

Intertidal communities differ between breakwaters and natural rocky areas on ice-scoured Northwest Atlantic coasts

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Introduction

In preparation for a study of habitat for intertidal organisms on rocky breakwaters throughout the southern Gulf of St. Lawrence, a preliminary analysis was carried out to determine whether significant changes occurred in biota growing on breakwaters over the months of June, July and August in 2010.

Methods

Percent cover of macroalgae and macroinvertebrates was quantified on six breakwaters near the Arisaig area in Nova Scotia once per month in the summer: 23-30 June, 12-16 July and 16-20 August 2010. Sampling procedures for percent cover estimates along breakwaters, both on the exposed and sheltered sides, followed the methodology detailed in the paper. We sampled 8 quadrats per time x site x exposure combination (i.e., 8 quadrats per transect). Breakwaters selected for sampling were a subset of the breakwaters included in the paper (Figure 1 in the paper) and, therefore, included the same selection criteria.

Univariate analyses were completed using SYSTAT® 11.0 (Systat Software Inc., USA) on taxa richness (number of taxa per quadrat) and total abundance (total percent cover per quadrat) of macroalgae and macroinvertebrates. The mixed-model ANOVA included a time factor with three levels (June, July, and August 2010) as a fixed factor. Similar to the analyses in the paper, the factor “site” (six breakwaters) was a random factor, and the factor “exposure” (exposed and sheltered) was a fixed factor (Underwood 1997).

Multivariate analysis to investigate community composition was conducted using Plymouth Routines in Multivariate Ecological Research (PRIMER v6®, Primer-e Ltd., UK) software with the permutational multivariate analysis of variance (PERMANOVA®, Primer-e Ltd., Plymouth, UK) add-on (Anderson 2001, Anderson 2005, Clarke & Gorley 2006). Differences in community composition over the three time periods were analysed using mixed-model PERMANOVA, with time and exposure as fixed factors and site as a random factor. Non-metric multidimensional scaling (nMDS) was used to display multivariate patterns seen in the percent cover data for the three months with all sites combined.

Results and Discussion

Neither taxa richness nor total abundance (percent cover) of intertidal biota on breakwaters differed significantly over the months June, July and August at exposed or sheltered areas (Table S1, Figure S1, S2).

PERMANOVA showed that species composition changed significantly over time during the study period (Table S2). Post-hoc pairwise comparisons indicated that the significant difference in community composition was between the month of June and the other two months. There was no significant difference in community composition during the sampling period used for our paper (July and August; $p=0.235$; Table S2). The nMDS showed a large degree of overlap occurring between July and August sample times, while June was a separate grouping (Figure S3).

These results suggest that, over and above random site effects, there are no consistent or significant differences in the community structure of intertidal biota found on breakwaters of the southern Gulf of St. Lawrence in July and August. Therefore, consistent with recommendations and sampling protocols in other studies in the region (Heaven & Scrosati 2008), the recommendation from our results is to sample within the July-August period during which temporal changes in abundance are negligible. The Arisaig region was sampled in June for the purpose of this temporal study; we only used data collected in July-August for the paper.

References

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- Anderson MJ (2005) PERMANOVA: a FORTRAN computer program for permutational multivariate analysis of variance. Department of Statistics, University of Auckland, New Zealand
- Clarke KR Gorley RN (2006) Primer v6: User Manual. PRIMER-E, Plymouth
- Heaven CS, Scrosati R (2008) Benthic community composition across gradients of intertidal elevation, wave exposure, and ice scour in Atlantic Canada. *Mar Ecol Prog Ser* 369:13-23
- Underwood AJ (1997) Experiments in ecology: their logical design and interpretation using analysis of variance. Cambridge University Press, Cambridge.

Table S1. ANOVA results evaluating the temporal variation in taxa richness (number of taxa quadrat⁻¹, transformed using log₁₀(datum + 1)) and abundance (total percent cover per quadrat) across months (June, July, and August 2010) in the Arisaig region, central in our overall study, at six breakwaters with two wave-exposure levels (sheltered and exposed). The sources of variation of interest are the fixed factors (Time and Exposure) and their interaction (Time X Exposure). The factor Site is a random factor.

Source of Variation	df	Mean Squares	F-ratio	p-value
Richness				
Time	2	0.242	1.649	0.24
Exposure	1	0.006	0.008	0.932
Site	5	0.625	23.417	<0.0001
Time X Exposure	2	0.125	1.466	0.276
Time X Site	10	0.146	5.49	<0.0001
Exposure X Site	5	0.69	25.871	<0.0001
Time X Exposure X Site	10	0.086	3.205	0.001
Error	252	0.027		
Abundance				
Time	2	677.315	0.069	0.934
Exposure	1	1077.64	0.068	0.805
Site	5	33515.305	28.486	<0.0001
Time X Exposure	2	4497.81	1.724	0.227
Time X Site	10	9815.16	8.342	<0.0001
Exposure X Site	5	15904.784	13.518	<0.0001
Time X Exposure X Site	10	2608.311	2.217	0.017
Error	252	1176.566		

Table S2. PERMANOVA results evaluating the temporal variation in community composition across months (June, July, and August 2010) in the Arisaig region at six breakwaters with two wave-exposure levels (sheltered and exposed). Significant and interpretable p-values for fixed factors and their interaction are presented in bold. Pairwise comparisons were conducted for significant results for the Time factor to assess how months varied; p-values for these pairwise comparisons are included.

Source of Variation	df	Mean Squares	Pseudo F-ratio	p-value	June vs. July	June vs. Aug	July vs. Aug
Time	2	1.14E+05	17.83	0.001	0.001	0.001	0.235
Exposure	1	1.13E+04	1.16	0.361			
Site	5	1.94E+04	22.95	0.001			
Time X Exposure	2	2.12E+03	0.419	0.916			
Time X Site	10	6.40E+03	7.57	0.001			
Exposure X Site	5	9.77E+03	11.55	0.001			
Time X Exposure X Site	10	5.06E+03	5.98	0.001			
Error	252	8.46E+02					

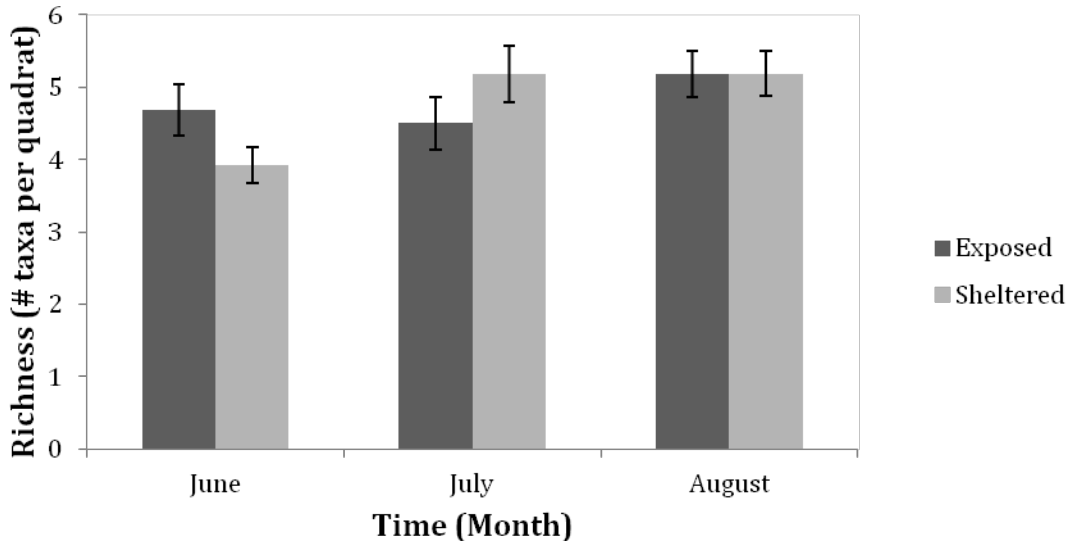


Figure S1. Mean (± 1 SE, n=6 breakwaters) taxa richness for sampling times in June, July, and August 2010 at both exposed and sheltered sides of breakwaters throughout the Arisaig region of the southern Gulf of Saint Lawrence.

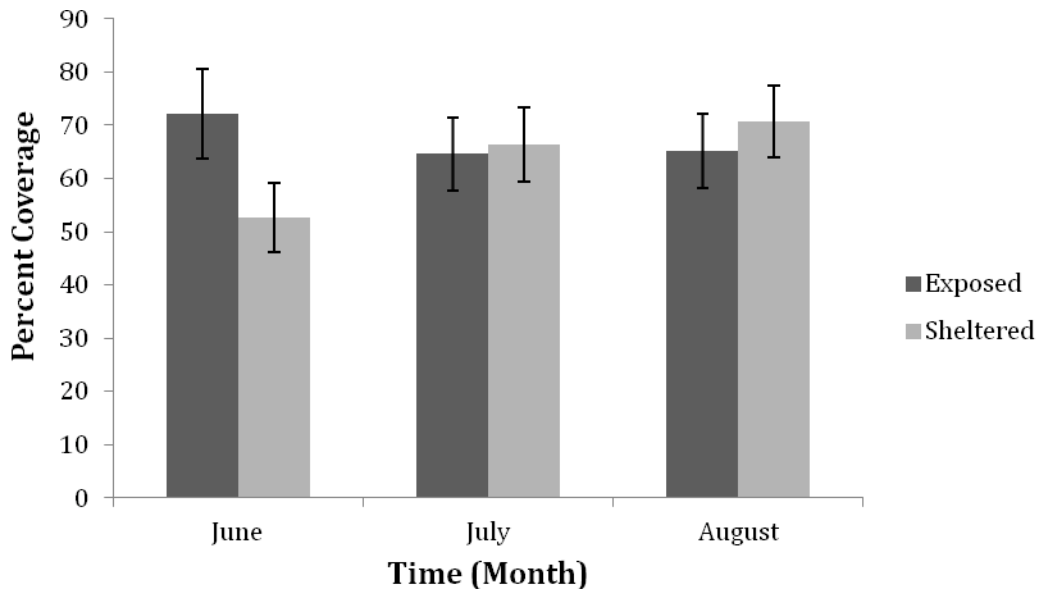


Figure S2. Mean (± 1 SE, n=6 breakwaters) percent cover for sampling times in June, July, and August 2010 at both exposed and sheltered sides throughout the Arisaig region of the southern Gulf of Saint Lawrence.

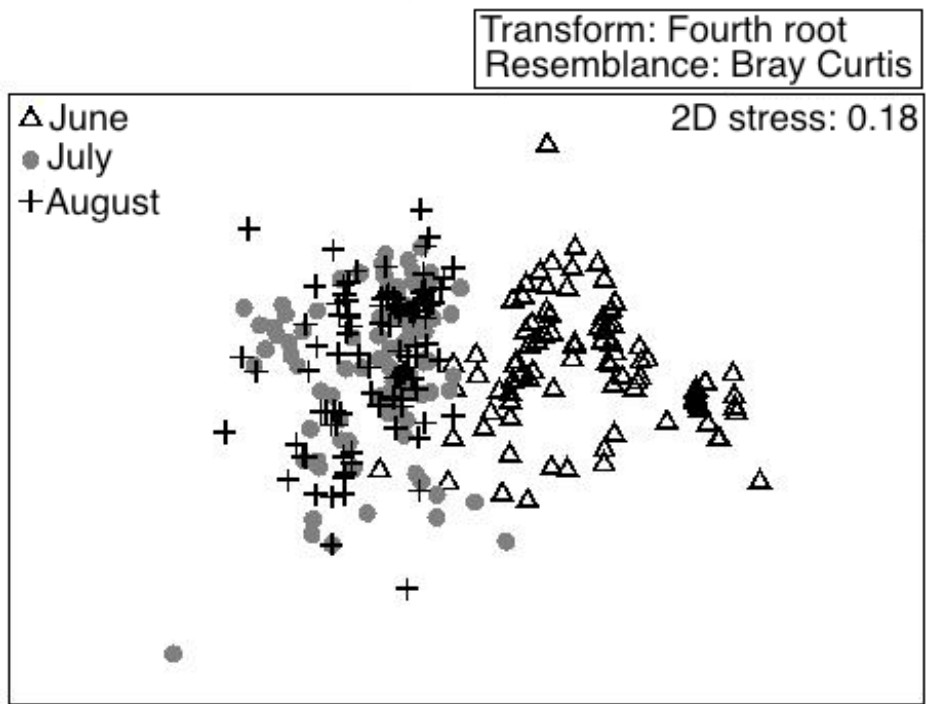


Figure S3. A two-dimensional nMDS plot showing dissimilarity between community composition sampled during June, July, and August 2010 at six breakwater sites near Arisaig, Nova Scotia, in the southern Gulf of St. Lawrence. Exposed and sheltered sites pooled within month (total: n=96 quadrats/month).