Bath Dispersion Marine Modelling Report

Shapinsay (Veantrow Bay), Orkney

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1 Summary

This report describes simulations of the dispersion of bath treatment medicines based on the outputs of a hydrodynamic model which was developed for the Orkney Isles, with a focus on the Veantrow Bay area to the north of the island of Shapinsay. The aim of the investigation was to provide a risk assessment for dispersion resulting from a proposed site expansion within the bay (details in Table 1.1).

A single scenario involving feeding at a fixed rate while stocking at peak biomass for a full year was simulated. This provides an upper limit on the anticipated impact.

Table 1.1 Summary of site details and model results

Site details	
Site Name	Shapinsay (Veantrow Bay)
SEPA ID	VEA1
Locality	Orkney Isles
Pen centre (OSGB easting/northing, m)	350176, 1021628
Biomass (T)	2472.4 (applied for)
Configuration	
Number of pens (configuration)	12 (100 m grid, 2 x 6)
Pen size	140 m circumference
Pen group distance to shore	1700 m
Pen grid orientation	347.4^{o}
Depth (m)	19.18 m
Bath medicines	
Recommended Azamethiphos consent (3 hr)	455.5 g
Recommended Azamethiphos consent (24 hr)	1366.5 g
Recommended Deltamethrin consent	55 g

2 Introduction

This report has been prepared by Scottish Sea Farms Ltd. to meet the requirements of the Scottish Environmental Protection Agency (SEPA) for an application for a site expansion in Veantrow Bay, Shapinsay, Orkney Islands ("VEA1"; Figure 2.1 and Figure 2.2) (Scottish Environment Protection Agency 2023), and in particular to investigate the movement of bath treatment medicines released from the site.

The report describes the application of a particle tracking model to estimate the spread of medicines from the proposed site. The particle tracking model is forced by the outputs of a hydrodynamic model which was developed specifically for this work. Full details of the development, calibration and validation of the hydrodynamic model are given in a dedicated report (Danish Hydraulic Institute 2022).

The modelling procedure follows the current version SEPA marine modelling guidance as available at March 2024 (Scottish Environment Protection Agency 2024), as far as possible.

The proposed site is composed of 12 x 140 m pens on a 100 m grid, with centre-point of cage grid at (OSGB 350176, 1021628) m. Key data relating to the site are summarised in Table 1.1.

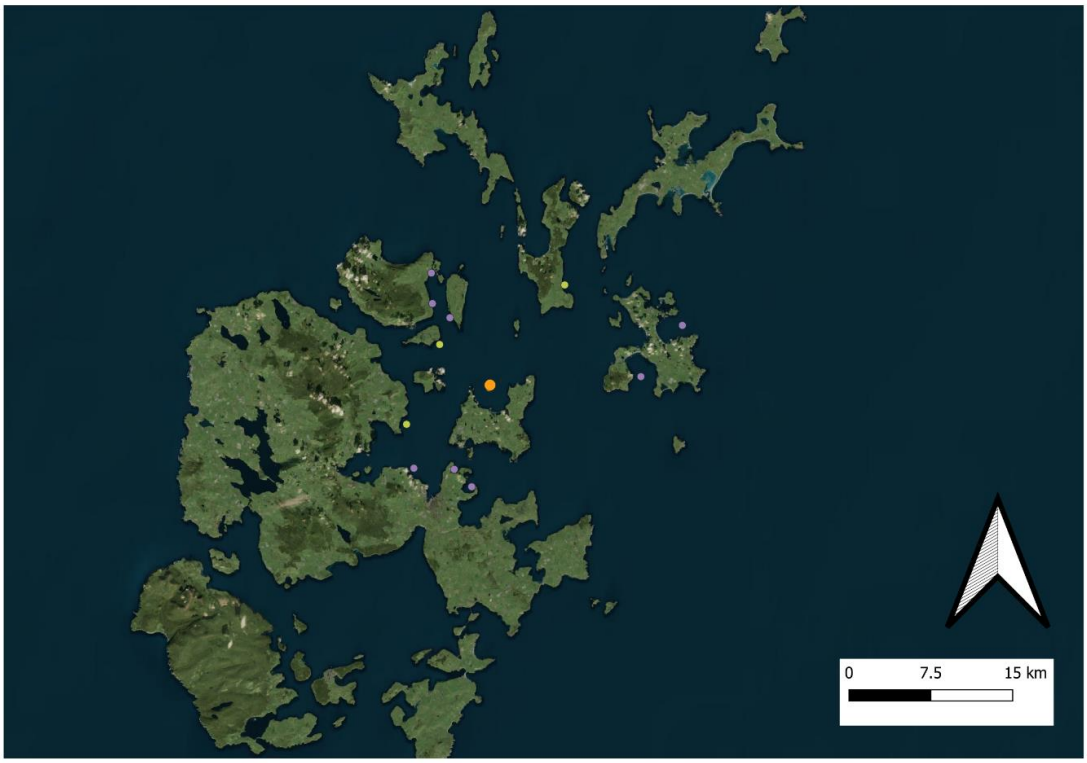


Figure 2.1 **Map showing broad location within Orkney Islands (Shapinsay site: orange disc; other salmon farms: green (SSF) and mauve (Cooke) discs).**

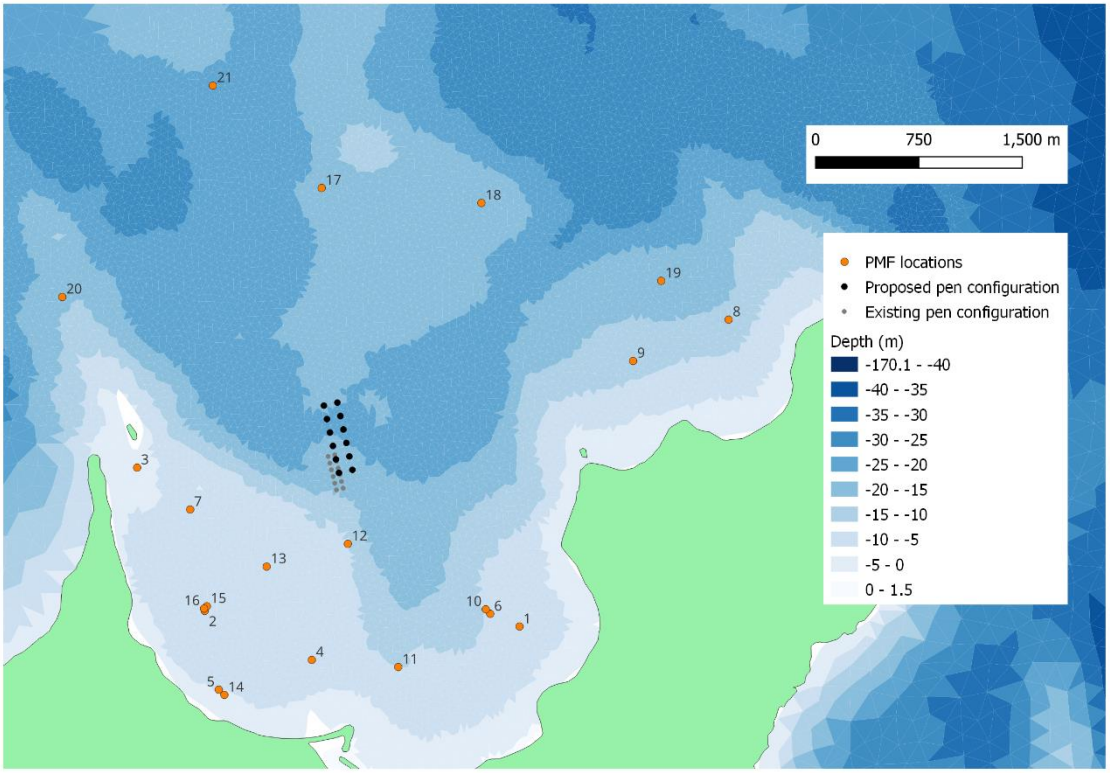


Figure 2.2 **Map of site location, showing proposed and existing site layouts (black/grey discs), and the locations of sensitive Priority Marine Feature (PMF) records identified by SEPA in their Risk Identification Report for the site (orange).**

3 Methodology

3.1 Dye and drogue study

A dye and drogue study was commissioned with Anderson Marine Surveys Limited (AMSL). This study was carried out in the proximity of the proposed site location, with the dual objectives of i) identifying horizontal dispersion parameters in the locality, and ii) checking that the movements predicted by the particle tracking model were realistic.

The dye/drogue study is described in detail elsewhere (Anderson Marine Surveys 2022) and key results and comparison with model predictions are described in the hydrodynamic model validation report.

3.2 Hydrodynamic model

The hydrodynamic model used in this work was the DHI MIKE 21 FM numerical modelling system, which has been developed for general simulation of water flows in estuaries, bays and coastal areas, in addition to wider ocean domains. MIKE 21 is a three-dimensional model which can account for density variation, currents and tidal elevation (Danish Hydraulic Institute 2017).

MIKE 21 is a finite volume hydrodynamic model, using an unstructured spatial mesh formulation which allows representation of fine scale features in coastline and bathymetry while retaining computational efficiency through a coarser mesh in simpler areas. Horizontal elements in the model can be triangular or quadrilateral; the model described here used exclusively triangular elements. This approach is particularly important for complex coastal regions such as the Scottish west coast. A similar method is used by other current hydrodynamic models such as FVCOM (Chen et al. 2013). This allows simulation of spatial domains that were not possible with earlier regular-grid models such as POLCOMS and ROMS, which were developed with wider ocean regions in mind.

The hydrodynamic model domain extended from the Moray Firth in the south to the Shetland Isles in the North, with the highest resolution areas focused on the Orkney Isles and in particular the focal site in Veantrow Bay (Figure 3.1). The hydrodynamic simulations covered two periods: i) a “climatological” year (25-year average meteorological and oceanographic forcing from 1993-2017), and ii) a 13-month period 01/06/2017-01/07/2018, which was validated against available current meter observations for the focal site and other nearby sites. The outputs of the latter (specific time period) simulation were applied here. The HD model output timestep was 30 minutes. Full details of the development, calibration and validation of the hydrodynamic model are given elsewhere (Danish Hydraulic Institute 2022, and in the HD model validation report submitted with this application).

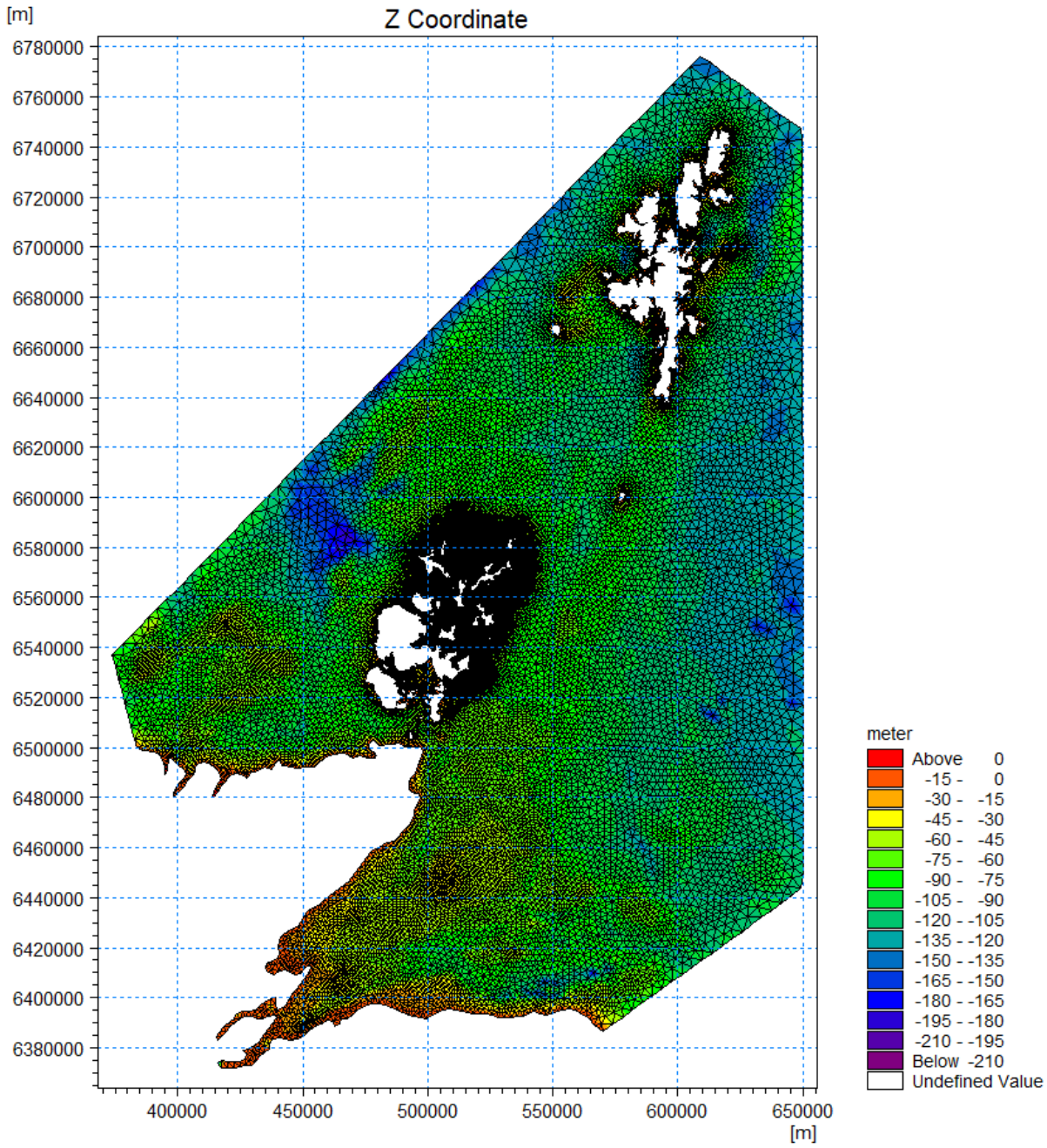


Figure 3.1: **Mesh for hydrodynamic model, showing the full extent of the spatial domain, which covers Orkney, Shetland, and a portion of the Scottish mainland coast. Resolution is highest around Orkney, in particular Veantrow Bay.**

3.3 Particle Tracking model

Particle tracking was also carried out using the DHI MIKE software suite (Danish Hydraulic Institute 2021). Flow fields (U/V/W velocities) generated by MIKE 21 were used to drive the movement of passive particles (no active horizontal or vertical movement) in the water column. Particles were subject to advection due to currents, and horizontal and vertical diffusion (described by a random walk formulation) at fixed rates of 0.1 and 0.001 $m^2 s^{-1}$ respectively. Current speeds at all depths were taken to be uniform and equal to the 2D depth averaged velocity computed by the HD model.

Each particle was assigned to represent a specific mass of medicine at the moment it was released (equal to total treatment mass, divided by the number of particles per release). This mass weighting is considered to decline exponentially over time at a fixed rate governed by the chemical half-life prescribed by SEPA. Presently the SEPA default value of half-life for Azamethiphos is 5.6 days; this was reduced from the previous value of 8.9 days in light of the latest evidence (Veterinary Medicines Directorate 2020). For Deltamethrin particles, no decline in mass over time was included.

The horizontal mesh used for particle tracking was finely resolved over a larger spatial extent than the mesh used to simulate the hydrodynamics. Resolution of hydrodynamic model mesh is constrained by computational processing capacity, and the need to obtain a balance between resolution and spatial extent of the model domain, which also has an impact on accuracy of predictions. High horizontal resolution in areas of deeper water requires a very short hydrodynamic model timestep, which is not feasible for a model of this spatial and temporal extent. The mesh used to carry out particle tracking simulations is shown in Figure 3.2, and histograms of mesh statistics are shown in Figure 3.2. In the highest resolution areas (extending 2-3 km around all sites), element side length is around 50 m, and element area is around 1100 m^2.

A timestep of 120 s (2 minutes) was used for particle tracking. Half-hourly hydrodynamic model velocities were interpolated temporally horizontally onto the particle tracking model mesh by the software during the model simulation.

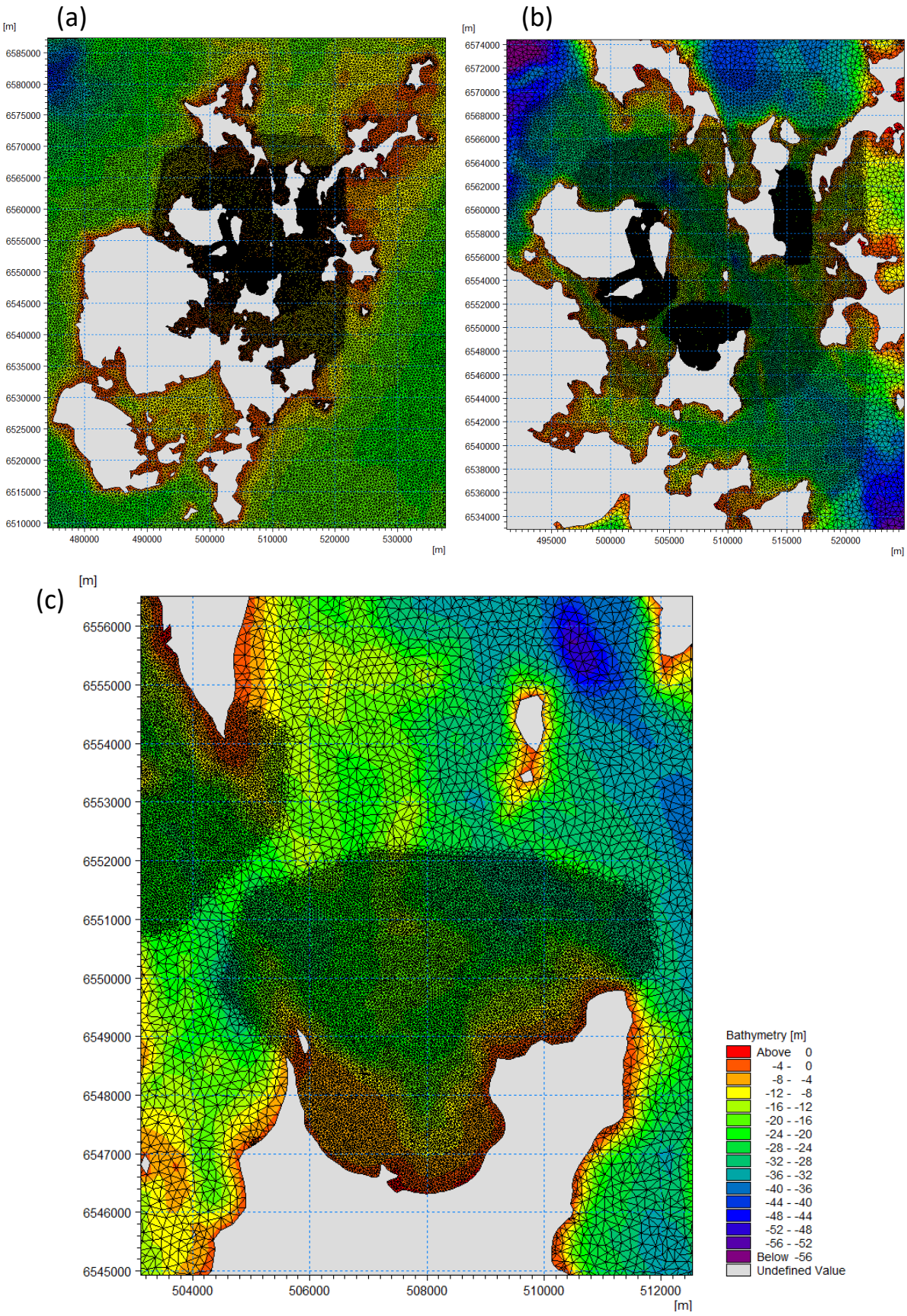


Figure 3.2 **Mesh used for particle tracking, covering the Orkney Islands at high resolution. (a) Whole mesh. (b) Expanded view of North Orkney area. (c) Close-up view of Veantrow Bay area (vertical scale only applies to this view).**

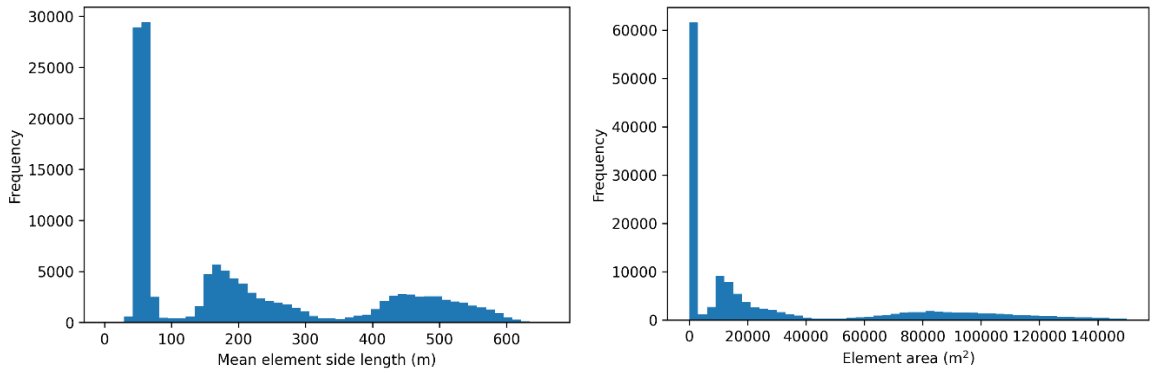


Figure 3.3 **Histograms of properties of the mesh used for impact assessment particle tracking. (a) Element side length (mean of the three sides of an element), and (b) element area.**

3.4 Dispersion model study

3.4.1 Approach

For particle tracking simulations, two release (treatment start) times were selected from the hydrodynamic model output:

- 22/07/2017 (release during SPRING tide)
- 30/07/2017 (release during NEAP tide)

Releases on these dates, and the corresponding periods over which particle dispersal would be assessed, are shown in Figure 3.4 (for an example treatment starting 24 hours prior to the treatment completion time).

Sensitivity to specific release time for neap and spring period dispersal was estimated by adjustment to the particle tracking simulation start time of +/- 6 hrs about the baseline value.

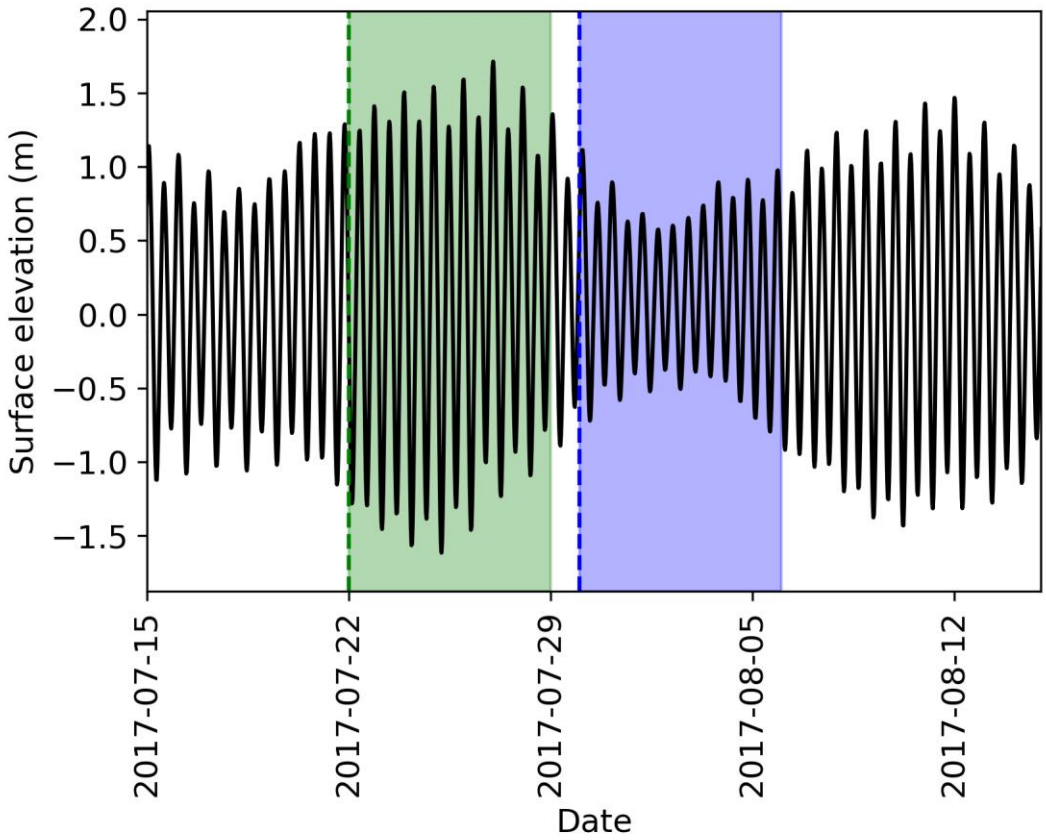


Figure 3.4 Surface elevation at relocated Shapinsay site. Particle dispersal period over spring tide is indicated in green, and dispersal over neap tide is shown in blue.

A scenario for particle release was defined in order to simulate a realistic schedule for treatment at the site. In this scenario, 3 pens were treated on four consecutive days, with a 3 hour interval (releases at 0, 3, 6, 24, 27, 30, 48, 51, 54, 72, 75, 78 hours from first release).

Bath treatment events were simulated using a release of 50,000 model particles per pen treated, with each particle representing an equal proportion of the total treatment mass (total 600,000 particles per simulation). Particles were released randomly within a pen's lateral area and over the top 3 m of the water column. Simulated particles were passive, neutrally buoyant, and subject to both horizontal and vertical advection (derived from hydrodynamic model flow fields) and dispersion (set to fixed constant values; by default 0.1 m^2 s^{-1} horizontally and 0.001 m^2 s^{-1} vertically).

3.4.2 Azamethiphos

The initial treatment mass (derived as the 3 hr limit from BathAuto) for Azamethiphos was 455.5 g (Appendix 7.1).

As per present SEPA guidance, half-life for particles in Azamethiphos simulations was set to 5.6 days (via a mass decay rate of 1.43 x 10^{-6} s^{-1})

Sensitivity to horizontal dispersion was tested with additional simulations using horizontal dispersion coefficients of 0.05, and 0.5 m^2 s^{-1}. The effect of changing the release point in the tidal cycle was assessed via sensitivity simulations with all release times shifted 6 hours earlier, or 6 hours later. The set of dispersion sensitivity simulations carried out for Azamethiphos is summarised in Table 3.1.

Table 3.1 Summary of dispersion simulation parameters for sensitivity testing in the main set of runs.

ID	Tide	Dispersion	Timing adjustment (hr)
1	Neap	0.1	0
2	Neap	0.1	-6
3	Neap	0.1	+6
4	Neap	0.05	0
5	Neap	0.5	0
6	Spring	0.1	0
7	Spring	0.1	-6
8	Spring	0.1	+6
9	Spring	0.05	0
10	Spring	0.5	0

Assessments against 72 hr EQS/MAC values were made using aggregated outputs for all pen releases within a given treatment schedule, and for individual first pen releases for 3 hr EQS. For 3 hr EQS, results from all individual releases within the baseline spring and neap treatment schedules were also assessed. Output statistics were generated for all particle dispersion simulations in accordance with the current version of SEPA guidance (December 2023). The following values were calculated, based on concentrations within the top 5 m of the water column, as per SEPA guidelines:

- Timeseries of area > 3 hr EQS (threshold 250 ng l^{-1})
- Timeseries of area > 72 hr EQS (threshold 40 ng l^{-1})
- Timeseries of maximum concentration vs 72 hr MAC (threshold 100 ng l^{-1})

The 3 hr EQS area was derived from the calculated BathAuto ellipse at that time (Appendix 7.1), as per present SEPA guidance. Plots of medicine mass distribution at the specific EQS times were generated.

3.4.3 Deltamethrin

The initial treatment mass for Deltamethrin (derived as the 6 hr limit from BathAuto) was taken to be 30.92 g (Appendix 7.1).

As per present SEPA guidance, particles in Deltamethrin simulations were set to have no decay over time.

Assessments were made based on individual pen releases, for all releases within the baseline spring and neap treatment schedules. The following value was calculated, based on concentrations within the top 5 m of the water column, as per SEPA guidelines:

- Timeseries of area > 6 hr EQS (threshold 6 ng l^{-1})

The 6 hr EQS area was derived from the calculated BathAuto ellipse at that time (Appendix 7.1), as per present SEPA guidance. Plots of medicine mass distribution at the 6 hr after each individual pen release were generated.

3.4.4 Priority Marine Feature (PMF) locations

Several points in the locality of the farm have been identified as locations where sensitive Priority Marine Features have been previously recorded, primarily due to the presence of maerl, and were identified in SEPA's screening risk identification report (summarised in Figure 2.2 and Table 3.2). For each of these locations, timeseries of concentration within were generated, in addition to vertical profiles of concentration at EQS time points.

A visual seabed survey of the area around the site was carried out, identifying the presence of maerl in additional locations and confirming the presence or absence of maerl in locations of previous

records. These locations are shown visually in Figure 3.5, classified according to the percentage cover of maerl at each location. For maerl beds to be classed as a PMF, 20% cover of maerl is required. For the purposes of this assessment all locations with maerl cover greater than 5% have been included (see Appendix 7.2), and predicted concentration of bath medicines extracted from the model (timeseries and vertical transects).

Table 3.2 PMF record locations in the proximity of the proposed site, extracted from the GEMS database. Numbering here is used in later plots presenting results of impact calculations.

Number	Type	Easting (UTM30N)	Northing (UTM30N)
1	Maerl beds	508735	6547467
2	Maerl beds	506448	6547546
3	Seagrass beds	505942	6548578
4	Maerl beds	507231	6547202
5	Maerl beds	506559	6546976
6	Maerl beds	508521	6547556
7	Maerl beds	506332	6548280
8	Maerl beds	510219	6549716
9	Maerl beds	509530	6549406
10	Maerl beds	508488	6547588
11	Maerl beds	507859	6547160
12	Maerl beds	507480	6548048
13	Maerl beds	506893	6547874
14	Maerl beds	506600	6546939
15	Maerl beds	506463	6547580
16	Maerl beds	506443	6547563
17	Maerl beds	507251	6550627
18	Maerl beds	508412	6550536
19	Maerl beds	509726	6549990
20	Maerl beds	505380	6549808
21	Maerl beds	506450	6551358

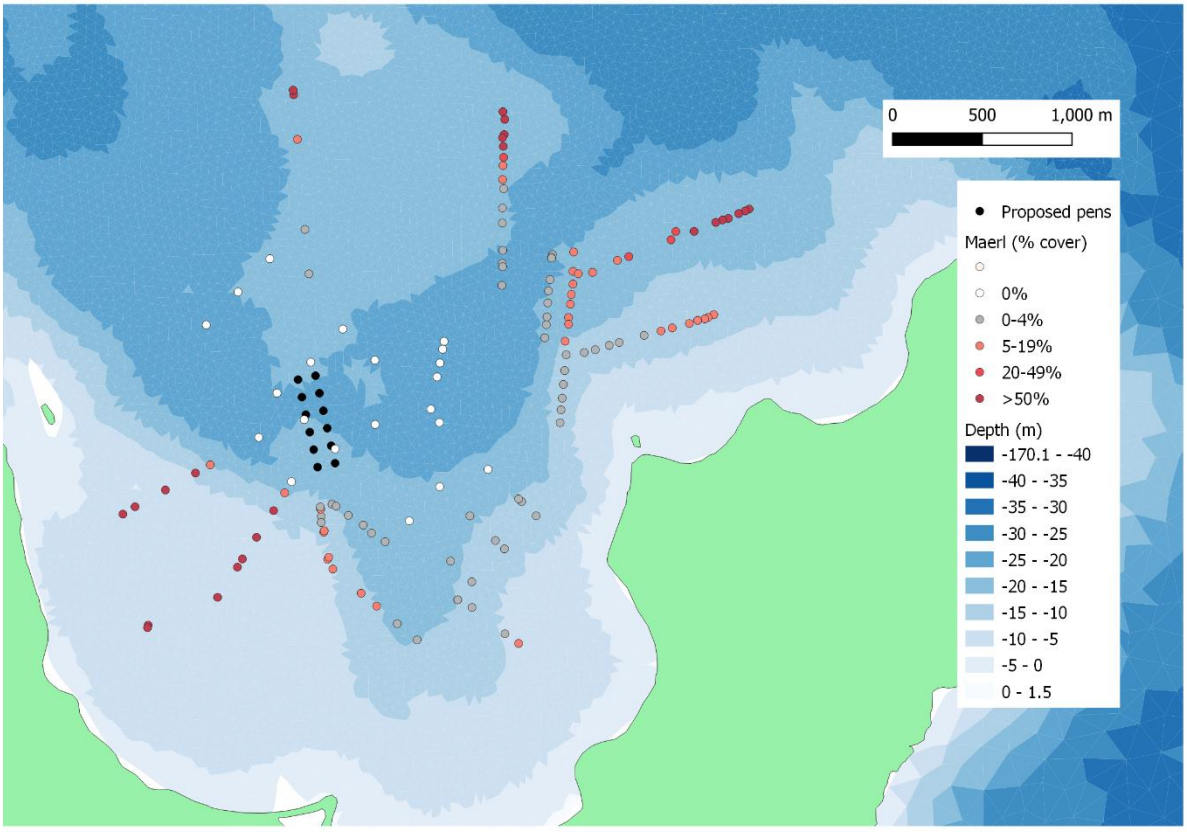


Figure 3.5: Visual survey locations and percentage cover of maerl on the seabed (shaded discs white to red). The location of the proposed pens is shown by black discs, and depth of the water by blue background.

4 Results

4.1 Azamethiphos

4.1.1 3 hr EQS

This section assesses compliance with the 3 hr EQS for baseline pen releases under neap and spring tidal conditions. As noted above, the **3 hr EQS threshold for area over 250 ng l^{-1} concentration, derived using BathAuto, was 0.190 km^2** (Appendix 7.1).

Timeseries of area above the 3 hr EQS threshold concentration for individual pen releases of 455.5 g are shown in Figure 4.1, under both neap and spring tide conditions. Times are given relative to the initial release time for each individual pen, aligning timeseries for all pens to a common start point.

Initial trajectories of the areal extent of the plume are similar for the first two hours post release, but after this point the area covered shows substantial variability between pens, particularly in the neap tide case. It is clear from the figure that none of the individual pen releases exceeds the 3 hr EQS, achieving compliance by a large margin in all cases.

In addition to the variation in spatial extent of dispersion, the overall pattern of patch movement from each pen release varies between pens, largely governed by the state of tide at the time of release (Figure 4.2, and Figure 4.3).

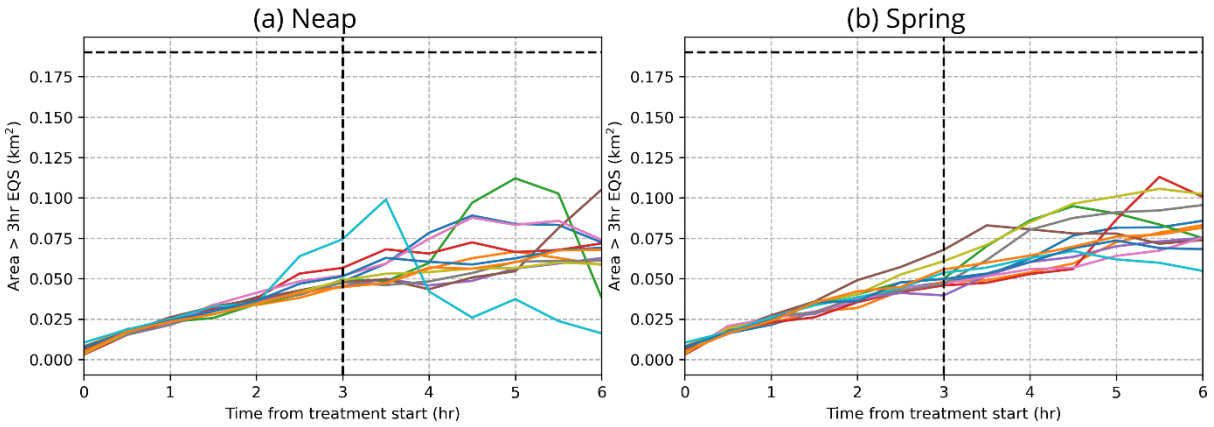


Figure 4.1 Individual pen releases (455.5 g/pen). Area above the 3 hr EQS concentration threshold (250 ng l^{-1}) for each pen under the baseline (a) neap and (b) spring tide scenarios. Horizontal dotted line indicates the 3 hr ellipse area derived using BathAuto (defining the allowable EQS area). Time is given relative to the time of each pen release, to enable direct comparison of results.

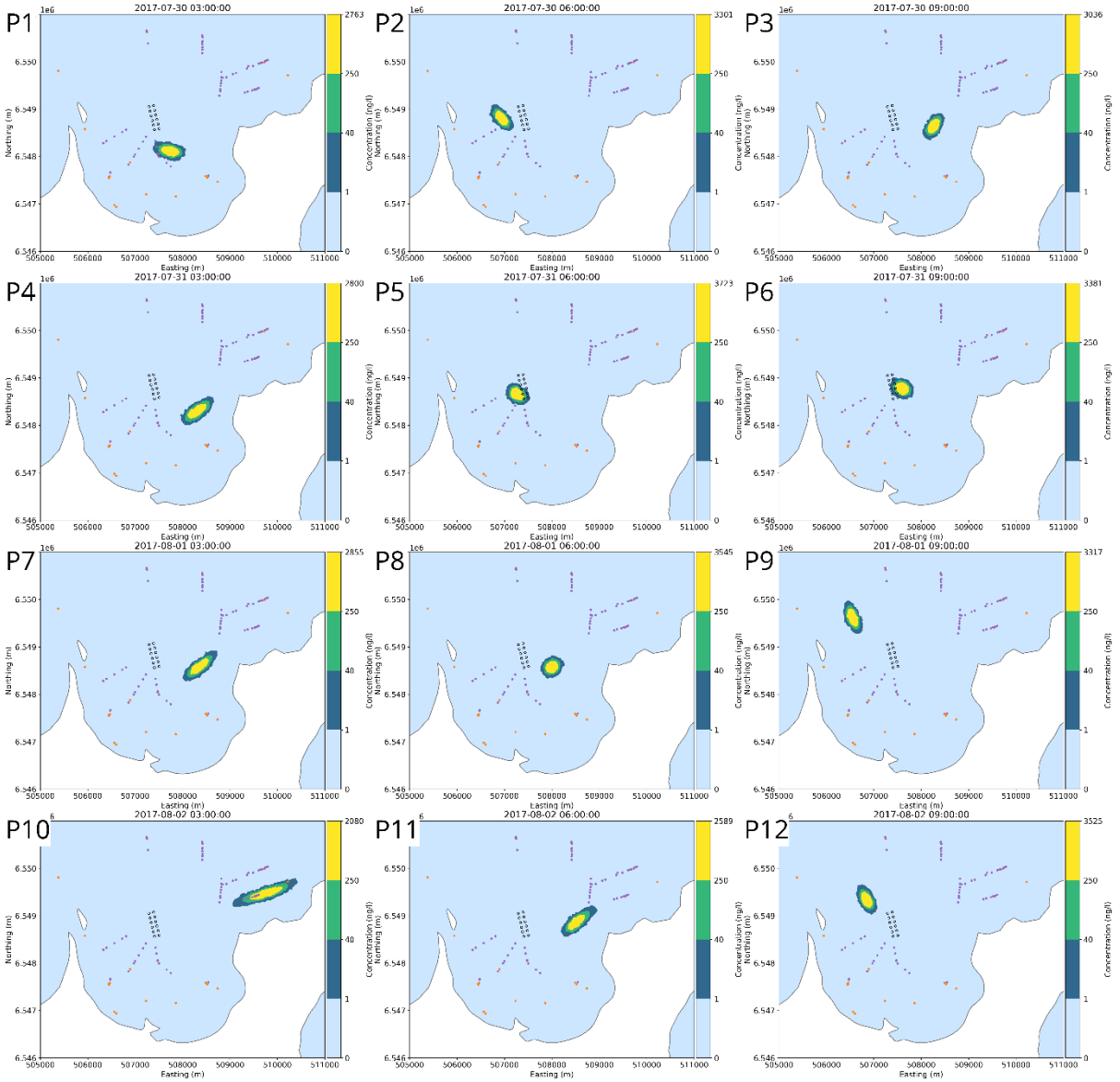


Figure 4.2 Predicted surface concentration of Azamethiphos at 3 hrs post release, for individual pen treatments 1-12 (neap tide conditions, plumes from each pen shown in isolation) at 455.5 g/pen. Contours are shown at EQS concentration thresholds, and at a nominal 1 ng/l.

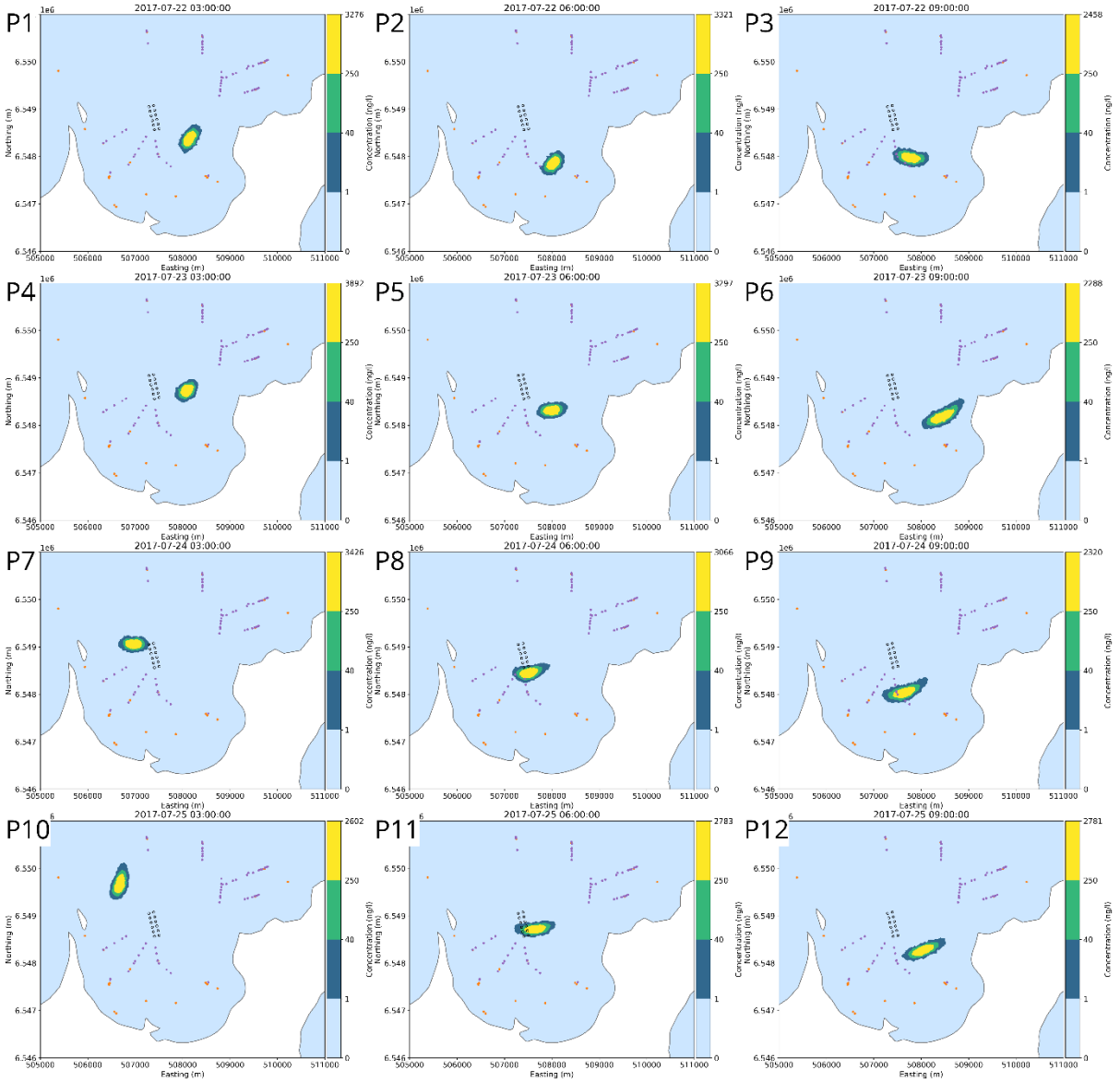


Figure 4.3 Predicted surface concentration of Azamethiphos at 3 hrs post release, for individual pen treatments 1-12 (spring tide conditions, plumes from each pen shown in isolation) at 455.5 g/pen. Contours are shown at EQS concentration thresholds and at a nominal 1 ng/l.

4.1.2 72 hr limit EQS and MAC – neap and spring baseline

This section assesses compliance with the 72 hr MAC and EQS for baseline pen releases under neap and spring tidal conditions. The 72 hr MAC is 100 ng l^{-1}, and the 72 hr EQS threshold for area 40 ng l^{-1} concentration is 0.5 km^2.

The 72 hr EQS criterion is easily met in the baseline simulations (Figure 4.4 a). However, the MAC criterion is not, with the maximum concentration predicted by the model being consistently over the allowable MAC throughout the 24 hr window following 72 hr after treatment completion (Figure 4.4 b).

In the snapshot map of modelled concentration at 72 hrs, the locations where the 100 ng l^{-1} MAC is exceeded are in coastal elements (Figure 4.5). This is discussed in more detail in Section 4.1.4.

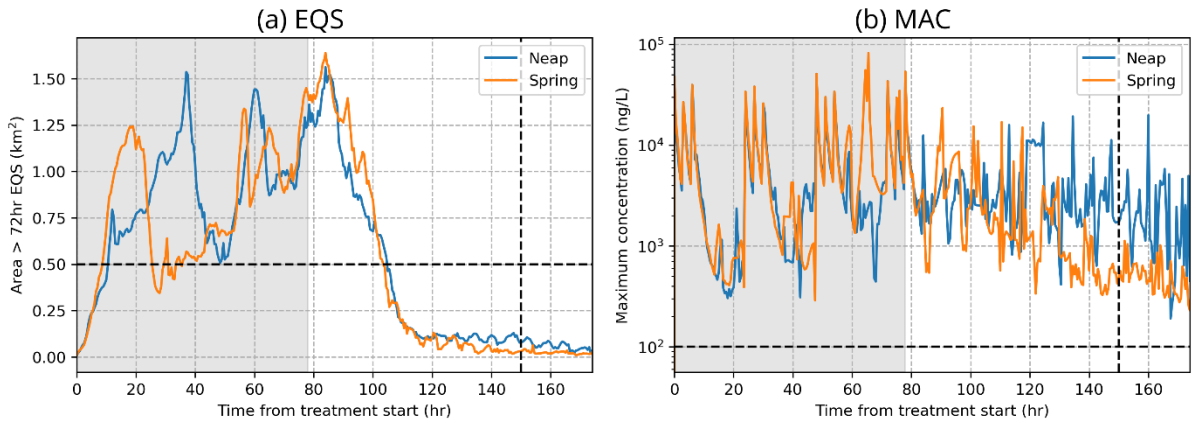


Figure 4.4 Baseline simulations; 455.5 g/pen release. (a) Area above 72 hr EQS of 40 ng l^{-1} for baseline simulations (neap tide: blue; spring tide: orange). Timeseries of predicted area with concentration higher than the 72 hr EQS concentration, allowing comparison with the allowable areal extent of that concentration (horizontal dashed line) at 72 hrs after the final treatment release (vertical dashed line). (b) Timeseries of predicted maximum concentration within the domain, allowing comparison against MAC (horizontal dashed line) at 72 hrs after the final treatment release (vertical dashed line). Time is given relative to the time of initial release, to enable direct comparison of results.

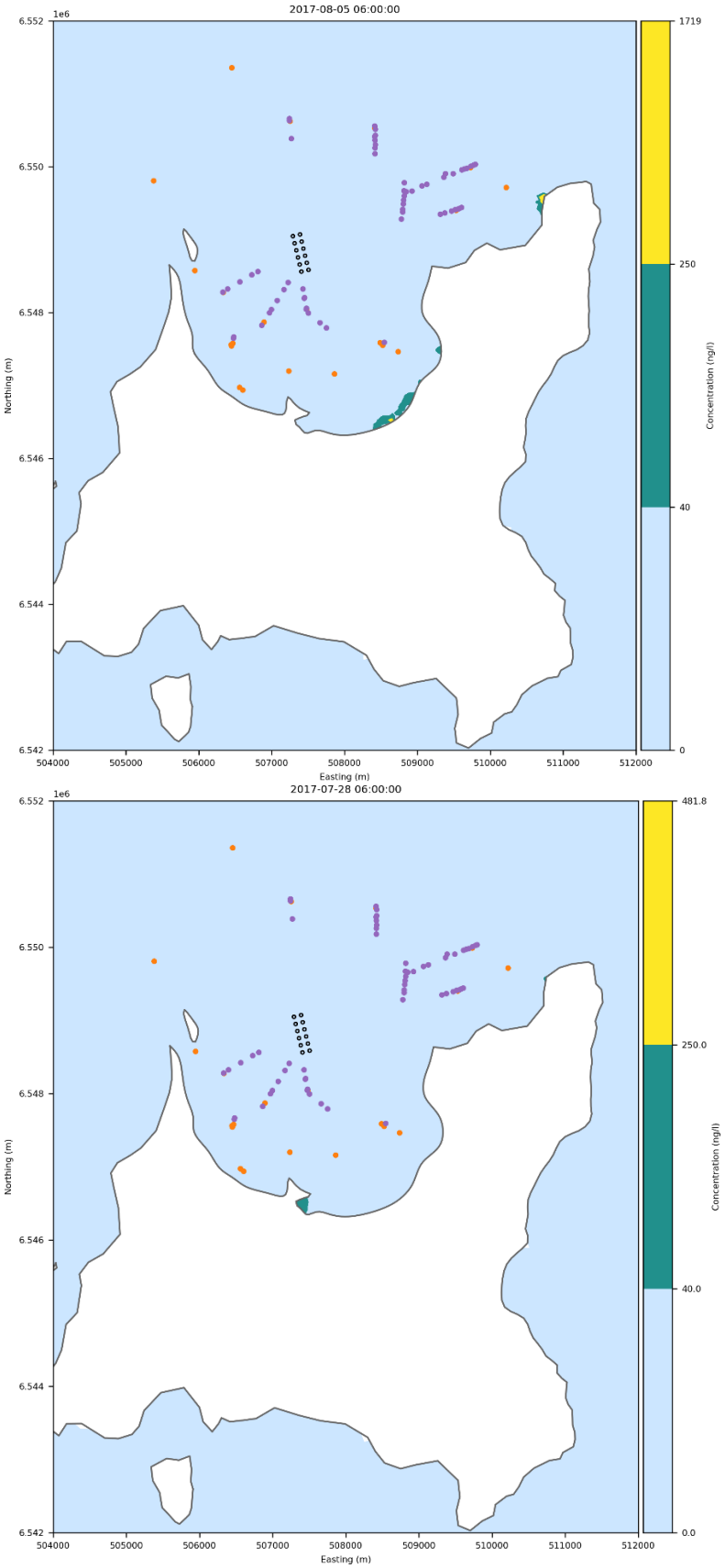


Figure 4.5 Predicted surface concentration of Azamethiphos at 72 hours after treatment is complete (455.5 g/pen release). Contours at EQS concentration thresholds. (a) Neap tide, and (b) spring tide.

4.1.3 Sensitivity

Release time

The impact of changing release time by +/- 6 hr from the baseline neap and spring release times is shown in Figure 4.6. Changing the release time in this way does not have any impact on the outcome in relation to the EQS and MAC criteria. Both EQS criteria remain easily met, and the MAC criterion is breached by all simulations. This is discussed in more detail in Section 4.1.4.

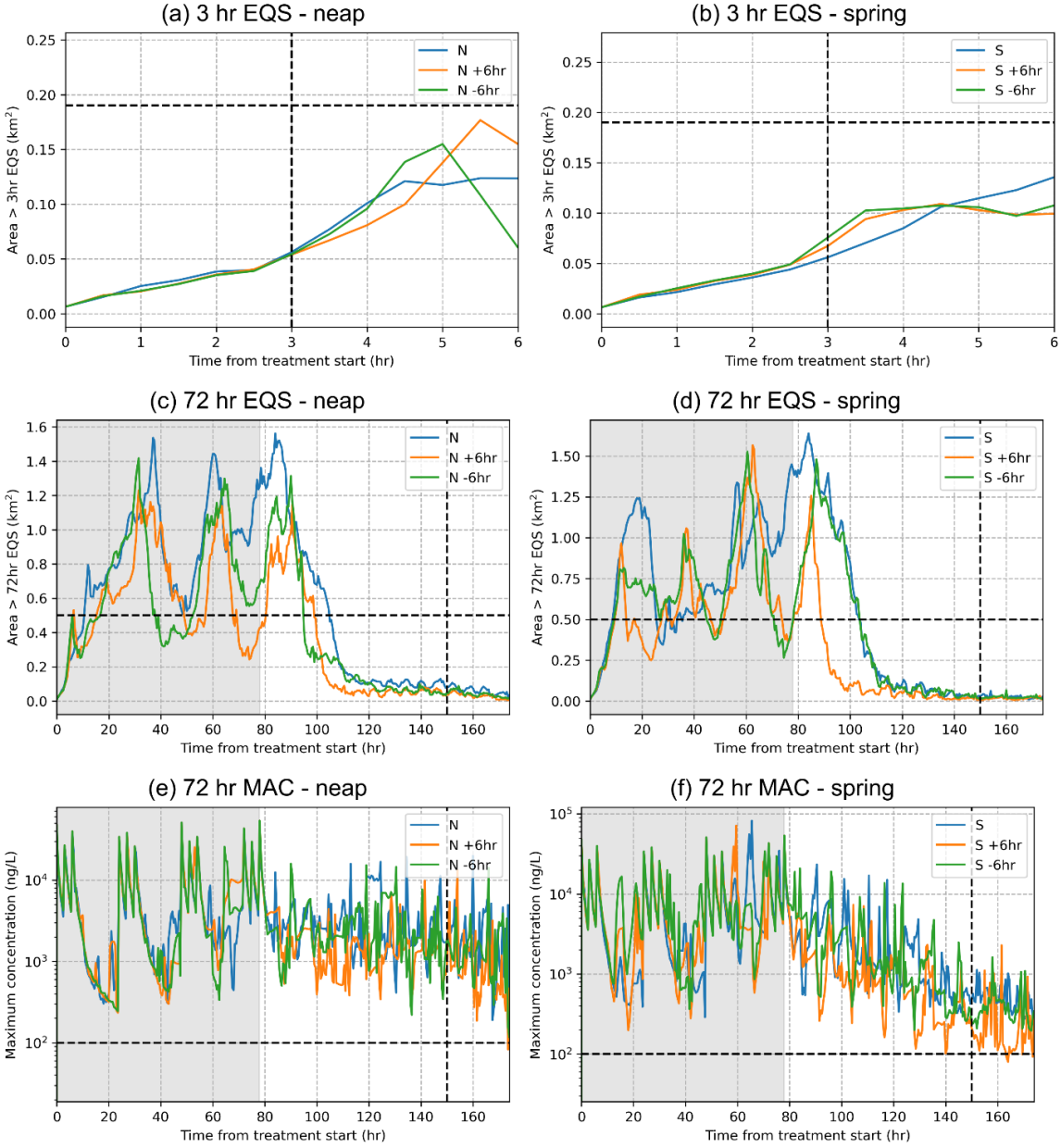


Figure 4.6 Sensitivity to release time, showing the effect of adjusting release time +/-6 hrs from the baseline time (455.5 g/pen release). (a, b) Area of plume with concentration greater than 250 ng l^{-1} (3 hr EQS level), up to 3 hrs, for the first pen treated (6 hr trajectories for all individual pens shown for the baseline case in Figure 4.1a). (c, d) Maximum concentration anywhere within the domain. (e, f) Area of plume with concentration greater than 40 ng l^{-1} (72 hr EQS level). Horizontal dashed lines indicate EQS/MAC maximum allowable thresholds, and vertical lines indicate the relevant time for assessment. Time is given relative to the time of initial release, to enable direct comparison of results.

Dispersion coefficient

The impact of changing the dispersion coefficient from the baseline value, under neap and spring releases, is shown in Figure 4.6.

It is clear from the plots that changing the dispersion coefficient does not have any impact on the outcome in relation to the EQS and MAC criteria. Both EQS criteria remain easily met, and the MAC criterion is breached by all simulations. This is discussed in more detail in Section 4.1.4.

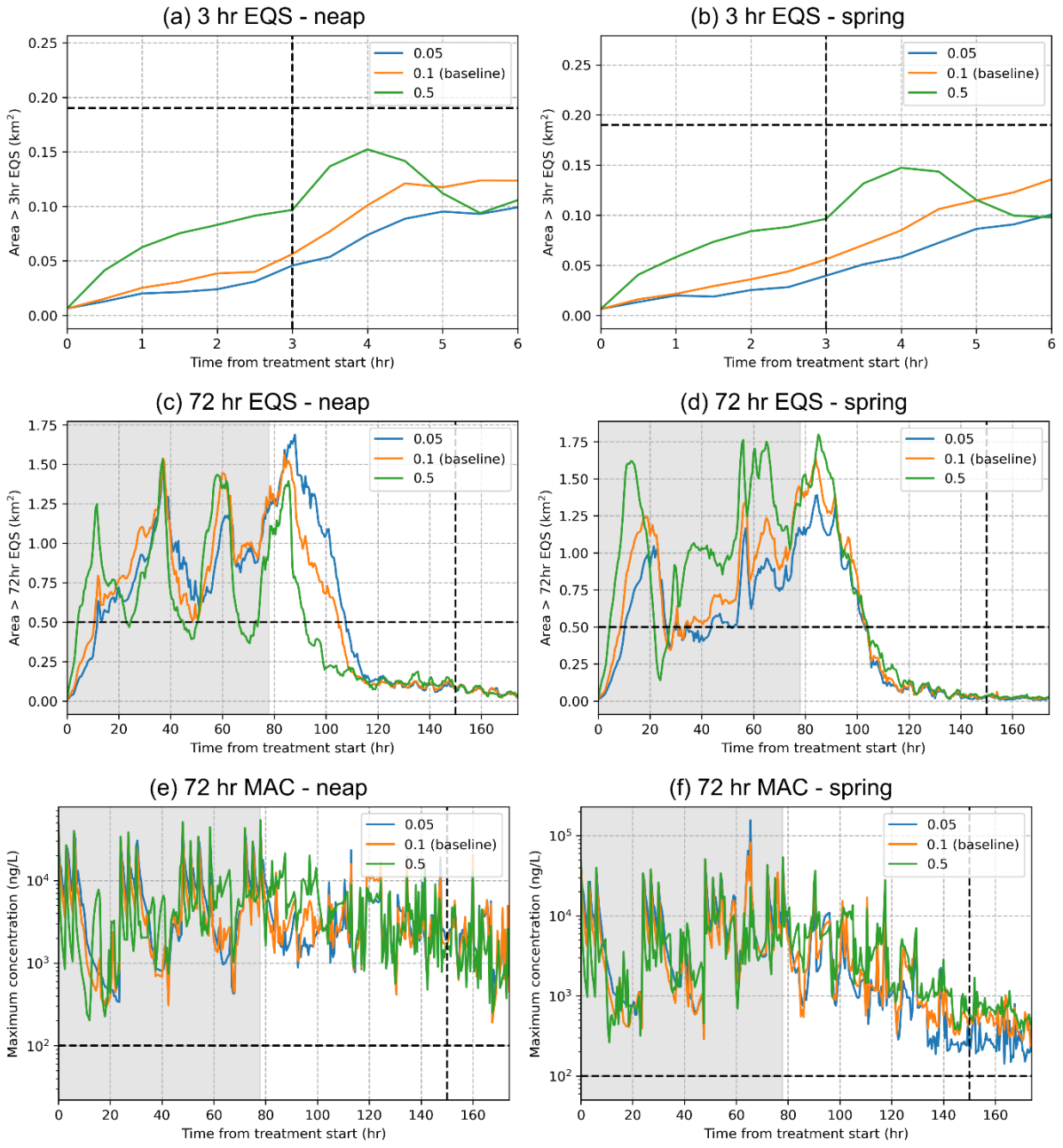


Figure 4.7 Sensitivity to dispersion coefficient (455.5 g/pen release). (a, b) Area of plume with concentration greater than 250 ng l^{-1} (3 hr EQS level), up to 3 hrs, for the first pen treated. (c, d) Maximum concentration anywhere within the domain. (e, f) Area of plume with concentration greater than 40 ng l^{-1} (72 hr EQS level). Horizontal dashed lines indicate EQS/MAC maximum allowable thresholds, and vertical lines indicate the relevant time for assessment.

4.1.4 72 hr MAC breaches

Plots of the timeseries of maximum concentration in the model and snapshot maps of the concentration at 72 hrs indicate breaches of the allowable 72 hr MAC, and also indicate that this appears to occur at locations along the coastline.

Figure 4.8 shows an ensemble of maximum concentration in all Azamethiphos simulations carried out. Figure 4.9 shows the same data, with a restricted time window of 140-174 hrs after the initial treatment release, to improve clarity of the assessment window.

Figure 4.10 shows a map of concentration at 72 hrs post completion of bath treatments for the spring tide case, overlaid with locations where a MAC exceedance occurred in ANY of the simulations carried out, at ANY time within the 24 hr assessment window (magenta points). Exceedance within any simulation only occurs at isolated locations at a given moment in time.

Artefacts can be introduced into the modelled concentration field by various means. In the case of modelling dispersal within an embayment, these can arise from the particle advection algorithm (which can lead to artificial aggregations of particles close to the coastline; see DHI 2015 for numerical method description), and due to water with a depth shallower than that used for computation of a depth average.

Concentration fields were re-analysed after removal of locations from the concentration field that are either located on the coastline, or have an average depth less than 5 m (the assessment depth) + half the tidal range (meaning that they have a water depth less than 5 m for at least part of the tidal cycle, potentially resulting in artificially high concentrations when averaged over the top 5 m). After removal of these points was made, the maximum concentration within the model domain was generally over an order of magnitude below the allowable MAC for the duration of the assessment window (Figure 4.11), with a single spike arising in the neap low dispersion sensitivity simulation.

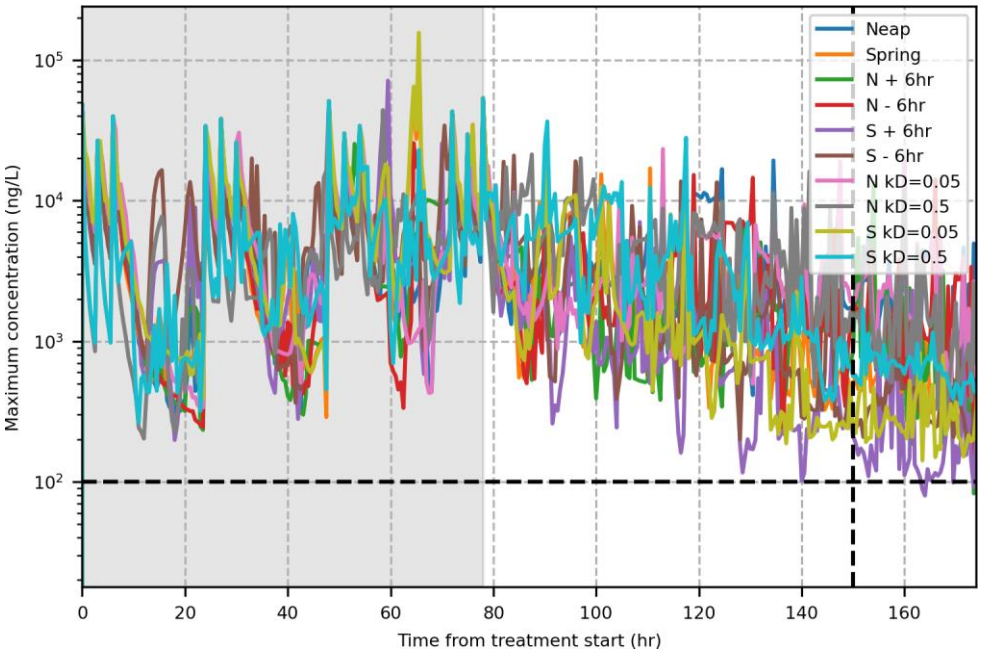


Figure 4.8 72 hr MAC; ensemble of individual pen releases (455.5 g/release). Maximum concentration anywhere within the domain. Colours: blue = neap baseline, orange = spring baseline, green = neap+6hr, red = neap-6hr, purple = spring+6hr, brown = spring-6hr, pink = neap baseline with dispersion of 0.05 m^2s^{-1}, grey = neap 0.5 m^2s^{-1}, yellow = spring 0.05 m^2s^{-1}, blue = spring 0.5 m^2s^{-1}. Horizontal dashed line indicates the maximum allowable area, assessment time of 3 hr is indicated by vertical dashed line. Time is given relative to the time of first pen release, to enable direct comparison of results.

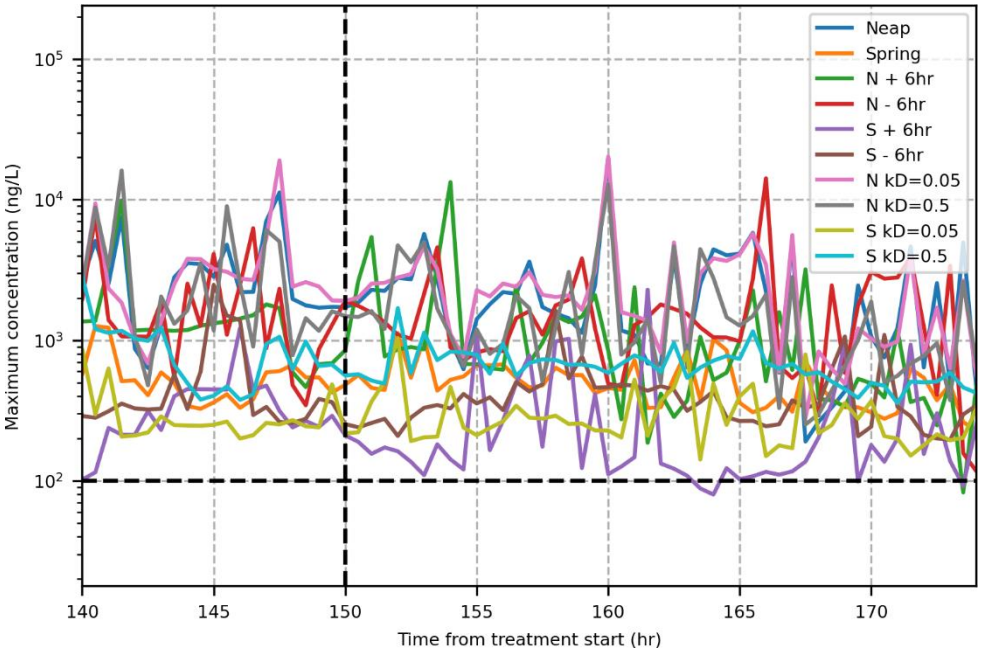


Figure 4.9 72 hr MAC; ensemble of individual pen releases (455.5 g/release). Maximum concentration anywhere within the domain. As previous figure but showing results from hours 140-174 only for closer inspection.

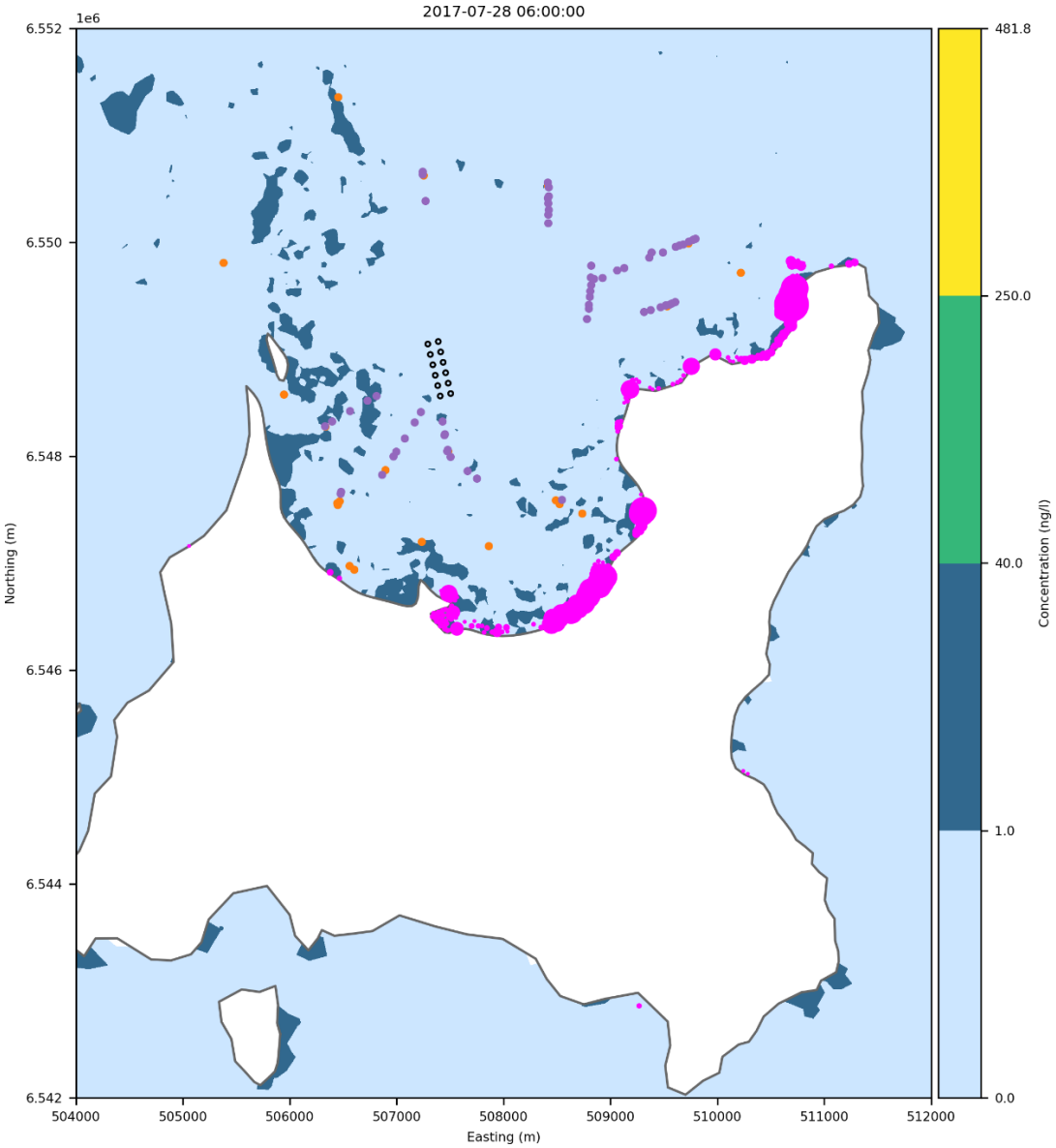


Figure 4.10 Baseline spring simulation predicted concentration at 72 hours after treatment is complete (455.5 g/pen release). Contours at EQS concentration thresholds, and a nominal 1 ng l^{-1}. Magenta points indicate location of MAC exceedances within 24 hr of the assessment time (72 hr after treatment completion) in ALL sensitivity runs.

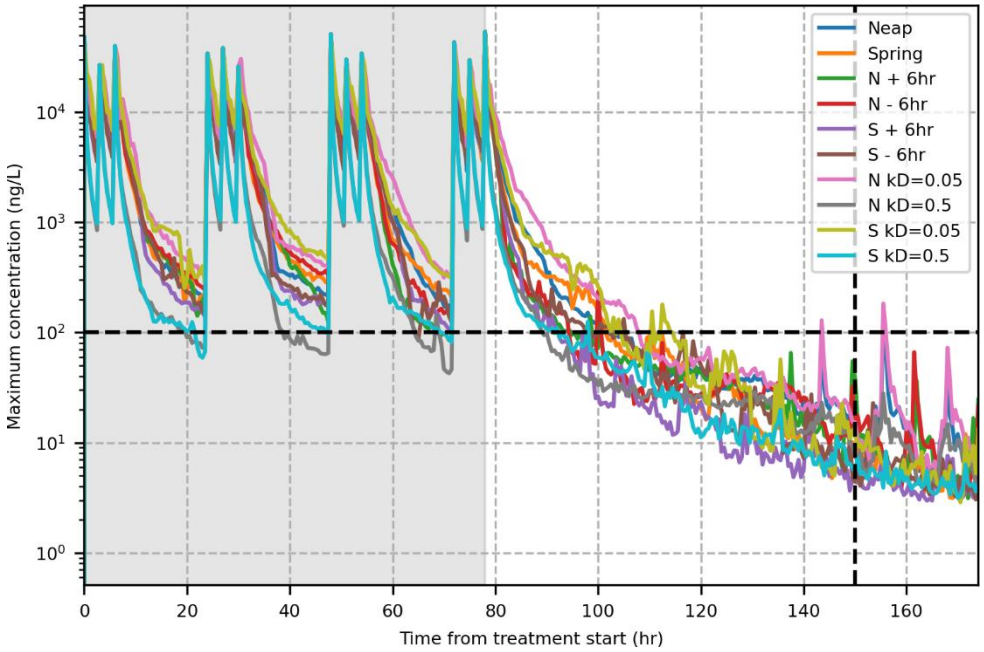


Figure 4.11 72 hr MAC; ensemble of individual pen releases (455.5 g/release). Maximum concentration anywhere within the domain, with coastal and shallow elements removed. Colours: blue = neap baseline, orange = spring baseline, green = neap+6hr, red = neap-6hr, purple = spring+6hr, brown = spring-6hr, pink = neap baseline with dispersion of 0.05 m^2s^{-1}, grey = neap 0.5 m^2s^{-1}, yellow = spring 0.05 m^2s^{-1}, blue = spring 0.5 m^2s^{-1}. Horizontal dashed line indicates the maximum allowable area, assessment time of 3 hr is indicated by vertical dashed line. Time is given relative to the time of pen release, to enable direct comparison of results.

4.1.5 Concentrations at sensitive feature locations

4.1.5.1 Database PMF locations

Figure 4.12 shows timeseries of concentration at the seabed (averaged over bottom 3 m of water column) at database PMF locations. Concentrations are generally well below EQS thresholds, with some peaks above the 72 hr EQS and MAC threshold in the neap tide simulation, and some isolated peaks over the 3 hr EQS threshold in the spring tide simulation.

Vertical transects of concentration at EQS times are shown in Appendix 7.4.1. At 3 hrs, concentration is non-zero at a single location in the neap tide simulation (although zero/near-zero at the bed), and is zero at all locations in the spring tide simulation. At 72 hrs, concentrations are non-zero at most locations, reaching a maximum of around 4 ng l^{-1} and 2 ng l^{-1} (at any depth) in the neap and spring tide simulations respectively.

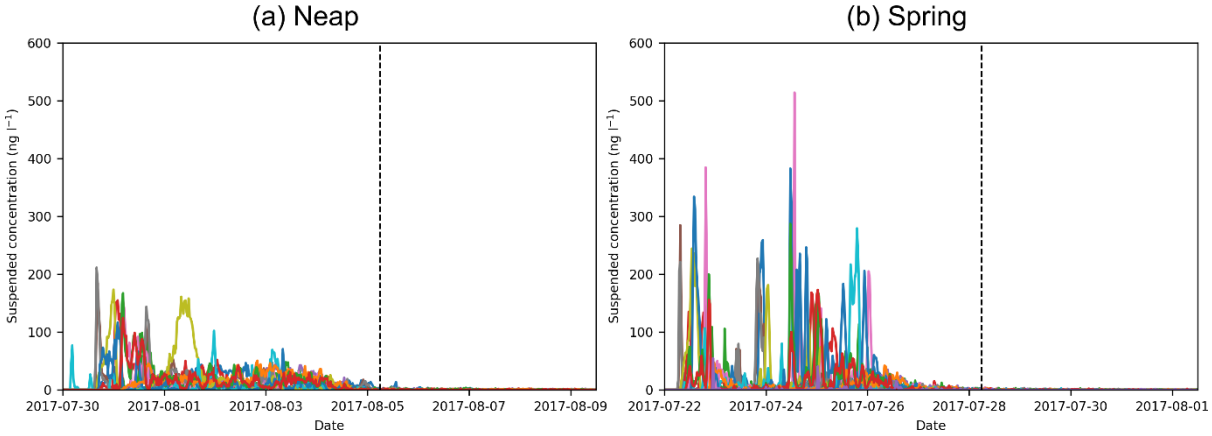


Figure 4.12 Predicted concentration of Azamethiphos at database PMF locations, averaged over bottom 3 m of the water column. (a) Baseline neap tide simulation, and (b) baseline spring tide simulation. Individual locations are not labelled here; a summary of concentration statistics is provided in Appendix 7.3.

4.1.5.2 Visual survey locations with >5% maerl coverage

Figure 4.13 shows timeseries of concentration at the seabed (averaged over bottom 3 m of water column) at visual survey locations with over 5% maerl coverage. In the neap tide simulation, concentrations are generally well below EQS thresholds, with several peaks above the 72 hr EQS and MAC thresholds. The spring tide simulation demonstrates somewhat higher levels with more sustained peaks than the other cases presented, although the concentrations are still generally low for most of the simulation.

Vertical transects of concentration at EQS times are shown in Appendix Section 0. At 3 hrs, concentration is non-zero at several locations in the neap tide simulation (although zero/near-zero at the bed in all cases), and is zero at all locations in the spring tide simulation. At 72 hrs, concentrations are non-zero at most locations, but reach a maximum of around 2 ng l^{-1} and 2.5 ng l^{-1} (at any depth) in the neap and spring tide simulations respectively.

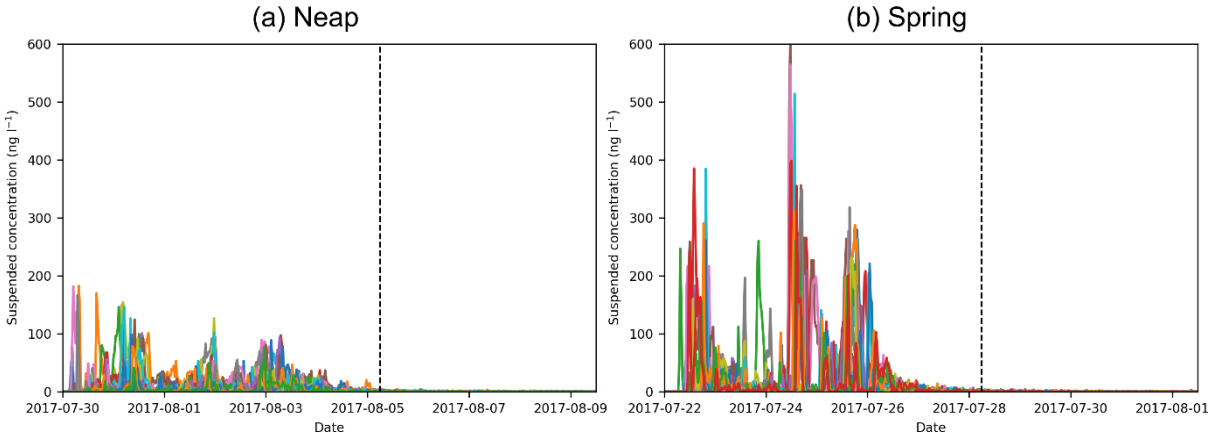


Figure 4.13 Predicted concentration of Azamethiphos at database PMF locations (averaged over bottom 3 m of the water column). (a) Baseline neap tide simulation, and (b) baseline spring tide simulation.

4.2 Deltamethrin

4.2.1 6 hr EQS

Compliance with the 6 hr EQS for baseline pen releases is assessed under neap and spring tidal conditions. As noted in Section 3.4.3, the **6 hr EQS threshold for area over 6 ng l^{-1} concentration, derived using BathAuto, was 0.537 km^2** (Appendix 7.1).

Simulations carried out using the Deltamethrin medicine mass arising from BathAuto passed the 6 hr EQS by a large margin and so medicine mass was increased in HD model driven simulations, to arrive at a mass of 55 g.

Figure 4.14 and Figure 4.15 shows predicted timeseries of area over the 6 hr EQS for all individual pens in the site (releases made on the same schedule as that used for Azamethiphos simulations), for neap and spring time simulations respectively. All individual pen releases pass the required EQS, being below the BathAuto area.

Figure 4.16 and Figure 4.17 show the predicted surface concentration of Deltamethrin for each individual pen release at 6 hrs after that release. Spread pattern varies greatly between pen releases, due to timing in relation to the state of the tide. In general, transport is initially to the SE and later E around the headland at the NE of Shapinsay island.

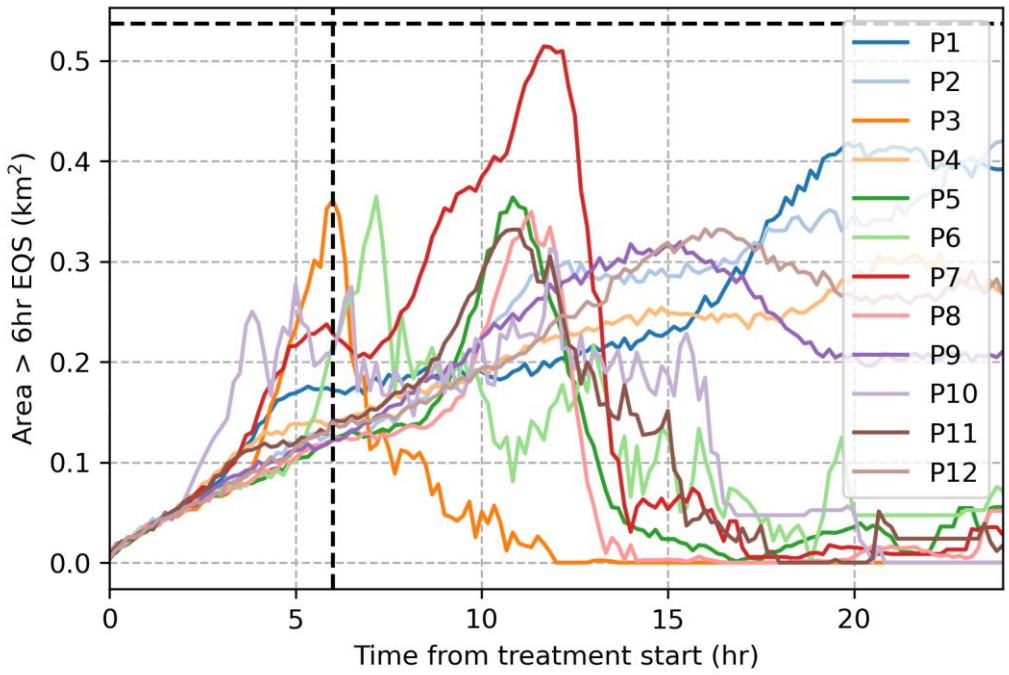


Figure 4.14 Individual pen releases of Deltamethrin (55 g/pen). Area above the 6 hr EQS concentration threshold (6 ng l^{-1}) for each pen under the baseline neap tide scenarios. Horizontal dotted line indicates the 6 hr ellipse area derived using BathAuto (defining the allowable EQS area). Time is given relative to the time of each pen release, to enable direct comparison of results.

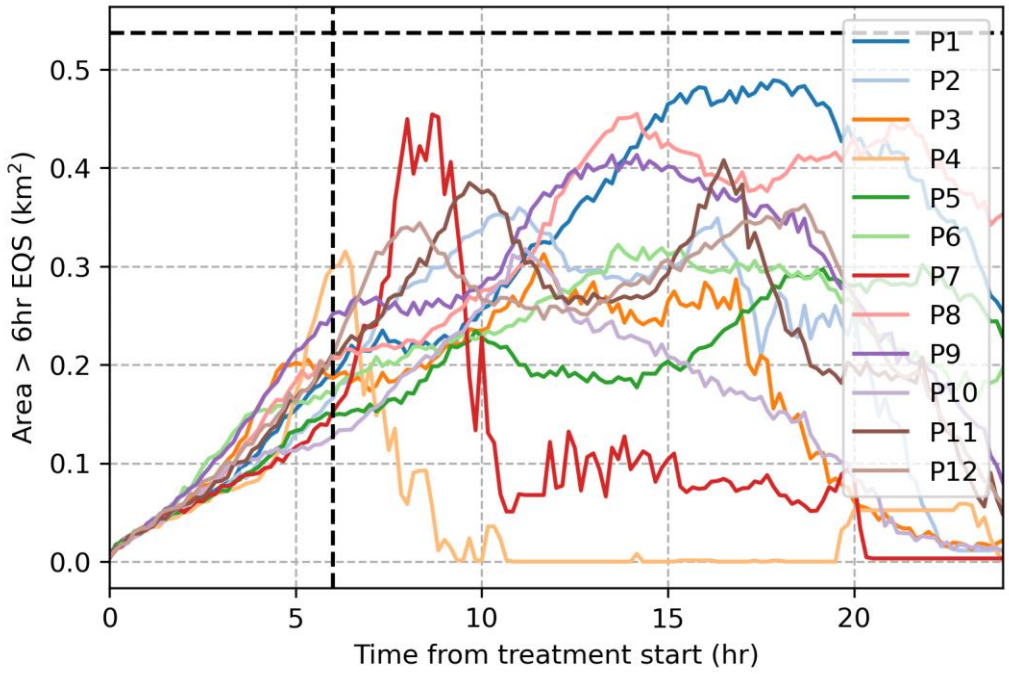


Figure 4.15 Individual pen releases of Deltamethrin (55 g/pen). Area above the 6 hr EQS concentration threshold (6 ng l^{-1}) for each pen under the baseline spring tide scenarios. Horizontal dotted line indicates the 6 hr ellipse area derived using BathAuto (defining the allowable EQS area). Time is given relative to the time of each pen release, to enable direct comparison of results.

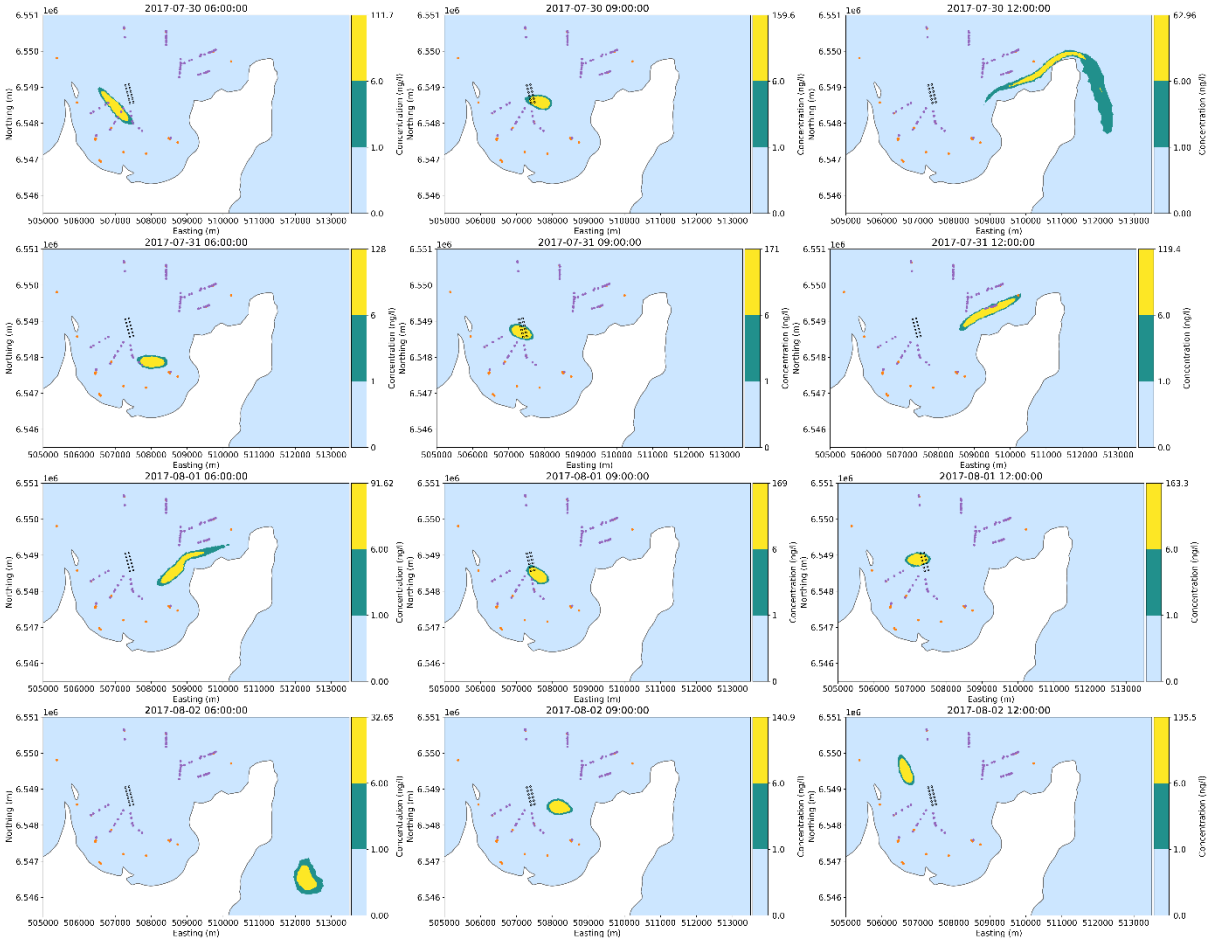


Figure 4.16 Predicted surface concentration of Deltamethrin at 6 hrs post release, for individual pen treatments 1-12 (neap tide conditions, plumes from each pen shown in isolation) at 55 g/pen. Contours are shown at EQS concentration thresholds, and at a nominal 1 ng/l.

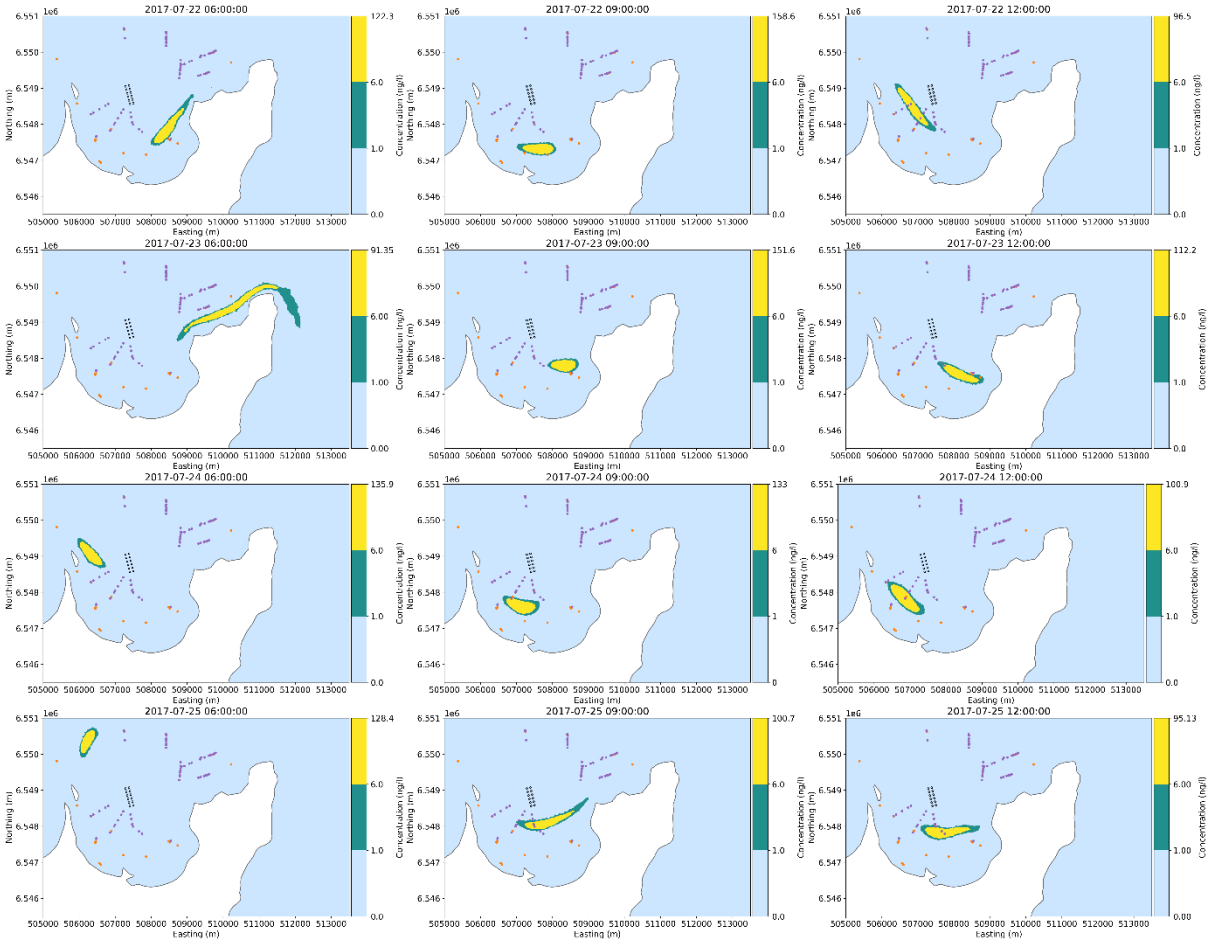


Figure 4.17 Predicted surface concentration of Deltamethrin at 6 hrs post release, for individual pen treatments 1-12 (spring tide conditions, plumes from each pen shown in isolation) at 55 g/pen. Contours are shown at EQS concentration thresholds, and at a nominal 1 ng/l.

4.2.2 Concentrations at sensitive feature locations

4.2.2.1 Database PMF locations

Timeseries of near-bed (averaged over the bottom 3 m of the water column) concentrations of Deltamethrin at PMF locations are shown in Figure 4.18 and Figure 4.19 for baseline neap and spring tide simulations respectively (individual pen releases shown by different lines). In general, concentration is zero at the EQS time, except for a small number of the PMF locations.

Vertical transects for those combinations of pen release and PMF location where a non-zero concentration was found anywhere in the water column at 6 hr after pen release are provided in Appendix Section 7.4.2.1.

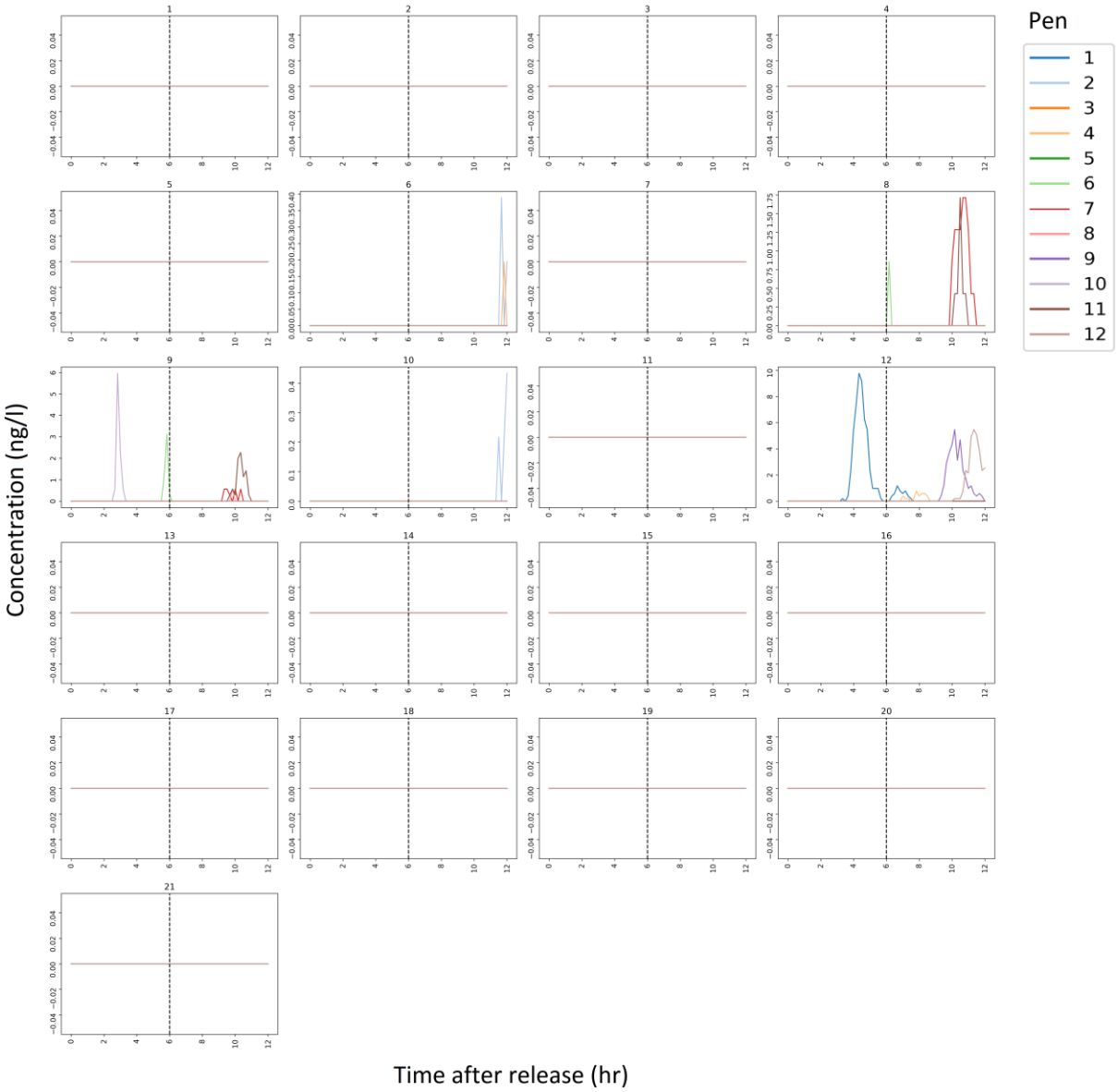


Figure 4.18 Predicted concentration of Deltamethrin at database PMF locations, averaged over bottom 3 m of the water column (baseline neap tide simulation).

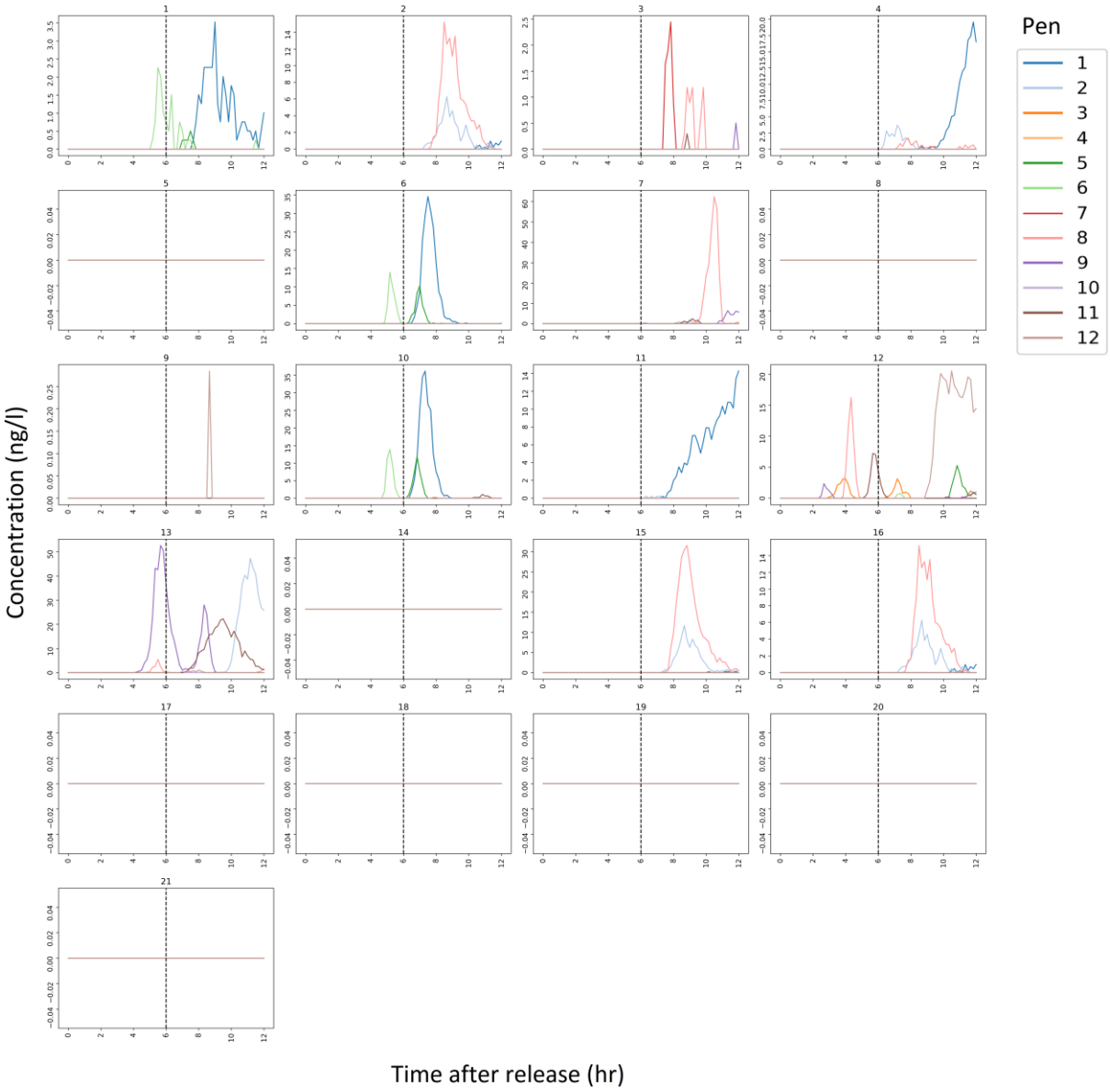


Figure 4.19 Predicted concentration of Deltamethrin at database PMF locations, averaged over bottom 3 m of the water column (baseline spring tide simulation).

4.2.2.2 Visual survey locations with >5% maerl coverage

Timeseries of near-bed (averaged over the bottom 3 m of the water column) concentrations of Deltamethrin at visual survey >5% maerl locations are shown in Figure 4.20 and Figure 4.21 for baseline neap and spring tide simulations respectively (individual pen releases shown by different lines). Again in general, concentration is zero at the EQS time, except for a small number of the locations.

Vertical transects for those combinations of pen release and location where a non-zero concentration was found anywhere in the water column at 6 hr after pen release are provided in Appendix Section 0.

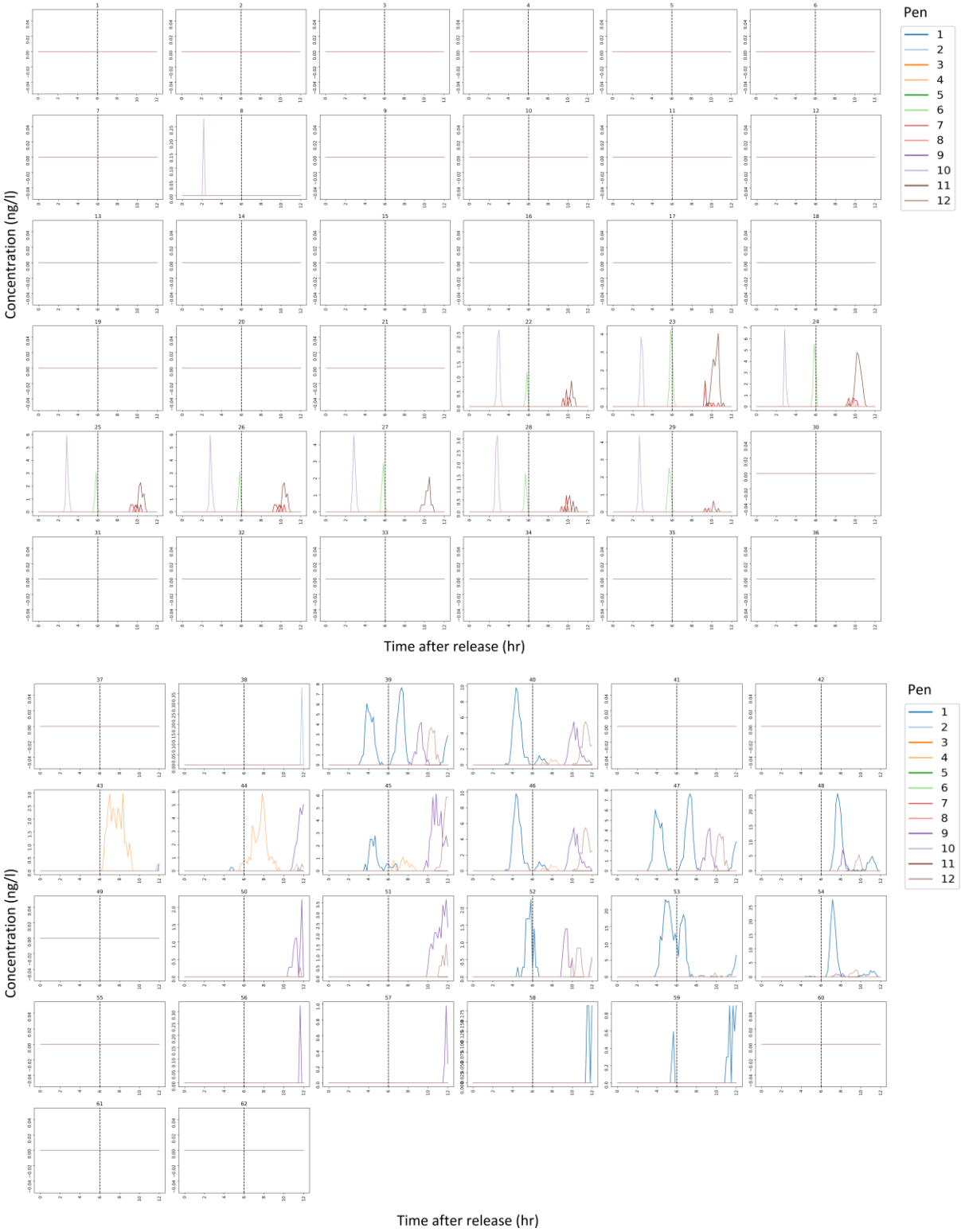


Figure 4.20 Predicted concentration of Deltamethrin at visual survey >5% maerl locations, averaged over bottom 3 m of the water column (baseline neap tide simulation).

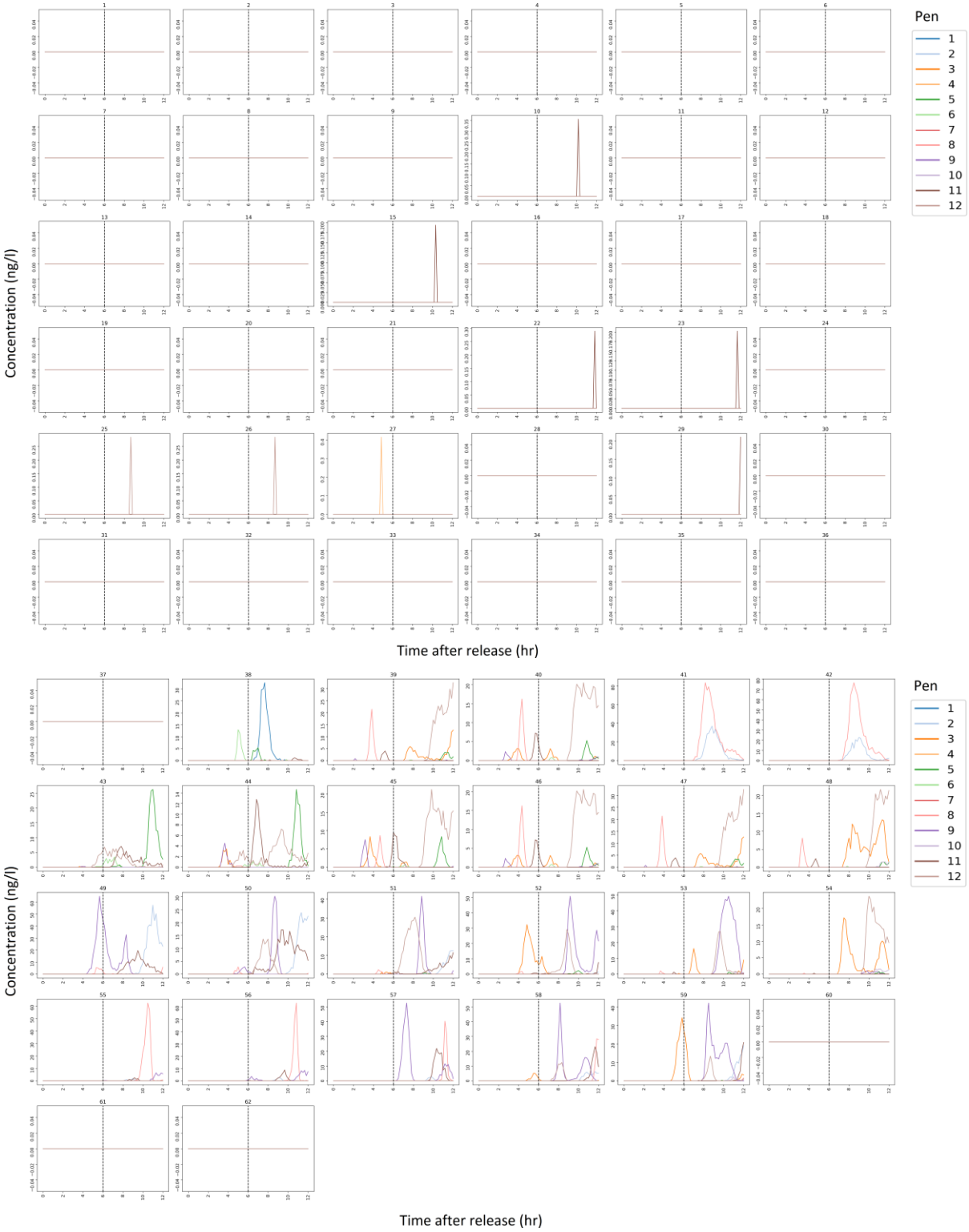


Figure 4.21 Predicted concentration of Deltamethrin at visual survey >5% maerl locations, averaged over bottom 3 m of the water column (baseline spring tide simulation).

5 Discussion and Conclusions

The location of the proposed expanded Veantrow Bay site is in an area of slightly higher flows in comparison with the existing site location. The dominant flow is towards the east, and most bath medicine is transported around the headland to the east and out of the bay. The currents predicted by the HD model corresponded well to observed current meter records (Danish Hydraulic Institute 2022).

EQS criteria were passed easily for both Azamethiphos and Deltamethrin.

Model artefacts leading to interaction with the coastline were noted, which due to the particle tracking algorithm lead to an exceedance of the Azamethiphos MAC criterion. Removing coastal locations from the analysis lead to all simulations having a maximum concentration around an order of magnitude below the MAC criterion.

A limited interaction with recorded PMFs (or locations with >5% maerl coverage identified during the visual survey conducted as part of this application) was predicted, thought concentrations were not particularly high in relation to EQS thresholds and were spikes rather than sustained concentrations. After completion of the treatment window, concentrations became close to zero fairly quickly.

Based on the results of this study, for Azamethiphos, a treatment limit of 455.5 g per treatment (3 hr limit) and 1366.5 g per day (24 hr limit) is recommended. For Deltamethrin, a limit of 55 g per treatment is recommended.

6 References

Anderson Marine Surveys (2022) NE Shapinsay, Orkney: Dye dispersion study.

Chen C, Beardsley RC, Cowles G (2013) An Unstructured Grid, Finite-Volume Coastal Ocean Model: FVCOM User Manual, 4th Edition.

Danish Hydraulic Institute (2017) MIKE 21 & 3 Flow Model FM Hydrodynamic and Transport Module Scientific Documentation.

Danish Hydraulic Institute (2021) MIKE 21 Flow Model FM - Particle Tracking Module User Guide.

Danish Hydraulic Institute (2022) North Orkney Aquaculture Modelling Hydrodynamic Climatology and Hindcast Models.

DHI (2015) Particle Tracking Module Scientific Documentation.

Scottish Environment Protection Agency (2023) Aquaculture Modelling Screening & Risk Identification Report: Shapinsay, Veantrow Bay (VEA1).

Scottish Environment Protection Agency (2024) Interim Marine Modelling Guidance for Aquaculture Applications.

Veterinary Medicines Directorate (2020) Summary of Product Characteristics: Salmosan Vet.

7 Appendices

7.1 BathAuto calculations

Input data

Distance to shore (km) :	1.70
Average water depth (m) :	19.18
# of cages :	12
Cage shape :	Round
Diameter/Width (m) :	44.6
Working depth (m) :	7.5
Stocking density (kg/m3) :	17.62
Mean current speed (m/s) :	0.120

Amamethiphos

Mixing Zone depth =	9.59	m			
cage depth =	2.92	m	stocking density =	17.62	kg/m^3
cage width =	44.56	m	shallowing proportion =	39%	
cage shape =	Round		cage biomass =	206t	
cage volume =	4554.38	m^3	treatable biomass =	206t	
treatment conc'n =	100,000	ng/l			
treatment mass =	0.4554	kg			
EQS conc'n =	250	ng/l	required dilutions =	400	

actual dilutions =	400

distance from cage to shore	diffusion coefficient	mean current speed	Mixing Zone ellipse semi-axis MAJOR	Mixing Zone ellipse semi-axis MINOR	time	Mixing Zone ellipse area	treatment volume	number of cages that can be treated	mean conc'n due to single treatment	permitted mass	peak conc'n due to single treatment	area where conc >EQS
[m]	[m^2/s]	[m/s]	[m]	[m]	[h]	[m^2]	[m^3]		[ng/l]	[g]	[ng/l]	[km^2]
1710	0.10	0.12	651	93	3.00h	190005	4555	1.0	249.9	455.54	416.6	0.095

Deltamethrin

Mixing Zone depth =	9.59	m			
cage depth =	3	m	stocking density =	17.62	kg/m^3
cage width =	44.56	m	shallowing proportion =	40%	
cage shape =	Round		cage biomass =	206t	
cage volume =	4679.16	m^3	treatable biomass =	681t	
treatment conc'n =	2,000	ng/l			
treatment mass =	0.0094	kg			
EQS conc'n =	6	ng/l	required dilutions =	333.3333	

actual dilutions =	1101

distance from cage to shore	diffusion coefficient	mean current speed	Mixing Zone ellipse semi-axis MAJOR	Mixing Zone ellipse semi-axis MINOR	time	Mixing Zone ellipse area	treatment volume	number of cages that can be treated	mean conc'n due to single treatment	permitted mass	peak conc'n due to single treatment	area where conc >EQS
[m]	[m^2/s]	[m/s]	[m]	[m]	[h]	[m^2]	[m^3]		[ng/l]	[g]	[ng/l]	[km^2]
1710	0.10	0.12	1301	131	6.00h	537414	15461	3.3	1.8	30.92	3.0	0.269

7.2 Visual survey PMF locations

Table T1: Locations identified during the visual seabed survey at which greater than 5% cover of maerl was identified.

Seabed Image ID	Transect ID	Easting	Northing	Depth (m)	Biotope Designation	Estimated Maerl Density (% cover)	Transect description, biota observed	SACFOR
HD-T300001	T3-1	508817	6549783	21	SS.SMx.CMx	5-19%	Sandy sediments with scattered deposits of shell debris and gravel. Small quantities of live and dead maerl observed amongst the gravel and shell debris. Gravelly sediment areas more extensive that those observed in Transect 2 with slightly higher proportions of maerl fragments present.	
HD-T300002	T3-2	508815	6549675	19	SS.SMx.CMx	5-19%	Coarser, shelly sediment types and areas of rocky seabed observed in shallower, southern part of transect.	
HD-T300003	T3-3	508816	6549604	19	SS.SMx.CMx	5-19%	Seaweed - primarily Laminaria spp. (including L. saccharina), abundance increasing in shallower waters to the south.	O-F
HD-T300004	T3-4	508808	6549546	19	SS.SMx.CMx	5-19%	Starfish (Asterias rubens)	R
HD-T300005	T3-5	508803	6549492	18	SS.SMx.CMx	5-19%	Urchins (Echinus esculentus)	R
HD-T300006	T3-6	508794	6549417	18	SS.SMx.CMx	5-19%		
HD-T300007	T3-7	508795	6549380	17	SS.SMx.CMx	5-19%		
HD-T300008	T3-8	508777	6549285	15	SS.SMp.KSwSS	5-19%		
HD-T400001	T4-1	509792	6550037	18	SS.SMp.Mrl.Pcal	>50%	Maerl bed habitat observed at the eastern end of transect gradually becoming more patchy and less dense to the west where higher proportions of gravelly and shelly sediments become more prevalent.	
HD-T400002	T4-2	509770	6550026	18	SS.SMp.Mrl.Pcal	>50%	High abundance of seaweed cover was observed along the entire transect - primarily Laminaria spp. (including L. saccharina).	C-F
HD-T400003	T4-3	509734	6550011	18	SS.SMp.Mrl.Pcal	>50%	Starfish (Asterias rubens and Luidia ciliaris)	R
HD-T400004	T4-4	509677	6549983	17	SS.SMp.Mrl.Pcal	>50%	Urchins (Echinus esculentus)	R-O
HD-T400006	T4-6	509645	6549974	16	SS.SMp.Mrl.Pcal	>50%	Brittle star (Amphipholis squamata) - R overall but C-A patches of at western end of transect.	R
HD-T400014	T4-14	509607	6549960	18	SS.SMp.Mrl.Pcal	>50%		
HD-T400013	T4-13	509487	6549908	18	SS.SMp.Mrl.Pcal	>50%		
HD-T400012	T4-12	509385	6549906	17	SS.SMp.Mrl.Pcal	20-49%		
HD-T400011	T4-11	509359	6549859	16	SS.SMp.Mrl.Pcal	20-49%		
HD-T400010	T4-10	509125	6549762	16	SS.SMp.Mrl.Pcal	20-49%		
HD-T400009	T4-9	509062	6549740	16	SS.SMp.KSwSS	5-19%		
HD-T400008	T4-8	508924	6549671	16	SS.SMp.KSwSS	5-19%		
HD-T400007	T4-7	508845	6549662	17	SS.SMp.KSwSS	5-19%		
HD-T500001	T5-1	509604	6549445	12	SS.SMp.KSwSS	5-19%	Mixed sandy sediments with patches of shell debris and gravel. Small quantities of live and dead maerl observed amongst the gravel and shell debris. Mearl density highest in eastern part of transect.	
HD-T500002	T5-2	509572	6549429	12	SS.SMp.KSwSS	5-19%	High abundance of seaweed cover was observed along the entire transect - primarily Laminaria spp. (including L. saccharina).	C-F

Seabed Image ID	Transect ID	Easting	Northing	Depth (m)	Biotope Designation	Estimated Maerl Density (% cover)	Transect description, biota observed	SACFOR
HD-T500003	T5-3	509554	6549421	12	SS.SMp.KSwSS	5-19%	Starfish (Asterias rubens)	R
HD-T500004	T5-4	509514	6549412	12	SS.SMp.KSwSS	5-19%	Urchins (Echinus esculentus)	R
HD-T500005	T5-5	509514	6549412	12	SS.SMp.KSwSS	5-19%		
HD-T500006	T5-6	509468	6549394	12	SS.SMp.KSwSS	5-19%		
HD-T500007	T5-7	509373	6549368	13	SS.SMp.KSwSS	5-19%		
HD-T500008	T5-8	509311	6549350	13	SS.SMp.KSwSS	5-19%		
HD-T600001	T6-1	508411	6550559	15	SS.SMp.Mrl.Pcal	>50%	Maerl bed habitat and gravelly, shelly sediments observed at the northern end of transect gradually becoming more patchy and less dense to the south where rippled fine sandy sediments become more prevalent with occasional patches of shell debris and gravel.	
HD-T600002	T6-2	508422	6550517	15	SS.SMp.Mrl.Pcal	>50%	High abundance of seaweed cover was observed along in the northern part of the transect decreasing in the south - primarily Laminaria spp. (including L. saccharina).	O-F
HD-T600003	T6-3	508420	6550432	16	SS.SMp.Mrl.Pcal	>50%	Starfish (Asterias rubens and Luidia ciliaris)	R
HD-T600004	T6-4	508411	6550414	17	SS.SMp.Mrl.Pcal	>50%	Urchins (Echinus esculentus)	R
HD-T600005	T6-5	508416	6550366	18	SS.SMp.Mrl.Pcal	>50%	Burrowing anemones observed in Mearl bed habitat in the north	P
HD-T600006	T6-6	508419	6550305	18	SS.SMp.Mrl.Pcal	20-49%		
HD-T600007	T6-7	508416	6550259	19	SS.SSa.CFiSa	5-19%		
HD-T600008	T6-8	508415	6550181	19	SS.SSa.CFiSa	5-19%		
HD-T7B-0007	T7B-7	508543	6547596	8.9	SS.SMp.KSwSS	5-19%	Mixed muddy sediments becoming more mixed in shallower water. Burrowed polychaetes. Patches of live and dead maerl fragments observed becoming denser/more frequent in the shallower water – in depths of approx. 9-12 m.	
HD-T8-0004	T8-4	507447	6548200	10.9	SS.SMp.KSwSS	5-19%	Urchins (Echinus esculentus)	R
HD-T8-0005	T8-5	507471	6548049	9.9	SS.SMp.KSwSS	5-19%		
HD-T9-0001	T9-1	506476	6547667	7.6	SS.SMp.Mrl.Pcal	>50%	High abundance of seaweed cover was observed along the entire transect – primarily bootlace weed (Chorda filum) and Laminaria spp. (including L. saccharina).	
HD-T9-0002	T9-2	506473	6547653	7.4	SS.SMp.Mrl.Pcal	>50%	Based on limited observations of seabed beneath seaweed cover, substrate is mixed sediment containing live and dead maerl and shell debris.	
153011_1	C07-3	507748	6547792	12	SS.SMp.KSwSS	5-19%	Urchins (Echinus esculentus)	P
153542_1	C07-4	507661	6547863	10	SS.SMp.KSwSS	5-19%		
154412_1	C07-5	507501	6547995	7	SS.SMp.KSwSS	5-19%		
155128_1	C08-1	507477	6548061	7	SS.SMp.KSwSS	5-19%	Mixed muddy sediments. High seaweed/algae coverage – including Laminaria spp. Some dense patches of maerl recorded in southern part of transect becoming more scattered in the north.	
155715_1	C08-2	507450	6548208	8	SS.SMp.KSwSS	5-19%	Starfish (Asterias rubens)	P
160222_1	C08-3	507428	6548328	10	SS.SMp.KSwSS	5-19%	Urchins (Echinus esculentus)	P
135236_1	C09-1	506861	6547828	4	SS.SMp.Mrl.Pcal	>50%	High abundance of seaweed cover was observed in water depths of less than approx. 10 m – primarily bootlace	

Seabed Image ID	Transect ID	Easting	Northing	Depth (m)	Biotope Designation	Estimated Maerl Density (% cover)	Transect description, biota observed	SACFOR
							weed (Chorda filum) and Laminaria spp.	
140400_1	C09-2	506969	6547998	4	SS.SMp.Mrl.Pcal	>50%	Seabed beneath seaweed cover, primarily composed of live maerl in shallow waters gradually becoming less dense as depth increased.	
140653_1	C09-3	506996	6548044	4	SS.SMp.Mrl.Pcal	>50%	Mixed muddy sediments with scattering of maerl recorded in deeper waters in the east of the transect.	
141422_1	C09-4	507073	6548166	5	SS.SMp.Mrl.Pcal	>50%		
142223_1	C09-5	507166	6548316	8	SS.SMp.Mrl.Pcal	>50%		
142745_1	C09-6	507226	6548416	12	SS.Sa.CMuSa	5-19%		
125154_1	C10-1	506326	6548284	4	SS.SMp.Mrl.Pcal	>50%	High abundance of seaweed cover was observed in water depths of less than approx. 10 m – primarily bootlace weed (Chorda filum) and Laminaria spp.	
125747_1	C10-2	506393	6548326	4	SS.SMp.Mrl.Pcal	>50%	Seabed beneath seaweed cover, primarily composed of live maerl in shallow waters gradually becoming less dense as depth increased.	
130805_1	C10-3	506561	6548422	5	SS.SMp.Mrl.Pcal	>50%	Mixed muddy sediments with scattering of maerl recorded in deeper waters in the east of the transect.	
131828_1	C10-4	506727	6548519	8	SS.SMp.Mrl.Pcal	>50%		
132357_1	C10-5	506809	6548566	12	SS.Sa.CMuSa	5-19%		
173840_1	C11-3	507268	6550388	17	SS.SSa.CFiSa	5-19%	Fine sandy sediments becoming more mixed as water depth decreased to the north with occasional patches of shell debris and gravel. Maerl more frequent at the as water depth decreases becoming dense at the northern end of the transect.	
174828_1	C11-4	507243	6550636	14	SS.SSa.CFiSa	>50%		
175032_1	C11-5	507240	6550662	14	SS.SSa.CFiSa	>50%		

7.3 PMF and sensitive feature near bed concentration statistics

7.3.1 PMF locations, neap simulation

ID	Easting	Northing	Suspended average (g m^{-2})	Suspended maximum (g m^{-2})	Suspended % non-zero	Suspended % over 40 ng
1	508735	6547467	6.54	64.25	54.8	2
2	506448	6547546	8.37	120.41	53.6	4.4
3	505942	6548578	4.14	93.33	40.7	2
4	507231	6547202	7.16	149.73	51	3.8
5	506559	6546976	7.8	45.35	63.3	1.2
6	508521	6547556	7.02	178.63	52.2	2.8
7	506332	6548280	6.16	149.62	43.5	3.8
8	510219	6549716	0.59	19.23	16.3	0
9	509530	6549406	0.78	15.85	25.4	0
10	508488	6547588	6.98	204.58	52.4	2.4
11	507859	6547160	11.54	167.72	53	8.3
12	507480	6548048	4.11	98.79	40.9	3.2
13	506893	6547874	5.55	112.69	50.2	4.2
14	506600	6546939	8.44	48.73	64.3	2.2
15	506463	6547580	8.72	161.78	54.4	4.6
16	506443	6547563	8.37	120.41	53.6	4.4
17	507251	6550627	0.2	10.15	7.3	0
18	508412	6550536	0.28	8.34	13.5	0
19	509726	6549990	0.28	21.36	11.7	0
20	505380	6549808	0.39	20.61	11.9	0
21	506450	6551358	0.21	11.43	8.5	0

7.3.2 PMF locations, spring simulation

ID	Easting	Northing	Suspended average (g m^{-2})	Suspended maximum (g m^{-2})	Suspended % non-zero	Suspended % over 40 ng
1	508735	6547467	5.81	250.68	40.3	1.2
2	506448	6547546	7.58	167.33	44	4.8
3	505942	6548578	5.44	180.48	37.3	3.4
4	507231	6547202	7.33	162.92	41.7	5.4
5	506559	6546976	3.92	42.55	51	0.2
6	508521	6547556	5.93	275.58	43.3	3
7	506332	6548280	9.34	497.59	44.6	5.6
8	510219	6549716	0.31	12.92	9.3	0
9	509530	6549406	0.62	23.49	15.5	0
10	508488	6547588	6.11	219.79	44	2.8
11	507859	6547160	8.56	236.31	40.7	5.4
12	507480	6548048	6.56	270.32	43.8	3
13	506893	6547874	14.43	370.44	41.9	9.1
14	506600	6546939	3.93	51.81	49.2	0.8
15	506463	6547580	9.09	277.85	40.7	6
16	506443	6547563	7.58	167.33	44	4.8
17	507251	6550627	0.14	5.6	5.6	0
18	508412	6550536	0.07	4.31	4.8	0
19	509726	6549990	0.1	6.61	6.7	0
20	505380	6549808	0.43	52.78	8.3	0.2
21	506450	6551358	0.22	19.78	6.7	0

7.3.3 Visual survey locations, neap simulation

ID	Easting	Northing	Suspended average (g m^{-2})	Suspended maximum (g m^{-2})	Suspended % non-zero	Suspended % over 40 ng
14	508817	6549783	0.24	6.01	11.3	0
15	508815	6549675	0.34	18.03	15.5	0
16	508816	6549604	0.29	9.16	17.9	0
17	508808	6549546	0.33	15.8	13.7	0
18	508803	6549492	0.26	10.63	13.1	0
19	508794	6549417	0.33	12.05	18.1	0
20	508795	6549380	0.31	11.3	18.3	0
21	508777	6549285	0.43	11.48	18.3	0
28	509792	6550037	0.26	15.8	9.9	0
29	509770	6550026	0.27	26.58	9.3	0
30	509734	6550011	0.28	21.36	11.7	0
31	509677	6549983	0.23	11.8	12.9	0
32	509645	6549974	0.27	14.43	13.9	0
33	509607	6549960	0.26	13.77	13.1	0
34	509487	6549908	0.24	8.19	14.9	0

ID	Easting	Northing	Suspended average (g m^{-2})	Suspended maximum (g m^{-2})	Suspended % non-zero	Suspended % over 40 ng
35	509385	6549906	0.28	11.93	12.7	0
36	509359	6549859	0.27	8.75	9.3	0
37	509125	6549762	0.3	9.79	18.8	0
38	509062	6549740	0.33	21.59	11.9	0
39	508924	6549671	0.32	9.71	14.3	0
40	508845	6549662	0.32	15.67	11.9	0
41	509604	6549445	0.76	20.93	23.4	0
42	509572	6549429	1.03	24.77	29.4	0
43	509554	6549421	1.01	51.47	26.6	0.2
44	509514	6549412	0.78	15.85	25.4	0
45	509514	6549412	0.78	15.85	25.4	0
46	509468	6549394	0.79	26.4	17.9	0
47	509373	6549368	0.63	15.15	27.2	0
48	509311	6549350	0.62	12.76	25.8	0
54	508411	6550559	0.28	8.48	15.9	0
55	508422	6550517	0.28	8.34	13.5	0
56	508420	6550432	0.27	14.48	10.5	0
57	508411	6550414	0.19	6.94	10.3	0
58	508416	6550366	0.18	14.67	7.9	0
59	508419	6550305	0.23	18.4	9.9	0
60	508416	6550259	0.24	5.92	9.7	0
61	508415	6550181	0.18	5.96	10.9	0
75	508543	6547596	7.04	164.51	47.2	2.6
83	507447	6548200	2.6	85.86	33.9	1.2
84	507471	6548049	4.11	98.79	40.9	3.2
85	506476	6547667	7.23	110.06	47.6	2.6
86	506473	6547653	7.69	144.83	44.4	3.6
111	507748	6547792	5.86	86.51	44.8	4.4
112	507661	6547863	6.19	91.94	44.6	6
113	507501	6547995	4.47	122.46	44.8	2.8
114	507477	6548061	4.11	98.79	40.9	3.2
115	507450	6548208	2.6	85.86	33.9	1.2
116	507428	6548328	2.03	176.89	24.8	0.4
118	506861	6547828	5.75	141.5	40.5	3.8
119	506969	6547998	4.57	94.15	43.8	2.2
120	506996	6548044	4.65	91.05	45	2.2
121	507073	6548166	3.75	78.11	44	1.8
122	507166	6548316	3.35	175.91	30.6	1.8
123	507226	6548416	1.87	161.3	28.8	0.8
125	506326	6548284	6.16	149.62	43.5	3.8
126	506393	6548326	5.13	142.14	42.5	2.8
127	506561	6548422	3.62	95.38	39.7	1.4
128	506727	6548519	3.04	75.77	43.8	1.6
129	506809	6548566	2.4	71.89	31	0.8
133	507268	6550388	0.2	4.22	12.1	0
134	507243	6550636	0.27	9.13	13.9	0
135	507240	6550662	0.17	4.37	11.1	0

7.3.4 Visual survey locations, spring simulation

ID	Easting	Northing	Suspended average (g m^{-2})	Suspended maximum (g m^{-2})	Suspended % non-zero	Suspended % over 40 ng
14	508817	6549783	0.12	22.6	5	0
15	508815	6549675	0.07	3.76	4.4	0
16	508816	6549604	0.16	21.46	9.1	0
17	508808	6549546	0.16	12.45	6	0
18	508803	6549492	0.14	5.8	6.7	0
19	508794	6549417	0.23	17.4	9.1	0
20	508795	6549380	0.25	14.63	11.3	0
21	508777	6549285	0.37	15.7	10.5	0
28	509792	6550037	0.1	5.95	5.8	0
29	509770	6550026	0.08	4.75	3.6	0
30	509734	6550011	0.1	6.61	6.7	0
31	509677	6549983	0.11	4.3	7.9	0
32	509645	6549974	0.1	10.04	6.5	0
33	509607	6549960	0.1	7.61	6.9	0
34	509487	6549908	0.09	8.29	7.3	0
35	509385	6549906	0.1	10.51	3.8	0
36	509359	6549859	0.13	19.76	3.8	0
37	509125	6549762	0.11	6.68	7.5	0
38	509062	6549740	0.11	4.74	4.6	0
39	508924	6549671	0.09	3.8	5.2	0

ID	Easting	Northing	Suspended average (g m^{-2})	Suspended maximum (g m^{-2})	Suspended % non-zero	Suspended % over 40 ng
40	508845	6549662	0.14	7.61	6.9	0
41	509604	6549445	0.56	19.76	17.3	0
42	509572	6549429	0.64	31.85	19	0
43	509554	6549421	0.64	40.39	15.3	0.2
44	509514	6549412	0.62	23.49	15.5	0
45	509514	6549412	0.62	23.49	15.5	0
46	509468	6549394	0.61	28.37	12.5	0
47	509373	6549368	0.49	29.97	15.5	0
48	509311	6549350	0.59	40.93	17.9	0.2
54	508411	6550559	0.06	2.72	5.4	0
55	508422	6550517	0.07	4.31	4.8	0
56	508420	6550432	0.1	5.45	5	0
57	508411	6550414	0.09	3.41	6.2	0
58	508416	6550366	0.09	4.16	5.4	0
59	508419	6550305	0.08	4.16	4	0
60	508416	6550259	0.12	8.31	5	0
61	508415	6550181	0.1	6.96	5.8	0
75	508543	6547596	6.1	251.85	34.9	2.8
83	507447	6548200	6.26	278.19	38.5	2.6
84	507471	6548049	6.56	270.32	43.8	3
85	506476	6547667	15.15	591.18	42.5	9.5
86	506473	6547653	13.35	546.14	38.5	8.1
111	507748	6547792	5.58	190.21	36.5	5
112	507661	6547863	5.27	160.01	41.3	3.6
113	507501	6547995	6.59	253.81	40.1	4
114	507477	6548061	6.56	270.32	43.8	3
115	507450	6548208	6.26	278.19	38.5	2.6
116	507428	6548328	4.37	212.05	31.2	3
118	506861	6547828	14.38	385.44	34.1	8.9
119	506969	6547998	11.36	243.71	40.9	7.5
120	506996	6548044	11.78	344.82	39.1	7.7
121	507073	6548166	8.43	268.44	38.5	5.2
122	507166	6548316	7.95	337.28	33.3	4.2
123	507226	6548416	5.26	224.41	38.1	3
125	506326	6548284	9.34	497.59	44.6	5.6
126	506393	6548326	8.17	253.03	39.3	5
127	506561	6548422	8.64	302.51	43.5	5
128	506727	6548519	9.02	252.62	48.6	6.2
129	506809	6548566	9.28	343.56	37.9	6.7
133	507268	6550388	0.23	6.82	9.5	0
134	507243	6550636	0.1	5.21	5.6	0
135	507240	6550662	0.11	10.88	6.7	0

7.4 Vertical transects

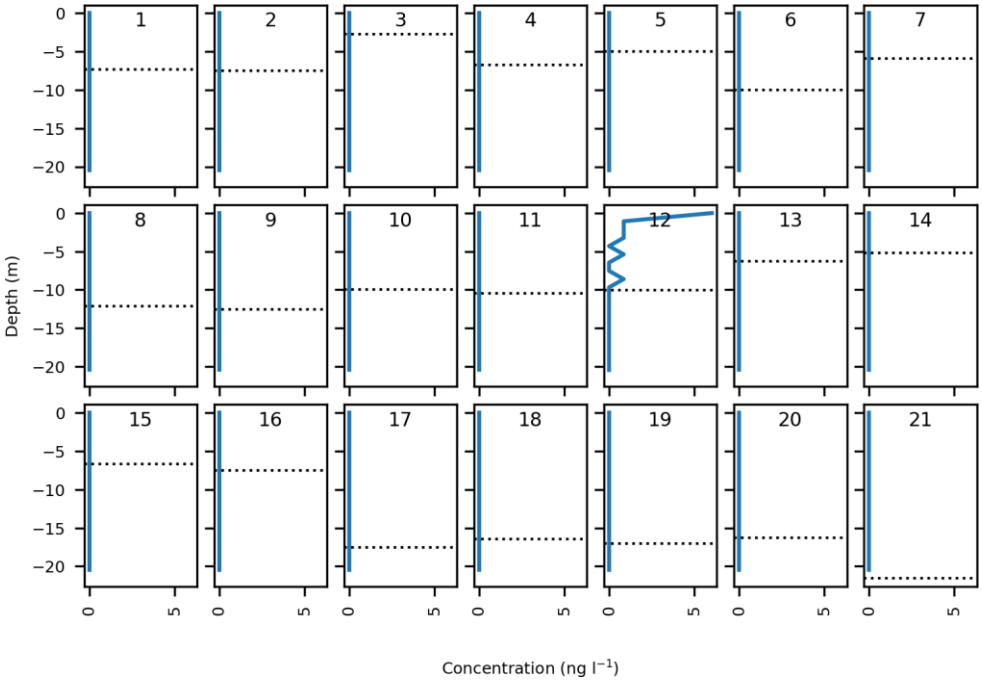
Concentrations are provided for each numbers database or visual survey location. Horizontal dotted line indicates the depth of the seabed at the node closest to the location of the PMF. In some cases this may be slightly shallower than the deepest bin on the vertical transect, which is computed by identifying all particles within +/- 50 m in x and y coordinates from the focal location.

7.4.1 Azamethiphos

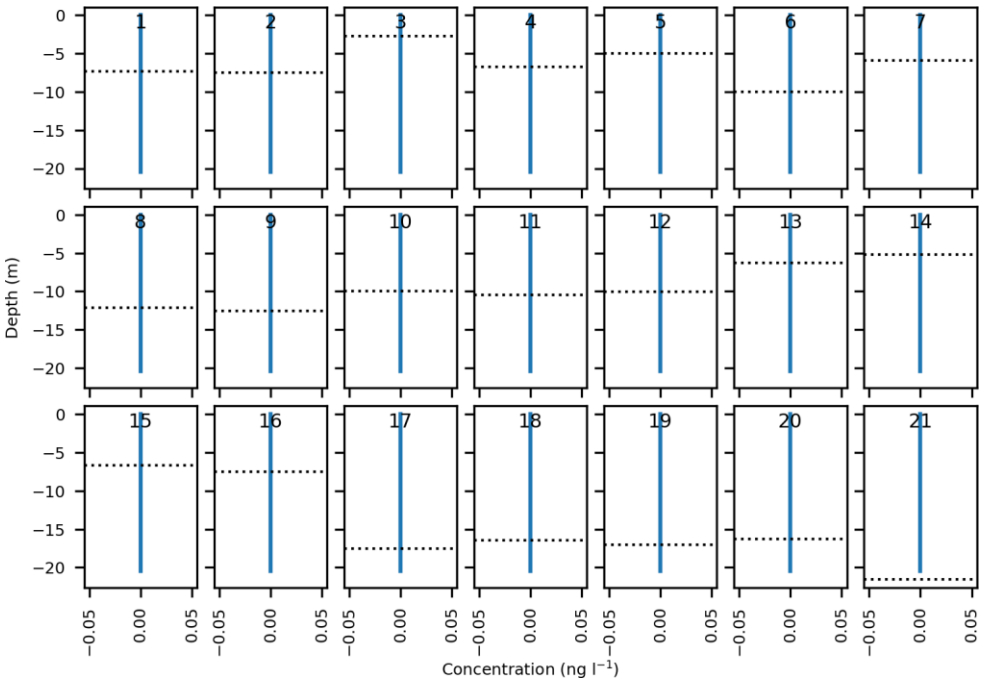
7.4.1.1 Database PMF locations

3 hr EQS time

Neap baseline simulation

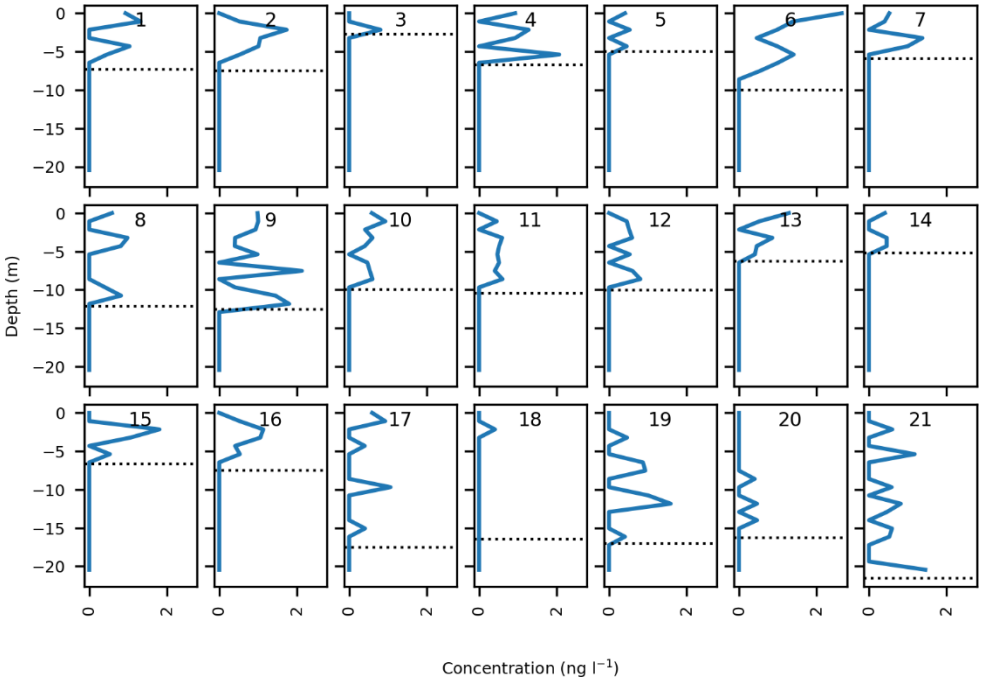


Spring baseline simulation

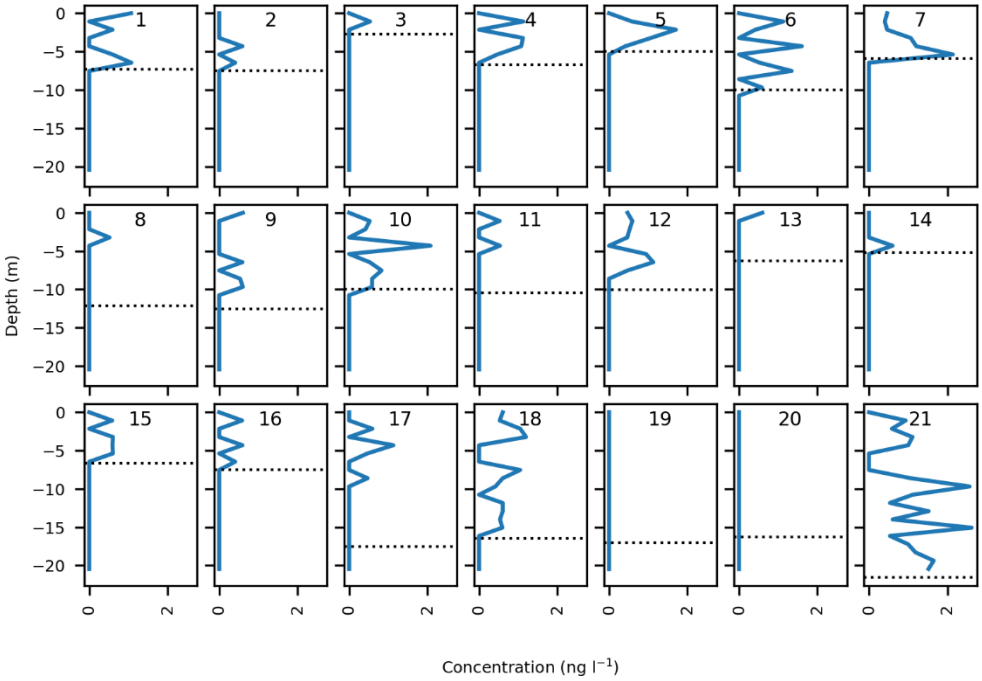


72 hr EQS time

Neap baseline simulation



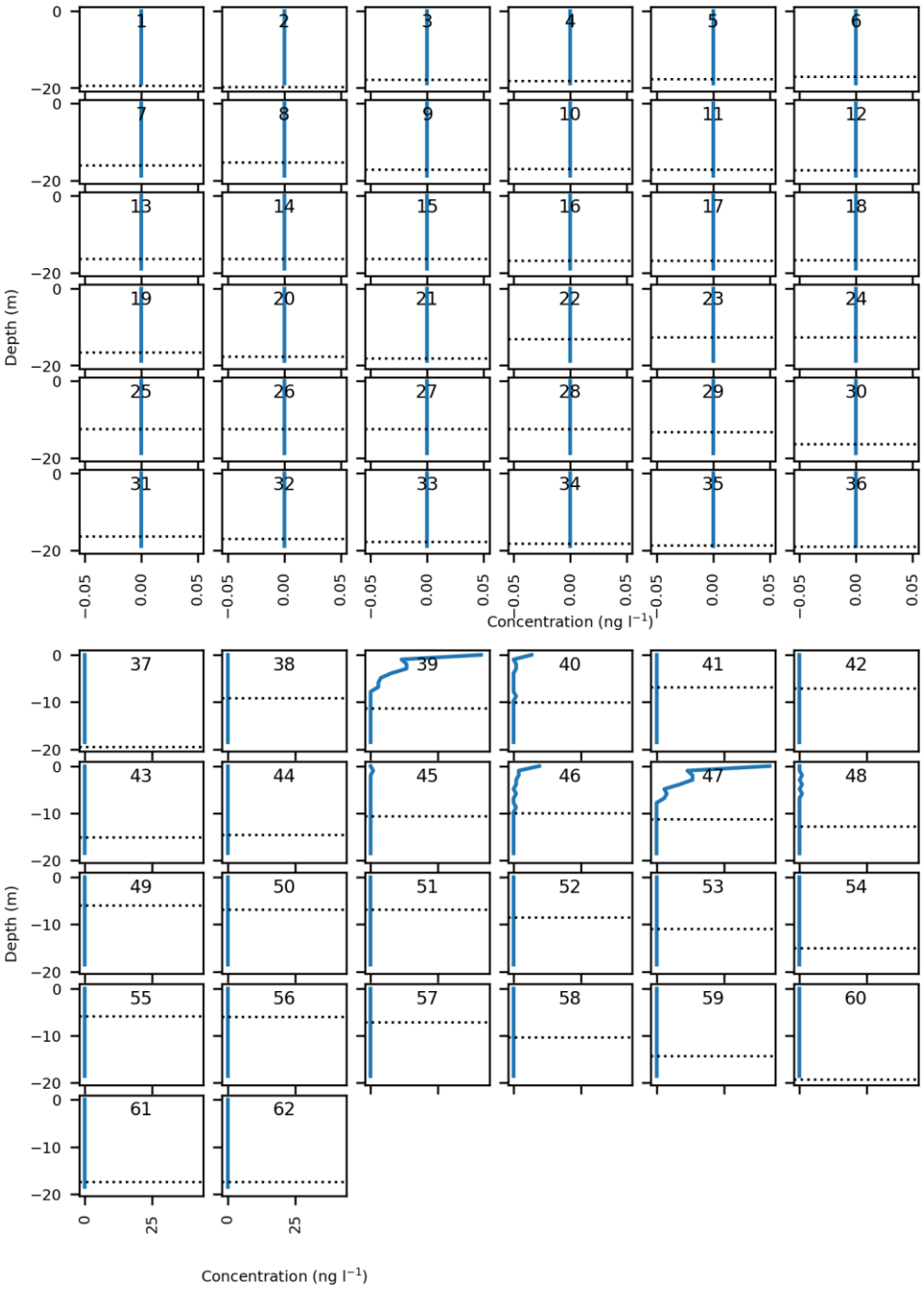
Spring baseline simulation



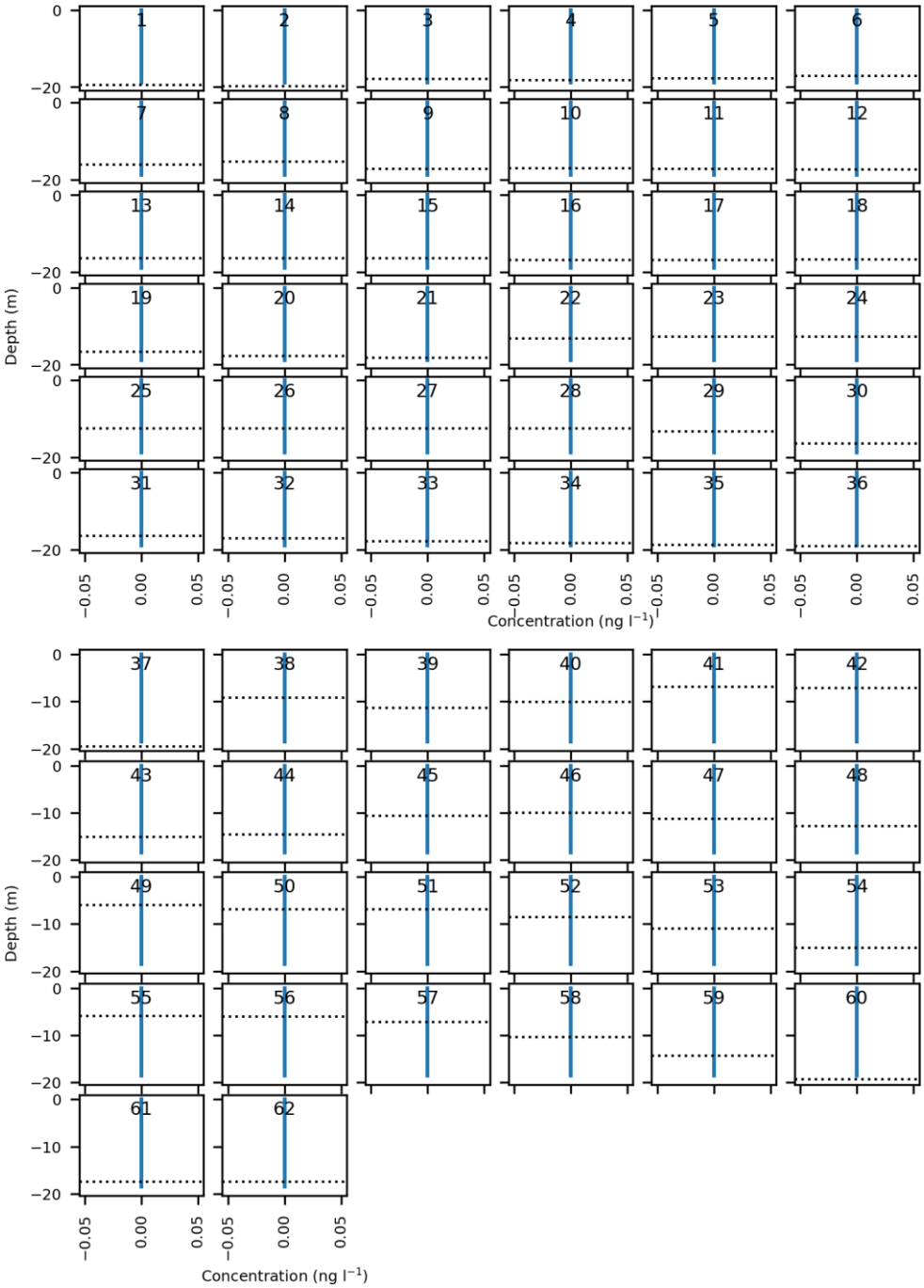
7.4.1.2 Visual survey locations with >5% maerl coverage

3 hr EQS time

Neap baseline simulation

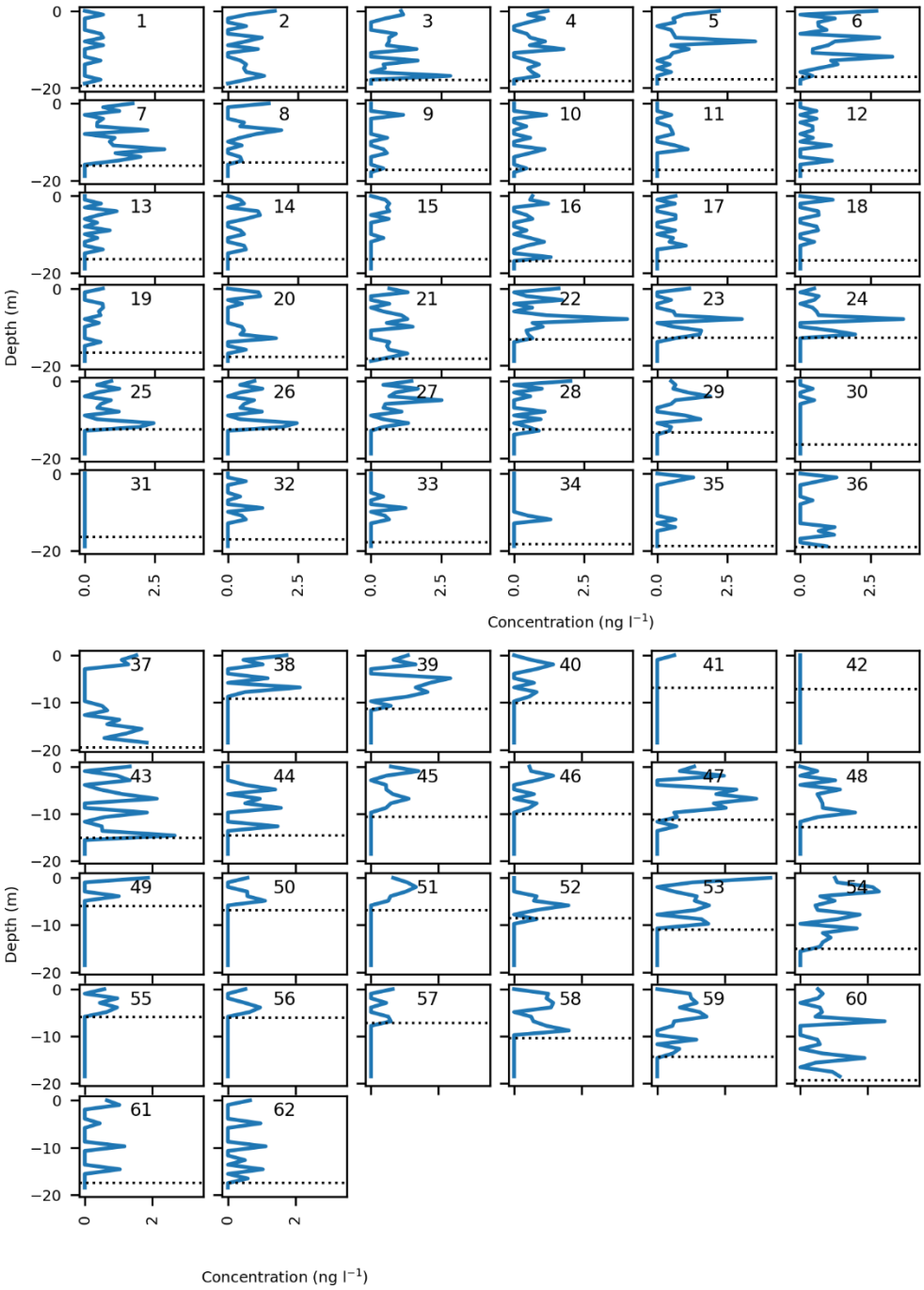


Spring baseline simulation

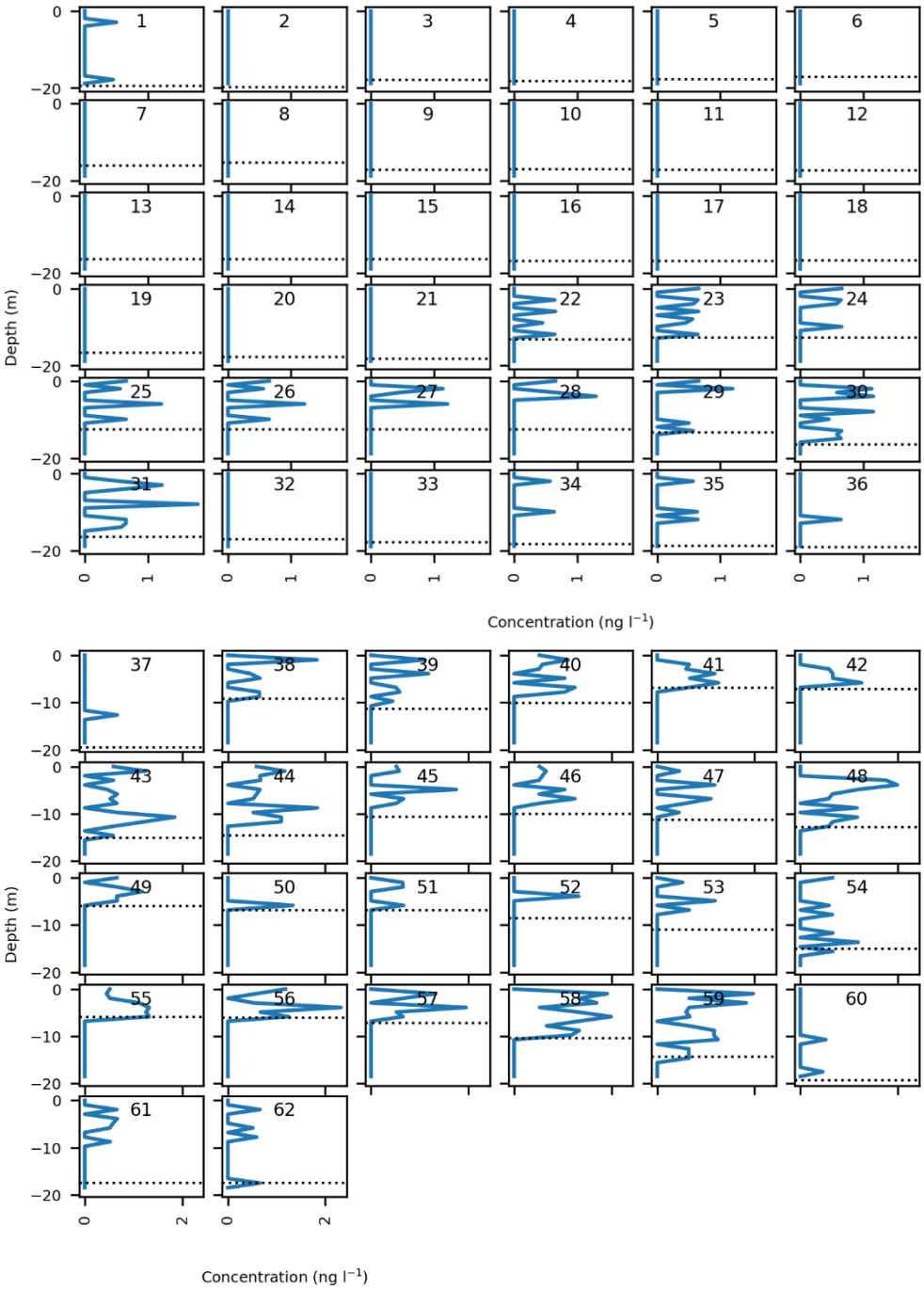


72 hr EQS time

Neap baseline simulation



Spring baseline simulation



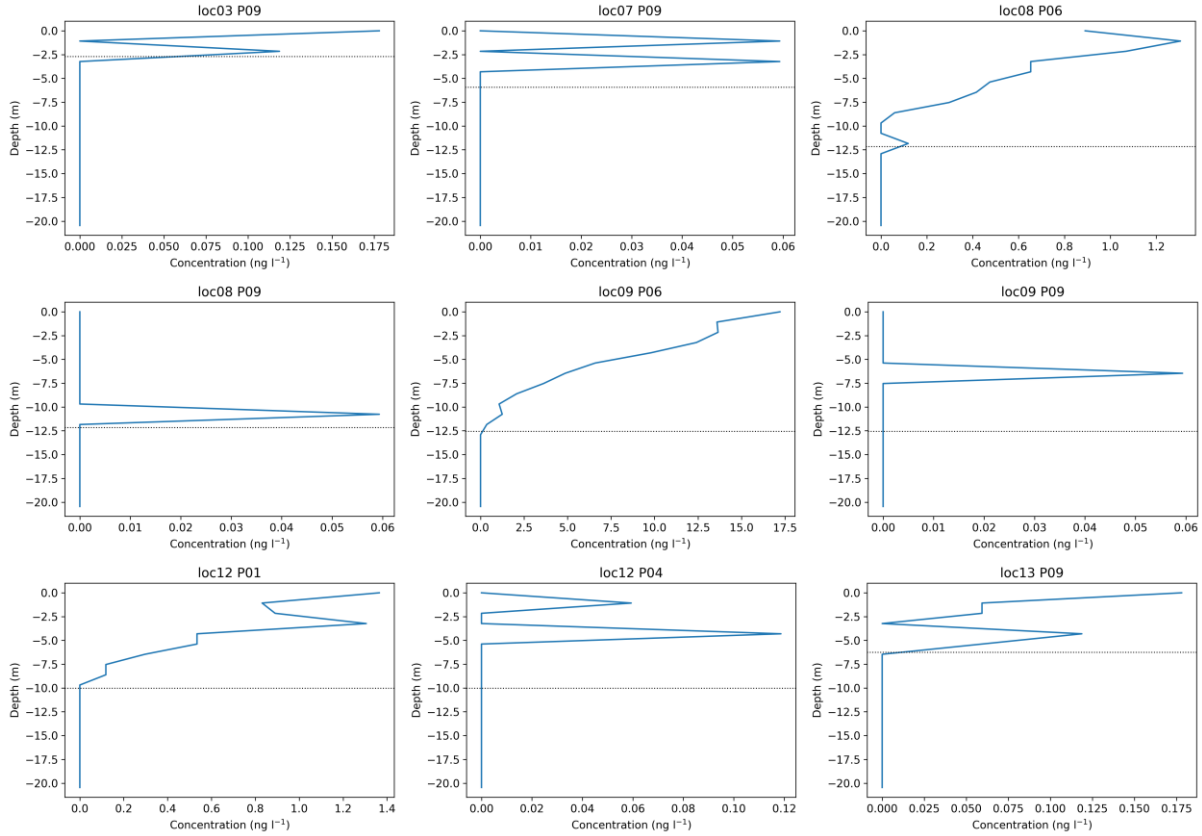
7.4.2 Deltamethrin

Plots of vertical transects in this section are provided for 6 hr after the release time for all individual pen releases that caused a non-zero concentration of bath medicine at the 6 hr time point. Concentration of bath medicine was zero at this time for all other combinations of pen release and PMF location.

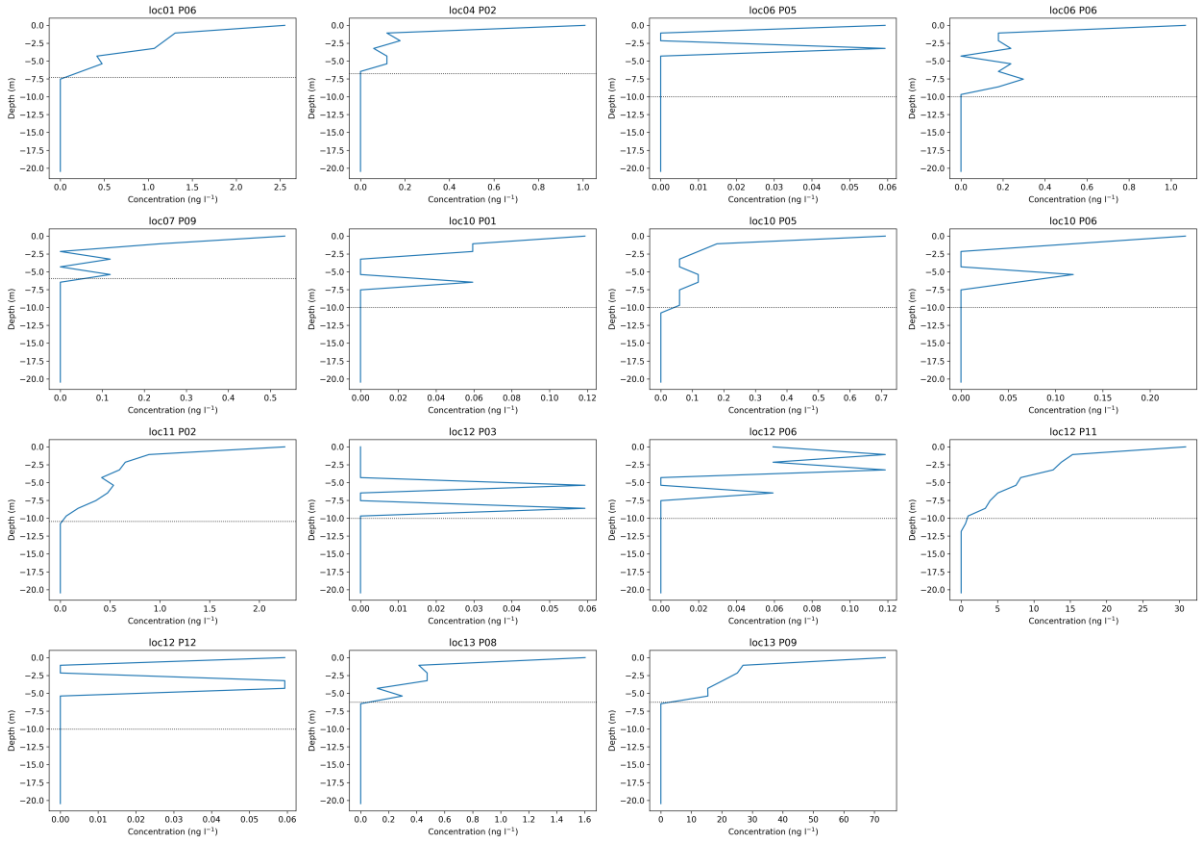
Horizontal dotted line indicates the depth of the seabed at the node closest to the location of the PMF. In some cases this may be slightly shallower than the deepest bin on the vertical transect, which is computed by identifying all particles within +/- 50 m in x and y coordinates from the focal location.

7.4.2.1 Database PMF locations

Neap baseline simulation



Spring baseline simulation



7.4.2.2 Visual survey locations >5% maerl coverage

Neap baseline simulation

Spring baseline simulation