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Runswick Bay artificial rock pool monitoring: 2019 results

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EXECUTIVE SUMMARY

The purpose of this project is to assess the success of artificial rock pools as ecological enhancement interventions, which were incorporated into a new coastal defence scheme at Runswick Bay, North Yorkshire in summer 2018.

During construction of the new rock armour defence at Runswick Bay, 70 saw-cut artificial rock pools were installed on the granite boulders. This report details the findings from the second field survey conducted during July 2019 and is compared with the first survey carried out two months post-construction (August 2018). The survey compared the species richness, total abundance and species diversity of fauna and flora found both inside the artificial rock pools and on the adjacent granite rock faces. In addition, water parameters including water temperature, pH and salinity were collected to ascertain any variation between the water in the pools compared to the sea.

The survey found that the majority of artificial rock pools were retaining water effectively. Pools which were not retaining water were smothered in algal wreckage which had been washed up onto the beach. The water temperature was slightly higher in the artificial rock pools but the pH and salinity did not differ between the rock pools and the sea.

This study has shown that the construction of artificial rock pools on the granite rock armour has increased the species richness compared to the un-manipulated areas of the boulders. Eleven species were observed in the rock pools which were absent from the adjacent rock surfaces, showing that the provision of water-retaining features and increased surface heterogeneity has enabled species to survive on the rock armour when the tide goes out. The majority of these new species were mobile fauna, including crabs and fish, and a high proportion of them were small juveniles. The height at which the rock pools were installed was shown to have an impact on the assemblages found within the rock pools.

These artificial rock pools will continue to be monitored over the next year to observe community succession and development over time.

CONTENTS

1. INTRODUCTION

The Runswick Bay Coastal Protection Scheme was constructed in 2018 and included repairs to the existing concrete seawall and the placement of 9,500 tonnes of granite rock armour to protect 250 m of seawall frontage. Runswick Bay was designated a Marine Conservation Zone (MCZ) (Marine and Coastal Access Act 2009) in 2016 for low energy intertidal rock, moderate energy intertidal rock, high energy intertidal rock and intertidal sand and muddy sand biotopes. To limit the potential damage caused to the protected features of the MCZ by the construction of the new sea defence, various measures were put in place, including designated access routes for machinery, protection of existing colonised boulders and ecological enhancement techniques. The ecological enhancement techniques which were incorporated into the new coastal defence scheme at Runswick Bay included the construction of 70 artificial rock pools which were saw-cut into the boulders.

Artificial structures typically lack optimal habitats for intertidal species due to the absence of habitat heterogeneity and water retaining features. On natural rocky shores, rock pools provide intertidal organisms with a refuge from biotic and abiotic stresses such as predation and desiccation (Little *et al*. 2009, Firth *et al*. 2014, White *et al*. 2014).

Ecological enhancement integrates ecology and engineering to create multifunctional structures which provide both protection from coastal erosion and also a suitable habitat for intertidal organisms (ITRC 2004, Hall *et al*. 2018). Previous ecological enhancement studies have shown that water retaining features and habitat heterogeneity are important to promote biodiversity on artificial structures (Firth *et al*. 2013, Browne and Chapman 2014, Evans *et al*. 2015). Existing trials at Runswick Bay have shown how increased habitat heterogeneity can lead to increased species richness and diversity on granite boulders (Hall *et al*. 2018).

The aim of this survey it to determine if the artificial rock pools have increased species richness, total abundance and species diversity compared to the control rock faces since installation in 2018 (~13 months). The survey which was conducted two months post installation showed initial success; this survey is to determine the longer term success of the interventions.

2. METHODS

2.1 Site description

Runswick Bay is a moderately exposed sandy shore with large shale bedrock platforms. It has an easterly prevailing wind direction and the tidal range is 5.6 m during spring tides and 4.2 m during neap tides. The new rock armour was placed on top of the shale bedrock at the foot of the seawall (Figure 2.1). Existing boulders were moved during construction and replaced in front of the granite rock armour to test if “seeding” would increase colonisation rates.

Figure 2.1. Location of new granite rock armour at the foot of the seawall, note the green (colonised) natural boulders which have been placed in front of the granite rock (July 2019).

2.2 Installation of artificial rock pools

The 70 artificial rock pools were installed using a circular saw and breaker. The circular saw was used to make two sets of parallel cuts which were perpendicular to each other to form a cross shape. A breaker was then used to break up the cuts and form pools of approximately 300 mm diameter and 150 mm depth (Figure 2.2).

Figure 2.2. Examples of saw cut artificial rock pools roughly 300 mm diameter x 150 mm deep.

2.3 Survey protocol

Surveys were conducted between 14th and 15th July 2019 by Dr Sue Hull and Dr Alice Hall.

The abundance of fauna and flora were recorded in-situ inside the rock pools and compared to the adjacent rock face to determine if the artificial rock pools had a positive effect on increasing biodiversity on the rock armour.

The percentage cover of algae and count data for barnacles and mobile species such as fish and crabs were recorded to measure species abundance. All organisms were identified to the lowest taxonomic resolution possible. Photographs of all rock pool and control areas were taken to illustrate changes in assemblages over time. Water parameters, including temperature, pH and salinity were recorded inside the rock pools and compared to a sample of seawater.

3. RESULTS

3.1 Community assemblages

A total of twenty-two species were record within the artificial rock pools, compared with eleven species recorded on the adjacent control rock faces. Six of the additional species present within the rock pools were mobile species, including the intertidal fish Shanny (*Lipophrys pholis*), the intertidal crab (*Carcinus maenas*) and three intertidal snail species (*Littorina littorea, Littorina saxatilis* and *Melarhaphe neritoides*) (Figure 3.1). Results indicate that the artificial rock pools supported significantly greater species richness, species diversity and total abundance than the adjacent rock face controls (Figure 3.2, Table 3.1). The results also show that there was a significant increase in species richness, species diversity, % cover of algae and total abundance of animals between 2018 and 2019, both in the rock pools and control sites (Figure 3.2, Table 3.1).

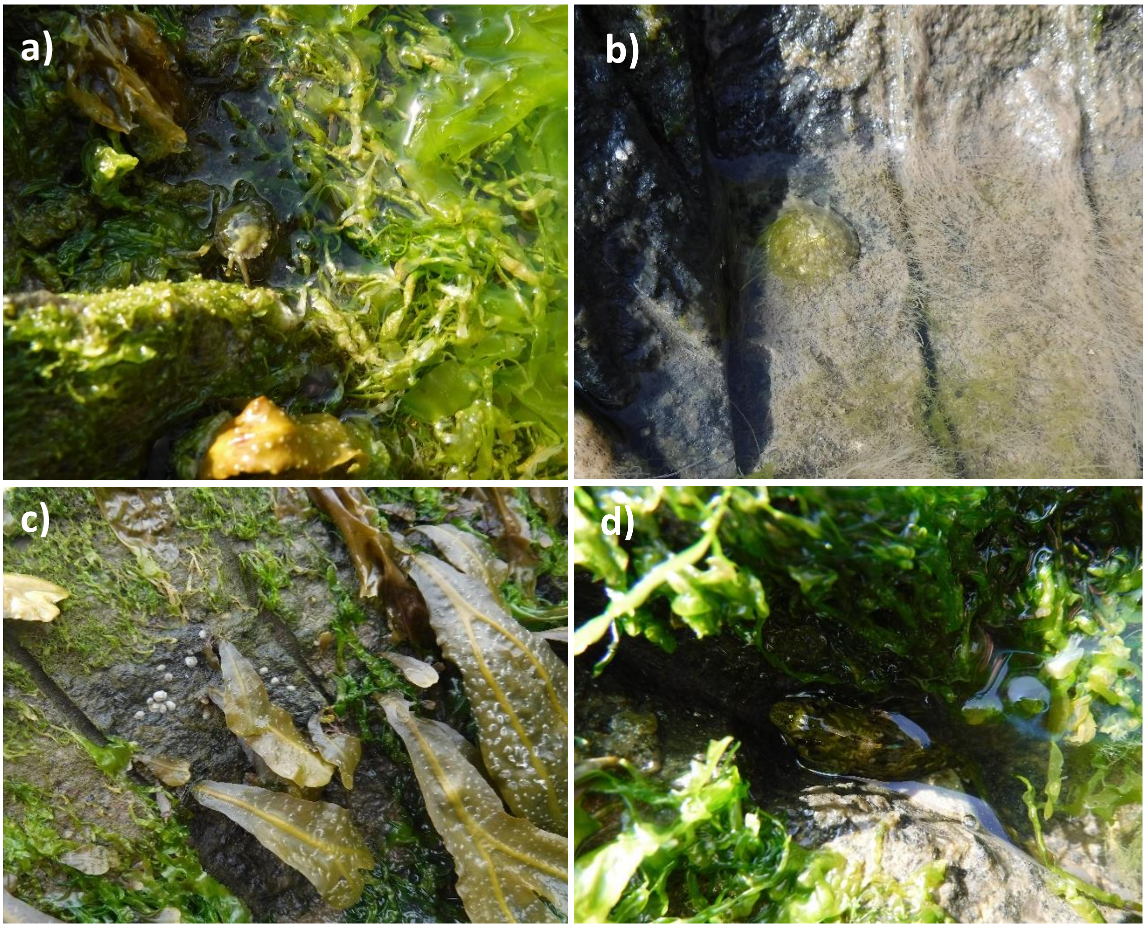

Figure 3.1. a) Green shore crab (*Carcinus maenas*), b) Common limpet (*Patella vulgata*), c) Acorn barnacles (*Semibalanus balanoides*) and d) Shanny (*Lipophrys pholis).* Images from July 2019*.*

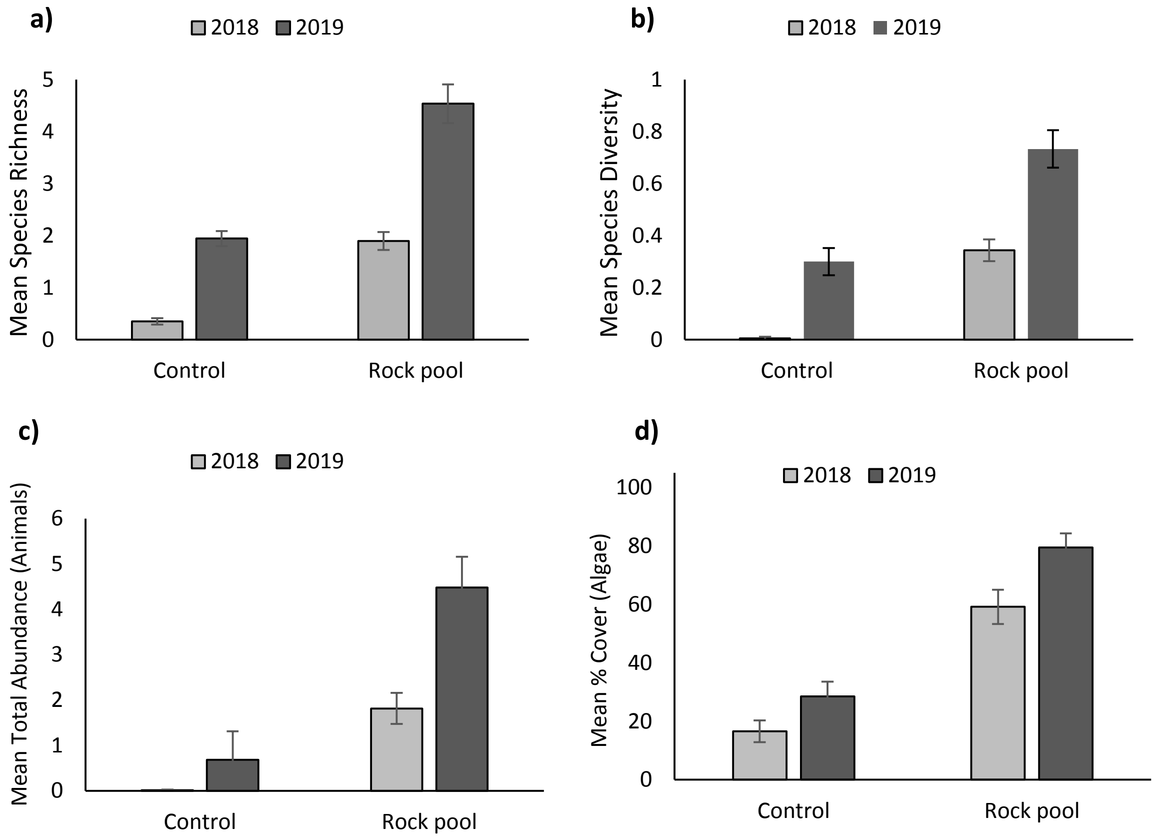

Figure 3.2. a) Mean species richness, b) mean species diversity (Shannon Wiener), c) mean total abundance of animals and d) mean total abundance of plants recorded in controls and rock pools in August 2018 (light grey bars) and July 2019 (dark grey bars) (+/- SE).

Table 3.1. Analysis of variance (ANOVA) results for comparison of species richness (algae & animals) , species diversity richness (algae & animals) and % cover of algae and total abundance of animals between pools (artificial rock pools) and control (adjacent rock face) and Year (2018/2019) NS= Not significant *= low significance **=medium significance * = highly significant.**

	Species Richness			Species Diversity			% Cover algae			Total abundance of animals		
	df	*f*	*p*	*df*	*f*	*p*	*df*	*f*	*p*	*df*	*f*	*p*
Pool/Control	1	86.156	<0.001 ***	1	61.769	<0.001 ***	1	84.460	<0.001 ***	1	36.657	<0.001 ***
Year	1	29.373	<0.001 ***	1	21.131	<0.001 ***	1	10.025	0.001 **	1	9.245	0.001 **
Pool/Control * Year	1	1.088	0.338 NS	1	1.045	0.352 NS	1	0.724	0.395 NS	1	4.053	0.045 *

The multidimensional scaling plot (MDS) in Figure 3.3 illustrates the separation in algal communities between artificial rock pools and the control rock face. Each individual triangular symbol represents a sample rock pool, the closer together the points the more similar the communities are. The similarity percentage analysis (SIMPER) found that 93.65 % of the overall 87.93 % dissimilarity between algal communities found in rock pools and controls was attributed to six taxa; *Ulva intestinalis, Ulva linza*, brown filamentous algae, *Ulva* sp., green filamentous algae, *Porphyra* sp.

Table 3.3 illustrates the average species % cover in the artificial rock pools compared to the control rock face and Table 3.3 gives a full species list of all species recorded..

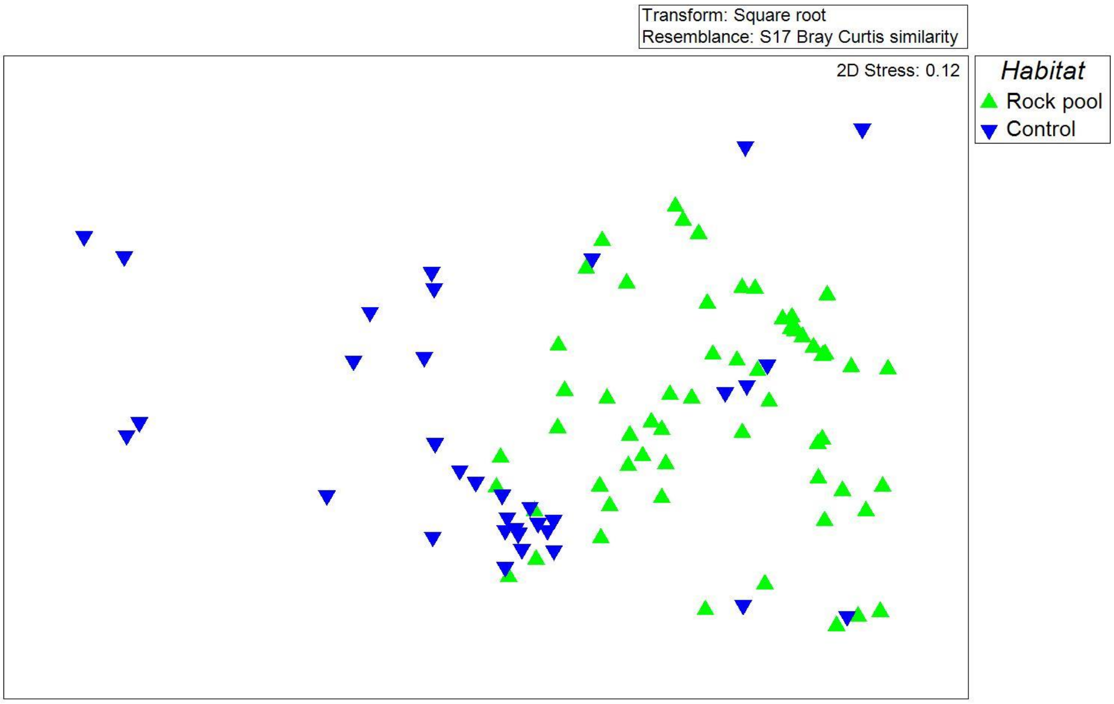

Figure 3.3. Multidimensional scaling plot of the samples in the rock pools and control areas on the rock armour (July 2019). This figure illustrates the separation in communities between artificial rock pools and the control rock face. Each individual triangular symbol represents a sample rock pool, the closer together the points the more similar the communities are(% cover data only).

Table 3.2. SIMPER analysis on algal community similarity between artificial rock pools and adjacent control rock faces on the granite rock armour in July 2019.

Species	Pool Average Abundance	Control Average Abundance	Average. Dissimilarity	Dissimilarity /SD	Contribution %
Ulva intestinalis	41.2	6.16	30.55	1.04	34.75
Ulva linza	13.4	29.65	22.74	1	25.87
Brown filamentous	14.6	2.32	11.13	0.55	12.66
Ulva sp.	8.69	2.43	9.58	0.48	10.9
Green filamentous	0.31	5.46	4.47	0.37	5.08

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Porphyra sp.	1.2	6.03	3.86	0.72	4.39

Table 3.3. Species list and average abundance for fauna and flora recorded in the artificial rockpools and on the control rock face in July 2019 (%= %cover, c= counts).

	Species	Rock pool Average Abundance	Control Average Abundance
Algae	Brown filamentous *(%)*	14.6	2.32
	Ceramium sp. *(%)*	0.03	0.00
	Cladophora sericea (%)	0.45	0.00
	Fucus vesiculosus (%)	3.08	1.92
	Green filamentous *(%)*	0.31	5.46
	Pilayella sp. *(%)*	0.02	0.00
	Porphyra sp. *(%)*	1.2	6.03
	Scytosiphon lomentaria (%)	0.06	0.00
	Ulva intestinalis (%)	41.2	6.16
	Ulva lactuca (%)	2.6	0.00
	Ulva linza (%)	13.4	29.65
	Ulva sp. *(%)*	8.69	2.43
Crustacea	Amphipoda (c)	0.23	0.00
	Carcinus maenas (c)	2.28	0.00
	Ligia oceanica (c)	0.31	0.05
	Semibalanus balanoides(c)	0.92	1.19
Mollusca	*Littorina littorea* (c)	0.32	0.00
	Littorina obtusata (c)	0.06	0.03
	Littorina saxatilis (c)	0.15	0.00
	Melarhaphe neritoides (c)	0.02	0.00
	Patella vulgata (c)	0.52	0.03
Pisces	*Lipophrys pholis* (c)	0.02	0.00
Total number of species		**22**	**11**

3.2 Water parameters

The mean temperature recorded in artificial rock pools (23◦C) was higher than that recorded in the seawater (19.9◦C). The salinity and pH recorded in the rock pools and the seawater were very similar (Figure 3.4). Please note that this summer was a particularly warm summer.

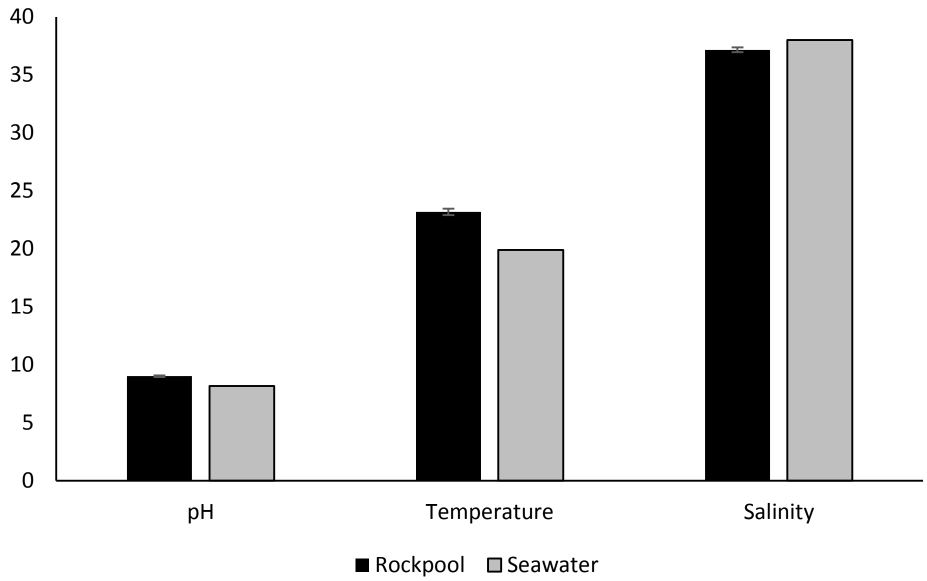

Figure 3.4. Comparison of mean water pH, temperature and salinity between artificial rock pools and seawater in July 2019 (+/- S.E).

3.3 Rock pool tidal height

Out of the 70 artificial rock pools, 29 were installed above the Splash zone, 10 within the Splash zone, four in the Upper zone, one in the Upper Mid zone and one in the Mid zone. Only five pools were empty in July 2019 (four in the Upper and one in the Upper Mid) and this was due to a build-up of algal wreckage filling the pools. Figure 3.5 illustrates the variation in communities within the rock pools at different tidal heights. Pools which are located above the Splash zone and within the Splash zone are more prone to algal bleaching due to more extreme environmental conditions such as higher temperatures. The most diverse rock pools were found in the Mid and Upper Mid tidal zones, as they are regularly replenished with seawater and exposed to the air for shorter periods of time at low tide.

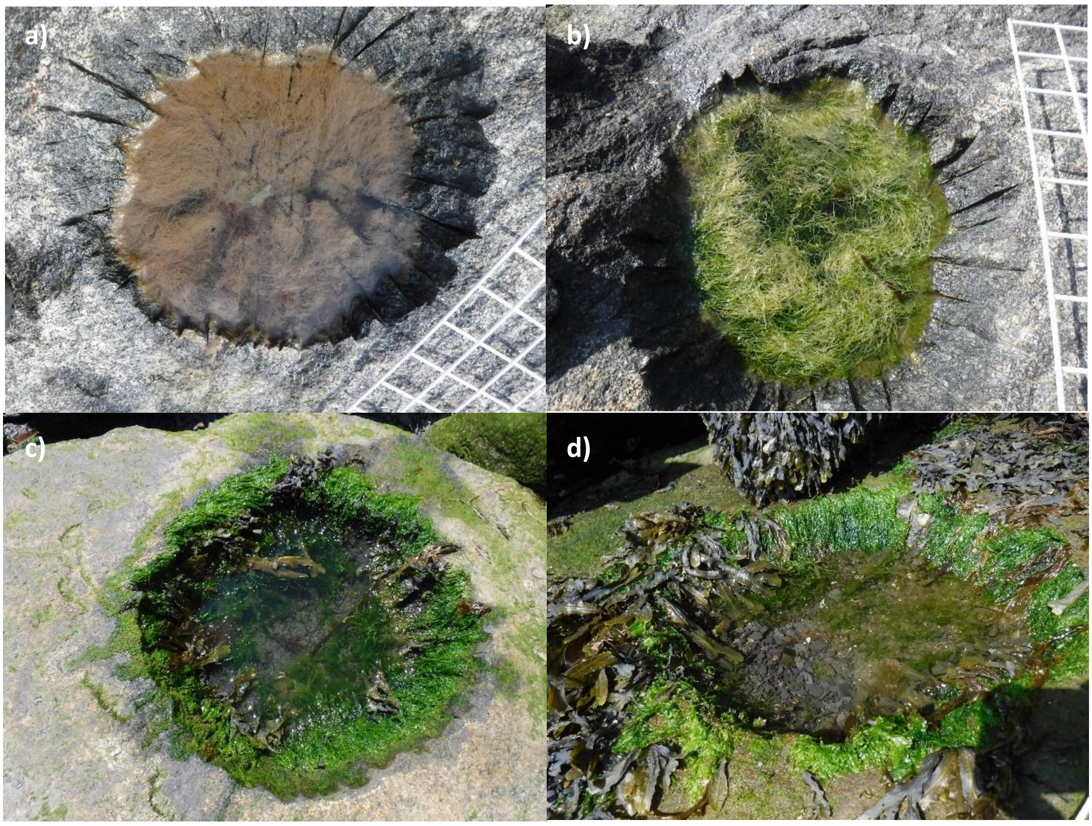

Figure 3.5 Images of rock pools from differing tidal heights a) Above Splash zone rock pool with brown filamentous algae, b) Splash zone pool with bleached Ulva sp., c) Upper Mid zone pool with multiple species including *Ulva* sp., *Fucus vesiculosus* and Porphyra sp., d) Mid zone pool with *Fucus vesiculosus, Ulva* sp., and filamentous brown algae.

4. DISCUSSION

The water retention and increased habitat heterogeneity created by the saw-cut artificial rock pools on the granite boulders at Runswick Bay has provided habitat for intertidal organisms to survive on the rock armour where otherwise they would be absent. The rock pools have increased the species richness, species diversity and total abundance of the granite boulders compared to an un-manipulated control area. The artificial rock pools provide areas of increased surface texture, cracks and crevices which is more characteristic of natural shores, supporting previous studies (Metaxas and Scheibling 1993, White *et al*. 2014).

The greatest difference found between the 2018 and 2019 surveys was the colonisation of *Fucus vesiculosus*, which is a brown canopy alga. This alga provides a refuge habitat for additional species such as marine snails and crustaceans. The Mid shore and Upper Mid shore pools were well colonised by *F. vesiculosus* which is a very encouraging sign (Figure 2.3c). The barnacle *Semibalanus balanoides* had also colonised several of the rock pools located within the Mid and Upper Mid shore (Figure 2.3c). The communities have developed quicker than other previous artificial rock pool studies; for example, the artificial rock pools (Vertipools) installed in the Isle of Wight took three years for wrack (*Fucus spiralis*). to colonise and five years for grazers such as limpets *Patella vulgata* to colonise (Hall et al. 2019). Yet, at Runswick Bay, within 13 months the artificial rock pools had been colonised by both *Fucus vesiculosus* and *P. vulgata*. Grazers are an important group in intertidal food webs and they can prevent the dominance of opportunistic green algae such as *Ulva* sp.

The tidal height of artificial rockpools has shown to affect the communities present within the rock pools, supporting previous research (Firth et al. 2016). The pools located beyond the Splash zone do not provide optimal conditions as they are exposed to the air during low tide for much longer periods of time; on some tides they might not actually be replenished by the incoming tide. The Above-Splash zone pools were typically colonised by brown filamentous algae or bleached green filamentous algae and did not support mobile species such as fish and crabs. The Upper Mid shore pools supported the greatest number and the greatest diversity of species, including mobile species, grazers and filter feeders. Other artificial rock pool studies have found comparable results, with greater diversity and abundance being recorded in mid-shore pools (Browne and Chapman 2011, Firth et al. 2016). The height at which saw-cut rock pools are installed on future projects should be planned carefully and we suggest they should be installed below the splash zone, ideally between the upper and mid-tidal zone. Sea level rise will also need to be considered in the position of rock pools, especially on structures with a long term life expectancy.

Incorporating artificial rock pools into the granite rock armour in Runswick Bay has been successful to date; the number of species utilising the pools has increased since last year's surveys in August 2018. The seeding of natural boulders at the Runswick Bay site could explain the increased speed of colonisation in comparisons to other artificial rock pool studies; however, further investigation would be required to validate this assumption. Continued monitoring of ecological community development will be undertaken using the same methodology in 2020 to assess the longer-term success of this ecological enhancement technique.

5. REFERENCES

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