Eden-1
Nutrient Modelling Overview 2025

Disaster Bay, NSW

Document details	The details entered below are automatically shown on the cover and the main page footer. **PLEASE NOTE:** This table must NOT be removed from this document.
Document title	Eden-1 Nutrient Modelling 2024
Document subtitle	Disaster Bay
Lease Area	AL21/004
Lease Size	200 ha
Kelp Species	*Ecklonia radiata*
NSW Case ID	SSD-41680467
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Cover Image Credit	Wild *Ecklonia radiata* 2024
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1.0 PROJECT DETAILS

Eden-1 Kelp Aquaculture Farm

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- **Location:** Offshore in Disaster Bay
- **Growing Period:** Autumn, Winter, Spring (March–December)
- **Disaster Bay Size:** Approx 45 km2
- **Flushing rate:** Every 5 – 8 days (complete exchange)
- **Estimated Biomass:** 1,500 tonnes per annum

1.1 Overview

A review of nutrient modelling for Disaster Bay has been completed to ensure that projected kelp production is grounded in site-specific oceanographic reality rather than coarse, ocean-scale datasets. Disaster Bay encompasses approximately 4,500 hectares (~45 km2) of open coastal embayment and is characterised by high flushing rates, strong exchange with the Tasman Sea, and persistent influence from the East Australian Current (EAC) and associated eddy systems. The broader NSW south-east coast is subject to seasonally persistent upwelling from spring through autumn, driven primarily by EAC dynamics and wind forcing, resulting in episodic but substantial injections of nitrate-rich deeper waters into the photic zone. These physical processes mean nutrient availability in Disaster Bay is not static; it is dynamically replenished through vertical mixing, upwelling pulses, and lateral advection.

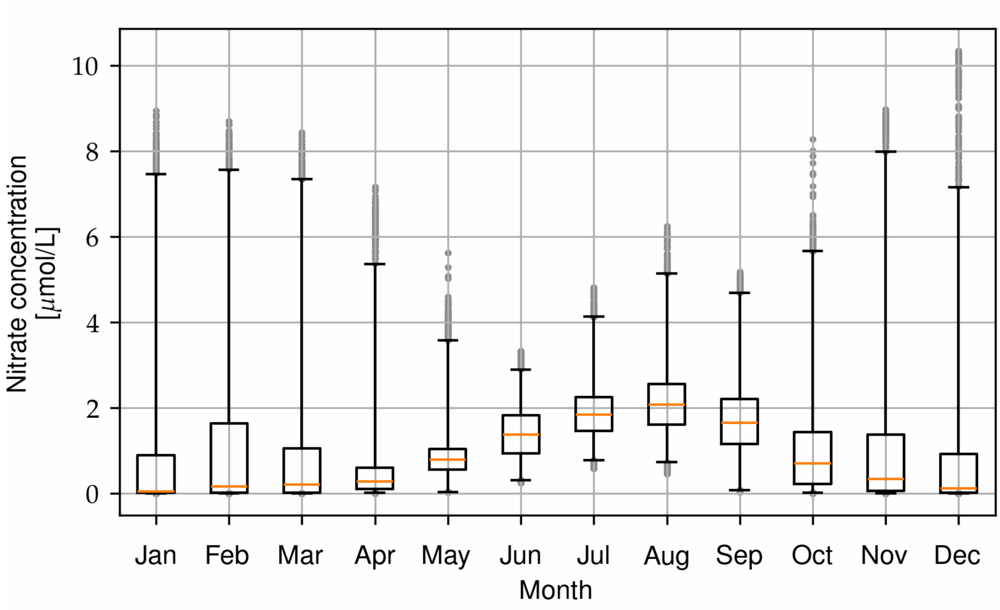
1.2 Kelp Growth

- Nitrate/phosphate concentration are a significant driver in kelp growth rates.
- Nitrates and phosphates rise from the ocean depths through upwelling which is dependent on temperature and salinity profiles. Coastal nitrates and phosphates are also dependent on local currents.
- *Ecklonia radiata* is the most temperature-tolerant genus in the order and many species are found in warm-temperate and subtropical waters [2]
- From a study of native west coast *Ecklonia radiata*, the growth of the forest becomes negative when temperatures exceed 23¬∞C [5]. It should be noted that in the case of farming where seeding is done manually, only the growth rate of *Ecklonia radiata* will be reduced and therefore yield, rather than a natural reduction of the forest size.
- Fully grown *Ecklonia radiata* can withstand water velocities of 2-5 m/s (Thomsen et al. 2004, de Bettignies et al. 2013b) [3]. It is likely that the integrity of *Ecklonia radiata* farms during significant wave events will be more dependent on the mechanics of the seeding line structures themselves. Conversely, it has been found that increased wave exposure reduces biofouling with approximately 40% less biofouling at exposed locations [4].

1.3 Disaster Bay

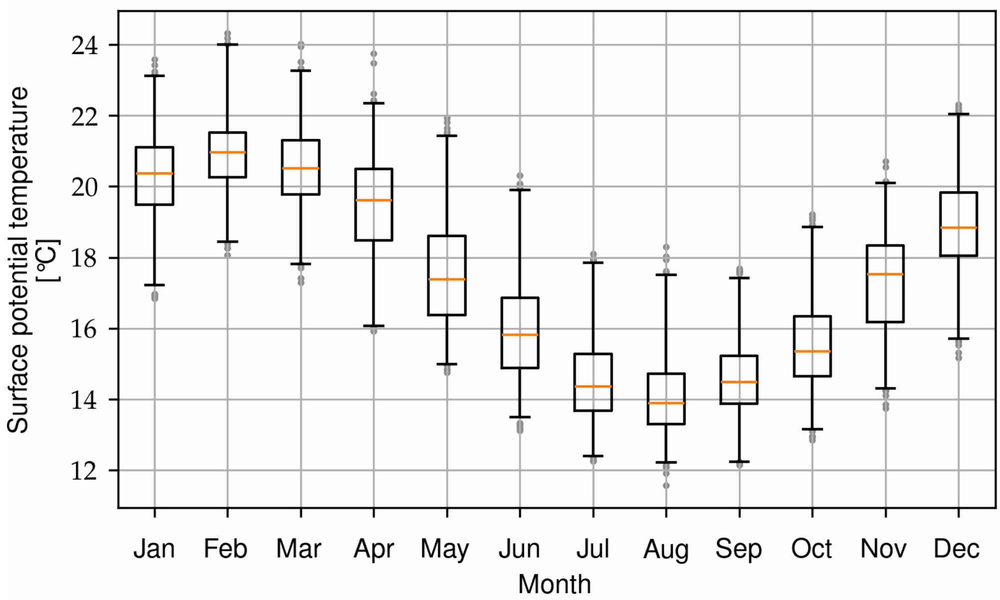
- Modelling utilised information from the European Copernicus Marine Service's Global Ocean Physics Reanalysis which is an ocean scale dataset (50x50km) reanalysis based on ocean modelling and historic observations to determine the approximate nitrate concentrations in disaster bay.
- Nitrate concentration from 0-10m in depth is shown in the figure below. The red line indicates the mean for each month, the box represents the inter-quartile range, and the whiskers represent the 0.5 and 99.5 percentiles.

Disaster Bay Nitrate Concentration from 0-10m in Depth Modelling 2024



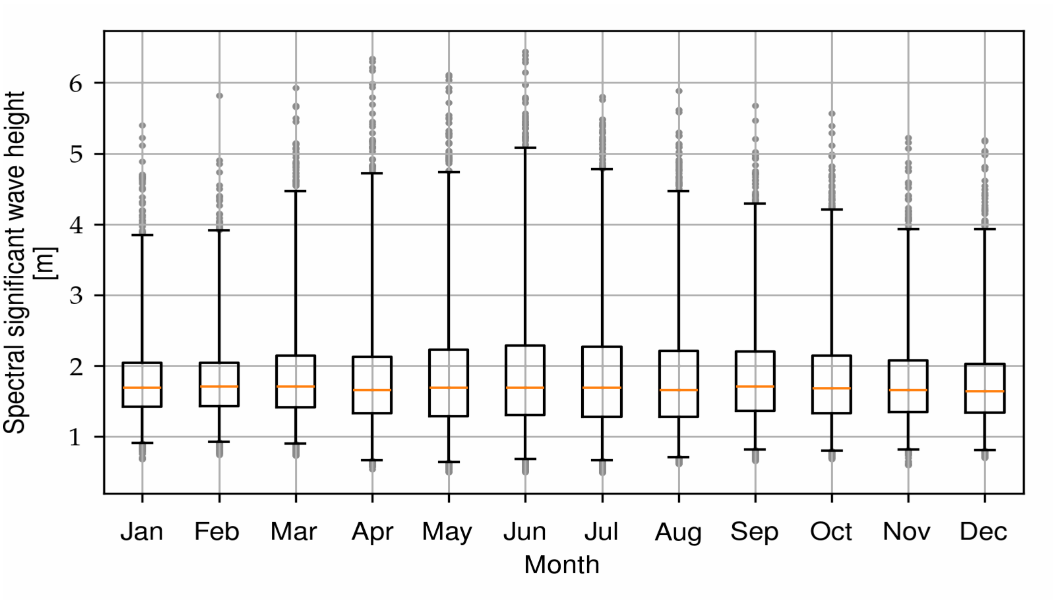
- From a nitrate concentration perspective, there is enough nutrients to conservatively support 1250ha of kelp farms (0.5 percentile). However as Disaster Bay is only 3600ha local farm dynamics may reduce the nutrient fluxes as they will be impeded by the farms themselves.

Disaster Bay Sea Surface Temperature Modelling 2024



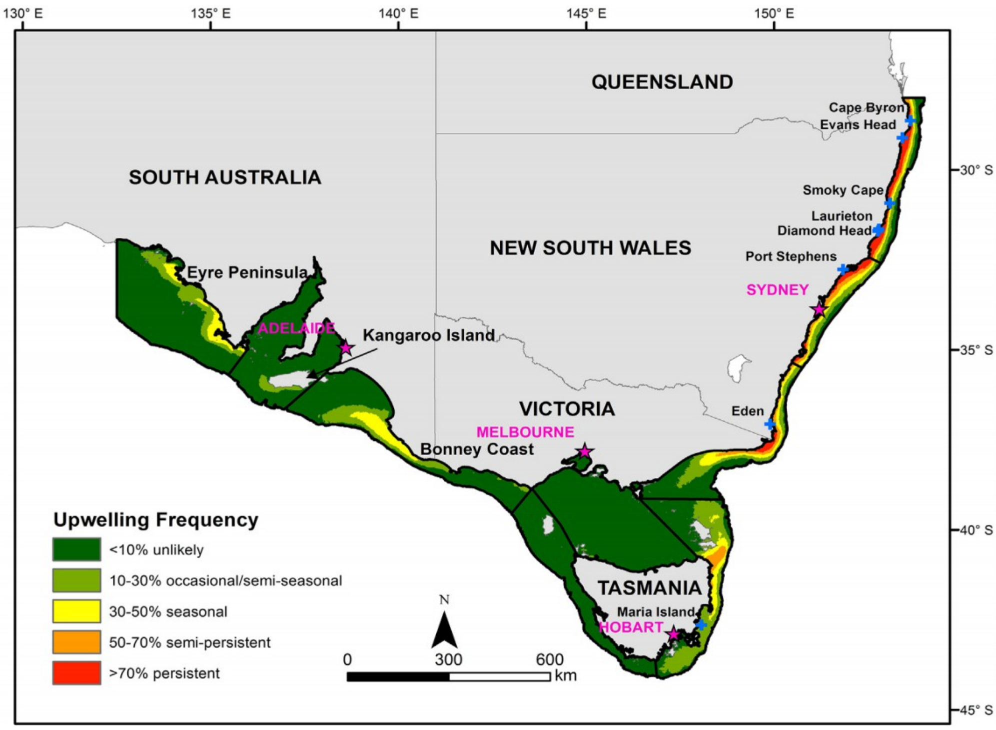
- During growth periods (correlating with high nitrogen concentration), the surface temperatures are significantly below the indicative 23°C in which kelp growth becomes significantly reduced, even if you add 2-3°C due to warming from climate change. However, this is based on ocean scale observations and measurements, and the local temperature in the bay may be affected by local dynamics which can be explored using regional ocean modelling.
- Wave height is relatively consistent over the year, with higher maximum wave heights during the colder months of the year, see modelling below.

Disaster Bay Wave Height Modelling 2024



1.4 Upwelling Systems

- Upwelling Modelling [1]: The NSW coastal upwelling system is a more or less persistent system occurring continuously from austral spring to autumn. The WVIC/SA coastal upwelling system is a seasonal upwelling system that occurred in the austral summer. See below image below from Mapping the spatial and temporal variability of the upwelling systems of the Australian south-eastern coast using 14-year of MODIS data: https://www.sciencedirect.com/science/article/pii/S0034425719301397.



- The NSW coastal upwelling system, especially the northern and central parts, is mainly driven by the EAC and its eddies; while, the WVIC/SA coastal upwelling is a typical wind-driven system.
- The El Nino events tend to strengthen upwelling intensity, with La Nina occurring weakening the upwelling intensity.

- There are less upwelling areas mapped along the Tasmanian coast and uncertainties in their forcing mechanisms.

1.5 Nutrient Modelling

- Currently modelling using Macroalgae Growth Model (MAG) [].
- Utilising a limited nitrate uptake model combined with exudation and death submodels to determine production and growth of biomass.
- Initial modelling shows 22-33 tonnes/ha, but improvements are being made due to difficulty in parameterising the model. A full uncertainty analysis and effect of seeding times is being undertaken.
- Upon funding, a regional ocean modelling analysis will be combined with MAG using MACMODS (MacroAlgae Cultivation MODeling System) from UC Irving. Funding required due compute costs from significantly increased computational complexity of regional analyses.
- Parameterisation of the models for *Ecklonia Radiata* are based on approximate values from reference literature detailed below.

Biological Model Parameters 2024

Variable	ID	Units	Notes
Nitrogen Uptake Rate	V	µmol-N/g-DW.hr	Dependant on V_max, Q, Q_max, Q_min
Fractional Exudation Rate	E	1/day	
Fractional Growth Rate	µ	1/day	
Total Fractional Death Rate	d_M	1/day	
Maximum Uptake Rate	V_max		
Maximum amount of nitrogen stored internally.	Q_max	mg-N/g-DW	
Minimum amount of nitrogen that should be found in a seaweed cell (structural nitrogen).	Q_min	mg-N/g-DW	
Half-saturation constant	K_m	µM	
Biomass density at which seaweed grows by a fraction k_R = 0.05/day under ideal conditions	B_cap	g-DW/m^2	
5degC Optimal Temperature Range	T_opt	degC	

Physical Model Parameters 2024

Variable	ID	Units	Notes
External concentration of nitrogen	C		
Molecular diffusivity of nitrate at 18 degC	D	m^2/s	7.3×10^−10
Wave Period	T_w		
Drag coefficient	C_D		
Molecular kinematic	v	m^2/s	10^−6
viscosity			
Daily-averaged saturating irradiance	I_s	W/m^2	
Daily-averaged compensating irradiance	I_c	W/m^2	
Fraction of daylight	f		
Wave power	P	W	

1.6 References

[1] Z Huanga, X H Wang. Mapping the spatial and temporal variability of the upwelling systems of the Australian south-eastern coast using 14-year of MODIS data. 2019, Remote Sensing of Environment 227

[2] T Wernberg, M Thomsen. The effect of wave exposure on the morphology of Ecklonia radiata. 2005, Aquatic botany 83.

[3] T Wernberg, M A Coleman, et. al. Biology and Ecology of the Globally Significant Kelp Ecklonia radiata. 2019, Oceanography and Marine Biology An Annual Review, Volume 57

[4] W Visch, G Nylund, H Pavia. Growth and biofouling in kelp aquaculture (Saccharina latissima) : the effect of location and wave exposure. 2020, Journal of Applied Phycology 32:3199 .

[5] Z Huang, X Wang. Mapping the spatial and temporal variability of the upwelling systems of the Australian south-eastern coast using 14-year of MODIS data. 2019, Remote Sensing of Environment 227.

[6] I Arzeno-Soltero, B Saenz, C Frieder, M Long, J DeAngelo, S Davis, K Davis. Large global variations in the carbon dioxide removal potential of seaweed farming due to biophysical constraints. 2023, Communications Earth & Environment volume 4.

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