Site-specific fisheries resource impact assessment –
P H Redwood & Co Ltd - U010672
Forsyth Bay, Marlborough Sounds

NIWA Client Report: CHC2004-018-8
March 2004

NIWA Project: FRI04401

Site-specific fisheries resource impact assessment - P H Redwood & Co Ltd. - U010672, Forsyth Bay, Marlborough Sounds

Prepared for

P H Redwood & Co Ltd. - U010672

By NIWA

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1. Introduction

As part of the Fisheries Resource Impact Assessment protocol, applicants are required to provide a report for their specific sites. This report describes the generic methodology used to meet this protocol and then provides a tabulated information summary of this particular site, supported by data appendices. Detailed benthic drop camera and side-scan sonar images are provided "by-exception", that is if a key issue is identifiable, such as rocky reefs, scallop beds, or unique benthic fauna, images will be in the summary table.

2. Site-specific surveys

2.1 Hydrodynamics

The FRIA requires that some consideration be given to the effect of the farm on the local currents. Recent work by NIWA (Plew et al. 2003, Figure 1) has shown that there is the potential that the farm will reduce the currents in and around the farm. Jackson and Winant (1983) found that the flow in large kelp beds (km scale) slowed down by around 67%. Observations extending from the work of Plew et al. (2003) show similar behaviour in large mussel farms. In terms of flow distortion by smaller farms such as the present site, the latest developments in our understanding (Plew et al. 2003) suggest that there will be a reduction in flow across farms. A percentage reduction in current at the downstream end of the farm is estimated from Figure 1, by viewing U/U_0 as the reduced velocity relative to the velocity if the farm were not there; $U/U_0=1$ means there is no flow reduction, $U/U_0=0.75$ means there is a 25% reduction in flow.

Records of 2 days of current data were gathered for each applicant site. The local current speed (cm s^{-1}) was calculated from the velocity magnitude averaged through the top 14 m of the water column over a period of 48 hours. This was compared with contemporary recordings from a longer term mooring at the centre of Forsyth Bay to estimate a local current magnitude parameter - the ratio of the mean current speed at the site to the mean at the central site. Using simultaneous measurements over longer than a single tidal period is vital as the flow in Forsyth Bay is not particularly regular or completely controlled by the tides. The tidal magnitude data were resolved from ADP measurements recorded near the farm.

Lagrangian drifter tracks were used to illustrate the movement of discrete parcels of water. In many studies moored current meters are used to determine trajectories of

water masses passing through farms. This is viable away from the coast but must be treated with care near shorelines. It points to the need to consider (i) dispersion and (ii) Lagrangian information when identifying provenance and downstream trajectories.

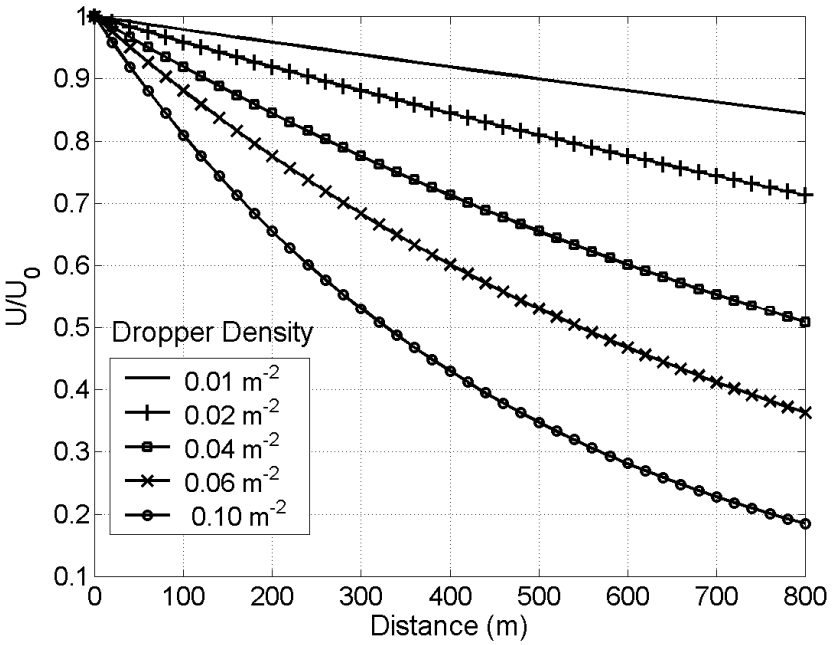


Figure 1 : Scaling analysis from Plew et al. (2003) for proportional velocity decay through energy loss from a unidirectional flow. Each curve represents a different mussel line density (dropper per unit area) with the diagonally crossed line (0.06) being comparable to typical densities here. A modified drag coefficient of C_d = 1.0 x sin(25^o) = 0.42 is used.

2.2 Water utilisation and biodeposition

The zone of influence (ZOI) of each farm was seen in the context of the cumulative effect of all farms on the proportion of water processed in Forsyth Bay and the areas of biodeposition. The localised ZOI for the farm and extension with different mussel stocking scenarios is compared to the cumulative effects. The average localised percentage water processed per site was calculated over the area demarcated by the surveyed farm boundaries and proposed extensions. Biodeposition rate (or Benthic Deposition Parameter in kg faeces/day/100m^2) is given as a range for the area from the edge of a farm to as far as particles disperse from the farm boundary based on Hartstein's model, (Hartstein, 2003).

2.3 Sediments and side-scan sonar sampling

In general, for site-specific surveys, at least two samples were taken within an existing farm and three within an extension addition to several 'regional' samples taken throughout the central portion of the bay. Three replicate samples were taken at each of the regional stations using a Van Veen grab (bite area ca 0.13 m^2, max bite depth 22 cm). The sampling strategy for individual sites was different. Five replicate samples were taken in each application site. For existing farms applying for an extension, two samples were taken within the existing farm and three within the extension. For new farm applications, 5 random samples were taken. Where an existing farm was applying for a renewal of its permit, then 3 samples were taken outside the farm and 2 samples from within the farm.

Two core samples were taken through the lid of each grab sample, and the depth of the redox discontinuity (black) layer was measured to the nearest millimetre using a ruler. One core sample was retained to determine organic content and the other, for grain-size analyses.

Grain-size distribution was determined by oven drying a sample of sediment at 100 ^oC overnight and washing a weighed subsample through stacked 200-µm and 63-µm sieves. The fraction retained on each sieve was dried and weighed and the weight of material passing the 63-µm sieve, obtained by subtraction from the original weight. Dry weights for each fraction were expressed as percentages of the total dry weight.

The amount of organic matter in the sediments was determined by freeze-drying each sample, grinding, and combusting in a furnace at 500^oC for 4 hours, and reweighing. The weight of organic matter was determined by subtracting the combusted weight from the original (freeze-dried) weight and expressed as a percentage.

Side-scan sonar transects were run using a high-frequency (675 kHz) Tritech towfish at boat speeds of 1-2 knots. The side-scan was interfaced with GPS, recording positions every 2 seconds. The side-scan images and GPS positions were recorded using SeaNet software on to a laptop in real-time.

All side-scan transects were analysed by running the profiles back and recording the positions or boundaries of sediment types, which were then coded and used in the GIS map production. In addition, each side-scan transect was saved as a series of bitmap files and stitched together to provide a visual record that could then be placed into GIS along with the adjacent farm boundaries or application site. Side-scan data as images are presented by exception only in each site-specific report.

Drop camera Images (0.175 m^2) were taken at 6 stations within an extension and 2 in an existing farm. These were compared to the 15 'regional' samples taken in the central part of the bay.

2.4 Fauna

Sampling strategies for benthic infauna and habitats at farm and/or extension sites were indicated in Technical Appendix II of the FRIA Guide (Ministry of Fisheries 2002), and consolidated in the NIWA proposal agreed upon between MFish and NIWA. (Ross et al. 2003). The remainder of the grab samples described above was washed through 2 stacked sieves of 1-cm and 1-mm mesh and all material retained, including animals, was bagged, labelled and preserved in 70% isopropyl alcohol. Animals were identified to the lowest possible taxonomic level, and enumerated on return to the laboratory.

A custom-built drop camera equipped with digital still camera and strobe light source was deployed at 21 bay-wide and various site-specific stations. These stations were positioned to cover benthic habitats not sampled by the Van Veen grab with a view to integrating information for a more comprehensive assessment of the benthos. The images covered 0.175 m^2 and were analysed to semi-quantify the epibenthos and the texture of the sediment (i.e. abundances classes and visual estimates of percentage mud, sand and shell/gravel). Drop camera Images were generally taken at 6 stations within an extension and 2 in an existing farm. These were compared to the 'regional' samples taken in the central part of the bay.

The objective of the statistical analyses of benthic fauna samples was to identify any differences between assemblages living below the mussel farm and those in the adjacent extension area, so that any actual impacts could be identified and used to predict future changes. We used canonical analysis of principal coordinates (CAP: Anderson & Willis 2003) to identify differences in the assemblages of animals in samples taken inside and outside farms.

For site-specific reports we identify the farmed and unfarmed samples on an ordination plot, and present abundances of organisms inside and outside each farm.

3. Summary information for U010672

The P H Redwood & Co Ltd. site has 2 extensions to an existing farm Li 185 in the southern extent of Forsyth Bay, parallel and west of a headland. The proposed extension to the north (U010672) is located at -41.009298; 174.030019 and is 2.53 Ha.

Extension U010672 to the west of the farm is located at -41.009193; 174.030590 and is 2.81 Ha. Hydrodynamically, these two extensions will be dealt with together. The benthic information will be reported for each site in separate reports. As a region, the hydrodynamics is dominated by tidal flows from the Allen Strait.

P H Redwood & Co Ltd.. - U010672

CURRENTS

Summary Information

Speed: mean = 4.3 cm s^{-1}

Magnitude parameter = 0.45

Flushing time-scale = 2.6 days

Deposition parameter = 56 m

Estimated downstream reduction in current – 25%

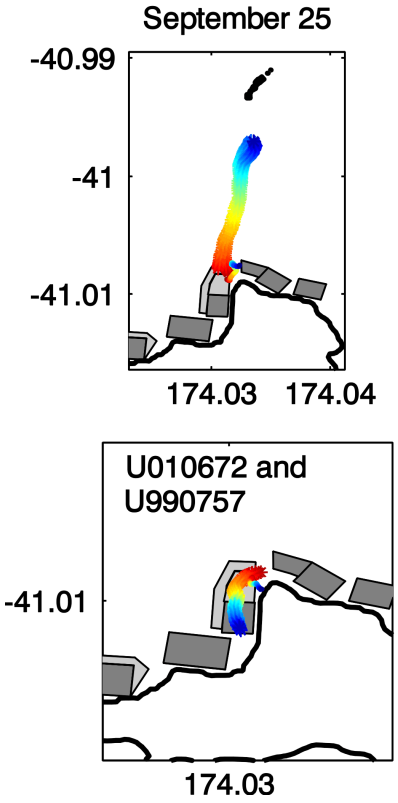


Figure 2a and b. Drogue trajectories were plotted over 3.4 and 3.3 hour periods with drogues travelling average distances of 490 and 500 m.

Comments

The magnitude parameter 0.45 indicates only a moderate level of circulation given that the Allen Strait entrance is nearby.

The ADP data (Appendix 1) show that while the pressure track shows regular tidal behaviour, the velocity structure is irregular. This is consistent with a good deal of sub-bay eddy activity (see direction contour in Appendix 1) taking place as the bay fills and empties. The velocity roses show the patchy directional nature of the flow.

The frequency range of the ADP did not permit near surface measurements. However, the deeper measurements were sufficient to show the relatively short residence time here. The ADP data at this location has weak tidal correlation.

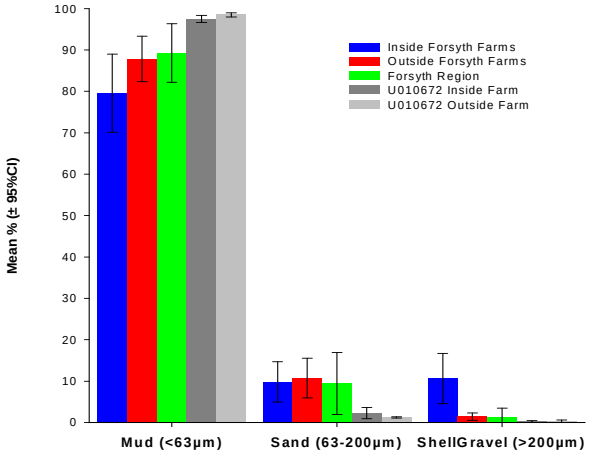
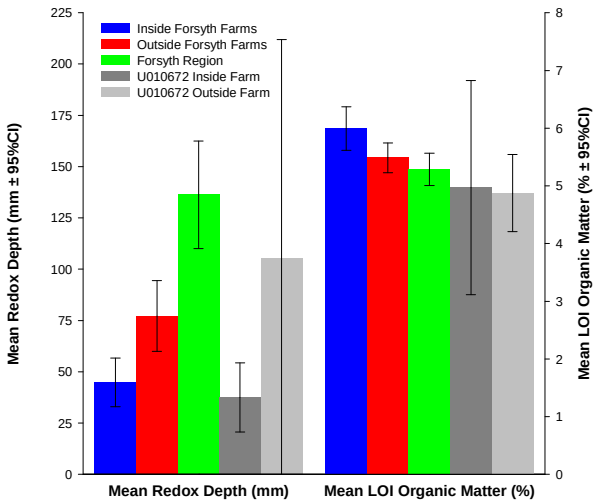
Drogue and ADP trajectories were plotted over 3.4 and 3.3 hour periods with drogues travelling average distances of 490 and 500 m (Figure 2). These are indicative of two modes of flow – one where the flow shoots out into the southern central part of Forsyth Bay and the other where the drogue seems to stay and circle in the embayment. This suggests a high degree of heterogeneity and dispersion.

The 25% estimate reduction in flow is a near-appreciable level of flow distortion, but given the heterogeneity in flow indicated by the drogues it is within the variability one would expect from being near the shore-line. Hence, from the perspective of a single farm (pair), flow redirection should not be significant.

<table>
<tr><th></th><th colspan="4">Summary Information</th><th>Comments</th></tr>
<tr><td rowspan="7">WATER UTILISATION</td><td>number</td><td colspan="2">Mussel density stocking scenarios</td><td>Average % water processed for Li 185 and U010672 + U010672</td><td>Average % waster processed for all farms bay-wide</td><td rowspan="7">This table shows the average percentage water processed in the localised area of Li 185 and the proposed extensions (U010672 + U010672) considering six different mussel density scenarios. The localised area is demarcated by the boundary of the farm and extensions. This site processed three times more water (depending on mussel stocking) than the average for all farms, which is synonymous with the cumulative effect in Forsyth Bay. This can be expected considering the heterogeneity of local hydrodynamics (Figure 2). While water from Allen Strait ensures good flushing (2.7 days residence time), local nearshore eddies (Figure 2 b) would account for more water being processed by mussels.</td></tr>
<tr><td>1</td><td colspan="2">Current on Li 185</td><td>1.01</td><td>0.27</td></tr>
<tr><td>2</td><td colspan="2">Current on Li 185 and extension</td><td>1.37</td><td>0.42</td></tr>
<tr><td>3</td><td colspan="2">Standardised on Li 185</td><td>2.57</td><td>0.74</td></tr>
<tr><td>4</td><td colspan="2">Standardised on Li 185 and in extension</td><td>3.28</td><td>1.03</td></tr>
<tr><td>5</td><td colspan="2">Current on Li 185 stretched into extension</td><td>1.02</td><td>0.35</td></tr>
<tr><td>6</td><td colspan="2">Standardised on Li 185 stretched into extension</td><td>2.60</td><td>0.84</td></tr>
<tr><td rowspan="4">BENTHIC DEPOSITION PARAMAETER</td><td colspan="3">Mussel density stocking scenarios</td><td>Benthic Deposition Parameter range (kg/day/100m^2) over the benthic zone of influence for Li 185</td><td>Benthic Deposition Parameter range (kg/day/100m^2) over the benthic zone of influence for all farms in Forsyth Bay</td><td rowspan="4">The benthic deposition parameter (BDP) is given as a range, the highest value being the centre of a site, the lowest, the most outer edge of the benthic zone of influence (BZOI).

Based on stocking densities in September 2003, BDPs measured as kg faeces /day /100m^2, was at the middle of the bay-wide range. The bay-wide range considers the entire spectrum of BDPs for all farms in Forsyth Bay. Standardised stocking placed deposition in the upper end of this bay-wide range.

The zone of influence (ZOI) did not overlap with any adjacent farm and /or extension.</td></tr>
<tr><td colspan="3">Current stocking on Li 185</td><td>0.01 to 0.75</td><td>0.01 to 1.00</td></tr>
<tr><td colspan="3">Standardised stocking on Li 185</td><td>0.03 to 0.75</td><td>0.01 to 1.25</td></tr>
<tr><td colspan="3">Standardised on Li 185 and in extensions</td><td>0.05 to 1.00</td><td>0.01 to 2.00</td></tr>
</table>

	Summary Information	Comments
SEDIMENT	 **Figure 3.**  **Figure 4.** Data presented as mean percentage ± 95% confidence level Raw data on Redox and % organics are given in Appendix 3.	Station locations are shown in Appendix 2, and co-ordinates of grab samples, drop camera stations and sediment data in Appendix 3. Sediment inside License 185 and outside the farm in the extension area U010672 was relatively more fined grained and muddy than the rest of Forsyth Bay (Figure 3). Redox depth inside and outside License U010672 was very similar to inside and outside Forsyth Bay farm averages, and extremely variable in the proposed extension (Figure 4) Concentrations of organic matter in sediments inside and outside the farm were comparable to those for the remainder of Forsyth Bay (Figure 4) Side-scan and drop camera images showed no evidence of reef, cobbles or beds of surface-living shellfish in extension area (Appendices 3 & 4).

BENTHIC FAUNA

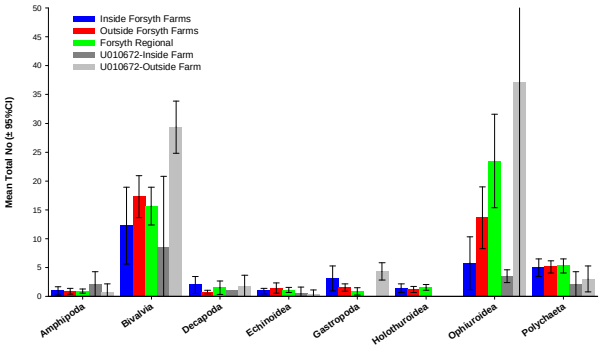


Figure 5. For each taxon, mean abundances are given for samples taken within Forsyth Bay farms, outside (adjacent to) Forsyth Bay farms, and regional samples

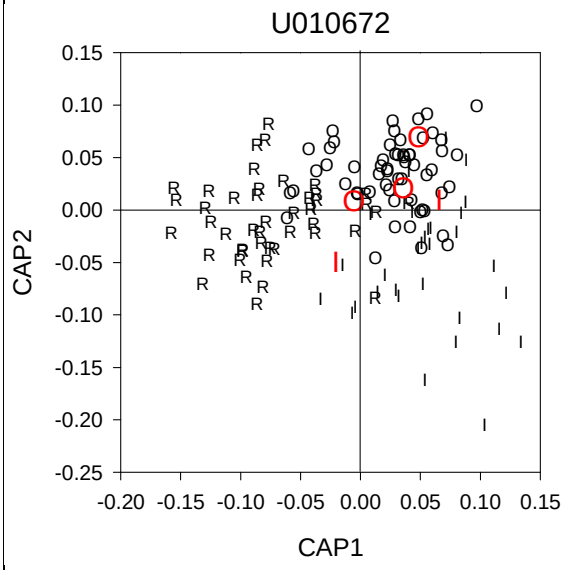


Figure 6. Samples from Licence U010672 highlighted in red. I = sample taken inside farm, O = sample taken outside farm, R = regional samples

For each taxon, mean abundances are given for samples taken within Forsyth Bay farms, outside (adjacent to) Forsyth Bay farms, and regional samples (Figure 5).

The diversity indices of fauna inside Licence 185 and outside the farm in the extension area U010672 were very similar, however there were greater abundances in the extension area, especially bivalves and the brittle star *Amphiura rosea* (Appendix 6). The gastropod *Zeacolpus pagoda* was absent inside the farm, but was common in the extension area.

The results of the CAP analysis (Figure 6) showed that both samples from inside Lic. 185 were on the edge of being associated with the grouping of Forsyth Bay inside farm samples (Figure 5), suggesting only a slight shift in benthic species composition as a result of the mussel farming at Lic. 185.

There are no known areas of reef, populations of horse mussels, scallops, or other features potentially important for fisheries management, within the application area (Appendix 7). The seafloor below the extension area appears to be very fine-grained mud, which is dominated by bivalves, especially *Ennucula strangei* and *Theora lubrica*. Although the sediments beneath the existing farm were relatively coarse, faunal diversity in sediments below the existing farm area differed little from that in the extension area. Fewer individuals were however found beneath the existing farm but it is unclear whether this is a result of impacts from the farm or due to the different sediment regimes.

Faunas dominated by deposit feeders in the extension area, are characteristic of muddy, depositional seabed habitats. Consequently, the fauna is not likely to change substantially following installation of mussel lines. The brittlestar species *Amphiura rosea*, which was more common in the extension area #4, is likely to decrease in abundance. The heart urchin *Echinocardium cordatum*, whose abundance is also often low beneath marine farms, was uncommon at this site. Species expected to be common beneath the existing farm like the gastropod *Maoricolpus roseus* and the sea cucumber *Chirodota nigra*, were not present. It is likely that numbers of individuals of common species may decrease slightly but, given the large spatial variability in the fauna, this is unlikely to have any detectable effect on fisheries resources.

EFFECTS ON FISHING	.	This discussion is based on Ministry of Fisheries *Fishing Analysis: Area 1 – Forsyth Bay*, dated 29 October 2003. A survey of recreational fishing diaries indicated relatively high fishing effort in the general area. The application also extends across one of the "few remaining open sections of coastline at the southern end of Forsyth Bay" and is located near a reef. Commercial fishing at the site is, in any case, restricted by the presence of existing farms and a nearby reef. The MFish analyst concluded that the application was unlikely to have an undue adverse effect on commercial fishing. Among representatives of customary fishers, Ngai Kuia objected to the application on the grounds that the site is a customary fishing and food-gathering area. Anecdotal evidence suggested that alternative fishing sites are limited and the MFish analyst expressed concern about effects of these applications and of cumulative reduction in access to hard shore and sand habitats along the coastal fringe. This site is soft muddy habitat and some distance from the coastal fringe. This site will cover approximately 0.0004% of the modelled available mud habitat in Forsyth Bay.
ISSUES	There are no biological or fisheries related issues highlighted for this site	

4. References

Anderson, M.J.; Willis, T.J. 2003. Canonical analysis of principal coordinates: a useful method of constrained ordination for ecology. *Ecology 84(2)*: 511-525

Hartstein, N. 2003. Supply and Dispersal of Mussel Farm Debris and its Impacts on Benthic Habitats in Contrasting Hydrodynamic Regimes, PhD Thesis, IAAS University of Auckland/NIWA. 181 p

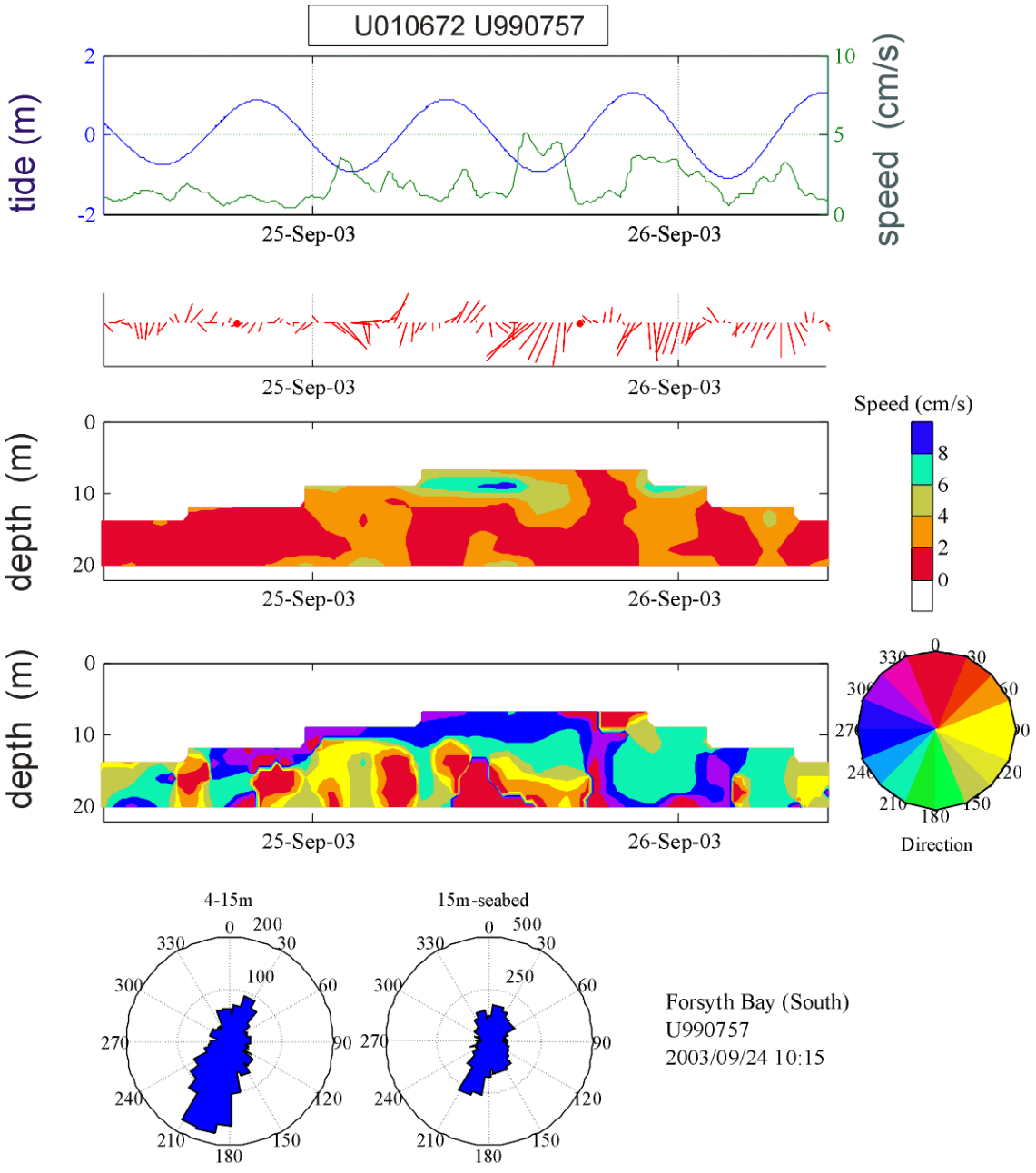
Jackson, G.A., Winant, C.D. 1983. Effects of kelp forest on coastal currents. *Continental. Shelf Research. 2*: 75-80

Plew, D.; Stevens, C.; Spigel, R.; Hartstein, N. 2003, Hydrodynamic implications of large offshore mussel farms. Submitted to the *IEEE Journal of Oceanic Engineering Special Issue on Offshore Aquaculture, May 2003*

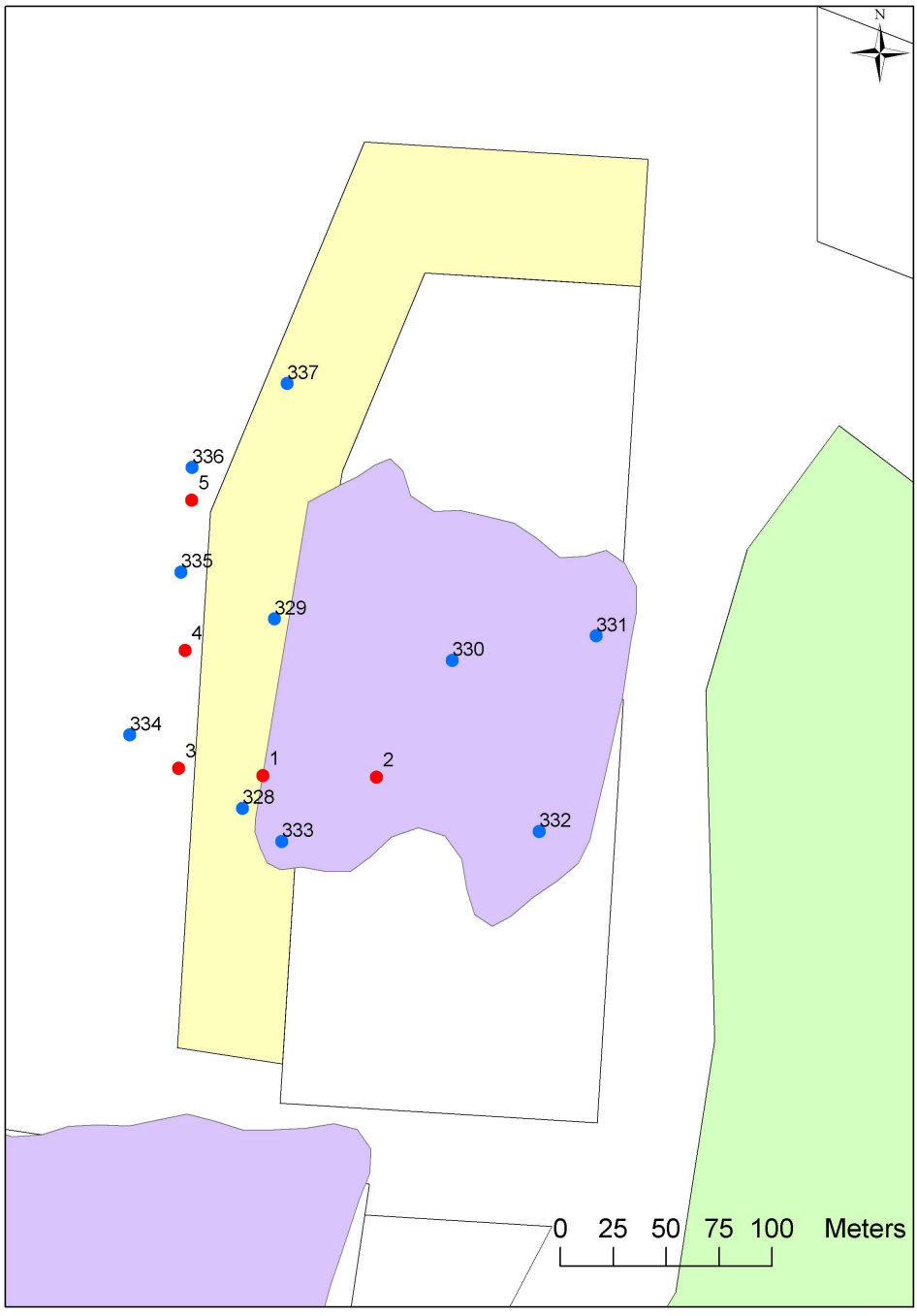
Ross, A.; Grange, K.R.; Stevens, C. 2003. Review and proposal on fulfilling ecological aspects of the Fisheries Resource Impact Assessment. Proposal to the Ministry of Fisheries, National Institute of Water and Atmospheric Research Ltd, Christchurch, New Zealand: 14 p.

5. APPENDIX FOR U010672

Appendix 1 **The farm-specific ADP mooring data. Plotted are (from top) tidal phase in the form of water depth and current magnitude; directional feather plot giving an indication of average flow vector; speed contours; contours of direction of flow with respect to North; and velocity "roses" at three depth ranges giving an envelope of the flow.**



Appendix 2: Location of benthic sampling stations (red dots, 1-5 indicate grab sample positions, blue dots indicate drop camera locations: numbering as in Appendix 3) for Resource Consent U010672, Forsyth Bay. Existing farm = purple, extension site = yellow

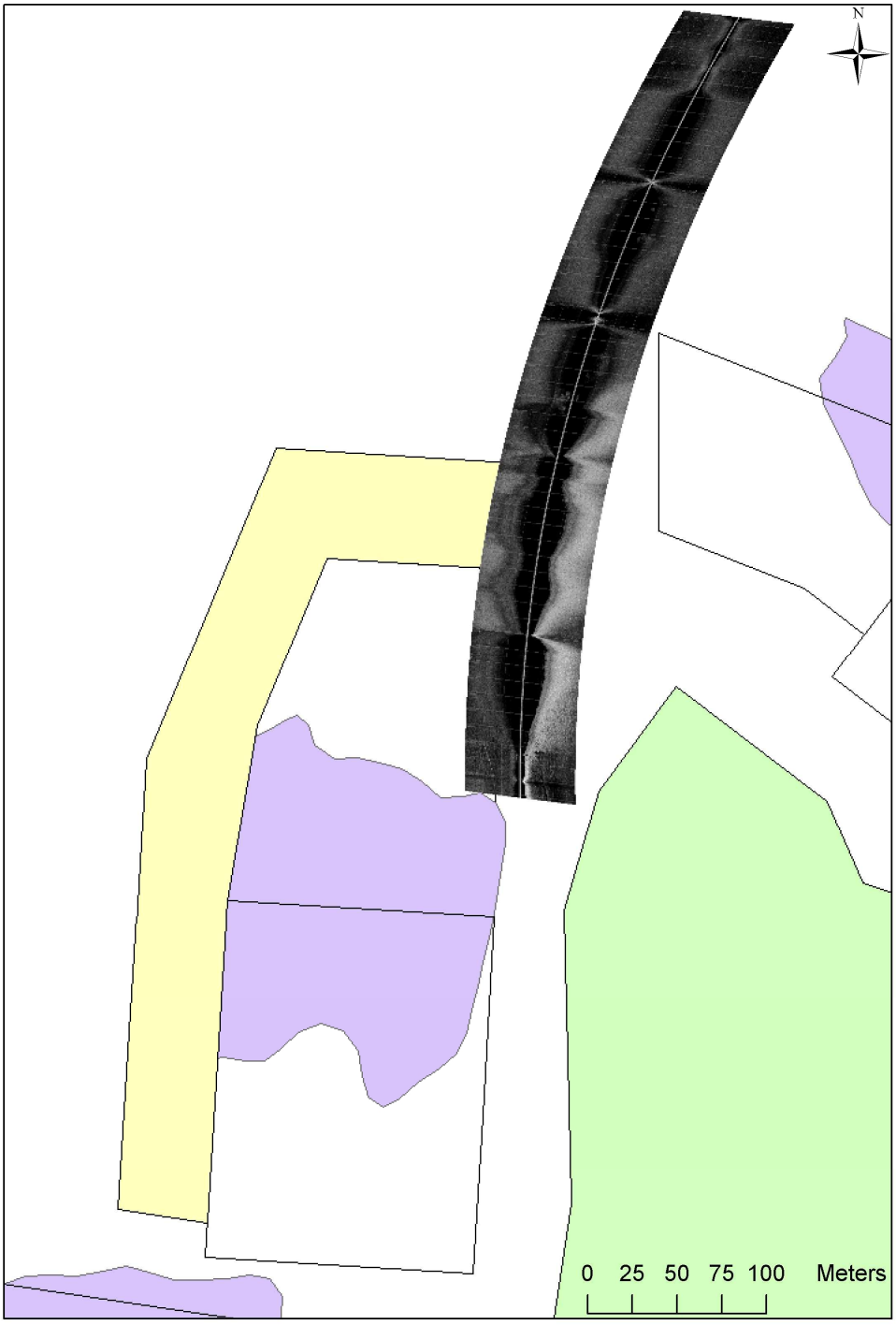


Appendix 3: Positions and depths of grab sampling and drop camera stations for U010672. Positions are shown in New Zealand Map Grid.

Grab sample			Depth (m)	Easting	Northing	Redox depth (mm)	% Organic Matter	Sediment Grain Size %<63µm (g)	%63-200µm (g)	%>200mm (g)
1	Inside	31		2596580.684	6021286.94	60	4.1	97.9	1.7	0.4
2	Inside	27		2596634.419	6021286.3	45	5.8	97.2	2.9	0.0
3	Outside	31		2596541.003	6021290.49	60	5.0	98.1	1.2	0.8
4	Outside	31		2596543.994	6021345.98	45	4.3	98.8	1.2	0.0
5	Outside	33		2596547.167	6021416.89	60	5.3	98.6	1.4	0.1

Drop camera					Estimated Grain Size %<63µm (g)	%63-200µm (g)	%>200mm (g)
328	Inside	31	2596571	6021272	96.5	3	0.5
329	Inside	31	2596586	6021361	92	3	5
330	Inside	28	2596670	6021341	50	10	40
331	Inside	23	2596738	6021353	10	35	40
332	Inside	23	2596711	6021261	25	30	40
333	Outside	29	2596590	6021256	96.5	3	0.5
334	Outside	32	2596518	6021306	96.5	3	0.5
335	Outside	32	2596542	6021383	96.5	3	0.5
336	Outside	33	2596547	6021432	96.5	3	0.5
337	Outside	34	2596592	6021472	96.5	3	0.5

Appendix 4 Location of side-scan sampling track for Resource Consent U010672, Forsyth Bay. Existing farm = purple, existing consent area = white, extension site = yellow.



Appendix 5 Summary of information obtained from side-scan sonar records U010672 Forsyth Bay. GPS coordinates (latitude/longitude and NZ grid references) were taken at the beginning and end of each track, and approximately every 50 seconds during the duration of each record. Additionally, coordinates were noted when features of interest were present. Coordinates refer to the central line of the side-scan swath.

Station Farm	FileName	Time	Easting	Northing	SedimentClass	BenthicType	Notes
U010672	U990757	02:39:40	2596758	6021399	Cobble/Boulders	Hard Bottom	Boulders shore side
U010672	U990757		2596770	6021480	Mud/Sand/Cobble	Soft Sediment/Cobble	Cobble shore side, sandier shore side
U010672	U990757		2596785	6021523	Mud/Sand/Cobble	Soft Sediment/Cobble	Cobble shore side, sandier shore side
U010672	U990757		2596784	6021578	Mud/Sand some shell	Soft Sediment	Sandier shore side
U010672	U990757		2596808	6021670	Mud/Sand some shell	Soft Sediment	Sandier shore side
U010672	U990757	02:43:45	2596812	6021685	Mud/Sand some shell	Soft Sediment	Sandier shore side, sand to mud transition visible on shore side
U010672	U990757		2596814	6021715	Mud/Sand	Soft Sediment	
U010672	U990757		2596815	6021715	Mud/Sand	Soft Sediment	
U010672	U990757		2596858	6021775	Mud/Sand	Soft Sediment	
U010672	U990757		2596881	6021827	Mud/Sand	Soft Sediment	
U010672	U990757	02:47:50	2596894	6021836	Mud/Sand	Soft Sediment	

Appendix 6. Species collected by Van Veen benthic grab Forsyth Bay. Numbers are per grab (ca 0.13 m^2). Replicates 1 & 2 are from inside the existing farm (Lic. 185) and samples 3-5 are from inside the extension zone (U010672).

Inside/outside farm	Inside		Outside		
TAXON	**1**	**2**	**3**	**4**	**5**
ANTHOZOA					
Edwardsia sp.					1
POLYCHAETA					
Glyceridae		1			
Lepidonotus sp.	1			1	
Lumbrineridae	1		1		
Maldanidae				2	
Orbiniidae	1		1		1
Sigalionidae				2	1
Priapulopsis australis					1
GASTROPODA					
Zeacolpus pagoda			5	5	3
BIVALVIA					
Ennucula strangei	10	1	20	8	20
Neilo australis			5	1	3
Nemocardium pulchellum			1	1	2
Nucula nitidula		1		4	
Sacella bellula				1	
Theora lubrica	4	1	3	11	8
CRUSTACEA					
Ampelisca chiltoni				1	
Callianassa sp. A	1		2		
Ceradocus rubromaculatus		3			
Cirolana sp. B	1			2	
Hemiplax hirtipes		1	1	2	
Parawaldeckia parata				1	
Torridoharpinia hurleyi	1				
ECHINODERMATA					
Amphiura rosea	3	4	28	70	13
Echinocardium cordatum	1		1		
Total no. individuals	24	12	68	112	53
Total no. of taxa	10	7	11	15	10
Shannon-Wiener diversity (loge)	1.85	1.748	1.661	1.508	1.746
Margalefs species richness (d)	2.832	2.415	2.37	2.967	2.267
Pielou's evenness (j')	0.8036	0.8984	0.6926	0.557	0.7584

Appendix 7 Results of conspicuous epibenthic species identified from drop camera photos. Photo locations from Appendix 2.

Site/Inside/Outside	In	In	In	In	In	Out	Out	Out	Out	Out
Photo No.	**328**	**329**	**330**	**331**	**332**	**333**	**334**	**335**	**336**	**337**
PORIFERA										
Anchorina alata										
GASTROPODA										
Maoricolpus roseus					1					
ALGAE										
Red algae	Y	Y	Y		Y	Y				
Ulva sp.		Y	Y							
OTHER										
Dead mussel shell		Y								
Holes	3						3		5	