BRING HEAD, SCAPA FLOW

NewDEPOMOD and BathAuto Report

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1. Executive Summary

This report presents modelling undertaken by Scottish Sea Farms Ltd. for the proposed modification of the marine fish farm at Bring Head, Scapa Flow, Orkney (CAR/L/1015854). The proposal would relocate the centre point 198m ENE, replacing the existing infrastructure with two groups of six 120m circumference cages and increasing the maximum biomass from 968t to 2,500t. Impact assessment followed current SEPA modelling guidance where solid and sea lice treatment discharges are simulated with NewDEPOMOD configured to the standard default approach, while bath treatment releases are modelled using BathAuto. Results indicate that the environmental impact from this proposal would meet the relevant EQS criteria. Proposed benthic sampling stations along four transects are detailed in the Environmental Monitoring Plan. Site details and recommended consent limits are summarised in Table 1.1.

Table 1.1 Recommended consent limits at Bring Head.

Infrastructure	Cage number and size: 12no. 120m circumference. Arrangement: (2x6) x2 Cage separation: 70m Net depth: 12m
Biomass	A maximum biomass of 2,500t and stocking density 15.15kg/m³
Emamectin Benzoate (Slice)	A maximum treatment quantity (MTQ) and a total allowable quantity (TAQ) of 875g. These are sufficient to treat the maximum biomass of 2,500t
Azamethiphos (Salmosan)	The total quantity of azamethiphos to be discharged should not exceed 609g in a 3-hour or 629.1g in a 24-hour period. The 24-hour limit is equivalent to a treatment volume of 6,091m³ which can be used to treat a single cage with a treatment depth of 1.83m three times per day.
Deltamethrin (Alphamax)	The total quantity of deltamethrin to be discharged in a 3-hour period should not exceed 41.34g. The equivalent treatment volume is 20,668m³, exceeding the normal cage volume and therefore permitting flexibility in the treatment depth used

2. Introduction

This document is a technical summary of an assessment undertaken by Scottish Sea Farms Ltd. using NewDEPMOD and BathAuto for a proposed relocation and change to the configuration of the Bring Head marine fish farm. Information on the methodologies employed and in the accompanying modelling files are intended to support an application to the Scottish Environment Protection Agency (SEPA) under the Controlled Activities Regulations ((CAR) 2011) to vary the existing permit for the site by providing the recommended maximum biomass and proposed quantities of the sea lice treatments Slice, Salmosan and Alphamax, as well as proposing a benthic monitoring plan.

2.1 Site details

The Bring Head marine fish farm is located to the north of Hoy, Orkney towards the western entrance to Scapa Flow (Figure 2.1). The site is strongly influenced by tidal currents with a mean spring range of 2.9m (Stromness), as well as being exposed to a fetch across the breadth of Scapa Flow to the east. The proposed relocation of the site increases the distance to the shore from 293 m to 485 m into deeper, more dispersive waters and increasing the mean depth beneath the cages from approximately 20.6 mCD to 32.0 mCD. Details of the existing and proposed infrastructure are provided in Table 2.1.

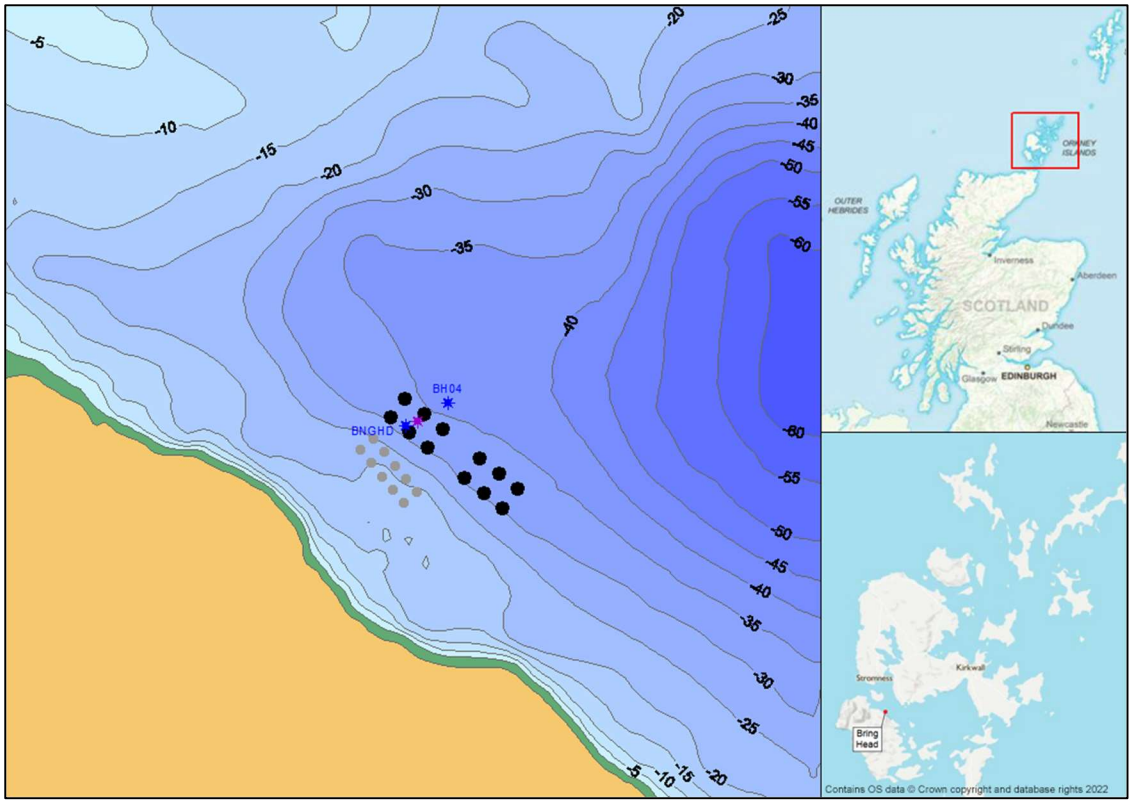

Figure 2.1 Location of the Bring Head marine fish farm illustrating the ADCP deployments and the weighted average position (purple) relative to the proposed and existing cages (black and grey respectively). Bathymetry derived from Admiralty Chart ref. 35-0.

Table 2.1 Bring Head site infrastructure and consent details.

	Existing	**Proposed**
Cage group centre location	327382E, 1002164N	Group 1: 327681E, 1002128N Group 2: 327464E, 1002304N
Number of cages	10	12
Cage circumference	80m	120m
Net depth (m)	10m	12m
Mooring grid spacing	50m	70m
Orientation	321°	309°
Layout	2 x 5	2no. 2 x 3
Average water depth	21mCD	32mCD
Distance to shore (site centre)	293m	485
Maximum biomass	968t	2500t
Emamectin benzoate	MTQ: 338.8g, TAQ: 1245.6g	MTQ/TAQ: 875g
Azamethiphos	3hr: 305.5g, 24hr: 305.5g	3hr: 609g, 24hr: 629.1g
Deltamethrin	3hr: 45.23g	3hr: 41.34g
Stocking density	19kg m^{-3}	15.15kg m^{-3}

3. Model input details

NewDEPOMOD version 1.4.0 final was configured according to the "standard default" approach as outlined by SEPA (SEPA 2019, SEPA 2022a). The project was named *BringHead2022* and was generated using the User Interface with the input, physical, configuration and model properties files subsequently modified according to the aforementioned guidance.

The proposed site has a predicted Wave Exposure Index of 2.89 at the overall centre point (327573E, 1002216N) (Marine Scotland, 2015). As this is greater than 2.8 to meet the extent EQS the total area impacted with deposition above 250g m^{-2} should not exceed 120% of the calculated 100m mixing zone area. The mean deposition within the mixing zone should not exceed 4,000g m^{-2} to satisfy the intensity EQS. Assessment is based the mean deposition over the final 90-days of output from the model run.

3.1 Hydrographic data

The standard default approach requires a uniform flow field from one or more current meter deployments with a combined duration of at least 90-days. Two hydrographic surveys have been undertaken at the proposed site (in 2018 & 2022) and these data are used to create the 90-day composite flowmetry. Full details of these surveys including data collection, processing, summary statistics and the creation of the composite 90-day dataset can be found in the accompanying document *Bring Head Modelling Data Collection* Report, March 2022. These data have been approved by SEPA to use in a modelling assessment.

Summary statistics for the 90-day composite flowmetry are repeated in Table 3.1. Located on the southern side of Hoy Sound the site is significantly influenced by the strong tidal streams present in the sound. Currents are primarily bi-directional through the water column along a NW-SE axis aligned with the local topography. Some variation is observed in the vertical profile with a greater influence of currents to the NW present near the seabed. The flow field across the model domain is likely to be highly dynamic resulting from the strong flood tidal streams flowing around the island of Graemsay and merging and slowing in this part of Hoy Sound, generating large scale eddies around the principal SE current. This is evident in observations from the site which all show a counter-flow to the NW for the latter part of the flood tide while water levels are still rising at Bring Head and elsewhere in Scapa Flow.

Compared to the 2008 hydrographic study conducted inshore of the existing site the proposed location is very similar in terms of magnitude although current speeds above the resuspension threshold are less frequent in the former (Xodus 2008). Modern observations further from the shore exhibit greater bias for flow to the NW reflected in the lower residual speeds recorded in 2008, indicating that flow along the tidal axis is more balanced closer to the shore.

Table 3.1 Summary statistics for the 90-day composite dataset at Bring Head.

Weighted average position and depth (m)	327467E 1002307N, 37.37mCD		
	Near-bed	**Cage-bottom**	**Sub-surface**
Weighted average height above seabed (m)	2.87	27.60	32.60
Mean velocity (m s^{-1})	0.136	0.153	0.154
Min velocity (m s^{-1})	0.001	0.004	0.001
Max velocity (m s^{-1})	0.507	0.557	0.563
Ranked percentage 0.095 m s^{-1}	30.7%	28.6%	28.0%
Major axis (°G)	315	315	310
Amplitude anisotropy	2.46	2.89	2.78

Continued…

Table 3.1 continued.

Residual velocity (m s^{-1})	0.053	0.040	0.031
Residual direction (°G)	316.2	301.3	309.1
Residual to mean velocity ratio	38.6%	26.0%	20.2%
Parallel Residual (m s^{-1})	0.053	0.038	0.031
Normal Residual (m s^{-1})	0.001	-0.009	0.000
Parallel tidal amplitude (m s^{-1})	0.189	0.229	0.233
Normal tidal amplitude (m s^{-1})	0.077	0.079	0.084

The height above seabed values for 'Flowmetry.meterDepths' and 'Flowmetry.siteDepth', as well as the 'Flowmetry.siteX/YCoordinates' were derived from the weighted mean of these parameters from both deployments.

The residual current in the near-bed layer of the 90-day composite dataset is 38.6% of the mean velocity, exceeding the threshold defined by SEPA whereupon the residual component should be removed from the flow data and used in the standard default approach to determine maximum biomass. To aid monitoring transect planning comparative runs were also undertaken with the full flow and the tide only flowmetries, the later derived from harmonic analysis of the 90-day composite dataset.

The vertical dispersion coefficient for the resuspension phase ($\sigma_{z,r}$) is defined using the mean flow speed (u) in the near-seabed layer from the 90-day composite dataset according to:

$$\sigma_{z,r} = 0.0003\ u^{-0.762}$$

Table 3.2 details the vertical dispersion coefficients for the flowmetries used.

Table 3.2 Flowmetry specific vertical dispersion coefficients.

Flowmetry	Near-bed mean speed (m s^{-1})	Vertical dispersion coefficient (m^2 $s^{-1)}$
Full Flow	0.136	0.001369879
No residual	0.126	0.001451467
Tide only	0.099	0.001742579

3.2 Bathymetry

The area is well represented in the local Admiralty Chart (ref. 35-0 *Scapa Flow & Approaches*, 1:30,000) and has comprehensive coverage of bathymetry survey data on the UKHO Marine Data Portal. Plotting the latter indicate that the charts are based on bathymetry surveys commissioned by Orkney Islands Council in 2009. The model domain is a 2 km x 2 km regular grid made up of 25 m grid cells with the following bounding coordinates:

Domain.spatial.minX= 326378
Domain.spatial.maxX= 328378
Domain.spatial.minY= 1001305
Domain.spatial.maxY= 1003305

Digitised chart data were interpolated from a file of irregularly distributed point samples (X,Y,Z) to create a regular two-dimensional array of depths using MATLAB. The mean tidal level was added on to all wet values and all values below half of the tidal range were converted to dry values (10). Remaining wet values were then replaced by the weighted mean ADCP depth (-37.37m) to create

the uniform bathymetry array required under the standard default approach NewDEPOMOD configuration.

The site is located on the steeply shelving southern shore of Hoy Sound at the western extent of the Bring Deeps, the deepest part of Scapa Flow. Further to the west the seabed shoals rapidly into The Fleshes/Burra Sound on the southern side of Graemsay.

3.3 NewDEPOMOD inputs

As per standard default approach requirements the waste discharge timeseries was based on the site constantly being at the proposed maximum biomass for a 365-day simulation period. This is generated using the parameters outlined in SEPA 2022a, namely a feed rate of 7 kg per tonne biomass per day, a waste feed rate of 3%, feed water content at 9% and feed digestibility of 85%.

The infeed treatment emamectin benzoate (EMBZ) is modelled over a 118-day simulation period using the recommended dose rate of 50 µg of EMBZ per kg of biomass per day for the 7-day treatment period, with 97% of the medicated feed consumed and 3% associated with waste feed. Of the consumed feed 10% of the EMBZ load is excreted immediately with the remaining 90% excreted at an exponential rate according to an excretion half-life of 36 days.

Both the proposed and the existing configurations were modelled, with cage positions for the later derived from AutoDEPOMOD modelling for the site (Xodus 2008).

3.4 NewDEPOMOD run details

All runs are undertaken with 10 particles and are detailed in Table 3.3 below.

Table 3.3 Model run details

Identifier	Layout	Run type	Flowmetry
1	Existing	Biomass	No residual
2	Proposed	Biomass	No residual
3	Proposed	Biomass	Full flow
4	Proposed	Biomass	Tide only
5	Existing	EmBZ	No residual
6	Proposed	EmBZ	No residual

To establish the maximum permissible quantity of EmBZ for the proposal, compliance is assessed against the requirements for applications at existing farms already authorised to use emamectin benzoate as outlined in current SEPA guidance (SEPA 2022a, SEPA 2021a) and the Interim Position Statement on emamectin benzoate discharges (SEPA 2022b).

For proposals at existing sites the overall intention is that the risk of environmental harm is not increased which requires the existing infrastructure to be modelled at the presently licenced TAQ to establish the extent of deposition at the interim EQS (0.0655 µg kg^{-1} wet weight sediment). A quantity of emamectin benzoate is determined by varying the overtreatment factor until the degree of non-overlap between the area of existing impact at the EQS and that resulting from the proposal is not considered significant; namely that the seabed impacted by new areas of deposition is below 15% of the existing impact.

3.5 BathAuto inputs

The SEPA tool *BathAuto_v5.xls* was used to determine the recommended quantities of bath treatments for the proposed cage configuration at Bring Head. Input parameters follow guidance given in SEPA 2019 with the revised 5.6-day half-life adopted for azamethiphos (Table 3.4). The average water depth was determined using Admiralty chart bathymetry for an area of 4 km^2

(equivalent to the NewDEPOMOD model domain). The hydrographic input data were taken from *BH90d_ver2_NS_HGdata_analysis_v7.xls* for the 90-day composite data set used to represent the near-surface layer in NewDEPOMOD.

Table 3.4 BathAuto input parameters for Bring Head.

Loch Data	
Loch/Strait/Open water:	Open Water
Loch area (km^2):	(only required for loch)
Loch length (km):	(only required for loch)
Distance to head (km):	3.63
Distance to shore (km):	0.49
Width of Strait (km):	(only required for strait)
Average water depth (m):	26.98
Flushing time (days):	n/a
Cage Data	
No. of cages:	12
Cage shape:	Round
Diameter/Width (m):	38.2
Working depth (m):	12
Stocking density (kg/m^3):	15.15
Treatment (Azamethiphos)	
No. of cages possible to treat in 3 hours:	2
Initial Treatment Depth (m):	1.83
Treatment Depth Reduction Increment (m):	0.01
Half-life (days):	5.6
Treatment (Deltamethrin)	
No. of cages possible to treat in 3 hours:	2
Initial Treatment Depth (m):	9.2
Hydrographic data analysis	
Mean current speed (m/s):	0.154
Residual Parallel Component U (m/s):	0.031
Residual Normal Component V (m/s):	0.000
Tidal Amplitude Parallel Component U (m/s):	0.233
Tidal Amplitude Normal Component V (m/s):	0.084

4. Modelling Results

4.1 Biomass results

Output was analysed using MATLAB with scripts derived from SEPA on the aggregate surface of the final 90 days of the model run. EQS compliance is achieved at a maximum biomass of 2,500t with deposition covering 60% of the available mixing zone area (expanded) and at a level of 9% of the intensity EQS standard (Table 4.1, Figure 4.1).

Table 4.1 Bring Head NewDEPOMOD biomass results assessment, Run 2

Parameter	Value	Units
Extent EQS		
100m composite mixing zone target area	187,430	m^2
100m composite mixing zone target area (120%)	224,916	m^2
Area of mean deposition >250g solids m^{-2} yr^{-1}	135,000	m^2
Intensity EQS		
Mean Mixing Zone deposition standard	4,000	g m^{-2} yr^{-1}
Mean deposition within 250g m^{-2} yr^{-1} solids contour	350	g m^{-2} yr^{-1}

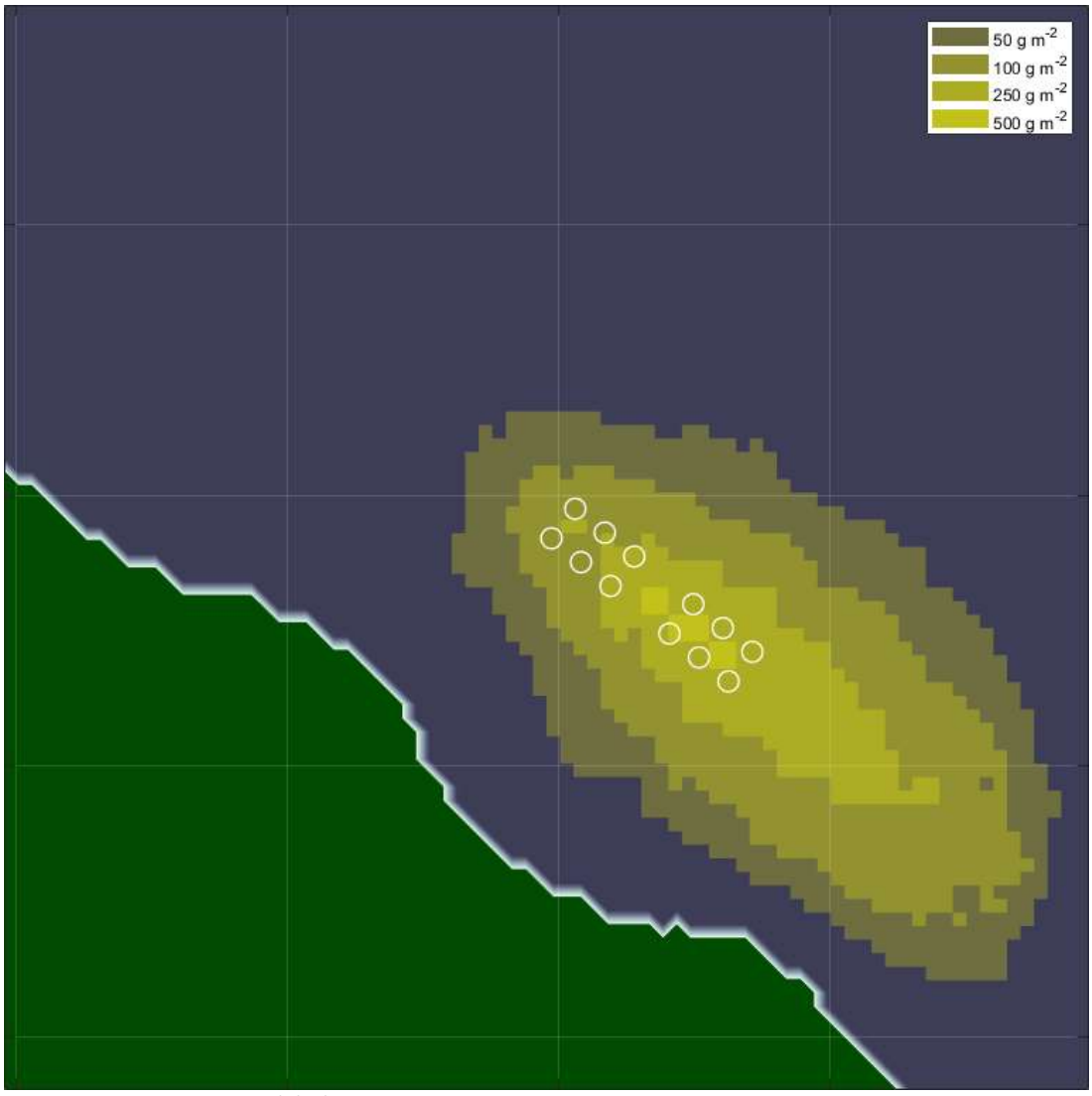

Figure 4.1 Mean solids deposition from the last 90-days of model Run 2, with residual currents removed.

It is unlikely that simulations forced by flowmetry that have had the residual component removed in the near-seabed layer can adequately represent the spatial distribution of benthic impact at the site. Compared to the full flow flowmetry (Run 3), resultant transport in the opposing direction to the residual current is reflected in the displacement of deposited material to the SE in the model output. The intensity of deposition is also unlikely to be represented by NewDEPOMOD given the benthic monitoring results out to 50m from the existing site.

Considering this, two additional simulations were undertaken in order to represent the area to the northwest; one forced by the full flow observed hydrographic data (Run 3, Figure 4.2, lower plot) and the second using the astronomic tide derived from the harmonic constituents extracted from the observed flow data using the UTide toolbox in MATLAB (Run 4). The resulting synthetic flowmetry is a reproduction of the tidal component of the flow. Both forcings produced similar output and neither resulted in peak deposition which exceeded 250g m^{-2} yr^{-1}.

4.1.1 Proposed Environmental Monitoring Plan

Benthic monitoring transects and sampling stations are defined according to draft SEPA guidance (SEPA 2021b) to inform the proposed Environmental Monitoring Plan submitted with this application. Four sampling transects (T1-T4) have been positioned at orthogonal angles from the cage groups with seven sampling stations placed along each transect (Figures 4.2-3, Table 4.2). T2 is situated to avoid the area of seabed occupied by the existing cage group. As the predicted deposition forced by the full flow flowmetry lies to the NW, T3 is defined with a similar length to T1 although station spacing here accommodates the required exclusion buffers around two submarine power cables.

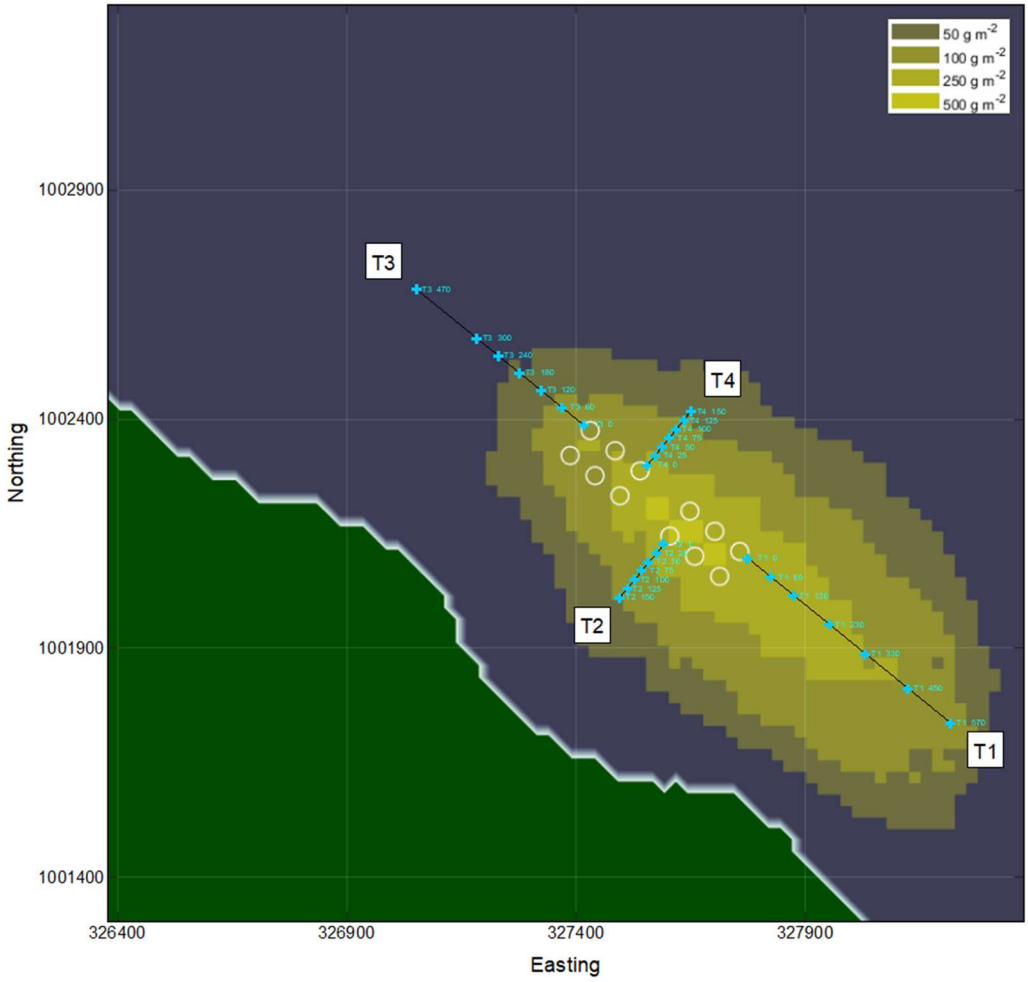

Figure 4.2 Bring Head proposed monitoring transects overlain on deposition using flowmetry with residual removed (Run 2).

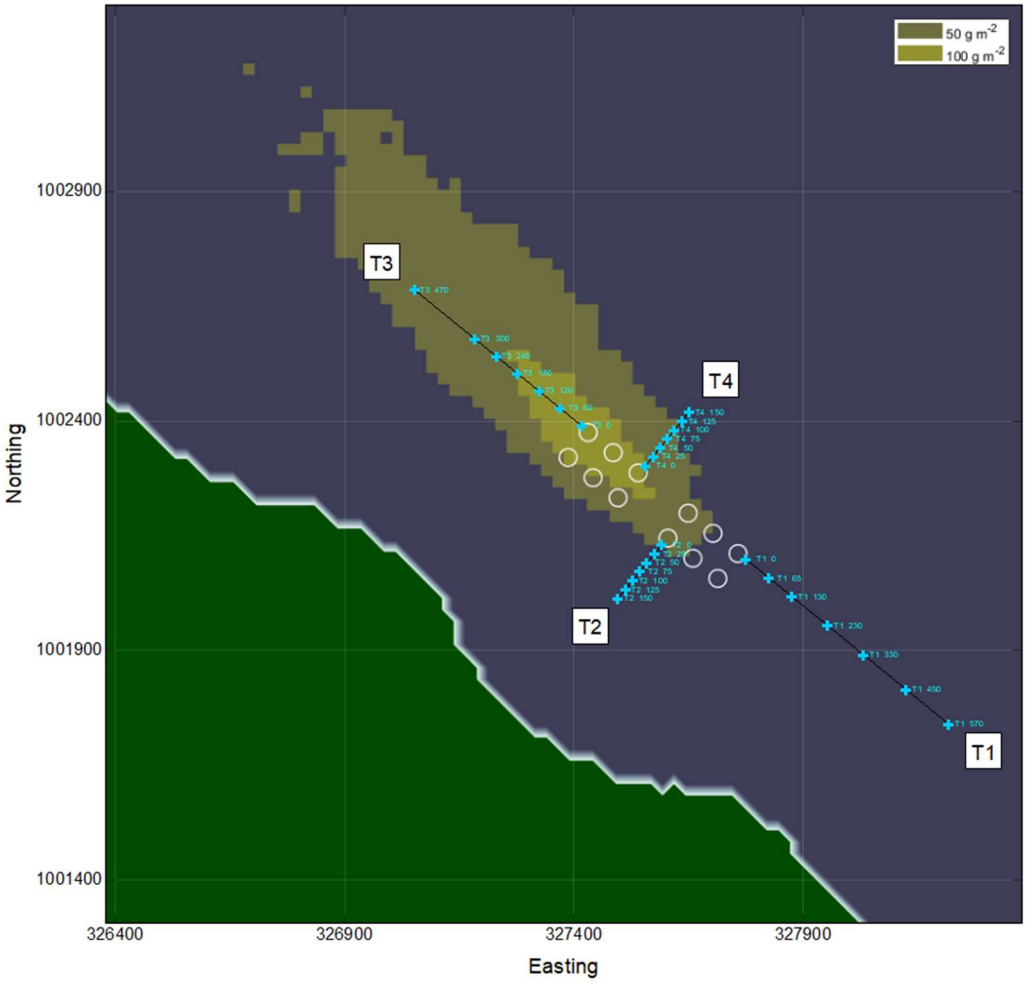

Figure 4.3 Bring Head proposed monitoring transects overlain on deposition using full flow flowmetry (Run 3).

Table 4.2 Bring Head monitoring transect and sampling station details.

Transect	Origin	Bearing °G	Station Distances (m)
T1	327775E, 1002093N	129	0, 65, 130, 230, 330, 450, 570
T2	327590E, 1002125N	219	0, 25, 50, 75, 100, 125, 150
T3	327416E, 1002388N	309	0, 60, 120, 180, 240, 300, 470
T4	327557E, 1002298N	39	0, 25, 50, 75, 100, 125, 150

4.2 Emamectin benzoate results

Output for the existing and proposed layouts were analysed using MATLAB with scripts derived from SEPA on the aggregate surface for the final 2 days of the model runs.

With a proposed treatment quantity of 875g, sufficient to treat the proposal at maximum biomass, NewDEPOMOD estimates that the areas of newly impacted seabed would account for 6.05% of the existing impact area and are therefore comfortably below the 15% threshold. Additionally, a smaller proportion of the initial mass released will be exported from the model domain, decreasing from 51% to 48%. The proposed quantity is 70% of that presently licenced for use.

4.3 BathAuto results

The recommended consent limits in terms of the active ingredients of the two bath treatments intended for use at the proposal are given below.

4.3.1 Azamethiphos (Salmosan)

Recommended consent mass (3h): 609g
Equivalent treatable volume: 6,090m^3

Recommended consent mass (24h): 629.1g
Equivalent treatable volume: 6,291m^3

Treatment depth – 1.83 m (15.3% of the full cage volume)

Number of cages per treatment: 1 every 3 hours, 3 times per day.

4.3.2 Deltamethrin (Alphamax)

Recommended consent mass (3h): 41.34g
Equivalent treatable volume: 20,668m^3

Treatment depth – the available treatable volume exceeds the full working cage volume permitting flexibility in the treatment depth selected, likely limited to 35% of the full cage volume in the CAR licence or a treatment depth of 4.2m. This would potentially allow for multiple cages to be treated every 3-hours.

5. Conclusions

NewDEPOMOD simulations using the conservative standard default approach demonstrate that the proposed re-configuration of the Bring Head fish farm would meet the relevant EQS criteria. At the proposed maximum biomass of 2,500 tonnes 60% of the available mixing zone area would be utilised at this moderately exposed site with the mean deposition within this area at level which is 9% of that permitted.

The residual flow has been removed from the near-seabed data forcing the model as part of this approach to ensure the most conservative representation of the impact. This results in a depositional footprint which has a bias to the southeast that is counter to what would be expected from the observed currents. An initial environmental monitoring plan is therefore proposed to cover the entirety of this area and potential impact, the results from which will be used to calibrate and validate more advanced NewDEPOMOD simulations using accurate bathymetry and a spatially varying flow field derived from a hydrodynamic model.

Sea lice treatments have been remodelled for the proposed reconfiguration which demonstrates that there are adequate medicinal options to treat the whole site timeously. Modelling emamectin benzoate at a quantity equivalent to treating the proposal while at maximum biomass demonstrates that the depositional footprint largely overlaps the area already impacted at the licenced quantity by the existing fish farm, and that new areas of impacted seabed are not significant (<15% of existing). Furthermore, the material exported from the vicinity of the cage group is reduced at the proposed quantity. This has been derived through the application of the SEPA Interim Position Statement at farms already authorised to use emamectin benzoate where impact from the proposal remains within the existing environmental footprint.

To use the maximum quantity of azamethiphos in a 24-hour period a single cage reduced to 15.3% of the working volume every three hours with three treatments per day is permissible without exceeding Environmental Quality Standards. Treatment of the entire site could feasibility be completed within four days. The 3-hour limit would permit a larger treatment volume through reducing the number of cages treated per day.

The quantity of deltamethrin equates to a treatable volume that far exceeds the full working cage volume permitting flexibility in the treatment depth selected. In practice this would be no greater than 4.2m (35% of the working volume) potentially allowing treatment of multiple cages every three hours. Treatment of the entire site could be completed within three days or less.

6. References

Marine Scotland (2015). Wave Exposure Index (Wave Fetch Model) via Marine Scotland Maps: National Marine Plan Interactive (NMPi). Available online: https://marinescotland.atkinsgeospatial.com/nmpi/default.aspx?layers=780 (Accessed 02/07/2020).

SEPA (2019). Regulatory Modelling Guidance for the Aquaculture Sector. Version 1.1. Available online: https://www.sepa.org.uk/media/450279/regulatory-modelling-guidance-for-the-aquaculture-sector.pdf. (Accessed 08/07/2019).

SEPA (2022a). NewDepomod Draft Guidance – 25/01/2022. Available online: https://www.sepa.org.uk/media/594117/220207_-regulatory-modelling-guidance-for-the-aquaculture-sector_interim-update.zip. (Accessed 16/02/2022).

SEPA (2021a). Application of the Interim Position Statement on emamectin benzoate discharges – Technical Guidance. Available at https://www.sepa.org.uk/media/483186/application-of-the-interim-position-statement-on-emamectin-benzoate-discharges.pdf (accessed: 20/07/21).

SEPA (2021b). Seabed environmental standards Demonstrating compliance (Draft). 19 July 2021

SEPA (2022b). Interim position statement for protecting the water environment in relation to emamectin benzoate in finfish farm regulation (July 2022). Available online: https://www.sepa.org.uk/media/594312/position-statement-embz-july-2022.pdf (accessed: 01/08/22).

Xodus AURORA (2008). Bring Head Chemo-therapeutant Modelling Technical Report, August 2008.