FISHNISH A, SOUND OF MULL

MODELLING DATA COLLECTION REPORT

Report To	Scottish Environment Protection Agency
Deployment ID	DPL3, DPL1Y000 & DPL1X000
Status	V1
Date	08/04/2022

Scottish Sea Farms Ltd
[redacted]

1. Site Description

Hydrographic surveys were carried out at the SSF marine cage fish farm (MCFF) Fishnish A. Current speed and direction, depth and meteorological data were collected as part of this survey for use with SEPA's particle tracking model NewDEPOMOD to assess this site's suitability for future development.

The survey area is located within Fishnish Bay, Sound of Mull adjacent to the existing SSF Fishnish A site. The site is sheltered from most southerly directions winds with the greatest exposure to the wind from the north west.

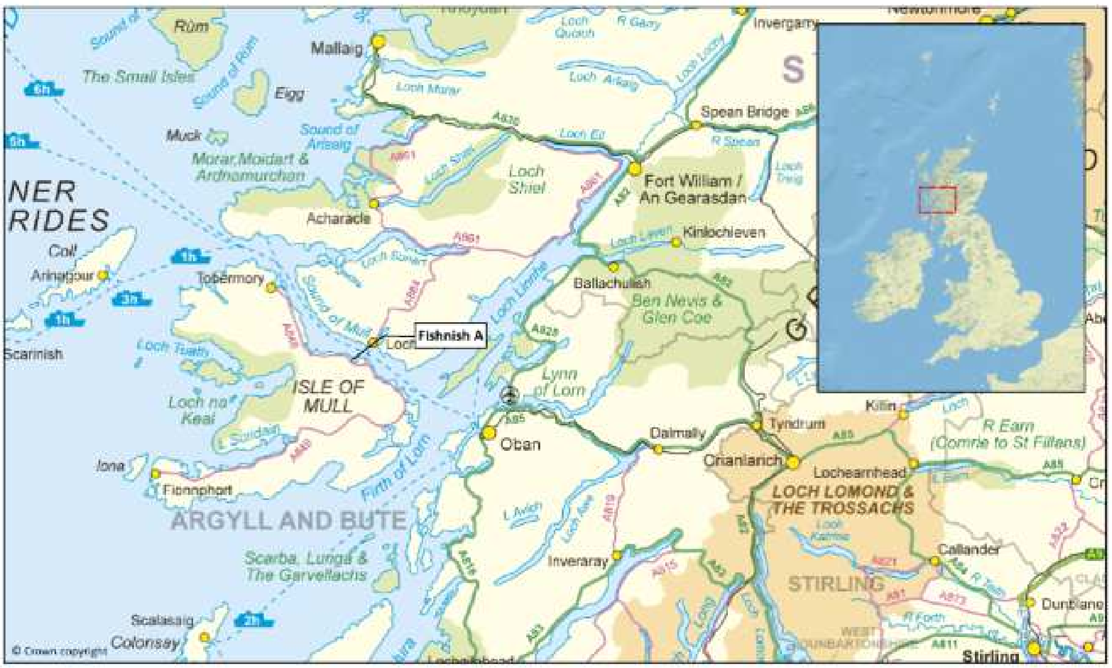


Figure 1: Survey location

2. Scope

SSF Hydrographic surveys were carried out at this location in March 2015, December 2017 & January 2018. These surveys are presented in this report along with the summary statistics.

3. Methods

a. Instrument deployment

In each survey an Acoustic Doppler Current Profiler (ADCP) was deployed at the survey location. Specifically, a 600 kHz RDI Workhorse mounted in a fiberglass Seaspider frame was deployed in a u-shaped mooring with ground rope running to weights attached to surface buoys. The current meters were deployed within 150 m the site centre;

- 2015 – 56 30.987 N 05 50.025 W (164255,742632) 20/03/2015 to 07/04/2015
- 2017 - 56 30.917 N 05 50.148 W (164121, 742510) 13/12/2017 to 12/01/2018
- 2018 - 56 31.004 N 05 50.328 W (163946, 742683) 26/01/2018 to 13/03/2018

Position fixes were obtained using a Garmin GPSmap 76S in WGS84. The GPS position accuracy was compared against a known location and checked for consistency at the end of the survey.

Current flow and direction were recorded at throughout the water column using 1 m bins with an averaging period of 20 minutes.

Deployment configuration:

Table 1: ADCP configuration for Fishnish A 2015, 2017 & 2018 hydrographic surveys

Frequency	614 kHz
Pings/Ens	400
Ensemble Interval (s)	1200
1st Bin Range (m)	2.10
Bin Size (m)	1

b. Data processing

All datasets are first opened in the Teledyne's data processing software package Velocity where they are given an initial inspection (e.g. orientation, pitch, roll, heading) to check that the meter has remained undisturbed and there are no obvious breaks in the data. Any side lobe interference is removed. If a dataset passes this first check the valid cells are exported in ASCII format and then examined in detail using Teledyne's *QA/QC Parameter for Acoustic Doppler Current Profilers* application. Appropriate depth cells representing the bed, cage bottom and surface currents were determined as outlined in SEPA's Regulatory Modelling Guidance for the Aquaculture Sector (July 2019, v1.1) and these data analysed using the SEPA tool *HGdata_analysis_v7.11.xls.* All bearings were corrected from magnetic north to grid north using the appropriate Grid Magnetic Angle using declinations obtained for the survey position and date from the IGRF 2020 Model provided online by NOAA, and from a grid convergence angle calculated from the deployment National Grid Reference by the HGdata_analysis spreadsheet.

4. Flow data

a. Deployment position

Deployment positions are given in Table 2 and Figure 3 below. The ADCPs were within 150 m of the existing site centre and within 100 m of the nearest cage (2018 deployment 105 m). Recorded depths were corrected to chart datum using predicted tidal heights from Craignure obtained from Admiralty TotalTide (ATT).

Table 2: Recorded location and depth of Fishnish A 2015, 2018 and 2020 current meter deployments

Date & time (UT)	Latitude	Longitude	Easting	Northing	Depth (mCD)
20/03/2015 13:13	56° 30.987 N	05° 50.025 W	164255	742632	37.2
13/12/2017 11:27:58	56° 30.917 N	05° 50.148 W	164121	742510	28.7
26/01/2018 11:37:31	56° 31.004 N	05° 50.328 W	163946	742683	27.6

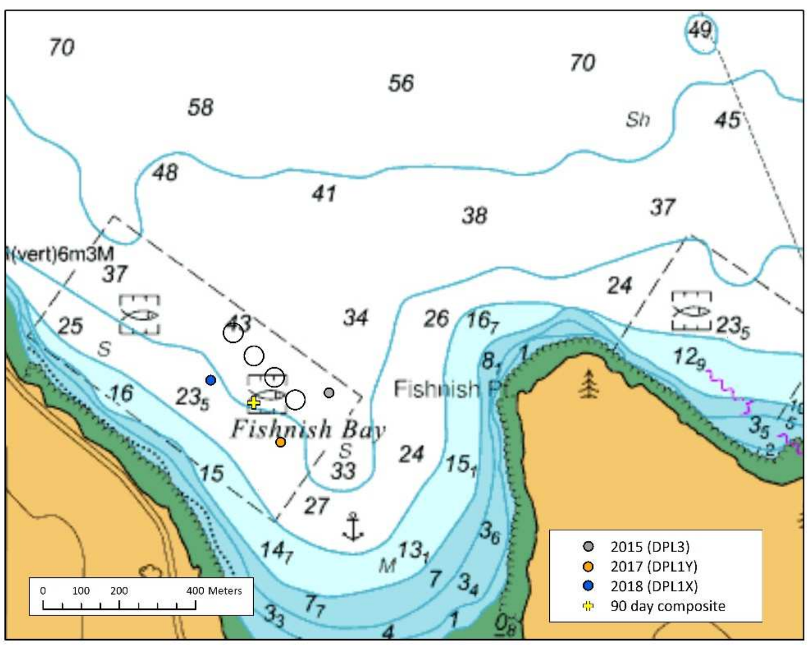


Figure 3: Recorded location of Fishnish 2015, 2017 & 2018 current meter deployments and the 90 day composite position used for NewDepomod modelling

b. Description

i. Quality

2015

Valid ensembles were collected during this deployment for the period 20/03/2015 13:46:14-07/04/2015 10:46:14 giving 17.88 days of data with valid bins 1 - 35. Pitch, roll and heading remain undisturbed during the deployment, except for a small disturbance in pitch and roll of less than 2.5 degrees. This is not reflected in the heading or the pressure record and may have been caused by the meter settling. Plots of heading, pitch, roll and sensor depth are presented at Appendix A.

The recorded pressure was compared with the estimated tidal heights for Craignure. Both range and timing are relatively consistent with those predicted. The pressure record indicates that the mean depth during the deployment, including the height of the frame, was 39.4 m and the sensor depth at deployment was 37.2 mCD.

The standard deviation (SD) for each ensemble at each cell is calculated according to:

$$cell\ SD = \frac{single\ ping\ SD}{\sqrt{\frac{(PG1 + PG4)}{100} * no.of\ pings}}$$

Where the single ping SD is specific to the a 600 kHz Workhorse for a cell size of 1.0 m (0.0699 m s^{-1}), PG1 (percent good 1) and PG4 are the percentages of 3 and 4 beam solutions respectively (i.e. valid pings) and the number of pings is that per ensemble programmed for the deployment (400).

The mean SD for bins 1 to 27 is 0.0036 m $s^{-1}$and is therefore well within the SEPA guideline threshold for horizontal precision of exceeding 10% of the mean velocity recorded (0.1316 m s^{-1}, cells 1-35).

2017

Valid ensembles were collected during this deployment for the period 13/12/2017 11:27:58 – 19/01/2018 09:07:58 giving 36.9 days of data with valid bins 1 - 27. Pitch and roll remain undisturbed during the deployment while there is some minor drift in the heading this was insignificant over the length of the survey with an overall change 3.08 degrees. This could be attributed to the meter settling. Plots of heading, pitch, roll and sensor depth are presented at Appendix B.

The recorded pressure was compared with the estimated tidal heights for Craignure. Both range and timing are relatively consistent with those predicted. The pressure record indicates that the mean depth during the deployment, including the height of the frame, was 30.90 m and the sensor depth at deployment was 28.68 mCD.

The standard deviation (SD) for each ensemble at each cell is calculated according to:

$$cell\ SD = \frac{single\ ping\ SD}{\sqrt{\frac{(PG1 + PG4)}{100} * no.of\ pings}}$$

Where the single ping SD is specific to the a 600 kHz Workhorse for a cell size of 1.0 m (0.0699 m s^{-1}), PG1 (percent good 1) and PG4 are the percentages of 3 and 4 beam solutions respectively (i.e. valid pings) and the number of pings is that per ensemble programmed for the deployment (400).

The mean SD for bins 1 to 27 is 0.0036 m $s^{-1}$and is therefore well within the SEPA guideline threshold for horizontal precision of exceeding 10% of the mean velocity recorded (0.1184 m s^{-1}, cells 1-27).

In bins 15 – 23 there is an indication that a possible rope or mooring line is causing occasional interference in two of the beams. There is minimal impact on the bins selected for modelling and repairs have been carried out at the following locations:

Bin 15

- 22/12/2017 01:47-22/12/2017 02:07
- 27/12/2017 15:47
- 28/12/2017 04:27
- 05/01/2018 01:27
- 05/01/2018 13:27
- 06/01/2018 01:47
- 06/01/2018 14:27

Bin 23

- 17/12/2017 07:27
- 31/12/2017 17:07 - 31/12/2017 17:47
- 01/01/2018 17:47

Repairs were made by taking the average of the good cells either side of the cells requiring repair. This was also verified by checking for agreement with surrounding bins and corresponding tidal phase within the record. A total of 13 cells were repaired.

2018

Valid ensembles were collected during this deployment for the period 26/01/2018 11:37:31 – 13/03/2018 03:57:31 giving 45.68 days of data with valid bins 1-24. Plots of heading, pitch, roll and sensor depth are presented at Appendix C.

The recorded pressure was compared with the estimated tidal heights for Craignure. Both range and timing are consistent with those predicted. The pressure record indicates that the mean depth during the deployment, including the height of the frame, was 29.77 m and the sensor depth at deployment was 27.56 mCD.

The standard deviation (SD) for each ensemble at each cell is again calculated according to:

$$cell\ SD = \frac{single\ ping\ SD}{\sqrt{\frac{(PG1 + PG4)}{100} * no.of\ pings}}$$

Where the single ping SD is specific to the a 600 kHz Workhorse for a cell size of 1.0 m (0.0699 m s^{-1}), PG1 (percent good 1) and PG4 are the percentages of 3 and 4 beam solutions respectively (i.e. valid pings) and the number of pings is that per ensemble programmed for the deployment (400).

The mean SD for bins 1 to 24 is 0.0035 m $s^{-1}$and is therefore well within the SEPA guideline threshold for horizontal precision of exceeding 10% of the mean velocity recorded (0.1275 m s^{-1}, cells 1-24).

ii. Depth cell selection

Bins 1, 22, 30 (2015), 1, 15, 23 (2017) and 1, 13, 22 (2018) were selected to represent near-bed, pen-bottom and sub-surface conditions respectively, detailed in Table 3. The near-bed cell is at a depth within 3 m above the seabed. The pen-bottom cell was selected from a depth corresponding to the bottom of the pens at the mean depth observed during the deployment period. The sub-surface cell was selected from a depth to be within 5 m of the lowest observed tide during the deployment, while being below potential effects from wave breaking or side-lobe interference.

Table 3: Depth cell selection

Number	m from seabed
2015	
1	2.8
22	23.8
30	31.8
2017	
1	2.7
15	16.7
23	24.7
2018	
1	2.7
13	14.7
22	22.7

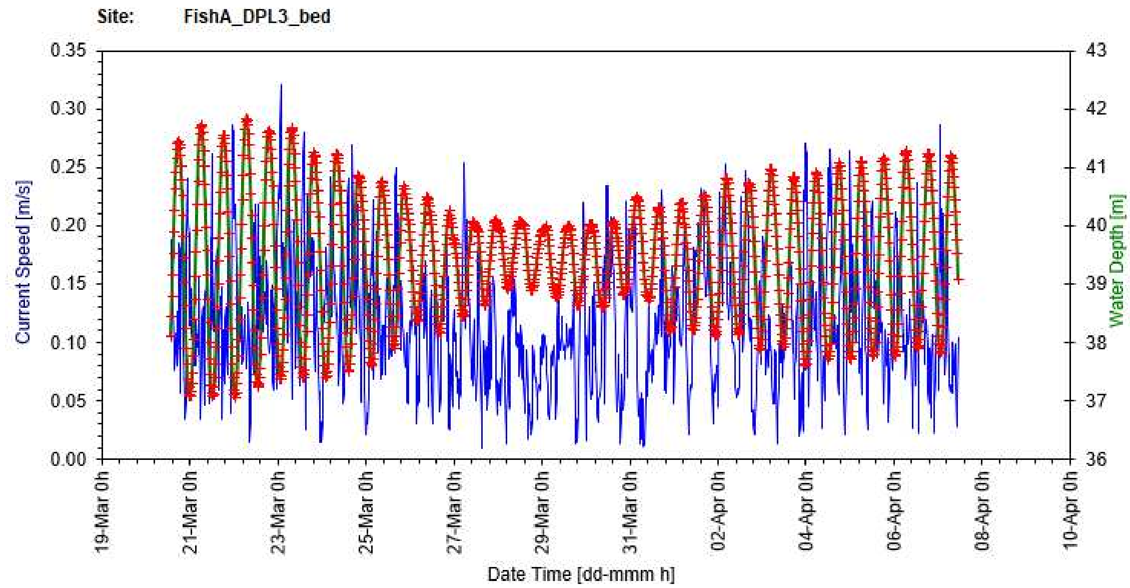
iii. Analysis

The summary statistics for the three datasets are given in Tables 4, 5 & 6 below.

2015

Table 4: Fishnish A (DPL3) hydrographic summary statistics.

	Near-bed	**Pen-bottom**	**Sub-surface**
Mean velocity (m s^{-1})	0.116	0.131	0.141
Min velocity (m s^{-1})	0.001	0.003	0.004
Max velocity (m s^{-1})	0.321	0.32	0.404
Ranked percentage 0.095 m s^{-1}	36 %	29 %	27 %
Major axis (°G)	050	80	090
Amplitude anisotropy	1.53	1.46	1.67
Residual velocity (m s^{-1})	0.03	0.06	0.06
Residual direction (°G)	032	084	082
Parallel Residual (m s^{-1})	0.031	0.055	0.062
Normal Residual (m s^{-1})	-0.010	0.004	-0.009
Parallel tidal amplitude (m s^{-1})	0.147	0.155	0.176
Normal tidal amplitude (m s^{-1})	0.096	0.106	0.105
	Min	**Max**	**Range**
Depth (m)	37.05	41.84	4.4



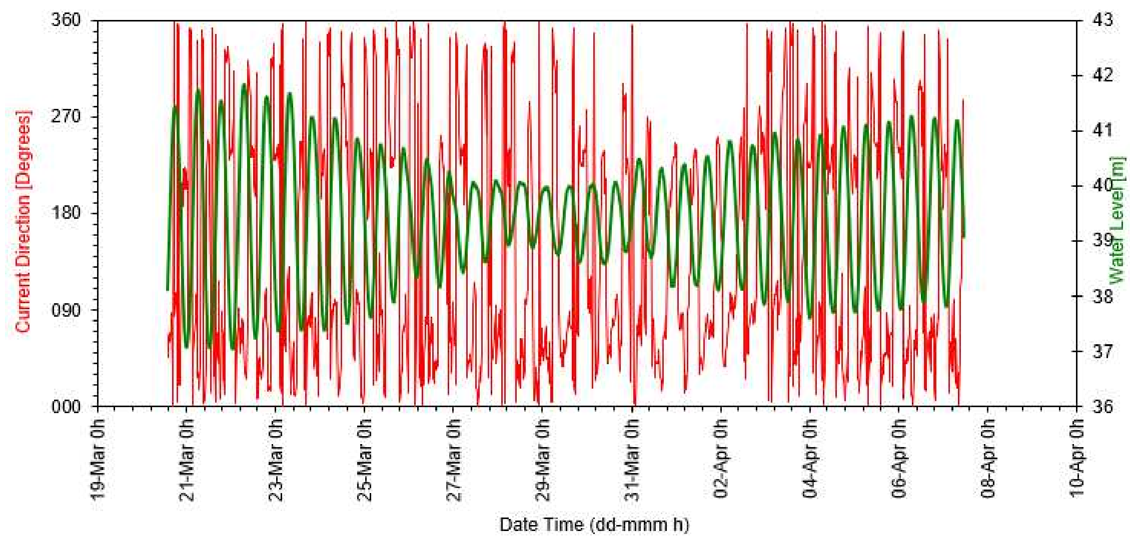


Figure 5: Near-bed time series plots for current speed and direction against water level

Figure 5: Near-bed time series plots for current speed and direction against water level

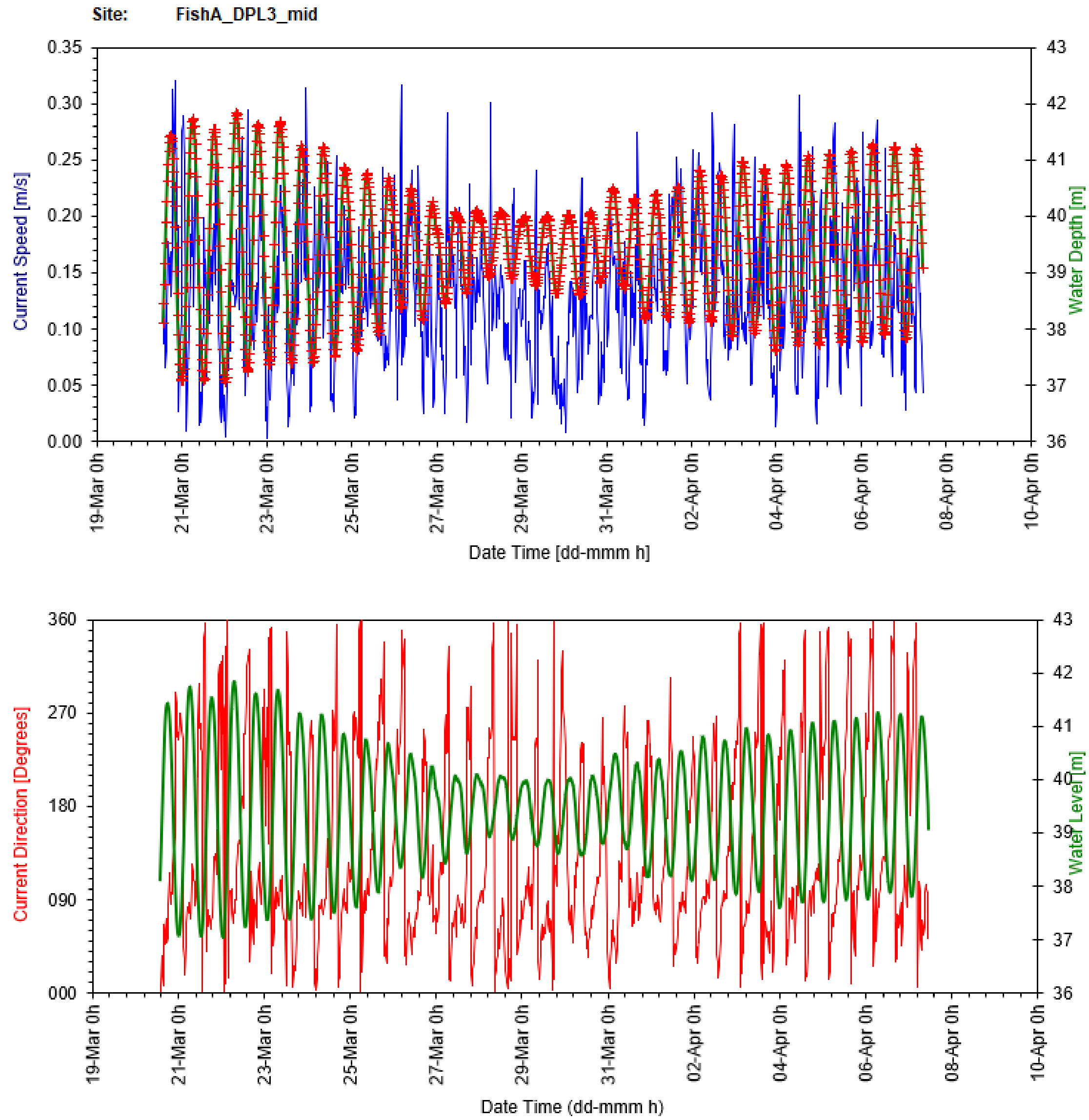


Figure 6: Cage bottom time series plots for current speed and direction against water level

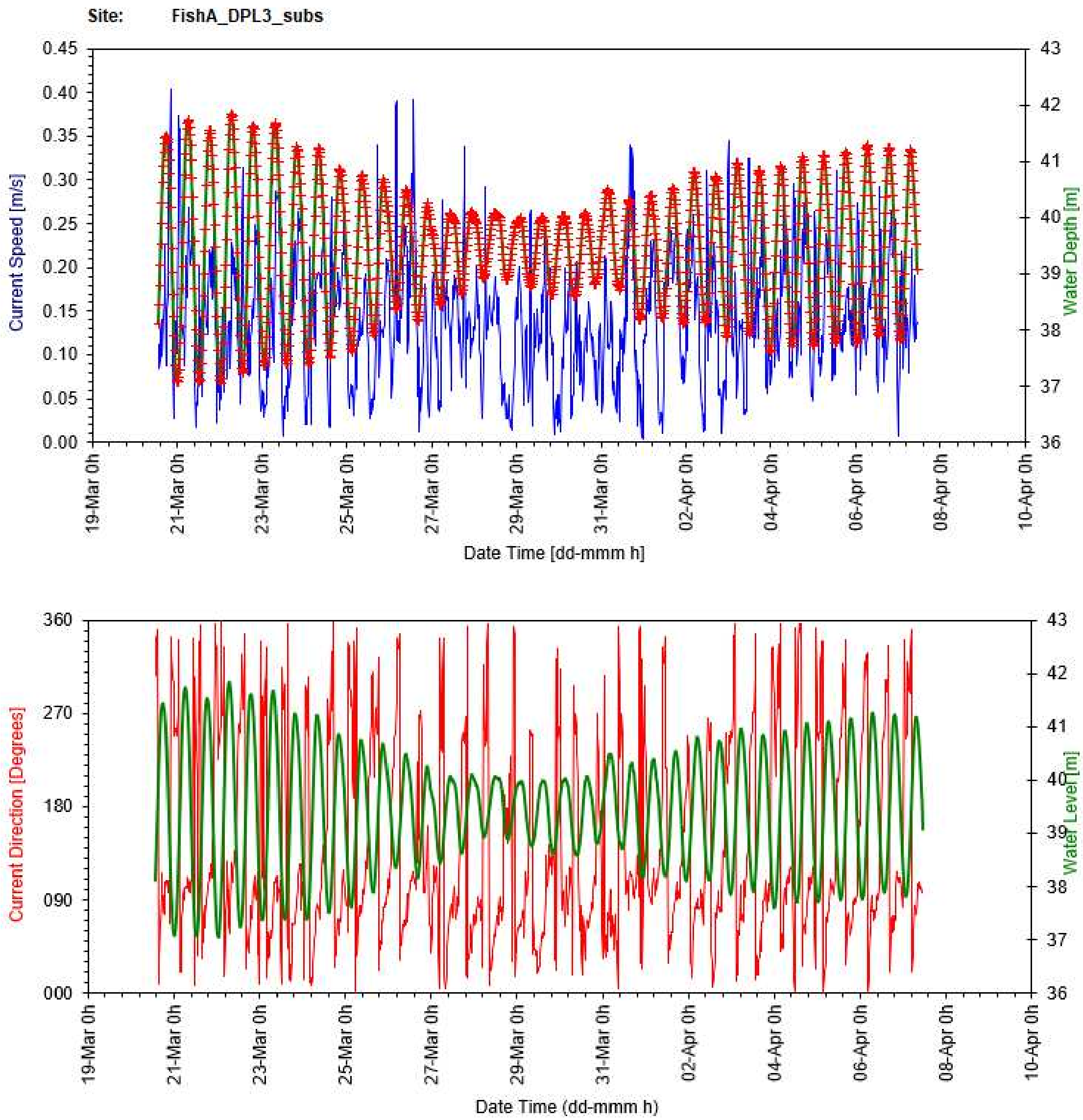
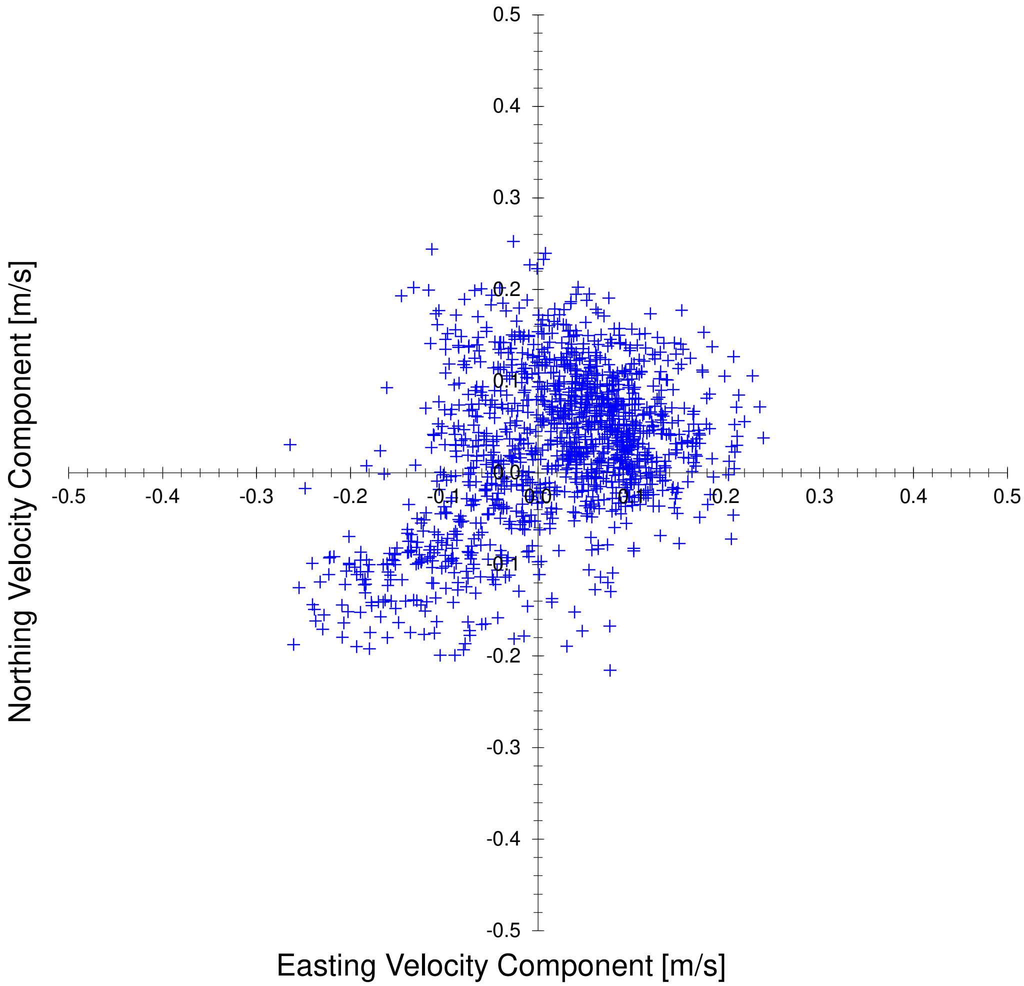


Figure 7: Subsurface time series plots for current speed and direction against water level


Northing Velocity Component [m/s]
Easting Velocity Component [m/s]

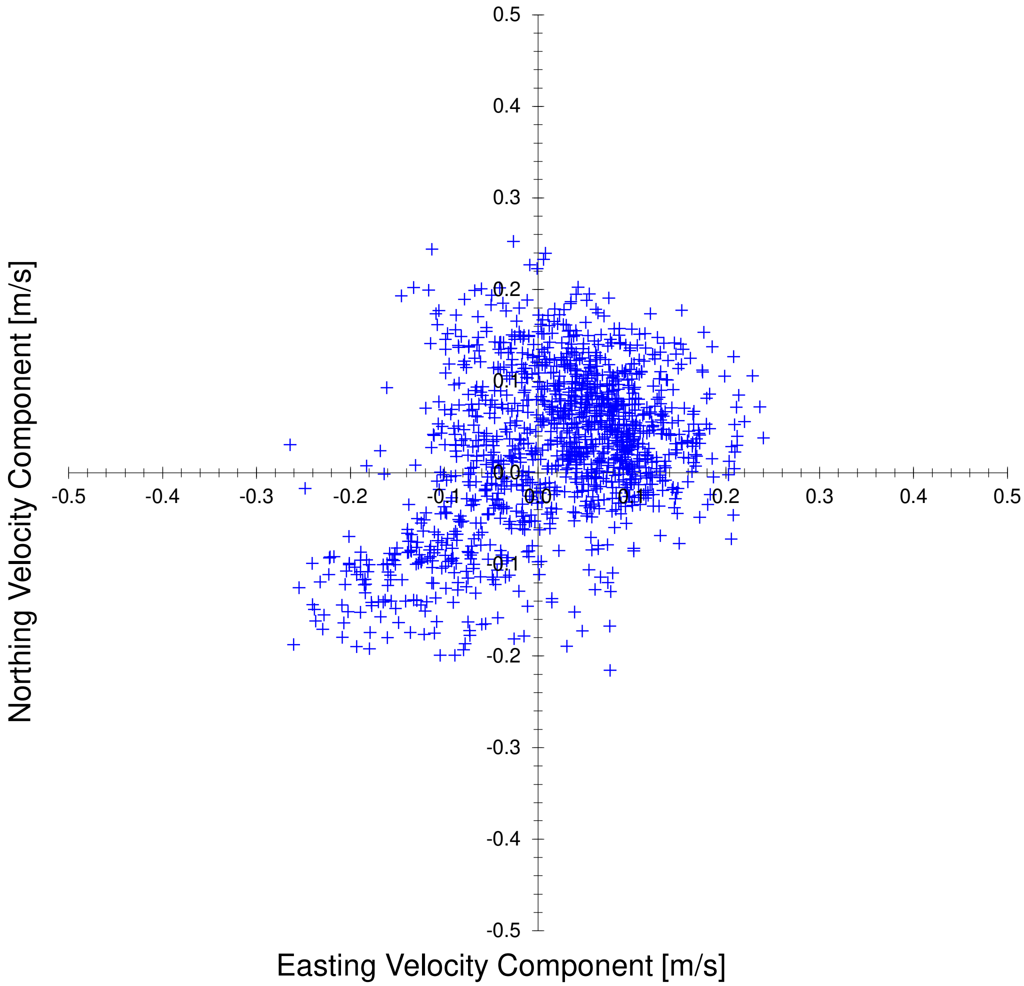


Figure 8: Near-bed scatter plot of easting and northing velocity components

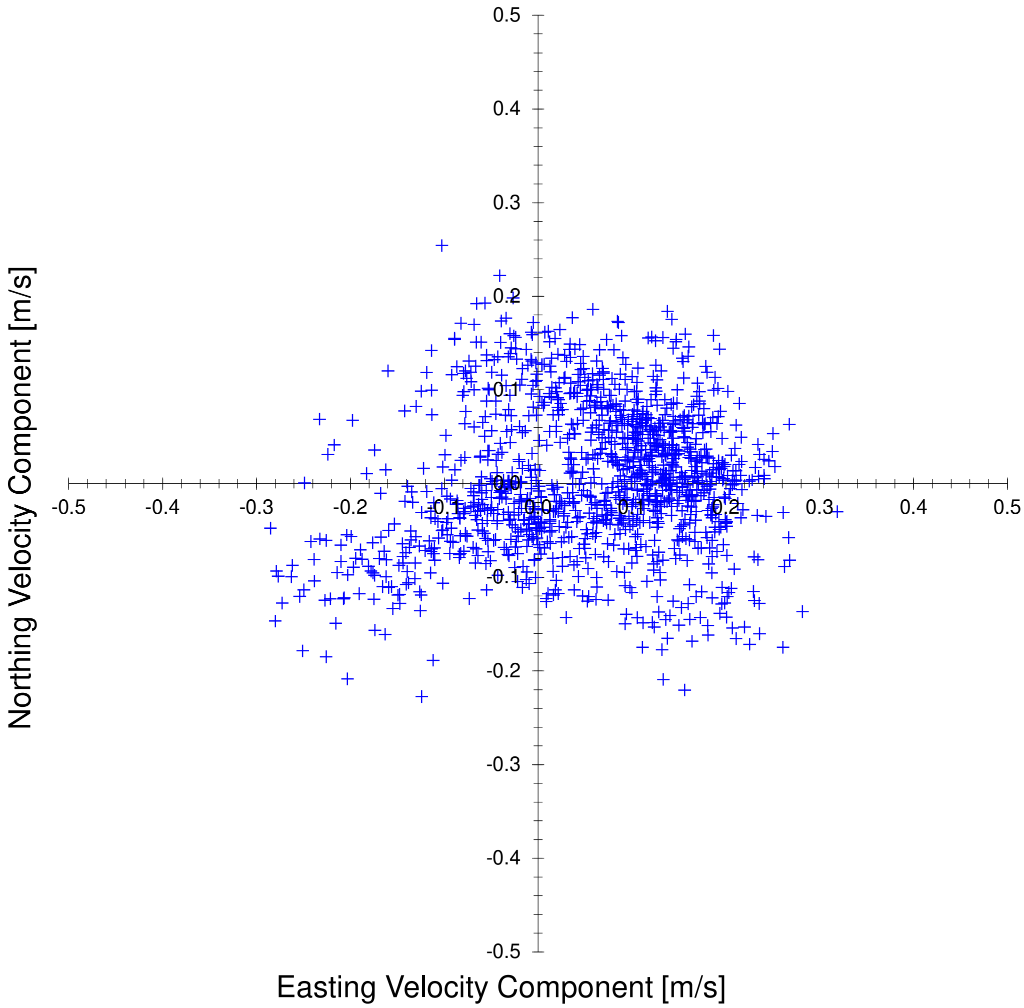


Figure 9: Cage bottom scatter plot of easting and northing velocity components

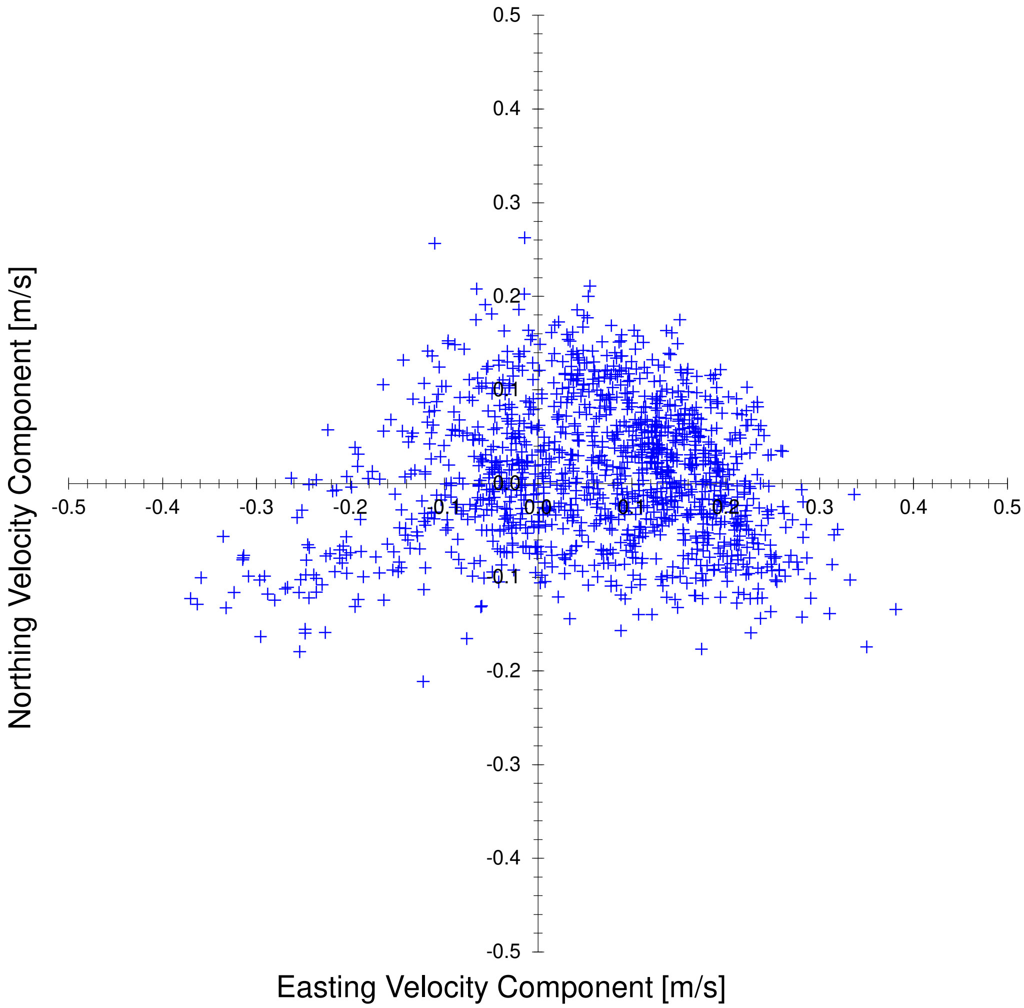


Figure 10: Subsurface scatter plot of easting and northing velocity components

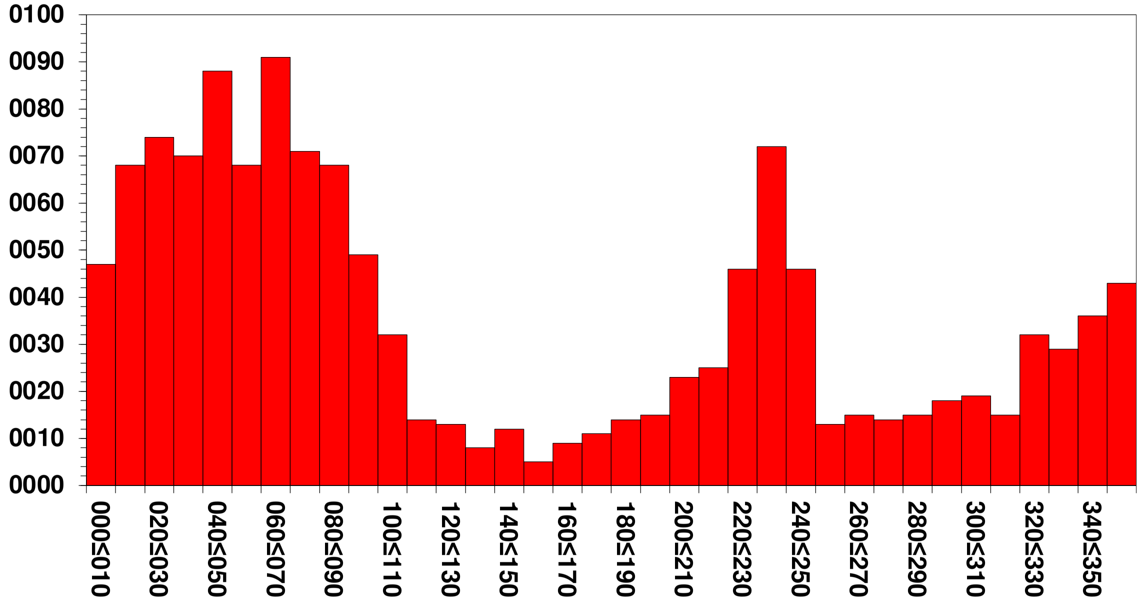


Figure 11: Near-bed current direction frequency plot.

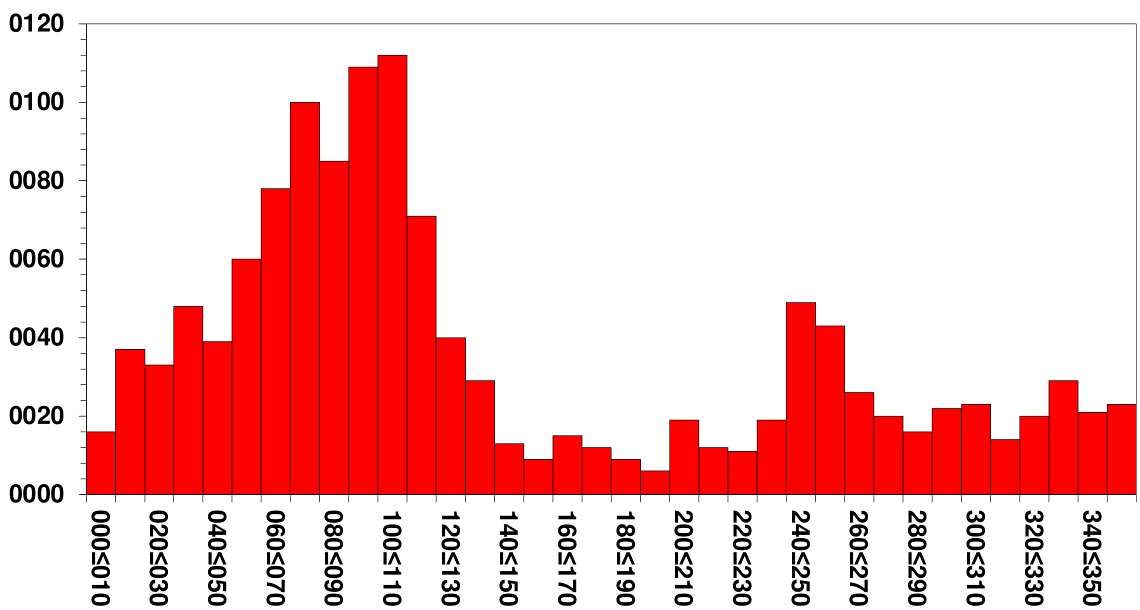


Figure 12: Cage bottom current direction frequency plot.

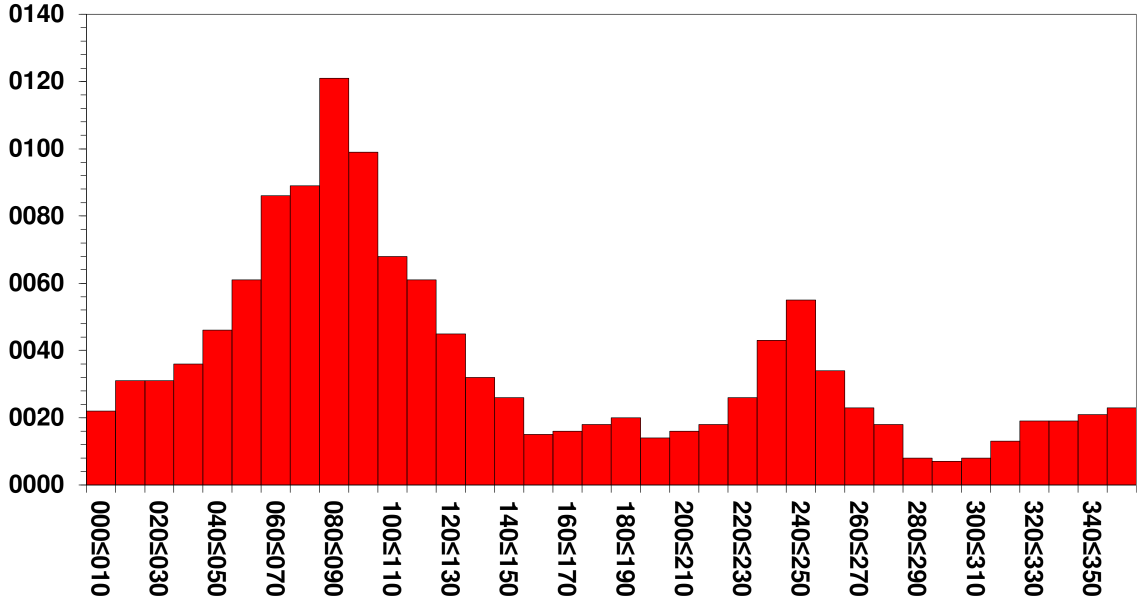


Figure 13: Subsurface current direction frequency plot.

2017

Table 5: Fishnish A (DPL1Y000) hydrographic summary statistics.

	Near-bed	Cage bottom	Sub-surface
Mean velocity (m s^{-1})	0.115	0.109	0.099
Min velocity (m s^{-1})	0.002	0.001	0.000
Max velocity (m s^{-1})	0.390	0.432	0.428
Ranked percentage 0.095 m s^{-1}	45 %	49 %	53 %
Major axis (°G)	140	125	125
Amplitude anisotropy	2.13	2.77	1.82
Residual velocity (m s^{-1})	0.06	0.07	0.06
Residual direction (°G)	123	135	132
Parallel Residual (m s^{-1})	0.056	0.073	0.064
Normal Residual (m s^{-1})	-0.018	0.012	0.008
Parallel tidal amplitude (m s^{-1})	0.153	0.139	0.121
Normal tidal amplitude (m s^{-1})	0.072	0.050	0.066
	Min	**Max**	**Range**
Depth (m)	28.72	33.12	4.4

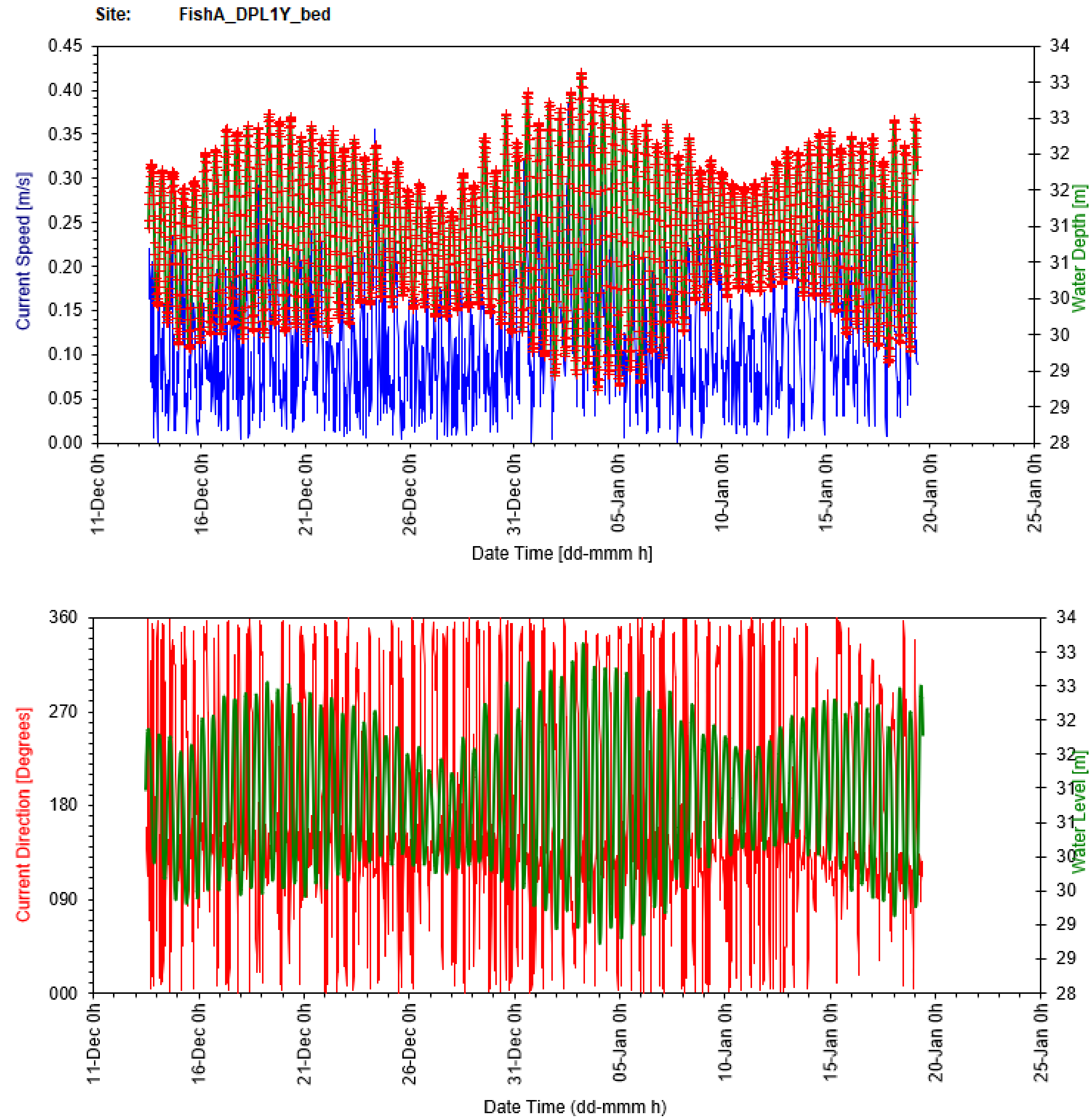
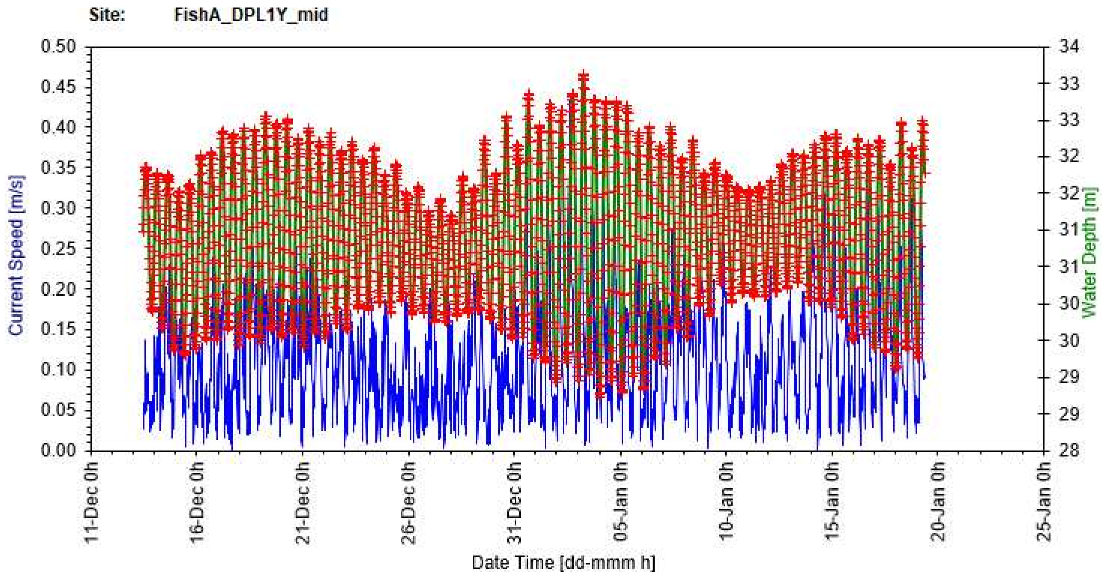


Figure 14: Near-bed time series plots for current speed and direction against water level



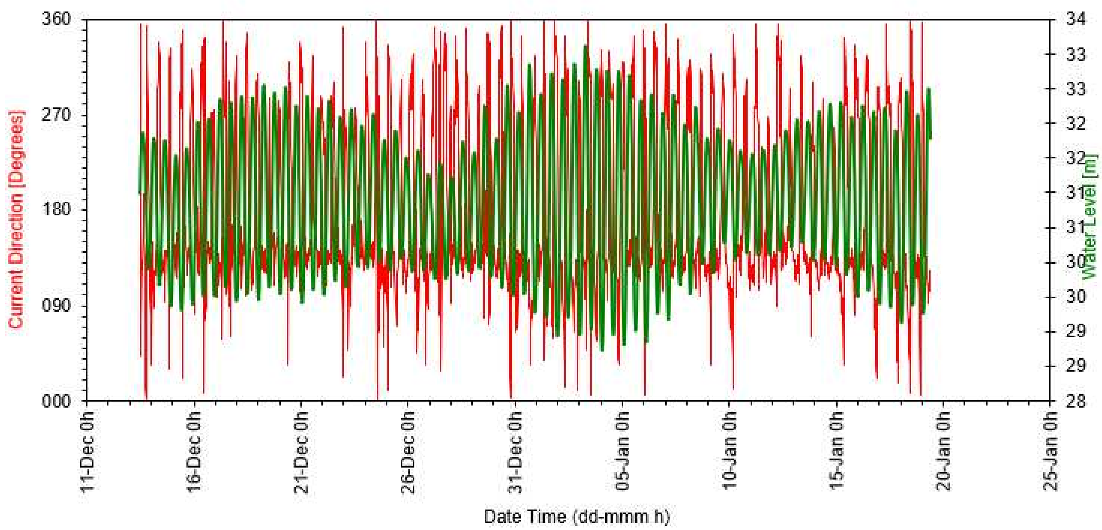


Figure 15: Cage bottom time series plots for current speed and direction against water level

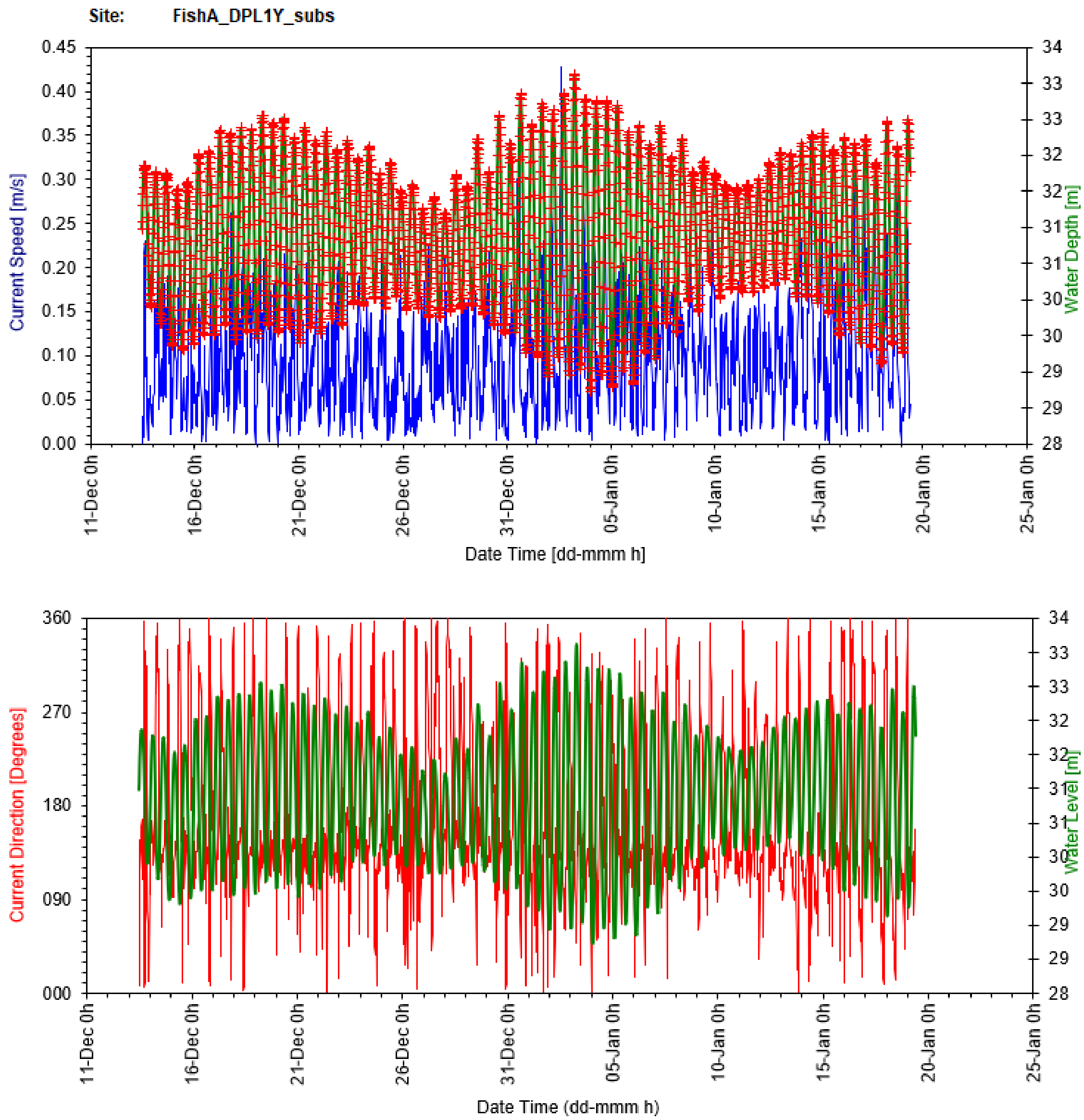


Figure 16: Subsurface time series plots for current speed and direction against water level

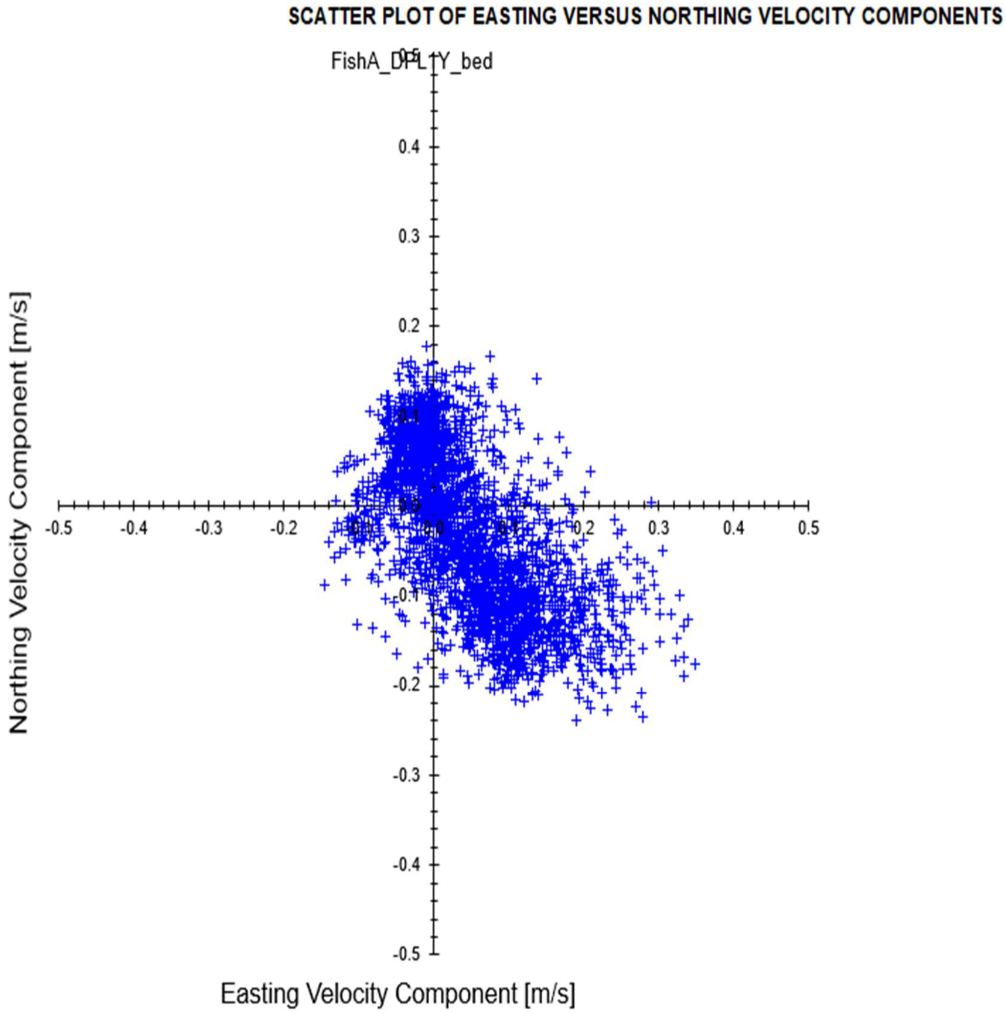


Figure 17: Near-bed scatter plot of easting and northing velocity components

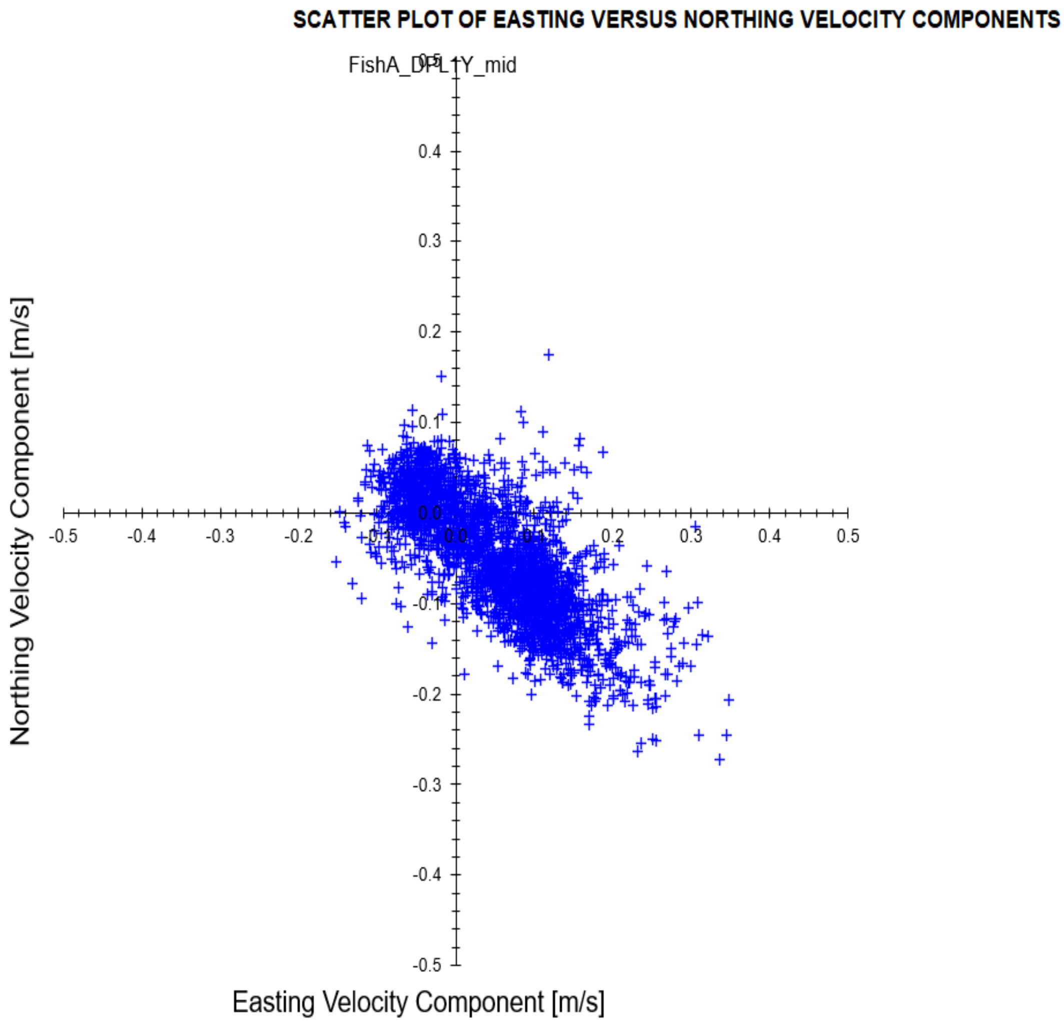


Figure 18: Cage bottom scatter plot of easting and northing velocity components

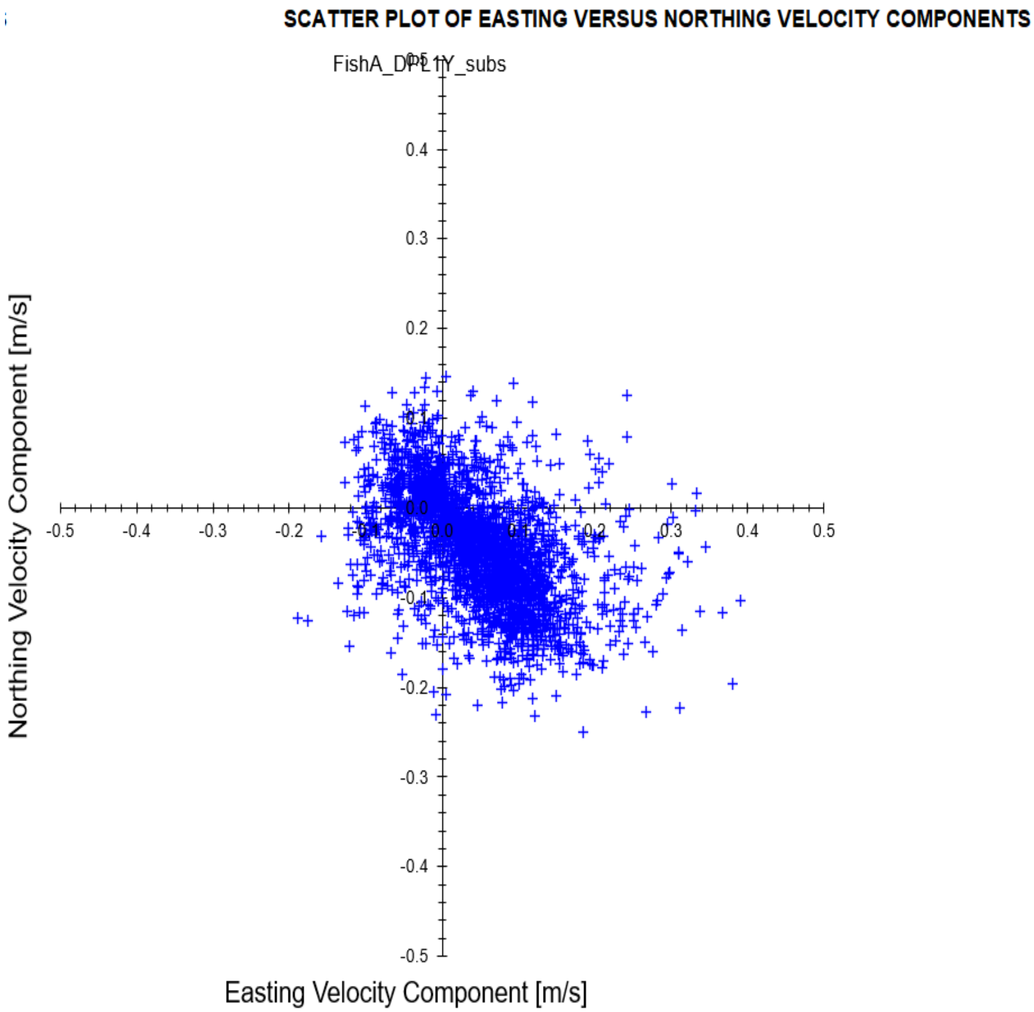


Figure 19: Subsurface scatter plot of easting and northing velocity components

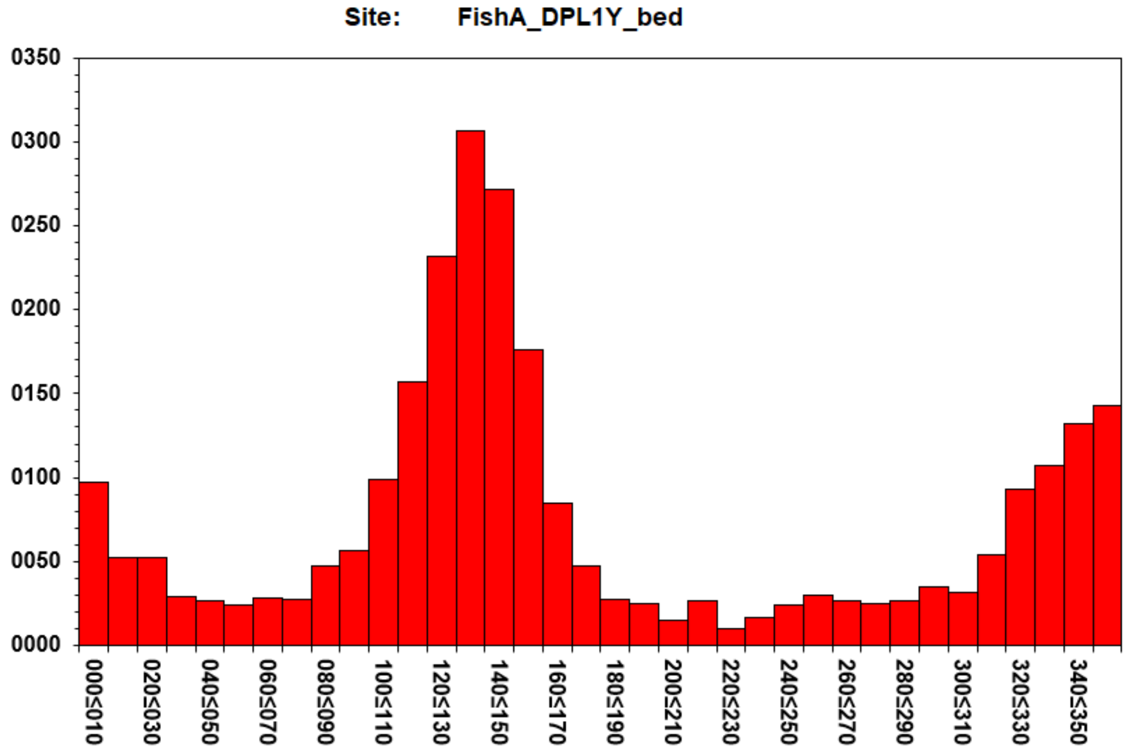


Figure 20: Near-bed current direction frequency plot.

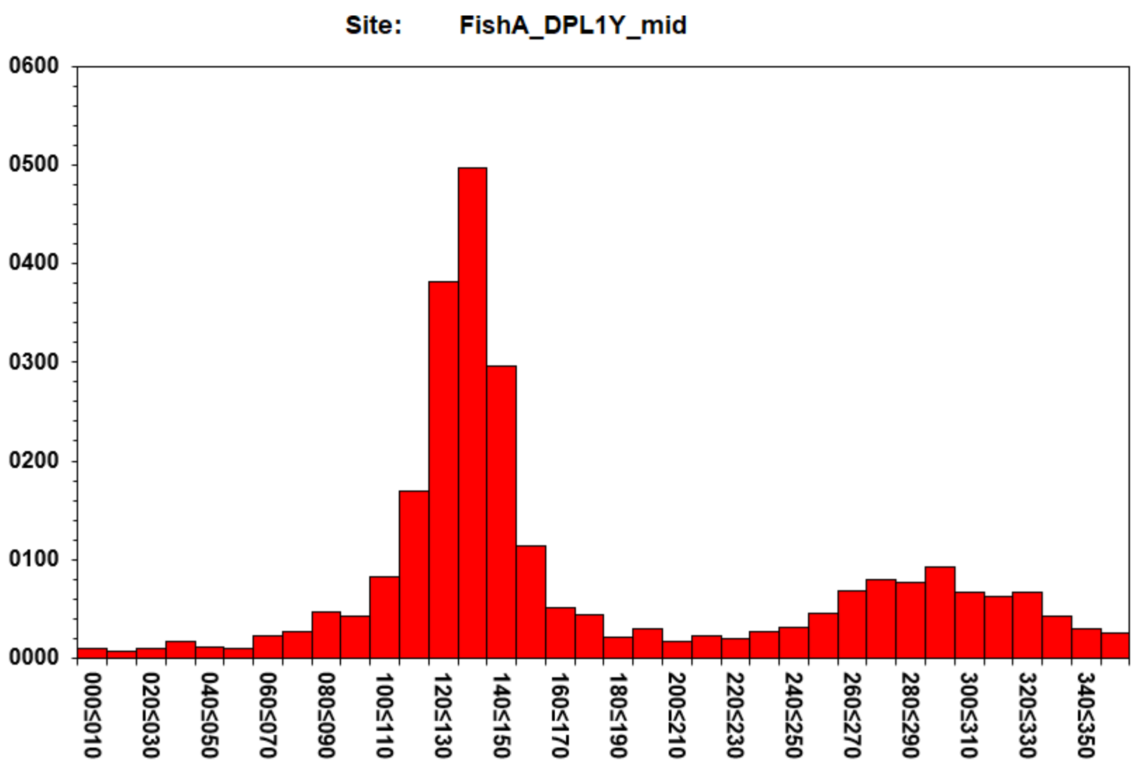


Figure 21: Cage bottom current direction frequency plot.

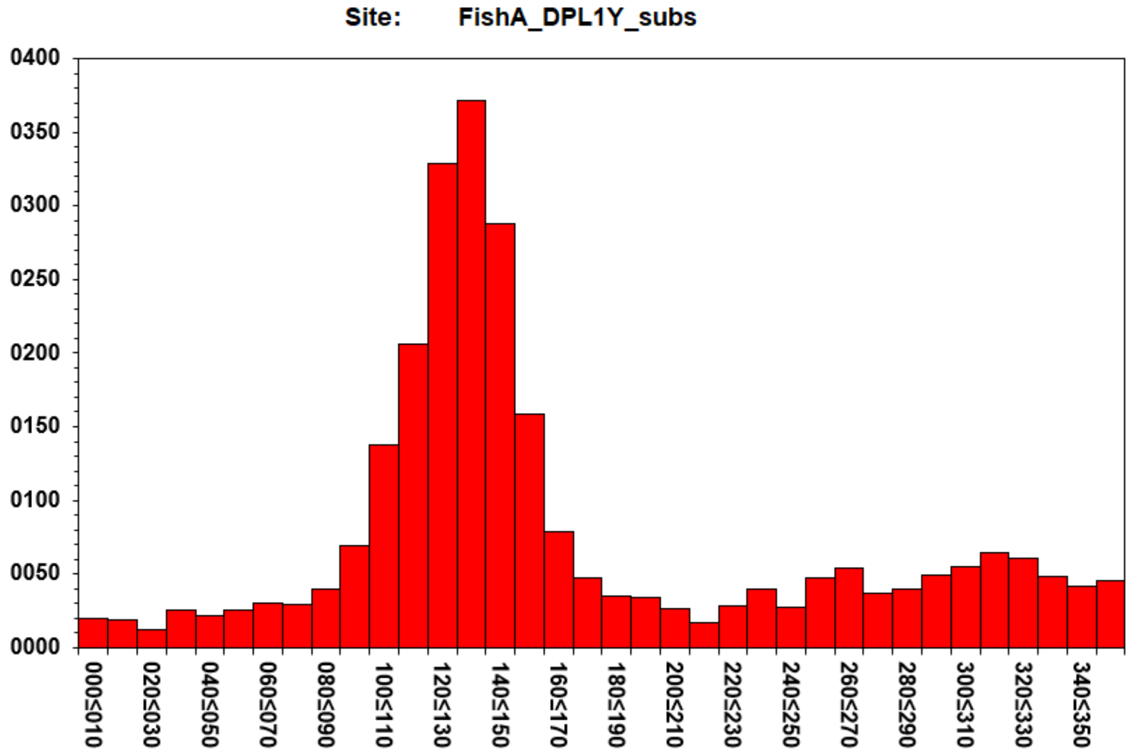


Figure 22: Subsurface current direction frequency plot.

2018

Table 6: Fishnish A 2018 hydrographic summary statistics

	Near-bed	Pen-bottom	Sub-surface
Mean velocity (m s^{-1})	0.121	0.130	0.130
Min velocity (m s^{-1})	0.004	0.003	0.004
Max velocity (m s^{-1})	0.445	0.403	0.395
Ranked percentage 0.095 m s^{-1}	36 %	29 %	33 %
Major axis (°G)	130	125	125
Amplitude anisotropy	2.28	2.84	2.34
Residual velocity (m s^{-1})	0.04	0.06	0.05
Residual direction (°G)	123	156	160
Parallel Residual (m s^{-1})	0.035	0.053	0.041
Normal Residual (m s^{-1})	-0.004	0.032	0.028
Parallel tidal amplitude (m s^{-1})	0.171	0.174	0.182
Normal tidal amplitude (m s^{-1})	0.075	0.061	0.078
	Min	**Max**	**Range**
Depth (m)	27.39	31.83	4.44

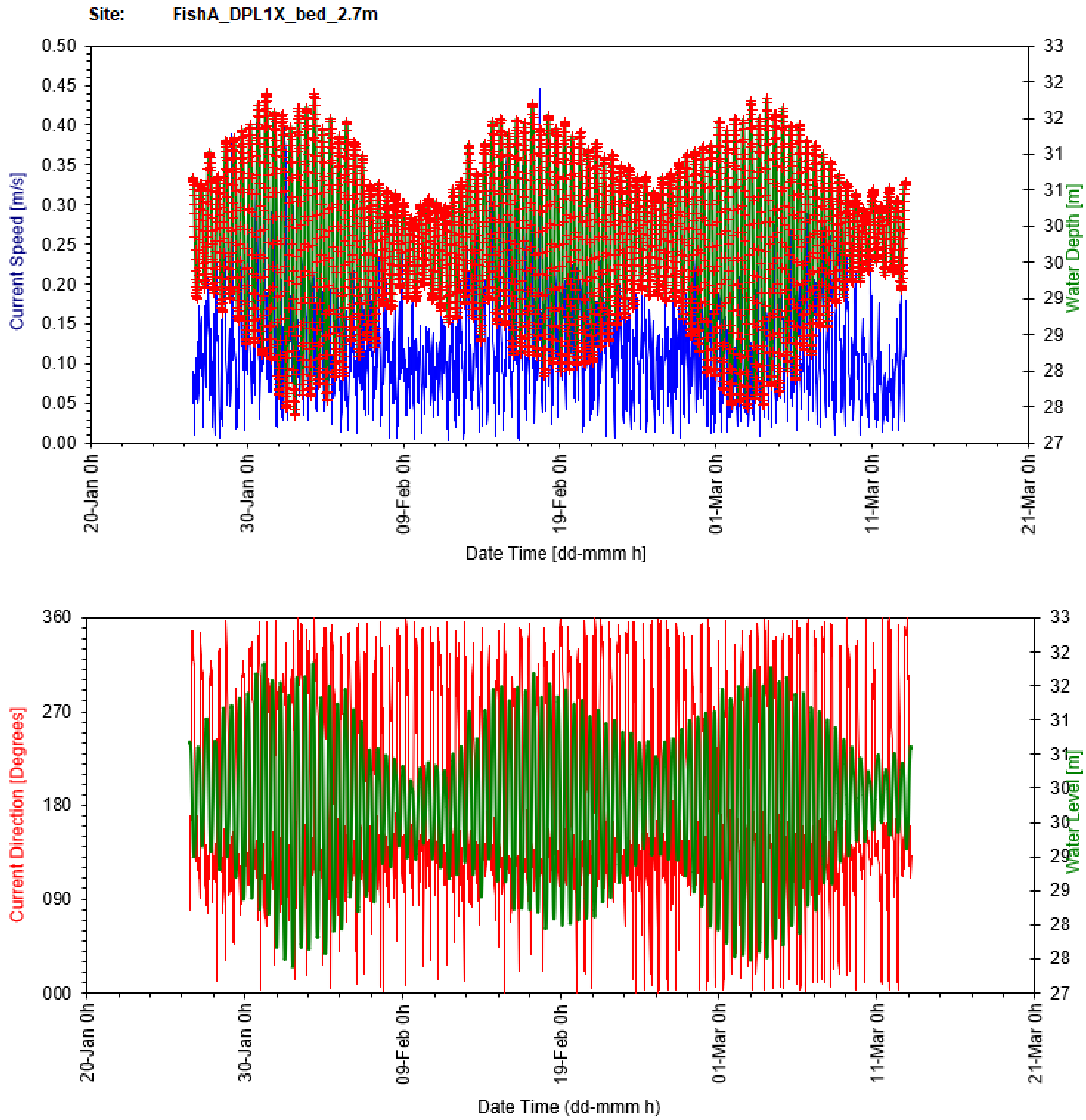


Figure 23: Near-bed time series plots for current speed and direction against water level

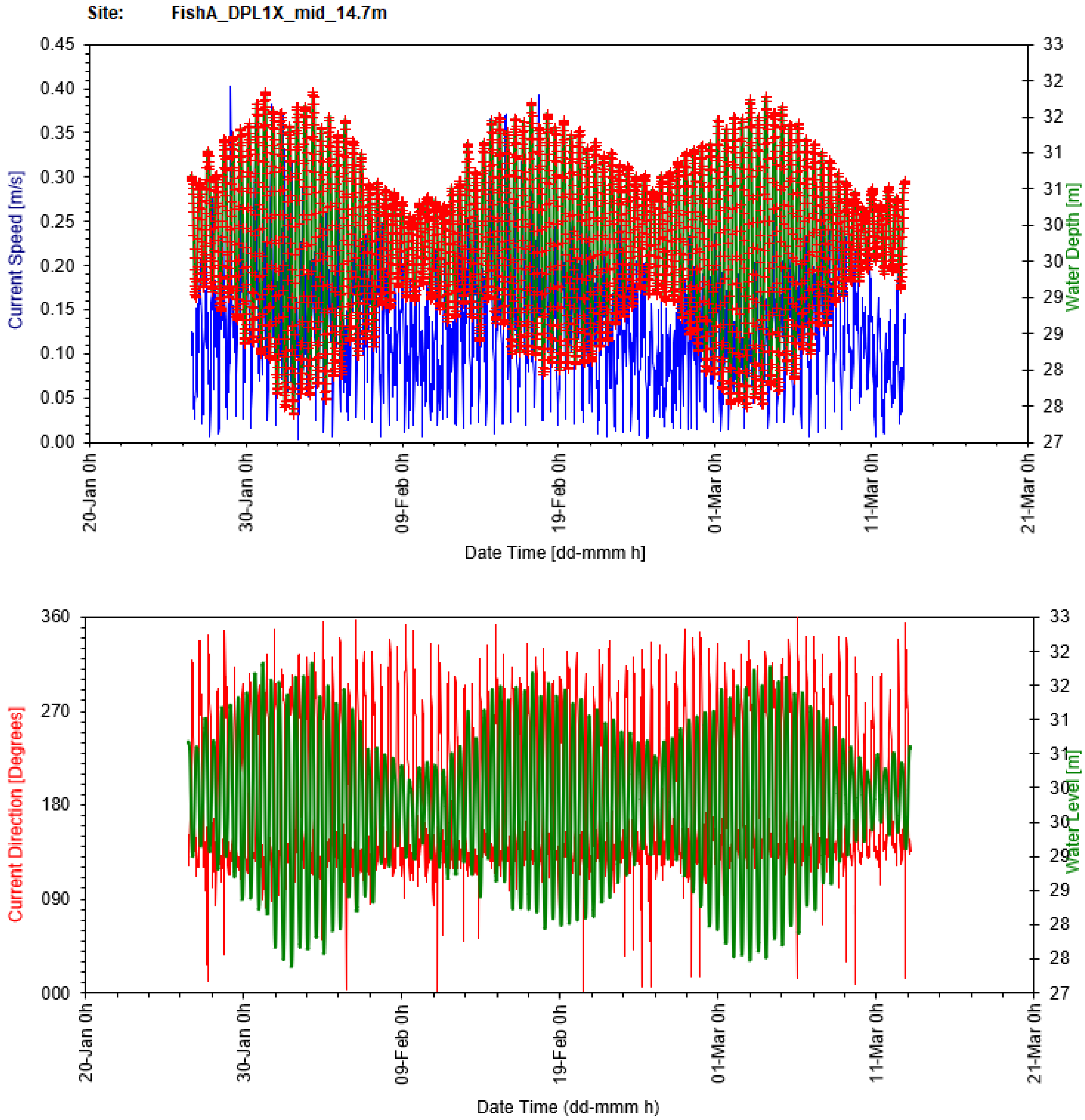
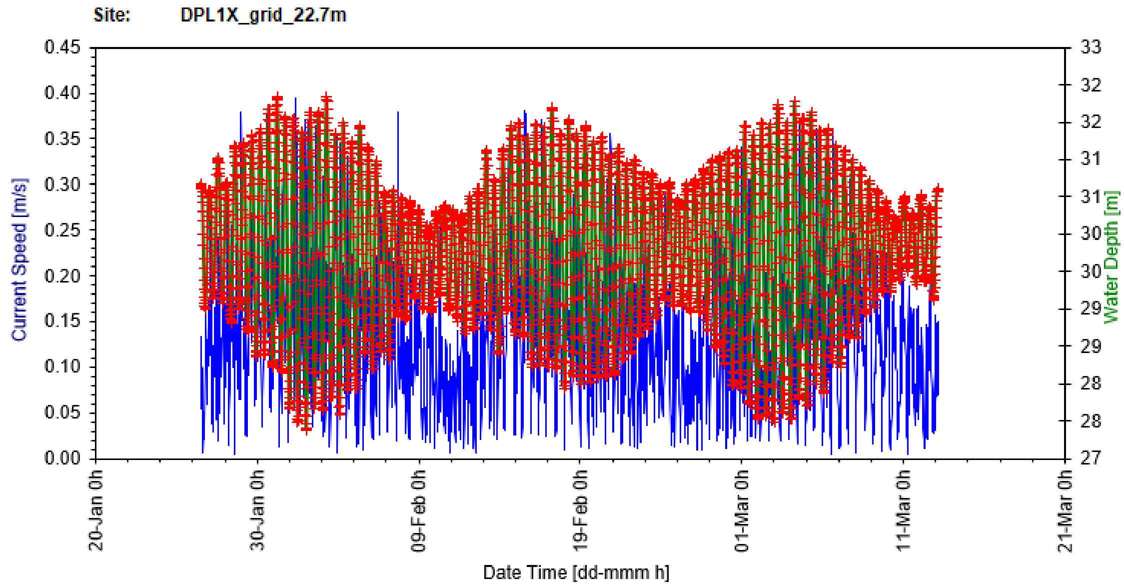


Figure 24: Cage bottom time series plots for current speed and direction against water level



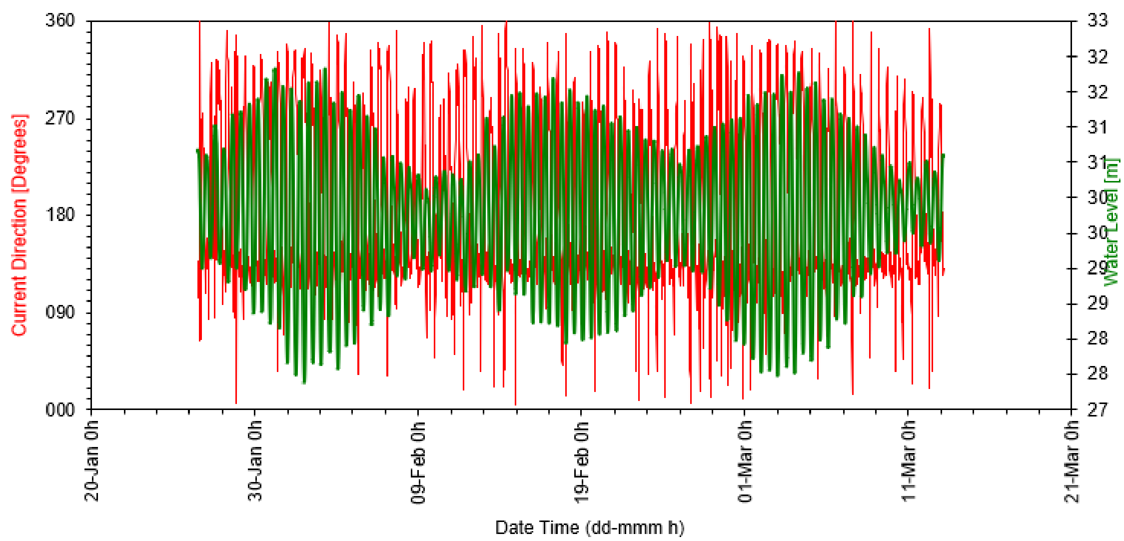


Figure 25: Subsurface time series plots for current speed and direction against water level

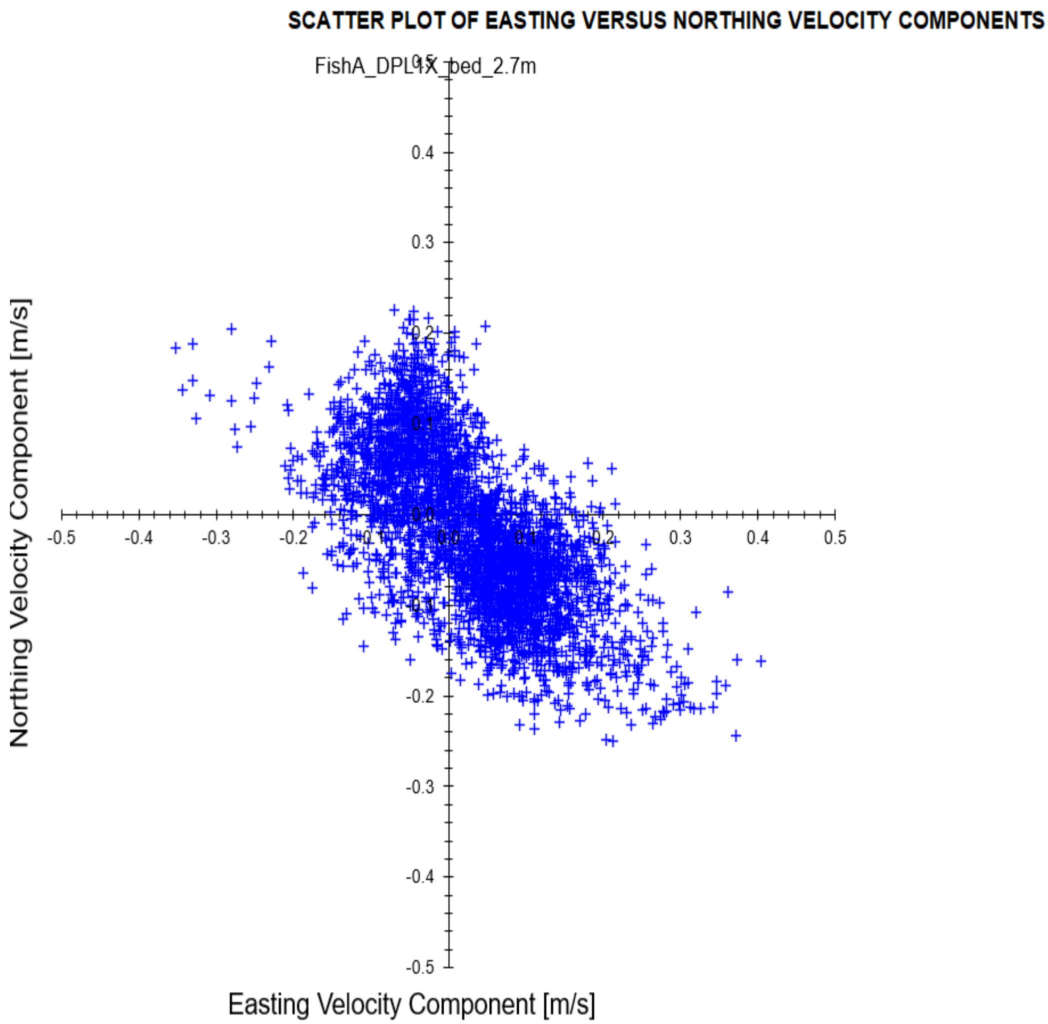


Figure 26: Near-bed scatter plot of easting and northing velocity components

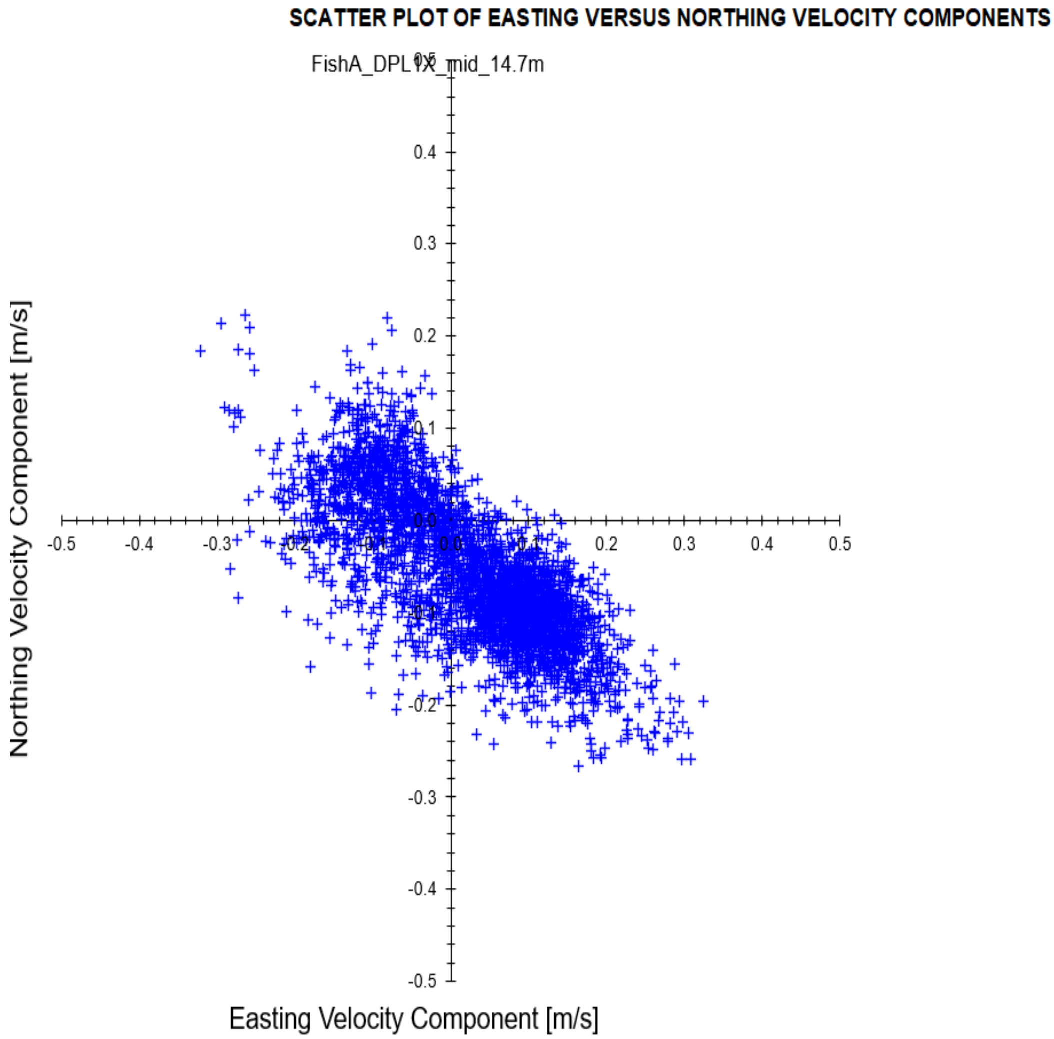


Figure 27: Cage bottom scatter plot of easting and northing velocity components

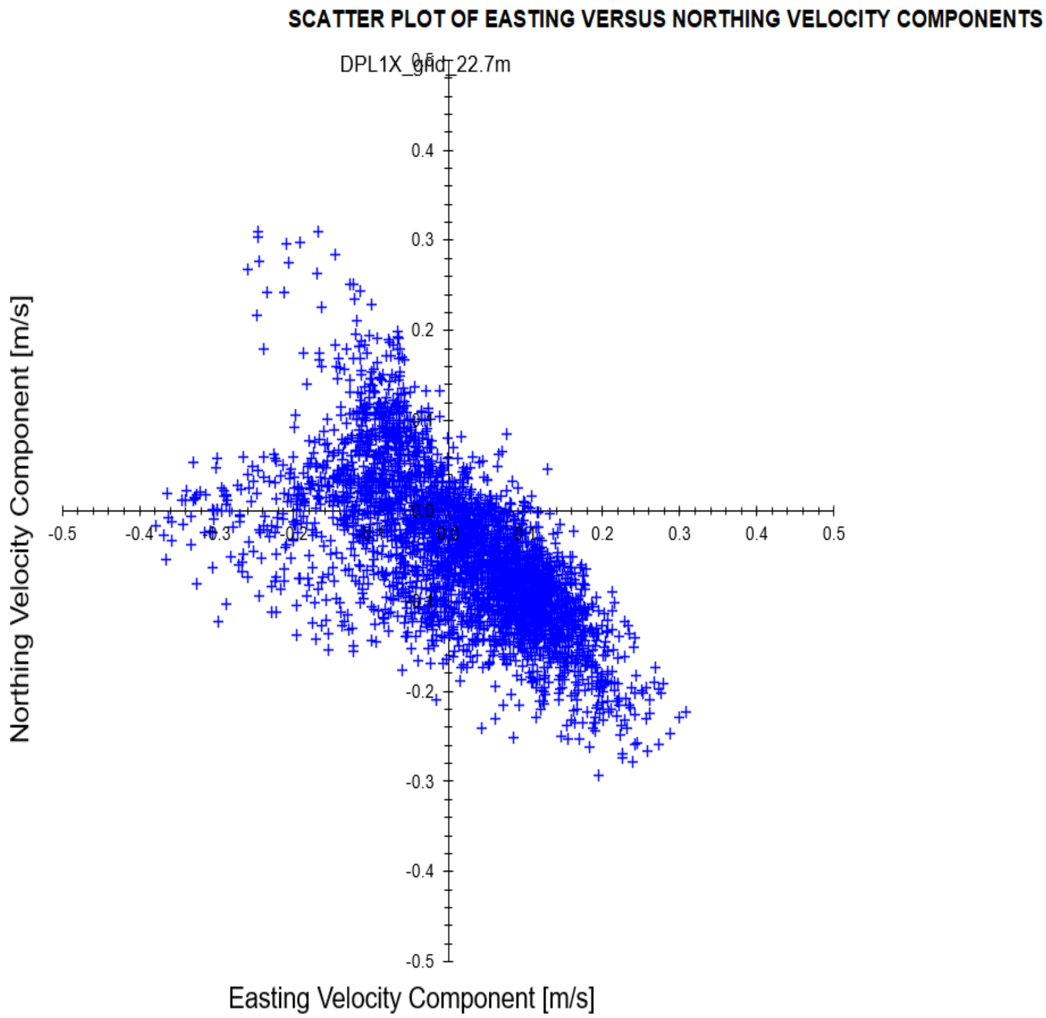


Figure 28: Subsurface scatter plot of easting and northing velocity components

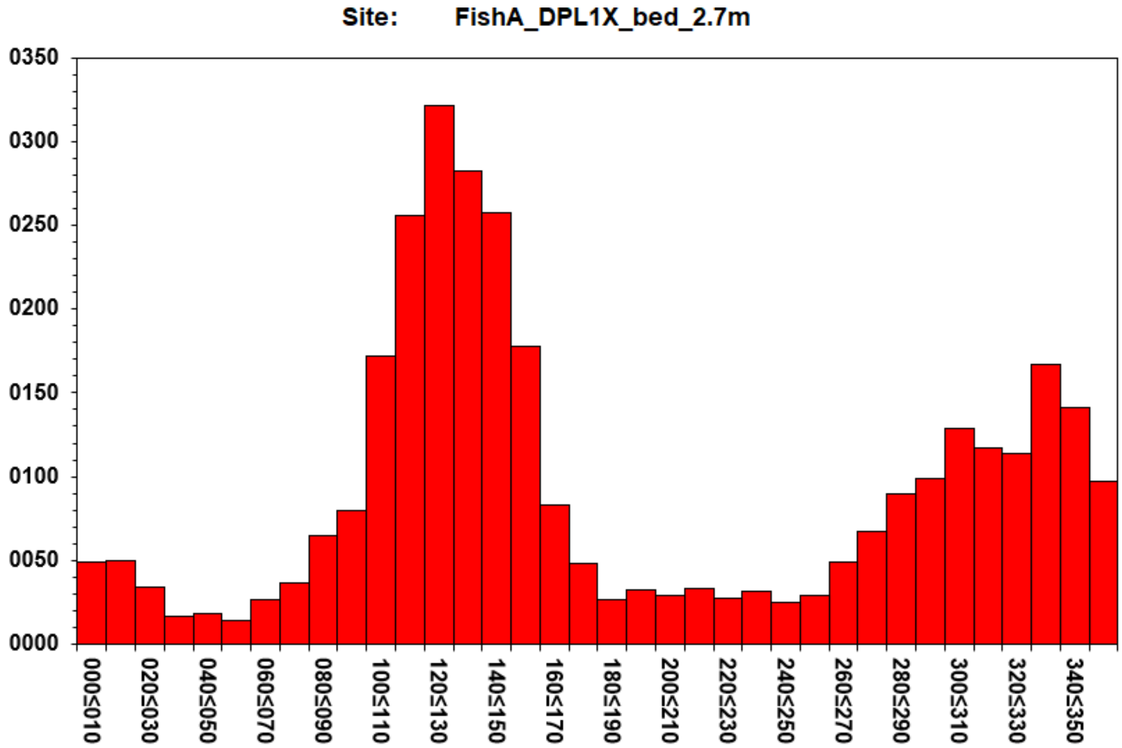


Figure 29: Near-bed current direction frequency plot.

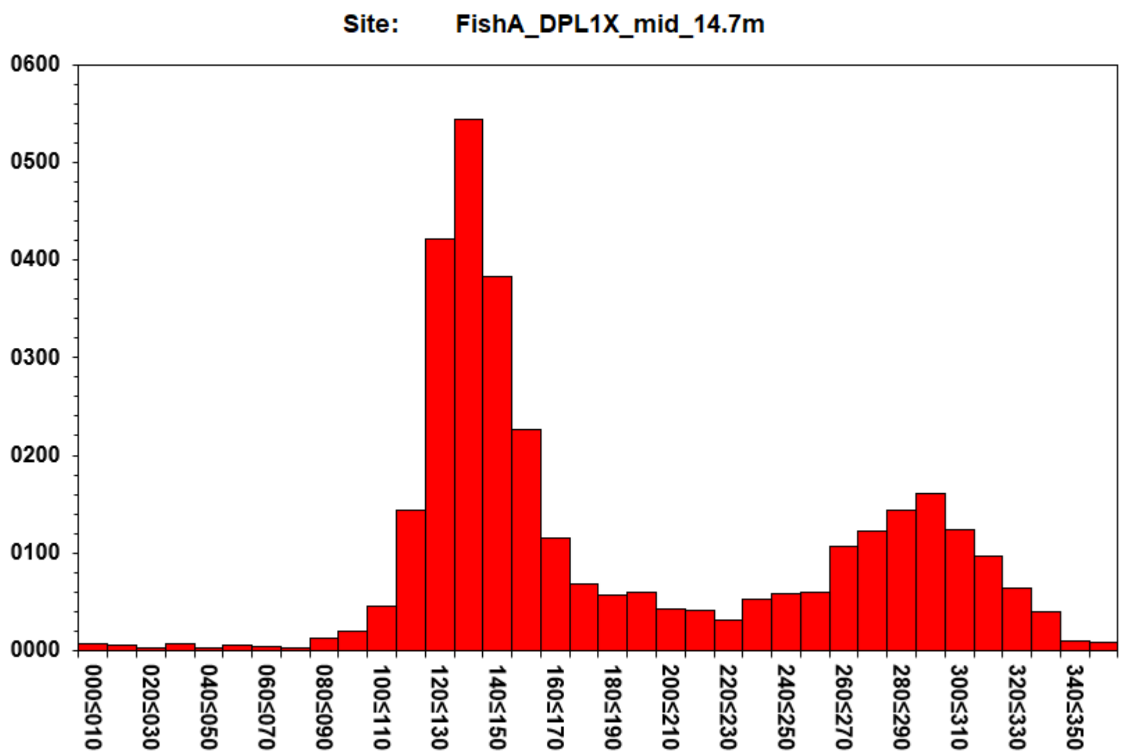


Figure 30: Cage bottom current direction frequency plot.

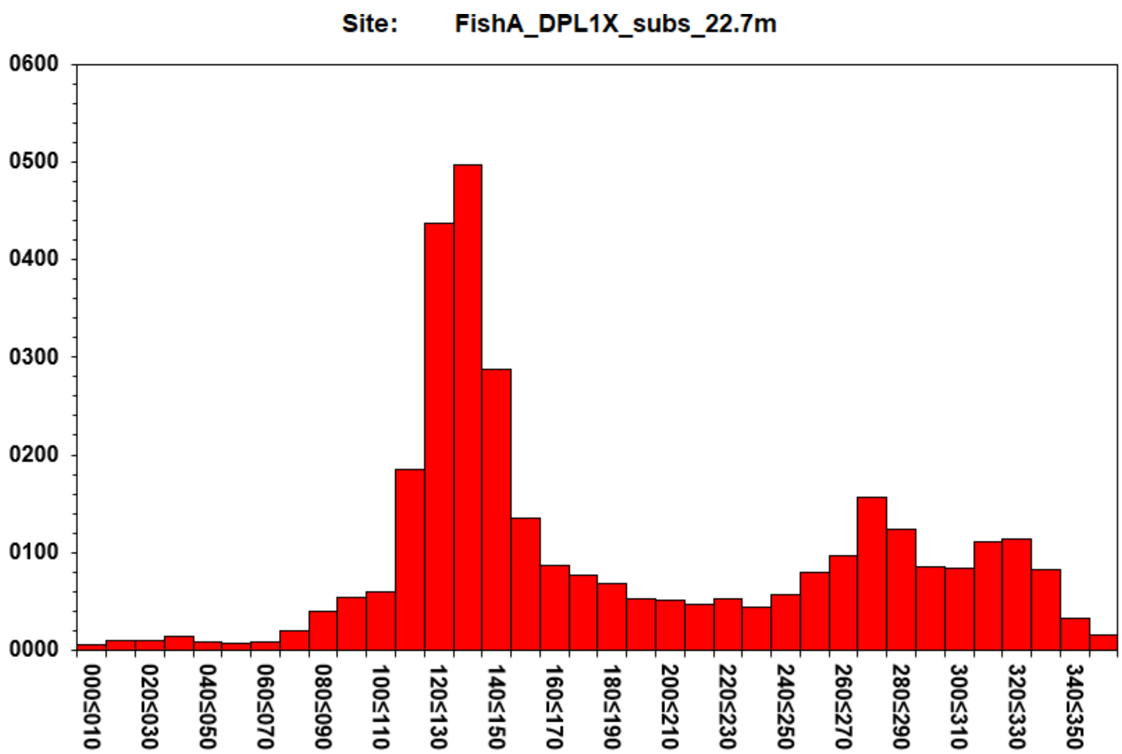


Figure 31: Subsurface current direction frequency plot.

iv. Summary

The data is indicative of a well flushed site with a strong tidal component. Current direction follows into Fishnish Bay and is consistent with the local bathymetry. Generally the strongest currents are near the surface and while strongly directional strong wind events can be seen to have an impact on both speed and direction at the surface.

v. 90 day composite

Subsets of the above datasets were used to create a 90 day long composite of the 3 surveys to be used within NewDepomod for modelling with SEPA's Standard Default Approach. While there is an option to stitch the 3 datasets together to make up 90 days without the need to repeat data the joins between spring tides was less than ideal. Therefore we have chosen to create the following 90 day stitch which includes a small section of repeated data (4.36 days) as we feel this better represents the spring/neap cycle. The start and end points of each section are detailed in Table 7 below.

Table 7: Subsets used to create 90 day composite

Identifier	part	start	Tide height (m)	Tide timing	end	Tide height (m)	Tide timing
DPL3	1	20/03/2015 13:46	0.9	1.67 hrs after LW	04/04/2015 14:06:14	1.4	1.8 hrs after LW
DPL1Y	2	18/12/2017 14:07:58	1.9	2hrs after LW	17/01/2018 14:07:58	1.7	1.8 hrs after LW
DPL1X	3	31/01/2018 14:17:31	1.7	2.17 hrs after LW	13/03/2018 03:57	3.2	0.22 hrs after HW
DPL1X (repeat)	4	11/02/2018 16:37:31	3.1	0.67 hrs after HW	16/02/2018 01:17:31	1.0	0.83 hrs after LW

Table 8: 90 day composite summary statistics

	Near-bed	Pen-bottom	Sub-surface
Mean velocity (m s^{-1})	0.118	0.123	0.121
Min velocity (m s^{-1})	0.002	0.002	0.000
Max velocity (m s^{-1})	0.445	0.432	0.428
Ranked percentage 0.095 m s^{-1}	39 %	35 %	39 %
Major axis (°G)	135	120	120
Amplitude anisotropy	1.74	1.9	1.75
Residual velocity (m s^{-1})	0.04	0.06	0.05
Residual direction (°G)	115	138	135
Parallel Residual (m s^{-1})	0.036	0.057	0.049
Normal Residual (m s^{-1})	-0.014	0.019	0.013
Parallel tidal amplitude (m s^{-1})	0.158	0.157	0.161
Normal tidal amplitude (m s^{-1})	0.091	0.083	0.092
	Min	**Max**	**Range**
Normalised Depth (m)	-2.36	2.43	4.79

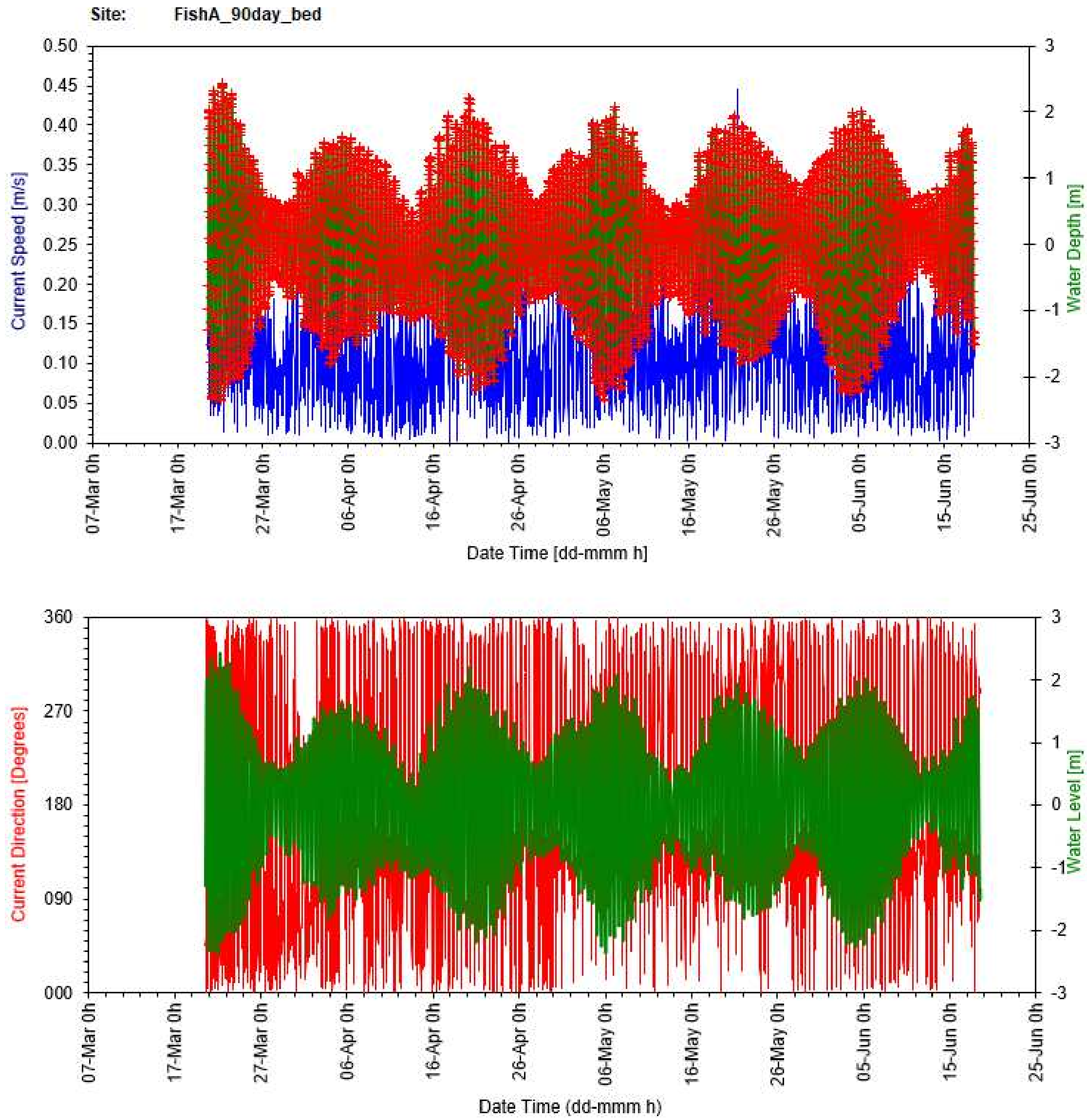


Figure 32: Bed time series plots for current speed and direction against water level

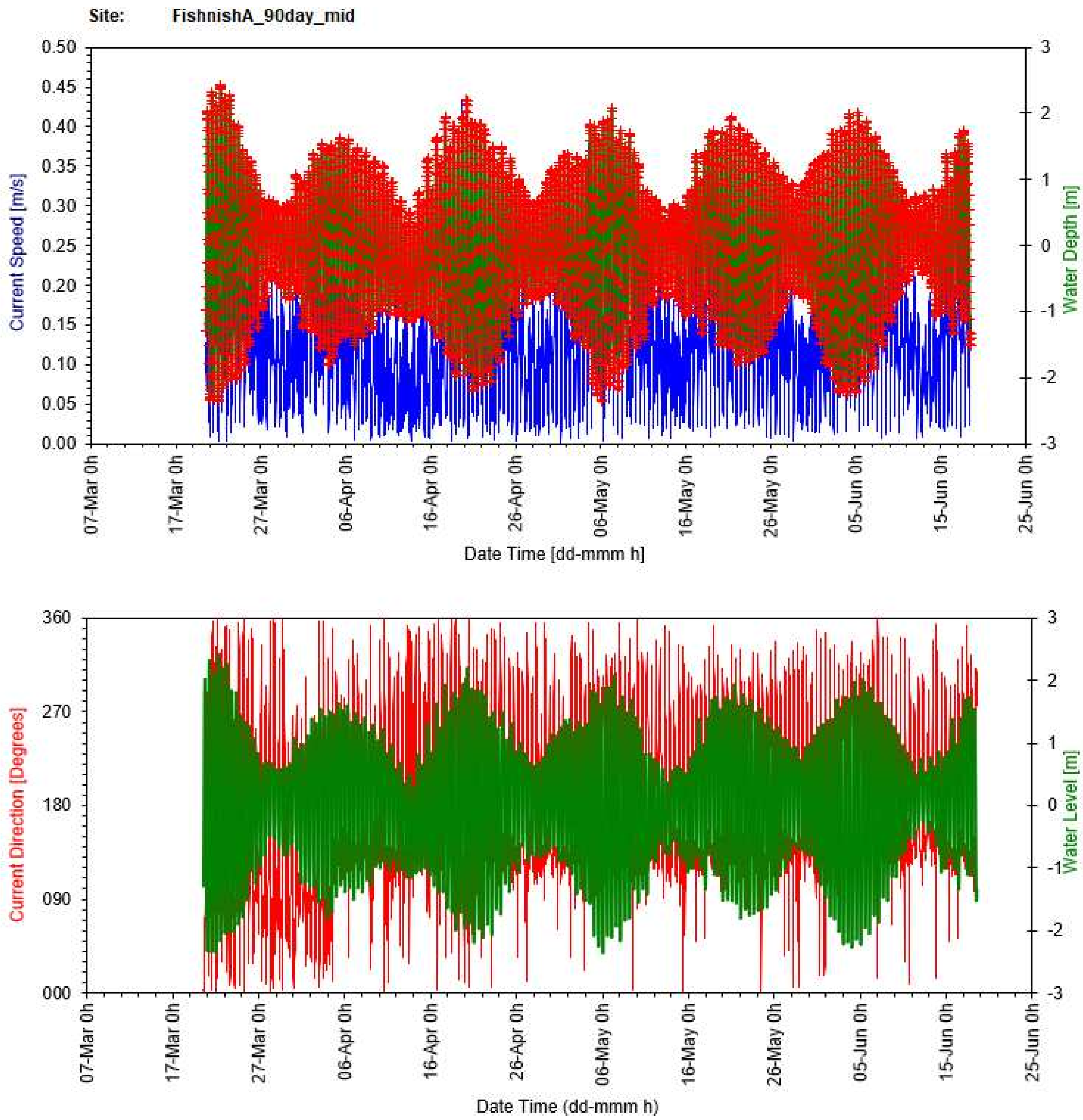


Figure 33: Mid time series plots for current speed and direction against water level

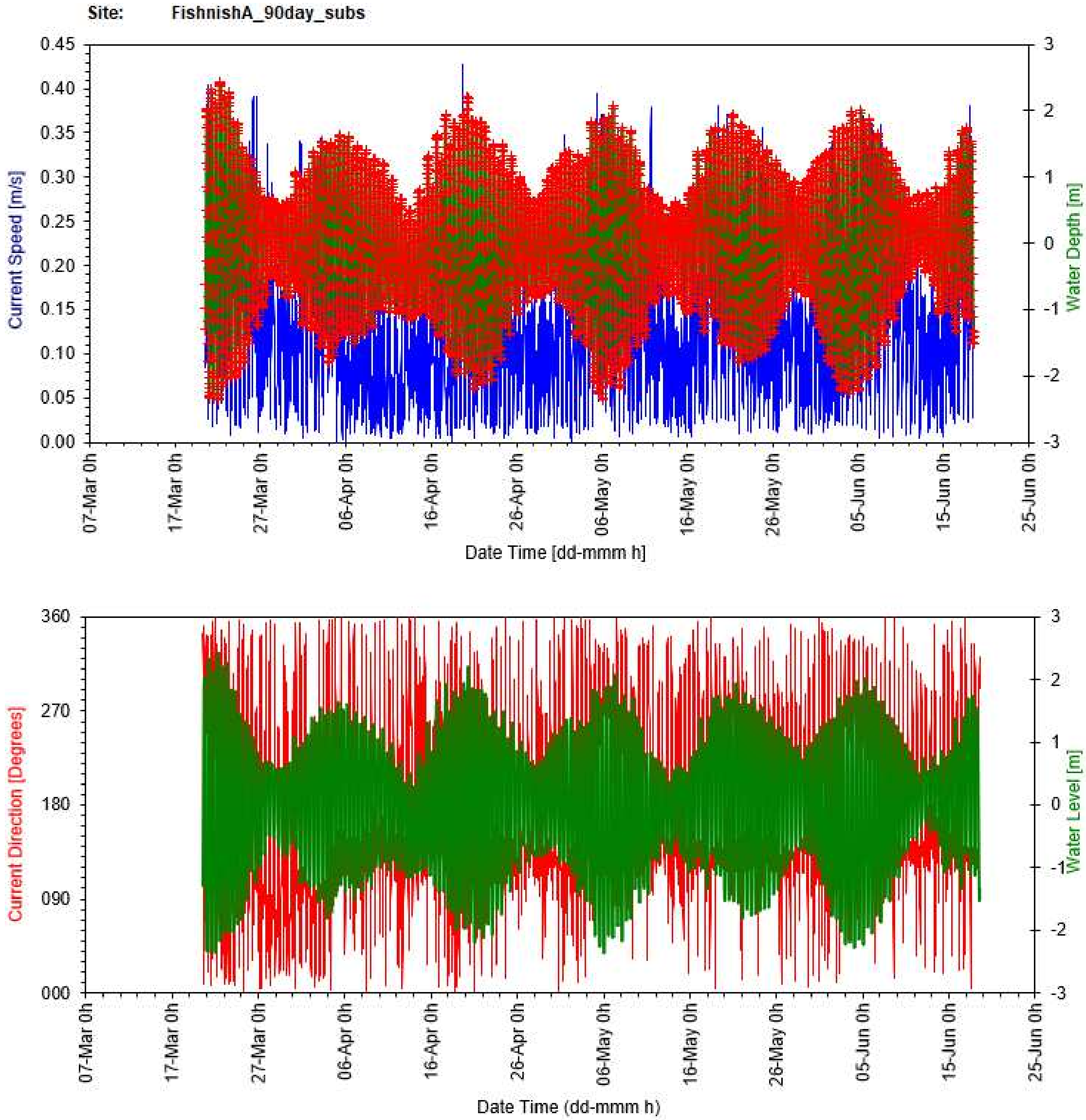


Figure 34: Subsurface time series plots for current speed and direction against water level

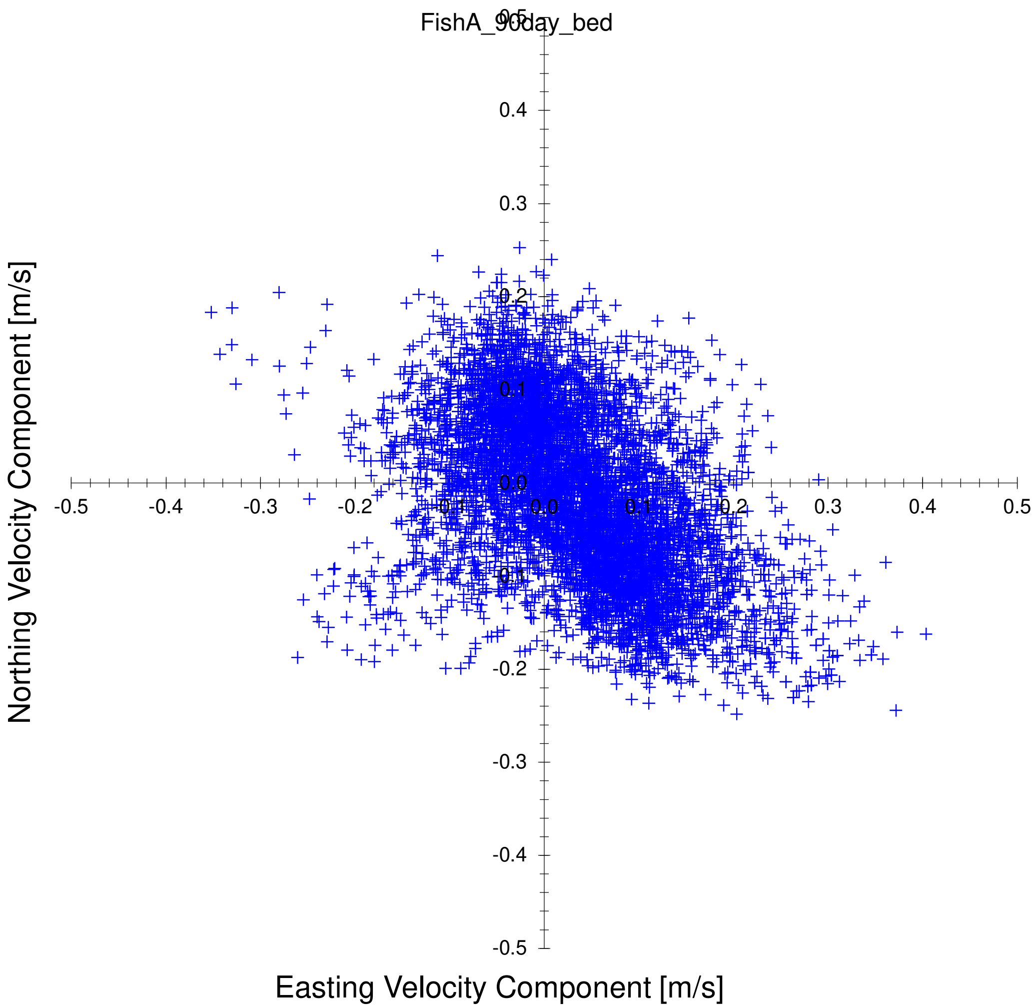


Figure 35: Bed scatter plot of easting and northing velocity components

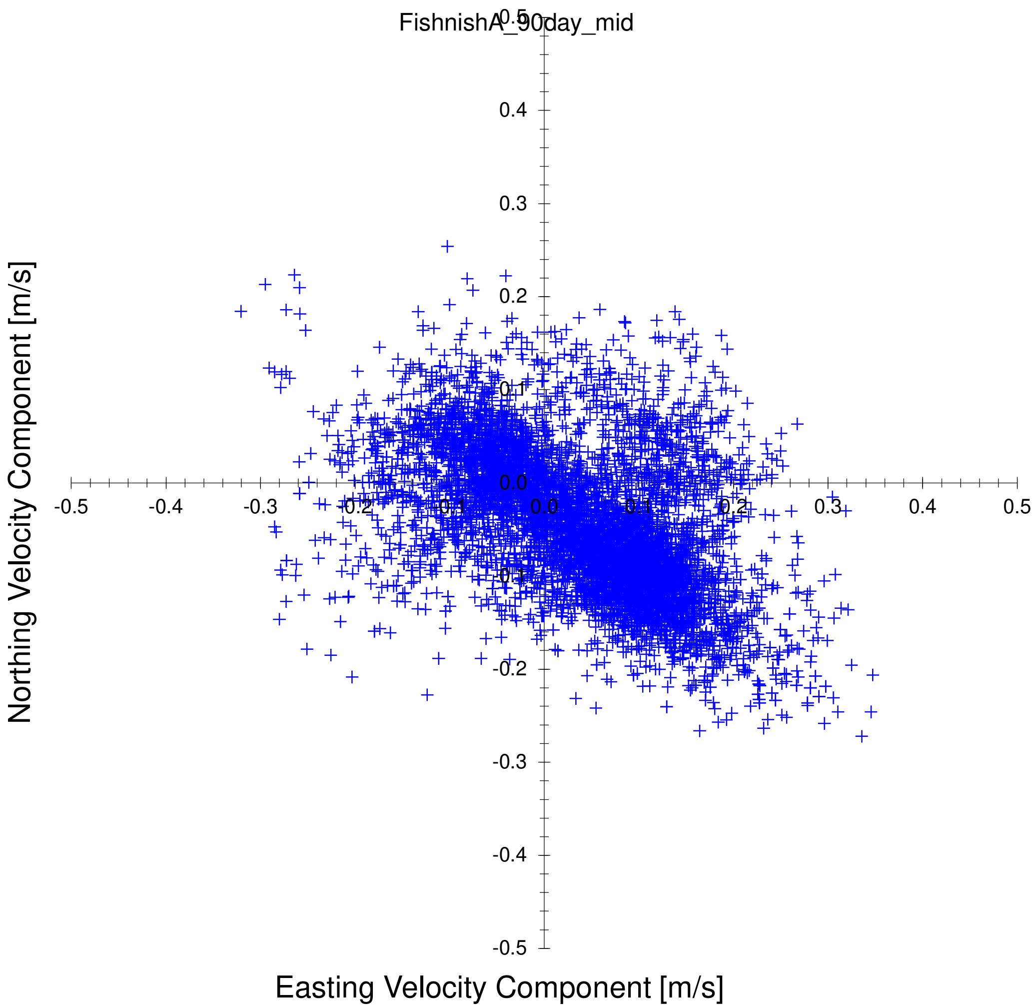


Figure 36: Mid scatter plot of easting and northing velocity components

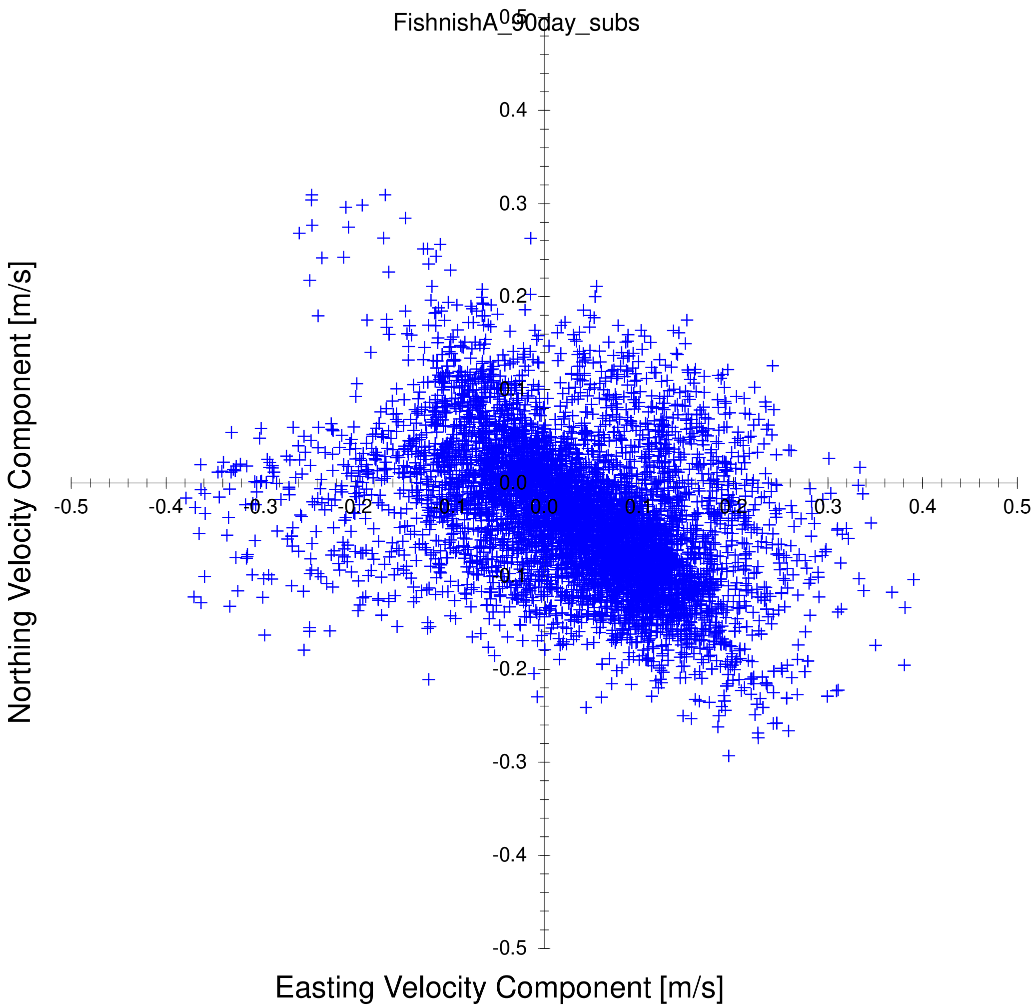


Figure 37: Subsurface scatter plot of easting and northing velocity components

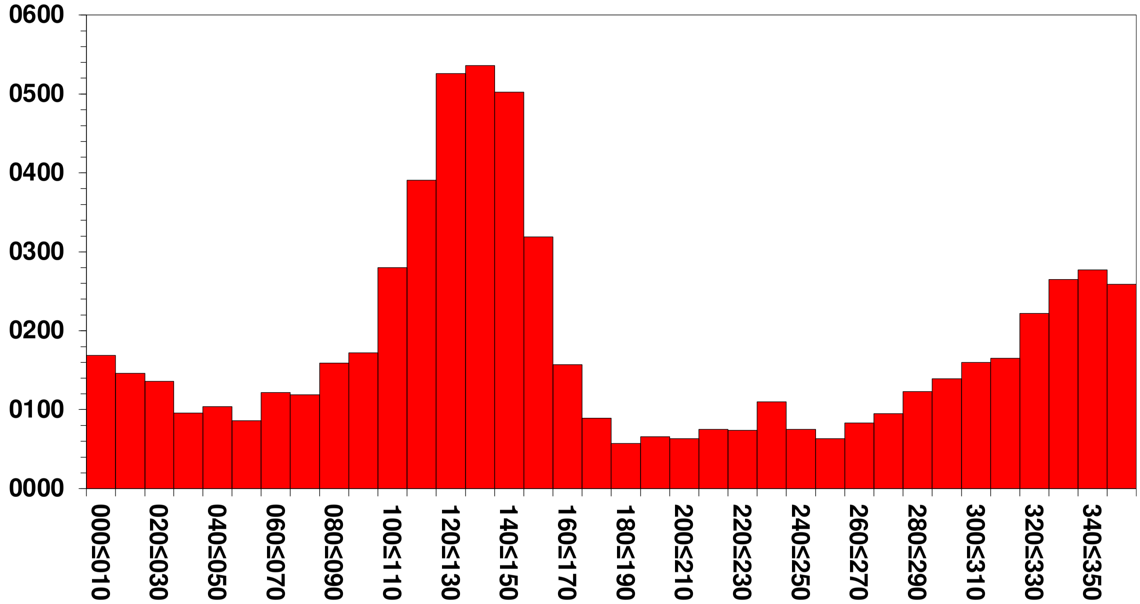


Figure 38: Bed current direction frequency plot.

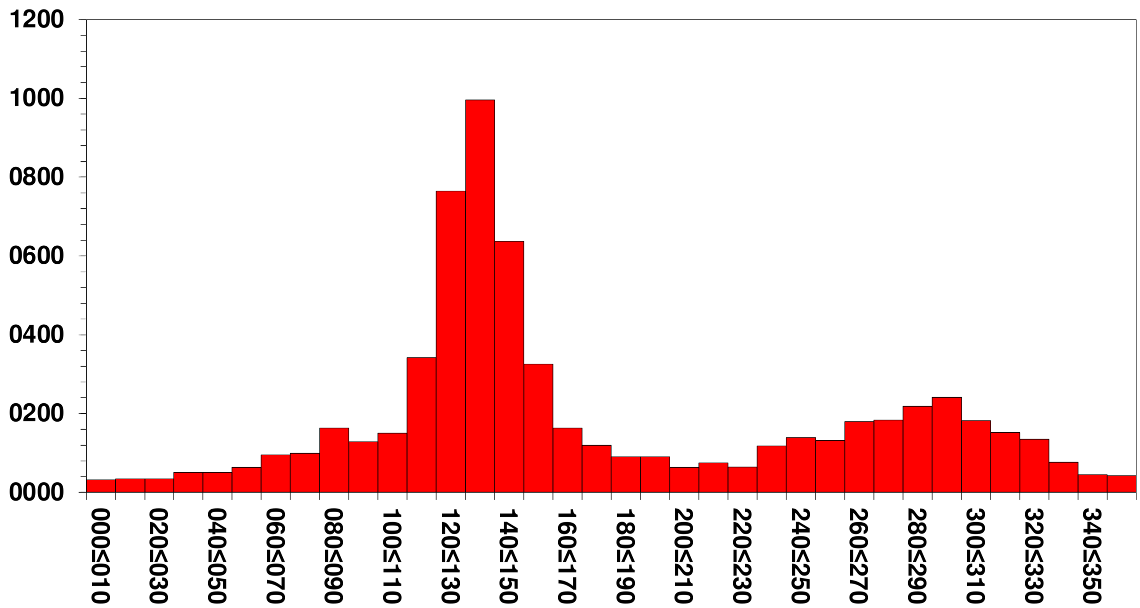


Figure 39: Mid current direction frequency plot.

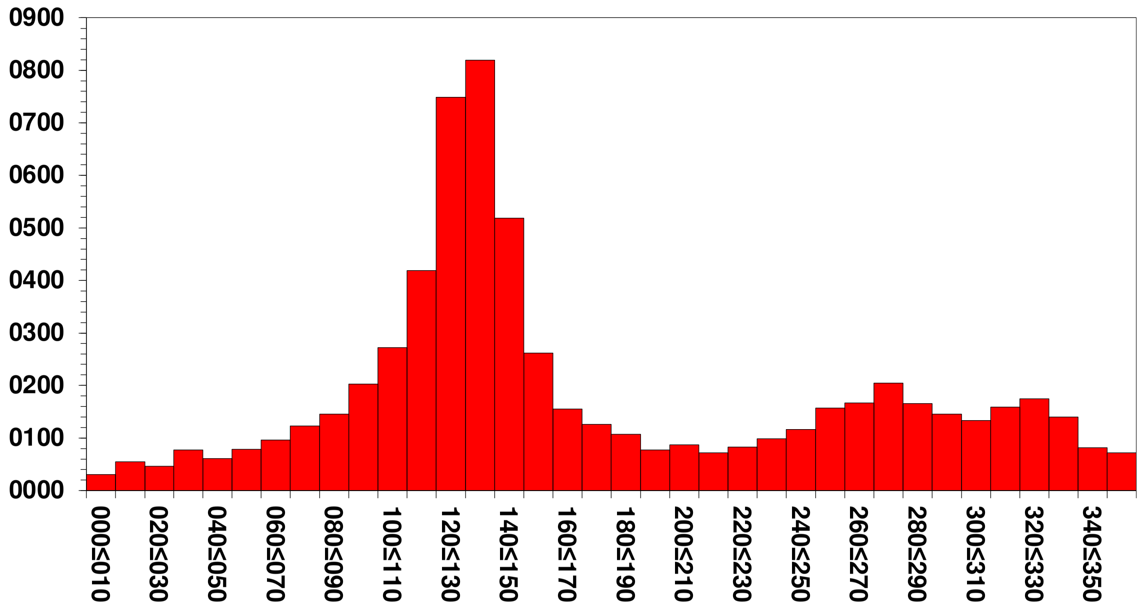


Figure 40: Subsurface current direction frequency plot.

3. Equipment set-up parameters and specifications

Table 7: ADCP configuration for Fishnish A 2015m 2017 and 2018 depoyments

Date	2015	2017	2018
Instrument	600 kHz RDI Workhorse	600 kHz RDI Workhorse	600 kHz RDI Workhorse
Serial number	18112	3821	3821
Deployment name	DPL3	DPL1Y000	DPL1X000
First viable ensemble (no.)	20/03/2015 13:46 (13)	13/12/2017 11:27:58 (6)	26/01/2018 11:37:31 (4)
Last viable ensemble (no.)	07/04/2015 10:46 (1300)	19/01/2018 09:07:58 (2663)	13/03/2018 03:57:31 (3293)
Frequency	614 kHz	614 kHz	614 kHz
Cell size (m)	1.0	1.0	1.0
Blanking distance (m)	0.88	0.88	0.88
No. of cells	41	41	41
First cell range (m)	2.1	2.1	2.1
Ensemble interval (s)	1200	1200	1200
Number of pings	400	400	400
Ping interval (s)	3.00	3.00	3.00
Bandwidth (%)	25	25	25
Theoretical standard deviation (m s^{-1})	0.0035	0.0035	0.0035

Depth Cell Size[1]	V20 (1000 kHz)		V50 (500 kHz)		V100 (300 kHz)	
Depth Cell Size[1]	Range (m)[2,3] Wide/Narrow	Std Dev (cm/s)[3,4] Wide/Narrow	Range (m)[2,3] Wide/Narrow	Std Dev (cm/s)[3,4] Wide/Narrow	Range (m)[2,3] Wide/Narrow	Std Dev (cm/s)[3,4] Wide/Narrow
0.25 m	18.0/22.6	19.2/36.5				
0.3 m	19.3/24.0	11.1/20.8				
0.5 m	20.2/24.9	7.1/13.4	44.1/57.6	19.2/36.5		
1.0 m	22.1/26.9	3.6/6.7	50.5/64.6	7.1/13.5	94.5/120.6	10.9/20.6
2.0 m	24.5/29.4	1.7/3.2	56.0/70.6	3.6/6.7	103.5/130.4	5.5/10.3
4.0 m	26.9/32.0	0.8/1.6	63.1/78.2	1.7/3.2	114.6/142.3	2.7/5.2
6.0 m			67.4/82.8	1.1/2.1	121.7/151.5	1.8/3.3

Self-Contained (SC) Communications and Recording	Wireless/Ethernet Internal memory	802.11 b/g/n / TCPIP One 16 GB Micro SD Card included
Real-Time (RT) Communications	Serial/Ethernet	RS232 and RS422 / TCPIP (setup) UDP (output)
Profile Parameters	Velocity accuracy Velocity resolution Velocity range Ping rate	V20/V50: 0.3% of the water velocity relative to the ADCP ± 0.3 cm/s V100: 0.5% of the water velocity relative to the ADCP ± 0.5 cm/s 0.1 cm/s ± 5m/s (default); ± 20m/s (maximum) Up to 4 Hz (SC); Up to 16 Hz (RT)
Echo Intensity Profile	Vertical resolution Dynamic range Precision	Depth cell size 80 dB ±1.5 dB
Transducer and Hardware	Beam angle Configuration Depth rating Materials	25° 4-beam, convex; 5th beam vertical 200 m Transducer, housing, and end cap: plastic Connector: metal shell
Standard Sensors	Temperature (mounted on transducer) Compass (magneto-inductive sensor) Tilt (MEMS accelerometers) Pressure sensor (mounted on transducer) Recorder	Range -5° to 45°C, precision ± 0.4°C, resolution 0.1° Accuracy 2° RMS, resolution 0.1°, max. dip angle 85° Pitch range ± 90°, roll range ± 180°, accuracy 2° RMS, precision 0.05° RMS, resolution 0.1° Range 300m, accuracy 0.1% FS 16GB Micro SD Card

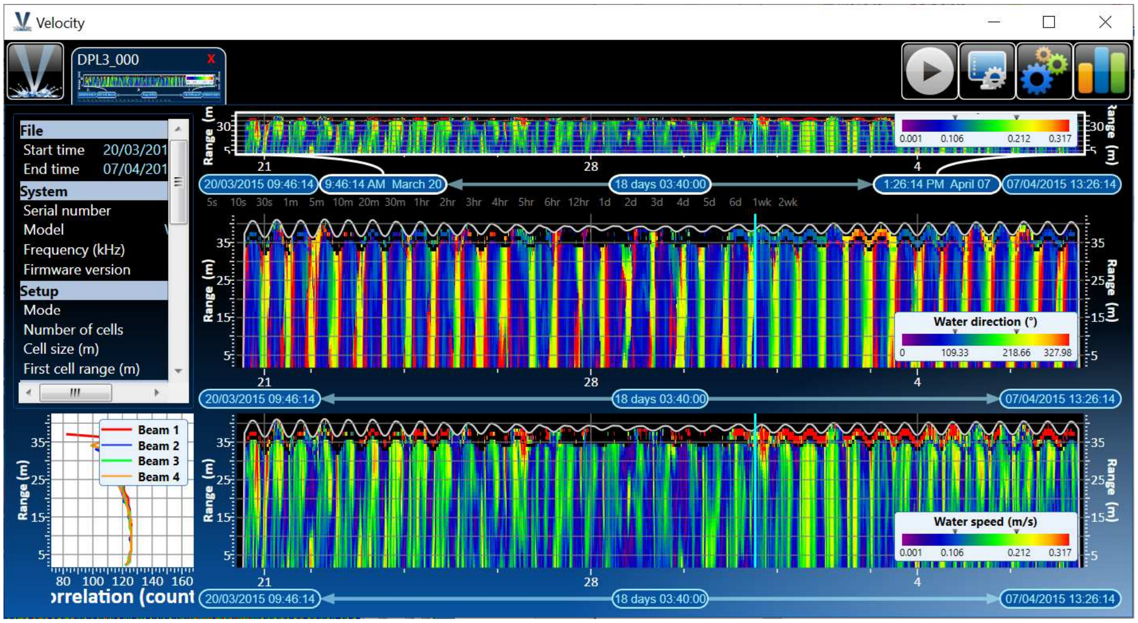
Figure 32: Teledyne RDI Sentinel V50 technical specifications

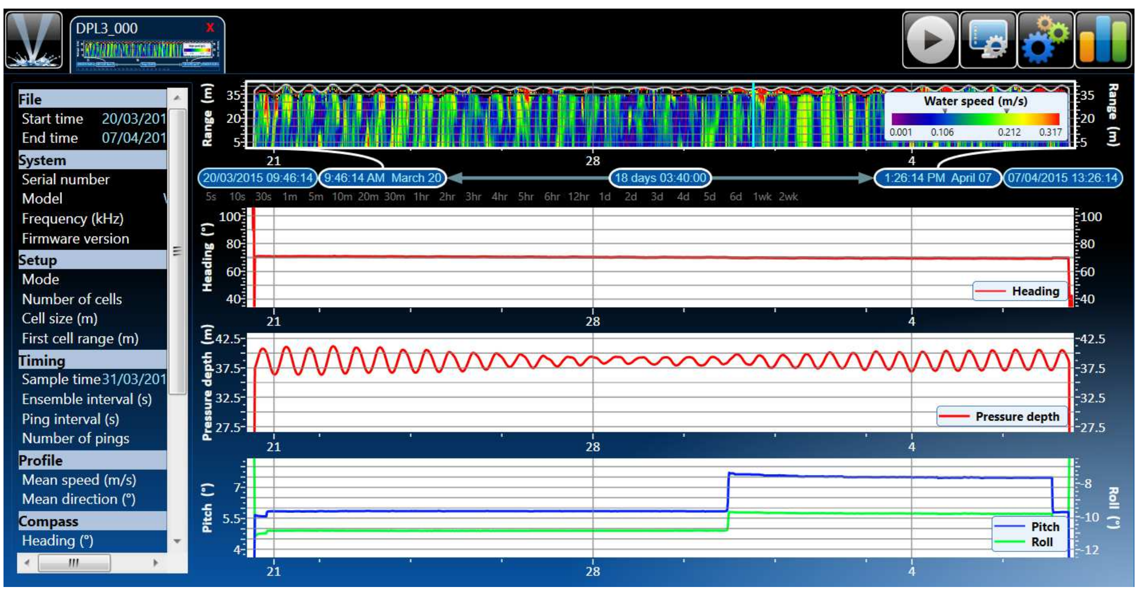
4. List of data files

Raw current meter data, ASCII format, exported from DPL3_000.000 DPL1Y000.000 DPL1x000.000	*DPL3_000.000.txt* *DPL1Y000.000.txt* *DPL1X000.000.txt*
Processed HG data	*FishnishA_90day_bed_hgdata_analysis_v7.xls* *FishnishA_90day_mid_hgdata_analysis_v7.xls* *FishnishA_90day_subs_hgdata_analysis_v7.xls* HG Analysis files for 2015, 2017 and 2018 full datasets have also been included.

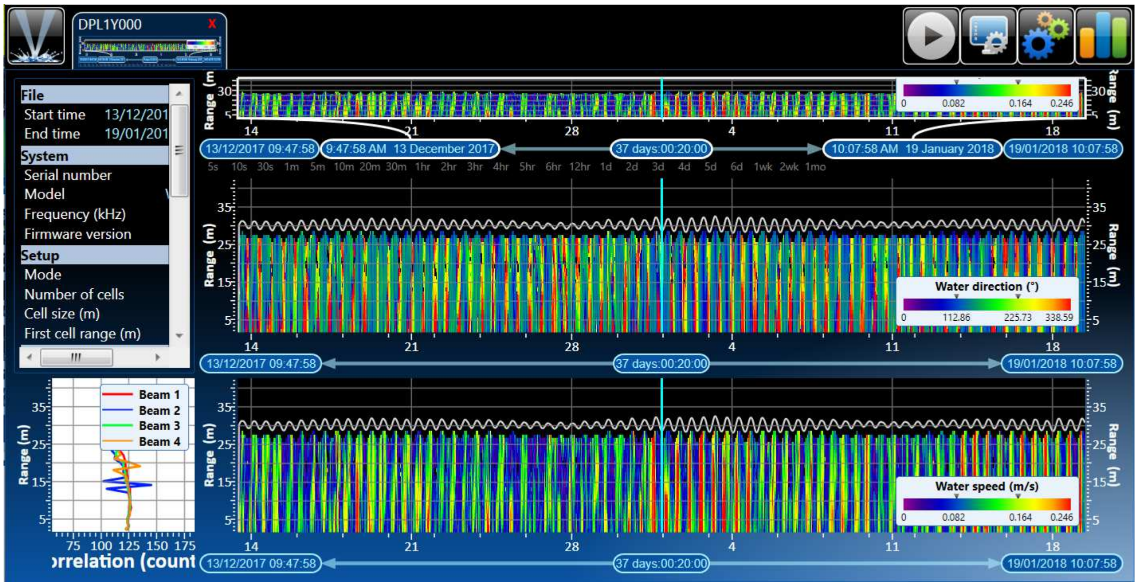
5. Appendices

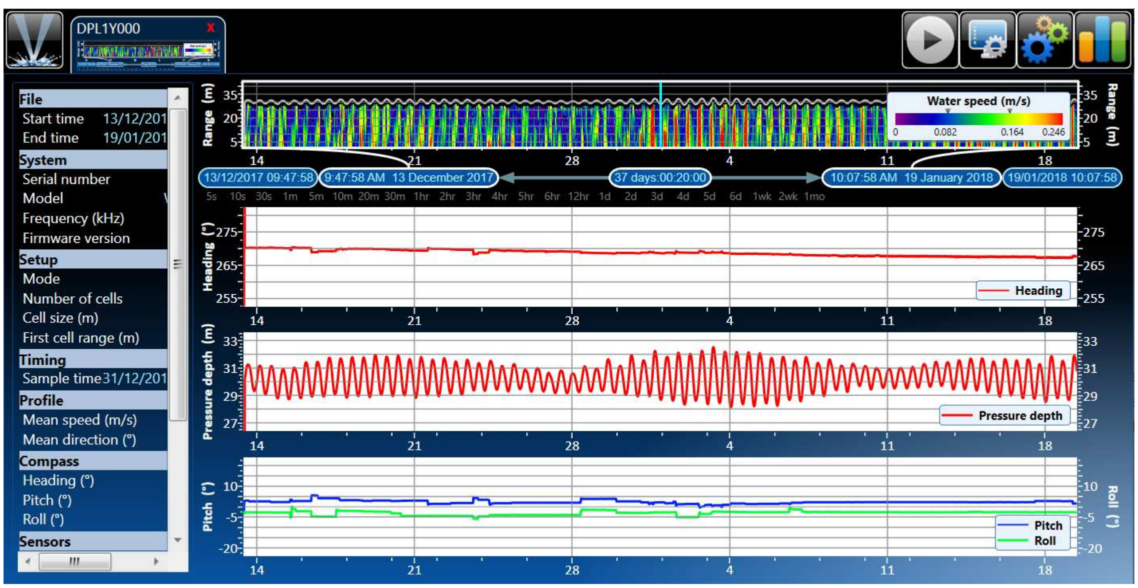
Appendix A 2015 dataset - Screenshots of DPL3_000.000.*pdv* from Teledyne's *Velocity* data processing software (entire dataset).





Appendix B 2017 dataset - Screenshots of *DPL1Y000.000.pdv* from Teledyne's *Velocity* data processing software (entire dataset).





Appendix C 2018 dataset - Screenshots of *DPL1X000.000.pdv* from Teledyne's *Velocity* data processing software (entire dataset).