INTRODUCTION, QUALIFICATIONS & EXPERIENCE

1. My full name is Bryony Black. I hold a Diploma in Marine Science, a Bachelor of Applied Science (Environmental Studies) from Auckland University of Technology and am currently completing my honours in Environmental Management.
2. I have undertaken two theses during my studies; the first examined the subtidal environs surrounding Nugget Point, Catlins prior to the application of a Mataitai within the area. The Ministry of Fisheries requested the use of this data for the Mataitai application and I subsequently enlisted the help of Dive Otago to continue the surveying on a bi-annual basis. The second thesis investigated the dispersal and management of the invasive seaweed *Undaria pinnatifida* in New Zealand harbours using a case study of the Otago Harbour and two years worth of data collected by Otago Girls' High School around Quarantine Island. Environment Bay of Plenty has since adopted many of my management strategies in order to control further dispersal within Port Tauranga. Undaria monitoring continues around Quarantine Island.
3. I am a trained PADI SCUBA Dive Master and have spent much time diving within the Otago Harbour.
4. I have worked as a Marine Scientist on the Great Barrier Reef documenting the effects of sedimentation and tourism on a high use area off the Whitsunday Islands, Queensland. I have also worked for Geological and Nuclear Sciences; the NZ Aquarium and Marine Studies Centre in Portobello and prior to this, the Ministry of Fisheries based in Dunedin and Invercargill.
5. Within each of these organisations gathering and interpreting data was vital in order to provide an assessment of the issue at hand. Within the Ministry of Fisheries I undertook a social science role and assessed the use of qualitative data in the form of Local Ecological Knowledge to manage a fishery resource, an area that is becomingly increasingly

recognised within resource management. I am currently co-writing a paper regarding this research.

6. I resided on Quarantine Island in the Otago Harbour for 5 years and my family were the sole residents on Quarantine Island for a total of 12 years from 1997 until 2009. Therefore I am thoroughly familiar with the Otago Harbour.
7. My evidence is given in opposition to applications for resource consents lodged with the Otago Regional Council (ORC) by Port Otago Ltd. (POL) in relation to Project Next Generation.
8. 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.

SCOPE OF EVIDENCE

9. I have been employed by Southern Clams Ltd. (SCL) since July 2010 to assess the ecological impacts of Project Next Generation with regard to the Otago Harbour and more specifically SCL harvesting sites 1804 and 1805.
10. The evidence I have prepared presents my own interpretation of the technical reports presented in support of Port Otago Ltd's Assessment of Environmental Effects for Project Next Generation. It also addresses potential effects of suspended sediment and sediment deposition on *Austrovenus stutchburyi* (NZ littleneck clam, cockle or tuaki) as a result of the Project Next Generation dredging.

OPENING STATEMENTS

11. The proposal by POL to deepen and widen the existing harbour channel is a major cause for concern to SCL due to a number of potential negative effects on *Austrovenus stutchburyi* (Austrovenus) and therefore their harvesting research.
12. The removal of up to 7.2 million m3 of sediment from the lower Otago Harbour poses 3 main issues with regard to SCL's research;

12.1 The direct and indirect impacts of ongoing sediment deposition on clams due to the capital dredging regime.

12.2 The direct and indirect impacts of dredging-related suspended sediment concentrations (SSC) on clams (larval, juvenile and adult stages).

12.3 The lack of a clear and concise time frame within which the Project Next Generation will occur.

BACKGROUND INFORMATION

13. Please refer to the References section for a list of the papers mentioned here.

Archambault (2004), Turner & Miller (1991) and Bricelj (1984) are American papers and focus on another commercially harvested species of hard clam *Mercenaria mercenaria* (Mercenaria) which in all respects is very similar to our own *Austrovenus stutchburyi* (Austrovenus) clam species. Mercenaria is an edible marine bivalve mollusc, like Austrovenus, which is native to the eastern shores of North America. This species, also like Austrovenus, is in the family Veneridae, the venus clams. Clams represent a large commercial fishery in the US, and there has been much research on these species. The basic similarities between the two species (such as feeding mechanisms and similar life cycle) mean that the effects on Mercenaria can be transferred to Austrovenus.

14. Austrovenus is a marine bivalve mollusc found only in NZ.

14.1 Stable fine sand sediments appear to be essential for littleneck clams to flourish and they can burrow down to 2-3cm. They are virtually absent from open coast beaches where mobile, well-sorted sands are inhabited by a variety of other bivalve species collectively known as surf clams. Littleneck clams are also absent from excessively muddy sediments (Irwin, 1999).

14.2 They are suspension feeders meaning they feed by straining suspended matter and food particles from water.

14.3 Sexes are separate and maturity appears to be a function of size not age (~18mm shell length).

14.4 Clams broadcast spawn over an extended summer-autumn season and their planktonic larval stage lasts approx. 3 weeks after fertilisation. Significant depression of larval settlement has been recorded for areas of otherwise suitable substrate from which all live cockles have been removed. This suggests the presence of some conditioning factor as some population of adults seems to be required to stimulate settlement of spat.

14.5 Natural mortality occurs from predation (birds, crabs & whelks) and also being smothered by sediments during storms or strong tides (Ministry of Fisheries, 2008)

IMPACTS OF SEDIMENT DEPOSITION ON CLAMS

15. The levels of sediment deposition modelled by Bell et al. (2009) most probably will have adverse and long lasting impacts on the ecologically significant clam beds within the Otago Harbour. This has serious implications for the ongoing viability of Southern Clams Ltd research and potential future harvesting.
16. Table 2 outlines the general effects of sedimentation on macrofauna. James et al. (2009) also point out that suspension feeders are particularly vulnerable to increased sediment levels and persistent high turbidities can result in changes in species assemblages from dominance by suspension feeder fauna to ones dominated by deposit feeders. This may then take years to revert back to the original species assemblage and decades to return to a similar biomass.

Table 1: Direct effects of sudden increases in sedimentation on resident macrofauna (from Norkko et al., 1999)

Smothering of sediment surface	Turns underlying sediments anaerobic
	Suffocates organisms that cannot climb through deposited layer
	Makes surface sediments unsuitable for recruitment
	Removes productivity by phytobenthos
	Changes conditions for epibenthos
Changes in sediment particle-size	Influences size and type of particles available for deposit/suspension feeders
	Changes sediment porosity and sediment stability thus influencing biogeochemical fluxes
	Changes suitability for surfaces for recruitment
	Influences rates of animal movement and bioturbation
	Clogs feeding structures of suspension feeders
Changes in water-column turbidity	Limits light penetration affecting primary productivity of phytobenthos
Changes in sediment food quality	Depends on source and history of sediments – but sub-surface sediments with a short transition time to the estuary will lower food quality

17. Sediment deposition or burial can smother existing shellfish communities and alter the habitat from the preferred sand to silt, resulting in reduced densities or complete loss of populations (James et al. 2009).
18. Some of the areas most affected by deposition are the banks adjacent to the areas with the highest clay and silt loadings. These are the 'middle banks' on either side of Quarantine Island, Areas 16, 18 and 20, and correspond to SCL research sites 1804 and 1805.
19. No estimate of resuspension is taken into consideration throughout the deposition modelling (POL, 2010). Areas experiencing high turbidity through wind/wave exposure such as Areas 16, 20 and 18 will experience resuspension of sediment, and Hewitt and Norkko (2007) found that this was more detrimental to Austrovenus than those in areas which were relatively sheltered. Therefore, Austrovenus within areas receiving large amounts of sediment deposition (i.e. Areas 16 and 18 in particular) that also experience high turbidity from wind/wave action are likely to be more stressed and show greater sensitivity than if solely affected by sedimentation.
20. The sand and silt depositions are treated as separate entities up until Table 7.6 (Bell et al. 2009) where they are then added together. In relation to effects on the clam bed sites the silt and clay content of the deposition is of larger concern than the sand and by amalgamating these two sediment types confidence in the stated averages is further reduced.
21. The total predicted average deposition of sediment is predicted to be over 5.6 mm in 10% of Area 16 (21 ha) and over 15 mm in 1% of the area (2 ha) (Bell et al. 2009).
22. Significant deposition (over 3mm) of silt and clay-like sediments has been found to negatively affect bivalves over long term periods, with negative effects increasing with the depth of deposited sediment (Norkko et al. 1999; Berkenbusch et al. 2002; Norkko et al. 2002b; Anderson et al. 2004; Lohrer et al. 2004; Norkko et al. 2006)

23. Norkko et al. (1999) found that adult Austrovenus were unable to surface through clay/silt layers of 3cm, 6cm or 9cm and slow reburial rates were also apparent with clear differences becoming obvious after 6 days

23.1 Also after 6 days many of the affected Austrovenus exhibited bivalve stress response and subsequently made them more susceptible to increased predation and sublethal effects.

23.2 Within 7 days Austrovenus mortality was 100% in all three different plots and at higher temperatures (above the 11 degrees Celsius used in this study) the negative response of Austrovenus to the sediment layer would be even more rapid as the metabolic rates of the animal increases with temperature.

23.3 120 days after the initial sediment deposition, complete recovery had still not occurred within the 3 plots.

23.4 Repeated depositional events were found to do more damage than single ones.

24. The dredging in some areas will exceed an 80mm deposition layer near SCL Research Site 1804 which may, according to Norkko et al. (1999), result in a significant mortality rate of large Austrovenus. Bell et al. (2009) comments that erosion of deposited material over the dredging period will decrease the total deposition, however, Norkko et al. (2006) found that when deposited layers of clay exceeded 7mm minimal erosion was observed over a 10-day period.

25. The recovery of disturbed habitats and benthic communities from excess sediment deposition has been found to take longer within coarse sediment habitats and for longer lived benthic species, such as clams (Newell et al. 1998).

26. Recovery often depends on larval re-colonisation (from the water column – which will be adversely affected by the increased SSC levels due to dredging) and can take up to 10 years for shell/sand habitats (Newell et al. 1998).

SUMMARY OF THE EFFECTS OF SEDIMENTATION ON CLAMS

27. The following effects of sedimentation;

    27.1 Reduced Austrovenus growth rates and decreased condition,

    27.2 Changes in macrofaunal assemblages,

    27.3 Smothering, slower reburial rates & increased stress responses,

    27.4 Increases in predators & greater vulnerability to predation, and

    27.5 Slower recolonisation;

    have been reported within the scientific reports referred to. These represent devastating consequences to the ecologically important Austrovenus beds within the Otago Harbour and could destroy Southern Clams Ltd ability to continue their research within this area.

28. The majority of sedimentation studies focus on clay and silt (Norkko et al., 1999; Berkenbusch et al., 2002; Norkko et al., 2002a; Norkko et al., 2002b; Anderson et al., 2004; Lohrer et al., 2004; Norkko et al., 2006) as these sediment types are most commonly deposited in significant amounts and are known to adversely affect benthic fauna.

29. The results from these studies are still pertinent to the dredging programme however for a number of reasons;

    29.1 They document the effects of various depths of sediments on suspension feeders which range from increased stress responses to mortality

    29.2 Port Otago Ltd. (2010) repeatedly disregards any adverse effects occurring to suspension feeding bivalves (and other benthos) due to the increased sedimentation caused by the proposed dredging project

30. As a consequence of this there is little credible research on the effects of their project on the fauna of the Otago Harbour. Therefore the afore-mentioned studies are one of the only benchmarks from which potential impacts can be assessed.

MODELLING OF SUSPENDED SEDIMENTS

31. The range of SSCs predicted by Bell et al. (2009) within the SCL sites 1804 & 1805 have been found to have adverse effects on clam species, ranging from minor effects such as affecting feeding rates to mortality of entire clam beds (Bricelj & Malouf 1984; Bricelj et al. 1984; Hewitt et al. 2001; Norkko et al. 2006; Hewitt & Norkko 2007)

32. Figure 1 is an example of the predicted SSC levels over a 14 day period from the Basin East discharge source; this is 1 of the 5 discharge point sources. Average SSC is modelled to be anywhere between 2-500 mg/l within both SCL research sites.

33. Figure 2 shows SSC levels above 1000mg/l within SCL site 1804 over a 14 day period. This level of sediment concentration within an area that potentially has the largest biomass of Austrovenus in NZ is not acknowledged within any of POL's supporting documents

34. Southern Clams Ltd. has consent and quota to remove shellfish from the Otago Harbour and represents an economically important business to Dunedin. However, attempting to interpret the levels of SSCs within their well researched sites from these images is extremely difficult. There can therefore, be little confidence in the fact that these ecologically important sites have been considered and assessed by POL.

Comment [BB1]: Is this better Roger?

35. All SSCs are given as averages over the water depth range (mid-tide to seabed). However as sediments are discharged at depth and they preferentially settle the SSC will be distributed unevenly through the water column resulting in much higher-than-the-average SSC estimate near the seabed (James et al., 2009), where it would have the largest impacts on the Austrovenus beds.

36. The re-suspension of sediments is not taken into account during the estimated modelling of SSCs within the Otago Harbour. Areas which are exposed and receive significant wind/wave action (such as SCL sites 1804 and 1805) will obviously incur elevated levels of suspended sediments and again this may be over a long period of time due to natural weather elements. However, the actual levels are unknown due to the insufficient preliminary work carried out by Port Otago Ltd. This could lead to a gross

underestimation of concentrations and duration, and therefore the effects on the surrounding marine life.

37. Background SSC levels are omitted from the modelling, however these will add to the elevated levels and due to the increased turbidity from the dredging may remain in the water column longer than they would naturally. This would be an indirect effect of the dredging that hasn't been taken into account within the modelling. There should be an assessment of plume dispersion in conjunction with storm events as well as the associated 'normal' conditions i.e. tides and prevailing winds; that the current modelling has been based on.
38. John Jillett (see written statement in Appendices) observed that during the previous capital dredging in 1977, which removed less than half of what is currently being proposed, there was an approximate 10-fold increase in the quantity of suspended sediment during stormy weather and that previous storm conditions came to apply during fine weather. This was far and above what the 'expected' levels would be.
39. The preliminary use of the backhoe or grab dredge for the first 9 metres (below chart datum) of the Swinging Area (POL. 2010) is not modelled. Instead the use of the small trailing suction dredge 'New Era' is considered. This again shows discrepancies within the project and a lack of coherent information within the resource consent application.
40. The claim that the marine environs is already altered therefore increased dredging would do little damage is a badly informed comment (POL., 2010) It has simply been assumed that there are little or no adverse effects on the flora and fauna of the Otago Harbour. John Jillett's historical evidence (see Appendices) proves otherwise and it would be pertinent to learn from previous mistaken assumptions regarding the resilience of the flora and fauna in the Otago Harbour.
41. Therefore when assessing the potential ecological impacts of Port Otago Ltd's (POL) Next Generation dredging project they should be considered alongside the known impacts of the current dredging regime, with regard to sedimentation and suspended sediment levels. Further information

regarding the current dredging programme should be realised prior to further alterations occurring.

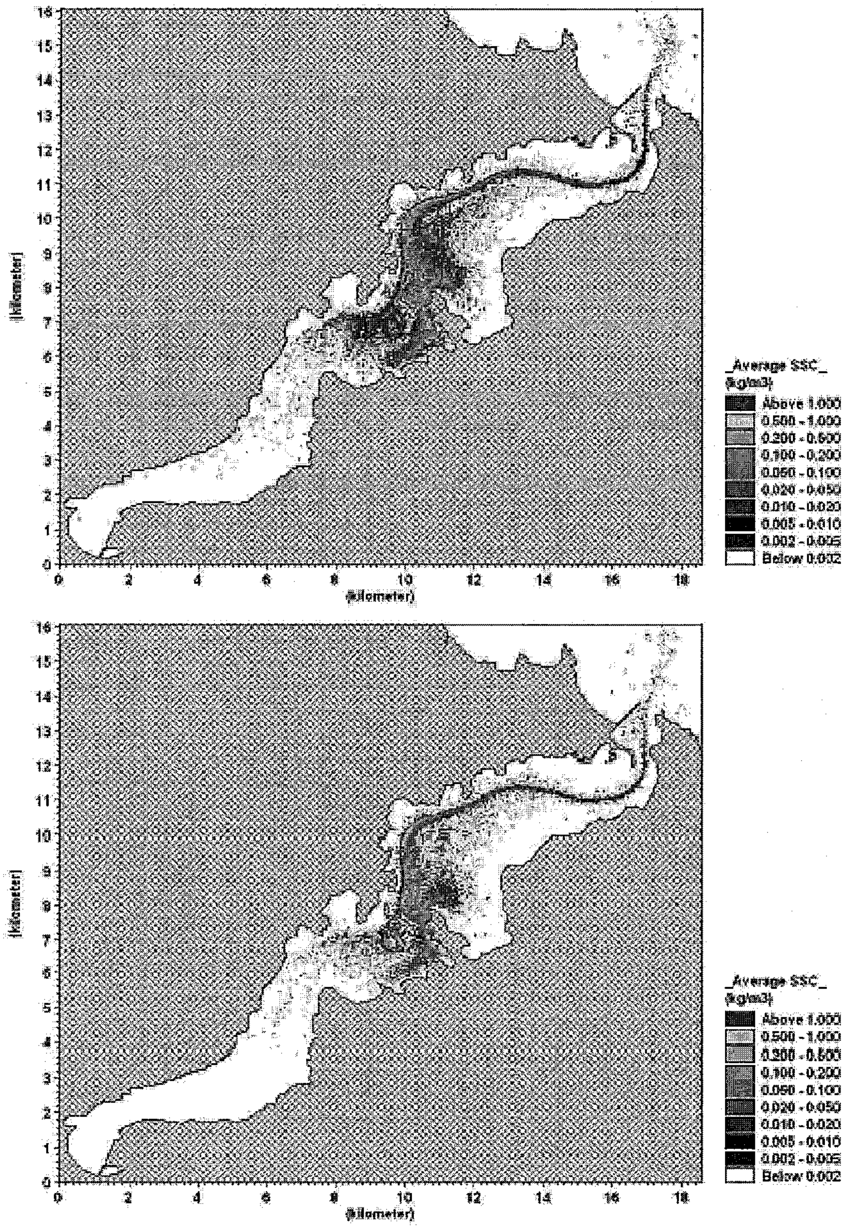

Figure 1: 14 day average SSC in kg/m3 for a Basin-east discharge source for predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM) (from Bell et al. 2009).

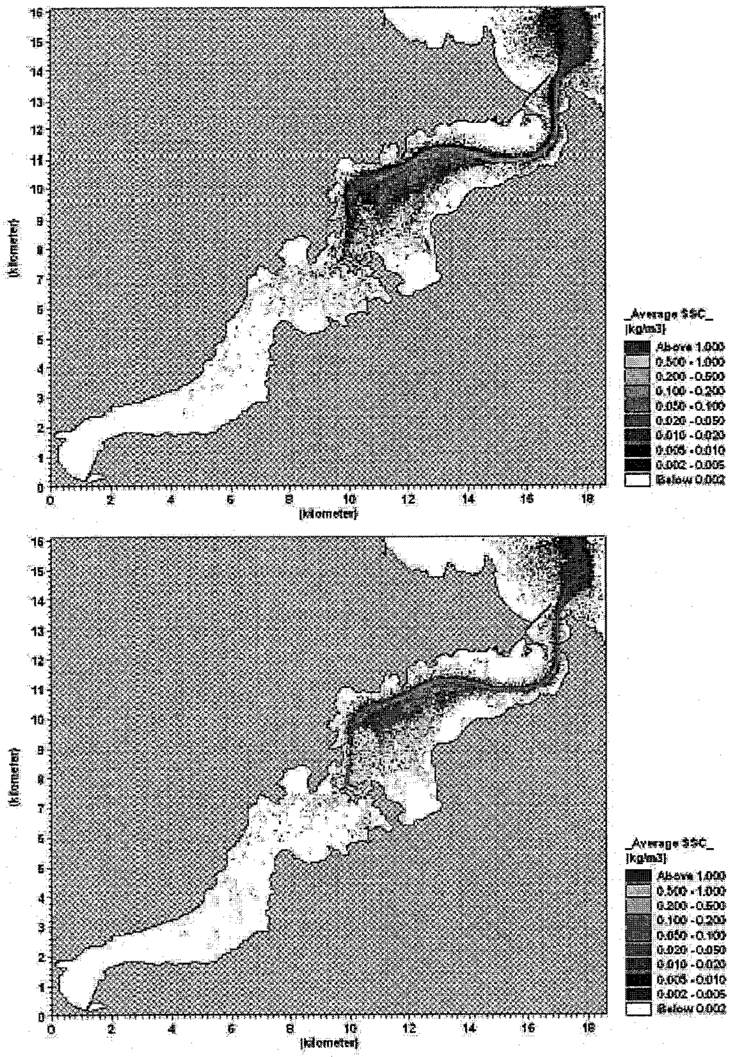

Figure 2: 14 day average SSC in kg/m3 for a Harington Bend discharge source for predominantly-silt claims (TOP) and predominantly-sand claims (BOTTOM) (from Bell et al. 2009).

THE EFFECTS OF SUSPENDED SEDIMENTS ON CLAMS

42. Hewitt & Norkko (2007) found that Austrovenus biomass responses measured over three months in the field suggested increased sensitivity to suspended sediment concentrations. A negative trend was observed with regard to Austrovenus' biological responses with clear changes in both clearance and filtration rates occurring for this species. Responses to

suspended sediment concentrations observed on the 2nd day were markedly different from those on the 14th day. This negative trend may well have continued had the experiment lasted longer.

43. Hewitt and Norkko (2007) also reported that when high suspended sediment levels (100mg/l) occur for >25% of the time (19 days), regardless of how many events are contained therein, there is not sufficient time to recover condition and biomass is lost. This is important as Port Otago propose to dredge 24 hours a day, 7 days a week within each area.

44. Greater biological changes would be expected to be observed as durations increase from small to medium time scales than from medium to large time scales (Hewitt & Norkko, 2007). Therefore it could be assumed that SSC threshold levels for Austrovenus will reduce over time as it becomes more sensitive to the stressor and any initial benefit would soon disappear (Figure 3).

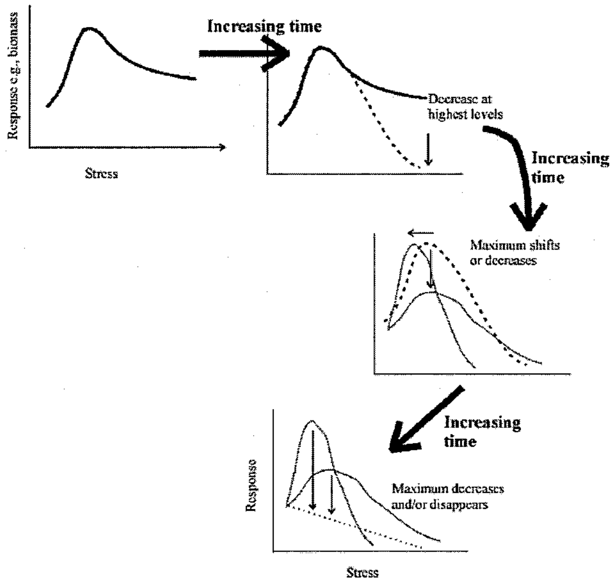

Figure 3: Conceptual model of feeding or biomass response to increasing time scale of stress (from Hewitt & Norkko, 2007).

45. Hewitt et al. (2001) report that concentration and duration of suspended sediments together produces adverse effects on Austrovenus. Results

from their study found condition decreased after 450mg/L over a 9 day period, suggesting that Austrovenus would have difficulties coping with SSC higher than 400mg/L over long periods (14 days).

46. Hewitt et al. (2001) also detected adverse effects from high SSCs on adult Austrovenus reproductive states which would have significant implications on the ability of Austrovenus to recruit within the harbour. This study highlights that suspension-feeding bivalves respond to increases in SSCs in a measurable way, therefore their use as a bio-indicator of suspended sediment change and their inclusion in long-term monitoring or impact assessment programmes was recommended.
47. Significant growth reduction in juvenile clams has been observed at 44 mg/L of SSC of natural silt over a 3 week period (Bricelj et al., 1984). The same study also found the condition of the clams was also significantly reduced at this SSC level.
48. The thought that clams benefited from a silt addition to their algal diet was found to be false for this species and Bricelj et al. (1984) even went so far as to state that other species (such as mussels, surf clams and oysters) would be better suited for culturing efforts within turbid waters as hard clams struggled to cope with long exposures to a relatively low silt-based SSC.
49. Turner and Miller (1991) discovered that during a simulated storm event (SSC 193mg/L) lasting only 1.5 days the shell growth of the hard clams (20 mm) decreased by 38% compared to a non-storm period despite phytoplankton levels being high. Significantly more pseudofaeces were produced which also may indicate food dilution occurring, which would have significant consequences for the clams over a prolonged duration.
50. A 90% decrease in shell and tissue growth was observed in juvenile hard clams when affected by suspended clay sediments. This is a significant biological response to a stressor and further results suggested that repeated clay applications in the field are more detrimental to clams in high-energy environments than those favouring sedimentation. This is due to a prolonged in situ re-suspension of sediments and the 'food

dilution effect' whereby increased SSCs cause a reduction in clearance rates and thus reduce algal ingestion rates (Archambault et al., 2004).

51. The fact that larval and juvenile clam's exhibit greater sensitivity to elevated SSCs than adults (Archambault et al. 2004) has serious implications for the ongoing viability of Southern Clams Ltd research and potential future harvesting.

TURBIDITY & SUSPENDED SEDIMENT CONCENTRATIONS

52. Ellison et al. (2010) found that the Pearsons Correlation test indicated a strong positive relationship between marine turbidity (NTU) and SSCs.
53. May et al. (2003) found that ongoing levels of turbidity and high SSCs (above 100mg/l) would negatively affect phytoplankton levels. When SSCs of 300mg/l were reached phytoplankton died off. Fetch was also a contributing factor as it increases the potential for re-suspending sediment and creating an increased turbid environment.
54. This has implications for all biota within Otago Harbour as phytoplankton provide a large percentage of the food source within this environment.
55. There has been no sufficient baseline assessment of NTUs within the Otago Harbour and it appears that there has been very little regard for the ecological impact that this level of turbidity may have on the clam beds within this area. The 3 month turbidity data set compiled by Port Otago in November 2008 found the highest NTU and SSC during a storm event to be 6.44 and 6.5mg/l respectively. Although every environment is unique the general correlation between NTU & SSC has been found to be 1:2 or greater (Trimarchi & Keane, 2007) therefore I would suggest these readings be taken again over a longer period of time.
56. In order to assess any impacts it would be pertinent to take turbidity and SSC readings for at least 12 months prior to any increase in dredging in order to create a sound correlation between these two important environmental indicators. Without these data sets it is difficult to assess any impacts on the flora and fauna adequately.

INVERTEBRATE STRESS INDEX

57. Newcombe and MacDonald (1991) addressed the need for resource managers to be able to better predict the effects of suspended sediments on aquatic fish and invertebrates. Through a review of over 70 scientific papers a database of effects was compiled (Table 1). A regression analysis indicated that concentration alone is a poor indicator of suspended sediment effects, whereas concentration AND duration of exposure together provided a much greater indicator. A species stress index was subsequently created from this review.
58. It should be pointed out that this study focussed on Aquatic biota rather than marine biota. However, within the invertebrates the feeding mechanisms are similar (i.e. suspension feeders) therefore the effects on aquatic invertebrates can be translated to give an idea of what would happen within the marine environment. The key point of this index is that it is not just a function of concentration, but of duration also.

Table 2: Ranking of effects of suspended sediments on fish & aquatic life (from Newcombe & MacDonald, 1991)

RANK	DESCRIPTION OF EFFECT (SEVERITY)
1	Increased coughing rate
2	Alarm reaction, avoidance reaction
3	Avoidance response, abandonment of cover
4	Reduction in feeding rates
5	Impaired homing
6	Poor condition of organism
7	Moderate habitat degradation
8	Physiological stress and histological changes
9	Reduction in growth rates
10	0-20% mortality
11	>20-40% mortality
12	>40-60% mortality, severe habitat degradation
13	>60-80% mortality
14	>80-100% mortality

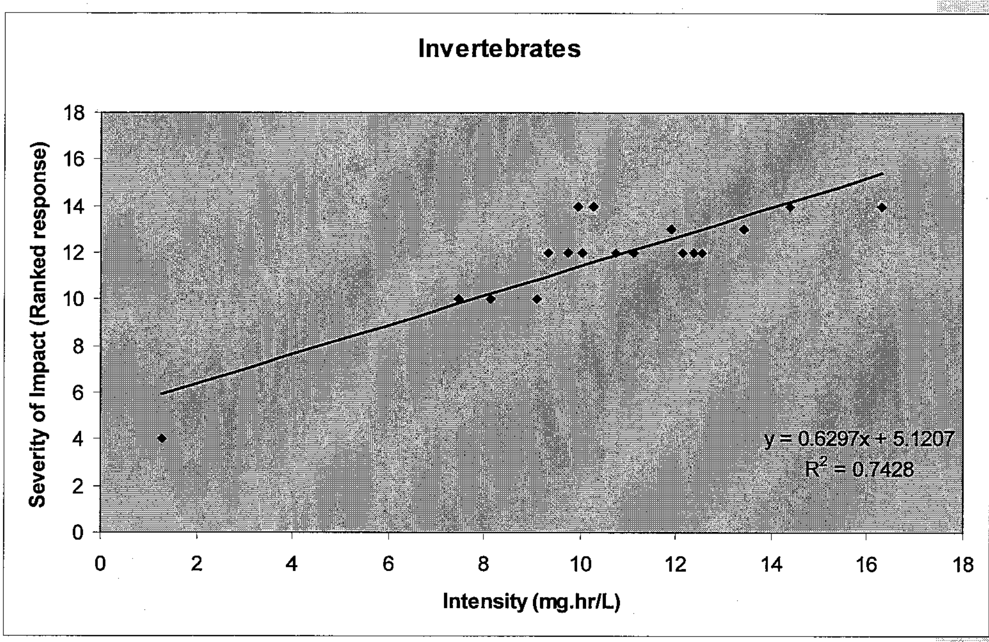

Figure 4: Relationship between loge (ln) of suspended sediment intensity and severity of effects on aquatic invertebrates. Severity of effect = 0.6297 loge intensity + 5.1207. R2 = 0.7428. *N* = 18. Intensity is concentration (mg/l) x duration of exposure (hr) (adapted from Newcombe & MacDonald 1991).

59. Using table 7.4 from Bell et al. (2009) the severity was calculated of each dredging event within 3 'harbour sub-areas' that cover SCL sites 1804 (Area 16) and 1805 (Areas 18 and 20). Area 1 represents the main dredging channel, Back Beach in Port Chalmers, the north side of Quarantine Island and the Portobello Aquariums' jetty.

59.1 The results were then amalgamated from the 5 separate dredging sites to illustrate the overall time and effect from the capital dredging stage.

59.2 One of the reported time frames of capital dredging is 120 days so this was divided by 5 (5 sites) indicating that perhaps we could expect each area to be dredged for a period of 24 days.

59.3 Only the percentage of time for 150mg/l, 300mg/l and 500mg/l was calculated therefore giving us a conservative estimate.

60. The results (Figure 5) indicated that based on the estimated levels of SSCs an invertebrate mortality rate of 20-60% could be expected over the

different sites. Severe habitat degradation could also be expected within Areas 18 and 1. Again, these effects appear to be significantly more detrimental to the Otago Harbours' flora and fauna than Port Otago has reported.

61. These figures are not absolute by any means. However, this stress index and measure of severity does provide us with a convenient tool for predicting effects for a pollution episode of known intensity. So far this is the best estimate of the ecological damage which could occur as a result of capital dredging. Keep in mind that the marine environs is an extremely complex environment and resource managers are constantly discovering just how interconnected the entire food web is, therefore fish and other species would also struggle to survive if their food sources are.

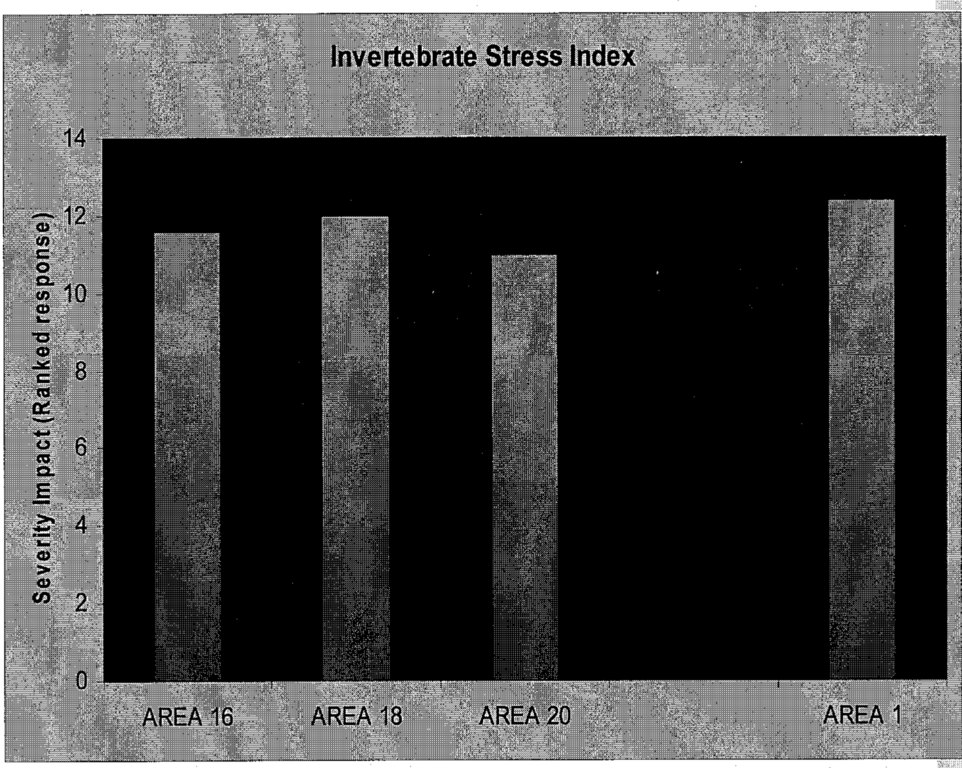

Figure 5: Severity impact on benthic invertebrates from the capital dredging stage of Project Next Generation based on Bell et al.'s (2009) modelled suspended sediment concentrations (mg/l) and duration (hrs). Concentrations 150mg/l, 300mg/l & 500mg/l are used over the 5 discharge source areas.

SUMMARY OF SUSPENDED SEDIMENT IMPACTS ON CLAMS

62. The levels of SSC estimated by Bell et al. (2009) will have detrimental effects on the substantial clam beds based not only on concentration but on duration also.
63. These adverse effects could potentially lead to the deterioration of the entire ecosystem through the removal of a key species.
64. As John Jillett stated it took 10-12 years before the harbour improved to the pre-dredging state, unfortunately the loss of the only significant Pipi (*Paphies australis*) was permanent.
65. Baseline research regarding turbidities and SSC levels within the harbour is not adequate to base impact assessments on. These important indicators should be monitored for 12 months prior to any increase in dredging occurs in order to cover seasonality changes.
66. The invertebrate stress index (from Newcombe & MacDonald, 1991) does not provide concrete values of severity however it does provide us with a useful assessment of what may happen. Given the findings of significant mortality to benthic invertebrates SCL has serious reservations about the quality of research documents presented by POL.

LACK OF TIMEFRAME WITHIN PROJECT NEXT GENERATION

67. The resource consent and AEE document prepared by POL does not adequately state their proposed programme of work over any given time period. There is no summary of when certain stages of the channel upgrading will take place despite the exact amount of material to be moved being known (i.e. 7.2 million m3).
68. The relevance of any modelling carried out by POL is therefore questionable due to the lack of one actual scenario being stipulated, or a variety of scenarios being modelled in their entirety.
69. As is mentioned previously the marine environment is dynamic, complex and interconnected. Therefore, regardless of which 'stage' the dredging is at there will be compounding effects of an unknown period of time.

Trimarchi & Keane (2007) found in the Port of Hay Point that a 'short and sharp' approach to dredging was less damaging on the surrounding environs. This would also agree with Hewitt & Norkko's (2007) findings that over time a species response to a stressor declines. However unfortunately 'short and sharp' in dredging terms would still have significant impacts and for the proposed amount of sediment to be removed it could never be short enough to not incur significantly detrimental effects on the Otago Harbour.

70. Timeframes given by POL vary within each of the three stages.

70.1 Preliminary dredging is estimated to take between 1 and 10 years. How can ecological impacts be assessed with such a large degree of uncertainty?

70.2 Second and third stage dredging is stated to take 120 days as is used in the modelling parameters, yet 6-8 months (180-240 days) of intensive dredging was cited in Port Otago's Resource Consent Application (POL., 2010). Again showing a major lack of coherent information within the resource consent application.

CONCLUSION

71. Currently the SSC and sediment deposition levels estimated by POL pose considerable threats to both the validity of the 5 year research consent granted to Southern Clams Ltd within the Otago Harbour and the growth, recruitment and biomass of the substantial cockle beds within the affected area.

72. As one of the largest resource users within the Otago Harbour, SCL would expect to have had specific ecological and biological impacts assessed in relation to their operational areas and species.

73. Instead, SCL have been largely ignored with minimal consultation throughout the entire process.

74. Duration of dredging needs to be better addressed by POL and modelling should take into consideration a variety of scenarios which include;

74.1 The compounding effects of all 3 stages of dredging

74.2 Storm events and background SSCs

74.3 The resuspension of SSCs and the net influx of the harbour

75. These concerns represent potential detrimental effects for both the overall ecology of the Otago Harbour and the economy of Dunedin through the probable limitation of a successful and well-managed fishery within the harbour and should therefore be addressed and mitigated prior to any resource consent being given.

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APPENDICES

A) Map showing SCL research sites 1804 and 1805 within the Otago Harbour.

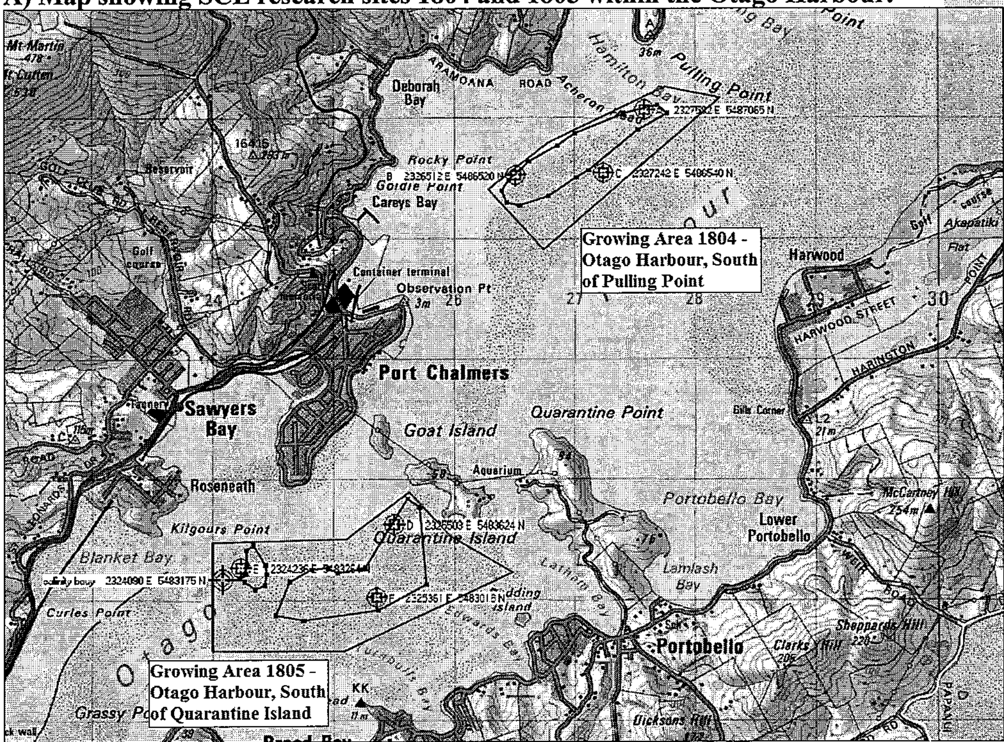

Figure 6: Southern Clams Ltd research sites within the Otago Harbour

B) Written statement by John Jillett regarding the effects of historical dredging in the Otago Harbour

Statement On The Historic Ecological Effects Of Capital Dredging In Otago Harbour, 1977

My name is John Jillett, former director of the Portobello Marine Laboratory (1974 – 1993). I was a member of academic staff of the Marine Laboratory, Department of Zoology and later Department of Marine Science at the University of Otago for over 30 years, from 1966 until my retirement in 1997. I have continued to maintain my interest in marine ecology, following on from my own research and the supervision of many Otago postgraduate students through my career.

I have been asked to outline my recollections of environmental effects resulting from capital dredging undertaken for the development of Port Chalmers as a container port in about 1977. There is no doubt in my mind that this dredging work had by far the greatest deleterious impact on the ecological health of the Otago Harbour in my whole 45-year experience at Otago University.

Capital dredging operations, especially the cutting of the new turning basin, necessitated the disturbance of fine sediments and resulted in the suspension over a prolonged period of large quantities of fine silts and clays in the water column. These fine suspended sediments became widely distributed throughout the harbour by tidal currents. During these operations the display tanks in the public aquarium at Portobello generally became so cloudy it was not possible to see the back walls. Settlement of suspended sediments necessitated a greatly increased onerous workload to keep the tanks clean. As a result the seawater supply to the laboratory and aquarium has since been routinely cleaned by sand filtration, the filters having been installed in the mid-1980s.

Two research projects in particular, being undertaken at the Portobello Marine Laboratory, bridged the 1977 capital dredging work and resulted in direct and indirect observations of its ecological effects. One was a postdoctoral study of grazing interactions and competition between intertidal grazing molluscs and algae on open coast and harbour rocky shores. The second study concerned growth, reproduction and feeding of Bluff oysters suspended from a raft in harbour waters off the marine laboratory.

In the study of intertidal grazer interactions, the spread of a continuous mantle of fine silt and clay over intertidal rock surfaces completely sabotaged the objectives of the study and many of the grazing molluscs originally present died, apparently through starvation. Their normal food is derived from microscopic films of algae that were smothered by the sediment mantle.

In the oyster study several seawater parameters were being monitored, these included suspended sediments, phytoplankton standing crops and nutrients in harbour waters. The monitoring programme was extended to measure the quantities of suspended sediments on a more frequent basis. The approximate values for suspended sediments in harbour waters during the 1977 dredging operations were as follows:

	Normal Values	**Values During Dredging**
Calm conditions	4 – 8 g.m^{-3}	18 – 25 g.m^{-3}
Storm Conditions	18 – 25 g.m^{-3}	200 –350 g.m-3

In other words the previous storm conditions came to apply during fine weather and there was something like a 10-fold increase in the quantity of suspended sediment during stormy weather.

The effects of dredging included the smothering of benthic organisms, the loss of condition through starvation of filter feeders such as sponges, ascidians and bivalves. During this period the only significant population of pipi (*Paphies australis*) within the harbour disappeared. Macroalgae also suffered through being cloaked with sediment that reduced the amount of light available for photosynthesis.

These effects were long-lasting and it took 10 to 12 years, that is until the mid-1980s, before harbour ecology improved to the pre-dredging state. Since then the general ecological health of the harbour has further improved to a better condition than at any previous time in my experience.

There is no doubt in my mind that "incremental" dredging, undertaken progressively over a prolonged period, is much more environmentally sympathetic than intense capital dredging with a short time frame.

Note: The original data gathered on suspended sediment disappeared from the marine laboratory files many years ago and subsequent efforts to locate them have failed. Therefore I have not been able to be exactly precise about the quantities and timing.

John Jillett ONZM MSc PhD

51 Every Street
Dunedin 9013

7 April, 2011