SEPA
Scottish Environment Protection Agency
Buidheann Dìon Àrainneachd na h-Alba

FISH FARM SURVEY REPORT

EVALUATION OF A NEW SEABED MONITORING APPROACH TO INVESTIGATE THE IMPACTS OF MARINE CAGE FISH FARMS

October 2018

Scope

The purpose of this report is to present the findings from a SEPA marine cage fish farm survey. It presents key findings from the data collected during the survey including the impact of the fish farms surveyed on benthic ecology and the levels of sea lice medicines found in sediments.

Executive summary

Purpose

In May and June 2017 SEPA conducted a large survey of marine fish farm sites in Shetland. The purpose of the survey was to:

i. Trial a proposed approach for measuring the area of benthic impact from marine cage fish farms.
ii. Use new sampling and analysis methods to establish environmental concentrations of the sea lice medicine emamectin benzoate near to and beyond the fish farms surveyed.
iii. To assess the impact of individual fish farms on a water body.

Method

At each farm two or three transects were sampled, along with a minimum of two reference stations. In total, eight fish farms and one water body were surveyed equating to 302 samples at 93 sample stations for chemical analysis and 296 samples at 142 sample stations for ecological analysis. Samples for chemical analysis were analysed for the sea lice medicines emamectin benzoate (EmBz) and teflubenzuron (Tef), as well as the supporting parameters total organic carbon (TOC), loss on ignition (LOI) and particle size (PSA). The area of benthic impact was derived by determining the Infaunal Quality Index (IQI), a measure of ecological status at each sampling station along each transect. IQI ecological status thresholds were then used to calculate an elliptical area of impact.

The new ultra-sensitive analytical method developed by SEPA in 2017 for the analysis of EmBz in marine sediment is approximately 25 times more sensitive than the previous method. This increased sensitivity enabled this survey to detect levels of EmBz in the marine environment at concentrations that have so far not been reported in the scientific literature.

Results: sea lice medicines

EmBz is only used in the UK as a fish medicine for the treatment of sea lice infestations. Tef has not been available in the UK as a sea lice medicine since 2015 and the last reported treatment in the farms included in the survey was in September 2013.

The presence of a chemical in the environment does not necessarily mean that it is causing harm. We judge the environmental significance of detectible concentrations of a chemical by comparing them with environmental quality standards (EQS).

SEPA regulates fish farms by reference to two standards a near-field standard (applies from the edge of the cage up to 100m) and a far-field standard (applies at and beyond 100m from cage edge). Recent studies have suggested that the standards for EmBz should be much tighter and we have consequently reported our results against the current standards and the proposed standards.

The ultra-sensitive analytical techniques used in this survey found that EmBz was more widely distributed in the environment (in 98% of samples taken) than had been found in previous surveys. In general, concentrations of EmBz decreased with increasing distance from farms. Concentrations at cage edge were above the current near-field standard at 17% of stations and were above the current far-field standard at 7% of stations. When concentrations were

compared to the lower proposed EmBz standards 100% of near-field stations and 75% of far-field stations had concentrations above the standards.

Tef was also detected in 46% of sampling stations. There were no exceedences of the near-field standard but 36% of sampling stations (further than 100m from the cages) exceeded the far-field standard. Tef is known to persist in marine sediments and its detection in this survey may reflect its historic use and chemical properties.

Results: ecology

Results from the benthic ecology analysis show a gradient of impact, decreasing with distance from the farms. Survey averaged IQI results followed a broad spatial gradient related to distance from cages, with typically low IQI values associated with a Poor classification at the cage edge, progressing to Moderate and Good along the transects.

The multi-directional transect approach allowed ecological impact to be calculated (using Good status as a threshold) around seven of the eight marine cage fish farms included in the survey. This demonstrates that this approach is suitable for assessing the impacts of marine cage fish farms.

A statistical analysis of the ecological data showed that seabed community composition was most associated with particle size, and secondarily with TOC and EmBz. This analysis also showed that EmBz concentration had the single biggest negative effect on both total crustacean abundance and species richness. It was also the most important environmental factor affecting the distribution of individual crustacean species.

Both the sea lice medicine residue and benthic ecology results suggest that the impacts of individual farms may not be contained to the immediate vicinity of the farm.

Conclusions

This survey demonstrates the successful application of new, improved monitoring and analysis techniques for assessing the impacts of marine cage fish farms. The survey provides a strong scientific basis from which we can develop the monitoring of fish farms and will inform the development of SEPA's regulatory approach.

The new ultra-sensitive test for EmBz found that the chemical was present at nearly all sampling stations. This indicates that environmental exposure to EmBz was wider than has previously been found. Tef was also found to be present at a number of locations. A small proportion of these sampling stations also failed the current EQS for both these chemicals and a significant portion failed the proposed EQS for EmBz.

Statistical analysis showed that EmBz had the biggest negative effect on the crustacean abundance and richness. This effect was detectable below the current EQS, this adds to the weight of evidence that the current EQS may not be protective of benthic ecology beyond the 100m from the cages.

These results indicate that the impacts of farms may extend beyond their immediate vicinity. Further work is now required to understand the wider-scale cumulative impacts.

Glossary of abbreviations & terms

AMBI – AZTI Marine Biotic Index (AZTI relates to the name of the organisation that developed this marine biotic index): AZTI Marine Biotic Index (AMBI) is a measure of overall pollution sensitivity for a benthic assemblage.

AZE – Allowable Zone of Effect: The modelled footprint of the area predicted to be impacted by the fish farm. Compliance assessment is measured at the cage edge and the AZE.

CAR – Water Environment (Controlled Activities) (Scotland) Regulations 2011. https://www.sepa.org.uk/media/34761/car_a_practical_guide.pdf.

EmBz – Emamectin Benzoate: In feed medicine for the control of sea lice in farmed finfish.

EQS – Environmental Quality Standard: The legal allowable concentration of a chemical in the environment according to *Supporting Guidance WAT-SG-53 Environmental Quality Standard and Standards for Discharges to Surface Water.*

Far-field – a sample taken greater than 100m from cage edge.

GPS – Global Positioning System.

IQI – Infaunal Quality Index: The environmental quality ratio used to derive ecological status in marine sediments in the UK.

LOD – Limit of Detection: the analytical concentration detection limit, below which concentrations cannot be established using the prescribed analytical method.

LOI – Loss on Ignition (%): A measure of the proportion of organic material in a sediment sample derived by assessing the amount of material lost upon ignition of the sediment.

MCFF – Marine Cage Fish Farm.

Near-field – on the seabed at the cage edge.

NMBAQCS – North East Atlantic Biological Analytical Quality Control Scheme: The quality assurance scheme used by European member states for marine biological data.

PSA – Particle Size Analysis: The percentage of particle size classes within a sediment sample, in this report this refers to the <63µm fraction unless otherwise stated.

QuEChERS - Quick, Easy, Cheap, Effective, Rugged and Safe: The method employed for solid phase extraction of EmBz from marine sediment.

Reference station – a site that is thought to be representative of background conditions of the water body.

Richness – Number of species in a sample.

SEPA – Scottish Environment Protection Agency.

Tef – Teflubenzuron: An in feed medicine for the control of sea lice in farmed finfish.

TOC – Total Organic Carbon (%): The proportion of organic carbon within a sediment sample.

WASSP – Wide Angle Sonar Seafloor Profiler: The technology used to map seabed bathymetry.

WB ID – Water Body Identification: The code used to identify individual water bodies under WFD.

WFD – Water Framework Directive.

WRc – Water Research Centre.

WFD class band widths relate to biological changes as a result of disturbance as follows:

Status	**Disturbance**
High	negligible
Good	slight
Moderate	moderate
Poor	major
Bad	severe

Contents

1 Introduction

1.1 Background to the survey

SEPA is currently reviewing a number of aspects of marine finfish aquaculture regulation including, how benthic impacts are defined, standards for sea lice medicine residues and the combined impacts of multiple farms on a water body.

To gain greater understanding to inform these three key work areas SEPA conducted a large aquaculture survey in Shetland in the early summer of 2017. The aims of the survey were to:

i. Trial a new proposed approach for measuring the area of benthic impact from marine cage fish farms (MCFF).
ii. Use new sampling and analysis methods to establish environmental concentrations of emamectin benzoate near to and beyond the MCFFs surveyed.
iii. To assess the impact of individual MCFFs on a water body.

This report details the results of the survey in line with these aims.

1.2 Background to site selection & conditions

Shetland contains a high density of MCFFs and provided varying flow and sediment conditions within a relatively small geographical area, allowing intensive testing of the methodologies at farms during the survey period.

It was not possible to obtain samples from all of the sites initially planned for the survey due to a variety of weather conditions and mechanical issues. Alternative sites were selected whilst on-survey that matched the conditions of the sites that could not be sampled. The final sites sampled are within three geographical areas: Colgrave Sound, East Mainland and Clift Sound, and are outlined in the map in Figure 1.

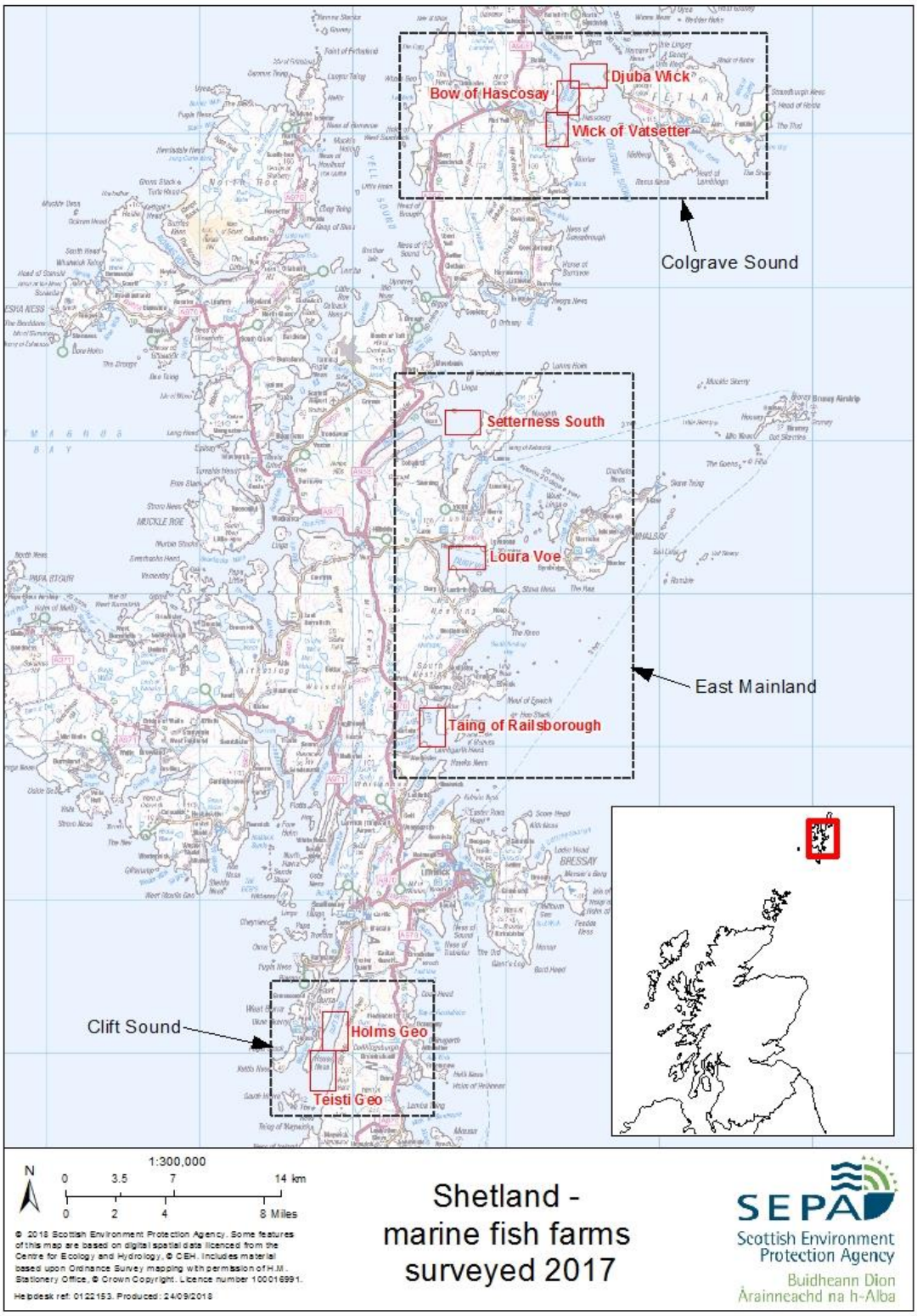

Figure 1. Location of MCFFs surveyed in 2017

1.2.1 Colgrave Sound

Within the Colgrave Sound area of Shetland lies the Bluemull Sound to West Fetlar water body (**WB ID 200289**). The water body has a surface area of 81km^2 and water body classification of Good for 2016. It contains 13 active MCFFs, of which three were sampled during this survey; Djuba Wick, Bow of Hascosay and Wick of Vatsetter.

Colgrave Sound is a highly dynamic area with strong currents circulating around the sound. SEPA has recently developed a hydrodynamic model for the area that shows fast flow in most parts of the sound with the exceptions of the more sheltered voes, bays and inlets where deposited material may accumulate. The sediment type in the region is largely coarse sand and maerl beds with patchy areas of finer muddier sediments, according to UKSeaMap[1].

1.2.2 East Mainland

There are four waterbodies in this area that included MCFFs sampled during the survey.

Setterness South MCFF is in Yell Sound (**WB ID 200503**) with a surface area of 171km^2 and a water body classification of Good for 2016. There are 12 licensed MCFFs of which seven are currently active. The sediment type varies between coarse sediment and rock throughout Yell Sound, but is mostly sand and muddy sand around the farm.

Loura Voe MCFF is in Dury Voe (**WB ID 200267**) with a surface area of 14km^2 and water body classification of Good for 2016. It contains three active MCFFs and is a moderate size water body, with less dynamic flow in comparison to Colgrave Sound. The sediment type is hard and rocky throughout the voe.

Taing of Railsborough is the only active MCFF in Cat Firth (**WB ID 200260**), which is a small water body with a surface area of 3.5km^2, and a water body classification of Good for 2016. Flow is more sluggish and less dynamic in comparison to Colgrave Sound and the sediment type is sand to muddy sand.

Vidlin Voe (**WB ID 200273**) is a small water body with a surface area of 2.9km^2 and a water body classification of Good for 2016. There are four licenced MCFFs in the water body, two of which are currently active. Sampling in this water body was at reference stations remote from the MCFFs designed to assess overall water body impacts. The sediment type is a combination of rock, coarse sediments and mixed sediments.

1.2.3 Clift Sound

Clift Sound (**WB ID 200468**) is a long narrow water body with a surface area of 8.5km^2, and a water body classification of Good for 2016. Of the three active MCFFs in the water body two (Holms Geo MCFF and Teisti Geo MCFF) were sampled during the survey. Clift Sound has a less dynamic flow in comparison to Colgrave Sound and the sediment type varies between sandy mud and mud further in the sound and around Holms Geo MCFF, and muddy sand to sand closer at the mouth of the sound and around Teisti Geo MCFF.

2 Methods

2.1 Sampling

The survey took place in May and June 2017. At each MCFF three transects were sampled using a 0.045m^2 Van Veen grab. Transect length was determined according to the modelled impact footprint, and positioned so that the sampling transects extended beyond the modelled area of impact. Along each transect four to six locations were sampled for ecological analysis, with chemical residue samples being collected at three sampling points along each transect. Two to three reference stations were also sampled for ecological and chemical parameters. These were at a minimum distance of 500m from the farms where no impact was expected to have occurred.

A Trimble GPS device was used to record an accurate (+/- 0.15m) boat location each time a grab sample was deployed. Sediment grab samples were also taken for particle size analysis (PSA) to support the assessment of chemical and ecological parameters.

2.2 Laboratory analysis

All ecology samples were analysed in accordance to SEPA procedure ME-P-008[a] by NMBAQC accredited analysts and subject to quality assurance.

Chemical samples were analysed according to SEPA in-house procedures for the sea lice medicines emamectin benzoate (EmBz) and teflubenzuron (Tef) and the supporting parameters Particle Size Analysis (PSA), Loss On Ignition (LOI), Total Organic Carbon (TOC) and moisture content.

EmBz was analysed using the newly developed SEPA method which is UKAS accredited to ISO17025 and has a method detection limit of 0.0034µg/kg dry weight of sediment.

Fuller details of the methodologies and procedures used are provided in Appendix 2. The new SEPA EmBz analytical method is being prepared for submission to a peer reviewed scientific journal for publication.

2.3 Data analysis

Where sea lice medicine residues were reported as below the limit of detection (<LOD), values were halved for the purposes of data analysis as per WFD convention. Sea lice medicine residues were compared to the most relevant environmental quality standard and for EmBz, results were also compared to the most relevant of the values proposed as EQS in the 2017 WRc review[2]. The standards are provided in Table 1. For the purposes of these analyses, cage edge (0m) were compared to the near-field standards, stations at greater than or equal to 100m were compared to the far-field standards and those between were compared to both.

The ecological data collected from the survey were used to generate the Infaunal Quality Index (IQI) at each sample station for the purposes of ecological status classification. IQI is a measure of seabed community response to disturbance. These IQI values were used within a statistical model to determine the distance from the cages along each transect where an IQI value of 0.75 (High status) and 0.64 (Good status) was reached. An elliptical area was then

[a] Codes refer to SEPAs internal Q-pulse documentation system

calculated from these three distance values to identify the area of the seabed that falls below 0.75 and 0.64 IQI.

Table 1. Environmental standards for sea lice medicines in marine sediments

	Current SEPA EmBz Standard	WRc proposed EmBz Standard	SEPA Tef Standard
	(in µg/kg wet wt sediment)	**(in µg/kg dry wt sediment)**	**(in µg/kg dry wt sediment)**
Near-Field "Trigger Value" EQS	7.63	0.120	1000
Far-Field EQS	0.763	0.012	2.00

The environmental factors that explained the distribution of the seabed fauna around MCFFs were determined using canonical correspondence analysis, a multivariate statistical technique. The particular effects relating to crustaceans were further analysed using generalised linear mixed effects modelling.

Fuller details of the statistical methodology and the resultant analysis will be presented in a paper which is currently being prepared for submission to a peer reviewed scientific journal for publication.

3 Results

In total, eight MCFFs and one separate water body were sampled during the survey. The results are presented in appendix 3. This equated to 279 chemistry replicate samples at 93 sample stations, with an additional 23 composite samples taken at the Bow of Hascosay and Holms Geo farms, and 296 ecology samples at 142 stations. Additional chemistry composite samples for chemical analysis were taken at two farms to assess variability between chemical replicate samples.

3.1 Chemistry overview

EmBz was widely detected in the sediments around the farms surveyed. At three sites, concentrations detected at cage edge were above the current SEPA near-field standard and at four sites they were above the current SEPA far-field standard. When comparing concentrations to the lower proposed WRc EmBz standards 17 cage edge sites and 49 far-field sites had concentrations above the proposed standards.

Tef was detected in a number of samples collected, with 22 sites having concentrations above the current SEPA far-field EQS. A breakdown of the number of sites with replicate mean averaged samples above the current EQS for EmBz and Tef, and the WRc proposed EQS for EmBz are detailed in Table 2.

Results are presented on a farm basis in the report cards in the appendix 1.

Table 2. Number of sample sites with samples above the current and proposed EmBz EQS and the current Tef EQS.

Site location / EQS Class	Number (and percentage) of sites with EmBz above the current EQS	Number (and percentage) of sites with EmBz above WRc proposed EQS	Number (and percentage) of sites with Teflubenzuron above EQS
Cage Edge	3 (17%)	17 (100%)	0 (0%)
Cage Edge to 100m	0 (0%) near-field EQS 2 (18%) far-field EQS	8 (72%) near-field EQS 9 (82%) far-field EQS	0 (0%) near-field EQS 3 (27%) far-field EQS
Far-Field (>100m)	4 (7%)	49 (75%)	22 (36%)

3.2 Ecology overview

A summary of the IQI results (index value and associated ecological class) for the whole survey by sample station distance from MCFF cage is detailed in Figure 2.

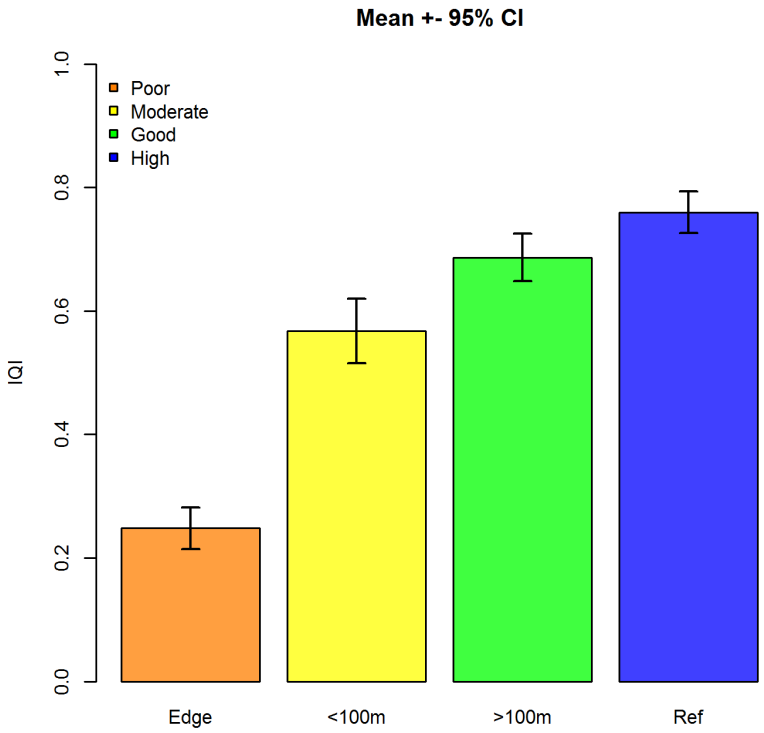

Figure 2. Average IQI and ecological class according to distance from farm.

Survey averaged IQI results followed a broad spatial gradient related to distance from cages, with low IQI values associated with a Poor classification at the cage edge, progressing to Moderate within 100m from the cages, Good above 100m along the transect and High at the reference stations.

3.3 Spatial extent of ecology impacts

Not all planned transects could be completed to a length that allowed for IQI to reach 0.75, this was in some instances due to the geographical location of the farm (e.g. close to the shoreline). At some farm transects the IQI value fluctuated, reaching High status but decreasing again at a greater distance along the transect.

When these issues occurred, the High status distance could not be calculated using the method employed and as such, the High status elliptical area could not be calculated.

There were also instances where the reference stations had IQI values less than High status, only one reference station had an IQI value below Good status. IQI scores by distance from cage are shown in Figure 3, with reference stations shown in blue and the Good - Moderate boundary by the dashed line.

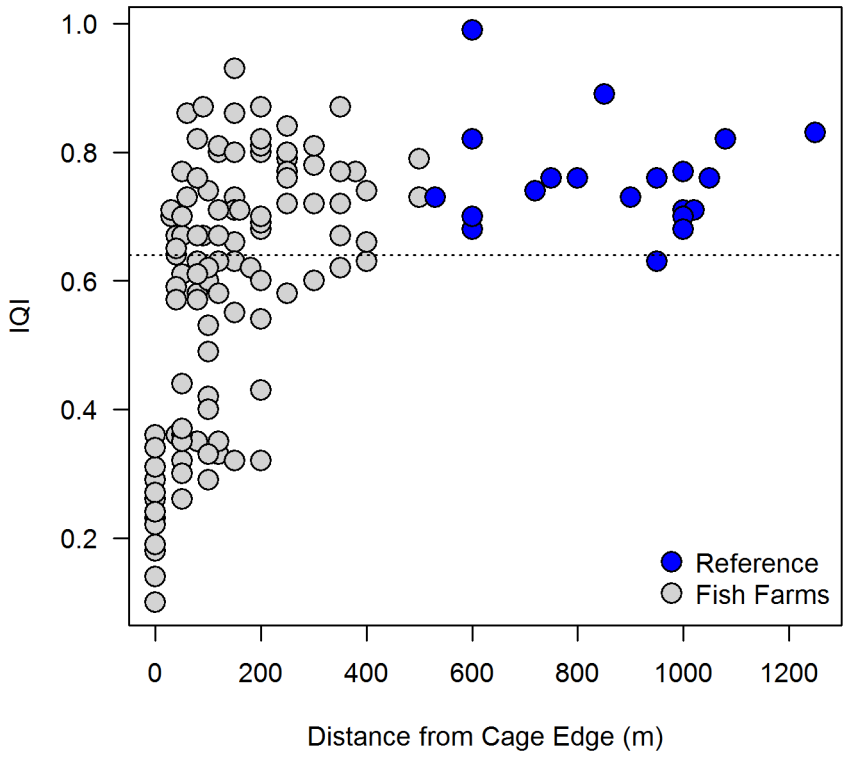

Figure 3: IQI versus distance from cage edge. Dashed line indicates 0.64 Good-Moderate boundary IQI.

3.4 Results of statistical analysis

This section describes the statistical analysis of the ecology data to identify the environmental factors important in describing change in seabed ecology. The statistical analysis used two approaches, a generalised linear mixed modelling (GLMM) approach to determine the effects of environmental parameters on specific benthic ecology parameters (e.g. crustacean abundance and richness) and a canonical correspondence analysis (CCA) to determine the environmental variables that had the biggest effect on the overall benthic community composition. These statistical analyses were possible because chemical and ecological data were collected concurrently.

The CCA analysis showed that overall community composition was most strongly associated with sediment particle size and secondarily with TOC and EmBz concentration. Coarser sediment communities were organised principally along the gradient of EmBz over TOC. The majority of crustacean species in the dataset were restricted to these courser sediments, demonstrating a community level effect particularly for crustaceans that was attributable to variation in EmBz concentration. The majority of crustaceans found in this study were amphipods, which respond to impact differently according to lifestyle. The species with the following characteristics were found at the highest abundance at stations with low EmBz concentration: interstitial burrowing, low mobility and were obligate (by necessity) deposit feeding detrivores.

Further statistical analysis showed that EmBz concentration had the single biggest negative effect on both total crustacean abundance and species richness. It was also the most important environmental factor affecting the distribution of individual crustacean species.

After refinement and selection, the best fitting GLMMs of crustacean abundance and diversity contained the fixed predictors EmBz concentration and predominant direction of flow relative to the fish farm, with EmBz concentration having by far the biggest effect. The effect of EmBz on both crustacean abundance and richness is shown in Figure 4 respectively (note – EmBz was log transformed within the model meaning the relationship is therefore not linear i.e. rate of abundance and diversity reduction increases as concentration increases).

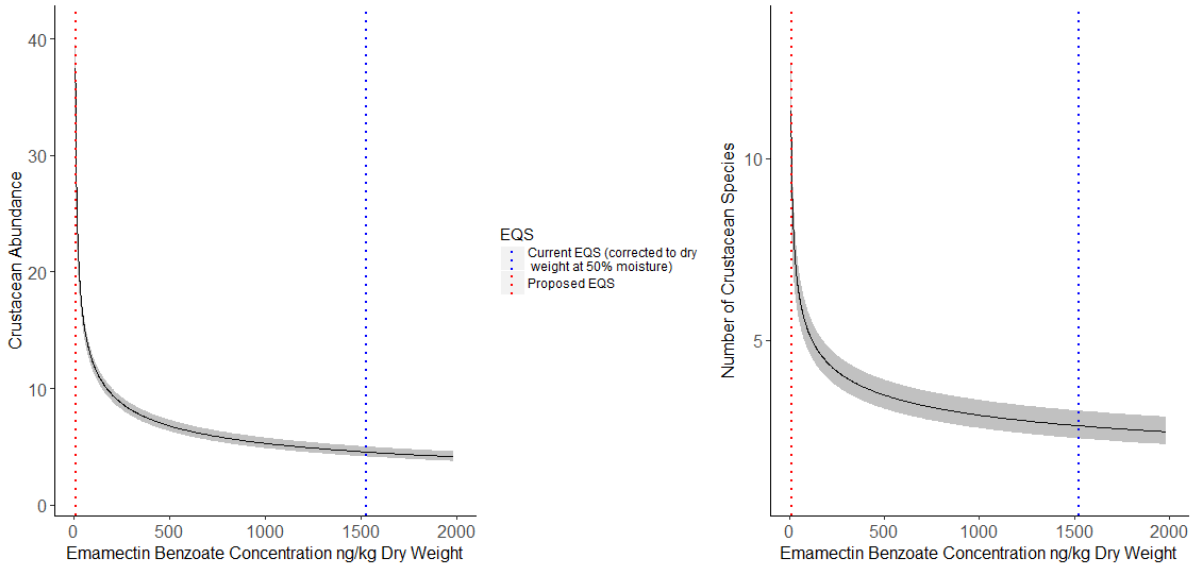

Figure 4: Modelled effect of emamectin benzoate on (a) crustacean abundance and (b) crustacean richness with 95% confidence banding

These findings demonstrate a marked effect of EmBz on the most sensitive group (crustaceans). In terms of EQS values, the plots in Figures 4a and 4b have been labelled with both the current far field EQS (blue line, normalised to sediment moisture content of 50%) and the WRc proposed far field EQS (red line). What this demonstrates is that concentrations at the current EQS are associated with a reduction in crustacean abundance and in crustacean species diversity within this statistical model.

Each fish farm site was considered separately in the model to account for differences between sites not explained by the model predictor. Removing EmBz from the model selection process for both crustacean abundance and species richness demonstrated a significant, albeit weaker effect for TOC. This highlights a degree of collinearity between EmBz and TOC, which to some extent is expected. Both EmBz and TOC were sourced from the same fish farm effluent, meaning they both decrease with distance from the cages. Both EmBz and TOC have demonstrable effects on crustaceans. EmBz interferes with the gamma aminobutyric acid and

chloride channels in crustaceans, which causes a loss of cell function and paralysis. Organic enrichment alters oxygen availability and increases sulphide concentrations within sediment, impacting on sensitive crustacean species inhabiting the sediment surface and subsurface.

These results support the key findings of the PAMP 2 report[3], which linked crustacean impacts to the use of EmBz using national operator returns data. Fuller details of the statistical methodology and the resultant analysis will be presented in a paper which is currently being prepared for submission to a peer reviewed scientific journal for publication (Bloodworth *et al*. in prep).

3.5 Water body survey: Vidlin Voe

A water body survey was conducted in Vidlin Voe, with sample points spread across the voe to assess the overall status.

The water body contains two active MCFFs (Vidlin North and Vidlin Outer) that have been in operation for approximately 20 years. Operator seabed surveys of local impacts associated with both sites have been unsatisfactory in recent years. This suggests the impact footprint of both farms has merged. Operator reported EmBz results have all been below the EQS for near-field and far-field in recent years.

EmBz exposure was investigated in the voe and is indicated by the presence of EmBz at all stations in Vidlin Voe that were analysed, with concentrations in the range of 0.034 – 0.251 µg/kg dry weight of sediment. These results confirm exposure in the range between the current SEPA far-field EQS and the WRc proposed far-field EQS and distribution beyond the immediate vicinity of the farms.

The sediment samples from the survey have IQI values that ranged from 0.66 (Good ecological status) to 0.89 (High ecological status). However, it should be noted that the survey was carried out at the initial stages of the production cycle following a seven month fallow period when low levels of organic enrichment would be expected.

3.6 Site analysis

Site background information is presented alongside key findings from the survey for each site in a report card format in Figures 6 to 13 (see appendix 1). The report cards detail the outcome of the area of impact calculation. A guide on how to use the report cards is given in Figure 5 (see appendix 1).

4 Discussion

This aquaculture survey lasted almost one month in total and generated extensive data for eight MCFFs and one water body. The survey was ambitious in its aims which were to:

i. Trial a proposed approach for measuring the area of benthic impact from MCFFs.
ii. Use new sampling and analysis methods to establish environmental concentrations of the sea lice medicine emamectin benzoate near to and beyond the MCFFs surveyed.
iii. To assess the impact of individual MCFFs on a water body.

The following section discusses the results of the survey within the context of the survey aims.

4.1 Defining the areas of benthic impact from a MCFF

The first aim of the survey was to test a new methodology to measure the area of impact on the seabed around a MCFF.

High ecological status (IQI value of 0.75 or greater) indicates a negligible level of impact to the environment, Good ecological status (IQI of 0.64 to <0.75) indicates that the environment is slightly impacted. To define the area at less-than-High-status and less-than-Good-status an ellipse was calculated from the points along each surveyed transect where the 0.75 and 0.64 IQI conditions were met.

The current monitoring regime requires operators to monitor within one month of returning to 75% biomass following peak biomass. This assumes a worst case scenario in case of organic enrichment. At the time of this SEPA survey two of the eight farms included were at or near peak biomass, so whilst suitable for testing the methodology the ellipses calculated may not be fully reflective of those which would be calculated from data collected at the time when worst case organic enrichment is expected.

It was possible to calculate a less-than-high-status area for four of the eight farms surveyed: Djuba Wick MCFF (0.08km^2), Bow of Hascosay MCFF (0.08 km^2), Holms Geo MCFF (0.09km^2) and Teisti Geo MCFF (0.26km^2). It was not possible to calculate the less-than-high-status area for the other four farms. The reasons for this may be: length of transects required; type of substrate, potential for other influences over these distances including the potential for interactions of footprints from other farms; the ability to robustly discriminate between an IQI of 0.75 and background or reference conditions.

It was possible to define a less-than-good-status ellipse area for seven of the eight farms: Djuba Wick MCFF (0.06), Bow of Hascosay MCFF (0.05), Holms Geo MCFF (0.06) and Teisti Geo MCFF (0.19) Setterness South MCFF (0.34), Loura Voe MCFF (0.07) and Taing of Railsborough MCFF (0.08).

No area could be calculated at Wick of Vatsetter MCFF. This was due to the presence of hard substrate, for which the sampling method used was inappropriate. To address this issue, SEPA is looking to develop monitoring approaches for farms situated over hard substrates. Overall, the survey demonstrated that it was possible to define the area less-than-Good for most sites.

4.2 Environmental concentration of sea lice medicines

The new analytical method developed by SEPA in 2017 for the analysis of EmBz in marine sediment is approximately 25 times more sensitive than the previous SEPA method. This increased sensitivity means that this survey had the ability to detect levels of EmBz in the marine environment at concentrations that have so far not been reported in the scientific literature.

The key finding highlighted in both the survey-wide summary of results and the farm-by-farm summary of the results is that EmBz is much more widely distributed in the environment than has previously been found. In general, concentrations of EmBz decrease with increasing distance from the farms. The nature of the environment and EmBz properties suggest that the low level detections at considerable distances from farms could be indicative of movement of sediments over longer distances from the farms sampled or could be residues from other farms in the surrounding areas.

SEPA's current regulatory approach requires operators to monitor residues of EmBz in sediments collected from cage edge and at a distance (usually 100m) from cage edge. One result is returned for each location, that result being derived from three replicate samples collected at each location. Sampling should be undertaken at the time when residues are at their maxima (this is between 80 and 169 days post-last-treatment). The majority of farms included in this survey were sampled outside this period. Six of the eight farms included in the survey had met the required EmBz standards in their last returns. Two farms did not return data that met the standards, one sampled outside the required period and the other did not return EmBz residue data.

The results presented in section 3.1 demonstrate that three of the eight farms had cage edge stations with residues above the near-field trigger level and two of the eight farms had residues above the far-field EQS (at least one station sampled). These results highlight the difficulty in assessing environmental harm or protection using a small number of data points. This is particularly challenging, when the substance of concern has highly variable sediment concentrations, is relatively persistent, is likely to be bound to sediment, is biologically active at low concentrations and is discharged to a highly dynamic system. The methodology trialled in this survey clearly demonstrates the value of multi-directional sampling in understanding dispersion and the exposure of the environment to EmBz.

Given that treatment rates have been set to meet the current EQS it is not surprising that when the results are compared against the proposed WRc EmBz EQS, all cage edge stations were observed above the near-field standard and three-quarters of stations >100m from the cages were above the far-field standard. However, this comparison has assisted SEPA in evaluating the suitability and robustness of the newly developed EmBz analytical methodology.

Tef has not been available in the UK as a sea lice medicine since 2015 and the last reported treatment at the farms included in the survey was at Loura Voe MCFF in September 2013 (with treatments at Holms Geo MCFF and Teisti Geo MCFF on May 2013). In this survey Tef was detected at 46% of sampling stations, with 36% of all far-field stations (beyond 100m) being observed above the EQS. Tef is known to persist in the environment and therefore its detection is not surprising. These data demonstrate the legacy that persistent substances such as Tef can have in the environment even after uses cease.

4.3 Combined impact of multiple farms

The ecological impacts identified in this study were found in the vicinity of farm cages. Impacts upon ecological status decreased with distance from farm cages.

The new analytical methods for EmBz has demonstrated that it is widely distributed in the environment and that concentrations were above the proposed far-field standard at three-quarters of stations >100m from the cages. Some results for Tef also exceed far-field standards. It is, therefore, likely that wider impacts may occur particularly where farms are in close proximity to one another.

A potential hotspot of EmBz accumulation further away from the farms was observed. At Holms Geo relatively high concentrations of EmBz were found in the northernmost reference station (0.958 µg/kg dry weight) sample. This reference site is situated approximately half way between Holms Geo MCFF and another farm, Lippie Geo MCFF, further to the North in the same water body.

The study provided evidence of ecological impacts in the vicinity of MCFFs but did not demonstrate clear evidence of ecological impacts in reference stations. Reference stations were located to assess baseline conditions, all but one of the reference stations had ecological status of High or Good status. This suggests that using IQI we are not seeing degradation of background conditions. The particular effects of EmBz on crustaceans at reference sites would require additional dedicated survey work to assess.

It is clear that consideration of interactions and of cumulative impacts is needed to fully understand and assess environmental capacity. The risk of cumulative impacts can be informed by using hydrodynamic models being developed by SEPA. These models will inform the development of future monitoring programmes which will monitor impacts caused by cumulative impacts.

5 Conclusions

This survey demonstrates the successful application of new, improved monitoring and analysis techniques for assessing the impacts of MCFFs. The survey provides a strong scientific basis from which we can develop the monitoring of MCFFs and will inform the development of SEPA's regulatory approach.

The new highly sensitive test for EmBz found that the chemical was present at nearly all sampling stations. This indicates that environmental exposure to EmBz was wider than has previously been found. Tef was also found to be present at a number of locations. A small proportion of these sampling stations also failed the current environmental quality standards for both these chemicals and a significant portion failed the proposed environmental quality standard for EmBz.

Statistical analysis showed that EmBz had the biggest negative effect on the crustacean abundance and richness. This effect was detectable below the current EQS, this adds to the weight of evidence that the current EQS may not be protective of benthic ecology beyond the 100m from the cages.

These results indicate that the impacts of farms may extend beyond their immediate vicinity. Further work is now required and is ongoing to understand the wider-scale cumulative impacts.

6 Authors and Acknowledgements

The main authors of this report were Jack Bloodworth, Michelle Elliott, Jennifer Best and Malcolm Baptie. The survey, analytical method development and analysis, as well as the interpretation of the survey results has been a large undertaking involving a number of SEPA staff across a range of functions and portfolios. The authors acknowledge the hard work to produce this report from, but not exclusive to: the marine ecology and chemistry teams who conducted the survey, the boat crew of the Sir John Murray, the chemistry teams that developed the new EmBz and LOI methods, the chemistry teams that undertook the analysis of the samples, the marine ecology teams that undertook the ecological analysis of the samples and the countless people who provided detailed feedback on the interpretation of the results and the report drafts. The authors also acknowledge the help of Biomathematics and Statistics Scotland (BioSS) for advice with the statistical interpretation of the results.

7 References

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Appendix 1 – Survey Report Cards

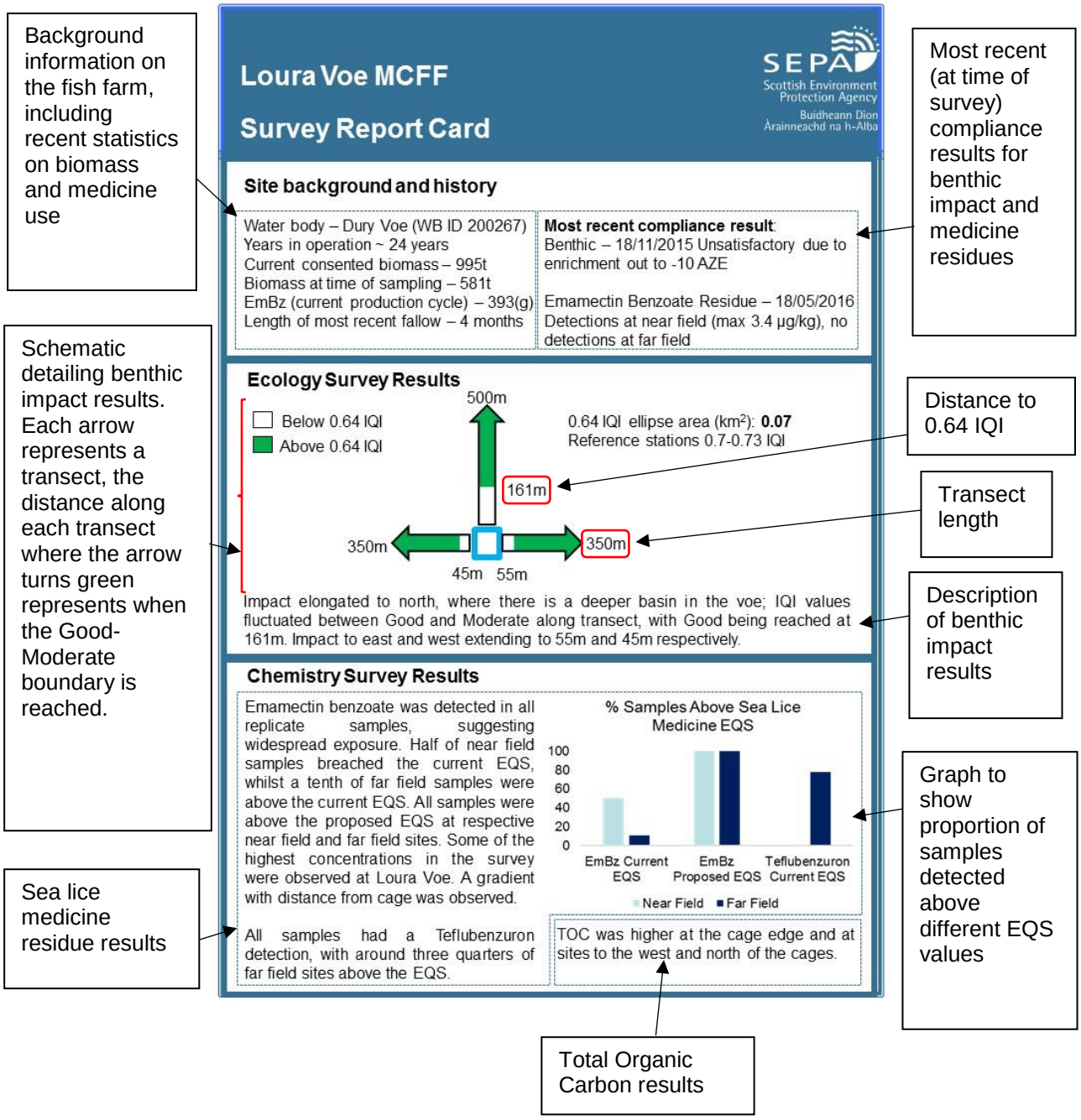


Figure 5: How to use the survey report cards

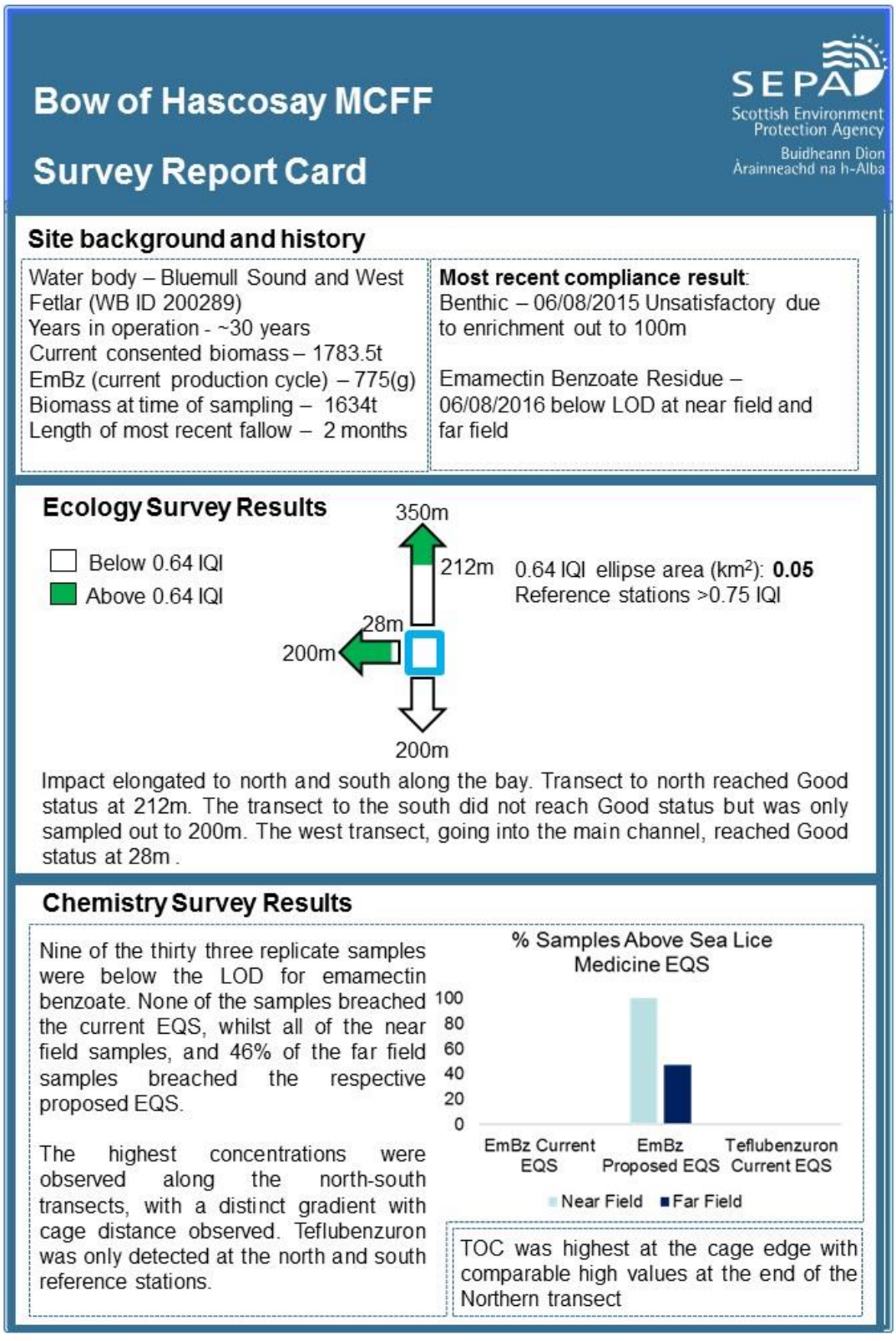


Figure 6: Survey report card for Bow of Hascosay

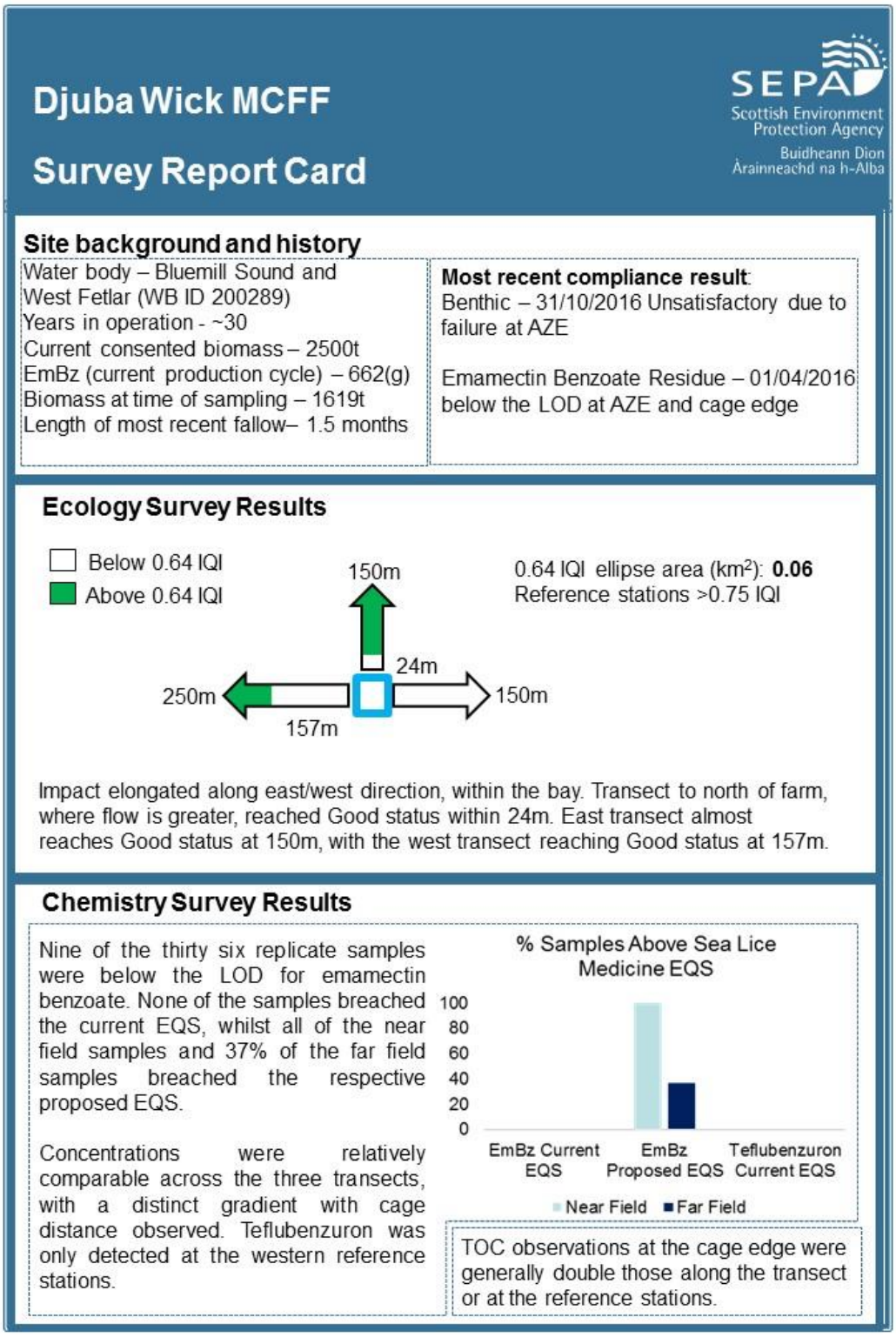


Figure 7: Survey report card for Djuba Wick

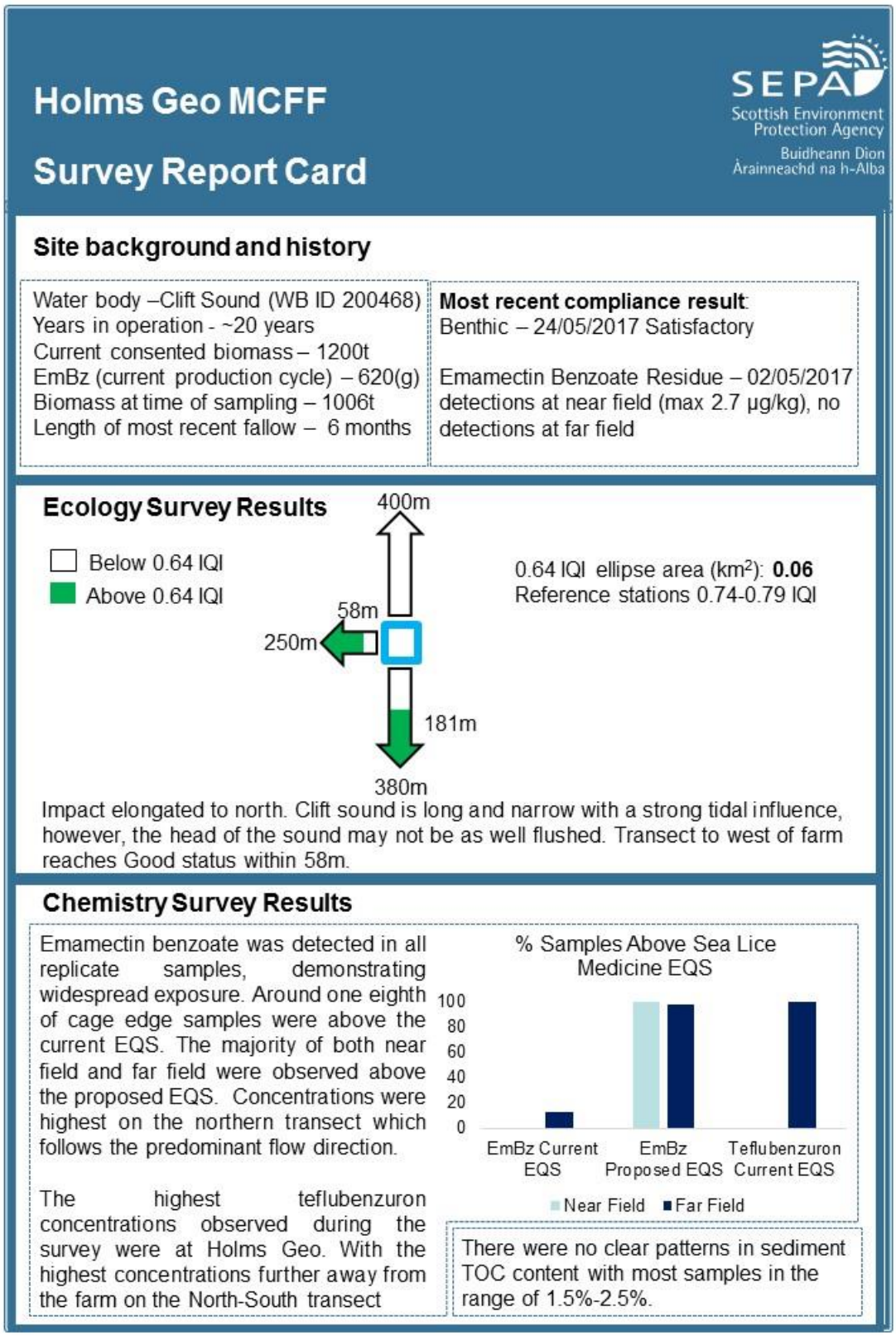


Figure 8: Survey report card for Holms Geo

Loura Voe MCFF

Survey Report Card

SEPA Scottish Environment Protection Agency
Buidheann Dìon Àrainneachd na h-Alba

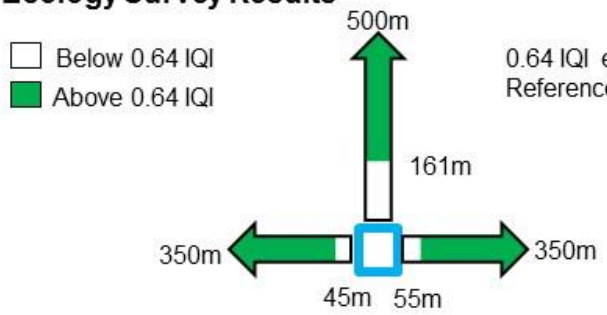
Site background and history

Water body – Dury Voe (WB ID 200267)
Years in operation ~ 24 years
Current consented biomass – 995t
Biomass at time of sampling – 581t
EmBz (current production cycle) – 393(g)
Length of most recent fallow – 4 months

Most recent compliance result:
Benthic – 18/11/2015 Unsatisfactory due to enrichment out to -10 AZE

Emamectin Benzoate Residue – 18/05/2016
Detections at near field (max 3.4 µg/kg), no detections at far field

Ecology Survey Results



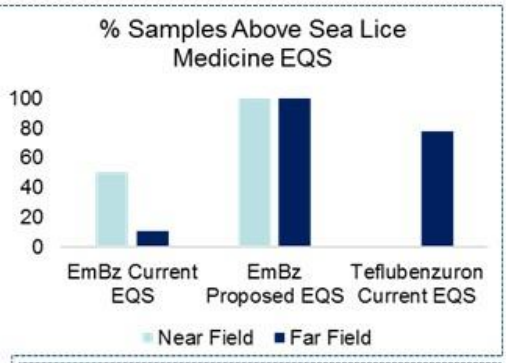
0.64 IQI ellipse area (km²): **0.07**
Reference stations 0.7-0.73 IQI

Impact elongated to north, where there is a deeper basin in the voe; IQI values fluctuated between Good and Moderate along transect, with Good being reached at 161m. Impact to east and west extending to 55m and 45m respectively.

Chemistry Survey Results

Emamectin benzoate was detected in all replicate samples, suggesting widespread exposure. Half of near field samples breached the current EQS, whilst a tenth of far field samples were above the current EQS. All samples were above the proposed EQS at respective near field and far field sites. Some of the highest concentrations in the survey were observed at Loura Voe. A gradient with distance from cage was observed.

All samples had a Teflubenzuron detection, with around three quarters of far field sites above the EQS.



TOC was higher at the cage edge and at sites to the west and north of the cages.

Figure 9: Survey report card for Loura Voe

Setterness South MCFF

Survey Report Card

SEPA Scottish Environment Protection Agency
Buidheann Dion Àrainneachd na h-Alba

Site background and history

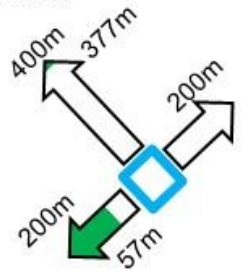
Water body – Yell Sound (WB ID 200503
Years in operation - ~20 years
Current consented biomass – 2357t
EmBz (current production cycle) – 1366(g)
Biomass at time of sampling – 390
Length of most recent fallow – 1.5 months

Most recent compliance result:
Benthic – 21/11/2016 Satisfactory

Emamectin Benzoate Residue – 13/10/2014 Detections at cage edge (max 7.58 µg/kg), below the LOD at far field.

Ecology Survey Results

Below 0.64 IQI
Above 0.64 IQI



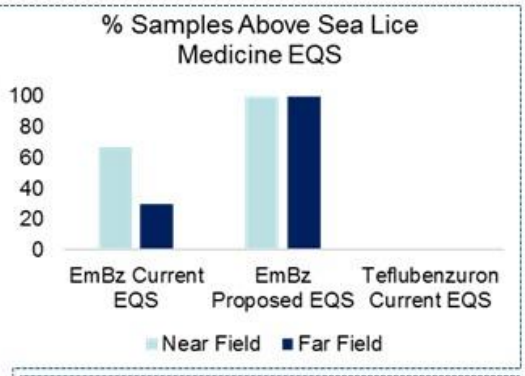
0.64 IQI ellipse area (km^2): **0.34**
Reference stations 0.63-0.76 IQI

Northwest and southwest transects reached Good status but the northeast only reached Moderate. One reference station was also at Moderate. This indicates impact is widespread, not localised to the farm and suggests a possible combined impact from multiple farms or other sources.

Chemistry Survey Results

Emamectin benzoate was detected in all replicate samples, suggesting widespread exposure. Two thirds of near field samples breached the current EQS, whilst a third of far field samples were above the current EQS. All samples were above the proposed EQS. Some of the highest concentrations in the survey were observed at Setterness South

A concentration gradient against distance from farm was observed, with all transects having relatedly comparable concentrations. Teflubenzuron was only detected at one reference station.



TOC did not follow a distance from farm gradient with some reference stations having comparable values to cage edge.

Figure 10: Survey report card for Setterness South

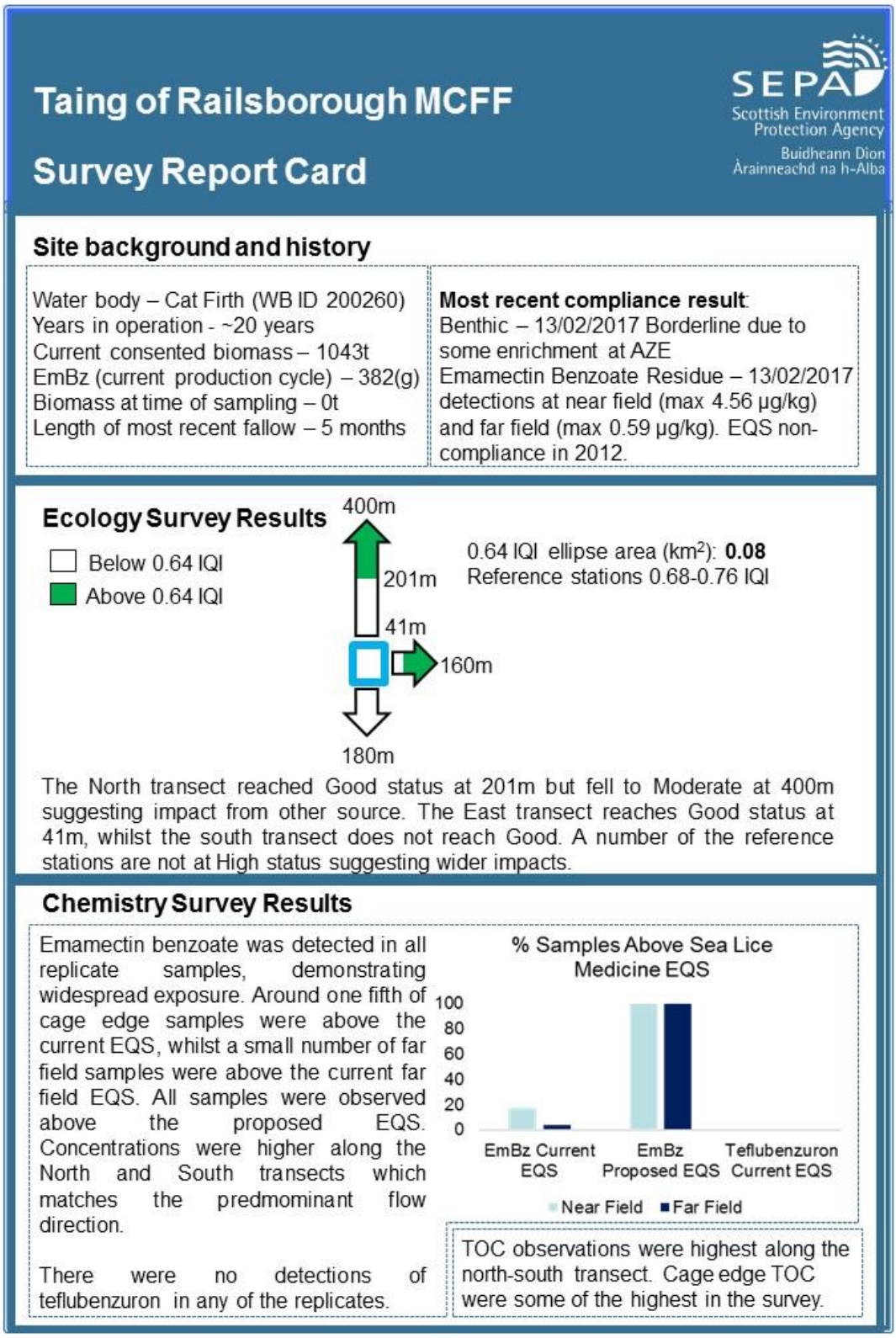


Figure 11: Survey report card for Taing of Railsborough

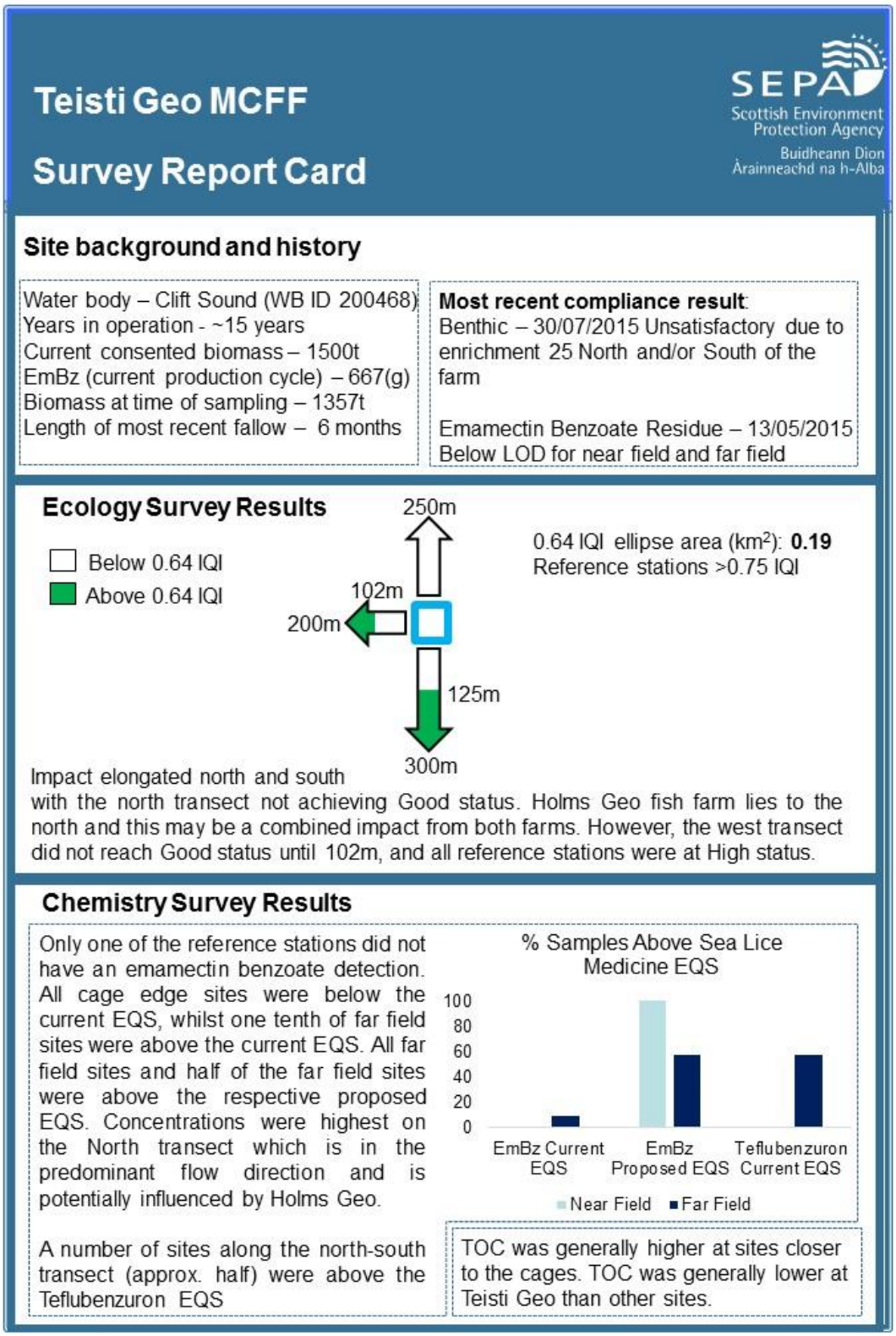


Figure 12: Survey report card for Teisti Geo

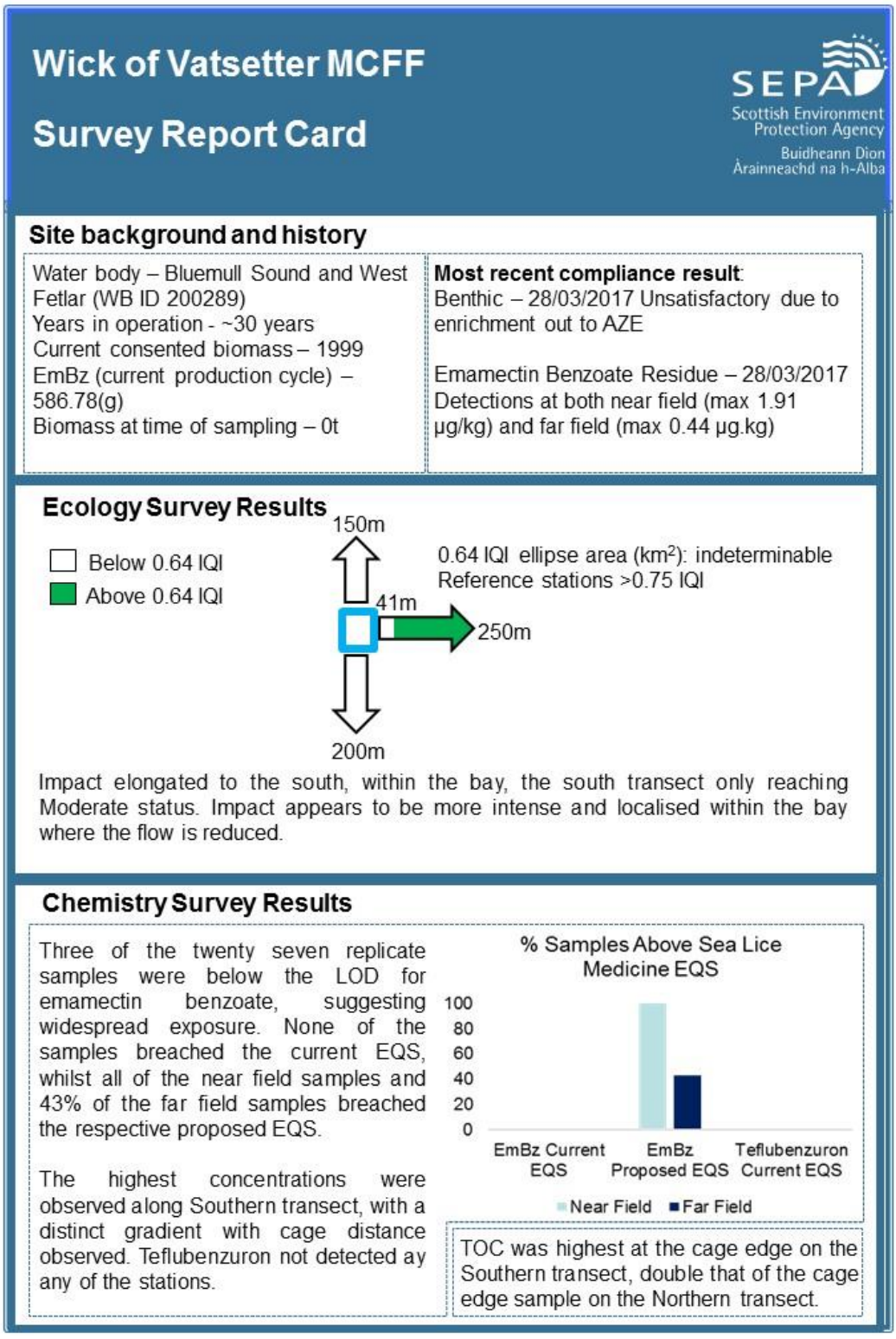


Figure 13: Survey report card for Wick of Vatsetter

Appendix 2 - Detailed methodology

Survey

The survey took place between 31st May 2017 and 22nd June 2017. At each MCFF two to three transects were sampled. Transects were at right angles to the cages, the length of each transect was determined according to the modelled impact footprint, so that sampling extended beyond the modelled impacted area. Along each transect 4-6 were taken for ecological analysis, with chemical residue samples being collected at 3 sampling points along each transect where possible. Two to three reference stations were also sampled for ecological and chemical analyses, in locations where no impact was expected to have occurred. Trimble GPS units were used to collect accurate GPS data (+/- 0.15m) of each sampling station and were also used to record the supporting sampling information. For both chemical and ecological sampling, sediment grabs were taken for both chemical and ecological analysis from the seabed using a standard 0.045m^2 grab attached to a winch from the SEPA survey vessel *Iona*.

At each sampling station two benthic invertebrate grab samples were collected and a core was taken from a third grab for particle size analysis in accordance to sampling procedure ME-P-007.

At each chemical residue sampling station three separate grabs were taken for chemical analysis and samples were collected in accordance with procedure ES-MACH-PT-901. From each grab, two separate samples were taken using a stainless steel corer to a depth of 5cm, one for sea lice medicine residue analysis and one for supporting parameters. At the Bow of Hascosay and Holms Geo a composite sample derived from the three replicate samples was also taken. All samples were frozen on the day of collection and returned to the SEPA laboratory in North Lanarkshire for analysis.

Laboratory analysis

All benthic invertebrate samples were analysed in accordance to SEPA procedure ME-P-008 whether they were analysed internally or by an external contractor and the quality assurance was carried out in accordance to the NMBAQC. Ecology particle size analysis samples were analysed in accordance with procedure ME-P-015 and subject to the North East Biological Analytical Quality Control Scheme (NMBAQCS) quality assurance protocol.

Chemical residue samples were analysed for the sea lice medicines Emamectin Benzoate, and Teflubenzuron and for supporting parameters: Particle Size Analysis (PSA) fraction below 63 µm; Percentage Loss On Ignition (LOI); percentage total organic carbon and percentage moisture content.

PSA was undertaken using sieving and weighing followed by analysis of the <2mm fraction by laser granulometry (SEPA method ES-MACH-PS-203) to determine the percentage of the sample below 63µm.

LOI analysis followed the British Standard method BS EN 15169:2007, using a drying temperature of 105˚C and an ignition temperature of 550˚C (SEPA method ES-INR-P-012).

TOC was analysed using an elemental analyser following a method ES-MACH-PS-202 that compliant with British Standard BS EN 13137 and uses acid digestion to remove inorganic carbon (e.g. carbonates) prior to analysis

Tef is analysed using Liquid Chromatography with tandem mass spectrometer detection (LC-MS/MS) following extraction of sediment using an Accelerated Solvent Extraction (ASE)

technique. (SEPA method ES-TORG-P-207). The Limit of Detection (LOD) for this method is 0.05µg/kg dry weight sediment.

EmBz samples were prepared using a manual QuEChERS (Quick, Easy, Cheap, Effective, Rugged and Safe) method using acetonitrile and magnesium sulphate. Analysis was completed using liquid chromatography with an Orbitrap Exactive High Resolution Accurate Mass Spectrometer (SEPA method ES-TORG-P-216). The LOD for the method is 0.0034 µg/kg dry weight sediment. The new SEPA EmBz analytical method is being prepared for submission to a peer reviewed scientific journal for publication.

Calculation of the IQI and area of impact

Infaunal Quality Index (IQI) Tool

The IQI tool was developed to assess the quality of the seabed for Water Framework Directive purposes. It is available on the UKTAG website[b].

It is derived from three separate metrics: number of taxa, AZTI Marine Biotic Index (AMBI) and Simpsons Eveness. It also incorporates associated particle size analysis data and sets salinity parameters based on whether it is coastal or transitional waters. It uses a large database of historical data to set reference conditions. Intercalibration with other European tools results in a tool that provides a robust assessment of the quality of the seabed.

The WFD classification boundaries for the IQI tool are shown in Table 3.

Table 3. WFD class boundaries based on IQI

IQI Value	Status	Level of Disturbance
0.75	High	negligible
0.64	Good	slight
0.44	Moderate	moderate
0.24	Poor	major
0	Bad	severe

IQI values were calculated for each station by combining the species data for two pooled 0.045m^2 grabs.

Determining the distance of impact (0.75 and 0.64 IQI) along each transect

The distance calculation uses the calculated IQI values from the survey and their distances from the cages as inputs into Self-starting logistic and non-linear least squares models. The

[b] https://www.wfduk.org/resources%20/coastal-and-transitional-waters-benthic-invertebrate-fauna.

model is used to predict the distance away from the cages in which the 0.75 or 0.64 IQI is reached. This is completed across all MCFF locations and transects separately.

Calculating the elliptical impact area

The distance from the cage where the IQI reaches 0.75 or 0.64 along a transect is converted to a location using the direction of the transect from the cages. Having established these coordinates, an impacted elliptical area is calculated by generating a spanning ellipsoid (the smallest ellipsoid in which the 0.75 or 0.64 IQI positions lie just inside or on the boundary of the resulting polygon). The method is implemented in an R function which uses the ellipsoid hull package[c].

[c] https://www.rdocumentation.org/packages/cluster/versions/2.0.6/topics/ellipsoidhull

Appendix 3 – Results Table

Table 4: Mean chemical and ecological results at each sampling location, SEPA fish farm survey 2017

Marine cage fish farm/water body	Location (Easting/ Northing)	Transect	Transect Distance	IQI	Species Richness	PSA %<63	Emamectin Benzoate (µg/kg dry weight)	Emamectin Benzoate (µg/kg wet weight)	Teflubenz-uron (µg/kg dry weight)	Total Organic Carbon (%)
Bow of Hascosay	454506/1192491	North	0	0.36	21	4.2	0.627	0.420	<0.06	0.76
	454522/1192538		50	0.32	18	5.8	-	-	-	-
	454537/1192586		100	0.42	34	6.4	0.478	0.342	0.05	0.49
	454568/1192681		200	0.70	34	3.9	-	-	-	-
	454613/1192824		350	0.72	64	0.0	0.014	0.009	0.06	0.77
	454443/1192193	South	0	0.31	13	6.8	0.637	0.433	<0.06	1.03
	454429/1192156		40	0.36	23	9.7	-	-	-	-
	454414/1192118		80	0.35	18	7.1	0.593	0.399	<0.06	0.95
	454400/1192081		120	0.33	33	5.5	-	-	-	-
	454371/1192006		200	0.54	38	7.9	0.088	0.064	<0.06	0.40
	454433/1192305	West	0	0.29	15	3.7	0.668	0.465	<0.06	0.40
	454395/1192318		40	0.67	49	4.0	-	-	-	-
	454358/1192331		80	0.82	116	-	0.008	0.006	<0.06	0.70
	454320/1192344		120	0.80	102	2.8	-	-	-	-
	454244/1192370		200	0.80	108	17.0	<0.003	<0.002	<0.06	0.42
	454643/1193586	Ref1	1080	0.82	99	1.6	0.009	0.006	0.15	0.53
	454096/1193075	Ref2	600	0.68	66	1.7	0.004	0.003	<0.06	0.44
Djuba Wick	455873/1193327	East	0	0.31	16	7.1	0.155	0.107	<0.06	1.30
	455903/1193322		30	0.70	26	6.9	-	-	-	-
	455932/1193316		60	0.73	43	3.6	0.036	0.026	<0.06	0.44
	455962/1193311		90	0.67	64	3.3	-	-	-	-
	456015/1193301		150	0.66	69	2.3	0.008	0.006	<0.06	0.40
	455797/1193540	North	0	0.36	25	3.4	0.262	0.175	<0.06	0.53

	455797/1193575		30	0.71	41	2.7	-	-	-	-
	455829/1193598		60	0.86	86	3.2	0.009	0.006	0.04	0.51
	455838/1193630		90	0.87	66	3.2	-	-	-	-
	455876/1193677		150	0.93	108	2.9	<0.003	<0.002	<0.06	0.46
	455677/1193406	West	0	0.23	10	10.1	0.462	0.308	<0.06	1.55
	455635/1193444		50	0.36	36	5.2	-	-	-	-
	455562/1193418		100	0.49	50	5.4	0.095	0.064	<0.06	0.63
	455469/1193541		250	0.84	109	4.6	-	-	-	-
	456001/1193906	Ref1	600	0.99	95	0.3	<0.003	<0.002	<0.06	0.49
	454948/1193900	Ref2	Ref2	0.81	152	3.8	0.018	0.011	0.24	0.53
Holms Geo	438819/1131135	North	0	0.10	4	31.8	5.790	3.555	20.1	1.73
	438903/1131388		50	0.77	58	70.7	-	-	-	-
	438908/1131425		100	0.74	53	51.4	1.289	0.731	79.1	1.85
	438927/1131492		200	0.68	57	39.7	1.203	0.682	40.7	1.78
	438955/1131572		300	0.72	67	44.7	-	-	-	-
	438998/1131693		400	0.74	54	61.1	1.649	0.846	145	2.17
	438797/1131044	South	0	0.22	14	30.6	5.094	3.023	3.57	2.00
	438758/1130963		80	0.58	35	38.0	1.749	1.077	96.2	1.42
	438755/1130931		120	0.35	31	33.8	-	-	-	-
	438708/1130808		250	0.79	73	48.0	-	-	-	-
	438646/1130696		380	0.77	75	44.7	0.802	0.462	95.5	1.43
	438781/1131146	West	80	0.76	61	49.5	-	-	-	-
	438743/1131158		120	0.81	61	65.7	0.313	0.177	44.8	1.77
	438705/1131170		200	0.81	69	51.3	-	-	-	-
	438628/1131194		250	0.80	95	43.7	0.253	0.157	51.3	1.67
	439147/1131998	Ref1	720	0.74	48	47.0	0.958	0.512	113	2.23
	438490/1130301	Ref2	800	0.76	61	40.4	0.306	0.192	109	1.18
	438701/1131743	Ref3	500	0.79	102	39.9	0.107	0.066	30.1	1.72
Loura Voe	447386/1161947	East	50	0.61	52	24.4	2.240	1.344	-	1.44
	447484/1161943		150	0.73	64	36.1	-	-	-	-
	447585/1161937		250	0.77	84	26.6	0.439	0.276	7.62	1.33

	447666/1161984		350	0.77	86	39.4	0.402	0.249	13.3	1.29
	447329/1161955	North	0	0.14	7	18.9	19.666	10.475	-	4.24
	447317/1162014		50	0.35	22	18.2	-	-	-	-
	447336/1162080		100	0.53	37	36.3	0.728	0.381	15.4	2.35
	447327/1162201		200	0.69	46	44.6	-	-	-	-
	447340/1162247		350	0.62	36	38.6	0.316	0.160	6.83	2.53
	447346/1162459		500	0.73	56	49.5	0.119	0.067	19	1.77
	447261/1161957	West	0	0.26	5	24.6	9.807	5.456	-	2.74
	447179/1161978		50	0.67	38	43.8	-	-	-	-
	447092/1161988		150	0.71	50	35.7	0.368	0.206	23.3	2.58
	446984/1161999		250	0.72	55	24.9	-	-	-	-
	446906/1162018		350	0.87	64	42.7	0.139	0.085	14.3	1.50
	447848/1162226	Ref1	600	0.70	53	29.3	0.770	0.453	12.6	1.36
	448228/1162456	Ref2	1000	0.71	48	32.8	0.079	0.045	1.1	0.94
	446935/1162315	Ref3	530	0.73	50	44.8	0.104	0.052	7.48	2.93
	446795/1162758	Ref4	900	0.73	73	17.7	0.057	0.036	2.72	1.38
Setterness South	447395/1170969	North East	0	0.19	9	20.8	20.668	11.927	<0.06	1.64
	447432/1171014		50	0.37	29	18.4	-	-	-	-
	447471/1171044		100	0.60	34	24.2	-	-	-	-
	447509/1171059		150	0.63	36	15.5	1.964	1.186	<0.06	1.10
	447616/1171167		300	0.60	34	21.9	0.651	0.401	<0.06	0.82
	447285/1171050	North West	100	0.33	24	24.8	25.234	12.962	<0.06	2.00
	447268/1171100		150	0.32	29	19.7	-	-	-	-
	447238/1171110		200	0.32	24	18.7	4.163	2.436	<0.06	1.08
	447084/1171261		400	0.63	41	19.6	0.582	0.353	<0.06	1.22
	447059/1171213		350	0.67	55	25.5	-	-	-	-
	447154/1170813	South West	0	0.26	18	15.2	13.533	7.503	<0.06	1.56
	447125/1170784		40	0.59	51	23.4	-	-	-	-

	447097/1170756		80	0.63	47	20.8	1.032	0.600	<0.06	1.44
	447068/1170728		120	0.67	46	34.8	-	-	-	-
	447012/1170672		200	0.70	45	38.1	0.656	0.360	<0.06	1.71
	446655/1171656	Ref1	950	0.63	49	15.7	0.243	0.146	0.12	1.35
	446141/1170618	Ref2	1020	0.71	70	29.9	0.284	0.168	-	1.63
	448140/1171563	Ref3	950	0.76	62	10.6	0.245	0.160	<0.06	0.87
Taing of Railsborough	445184/1151201	East	0	0.27	13	20.1	9.830	4.813	<0.06	4.19
	445224/1151209		40	0.64	32	27.2	-	-	-	-
	445263/1151217		80	0.67	39	19.0	0.627	0.371	<0.06	1.26
	445302/1151225		120	0.71	45	29.2	-	-	-	-
	445341/1151233		160	0.71	42	36.2	0.351	0.213	0.05	1.42
	445128/1151399	North	0	0.22	16	22.0	17.733	8.130	<0.06	3.81
	445116/1151448		50	0.30	14	28.0	-	-	-	-
	445092/1151545		150	0.55	17	29.4	1.048	0.560	<0.06	1.98
	445057/1151691		300	0.78	75	34.1	-	-	-	-
	445034/1151788		400	0.66	51	32.3	0.428	0.243	0.04	2.36
	445190/1151162	South	40	0.57	18	26.8	-	-	-	-
	445196/1151122		80	0.57	26	23.6	1.321	0.725	<0.06	1.68
	445202/1151083		120	0.63	27	26.6	-	-	-	-
	445211/1151025		180	0.62	29	27.0	0.620	0.355	<0.06	1.70
	445442/1152181	Ref1	1000	0.70	70	32.9	0.039	0.020	<0.06	2.89
	445402/1150173	Ref2	1000	0.68	50	30.5	0.074	0.040	<0.06	1.75
	444892/1152375	Ref3	1050	0.76	98	33.4	0.052	0.032	<0.06	1.48
Teisti Geo	438476/1129608	North	50	0.26	23	21.4	-	-	-	-
	438480/1129649		100	0.29	28	17.8	1.188	0.749	18.2	0.66
	438495/1129734		200	0.43	17	15.3	-	-	-	-
	438510/1129778		250	0.58	31	17.1	0.369	0.243	5.84	0.50
	438377/1129224	South	0	0.18	7	10.0	0.638	0.406	3.44	0.57
	438345/1129171		50	0.70	70	8.7	-	-	-	-
	438344/1129098		100	0.40	57	14.6	0.378	0.214	5.42	0.94

	438324/1129041		200	0.82	52	5.5	-	-	-	-
	438371/1129005		300	0.81	47	4.9	0.007	0.004	0.36	0.33
	438469/1129569	West	0	0.19	9	12.5	2.633	1.578	1.25	2.97
	438409/1129565		50	0.44	35	6.2	0.726	0.437	18.1	2.28
	438354/1129572		100	0.62	32	12.5	-	-	-	-
	438248/1129592		200	0.87	137	1.1	-	-	-	-
	437727/1128893	Ref2	750	0.76	67	25.6	0.006	0.004	0.07	0.31
	438168/1128297	Ref3	1000	0.77	16	0.0	<0.003	<0.002	<0.06	0.20
Wick of Vatsetter	453652/1190359	East	50	0.70	58	0.0	-	-	-	-
	453758/1190348		150	0.86	60	0.0	0.021	0.015	-	0.20
	453836/1190369		250	0.76	58	2.9	-	-	-	-
	453594/1190372	North	0	0.24	12	4.1	-	-	-	-
	453574/1190519		150	0.80	137	0.3	0.007	0.005	-	0.24
	453524/1190219	South	0	0.34	12	5.0	0.681	0.448	<0.06	0.91
	453523/1190179		40	0.65	23	3.0	-	-	-	-
	453522/1190139		80	0.61	35	2.7	0.170	0.117	-	0.43
	453521/1190099		120	0.58	41	1.9	-	-	-	-
	453519/1190019		200	0.60	34	3.4	0.027	0.020	-	0.34
	453096/1191056	Ref1	850	0.89	30	0.0	0.005	0.004	<0.06	0.26
	453396/1190884	Ref2	600	0.82	32	0.0	<0.003	<0.002	<0.06	0.24
	453416/1191554	Ref3	1250	0.83	127	0.0	<0.003	<0.002	0.15	0.23
Vidlin Voe	447999/1167427	Ref	-	0.73	68	18.9	0.179	0.115	<0.06	1.56
	448165/1167655		-	0.89	42	0.0	-	-	-	-
	448271/1166319		-	0.84	54	17.8	0.036	0.027	0.1	0.66
	448512/1166842		-	0.66	57	28.2	-	-	-	-
	448945/1167926		-	0.72	55	18.1	0.214	0.134	<0.06	1.12
	449041/1168278		-	0.68	68	12.1	-	-	-	-

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www.sepa.org.uk
03000 99 66 99
The Castle Business Park, Strathallan House, Stirling FK9 4TZ

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Scottish Environment Protection Agency
Buidheann Dìon Àrainneachd na h-Alba