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Physical surrogates for macrofaunal distributions and abundance in a tropical gulf

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Abstract. The characterisation of benthic habitats based on their abiotic (physical and chemical) attributes remains poorly defined in the marine environment, but is becoming increasingly central in the development of marine management plans in Australia and elsewhere in the world. The current study tested this link between physical and biological datasets for the southern Gulf of Carpentaria, Australia. The results presented were based on a range of physical factors, including the sediment composition (grain size and carbonate content), sediment mobility, water depth and organic carbon flux, and their relationship to the distribution and diversity of benthic macrofauna was tested. The results reveal the importance of process-based indices, such as sediment mobility, in addition to other environmental factors in defining the distribution of the benthic macrofauna. The distribution of the benthic macrofauna changes gradationally across the south-eastern Gulf, associated with changes in the per cent mud and gravel, the seabed exposure and the water depth. Patterns of diversity also reveal the importance of physical processes such as sediment mobility in defining benthic habitats. The species–environment relationships observed at the small scale of the current study are consistent with broader associations observed for other organisms within the Gulf.

Appendix 1. Counts in number m^{-2} for key taxa at each site. The number of benthic foraminifera g^{-1} of sand is also shown

Density of taxa (# m^{-2})	1BS1	4BS4	6BS6	7BS7	8BS8	9BS9	10BS10	11BS11	12BS12	13BS13	14BS14	15BS15
Basket star	0	0	0	0	0	0.037	0	0	0	0	0	0
Brittlestar	0	0.003	0.007	0.058	0	0.022	0	0	0	0	0.016	0
Brittlestar 70A	0	0	0	0	0	0	0	0	0	0	0	0
Chicoreus longirostrus	0	0.003	0.011	0.008	0.016	0	0.022	0	0	0	0	0
Cigclisula 63	0	0	0.002	0.025	0.016	0.097	0.022	0	0	0	0.004	0
Crinoids	0	0	0	0.008	0.029	0.045	0.043	0	0	0	0	0
Ebalia lambriformis	0	0	0	0.033	0.010	0.007	0.011	0.036	0.026	0.027	0.043	0
Gorgonian 10	0	0	0.002	0	0	0	0.108	0	0.003	0.009	0	0
Hydroid 63B	0	0	0	0.008	0.003	0.082	0.119	0	0.003	0	0	0
Hydroid 63C	0	0.003	0.005	0.008	0.096	0.060	0.076	0	0.003	0.009	0.004	0
Hydroid 63D	0	0	0	0	0	0	0.011	0	0	0	0	0
Hydroid 70	0	0	0	0	0	0	0	0	0	0	0	0
Hydroid 9	0	0	0.002	0	0	0.037	0.011	0	0.003	0	0.004	0
Iconaster 65	0	0	0.002	0	0.006	0	0	0	0.016	0.009	0	0
Ircinia 53	0	0	0	0	0	0	0	0	0	0	0	0
Leucosia ocellata	0	0	0.007	0.025	0.003	0	0.011	0.018	0.016	0.009	0	0
Luidia 85	0	0	0	0.008	0.016	0	0.022	0	0.013	0	0.004	0
Luidia maculata	0	0	0	0	0.006	0.007	0	0	0.010	0	0	0
Matuta inermis	0	0	0	0	0	0	0	0	0	0	0	0
Metalia 29	0	0	0	0.008	0.003	0	0	0.098	0.151	0.036	0	0.429
Paphia undulata	0	0.003	0	0.050	0.010	0	0.022	0.009	0.003	0	0.004	0
Penaeid sp.	0	0	0	0	0.003	0	0	0	0.003	0.267	0	0
Peronella 68	0	0	0.016	0.017	0	0	0	0	0	0	0	0.009
Polycarpa chinensis	0	0	0.002	0.041	0.087	0.007	0	0	0	0	0	0
Polychaete tube	0.022	0.032	0.007	0.017	0.016	0	0	0	0.026	0.009	0.122	0
Portunus acerbiterminalis	0	0	0	0	0	0	0	0	0.016	0.018	0	0
Portunus gracilimanus	0	0	0.002	0.033	0.006	0	0	0	0	0	0.008	0
Retiflustre cornea	0	0	0	0	0.013	0	0	0	0	0	0	0
Salmaicus 53	0	0	0	0	0.006	0	0	0	0	0	0	0
Scrupocellaria 9B	0.004	0	0	0.008	0.003	0.022	0.022	0	0	0	0.004	0
Sponge 63	0	0	0	0	0	0.037	0.011	0	0	0	0	0
Sponge pieces	0	0.009	0.005	0	0.013	0.015	0.054	0	0	0	0	0
Tryphyllozoon 63	0.004	0.003	0.014	0.033	0	0.022	0.022	0	0	0	0	0
Benthic forams g^{-1}	16014.6	1505.6	3356.1	2441.5	1457.9	242.9	1350.3	800.2	1275.5	358.7	1817.4	5438.4

Appendix 1 continued

Density of taxa (# m^{-2})	16BS16	17BS17	18BS18	19BS19	20BS20	21BS21	22BS22	24BS23	26BS24	29BS25	32BS27	33BS28
Basket star	0	0	0	0	0	0	0.009	0	0	0	0	0
Brittlestar	0.037	0	0	0.003	0.004	0.008	0.019	0	0	0.025	0.009	0
Brittlestar 70A	0	0	0	0	0	0	0	0	0	0	0	0
Chicoreus longirostrus	0.019	0	0	0	0.007	0.008	0.009	0	0.004	0	0	0
Cigclisula 63	0.007	0	0	0.003	0.011	0.008	0	0	0	0.003	0.017	0.007
Crinoids	0.007	0.010	0.044	0.003	0.004	0	0	0.004	0	0	0	0
Ebalia lambriformis	0.030	0	0	0	0.004	0.015	0.009	0	0.042	0.014	0.017	0
Gorgonian 10	0.004	0.005	0	0	0	0	0	0.004	0	0	0	0
Hydroid 63B	0	0	0	0	0	0	0	0	0	0	0	0
Hydroid 63C	0.026	0.010	0.044	0.003	0.004	0.023	0	0	0.008	0.006	0.121	0.014
Hydroid 63D	0	0	0	0	0	0	0	0	0	0	0	0
Hydroid 70	0	0	0	0	0	0	0	0	0	0	0	0
Hydroid 9	0	0	0.004	0.003	0	0.015	0	0	0	0.006	0.009	0.007
Iconaster 65	0.034	0.010	0.004	0.006	0	0.015	0.047	0	0	0	0	0.048
Ircinia 53	0	0	0	0	0	0	0	0	0	0	0	0
Leucosia ocellata	0.004	0.005	0	0	0	0	0	0	0.004	0.006	0	0.007
Luidia 85	0.019	0.010	0	0	0.022	0.008	0.047	0.004	0.013	0.017	0	0
Luidia maculata	0.004	0.015	0	0	0	0	0	0	0	0.003	0.009	0
Matuta inermis	0	0	0	0.262	0.007	0	0	0	0	0	0	0
Metalia 29	0.026	0.005	0	0	0	24.188	0	0	0.030	0.130	0.009	0
Paphia undulata	0	0	0	0	0	0.008	0	0	0	0	0	0
Penaeid sp.	0	0	0	0.009	0	0	0	0	0	0	0	0
Peronella 68	0	0	0.009	0	0	0	0.047	0	0	0	0	0
Polycarpa chinensis	0.007	0	0	0	0	0	0	0	0	0	0.035	0.007
Polychaete tube	0.004	0.005	0.004	0	0.004	0.077	0.009	0.022	0	0	0.043	0.007
Portunus acerbiterminalis	0.004	0.005	0.036	0.003	0	0.023	0	0	0.042	0	0	0
Portunus gracilimanus	0.004	0	0	0.003	0	0	0	0	0.004	0	0.017	0
Retiflustre cornea	0	0	0	0	0	0	0	0	0	0	0	0
Salmaicus 53	0.022	0	0	0	0	0	0	0	0	0.008	0	0
Scrupocellaria 9B	0	0.005	0.013	0	0.004	0	0.009	0	0	0	0	0
Sponge 63	0	0	0	0	0	0	0	0	0	0	0	0
Sponge pieces	0.019	0	0	0	0	0	0.009	0	0	0	0	0.007
Tryphyllozoon 63	0.007	0	0	0.003	0.007	0	0.009	0	0	0	0	0
Benthic forams g^{-1}	2245.2	1758.6	985.8	2209.7	93.4	3758.7	743.1	406.6	2916.7	2346.2	1072.6	2458.0

Appendix 1 continued

Density of taxa (# m^{-2})	34BS29	35BS30	37BS31	38BS32	45BS33	47BS35	53BS37	55BS38	58BS39	59BS40	61BS42	63BS43
Basket star	0	0	0	0	0.005	0.005	0	0	0.010	0	0.008	0.007
Brittlestar	0	0.037	0.093	0.004	0	0	0.022	0	0.030	0.008	0	0.020
Brittlestar 70A	0	0	0	0	0.010	0.005	0	0.037	0	0	0.008	0
Chicoreus longirostrus	0	0	0.004	0.004	0	0	0	0	0	0	0	0
Cigclisula 63	0	0	0.004	0	0.043	0.016	0.056	0.029	0.020	0.004	0.031	0.007
Crinoids	0	0	0.008	0	0.038	0.031	0	0.007	0	0	0.034	0.026
Ebalia lambriformis	0.006	0.037	0.008	0	0	0	0	0	0	0.004	0	0
Gorgonian 10	0	0.009	0.004	0.004	0	0	0	0	0	0	0	0
Hydroid 63B	0	0	0	0	0.005	0.021	0	0.007	0.010	0.004	0.015	0.007
Hydroid 63C	0.006	0.037	0.013	0	0	0.005	0	0	0.010	0.004	0.019	0.007
Hydroid 63D	0	0	0	0	0.005	0	0.034	0.037	0	0	0.015	0.007
Hydroid 70	0	0	0	0	0	0	0	0.015	0	0	0.038	0
Hydroid 9	0	0.009	0.004	0.004	0.005	0	0	0.015	0	0	0.008	0
Iconaster 65	0.003	0.009	0	0.035	0.010	0	0	0	0	0	0	0
Ircinia 53	0	0	0	0	0.005	0	0.022	0.007	0	0	0.004	0
Leucosia ocellata	0	0	0.004	0	0	0	0	0	0	0	0	0
Luidia 85	0.006	0.028	0	0.004	0	0	0	0	0	0	0	0
Luidia maculata	0.003	0.009	0.004	0.004	0	0.005	0	0	0.010	0	0.004	0
Matuta inermis	0.003	0	0	0	0	0	0	0	0	0	0	0
Metalia 29	0	0	0.219	0	0	0	0	0	0	0	0	0
Paphia undulata	0	0	0.008	0	0	0	0	0	0	0	0	0
Penaeid sp.	0	0	0	0	0	0	0	0	0.040	0	0	0
Peronella 68	0	0	0	0	0	0	0	0	0	0	0	0
Polycarpa chinensis	0.012	0.019	0.004	0	0	0	0	0	0	0	0	0
Polychaete tube	0	0	0.042	0	0.005	0	0	0	0	0	0	0
Portunus acerbiterminalis	0.003	0	0	0	0	0	0	0	0	0	0	0
Portunus gracilimanus	0	0	0.004	0	0	0.005	0	0	0	0	0	0
Retiflustre cornea	0	0	0	0	0	0	0	0	0	0	0	0
Salmaicus 53	0	0.019	0	0	0	0.016	0.011	0	0	0	0	0
Scrupocellaria 9B	0.003	0	0	0	0	0	0	0	0.010	0.004	0.008	0
Sponge 63	0	0	0	0	0.067	0.021	0	0.007	0.010	0	0.004	0.013
Sponge pieces	0	0	0.004	0.004	0	0	0	0.007	0	0.012	0.019	0
Tryphyllozoon 63	0	0	0.004	0	0	0	0.011	0	0.010	0.004	0.019	0.007
Benthic forams g^{-1}	1720.1	1794.0	1198.4	698.5	534.2	213.1	726.5	471.5	468.3	505.7	678.7	617.6

Appendix 1 continued

Density of taxa (# m^{-2})	64BS44	65BS45	68BS46	70BS48	73BS49	74BS50	75BS51	79BS52	80BS53	81BS54	83BS55	85BS56
Basket star	0.002	0.006	0	0.076	0.019	0.074	0.015	0	0	0	0	0
Brittlestar	0.002	0.064	0.005	0	0.010	0.052	0	0	0	0	0	0.029
Brittlestar 70A	0	0	0	0.008	0	0.104	0.083	0	0	0	0	0
Chicoreus longirostrus	0	0	0	0	0.005	0.015	0.008	0	0	0.005	0	0
Cigclisula 63	0.010	0.017	0.009	0.015	0.014	0.112	0.068	0.017	0	0	0	0
Crinoids	0	0.017	0	0.083	0.014	0.171	0.205	0	0.028	0	0	0.014
Ebalia lambriformis	0	0.023	0	0.015	0	0.015	0	0	0	0	0	0
Gorgonian 10	0	0	0	0	0	0	0	0	0	0	0	0
Hydroid 63B	0.010	0.006	0	0.008	0.005	0.030	0.061	0	0	0	0	0
Hydroid 63C	0.002	0	0	0	0	0	0.061	0	0	0	0	0
Hydroid 63D	0.002	0	0	0	0	0.007	0.023	0	0.009	0	0	0
Hydroid 70	0	0	0	0.008	0	0.007	0.076	0	0	0	0	0
Hydroid 9	0.002	0.006	0	0.008	0.019	0.007	0.038	0	0.009	0	0	0
Iconaster 65	0	0.006	0	0	0	0	0	0.009	0.009	0	0	0
Ircinia 53	0.003	0	0	0	0	0.007	0.008	0	0	0	0	0
Leucosia ocellata	0	0	0	0	0	0	0	0	0	0	0	0
Luidia 85	0	0	0	0	0	0	0	0	0	0	0	0.014
Luidia maculata	0	0	0	0	0	0	0	0	0	0	0	0
Matuta inermis	0	0	0.037	0.008	0	0	0	0	0	0	0	0
Metalia 29	0	0	0	0	0	0	0	0	0	0	0	0
Paphia undulata	0.003	0	0	0	0	0	0	0.009	0	0	0	0.014
Penaeid sp.	0	0	0	0	0	0	0	0	0	0.016	0	0
Peronella 68	0	0	0.005	0	0	0.007	0	0.017	0	0	0	0
Polycarpa chinensis	0	0	0	0	0	0	0	0.009	0	0	0	0
Polychaete tube	0	0	0	0.023	0	0	0.008	0.043	0.055	0	0	0
Portunus acerbiterminalis	0.002	0	0	0	0	0	0	0	0	0	0	0
Portunus gracilimanus	0	0.017	0	0.015	0	0	0	0.009	0	0	0	0.043
Retiflustre cornea	0	0	0	0	0	0	0	0.009	0.009	0.005	0	0
Salmaicus 53	0	0.017	0	0.008	0	0	0.008	0	0	0	0	0
Scrupocellaria 9B	0.002	0	0	0	0	0.007	0.015	0.009	0	0	0	0
Sponge *63*	0.003	0.075	0	0.008	0.005	0	0	0	0	0	0	0
Sponge pieces	0.002	0	0	0	0	0.022	0.008	0	0.018	0	0	0.145
Tryphyllozoon 63	0	0.006	0	0	0	0.022	0.136	0.043	0.009	0	0	0.014
Benthic forams g^{-1}	591.4	519.0	474.1	387.9	594.0	137.3	129.5	2738.1	1813.9	4116.0	152.2	4147.6

Appendix 1 continued

Density of taxa (# m^{-2})	89BS57	90BS58	91BS59	102BS60	104BS62
Basket star	0.006	0.005	0.014	0	0
Brittlestar	0	0	0	0.039	0.005
Brittlestar 70A	0	0.014	0.018	0	0
Chicoreus longirostrus	0	0	0.005	0.005	0.005
Cigclisula 63	0	0.005	0	0.005	0
Crinoids	0	0.005	0.081	0.024	0.010
Ebalia lambriformis	0	0	0	0	0
Gorgonian 10	0	0	0	0	0
Hydroid 63B	0	0	0	0	0
Hydroid 63C	0	0.019	0.005	0	0
Hydroid 63D	0	0	0	0	0
Hydroid 70	0	0	0	0	0
Hydroid 9	0	0.005	0.005	0.005	0
Iconaster 65	0	0	0.005	0.010	0
Ircinia 53	0	0	0.005	0	0
Leucosia ocellata	0	0	0	0	0
Luidia 85	0	0	0	0.005	0
Luidia maculata	0	0.005	0	0.005	0.005
Matuta inermis	0	0	0	0	0
Metalia 29	0	0	0	0	0
Paphia undulata	0	0	0	0	0
Penaeid sp.	0.006	0	0	0	0
Peronella 68	0	0	0	0	0.010
Polycarpa chinensis	0	0	0.005	0.005	0
Polychaete tube	0.006	0.005	0	0	0
Portunus acerbiterminalis	0	0	0	0	0
Portunus gracilimanus	0	0	0	0.005	0
Retiflustre cornea	0	0	0.005	0.049	0.014
Salmaicus 53	0	0	0.005	0	0
Scrupocellaria 9B	0	0	0	0.005	0
Sponge 63	0	0	0	0	0
Sponge pieces	0	0	0.014	0.005	0
Tryphyllozoon 63	0	0.005	0	0.005	0
Benthic forams g^{-1}	3381.2	518.9	714.0	1439.9	2583.3