NIWA
Taihoro Nukurangi

Site assessment for potential finfish site: Oyster Bay

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Reviewed by

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Executive summary

- The currents at the entrance to Oyster Bay, Tory Channel, are dominated by the tides, and flow in a predominantly NW-SW direction. The currents are influenced by the adjacent headlands of the bay, which are likely to increase the dispersion of waste feed and faecal material.

- Depths seaward of the existing mussel farm consent range from 20-30 m and are therefore suitable for the development of a finfish farm.

- The sea floor habitats are dominated by soft sediments with varying quantities of shell material and sparse epifauna, apart from an isolated mound of an unidentified sabellid tubeworm at a distance of about 200 m from the offshore boundary of the existing consent. Modelling suggests this mound will be beyond any significant depositional footprint should the farm be established in the new locality seaward of the existing site.

- DEPOMOD simulations were modelled with annual productions of 1000 and 2000 t. These simulations used a food-conversion ratio (FCR) of 1.85, 85% digestibility, and farm orientations of 240 and 300 degrees to align with and perpendicular to the direction of tidal currents respectively.

- Footprint sizes increased with increased production, and orientation of the pens within the farm site. Orientation of the pens perpendicular to the dominant current direction produced a more dispersed deposition footprint, without an obvious below-cage deposition maximum. The current speeds at the site are likely to carry depositional material and nutrients from the farm towards the shoreline on the western entrance to Oyster Bay. The shoreline reefs along that coast are shallower than 10 m. Wave action and increased tidal turbulence around the headlands of the bay are likely to increase dispersion and reduce settlement of particles on to the reefs.

1 Introduction

The existing owners of the resource consent for marine farm 8049 in Oyster Bay, Queen Charlotte Sound, wish to assess the feasibility of shifting the consent area into deeper water. They also propose to farm finfish at the relocated site, rather than shellfish.

A recent ecological survey of the sea floor habitats in the vicinity of Site 8409 (Anderson & Grange 2013) showed the present consent area lies in water depths of ~10 m along the inshore boundary, which is in close proximity (~ 30 m) to nearshore reefs that run along the shoreline inshore of the site. From the preliminary survey of the sea floor seaward of the existing site, the habitats are a mixture of soft sediments (sand and mud) with large quantities of dead shell material, along with sparsely distributed epifauna including ascidians, brittle stars and screw shells. There are no offshore reefs within at least 150 m of the present site's seaward boundary. Anderson & Grange (2013), however, did identify several constraints that may determine the size and position of any relocation, including the water depth, the location of a potential patch reef, potential navigation issues, and the boundary between CMZ2 and CMZ1 - where aquaculture is presently prohibited. Given those constraints, an area of about 3.9 ha was identified as potentially suitable for relocation.

This report presents the results of a second survey to provide a more comprehensive description and location of the patch reef, to assess the tidal currents at the proposed relocated site, and to model the extent and quantity of any deposition to the sea floor should the conversion to finfish go ahead. The assessment of potential effects was informed by an ADCP deployment, additional ROV and side-scan sonar sampling, and DEPOMOD modelling for two annual production estimates of salmon.

2 Approach

2.1 Site Assessment

Based on the approximate location of an area identified as potentially forming a patch reef in Anderson & Grange (2013), high-frequency side-scan sonar transects were run across the area to provide GPS co-ordinates and sonar images of the reef.

Once defined, the reef was sampled using a remote-operated vehicle (ROV) rather than divers as the reef was in water depths greater than 30 m. ROV tracks were flown haphazardly over and around the area of interest, and both video and still photos of the habitat and dominant species taken.

2.2 ADCP observations

An RD Instruments Acoustic Doppler Current Profiler (ADCP) was deployed in Oyster Bay on August 1, 2013. It was recovered on September 13, 2013. An ADCP uses the Doppler shift to measure currents in the ocean. It measures currents in 'depth-bins' above the seabed and allows for flow data to be obtained for the whole water column. A well-known limitation of ADCPs is the loss of data near the surface which is typically estimated as 10% of the water depth.

In Oyster Bay, an ADCP was deployed close the farm in a water depth of approximately 36 m (Latitude: 41^{o} 14.827' S, Longitude: 174^{o} 14.159' E) (Figure 2-1). Observations of current speed and direction were collected every 10 minutes. The bin intervals were 1 m thick and data sampled water depths from 5 to 34 m. Attached to the ADCP frame was a Seabird temperature logger (SBE56) which measured near-bed temperatures every 10 minutes.

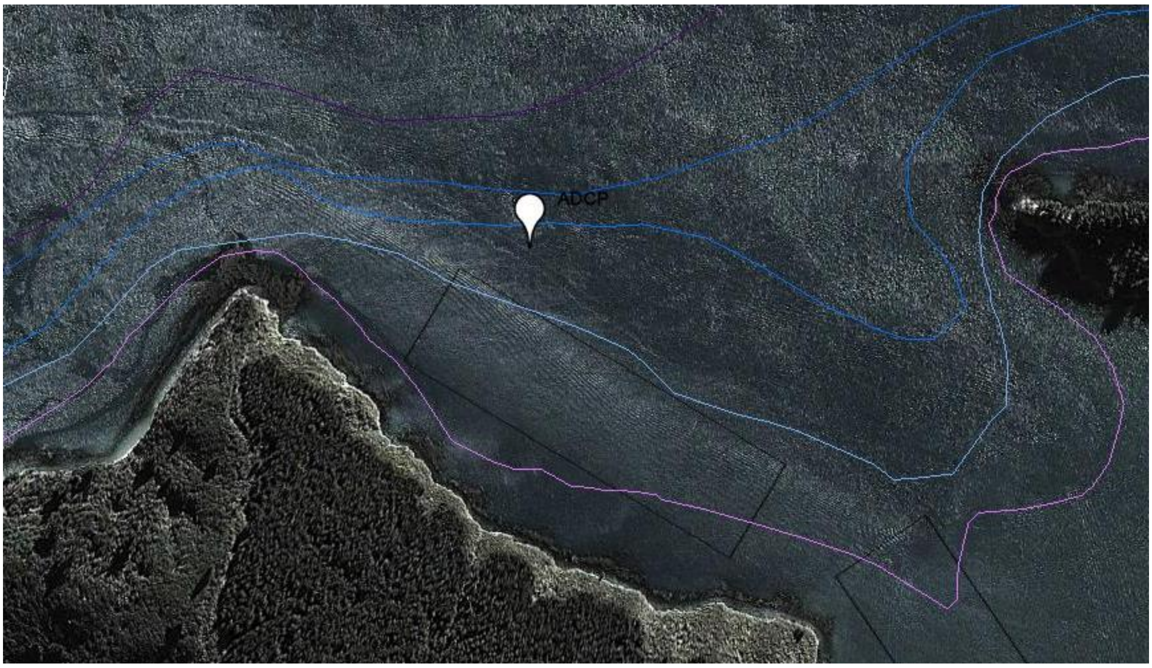


Figure 2-1: Position of ADCP in relation to existing farm consent boundaries, Oyster Bay.

2.3 DEPOMOD Modelling

Numerical modelling to predict aquaculture impacts can take on various forms. The model used for Oyster Bay simulations was DEPOMOD (Cromey et al. 2002). This type of model is a relatively simple tool that considers individual sites, hence requires less observational data. It is cost-effective and therefore has been widely used as a quick assessment tool to delineate benthic footprints. DEPOMOD is a commercial model that was developed in Scotland to predict organic deposition resulting from fish faeces and uneaten feed beneath finfish aquaculture sites and is used in many other countries, including NZ.

DEPOMOD was used to predict annual benthic deposition footprints around the proposed site. The model requires data on bathymetry, current velocities, cage dimensions and positions, and feed rates per cage. The current data were obtained from an ADCP that was moored onsite for six weeks. Time-series of ADCP were extracted into 5 depth layers (5, 12, 20, 26 and 34m). The domain size for this study was 300 × 300 m^2 and the grid cell size was 3 × 3 m^2. One grid was used for the entire domain. The model was run using the scenario of continuous feed release. The following parameters were set: 3% for feed wastage rates, 9% for water content, 85% for digestibility, settling velocity of 0.032m s^{-1} and 0.095 m s^{-1} respectively for faeces and feed. For the turbulence sub-model, horizontal and vertical coefficients were set to be 0.1 m^2 s^{-1} and 0.001 m^2 s^{-1} respectively. The model was set to run for a period of a year with constant feed supply every day, evenly spread into 4 pens.

Totaranui Ltd require predictions of possible environmental effects of a proposed finfish farm adjacent to the existing Site 8049. Since there are no finfish cages presently at Oyster Bay, benthic deposition was based on a number of plausible annual production estimates and two farm sea pen layout scenarios, i.e. two orientations for the farm (240 and 300 degrees), 85% digestibility, and a FCR of 1.85 (Richard Paine, Totaranui Ltd, pers. comm.).

The DEPOMOD rectangular grid cells containing data for the deposition were converted to ESRI map grids using ArcGIS 10. The grids were set at 10m cell size. These grids were then displayed as contour plots in ArcMap with unit scales spanning the minima and maxima for the deposition rates.

Table 2-1: Parameters used in DEPOMOD simulations for Oyster Bay.

Farm setup (rows x # pens)	Cage dimensions (m)	Cage volume (m^3)	Annual production (tonnes)	Annual feed usages (tonnes)	Monthly FCR	Farm orientation (degrees)
1 x 4	32 x 20	16,084	1000	1650	1.85	300
1 x 4	32 x 20	16,084	2000	3300	1.85	300
1 x 4	32 x 20	16,084	1000	1650	1.85	240
1 x 4	32 x 20	16,084	2000	3300	1.85	240

3 Results

3.1 Side-scan sonar results

The majority of the sea floor in Oyster Bay adjacent to the existing farm site is relatively featureless soft sediment. The “patch reef” identified in Anderson & Grange (2013) was clearly visible in the side-scan sonar images as an isolated mound approximately 15 x 12 m in area and 1-2 m in height. This mound was surrounded by flat, featureless sea floor (Figure 3-1) and therefore appeared to be unrelated to the reef systems along the shorelines.

Figure 3-1: Side-scan sonar image of tubeworm mound, Oyster Bay.

3.2 ROV observations

The mound identified in the side-scan sonar images and the surrounding sea floor in depths of 31-32 m were sampled by a small VideoRay remote-operated vehicle (ROV). The mound was almost entirely comprised of a dense population of a small sabellid polychaete, probably the species generally known as *Bispira bispira-A* (Geoff Read, NIWA, *pers. comm*) (Figure 3-2). The body of the polychaete remains buried in soft sediment and is encased in a soft, parchment-like tube, with the feeding tentacles extended into the water column. The feeding crowns are approximately 1-2 cm in diameter.

A few other species were recorded among the tubeworms, including the snake star *Ophiopsammus maculatus* and a burrowing holothurian sea cucumber. The holothurian was also common on the soft sediment surrounding the tubeworm mound (Figure 3-3) and although specimens were unable to be collected by the ROV, the species is probably *Pentadactyla longidentis* judging by the brown colour and large (> 5 cm) tentacles (Niki Davey, NIWA, *pers. comm*).

Figure 3-2: Images from ROV showing tubeworm mound, Oyster Bay.

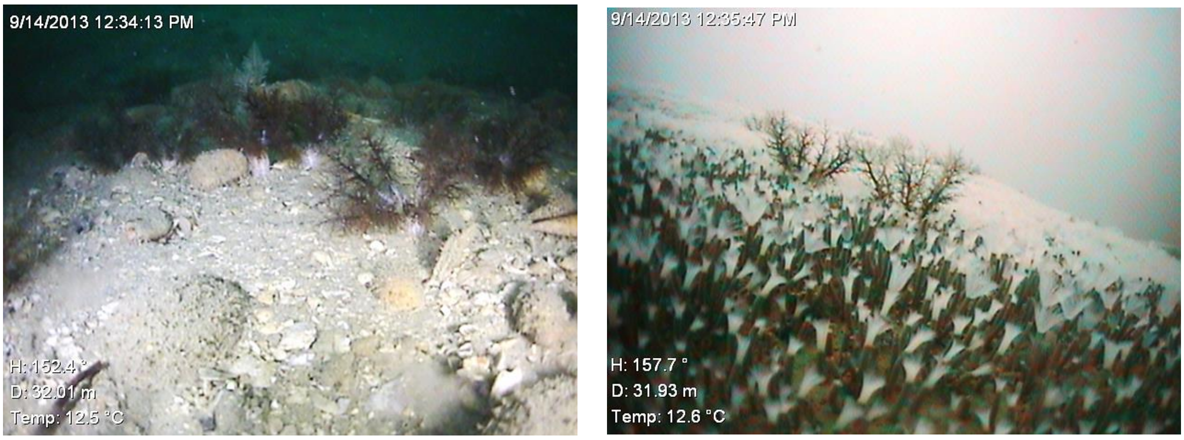


Figure 3-3: Unidentified holothurians buried in sandy sea floor and within the tubeworm mound, Oyster Bay.

3.3 Currents at Oyster Bay

Water level and current meter data cover three spring-neap cycles during August and September 2013 (Figure 3-4). Mean current speeds were between 0.2 and 0.25 ms^{-1} for the duration of the deployment, with similar speeds throughout the water column (5 to 34 m water depth). Spring tides occurred near to 10/8, 22/8 and 6/9. For several days around the larger tidal range, faster current speeds of around 0.45 ms^{-1} were recorded. The timing of the faster flows was at two different times in the tidal cycle with 1) at low water when there was an abrubt shift in flow direciton from 310º to 260º, and 2) at mid-flood in the lower 20 m of the water column.

During neap tides, current speeds ranged from 0.1 to 0.2 ms^{-1} and oscillated between similar directions of 310º and 250º. The lowest speeds were present at high water and for several hours of the ebb tide, directed towards the south west.

Five 'bins' of data were extracted from the ADCP time series for more in-depth analysis (see Appendix 1). Current rose plots that combine speed and direction with percentage occurrences of these were generated for 5, 12, 20, 26 and 34 m water depths. The convention for ocean currents is that direction shows where the water is moving towards. Near-surface current rose at 5m (Figure 3-5) shows ebb flows of up to 0.15 ms^{-1} that were directed to the northwest (310º). Higher flows of 0.25 ms^{-1} flowed towards the south-west (200º to 240º) during the flood tide. A similar response was observed at 12 m (Figure 3-6). These top two bins showed a greater spread of both speeds and associated directions. This is most likely due to the shedding of tidal flows from the nearby headland.

Deeper in the water column at 20 and 26 m (Figure 3-7), currents flowed in the same two main directions of 310º and approx. 240º for the ebb and flood tides, respectively. Of interest for material transport was the higher southwest flows observed on the mid-flood in the lower water column. These current speeds ranged from 0.25 to 0.4 ms^{-1}, depending on the stage of the spring-neap cycle. The nearbed current rose (Figure 3-9) showed slowed currents toward the northwest during the ebb, but similar speeds of 0.3 to 0.4 ms^{-1} towards 240º persisted during the flood tides.

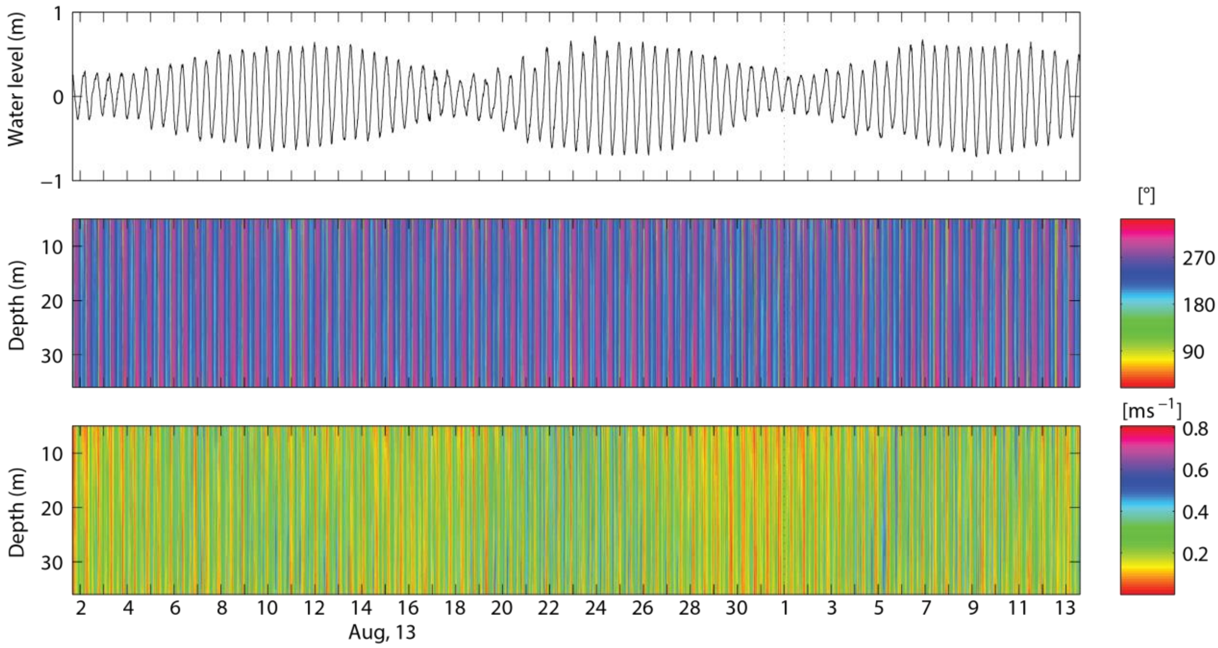


Figure 3-4: Time series of water level, current direction and speed at Oyster Bay during August and September 2013.

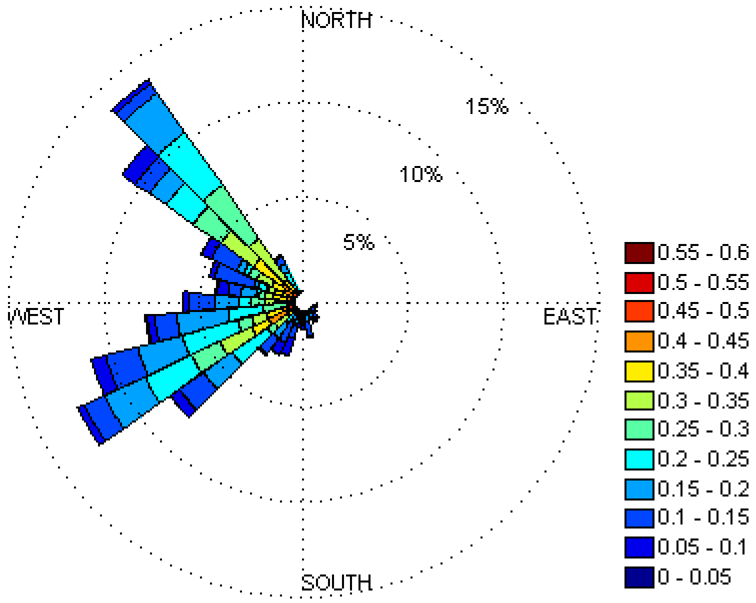


Figure 3-5: Current roses showing percentage distribution of speeds and direction at 5 m in the water column. .

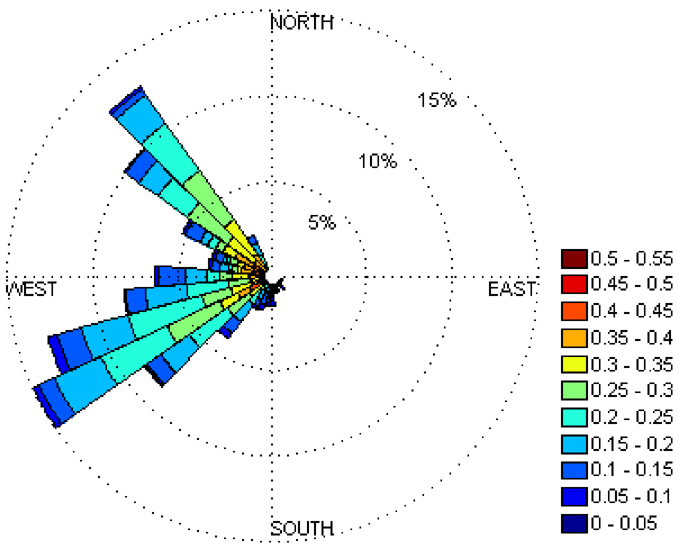


Figure 3-6: Current roses showing percentage distribution of speeds and direction at 12 m in the water column.

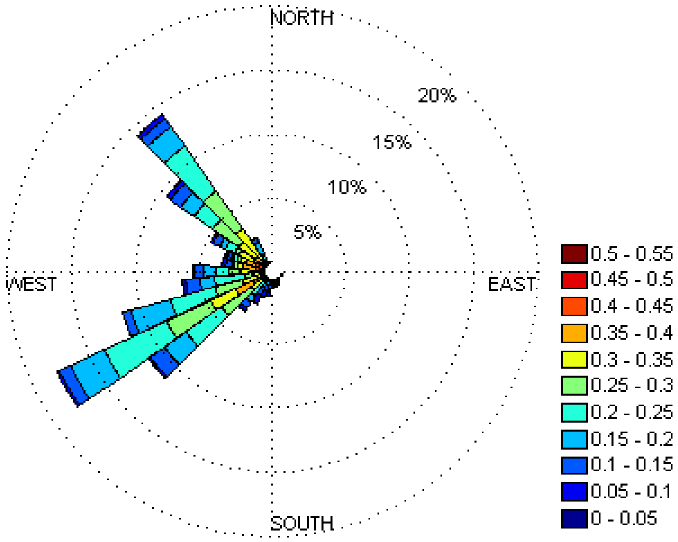


Figure 3-7: Current roses showing percentage distribution of speeds and direction at 20 m in the water column.

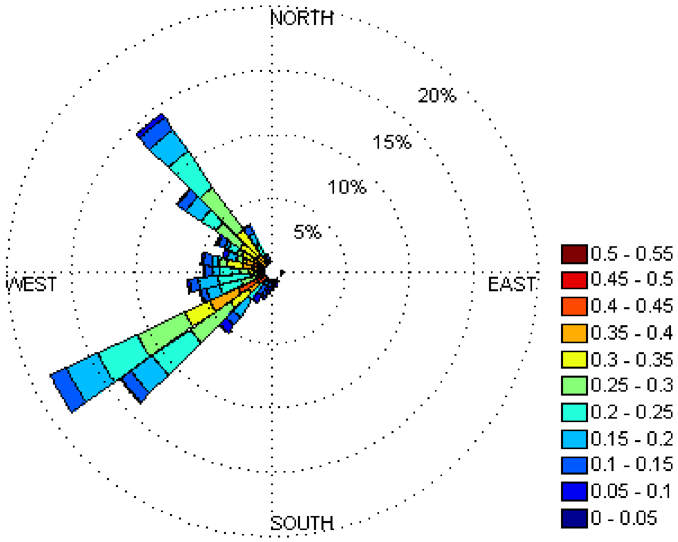


Figure 3-8: Current roses showing percentage distribution of speeds and direction at 26 m in the water column.

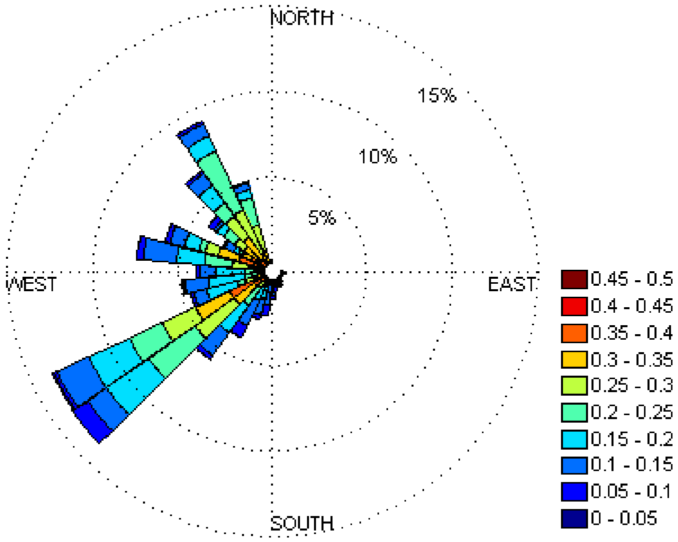
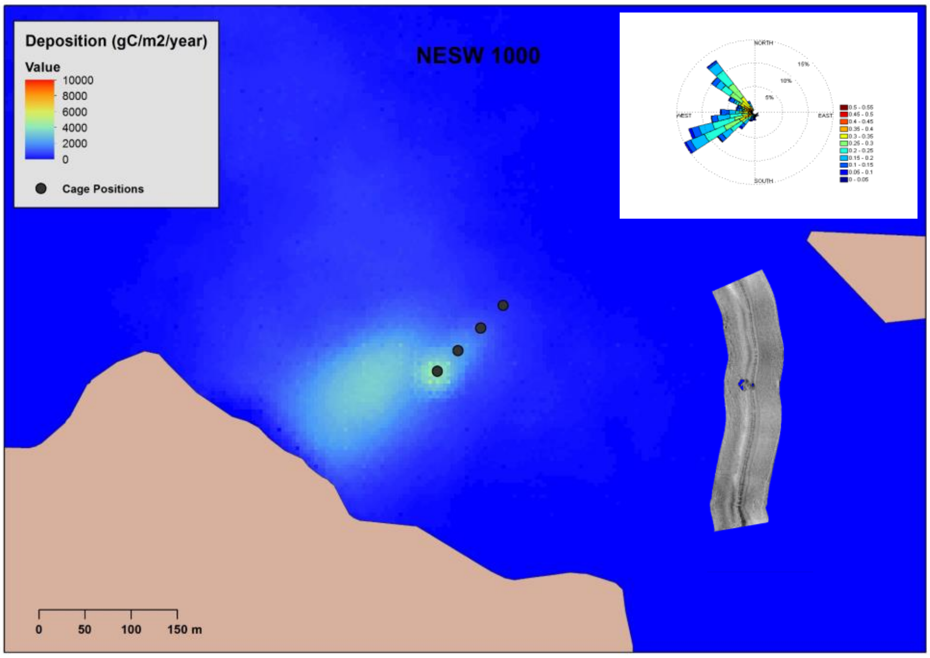


Figure 3-9: Current roses showing percentage distribution of speeds and direction at 34 m in the water column.

3.4 Modelling outputs

3.4.1 Deposition

The predicted depositional footprints are similar in extent for two estimates of annual production (1000 and 2000 tonnes), but differ in shape and intensity depending on the orientation of the pens within the proposed farm (Figure 3-10 and 3-11). For a pen configuration NE-SW (240º), the pens lie approximately along the same direction as the prevailing current, with the result that deposition builds up beneath the innermost pen and between that pen and the shore. For a pen configuration NW-SE (300º), the pens lie across the prevailing current and, while there is some deposition directly beneath the pens, the main depositional area is between the farm and the shore. The depositional footprint is more constrained with the 240º orientation, but the intensity is greater, reaching ~ 5 kg C/m^2/yr under a 1000 t production and ~8-9 kg C/m^2/yr under a 2000 t production beneath the inner pen. With the 300º configuration, the depositional footprint spreads to both the NW and SE of the farm, but the intensity is ~3 kg C/m^2/yr with a production of 1000 t, increasing to ~5-6 kg C/m^2/yr with a production of 2000 t.



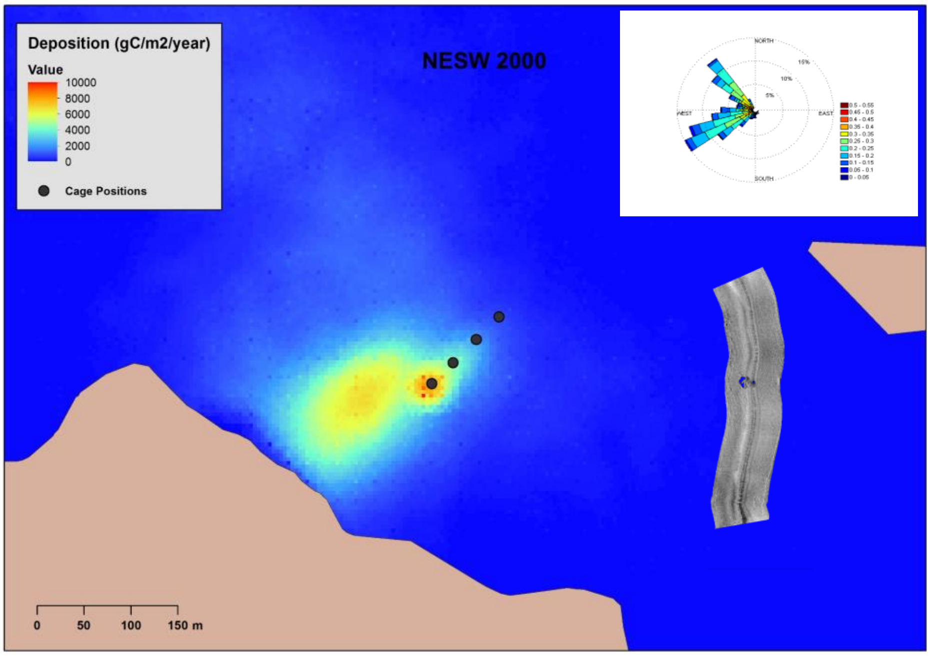


Figure 3-10:Predicted spatial footprints and density of organic deposition (g C m^{-2} yr^{-1}) at Oyster Bay for 1000 (top) and 2000 (bottom) tonnes annual production for 1 x 4 farm scenario and FCR of 1.85. Farm orientation = 240º, the current rose shoes the direction and speed of tidal flows, and the side-scan sonar image shows the position of the tubeworm mound.

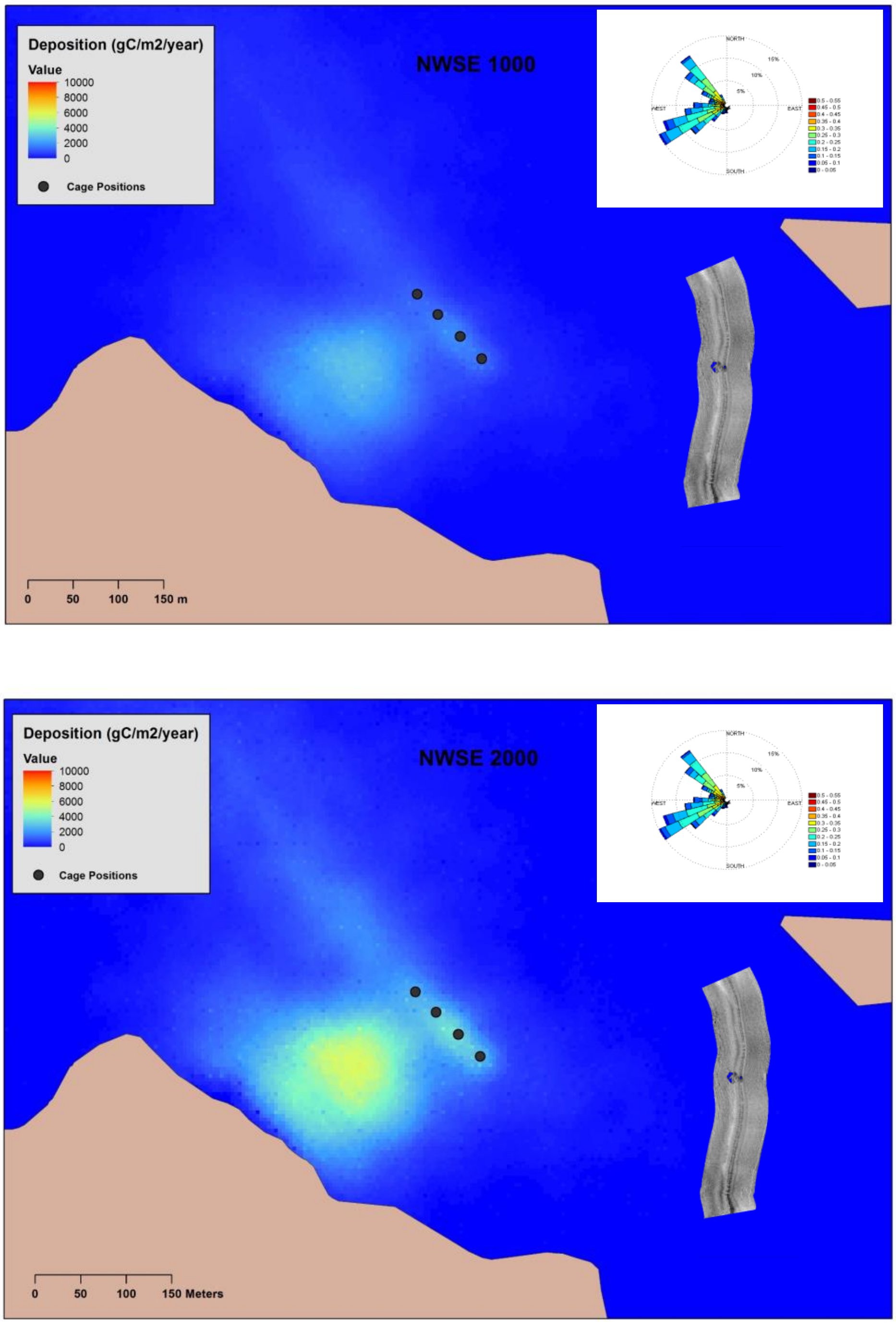


Figure 3-11: Predicted spatial footprints and density of organic deposition (g C m^{-2} yr^{-1}) at Oyster Bay for 1000 (top) and 2000 (bottom) tonnes annual production for 1 x 4 farm scenario and FCR of 1.85. Farm orientation = 300º, the current rose shoes the direction and speed of tidal flows, and the side-scan sonar image shows the position of the tubeworm mound.

3.4.2 Benthic deposition assessment

Outputs from the DEPOMOD modelling allow an estimate of the maximum deposition within the footprint around the proposed farm. There is a module within DEPOMOD, called the Infauna Trophic Index (ITI) that allows an assessment of the effects to benthic communities and species over a range of deposition rates. However, that module has not been fully tested for New Zealand benthic habitats, and there is some uncertainty how it behaves on a steeply sloping sea floor, such as that inshore of the proposed farm in Oyster Bay. ITI analyses for the deposition estimates for both annual production scenarios modelled here suggest only mild enrichment of the benthic habitats leading to a predominance of small deposit feeders such as polychaetes, apart from the more concentrated high deposition area beneath the inshore pen with a farm orientation of 240º and an annual production of 2000 t, where there would likely be low species diversity.

Keeley (2012); Keeley et al (2013) developed another assessment of benthic effects for various deposition concentrations as part of the recent EPA hearings associated with proposed new farms for NZ King Salmon. Over a range of potential and actual farm locations (including high and low flow sites) Keeley (2012) related benthic deposition to an Enrichment Stage (ES) that ranged from ES1 (pristine or natural conditions) to ES7 where the sediments became highly enriched and anoxic. Although each of the ES levels were not directly related to a value of deposition due to factors such as current flow, depth, native species and sediment type, it is possible to make some assessment on potential ES effects if the deposition is estimated. The concept of ES has recently been stipulated in consent conditions for both NZ King Salmon and the Ngai Tahu hapuku farm in Beatrix Bay.

Results from DEPOMOD for the current assessment estimate that deposition for a 1000 t annual production would result in a small area (approximately 100 m x 100 m) receiving a maximum deposition of 2-3 kg C/m^2/y, rising to 5-6 kg C/m^2/y (and a slightly larger footprint) for a 2000 t production, if the farm pens were aligned across the tidal current, i.e. 300º. For a farm orientation of 240º and an annual production of 2000 t, the maximum deposition within an area of approximately 100m x 75 m would reach 7-8 kg C/m^2/y (Table 3-1).

Table 3-1: Predicted ES scores for each farm production and orientation.

Annual production (t)	Orientation (º)	Footprint	Max deposition in footprint (kg C/m^2/y)	Predicted ES
1000	240	100 x 70 m	5-6	3-4
1000	300	100 x 100 m	2-3	2-3
2000	240	150 x 80 m	7-8	4-5
2000	300	160 x 160 m	5-6	3-4

Although the depositional footprints extend towards the shore in all scenarios, the deposition is calculated to be small (< 3 kg C/m^2/y).

4 Conclusions

4.1 Farm footprints

Estimates of benthic deposition and infaunal impacts were assessed using DEPOMOD for two estimates of annual production (1000 and 2000 tonnes). Maximum impacts were predicted below and shoreward of the proposed pens with depositional footprints spanning an area of approximately 10,000 – 25,000 m^2 depending on the annual production. DEPOMOD does have limitations and these will be discussed to provide context for these predicted footprints. Generally, DEPOMOD does a good job when a farm is oriented in the main tidal flow (Cromey el al., 20002), meaning that tidal ellipses and footprints tend to be closely aligned. This is the case in Oyster Bay where the tidal currents are aligned in a NW and SW direction.

The close match between model footprints and current observations for the 300º farm orientation (i.e. the footprint has a bimodal pattern like the current roses), indicates this to be the preferred alignment at Oyster Bay, and this would be well suited to finfish aquaculture due to the moderately high current speeds measured in the vicinity of the headland.

A major consideration for dispersal is the proximity of the proposed farm to the nearby headland. Tidal flows around headlands can generate eddies which have dispersive characteristics greater than the routinely used 0.1 m^2s^{-1} in DEPOMOD. A schematic below shows what happens with tidally cyclic flow in the presence of a headland, with steady flows able to induce a simple eddy (top) or a train of eddies (bottom). Higher dispersion along the main direction of flow has been shown to decrease predicted fluxes of material directly below the farm (Cromey and Black, 2005). Essentially, the higher dispersion increased the spread of deposition slightly further from the farm, i.e. at the 25 to 100 m range, became evident but the overall footprint size did not increase.

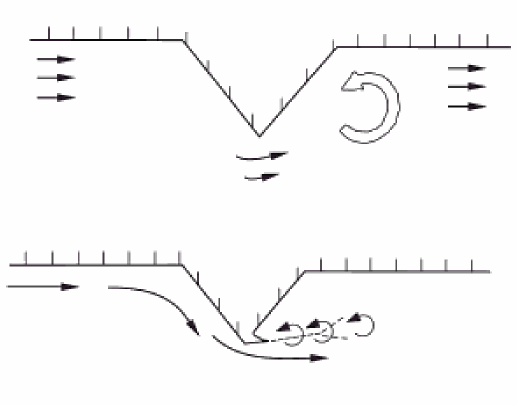


Figure 4-1: Schematic of tidal eddy shedding in the vicinity of a headland for a simple eddy (top) or a train of eddies (bottom).

4.2 Site Assessment

The benthic habitats in the vicinity of the existing marine farm consent area, and the potential relocation site slightly offshore (but still within the CMZ2 boundary) are dominated by soft sediments of sand and mud, with shell gravel and dead shells that support species such turret shells, brittle stars, and sea cucumbers (Anderson & Grange 2013). These habitats are widespread within Tory Channel.

Approximately 250 m east of the potential relocation site is an isolated, solitary mound, formed by a dense bed of parchment tubeworms. The mound covers an area of about 15 x 12 m and is 1-2 m high. The species of tubeworm forming the mound is not formally described, but is known as *Bispira bispira-A*, which has also been recorded from other sites in Queen Charlotte Sound (Davidson et al, 2011) and Port Underwood. Dr Geoff Read, a polychaete taxonomist at NIWA regards the species as a native but closely related to a similar Australian species. Sabellid polychaetes such as this are able to clone off juveniles so are suited to rapidly colonising areas, and the mound in Oyster Bay may have been originally formed around an object on the sea floor.

It is unknown how the sabellid polychaetes comprising the mound would respond to increased sedimentation and nutrients released from a nearby finfish farm, but the other dominant species on the mound and adjacent sea floor, the holothurian *Pentadactyla*, is likely to be tolerant of increased nutrient release (holothurians generally are recorded in large numbers beneath marine farms). However, the predicted depositional footprints at both farm orientations and annual production scenarios show no deposition on the tubeworm mound due to the prevailing tidal currents.

The deposition estimates modelled for potential annual production of finfish from the site indicate that there is likely to be some replacement of existing benthic species by opportunistic species beneath and shoreward of the sea pens, but the predicted ES values within the area of maximum deposition indicate only very slight enrichment accompanied by minor reductions in species diversity, increases in infaunal abundance, and some increase in organic content within the sediments.

The depositional footprints do, however, show deposition is likely to reach the shoreline west of the proposed farm. There are several mitigating circumstances that will reduce potential effects. The shoreline is fringed with reef containing kelp, other seaweeds, and invertebrates. The reefs are clearly visible in the side-scan sonar images (Figure 4-2).

Figure 4-2: Side-scan sonar image (width 60 m) of reef and rocky structures along the shoreline, Oyster Bay. The reef structures lie almost entirely shallower than the 10 m depth contour (pink line).

The reef structures do not extend more than 30 m from the shore, and tend to be shallower than 10 m depth. At this depth, wave action, in combination with tidal currents, would very likely resuspend material that may be carried on to the reefs, particularly close to the headland of the bay. In addition, Figure 3-1 also shows the wake from a passing Cook Strait ferry. These wakes will also tend to resuspend material from the reef.

The potential effects on those shoreline habitats are difficult to predict with certainty. Increased nutrients released from the farm could stimulate increased growth of kelp and other algae, and wave action and current eddies will help resuspend and carry away biodeposits from the farm that may reach the reefs. The predicted deposition from a farm with annual production of 2000 t will alter existing benthic habitats, but are highly unlikely to cause anoxic conditions, even directly beneath the pens.

5 Acknowledgements

The authors thank Dan Cairney and Mike Page for excellent boat skills during the field work. We also want to thank Mike Brewer and Fiona Elliot for the successful deployment and recovery of the ADCP in the salmon farm environment.

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Appendix A Time series plots: ADCP observations

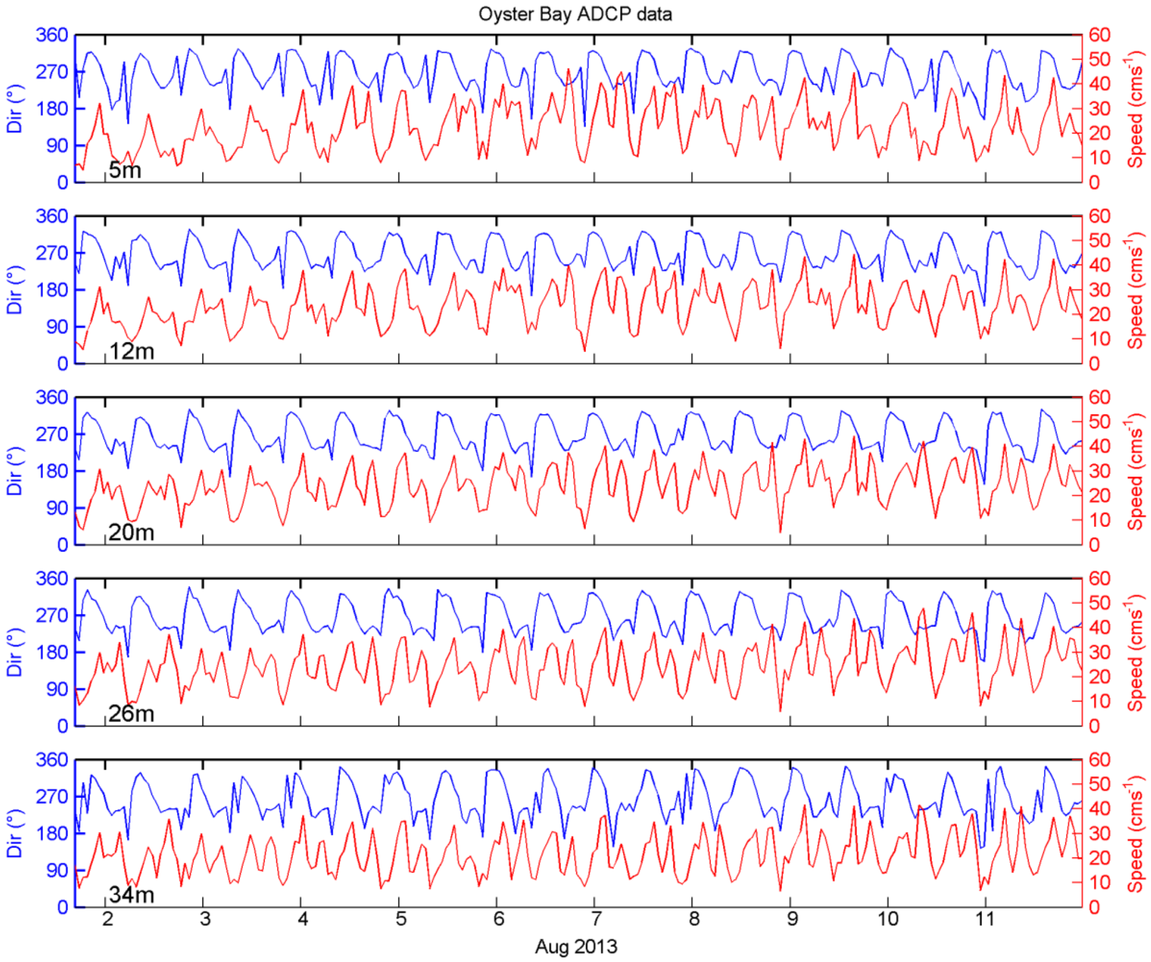

Figure A-1: Top to bottom panels show time series of current speed (red line) and direction (blue line) at 5, 12, 20, 26 and 34 m from Aug 1 to 12, 2013.

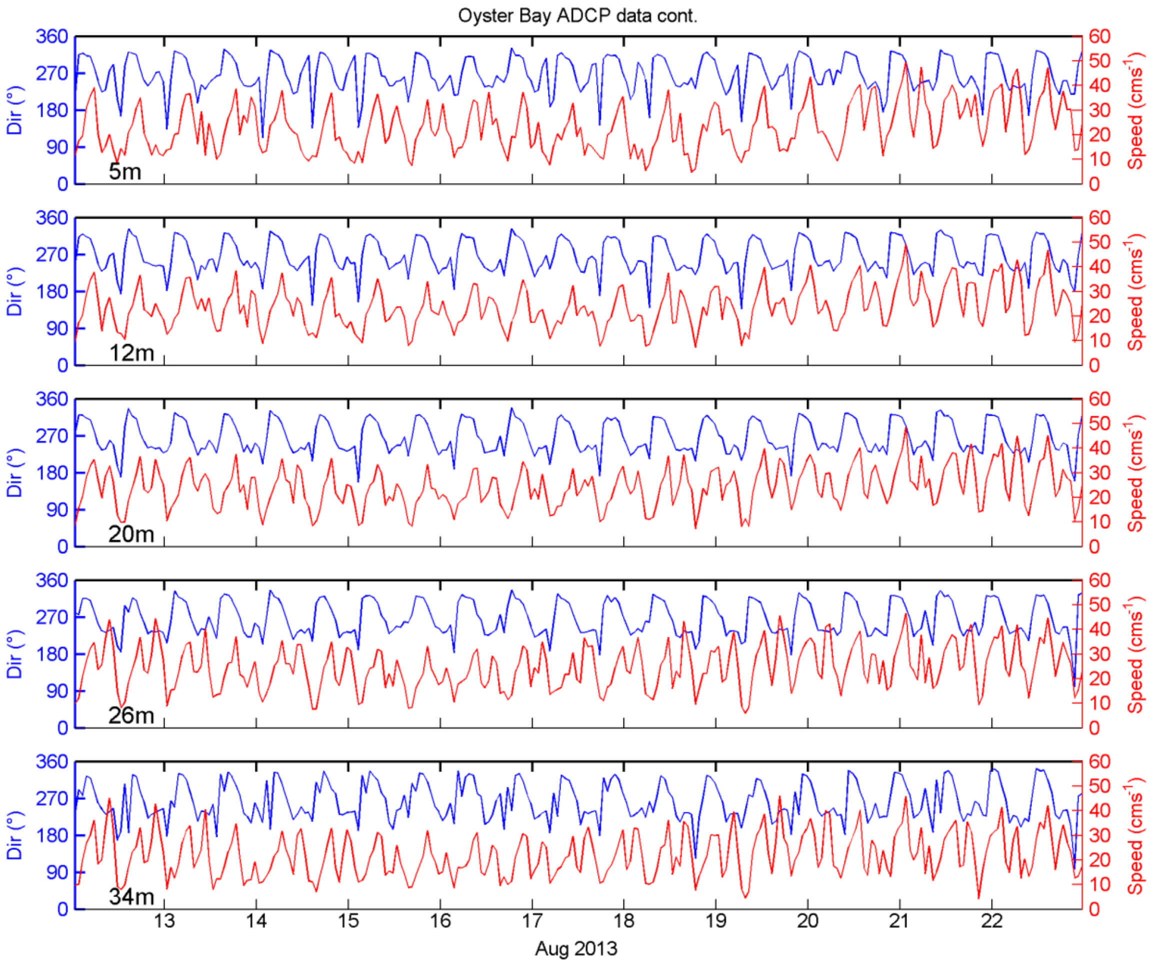

Figure A-2: Top to bottom panels show time series of current speed (red line) and direction (blue line) at 5, 12, 20, 26 and 34 m from Aug 12 to 23, 2013.

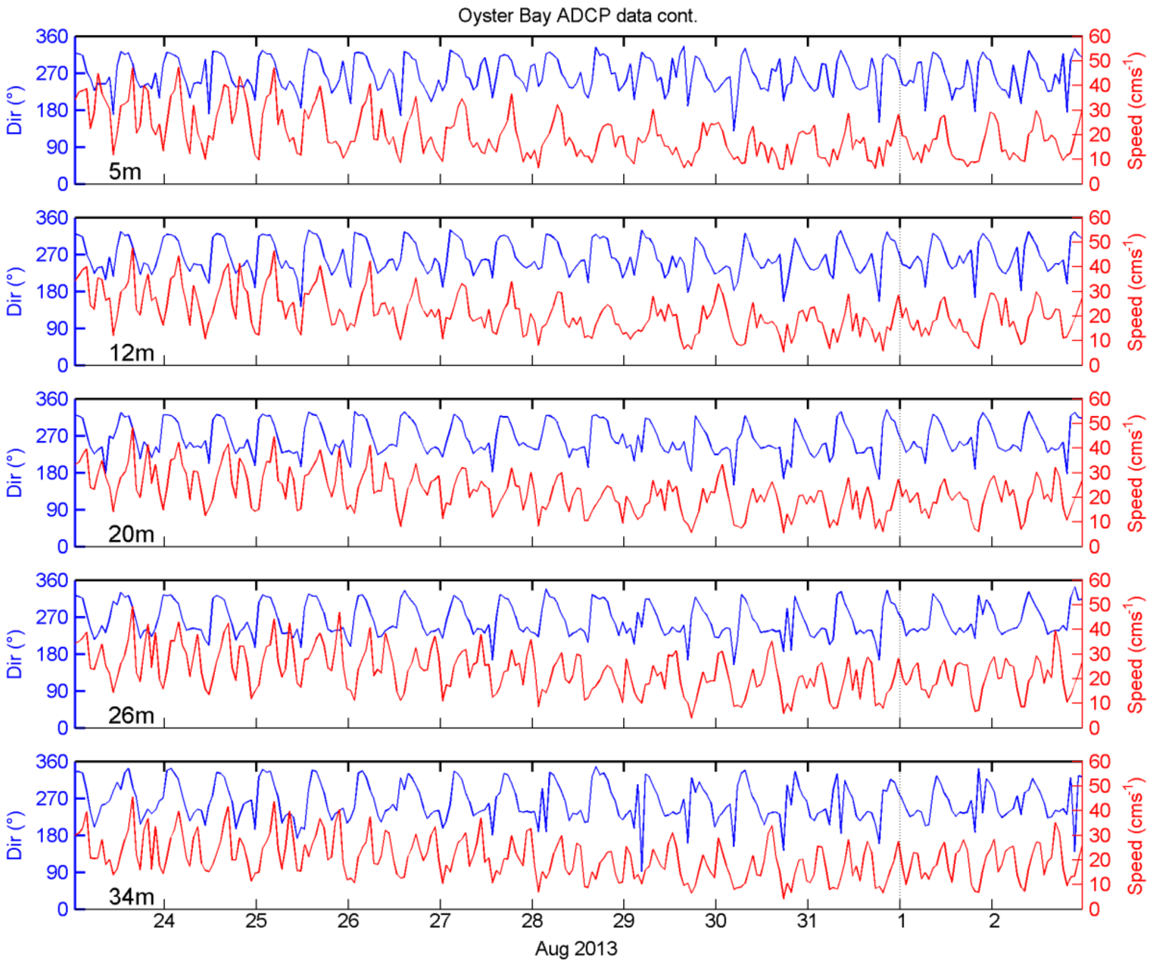

Figure A-3: Top to bottom panels show time series of current speed (red line) and direction (blue line) at 5, 12, 20, 26 and 34 m from Aug 23 to Sep 3, 2013.

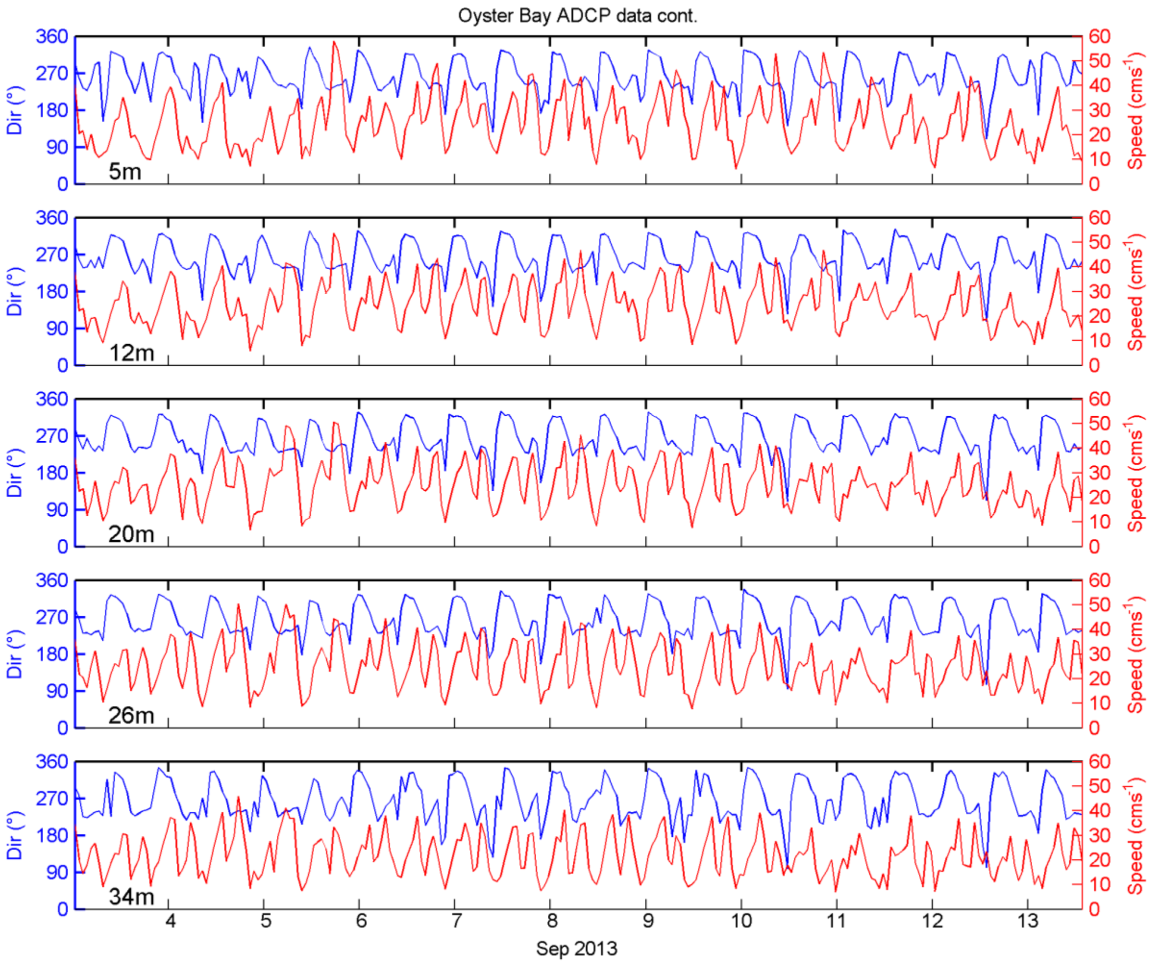

Figure A-4: Top to bottom panels show time series of current speed (red line) and direction (blue line) at 5, 12, 20, 26 and 34 m from Sep 3 to 13, 2013.