCIAL APPLICATIONS**
Pharma/nutraceuticals | Agriculture | Aquaculture feed | Bioremediation

**COMMERCIAL POTENTIAL**
This species is a potential source of phycocolloids (e.g., agar, carrageenan) and contains compounds with potential pharmaceutical and agricultural applications.

**CULTIVATION METHODS**
No existing cultivation of *P. peperocarpos*, however, species within the same order have been successfully cultivated in other parts of the world since the 1970s.

**PROPOSED METHODS**
Seedlings or cuttings, on rope, in water.

**PROPOSED LOCATION**
Exposed coastal areas along Bass Coast, South Gippsland, or East Gippsland.

**GIPPSLAND DISTRIBUTION**
Common in deep water on exposed coasts throughout Bass Coast, South Gippsland, and East Gippsland LGAs. Not found in embayments.

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**Phylum** Rhodophyta – **Class** Florideophyceae – **Order** Gigartinales – **Family** Plocamiaceae

**Phylum** Rhodophyta – **Class** Florideophyceae – **Order** Gigartinales – **Family** Phacelocarpaceae
RECOMMENDATIONS

Below is a summary of the recommendations based on the results of this study. For more detailed information please see the Technical Report.

ECONOMIC FEASIBILITY

To understand the true potential of a seaweed industry in Gippsland, economic feasibility assessments will need to be conducted. This includes operational costs and market value. The seaweed species recommended here exhibit potential applications across all existing seaweed markets in Australia. Existing and developing markets in Australia span a range of industries including manufacturing, agriculture, pharmaceuticals, cosmetics and bioremediation.

The recommended first-pass economic assessment would consider four key areas:

1. Seaweed aquaculture configurations
2. Site-specific costs
3. Estimates of benefits (financial, economic, and environmental)
4. High level commercial assessment of commercial products

FINE–SCALE SITE SELECTION

To progress establishment of seaweed aquaculture in Gippsland, fine-scale site selection assessments will be required to determine the most appropriate sites within the areas suggested here. Site selection assessments should consider the whole process from seaweed cultivation through to product processing; thus, will depend not only on the immediate environmental conditions but also on the proximity to potential land-based processing facilities, for example.

Fine-scale site selection would be conducted somewhat similarly to this first-pass assessment, however at a finer resolution e.g., entire Gippsland coastline versus eastern end of Western Port. There are various methods and approaches for site selection, most of which include gathering site specific existing data on environmental conditions, collecting water quality data across seasons, liaising with local stakeholders, and determining site-specific infrastructure requirements.

OPTIMISING SEAWEED CULTIVATION

Once suitable seaweed aquaculture sites and species have been selected, experimental research is recommended to optimise cultivation techniques specific to seaweed species in Gippsland. In order to maximise production, research will also need to be conducted at the nursery stage, which will then extend to in-water cultivation research to optimise yield. During the in-water research phase, environmental impact assessments are recommended to ensure minimal interference with existing habitats.
FURTHER RESEARCH OPPORTUNITIES

There remains various knowledge gaps regarding southern Australian seaweed species and their commercial potential, as highlighted throughout the Technical Report. The Australian Seaweed Industry Blueprint 2020 has identified key research gaps with an R&D plan to address the current challenges and close research gaps. This plan can be used as guide to focus future research for establishing seaweed aquaculture as a sustainable industry in Gippsland. The three key factors to structure future R&D are:

1. Industry leadership and collaboration to ensure commercially focused R&D and engagement with relevant stakeholders.
2. Production capability and scale to expand and optimise seaweed aquaculture, researching cultivation techniques for local species and methods for upscaling cultivation and production processes, via carefully designed experiments.
3. Innovation for the future to maximise the value of the industry in Gippsland, developing unique cultivation methods and investigating novel species and applications of native species. See https://mbcrc.com/ for industry-research partnership opportunities.

LAND-BASED OPPORTUNITIES

Whilst there is strong local interest among multiple stakeholders for Gippsland to be actively involved in seaweed aquaculture, there are additional opportunities for involvement in the emerging Australian seaweed sector. These are independent of whether seaweed aquaculture is economically viable and logistically feasible or not, and include:

- Establishing modular nursery facilities for seedling cultivation of multiple species for deployment and cultivation in other areas in Victoria or other states (dependent on biosecurity risks and associated regulations).
- Establishing:
  - on-land, tumbling-tank cultivation systems;
  - assessment of seaweed bioremediation potential for land-based applications in IMTA.
- Establishing post-processing facilities where seaweed biomass produced in other areas in Victoria or bordering states could be washed, dried, and packed to be dispatched to other companies for further commercialisation.
- Developing analytical laboratory facilities for screening seaweeds for identification of interesting compounds and/or extraction of these for further commercial applications in the food, pharma/nutraceutical and cosmetic sectors.

Deakin University | Summary Report
SUMMARY

Seaweed aquaculture is known to have various positive environmental benefits. For example, in areas with excess nutrients, such as the embayments, seaweed aquaculture is likely to positively impact the surrounding marine environment by reducing nutrients thereby improving water quality. Seaweed farms also act as important habitat for various marine organisms. Establishing in-water seaweed aquaculture in Gippsland could increase diversity of marine life and improve recreational fishing in the area.

There are various risks associated with aquaculture that must be considered also. Whilst small- to intermediate-scale ventures are likely to pose minimal risk to the surrounding environment, up-scaling to meet industry growth demands may be accompanied by increased environmental risk. Risks include: alteration of genetic composition of local seaweed species, spread of disease and pests, local hydrodynamic changes, and disturbance of the surrounding marine environment. Many of these risk factors can be mitigated via appropriate planning, preliminary assessment, ongoing monitoring, and effective management. At small scales, benefits of seaweed aquaculture are likely to outweigh any negative impacts.

Gippsland shows considerable potential for developing a seaweed aquaculture industry, with multiple options for available areas and cultivable species.

The embayment regions in Gippsland (Western Port, Corner Inlet, Gippsland Lakes) show potential for cultivation of various species of commercial value. The main environmental limitations for seaweed aquaculture in the Gippsland embayments pertain to water quality, therefore, seaweeds with wide environmental tolerances and high capacity for nutrient uptake are best suited to these areas.

There are vast areas available for potential seaweed aquaculture along the Gippsland coast, with various species of commercial value. However, there remains substantial knowledge gaps for cultivation techniques for some of these species. The main limiting factor for seaweed aquaculture along the Gippsland coast is wave exposure and accessibility.

The outcomes of this report provide a preliminary, and promising, assessment into the potential seaweed species that could be grown and the areas they could be grown in throughout Gippsland to develop a seaweed aquaculture industry. Beyond this assessment, economic feasibility studies, fine-scale site selection; extensive research into species-specific optimisation of cultivation techniques and product development, including consideration of future-proofing for a warming climate; are recommended to continue establishing the pathway for seaweed aquaculture as a sustainable, profitable new industry for the Gippsland region.
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