Research Proposal

Investigations into the Ecosystem Effects of Commercial Harvest of Clams (*Austrovenus stutchburyi*) in Otago Harbour (COC3), Otago

prepared by

Ryder Consulting

January 2009

ryderconsulting
ecology + planning + project management

Research Proposal

Investigations into the Feasibility of Commercial Harvest of Clams (*Austrovenus stutchburyi*) in Otago Harbour (COC3), Otago

prepared by

Dr Brian Stewart

Ryder Consulting

January 2009

Ryder Consulting Ltd.
PO Box 1023
Dunedin
New Zealand
Ph: 03 477 2113
Fax: 03 477 3119

Table of Contents

1. Introduction

Otago Harbour contains what is probably the biggest and most productive resource of clams (*Austrovenus stutchburyi*) in New Zealand (Breen *et al*. 1999). At around 70,000t total biomass estimate, it represents a significant shellfish resource. Since 1988 Southern Clams Ltd has maintained that the commercial harvest of clams, specifically from the middle banks of the Harbour, is a natural and sustainable use of the resource. Furthermore, a sustainably managed clam fishery could provide long-term social and economic benefits to the local area.

Otago Harbour was closed for commercial harvesting of shellfish, under a regulation passed in the 1960's. The reason given at the time was concern over the sanitary status of the shellfish growing waters. Since that time all sewage outfalls into the harbour have been closed and polluting industrial sources no longer discharge into the harbour's waters.

Otago Harbour currently remains closed, but the reason for its closure is, according to Southern Clams Ltd, no longer valid. Following more than two year's shellfish sanitation research by Southern Clams Ltd, it is clear that the growing waters, and shellfish on the middle banks of the harbour, are of better bacteriological quality than either of the two areas currently certified (Waitati and Papanui Inlets). Due to one of these historical harvest areas (Papanui Inlet) being currently closed because of high bacteriological levels, all harvesting is presently from Waitati Inlet, thus leaving the company with an insecure supply base, and no alternative areas for harvest in the event of closure.

Southern Clams Ltd's declared intention to harvest in the Harbour dates back to 1998, and has recently been met with strong concern from some parties. Critical opposition to harvesting clams (cockles) in Otago Harbour has focused on the impact of harvesting, including effects on birds and fish. Critics state that while the clam harvesting techniques and management regimes proposed are the same as the company's practices in two well developed commercial harvest areas nearby, the Harbour proposal is neither on the same scale, nor is it in the same habitat. Consequently it is argued that ecological effects may differ and the studies carried out on the impact of harvesting undertaken on other areas will not necessarily be applicable in the Harbour. There is a sizeable body of information on clam fisheries in New Zealand, (e.g. Larcombe 1971; Martin 1984; Dobbinson *et al*. 1989; Irwin 1999, 2004; Stewart 2008) and overseas (e.g. McLaughlin *et al*. 2007; Kraan *et al*. 2007), and effects on associated fauna (e.g. Schmechel 2001; Van Gils *et al*. 2006) and flora (e.g. Reed and Hovel 2006). However, none of these papers specifically addresses the

situation encountered in Otago Harbour. It should be noted that the harvest methods used by Southern Clams Ltd (body dredge) are generally not used elsewhere, so research findings from other locales may have little relevance to the Otago situation. Breen *et al*. (1999) carried out investigations into clam biomass and associated ecosystems on a number of Otago Inlets, including the Otago harbour, some 10 years ago. They calculated the recruited biomass of clams (i.e. ≥30mm) on the middle banks of the Harbour to be in the order of 8091t and 5546t for beds 1804 and 1805 respectively (Breen *et al*. 1999), but the information is in need of updating to determine it's continued relevance.

To address these concerns Southern Clams Ltd has commissioned the following experiments and/or studies.

2. Infaunal Community and Biomass Surveys

2.1 Overview

The ultimate goal of this experiment is to measure and record the ecological impact of commercial scale harvesting in Otago Harbour over a long enough time-frame to discern trends, and determine if harvesting is sustainable from both a commercial and ecological point of view. Much of this involves replicating work (i.e. biomass and infaunal response surveys) done in other harvested areas in Otago over the past 25 years. This experiment differs from previous research, however, in proposing a "macro" scale experiment where treatment is designed to have a measurable impact over a significant area, with a focus on intra-specific interactions and effects.

To achieve this goal the impact of commercial harvesting, using currently practiced methods, is to be monitored for the target species (*Austrovenus stutchburyi*), for the associated infauna, and for the substrate in a phased experiment. The measurements and monitoring are to take place over five years, covering a large part of two intertidal banks. It should be pointed out here that the harvestable area will not cover the full areal extent of either bank as some portions will simply be not suitable for harvest, will be *Zostera* beds, or will be not suitable *Austrovenus* habitat. Overall, the beds under investigation comprise 181ha, or around 6.5% of the intertidal area of Otago Harbour. Note that the biomass calculated for beds 1804 and 1805 by Breen *et al*. (1999) is for a larger overall area (184ha on bed 1804 and 142ha on bed 1805) than that proposed here. The experimental design involves removing approximately 50% of the initial clam biomass from the treatment (harvested) area, over a five year time-frame. Phases II and III will not commence until

significant recovery of the infaunal communities has been established following the Phase I or Phase II harvesting experiment, as applicable.

2.2 Aims

To assess the ecology of beds 1804 and 1805 and determine how clam harvesting operations affect infaunal abundance and diversity, and substrate structure, over a long enough timeframe to determine significant trends.

2.3 Evaluation Criteria

Changes to infaunal communities should show no significant difference ($p < 0.05$) among treatment and control sites after a recovery period of 38 - 80days. Clam biomass in treatment areas will not be reduced to <65% of virgin biomass over the treatment areas at the end of each phase.

2.4 Methods

The area to be surveyed will be broken up into grids (Figures 1 and 2), the boundaries of which have been based on the following criteria:

Size: Are of a size sufficient to demonstrate broader impacts of disturbance and density reduction. i.e. preferably at least 300m wide bands. Controls are to be large enough to minimise boundary influences.

Biomass: That the control and treatment areas are similar in biomass and density of the target species.

Ecology: The control and treatment areas are similar ecologically. i.e. there are similar substrates, over a similar range of depths, with a similar range of current flow rates, containing similar ranges of both faunal and floral species, at similar densities.

The proposed grids align with grids used in the original resource survey, the methods for which are included in Appendix 1 for reference and comparison. The proposed spatial scale and time-frame for treatments are achievable using current methods and technology, as practiced by Southern Clams Ltd. GPS mapping and weight recording for every harvest are part of the companies usual stock management routine.

2.3.1 Phase I

For Phase I Southern Clams Ltd (SCL) will harvest five 100m x 50m rectangles (0.5ha blocks) on each of beds 1804 and 1805, in the locations as shown in Figures 1 and 2, sometime in February/March 2009. The Southern Clams harvesting crew will, at some point during the harvest of the 0.5ha blocks on bed 1804, harvest a single smaller 20m x 20m block randomly located within each half hectare block on successive days. In the following week, or as soon as practicable afterwards, the second bed (1805) would be harvested in the same way (i.e. ten 0.5ha blocks, each containing a 20m x 20m block, over both beds over a 10-14 day period) (Figure 3). The position of each 20m x 20m block (survey sites) would be noted using GPS and the centre of each block marked using a stake driven into the substrate. Co-ordinates will be mapped using the mapping program "Fugawi®" with co-ordinates being available throughout the experiment. A 0.5ha control plot will be left unharvested adjacent to each 0.5ha harvest plot (Figure 3). The harvest and control blocks will be aligned such that they straddle the border between treatment and control strips, as shown in Figure 3. There will be a 10m wide buffer left between harvest and control plots to minimize the possibility of harvest effects affecting control sample sites.

When harvesting of all of the 20m x 20m blocks on a single bed has been completed Ryder Consulting would be informed. At this point harvesting of each of the 0.5ha blocks would continue, with harvesting contiguous with the marked survey sites. Irwin (2004) found that infaunal communities appeared to fully recover within 30 days after clam harvesting. Based on this Ryder Consulting Ltd will survey all ten of the 20m x 20m treatment sites no less than 38 and no more than 48 days after harvesting has taken place.

Infaunal sampling

The infaunal sampling survey would comprise eight 180mm diameter x 200mm deep cores in each of the ten treatment areas (5 per bed) giving a total of 40 cores for the treatment area of each bed (Figure 3). Cores would be sieved using a 500μm Endicott® sieve and retained invertebrates, including clams, would be collected for identification, counting and weighing.

Substrate Sampling

For substrate analysis an additional two 80mm diameter x 200mm deep cores would be collected at each sampling site within each treatment and control area. Three 20mm thick subsamples (slices) of substrate (0-20mm depth, 90-110mm depth and 190-210mm depth) will be taken from each core for gain size analysis and organic content. Thus, 30 samples per treatment area per bed would be subjected to such analysis. Samples would be analysed as in the initial baseline survey (Stewart

2008). i.e. Substrate samples will be oven dried at 60˚C for 24 hours, then weighed to the nearest 0.001g. Dried sediment will then be sieved for 10 minutes on an Endicott sieve shaker using sieves with 2mm, 500μm, 250μm and 63μm mesh sizes. At the completion of shaking each fraction will be weighed to give a percentage of the original mass. Fractions will then be recombined, reweighed and ashed in a muffle furnace at 550˚C for four hours, then reweighed and the percentage loss on ashing calculated.

Figure 1. *Sanitation area 1804. Green squares denote Phase I with 0.5ha (within yellow borders) treatment and 0.5ha (within blue borders) as control. Remainder of yellow line yellow encloses Phases II and III. Blue outlined areas remain unharvested (control) for the duration of the experiment. The two harvest areas on this bed comprise 40ha.*

Biomass of clams and the five most significant other invertebrates would be calculated for each of the five treatment sites, as in Breen *et al*. (1999) and Stewart 2008 (see Appendix 1). Biomass and size frequency distribution of the various size classes of clams (2-<19mm, ≥19-<30mm, ≥30mm and ≥28mm) has been determined during the baseline survey (Stewart 2008), and will also be determined for the various phases of this experiment. Target CVs for biomass surveys are <10%. This will provide a comprehensive data set on clam size/frequency and will give an insight into recruitment over the duration of the experiment.

The survey of control sites would be conducted in the exact same manner as that outlined above for treatment sites. i.e. 40 control cores per bed for infaunal analysis and 30 control samples per bed for substrate analysis. As stated above, control sites would be located adjacent to treatment areas with an appropriate buffer between (Figure 3). Control half hectares would be identified using GPS and avoided in all future harvesting until the conclusion of Phase III of the experiment. As already stated, all co-ordinates will be recorded using "Fugawi®" and will be available for reference to harvesting crews.

Figure 2. *Sanitation area 1805. Green squares denote Phase I with 0.5ha (within yellow borders) treatment and 0.5ha (within blue borders) as control. Remainder of yellow line yellow encloses Phases II and III. Blue outlined areas remain unharvested (control) for the duration of the experiment. The three harvest areas on this bed comprise 49ha.*

The above survey protocol would mean that each of the sanitation areas could be surveyed in a single day. Samples would then be processed as quickly as possible and data from treatment and control sites will be analysed using a variety of uni- and multivariate techniques to determine significant difference in infaunal communities at treatment and control sites at the 95% confidence level. Analyses will include ANOSIM, SIMPER, and MDS, using Primer 5 (Clarke and Gorley 2001). To analyse changes in numbers of species and animal abundances pre- and post-harvest, univariate statistics (ANOVA) will be used. Diversity indices for each sample site will also be determined. Clam biomass data will be analysed to determine the effect of removal of *Austrovenus stutchburyi* from treatment areas and compared with control areas and baseline data. At the conclusion of the Phase I survey, and after data analysis, a report detailing the findings of that

survey will be prepared and presented to SCL and the Shellfish Working Group (SWG) at the Ministry of Fisheries as quickly as possible.

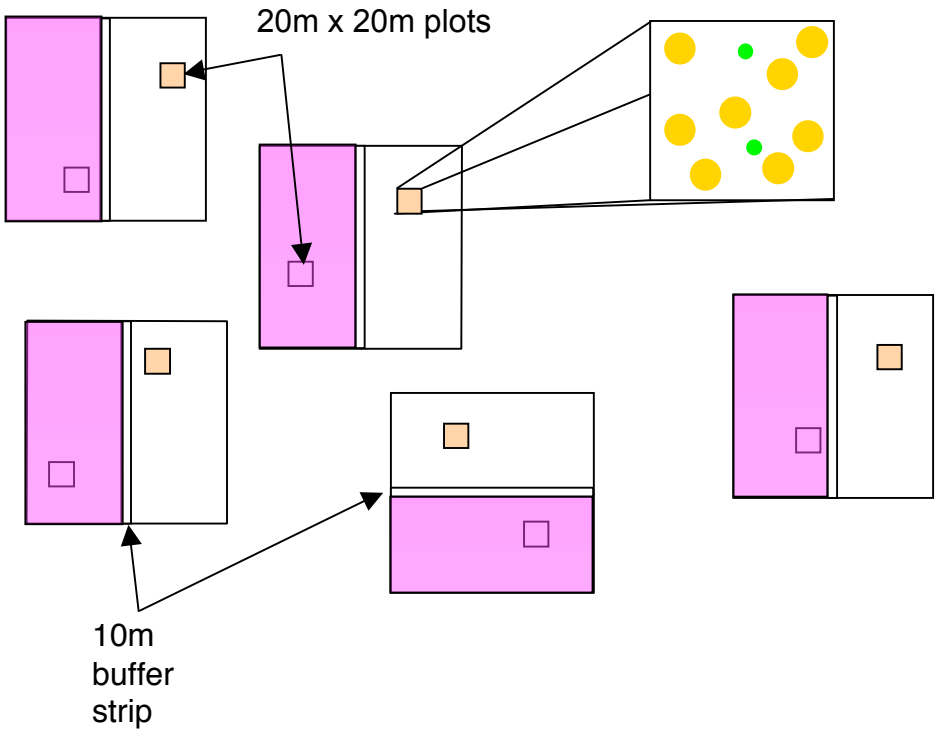

Figure 3. *Survey design for each sanitation area (bed). Each large block is 1ha comprising 0.5ha treatment area and 0.5ha control area (pink shading). Coloured squares indicate treatment plots harvested on successive days. Plain squares are control plots. In the magnified image at upper right orange dots indicate infaunal samples, green dot indicates substrate samples.* ***Note: Relationship of blocks to each other not to scale.***

Should infaunal differences among treatment and control sites be significant ($p < 0.05$) a second survey, as described above for the initial survey, will be carried out approximately 80 days after harvest and the data processed as before. Should differences among infaunal communities at treatment and control sites still be significant ($p < 0.05$) at the 80 day survey a third survey, as described above for the initial survey, will be carried out approximately 160 days after harvest and the data processed as before.

2.3.2 Phase II

Providing no significant adverse ecological effects are observed, and on advice from the SWG, the Ministry of Fisheries will permit Southern Clams to move to the next phase (Phase II) of this experimental harvest. This would entail harvesting an enlarged area on each bed such that after 3 years (late summer 2012) 25ha of each bed had been harvested. The aim at this stage will be to have removed 1800-2200t, or approximately 15% of the virgin biomass, of *Austrovenus*

stutchburyi. A survey, as described in Phase 1 (above), will be conducted at a time prescribed by the Ministry of Fisheries. Once again, infaunal survey data will be analysed and results presented to the SWG. At this stage bed morphology results and results of avifaunal surveys (see below) will also be presented. If biomass has not been reduced to <65% of virgin biomass of target species over the treatment sites, and differences among infaunal populations of treatment and control sites are not significant the Ministry of Fisheries may give approval for the experiment to move to Phase III.

2.3.3 Phase III

In Phase III the total treatment area will be enlarged such that by the end of five years (late summer 2014) approximately half of the harvestable area of each bed will have been subject to harvest. As already stated, the entire area of each bed may not necessarily be available for harvest. A survey, as described for Phases 1 and II (above), will be conducted at a time prescribed by the Ministry of Fisheries. In addition, a full biomass survey of the beds under investigation, as described in Stewart (2008), will be carried out during Phase III. At the conclusion of Phase III a report detailing the findings of all surveys will be prepared and presented to SCL and the SWG.

Half of the commercially harvested areas will remain untouched and act as controls. These control areas, outlined in blue in Figures 1 and 2, will have already been GPS mapped for future reference during Phase I. Thus, by the end of the experiment, and including the baseline survey, four surveys will have been carried out, three of which will have included a full clam biomass survey. This will allow the state of the beds and effects of harvesting over a large spatial area to be rigorously compared through a reasonably long (>5year) timeframe. A proposed timeline is attached at the end of this report.

3. *Zostera* Mapping

Eelgrass beds (*Zostera* spp.) provide important feeding, spawning and nursery habitat for a number of epifaunal species and fish (e.g. Reed and Hovel 2006). SCL acknowledges that it is imperative that these areas remain unaffected by clam harvesting. To this end SCL has undertaken to map *Zostera* beds on both sanitation areas (beds 1804 and 1805) on an annual basis using hand-held GPS units. To ensure that there is the least possibility of harvesting affecting the *Zostera* beds, and appreciating that the beds are dynamic systems, SCL has undertaken to leave an unharvested 30m wide buffer strip around all *Zostera* beds. The buffer strip would, of course, move as beds changed size and shape such that a 30m buffer zone would be maintained through time. As a gesture of

good faith SCL has already begun GPS mapping of *Zostera* beds and is nearing completion of initial mapping. Maps showing location and size of *Zostera* beds will be provided in Phase I, II and II reports. It should be noted here that no commercial harvesting of clams is ever undertaken by SCL on *Zostera* beds as the nature of the root systems and associated substrate makes the movement of body dredges though it impossible.

4. Bed Morphology

To further assess the effects of harvesting on the sanitation beds the Ministry of Fisheries has requested that an investigation onto bed morphology be carried out. This would entail the recording of changes to bank volume, position and contour. The details of such an investigation are yet to be finalized, but should comprise no less that two transects per bed running through the treatment/control areas. An initial survey should take place before harvesting commences. The surveys should determine elevation at numerous points along each transect to an accuracy of ± 5cm and ± 10cm for horizontal changes. The will be repeated after one year and then again at intervals to be determined in consultation with the SWG.

5. Avifaunal Surveys, as Proposed by Derek Onley

5.1 Overview

Effects of clam harvesting on avifauna of associated shellfish beds are not well documented and leave significant gaps in our knowledge of such associations (e.g. Schmechel, 2001, McLaughlin *et al*. 2007). No information exists in this regard for Otago Harbour. In an effort to address this dearth of information Southern Clams Ltd has engaged in an agreement with Derek Onley, an independent ornithologist, to undertake a long-term series of observations on the avifauna associated with each of the sanitation areas shown in Figures 1 and 2, as outlined below.

Although there are very few published accounts of birds in Otago Harbour the Ornithological Society of New Zealand has organised a biannual count of waders over most of the country since the 1980's and the earlier counts for Otago Harbour are summarised in Sagar *et al*. (1999). There are also counts of gulls and waders in several papers dealing with parasite cycles. Fortunately the local Ornithological Society has an excellent archive that has up to date biannual wader counts, the results of 2 surveys of all the bird species in Otago Harbour, and a collection of incidental observations. Unfortunately the last Harbour surveys date from 1977/78 and 1988/89 and were

done at high tide. The monthly counts, however, do give some indication of major seasonal trends. There is a possibility that the Society will carry out another survey next year.

This information gives a good idea of the main bird species in the harbour, a reasonable idea of the numbers involved and a somewhat less satisfactory indication of seasonal changes. The most numerous species and those that are likely to be present in the proposed treatment area are South Island pied oystercatcher, bar-tailed godwit, black-backed gull, red-billed gull, black-billed gull and white-fronted tern, with smaller numbers of little shag, black shag, black-fronted tern, white-faced heron and variable oystercatcher.

Although this information is helpful and the ongoing wader counts could provide an indication of trends throughout the Harbour, there are no data available on the birds of the proposed treatment areas. It would, therefore, appear essential to carry out a baseline survey and it proposed that the areas be surveyed over low tide approximately every two weeks for at least a year. It would be useful to time these visits to include neap and spring tides.

5.2 Assessment of the effects of harvesting on bird numbers

5.2.1 Aims

1. To assess the impacts of harvesting upon bird numbers
2. To assess the impacts of harvesting upon bird community composition
3. To assess the impacts of harvesting upon bird behaviour

5.2.2 Evaluation Criteria

That there are no significant declines ($P<0.05$) in bird numbers or significant changes in behaviour, consistent with a decrease in prey availability at treatment sites, that are attributable to harvesting operations.

5.3 Methods

The birds would best be observed from a distance, as walking around on the banks and even approaching closely in a boat disturbs them and interferes with feeding patterns. The area to the west of Quarantine Island can be watched easily from Wickcliffe Terrace on Port Chalmers headland, but the eastern bank is more problematic and the best vantage point is yet to be determined.

A method of relating these distant bird observations to the location of the proposed harvesting and sanitation areas is required. This will be investigated in the first few visits but the low elevation of possible vantage points for the eastern area may mean that any clear relationship between bird and treatment area location will be difficult to determine. Use of channel markers and lines of sight from Wickcliffe Terrace look feasible and a grid system may well be able to be set up.

Early on, a few more visits may be necessary to assess the best time to count and to check on the situation at higher stages of the tide when the area is likely to be used by feeding terns, shags and gulls. Data would also be gathered on behaviour; essentially whether the area is used for feeding or roosting. If the Southern Clams barge is going out at low tide at any time it would be useful for an experienced observer to accompany the vessel to check on feeding behaviour and to ensure that the observations from the shore are not missing anything.

It is suggested that observations should start as soon as possible. Initially the visits may take up to 4 hours but it is expected that visit time will be reduced as the area becomes more familiar and the best times to observe are sorted out. Continuation and frequency of visits can be assessed at the end of one year.

Ryder Consulting Ltd intends to survey the treatment and control areas close by as soon as practicable 38-48 days after the conclusion of harvesting. It would seem sensible if the birds were surveyed in the same areas at a similar time. To do this from a distance requires a method of identifying the treatment areas. Some form of marker at each site is a possibility but the methods have yet to be finalised. Buoys may be the preferred marker as they are less likely to foul with weed and will pose less of a hazard for boating.

As it seems likely that harvesting will start before one full year's baseline avifauna information has been gathered, the comparison of treatment with control areas would become a standard part of the fortnightly survey.

For two of the key species, pied oystercatcher and bar-tailed godwit, the Ornithological Society counts allow comparison of the Otago Harbour trends with national trends. An assessment of the importance of the treatment areas to these two species would be possible with the proposed survey and, after treatment begins, any changes in the distribution of the species across the two banks can be monitored. Levels of change that may require re-assessment of harvesting regime will become clearer when variation in baseline counts are apparent.

Assessment of the other species, notably gulls, terns and shags relies on the fortnightly counts and observations of behaviour and numbers in treatment and control areas.

It is expected that observations of avifauna will take in the vicinity of 120 hours over a 12 month period, with a further 80 hours for research and write-up.

It should be pointed out that harvesting only takes place in water depths of 25-110cm, and never over low water when wading birds are likely to be feeding on the beds. As a consequence, the issue of disturbance of wading birds (in this case almost entirely pied and variable oystercatchers and bar-tailed godwits) by harvest activities over low tide is unlikely to be important. What will likely be more important is the effect of harvesting on food supplies for the birds, with the composition of infaunal communities possibly changing due to the disturbance and sorting of sediments. This in turn, may have an effect on avifaunal diversity and abundance on the affected beds. It is essential to gather good baseline data on the birds using the proposed harvesting areas at low tide and it is envisaged that the proposed programme of monitoring treatment and control areas will allow some conclusions to be drawn regarding this issue.

Nothing is known about numbers, seasonality and variability, especially of gulls, terns, shags and herons. This is essential and is a requirement before any proposals for monitoring can be finalised. Practical considerations (e.g. visibility) and disturbance issues will play a major part in study design.

The basic monitoring regime outlined above may indicate areas where further research is required. For example, an investigation of prey selection and preferences may prove to be useful.

6. Caveat

It should be noted that at some point in the foreseeable future Port Otago Ltd intends to carry out an extensive dredging programme to widen and deepen the turning basin at Port Chalmers and along the deepwater channel from Port Chalmers to the harbour entrance. The inclusion of large-scale control areas in the above experiment will allow any effects from Port Otago Ltd's proposed dredging programme to be monitored and compared with the effects of clam harvesting. However, it should also be noted that such dredging may have significant adverse effects on the clams (e.g. high sedimentation rates, feeding impairment) and thus the experiment would be suspended for the duration of dredging and for a suitable recovery time following cessation of dredging. Post dredging effects may be prolonged, e.g. continued sediment re-suspension (Jillett, pers. Comm.).

Consequently experimental harvest would resume only after a suitable recovery time has passed (e.g. 38-80 days). Effects of dredging on the morphology or the beds and on *Zostera* beds or avifauna are unknown at this point but should be able to be established, at least in the long term, under the proposed monitoring regime.

Port Otago has a consent to remove 450,000m^{-3} of sediment annually from the channel that runs adjacent to the proposed experimental beds. This "channel maintenance" programmes' impact on the middle banks of the harbour have never been monitored.

7. Acknowledgements

The Ministry of Fisheries has provided critical evaluation of the various drafts of this proposal. Southern Clams staff have been instrumental in providing advice on practical aspects of design, particularly issues of temporal and spatial scale.

8. Time Line (NB. Only indicative at this stage)

Key				
	Ryder Consulting (Infauna Surveys)	Southern Clams (Zostera)	Ryder Consulting (Final Reporting)
	Derek Onley (Avifaunal Surveys)	Southern Clams(Phase I Harvest)	Ryder Consulting (Biomass Surveys)
	Ministry of fisheries (Approvals)	Southern Clams (Pase II Harvest)	
	Surveying Dpt? (Bed Morphology)	Southern Clams Phase III Harvest)	

2008	December	Submit experimental protocol for infaunal and clam surveys
2009	January	Submit experimental protocol for avifaunal surveys
	February	Submit morphology protocol — Phase I Harvesting
	March	Phase I infaunal survey — First morphological survey
	April	Present Phase I findings to SWG
	May	MoF give approval for Phase II if no adverse effects observed
	June	
	July	
	August	
	September	
	October	
	November	First morphology report due
	December	
2010	January	Zostera bed mapping report due
	February	
	March	
	April	
	May	
	June	
	July	
	August	
	September	Phase II Harvesting
	October	
	November	
	December	
2011	January	Zostera bed mapping report due
	February	Second morphological survey
	March	
	April	
	May	
	June	
	July	
	August	
	September	
	October	
	November	
	December	
2012	January	Zostera bed mapping report due
	February	Phase II infaunal survey
	March	Clam biomass survey — First avifauna report due
	April	Second morphology report due — Phase II & Biomass results presented
	May	MoF give approval for Phase III if no adverse effects observed
	June	
	July	
	August	
	September	
	October	
	November	
	December	
2013	January	Zostera bed mapping report due
	February	
	March	
	April	Phase III Harvesting
	May	
	June	
	July	
	August	
	September	
	October	
	November	
	December	
2014	January	Third morphological survey
	February	
	March	Phase III infaunal survey — Clam biomass survey
	April	Final avifauna report due — Final morphology report due
	May	Final Zosera report due — Phase III & Biomass results presented
	June	Final report summarising all findings presented to SWG
	July	
	August	Apply to MoF for approval for commercial harvesting if no adverse effects observed?
	September	Note: this is not a requisite of the experimental plan
	October	
	November	
	December	

9. References

Breen P. A., Carbines, G. C. and Kendrick, T. H. (1999). Stock assessment of cockles in Papanui and Waitati Inlets, Otago Harbour, and Purakanui, Otago. Final Report for the Ministry of Fisheries research project COC9701 dated July 1999.

Clarke, K.R. and Gorley, R.N., 2001. *Primer v5: User manual/tutorial*. Primer-E, Plymouth.

Dobbinson, S. J., Barker, M. F. and Jillett, J. B. 1989. Experimental shore level transplantation of the New Zealand cockle *Chione stutchburyi*. J. Shellfish Res. 8:192-212.

Irwin, C.R. (1999). The effects of harvesting on the reproductive and population biology of the New Zealand Littleneck Clam (Austrovenus stutchburyi) in Waitati Inlet. Unpublished Msc thesis, University of Otago, Dunedin, New Zealand.

Irwin, C.R., 2004. Impacts of Clam Harvesting. Unpublished PhD, University of Otago, Dunedin, New Zealand.

Kraan, C., Piersma, T., Dekinga, A., Koolhaas, A. and Van der Meer, J. (2007). Dredging for edible cockles (*Cerastoderma edule*) on intertidal flats: short-term consequences of fisher patch-choice decisions for target and non-target benthic fauna. ICES Journal of Marine Science 64: 1735 - 1742.

Larcombe M.F. (1971). The ecology, population dynamics and energetics of some soft shore molluscs. Unpublished PhD thesis, University of Auckland. pp 250.

McLaughlin, E., Portig, A., and Johnson, M. P. 2007. Can traditional harvesting methods for cockles be accommodated in a Special Area of Conservation? – ICES Journal of Marine Science, 64: 309–317.

Martin, N.D. (1984). *Chione stutchburyi* population responses to exploitation. MSc thesis. University of Auckland. 75pp.

Reed, B.J, and Hovel, K.A. (2006). Seagrass habitat disturbance: How loss and fragmentation of eelgrass *Zostera marina* influences epifaunal abundance and diversity. *Marine Ecology*

Progress Series: 326:133-143.

Sagar, P.M., Shankar, U. and Brown, S. 1999. Distribution and Numbers of Waders in New Zealand, 1983-1994; *Notornis*: 1–44.

Schmechel, F. 2001. Potential impacts of mechanical cockle harvesting on shorebirds in Golden and Tasman Bays, New Zealand; *DOC Science Internal Series* 19.

Stewart B.G., 2008. Clam (*Austrovenus stutchburyi*) resource and habitat survey in Otago Harbour (COC3), Otago, 2008. Report prepared for Southern Clams Ltd by Ryder Consulting.

Van Gils, J.A. Piersma, T. Dekinga, A. Spaans, B. and Kraan, C. 2006. Shellfish-dredging pushes a flexible avian top predator out of a marine protected area. PLoS Biology 4(12): 2399-2404.

Appendix 1

Methods used for Baseline Survey (Stewart 2008).

11.2 Methods:

11.2.1 Specific Objective 1: Biomass

Based on the previous surveys by Wildish (1984a,b), Stewart *et al*. (1992), Breen *et al*. (1999), Wing *et al*. (2002) and Stewart (2006) a two phase stratified random sampling regime was undertaken. Strata were assigned to Areas 1804 and 1805 (Figure 1) according to the density of clams found in preliminary surveys carried out by Southern Clams Ltd. It should be pointed out that the surveyed areas do not comprise the entire sanitation area in either case. For Arera 1804 the survey area comprised 82% of the sanitation area. For Area 1805, the surveyed area comprised 51% of the sanitation area (Figure 1). In "extensive" areas (i.e. areas with a low known density of clams) strata were 200m x 200m (Figures 2 and 3). Sukhatme (1954) suggests that sampling effort should be higher where species are more densely aggregated. Consequently, in "intensive" areas (i.e. areas with a high known density of clams) strata were 100m x 100m (Figures 2 and 3), as in previous surveys (e.g. Wildish 1984a,b; Stewart *et al*. 1992; Breen *et al*. 1999; Wing *et al*. 2002; and Stewart 2006, 2008).

A minimum of three stations was assigned to each stratum, in both intensive and extensive areas (Figures 1 and 2). Breen *et al*. (1999) showed that the 20% target coefficient of variation (c.v.) could be met by sampling approximately 80 stations at each site, and opted for a target of 100 stations per site. However, additional work was required to meet the target c.v. (Breen *et al*. 1999). Stewart *et al*. (1992), Wing *et al*. (2002) and Stewart (2006, 2008) used considerably more stations and achieved very low c.v's. Southern Clams Ltd required a lower target c.v. than 20% and stipulated 10%. For this survey then, the aim was to achieve similar c.v.'s to Stewart *et al*. (1992), Wing *et al*. (2002) and Stewart (2006, 2008). Thus, an initial target of approximately 130-140 stations was allocated within phase 1 for each area. At the completion of phase 1 sampling, mean and variance were calculated for stations within each stratum and Phase 2 stations were added iteratively to strata using the "area mean squared" method described in Francis (1984) and Manly *et al*. (2002). Ultimately, 158 stations were allocated over 48 strata in Area 1804 and 150 stations allocated over 43 strata in Area 1805 (Figures 2 and 3). The position of each station within each stratum was assigned randomly using grid co-ordinates generated by a random number program in conjunction with the GPS program Fugawi™ and was located using hand-held GPS.

Biomass was then estimated for each "Area". The areas used are, in actuality, sub areas within shellfish sanitation areas 1804 and 1805. Boundaries of areas may vary slightly from year to year according to clam density encountered by harvesters. Surveyed areas for 2008 are outlined in red and labelled in yellow in Figures 1, 2 and 3.

At each station a 316mm x 316mm ($0.1m^2$) quadrat was excavated to a depth of 100mm using a venturi suction device, as employed by Wing *et al*. (2002) and Stewart (2006, 2008), to ensure all live clams were retrieved. Samples were sieved on site using a 2mm mesh size and all live clams were removed from the sample, bagged in labelled polythene bags, and stored in chilly-bins for later analysis.

In the laboratory all samples from individual quadrats were weighed to the nearest 0.1g. Subsamples of clams, 443 from 1804 and 525 from 1805, were individually measured along the longest shell dimension (shell length) to the nearest 0.1mm using vernier callipers and weighed to the nearest 0.1g.

Thus the biomass for any size group within any area could be estimated from the mean biomass density for a particular size group in that area and the areal size of that area. The same applies to any size group within any stratum. Biomasses were calculated for what were formerly termed commercial sized clams (≥30mm) and non-commercial clams (<30mm) in each area and for clams ≥28mm and <28mm. In addition, biomasses were calculated for each area for the following sizes classes: >2 - <19mm and ≥19 - <30mm, which have also been used in previous surveys. Total biomass for the area was calculated by summing biomasses for all strata within each area. Clams <19mm generally have poorly developed gonads and are, therefore, considered juveniles (Larcombe 1971).

Subsample data were log transformed to fit the assumption of normal distribution and a regression line fitted using least squares in Microsoft Excel®. Weight per unit length for any clams in the Harbour could then be calculated using the equation for the relevant length/weight regression line. Residuals for the log transformed data and line fit for each inlet were also plotted in Excel®. Size/frequency histograms were produced for size classes of clams within each inlet. After measurement all shellfish were returned to Otago Harbour.

For the calculation of 95% confidence intervals, estimates of the sample variance in each stratum were made based on the total biomass values for each quadrat, as in Stewart *et al.* (1992) using:

$$S_i^2 = \Sigma(x_{ij}-x_i)^2/(n_i-1)$$

Where S^2_i equals the sample variance for stratum i; $x_{ij}-x_i$ equals the difference between each quadrats total biomass (x_{ij}) and the mean quadrat biomass value (x_i); and n_i equals the number of quadrats taken in stratum i. These sample variances were then used to produce 95% confidence intervals for each inlet biomass estimate using:

$$\pm 1.96\sqrt{\Sigma N_i^2 S_i^2/n_i}$$

Where N_i equals the number of possible quadrats that could be placed in stratum i.

Figure 1. *Mid portion of Otago Harbour showing the location of sanitation areas 1804 and 1805 with strata superimposed.*

Figure 2. *Area 1804, Otago Harbour, showing location of sampling stations, 200m grid squares and 100m grid squares.*

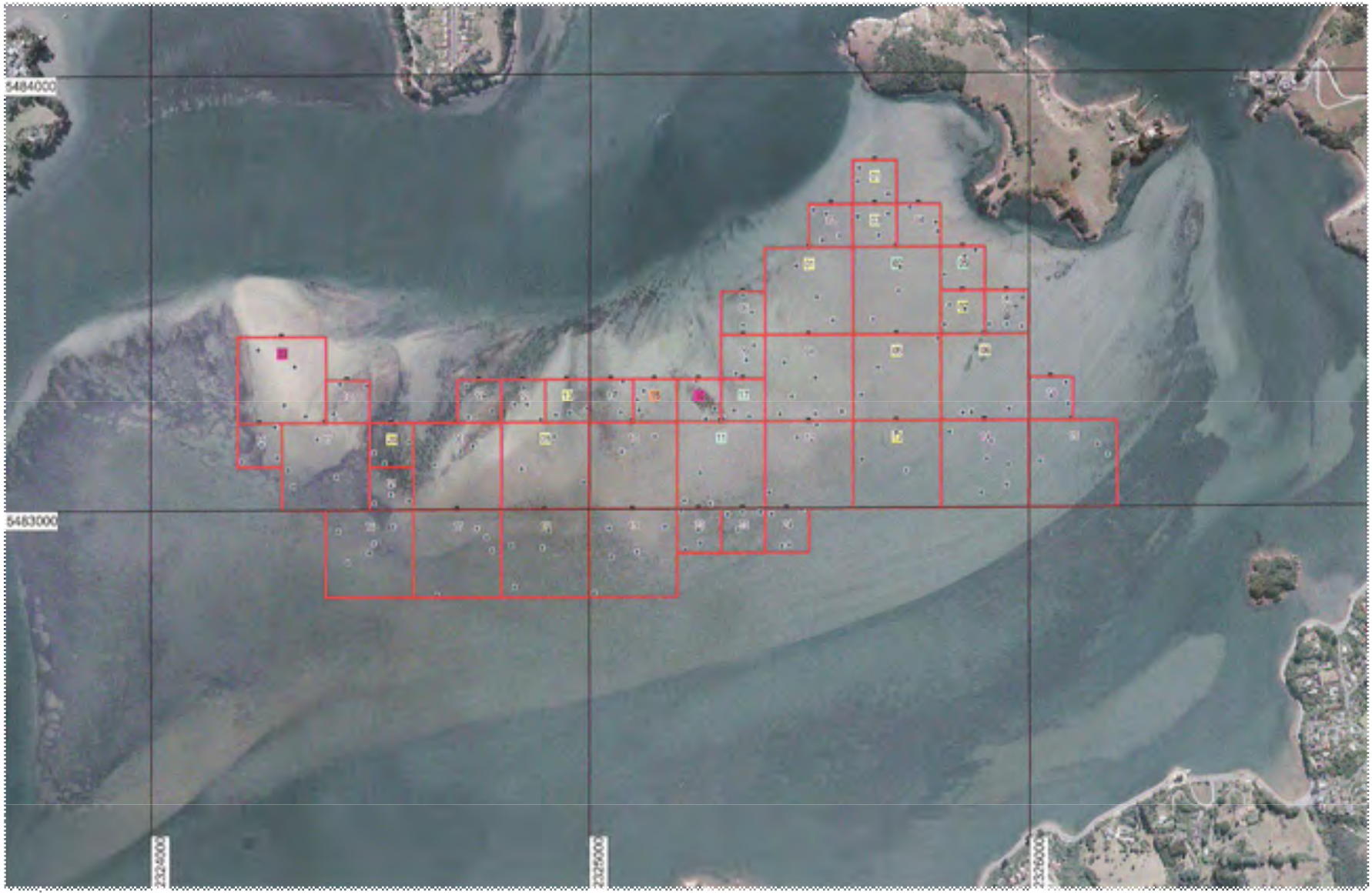

Figure 3. *Area 1805, Otago Harbour, showing location of sampling stations, 200m grid squares and 100m grid squares.*

11.2.2 Specific Objective 2: Yield

Previous surveys (Breen *et al*. 1999, Wing *et al*. 2002, Stewart 2006) calculated yield per recruit using von Bertalanffy growth parameters and the Ricker equation. A similar approach was taken for this survey. Following Annala and Sullivan (1996) biomass yield estimates (yield per recruit) for clams in Waitati Inlet were calculated using their Method 1 for maximum constant yield (MCY) and their Method 1 for current annual yield (CAY).

i.e. $$MCY = 0.25\ F_{0.1}\ B_0$$

where $F_{0.1}$ is the fishing mortality at the point on a YPR curve where the slope is 0.1 of that at F_o, and B_0 is the recruited biomass, and

$$CAY = (F_{0.1}/ Z)\ (1\text{-}\exp(\text{-}Z)\ B_{beg}$$

where Z is the total mortality.

These calculations require an estimate of $F_{0.1}$ (Hilborn and Walters 1992) that requires the plotting of a von Bertalanffy growth curve using

$$Lt = L_\infty(1-\exp\text{-}(K(t\text{-}t_0))$$

to estimate asymptotic size (L_∞) and the rate at which asymptotic size is approached (K). Yield able to be taken from the surveyed area was calculated from the biomass estimates for clams ≥28mm as determined in Objective 1 from this survey, coupled with estimates of von Bertalanffy growth curve parameters calculated from growth data collected over 2004-2006 (Stewart 2006). In previous surveys Breen *et al*. (1999), Wing *et al* (2002), and Stewart (2006) used parameters for Papanui Inlet: i.e. L_∞ = 40.296mm, K = 0.311, t_0 = 0.0mm, size at recruitment = 30mm to calculate MCY. $F_{0.1}$ was calculated as being the fishing mortality rate at which the slope of the yield per recruit curve, as a function of fishing mortality, is 10% of its value near the origin as in Breen *et al*. (1999), Wing *et al*. (2002), and Stewart (2006). For the current survey, $F_{0.1}$ was estimated for M = 0.2, 0.3 and 0.4/yr, where M = the instantaneous mortality.

11.2.3 Specific Objective 3: Assess Biota

To assess the flora and fauna associated with the clam population within the areas to be investigated, four 10m x 10m quadrats were sampled within a control area at each site and four in an impact area at each site. Quadrats were photographed and percentage cover of macroalgae estimated. Ten randomly placed 200mm deep core samples were collected from each quadrat using a 125mm diameter coring device. Cores were photographed to allow determination of the depth of the redox discontinuity layer if present. Cores were then sieved using a 500μm sieve and all

animals retained preserved and returned to the laboratory. Animals were identified to a minimum of family level in the laboratory and enumerated.

Simple measures of species diversity (number of different 'types' of animals per sample) and animal abundance (number of animals per sample) were calculated from the collected data. A diversity index was also calculated using the Shannon-Weiner method (Zar 1996). Such indices provide a ready method for comparing diversity at sites from year to year or, in this case, before and after harvesting and for comparing impact sites with control sites. For other community analyses the data was transformed (log(x+1)) to meet the statistical requirements of the tests used.
In addition, variability among sites was measured using the Index of Multivariate Dispersion (IMD) (Warwick 1993), with IMD values calculated for the invertebrate samples at each location and compared visually. Ordination was used to 'graph' the invertebrate communities. In such plots, how close the core values appear to each other reflects how similar they are in terms of species composition and abundance patterns.

The survey will be repeated immediately after harvesting has taken place. Analysis of similarities will be used to test whether there were significant differences between the invertebrate communities at different locations and among treatments. Finally, analysis of similarities will be used once more to test whether there is a significant difference between communities before and after impact and among impact and control sites. Irwin's (1999) research on the impact of harvesting in Waitati Inlet demonstrates that most effects are barely detectable after 30 days.

This longitudinal study, with re-surveys over a five year period in a similar ecosystem, should provide an even better understanding of long-term harvest impacts. The species that are responsible for differences between the groupings will be identified using similarity percentages (Warwick and Clarke 1993).

11.2.4 Specific Objective 4: Characterise substrate

As an adjunct to the faunal sampling an investigation of the effects of harvesting on substrate was also undertaken. This involved a BACI (Before, After, Control, Impact) design (Kingsford and Battershill, 1998) in which three random cores 80mm diameter and 200mm deep were collected from each of four representative $1m^2$ quadrats within a control area and four representative $1m^2$ quadrats within an area designated for harvesting, giving a total of 24 cores per sanitation area. The survey will be repeated immediately after harvesting has taken place. These same sites will be re-sampled at 3 years and 5 years. Individual core samples from each quadrat were subsampled at 50mm 100mm and 200mm depths with each subsample being processed at Ryder Consulting's laboratory for grain size analysis and analysis of simple organic content by loss on ignition (e.g. Irwin 1999).