BEFORE THE OTAGO REGIONAL COUNCIL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of an application for resource consents for Project Next Generation
BY	**PORT OTAGO LIMITED**
	Applicant

STATEMENT OF EVIDENCE OF PETER KEITH PROBERT ON BEHALF OF PORT OTAGO LIMITED

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INTRODUCTION, QUALIFICATIONS & EXPERIENCE

1. My full name is Peter Keith Probert. I am an Associate Professor in the Department of Marine Science at the University of Otago. I have a BSc Honours degree in Zoology and a PhD in marine biology, both from the University of London. My professional work has been in the area of marine environmental studies, and in particular in the area of seabed, or benthic, ecology. I have worked in this field in the United Kingdom and in New Zealand as a postdoctoral researcher since 1973. In the United Kingdom I worked for the Nature Conservancy Council and in the oil industry carrying out marine environmental impact studies. In New Zealand I have worked for the New Zealand Oceanographic Institute (now part of NIWA) and for the University of Otago on the staff of the Portobello Marine Laboratory and then the Department of Marine Science. I have authored or co-authored a number of publications on marine biology and ecology including three books, ten book chapters, and some 55 peer-reviewed journal articles. Most of these publications concern marine biology and ecology of the New Zealand region, and several concern marine benthic ecology of local coastal and offshsore waters. I have also authored or co-authored more than 30 reports on various marine environmental studies. A number of these have been concerned with the marine environmental effects of proposed development or activities in Otago Harbour or adjacent waters.

2. I have read the Code of Conduct for Expert Witnesses contained in the Environment Court Consolidated Practice Note 2006 and I agree to comply with it. I have complied with it in the preparation of this evidence.

BACKGROUND INFORMATION

3. My involvement in Project Next Generation has concerned the marine environmental implications of dredging and dredge material disposal, in particular the implications for the benthic habitats and communities of Otago Harbour. In preparing my evidence I have consulted various papers and reports relevant to the marine biology and ecology of Otago Harbour that date from before Project Next Generation, as well

as reports written specifically for the Project, namely (1) Summary of existing ecological information and scoping of further assessments for Port Otago dredging project (NIWA, October 2007), (2) Benthic habitat structures and macrofauna of Lower Otago Harbour (Benthic Science Limited, December 2008), (3) Benthic habitat structures and macrofauna of Lower Otago Harbour: supplemental information from Te Rauone Beach and Latham Bay (Benthic Science Limited, February 2010), (4) Observations of rocky shore habitats in Lower Otago Harbour (Benthic Science Limited, April 2009), (5) Biological resources of Otago Harbour and offshore: assessment of effects of proposed dredging and disposal by Port Otago Ltd (NIWA, August 2009), (6) Project Next Generation: Resource consent applications and Assessment of Environmental Effects (Port Otago Limited, May 2010).

SCOPE OF EVIDENCE

4. I have been asked by Port Otago Limited (POL) to prepare evidence on the benthic ecology of Otago Harbour for Project Next Generation. In my evidence I discuss:

    a. The previous state of knowledge on the Harbour benthic habitats and communities.

    b. The studies undertaken as part of Project Next Generation to supplement this knowledge and provide a more comprehensive and detailed picture of the benthic ecology of the Harbour; in particular the initial scoping report that identified additional work to be undertaken, the detailed benthic harbour survey, and the supplemental reports on (a) Te Rauone and Latham Bay areas, and (b) the rocky shores.

    c. The adequacy of this information for assessing marine environmental effects and as a basis for possible monitoring work.

5. Other witnesses will assess the potential impact of Project Next Generation upon the benthic ecology of Otago Harbour, the physical features of the environment and birdlife, mammals and fish. My

evidence establishes the baseline benthic environment that exists in Otago Harbour today.

EXECUTIVE SUMMARY

6. Otago Harbour is biologically and ecologically an important feature of the coastal environment of southern New Zealand. Although considerably modified by humans, the Harbour contains a range of sheltered intertidal and shallow subtidal benthic habitats and communities of rocky and sediment substrata.

7. The Lower Harbour, the focus of this evidence, appears to be biologically more diverse than the Upper Harbour. Important sediment habitats in the Lower Harbour extend from significant saltmarsh at Aramoana, to extensive sandflat areas, to deeper channel habitats.

8. Surveys indicate that benthic habitat of the Lower Harbour is essentially a patchwork of areas characterised by such features as algal mats, seagrass, cockle beds, rippled sand, tube mats, shell hash, and mudstone pavement, and with no clear correspondence between these structural features and the composition of the macrofauna of the underlying sediment. The macrofauna is dominated by species of annelid worms, molluscs, and small crustaceans. The fauna appears to be typical of comparable sheltered sediment habitats for this biogeographic region, and no fauna endemic to the Harbour were identified.

9. The Lower Harbour also contains rocky intertidal and shallow subtidal habitat. The seaweeds and invertebrates identified from the rocky areas surveyed were species commonly found in sheltered inlets in southern New Zealand. As a result of surveys carried out as part of Project Next Generation, together with the findings from earlier studies, we now have a significantly improved understanding of the benthos of Otago Harbour, particularly knowledge of sediment habitats

of the Lower Harbour, their distribution and associated species of macrofauna.

THE PROPOSAL

10. My evidence relates to the Project Next Generation proposal to deepen, widen and dredge the Otago Harbour channel, swinging areas and berths.

THE SITE AND ITS CONTEXT

11. Otago Harbour is a marine inlet aligned roughly southwest to northeast and bounded by dissected hills, remnants of the Dunedin Volcano. The Harbour is some 22-23 km long, generally only about 2 km wide, and with an area of some 46 km^2. The Harbour is effectively divided into Upper and Lower Harbour basins by peninsulas at Portobello and Port Chalmers and the islands between them, namely Quarantine and Goat islands.

12. The Harbour is mostly shallow, with water depths of only a few metres. Extensive sediment flats are exposed at low tide, mainly in the middle and outer reaches, which amount to some 30% of the Harbour area at low water of spring tides. The only naturally deep areas are tidal colks between the islands where water depths of around 30 m occur. Otherwise, the most extensive deeper water habitat in the Harbour occurs along the shipping channel.

13. Water in the Harbour is derived largely from the Southland Current that flows northwards along the southeast coast of the South Island. Inshore, this Southland Current water is influenced by freshwater runoff, particularly from the Clutha River. It is this modified coastal water that enters the Harbour on flood tides. Within the Harbour this coastal water is further influenced by catchment runoff and input from the Water of Leith at the head of the Harbour.

14. The constriction caused by the halfway islands and peninsulas means that water in the Lower Harbour basin turns over more quickly than that in the Upper Harbour basin. The residence time of water in the Lower Harbour has been calculated at about 14 hours, whereas residence time estimates for the Upper Harbour Basin range from 4 to 15 days. The Lower Harbour basin is thus less susceptible to variations in salinity and temperature and to any build up of contaminants.

15. Water temperature in the Harbour averages between about 6°C and 16°C, but with the Lower Harbour somewhat less variable than the Upper Harbour. In terms of salinity, the main freshwater input is the Water of Leith, but that inflow is small relative to the size of the Harbour, so there is not a strong gradient in salinity along the Harbour. Salinity in the Upper Harbour can fall to less than 30, but in the Lower Harbour is essentially full strength seawater at around 34-35. (Salinity is expressed as a ratio with no physical units.)

16. Nutrient (notably nitrate and phosphate) levels can be elevated in the Harbour as a result of catchment runoff, and turbidity levels can be high as a result of runoff and resuspension of fines following periods of high rainfall and / or wind-wave disturbance.

17. The main source of sediment for Otago Harbour is the Clutha River, which supplies sediment to the inner shelf, forming a nearshore zone of fine sand[1]. Sediment in this zone is carried northeastwards by the prevailing hydraulic regime and swept in to the Harbour on flood tides where it is deposited; hence the need to dredge the Harbour to maintain navigable channels.

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[1] Carter, R.M., Carter, L., Williams, J.J. and Landis, C.A. (1985). Modern and relict sedimentation on the South Otago continental shelf, New Zealand. *New Zealand Oceanographic Institute Memoir* 93: 43 pp.

EVIDENCE

Previous studies of the marine biology and ecology of Otago Harbour

18. Numerous marine biological studies have been undertaken in Otago Harbour, particularly on account of the marine laboratory at Portobello which was established more than a century ago. For the past 60 years the laboratory has been part of the University of Otago, and a range of studies have been carried out in the Harbour by staff and research students associated with the Laboratory and by visiting researchers. Many of these studies have concerned the biology and ecology of particular species, and in fact relatively few have addressed the broader scale ecology of the Harbour. A number of studies have also been carried out over recent decades that have examined marine environmental implications of various activities impacting the Harbour, including reclamations, dredging, shoreline alterations, industrial developments and shellfisheries. As a result of these various studies a broad understanding has developed of the main marine habitats, communities and key species occurring in Otago Harbour.

19. The Otago Harbour Planning Study undertaken by the Otago Regional Council and Dunedin City Council in the early 1990s provided a useful overview of the Harbour environment and of the human activities affecting it. For that study I contributed an overview of the biology and ecology of the harbour[2]. Much of that review is still relevant so I have drawn on it here, updated where necessary, to provide a summary of our understanding of the Harbour's marine biology, up to the start of Project Next Generation. I will then review the further studies that have been undertaken as part of Project Next Generation to better understand the biology and ecology of the Harbour. I am not covering in my evidence information on fisheries, seabirds, and marine mammals in the Harbour as these are being dealt with by other witnesses.

[2] Probert, P.K. (1991). Marine biology and ecology of Otago Harbour (excluding seabirds and marine mammals). In: Otago Harbour Planning Study, Stage One. Report of the Ecosystems and Physical Systems Working Group. ORC and DCC Joint Discussion Series No 2: 104–128.

20. Among the most relevant studies here are those that have examined the seabed, or benthic, communities of the Harbour. Benthic habitats of the Harbour are mainly those of sediment substrata. A study by Ralph and Yaldwyn in the mid-1950s was among the first to identify soft-bottom benthic communities of the Harbour, although this was a purely descriptive study and confined to the middle reaches of the Harbour[3].

21. A far more extensive, detailed and quantitative study of the sediment benthos was carried out by Rainer in the mid-1960s[4]. Rainer identified some 400 macroscopic benthic species associated with Harbour sediments and, using environmental criteria, distinguished four main community types associated with sediment substrata. These were called a mud community, a fine sand community, a stable shell-sand community, and an unstable sand community. These communities were chiefly characterised by various species of polychaete worms, molluscs such as bivalves and gastropods, and small crustaceans. This is typical of the gross faunal composition of such marine sediments.

22. Rainer assigned most of the samples from the Upper Harbour to his mud community. The fine sand community was found to occur mainly in the middle and Lower Harbour, the stable shell-sand community in the Lower Harbour, and the unstable sand community mainly at the Harbour mouth. Thus overall there is a gradation from communities of the Upper Harbour inhabiting muddy, organic sediments associated with low current speeds, to communities in the Lower Harbour occurring in sand or shell-sand substrata containing less organic matter and generally in areas of higher current velocities. This broad pattern is to be expected given the gradation in environmental conditions, in particular the increase in shelter up the Harbour, the

[3] Ralph, P.M. and Yaldwyn, J.C. (1956). Seafloor animals from the region of Portobello Marine Biological Station, Otago Harbour. *Tuatara* 6(2): 57-85.
[4] Rainer, S.F. (1981). Soft bottom benthic communities in Otago Harbour and Blueskin Bay, New Zealand. *New Zealand Oceanographic Institute Memoir 80.* 38 p.

effect of this shelter on the depositional environment, and the strong influence of sediment type on the composition of benthic communities.

23. Grove surveyed the subtidal sediment benthos of the Upper Harbour in 1993, which provided further information about these sheltered muddy sediments as well as the potential influence of human activities in this region of the Harbour[5].

24. Extensive sandflats, exposed at low water, are the predominant intertidal sediment habitat of the Harbour. The benthic community of these sandlfats is similar to Rainer's fine sand community. Among the larger and more conspicuous animals of the sandflats are the cockle or littleneck clam (*Austrovenus stutchburyi*), wedge shell (*Macomona liliana*), lugworm (*Abarenicola affinis*), ghost shrimp (*Callianassa filholi*) and mantis shrimp (*Heterosquilla tricarinata*). Often dominant in terms of biomass is the cockle, which commonly occurs at densities of up several hundred per square metre. Cockles are filter feeders, extracting particles of food from a current of water that is drawn through their gills. Extensive cockle beds can significantly influence the particulate load of inlets, and thereby the amount of organic matter being transferred from the water column to the sediment.

25. Also conspicuous on intertidal sandflats are seagrass (*Zostera muelleri*) beds. Seagrass plays an important role as habitat for many associated organisms, as a source of organic detritus, and in stabilising sediments.

26. Otago Harbour also includes a significant area of saltmarsh above the sandflats of Aramoana. The lower marsh is dominated by sea primrose (*Samolus repens*) and glasswort (*Sarcocornia quinqueflora*),

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[5] Grove, S.L. and Probert, P.K. (1999). Sediment macrobenthos of Upper Otago Harbour, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 33: 469-480.

and in places seablite (*Suaeda novae-zelandiae*); the middle marsh also contains remuremu (*Selliera radicans*), a bog-rush (*Scirpus cernuus*) and arrow grass (*Triglochin striatum*); whilst conspicuous in the upper marsh is marsh ribbonwood (*Plagianthus divaricatus*). The lower marsh fauna includes sandhoppers, crabs, mudsnails, and insects, and which provide food for wading birds[6]. The Aramoana saltmarsh is among the most extensive and intact on the South Island east coast, and is protected as part of an Ecological Area under the Conservation Act 1987.

27. Natural rocky intertidal and subtidal habitat is less well represented in the Harbour. Intertidally, there are in fact few stretches of unmodified rocky shore remaining in the Harbour. Most of the shoreline is bounded by stone walls retaining a road or railway line. The most extensive stretches of natural rocky shore that remain are in the middle reaches of the Harbour, around the Portobello peninsula, the islands, and outer Sawyers Bay area. Hard shore areas in the Harbour range from sheltered to extremely sheltered, and this is reflected by the seaweeds and invertebrates that inhabit these shores and their intertidal zonation.

28. Still very relevant is the account by Batham, published in the mid-1950s, of the ecology of the rocky shore at Aquarium Point, Portobello, and the distribution of the principal zone-forming species[7]. Batham's account indicates that these natural rocky shores support a diverse biota, but one that is typical of the region for this habitat. Among the more conspicuous species are lichens and winkles on the upper shore, topshells and chitons in the mid-shore zone, and typically a zone of the necklace weed below the level of mean spring tides. Below this level, bladder kelp and sea tulips are often conspicuous.

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[6] Partridge, T.R. and Wilson, J.B. (1975). The ecology of Aramoana, Otago Harbour. 4. Plant communities at Aramoana. Report commissioned by the Dunedin Metropolitan Regional Planning Authority and supported by the Otago Harbour Board.

[7] Batham, E.J. (1956). Ecology of southern New Zealand sheltered rocky shore. *Transactions of the Royal Society of New Zealand* 84: 447–465.

29. Observations of the stone walls indicate that they support a less diverse biota, probably because the natural shores tend to be topographically more complex and so provide a greater range of microhabitats. It also appears that the diversity of the rock wall biota decreases towards the Upper Harbour, which probably reflects the greater environmental variability of the Upper Harbour waters associated with longer residence times.

30. The Harbour also has considerable stretches of mixed shore consisting of boulders and rock fragments of varying size interspersed with finer grained sediments. These provide for a range of microhabitats, from organisms that need a hard surface for attachment to those than burrow into soft substrata.

31. Otago Harbour has been considerably modified by human activities. Among the more significant changes have been physical alterations to the Harbour's shoreline and seabed. Extensive reclamation has been carried out, particularly around the head of the Harbour. It has been estimated that overall the amount reclaimed represents about 8% of the original mean area of the Harbour at high water. There have also been extensive alterations to shorelines with the construction of retaining walls, with the consequent loss of natural intertidal areas. Capital and maintenance dredging to maintain navigable shipping channels has also physically altered the Harbour.

32. Water quality in the Harbour has potentially been influenced by various activities, including changes in land use of the catchment area, soil erosion and runoff of nutrients and contaminants, point-source effluents, and atmospheric inputs. Alien species have also been deliberately or inadvertently introduced to the Harbour, including quinnat (chinook) salmon and the Asian kelp *Undaria pinnatifida*. The Harbour does not currently support any commercial fisheries, but there is a proposal to develop a cockle fishery.

33. Otago Harbour has been considerably modified by humans over the years, and changes have directly affected the ecology of the Harbour, including benthic habitats and communities. Benthic ecology of the Harbour may also be affected, directly or indirectly, by changes in the wider marine area, for example as a result of climate change and through shifts in the composition of fish communities due to exploitation.

Studies carried out as part of Project Next Generation

34. I now provide an overview of further marine ecological studies that have been carried out in Otago Harbour as part of Project Next Generation.

35. The first stage in this exercise was to produce a summary report[8] that provides an overview of the present status of knowledge of the marine ecology of the Harbour and the region offshore that could potentially be a receiving area for dredged material, that identifies gaps in our understanding, and scopes the type of work that would be required as part of a detailed Assessment of Environmental Effects.

36. This report covered the ecological aspects and included the state of knowledge of the benthic ecology, birds, mammals, and fisheries, including maps showing important habitats, distribution of major species, and some commentary on potential effects. Also included were a risk table summarizing potential areas / issues that may need to be addressed, and a summary of ecological studies that needed to be carried out.

37. As already mentioned, a number of ecological studies have been carried out in Otago Harbour, as well as in the offshore region, that are

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[8] James, M., Probert, K., Boyd, R. and John, A. (2007). Summary of existing ecological information and scoping of further assessments for Port Otago dredging project. NIWA Client Report: HAM2007-156, 46 pp.

directly relevant to Project Next Generation. Nevertheless, gaps in our knowledge were identified that required further studies to enable a full assessment of potential effects to be made. It is also recognised that it is important to provide adequate baseline data by which to assess and monitor significant impacts as the project proceeds.

38. With regard to the benthic ecology of Otago Harbour, our level of understanding of the benthic communities of the Lower Harbour, and in particular of areas adjacent to the main channel, was identified as a significant information gap. It was recognised that appropriate surveys would better enable the vulnerability of the benthic communities of these areas to be assessed with regard to dredging.

Benthic survey of the Lower Harbour

39. Benthic surveys were carried out in 2008 and 2009. The main survey of the Lower Harbour was undertaken in 2008[9], and this was augmented by further sampling in 2009 in areas near Te Rauone Beach, Latham Bay, Edwards Bay and the channel near Sawyers Bay[10]. The benthic survey comprised two main components, first a photographic survey to identify basic physical and biological characteristics of the seabed, and secondly a grab sampling survey to determine the fauna inhabiting the sediments.

40. For the photographic sampling, an underwater camera in a weighted frame was used and at each site this was lowered to obtain seabed images. Replicate photographs of the seafloor (each covering an area of 0.064 m^2) were taken at 147 sites, and 807 images were used in the final analysis. Most of the photo sites were arranged along transects located across the channel so as to characterise the channel bottom

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[9] Paavo, B. and Probert, K. (2008). Benthic habitat structures and macrofauna of Lower Otago Harbour. Benthic Science Ltd. 60 pp.

[10] Paavo, B. (2009). Benthic habitat structures and macrofauna of Otago Harbour: supplemental information from Te Rauone Beach and Latham Bay. Benthic Science Ltd. 53 pp.

slopes and adjacent areas. The remaining sites were placed so as to include all Lower Harbour depths in 2-metre intervals and to include one site within every square kilometre.

41. From the seabed features evident in the photos it was possible to identify up to 11 main categories based on such criteria as substratum type, current ripples, shell material, algal mats, tubes, burrows and mounds of sediment-dwelling invertebrates, and presence of attached animals (such as sponges, hydroids, and sea squirts). Abundance of live cockles could be determined by counting visible siphons. This method was validated by physical sampling at some locations.

42. On the basis of this photo survey, grab sampling sites were allocated. A stratified random approach was used to ensure representative coverage of the identified habitat types. A total of 122 benthic grab samples (each 0.05 m^2) were taken and sieved on a 1 mm mesh to extract the sediment-dwelling invertebrates. Approximately 39,000 individuals were identified representing more than 150 taxonomic groups. Individuals were identified to the lowest practicable level, though not necessarily to species. Grab samples were dominated by molluscs, annelid worms and arthropods. The fauna appears to be typical of comparable sheltered sediment habitats of this biogeographic region, and no fauna endemic to the Harbour were identified.

43. According to the habitat classification, sandflats supporting algal mats comprised 29% of the classified area, inlet features with seagrasses and cockle beds 28%, rippled sand 13%, sand with sparse shell and algae 11%, macrofaunal tube mats 10%, shell hash 8%, and mudstone pavement 2% (see Figure below). However, no clear pattern was found relating habitat type to composition of the sediment macrofauna. In this respect the Lower Harbour is essentially a patchwork of different habitat types on the scale of tens to hundreds of metres. In effect, as far as these sediment-dwelling invertebrates are concerned, the Harbour appears to support one community. However,

while patchiness was the norm, some continuous areas typical of inlet sandflats were present along the northern portion of the Lower Harbour channel, whilst algal beds dominated the central areas. Cockles were found at a number of sandflat sites in densities ranging from 15 to 625 / m^2. The highest densities were recorded off Harwood and on the sandbanks opposite Acheron Point.

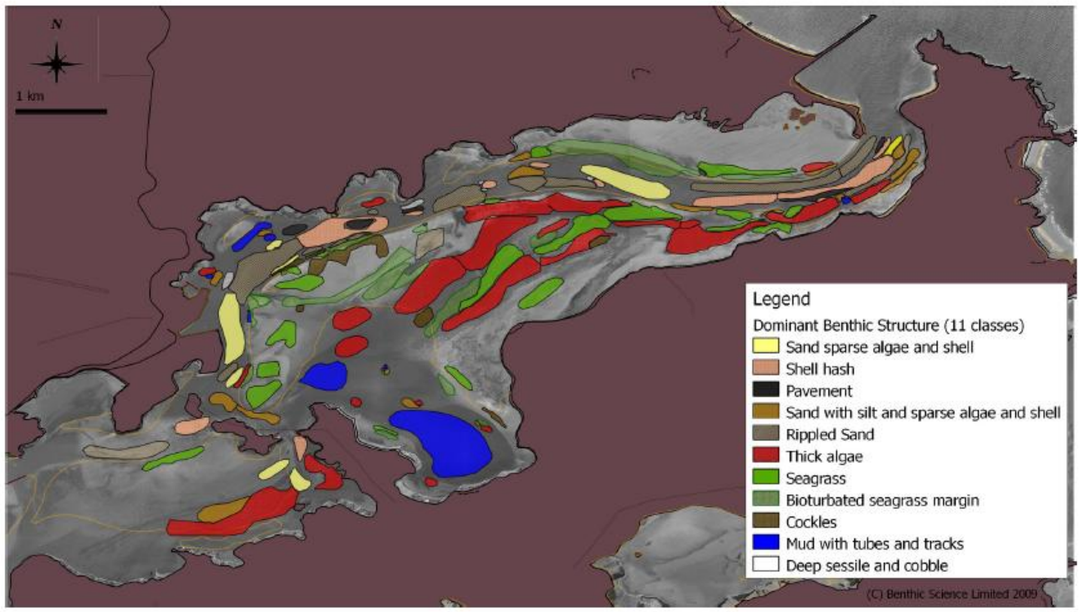

Figure 14. Interpolated dominant benthic structures (11 class scheme) from combined 2008 and 2009 photo survey data. (Background LINZ I44/J44 1999-2000 aerial imagery).

Dominant benthic structures (7-class scheme) from combined 2008 and 2009 photo survey data (from Paavo 2010).

44. This study represents the most comprehensive habitat mapping exercise that has so far been carried out in Otago Harbour. The findings essentially corroborate earlier studies. Rainer, for example, did identify benthic communities and recognised an overall gradation from animals associated mainly with clean sandy and shelly sediments in the outermost reaches of the Harbour to those characterising muddier sediment in the upper reaches. He did not, however, attempt to map these communities because of their inherently patchy distribution.

Rocky shore study

45. To augment knowledge of the rocky shore biota of the Lower Harbour, a survey was undertaken in March 2009 of exposed rocky shore sites[11]. Four sites were examined, three of them adjacent to the shipping channel, at Rocky Point (between Careys Bay and Deborah Bay), and at Acheron Point and Pulling Point (west and east of Hamilton Bay), and a fourth site on the north side of Quarantine Island (see Figure below). At each site, transects were run down the shore and quadrats (0.25 m^2) placed at each metre from the shoreward to the seaward end of the transect. The transects extended to 5 m water depth or the obvious subtidal habitat. The quadrats were photographed where tidal & visibility conditions permitted and the macroscopic algae and animals were identified.

Figure 2. Intertidal rocky shore survey sites (yellow circles) in lower Otago Harbour, Dunedin, New Zealand

Rocky shore survey sites (yellow circles) (from Paavo 2009).

[11] Paavo, B. (2009). Observations of rocky shore habitats in Lower Otago Harbour. Benthic Science Ltd. 46 pp.

46. The shoreward end of the transects at Rocky, Acheron, and Pulling Points terminated at the artificial seawall, whereas at Quarantine Island the shoreward end of the transects terminated against the natural rockface. Only a small proportion of the surveyed shoreline was bedrock. Most of the mid-shore zone consisted of pebbles, cobbles and occasional boulders. At each site the substratum gave way to gravel, sandy or muddy sediments at or just below mean low water.

47. In total 66 taxa were identified, of which 16 were algae and the other 50 invertebrates. Characteristic organisms included brown seaweeds (*Carpophyllum* spp., *Hormosira banksii)*, littorinid snails (*Austrolittorina* spp.), topshells (*Diloma* spp.), limpets (*Cellana* spp.), chitons (*Sypharochiton pelliserpentis*, *Chiton glaucus*), barnacles, (*Elminius modestus*, *Chamaesipho columna*), and half-crabs (*Petrolisthes elongatus*). The majority of invertebrate individuals were located in the mid-shore zone, whilst the lower shore and subtidal zones were dominated by sediment macrofauna and algal beds. Typical intertidal and shallow subtidal zonation patterns were evident at all sites, and all the organisms identified were species commonly found in shallow sheltered inlets in southern New Zealand. No rare or unusual species or communities were identified in the surveyed areas.

Brachiopods

48. Among the more noteworthy animals associated with the Harbour's rocky habitats are brachiopods, or lamp shells, including *Calloria inconspicua*, a pink-shelled endemic species found throughout New Zealand that occurs under low-tidal rocks. Brachiopods have a very rich fossil history and there are now relatively few living species. The occurrence of live brachiopods at such accessible locations is of considerable interest to marine biologists and palaeontologists worldwide.

49. Often associated with *Calloria* on sheltered rocky shores is a smaller brachiopod, *Pumilus antiquatus*, which reaches a shell length of about

6 mm. It is endemic to New Zealand and has been recorded only from Otago Harbour, Karitane, and Lyttelton Harbour. The Department of Conservation lists the species as nationally endangered[12]. According to the Ministry of Fisheries' National Aquatic Biodiversity Information System (NABIS), *Pumilus antiquatus* may have a wider distribution than that reported, as owing to its small size the species is easily overlooked, or mistaken as the juvenile of other species (typically of *Calloria inconspicua*). Searches during recent years have yielded very few specimens, even at historically rich localities. Three sites within the Otago Harbour have historically had populations of *P. antiquatus*, namely Pudding Island, Quarantine Island and Aquarium Point.

50. Last year a survey for *Pumilus* was carried out at seven sites within Otago Harbour, the three sites previously known to have populations, plus four more where the conditions were considered suitable[13]. The sites were near Harington Point, Dowling Bay Point, Hamilton Bay Point, Aquarium Point near the Portobello Marine Laboratory, Pudding Island, Quarantine Island (Portobello end), and Yellow Point at Broad Bay. The intertidal survey, led by brachiopod expert Jeffrey Robinson, was carried out by up to four observers wading in the water at very low tides and diving where water was too deep for wading. *Pumilus* was not, found at any of these sites, although the brachiopod *Calloria inconspicua* was found (at Pudding Island and Aquarium Point). The reason for this apparent decrease in abundance of *Pumilus* in the Harbour is not known. It was observed that sites where *P. antiquatus* was once abundant were often quite muddy with thin layers of silt on most surfaces, which could be from a number of sources, and which could interfere with the breathing/feeding appendages of the brachiopod. However, it was noted that other sediment sensitive species are still abundant at sites such as Pudding Island.

51. Two further sites north of Dunedin were included in this survey, at Karitane and Moeraki. *P. antiquatus* is known to be found at Karitane

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[12] Hitchmough, R., Bull, L. and Cromarty, P. (comp.). (2007). New Zealand threat classification system lists 2005. Wellington: Department of Conservation.

[13] Robinson, J. (2010). Otago Harbour survey of *Pumilus antiquatus* for Port of Otago. Report for Port Otago Ltd, 3 pp.

from a water depth of about 15 metres, but none were found during this survey by snorkel divers working to depths of 8-10 metres. However, two other brachiopod species were observed (*C. inconspicua* and *Notosaria nigricans*). No brachiopods were found at Moeraki. This survey suggests that if there has been a decline in the abundance of *P. antiquatus*, that such a change is not confined to Otago Harbour.

Summary of the baseline environment

52. Otago Harbour is clearly an important feature of the coastal environment of southern New Zealand. It is the only large non-estuarine inlet on the southeast coast of the South Island and represents a significant example of a shallow marine inlet with a range of sheltered habitats in southern temperate waters, and a correspondingly diverse marine biota.

53. As a result of studies carried out as a part of Project Next Generation we now have a significantly better understanding of the benthic biology and ecology of Otago Harbour. Benthic surveys undertaken for Project Next Generation are the most detailed to date for the Lower Harbour. This information should provide an adequate basis by which to assess effects on the Harbour benthos of dredging, deepening and widening of the Harbour entrance and channel, and by which to develop appropriate monitoring programmes that may be necessary, in particular monitoring of direct physical effects on the benthic habitat and any effects of increases in turbidity, suspended sediments and settled sediments on habitats and communities.

RESPONSE TO SUBMISSIONS

54. The submission from Friends of the Harbour (FROTH) points out that the brachiopod or lamp shell P*umilus antiquatus* is not mentioned in the AEE. However, as mentioned earlier in this evidence, a survey of

this species was carried out at a number of sites in the Harbour, although no specimens were found.

55. The submission by Dr Peter Evan Walker and Ms Jennifer Erica Aimers expresses concern about gaps in current knowledge to accurately assess potential effects. The gaps are not, however, specified, and whether any of them concern the adequacy of information about benthic ecology of the Harbour.

56. These appear to be the only submissions that question, or possibly question, the state of knowledge on Otago Harbour benthos, the subject of this evidence.

57. The submission by Associate Professor Mike Barker refers to "at least two rare and several unusual species not mentioned in the various reports that occur within the harbour and are critically endangered as they are found close to the central harbour area that is likely to be most affected by suspended sediment."[14] He refers specifically to two seastar species, *Allostichaster polyplax* and *Allostichaster insignis*, and two brachiopod species, *Pumilus antiquatus* and *Calloria inconspicua*.

58. The brachiopod species referred to have already been discussed. With regard to the seastars, Associate Professor Barker has undertaken research on this group over a number of years, including in Otago Harbour, and according to him *A. polyplax* is known from only one locality in the Harbour, the rocky shore immediately south of the Portobello Marine Laboratory. He points out that while the species is believed to be quite common, it is known from only one other locality on the New Zealand coast (Raglan Harbour) from an observation in the 1970s.

[14] Submission of Mike Barker, page 2.

59. The NIWA Biodiversity Memoir by McKnight (2006)[15] on this group of seastars lists *A. polyplax* as "not common", but states that the species is said to occur throughout New Zealand and the Chatham Islands, and also from southern and eastern Australia, and has a bathymetric range of 0–238 metres. This species may be relatively widely distributed in coastal waters of this part of the south-west Pacific but appears nowhere to be common, including in Otago Harbour.

60. Associate Professor Barker states that *Allostichaster insignis* "is also very abundant in the intertidal and shallow subtidal close to Quarantine Point and the Portobello Marine Laboratory although it also occurs at other sites within the harbour".[16] McKnight (2006) records *Allostichaster insignis* as "relatively common" and widespread in New Zealand, with most records from south of Cook Strait, and with a bathymetric range of 0–322 metres. Although more common than *A. polyplax*, *A. insignis* also appears to have a patchy local distribution. This is probably the case for many other benthic species that, although relatively widely distributed, occur patchily or sporadically. A problem in a country such as New Zealand, which has a large and diverse marine estate and a relatively short history of intensive marine scientific investigation, is that knowledge of the coastal marine flora and fauna is generally poor.

61. The submission from Southern Clams Limited states that the surveys of benthic fauna are "grossly inadequate in terms of study design, being a one-off survey of a seasonally and annual variable community, biased towards shipping channels not inter-tidal areas.[17]" The benthic

[15] McKnight, D.G. (2006). The marine fauna of New Zealand. 3, Echinodermata: Asteroidea (Sea-stars) : Orders Velatida, Spinulosida, Forcipulatida, Brisingida : with addenda to Paxillosida, Valvatida. *NIWA Biodiversity Memoir* 120, 187 pp.

[16] Submission of Mike Barker, page 2.

[17] Submission of Southern Clams Limited, page 6.

survey work was undertaken in two phases, the first in late summer / early autumn 2008 and the second phase in winter 2009. Benthic macrofaunal populations of the harbour would be expected to exhibit seasonal and inter-annual variability. However, surveys designed to adequately capture such variability would need to be carried out over a period of at least a few years. There was not an opportunity to undertake survey work of this duration. The benthic survey work focused on subtidal sites in the area of the shipping channel as this is the area most directly impacted by the dredging. Shallow areas, including sandflats, were included in the benthic surveys, but intertidal areas of the harbour are the regions already best known as a result of previous studies so there was less intensive sampling of these areas.

62. The macrofaunal sampling was based on a stratified random approach such that sampling effort was proportional to the benthic categories recognised so as to try and ensure representative coverage of the benthic categories recognised.

63. The benthic surveys involved analysis of some 800 seabed images from 147 sites, processing and analysis of 122 grab samples, which entailed identification of 39,000 organisms representing more than 150 taxonomic groups. This level of sampling is at least comparable, if not greater than many studies of benthic community analysis published in peer-reviewed scientific journals. Undertaking benthic surveys – particularly the processing and identification of organisms – is very time consuming so a balance needs to be struck between what is practicable and what will provide adequate coverage. I believe that the benthic surveys of the Harbour that were carried out are adequate for this project. The submission from Southern Clams Limited also states that the benthic report significantly underestimates the biomass of *Austrovenus* (i.e. littleneck clams or cockles) in Otago Harbour[18]. For none of the macrofaunal species sampled was biomass estimated.

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[18] Submission of Southern Clams Limited, page 6

CONCLUSIONS

64. Otago Harbour contains an important range of sheltered intertidal and shallow subtidal benthic habitats of rocky and sediment substrata that are not widely represented elsewhere in this biogeographic region. Surveys of the Lower Harbour indicate a complex habitat patchwork, though supporting essentially one main community type of sediment-dwelling invertebrates. The information now available on benthic ecology of Otago Harbour is considered to provide an adequate basis to assess effects on the Harbour benthos of dredging for Project Next Generation, and by which to develop appropriate monitoring programmes.

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