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The dominant urchin in southeastern Australia is an omnivore, not a herbivore

Supplementary Information

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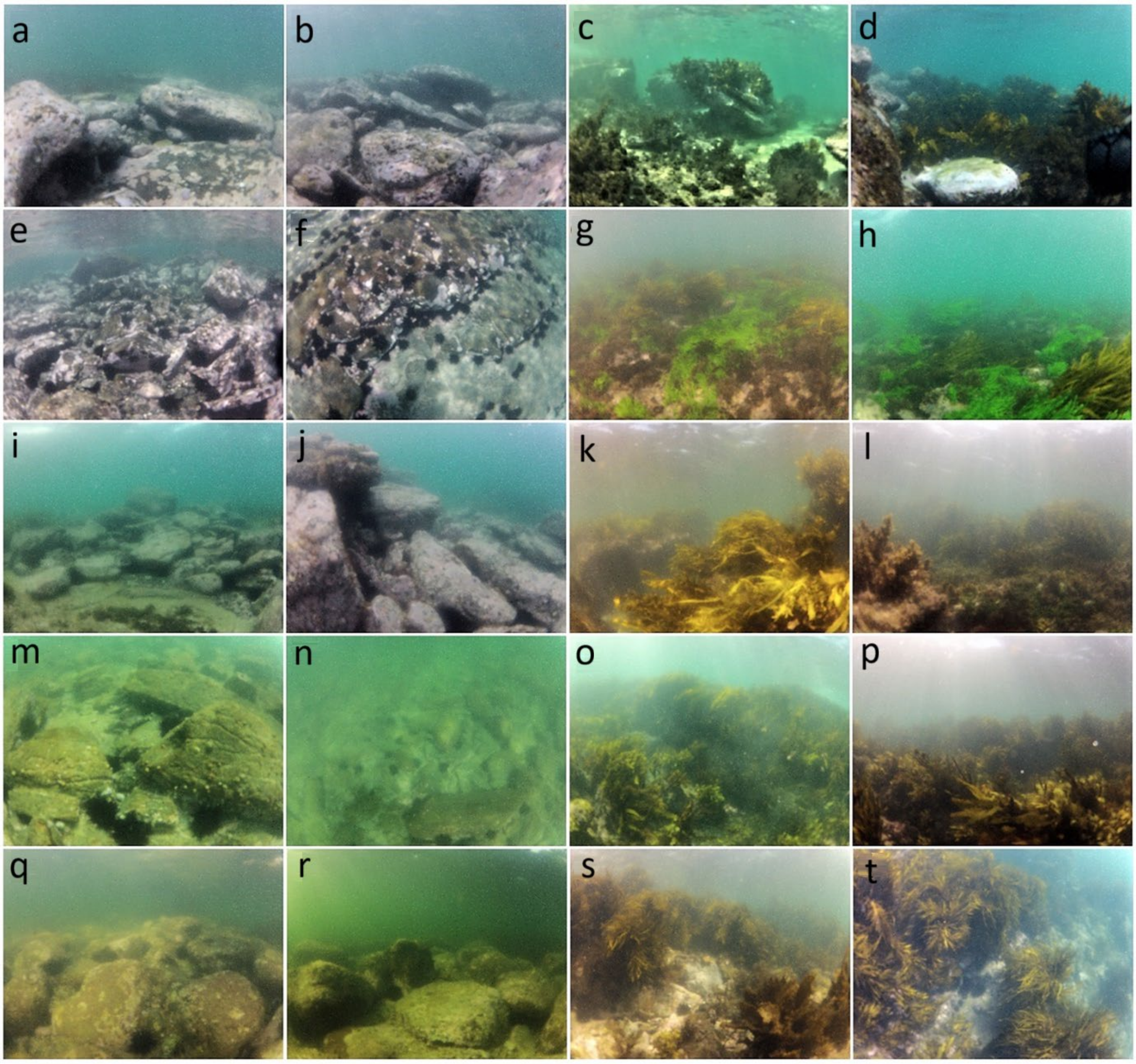
Supplementary Information S1: Study sites

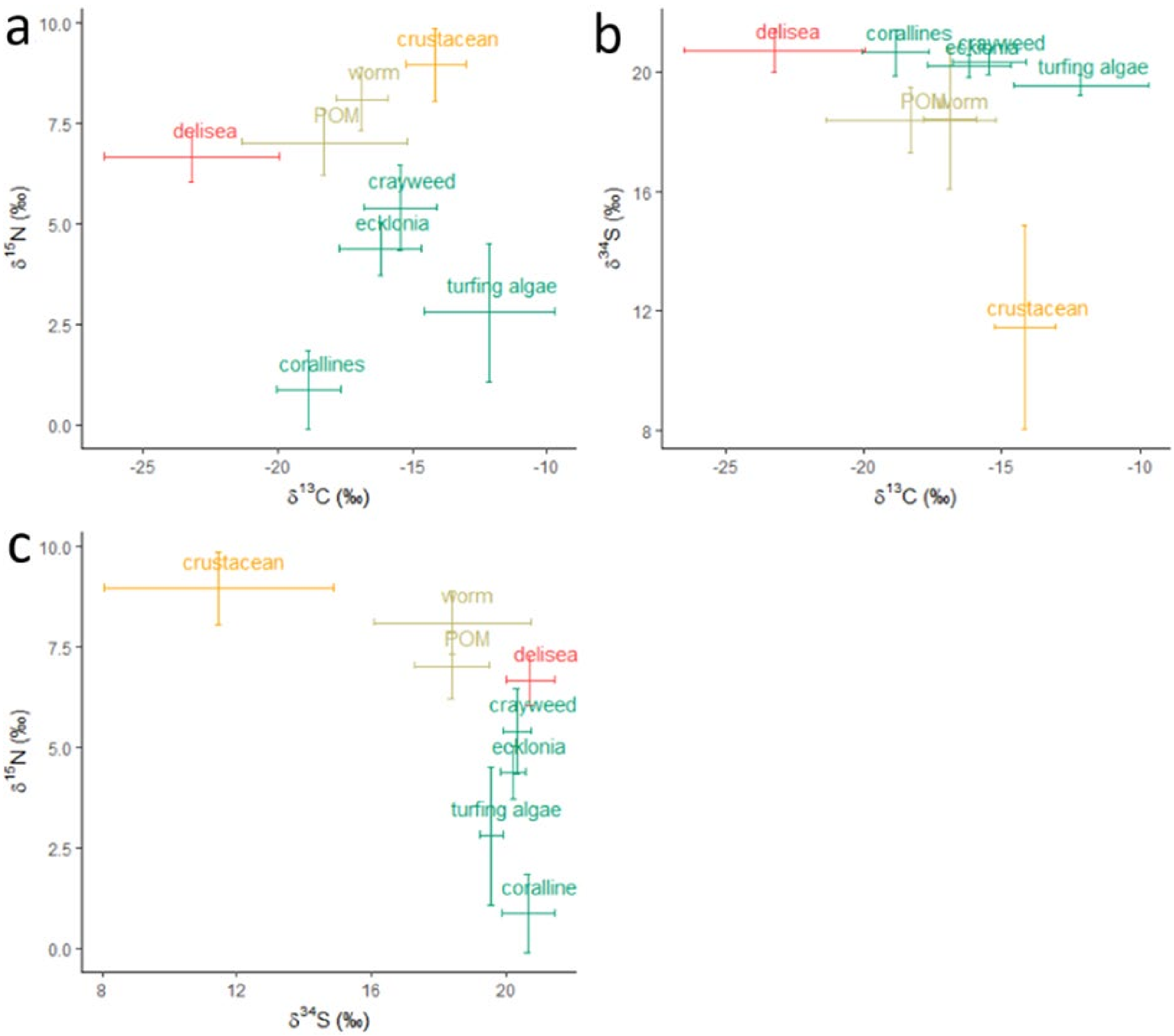


Supplementary Figure S1. Photo characterization of habitats where urchins were collected. Urchin barren habitats are shown first followed by macroalgae habitats, including (a and b) Malabar [Sydney barren site], (c and d) Little Bay [Sydney macroalgae site], (e and f) Bass Point [Wollongong barren site], (g and h) Sandon Point [Wollongong macroalgae site], (i and j) Bendalong Point [Bendalong barren site], (k and l) Washerwomans Beach [Bendalong macroalgae site], (m and n) Horseshoe Bay [Bermagui barren site], (o and p) Yallumgo Cove [Bermagui macroalgae site], (q and r) Russ Bay [Eden barren site] and (s and t) Aslings Beach [Eden macroalgae site].

Supplementary Table S1. Urchin sizes for *Centrostephanus rodgersii* collected between locations (Sydney, Wollongong, Bendalong, Bermagui or Eden) and habitats (macroalgal forest or barrens). Body size is shown via Test Diameter (TD, mm) ± Standard Deviation (SD).

Location	Habitat	TD range	TD ± SD
Sydney	macroalgal forest	66.1 – 96.1	82.2 ± 9.5
-	barrens	63.0 – 93.0	77.8 ± 8.0
Wollongong	macroalgal forest	65.1 – 96.1	86.5 ± 9.0
-	barrens	63.5 – 82.1	70.7 ± 5.0
Bendalong	macroalgal forest	90.0 – 115.0	102.3 ± 7.6
-	barrens	65.0 – 96.1	78.1 ± 8.5
Bermagui	macroalgal forest	73.2 – 111.0	93.1 ± 10.6
-	barrens	82.1 – 103.0	78.1 ± 8.5
Eden	macroalgal forest	69.5 – 97.7	89.0 ± 9.3
-	barrens	65.0 – 92.5	80.1 ± 9.8

Supplementary Information S2: Bayesian mixing models structure



Supplementary Figure S2. Biplots showing mean isotope data among all locations for sources *Ecklonia radiata* (Ecklonia), *Phyllospora comosa* (crayweed), *Delisea pulchra* (Delisea), articulated corallines (corallines), turfing algae, Particulate Organic Matter (POM), *Serpulidae* spp. (worm) and *Penaidae* spp. (crustacean). Separate comparisons are shown for (a) $\delta^{13}C$ / $\delta^{15}N$, (b) $\delta^{13}C$ / $\delta^{34}S$ and (c) $\delta^{34}S$ / $\delta^{15}N$. Colors shown (green, khaki, red, orange) correspond to source groupings used in Bayesian isotope mixing models.

Supplementary Table S2. Trophic Discrimination Factors (TDF's) for Carbon (^{13}C), Nitrogen (^{15}N) and Sulfur (^{34}S). Values are shown ± Standard Deviation (SD) for each isotope along with their respective literature sources

Taxa	^{13}C ± SD	^{15}N ± SD	^{34}S ± SD	Literature source
Invertebrates	-	-	0.60 ± 0.30	Raoult et al., 2024
Asteroidea; *L. groenlandics*	0.90 ± 0.35	2.35 ± 0.65	-	North et al., 2019
Asteroidea; *L. polaris*	1.15 ± 0.25	1.80 ± 0.55	-	North et al., 2019
Echinoidea: *T. depressus* and *E. thouarsii*	0.40 ± 1.30	3.20 ± 0.40	-	Acosta-Pachón et al., 2024
Echinoidea; *H. pulcherrimus*	0.75 ± 0.10	2.75 ± 0.11	-	Zhang et al., 2021
Marine omnivores	0.60 ± 1.47	3.45 ± 1.97	-	McCutchan et al., 2023
Marine ecosystems	0.39 ± 1.30	3.40 ± 0.98	-	Post 2002
Echinoid TDF	0.58 ± 0.70	2.98 ± 0.26	0.60 ± 0.30	This manuscript
All Echinoderm TDF	0.80 ± 0.50	2.53 ± 0.43	0.60 ± 0.30	This manuscript
All TDF	0.70 ± 0.58	2.83 ± 0.78	0.60 ± 0.30	This manuscript

Supplementary Table S3. Results of sensitivity analyses using Aikake's Information Criterion (AIC) to select the best fitting Trophic Discrimination Factor (TDF). AIC values are shown between urchins in (a) macroalgal forests and (b) barrens. TDF's with the best fit shown by lowest AIC value are shown with an asterisk (*).

(a)

TDF	**AIC ^{13}C**	**AIC ^{15}N**	**AIC ^{34}S**
Echinoid	-1.13 *	20.49	7.06
All Echinoderm	12.46	24.82	-3.97 *
All TDF	20.30	12.31 *	6.92

(b)

TDF	**AIC ^{13}C**	**AIC ^{15}N**	**AIC ^{34}S**
Echinoid	-19.19 *	13.74 *	7.00
All Echinoderm	-2.24	19.19	-3.33 *
All TDF	3.44	15.17	9.75

Supplementary Table S4. Results of 95 % mixing region polygons for (a) “Analysis 1: Comparison of diet composition Between Locations Forests and Barrens” and (b) “Analysis 2: Spatial consistency in Diet composition within Forests and Barrens” showing the proportion of posterior distributions centered around source groupings, a proxy for model accuracy. Means are shown ± Standard Error (SE) for each analysis and isotope comparison while averaged values across all comparisons are shown in bold.

Analysis	Factor	$^{13}C : ^{15}N \pm SE$	$^{13}C : ^{34}S \pm SE$	$^{34}S : ^{15}N \pm SE$	Total ± SE %
(a) Analysis 1	macroalgal forest	53.59 ± 21.37	51.99 ± 22.31	62.98 ± 14.47	**56.19 ± 19.38**
	barrens	45.8 ± 22.6	40.7 ± 18.7	67.41 ± 14.85	**51.32 18.59**
(b) Analysis 2	Sydney (macroalgal forest)	63.91 ± 81	50.24 ± 25.73	88.65 ± 3.54	**67.60 ± 17.98**
	Sydney (barrens)	34.97 ± 16.28	24.23 ± 12.67	81.88 ± 6.40	**47.03 ± 11.78**
	Wollongong (macroalgal forest)	67.42 ± 8.99	66.37 ± 8.87	63.03 ± 13.55	**65.61 ± 10.47**
	Wollongong (barrens)	48.41 ± 26.72	39.67 ± 23.81	69.85 ± 9.66	**52.64 ± 20.06**
	Bendalong (macroalgal forest)	81.00 ± 11.82	72.26 ± 11.65	75.37 ± 5.98	**76.21 ± 9.82**
	Bendalong (barrens)	69.14 ± 14.11	56.74 ± 11.98	8.48 ± 6.59	**44.79 ± 10.90**
	Bermagui (macroalgal forest)	21.69 ± 5.53	17.40 ± 5.70	52.46 ± 16.41	**30.52 ± 9.21**
	Bermagui (barrens)	35.93 ± 11.53	28.32 ± 6.46	68.20 ± 7.79	**44.15 ± 8.59**
	Eden (macroalgal forest)	41.51 ± 13.59	43.57 ± 11.59	36.28 ± 11.20	**40.45 ± 12.12**
	Eden (barrens)	17.39 ± 9.20	22.36 ± 7.54	21.95 ± 6.54	**20.57 ± 7.76**

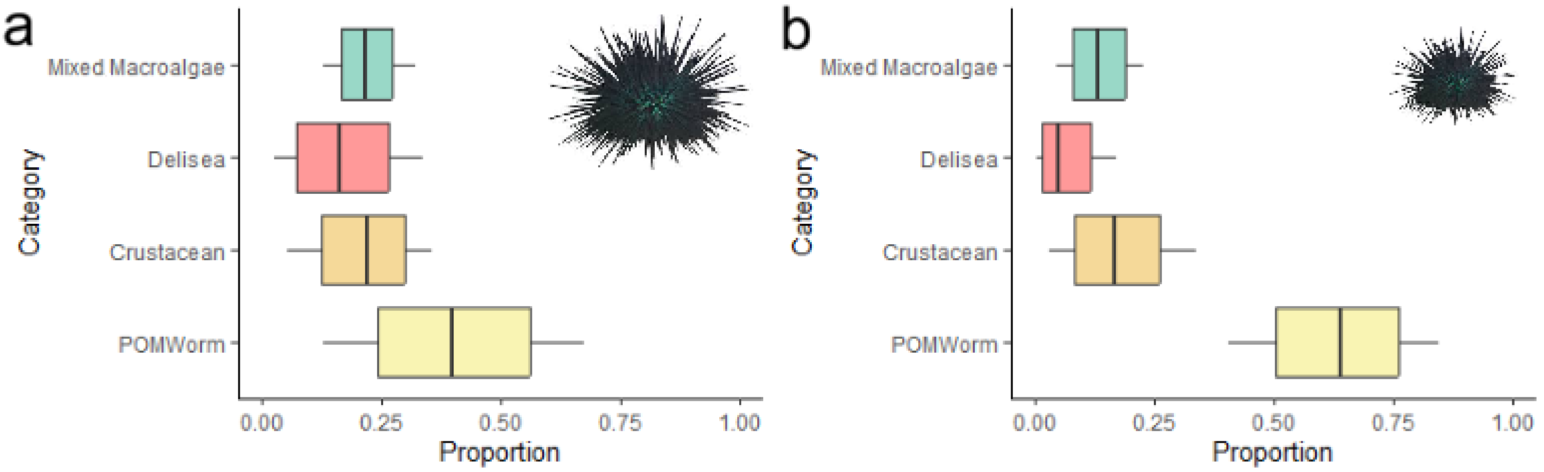
Supplementary Information 3:

Methods

To test size effects, for this initial investigation we chose a representative location with the greatest size range of collected urchins across habitats (Bendalong; 50 mm TD range, $\bar{x}$ = 90.2 ± 14.6 mm TD). We chose the model location of Bendalong to assess effects of urchin body size because although our collections of *C. rodgersii* aimed to standardize size across habitats within locations, some size differences between barrens and macroalgal habitats were unavoidable, with urchins being smaller on average in barrens. This provided the opportunity for an initial test of how urchin body size affects the importance of macroalgae compared to POM and invertebrates, which has never been examined quantitatively for *C. rodgersii*.

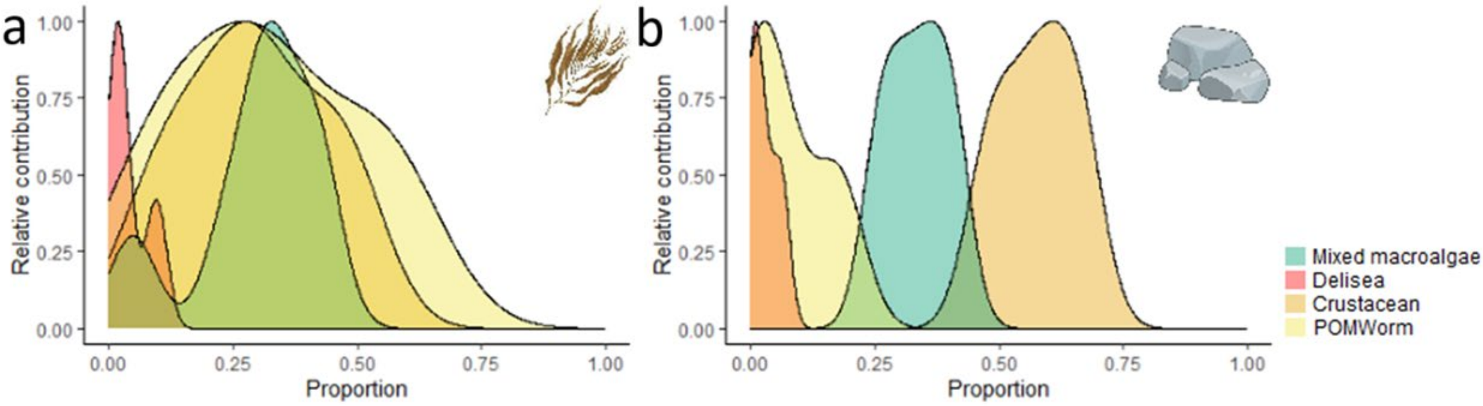
Results

The examination of nutrient sources related to urchin size (conducted only at Bendalong) indicated that smaller urchins were heavily reliant on POM/Worm compared to large urchins, although POM/Worm was also the dominant nutrition source for large urchins. Small urchins had proportionally lower levels of Mixed Macroalgae signature (~ 8 %), *Delisea pulchura* (~ 11 %) and crustaceans (~ 5 %) while the importance of POM and worm was much higher (~ 23 %; Fig. S3). These patterns provided weak support for the hypothesis that large urchins rely more on macroalgae (~ 8 % Mixed Macroalgae increase from small to large) but importantly, provided further indication that non-macroalgal sources such as invertebrates and POM are important nutritional sources for urchins, irrespective of their size.

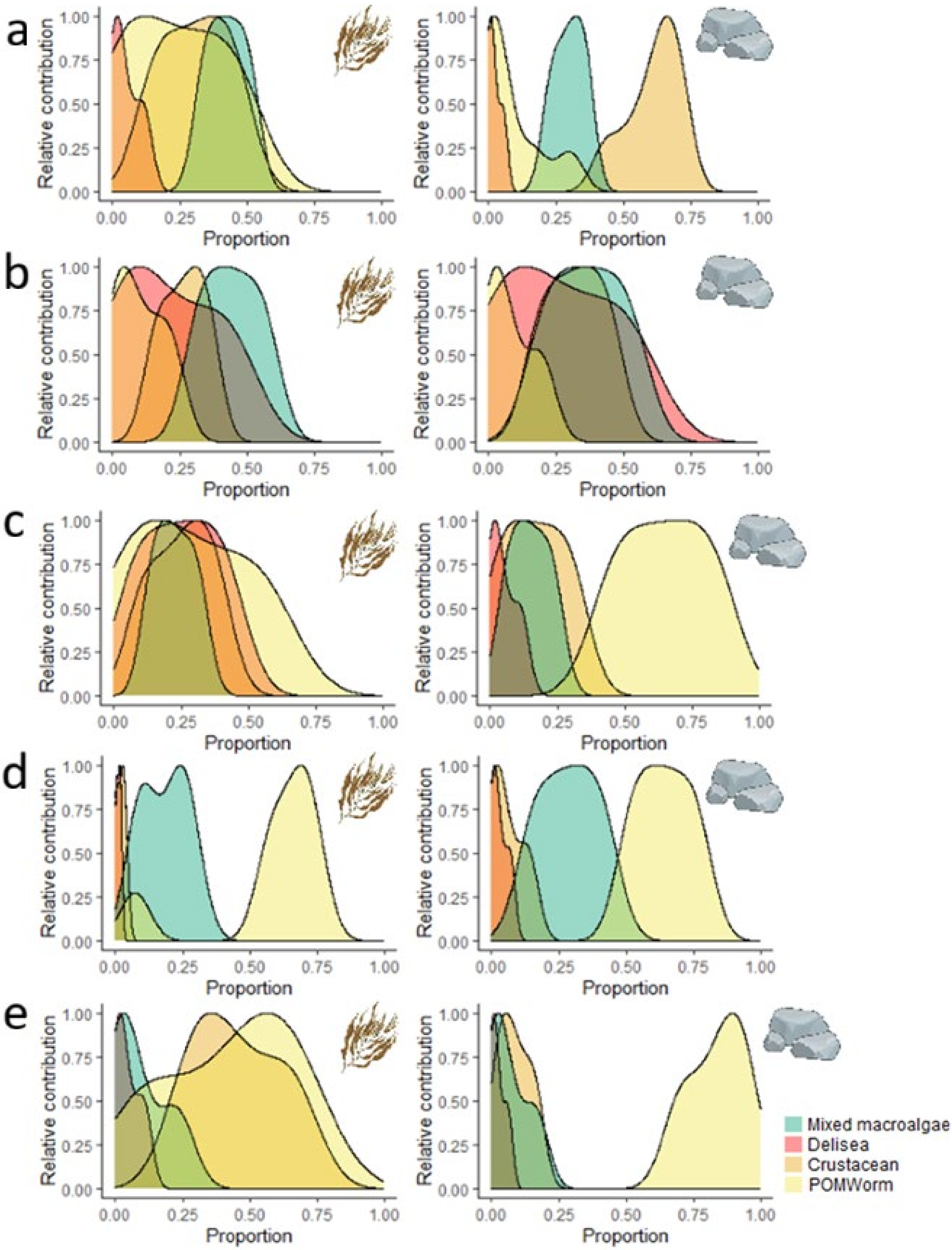


Supplementary Figure S3. Posterior densities from Bayesian isotope mixing models ($\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$) showing relative nutritional contribution of potential sources in "Analysis 3: Size Comparison at one Model Location" for *Centrostephanus rodgersii* of (A) large (shown by a large urchin) and (B) small body size (shown by a small urchin). Size categories were determined at the cutoff of 80 millimetres Test Diameter (TD, mm). Source proportions are shown top and bottom for potential source groupings Mixed Macroalgae (*Ecklonia radiata, Phyllospora comosa*, articulated corallines, turfing algae; shown green), POM and Worm (Particulate Organic Matter "POM" and Serpulidae spp.; shown khaki), Crustacean (Penaidae spp.; shown orange) and Delisea (*Delisea pulchra*; shown red) while boxes, whiskers and middle lines show quartiles, ranges and medians, respectively.

Supplementary Information 4: Bayesian mixing models posterior density



Supplementary Figure S4. Relative contributions of sources calculated for $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ for *Centrostephanus rodgersii* in "Analysis 1: Comparison of diet composition Between Locations Forests and Barrens", showing results between (a) macroalgal forests (shown by macroalgae) and (b) barrens habitats (shown by a rock) between four source groups; Mixed Macroalgae (*Ecklonia radiata, Phyllospora comosa*, articulated corallines, turfing algae; shown green), Foliose red Macroalgae (*Delisea pulchra*; shown red), Crustacean (Penaidae spp.; shown orange) and POM and Worm (Particulate Organic Matter "POM" and Serpulidae spp.; shown khaki). Greater width of source groups shown in density plots indicate more consistent source contributions.



a
b
c
d
e
Relative contribution
Proportion
0.00
0.25
0.50
0.75
1.00
Mixed macroalgae
Delisea
Crustacean
POMWorm

Supplementary Figure S5. Relative contributions of sources calculated for $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ for *Centrostephanus rodgersii* in "Analysis 2: Spatial consistency in Diet composition within Forests and Barrens", showing results between macroalgal forests (shown by macroalgae) and barrens habitats (shown by a rock) at (a) Sydney, (b) Wollongong, (c) Bendalong, (d) Bermagui and (e) Eden locations between four source groups; Mixed Macroalgae (*Ecklonia radiata, Phyllospora comosa*, articulated corallines, turfing algae; shown green), Foliose red Macroalgae (*Delisea pulchra*; shown red), Crustacean (Penaidae spp.; shown orange) and POM and Worm (Particulate Organic Matter "POM" and Serpulidae spp.; shown khaki). Greater width of source groups shown in density plots indicate more consistent source contributions.