



A proposed rationale for  
the ratification of the  
Site Optimisation Plan  
for salmon farming in  
Loch Roag, Lewis, Western Isles.

**Acknowledgements**

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## **Executive summary.**

A proposed rationale for the ratification of the Site Optimisation Plan for salmon farming in Loch Roag, Lewis, Western Isles.

## Executive summary

### Background.

The implementation of Loch Roag Site Optimisation Plan (LR SOP) is a pilot for the launching of SOP's throughout the Scottish aquaculture industry. It is the first step in the Western Isles SOP, an initiative in which many local and national organisations have played a part. It follows the objectives set out in the Scottish Executive's *Strategic Framework for Scottish Aquaculture*, the culmination of a number of initiatives during the last seven years or so. The principle objectives of the LR SOP are seen as being aquaculture site amalgamation and relocation to the benefit of sea lice management, environmental sustainability, wild salmonid stocks, navigation and the economic and logistical viability of the aquaculture businesses concerned.

### Loch Roag; current status.

Loch Roag is divided into East and West lochs. There are two Special Areas of Conservation within the wider Loch Roag catchment, the tidal lagoons of Loch Shader and Tob Valasay and the Loch Langavat system. The latter is a specific concern to be addressed by the SOP, due to the fact that wild salmonids pass through Loch Roag when migrating to and from their natal waters. The introduction of measures to protect wild salmon though the SOP is an essential element of the Management Agreement for the loch.

Other issues to be addressed in the LR SOP include local shipping, the local inshore fishery resource and local tourism, where the potential for both environmental and visual impact of aquaculture are important considerations. It is also hoped that the SOP will boost employment in the communities that live around the loch.

### Rationalisation measures.

The establishment of an Area Management Agreement between the Loch Roag stakeholders is central to the SOP's objectives. The agreement incorporates a number of measures including the distancing of salmon farm sites from the Grimersta Estuary (Loch Langavat system), alternation of farmed salmon stocking between the west loch (even years) and the east loch (odd years), single generation salmon farm stocking, synchronised site fallowing, synchronised and strategic farm lice treatment protocols and measures to reduce the risk of farmed salmon escapes, all in the interests of the health, both of farmed fish and local wild salmon stocks.

Farm site amalgamation and relocation will also allow the introduction of clear navigational lanes to serve the loch's piers, slipways and anchorages and to improve the logistical and economic viability of farm operation. The SOP proposes the relinquishing of eleven farm consents, the introduction of two completely new consents and a biomass increase for five sites, resulting in a total of twelve sites post-SOP. The impacts in respect of farm nutrient discharges are considered in depth. This analysis demonstrates an acceptable balance between production and tidal flushing in both the east and the west loch, post-SOP. It further confirms that aquaculture production will be well within the carrying capacity of the loch.



## **Main Report.**

## A proposed rationale for the ratification of the Site Optimisation Plan for salmon farming in Loch Roag, Lewis, Western Isles.

### Main Report.

### Preface.

This document is intended to accompany all applications to the Crown Estate for lease modifications and new site applications arising from the amalgamation and relocation of fish farm sites as part of the Loch Roag Site Optimisation Plan.

Thus this report has several clear objectives, designed to assist in the SOP process:-

1. To validate the actions proposed under the terms of the SOP.
2. To provide the necessary data and information on Loch Roag and its environs.
3. To describe the pressures for change and the changes proposed.
4. To describe the benefits that the aquaculture industry could achieve as a result of the SOP process.
5. To give a measure of the potential for environmental improvement and sustainability, that could result from the implementation of the SOP.
6. To describe the reduction in pressures and to indicate the potential improvements that should accrue to the wild salmonid fish stocks in the area as a result of the SOP.

It is intended that the report also serves as an initial source of information to support the required development consent applications, some of which will invoke the Environmental Impact Assessment (EIA) process. The document should also bring a greater understanding of the environmental consequences of the proposed SOP and address specific environmental and human interaction issues, at a collective, inter-company level.

The applications accompanying this document are submitted for consideration by the Crown and other responsible bodies. The linked nature of the proposals requires that adjacent aquaculture activities be considered together but it is the wish of the applicants that responses to each application be directed back to the individual businesses concerned, rather than to the WIAA.

## Section 1.

### Background.

#### 1.1. The Western Isles Site Optimisation Plan (WI SOP)

It is necessary for any industry to review its operating practices on a regular basis. In a sense, the development of the Loch Roag Site Optimisation Plan (LR SOP) has offered such an opportunity, albeit on an inter-company basis. The LR SOP is a response to each participant's economic drivers, their growing understanding of the environment within which they operate and to an evolving regulatory framework, which offers both new constraints and new opportunities. SOP's for Western Isles salmon farms arose from the work of the Western Isles Aquaculture Task Force, initiated by the Western Isles Aquaculture Association (WIAA) and the Western Isles Council (Comhairle nan Eilean Siar; CnES) in 2003, (Rodger, A. *et al* 2004). They were also a response to the economic and regulatory climate within which salmonid aquaculture operated in the Western Isles at the time.

In March 2004, a meeting was called by the WIAA which brought together Calum MacDonald MP, Alasdair Morrison MSP and parties from the Crown Estate (CE), CnES, Highlands and Islands Enterprise (HIE), the Scottish Environment Protection Agency (SEPA), the Scottish Executive Environment and Rural Affairs Department – Aquaculture branch (SEERAD – aqua), Scottish Natural Heritage (SNH), Western Isles Enterprise (WIE), the Western Isles Fisheries Trust (WIFT) and the Western Isles Fisherman's Association (WIFA). The primary purpose of this meeting was to agree the terms of the Western Isles Site Optimisation Plan. This primarily comprised the separation of clusters of salmon farm sites into separate tidal excursions, each cluster to be covered by its own Site Optimisation Plan and Area Management Agreement. These objectives were in line, not only with the aspirations of the National Relocation Initiative of 2003, but also with a number of recommendations which had gone before, including the Concordat of the Tripartite Working Group (1999) and the Report of the Joint Government / Industry Working Group on Infectious Salmon Anaemia (2000).

The SOP's were seen as a vehicle, to bring together the different aspirations of the industry and the regulators, into a framework for action. More specifically the WI SOP sought to:-

- Improve production efficiencies, in respect of the use of plant, personnel and infrastructure leading to a net reduction in operating costs.
- Improve site-specific environmental performance, by matching salmon production to site and loch environmental carrying capacity.

- Amalgamate the spatial footprint of aquaculture to offer new opportunities for aquaculture development or for other, complementary uses of the local marine resource, for example fishing, tourism and recreational activities.

## 1.2. The Loch Roag Site Optimisation Plan (LR SOP).

The Loch Roag SOP is the first Site Optimisation Plan to be implemented in Scotland and is being viewed as a pilot project by regulators and industry alike. The LR SOP is one element of the wider Western Isles SOP. A number of pressures on the aquaculture industry operating in Loch Roag have been highlighted by the WI SOP:-

- The need for operators to improve their economic, environmental and logistical efficiency, through site amalgamation and relocation,
- A requirement to develop an Area Management Agreement within the loch in support of sea lice management and other fish health measures.
- A requirement to respond to the management actions of the Langavat Special Area of Conservation, an SAC for Atlantic salmon in its freshwater stages in the main freshwater system discharging to the loch.
- A requirement to relocate salmon farm sea-sites away from the vicinity of important wild salmon river estuaries to more appropriate site locations.
- The need to operate within the bounds of a prescribed navigation area, designated by the Harbour Authority for the loch, Comhairle nan Eilean Siar.

The WI SOP can be seen as a means to allow the delivery of aspects of the Strategic Framework for Scottish Aquaculture (2003). In this respect it is hoped that the work to date has contributed to the following objectives of the Strategic Framework for Scottish Aquaculture and related debates on:-

- Location and Relocation of Farms.
- Sea lice management.
- Environmental Impact Assessment.
- Local Authority zoning plans.

At a more local level the LR SOP should also assist with:-

- The further development of the significant salmonid sport fishery in the surrounding catchment, and associated business aspirations.
- The management of the Harbour Order Area.
- The management of the two aquatic Special Areas of Conservation (SAC's) in the area.

It is also anticipated that the LR SOP and its process will contribute to the wider Integrated Coastal Zone Management (ICZM) debate. The Loch Roag SOP is being co-ordinated by Andrew Rodger, a consultant acting for the Western Isles Aquaculture Association (WIAA).

### 1.3. Loch Roag in the context of aquaculture development; Western Isles and Scotland as a whole.

The history and development of the aquaculture industry in the Western Isles mirrors its development on the Scottish mainland and in the Northern Isles. Since its commercial inception in the 1970's, the Scottish industry has shown the most rapid growth of any food production sector in the country. Aquaculture is now a major economic force in many remote, fragile communities, where a range of geographical, economic and environmental factors generally limits employment opportunities. The total number of biomass consents for salmon farming in the Western Isles now stands at eighty eight, with a total consent biomass of 55,908 tonnes, although not all of these are currently fully taken up.

Loch Roag has been regarded for many years as an ideal area for aquaculture development. As a result, the loch currently supports almost one quarter of the Western Isles aquaculture tonnage. Fish farm businesses currently operate 21 sites in the loch, for a maximum standing biomass of 12,990 tonnes of salmon and 385 tonnes of halibut. The loch also has a longline capacity for the production of over 1,000 tonnes of mussels.

Despite the economic benefits of the development of this new Scottish industry over the last three decades, there has been a persistent and growing lobby from some quarters as to the direct environmental impacts that may arise, in particular from finfish aquaculture. These can be summarised under three main headings:-

- The potential for pollution that may arise from fish farm discharges.

- The potential for impacts on sea life that may arise from waste medicines and treatments used on fish farming installations, in particular lice treatments, antibiotics and cage net antifouling.
- The potential for impacts on wild salmonid stocks that may result either from increases in sea lice infestation pressure, emanating from farmed salmon, or from possible impacts of escaped farmed fish, in particular on the breeding of wild fish.
- The industry itself has been concerned about these potential pressures and has worked hard, in cooperation with all relevant bodies, to mitigate any possible impacts of its activities. As a result, there have been a series of initiatives involving the Scottish Executive and other key players, to examine many of the issues that face the industry, including its interaction with the environment and its potential to impact upon wild salmonid stocks.

#### 1.4. A rationale for the introduction of the Loch Roag SOP.

The principle requirement for the ratification of the SOP will be the consideration of the impacts arising from all salmon farming sites in the loch. This is the function of Environmental Impact Assessment (EIA) process.

This document describes the resulting actions being proposed by the WIAA further to consultations, with respective relevant authorities and stakeholders, on the most pertinent environmental issues, which face the collective aquaculture sector operating in Loch Roag. It is therefore recommended that this document acts as a significant component of the EIA process.

## Section 2.

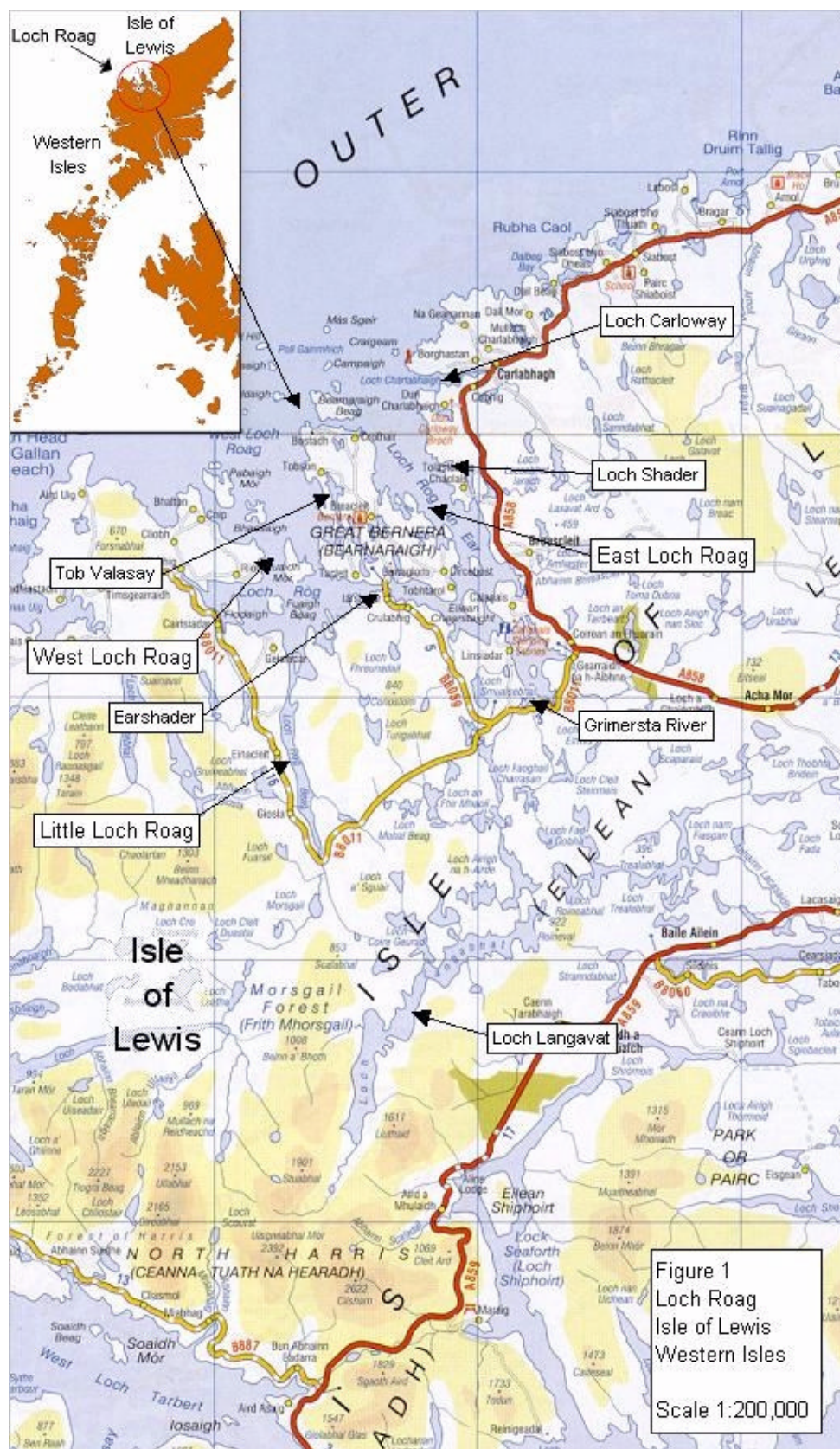
### Loch Roag; current status.

#### 2.1. General geography and ecology.

Loch Roag is situated on the North West coast of the Isle of Lewis, the most northerly of the Western Isles. The loch comprises two inlets, East Loch Roag and West Loch Roag, which are separated by the island of Great Bernera. A narrow strait at Earshader divides the island from the mainland of the Isle of Lewis and connects East and West Loch Roag, as shown on the map in Figure 1. The maximum cross-sectional area of the strait at Earshader is some 1,295m<sup>2</sup>, allowing a maximum, calm weather, ebb / flood flow between the East Loch and the West Loch of some 51.8m<sup>3</sup>sec<sup>-1</sup>. In that this is only some 0.1% of the combined mean tidal influx into the East and West Lochs, (some 5,000m<sup>3</sup>sec<sup>-1</sup>), the two are regarded as hydrographically independent at their landward limit. Another, smaller sea loch, Little Loch Roag, drains into West Loch Roag at its southern extreme. Similarly, Loch Carloway drains into East Loch Roag on its north side. Many small islands are located the loch.

Within the wider Loch Roag system there are two designated SAC's. The first, SAC UK 0017074 comprises in the main, two tidal lagoons; Tob Valasay, and Loch Shader, which are considered to be two of the best examples of silled coastal lagoons in the United Kingdom. These support a high diversity of animal and plant species, within a range of freshwater, brackish and fully marine environments. Tob Valasay is situated on the west coast of Great Bernera. Loch Shader is situated at the northern end of East Loch Roag. Despite their separate locations, the two lagoons are combined within a single SAC, with a total area of 43.62ha. A map of SAC UK 17074 is given in Figure 2. A summary of the ecological diversity of the lagoons is given in the following excerpt from the SAC UK 17074 Synopsis, (JNCC, 2005):-

*“Loch Roag Lagoons is a complex of silled lagoons illustrating the range of variation from freshwater to marine conditions on the Atlantic coast of the Hebrides. Tòb Valasay has a complex salinity regime determined by the balance between fully marine water introduced over the sill and freshwater from run-off and small inlet streams. Its basins contain a diverse range of habitats, including rocky outcrops, boulders and muddy sand, with softer mud in the eastern basin, and boulders, cobbles and shell-gravel in the narrows. A range of communities are present, including beds of eelgrass *Zostera* spp. and tasselweed *Ruppia* spp., turfs of marine algae and stands of large brown algae.*







*Loch Shader is a smaller lagoon that is mainly brackish in character. It has soft, sheltered mud and sand sediments, with some boulders and cobbles on the shore and in shallow water. These substrates support a characteristic range of species. The narrows consists of a bedrock and boulder sill, supporting a more diverse community with a variety of species, including kelp Laminaria spp., anemones and sponges.”*

The ecology of these two lagoons is not considered to be at risk from salmon farming within the loch system, because of the sills at their outlets and the limited ingress of loch water relative to the outward residual flow.

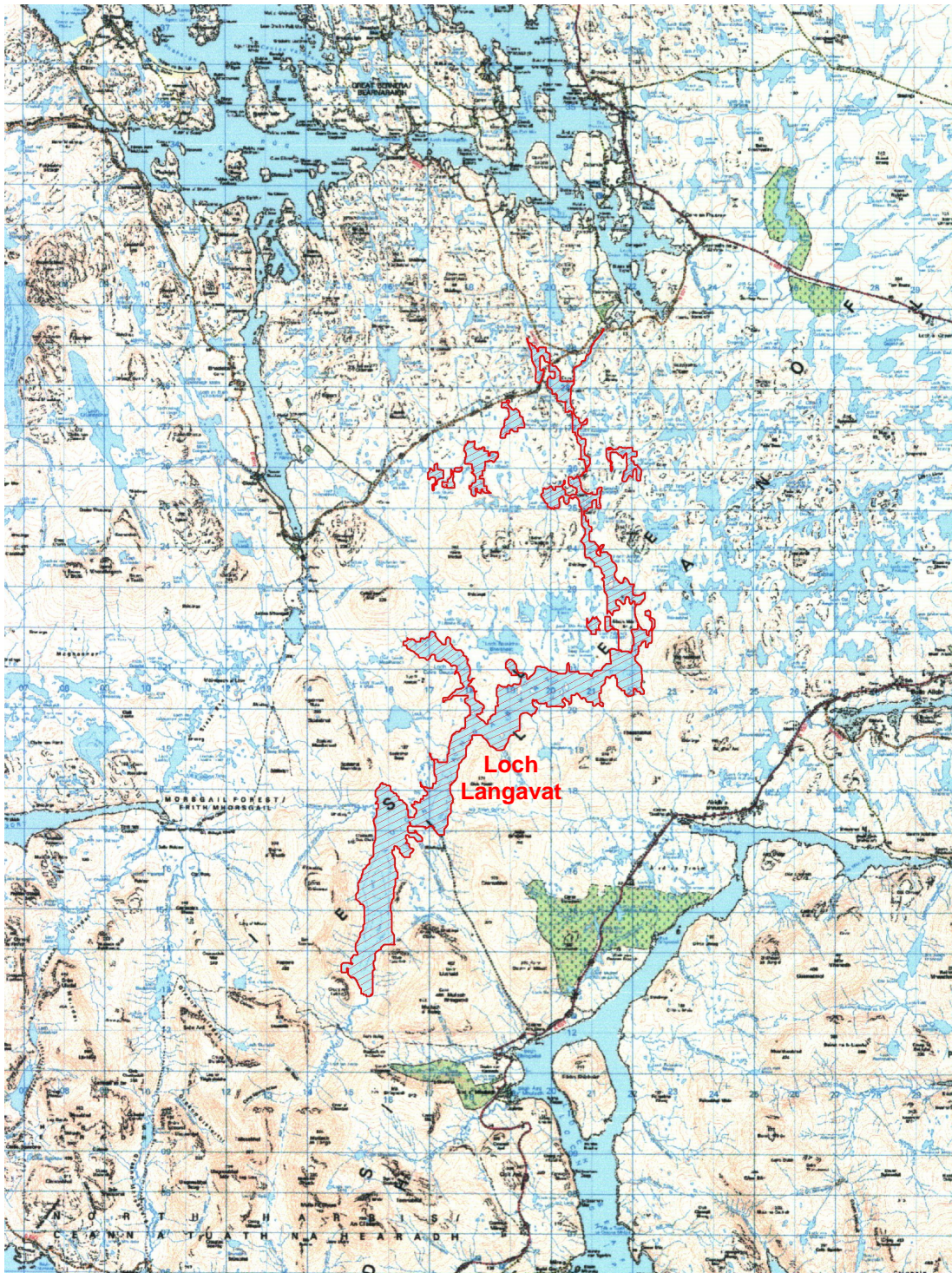
The second SAC within the Loch Roag system is the Langavat SAC, UK 0030255. This comprises inland lotic and lentic waters, designated for their stocks of wild Atlantic salmon, *Salmo salar*. This area encompasses the Grimersta river system, which drains the greater part of the catchment area of Loch Langavat and enters the sea at Loch Ceann Hulavig (East Loch Roag). The system has a high proportion of the lacustrine rearing area for salmon, contrasting with the more usual riverine salmonid habitat that predominates in Scotland. Other countries where this type of habitat is found are in Canada, on the Newfoundland coast and in parts of Iceland. Although the Grimersta River is small in comparison to many mainland systems, it supports the most prolific salmon population in the Western Isles and is considered to be one of the best salmon rivers in the United Kingdom. The land within the catchment, adjacent to the SAC, is mainly used for rough sheep grazing. Although a catchment nutrient budget has not been calculated, it is believed that land management is generally compatible with the conservation of the ecology of the area.

Although Loch Roag itself is not part of the Langavat SAC, the Grimersta River system discharges to the loch. The loch is therefore the route through which wild salmonids migrate to and from their marine habitat. In the case of wild salmon and wild sea trout, there is a view that “above natural” levels of infestation of smolt / post smolt by juvenile stages of the salmon louse, *Lepeophtheirus salmonis*, in or near river estuaries, has occurred in recent years, during the Spring migratory period. Infestive stages of the parasite arising from farmed salmon farm lice populations have been blamed for an increase in infestation pressure in their environs which, in turn, may have the potential to give rise to this phenomenon. The potential impact of salmon farms in the loch on infestation pressure exerted by *Lepeophtheirus* on wild salmonids in the area is an important issue for consideration in the context of the LR SOP.

A map of the Langavat SAC area is given in Figure 3.



Figure 3.  
Map of SAC UK 0030255; Loch Langavat.



## 2.2. Users of Loch Roag and environs.

### 2.2.1. Aquaculture Industry

Four fin fish farming companies operate within Loch Roag; Marine Harvest (Scotland) Limited in East Loch Roag, Carloway Seafoods Limited in Loch Carloway, West Loch Roag and Fjord Seafood Scotland Farming Limited and Hebridean Salmon Company Limited, which operate in both East and West Loch Roag. At least six shellfish farming companies also operate within the loch. Three of these, Hebridean Mussels Limited, Miavaig Mussels Limited and MacAulay, are participating in the LR SOP.

Table 1 shows the current location of fin fish farms within Loch Roag and the species farmed, giving current consent biomass. The current location of fish farm sites is also illustrated in Figure 4.

The current locations of fish farm sites create a number of constraints on future development, viability and sustainability that must be addressed by the LR SOP. These include:-

- Imbalance in biomass consented in each side of the loch relative to ambient hydrography.
- Proximity of some sites to wild salmonid river estuaries.
- Interference with conservation designations.
- Aesthetic constraints.
- Commercial / logistical constraints.

These are addressed individually, by modification of occupied areas, site relocation, site amalgamation, stocking alternation, fallowing and single generation stocking, as described in the following pages.



Table 1.

Fin Fish Farm Companies operating within Loch Roag, giving current consent biomass for each site.

Company	Site Name	Receiving Water	NGR	Species	Consented Biomass
Hebridean Salmon Company Ltd.	Barraglom	Loch Roag	NB 1680 3430	Salmon	490
Hebridean Salmon Company Ltd.	Earshader	Loch Roag	NB 1600 3400	Salmon	250
Fjord Scotland Seafood Farming Ltd.	Eilean Linngeam	Loch Roag	NB1425 3310	Salmon	550
Hebridean Salmon Company Ltd.	South Eughlam Island	Loch Roag	NB 1620 3950	Salmon	400
Hebridean Salmon Company Ltd.	East of Vacasay Island	Loch Roag	NB 1910 3610	Salmon	700
Marine Harvest (Scotland) Ltd.	Reef / Floday (N),	Loch Roag	NB 1040 3370	Salmon	430
Marine Harvest (Scotland) Ltd.	Carishade/ Floday (S)	Loch Roag	NB 1050 3350	Halibut	385
Hebridean Salmon Company Ltd.	Ghainnmich	Loch Roag	NB 1620 3900	Salmon	300
Hebridean Salmon Company Ltd.	Glean Scarista	Loch Roag	NB 1950 3260	Salmon	500
Marine Harvest (Scotland) Ltd.	Gousam Island	Loch Roag	NB 1110 3380	Salmon	850
Fjord Scotland Seafood Farming Ltd	Greinham Island	Loch Roag	NB 2010 3570	Salmon	700
Hebridean Salmon Company Ltd.	Kyles of Little Bernera	Loch Roag	NB 1480 4050	Salmon	600
Fjord Scotland Seafood Farming Ltd.	Kyles Vuia East	Loch Roag	NB 1380 3530	Salmon	1450
Carloway Seafoods Ltd.	Carloway North (Laimishader, Dunan site 1)	Loch Carloway	NB 1850 4240	Salmon	250
Carloway Seafoods Ltd.	Carloway South (Port Naduna, Dunan site 2)	Loch Carloway	NB 1840 4160	Salmon	500
Hebridean Salmon Company Ltd.	N.Kirkibost, Loch Risay	Loch Roag	NB 1750 3750	Salmon	1200
Fjord Scotland Seafood Farming Ltd.	Totarol (Keava), East Loch Roag	Loch Roag	NB 1920 3430	Salmon	500
Marine Harvest (Scotland) Ltd.	Floday / Sron a Ghobhainn	Loch Roag	NB 1100 3320	Salmon	430
Fjord Scotland Seafood Farming Ltd.	Tolsta	Loch Roag	NB 1990 3670	Salmon	800
Fjord Scotland Seafood Farming Ltd.	South Keava	Loch Roag	NB 2000 3460	Salmon	800
Marine Harvest (Scotland) Ltd.	Vuia Beag	Loch Roag	NB 1210 3310	Salmon	1290

Text highlighted in red shows consents, which are active but not in use.

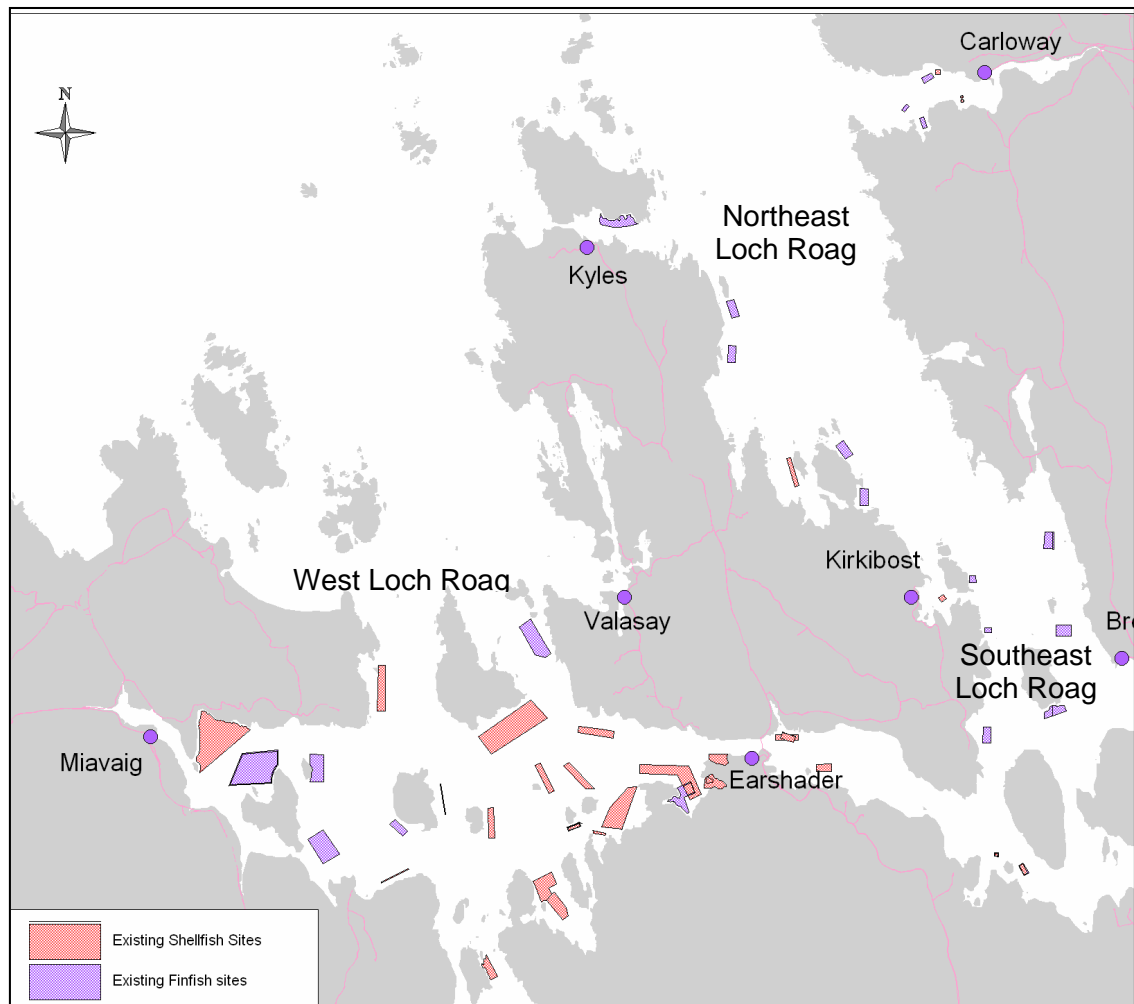


Figure 4.

Loch Roag; current location of fish and shellfish farm sites.

CnES piers and slipways marked ●

### 2.2.2. Wild Salmonid fisheries (Langavat SAC)

The Grimersta River system, which drains Loch Langavat and its catchment (see Section 2.1), is the main wild salmonid fishery resource within Loch Roag although other fisheries contribute to the overall catch taken from the Roag catchment area. Fishing on Loch Langavat is shared between six estates and two angling clubs, with the majority of the remainder of the system being managed as the Grimersta Fishery. A management agreement for Loch Langavat is currently being developed.

Catches comprise Atlantic salmon (*Salmo salar*), sea trout, and brown trout (*Salmo trutta*) and some Arctic char (*Salvelinus alpinus*). The Grimersta Estate owns the netting rights within East Loch Roag in the vicinity of the Langavat catchment. Some other estates also hold netting rights in Loch Roag. However netting rights have not been exercised in Loch Roag since the 1980's and the resource is now used exclusively for angling. A programme of juvenile salmon stocking is undertaken in accordance with the recommended management action plans.

Only limited data on individual fisheries within the loch was available at the time of compiling this report. However Figures 5 to 7 offer some historical perspective on wild salmonid fisheries in Scotland, the Western Isles and Lewis, relative to farmed salmon production.

Figure 5 shows catches by all methods for salmon and grilse and sea trout, for the most productive Scottish Statistical Regions, for the period 1952 to 2004. The following observations are made:-

- Following peak catches in the mid-sixties, primarily due to a peak in commercial fishing effort, catches of both salmon and sea trout have declined in all regions to a greater or lesser degree. The full dataset (Fisheries Research Services Reports) shows that this has been primarily due to a decline in the commercial fisheries, probably as the result of declines in both fishing effort and stocks.
- The east coast fisheries have always dominated catch statistics. West coast fisheries, including those of the Western Isles, have always made a relatively minor contribution to overall Scottish catches of both salmon and sea trout.
- The full dataset (Fisheries Research Services Reports) shows that salmonid catches have generally declined in all Scottish regions to 5% to 25% of their 50-year historic peak catch, for both salmon and sea trout.

Figure 6 shows catches by method of salmon and sea trout for the Statistical Region of the Western Isles. The following observations are made:-

- The commercial fishery accounted for the majority of salmon and grilse caught in the Western Isles until the mid-eighties. The main capture method was draft net (net and coble). Drift netting has been very little used in the Western Isles.
- There has never been an established commercial fishery for sea trout in the Western Isles. The Western Isles are almost unique in this respect amongst the Scottish Statistical Regions. Commercial catches have been limited to very small numbers of fish caught by draft net, mainly in the mid-sixties.
- The full dataset shows that, whilst Western Isles salmon catches have declined to 15 to 20% of their 50-year peak, inline with the catch performance of other statistical regions, sea trout catches, uniquely, still stand at around 40% of their 50-year peak.

There has been no commercial fishing of salmonids at all in the Western Isles since about 1990 and probably earlier than this in Loch Roag itself.

Figure 7 compares total Western Isles catches for salmon and grilse and sea trout with those for Lewis, with data for salmon farm production superimposed on the graphs. The following observations are made:-

- For the present, data for the entire Statistical District of Lewis is the best resolution available. This includes not only all Loch Roag catches (primarily Langavat / Grimersta) but also other, albeit smaller contributions, from a number of other Lewis Sub-Districts.

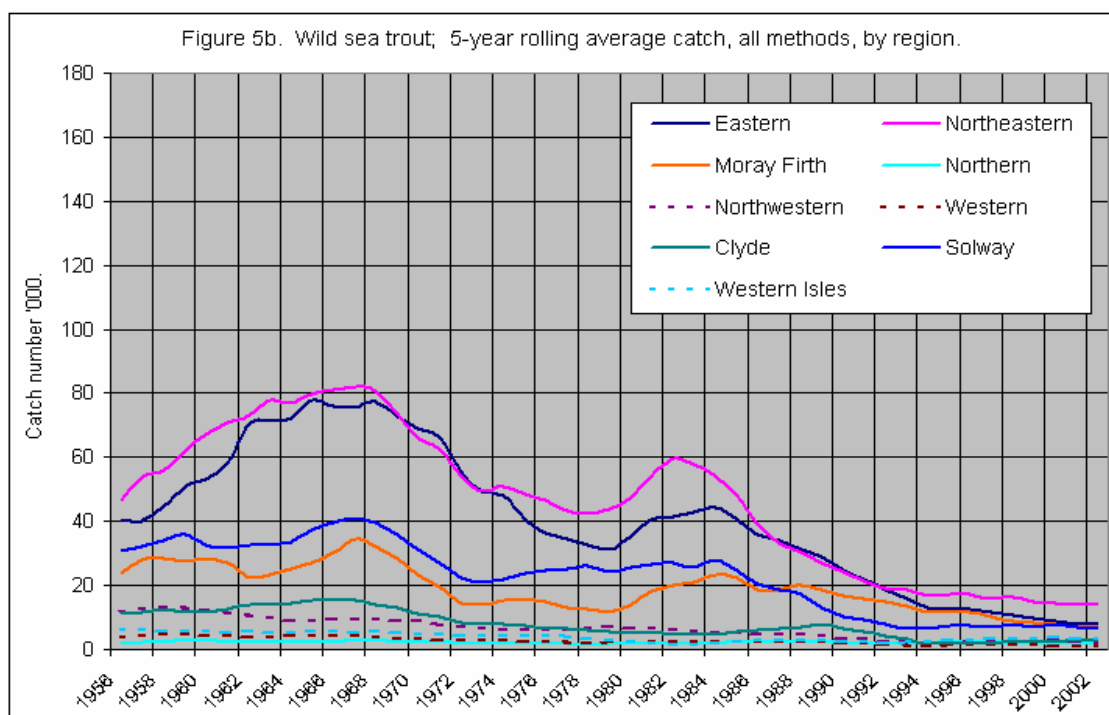
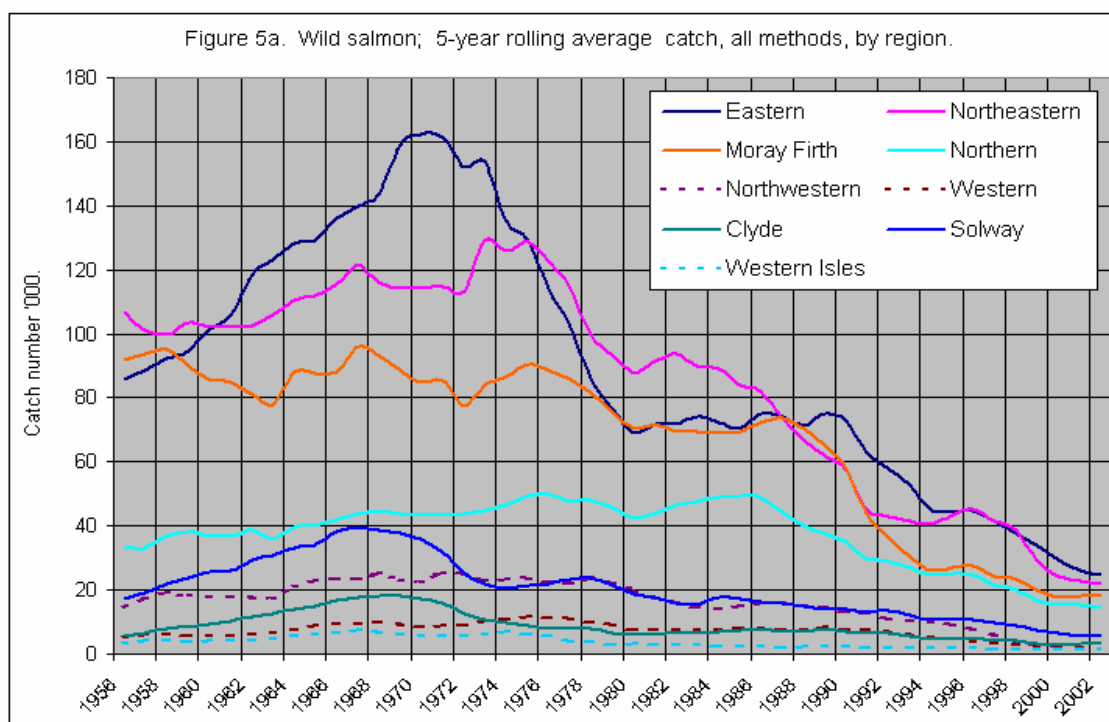


**Figure 5**

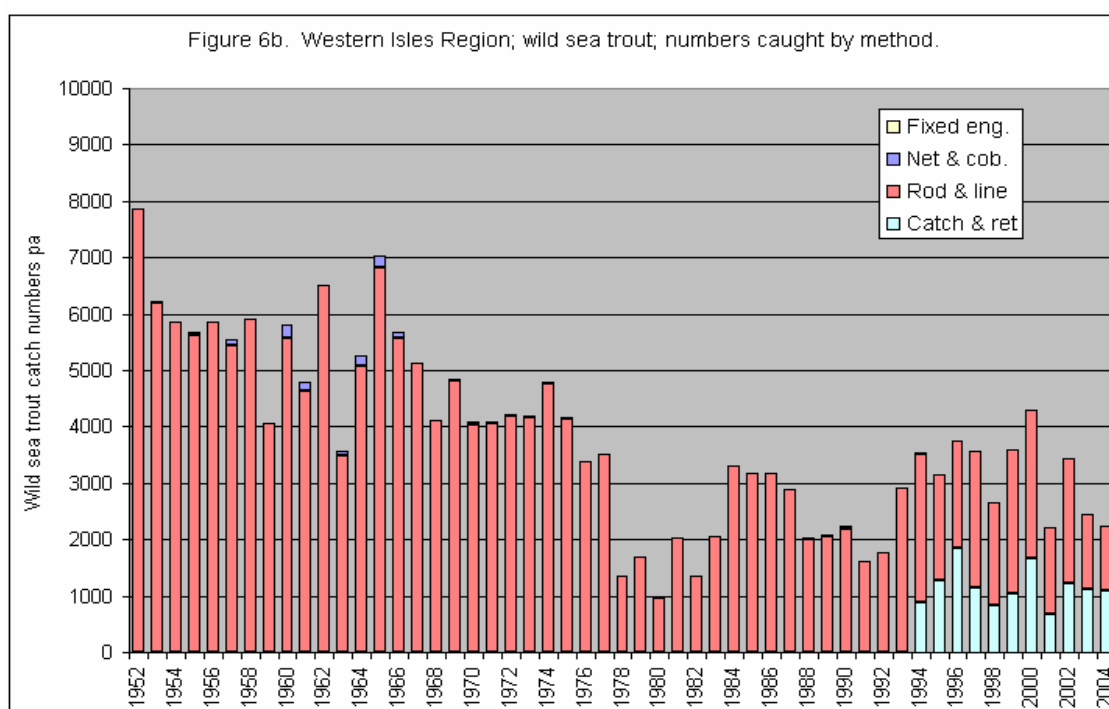
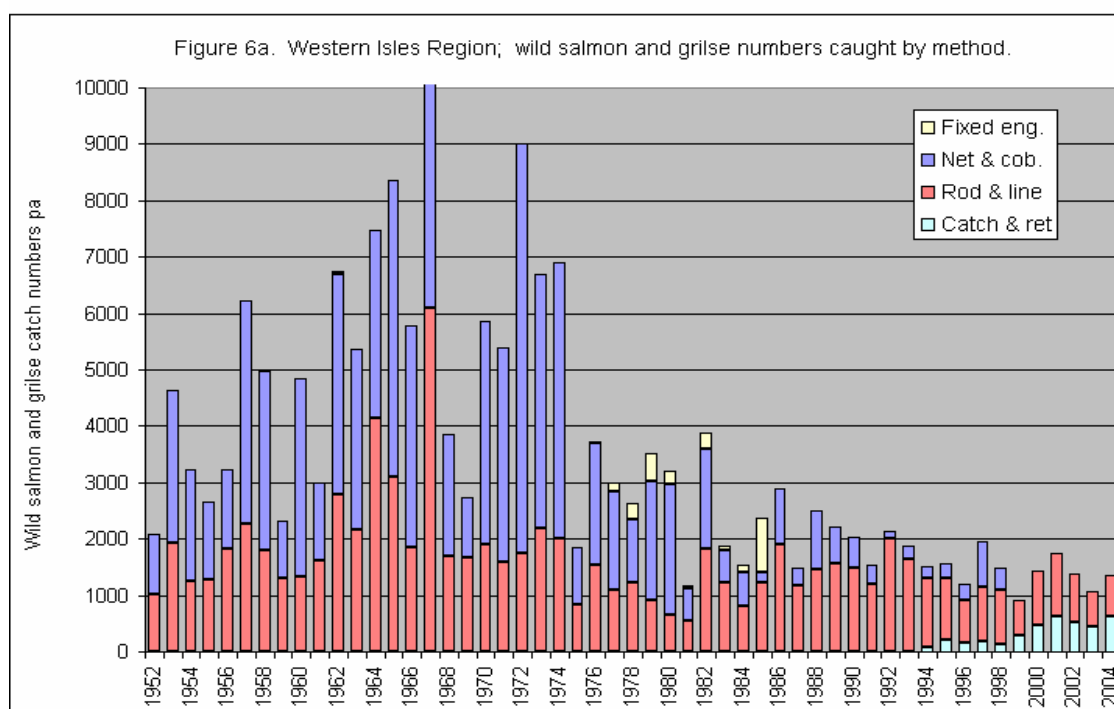
**Scottish wild salmon and sea trout catch, all methods, by selected Statistical Region. Plotted as 5-year rolling average catch.**

Notes.

1. Caught and returned fish are included in the data
2. Statistical regions with major salmon farming industries are denoted by hatched plot lines.

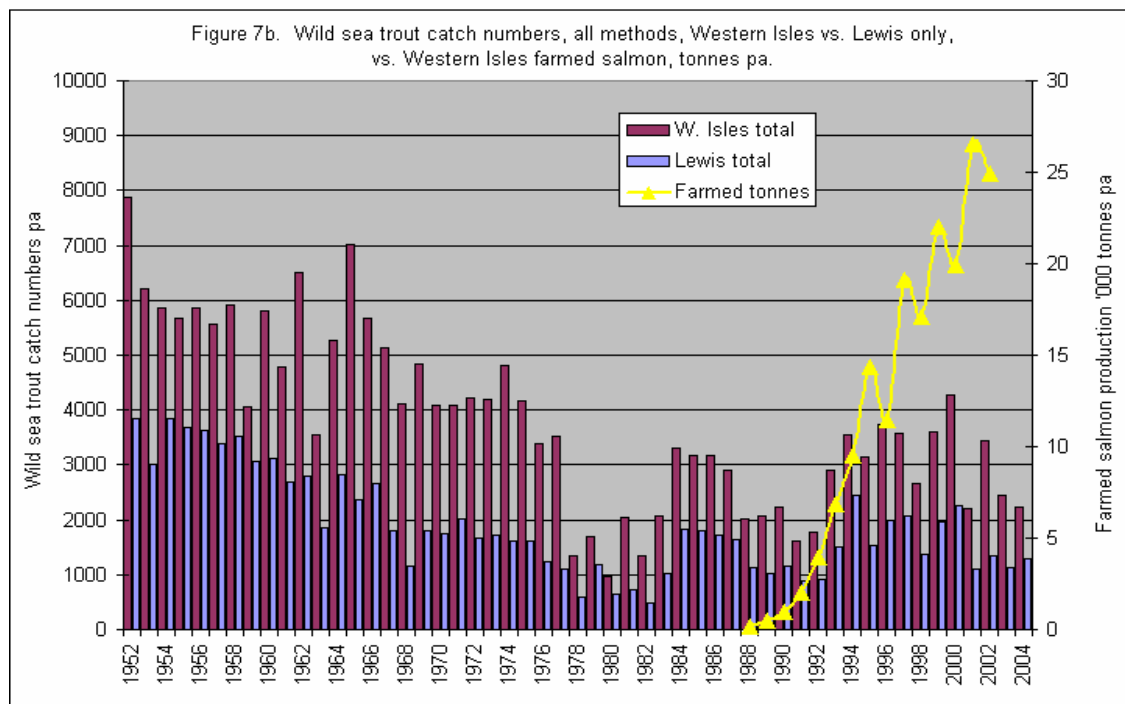
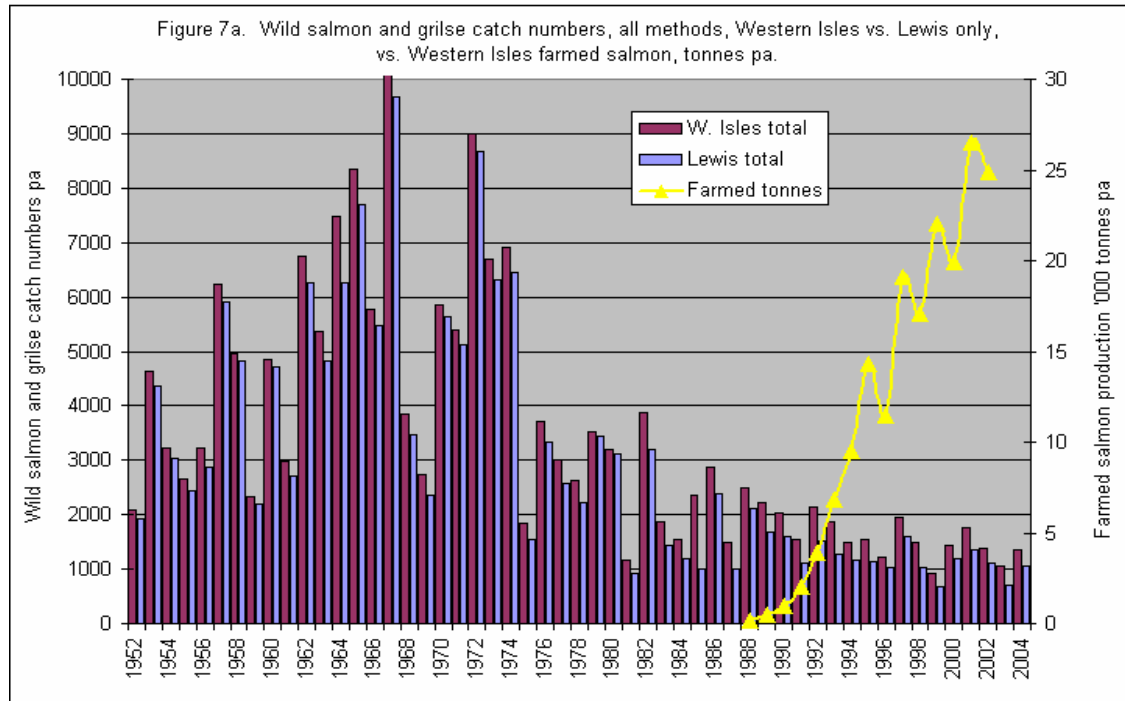


**Figure 6.**  
**Western Isles wild salmon and sea trout catch numbers**  
**all methods, 1952 to 2004.**



**Figure 7.**

**Wild salmon, grilse and sea trout catch numbers, all methods, 1952 to 2004;  
Western Isles versus Lewis only, versus Western Isles farmed salmon production,  
1988 to 2002; tonnes per annum.**



- What is notable from the dataset provided is that Lewis has accounted for an average of 84% (range 42% to 98%) of the total Western Isles salmon and grilse catch by all methods and 50% (range 28% to 70%) of the total sea trout catch. This is due primarily to the supremacy of the Grimersta System as a salmon fishery. The other two Statistical Districts in the Western Isles are District 59, Harris and District 60, the Uists, which accounts for the rest of the islands.
- Figure 7 also highlights the fact that the major decline in both salmon and sea trout catches in the Western Isles had occurred by the mid-eighties, since which time, catches have remained more stable. Salmon farming commenced in the Western Isles in about 1988.

A primary objective of the LR SOP is to promote sustainable exploitation and development of the wild salmonid fishery resource in the Roag catchment by the means highlighted in Section 3.

#### 2.2.3. Shipping

The Comhairle nan Eilean Siar (CnES; the Western Isles Council) is the Harbour Authority for Loch Roag. The limit of their jurisdiction in the loch is within a line running from Gallan Head via Old Hill to Tuimpan, and all waters below high water, including the navigable waters of all rivers streams and creeks connecting East and West Loch Roag. The Comhairle nan Eilean Siar control seven piers within the loch.

The bulk of shipping in the loch comprises inshore fishery and aquaculture vessels.

The separation of shipping lanes and aquaculture sites is an important consideration in the rationalisation of the use of Loch Roag waters.

#### 2.2.4. Capture fishery

There is some inshore fishery activity in the loch waters, comprising limited potting for shellfish, for the most part. Catches are landed at piers within the loch and further afield. No examination of capture fishery statistics has been made as part of this report. However, separation of shipping lanes and aquaculture, and the reduction in the number of aquaculture sites in the loch is expected to assist in the protection of the existing inshore fishery resource.

#### 2.2.5. Tourism

Tourism in the Western Isles is largely based on environmental, cultural, archaeological and outdoor pursuits. The main tourist season is from March to October but there is also a small steady, year-round trade. Gaelic culture is more prominent in the Western Isles than in any other

part of Scotland and is a unique selling point for Western Isles tourism. Data on the value of tourism to the local economy, gathered by MacPherson Research in 2003, calculated that the total number of visitors per annum was around 180,000, contributing some £39.3 million to the local economy (Western Isles Tourism 2002).

Work by MacPherson Research (Western Isles Tourism, 2003) also indicates that the volume of tourism has grown by 8.8% since 1997, with a 9.8% increase in average expenditure, resulting in an overall increase in the tourism value of 19.7% since that date.

Cultural heritage sites, such as museums and historical buildings, attract consistently high numbers of visitors during their stay on the islands. The Visitor Attraction Monitor 2003 (an annual postal survey of Scottish visitor Attractions; Scottish Tourist Board) compiles a list of the top cultural attractions, shown in Table 2.

Table 2  
List of main cultural tourist attractions in the Western Isles.

Main Attractions	Number of Visitors
<b>Paid</b>	
Black House, Arnol, Lewis	13,022
Gearrannan Blackhouse	7,321
Uig Heritage Centre, Lewis	803
<b>Unpaid</b>	
Taigh Chearsabhagh Arts	32,379
An Lanntair, Lewis	23,366 (estimate)
Calanais Visitor Centre	20,984 (estimate)
Museum nan Eilean, Lewis	17,043 (estimate)
Doune Broch Visitor Centre	12,409

One of the most famous archaeological sites in the Western Isles is the Standing Stones at Calanais, which pre-date Stonehenge. This is situated on the north side of East Loch Roag,

Other nearby sites are Cnoc Ceann a'Gharraidh (Callanish II), Cnoc Fillibhir Bheag (Callanish III), Ceann Hulavig (Callanish IV), Achmore and Dun Carloway.

In considering the potential for tourism development, the possible impacts of aquaculture must be taken into account. The primary impact for consideration in the SOP is probably visual impact, but other impacts could arise in respect of road and sea traffic, pier use, water quality and wildlife (in particular in respect of indigenous salmon stocks in that angling is an important segment of the tourism industry).

## 2.3. General Characteristics

### 2.3.1. Population

The population of the Western Isles has fallen steadily over the last century. The results of the 2001 Census indicate that this trend is continuing, with the population having fallen by a further 10%, to 26,502, since the 1991 Census (General Register Office for Scotland, Census of Population). The population decline is due to more deaths than births and net emigration, which is more prevalent in the age group of 18 – 30. The 2001 Census revealed that population decline in the Western Isles is more marked than in other areas of Scotland, including the Highlands and Islands area overall. The age balance of the remaining population has a higher percentage of individuals in the older age groups. The only large town in the Western Isles is Stornoway with a population of approximately 5,600. Tables 3 and 4 indicate recent trends in population for Lewis and Harris.

Table 3

Lewis and Harris; resident population change 1981 to 2001

(Source: General Register Office for Scotland)

Area	1991 Total	Change 1981-91	Percent change	2001 Total	Change 1991-2001	Percent change
Lewis	20,159	-561	-3	18,489	-1,670	-8
Harris	2,222	-267	-11	1,984	-238	-11

Area	1951	1961	1971	1981	1991	2001
Lewis	23,731	21,937	20,326	20,720	20,159	18,489
Harris	3,991	3,285	2,879	2,489	2,222	1,984

Table 4.

Lewis and Harris; Population by island area.

(Source: General Register Office for Scotland)

Note: Figures for 1951 to 1981 are ' persons present ' whilst 1981, 1991 and 2001 are ' persons resident '.

A number of initiatives are now under way in an attempt to stabilise the population and to generally improve the Western Isles economy. The Western Isles Transitional Programme Strategy 2001-2006 has identified four strategic issues for attention:-

- How best to increase the incomes and prosperity of the Western Isles relative to the performance of the Highlands and Islands, Scotland and the EU.
- How best to reduce social and economic disparities within the Western Isles.
- How to ensure that all individuals and communities within the Western Isles can realise their potential and therefore make a full contribution to the development of the Western Isles.
- How to build on the quality of the natural and cultural heritage resources of the Western Isles through the promotion of sustainable economic development.

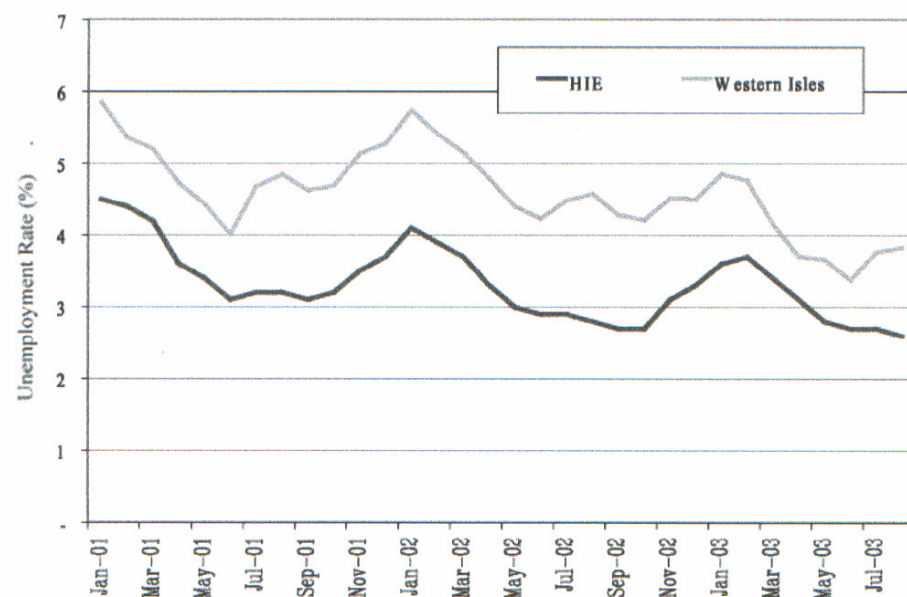
### 2.3.2. Economy and employment

Economy and employment throughout the Western Isles is traditionally resource-based. Historically, crofting and fishing have been the main sources of income. Research undertaken by the Macaulay Land Use Research Institute Western Isles (Roberts et al, 1999) indicates that the economy has grown since the last assessment in 1988 / 89; however this growth is lower than all other regions of Scotland, including the Highlands and Islands and the Northern Isles. The lack of indigenous resources and high materials costs relative to the mainland are primary drivers in the estimated trade deficit of some £98 million.

There is limited private sector investment to the Western Isles, which relies heavily on a continuing need for public sector intervention from the UK and the EU.

Highland and Islands Enterprise (HIE) describes the Western Isles as an 'Economically Fragile Area' indicating a pressing need for sustainable growth opportunities within all sectors of economic, social, cultural and environmental development.

Unemployment in the Western Isles is some 2% higher than for the Highlands and Islands region as a whole, particularly in Lewis and Harris; see Figure 8. It is also prone to seasonal fluctuation. Reliance on areas such as tourism, farming and fishing are of major importance to the economy of the Islands. Unemployment decreased from 5.9% in January 2001 to 4.9% in January 2003, aided in part by increased employment in information technology-related services (Western Isles Economic Update, 2003).



Source: NOMIS (ONS)

Note: LEC rates estimated using GROS Census 2001 population.

Figure 8.  
Unemployment Rates, 2001-2003; Highlands and Islands (HIE) vs. the Western Isles.



Overall, the aquaculture and the fisheries sectors are important employers in the Western Isles, as primary income providers, as sources of raw material for the added value processing sector and as sources of export earnings. The Loch Roag SOP is expected to secure current non-seasonal aquaculture and aquaculture-related jobs and to provide further secure full-time employment in due course.

### 2.3.3. Climate

The Western Isles generally enjoy a temperate maritime climate, due to the effects of the warm ocean current of the Gulf Stream and its northerly extension, the North Atlantic Drift. There is little difference in air temperature between the islands, with a mean maximum of 16°C in August, and a mean minimum of 7°C in January and February. Hard frosts are rare. Annual rainfall is around 1200mm with 45% of the total falling between October to January. April and May tend to be relatively dry with an average rainfall of 63mm per month.

High winds are common in the Western Isles with mean monthly speeds of 6msec<sup>-1</sup> in July/August to about 8msec<sup>-1</sup> in December/January, though daily mean wind speeds of 16msec<sup>-1</sup> with gusts in excess of 26msec<sup>-1</sup> are not uncommon, even during the summer months. The prevailing wind direction is south-westerly, but some of the strongest winds arise from the north-westerly quarter.

To put these figures into context, Beaufort Wind Force 4, described as a Moderate Breeze on the Beaufort scale is a wind speed of 6.7msec<sup>-1</sup> (approx 14 knots) Force 7, or Near Gale, is 15.5msec<sup>-1</sup> (approx 28 knots) and Beaufort Wind Force 10, or Storm Force, is 26.4msec<sup>-1</sup>. Wind induction of water currents occurs at sustained wind speeds of over Beaufort Force 4. Direct winds in the range Near Gale Force 7 to Storm Force 10 increases wave climate from a mean significant wave height of 4.1m (heaped seas streaked with foam) to 8.8m (very high waves with tumbling crests). Although the prevailing direction of south-westerly is somewhat oblique to Loch Roag, the effects of south-westerly gales are still felt within loch waters. North westerly winds although less frequent, can be very strong and can blow storms from the Atlantic, over very long fetches, directly into the loch. A wind rose for Benbecula Airport is given in Figure 9.

Wind and wave climate are the most relevant meteorological parameters in respect of aquaculture activity for the following reasons:-

- Wind induction of tidal currents can increase current speeds and thereby assist with the dilution and dispersal of wastes, both in the water column and from the seabed.

- High winds and consequent storm wave conditions can limit access to installations, compromise safety standards, threaten the structural integrity of cage structures and their moorings and thereby have the potential to precipitate fish escapees, if installations and moorings are not correctly specified.

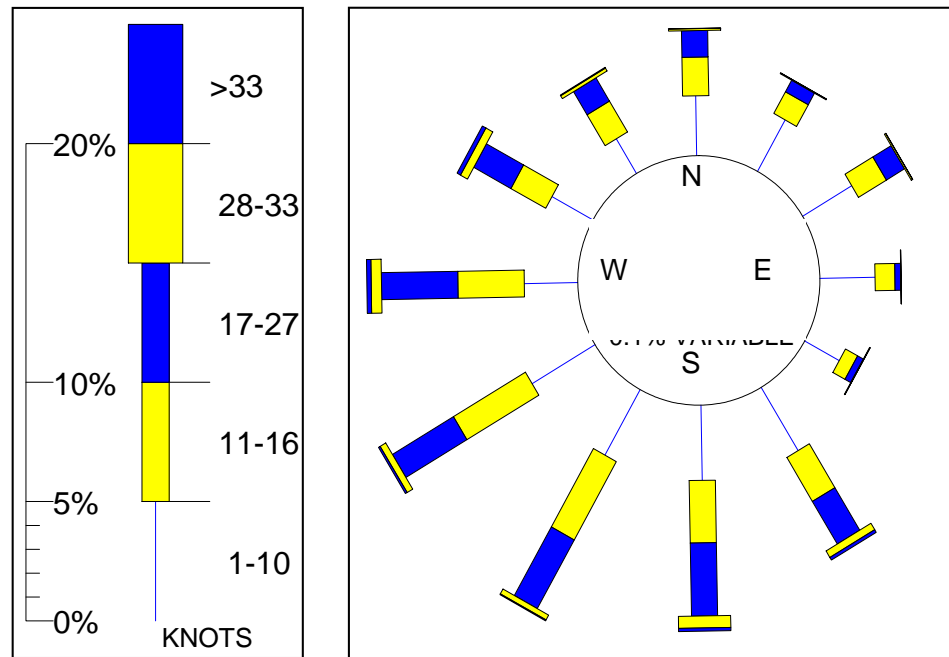


Figure 9  
30-year mean wind rose for Benbecula Airport at 30° sectors.

Limiting the number of escapees is of paramount importance to the salmon farming industry and wild fisheries and, in this case, to the well-being of the Langavat SAC in particular. The strong winds experienced in the Western Isles pose potential problems for fish farm plant and equipment used on the farm sites, thus a more in-depth wave climate analysis study to assess the mechanical and physical stresses to which the farm structures and stock would be subjected to by the local meteorological conditions and the continued accessibility of the site is recommended. From a positive aspect, wind induced currents will improve the flushing, to what extent would only be determined if further studies were to be undertaken.

## Section 3.

### Loch Roag SOP; rationalisation measures.

#### 3.1. Management Areas

Management Areas for the entire Scottish salmon farming industry were established in the Final Report of the *Joint Government / Industry Working Group on Infectious Salmon Anaemia (ISA) January 2000*. The Management Areas designated for the Western Isles are shown in Figure 10. As can be seen, Loch Roag salmon farm sites are isolated from all other Western Isles farm clusters, in Management Area 6a. Many of the practical issues that needed to be addressed if the Management Area concept is to work were further addressed by the Industry / Government document *A code of practice to avoid and minimise the impacts of Infectious Salmon Anaemia (ISA) August 2000*. The adoption of an Area Management Agreement between salmon farming and wild fishery interests within the Loch Roag Management Area is the cornerstone of the Loch Roag SOP as well as a requirement under the terms of the Langavat SAC.

#### 3.2. Area Management Agreement.

The following measures are incorporated into the Loch Roag SOP, in support the Area Management Agreement:-

- Removal of farm sites from the approaches to the Grimersta Estuary.  
Figure 11 shows that a total of eleven finfish farm leases are to be relinquished under the SOP. Ten of these are for salmon and the eleventh for halibut. The majority of the sites to be relinquished are in the inshore area closest to the estuary of the Grimersta River. Figure 12 shows the division of the loch into the East Loch Roag and West Loch Roag and the inshore area that is to be left clear of salmon farms. The inshore area left clear of salmon farms by this action is 9,157,000m<sup>2</sup>. This effectively creates a “firebreak”, not only between Loch Roag salmon farms and the Langavat fishery but also between the farmed salmon in East Loch Roag and those in West Loch Roag. This measure should enable the adoption of the Loch Roag AMA and also fulfil a primary management action for the Loch Langavat Special Area of Conservation.

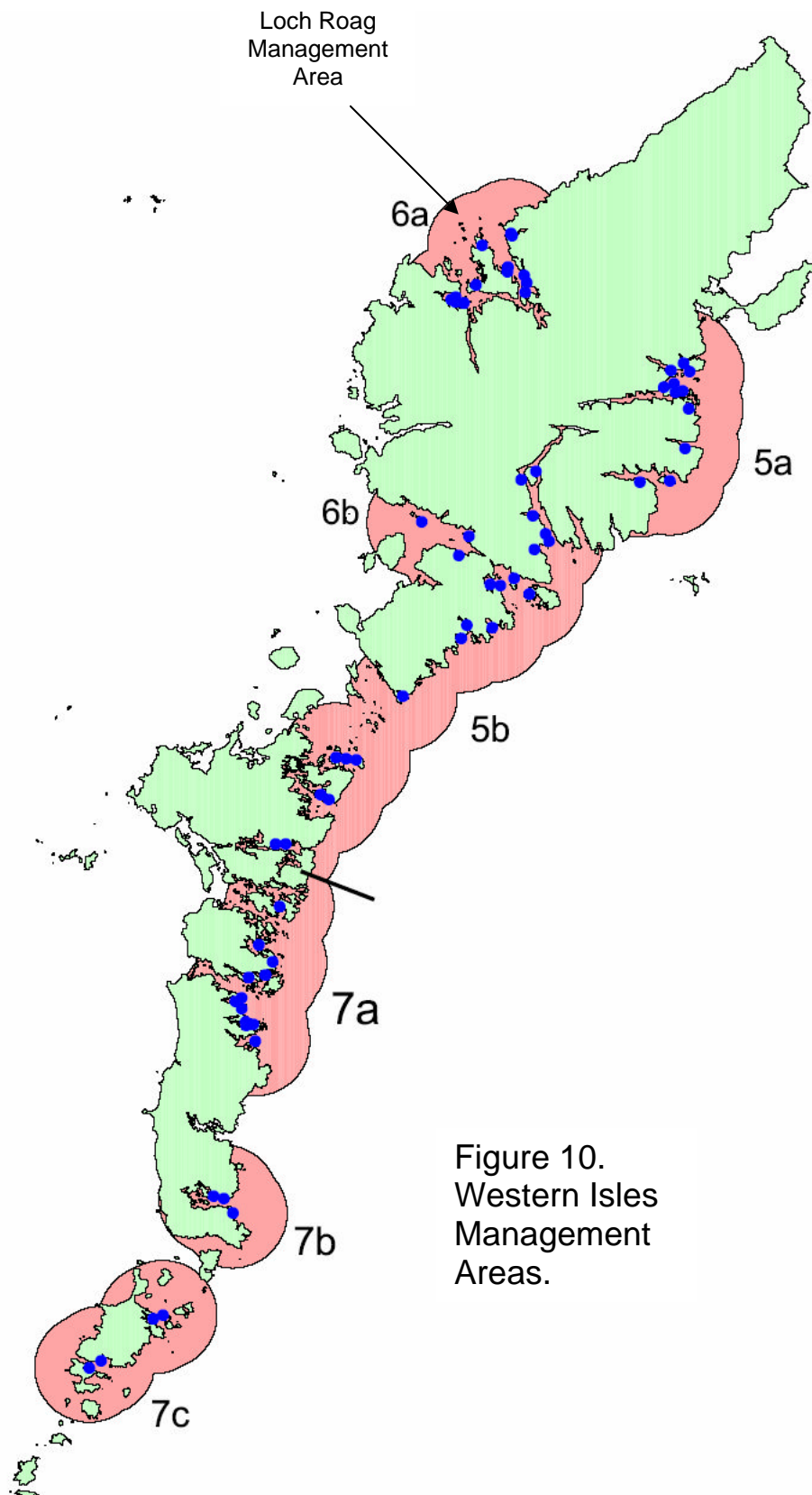


Figure 10.  
Western Isles  
Management  
Areas.

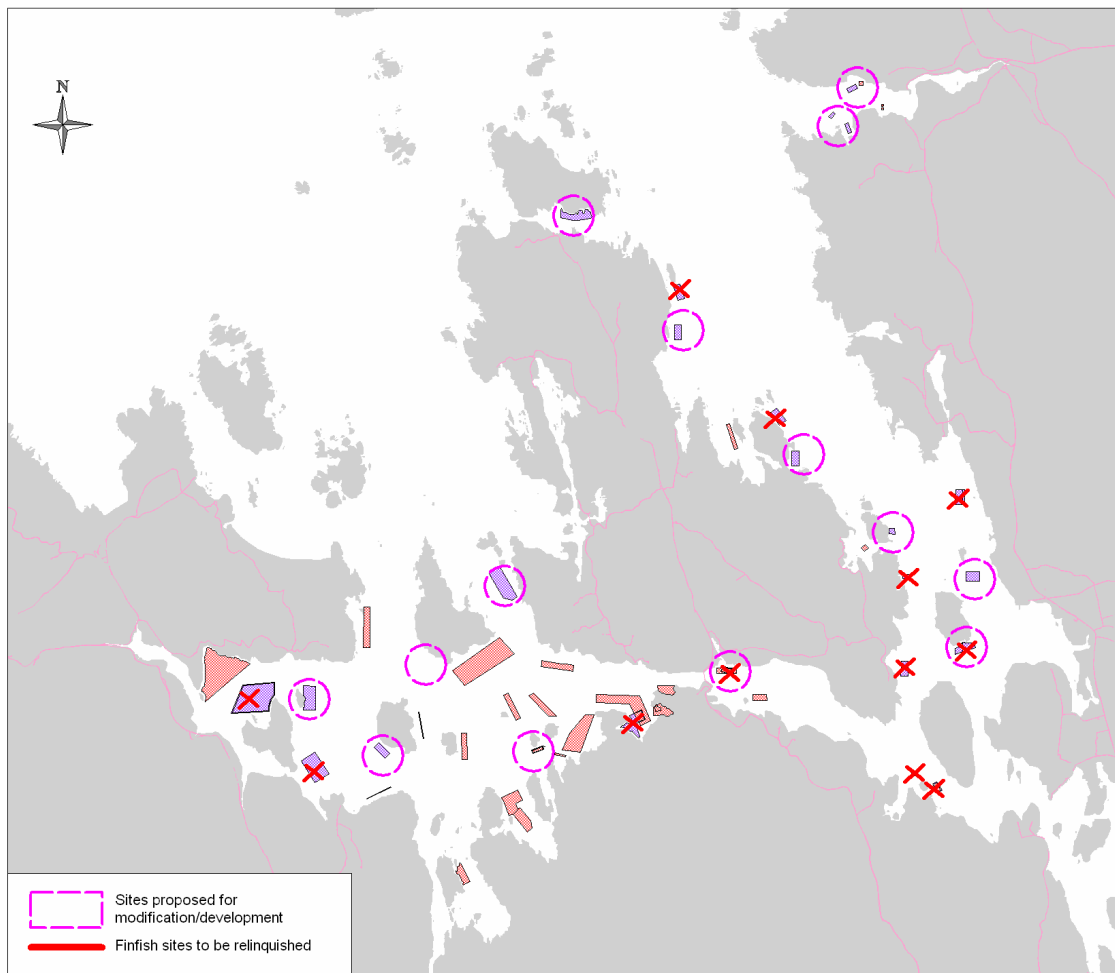


Figure 11.  
Overview of Loch Roag to show salmon farm sites to be relinquished as part of the SOP.

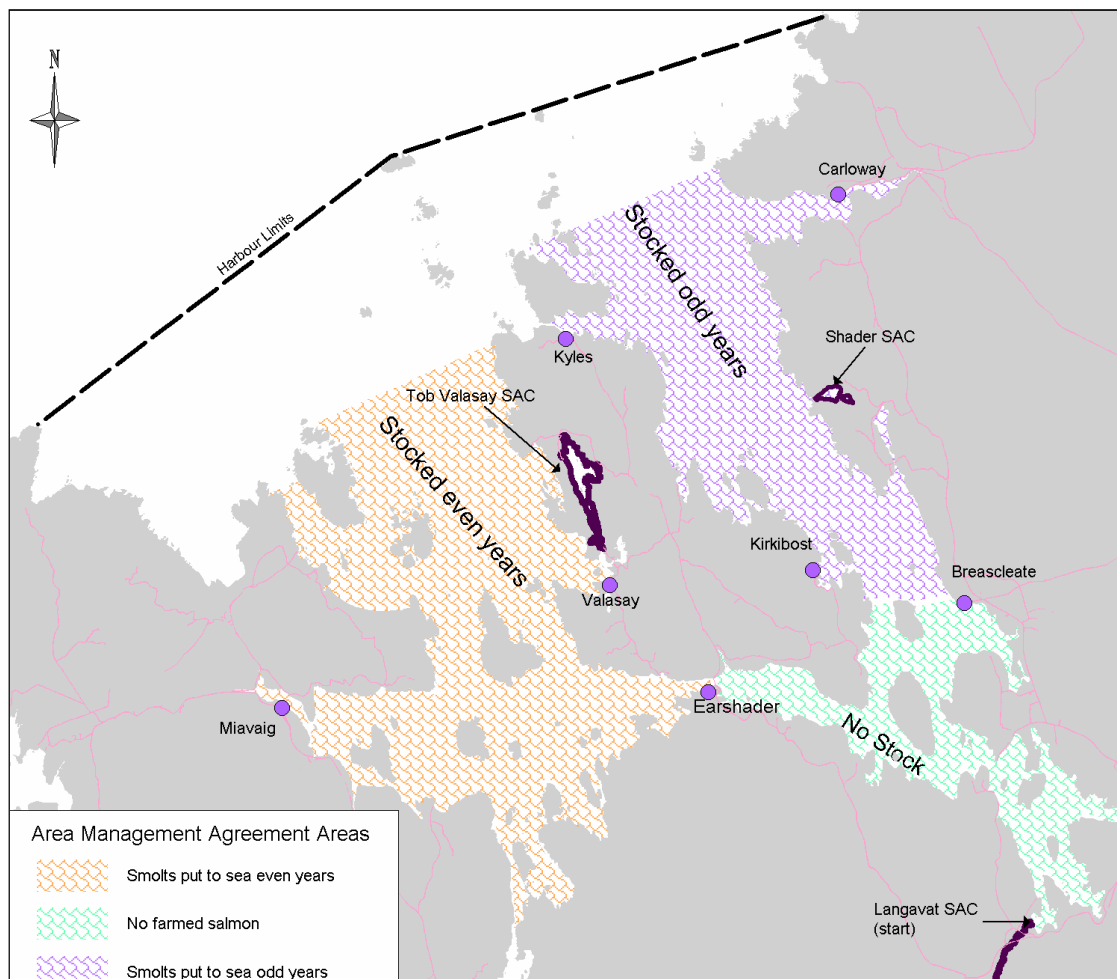


Figure 12.

Area management Agreement Zones, showing the absence of salmon farms from the approaches to the Grimersta River estuary post-SOP.

The main potential benefit of this action is the reduction of infestation pressure on wild salmonids from sea lice, *Lepeophtheirus salmonis*, arising from lice populations on salmon farms within the loch. The copepodid larva is the infestive stage of salmon louse. Nauplius I larvae hatch from egg strings carried by gravid female lice. These metamorphose through a nauplius II stage into copepodid larvae some 3 to 4 days after hatch, dependant on temperature. Copepodid larvae carry limited energy reserves and will die within 8 to 10 days unless they locate a suitable salmonid host. If a host is located, the copepodid attaches to it before metamorphosing into a chalimus larva and feeding.

Copepodid larvae exhibit a limited geotaxis, by which they can sink through the water column by some 6 meters on the ebb tide, to rise again on the flood. It may be by this means that natural populations of copepodid larvae (that is those arising from wild salmonids) are able to maintain their station in the shallow waters relatively close to river mouths, in order to infest emerging salmonid smolt. However, copepodids have no other means of directing their movement, other than an ability to dart a maximum of some 10cm towards a passing host. Removing sources of farmed-origin copepodids from river mouths into deeper waters greatly increases the potential for their seawards dispersal without finding hosts and therefore reduces the threat of additional lice infestation pressure from the immediate area of the estuary.

That said, removal of farms from estuaries does little to prevent the initial, seasonal infestation of farm sites from the original source of copepodids, the wild fisheries themselves. Equally, it does little to prevent reinfestation between farms. Whilst the distance between farm sites and river estuaries may have some function in the rate of infestation of farm sites nearby, infestation of salmon cages can be initiated by extremely low numbers of drifting copepodids because of the huge critical mass of suitable hosts that a stationary cage of farmed salmon represents. Thus additional strategies are required to control the spread of infestation within farm sites or between them. These strategies have also been developed as part of the SOP process and are set out below.

- Alternation of stocking

Figure 12 also illustrates the strategy of alternate stocking agreed for the east and west loch areas. As part of the SOP, East Loch Roag will be stocked in odd years (2007, 2009 etc) and West Loch Roag sites in even years (2008, 2010 etc). Along with intended reductions in overall fish numbers and biomass consents, alternate stocking reduces both the loch-wide peak biomass and numbers of farmed salmon in the intermediate weight range that offers sea lice the greatest host potential and surface area for infestation. This, in turn, has the potential to reduce the overall

numbers of ovigerous female lice carried by each farm and therefore, the generation rate and standing numbers of infestive copepodid larvae.

- Single generation stocking

Single generation stocking is implicit in alternation of stock. The simultaneous holding of more than one generation of stock on salmon farm sites offers an easy vertical path for the transmission of disease and parasites from one generation to the next. This practice, which currently persists on some sites in Loch Roag, will be discontinued with the instatement of the Loch Roag SOP.

- Synchronised fallowing

A policy of synchronised fallowing will also be operated in the East Loch in alternate odd years and in the West Loch in alternate even years. Fallowing is widely used in both agriculture and aquaculture as a means of breaking disease and parasite life cycles. The production and harvesting regime to be followed as part of the Loch Roag SOP will synchronised fallowing to occur for a period of 6 to 8 weeks, from approximately mid-February to approximately mid-April, in odd years in East Loch Roag and in even years in West Loch Roag, in turn. This is illustrated by the stocking timeline shown in Figure 21.

It is notable that the natural period of peak fecundity and growth in sea lice and the most susceptible period for the infestation of migrating wild salmonid smolts from both farmed and wild sources, both also coincide in nature with this spring period. The removal of all farmed stock (and therefore farmed lice hosts) from one or other side of the loch prior to the onset of wild salmonid migration is probably the most potent tool in the prevention of lice infestation of wild salmonid smolt by copepodid larvae from farmed sources.

- Lice treatment.

A policy of synchronised and strategic lice treatment will also be followed by Loch Roag salmon farmers under the SOP, the principles of which are set out in the *National treatment strategy for the control of sea lice of Scottish salmon farms; a code of practice* (SSGA / SQS 1998). The code of practice comprises a combination of sea lice monitoring and treatment with the overall intention of reducing female ovigerous lice numbers, in particular during the “susceptible” spring period. The use of strategic treatments prior to winter (to prevent the growth of juvenile lice over winter into a population of adult lice in early spring) and in early spring (in particular to target ovigerous female lice) is advocated. Early spring treatments should not be required on the fallowed side of the loch; the lower the loch-wide infestation pressure is maintained, the later will be the first required treatment on newly transferred stock.



The general benefits to fish health arising from synchronised fallowing fish treatment for health problems other than sea lice also benefits the long-term health security of wild stocks in the area.

▪ Farmed salmon escapes; preventative measures.

A number of measures following industry guidelines are built into the SOP to prevent and, in the event of, respond to salmon escapes, in particular as set down in *“A code of practice on the containment of farmed fish, official notification following escape of fish and possible measures to be employed to attempt recapture”* (SQS 2002) and *“What to do in the event of an escape of fish from a fish farm”* (SEERAD 2002). The primary aims of these measures are to:-

- Prevent the direct impacts of farmed fish on the breeding or genetic integrity of local wild stocks
- Prevent loss of stock in trade from salmon farms
- Prevent endangerment or equipment loss through storm or other damage to fish farm installations.

The strategies adopted under the SOP are both proactive and reactive:-

- Adequate specification and siting of salmon farm installations in respect of hydrography, in particular of wave climate.
- Separation of navigation and salmon farm installations (see Section 3.3. and Figures 13 and 14).
- Correct navigational marking of all salmon farm installations
- Full registration of all escapes.
- Loch wide measures aimed at recapture and prevention of ingress into the Langavat system.

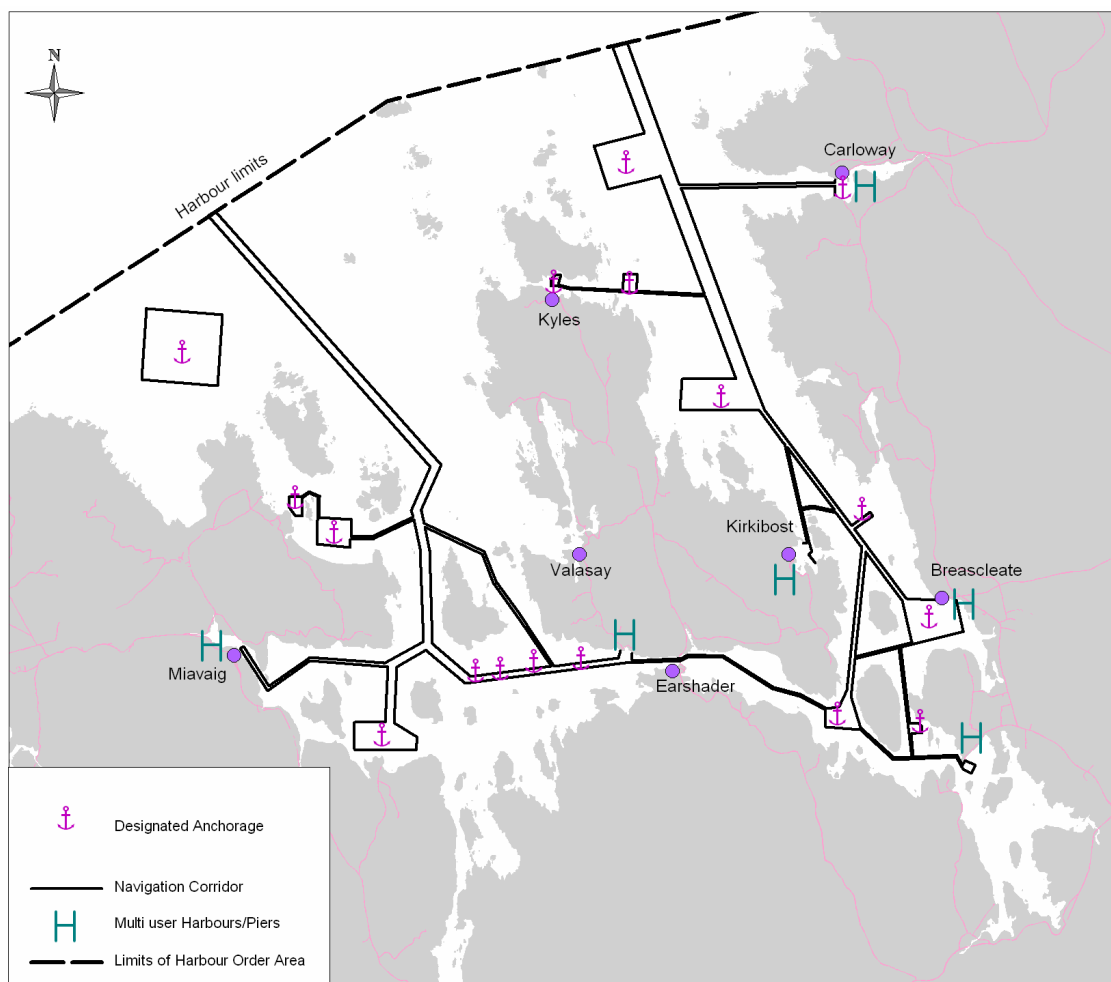


Figure 13.  
Designated navigational corridors for Loch Roag, showing multi-user harbours and piers and designated anchorages.

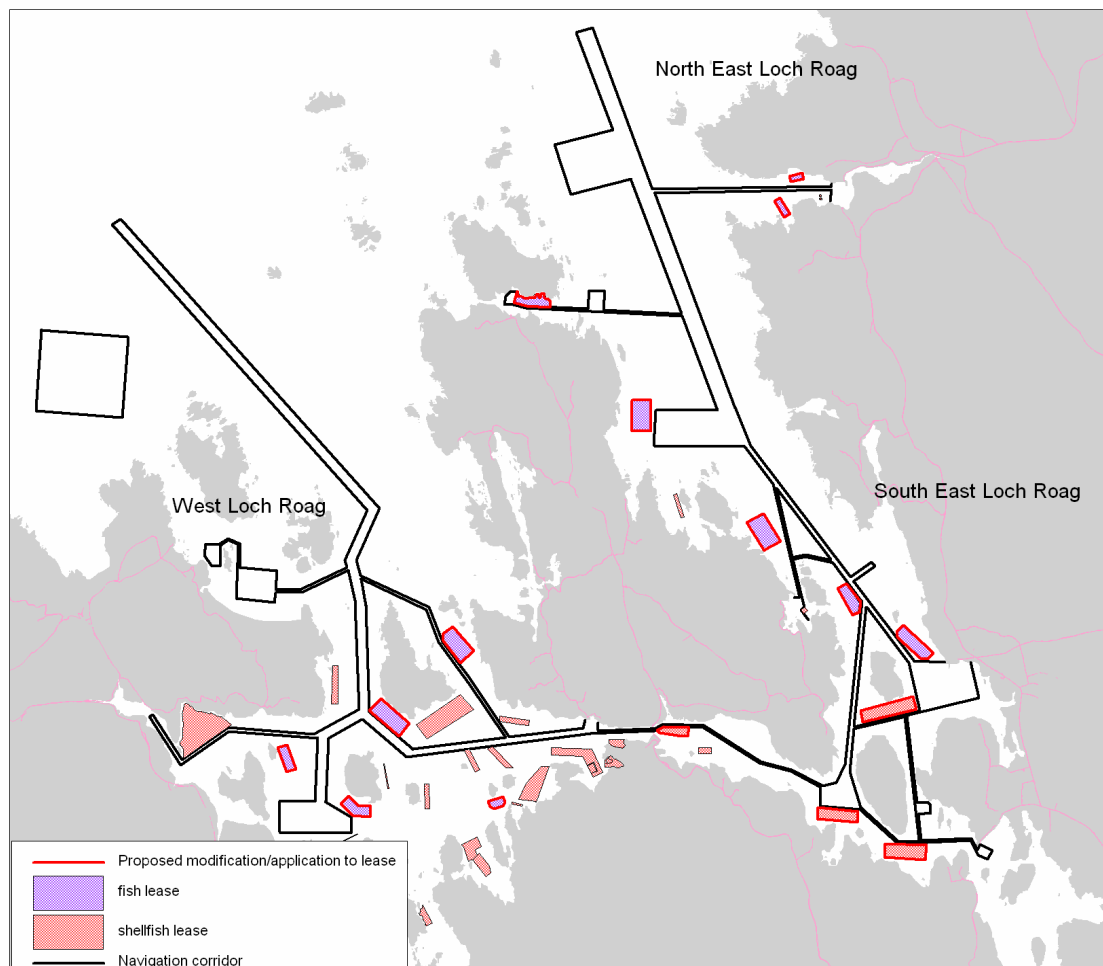


Figure 14.

Designated navigational corridors for Loch Roag, showing proposed post-SOP aquaculture locations.

### 3.3. Navigation.

As part of the SOP, Loch Roag salmon farmers will comply with navigational requirements established by the local authority, Comhairle nan Eilean Siar which is also the Harbour Authority for the loch. Figures 13 and 14 illustrate the proposed navigational channels between the piers in the loch, which also serve to provide routes between aquaculture installations, land bases and designated anchorages. Figures 18 to 20 show the final outcome of the rationalisation of salmon farm site locations and the provision of adequate navigation channels between them, post-SOP, in greater detail.

### 3.4. Consolidation and rationalisation of production locations.

The benefits arising from this SOP objective will be manifold:-

- Removal of sites from proximity to wild salmonid river estuaries Langavat SAC); see Section 3.2.
- Clearance of navigation routes and correct marking of salmon farm sites; see Section 3.3.
- Rationalisation and streamlining of Loch Roag aquaculture businesses; see Section 3.5.
- Matching of site specifications for full cycle site rotation, where this applies.
- Reduction of loch-wide peak monthly biogain and total standing biomass with consequent reduction of loch-wide nutrient and solids discharges by alternation of stocking between East Loch Roag and West Loch Roag

Consolidation and rationalisation entails the relinquishing of a total of eleven finfish farm consents and the application for and (hopefully) granting new or revised consents, the majority of the applications for which accompany this document.

Figure 11 gives an overview of the sites to be relinquished, modified or developed, whilst Figures 15 to 17 show the same information in greater detail. Figures 18 to 20 show Figure 14 on a larger scale; that is the proposed locations and sizes of sites post-SOP, with navigation channels superimposed.

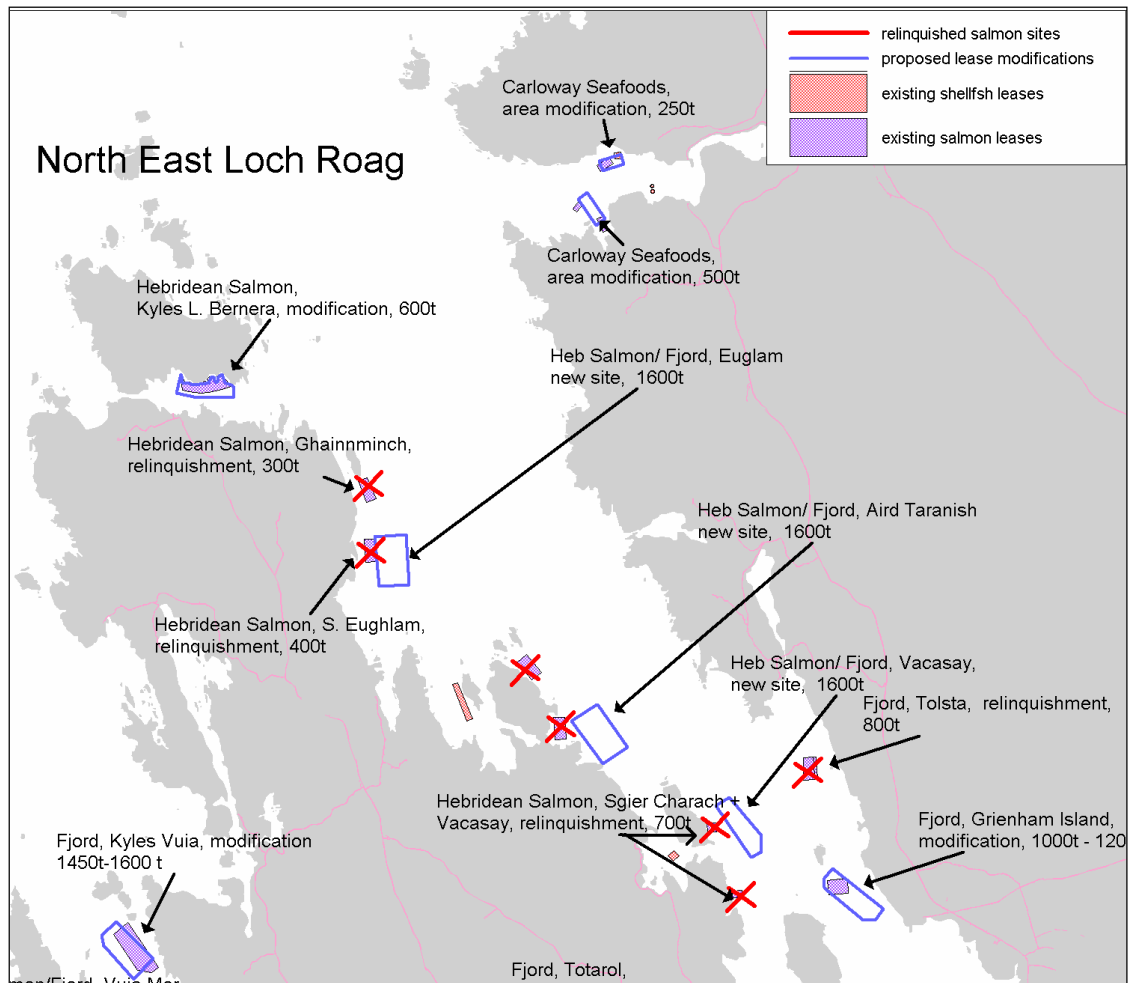


Figure 15.  
Northeast Loch Roag, showing relinquishment and modification of existing salmon farm site consents, plus new consents proposed, as part of the Loch Roag SOP.

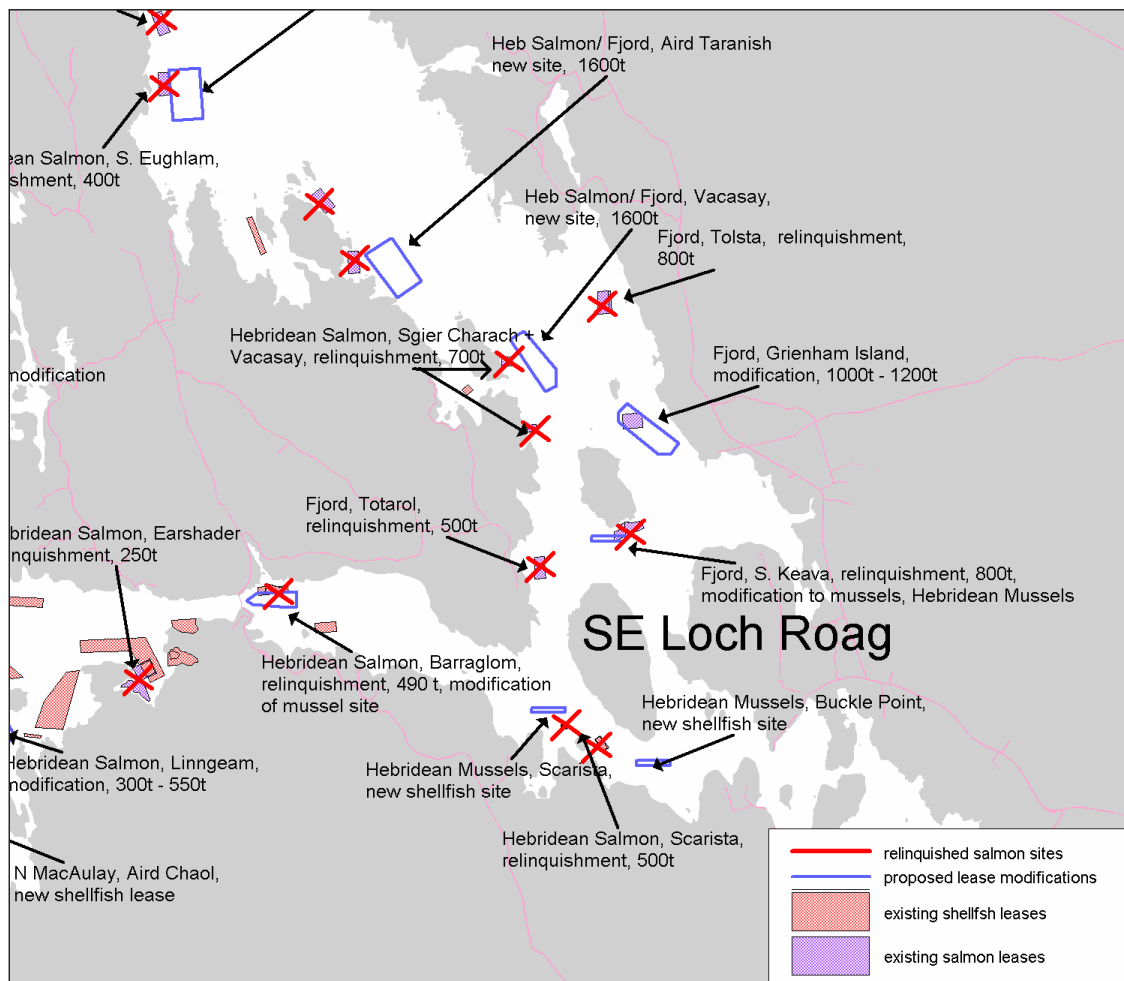


Figure 16.  
Southeast Loch Roag, showing relinquishment and modification of existing salmon farm site consents, plus new consents proposed, as part of the Loch Roag SOP.

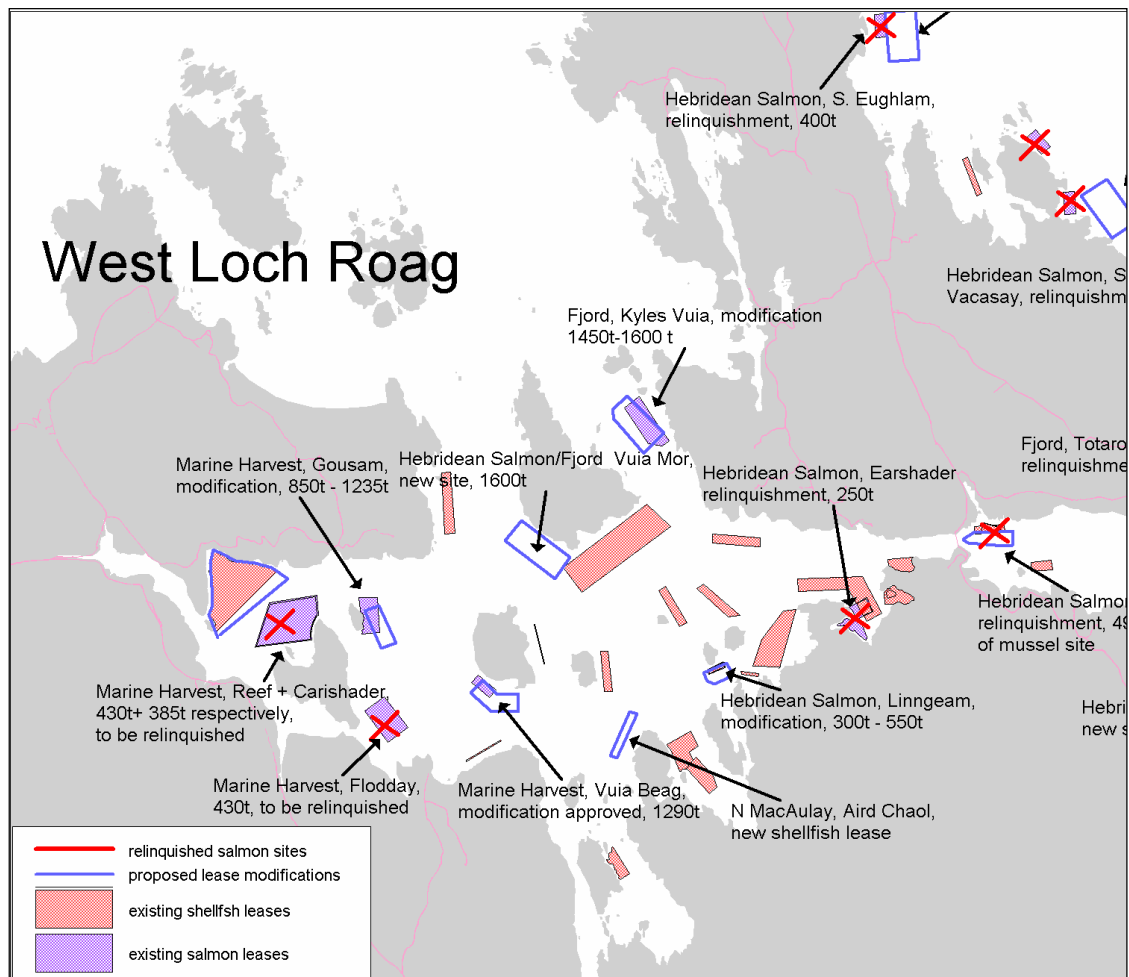


Figure 17.

West Loch Roag showing relinquishment and modification of existing salmon farm site consents, plus new consents proposed, as part of the Loch Roag SOP.

Company	Site Name	NGR	WLR	ELR	WLR	ELR
			Consented Biomass		Proposed Biomass	
Hebridean Salmon Company Ltd.	Barraglom	NB 1680 3430		490	0	0
Hebridean Salmon Company Ltd.	Earshader	NB 1600 3400	250			
Fjord Seafood Scotland Farming Ltd.	Eilean Linngeam	NB 1425 3310	550			
Hebridean Salmon Company Ltd.	S. Eughlam Island	NB 1620 3950		400	1235	1600
Hebridean Salmon Company Ltd.	E. of Vacasay Island	NB 1910 3610		700		1600
Marine Harvest (Scotland) Ltd.	Gousam		850			
Marine Harvest (Scotland) Ltd.	Carishader / Floday (S)	NB 1050 3350	385		0	
Marine Harvest (Scotland) Ltd.	Reef / Floday	NB 1040 3370	430		0	
Hebridean Salmon Company Ltd.	Glean Scarista	NB 1950 3260		500	0	0
Hebridean Salmon Company Ltd. / Fjord Seafood Scotland Farming Ltd.	Aird Taranaish					1600
Fjord Seafood Scotland Farming Ltd.	Greinham Island	NB 2010 3570		700		1000
Hebridean Salmon Company Ltd.	Kyles of Little Bernera	NB 1480 4050		600	1600	600
Fjord Seafood Scotland Farming Ltd.	Kyles Vuia East	NB 1380 3530	1450			
Carloway Seafoods Ltd.	Carloway N (Dunan site 1)	NB 1850 4240		250		250
Carloway Seafoods Ltd.	Carloway S (Dunan site 2)	NB 1840 4160		500	0	500
Hebridean Salmon Company Ltd.	N.Kirkibost, Loch Risay,	NB 1750 3750		1200		0
Fjord Seafood Scotland Farming Ltd.	Totarol (Keava)	NB 1920 3430		500		0
Marine Harvest (Scotland) Ltd	Floday / Sron a Ghobhainn,	NB 1100 3320	430		0	
Fjord Seafood Scotland Farming Ltd.	Tolsta	NB 1990 3670		800	0	0
Fjord Seafood Scotland Farming Ltd.	South Keava	NB 2000 3460		800		0
Marine Harvest (Scotland) Ltd.	Vuia Beag	NB 1210 3310	1290		1290	
Fjord Seafood Scotland Farming Ltd.	Vuia Mor	NB 1268 3432			1600	
Total Salmon biomass			5250	7740	6275	7150

Table 5.

Modification of fihfish farm consents proposed as part of the Loch Roag SOP.

Key; Black = consent unchanged; Red = consent relinquished; *Red italic = Haibut relinquished*; Green= consent increased; Blue = new consent.



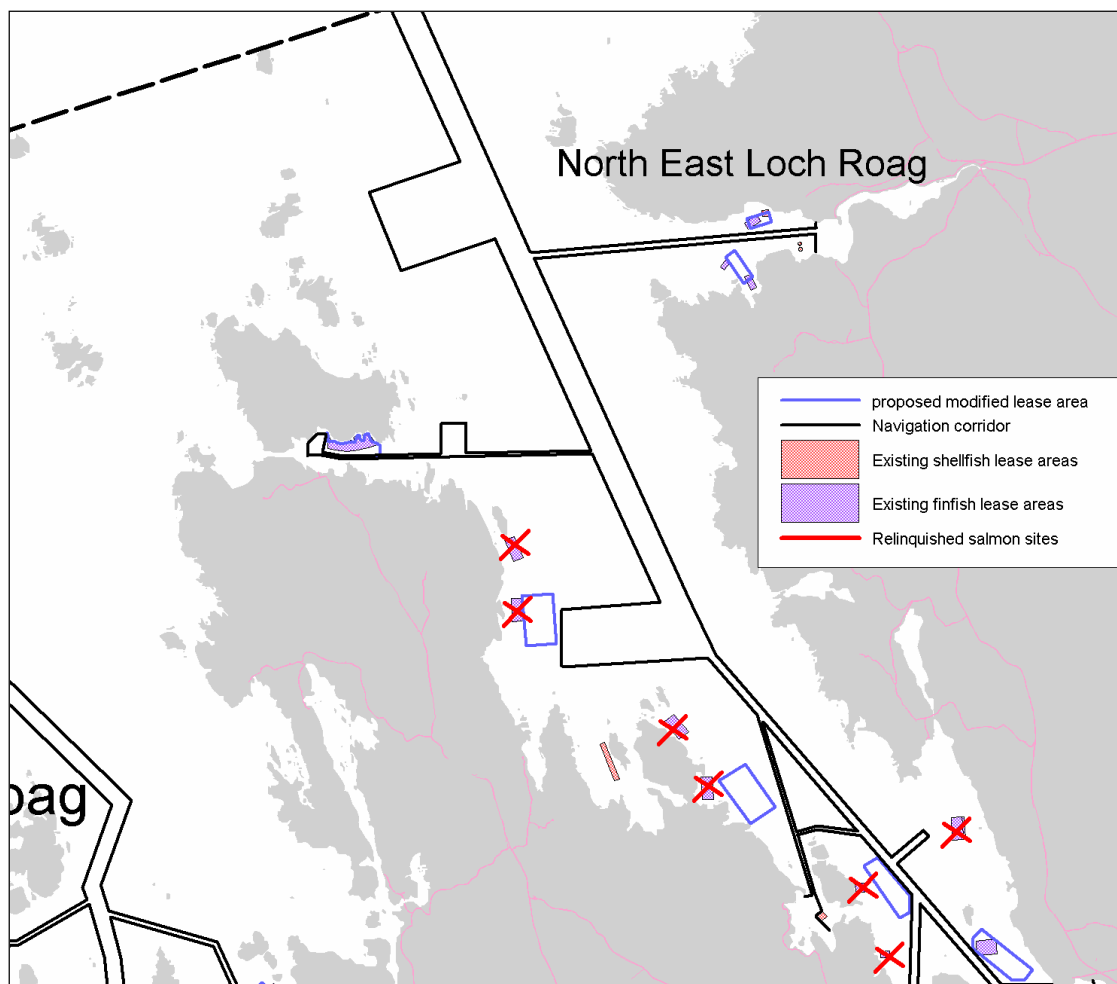


Figure 18.  
Northeast Loch Roag, showing the proposed salmon farm site locations with navigation channels, post-Loch Roag SOP.

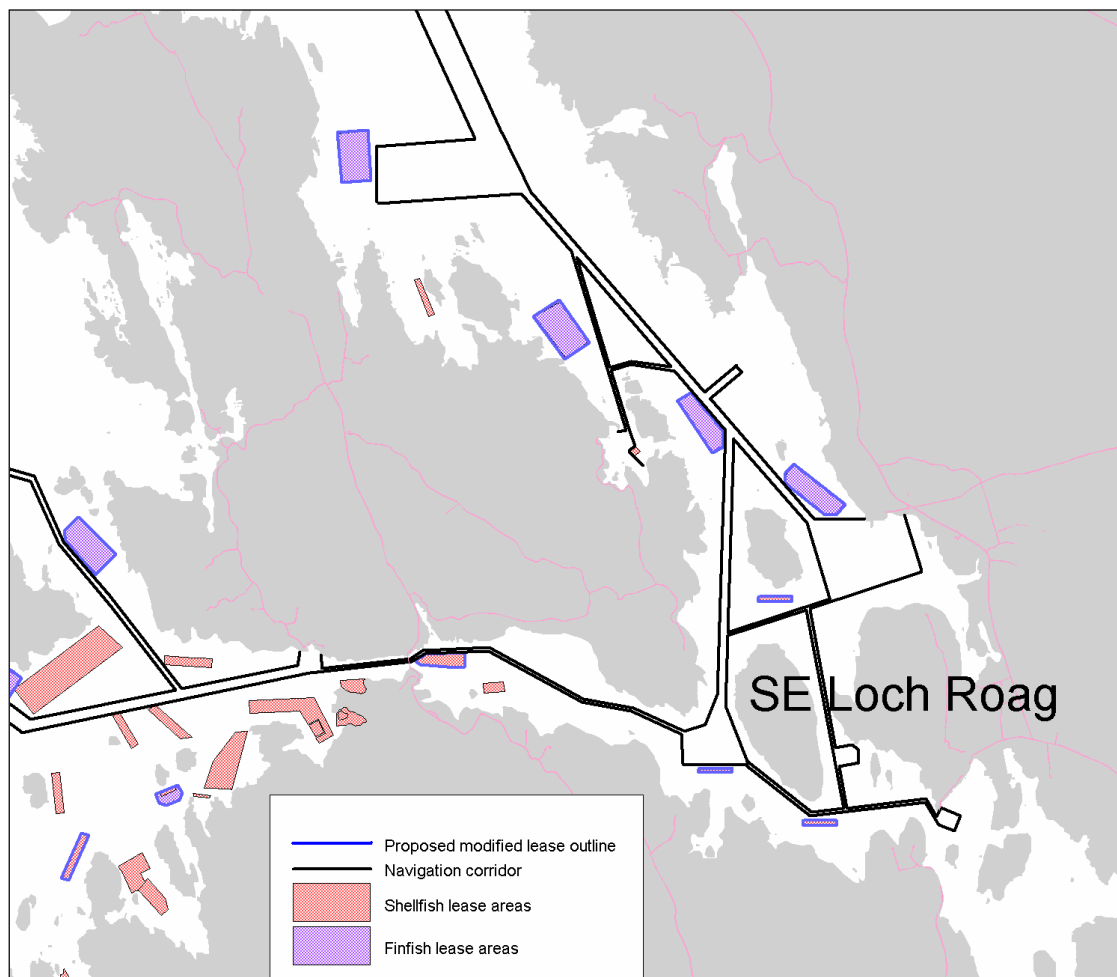


Figure 19.  
South East Loch Roag, showing the proposed salmon farm site locations with navigation channels, post-Loch Roag SOP.

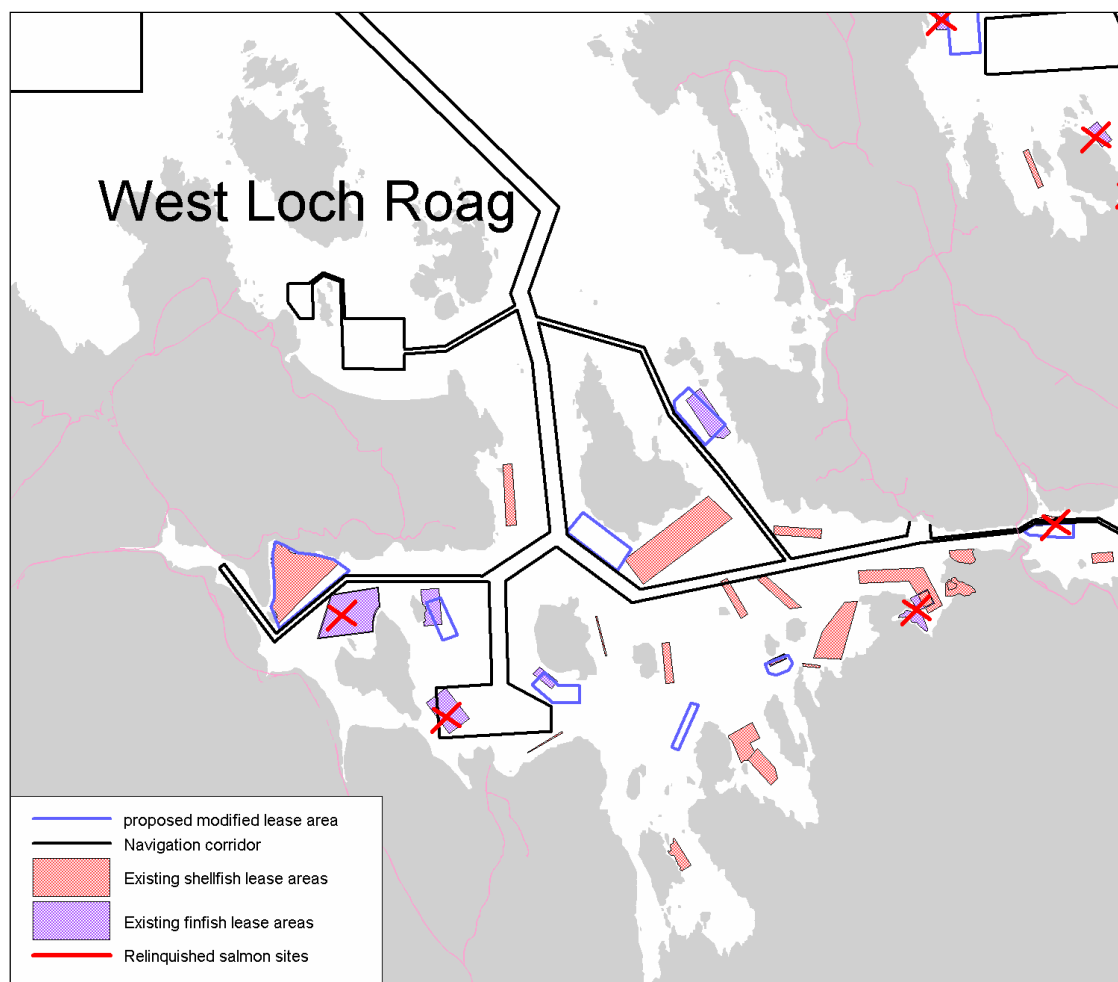


Figure 20.

West Loch Roag, showing the proposed salmon farm site locations with navigation channels, post-Loch Roag SOP.

### 3.5. Economic viability of Loch Roag aquaculture businesses.

The LR SOP offers a number of opportunities for improvement in logistical aspects of the salmon farming process in the loch and in overall operational viability. This is an important consideration for companies operating within the loch, because of the geographical disadvantages of operating in the Western Isles as opposed to mainland Scotland.

In respect of logistical considerations, the relinquishment of consents on some smaller sites, along with amalgamation of some others and the creation of some larger new sites has been carried out with a view to moving operations closer to the land-based headquarters and the piers used by each company operating in the loch.

In some cases the sites themselves have also been moved closer together, as a result, all activities involving sea movements between sites, and between sites and each land base have been shortened as far as possible. This increases the speed of movement and the economy of many husbandry and harvest-related activities, including day-to-day staff movements, maintenance, net changing, treatment, grading and, in particular, harvesting. The consequences for economic efficiencies arising from such rationalisation are clear, for example in terms of time and fuel cost savings.

Site amalgamation and enlargement in itself brings about a number of economies of scale, in terms of the capital and financial costs of cage equipment, service vessels, feed barges and other feeding systems, mooring systems and anchors, as well as in the operational costs associated with site by site operations such as crewing, feeding, maintenance, grading, treating and harvesting.

### 3.6. Production and discharge modelling; rationale and methodology.

The characteristics of farm production and consequent waste discharge are an important consideration in the operation of the Loch Roag salmon farming sector post-SOP, both for individual sites and loch-wide. The fate and possible impacts of discharges must also be examined. These hinge on qualitative and quantitative aspects of waste production, as well as the hydrography of the loch waters. This section firstly examines production and discharge models for proposed individual sites and then examines loch-wide scenarios for East Loch Roag and West Loch Roag separately. Production parameters are shown in a series of graphs in Figures 22 to 38. The numerical models from which the graphs are derived can be made available on request.

Taking the view of SEPA and others who have investigated the hydrography of Loch Roag, the low rate of exchange between East and West Loch Roag at Earshader relative to their tidal flushing rate indicates that the two bodies of water can be regarded, to all intents and purposes, as separate, (see Section 2.1). As a basis for what follows, Table 6 summarises the numbers of farms and consent biomasses in East and West Loch Roag pre and proposed post-SOP.

	Pre SOP	Post SOP
Consented biomass salmon East Loch, tonnes.	7740	7150
Consented biomass salmon West Loch, tonnes.	5250	6275
Consented biomass salmon total, tonnes.	12990	13625
Number of salmon farm consents in East Loch.	13	7
Number of salmon farm consents in West Loch.	7	5
Consented Biomass for halibut in East Loch.	385	0
Number of halibut farm consents in East Loch.	1	0

Table 6.  
Summary of finfish farming pre- and proposed post-SOP.

*Note that this document does not examine the extent of deposition or impacts of either solids or medicines discharges. This information is provided as part of the CoPA licence application and should also be attached to the CE lease applications for each site appended to this document insofar as they have been provided by the stakeholder companies at this stage.*

The individual production models, graphed in Figures 22 to 34, show a production cycle with each site reaching its proposed, post-SOP, maximum consent biomass. Maximum proposed fish numbers, mortality, mean input smolt weight, growth rate, cage specifications, stocking density data, feed type and specification, FCR and harvesting data have all been supplied by the companies as a basis for the production models given.

Production is modelled monthly for each site. Discharges, in terms of Biological Oxidation Demand of waste (BOD), Suspended / Settleable Solids (SS), and Nitrogen and Phosphorus, as total, settleable and soluble N or P have then been derived using FCR, Biogain (total monthly stock weight increase) and feed specification inputs provided, using the following standard formulae:-

1.  $BOD_5 = 686 - [(1671 \times FCR)] + [1544 \times FCR^2] - [354 \times (FCR^3)]$
2.  $SS = 398 - [(919 \times FCR)] + [650 \times FCR^2] - [83 \times (FCR^3)]$

Formulae 1 and 2 were originally derived by the Danish Ministry of the Environment for the calculation of BOD and SS wastes from Danish trout farms and have been used since for the estimation of BOD and SS wastes from farmed salmon by a number of feedstuff companies, for example BioMar UK (BioMar BioRhythm Manual, 2000). The equations describe trend lines through scatter plots of waste BOD and SS data, derived from empirical trials.

3.  $N \text{ total} = [(ration \text{ protein}\% \times 0.16) \times FCR \times 10] - 34$
4.  $N \text{ soluble} = [(ration \text{ protein}\% \times D \times 0.16) \times FCR \times 10] - 34$
5.  $N \text{ settleable} = [(ration \text{ protein}\% \times (100 - D) \times 0.16) \times FCR \times 10] - 34$

Formulae 3 to 5 calculate the total nitrogen in a given ration from the amount of protein that it contains and then subtract an assumed 3.4% (Ackefors and Ennell, 1990) nitrogen content of salmon, leaving the nitrogen that goes to waste. Settleable vs. soluble fractions are derived using D, the digestibility of the ration protein. A digestibility of 89% is used in the figures given

6.  $P \text{ total} = [(ration \text{ P}\%) \times FCR \times 10] - 5$
7.  $P \text{ soluble} = [(ration \text{ available P}\%) \times FCR \times 10] - 5$
8.  $P \text{ settleable} = [(100 - ration \text{ available P}\%) \times FCR \times 10] - 5$

Formulae 6 to 8 calculate the total Phosphorus in a given ration from the proximate analytical data provided by the feedstuff company. Ration Phosphorus content varies with feed size and specification. In the models generated for this report, ration Phosphorus varied between 1.2% and 2.0% of the ration by weight. The phosphorus content of salmon is generally taken as a nominal 0.5% by weight. The proportion of ration Phosphorus

that goes to waste can be calculated by subtracting salmon P content from ration P content. Settleable versus soluble Phosphorus fractions in the waste are then estimated on the basis of Phosphorus availability in the ration. A figure of 38% availability is generally used for this calculation.

The anticipated stocking, production, harvesting and fallowing timeline for the operation of the sites in West and East Loch Roag, on which the production and discharge models are based, is given in Figure 21.

### 3.7. Model outputs.

The outputs from the models for the five proposed West Loch Roag sites and the seven proposed East Loch Roag sites (plus Tolsta; see below) are given in the following figures:-

Figure 22. WLR Fjord-HSC Linngeam.

Proposed consent biomass post-SOP 550 tonnes.

Figure 23. WLR Fjord Vuia East.

Proposed consent biomass post-SOP 1,600 tonnes.

Figure 24. WLR Fjord Vuia Mor.

Proposed consent biomass post-SOP 1,600 tonnes.

Figure 25. WLR MHS Gousam.

Proposed consent biomass post-SOP 1,235 tonnes.

Figure 26. WLR MHS Vuia Beg.

Proposed consent biomass post-SOP 1,290 tonnes.

Figure 27. ELR Carloway Dunan 1.

Proposed consent biomass post-SOP 500 tonnes.

Figure 28. ELR Carloway Dunan 2.

Proposed consent biomass post-SOP 250 tonnes.

Figure 29. ELR Fjord Little Kyles of Bernera.

Proposed consent biomass post-SOP 600 tonnes.

Figure 30. ELR Fjord Tolsta.

Consent biomass 800 tonnes; will cease production once alternatives are in place (2007?).

Figure 31. ELR Fjord Greinham Island.

Proposed consent biomass post-SOP 1,000 tonnes.

Figure 32. ELR Fjord Vacasay.  
Proposed consent biomass post-SOP 1,600 tonnes.

Figure 33. ELR Fjord Taranaish.  
Proposed consent biomass post-SOP (2007?) 1,600 tonnes.

Figure 34. ELR Eughlam.  
Proposed consent biomass post-SOP (2007?) 1,600 tonnes.

This information is presented in a series of four graphs per Figure, giving:-

1. Monthly feed fed and resulting biogain (units tonnes per month).
2. Monthly-end biomass (units tonnes).
3. Monthly BOD and SS discharges (units tonnes per month).
4. Monthly soluble N and P discharges (units tonnes per month).

Following this, Figures 35 to 38 show four pairs of time-series graphs, comparing the same four parameters for East and West Loch Roag, loch-wide. These are derived from the summation of the individual model outputs for the sites in West Loch Roag and East Loch Roag respectively. The time series given is January 2006 to December 2013. This demonstrates the build-up of production to steady state during the early years post-SOP, after which peak consent biomass is reached in every cycle.

Figure 35. Loch wide, monthly feed and resulting biogain (units tonnes per month) for East Loch Roag and West Loch Roag respectively.

Figure 36 Loch wide, month-end biomass, for East and West Loch Roag (units tonnes).

Figure 37 Loch wide, monthly BOD and SS discharges for East and West Loch Roag (units tonnes per month).

Figure 38 Loch wide, monthly soluble N and P discharges for East and West Loch Roag (units tonnes per month).



**Figure 21.**  
Loch Roag; stocking, production, harvesting and fallowing timeline, 2005 to 2012.

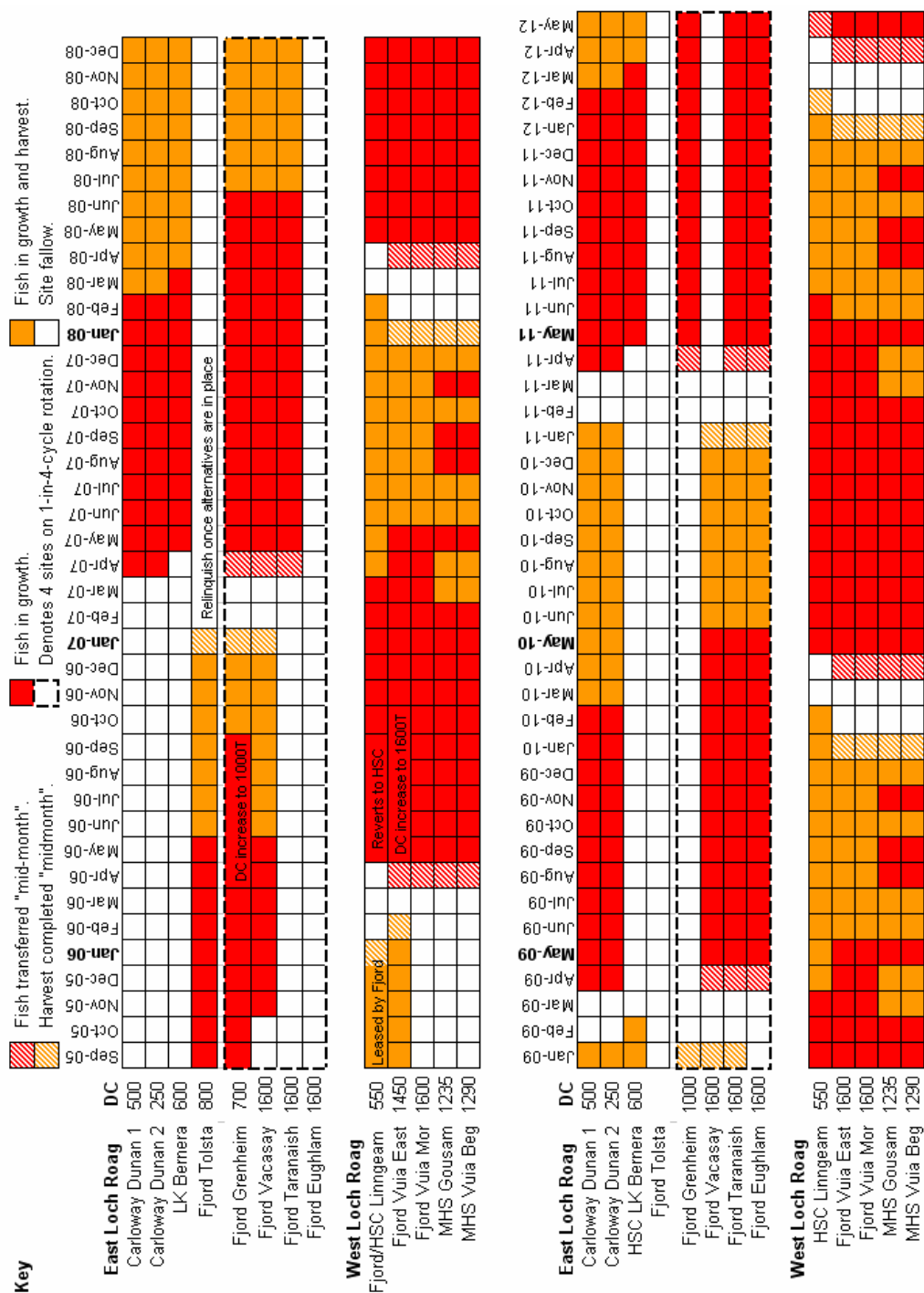


Figure 22.  
Production / discharge model for West Loch Roag farms; projected feeding, growth and waste parameters.  
WLR HSC Eilean Linngeam site ; note site reverts from Fjord end 2005 then HSC proposes biennial cycles from 2006 input.

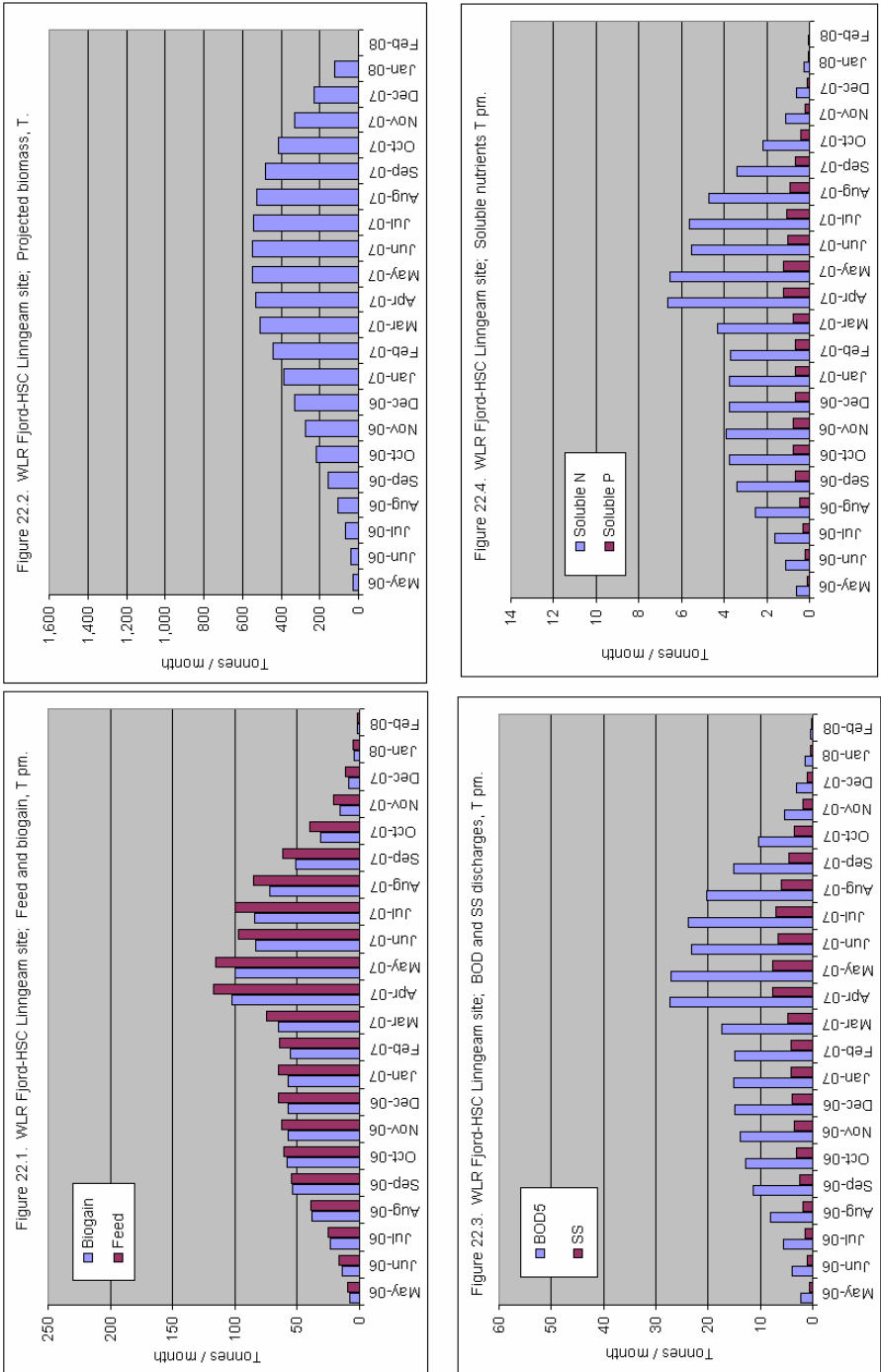


Figure 23.  
Production / discharge model for West Loch Roag farms; projected feeding, growth and waste parameters.  
Projected feeding, growth and waste parameters per cycle.  
WLR Fjord Vuia East site.

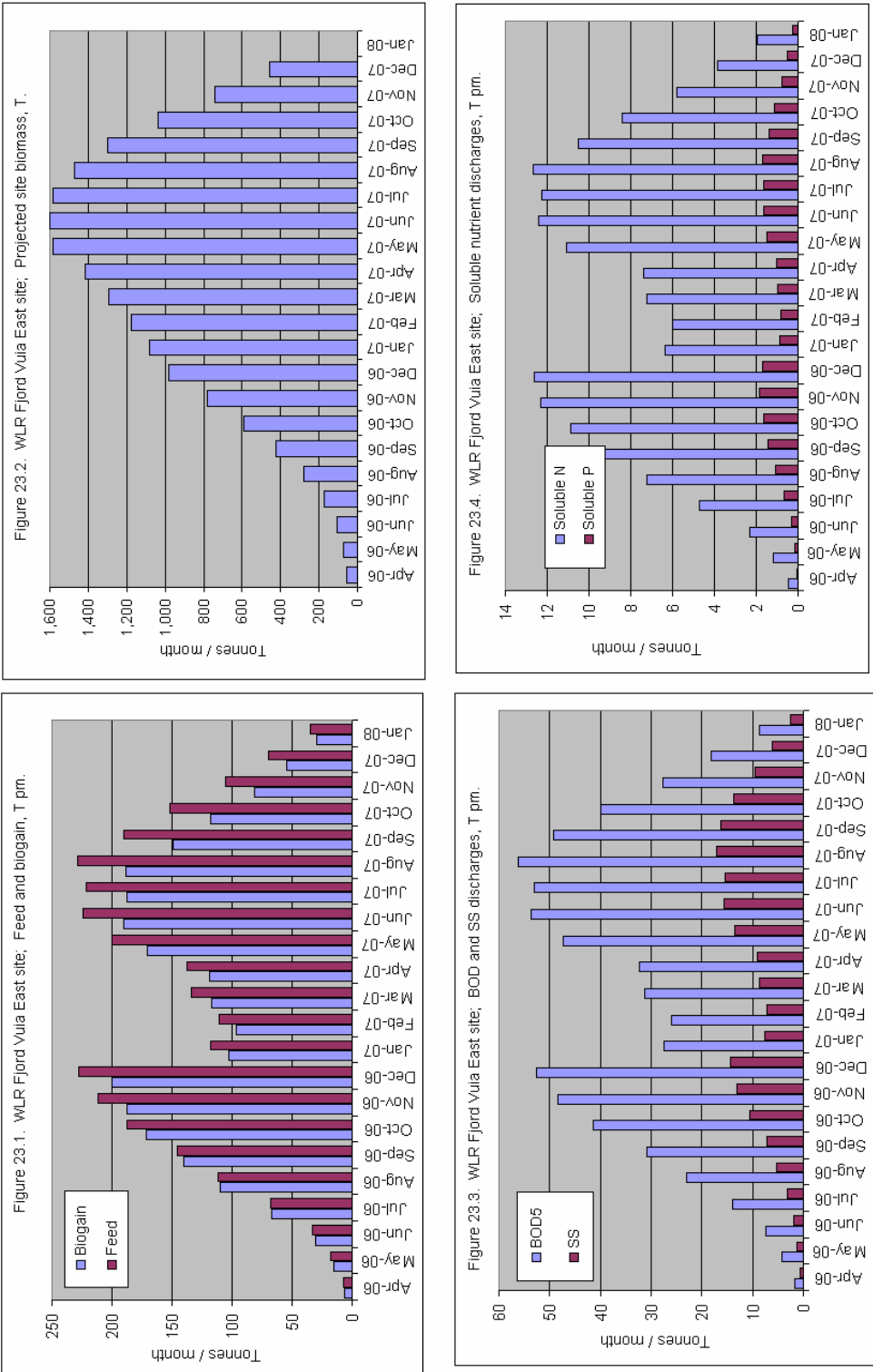
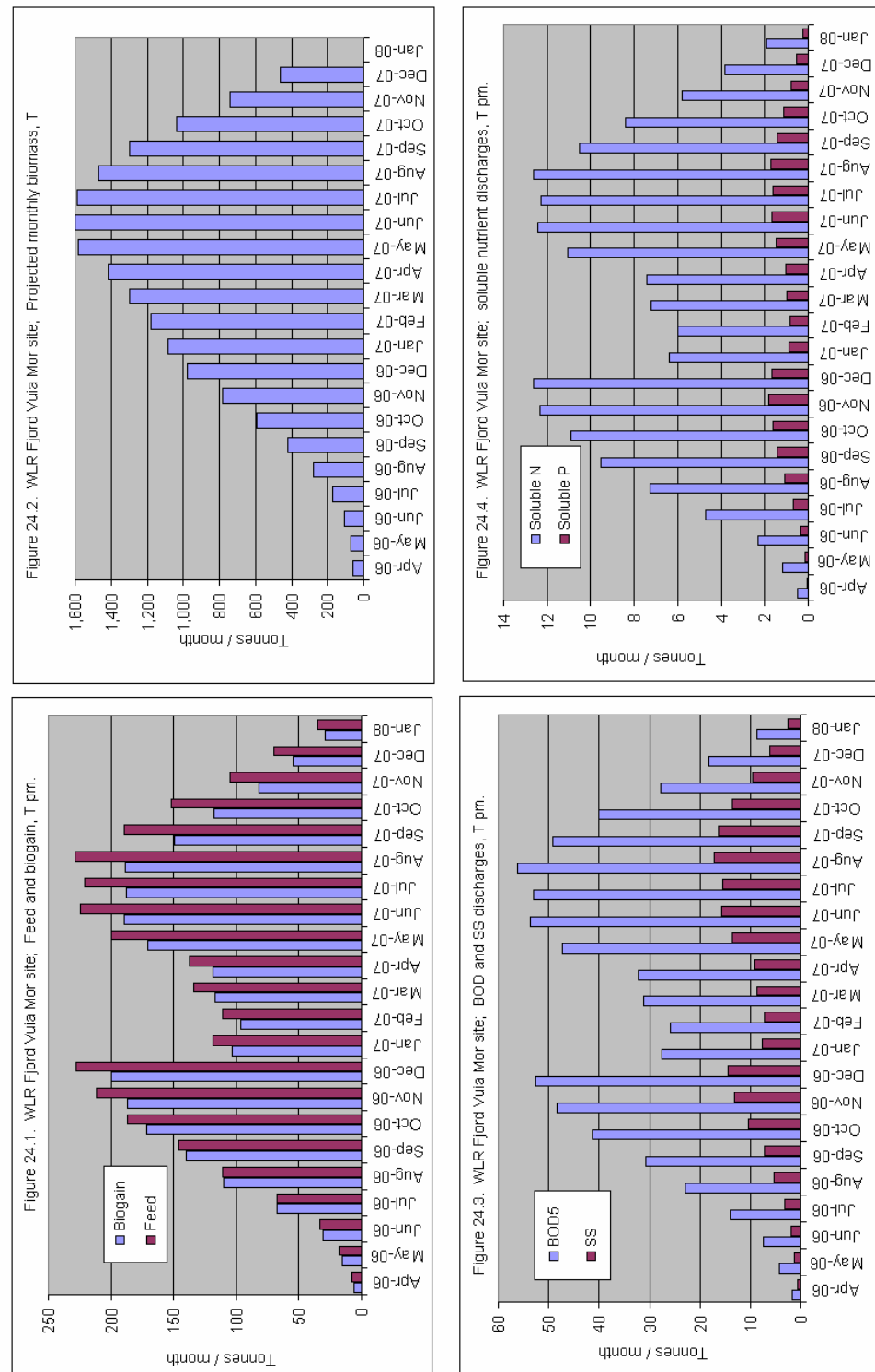


Figure 24.  
Production / discharge model for West Loch Roag farms; projected feeding, growth and waste parameters.  
Projected feeding, growth and waste parameters.  
WLR Fjord Vuia Mor site.



**Figure 25.**  
**Production / discharge model for West Loch Roag farms; projected feeding, growth and waste parameters.**  
**Projected feeding, growth and waste parameters per cycle.**  
**WLR MHS Gousam site.**

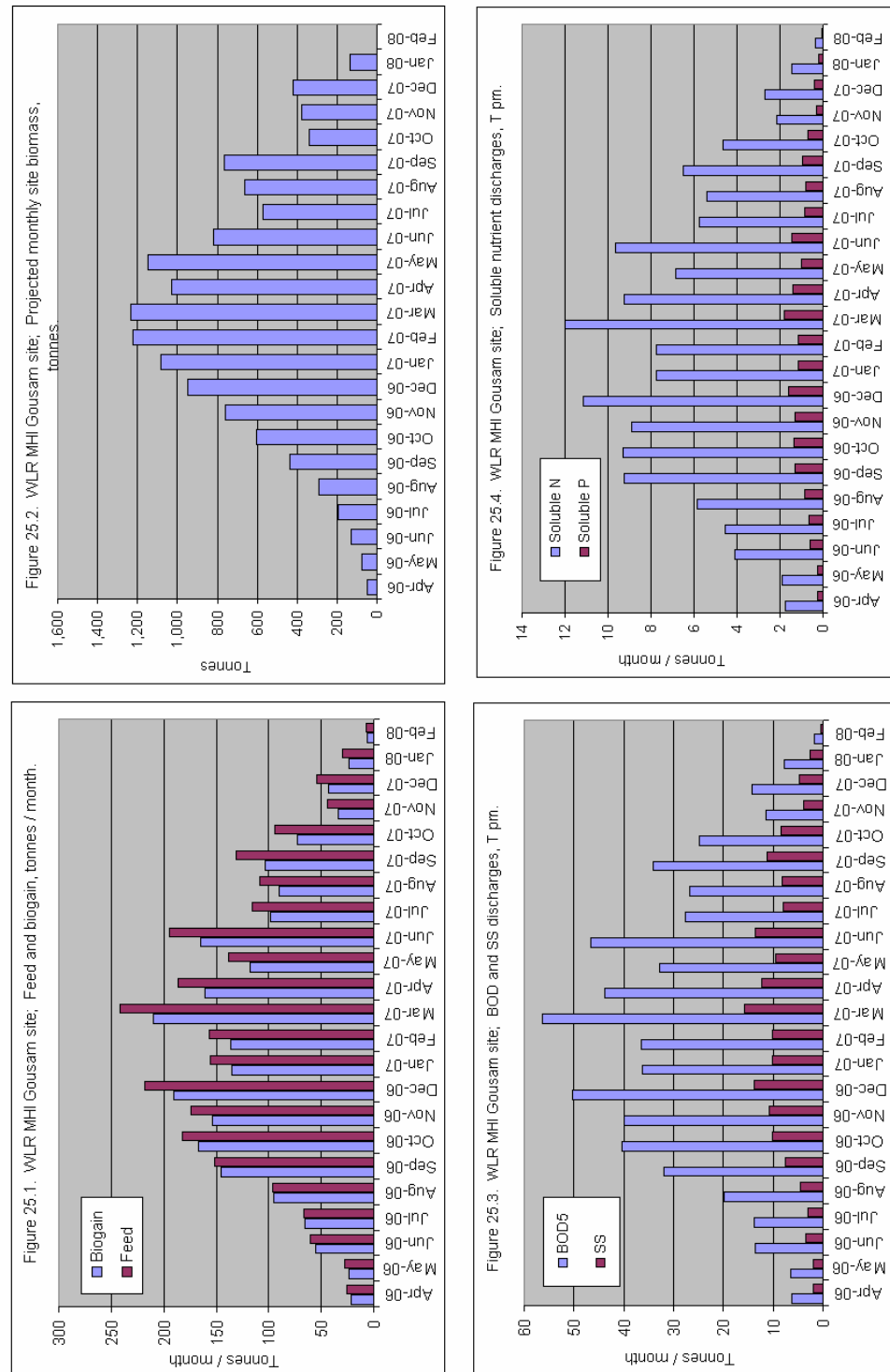


Figure 26.  
Production / discharge model for West Loch Roag farms; projected feeding, growth and waste parameters.  
Projected feeding, growth and waste parameters per cycle.  
WLR MHS Vuia Beg site; cycle commenced March 2005 (existing consent 700T).

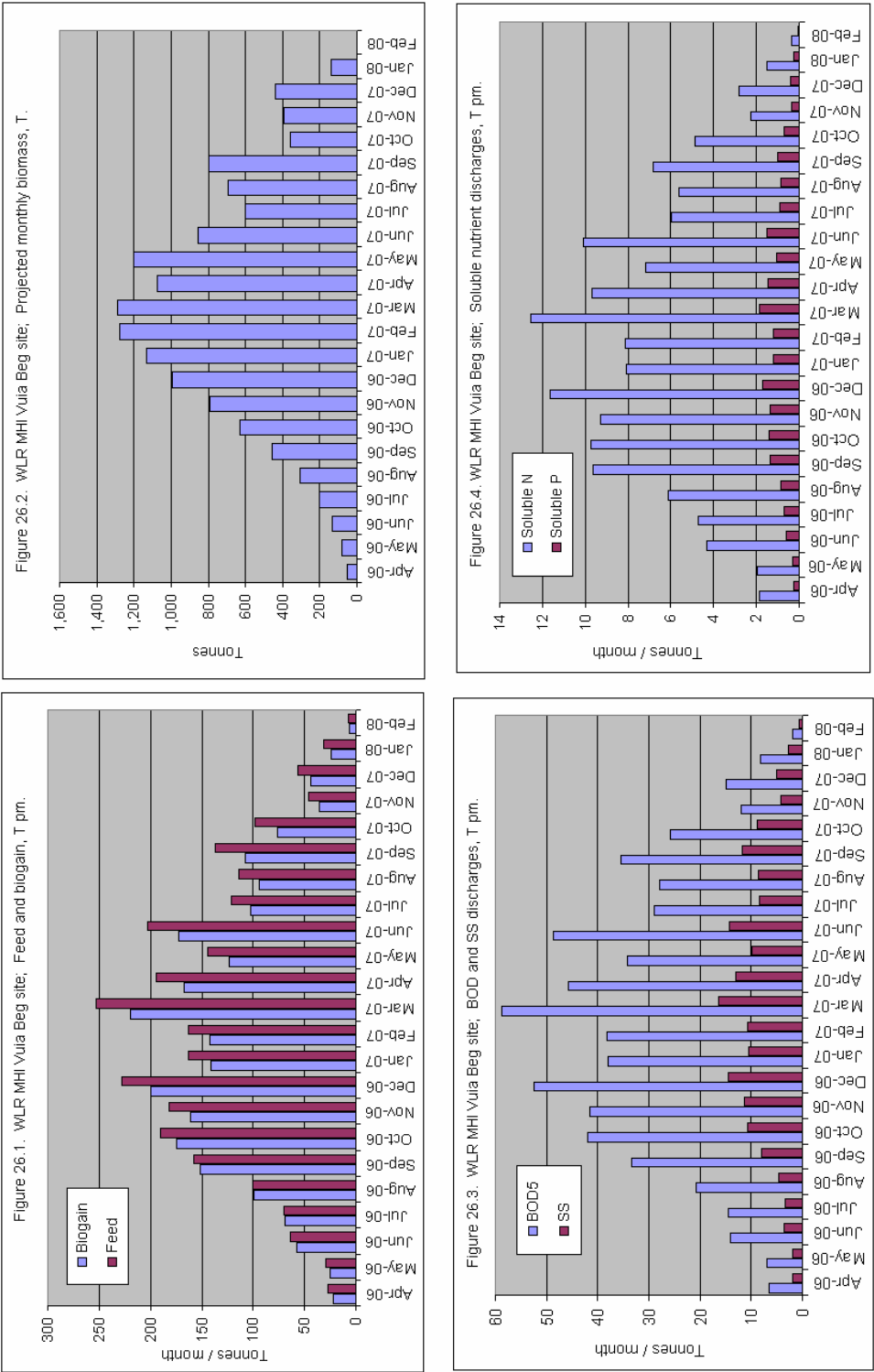


Figure 27  
Production / discharge model for East Loch Roag farms; projected feeding, growth and waste parameters.  
Projected feeding, growth and waste parameters per cycle.  
ELR Carloway Dunan 1 site.

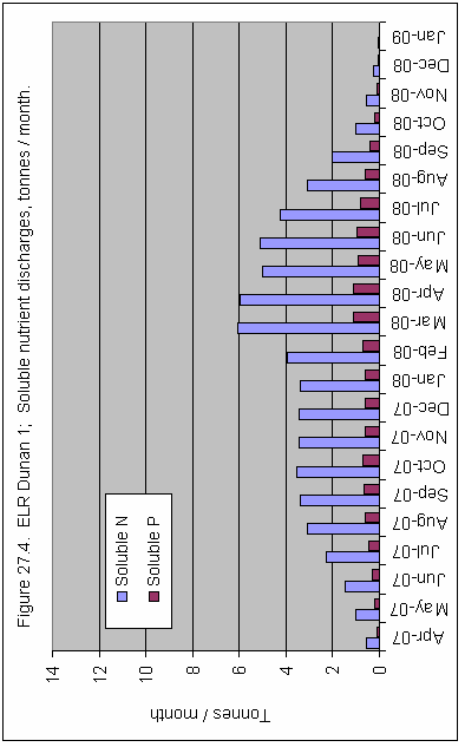
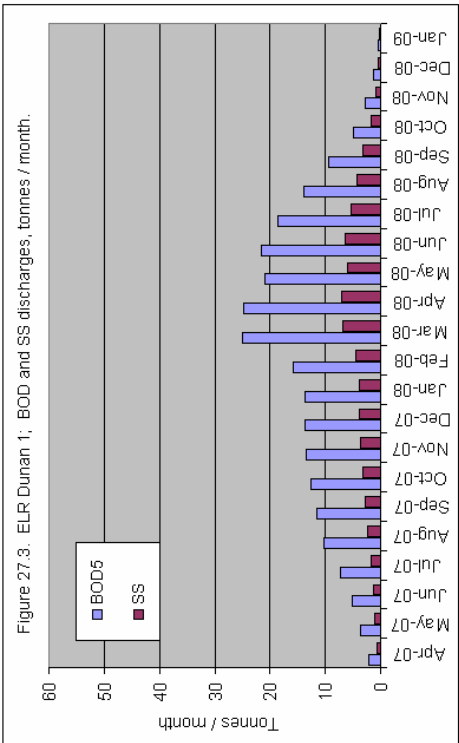
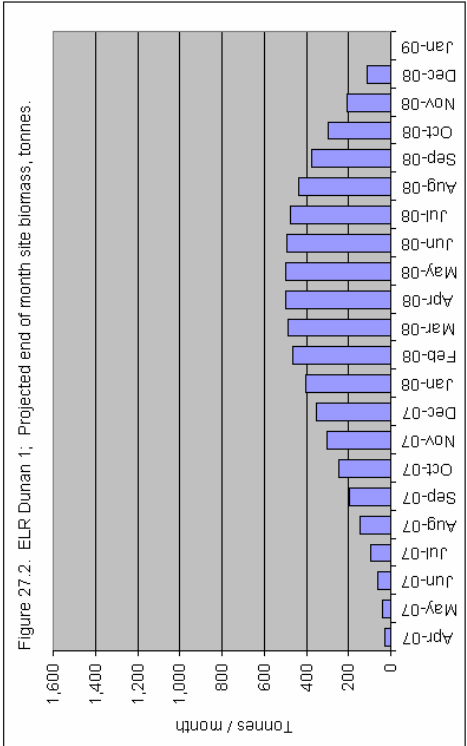
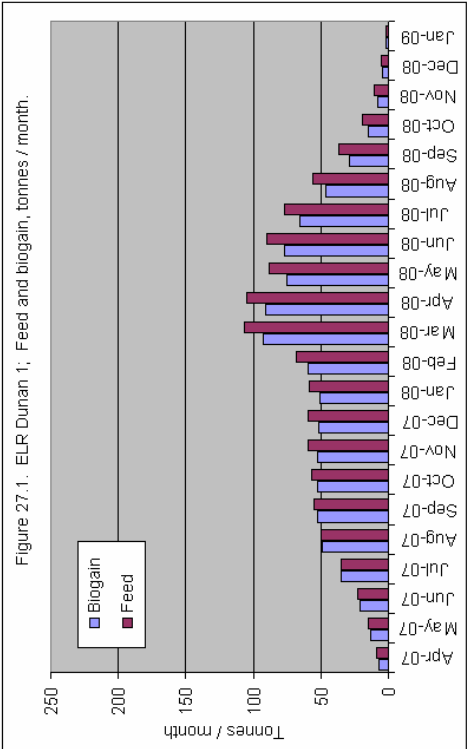


Figure 28.  
Production / discharge model for East Loch Roag farms; projected feeding, growth and waste parameters.  
Projected feeding, growth and waste parameters per cycle.  
ELR Carloway Dunan 2 site.

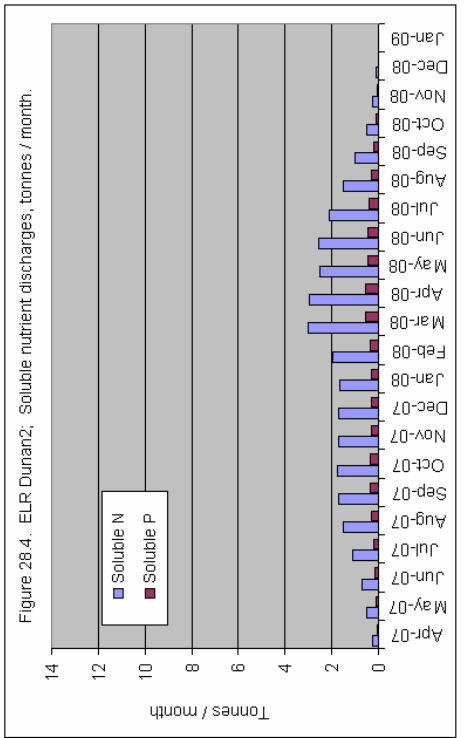
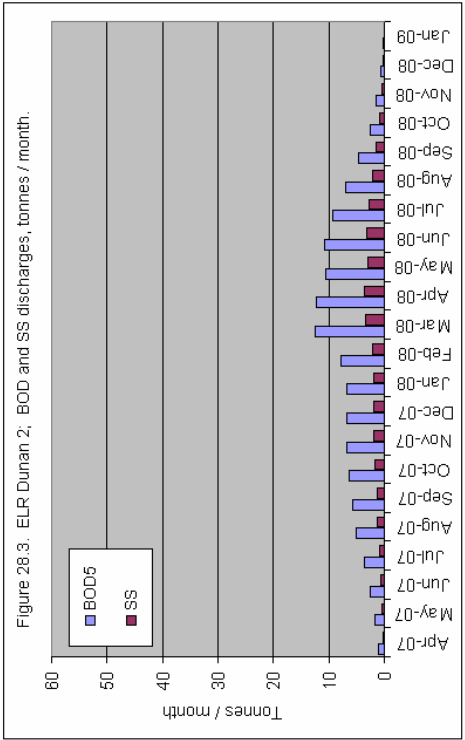
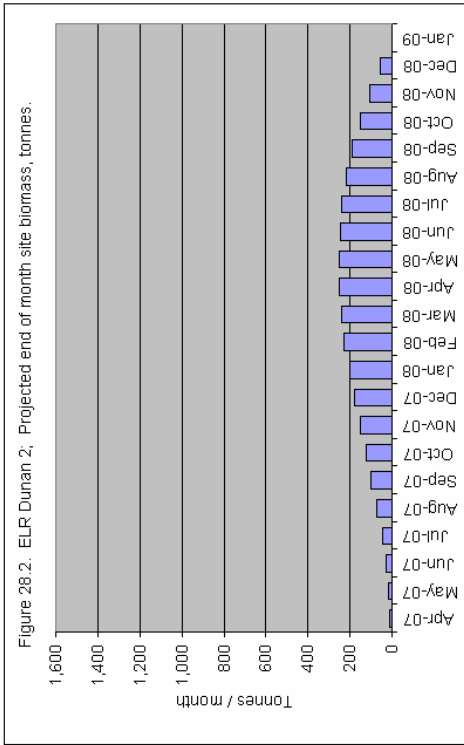
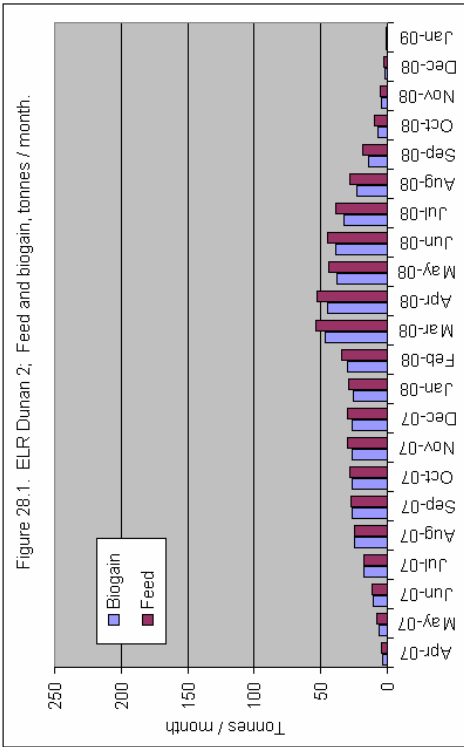




Figure 29.  
Production / discharge model for East Loch Roag farms.  
Projected feeding, growth and waste parameters.  
ELR HSC Little Kyles of Bernera site; second proposed cycle; 2011 input (first at full cycle at 600T consent biomass).

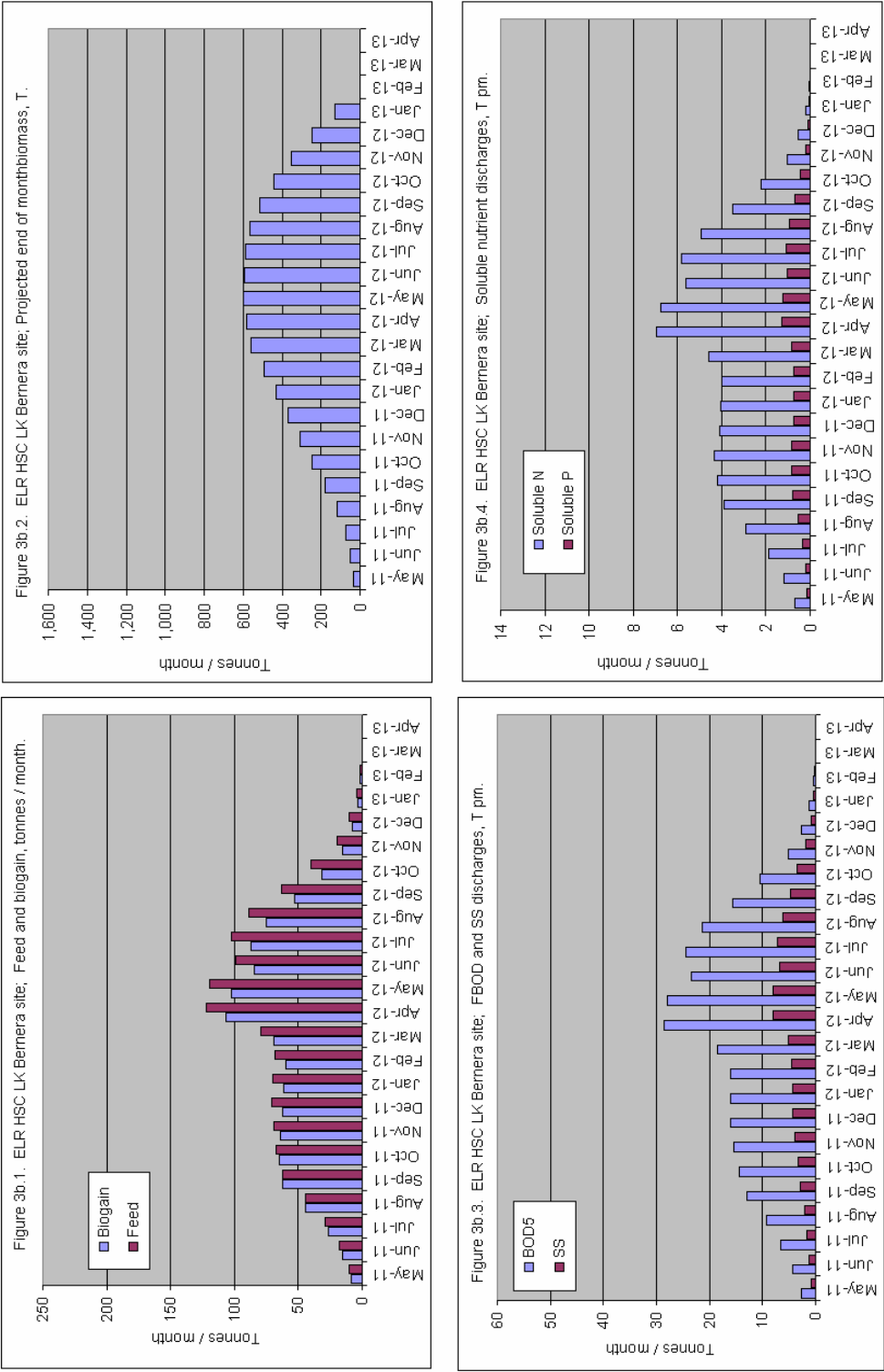


Figure 30.  
Production / discharge model for East Loch Roag farms; projected feeding, growth and waste parameters.  
ELR Fjord Tolsta site.  
Note Tolsta consent relinquished once alternatives are in place (by January 2007?).

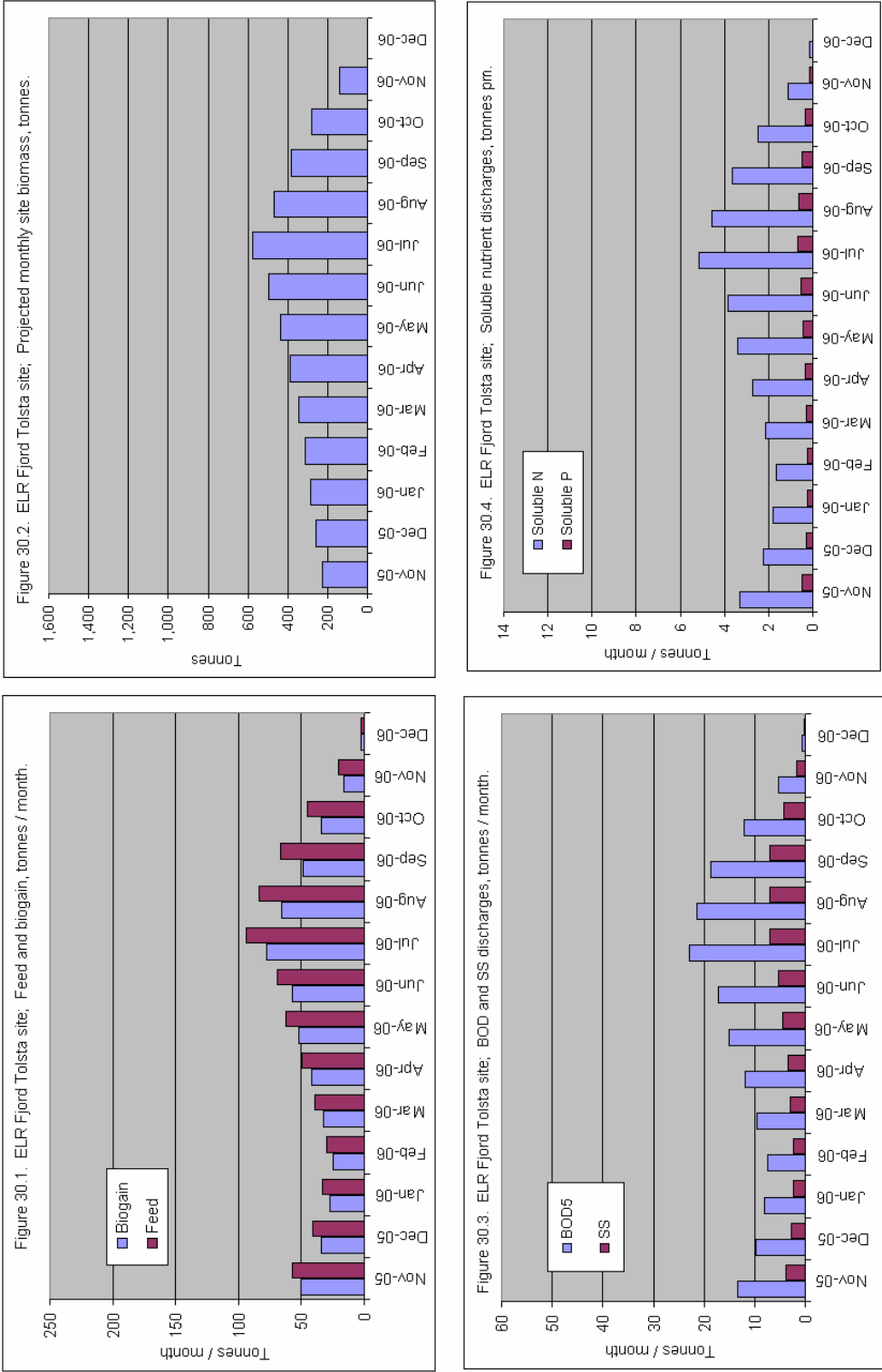


Figure 31.  
Production / discharge model for East Loch Roag farms; projected feeding, growth and waste parameters.  
ELR Fjord Greinham Island site; cycles commencing April 2007 and thereafter (requested consent 1,000T).  
Note all four ELR Fjord sites are on a 1-in-4-cycle rotation. Grenheim will be fallow from February 2009 to April 2011.

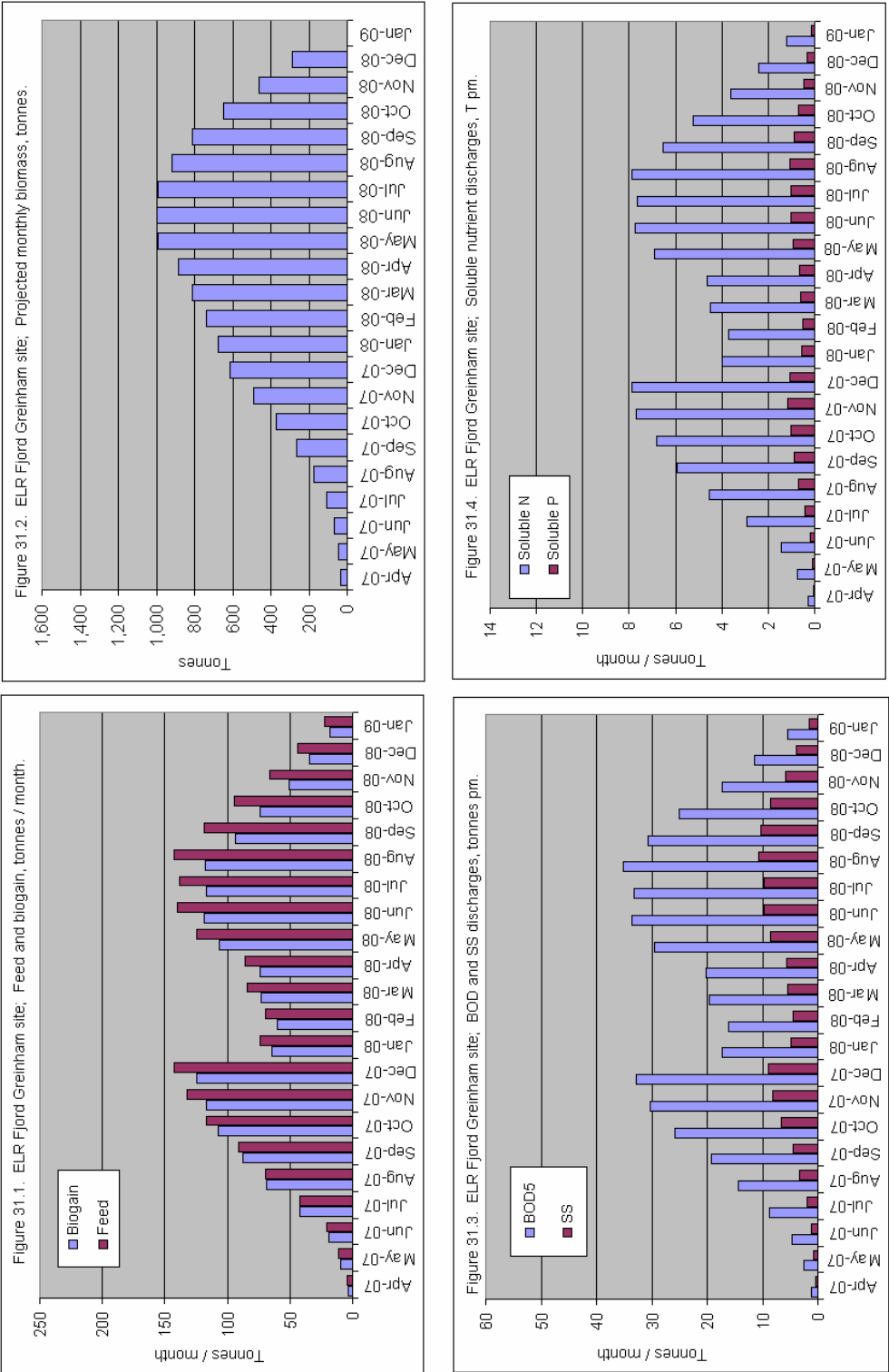
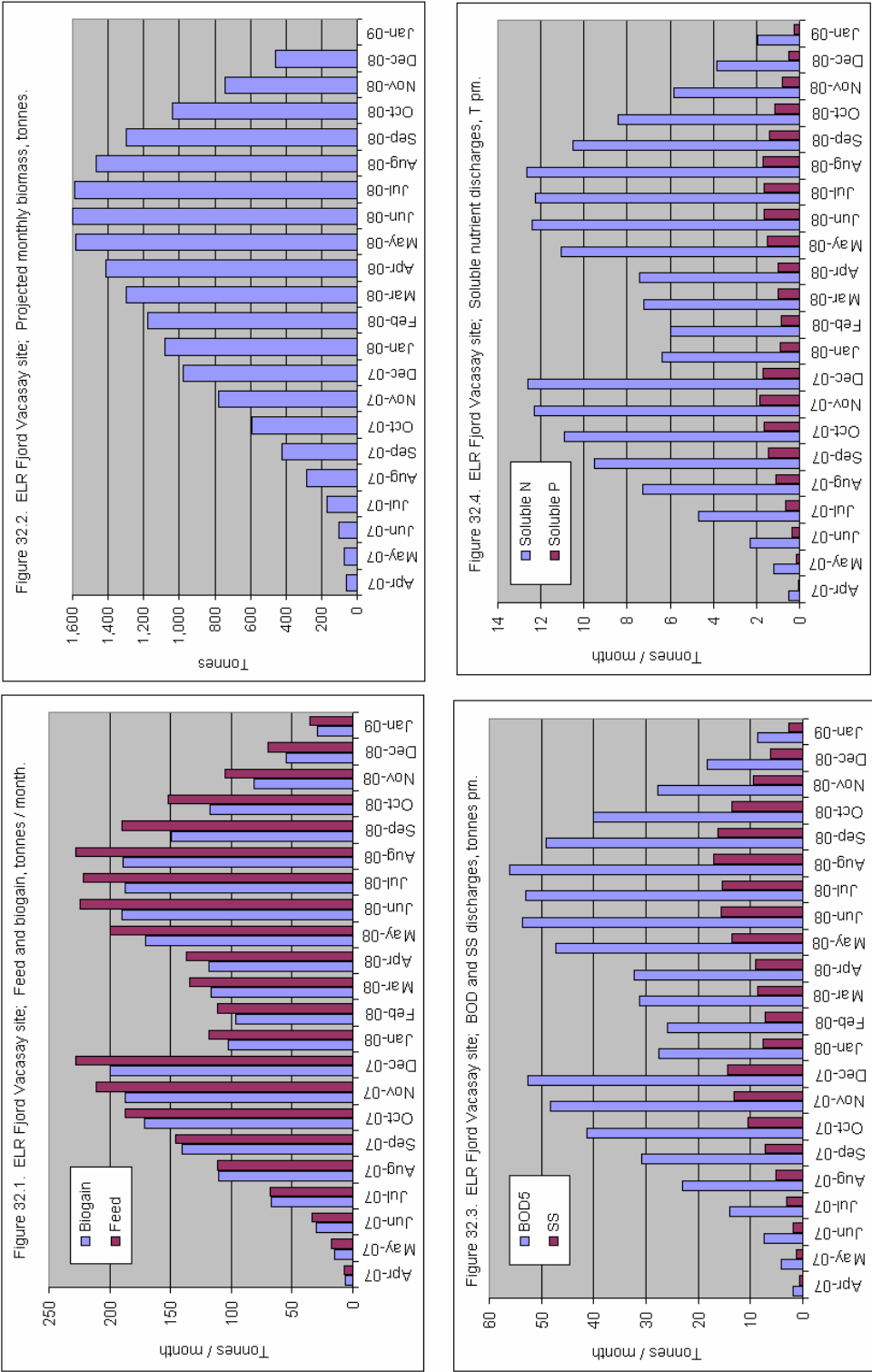
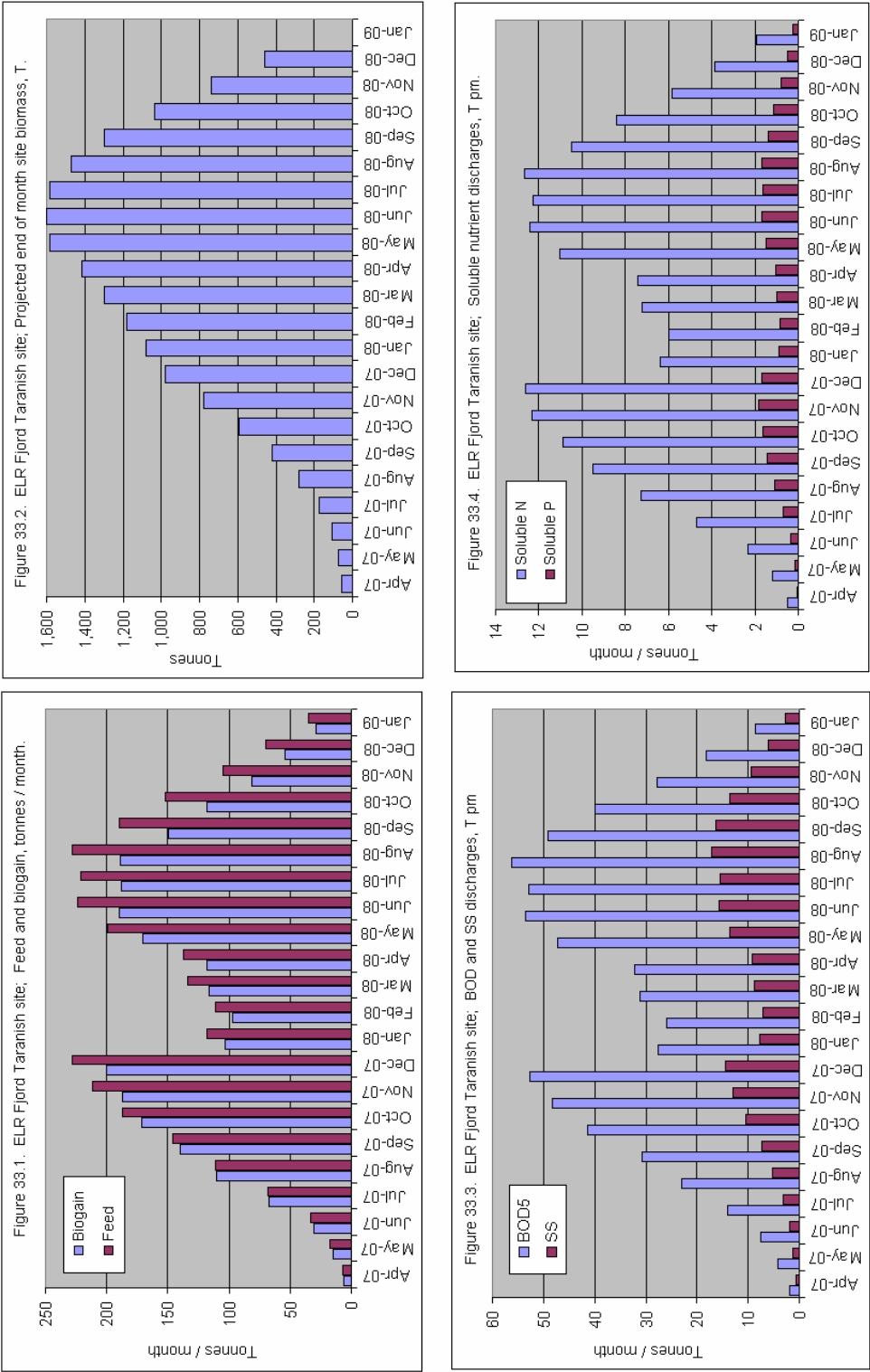


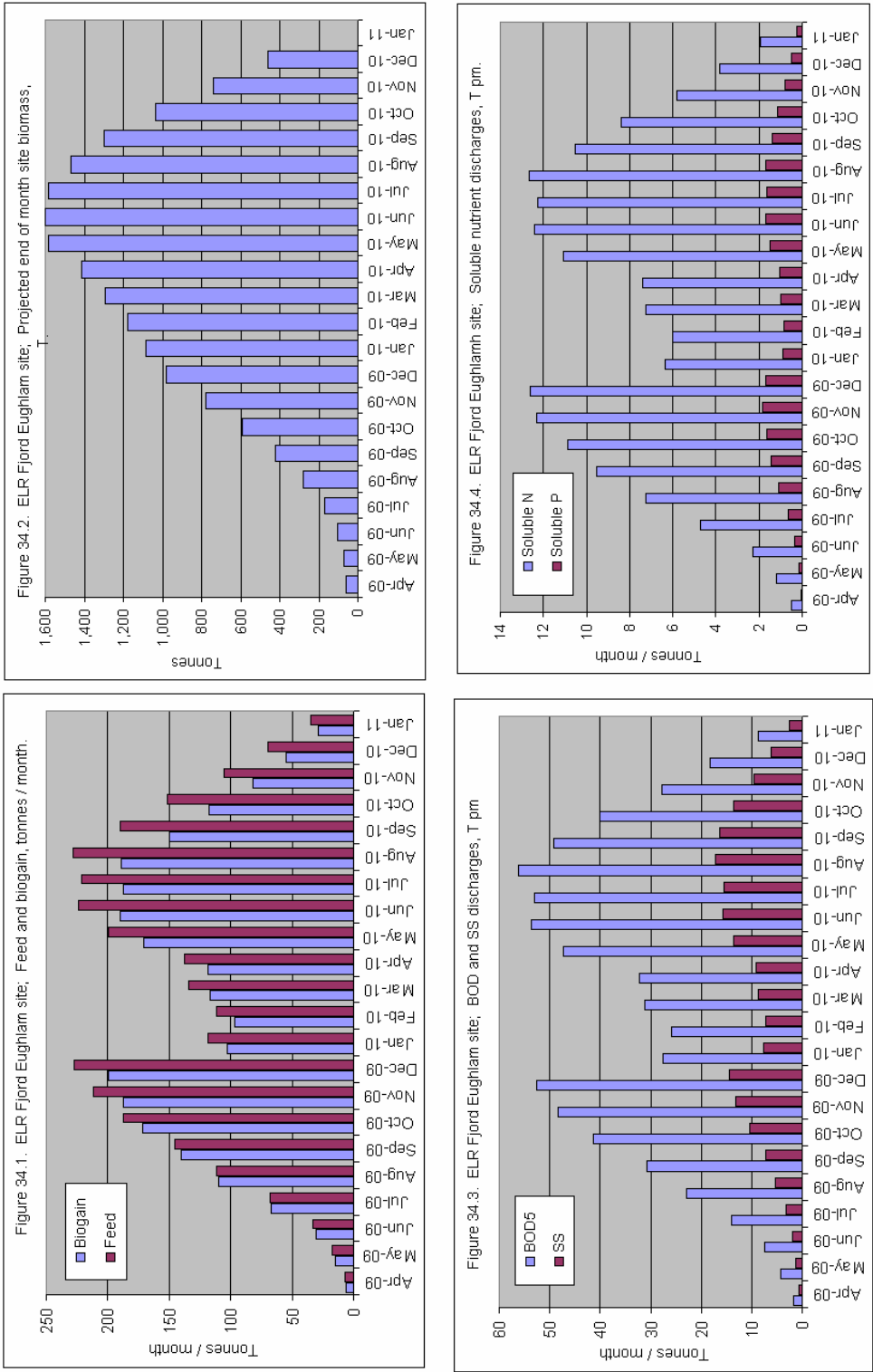
Figure 32.  
Production / discharge model for East Loch Roag farms; projected feeding, growth and waste parameters.  
ELR Fjord Vacasay site.  
Note all four ELR Fjord sites are on a 1-in-4-cycle rotation. Vacasay will be fallow from February 2011 to April 2013.



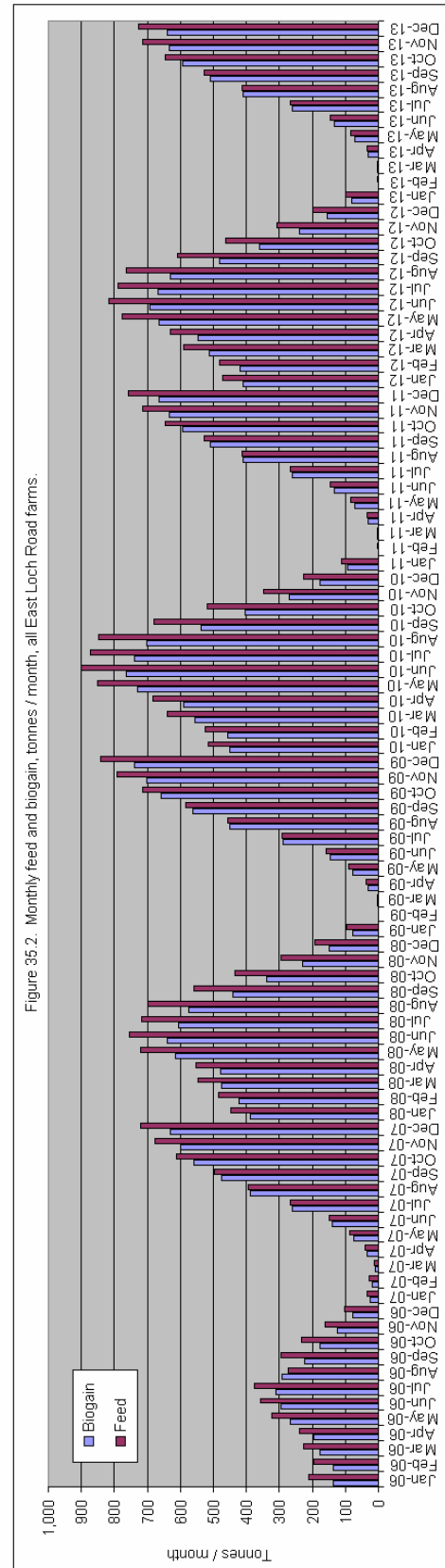
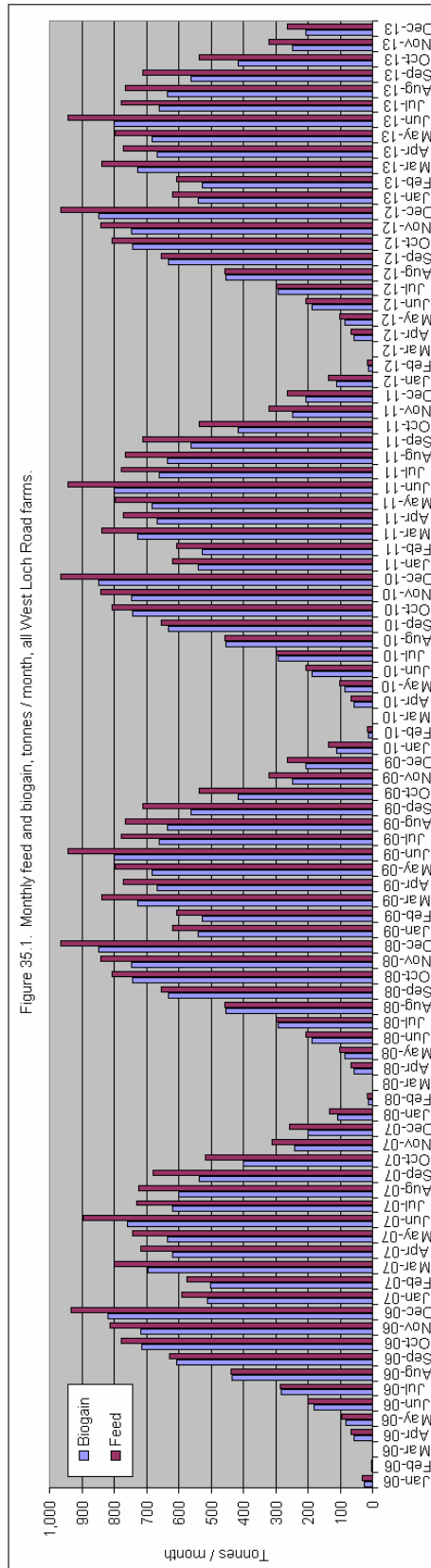
**Figure 33**  
Production / discharge model for East Loch Roag farms; projected feeding, growth and waste parameters.  
ELR Fjord Taranish site.  
Note all four ELR Fjord sites are on a 1-in-4-cycle rotation. Taranish will be fallow from February 2013 to April 2015.



**Figure 34.**  
Production / discharge model for East Loch Roag farms; projected feeding, growth and waste parameters.  
ELR Fjord Eughlam site (leased from HSC).  
Note all four ELR Fjord sites are on a 1-in-4-cycle rotation. Eughlam will be fallow until April 2009.



**Figure 35.**  
Combined production and discharge time series graphs for West and East Loch Roag farms.  
Projected combined monthly feeding and biogain cycles for all sites 2006 to 2013.  
Note identical scales



**Figure 36.**  
 Combined production and discharge time series graphs for West and East Loch Roag farms.  
 Projected combined month-end biomass for all sites 2006 to 2013.  
 Note identical scales.

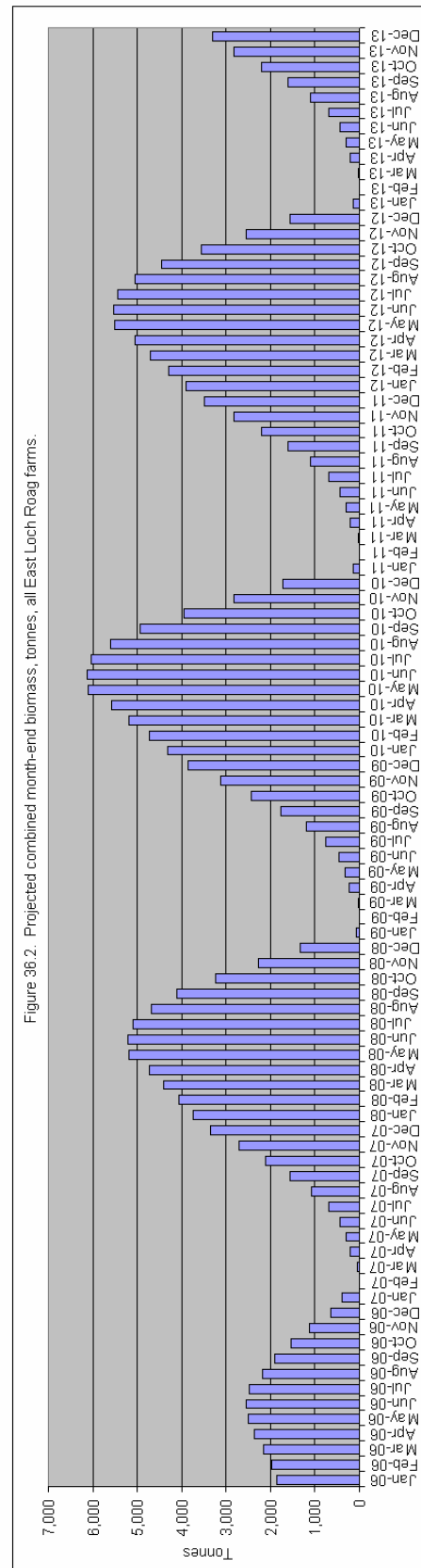
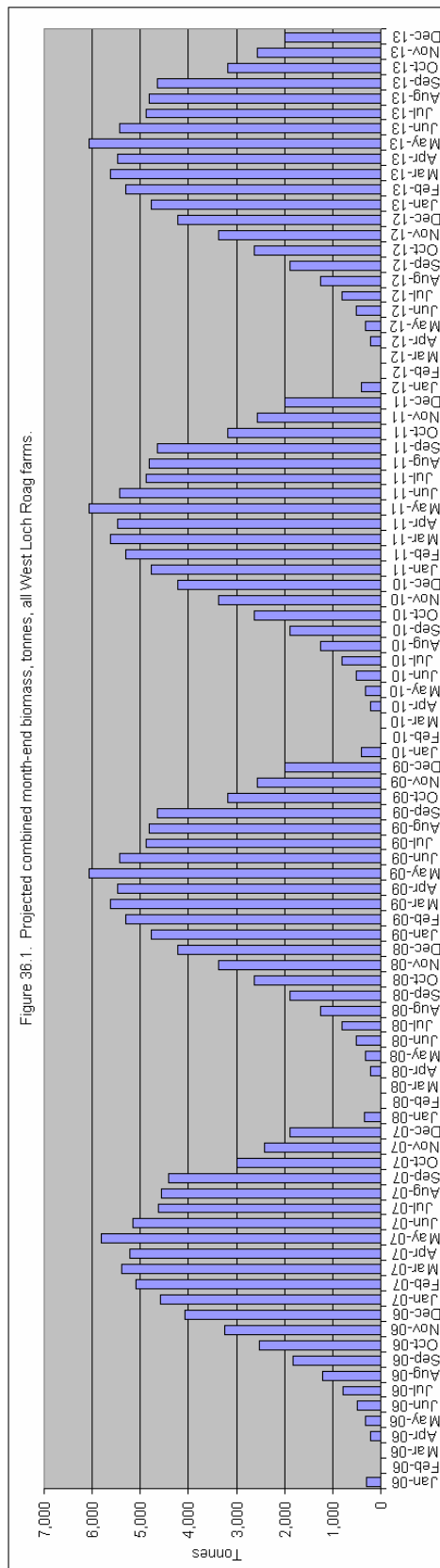




Figure 37.  
Combined production and discharge time series graphs for West and East Loch Roag farms.  
Projected combined monthly BOD and SS discharges for all sites 2006 to 2013.  
Note identical scales.

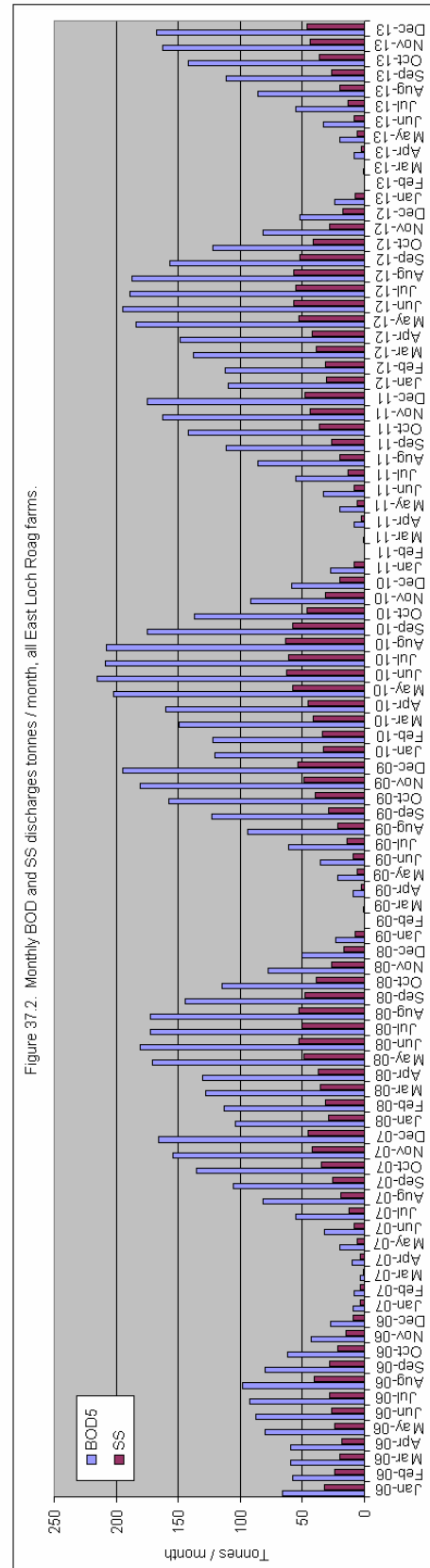
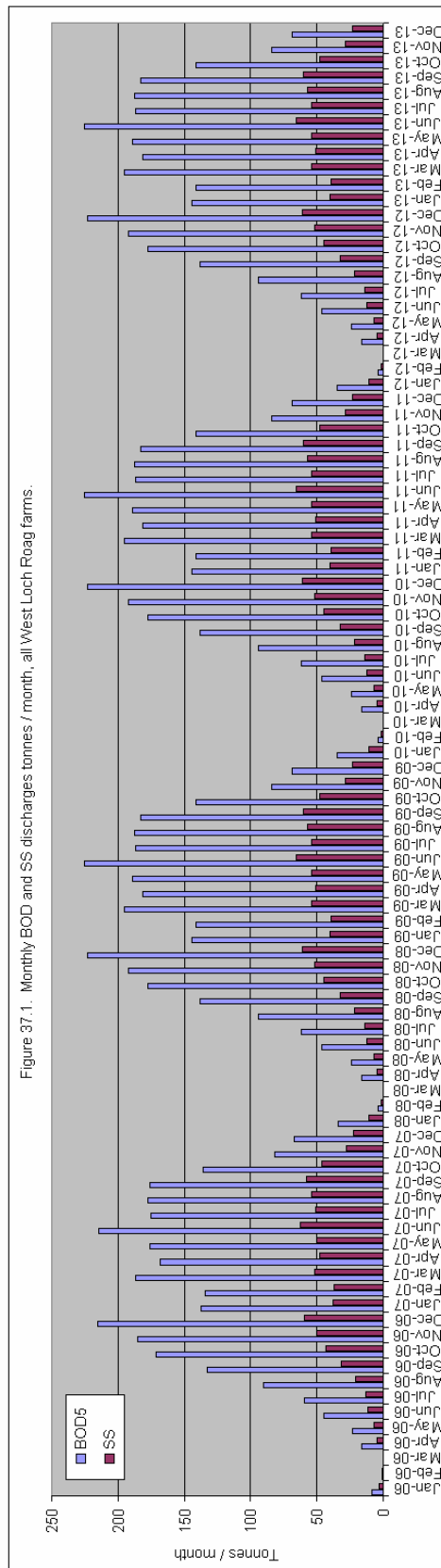
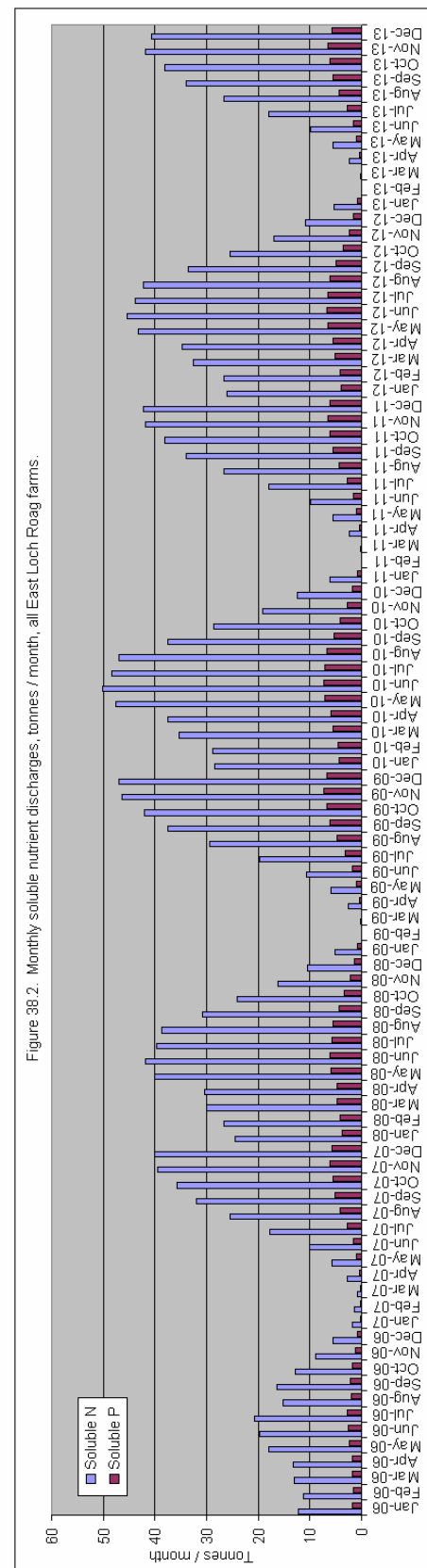
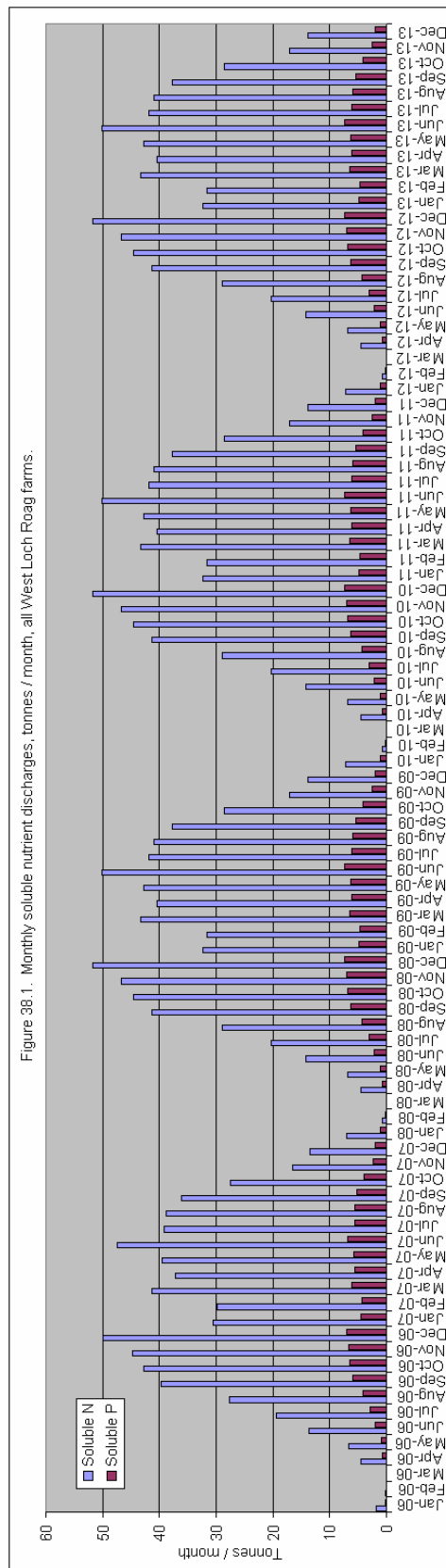


Figure 38.  
Combined production and discharge time series graphs for West and East Loch Roag farms.

Note identical scales.



The results of the modelling exercise for individual farm sites, shown graphically in Figures 22 to 34 and summarised in the timeline given in Figure 21, illustrate the following about the characteristics of the production and discharge cycles of the West Loch Roag and East Loch Roag salmon farms:-

- The ELR Fjord Tolsta site in East Loch Roag is currently operational and is projected to contribute to discharges January 2007 (see timeline in Figure 21 and Figure 30). Its current consent limit is 800 tonnes but it is not projected to reach a peak biomass of more than 574 tonnes in the current cycle. Fjord Seafood Scotland Farming Ltd. hope that the Tolsta consent can be relinquished following the completion of the current cycle, with the granting of leases and consents for the proposed ELR Fjord Taranaish and ELR Fjord Eughlam sites. Thus Fjord Tolsta is omitted from models following the final harvesting of the cages now on the site, in January 2007.
- The timeline in Figure 21 shows that a number of sites are currently operating on lower consent biomasses in 2005 to 2006 and will complete this production cycle early in 2006. Following this, some West Loch Roag farms which operate on transfers of fish in even years, expect to commence production on their proposed post-SOP biomass consents, with fish transfers in Spring 2006. East Loch Roag farms, which operate on fish transfers in odd years, expect to commence production on their post SOP consents in Spring 2007 earliest. Assuming the adoption of their proposed Post SOP consent biomasses, the models given then show production cycles based on the biomass of each site peaking at the maximum consent biomass level in each cycle. The individual site models given in Figures 22 to 34 illustrate this “steady state” production cycle.
- In general, proposed Loch Roag farm production cycles will be biennial, commencing with transfers of smolt during April and ending with the completion of harvesting during January. Taking these events as mid-April to mid-January respectively, the cycle is approximately 21 months long, out of a 24-month production cycle. Following on these sites will therefore generally be for a period of 8 to 12 weeks every two years, depending on exactly when in the transfer month and when in the final harvest month these actions occur.
- For the time being, due to limitations arising from their organic status, the organic farms in both East and West Loch Roag may present exceptions to this schedule. The ELR Carloway Dunan 1 and Dunan 2 sites may well commence production as early in April as possible and complete harvest as late in January as possible giving a minimum cycle length of a full 22 months, leaving a maximum of 8 weeks following per 2-year cycle. Due to low smolt size under current organic production limitations, it may be necessary for ELR HSC Little Kyles of Bernera and WLR Linngeam to

commence production at the very beginning of May and complete harvesting by February end, also giving a 22-month cycle but running up to one month later than other farms. The consequence of these production timescale differences may be a limitation of the length of the synchronous fallowing period available. Nonetheless, it is still expected that a synchronous fallowing period of all sites in the loch of at least six weeks should be achievable, in alternate years, on each side of the loch during spring period. This period is shown on the timeline in Figure 21 and in the production timescale graphs in Figures 35 to 38.

- As has already been pointed out, low fish numbers and complete synchronous fallowing during the spring period are important objectives for the following reasons:-
  - Conservation of the wild fisheries in the area (see Sections 2.2.2 and 3.2). It is particularly relevant that fallowing occurs during the spring period, when emerging wild salmonid smolt are most susceptible to infestation with lice copepodid larvae.
  - Breaking of on-farm disease and infestation cycles
  - Site recovery between cycles
- Figures 22 to 34 indicate that the sites seeking the maximum consent biomasses produce the highest discharges of BOD, SS and soluble Nitrogen and Phosphorus, as would be expected. Between the two sides of the loch, there are five out of twelve sites seeking 1,600 tonne consents. Three of these are Fjord Seafood Scotland Farming Ltd.-owned sites in East Loch Roag.
- The timeline in Figure 21 also illustrates a different mode of operation of some Fjord Seafood Scotland Farming Ltd. farm sites in East Loch Roag. Whilst the majority of the sites in the loch as a whole will be restocked biennially on an indefinite basis, it is understood that ELR Fjord Greinham, Vacasay, Taranaish and Eughlam, will rotate production such that each of the four sites is fallow for one complete cycle (that is about 25 months) once every four cycles. Eughlam will be fallow until April 2009, Greinham will be fallow from February 2009 until April 2011, Vacasay will be fallow from February 2011 until April 2013 and Taranaish will be fallow from February 2013 to April 2015 and so forth. From many viewpoints, this is regarded as a preferable method of operation, allowing for complete recovery of the under-site benthos during the production cycle schedule.
- A further implication of this strategy is that, whilst the proposed post-SOP consents for East Loch Roag will total 7,150 tonnes, the consents in use in any cycle will be somewhat less. This is illustrated in Figure 36.2, which

shows that, when ELR Fjord Greinham is on its long-fallow cycle, peak biomass will be 6,126 tonnes (since its consent biomass sought is 1,000 tonnes) but will be 5,526 tonnes when any of the other sites is on long-fallow (since their consent biomasses sought are 1,600 tonnes). Note that the actual peaks are slightly less than the “theoretical peaks” expected (6,150 tonnes and 5,550 tonnes) because different sites in the loch reach their individual maximum biomasses in different months.

- Thus the models predict the peak biomass reached in East Loch Roag will be 6,126 tonnes, in the June in even years, prior to harvest, once every four cycles, being 5,526 tonnes in the other three cycles. The peak biomass in West Loch Roag is expected to be 6,068 tonnes in the May in odd years before commencement of harvest, in every cycle. Discharges will also peak in the months of peak biomass as can be expected.
- Whilst the longest achievable site following period should be adopted by all sites as a matter of best practice, low stocking density is also a major factor as is the loading and consequent recovery of the benthos under fish farm sites. This is because low stocking density creates a larger but more dilute loading footprint for a given biomass, thereby reducing the potential for degradation of the infaunal community. It is notable that intended peak stocking densities for all sites in both East and West Loch Roag are in the “low to medium range” by general best practice standards. The four organic sites have the lowest peak stocking density, in the range 9.4 kgm<sup>-1</sup> to 11.5 kgm<sup>-1</sup>, whilst the non-organic sites have a peak stocking density ranging from 15.8 kgm<sup>-1</sup> to 21 kgm<sup>-1</sup>. Those sites operating with a peak biomass of over 20kgm<sup>-1</sup> are the five large Fjord Seafood Scotland Farming Ltd. sites with proposed consent biomasses of 1,600 tonnes. It may be worth considering a reduction of peak stocking density on these sites, best achieved by an increase in cage surface area, in particular for those sites that are restocking on a biennial (ELR Fjord Vuia East and ELR Fjord Vuia Mor) rather than a rotational ELR Fjord Greinham, Vacasay, Taranaish, Eughlam) basis.
- A review of FCR shows that mean FCR for all farms is projected to be in the range of 1.14 : 1 to 1.16 : 1. These lie within the expected range for current best practice and indicate that, whilst some improvement may be possible in the course of time, excess feeding or feed waste will not contribute unduly to waste loadings.
- Figures 35 to 38 show some interesting comparisons between the operation of farm sites West Loch Roag and East Loch Roag respectively. In particular, whilst the number of sites and total consent biomass sought for East Loch Roag is somewhat higher than that for West Loch Roag, (7 sites and 7150 tonnes for ELR against 5 sites and 6275 tonnes for WLR), the

maximum number of sites operational at any one time is five in West Loch Roag and six in East Loch Roag. This is due to the rotational fallowing of one site in four between ELR Fjord Greinham, Vacasay, Taranaish and Eughlam.

- A further consequence of this is that the cumulative peak biomass for East Loch Roag is expected to be somewhat lower than it is for West Loch Roag (see Figure 36), in three cycles in every four at 5,526 tonnes as opposed to 6,068 tonnes. Once in every four cycles, peak biomass will be almost the same for each side of the loch at 6,126 tonnes in ELR against 6,068 in WLR.
- Thus in most years (three out of every four cycles) discharges are expected to be about 8% lower for East Loch Roag relative to West Loch Roag; see Figures 37 and 38. However this difference must be investigated against the relative flushing of the waters of East Loch Roag and West Loch Roag, which is set out in Figures 39 to 42, following.
- A final observation on the alternation of stocking years in East Loch Roag and West Loch Roag is that this causes an alternation of production, stock and discharge peaks between the two sides of the loch. This is made clear by comparing the time series in Figures 35 to 38. As a result, if salmon production, biomass or waste discharges were to be summed for the whole of Loch Roag, annual data is smoothed, rather than showing peaks of coincident high production and troughs of coincident low production. This gives comfort that, in the fairly unlikely event that there may be some mixing of waters between the two sides of the loch, for example through tidal exchange, cumulative impacts arising from combined production peaks could not occur.
- Production in East Loch Roag is projected to vary in between 10,328 tonnes for cycles when ELR Fjord Greinham (one cycle in four) is fallow and 9,360 tonnes per cycle for the remaining three cycles in four, when one of Fjord Seafood Scotland Farming Ltd. ELR 1,600 tonne consent sites is fallow. Of this total, 2,580 tonnes will be organic, from the Carloway and HSC sites.
- Production in West Loch Roag is expected to be 8,439 tonnes per cycle, of which 1,064 tonnes will be organic, from the WLR HSC Linngeam site.

The flushing characteristics of East and West Loch Roag and the impacts of salmon farm discharges on the loch waters are now investigated in Tables 7 to 10 and Figures 39 to 42. Tables 7 and 9 calculate the estimated flushing times of West Loch Roag and East Loch Roag respectively. Flushing time is calculated by the use of a tidal prism model, the standard procedure for this

calculation. The calculations used are explained in the notes and detail is given in Tables 7 and 9.

The raw data required, in terms of the low water area and depth of the two sides of the loch (and therefore low water volume) and mean neap and spring tidal ranges were obtained from the raw data used for the Box Model developed by SEPA for East and West Loch Roag (*Box modelling of Nitrogen from marine caged fish farms in Loch Roag, Report Number MRO3/01; June 2001*). For the purposes of the current report, the entirety of the two sides of the loch was taken as the box on which the calculations were based.

Using the results of the flushing times and monthly flushing volumes thus calculated, Tables 8 and 10 estimate the monthly loads of nutrients and oxygen that flush in and out of West Loch Roag and East Loch Roag respectively. In the absence of monthly ambient nutrient data for the loch, data for 0m to 10m depths from the FRS monitoring database for the so-called Scottish Marine Waters Western Hebrides Sub-Area (WHEB), which lies just offshore, to the west of Lewis was used. The position of WHEB is illustrated in Figure 43. Nutrient and other biotic and abiotic water column data has been collected from this and other locations around the Scottish coast for over a century. The most recent nutrient data for WHEB, updating the database to 2004, was kindly supplied by George Slessor of FRS in advance of its publication (pers. comm. G Slessor), for the purpose of this document. The method of calculation of nutrient loads is given in the notes to Tables 8 and 10. The monthly farm discharges of Dissolved Inorganic Nitrogen and Phosphorus for the period 2006 to 2013 are those also given in Figures 38.1 and 38.2.

**Table 7.**  
**West Loch Roag flushing model**  
**Estimated flushing time.**

Notes

1. Tidal flushing in this case is calculated using a simple tidal prism flushing model.
2. WLR dimensions and tidal data are taken from the SEPA box model report.

Parameter	Notation	Data	Units
West Loch Roag low water sea area	A	53,300,000	m <sup>2</sup>
West Loch Roag mean LW depth	D	25.40	m
West Loch Roag mean LW volume	$V = A \times D$	1,353,820,000	m <sup>3</sup>
Mean tidal range neap tide	Rn	1.60	m
Mean tidal range spring tide	Rs	3.60	m
Thus mean neap tidal volume	$Pn = A \times Rn$	85,280,000	m <sup>3</sup>
Thus mean spring tidal volume	$Ps = A \times Rs$	191,880,000	m <sup>3</sup>
Mean neap flushing time (tidal cycles)	$Tn = (V + Pn) / Pn$	16.88	tidal cycles
Thus mean neap flushing time (days)	$Dn = Tn / 2$	8.44	days
Mean spring flushing time (tidal cycles)	$Ts = (V + Ps) / Ps$	8.06	tidal cycles
Thus mean spring flushing time (days)	$Ds = Ts / 2$	4.03	days
Mean neap daily flushing rate	$Fn = V / Dn$	160,452,741	m <sup>3</sup> / day
Mean spring daily flushing rate	$Fs = V / Ds$	336,120,828	m <sup>3</sup> / day
Thus mean monthly water flux into West Loch Roag	$W = ((Fn + Fs) / 2) \times 30.4167$	7,552,064,628	m <sup>3</sup> /month
Thus mean daily water exchange in West Loch Roag	$Wd = ((Fn + Fs) / 2)$	248,288,784	m <sup>3</sup> /day

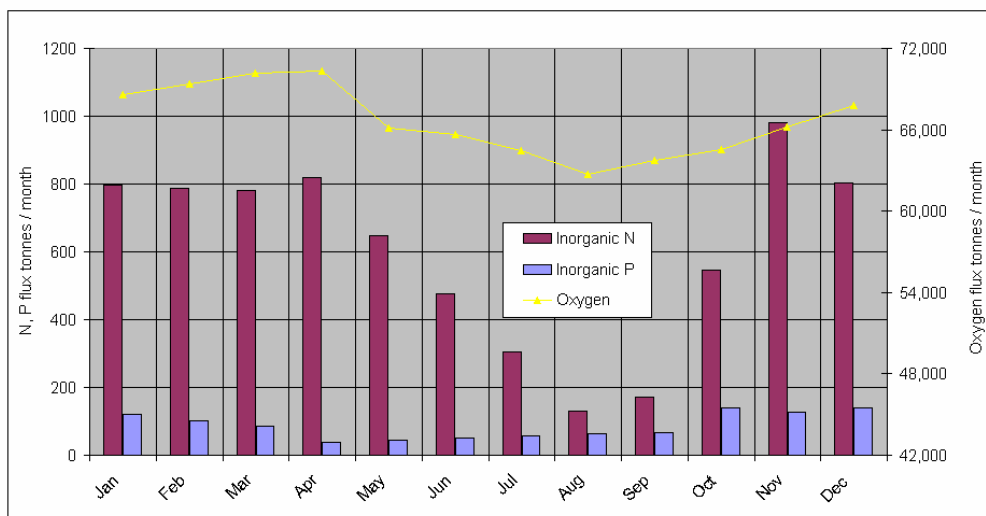
**Table 8.**  
**West Loch Roag flushing model**  
**Total estimated monthly and annual fluxes of nutrients and oxygen.**

Notes

1. Monthly nutrient flux is the quantity of a given solute entering the area in the mean monthly water flux.
2. Flux for each solute is derived by multiplying the total monthly / annual water flux (see Table 7) by the mean ambient solute concentration for that month, in the WHEB area
3. The flux figures thus calculated are simple estimates only, based on still-weather conditions.

Month	Mean ambient concentration			Monthly flux tonnes		
	Inorganic N µg/l	Inorganic P µg/l	DO mg/l	Inorganic N	Inorganic P	Oxygen
Jan	105.4	16.1	9.08	796.1	121.7	68,578
Feb	104.4	13.6	9.18	788.7	103.0	69,363
Mar	103.6	11.2	9.29	782.4	84.3	70,169
Apr	108.4	5.0	9.31	818.3	37.5	70,312
May	85.7	5.9	8.75	647.1	44.5	66,093
Jun	62.9	6.8	8.69	474.7	51.5	65,615
Jul	40.2	7.4	8.53	303.4	56.2	64,437
Aug	17.4	8.4	8.31	131.1	63.2	62,725
Sep	22.8	8.7	8.44	172.3	65.6	63,717
Oct	72.2	18.6	8.55	545.6	140.5	64,533
Nov	129.9	16.7	8.76	981.2	126.4	66,181
Dec	106.3	18.6	8.98	802.5	140.5	67,827
Total flux tonnes pa				7243.5	1034.8	799,549
Mean flux per month				603.6	86.2	66,629

**Figure 39.**  
**West Loch Roag**  
**Estimated monthly still-weather tidal fluxes of soluble nutrients and oxygen.**





**Table 9.**  
**East Loch Roag flushing model**  
**Estimated flushing time.**

Notes

1. Tidal flushing in this case is calculated using a simple tidal prism flushing model.
2. ELR dimensions and tidal data are taken from the SEPA box model report.

Parameter	Notation	Data	Units
East Loch Roag low water sea area	A	38,600,000	m <sup>2</sup>
East Loch Roag mean LW depth	D	20.20	m
East Loch Roag mean LW volume	$V = A \times D$	739,320,000	m <sup>3</sup>
Mean tidal range neap tide	Rn	1.60	m
Mean tidal range spring tide	Rs	3.60	m
Thus mean neap tidal volume	$Pn = A \times Rn$	58,560,000	m <sup>3</sup>
Thus mean spring tidal volume	$Ps = A \times Rs$	131,760,000	m <sup>3</sup>
Mean neap flushing time (tidal cycles)	$Tn = (V + Pn) / Pn$	13.63	tidal cycles
Thus mean neap flushing time (days)	$Dn = Tn / 2$	6.81	days
Mean spring flushing time (tidal cycles)	$Ts = (V + Ps) / Ps$	6.61	tidal cycles
Thus mean spring flushing time (days)	$Ds = Ts / 2$	3.31	days
Mean neap daily flushing rate	$Fn = V / Dn$	108,524,037	m <sup>3</sup> / day
Mean spring daily flushing rate	$Fs = V / Ds$	223,659,832	m <sup>3</sup> / day
Thus mean monthly water exchange in East Loch Roag	$W = ((Fn + Fs) / 2) \times 30.4167$	5,051,968,538	m <sup>3</sup> /month
Thus mean daily water exchange in East Loch Roag	$Wd = ((Fn + Fs) / 2)$	168,091,934	m <sup>3</sup> /day

**Table 10.**  
**East Loch Roag flushing model**  
**East Loch Roag; total estimated monthly and annual fluxes of nutrients and oxygen.**

Notes

1. Monthly nutrient flux is the quantity of a given solute entering the area in the mean monthly water flux.
2. Flux for each solute is derived by multiplying the total monthly / annual water flux (see Table 9) by the mean ambient solute concentration for that month, in the WHEB area
3. The flux figures thus calculated are simple estimates only, based on still-weather conditions.

Month	Mean ambient concentration			Monthly flux tonnes		
	Inorganic N µg/l	Inorganic P µg/l	DO mg/l	Inorganic N	Inorganic P	Oxygen
Jan	105.4	16.1	9.08	532.6	81.4	45,875
Feb	104.4	13.6	9.18	527.6	68.9	46,401
Mar	103.6	11.2	9.29	523.4	58.4	46,939
Apr	108.4	5.0	9.31	547.4	25.1	47,035
May	85.7	5.9	8.75	432.9	29.8	44,213
Jun	62.9	6.8	8.69	317.6	34.5	43,893
Jul	40.2	7.4	8.53	203.0	37.6	43,105
Aug	17.4	8.4	8.31	87.7	42.3	41,960
Sep	22.8	8.7	8.44	115.3	43.9	42,624
Oct	72.2	18.6	8.55	365.0	94.0	43,170
Nov	129.9	16.7	8.76	656.4	84.6	44,272
Dec	106.3	18.6	8.98	536.8	94.0	45,373
Total flux tonnes pa				4845.5	692.2	534,860
Mean flux per month				403.8	57.7	44,572

**Figure 40.**  
**East Loch Roag**  
**Estimated monthly still-weather tidal fluxes of soluble nutrients and oxygen.**

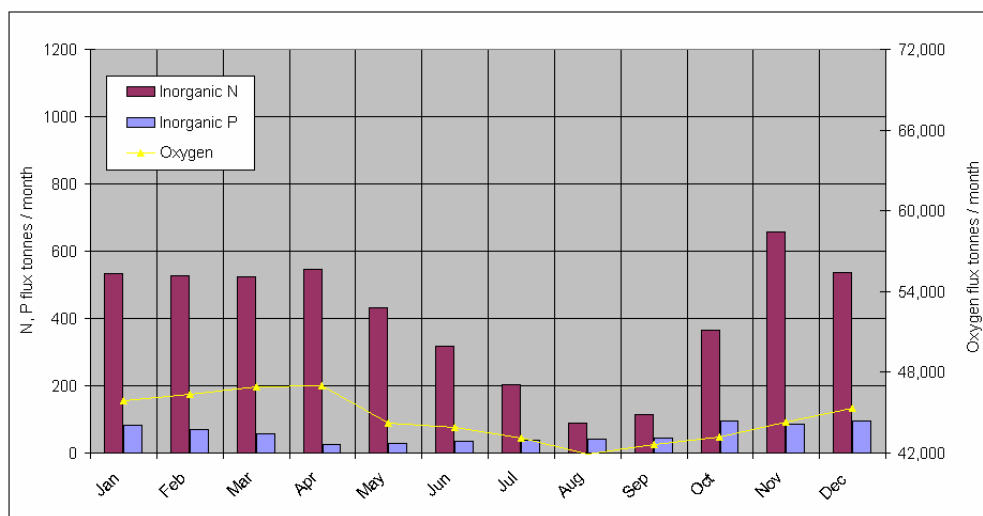


Figure 41.  
West Loch Roag vs East Loch Roag.  
Projected combined monthly soluble N discharges (tonnes) vs. tidal N flux (tonnes); all sites, 2006 to 2013.  
Note identical scales.

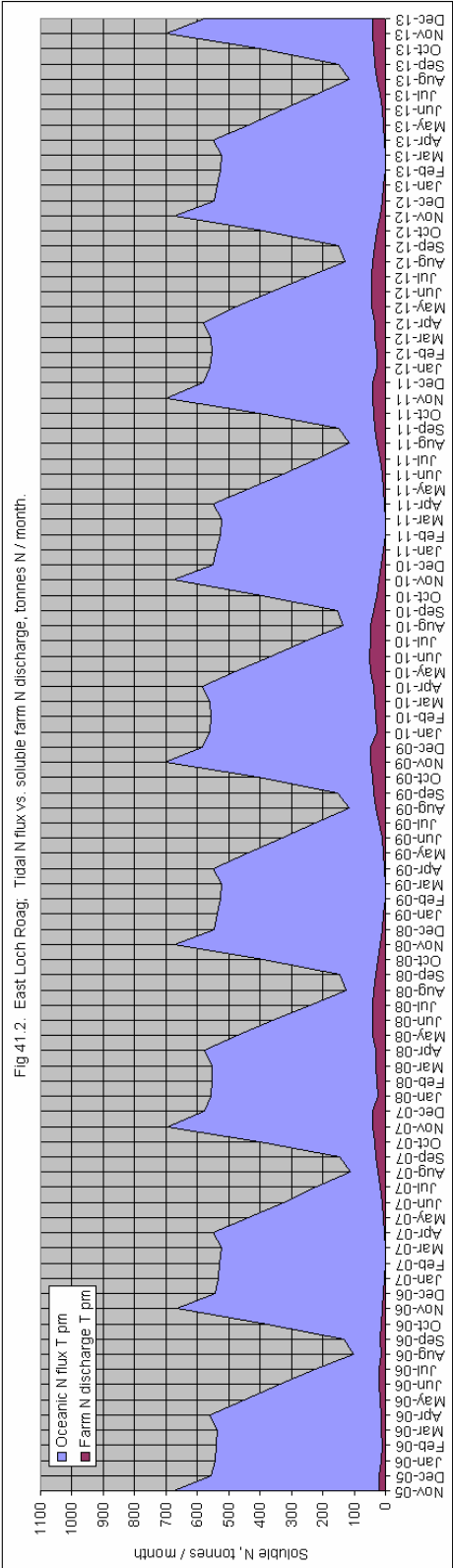
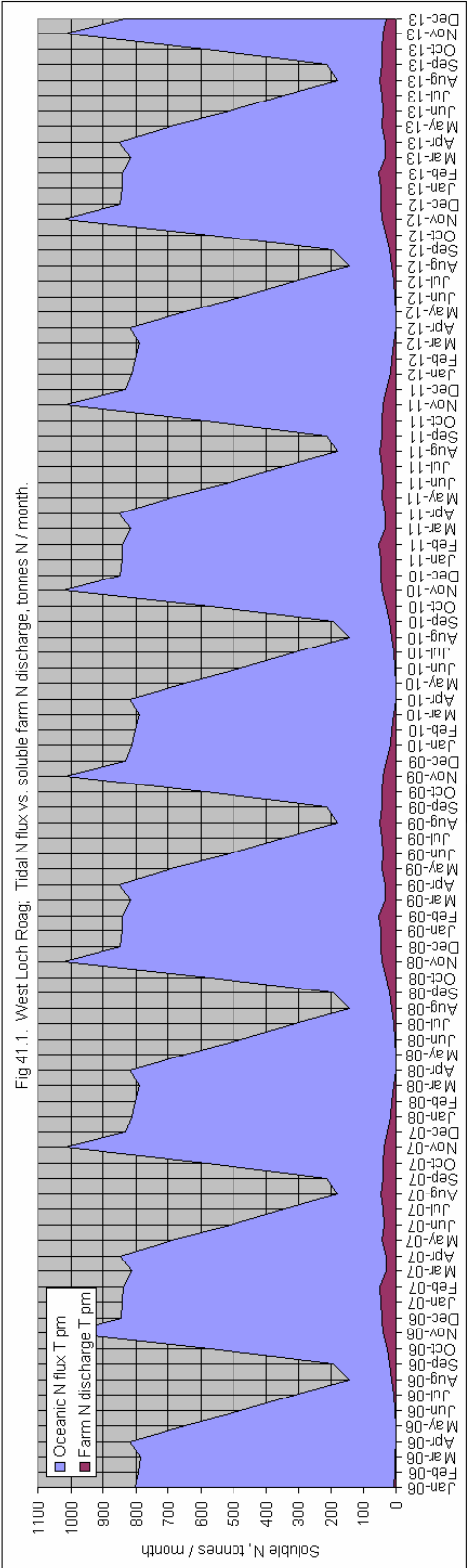
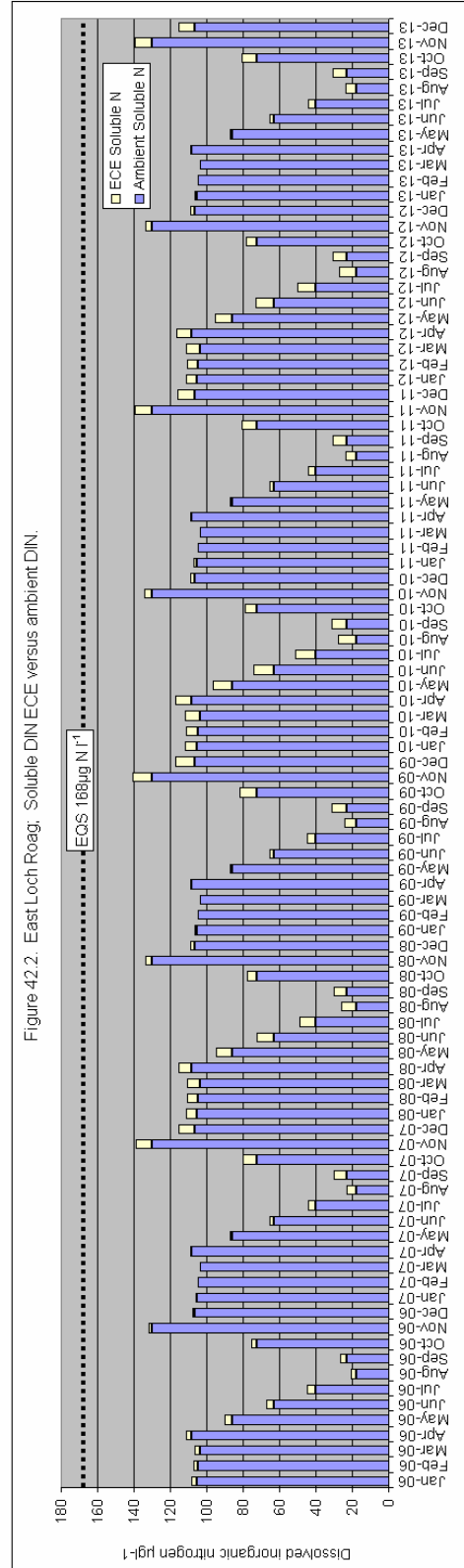
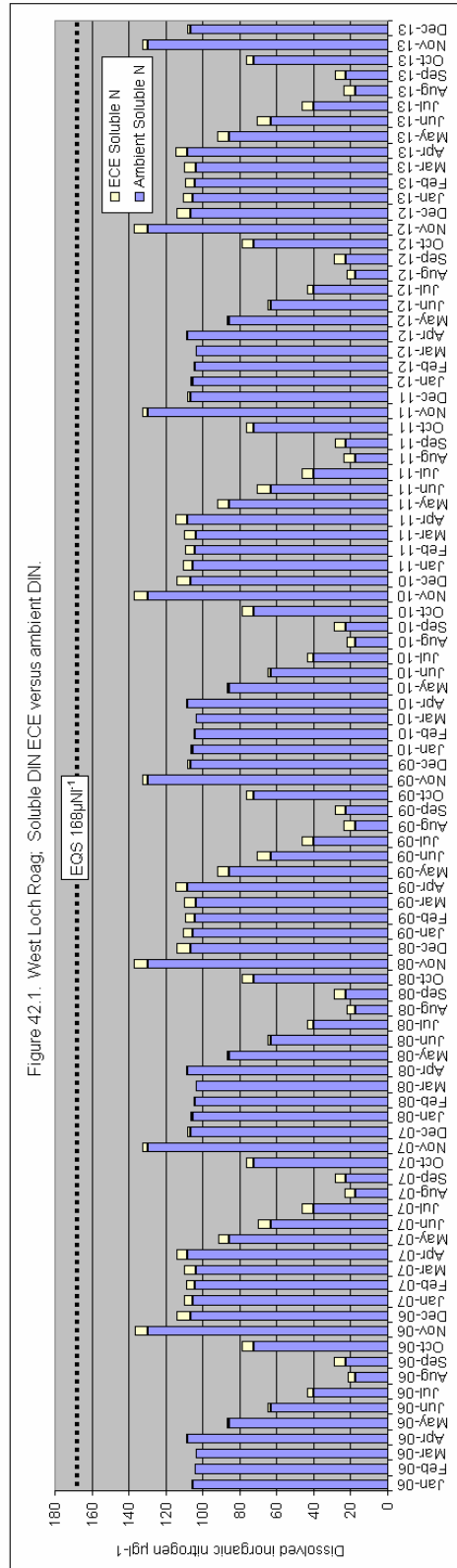


Figure 42.  
West Loch Roag vs East Loch Roag.  
Projected monthly equilibrium concentration enhancementment (ECE) of DIN in loch waters vs ambient DIN and EQS for DIN.  
January 2006 to December 2013.



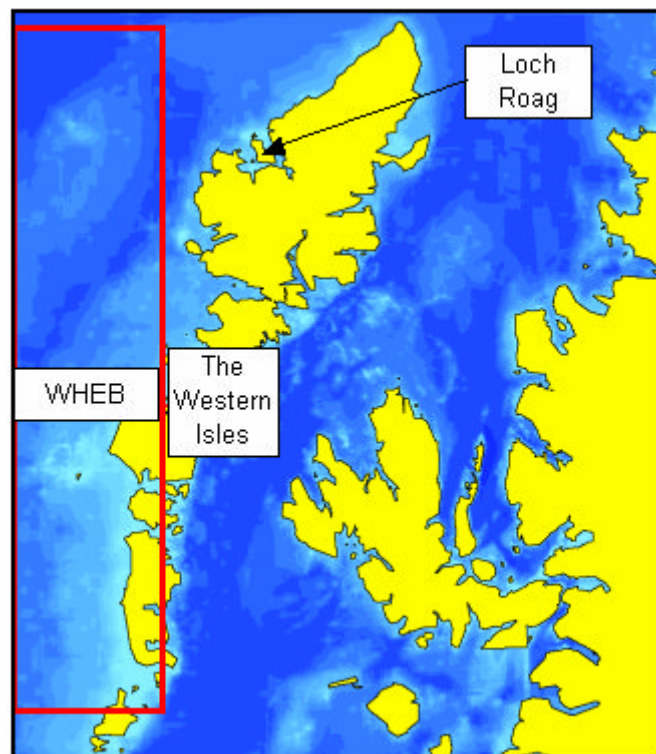


Figure 43. Scottish Marine Waters Western Hebrides Sub-Area (WHEB).

Figures 39 and 40 estimate the monthly amount of Nitrogen, Phosphorus and Oxygen (estimated on the basis of 100% DO saturation at the temperature range collected with the WHEB data) carried in and out of West Loch Roag and East Loch Roag as the result of calm-weather tidal flushing of the two loch areas. Figure 41 develops this theme, by showing the monthly turnover of Dissolved Inorganic Nitrogen (DIN) flushing the two sides of the loch, for the period November 2005 to December 2013, against the respective combined discharges of Nitrogen from the salmon farming operations in both areas.

Finally Figure 42 shows the comparison of monthly ambient DIN (taken from the WHEB database), against the Equilibrium Concentration Enhancement (ECE) that would arise as a result of the combined soluble Nitrogen discharges from the farms and their dilution by the tidal flushing, monthly. The two graphs show these two amounts, summed to give an indication of level of enhancement of ambient DIN that might arise from the farms, set against the SEPA Environmental Quality Standard (EQS) for the maximum likely ambient DIN that might apply prior to the onset of eutrophication in water bodies where mean water residence time exceeds three days, that is  $168\mu\text{g N l}^{-1}$ . It can be seen from Tables 7 and 9 that mean residence time in West Loch Roag is 4.03 to

8.33 days (Mean Spring to Mean Neap tide) and 3.31 to 6.81 days for East Loch Roag (black hatched line). Thus this EQS can be applied in both cases.

The findings of the modelling exercise on the cumulative impacts of soluble discharges from the salmon farms in West and East Loch Roag post-SOP and their likely relationship to tidal flushing, shown graphically in Figures 39 to 42 and Table 7 to 10, are as follows:-

- Tables 7 and 9 show us that West Loch Roag has roughly 50% more low water area than East Loch Roag (53,300,000m<sup>2</sup> as opposed to 38,600,000m<sup>2</sup>; SEPA data) and has about a 25% greater mean depth (25.4m versus 20.2m; SEPA data). It therefore has about 46% more volume. This has a considerable impact on tidal flushing, which is about 50% greater for West Loch Roag than East Loch Roag, as calculated in the tidal flushing models given.
- As a result, as Tables 8 and 9 and Figures 39 and 40 show, considerably more dissolved nutrients and oxygen flush through West Loch Roag than East Loch Roag. This is also reflected for DIN only, in Figure 41. Inorganic nitrogen is the first limiting nutrient for primary production in marine waters. Figure 41 also shows the cumulative amount of nitrogen discharged into each side of the loch from the salmon farms and indicates that their DIN contribution is small relative to tidally flushed nitrogen. Figure 38 has already established that the estimated combined nutrient discharges from West Loch Roag farms are about 8% higher than those from East Loch Roag farms in three cycles in every four and roughly equal in one cycle in every four.
- At this point, the use of FRS WHEB ambient biotic and abiotic data as the basis for predicting ambient nutrient levels in Loch Roag should be validated. In some EU and non-EU jurisdictions, it is mandatory that fish farmers monitor monthly ambient water column parameters. This is generally done at the farm site and at a control site nearby. The historical databases generated, some of which cover periods of over 20 years, have proven extremely useful for a number of tasks. Indeed fish farmers in such areas often hold more nutrient and physico-chemical data on the waters that they inhabit than any other party. Rightly or wrongly, there is no mandatory requirement for such monitoring in Scotland and, as far as is known, there is no reliable or extensive monthly dataset available for Loch Roag. Under these circumstances, the WHEB dataset is probably the best available; indeed at least some of the water in the WHEB sub-area is en route, either to or from flushing Loch Roag. It is therefore surmised that the only significant difference between the nutrient characteristics of WHEB water and Loch Roag water will arise from the direct inputs into Loch Roag from its catchment and from the activities within the loch itself, including

aquaculture. From other studies, in Lough Swilly, Clew Bay and elsewhere (Bass N; commissioned reports) it has been established that, where tidal flushing is relatively rapid (as in Loch Roag) catchment inputs generally account for no more than about 12%-15% of total nutrient load, even in catchments with well developed agricultural, livestock and forestry sectors and a substantial human population. These conditions do not apply to Loch Roag and it is therefore likely that the main difference between inward-flushing water and loch water will arise from the contributions of aquaculture.

- This perspective of the relationship between combined farm DIN discharges and ambient DIN (as represented by WHEB data) is given in Figure 42. This sums the estimated ambient DIN for West and East Loch Roag (which will be the same, since both are flushed from the same source) and the monthly Equilibrium Concentration Enhancement (ECE) of DIN, which would arise from the combined discharge of DIN from the farms in each side of the Loch. This figure is then compared with the EQS. It can be seen that the EQS convergence with the EQS value is never caused by salmon farming activity but by the natural trends of the nitrogen cycle, which causes a peak in ambient DIN in the winter months and a trough in ambient DIN in the summer to autumn months, when DIN is grazed down by primary production. Thus it is concluded that nutrient discharges from the salmon farms in Loch Roag will not contribute towards eutrophication of the loch waters at the production levels anticipated.
- The findings of this analysis show a greater level of detail but nonetheless confirm the recent FRS finding that, under the Locational Guidelines analysis, Loch Roag will retain its Grade 2 status post SOP.
- That said, it is noted that discharges of dissolved nutrients into East Loch Roag represented by the Equilibrium Concentration Enhancement (ECE) post-SOP make a higher percent contribution ambient nutrient concentrations in East Loch Roag relative to West Loch Roag. However it would appear that discharges are well within the carrying capacity of both sides of the loch.

## Section 4.

### Discussion and conclusions.

The current status of aquaculture in Loch Roag is such that site deployment and production methodologies have not been optimised or mitigated in the interests of:-

- The aquaculture businesses that operate within the loch.
- Other stakeholders.
- The loch environment.
- The wild salmonid stocks that inhabit the freshwaters that discharge to the loch and depend on the loch as a migratory route.

The concept of site optimisation of aquaculture in Scottish waters has matured through a series of steps, culminating in the development of the Scottish Executive's Locational Guidelines for Fish Farming and the Scottish Executive's Strategic Framework for Scottish Aquaculture. These documents provide a synthesis of ideas, which have been developed during the last seven years or so, which centre on the hydrographic and spatial separation of clusters of salmon farm sites within separate tidal excursions into separate Management Areas. The aspiration is that each Management Area can, in the course of time be subject to the implementation of a Site Optimisation Plan. Each plan can then be incorporated into an Area Management Agreement to protect the interests of all stakeholders within the area.

The Loch Roag Site Optimisation Plan (LR SOP) is the pilot for the introduction of SOP's throughout the Scottish aquaculture industry.

The current locations of fin fish farm sites in Loch Roag create numerous constraints that may be addressed in the manner set out above. These can be summarised as:-

- Imbalance in biomass consented in each side of the loch relative to hydrography.
- Proximity of some sites to wild salmonid river estuaries.
- Interference with conservation designations.
- Obstruction of navigation.
- Aesthetic constraints.
- Commercial / logistical constraints.

These are addressed individually, by the proposals set out in this document, by :-

- Modification of occupied areas, site relocation and site amalgamation, to distance sites from wild salmonid rivers, to address logistical considerations, to improve business viability, address aesthetic considerations, address inshore fishery issues and to leave shipping lanes unimpeded.
- Stocking alternation, biennial spring site following, site rotation in some cases and single generation stocking, to mitigate biomass and discharge peaks, allow

recovery of the seabed in the vicinity of sites between production cycles and to break on-farm infection and infestation cycles, which could also impact on wild salmonid stocks. In this latter case, spring site fallowing reduces the infestation pressure of sea lice infestive stages during the “susceptible” spring period, when wild salmonids are migrating through the loch waters.

- Synchronous and strategic treatment proposals for sea lice and fish diseases, to assist in parasite and disease control, which also has implications for farmed and wild salmonid stocks alike.

The Site Optimisation Plan resulting is regarded as a valid attempt to mitigate all constraints in the interests of all stakeholder parties.

Consideration is also given to projected production and waste discharge data for each side of the loch post-SOP implementation. The following observations are made:-

The division of the aquaculture business, in particular salmon farming in Loch Roag into two parts, occupying East and West Loch Roag respectively offers a number of opportunities to mitigate the overall impacts of aquaculture activity under the SOP:-

In particular, the stocking of West Loch Roag in even years and East Loch Roag in odd years reduces the potential for biomass peaks and consequent peaks in discharges. The overall result is an evening-out of biomass and discharges on a more or less annual basis in the loch as a whole.

Post SOP, the number of site consents will reduce from the current 13 to 7 sites in East Loch Roag and from the current seven to five sites in West Loch Roag. Total consent biomass will decrease from 7,740 tonnes to 7,150 tonnes in East Loch Roag and increase from 5,250 tonnes to 6,275 tonnes in West Loch Roag. These changes are broadly in line with the different flushing characteristics of the two sides of the loch.

This is further demonstrated by the calculation of flushing models for East and West Loch Roag, which show that the flushing of West Loch Roag is about 50% greater than the flushing of East Loch Roag. The model calculates that the mean flushing time for West Loch Roag varies between 4.03 days (mean spring tide) and 8.44 days (mean neap tide) and that for East Loch Roag from 3.31 days (mean spring tide) to 6.81 days (mean neap tide). These flushing times are relatively rapid for Scottish lochs by any standard.

Given ambient nutrient concentration data, derived from the FRS WHEB dataset and nutrient discharge data, derived by the model given for West Loch Roag and East Loch Roag respectively, the monthly Equilibrium Concentration Enhancement (ECE) for both sides of the loch can be calculated. ECE causes a projected peak in Dissolved Inorganic Nitrogen (DIN) concentration of 137ppm for West Loch Roag and 140ppm in East Loch Roag. In both cases, the anticipated peak DIN falls well short of



the EQS established for DIN by SEPA, of 168ppm DIN. The EQS given is the level at which phytoplankton may bloom in waters resident in lochs for more than three days. The fact that the ECE does not reach this level at any time is a strong indication that eutrophication will not occur within Loch Roag in the post-SDOP aquaculture scenario. It is therefore considered that the extent of aquaculture proposed is within the carrying capacity of the loch waters.

The Locational Guideline procedures in respect of DIN calculate ECE on an annual basis. Nutrient discharges and ECE are calculated monthly in this document. This gives a considerably higher estimate of discharge per tonne of salmon produced than estimated by the Locational Guidelines procedure. A number of reasons can be given for this, including the facts that:-

- Mortalities are fully accounted for in the models.
- Precise protein and phosphorus levels for each ration specification used.
- Discharges are calculated to their monthly, rather than annual, mean.

It is noted that the derived monthly ECE still falls well within the SEPA EQS in every month. This is felt to offer a considerable margin of safety for post-SOP aquaculture operations in the loch, whilst still being in broad agreement with the classification for the loch under the Locational Guidelines procedure.

On the basis of the parameters considered in this report, it is concluded that the proposals for the Loch Roag SOP should be accepted as a significant improvement in the environmental and resource management of the loch system relative current practice. It is suggested that the information provided herein be used as a baseline, from which point aquaculture development and performance can be monitored post-SOP, in respect of the loch environment, the viability of the businesses within it and other relevant indicators. This would best be achieved through the formalisation of a loch management group, to monitor the success of the SOP, to maintain dialogue and to act as a vehicle for the introduction of further initiatives. Such a body could be co-ordinated through WIAA but have membership drawn from amongst the relevant authorities and stakeholders.

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