Azamethiphos Dispersion Modelling
Scalpay, Inner Sound
CAR/L/1156482

Mowi Scotland Limited

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EXECUTIVE SUMMARY

Dispersion model simulations have been performed to assess whether bath treatments at Scalpay salmon farm will comply with pertinent environmental quality standards. A realistic treatment regime, with 2 pen treatments per day was simulated. Each pen required 458 g of azamethiphos (the active ingredient in Salmosan, Salmosan Vet and Azure) for treatment, resulting in a daily release of 916 g and a total discharge over 5 days of 5.5 kg. Simulations were performed separately for modelled neap and spring tides, and the sensitivity of the results to key model parameters was tested.

The model results (Table 1) confirmed that the treatment scenario proposed, with a daily release of no more than 916 g of azamethiphos should comfortably comply with the EQS. The peak concentration during the baseline simulation 72 hours after the final treatment was less than 0.1 μg/L, the maximum allowable concentration, and the area where concentrations exceeded the EQS of 0.04 μg/L was substantially less than the allowable 0.5 km^2. The baseline simulation presented here was designed to be relatively conservative.

Table 1. Summary of Results

Site Details	
Site Name:	Scalpay
Site Location:	Isle of Skye
Peak Biomass (T):	2,500
Pen Details	
Number of Pens:	12
Pen Circumference (m):	120
Working Depth (m):	12
Pen Group Configuration:	2 x (2 x 3)
Azamethiphos Consent	
Recommended 3-hour (kg):	0.458
Recommended 24-hour (kg):	0.916

1 INTRODUCTION

This report has been prepared by Mowi Scotland Ltd. to meet the requirements of the Scottish Environment Protection Agency (SEPA) for an application to increase the current consent of topical sealice veterinary medicines at the marine salmon farm Scalpay, Isle of Skye (Figure 1). The report presents results from coupled hydrodynamic and particle tracking modelling to describe the dispersion of bath treatments to determine EQS-compliant quantities for the current site biomass and equipment. The modelling procedure follows as far as possible guidance presented by SEPA in December 2023 (SEPA, 2023a).

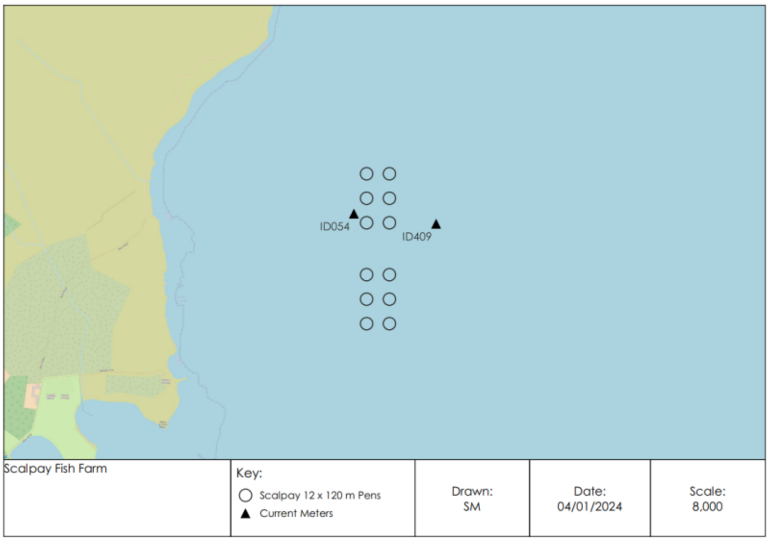

*Figure 1. Location of the salmon farm, Scalpay and the location of the ADCP deployments (▲) relative to the pen positions (**o**).*

1.1 Site Details

The site is situated south of the Isle of Scalpay, near the Isle of Skye (Figure 1). Details of the hydrographic data are provided in Table 2. The receiving water is defined as open water.

Table 2. Hydrographic Information

Hydrographic Data	ID409	ID054
Site:	Scalpay	Scalpay
Current Meter Position:	164296E 828813N	164044E 828844N
Depth of Deployment Position (m):	39.01	37.36
Surface Bin Centre Height Above Bed (m):	33.72	29.72
Middle Bin Centre Height Above Bed (m):	25.72	19.72
Bottom Bin Centre Height Above Bed (m):	3.72	2.72
Duration of Record (days):	85	28
Start of Record:	05/01/2023 14:00	06/08/2015 12:14
End of Record:	31/03/2023 09:00	03/09/2015 20:34
Current Meter Averaging Interval (min):	20	20
Magnetic Correction to Grid North:	-2.73	-4.08

2. MODEL DETAILS

2.1 Model Selection

The modelling approach adopted a coupled hydrodynamic and particle tracking method, whereby water currents in the region, modelled using a calibrated hydrodynamic model, advected particles representing the topical medicine around the model domain. Turbulent eddy diffusion was modelled using a random walk method. Outputs from the modelling were derived to assess the dispersion of the medicine following treatments against statutory Environmental Quality Standards. The modelling approach is described in full in the Hydrodynamic Model Description (Mowi, 2024), and is only summarised here.

For the hydrodynamics, the model used was FVCOM (Finite Volume Community Ocean Model), a prognostic, unstructured-grid, finite-volume, free-surface, 3-D primitive equation coastal ocean circulation model developed by the University of Massachusetts School of Marine Science and the Woods Hole Oceanographic Institute (Chen et al., 2003).

The model consists of equations describing the evolution and conservation of momentum, temperature, salinity and turbulence parameters, the latter using a turbulence closure sub-model. The horizontal grid is comprised of unstructured triangular cells and the irregular bottom is presented using generalized terrain-following coordinates. The General Ocean Turbulent Model (GOTM) developed by Burchard's research group in Germany (Burchard, 2002) has been added to FVCOM to provide optional vertical turbulent closure schemes.

For the particle tracking component, Mowi's in-house model UnPTRACK (Gillibrand, 2022) was used. The model used the hydrodynamic flow fields from the FVCOM model simulations. This model has been used previously to simulate sea lice dispersal (Gillibrand & Willis, 2007), the development of a harmful algal bloom (Gillibrand et al., 2016a) and the dispersion of cypermethrin from a fish farm (Willis et al., 2005). The approach for veterinary medicines is the same as for living organisms, except that medicine has no biological behaviour but instead undergoes chemical decay: the numerical particles in the model represent "droplets" of medicine of known mass, which reduces over time at a rate determined by a specified half-life. Particles are released at pen locations at specified times, according to a treatment schedule. The number of particles combined with their initial mass represents the mass of medicine required to treat a pen. The particles are then subject to advection, from the modelled flow fields, horizontal and vertical diffusion, and chemical decay. Concentrations of medicine can be calculated throughout the simulation and compared with relevant Environmental Quality Standards (EQS) e.g. 72 hours after the final treatment. Here, the dispersion of azamethiphos following treatment scenarios at Scalpay have been modelled to illustrate the quantities of medicine that disperse safely in the environment.

2.2 Model Domain and Boundary Conditions

The unstructured mesh used in the model was adapted from the East Coast of Lewis and Harris (ECLH) sub-model mesh of the Scottish Shelf Model (SSM; MS, 2016) (Figure 2). Model resolution was enhanced in the Caol Mor region particularly around the Mowi site at Scalpay (Figure 3). The spatial resolution of the model varied from 21 m in some inshore waters to 5 km along the open boundary. The model consisted of 50,730 nodes and 95,530 triangular elements. Bathymetry was taken from the UK Hydrographic Office, supplemented with a local depth survey (Figure 4). Given that topical medicine dispersion occurs in the upper water column, it was not considered necessary to use highly detailed bathymetry data in the immediate vicinity to the pens.

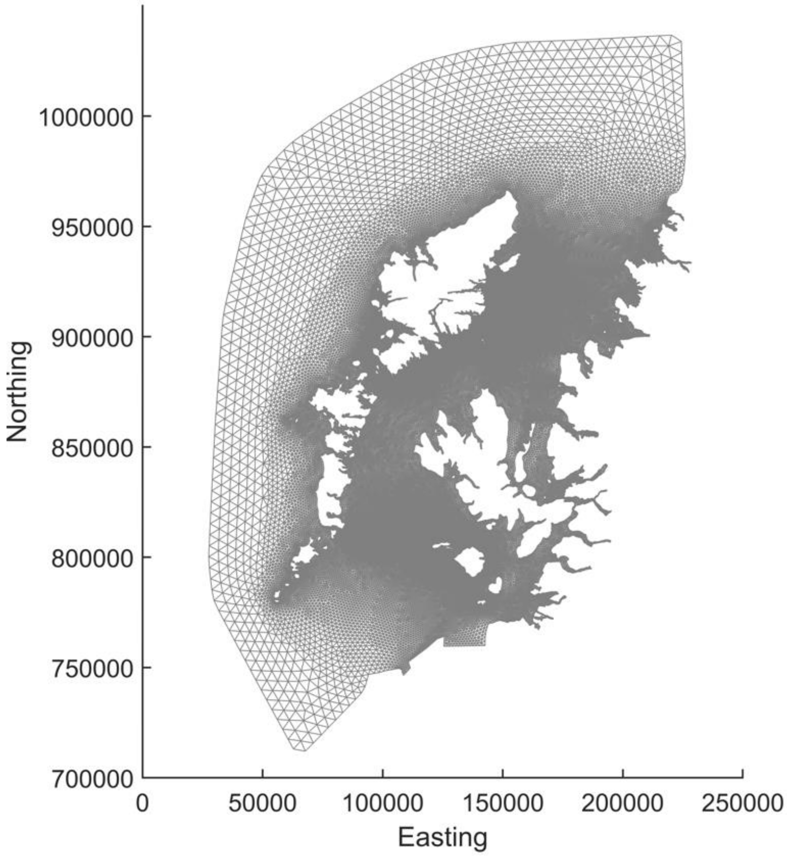

Figure 2. The mesh and domain of the modelling study, adapted from the ECLH sub-model.

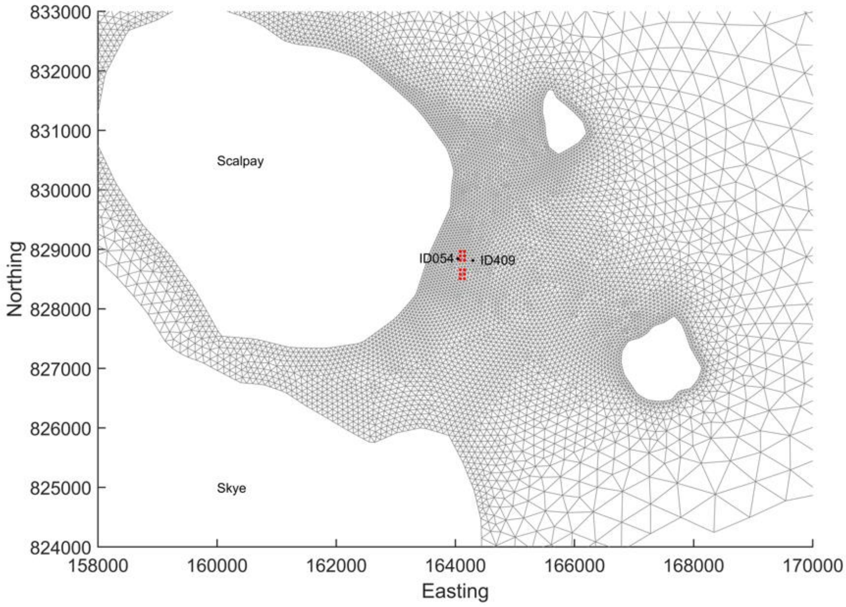

Figure 3. The unstructured mesh around the Scalpay site in the modified model grid, with the pen locations indicated (o).

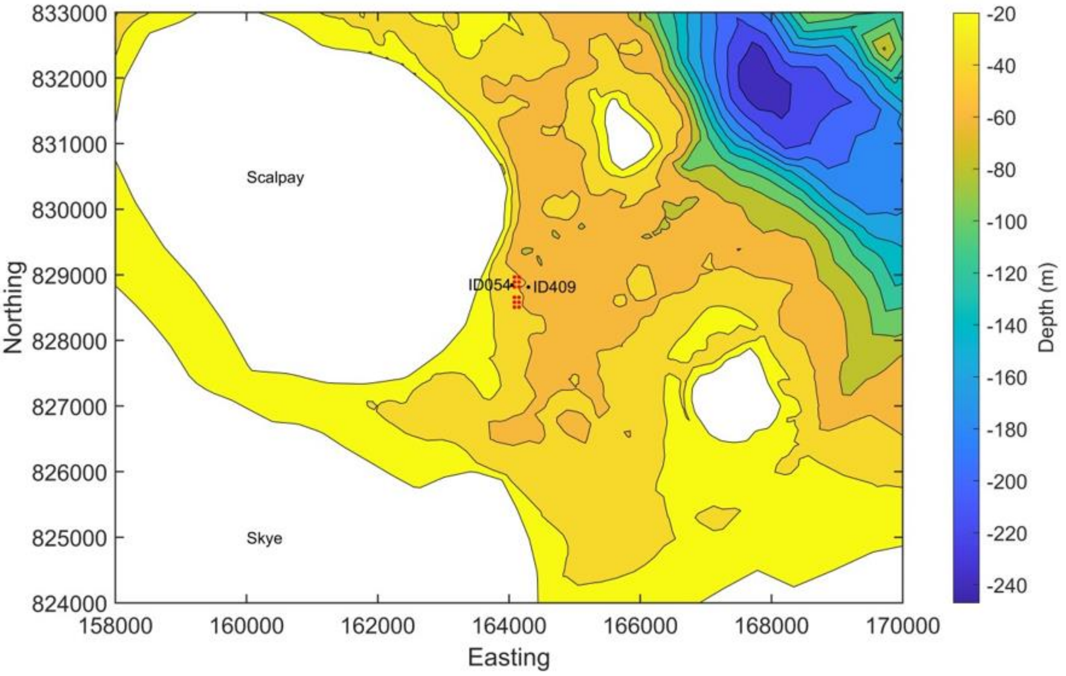

Figure 4. Model water depths (m) around the Scalpay salmon farm from the modified model. The pen locations indicated (●).

The model was forced along its open boundary by a time series of sea surface height (SSH) at each boundary node for the relevant simulation periods; FVCOM appears to perform better with time series boundary forcing than when tidal constituents are used. The SSH time series were generated using the RiCOM hydrodynamic model (Walters and Casulli, 1998; Gillibrand et al., 2016) on the ECLH grid, which was, in turn, forced by eight tidal constituents (M2, S2, N2, K2, O1, K1, P1 and Q1) taken from the full Marine Scotland Scottish Shelf Model (SSM; Marine Scotland, 2016) using the MATLAB© tidal analysis routine t_tide (Pawlowicz et al., 2002). Spatially- and temporally-varying wind speed and direction are taken from the ERA5 global reanalysis dataset (ECMWF, 2021) for the required simulation periods.

Full details of the calibration and validation of the hydrodynamic model are given in the Scalpay Hydrodynamic Model Description (Mowi, 2024).

2.3 Medicine Dispersion Modelling

The medicine dispersion modelling, performed using the UnPTRACK model (Gillibrand, 2022), simulates the dispersion of patches of medicine discharged from pens following treatment using tarpaulins. The UnPTRACK model uses the same unstructured mesh as the hydrodynamic model, and reads the flow fields directly from the hydrodynamic model output files. Therefore, no spatial or temporal interpolation of the current fields is required, although current velocities are interpolated to particle locations within UnPTRACK. The treatment scenario assumed 2 pens can be treated per day.

To simulate the worst-case scenario, the dispersion modelling was initially conducted using flow fields over a period of 9 days, centred on a small neap tidal range taken from the hydrodynamic model simulations. This is assumed to be the least dispersive set of ambient conditions, when medicine dispersion is least likely to meet the required EQS. Later simulations tested dispersion during spring tides.

A treatment depth of 4 m was chosen as a realistic net depth during application of the medicine for the 120 m pens. The initial mass released per pen was calculated from the reduced pen volume and a treatment concentration of ~100 µg L^{-1}, with a total mass of 5.5 kg of azamethiphos released during treatment (12 pens). Numerical particles were released from random positions within a pen radius of the centre and within the 0 – 4 m depth range. The simulations used *~1M* numerical particles in total, each particle representing 10 mg of azamethiphos.

Each simulation ran for a total of 221 hours (9.2 days). This covered the treatment period (123 hours), a dispersion period to the EQS assessment 72 hours after the final treatment, and an extra 25 hours to check for chance concentration peaks. At every hour of the simulation, particle locations and properties (including the decaying mass) were stored and subsequently concentrations calculated. Concentrations were calculated on a grid of 50m x 50m squares using a depth range of 0 – 5 m. Using a regular grid for calculating concentrations means that a known, constant, accuracy and precision of the calculated values applies across the grid.

From the calculated concentration fields, time series of two metrics were constructed for the whole simulation:

(i) The maximum concentration (µg/L) anywhere on the regular grid; and
(ii) The area (km^2) where the EQS was exceeded.

These results were used to assess whether the EQS or MAC was breached after the allotted period (72 hours after the final treatment).

Sensitivity analyses were conducted to assess the effects of:

(i) Horizontal diffusion coefficient, K_H
(ii) Vertical diffusion coefficient, K_V
(iii) Time of release

The dispersion simulations were performed separately over two separate neap tides to confirm the dispersion during the weakest tides, and a spring tide (Figure 5 and Figure 6).

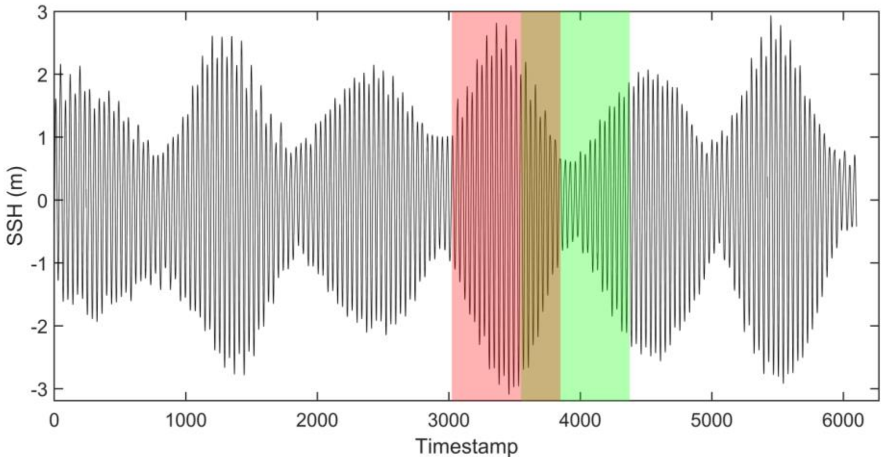

Figure 5. Sea surface height (SSH) at Scalpay from 5th January –31st March 2023 (ID409). Dispersion simulations were performed over neap tides (green, start day 23rd February 2023) and spring tides (red, start day 14th February 2023)

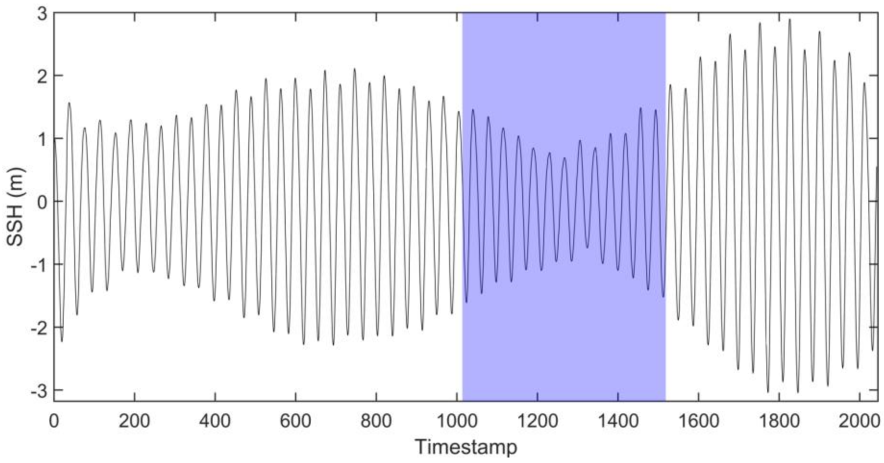

Figure 6. Sea surface height (SSH) at Scalpay from 6th August to 3rd September 2015 (ID054). Dispersion simulations were performed over neap tides (blue, start day 17th August 2015)

2.4 Medicine Dispersion Simulations

The pen locations and details of the medicine source are listed in Table 3. The time of release is relative to the start of the neap or spring period highlighted in Figure 5 and Figure 6.

All simulations used the release schedule and quantities outlined in Table 3. In Runs 2 – 7 (Table 4), the release schedule was set back or forward by a number of hours to investigate the effect of tidal state at the time of release on the results. Results for these simulations are still presented in terms of time relative to the first release.

Table 3. Details of the treatment release simulated by the dispersion model. The release time is relative to the start of the neap or spring period highlighted in Figure 5.

Pen	Easting	Northing	Net Depth (m)	Treatment Mass (kg)	Release Time (hr)
1	164153	828507	4	0.458	0
2	164153	828582	4	0.458	3
3	164153	828657	4	0.458	24
4	164083	828507	4	0.458	27
5	164083	828582	4	0.458	48
6	164083	828657	4	0.458	51
7	164153	828816	4	0.458	72
8	164153	828891	4	0.458	75
9	164153	828966	4	0.458	96
10	164083	828816	4	0.458	99
11	164083	828891	4	0.458	120
12	164083	828966	4	0.458	123

Table 4. Dispersion model simulation details for the treatment of the 12 pens at Scalpay.

Set	Run No.	T 1/2 (h)	Kh	Kv	Start Time
Neap Tides, Start day = 51 (25th February 2023, ID409)					
Baseline	1	134.4	0.1	0.001	00:00
1	2	134.4	0.1	0.001	00:00 -6h
	3	134.4	0.1	0.001	00:00 -4h
	4	134.4	0.1	0.001	00:00 -2h
	5	134.4	0.1	0.001	00:00 +2h
	6	134.4	0.1	0.001	00:00 +4h
	7	134.4	0.1	0.001	00:00 +6h
2	8	134.4	0.132	0.001	00:00
	9	134.4	0.05	0.001	00:00
3	10	134.4	0.1	0.0025	00:00
	11	134.4	0.1	0.005	00:00
Spring Tides, Start day = 40 (14th February 2023, ID409)					
4	12	134.4	0.1	0.001	00:00
5	13	134.4	0.132	0.001	00:00
	14	134.4	0.05	0.001	00:00
6	15	134.4	0.1	0.0025	00:00
	16	134.4	0.1	0.005	00:00
Neap Tides, Start day = 11 (17th January 2023, ID409)					
7	17	134.4	0.1	0.001	00:00
8	18	134.4	0.132	0.001	00:00
	19	134.4	0.05	0.001	00:00
9	20	134.4	0.1	0.0025	00:00
	21	134.4	0.1	0.005	00:00

2.5 3-hour EQS

In addition to the main simulations described above to assess compliance with the 72-hour EQS, simulations were also performed to assess compliance with the 3-hour EQS (SEPA, 2022). The 3-hour EQS is applied as a mixing zone EQS, whereby the area where concentrations exceed the EQS of 250 ng L^{-1} after 3 hours must be less than the 3-hour mixing zone. The 3-hour mixing zone is primarily a function of mean near-surface current speed at the site, and has traditionally been calculated by the BathAuto Excel spreadsheet. For calculation of the mixing zone, a mean surface current speed of 5.08 cm s^{-1} was used from ID409 (Table 5).

Table 5. Parameter values used in the calculation of the 3-hour mixing zone ellipse area and the resulting area

Parameter	Value
Mean current speed (ms^{-1})	0.0508
Area of 160m pen (km^2)	0.0020372
Distance from shore (km)	0.78
Mean water depth (m)	42.11
Treatment Depth (m)	4
Mixing zone ellipse area (km^2)	**0.08010585**

For the 3-hour EQS assessment, the baseline runs for neap and spring tides (Runs 1 and 14 in Table 4) were repeated, but with results output every 20 minutes and the runs were truncated, lasting only until 3 hours after the final treatment. The area of the medicine patch for each individual treatment was then calculated over the 3-hour period following its release, and the area exceeding 0.25 μg L^{-}1 determined. Concentrations from these simulations were calculated on a 10m x 10m grid (rather than a 50m x 50m grid) in order to more accurately calculate the smaller areas of medicine over the initial 3-hour period.

2.6 Interactions with Special Features

Several near-by features of interest have been identified (SEPA, 2023b) which are thought to be at potential risk from medicine influence and hence must be considered when modelling the treatment releases from Scalpay. Table 6 shows details of the features of interest, and the locations are indicated in Figure 7.

Table 6. Details of identified special features

Feature Name	Feature Type	Reason for Identification
Red Rocks and Longay	MPA	At risk from bath influence
Maerl Bed	PMF	At risk from bath influence
Flame Shell Bed	PMF	At risk from bath influence

Predicted concentrations of azamethiphos at the PMF locations during the simulation periods were extracted from the model results, and the mean and maximum concentrations with the MPA were also derived. The proportion of the MPA where the 3-hour (0.25 μg L^{-1}) and the 72-hour (0.10 μg L^{-1}) EQS were exceeded were calculated. These calculations were all made using a 5 m thick layer immediately above the seabed, since all three types of the special features are benthic habitats.

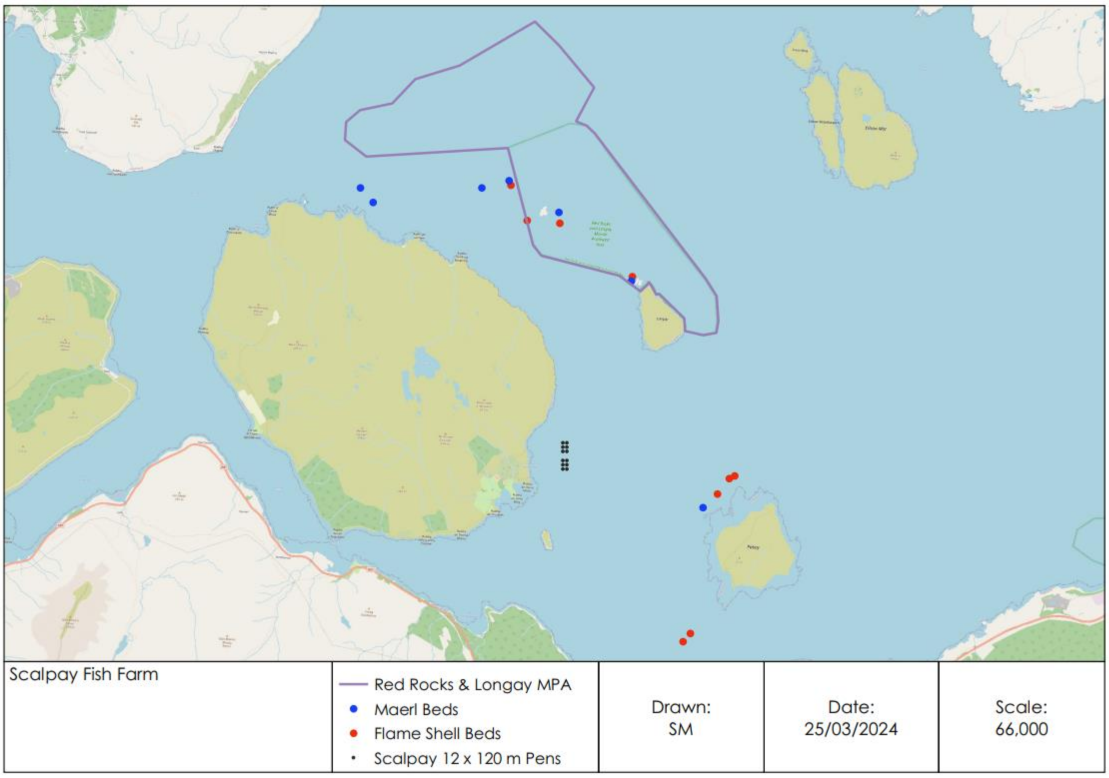

Figure 7. Identified special features near the Scalpay salmon farm

2.7 Diffusion Coefficients

Selection of the horizontal diffusion sensitivity parameter, K_H, was guided by dye releases conducted at the Scalpay site by Anderson Marine Surveys Ltd on the 5th and 6th March 2022, along with several other dye release studies undertaken at other salmon farm locations. Dye tracking studies proceed by releasing a known quantity of dye into the sea, and then attempting to map the resulting dye patch as it disperses over time by deploying a submersible fluorometer from a boat. Each survey of the patch takes a finite amount of time (typically less than 30 minutes) and is usually made up of several transects which attempt to criss-cross the patch. An estimate of horizontal diffusivity can be made from each transect, but the location of the transect relative to the centre of the patch (and the highest concentrations) is often uncertain. The estimates of horizontal diffusivity shown in Figure 8 come from these individual transects.

The analysis method is based on estimating the diffusion from individual transects through the dye patch from the variance in the dye concentrations along the transect. The dye survey at Scalpay gave a mean horizontal diffusivity of **0.132 m^2 s^{-1}**. There is considerable scatter in the data (Figure 8), arising from the difficulty of tracking dye in the marine environment which renders individual values highly uncertain. However, these data, and all other dye studies undertaken by Mowi in recent years, suggest that a horizontal diffusivity of 0.1 m^2 s^{-1} is a reasonable estimate of short term eddy diffusion in Scotland’s coastal marine environment. A similar conclusion was reached by Dale et al. (2020) following dye releases conducted in Loch Linnhe and adjacent waters.

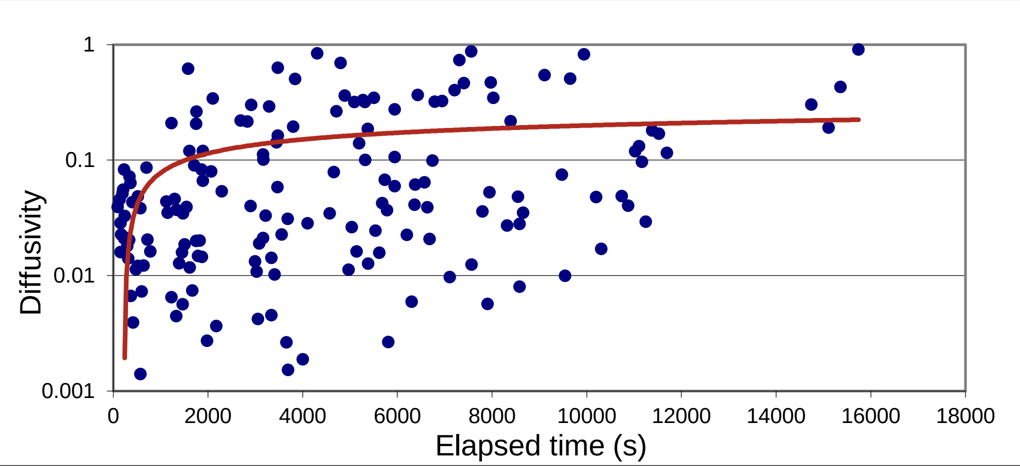

Figure 8. Estimated horizontal diffusivity (m^2 s^{-1}) from dye release experiments at Scalpay on the 5th and 6th March 2022.

Most of the simulations described here were conducted using a value of K_H = 0.1 m^2 s^{-1}, the minimum horizontal diffusion given for modelling bath treatments over periods greater than half-an-hour. However, the sensitivity of the model to K_H was explored.

3 RESULTS

3.1 Dispersion During Neap Tides, February 2023 (ID409)

A standard treatment of twelve 120 m pens, with a reduced net depth of 4 m and assuming 2 pens can be treated per day at a treatment concentration of ~100 µg/L, resulted in a treatment mass per pen of azamethiphos of 458 g, a daily (24-h) release of 916 g and a total treatment release of 5.5 kg over 123 hours. The dispersion of the medicine during and following treatment from Run001 (Table 4) is illustrated in Figure 9. After 24 hours, as the third treatment on day 2 was discharged, discrete patches of medicine are evident from the first two treatment releases from the first day. The maximum concentration at this time is roughly 100 µg/L, due to the release of the third treatment. After 72 hours, as the seventh treatment is discharged, discrete patches of medicine from the previous treatment releases are still evident, but the patches of medicine have rapidly dispersed and are already down to concentrations of the same order as the EQS (0.04 µg/L). The maximum concentration at this time was again around 100 µg/L, due to the release of the seventh treatment.

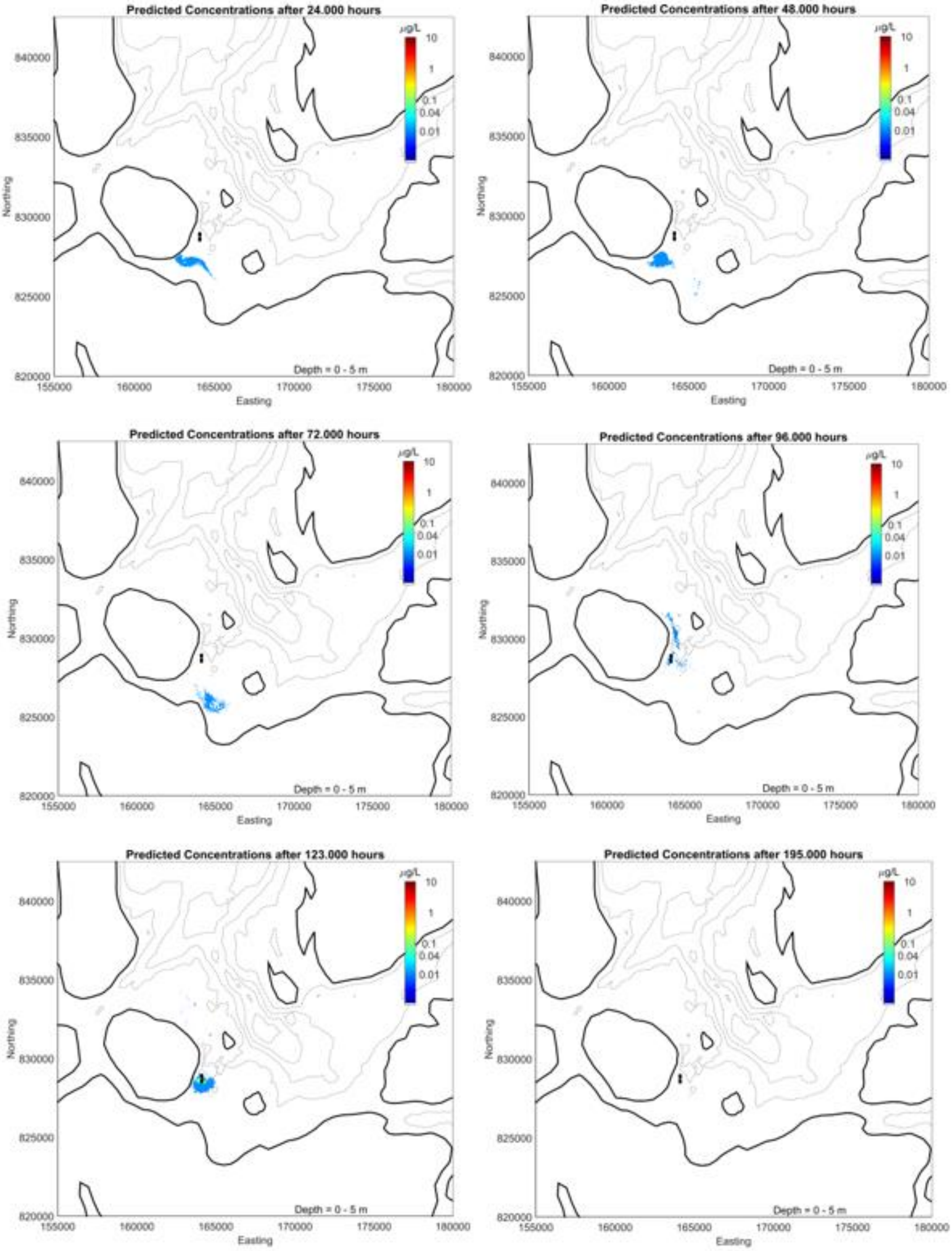

Figure 9. Predicted concentration fields for a dispersion simulation at neap tides after 24 hours (top left), 48 hours (top right), 72 hours (middle left), 96 hours (middle right), 123 hours (bottom left) and 195 hours (bottom right).

The treatment schedule completed after 123 hours (5.125 days). At this stage, the medicine released on earlier days has already dispersed into the sound of Raasay. It is noticeable that dispersion of the medicine does not happen in a gradual “diffusive” manner, but is largely driven by eddies and horizontal shear in the spatially-varying velocity field, which stretches and distorts the medicine patches and enhances dispersion. Following the final treatment at 123 hours, the treatment patches were rapidly dispersed and concentrations rapidly fell away below the EQS. Remnants of medicine are seen but at concentrations below the MAC.

The time series of maximum concentration from this simulation is shown in Figure 10 (blue). The 12 peaks in concentration of ~100 µg/L following each treatment event over the first 5 days are evident. Following the final treatment after 123 hours, the maximum concentration fell steadily away (Figure 10). A default half-life of 134.4 hours (5.5 days) was used. The maximum concentration seventy-two hours after the final treatment (time = 195 hours) was well below 0.1 µg/L, the maximum allowable concentration (MAC).

The area where the EQS of 0.04 µg/L was exceeded peaked at about 0.8 km^2 following the final treatment, but had fallen well below the 0.5 km^2 threshold immediately after; by 72 hours after the final treatment, the exceeded area was close to zero (Figure 9 and Figure 10).

These results indicate that, with a horizontal diffusion coefficient of 0.1 $m^2 s^{-1}$, and a medicine half-life of 134.4 hours, the environmental quality standards are comfortably achieved. In the following sections, the sensitivity of the model results to the medicine half-life, diffusion coefficients and tidal state are examined.

3.2 Sensitivity to Diffusion Coefficients

The model results were tested for sensitivity to the horizontal and vertical diffusion coefficients used. The horizontal diffusion coefficient used for the standard runs was K_H = 0.1 $m^2 s^{-1}$. Simulations were also performed with higher and lower values of K_H, specifically K_H = 0.132 $m^2 s^{-1}$ and K_H = 0.05 $m^2 s^{-1}$ (Table 4). The time series of maximum concentration and area exceeding the EQS are shown in Figure 10. The time series confirm that the MAC was not exceeded after 195 hours (72 hours after the final treatment) with any of the different horizontal diffusion coefficients. The area limit of 0.5 km^2 was also comfortably met in all cases.

Similarly, sensitivity to the vertical diffusion coefficient, K_V, was tested (Figure 11). The model results are not particularly sensitive to the vertical diffusion rate, but increased vertical diffusion, likely in the presence of wind and/or waves, led to slightly smaller areas where the EQS was exceeded.

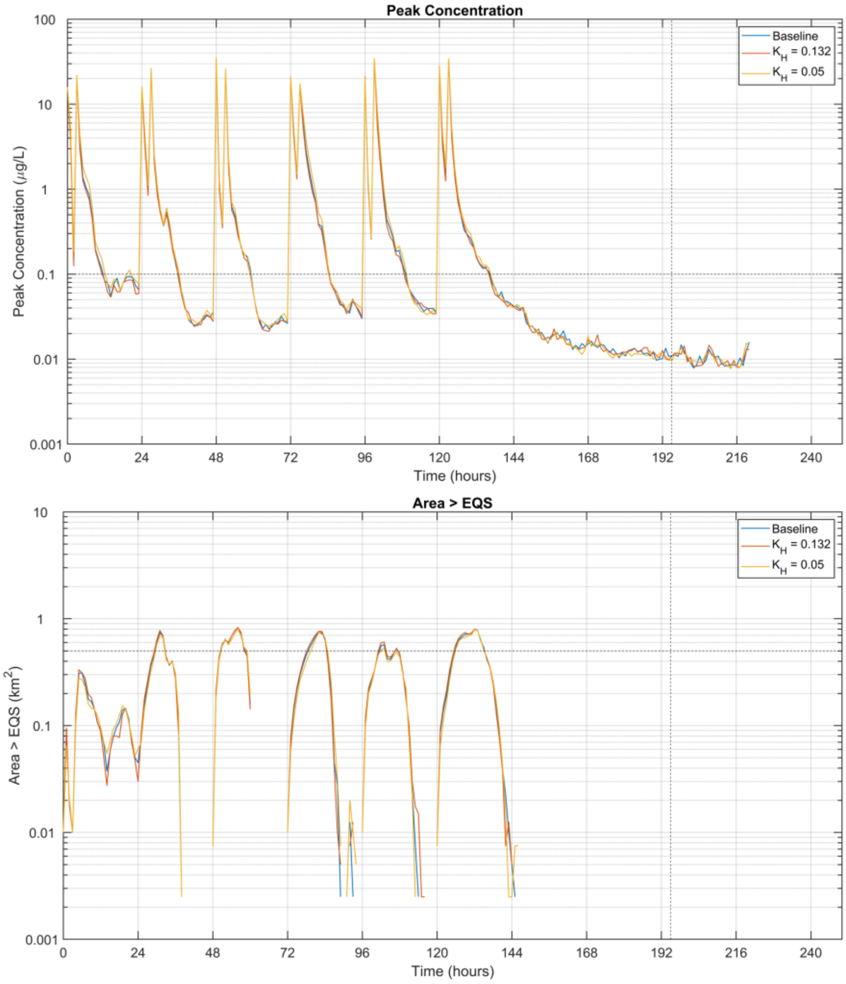

Figure 10. Time series of maximum concentration (top) and area exceeding the EQS (bottom) from the second set of model runs (Table 4). The model was run during neap tide with varying horizontal diffusion coefficient K_H (m^2 s^{-1}). The MAC and area limit 72 hours after the final treatment (Time = 195 h) of 0.1 µg/L and 0.5 km^2 are indicated by the horizontal dashed lines.

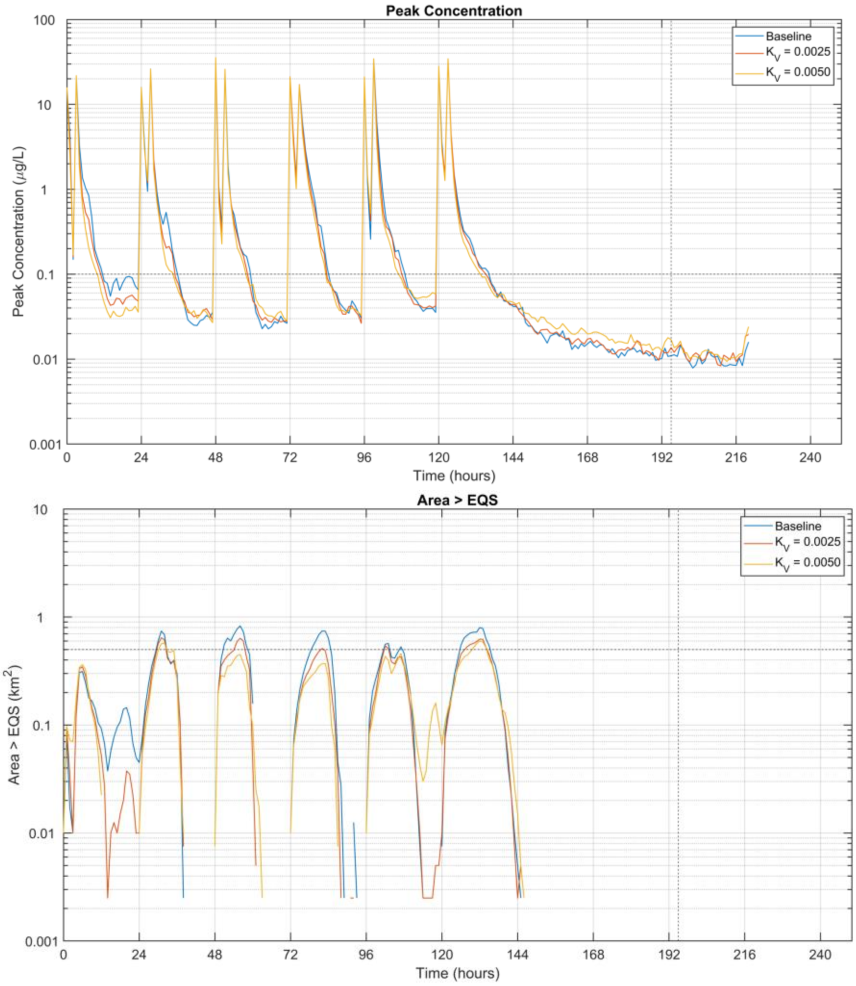

Figure 11. Time series of maximum concentration (top) and area exceeding the EQS (bottom) from the third set of model runs (Table 4). The model was run during neap tides with varying vertical diffusion coefficient K_V ($m^2\ s^{-1}$). The MAC and area limit 72 hours after the final treatment (Time = 195 h) of 0.1 µg/L and 0.5 km^2 are indicated by the horizontal dashed lines.

3.3 Sensitivity to Release Time

The baseline simulation was repeated with the time of the releases varied by up to ±6 hours, the purpose being to assess the influence, if any, of the state of the tide on subsequent dispersion. A half-life of 134.4 hours was used in these runs which is thought to still be conservative.

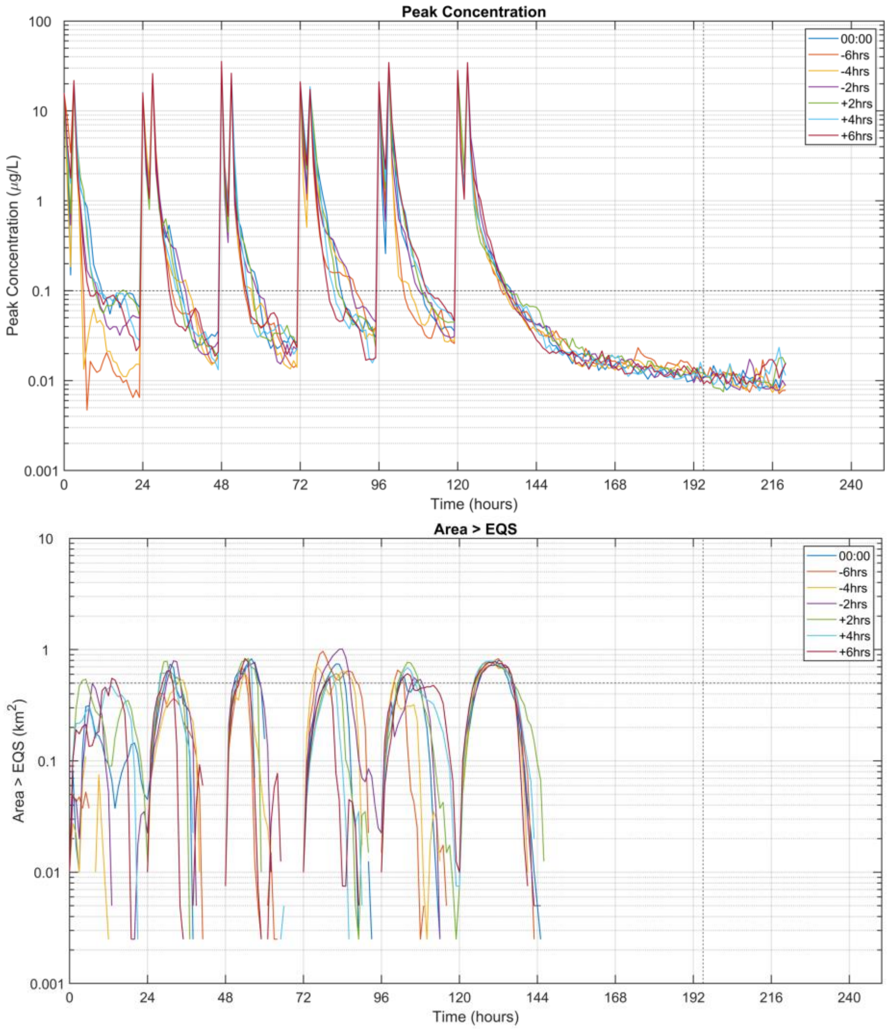

Figure 12. Time series of maximum concentration (top) and area exceeding the EQS (bottom) from the first set of model runs (Table 4). The model was run during neap tides with varying release times, relative to the baseline (Start = 0 h). The MAC and area limit 72 hours after the final treatment (Time = 195 h) of 0.1 µg/L and 0.5 km² are indicated by the horizontal dashed lines.

3.4 Dispersion during Spring Tides, February 2023 (ID409)

Dispersion simulations were carried out during modelled spring tides in February 2023 (Figure 5), repeating the main set carried out for neap tides (Table 4). The same treatment scenario of 2 treatments per day was simulated, with each treatment using 458 g of Azamethiphos. For all horizontal and vertical diffusion coefficients simulated, both the MAC and area EQS were achieved (Figure 13).

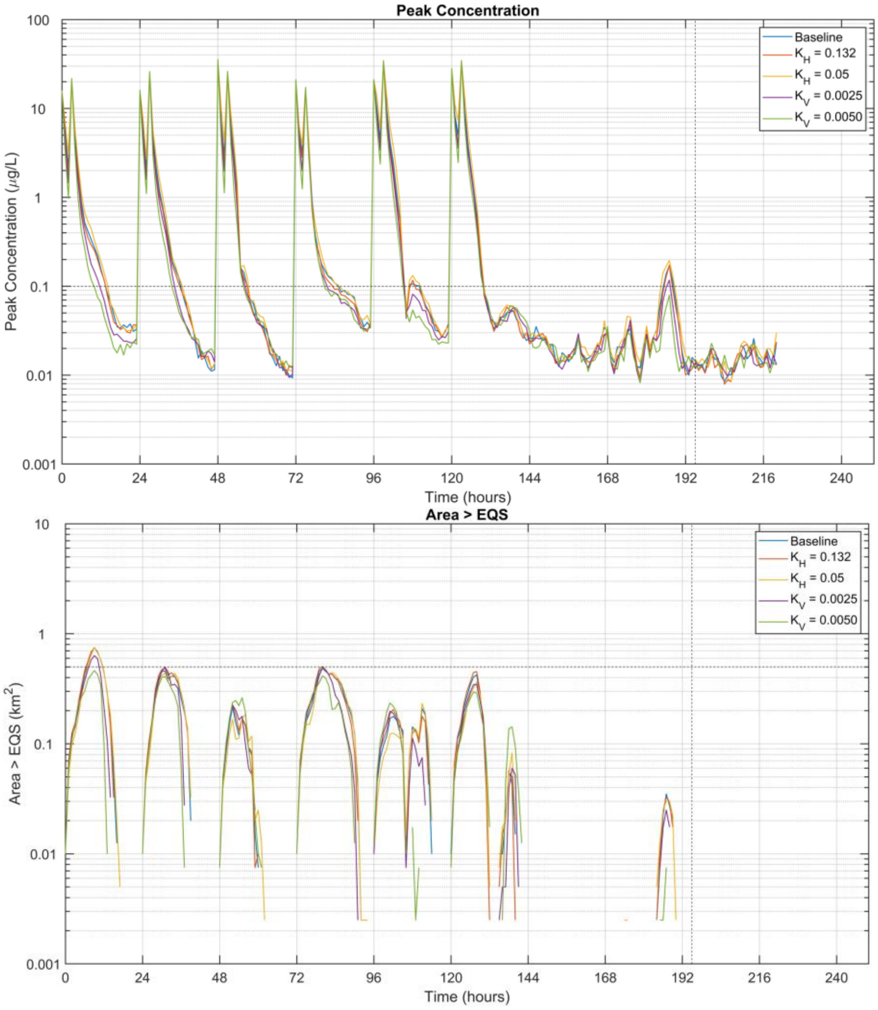

Figure 13. Time series of maximum concentration (top) and the area where concentrations exceeded the EQS (bottom) from the fourth, fifth and sixth set of model runs (Table 4). The model was run at spring tides with varying horizontal diffusion coefficient K_H ($m^2 s^{-2}$) and vertical diffusion coefficient K_V ($m^2 s^{-2}$). The MAC and area limit 72 hours after the final treatment (Time = 195 h) of 0.1 µg/L and 0.5 km^2 are indicated by the horizontal dashed lines.

3.5 Dispersion During Neap Tides, August 2015 (ID054)

A further set of dispersion simulations during modelled neap tides in August 2015 were carried out (Figure 5), repeating the main set carried out for neap tides in February 2023 (Table 4). The same treatment scenario of 2 treatments per day was simulated, with each treatment using 458 g of Azamethiphos. For all horizontal and vertical diffusion coefficients simulated, both the MAC and area EQS were comfortably achieved. These simulations demonstrate again that the modelled treatment regime will comfortably meet the EQS criteria.

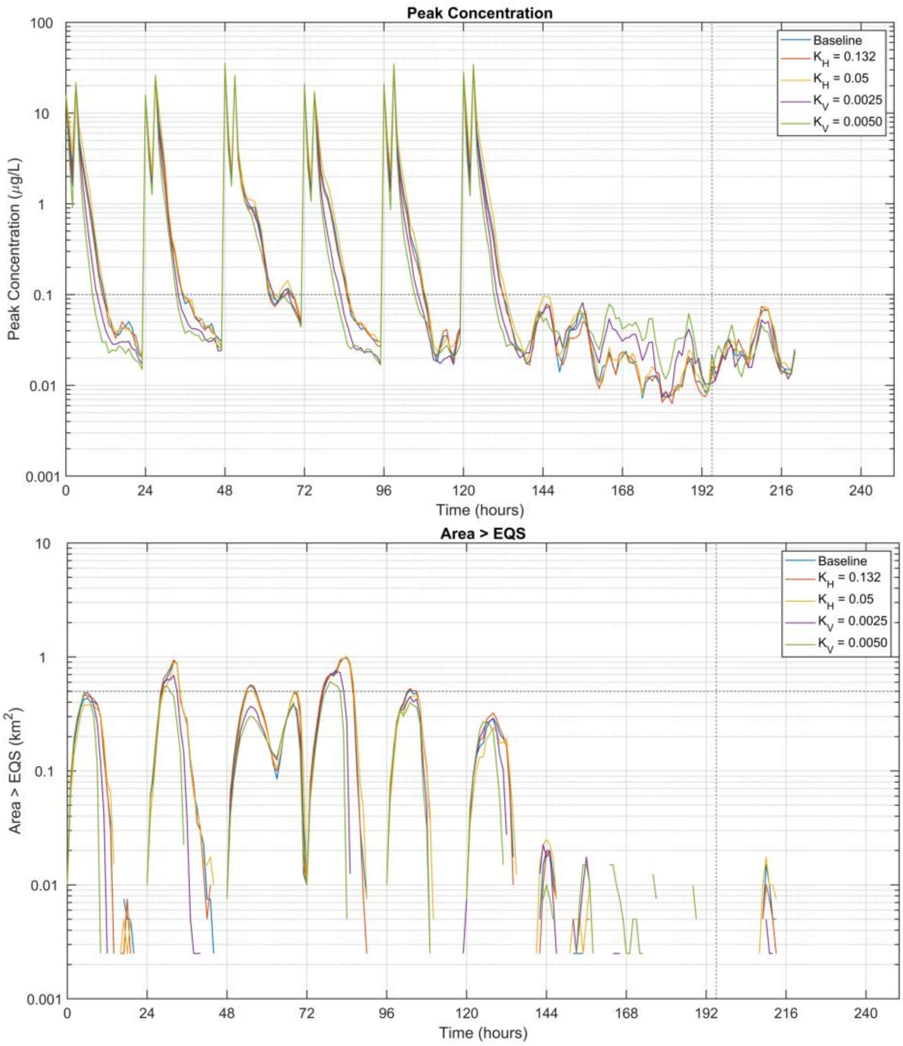

Figure 14. Time series of maximum concentration (top) and the area where concentrations exceeded the EQS (bottom) from the seventh, eighth and nineth set of model runs (Table 4). The model was run at neap tides from August 2015 with varying horizontal diffusion coefficient K_H ($m^2 s^{-2}$) and vertical diffusion coefficient K_V ($m^2 s^{-2}$). The MAC and area limit 72 hours after the final treatment (Time = 195 h) of 0.1 g/L and 0.5 km^2 are indicated by the horizontal dashed lines.

3.6 3-Hour EQS

The 3-hour mixing zone is primarily a function of mean near-surface current speed at the site, and has traditionally been calculated by the BathAuto Excel spreadsheet. For calculation of the mixing zone, a mean surface current speed of 5.08 cm s^{-1} was used from ID409 (Table 1) which was thought to be a representative value for the surface 0 – 5 m layer at Scalpay. The parameter values used in the calculation of the 3-hour mixing zone ellipse area are shown in Table 5.

The time series of the areas where the 3-hour EQS of 250 ng L^{-1} is exceeded for a single selected pen treatment at neap tide (first release on 23rd February 2023) are shown in Figure 15. The single pen treatment selected was the 6th release which is closest to the centre of the neap tide and hence is discharged during what is thought to be the least dispersive conditions.

The area exceeding the EQS was less than the allowable mixing zone (0.080105 km^2) after 3 hours.

For spring tide releases (first release on 15th February 2023), the area where concentrations exceeded the 3-hour EQS also complied with the allowable area (Figure 16). This demonstrates that the discharge quantity of 458 g of Azamethiphos from each of the twelve 120 m pens at Scalpay should not breach the 3-hour Environmental Quality Standard.

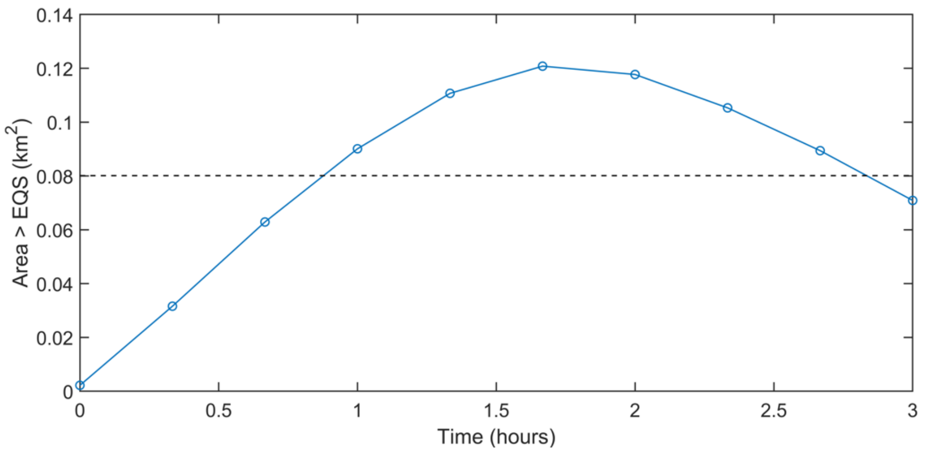

Figure 15. Time series of the area exceeding the 3-hour EQS for the sixth (middle) pen treatment during the 3 hours following release at neap tide. The 3-hour mixing zone area is indicated (---).

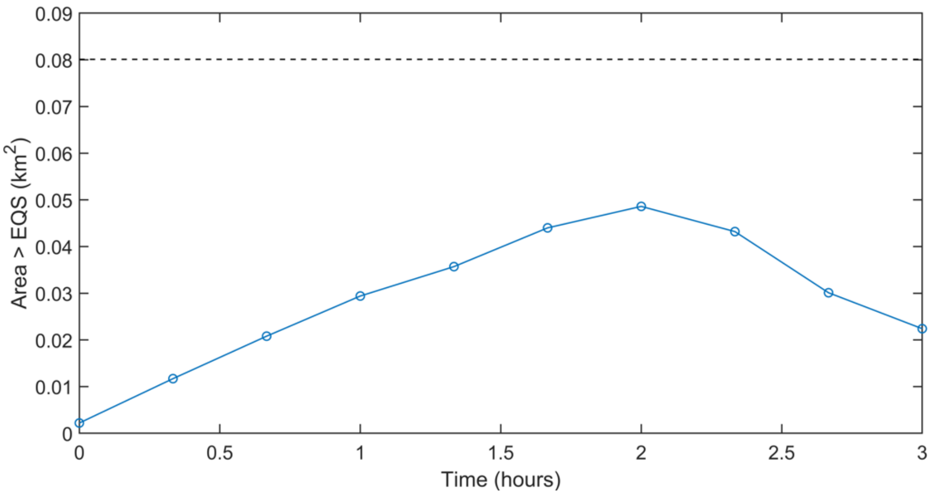

Figure 16. Time series of the area exceeding the 3-hour EQS for the sixth (middle) pen treatment during the 3 hours following release at spring tide. The 3-hour mixing zone area indicated (---).

3.7 Interactions with Special Features

Figure 17 shows the mean and maximum peak concentrations of Azamethiphos every hour within the Red Rock and Longay MPA at both neap and spring tides for a 5 m layer above the seabed. The concentrations shown during neap tide are minimal with maximum concentrations well below the 3 hour (0.25 µg/L) and 72 hour (0.10 µg/L) MAC for the duration of the simulation. For the duration of the simulation, both the mean and maximum peak concentrations measured in the Red Rock and Longay MPA are well below the 3 hour MAC at both neap and spring tides (Figure 17). The maximum peak concentrations in both the spring and neap simulations briefly breeched the 72 hour MAC but decreased immediately below the MAC and was well below this by the end of the simulation period.

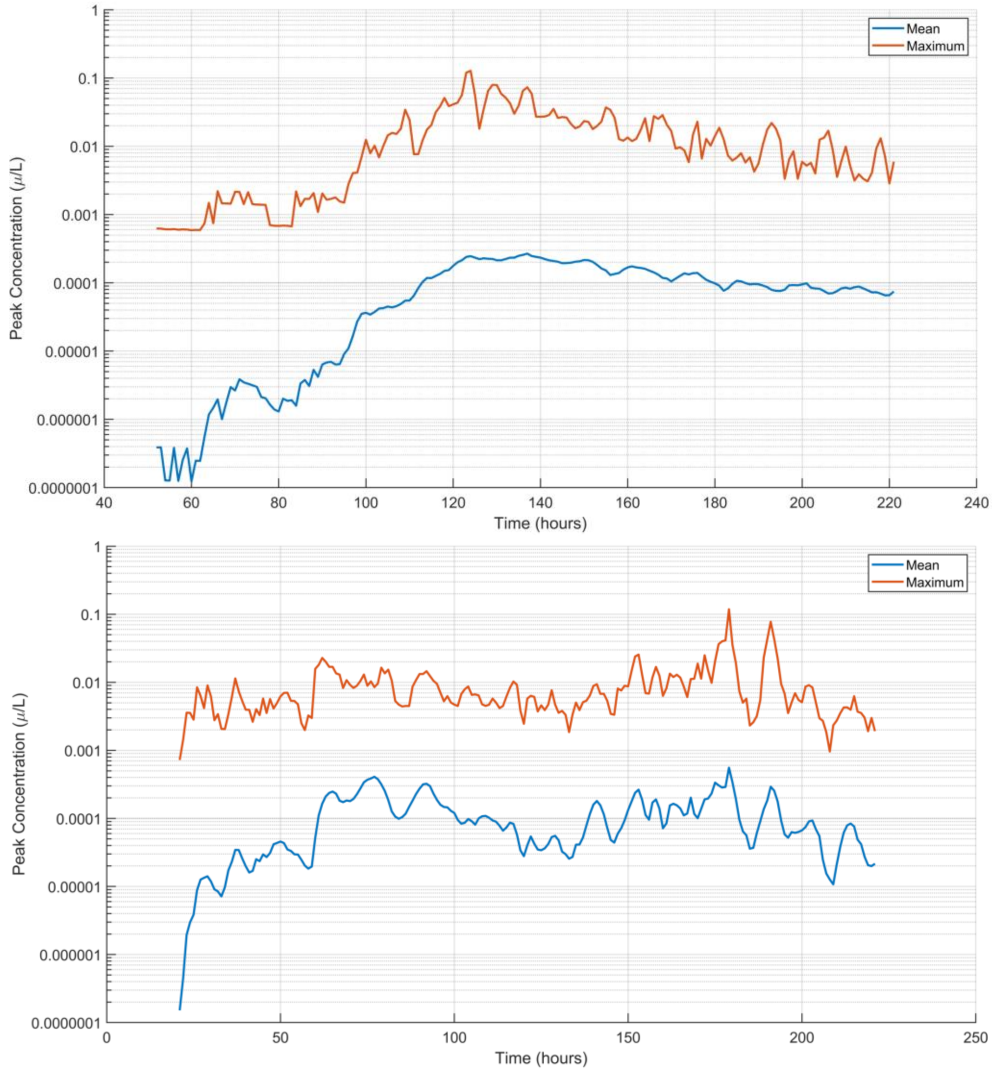

Figure 17. Mean and maximum peak concentrations within the Red Rock and Longay MPA over neap tides (top) and spring tides (bottom)

Figure 18 shows the hourly peak concentrations at each of the nine identified Flame Shell Bed locations (SEPA, 2023) for a 5 meter layer above the seabed. The concentrations are minimal throughout at both neap and spring tide and at the peak, are still more than an order of magnitude below the 3 hour MAC.

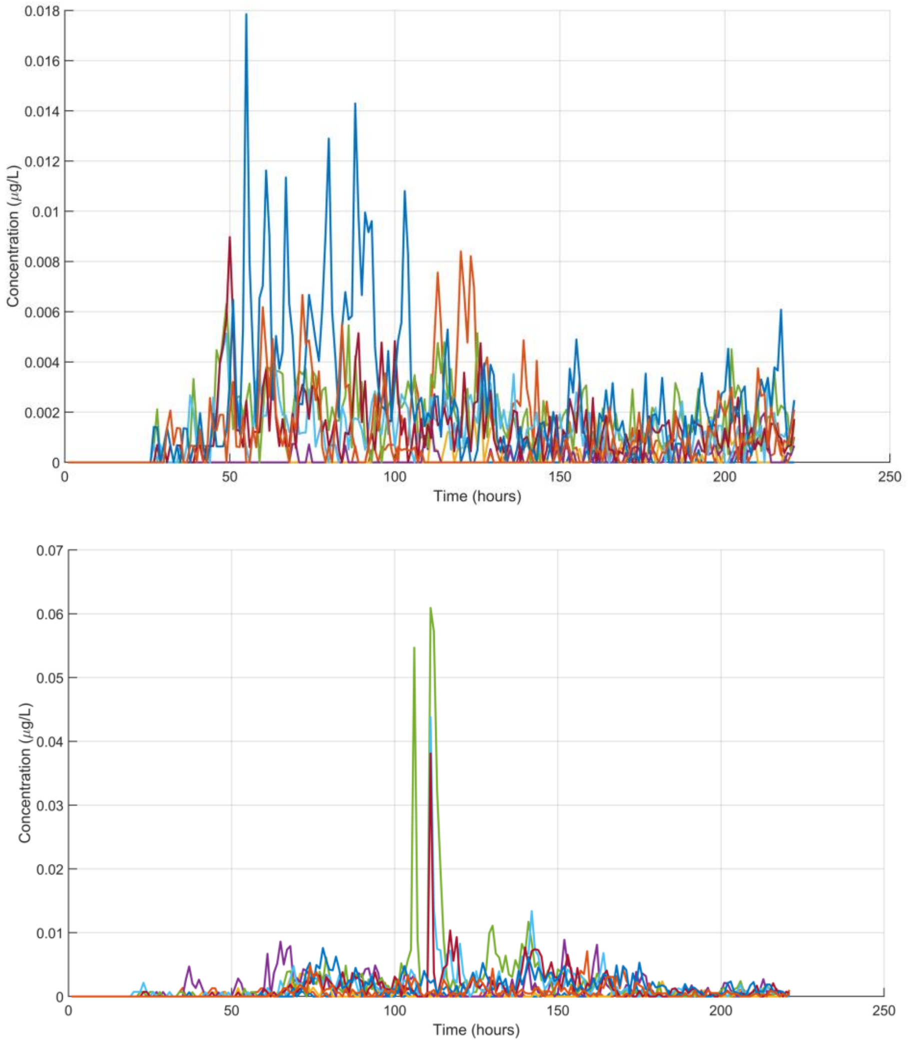

Figure 18. Peak concentrations at nine Flame Shell Bed PMF locations over neap (top) and spring (bottom) tides

Figure 19 shows the hourly peak concentrations at each of the seven identified Maerl Bed locations (SEPA, 2023). Over neap tides, the concentrations are very minimal with a maximum peak concentration of 0.0067 μg/L. During the spring tide, the concentration at one of the Maerl locations peaks at 0.3 μg/L, which breeches the 3 hour MAC (0.25 μg/L), for an instant but immediately falls away well below the MAC. The maximum peak concentrations for both the Flame Shell Beds and the Maerl Beds at spring tides fell away rapidly after 1 hour. These results indicate that the medicine releases from Scalpay fish farm will not have a detrimental effect on the near-by special features and that the medicine levels are well below environmental quality standards.

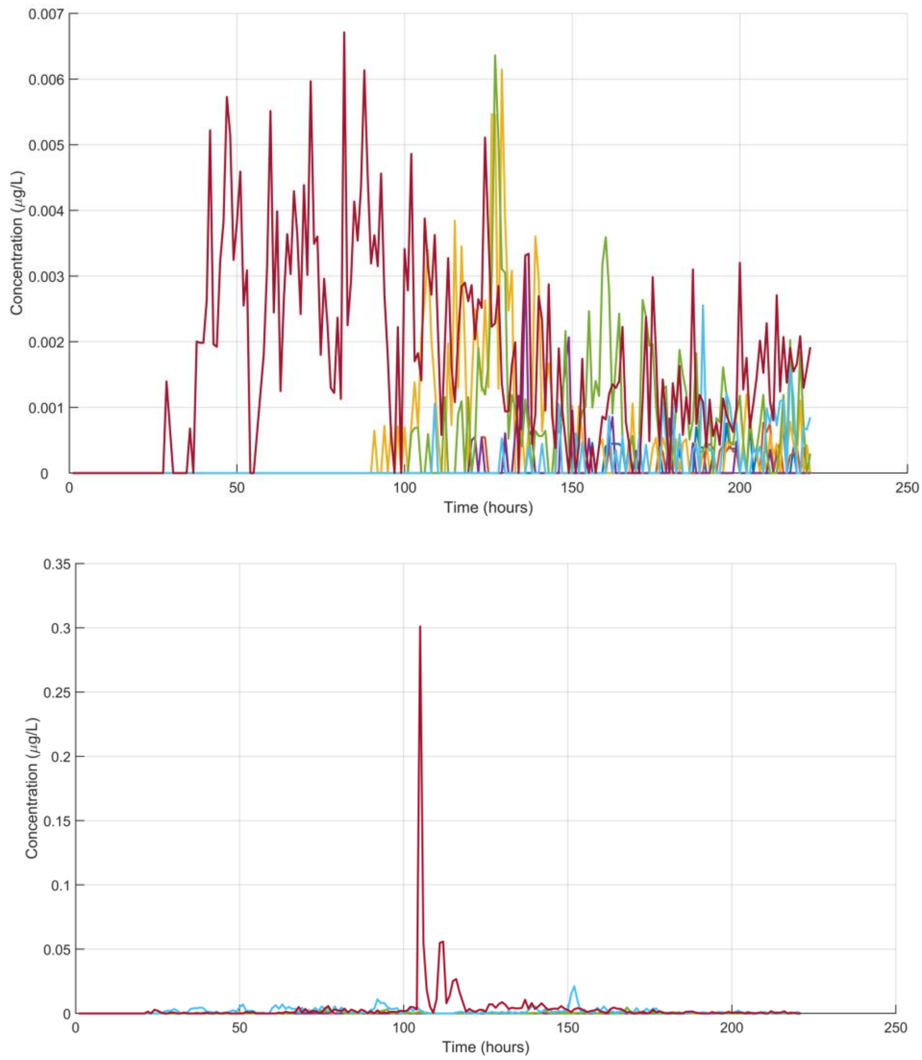

Figure 19. Peak concentrations at seven Maerl Bed PMF locations over neap (top) and spring (bottom) tides

4 SUMMARY AND CONCLUSIONS

A total of 23 dispersion simulations have been performed to assess whether bath treatments at Scalpay salmon farm will comply with pertinent environmental quality standards. A realistic treatment regime, with 2 pen treatments a day was simulated. Each pen required 458 g of Azamethiphos for treatment, resulting in a total discharge over 6 days of 5.5 kg. Simulations were performed separately for modelled neap and spring tides, and the sensitivity of the results to key model parameters was tested. Results are summarised in Table 7.

Table 7. Summary of Results

Site Details	
Site Name:	Scalpay
Site Location:	Isle of Skye
Peak Biomass (T):	2,500
Pen Details	
Number of Pens:	12
Pen Circumference (m):	120
Working Depth (m):	12
Pen Group Configuration:	2 x (2 x 3)
Azamethiphos Consent	
Recommended 3-hour (kg):	0.458
Recommended 24-hour (kg):	0.916

The model results confirmed that the treatment scenario proposed, with a daily release of no more than 916 g, should consistently comply with the EQS. The peak concentration during the baseline simulation after 195 hours (72 hours after the final treatment) was less than 0.1 µg/L, the maximum allowable concentration, and the area where concentrations exceeded the EQS of 0.04 µg/L was substantially less than the allowable 0.5 km^2. In all simulations performed, including sensitivity testing, the EQS and MAC criteria were met. Further simulations over a second neap tide demonstrated that the modelled treatment regime consistently complied with the relevant EQS and MAC. For the simulation during spring tides, greater dispersion meant that the MAC and EQS were met very comfortably. Peak concentrations near the seabed at the identified special features (SEPA, 2023) were found to be consistently less than both the 3-hour and 72-hour MAC over the full treatment simulation. Therefore, it is believed that the requested daily quantity of 916 g of azamethiphos can be safely discharged at Scalpay without breaching the MAC or EQS.

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