Supplementary Material

1. **Supplementary Methods**

    1.1 Model adjustments

We adjusted the analytical model by Zhu et al. (2022) to reflect the morphological and mechanical properties for the kelp species *Ecklonia radiata* (Figure S1), which is a small, stipitate kelp, reaching a maximum length of 2 m, although this varies considerably along its distribution and in response to environmental conditions (Wernberg et al., 2003; Fowler-Walker et al., 2006).

Figure S1
Typical example of an E. radiata sample collected within Port Phillip Bay, Victoria, Australia.

    1.2 Collection of data

The morphological characteristics were defined based on previous measurements of *E. radiata* at five sites in Port Phillip Bay, Victoria (Morris et al., 2020 and unpublished data; Table S1). Eleven individuals of *E. radiata* were hand collected by divers in 2017 and 2018 from Governors Reef, Mornington Peninsula (two sites), Ricketts Point and Williamstown and their components that included the length of the stipe, lamina and laterals were measured. The flexural rigidity of *E. radiata* lamina and laterals was measured from kelp samples collected from Port Phillip Bay in May 2022.

Table S1: E. radiata morphological measurements

	Total length (cm)	Stipe length (mm)	Stipe diameter (mm)	Lamina length (cm)	Lamina width (cm)	Lamina thickness (mm)	Lateral length (cm)	Lateral width (cm)	No. laterals
Average	29.55	53.25	9.29	24.23	5.37	2.04	22.31	4.59	47.64
SD	8.38	21.04	1.87	7.69	1.68	0.56	4.33	1.11	19.75
N	55	55	55	55	55	55	55	55	55

Five E. radiata samples were collected from Williamstown breakwater, Port Phillip Bay, Victoria (37° 51' 39.6" S 144° 53' 6" E) in May 2022 and the lamina and laterals were separated (Figure S2). Tensile testing was performed to determine the modulus of elasticity of E. radiata, required to identify the flexural rigidity of E. radiata components. For this study, it was assumed that the stipe operates as a rigid component in the canopy and thus the flexural rigidity was not included.
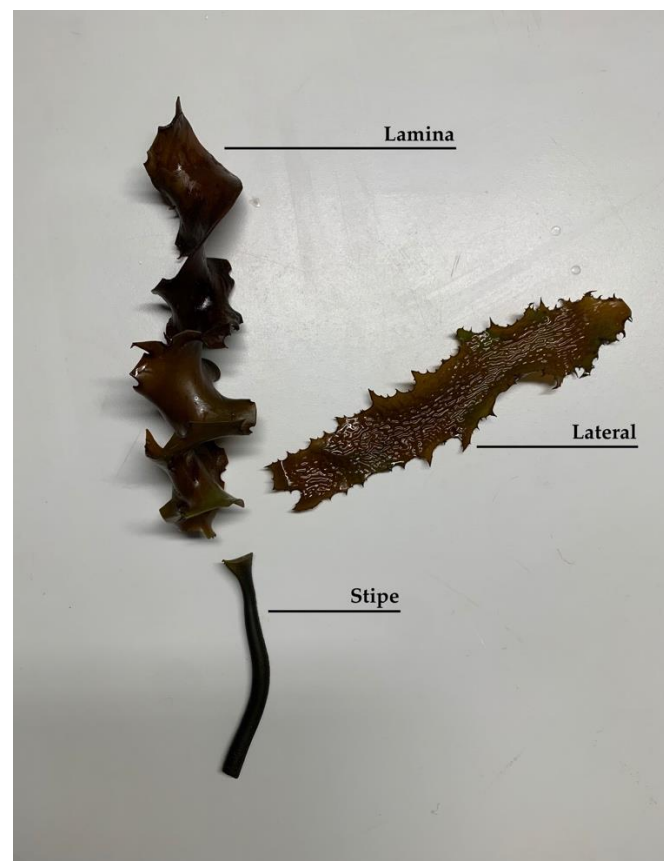

Figure S2
An example of an *E. radiata* sample collected from Williamstown breakwater with the holdfast, stipe, lamina and lateral samples separated and prepared for tensile testing.

Tensile testing involved the application of tensile force to a sample to breaking point using the Instron Universal testing machine applying force with a tensile grip, repeated for all 5 samples of each the lamina and lateral. This method provided a stress-strain curve from which the modulus of elasticity could be obtained by the slope using a linear regression of the curve. This was then

used to calculate the flexural rigidity of *E. radiata* components (equation 2). The modulus of elasticity and flexural rigidity values for lamina and laterals are displayed in Table S2.

$$Flexural\ rigidity = E \times I \quad,$$ (2)

where E is the modulus of elasticity and I is the second moment of area, defined for a rectangular cross-section in equation 3.

$$I = \frac{b_w \times (b_t)^3}{12},$$ (3)

where b_w is the blade width and b_t is the blade thickness.

Table S2: E. radiata mechanical properties

	Modulus of elasticity (MPa)		Second moment of area (m⁴)		Flexural rigidity (Nm²)	
	Lamina	Lateral	Lamina	Lateral	Lamina	Lateral
Average	2.02	1.18	1.62E-11	1.88E-12	3.49E-5	2.25E-6
SD	0.56	0.26	7.17E-12	1.42E-12	2.42E-5	1.93E-6
N	5	5	5	5	5	5