Technical Report 20

NIWA – Assessment of Ecological Effects arising from the Proposed Submerged Wave Focussing Structure

NIWA
Taihoro Nukurangi

Ecological assessment of a proposed wave focussing structure in Lyall Bay, Wellington

Prepared for Wellington International Airport Ltd

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Prepared by:
Jenny Beaumont

For any information regarding this report please contact:

Jennifer Beaumont
Marine Ecologist
Marine Ecology
+64-4-386 0300
jennifer.beaumont@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
Private Bag 14901
Kilbirnie
Wellington 6241

Phone +64 4 386 0300

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	Formatting checked by:	P Allen
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Executive summary

Wellington International Airport Limited (WIAL) proposes to extend their runway southwards into Lyall Bay (Huetepara) by approximately 400 m to further enable safe landing and takeoff of long-haul flights. A report by DHI (DHI 2015) into the effect of the runway extension on the surf break in Lyall Bay, Wellington, found that the airport runway extension would not cause a noticeable sheltering or reduction in wave height along the three inshore surf spots (the corner, middle beach and western beach). However, the design of the steep rock revetment, which encloses the airport extension, is expected to reduce wave refraction to the east which is expected to result in a reduction of surf rides at key surfing spots within Lyall Bay.

DHI have suggested that a submerged wave focusing structure may be the safest and most cost effective approach for mitigating and potentially further enhancing surfing amenity in Lyall Bay. The purpose of the structure is to focus wave energy towards a shoreward location along the middle or western section of Lyall Bay thereby forming a local wave peak. This will result in larger waves, longer ride lengths and an increase in overall surf amenity.

This desktop report discusses possible ecological impacts of the introduction of a wave focussing structure within Lyall Bay. The report concludes that the biggest ecological impact is likely to be the direct smothering of the benthic community below the structure, which is likely to be dominated by the deposit-feeding ghost-shrimp, *B. filholi*. However, the sparse existing benthic community within inner Lyall Bay as described by MacDiarmid, Anderson et al. (2015), together with the highly dynamic environment that the fauna and flora inhabit, will result in relatively minimal ecological impacts from the introduction of a wave focussing structure.

Note that this report is based on existing data from a recent survey (MacDiarmid, Anderson et al. 2015), the focus of which was the wider Lyall Bay area, rather than a detailed survey of the location of the wave focussing structure. The report is also based on preliminary indications of the placement and design of the wave focussing structure, without detailed knowledge of planned complexity of habitat, surface texture or modelling with respect to local hydrodynamics and movement/scour/accumulation of surrounding sediments.

Impacts during construction of the wave focussing structure have not been considered within this report, although it is noted that DHI have recommended the use of a floating barge with precision deployment. Should this method be used, minimal additional impacts would be anticipated, with the possible exception of the generation of a sediment plume.

1 Background

Wellington International Airport Limited (WIAL) proposes to extend their runway southwards into Lyall Bay (Huetepara) by approximately 400 m to further enable safe landing and takeoff of long-haul flights. Coastal environmental information is required primarily to support applications for coastal permits and consents and Notices of Requirement for the Airport runway upgrade. The statutory process is likely to be through a Board of Inquiry process administered by the Environmental Protection Agency (EPA), if it is designated as a project of national significance.

WIAL has previously engaged NIWA to provide reports on coastal hydrodynamics and sediment processes (Pritchard, Reeve et al. 2015), marine sediments and contamination (Depree, Olsen et al. 2015), and marine ecology of Lyall Bay (MacDiarmid, Anderson et al. 2015), and Aquatic Environmental Services (AES) contracted NIWA to contribute to an ecological impact assessment of the proposed runway extension (James, MacDiarmid et al. 2015).

A report by DHI (DHI 2015) into the effect of the runway extension on the surf break in Lyall Bay, Wellington, found that the airport runway extension would not cause a noticeable sheltering or reduction in wave height along the three inshore surf spots (referred to as the corner, middle beach and western beach by DHI (2015)). However, the design of the steep rock revetment, that will enclose the airport extension, is expected to reduce wave refraction to the east which will reduce the overall 'peakiness' of waves propagating further into the bay. This reduction in "peakiness" is expected to result in a reduction of surf rides at key surfing spots within Lyall Bay.

DHI have suggested that a submerged wave focusing structure may be the safest and most cost effective approach for mitigating and potentially further enhancing the surfing amenity in Lyall Bay. The purpose of the structure is to focus wave energy towards a shoreward location along the middle or western section of Lyall Bay thereby forming a local wave peak. This will result in larger waves, longer ride lengths and an increase in overall surf amenity.

This report is a desktop assessment of the ecological impact of the proposed wave focussing structure within Lyall Bay, Wellington.

2 Proposed wave focussing structure

A conceptual layout of the wave focussing structure, taken from DHI (2015), is given in Figure 1 and Figure 2. Approximate dimensions of the structure are given in Table 1. These figures and dimensions suggest that the top of the structure will be approximately 2.5 m higher than the existing seabed.

DHI (2015) suggested that rock would be the most suitable material for the construction of the wave focussing structure due to its proven ability in the marine environment and its ability to meet the design objectives. They also note that it is important that the machinery used for placement can be operated with a high level of accuracy in order to assure that the construction layout meets the design specifications and suggest that a barge-mounted long-arm excavator would be suitable for this.

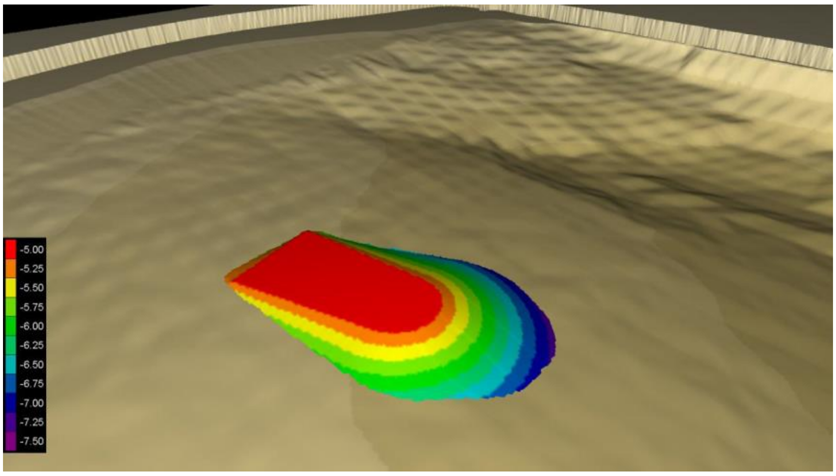

Figure 1: **Conceptual diagram of the wave focussing structure in Lyall Bay. From DHI (2015).**

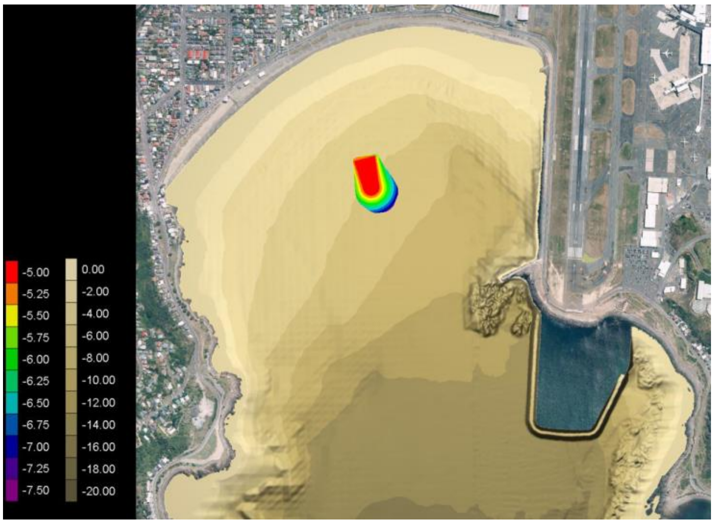

Figure 2: **Suggested location of the wave focussing structure in Lyall Bay. From DHI (2015).** The proposed runway extension is shown in dark blue with a yellow boundary, to the south of the existing runway.

Table 1: **Approximate dimensions of the submerged wave focussing structure. From DHI (2015).**

Specification	Value
Volume	17,000 m3
Footprint	20,000 m2
Crest Depth	-5.0 m
Length	180 m
Width	140 m
Toe Slope	1 in 30
Distance from shore to deepest point	450 m

3 Benthic communities in the vicinity of the wave focussing structure

Lyall Bay is the largest embayment along Wellington's southern coastline and is exposed to southerly swells. The sediments within the bay are dominated by well sorted fine sand (MacDiarmid, Anderson et al. 2015, and see table in Appendix A).

In 2014, NIWA sampled 13 sites within Lyall Bay using seafloor imaging, epibenthic sled tows and sediment cores in order to characterise the soft-sediment benthic communities for WIAL (MacDiarmid, Anderson et al. 2015). Of these 13 sites, three are in the approximate vicinity of the proposed wave focussing structure. These are sites 1, 2 and 6 (Figure 3). A habitat map taken from MacDiarmid, Anderson et al. (2015), shows habitats identified within Lyall Bay from the video imaging (Figure 4). Sites 1, 2 and 6 were dominated by rippled sand habitat with tracks and burrows.

Figure 3: Location of the 13 study sites sampled using seafloor imaging, epibenthic sled tows and sediment coring by MacDiarmid, Anderson et al. (2015). The proposed runway extension is marked by a black outline to the south of the existing runway.

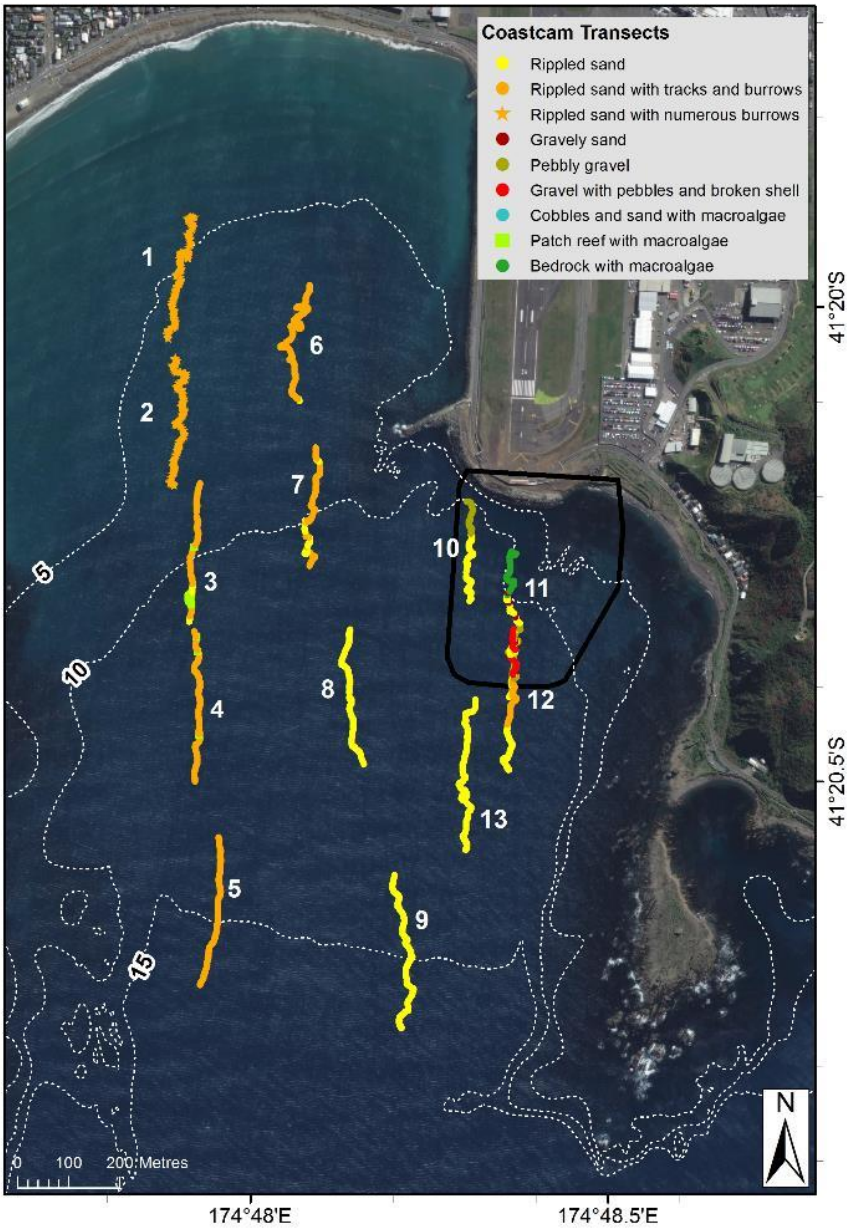

Figure 4: Habitat map of Lyall Bay generated from video observations. From MacDiarmid, Anderson et al. (2015).

Megafauna observed at these key sites using seafloor imaging was sparse and included an asteroid and a pagurid (Table 2, table adapted from MacDiarmid, Anderson et al. (2015)).

Table 2: Habitat and megafauna observed at each of the three sites. Table modified from MacDiarmid et al 2015

Transect	Depth (m)	Habitat	Epi-fauna and -flora observed
1	5.5–6.3	Rippled sand with numerous burrows	Nil
2	6.7-8.4	Rippled sand with numerous burrows	Asteroid x 1 (starfish)
6	7.9-9	Rippled sand with burrows	Pagurid x 1 (Hermit crab)

Numerous small burrows of infaunal invertebrates occurred along transects at sites 1 and 2 in depths of five to eight metres (Figure 5). The shape and form of these burrows is consistent with those inhabited by ghost shrimps (Thalassinidea), most probably *Biffarius filholi* which was captured in sediment cores from several sites including Site 1.

Figure 5: Numerous small burrows in rippled sand at Site 1 in Lyall Bay. The image area is approximately 0.24 m^2.

The low abundance of macrofauna observed in video footage was supported by similarly low catches in the dredge, with no individuals recorded at site 1, just 3 individuals at site 2, and 5 individuals at site 6 (Table 3). These epifaunal communities sampled in Lyall Bay were particularly low in overall abundance and species richness compared to those typically encountered in sandy substrates in sheltered harbours of similar depth (e.g. Mead et al 2005) and deeper sandy habitats on exposed coasts (e.g. Beaumont et al. 2013). This is most likely due to the regularity and magnitude of wave events that sweep the seafloor, removing organisms that are not buried or strongly attached (MacDiarmid, Anderson et al. 2015).

Table 3: Abundance of macrofauna recorded in dredge samples at sites 1, 2 and 6.

Taxonomy		Site		
Class	**Species**	**1**	**2**	**6**
Malacostraca	*Ovalipes catharus*	0	1	0
Malacostraca	*Tenagomysis* sp. *3*	0	0	1
Gastropoda	*Amalda australis*	0	2	3
Ophiuroidea	*Amphiuridae* nd	0	0	1

In total, 52 individual organisms from 16 species were recorded from sediment cores at the 3 sites Table 4. These were dominated by polychaete worms with 31 individuals across 8 species and followed by Decapoda with 13 individuals in a single species (the ghost shrimp, *Biffarius filholi*). A full species list for each site and depth fraction of sediment core is given in Appendix B.

It should be noted that the typical depth (up to 65 cm) and complexity of burrows dug by the ghost shrimp *Biffarius filholi* (Morton and Miller 1968) suggests that this species was dramatically under-sampled by the sediment corer used in the survey, which penetrated to a maximum depth of 30 cm (and more typically 15 cm). MacDiarmid, Anderson et al. (2015) noted that the density of burrow entrances of this species observed in the seafloor imaging were all likely to be currently in use because a southerly storm that generated 3 m waves in the bay the week prior to sampling will have obliterated any non-active burrows. They also suggested that this species may comprise the bulk of the macro-infaunal biomass in the shallow half of Lyall Bay (MacDiarmid, Anderson et al. 2015).

Table 4: Total faunal abundance by taxonomic Class recorded within sediment cores for the 3 key study sites (sites 1, 2, and 6) within inner Lyall Bay Presented as the number of individuals in each core section (0-5, 5-10 and 10-15 cm depths). Full taxonomic information of these data are given in Appendix B.

	Sediment depth, cm				
	0-5	**5-10**	**10-15**	**Total Number of Individuals**	**Total number of species**
Polychaeta	16	4	11	**31**	**8**
Ophiuroidea	0	1	1	**2**	**2**
Nematoda	1	0	1	**2**	**1**
Gastropoda	2	1	0	**3**	**3**
Decapoda	6	5	2	**13**	**1**
Bivalvia	1	0	0	**1**	**1**
Total	**26**	**11**	**15**	**52**	**16**

These densities are less than are typically encountered in sandy substrates in more sheltered harbours of similar depth and deeper sandy habitats (e.g. Probert and Anderson 1986, Mead et al 2005, Paavo 2011, Beaumont et al. 2013) but are similar to another study carried out on Wellington's

south coast (Smith et al. 2011). As with the epifauna, this low abundance is most likely due to the regularity and magnitude of wave events that sweep the seafloor removing organisms that are not deeply buried or strongly attached.

4 Ecological impacts

4.1 Smothering of benthic communities

An artificial structure such as the proposed wave focussing structure, when placed on soft or sandy sediments such as the seabed in Lyall bay, will necessarily result in the smothering of sediments and associated in- and epi-fauna and flora (animals and plants living within and on the sediments) which in most cases will lead to mortality (Foster, Steimle et al. 1994; Mead and Black 1999; Beaumont 2006). The proposed footprint of the preliminary design of the wave focussing reef was given as 20,000 m^2 (DHI 2015) which is just greater than 1 % of the 189 ha of total soft-sediment habitat within Lyall Bay (James, MacDiarmid et al. 2015). It is estimated that the soft-sediment habitat within the 5 to 10 m depth range, the depths within which the proposed wave focussing structure would be placed, is approximately 38 ha, in which case the wave focussing structure would smother approximately 5 % of this habitat. However, field studies by MacDiarmid et al (2015) have shown the benthic in- and epi- fauna and flora to be neither unique nor abundant within the study area. The only exception to this is the ghost shrimp, *B. filholi,* which occur at potentially higher densities than were recorded in the direct sampling carried out by MacDiarmid, Anderson et al. (2015), judging by the number of burrows observed in images such as in Figure 5 above. Ghost shrimps are deposit feeders (Berkenbusch and Rowden 2000), generally residing within their burrows. They may also provide a food source for some fish species and mobile predators.

4.2 Sediment changes

The introduction of a wave focussing structure may also alter local hydrodynamics resulting in some localised sand scour and sediment accumulation (Davis, VanBlaricom et al. 1982; Foster, Steimle et al. 1994; Manoukian, Fabi et al. 2011). Davis et al (1982) described sediment scour to a depth of 20-40 cm as far as 15 m from the reef edge, together with changes in sand ripple patterns and an increase in sediment grain size associated with introduced structures in 13 m water depth. For reefs in depths of 25 m, however, scouring only extended to 1-2m from the reef edge, with no grain size changes. Foster et al (1994) also noted some scouring around artificial reef modules in 9 to 13 m water depth, as well as sediment accumulation of up to 0.75 m in height, but no changes were observed in sediment characteristics (e.g. grain size). Manoukian, Fabi et al. (2011) carried out an acoustic survey of an artificial reef complex in Italy (12-15 m water depth, muddy sediments, 6 m high) and found significant scouring up to 10 m from the reef edge, with up to a meter of sediment accumulation at the base of the reef. In light of these results, it is considered possible that the shallow depth of the proposed wave focussing structure, together with the dynamic nature of the Lyall Bay environment, may result in significant scouring, sediment accumulation and/or changes in sediment grain size.

It is well established that sediment grain size can be a key driver in benthic community structure (Seiderer and Newell 1999; Dubois, Gelpi et al. 2009; Beaumont, Anderson et al. 2013). As a result the benthic community structure in sediments surrounding the wave focussing structure may be altered.

4.3 Introduction of hard substrates

The introduction of an artificial structure in Lyall Bay will also provide hard substrate for the colonisation of fouling species and also potentially shelter and refuge for mobile taxa (Davis, VanBlaricom et al. 1982; Mead and Black 1999) potentially increasing the biomass per unit area of seabed. Beaumont (2006) recorded increases in biomass per unit area of up to 30.8 times following the introduction of an artificial reef in 18 m deep on a muddy-sandy seabed in a relatively sheltered Scottish sea loch.

Areas of subtidal hard substrate surveyed in Lyall Bay by MacDiarmid et al (2015) were colonised by green, brown and red algae species, including the canopy-forming *Lessonia variegata*, *Macrocystis pyrifera* and *Ecklonia radiata*. Sessile invertebrates included sponges, bryozoans and ascidians. Mobile invertebrates included the sea urchin (*Evechinus chloroticus*), paua (*Haliotis iris*) and rock lobster (*Jasus edwardsii*), all in relatively low densities.

Fish observed on the reef during the surveys (MacDiarmid, Anderson et al. 2015) included spotty, banded wrasse, scarlet wrasse, blue moki, blue cod, variable triple fin, yellow-black triple-fin, blue eyed triple-fin, butterfish and marblefish. Of these, the spotty, banded wrasse and variable triple-fin were the most abundant. Other organisms known to inhabit the reefs in Lyall Bay include asteroids, gastropods, nudibranchs, chitons, holothurians, anemones, wandering anemones and octopus (Pete Notman, NIWA, *Pers obs*) and conger eels (Rob Stewart, NIWA, *Pers obs*).

It is, therefore, expected that some or all of these taxa might colonise a new artificial structure within Lyall Bay. However, while patch reefs observed in video transects at sites 3 and 4 were colonised by macroalgae, no macrofauna were reported (MacDiarmid, Anderson et al. 2015).

Figure 6 shows images of rocky reefs within Lyall Bay, taken by divers during subtidal transects for MacDiarmid, Anderson et al. (2015). It can be seen that some reefs have canopy forming macroalgae while others are encrusted by coralline algae or encrusting organisms. The community that colonises the wave focussing structure will depend on the texture, the habitat complexity and the topography of the structure. As the structure is in a high energy area and in shallow depths, sand scour from storms and wave surge may inhibit the development of biotic communities on the structure (Russell 1975; Cummings 1994). However, colonisation could be expected in sheltered crevices, on lee surfaces and perhaps on the more elevated parts of the reef.

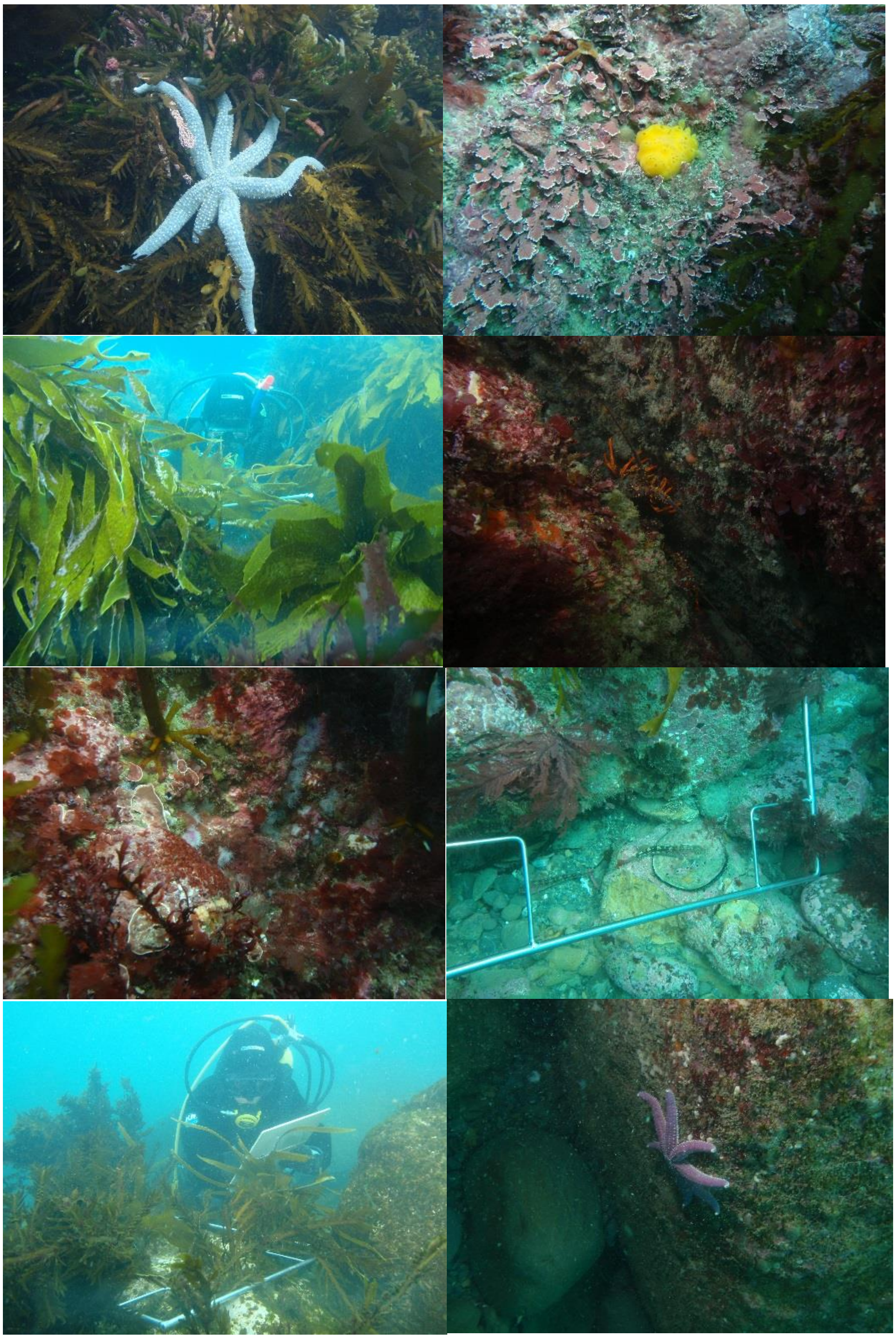

Figure 6: Photographs of faunal and floral communities on reefs within Lyall Bay, taken during the surveys for the report by MacDiarmid et al 2015. Photo credits: Pete Notman, NIWA.

In addition, drift algae and other organic detritus can build up at reef edges (Davis, VanBlaricom et al. 1982, Beaumont *Pers. Obs.*), the accumulation of which can limit soft-bottom fauna through oxygen depletion, reduce larval recruitment, and interference with feeding (Hull 1987; Raffaelli, Raven et al. 1998; Thomsen and McGlathery 2006). There may also be increased deposition of sand in the lee of the structure (Mead and Black 1999), resulting in some smothering of taxa. However, the dynamic nature of Lyall Bay would suggest that any organisms inhabiting these sediments are regularly

exposed to natural turn-over of sediments. As a result, this deposition is not thought likely to create significant change to the benthic community, unless the grain size of sediments is altered.

It should be noted that an increase in biomass, particularly with respect to mobile fauna, can have further detrimental effects on the soft-sediment communities surrounding the introduced wave structure. Davis et al (1982) noted a decrease in sea pen densities up to 100 m from the reef edge following the introduction of a reef, concluding that the sea pens were being predated by fish inhabiting the reef. Beaumont (2006) also found increased predation on communities recruiting to settlement panels up to 100 m from an artificial reef. However, no sea pens and limited epifauna/infauna were observed in the sediments surrounding the proposed wave focussing structure in Lyall Bay (MacDiarmid, Anderson et al. 2015) so the effects of predation from mobile predators may be limited.

5 Conclusions

Possible ecological impacts of the introduction of a wave focussing structure in Lyall Bay have been considered and discussed within this report. Overall, the existing sparse benthic community, coupled with the highly dynamic environment that the existing fauna and flora inhabit, suggest that the ecological impacts of the introduction of a wave focussing structure are likely to be minimal.

The biggest impact is likely to be the direct impact of smothering on the benthic community immediately below the structure, which is likely to be dominated by the deposit-feeding ghost-shrimp *B. filholi*. This species appears to be widely distributed in Lyall Bay, particularly at sites 1-7 (Figure 4 and MacDiarmid, Anderson et al. 2015) . Other possible impacts include changes to the benthic community structure following changes in sediment properties, sediment scouring and/or accumulation, as well as possible increase in biomass from colonisation of hard substrates and possible increased predation on soft-sediment communities as a result of mobile reef-dwelling predators feeding on surrounding sediment communities.

5.1 Limitations of this report

This report is based on existing data from a recent survey (MacDiarmid, Anderson et al. 2015), the focus of which was the wider Lyall Bay area rather than a detailed survey of the location of the wave focussing structure. The report is also based on preliminary indications of the placement and design of the wave focussing structure, without detailed knowledge of planned complexity of habitat, surface texture or modelling with respect to local hydrodynamics and movement/ scour/ accumulation of surrounding sediments.

Potential impacts on the modification of the beach level or ecology of sand dunes have not been considered within this report.

Wider impacts during the construction of the wave focussing structure have not been considered within this report. Although it is noted that DHI have recommended the use of a floating barge with precision deployment. Should this method be used, minimal additional impacts would be anticipated, with the possible exception of the generation of a sediment plume.

6 Acknowledgements

Thanks to David Bowden, NIWA for internally reviewing this report.

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Appendix A Sediment properties within Lyall Bay

Concentration and ratios of Chlorophyll-a (Chla), Phaeophytin (Phaeo), Particulate Nitrogen (PN) and Particulate Organic Carbon (POC) in surficial sediment samples in Lyall Bay. The detection limit of Chlorophyll-a and Phaeophytin is 0.1 µg/g, PN is 0.02%, and POC is 0.01%.

Site	Collection date	Chla (µg/g)	Phaeo (µg/g)	Chl:Phaeo	Chla/(Chla + Phaeo)	% PN	% POC	Molar C:N
1	27/08/2014	0.75	0.43	1.74	0.64	0.02	0.11	6.41
2	27/08/2014	1.33	0.44	3.02	0.75	0.03	0.21	8.16
3	27/08/2014	0.75	0.54	1.39	0.58	0.02	0.11	6.41
4	27/08/2014	0.55	0.50	1.10	0.52	<0.02	0.14	8.16
5	27/08/2014	0.46	0.68	0.68	0.40	0.02	0.14	8.16
6	28/08/2014	0.94	0.61	1.54	0.61	0.02	0.15	8.75
7	28/08/2014	0.56	0.38	1.47	0.60	0.02	0.10	5.83
8	28/08/2014	0.60	0.27	2.22	0.69	0.02	0.12	7.00
9	27/08/2014	0.67	0.25	2.68	0.73	0.02	0.09	5.25
10	28/08/2014	0.51	0.32	1.59	0.61	0.02	0.24	13.99
11	28/08/2014	0.38	0.54	0.70	0.41	0.02	0.24	13.99
12	28/08/2014	0.22	0.16	1.40	0.58	0.02	0.30	17.49
13	28/08/2014	0.45	0.42	1.07	0.52	0.02	0.10	5.83
	Mean	0.63	0.43	1.6	0.6	0.02	0.16	8.88
	Standard deviation	0.28	0.15	0.7	0.1	0.00	0.07	3.82

Appendix B Faunal data from sediment cores from the 3 key sites in inner Lyall Bay

0-5 cm sediment depth

Class	Family	Genus	Determination	Site # 01	02	06
Bivalvia	Arcidae		Arcidae	1	0	0
Decapoda	Callianassidae	*Biffarius*	*filholi*	3	0	3
Gastropoda	Eatoniellidae	*Eatoniella*	*Eatoniella olivacea*	1	0	0
Gastropoda	Eatoniellidae	*Eatoniella*	*Eatoniella* spp.	1	0	0
Nematoda	Thoracostomopsidae	*nd*	*Thoracostomopsidae nd*.	0	0	1
Polychaeta	Maldanidae	*Macroclymenella*	*Macroclymenella stewartensis*	0	0	2
Polychaeta	Nephtyidae	*Aglaophamus*	*Aglaophamus nd*	1	1	0
Polychaeta	Paraonidae	*Aricidea (Aedicirra)*	*Aricidea (Aedicirra) nd*	0	0	3
Polychaeta	Paraonidae	*Paraonella*	*Paraonella nd*	0	1	6
Polychaeta	Syllidae	*nd*	*Syllidae nd*	0	2	0

5-10 cm sediment depth

Class	Family	Genus		Site # 01	02	06
Decapoda	Callianassidae	*Biffarius*	*filholi*	3	2	0
Gastropoda	Trochidae	*Antisolarium*	*Antisolarium egenum*	1	0	0
Ophiuroidea	Amphiuridae	*Amphiura*	*Amphiura aster*	0	0	1
Polychaeta	Orbiniidae	*Scoloplos (Scoloplos)*	*Scoloplos (Scoloplos) nd*	0	2	0
Polychaeta	Spionidae	*Prionospio*	*Prionospio tridentata*	1	0	0
Polychaeta	Syllidae	*nd*	*Syllidae nd*	0	1	0

10-15 cm sediment depth

Class	Family	Genus		Site # 01	02	06
Decapoda	Callianassidae	*Biffarius*	*filholi*	0	2	0
Nematoda	Thoracostomopsidae	*nd*	*Thoracostomopsidae sp.*	0	1	0
Ophiuroidea	Amphiuridae	*nd*	*Amphiuridae nd*	0	0	1
Polychaeta	Paraonidae	*Aricidea (Strelzovia)*	*Aricidea (Strelzovia) nd*	1	0	0
Polychaeta	Paraonidae	*Paraonella*	*Paraonella nd*	0	2	1
Polychaeta	Syllidae	*nd*	*Syllidae nd*	6	1	0