ASSESSMENT OF EQUILIBRIUM CONCENTRATION ENHANCEMENT

Reintraid Finfish Pen Site, Loch a’ Chàirn Bhàin, Sutherland

Prepared for

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The data used in this document and their input and reporting have undergone a quality assurance review which follows established TransTech Ltd procedures. The information and results presented herein constitute an accurate representation of the data collected.

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1. EXECUTIVE SUMMARY

This report contains an assessment of equilibrium concentration enhancement (ECE) for nitrogen for the modification of Loch Duart Ltd's Reintraid pen site on Loch a' Chàirn Bhàin from 14 x 24 m square to 16 x 80 m circumference circular pens. The study includes an assessment of the cumulative impact from other existing fish farms in the wider area.

Along with the change to the equipment production at the site will increase from a maximum standing biomass of 1,300 tonnes to 1,834 tonnes.

The calculations reported within this document indicate that the proposed increase in biomass at the Reintraid site is not predicted to change the nutrient enhancement index of the water body i.e., enhancement will rise to a maximum of 0.47 µmol N l^{-1} which remains below the water body's upper limit of 1 µmol N l^{-1}.

The water body is also predicted to remain within OSPAR and UKTAG threshold levels even when seasonal variation (as observed on other Scottish sea lochs, voes and bays) is taken into account as the ECE value is estimated to be a maximum of 3.9% of the background level for coastal waters.

2. INTRODUCTION

Loch a' Chàirn Bhàin is defined by the Locational Guidelines for the Authorisation of Marine Fish Farms in Scottish Waters[1] as a Category 3 area with a nutrient enhancement index of 2. This area also includes lochs Glendhu and Glencoul. As Loch Duart Ltd will increase the biomass at the Reintraid pen site there is a requirement for additional supporting information on the resulting increase in nutrient loading.

Within the water body there are four CAR licenced seawater finfish farms i.e., the subject Reintraid site, Torgawn, Glendhu and Glencoul (Figure 1).

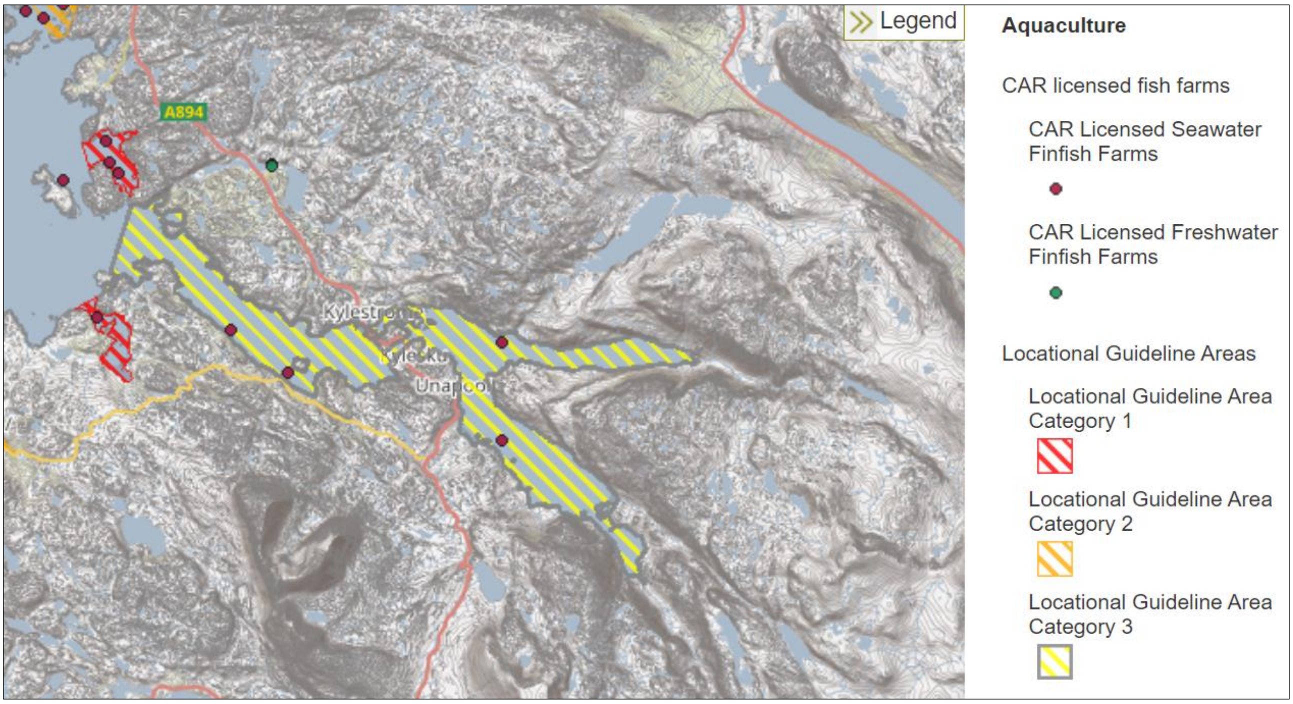

Figure 1. CAR licenced seawater finfish farms within Loch a' Chàirn Bhàin, Loch Glendhu and Loch Glencoul
(Source: http://aquaculture.scotland.gov.uk/map/map.aspx)

Table 1. CAR licenced seawater finfish farms within the study area
(Source: http://aquaculture.scotland.gov.uk/map/map.aspx)

#	Farm	Alternative Name(s)	Operator	Active Licence No.
1	Reintraid	n/a	Loch Duart	CAR/L/1002919
2	Torgawn	n/a	(Loch Duart)	CAR/L/1001827
3	Glendhu	Maldie Burn	Inactive (Wester Ross Salmon)	WPC/N/62381
4	Glencoul	Craig Island	Inactive (Wester Ross Salmon)	WPC/N/62380

3. NUTRIENT ENHANCEMENT CALCULATIONS

Nutrient enhancement calculations were carried out for modified Reintraid site and the licenced consents for the Torgawn site by applying the same methodology as that used by Marine Scotland Science in their Locational Guidelines(1).

Through the discharge of nutrients and chemicals, finfish production may have adverse, though currently poorly understood, effects on the plankton and bacterial populations of sea lochs and coastal waters.

Farmed salmonids excrete soluble nitrogen (in the form of ammonia) into the water column as a by-product of metabolism. The quantity emitted by each fish varies due to a number of factors, including food composition, fish age and size, and water temperature. The total quantity of ammonia emitted from a finfish farm then depends on the level of production and the stage of the production cycle. In order to estimate correctly the effects of nutrient emissions on the local ecosystem, it is imperative to have an accurate assessment of the quantities of nutrients being released.

To determine the enhancement of dissolved nitrogen above background levels within the study area a box model was used.

3.1. Calculation of flushing time and flushing rate

(source: http://www.scotland.gov.uk/Uploads/Documents/Report63.pdf)

The predominant exchange mechanism is assumed to be the semi-diurnal tide. The flushing time of the study area can be calculated by assuming that the water volume is replaced by the volume of water entering and leaving on each tide (the "tidal prism", see Gillibrand *et al*, 2002(2)) giving:

$$\mathrm{TF} = \frac{0.52 * \mathrm{V}}{0.7 * \mathrm{A} * \mathrm{R}}$$

Where:

TF is the Flushing Time (days)
V is the volume of the marine system basin (m^3)
A is the surface area of the marine system (m^2)
R is the spring tidal range (m)

The factor 0.52 is the number of days per tidal cycle (1 tidal cycle = 12.4 hours = 0.52 days), and the factor 0.7 approximates the mean tidal range from the spring tidal range (see Gillibrand *et al*, 2002(2)).

Using the above equation TF for the study area was calculated as follows:

A = 15,600,000 m^2 (LW area from Edwards and Sharpels, 1986[3])
V = 440,900,000 m^3 (LW volume from Edwards and Sharpels, 1986[3])
R = 4.2 m (from UKHO Admiralty Total Tide)

Calculation:

$$TF = \frac{0.52 * 440{,}900{,}000}{0.7 * 15{,}600{,}000 * 4.2}$$

= 4.998866213 days

The tidal prism method of calculating flushing times is known to overestimate the exchange of water and therefore under predict the flushing time[3, 4, 5]. The exchange rate of sea lochs, voes and bays can also be affected by wind strength and direction, and fluctuations in river flow. However, these variations are difficult to predict and vary from system to system. Tidal exchange is a steady and persistent process, not subject to meteorological fluctuations, and therefore forms the core exchange mechanism of these systems. The tidal prism method, therefore, while not complete, forms the best available method for estimating the flushing of marine systems.

The nutrient enhancement is strongly dependent on the flushing rate, Q ($m^3\ y^{-1}$), of the marine system, which is given by:

$$Q = \frac{365 * V}{TF}$$

where the factor 365 converts the units from $m^3\ d^{-1}$ to $m^3\ y^{-1}$. The flushing rate, then, is the total quantity of water that is exchanged over a year.

Calculation:

$$Q = \frac{365 * 440{,}900{,}000}{4.998866213}$$

= 32,193,000,000 $m^3\ y^{-1}$

3.2. Nutrient Model Parameters and Calculated Equilibrium Concentration Enhancement for Current and Proposed Maximum Biomass

The maximum biomass that will be held within the study area pre and post modification of the Reintraid site is 3,000.0 tonnes and 3,884.0 tonnes respectively. A breakdown of these figures is provided in Table 2.

Table 2. Maximum biomass at each farm within study area (current and proposed)

#	Farm	CURRENT Maximum biomass (tonnes)	PROPOSED Maximum biomass (tonnes)
1	Reintraid	1,300	1,834
2	Torgawn	600.0	No change
3	Glendhu	750.0	No change
4	Glencoul	700.0	No change
	TOTALS:	**3,350.0**	**3,884.0**

The parameters required by the model were defined as follows (Table 3):

Table 3. Model parameters

Parameter	CURRENT	PROPOSED
M (Tonnes)	3,350.0 (from Table 2)	3,884.0 (from Table 2)
S (kgN/T/year)*	48.2	
Q (m^3/year)	32,193,000,000	
ECE (kg N m^{-3})	5.01569 x 10^{-6}	5.81520 x 10^{-6}
ECE (μmol N l^{-1})	0.36	0.42

* This value has been obtained from Gillibrand *et al*, 2002(2) and assumes a feed wastage of 5%, 90% digestibility of the diet and a mean feed nitrogen content of 7.2% (wet weight). The figures were derived in 2002. Feed wastage and digestibility has improved since the Gillibrand *et al* study was undertaken and due to advances in the composition of fish feeds the nitrogen content has reduced from a mean of 7.2% to a current mean of approximately 6.5%. The nitrogen enhancement calculated above is therefore likely to overestimate what will occur in reality.

The above calculations reveal that the enhancement of dissolved nitrogen above background levels as a result of the finfish farming operations within the subject area is currently 0.36 μmol N l^{-1}. For the modified Reintraid site there will be an overall increase in maximum biomass of 534.0 tonnes. With this increase there will not be a significant impact on ECE which is predicted to rise slightly to 0.42 μmol N l^{-1}.

It should be noted that our calculations use data contained within the Sea Lochs Catalogue(3). This differs from that in the Locational Guidelines(1) i.e., the area and volume of the loch is smaller at 14,000,000 m^2 and 330,600,000 m^3 respectively. When the TF (4.2 days) and Q (28,727,000,000 m^3 y^{-1}) parameters provided in the Locational Guidelines(1) are used in the calculation, the corresponding pre and post modification ECE values are 0.40 and 0.47 μmol N l^{-1} respectively (i.e., 0.04 and 0.05 μmol N l^{-1} higher).

The index of nutrient enhancement, derived from predicted levels of ECE for nitrogen, using the nutrient enhancement model described by Marine Scotland Science is given in Table 4.

Table 4. Index of nutrient enhancement

Predicted ECE for nitrogenous nutrients arising from finfish farming (μmol l^{-1})	Nutrient enhancement index
> 10	5
3 – 10	4
1 – 3	3
0.3 – 1	2
<0.3	1
0	0

Given that no significant rise in ECE is predicted, the water body study area is forecast to remain at a nutrient enhancement index of 2.

4. NITROGEN INPUT ASSESSMENT AGAINST OSPAR & UKTAG THRESHOLD LEVEL

In Scottish sea lochs, voes and bays, under most conditions, algal growth is limited by dissolved nitrogen availability and the influence of phosphorus can safely be discounted[6].

Nitrogen inputs are assessed against OSPAR and UKTAG background levels. The calculated ECE from all fish farms in the water body is then added onto the background level for that water body and the result is then assessed as to whether it breaches the threshold, which is 50% above the background value (i.e., 252 µg N l^{-1}).

The enhancement of dissolved nitrogen above the background level as a result of the existing and proposed finfish farming operations within the study area is predicted to be a maximum of 0.47 µmol N l^{-1} (6.52 µg N l^{-1}).

The background value for coastal waters is 168 µg N l^{-1}, adding the calculated ECE onto this value gives 174.5 µg N l^{-1}, which is below the 50% above threshold of 252 µg N l^{-1}.

The ECE value does not account for nitrification and other removal mechanisms but is a maximum of 3.9% of the 168 µg N l^{-1} background level. This means that the study area will comfortably remain within threshold levels even when seasonal variation (as observed on other Scottish sea lochs, voes and bays) is taken into account.

This means that the study area will comfortably remain within threshold levels even when seasonal variation (as observed on other Scottish sea lochs, voes and bays) is taken into account.

It is therefore concluded that nutrient enrichment associated with the increase in biomass at the Reintraid site is unlikely to make a significant contribution to nutrient enhancement and consequently primary productivity.

5. MITIGATION

The particulate component of waste from finfish farms includes both uneaten feed and faeces. Fish feed is expensive and it is in Loch Duart's best interests to minimise waste. Feed wastage will be optimised by feeding fish to 80% satiation and monitored daily by surface appetite scoring. By optimising feeding less nitrogen derived from pellet waste will enter the water column.

6. CONCLUSIONS

The modification of the Reintraid site results in an overall increase in maximum biomass of 534.0 tonnes within the study area.

The modification is not predicted to change the nutrient enhancement index of the water body i.e., enhancement will rise from a maximum of 0.40 to 0.47 µmol N l^{-1} which remains below the 1 µmol N l^{-1} upper limit of index 2. Thus, no change to the waterbody's nutrient enhancement index is predicted.

The water body will also remain within OSPAR and UKTAG threshold levels even when seasonal variation (as observed on other Scottish sea lochs, voes and bays) is taken into account as the ECE value is predicted to be a maximum of 3.9% of the background level for coastal waters.

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