Supplemental Nutrient Modelling Report
Fish Holm, Shetland.

Report To	Scottish Environmental Protection Agency
Prepared for	Dingwall Registry, Scottish Environment Protection Agency, Graesser House, Fodderty Way, Dingwall, IV15 9XB
Status	Version 1.0
Date	5 June 2025

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1 List of abbreviations

CAR	Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended)
ECE	Equilibrium Concentration Enhancement
EQS	Environmental Quality Standard
MPFF	Marine Pen Fish Farm
MSS	Marine Scotland Science
OWExR	Open Water Exchange Rate [model]
SEPA	Scottish Environmental Protection Agency
SIC	Shetland Islands Council
SSF	Scottish Sea Farms Ltd.
UKTAG	UK Technical Advisory Group
WFD	Water Framework Directive

2 Summary

This report addresses comments issued on 23 April 2025 by SEPA (SEPA, 2025) relating to the nutrient assessment report (AMSL, 2024a) submitted by SSF as part of the Fish Holm MPFF planning application to SIC. The following are addressed:

- Clarification of CAR licences to be relinquished in the area should the Fish Holm application be granted,
- Outcome of amending the flushing time of the Swinister Voe categorised area to the nutrient enhancement calculations,
- Outcome of using the nitrogen source that reflects the species included on the MPFF CAR Licence based on the highest potential impact,
- Open water ECE calculations for the proposal and MPFFs within 2 km of the site,
- Availability of dye and drogue data, and
- Assessment of the transport of modelled bath treatment plumes away from the proposal.

3 CAR licence relinquishment

Application forms for the technical variation to the Fish Holm CAR licence have been amended to state that those licences held by SSF for Collafirth Delting Site 3 (COLL3) and Hamnavoe, Lunnaness (HAML1) will be relinquished, and as such their contribution to ECE calculations remain excluded from scenarios where Fish Holm is expanded.

4 Flushing time

The nutrient assessment report (AMSL, 2024a) uses a value for Flushing Time (Tf) of 4.9 days as given in the current Locational Guidelines (MSS, 2024). Flushing time is calculated according to:

$$Tf = (0.52 * V)/(0.7 * (A * R))$$

Where *V* is the volume (m^3), *A* the area (m^2) and *R* the tidal range (m) of a waterbody. A Tf of 4.9 days cannot be derived from the values of these parameters given in the Locational Guidelines. The correct value is 10.2 days, which reduces flushing rate (Q) by a factor of 0.48 (Table 1).

Table 1 Corrected flushing time/rate for Swinister Voe.

ID	Loch name	Length (km)	Area (km^2)	Volume (Mm^3)	Tidal range (m)	Flushing time (Tf, days)	Flushing rate (Q, $Mm^3\ yr^{-1}$)
SH24	Swinister Voe	6.30	14.90	367.53	1.8	10.18	13,177.69

The 'nutrient enhancement index' is reported as 3 in the Locational Guidelines, equating to a predicted ECE of 1-3 µmol N l^{-1}. When using the correct flushing time the predicted ECE rises to 3.46 µmol N l^{-1}, at the lower end of the band equivalent to a nutrient enhancement index of 4 (3 to 10 µmol N l^{-1}). Combined benthic and nutrient enhancement indices of 7 would mean that Swinister Voe is a Category 1 area (combined indices >6).

The three scenarios used to assess the potential effects of the proposal on the categorised area have been recalculated using a flushing time of 10.2 days (Table 2).

Table 2 Swinister Voe assessment scenarios and predicted ECE.

SEPA site ID	Site name	Licenced biomass (t)	Scenario biomass (t)		
			1 Baseline [1]	2 Proposed[2]	3 Worst-case[3]
FISH1	Fish Holm (existing)	1910	955		
FISH1	Fish Holm (proposed)	6000		3000	6000
LING1	Linga	2299	2299	2299	2299
SETN1	Setterness North	2500	2500	2500	2500
SETW1	Setterness South	2357.6	2357.6	2357.6	2357.6
SWI2	Bight of Foraness	2100	2100	2100	2100
COL3	Site 3, Collafirth Ness	1920	1920	1920	1920
DAL1	Dales Voe (South)	100	100	100	100
NWSCA1	Scarva Ayre	250	250	250	250
WTAI1	West Taing, Dales Voe	500	500	500	500
COLL3	Collafirth Delting Site 3	1200	1200		
HAML1	Hamnavoe	1910	1910		
	Total biomass (t)		16091.6	15026.6	18026.6
	Predicted ECE (µmol N l^{-1})		4.20	3.93	4.71

[1] Scenario 1 – Baseline: All 9 farms within the categorised area. Additionally, 50% of the soluble release from the existing Fish Holm MPFF transported into the categorised area (as evidenced in Section 7), along with 100% of the release from HAML1 (in lieu of any available modelling or dye/drogue tracking data).

[2] Scenario 2 – Proposed: 50% of the soluble release from the proposed Fish Holm MPFF transported into the categorised area, with CAR licences for COLL3 and HAML1 relinquished.

[3] Scenario 3 – Worst-case: As Scenario 2 but with 100% of the release from the proposed Fish Holm MPFF transported into the categorised area.

With the revised flushing time and the worst-case scenario of total transport of nutrient releases from Fish Holm being transported into the categorised area, the maximum predicted ECE would be 4.71 µmol N l^{-1}. The UKTAG background concentration for dissolved nitrogen in coastal waters is 12 µmol N l^{-1} with the

assessment threshold considered as background levels being exceeded by 50%, i.e. 18 µmol N l^{-1}. Even with the worst-case scenario nitrogen concentrations are below the threshold at 16.71µmol N l^{-1}.

5 Nitrogen source

Seven of the SSF farms in this assessment (six within the categorised area and Hamnavoe) are licenced to farm additional species which have an alternative nitrogen source rate than that used for Atlantic salmon (48.2 kg N $tonne^{-1}$ production). For the seven farms the licenced species with the highest source rate is cod at 72.3 kg N $tonne^{-1}$ production. While the effect of this is mitigated by a lower licenced biomass for this species on each CAR licence (Table 3), ECE has been recalculated for the three scenarios detailed above (Table 4). This shows a negligible increase in predicted ECE; by 0.1 µmol N l^{-1} for the baseline scenario and by 0.01 µmol N l^{-1} for the two proposed scenarios.

Table 3 Sites licenced to farm cod and the biomass used in the ECE calculation at a nitrogen source rate of 72.3 kg N $tonne^{-1}$ production.

SEPA site ID	Site name	Biomass (salmon, t)	Biomass (cod, t)
LING1	Linga	2299	1540
SETN1	Setterness North	2500	1675
SETW1	Setterness South	2357.6	1579.6
SWI2	Bight of Foraness	2100	1407
COL3	Site 3, Collafirth Ness[1]	1920	1287
COLL3	Collafirth Delting Site 3	1200	990
HAML1	Hamnavoe	1910	1280

[1] Also licenced for haddock, at the same biomass and with the same source rate as cod.

Table 4 Predicted ECE reflecting licenced species based on the nitrogen source rate with the highest potential impact.

Scenario	1 Baseline	2 Proposed	3 Worst-case
Predicted ECE (µmol N l^{-1})	4.30	3.94	4.72

6 Open water ECE calculations.

6.1 Description

The nutrient assessment report (AMSL, 2024a) addresses how nitrogenous discharges from Fish Holm may influence the nearby categorised area. To consider near field impact to the immediate surroundings an open water ECE assessment has been undertaken using the OWExR model (Gillibrand, 2006). This considers cumulative impacts from Fish Holm and three MPFFs within 2 km of the proposal: Setterness North, Linga and Hamnavoe (Figure 1).

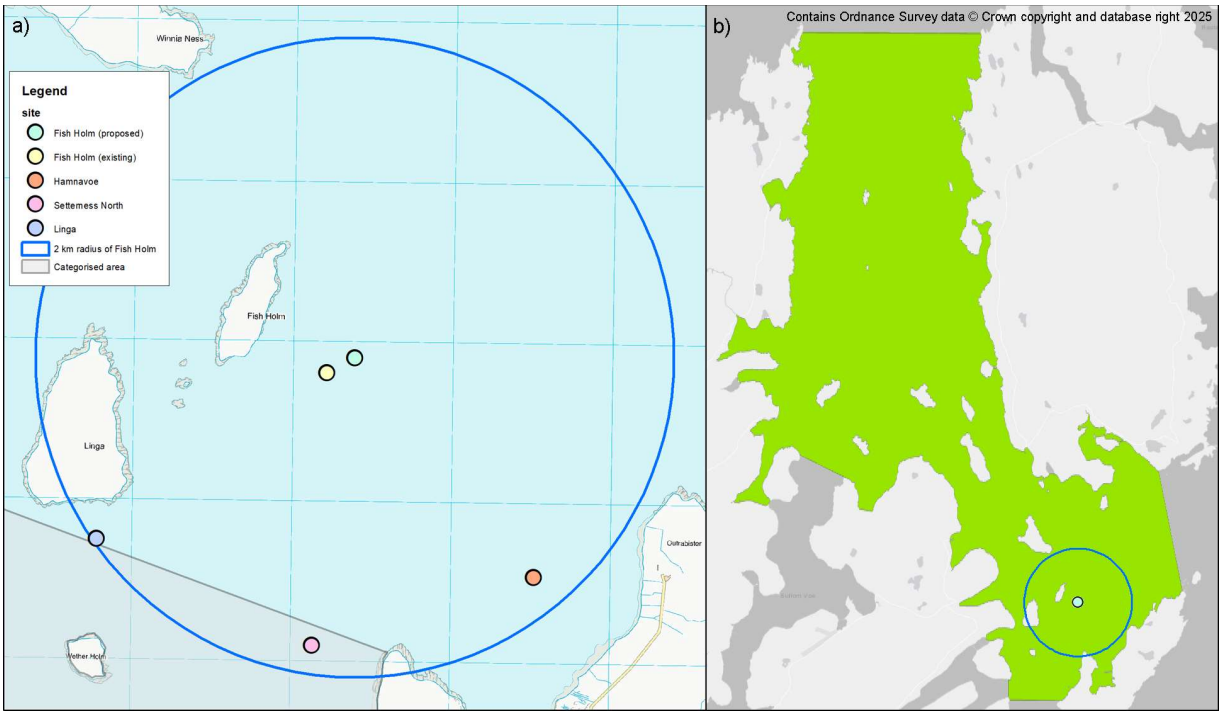

Figure 1 a) Locations of the MPFFs within 2 km of Fish Holm relative to the Swinister Voe categorised water body, and b) location of the study area within the Yell Sound WFD coastal water body.

The OWExR model predicts the concentration of nutrients within a plume of water centred on the site which represents a volume where the nutrient effluent source is rapidly mixed within the timescale of a tidal cycle. The dimensions of this plume and its exchange rate are calculated from parameters derived from hydrographic data where tidal amplitude velocities have been resolved to along-shore (parallel) and across-shore (normal) components. The depth of the plume is limited to that of the pen nets. The nutrient source from the fish farm is assumed to be continuous and derived from the maximum biomass to provide a worst-case source rate. The nutrient concentration is dependent on the rate at which the plume is exchanged by uncontaminated water.

6.2 OWExR model inputs

The nitrogen source rate (S, kg s^{-1}) is calculated according to:

$$S = M_s * 48.2 / 31{,}557{,}600$$

Where M_s is the site maximum licenced biomass, 48.2 is the nitrogen (kg) per tonne of production for Atlantic salmon, and 31,557,600 is the number of seconds in a year. Only salmon are considered here as additional licenced species with a higher nitrogen source has already been demonstrated to have only a negligible impact on ECE (Section 5). Table 5 lists the nitrogen source rate used for each site.

Table 5 Nitrogen source rates for the sites in the OWExR modelling.

SEPA site ID	Site name	Biomass (t)	Nitrogen source rate (kg s^{-1})
FISH1	Fish Holm (existing)	1910	0.002917
FISH1	Fish Holm (proposed)	6000	0.009164
LING1	Linga	2299	0.003511
SETN1	Setterness North	2500	0.003818
HAML1	Hamnavoe	1910	0.002917

Table 6 details the hydrographic surveys at each site that were the sources of the input parameters given in Table 7. As plume depth is limited to the pen net depth as stated on each sites CAR licence (Table 8), the mean values of the reported near-surface and cage-bottom equivalent layers are used for model inputs.

Table 6 Details of the hydrographic surveys at each site used source input parameters for the OWExR modelling.

SEPA site ID	Site name	Survey ID	Survey start	Survey end	Duration (days)
FISH1	Fish Holm	N008	21/04/2022	25/07/2022	95
LING1	Linga	SLING001	13/09/2006	02/10/2006	18[1]
SETN1	Setterness North	T012	03/12/2021	08/03/2022	95
HAML1	Hamnavoe	HAM03001	01/08/2009	18/08/2009	17[1]

[1] Analysis based on a 15-day subset.

Table 7 OWExR hydrographic input parameters.

Fish Holm N008	**Residual speed (m s^{-1})**	**Tidal major axis (°Grid)**	**Parallel amplitude (m s^{-1})**	**Normal amplitude (m s^{-1})**
Cage-bottom	0.0603	360	0.2114	0.1399
Near-surface	0.0730	5	0.1958	0.1387
Mean	0.0667	2.5	0.2036	0.1393
Linga SLING001	**Residual speed (m s^{-1})**	**Tidal major axis (°Grid)**	**Parallel amplitude (m s^{-1})**	**Normal amplitude (m s^{-1})**
Cage-bottom	0.0026	220	0.1255	0.0583
Near-surface	0.0657	70	0.1767	0.1166
Mean	0.0342	145	0.1511	0.0875
Setterness North T012	**Residual speed (m s^{-1})**	**Tidal major axis (°Grid)**	**Parallel amplitude (m s^{-1})**	**Normal amplitude (m s^{-1})**
Cage-bottom	0.0679	65	0.1214	0.1162
Near-surface	0.0784	120	0.1238	0.1200
Mean	0.0731	92.5	0.1226	0.1181
Hamnavoe HAM03001	**Residual speed (m s^{-1})**	**Tidal major axis (°Grid)**	**Parallel amplitude (m s^{-1})**	**Normal amplitude (m s^{-1})**
Cage-bottom	0.0356	25	0.1032	0.0816
Near-surface	0.0450	25	0.1067	0.0851
Mean	0.0403	25	0.1049	0.0833

Table 8 Pen net depth at each site.

SEPA site ID	Site name	Net depth (m)
FISH1	Fish Holm (existing)	15.0
FISH1	Fish Holm (proposed)	18.0
LING1	Linga	10.0
SETN1	Setterness North	17.5
HAML1	Hamnavoe	10.0

6.3 OWExR model outputs

Outputs from the model for each site are given in Table 9. Figure 2 illustrates the scale of each plume for the pre-expansion baseline and for the proposal, including the relinquishment of the CAR licence for Hamnavoe. Plumes are aligned along the mean tidal major axis to illustrate the area of influence.

Table 9 OWExR model outputs for Fish Holm and the sites within 2 km of the proposal.

Parameter	Units	Fish Holm (existing)	Fish Holm (proposed)	Linga	Setterness North	Hamnavoe
Plume						
Length (L)	km	2.92	2.92	2.16	1.76	1.50
Width (W)	km	2.00	2.00	1.25	1.69	1.19
Area (A)	km^2	5.82	5.82	2.71	2.97	1.79
Volume (V)	Mm^3	87.29	104.75	27.11	51.98	17.95
Flushing Time						
Minimum flushing time (FT_{MIN})	hrs	11.8	11.8	16.2	6.4	9.5
Median flushing time (FT_{MEDIAN})	hrs	12.1	12.1	17.2	6.6	10.2
Maximum flushing time (FT_{MAX})	hrs	12.1	12.1	17.6	6.7	10.4
ECE						
Minimum ECE (C_{MIN})	$\mu mol\ l^{-1}$	0.101	0.265	0.539	0.121	0.395
Median ECE (C_{MEDIAN})	$\mu mol\ l^{-1}$	0.104	0.272	0.574	0.125	0.426
Maximum ECE (C_{MAX})	$\mu mol\ l^{-1}$	0.104	0.273	0.586	0.126	0.433

Figure 2 Indicative plume extents and maximum ECE for a) the existing scenario, and b) following expansion at Fish Holm, including relinquishment of the Hamnavoe CAR licence. The Swinister Voe categorised area is demarked with the green line.

6.4 Discussion

Following expansion Fish Holm has a maximum ECE of 0.273 µmol N l^{-1} representing increase of 162% compared to the existing consent. This level remains within the 0 to 0.3 µmol N l^{-1} range equivalent to a nutrient enhancement index of 1. Among the sites assessed, Fish Holm has a largest plume forming over the 12.5hr semi-diurnal tidal period reflecting the dispersive currents observed. However, Figure 2 should be interpreted with caution regarding the indicative location of the plumes and the degree of overlap, as they are based solely on site-specific measurements. Consequently, confidence decreases with increasing distance from the source.

Despite the uncertainty, Figure 2 highlights the potential for plume interaction between Fish Holm, Setterness North and Linga. Under certain conditions these plumes may intersect, resulting in a cumulative concentration of up to 0.985 µmol N l^{-1}. This value lies at the upper end of the 0.3–1.0 µmol N l^{-1} range, corresponding to a nutrient enhancement index of 2. This would be more likely to occur on the flood tide to the south and therefore reflects the inclusion of dissolved nitrogen from Fish Holm as having the potential to influence to the categorised area.

7 Availability of dye and drogue data.

A dye and drogue dispersion study was undertaken at Fish Holm in April 2024 (AMSL, 2024b). Drogue movements from the site were compared against modelled drogue releases as part of the hydrodynamic model validation report (SSF, 2025b). Both documents and supporting data are included in the CAR application submission. Figure 3 illustrates the paths of the eight dye patch centres (maximum fluorescence) following releases throughout the tidal cycle. Paths represent an average tracking period of 56 minutes.

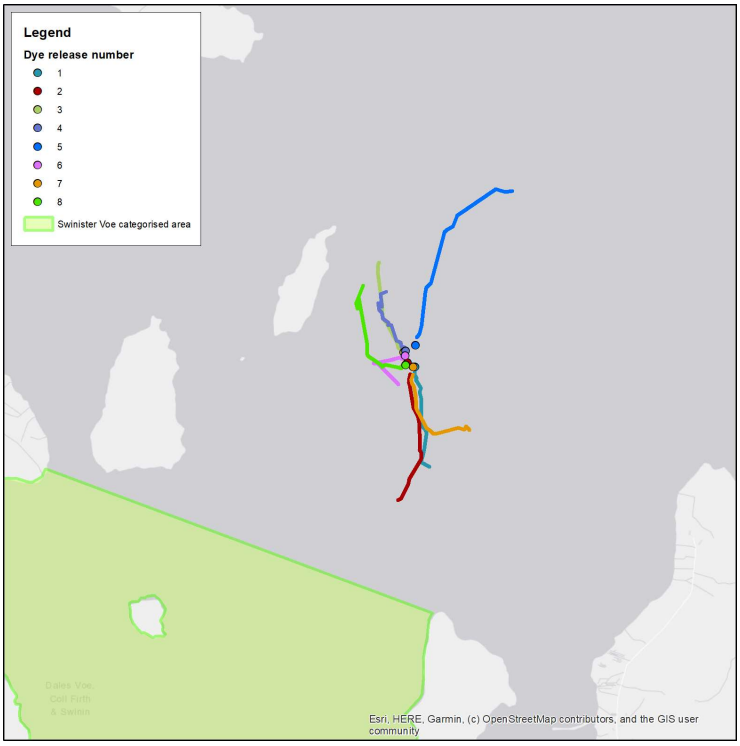

Figure 3 Advection paths of dye patch centres during release periods.

Figure 4 illustrates the tracks of seven drogue releases over the same period. For both dye and drogue releases, the tracks fall roughly on the same north-south axis of the tidal excursion plume calculated in the OWExR modelling in Section 6. The first six releases were tracked for a mean period of 1.3 hours and, as with the dye tracks, cover a large proportion of the 12.5-hour tidal excursion plume rectangle. The dispersive conditions of the wider area are highlighted by release 7. This occurred just after low water and was tracked over an eight-hour period (Figure 4b). The initial the path is to the south and then due east. After this the drogue reverses course and is transported back to the release point before passing to the north of Fish Holm and into Yell Sound where it is rapidly carried north. Individual markers on this plot are at two-minute intervals.

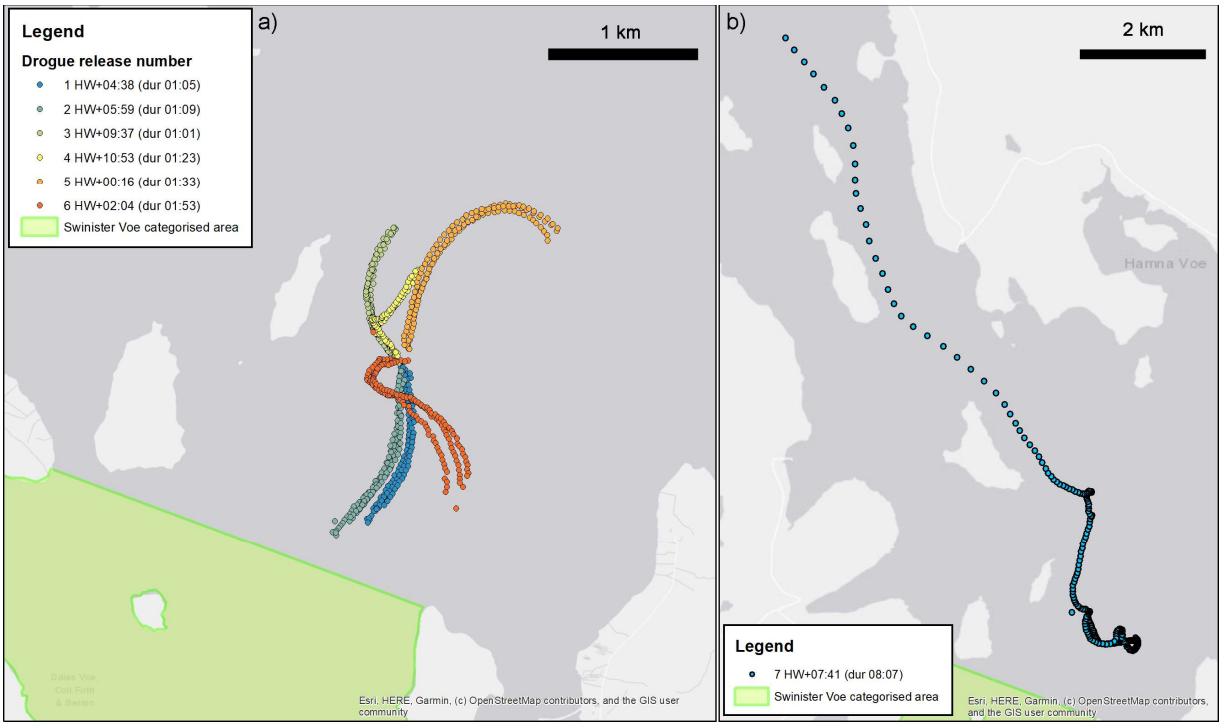

Figure 4 a) drogue tracks for releases 1 to 6, and b) drogue track for release 7, extended duration.

8 Assessment of the transport of modelled bath treatment plumes.

Simulations of bath treatment releases are described in the bath medicine dispersion report (SSF, 2025a) which accompanies the planning and the CAR applications. The treatments azamethiphos and deltamethrin are modelled during spring and neap tides, with 3 treatments per day over 4 days and as such plume transport at various times during the tidal cycle is represented. EQS assessment is undertaken at 3-hours post-treatment for azamethiphos and 6-hours post-treatment for deltamethrin. Plots of all 48 plumes simulated are included in the bath medicine dispersion report. Figures 5 and 6 overlay all plumes collating their locations at 3-hours and 6-hours post release at various points of the tidal cycle. Not all treatments result in a plume which indicates dispersive conditions lead to medicine concentrations below 1 ng l^{-1} or that the plume is transported beyond the extents of the plot.

Dispersive conditions are evident with most plumes being transported north into Yell Sound or are heading east towards the North Sea. There are no instances in the available snapshots of plumes being transported towards the constrained waters of Swinister Voe, highlighting that the risk of eutrophication is low.

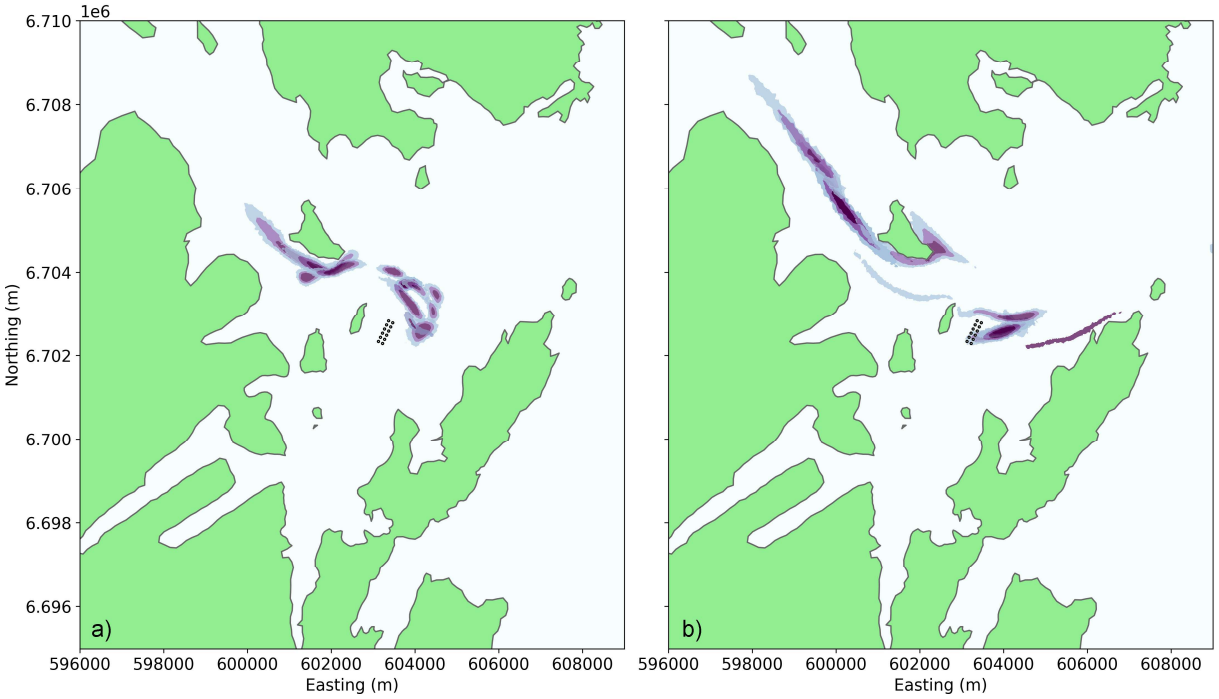

Figure 5 Azamethiphos plumes at 3 hours following release overlain for a) spring, and b) neap tides.

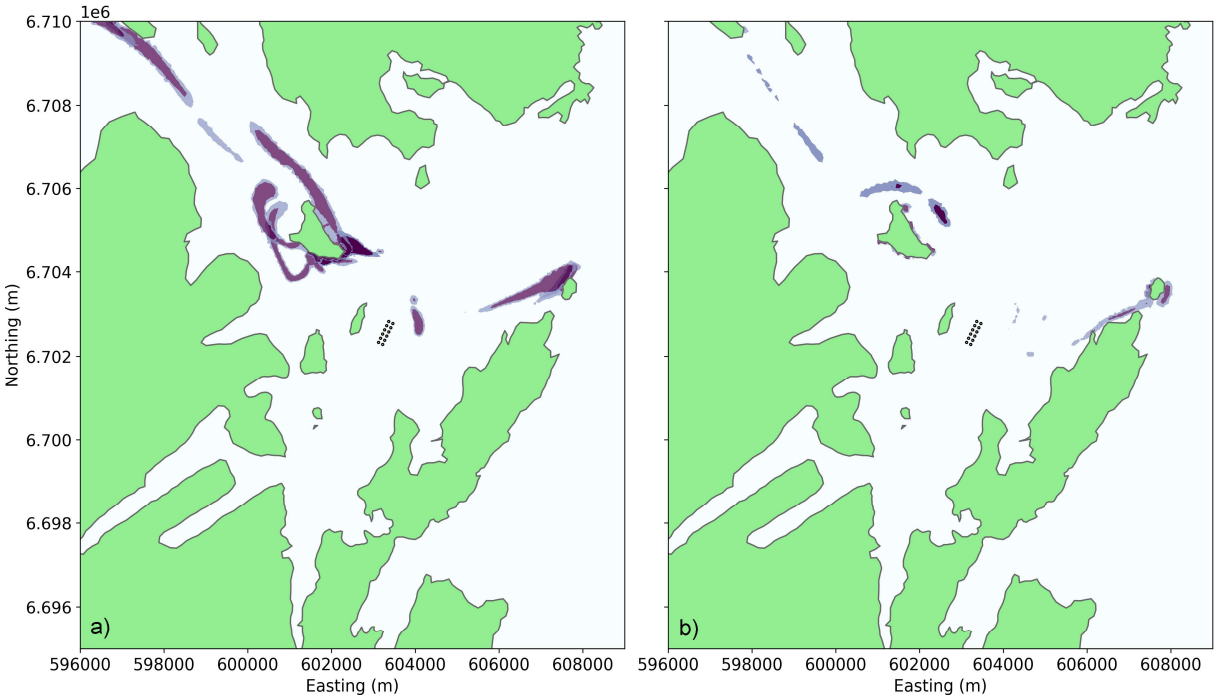

Figure 6 Deltamethrin plumes at 6 hours following release overlain for a) spring, and b) neap tides.

9 References

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