TOYNESS, 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 Toyness, Scapa Flow, Orkney (CAR/L/1015855). The proposal would relocate the centre point 127m SW, replacing the existing infrastructure with two groups of six 120m circumference cages and increasing the maximum biomass from 1342.9t 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 Protocol. Site details and recommended consent limits are summarised in Table 1.1.

Table 1.1 Recommended consent limits at Toyness.

Infrastructure	Cage number and size: 12no. 120m circumference. Arrangement: (2x6) x2 Cage separation: 80m 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 291.8g in a 3-hour or 566.1g in a 24-hour period. The 24-hour limit is equivalent to a treatment volume of 5,661m³ which can be used to treat a single cage with a treatment depth of 2.47m twice per day.
Deltamethrin (Alphamax)	The total quantity of deltamethrin to be discharged in a 3-hour period should not exceed 19.8g. The equivalent treatment volume is 9,905m³.

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 Toyness 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 an environmental monitoring plan.

2.1 Site details

The Toyness marine fish farm is located on the northern shore of Scapa Flow, Orkney (Figure 2.1). The site is influenced by tidal currents with a mean spring range of 2.9m (Stromness), as well as being influenced by strong wind forcing which can dominate the tidal pattern. This location is exposed to a 7 to 12 km fetch from the NE through to the SW across Scapa Flow. The proposed relocation of the site increases the distance to the shore from 297 m to 376 m into an area of comparable mean depth beneath the cages of 29mCD. Details of the existing and proposed infrastructure are provided in Table 2.1.

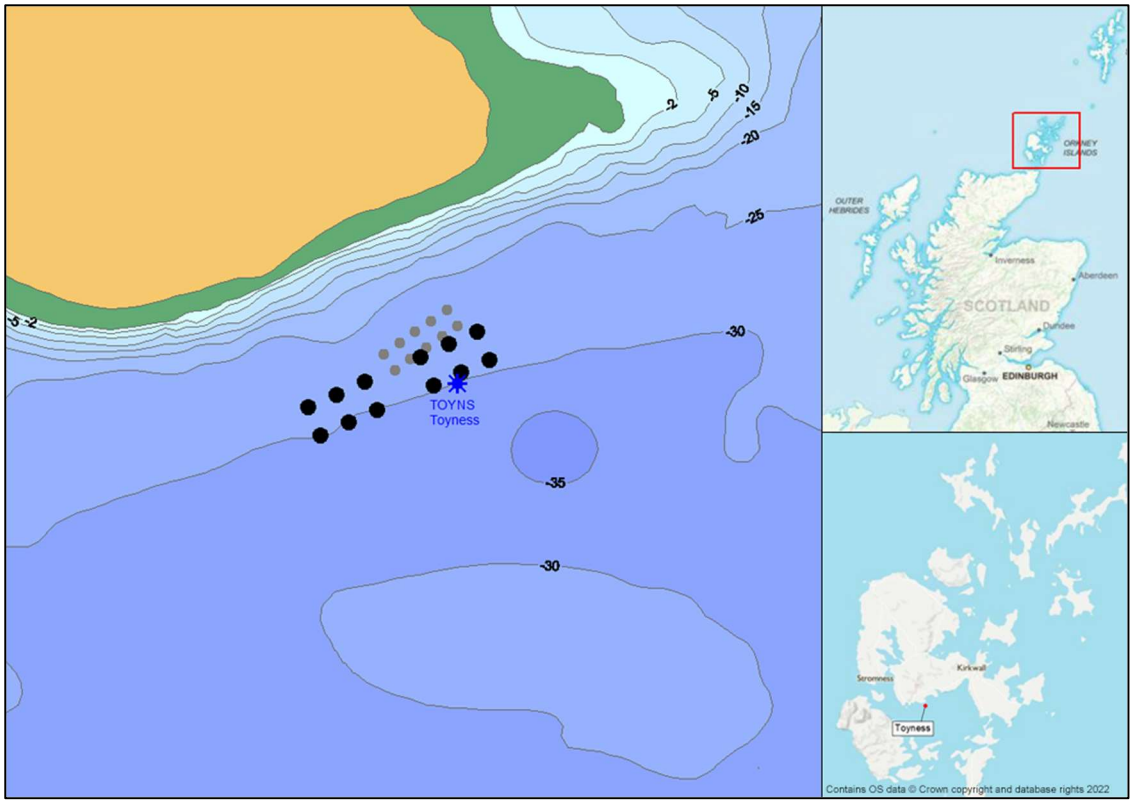


Figure 2.1 Location of the Toyness marine fish farm illustrating the ADCP deployments relative to the proposed and existing cages (black and grey respectively). Bathymetry derived from Admiralty Chart ref. 35-0.

Table 2.1 Toyness site infrastructure and consent details.

	Existing	**Proposed**
Cage group centre location	335441E, 1003699N	Group 1: 335239E, 1003520N Group 2: 335531E, 1003651N
Number of cages	10	12
Cage circumference	80m	120m
Net depth (m)	15m	12m
Mooring grid spacing	50m	80m
Orientation	55.0°	65.9°
Layout	2 x 5	2no. 2 x 3
Average water depth	28mCD	29mCD
Distance to shore (site centre)	297m	376m
Maximum biomass	1342.9t	2500t
Emamectin benzoate	MTQ: 470g, TAQ: 2350.1g	MTQ/TAQ: 875g
Azamethiphos	24hr: 458.2g	3hr: 291.8g, 24hr: 566.1g
Deltamethrin	3hr: 20.41g	3hr: 19.8g
Stocking density	17.6kg 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 2022). The project was named *Toyness2022* 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 2.94 at the overall centre point (335385E, 1003586N) (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, both in 2018, 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 *Toyness Modelling Data Collection* Report, March 2022. These data have been approved by SEPA to use in a modelling assessment.

Located on the northern shore of Scapa Flow data from the site demonstrate a clear tidal signature with the flood flowing to the ENE and ebb to the WSW, an axis aligned with the local topography. The site is also influenced by strong wind forcing which can suppress or enhance a particular tidal flow depending on the wind direction, in some cases producing periods of unidirectional flow over multiple tidal cycles.

Compared to the 2005 hydrographic study conducted SW of the existing site and inshore of the proposed location, the modern data are marginally less energic closer to the seabed with a lower mean speed and fewer instances of current speeds above the resuspension threshold. The 2005 data show the tidal axis aligned slightly more to the south however a shorter survey period may not capture the potential for wind influence.

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

Weighted average position and depth (m)	335537E 1003584N, 31.27mCD		
	Near-bed	**Cage-bottom**	**Sub-surface**
Weighted average height above seabed (m)	2.78	21.78	26.78
Mean velocity (m s^{-1})	0.059	0.073	0.074
Min velocity (m s^{-1})	0.001	0.001	0.001
Max velocity (m s^{-1})	0.241	0.344	0.369
Ranked percentage 0.095 m s^{-1}	84.0%	72.6%	72.2%
Major axis (°G)	250	255	255
Amplitude anisotropy	2.3	3.4	3.4
Residual velocity (m s^{-1})	0.029	0.023	0.014
Residual direction (°G)	258.5	247.5	234.9
Residual to mean velocity ratio	40.1%	31.0%	18.7%

Continued…

Table 3.1 continued.

Parallel Residual (m s^{-1})	0.028	0.022	0.013
Normal Residual (m s^{-1})	0.004	-0.003	-0.005
Parallel tidal amplitude (m s^{-1})	0.081	0.109	0.115
Normal tidal amplitude (m s^{-1})	0.035	0.032	0.034

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 40.1% 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 flowmetry.

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	0.059	0.002576145
No residual	0.054	0.002789901

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= 334511
Domain.spatial.maxX= 336511
Domain.spatial.minY= 1002574
Domain.spatial.maxY= 1004574

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 (-31.27m) to create the uniform bathymetry array required under the standard default approach NewDEPOMOD configuration.

Water depth increases rapidly close to the shore at the Toy Ness peninsular to a gently shelving area between 26-38 metres around the proposed site with little variation from this beyond the model domain.

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 2022, 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	Existing	EmBZ	No residual
5	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 2022, SEPA 2021a) and the Interim Position Statement on emamectin benzoate discharges (SEPA 2021c).

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 (0.01175 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 Toyness. Input parameters follow guidance given in SEPA 2019 with the recommended 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 *TN90d_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 Toyness.

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):	1.95
Distance to shore (km):	0.38
Width of Strait (km):	(only required for strait)
Average water depth (m):	27.1
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:	1
Initial Treatment Depth (m):	2.47
Treatment Depth Reduction Increment (m):	0.01
Half-life (days):	5.6
Treatment (Deltamethrin)	
No. of cages possible to treat in 3 hours:	1
Initial Treatment Depth (m):	8.6
Hydrographic data analysis	
Mean current speed (m/s):	0.074
Residual Parallel Component U (m/s):	0.013
Residual Normal Component V (m/s):	0.005
Tidal Amplitude Parallel Component U (m/s):	0.115
Tidal Amplitude Normal Component V (m/s):	0.034

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 2,500 tonnes with deposition covering 82% of the available mixing zone area (expanded) and at a level of 77% of the intensity EQS standard (Table 4.1, Figure 4.1).

Table 4.1 Toyness NewDEPOMOD biomass results assessment, Run 2.

Parameter	Value	Units
Extent EQS		
100m composite mixing zone target area	211,431	m^2
100m composite mixing zone target area (120%)	253,717	m^2
Area of mean deposition >250g solids m^{-2} yr^{-1}	207,500	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	3,076	g m^{-2} yr^{-1}

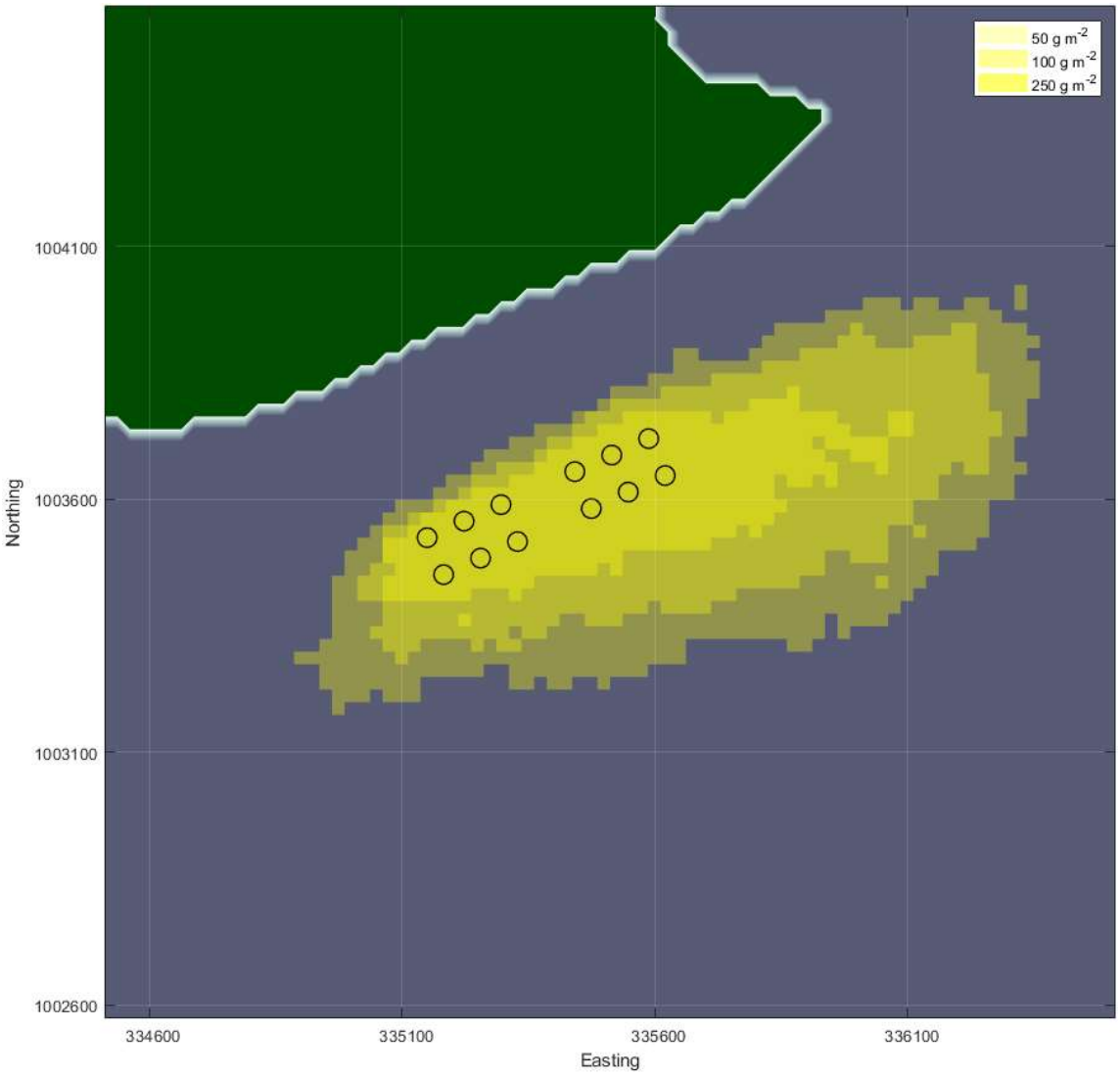
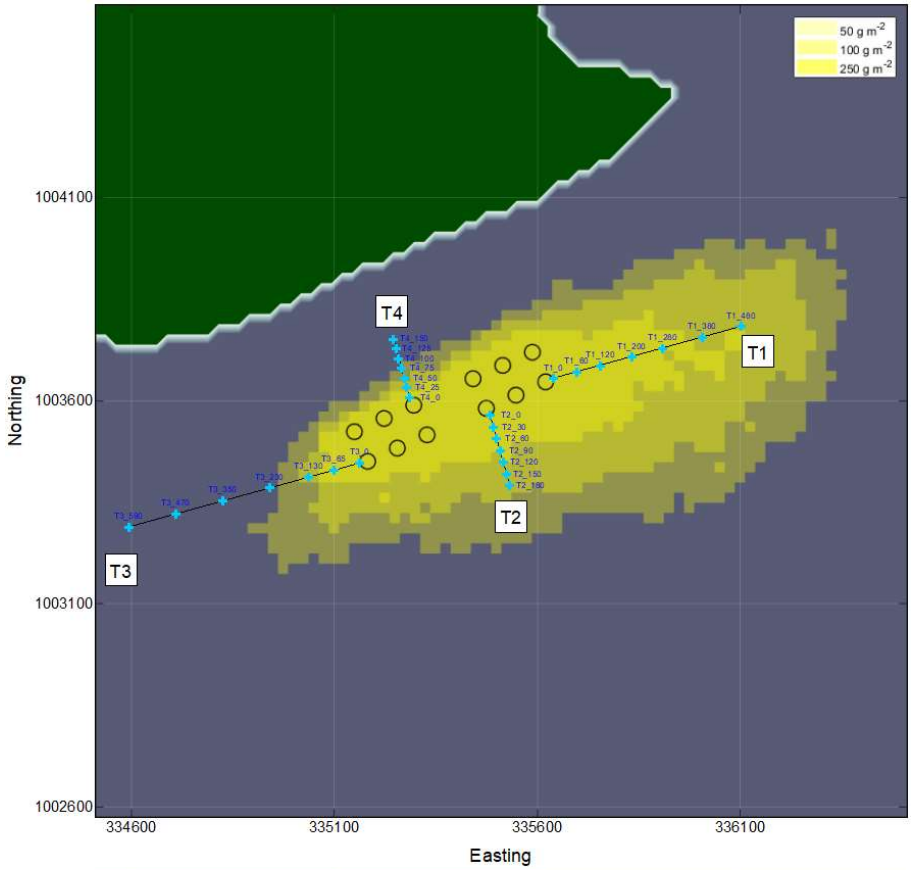


Figure 4.1 Mean solids deposition from the last 90-days of model Run 2, with residual currents removed.

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 NE in the model output. Considering this, an additional simulation was undertaken in order to represent the area to the southwest forced by the full flow hydrographic data including the residual currents (Run 3, Figure 4.2, lower plot).

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 (Figure 4.2, Table 4.2). T4 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 SW, T3 has been defined with a similar length to T1.



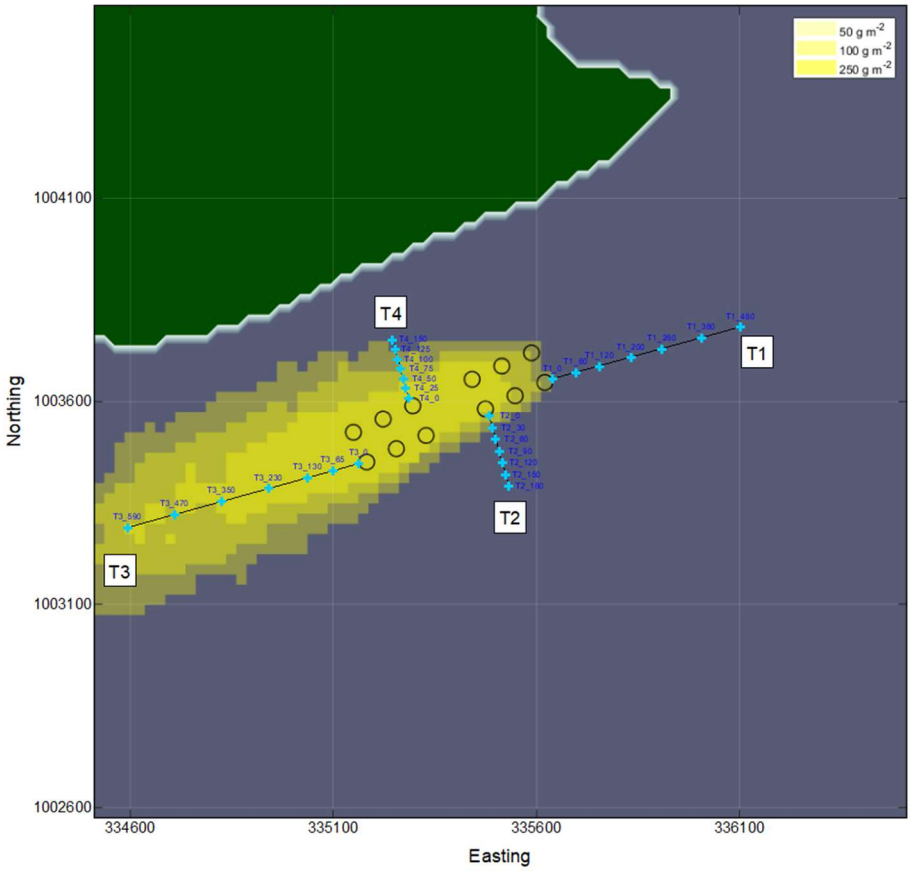


Figure 4.2 Toyness proposed monitoring transects overlain on deposition using flowmetry with residual removed (top) and full flow (bottom).

Table 4.2 Toyness monitoring transect and sampling station details.

Transect	Origin	Bearing °G	Station Distances (m)
T1	335639E, 1003653N	74.5	0, 60, 120, 200, 280, 380, 480
T2	335483E, 1003563N	164.5	0, 30, 60, 90, 120, 150, 180
T3	335162E, 1003446N	254.5	0, 65, 130, 230, 350, 470, 590
T4	335285E, 1003607N	344.5	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 9.6% 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 4.6% to 1.5%. The proposed quantity is 37% 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): 291.8g
Equivalent treatable volume: 2,918m^3

Recommended consent mass (24h): 566.1g
Equivalent treatable volume: 5,661m^3

Treatment depth – 2.47m (20.6% of the full cage volume)

Number of cages per treatment: 1 every 3 hours, 2 times per day.

4.3.2 Deltamethrin (Alphamax)

Recommended consent mass (3h): 19.81g
Equivalent treatable volume: 9,905m^3

Treatment Depth – up to 8.6m (72% of the full cage volume), 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 Toyness fish farm would meet the relevant EQS criteria. At the proposed maximum biomass of 2,500 tonnes 82% 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 77% 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 strong bias to the northeast that is counter to what would be expected from the observed currents. An initial environmental monitoring protocol 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 20.6% of the working volume every three hours with two treatments per day is permissible without exceeding Environmental Quality Standards. Treatment of the entire site could feasibility be completed within six days, although a greater reduction in the cage volume to around 13% may be feasible at certain times during the production cycle which would permit three treatments per day while remaining with the 24-hour limit.

The quantity of deltamethrin recommended would allow treatment of a single cage reduced to 72 % of the working volume every three hours without exceeding the EQS. In reality greater reductions, or treatment of multiple cages at an equivalent volume in the same time period would be favoured. Treatment of the entire site could be conducted 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 (2022). 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 (2021c). WAT-PS-17-03: Interim position statement for protecting the water environment until such time as a direction is issued on an EQS in relation to Emamectin Benzoate in finfish farm regulation (version 3, January 2021). Available online: https://www.sepa.org.uk/media/558670/interim-position-statement-on-emamectin-benzoate-discharges.pdf (accessed: 20/07/21).

Xodus AURORA (2008). Toy Ness Chemo-therapeutant Modelling Technical Report, November 2008.