Scottish Sanitary Survey Project

Sanitary Survey Report
Loch Roag: Ceabhagh and Eilean Chearstaigh
LH 381 and LH 344
April 2008

Cefas

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Report Distribution - Loch Roag: Ceabhagh and Eilean Chearstaigh

Date	Name	Agency*
	Linda Galbraith	Scottish Government
	Judith White	Scottish Government
	Ewan Gillespie	SEPA
	Douglas Sinclair	SEPA
	Stephan Walker	Scottish Water
	Alex Adrian	Crown Estate
	Colm Fraser	Comhairle nan Eilean Siar
	Cree McKenzie	Hebridean Mussels Ltd.**

* Distribution of both draft and final reports to relevant agency personnel is undertaken by FSAS.

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Acknowledgements

We are thankful to the following persons and agencies who provided assistance and information used in the following report.

Comhairle nan Eilean Siar
Mr. Cree McKenzie
SEPA Registry Office Dingwall
Scottish Water
Dr. Alan Lilly, Macaulay Land Research Institute

A note about Gaelic place names

Many of the place names in the Western Isles are given separate Gaelic and English spellings, and sometimes more than one spelling in either or both. Ordnance Survey maps provide Gaelic spellings predominantly, though historically many features were given English spellings as well. Various Scottish agencies have used English spellings to denote local services. In these cases, then English spelling will be retained to keep a clear track back to the source documentation. In all other cases, the Gaelic spelling is used.

The following are the most common names with multiple spellings for this area:

Gaelic	**English**
Bearnaraigh	Bernera
Bhreascleit	Breasclete
Calanais	Calanish or Callanish
Ceabhagh	Keava
Circebost	Kirkibost
Eilean Scarastaigh	Eilean Scarista
Gearraidh na h-Aibhne	Garynahine
Ghriomarstaidh	Grimersta
Iarsiadar	Earshader
Linsiadar	Linshader

1. General Description

Loch Roag is a remote complex of lochs and small islands on the western coast of the Isle of Lewis. Its shores are sparsely populated and the loch supports a significant number of shellfish and salmon farms. It is 7km long and has a maximum depth of 40m, though at the production areas examined for this report it is 0-20 metres in depth. Eilean Chearstaigh and Ceabhagh are located in the southeastern quadrant of the loch.

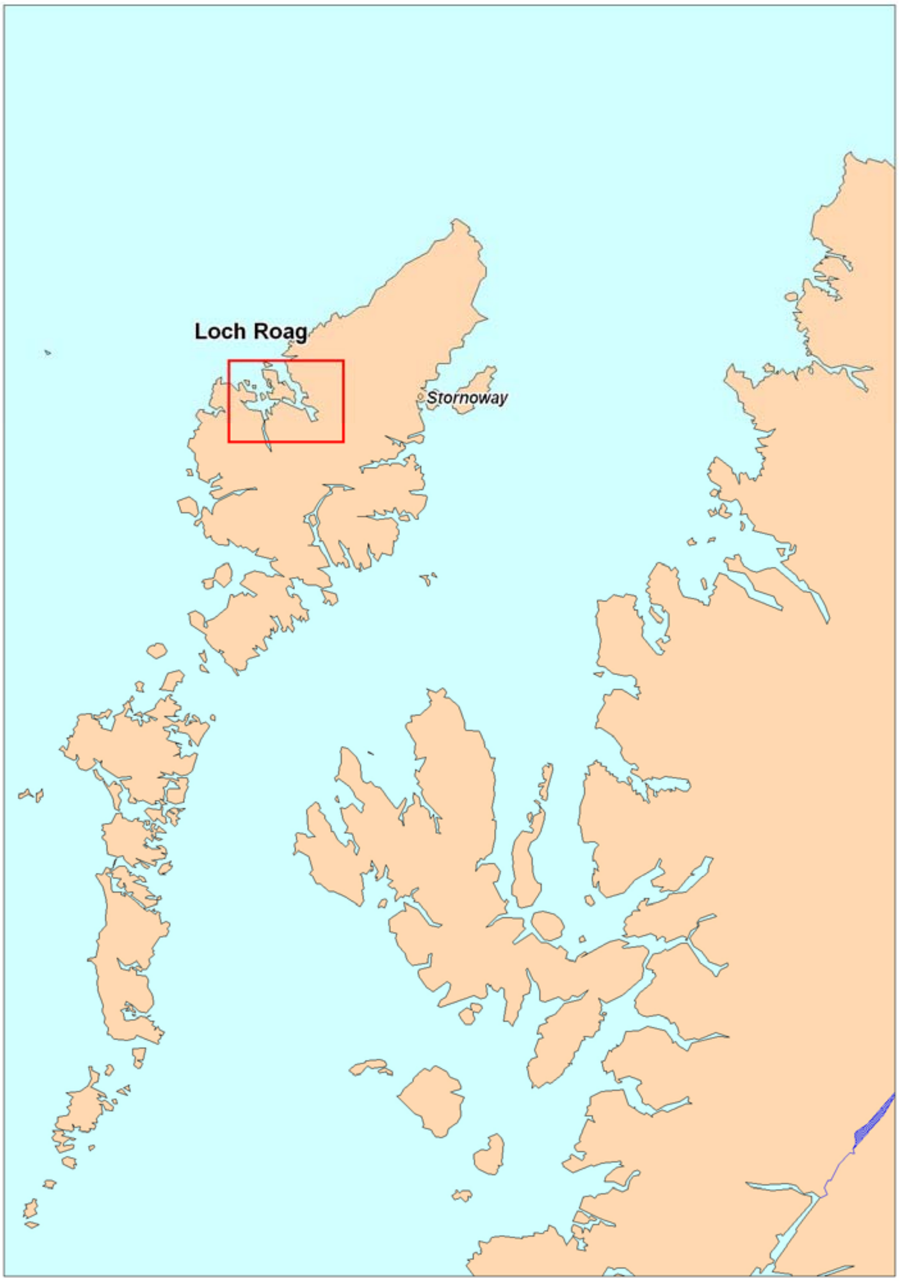


Figure 1.1 Location of Loch Roag

2. Fishery

The fisheries at Loch Roag Ceabhagh and Loch Roag Eilean Chearstaigh are comprised of three long line mussel (*Mytilus* sp.) farms as listed in Table 2.1 below:

Table 2.1. East Loch Roag shellfish farms

Production Area	Site	SIN	Species
Loch Roag Ceabhagh	Keava	LH 381 772	Common mussels
Loch Roag Eilean Chearstaigh	Buckle Point	LH 344 791	Common mussels
Loch Roag Eilean Chearstaigh	Eilean Scarastaigh	LH 344 697	Common mussels

Current production area boundaries for Loch Roag Eilean Chearstaigh are given as the area bounded by lines drawn between NB 1891 3352 and NB 1867 3308 and between NB 2094 3244 and NB 2114 3260 and between NB 2028 3360 and NB 2011 3360 and between NB 1941 3360 and NB 1908 3360.

The reported RMP grid reference is NB 196 328. This lies on the Crown Estate lease area for Eilean Scarastaigh. However, there are no mussel lines currently on this lease area. The RMP does not lie within the recorded boundaries of either of the mussel farms observed in the production area.

There are two mussel farms within the existing Eilean Chearstaigh production area: Buckle Point and Eilean Scarastaigh. The recorded position of each is mapped in Figure 1. The Eilean Scarastaigh mussel farm is actually located closer to the seabed lease for Aerd Baeg Lundale. Both farms contained three lines with 7 m pegged drop ropes. There is only one mussel farm within the proposed new production area at Keava. At the time of the shoreline survey, two lines were in place on the site with droppers to 10m.

At all 3 sites, mussels are grown on double-headed long lines. Long lines attached to floats are laid out in parallel lines anchored at either end within the approved lease area. Vertical lines containing plastic pegs (droppers) are attached to the long lines. New lines are placed before or during spawning between May and early June and spat settle on to the droppers from the surrounding water. The spat are then left to grow for up to three years before reaching marketable size.

Mature mussels are harvested by stripping the attached mussels from the droppers using a system of brushes mounted to a funnel. In some cases, harvested mussels are cleaned and sorted on the barge and in others they are taken back to a central facility for scrubbing and sorting.

Harvesting is done in rotation with different lines set out in different years to allow harvesting of some stock every year. The harvester at Loch Roag will harvest year round when possible in order to satisfy customer demand.

Spawning occurs in May, during which the meat yield declines substantially. Blooms of toxic algae typically occur during the summer, resulting in fishery closures during the summer months. These are unpredictable and sporadic, usually clearing up by September or October.

Figure 2.1 shows the relative positions of the mussel farms; Food Standard Agency Scotland designated Production Area and the seabed lease areas.

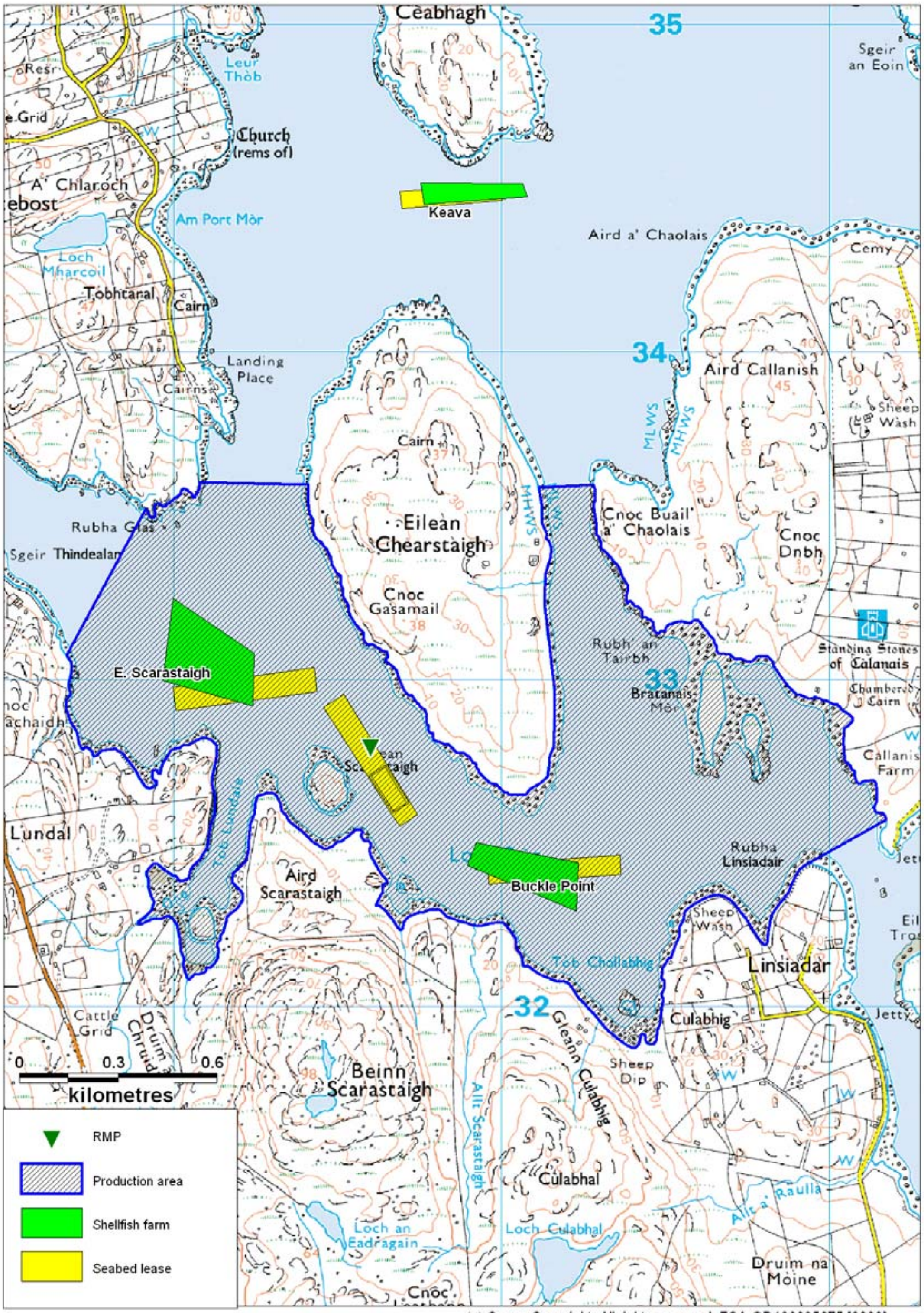
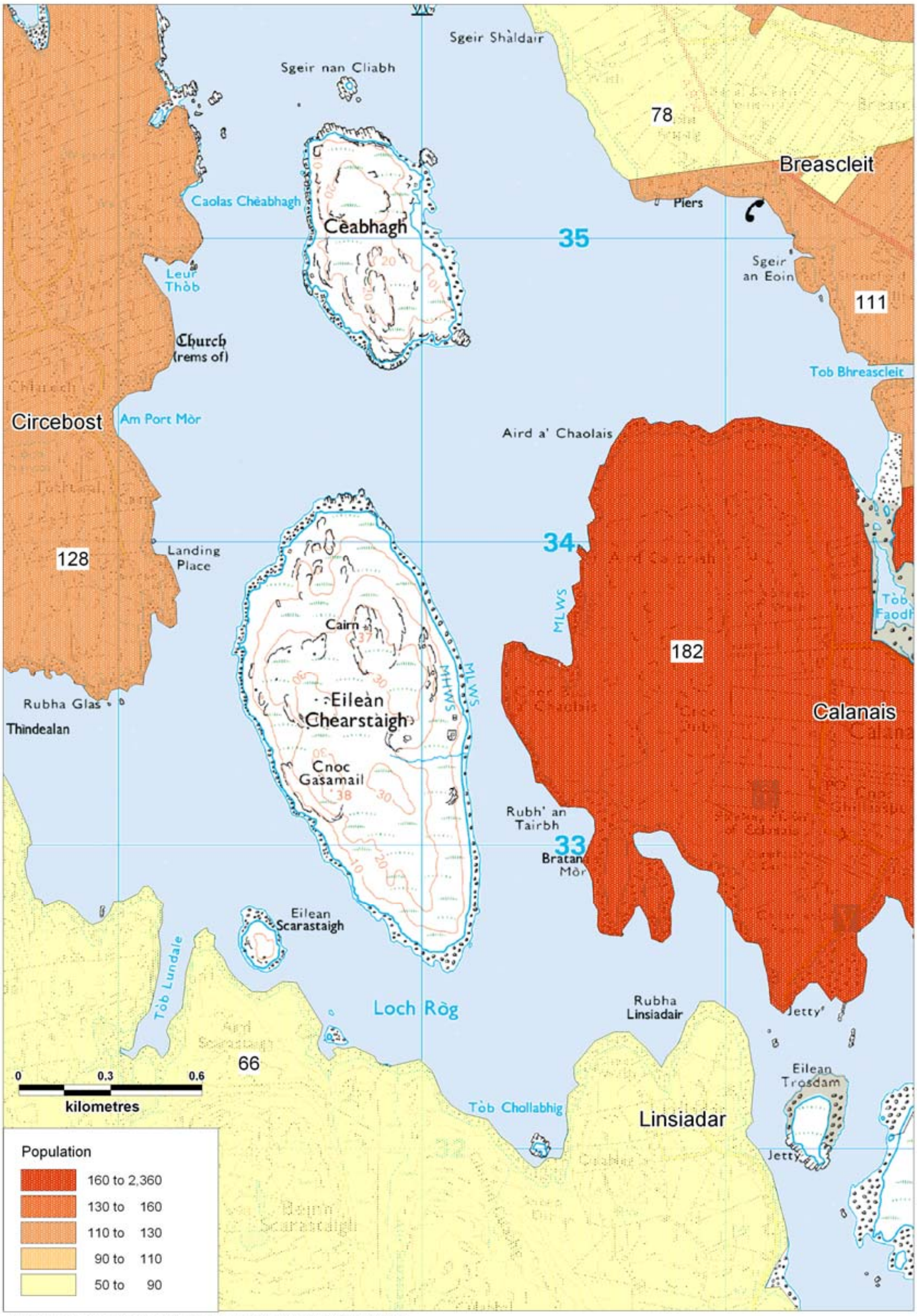


Figure 2.1 East Loch Roag fisheries

3. Human Population

The figure below shows information obtained from the General Register Office for Scotland on the population within the census output in the vicinity of Loch Roag Ceabhagh.



Population data Census Data [2001] - General Register Office for Scotland

Figure 3.1 Population of East Loch Roag

The population for the five census output areas bordering immediately on Loch Roag are:

60RJ000060	182
60RJ000061	66
60RJ000066	128
60RJ000068	78
06RJ000069	111
Total	565

The settlements surrounding Loch Roag are fairly dispersed. To the east is Calanais, to the northeast is Breascleit, to the northwest is Circebost and to the southeast is Linsiadar. However, most of the population is concentrated on the eastern side of the loch and any associated faecal pollution from human sources will be concentrated in these areas.

There is very little in the way of tourist accommodation in the vicinity and no organised campsites were apparent during the shoreline survey. While tourism in the Western Isles is an important economic activity, there was little to suggest that seasonal fluctuations in the population around the production areas would significantly impact the fishery.

4. Sewage Discharges

Community septic tanks and sewage discharges were identified by Scottish Water for the area surrounding Loch Roag Ceabhagh. They are detailed in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

Discharge Name	NGR of discharge	Discharge Type	Level of Treatment	Consented flow m3/day
Breasclete B	NB21203520	Continuous	Septic Tank	42
Breasclete C&D	NB21603470	Continuous	Septic Tank	27
Callanish A	NB21503370	Continuous	Septic Tank	25
Callanish C	NB221325	Continuous	Septic Tank	
Callanish D Garrynahine	NB23303150	Continuous	Septic Tank	10.5
Kirkibost dun Innes	NB18103420	Continuous	Septic Tank	10.8

No sanitary or microbiological data were available for these discharges.

A number of discharge consents are held by SEPA and are listed in Table 4.2. In some cases multiple consents applied to one discharge and in some cases had differing grid references. At the time of this writing, this had not been resolved.

Table 4.2 Discharge consents held by SEPA

Ref No.	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow (DWF) m3/d	Consented/ design PE	Notes
WPC/N/62411 CAR/L/1002956	NB 2160 3470 NB 21612 34605	Breasclete C	Continuous	Septic Tank	27	120	150mm internal diameter pipe
WPC/N/62487 CAR/L/1004180	NB 2150 3370 NB 21686 33600	Callanish, T'ob Breasclete	Continuous	Septic Tank	25	116	150mm internal diameter pipe
WPC/N/62406 CAR/L/1004087 CAR/L/1002373	NB 2120 3520 NB 21147 35171	Breasclete B	Continuous	Septic Tank	42	188	150mm internal diameter pipe

Older consents are currently being updated at SEPA. Whilst CAR numbers have been established for these discharges, their content has not yet been formally determined. Where more than one grid reference is given, one refers to the tank and the other to the outfall.

A number of septic tanks and/or outfalls were recorded during the shoreline survey. Their locations have been included in the mapped discharges in Figure 4.1. Observed septic tanks, covers and/or discharge pipes, including results from any associated samples, are listed in Table 4.3.

It was not possible to confirm all the discharge locations during the shoreline survey as information in hand at the time was incomplete and in some cases the condition of the shoreline prevented access or view.

None of the discharges to East Loch Roag receives more than primary treatment. In two instances, septic discharges were observed to be malfunctioning (Table 4.3, nos. 19 and 24) with raw waste apparent on the shoreline.

Table 4.3 Discharges and septic tanks observed during shoreline survey

No	NGR	Description	Sample No.	Type	E.coli (cfu/ 100ml)
1	NB 20850 35137	30cm plastic pipe from factory, not flowing	-	-	-
2	NB 20807 35134	3 x 22cm plastic pipes, 1 flowing circa 10L per second, water sample 2 taken from flowing pipe	Roag 2	Sea	0
3	NB 20949 35206	Septic overflow 110mm pipe	Roag 4	Fresh	200
4	NB 21160 35170	Inspection cover	-	-	-
5	NB 21143 35154	Concrete encased pipe to below water level	-	-	-
6	NB 21150 35190	Septic tank cover	-	-	-
7	NB 21223 35139	Septic tank cover.	-	-	-
8	NB 21157 35234	3 inspection covers	-	-	-
9	NB 21768 34795	Septic tank	-	-	-
10	NB 21763 34568	Inspection cover	-	-	-
11	NB 21654 33598	Community septic tank	-	-	-
12	NB 21640 33712	End of sewer pipe, 15cm diameter, flowing 0.5 L/s	-	-	-
13	NB 21880 33801	18cm metal pipe over stream	-	-	-
14	NB 21840 33902	Possible pumping station (silent)	-	-	-
15	NB 21733 34164	Inspection covers	-	-	-
16	NB 21738 34154	Septic tank cover, no overflow to shore	-	-	-
17	NB 22221 32697	Inspection cover	-	-	-
18	NB 22136 32677	Inspection cover	-	-	-
19	NB 18142 34219	Septic tank overflowing into small stream also line of rocks leading into sea covering pipe which might be blocked.	-	-	-
20	NB 18137 34218	Stream 100cmx3cmx0.4m/s, septic tank.	Roag 23	Fresh	>100000
21	NB 18146 34222	Water sample 25, septic tank.	Roag 25	Fresh	200
22	NB 19033 33881	Septic tank	-	-	-
23	NB 18997 34171	Septic tank in field	-	-	-
24	NB 18577 35636	Septic outflow from 2 houses, excrement evident on shoreline, water sample 29	Roag 29	Sea	36
25	NB 21152 31854	Septic tank	-	-	-
26	NB 21179 31717	Septic pipe to shore	-	-	-
27	NB 20796 32001	Septic tank to ditch	-	-	-
28	NB 22966 31727	Inspection cover in field 10m back from shore, pipe not visible, water sample 37	Roag 37	Sea	54

The mussel farm at Keava lies approximately 1.2 km from the nearest discharge at Breasclete (Bhreascleit) to the east and 0.7 km from the nearest private septic tank to the west. Either of these sources may impact water quality at the site. The septic tank discharge at Calanish A lies within the same bay as the Breasclete discharges and so may also impact Keava. However, the remaining Calanish discharges are over 5km away and are less likely to directly impact the mussel farm.

Of the two farms within the Eilean Chearstaigh production area, the westernmost is likely to be impacted by the discharge at Kirkibost dun Innes, which appeared to be malfunctioning on the day of survey. The farm at Buckle Point is not located within 1 km of any discharge, however faecal contaminants may be carried south from Kirkibost dun Innes or north from Calanish C &D and the private septic tanks at Linsiadar.

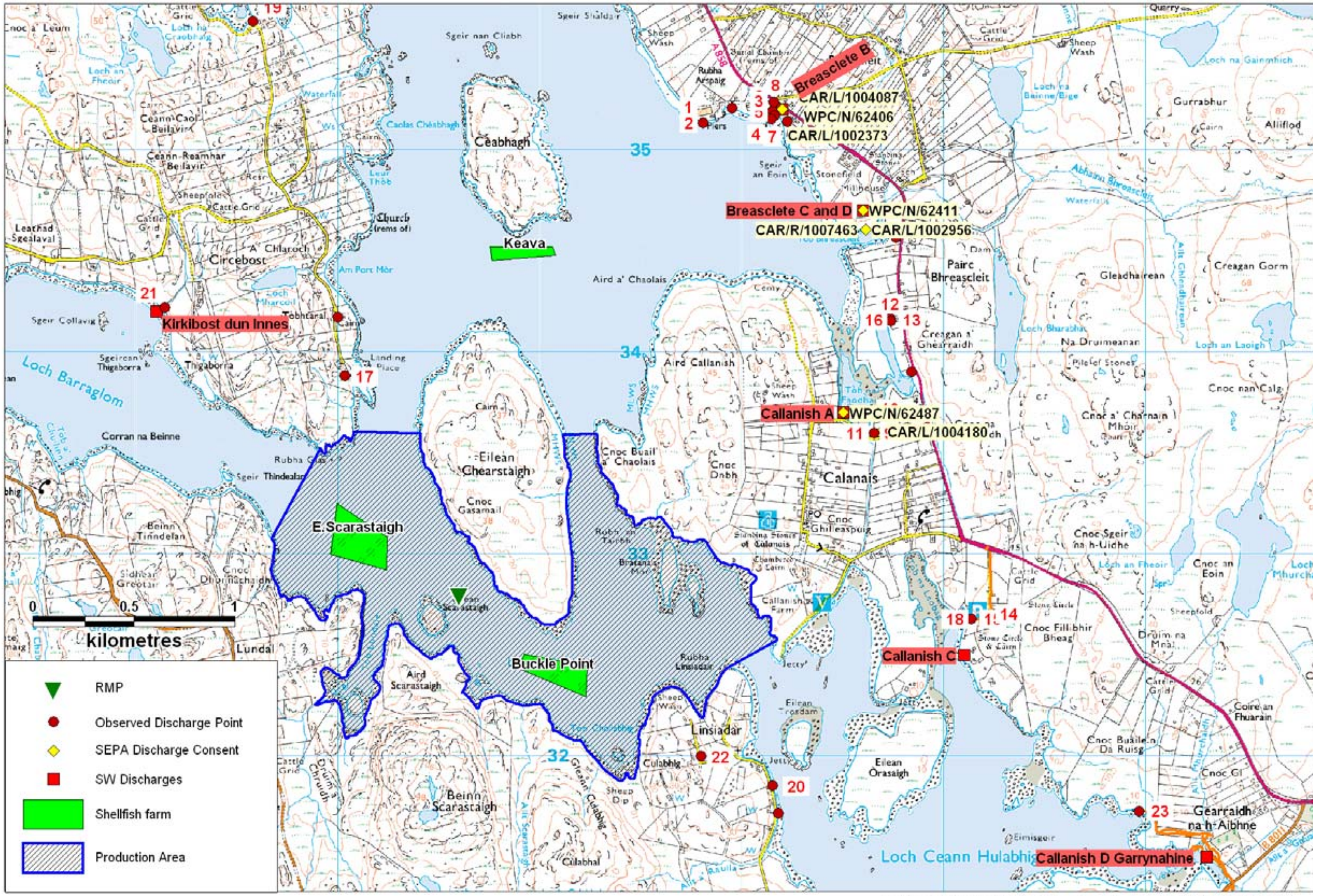


Figure 4.1 Discharges to East Loch Roag

5. Geology and soils

Component soils and their associations were identified using uncoloured soil maps (scale 1:50,000) obtained from the Macaulay Institute. The relevant soil associations and component soils were then investigated to establish basic characteristics. Seven main soil types were identified: 1) humus-iron podzols, 2) brown forest soils, 3) calcareous regosols, brown calcareous regosols, calcareous gleys, 4) peaty gleys, podzols, rankers, 5) non-calcareous gleys, peaty gleys: some humic gleys, peat, 6) organic soils and 7) alluvial soils (see glossary at the end of this section).

Humus-iron podzols are generally infertile and physically limiting soils for productive use. In terms of drainage, depending on the related soil association they generally have a low surface % runoff, of between 14.5 – 48.4%, indicating that they are generally freely draining.

Brown forest soils are characteristically well drained with their occurrence being restricted to warmer drier climates, and under natural conditions they often form beneath broadleaf woodland. With a very low surface % runoff of between 2 – 29.2%, brown forest soils can be categorised as freely draining.

Calcareous regosols, brown regosols and calcareous gleys are all characteristically freely draining soils containing free calcium carbonate within their profiles. These soil types have a very low surface % runoff at 14.5% and can be classified as freely draining soils.

Peaty gleys, peaty podzols and peaty rankers contribute to a large percentage of the soil composition of Scotland. They are all characteristically acidic, nutrient deficient and poorly draining. In addition, they also have a very high surface % runoff of between 48.4 – 60%, confirming that they are poorly draining.

Non-calcareous gleys, peaty gleys and humic gleys are generally developed under conditions of intermittent or permanent water logging. In Scotland, non-calcareous gleys within the Arkaig association are most common and have an average surface % runoff of 48.4%, indicating that they are generally poorly draining.

Organic soils often referred to as peat deposits and are composed of greater than 60% organic matter. Organic soils have a surface % runoff of 25.3% and although low, due to their water logged nature, results in them being poorly draining.

Alluvial soils are confined to principal river valleys and stream channels, with a wide soil textural range and variable drainage. However, the alluvial soils encountered within the Scottish regions mapped have an average surface % runoff of 44.3%, so it is likely that in this case they would be poorly draining.

Maps were produced using these seven soil type groups and whether they are characteristically freely or poorly draining. The map of component soils and their associated drainage classes for the area around Loch Roag can be found in Figure 5.1.

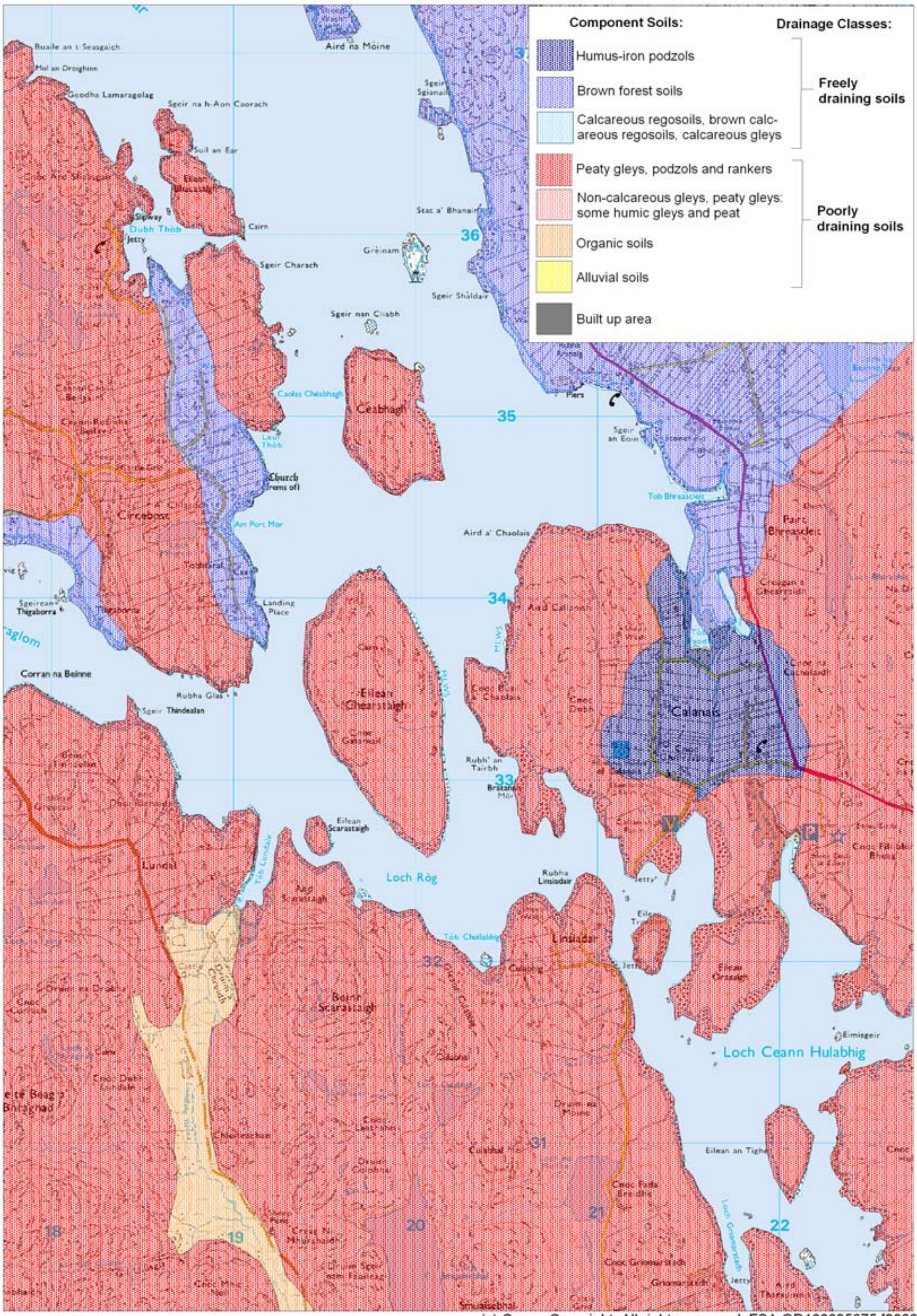


Figure 5.1 Component soils of East Loch Roag

There are four different types of component soils found in East Loch Roag. The most dominant are the peaty gleys, podzols and rankers which cover much of the coastline and mainland. Brown forest soils cover parts of the southern and eastern shorelines of Bearnaraigh and also much of the northeastern shoreline. Humus-iron podzols are found in the area of Calanais, where a number of small crofts are situated. Finally, an area of organic soil follows the Lundale river on the southern mainland opposite Eilean Chearstaigh.

In poorly draining soils (such as those found along much of the coastline of Loch Roag) surface run off is likely to be high, as peaty gleys, podzols and rankers are often waterlogged. Whereas, in the more freely draining soils found dotted along the coastline of Loch Roag, surface runoff is reduced as the permeability of the soil has increased.

In the case of East Loch Roag, the potential for runoff contaminated with *E. coli* from animal waste is generally high for most of the land surrounding Loch Roag. A notable exception is the area around Calanais, where more freely draining soils may help reduce the potential for runoff contaminated with animal waste from the crofts in the area.

For much of the area in red, it is possible that function of any soakaway systems may be impaired due to poor drainage. The Lundale River and Abhainn Ghriomarstaidh both discharge into the southern end of the loch after passing through poorly draining soils and may be subject to higher contamination from runoff.

The shoreline immediately adjacent the new mussel farm at Keava are largely classed as freely draining, though the island of Ceabhagh itself is classed as poorly draining. This would indicate that the potential from contaminated runoff from grazed areas on the mainland and Bearnaraigh is relatively low. There is, however, higher potential risk from contaminated runoff from Ceabhagh.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

Gley: A sticky, bluish-grey subsurface layer of clay developed under intermittent or permanent water logging.

Podzol: Infertile, non-productive soils. Formed in cool, humid climates, generally freely draining.

Rankers: Soils developed over noncalcareous material, usually rock, also called 'topsoil'.

Regosol: coarse-textured, unconsolidated soil lacking distinct horizons. In Scotland, it is formed from either quartzose or shelly sands.

6. Land Cover

The Land Cover Map 2000 data for the area is shown in Figure 6.1 below:

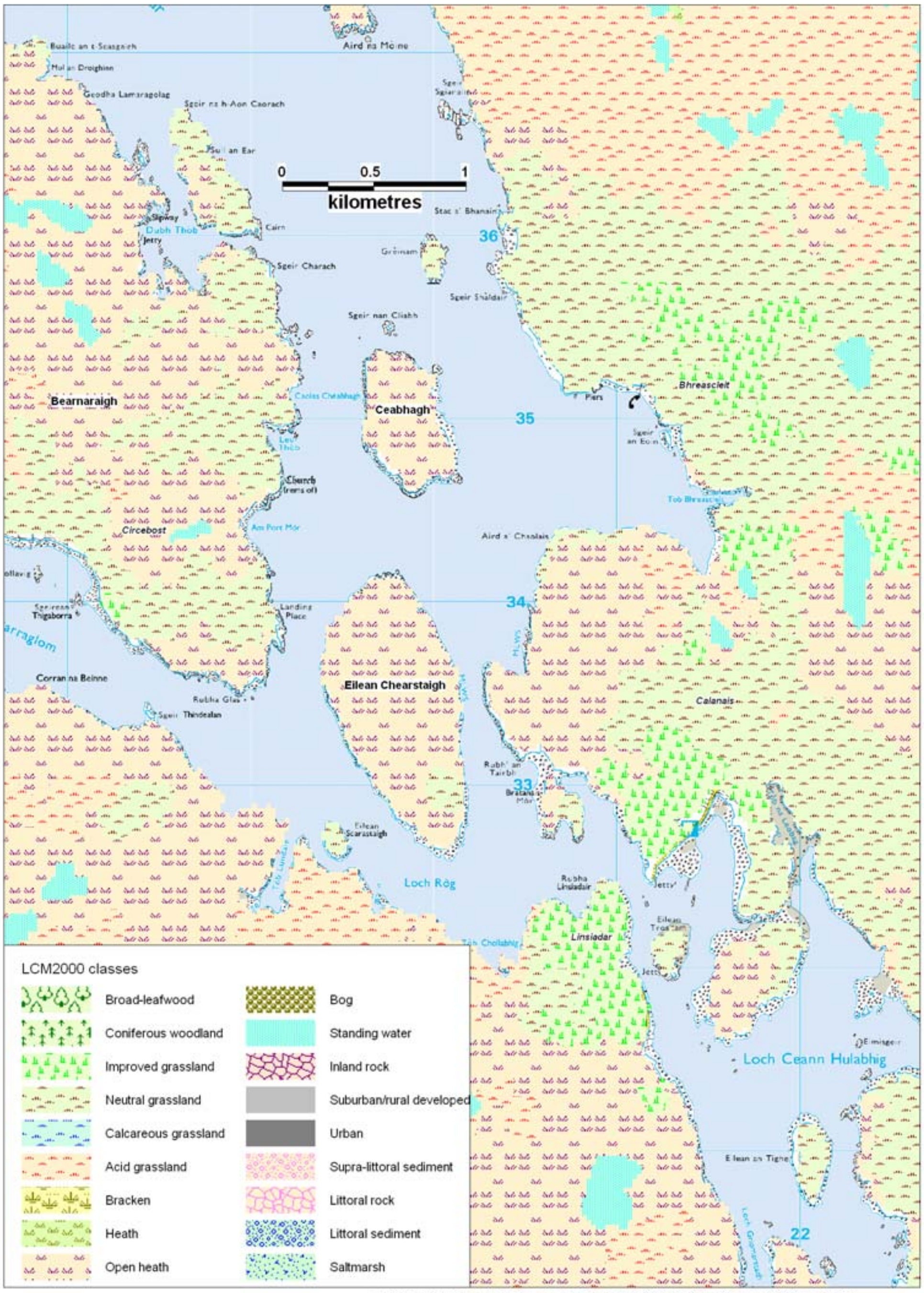


Figure 6.1 LCM2000 class data for East Loch Roag

There are four clear types of land cover in the Loch Roag Eilean Chearstaigh area. These are acid grassland, neutral grassland, improved grassland and open heath.

Much of the area is covered with grassland. Acid grassland is found to the south of Loch Roag and also to the northeast of the loch. There are large areas of neutral grassland on the eastern side of the loch around the settlements of Bhreascleit and Calanais, as well as patches around the islands of Bearnaraigh and Eilean

Chearstaigh. Improved grassland can be found coinciding with settlements and crofts at Bhreascleit, Calanais and Linsiadar along the eastern side of the loch.

Open heath covers much of the Eilean Chearstaigh Island, the western shoreline and some of the southern and eastern shoreline.

No developed areas are noted in the Landcover 2000 data, however there are some areas of hard standing along the eastern side of the loch associated with roads, homes and a visitor's centre.

The faecal coliform contribution would be expected to be highest from developed areas (approx 1.2 – $2.8x10^9$ cfu km^{-2} hr^{-1}), with intermediate contributions from the improved grassland (approximately $8.3x10^8$ cfu km^{-2} hr^{-1}) and lowest from the other land cover types (approximately $2.5x10^8$ cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, this being expected to be highest, at more than 100-fold, for the improved grassland.

Faecal coliform contribution associated with runoff from the areas of improved grassland and paved surfaces around Calanais and Bhreascleit may impact the fishery, especially the site at Keava and to a lesser extent the sites within the Eilean Chearstaigh production area.

7. Farm Animals

Regulation (EC) No. 854/2004 requires the competent authority to:

(a) make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area;
(b) examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste-water treatment, etc.

With regard to potential sources of pollution of animal origin, agricultural census data to parish level was requested from the Scottish Government. The request was declined on the grounds of confidentiality because the parishes in most cases contained only a small number of farms making it possible to determine specific data for individual farms. The only significant source of information was therefore the shoreline survey (see Appendix), which only relates to the time of the site visit on 21st – 24th August 2007.

The shoreline survey identified that sheep were grazed widely around the loch, an estimated 700 were observed. Cattle and several pigs were also observed in the area (see figure 7.1). The most significant concentrations of livestock were sheep on the east and north west side of the loch. The geographical spread of contamination at the shores of the loch attributable to livestock is likely to be concentrated within these areas. Therefore this factor should be taken into account when identifying the location of a routine monitoring point (RMP). However, care should be taken in doing so as the farm animal distributions observed relate to only one point in time and will not be representative of the distribution around the loch over the course of the year.

There is no local information available for the area surrounding East Loch Roag concerning the seasonal numbers of livestock. As in other areas where livestock are produced, it is likely that numbers of sheep will more than double after lambing in the spring and remain high until autumn when the lambs are sold. A similar pattern might be expected for cattle, though numbers would not double due to their lower reproduction rate.

The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

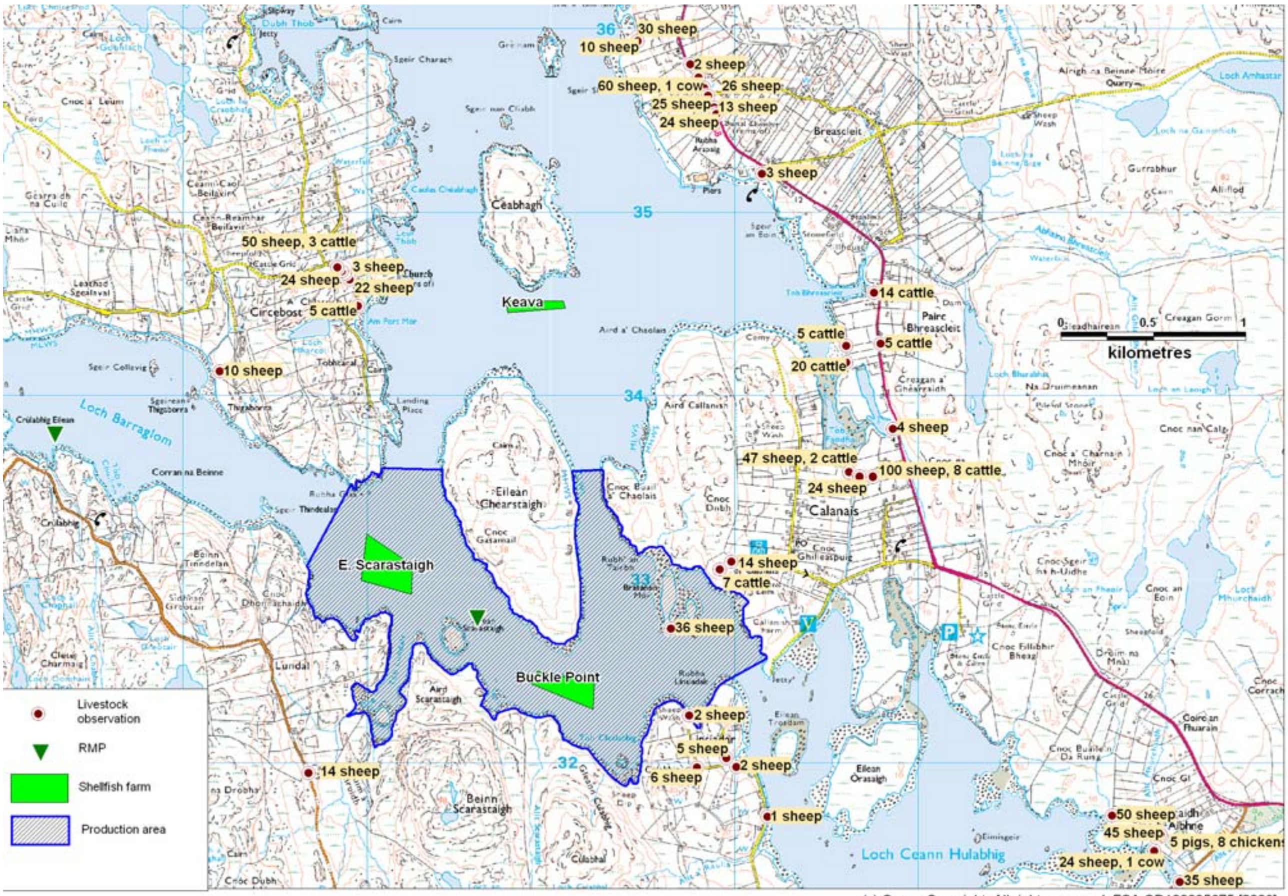


Figure 7.1 Livestock observations at East Loch Roag

8. Wildlife

8.1 Pinnipeds

Two species of pinniped (seals, sea lions, walruses) are commonly found around the coasts of Scotland: These are the European harbour, or common, seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). Both species can be found along the west coast of Scotland.

Common seals surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage. Survey results from 2000 showed minimum numbers in Loch Creran to be 67. There were a minimum of 527 common seals reported in the wider Firth of Lorn to the south of Loch Creran.

According to the Scottish Executive, in 2001 there were approximately 119,00 grey seals in Scottish waters, the majority of which were found in breeding colonies in Orkney and the Outer Hebrides.

A survey conducted by the Sea Mammal Research Unit in 2000, indicated that there was an estimated 600 common seals on the Isles of Lewis and Harris. It must be noted that these figures are likely to have changed slightly as a result of the year (2000) that the data was collected. Due to not being able to specify the exact location of the haul out sites the impact that they could potentially have on the shellfish farms is unpredictable.

Adult Grey seals weigh 150-220 kg and adult common seals 50-170kg. They are estimated to consume between 4 and 8% of their body weight per day in fish, squid, molluscs and crustaceans. No estimates of the volume of seal faeces passed per day were available, though it is reasonable to assume that what is ingested and not assimilated in the gut must also pass. Assuming 6% of a median body weight for harbour seals of 110kg, that would equate to 6.6kg consumed per day and probably very nearly that defecated.

The amount of *E. coli* and other faecal indicator bacteria contained in seal faeces has been reported as being similar to that found in raw sewage, with counts showing up to 1.21×10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle et al 2004).

Both bacterial and viral pathogens affecting humans and livestock have been found in wild and captive seals. *Salmonella* and *Campylobacter* spp., some of which were antibiotic-resistant, were isolated from juvenile Northern elephant seals (*Mirounga angustirostris*) with *Salmonella* found in 36.9% of animals stranded on the California coast (Stoddard et al 2005). *Salmonella* and *Campylobacter* are both enteric pathogens that can cause acute illness in humans and it is postulated that the elephant seals were picking up resistant bacteria from exposure to human sewage waste.

One of the *Salmonella* species isolated from the elephant seals, *Salmonella typhimurium*, is carried by a number of animal species and has been isolated from cattle, pigs, sheep, poultry, ducks, geese and game birds in England and Wales.

Serovar DT104, also associated with a wide variety of animal species, can cause severe disease in humans and is multi-drug resistant (Poppe et al 1998).

Seals will forage widely for food and it is likely that seals will feed near the mussel farms at some point in time. The population is relatively small in relation to the size of the area concerned and is highly mobile therefore it is likely that any impact will be limited in time and area and unpredictable.

8.2 Cetaceans

A variety of cetacean species are routinely observed around the west coast of Scotland.

Table 8.1 Cetacean sightings in 2007 – Western Scotland.

Common name	**Scientific name**	**No. sighted***
Minke whale	Balaenoptera acutorostrata	28
Killer whale	*Orcinus orca*	183
Long finned pilot whale	*Globicephala melas*	14
Bottlenose dolphin	*Tursiops truncatus*	
Risso's dolphin	*Grampus griseus*	145
Common dolphin	*Delphinus delphis*	6
Harbour porpoise	*Phocoena phocoena*	>500

*Numbers sighted are based on rough estimates based on reports received from various observers and whale watch groups. Source: Hebridean Whale and Dolphin Trust.

As the southeastern portion of Loch Roag is shallow it is unlikely that the loch would be visited by larger cetaceans. Smaller cetaceans such as dolphins may hunt in the area. Their presence, however, is likely to be fleeting and unpredictable and so cannot be taken into account with regard to establishing RMPs for the Eilean Chearstaigh and Keava production areas.

8.3 Seabirds

A number of bird species are found in the Western Isles, however seabirds and waterfowl are most likely to occur around or near the fisheries in significant numbers.

Seabird populations were investigated all over Britain as part of the SeaBird 2000 census and species with significant breeding populations in or near Loch Roag are listed below in table 8.2.

Table 8.2 Breeding seabirds of the Western Isles/ Loch Roag

Common name	**Species**	**Estimated Population**	**Common name**	**Species**	**Estimated Population**
Northern Fulmar	*Fulmaris glacialis*	118000	Great Cormorant	*Phalacrocorax carbo*	445*
European Shag	*Phalacrocorax aristotelis*	2661	Arctic Tern	*Sterna paradisaea*	4146*
Black-headed Gull	*Larus ridibundus*	1012	Common Gull	*Larus canus*	1707
Lesser Black-backed Gull	*Larus fuscus*	552	Herring Gull	*Larus argentatus*	2665
Great Black-backed Gull	*Larus marinus*	2007*	Black-legged Kittiwake	*Rissa tridactyla*	21152*
Common Guillemot	*Uria aalge*	120500	Black Guillemot	*Cepphus grille*	4577
Razorbill	*Alca torda*	37400			

*Population number based on Apparently Occupied Sites, Territories, Nests or Burrows. These may equate to more than one adult.

Of these, the following birds have been recorded in Loch Roag in large numbers: Northern Fulmars, Herring Gulls, Great Black-backed Gull, Black-legged Kittiwake, Common and Black Guillimots.

Exact distribution of nesting sites near the harvesting areas is not known.   Though nesting occurs in early summer and pelagic birds such as razorbills and guillemots will then disperse, the gulls are likely to be present in the area throughout the year. Impact to the fisheries is likely to be very localised where birds rest on mussel floats or lines.

Waterfowl (ducks and geese) are present in Loch Roag at various times from autumn through winter. Few of these birds would be expected to be present during the summer months. Over 100 Greylag Geese were observed during the shoreline survey in late August and goose droppings were present on grassy areas around the shoreline. Overwintering geese would tend to be found on farm fields and open grassland.

Wading birds would be concentrated on intertidal mud flats. However, mud flats in the area are few and small. None are located immediately adjacent the fishery and the impact of wading bird faeces from these is unpredictable.

8.4 Deer

Deer are present throughout much of Scotland in significant numbers. The Deer Commission of Scotland (DCS) conducts counts and undertakes culls of deer in areas that have large deer populations.

Four species of deer are routinely recorded in Scotland, with Red deer (*Cervus elaphus*) being the most numerous, followed by Roe deer (*Capreolus capreolus*), Sika deer (*Cervus nippon*) and Fallow deer (*Dama dama*).

Accurate counts of populations are not available, though estimates of the total populations are >200,000 Roe deer, >350,000 Red deer, < 8,000 Fallow deer and an unknown number of Sika deer. Where Sika deer and Red deer populations overlap, the two species interbreed further complicating counts.

Deer are present on Lewis, though no animals or droppings were observed during the shoreline survey. The DCS did not have information on counts or species distribution for the area. Deer stalking is offered on some of the private estates on the island which confirms that a population of deer is present though it is unknown how many are located in the vicinity of the production areas.

Deer, like cattle and other ruminants, shed *E. coli*, *Salmonella* and other potentially pathogenic bacteria via their faeces and it is likely that some of the faecal indicator organisms detected in the streams feeding into Loch Roag will be of deer origin.

8.5 Other

The European Otters (Lutra lutra) is present around Scotland with some areas hosting populations of international significance. Coastal otters, such as those likely to be found in Loch Roag, tend to be more active during the day, feeding on bottom-dwelling fish and crustaceans among the seaweed found on rocky inshore areas. An otter will occupy a home range extending along 4-5km of coastline, though these ranges may sometimes overlap (Scottish Natural Heritage website). Otters primarily forage within the 10m depth contour and feed on a variety of fish, crustaceans and shellfish (Paul Harvey, Shetland Sea Mammal Group, personal communication).

Otters leave faeces (also known as spraint) along the shoreline or along streams. Otters are known to occur in the rivers around Loch Roag, but at the time of writing no information had been successfully obtained regarding their populations. It is possibly that some of the faecal indicator organisms detected in the streams and rivers flowing into the loch will be of otter origin. The impact of this on the fisheries at Ceabhagh and Eilean Chearstaigh is not readily predictable but is expected to be insignificant.

Wildlife impacts to the fisheries in Loch Roag are likely to be very localised and unpredictable. While some wildlife species can harbour bacteria and viruses that can cause illness in humans, their faeces are considered to pose a lower risk to human health than either human or livestock faecal contamination. Deposition of faeces by wildlife in the area is likely to be widely distributed around the area and will not be considered in determination of sampling plans.

9. Meteorological data

The nearest weather station is for which wind and rainfall data is available is at Stornoway Airport, approximately 25 km to the west of the production area. It is likely that the weather patterns here are broadly similar but not identical to those on Loch Roag and surrounding land due to their proximity, but it is likely that there are some differences in the wind and rain received on any given day (Stornoway is on the east coast, Loch Roag is on the west coast). This section aims to describe the local rain and wind patterns and discuss how they may affect the bacterial quality of shellfish within Loch Roag.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and wastewater treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003).

Rainfall data was unavailable for 13 of 1464 days in 2003-2006 inclusive. Where the rainfall was recorded as 'Trace', this has been substituted for a value of 0.05 mm.

Figures 9.1 to 9.4 summarise the pattern of rainfall recorded at Stornoway. The box and whisker plots summarize the distribution of individual daily rainfall values (observations) by year (Figure 9.2) or by month (Figure 9.4). The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

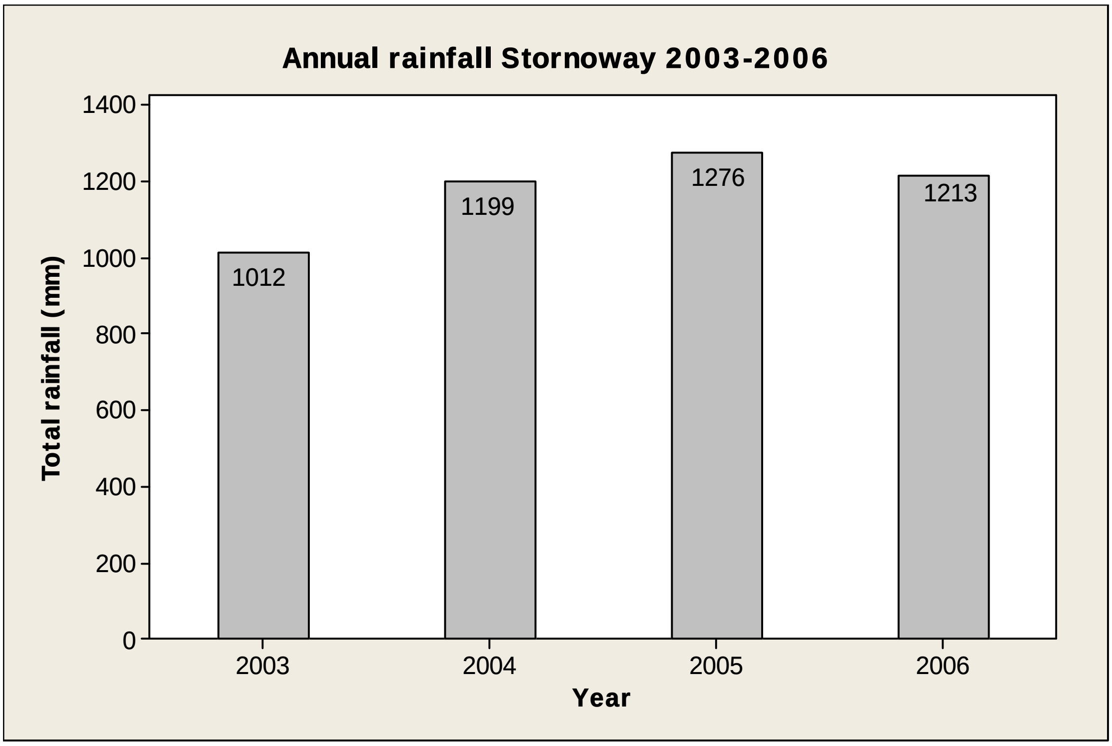


Figure 9.1 Stornoway total annual rainfall 2003 - 2006

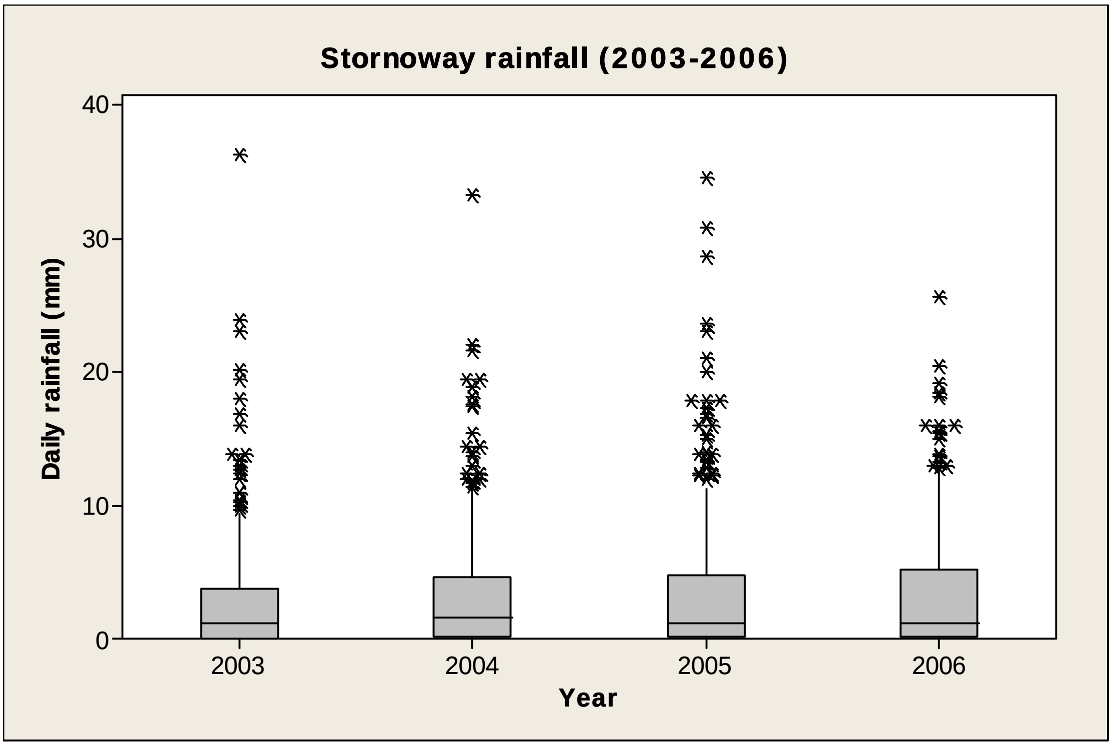


Figure 9.2 Boxplot of Stornoway daily rainfall by year 2003 - 2006

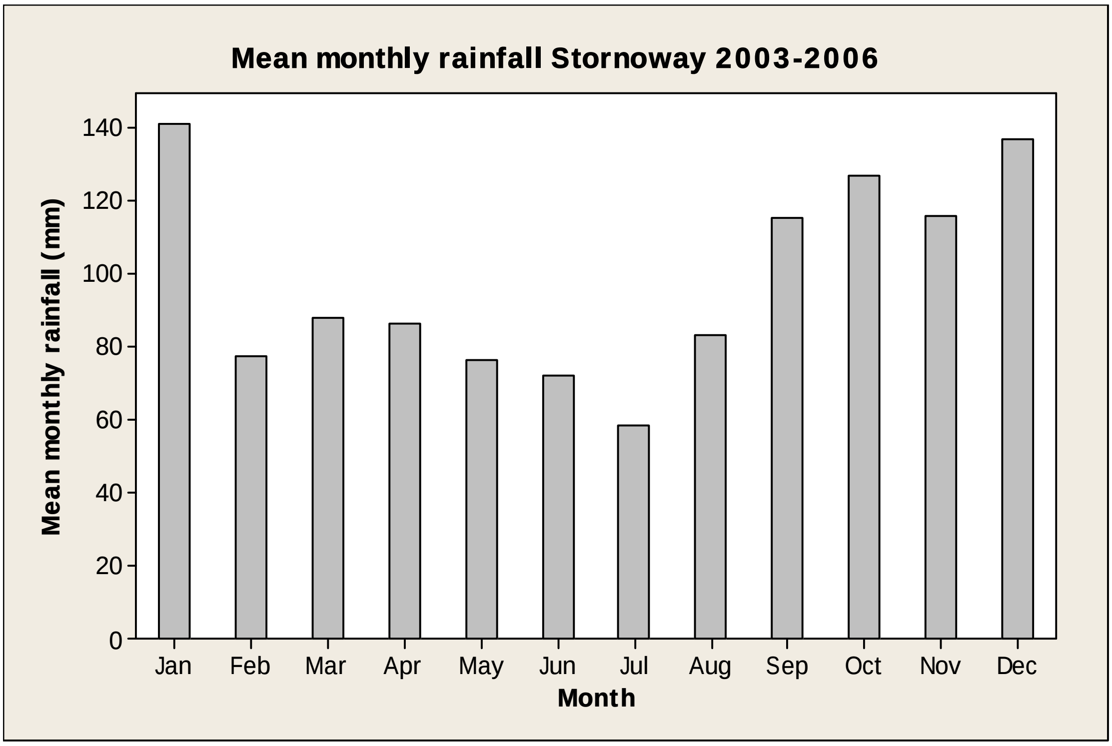


Figure 9.3 Stornoway mean monthly rainfall 2003 - 2006

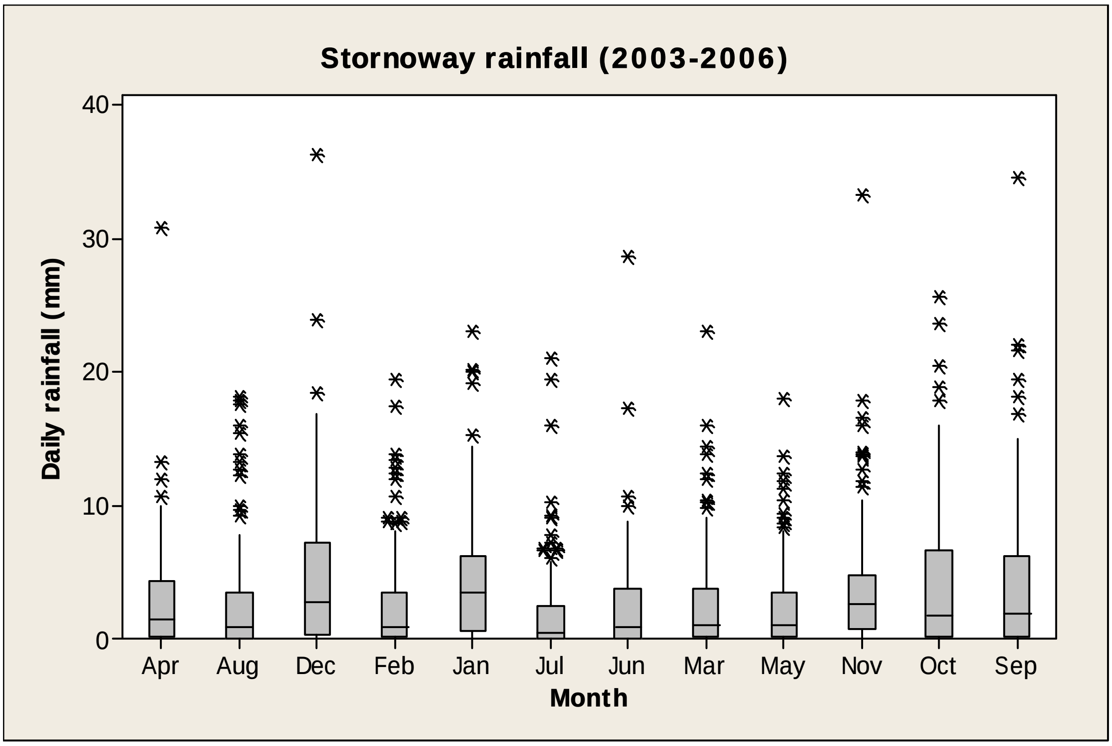


Figure 9.4 Boxplot of Stornoway daily rainfall by month 2003 - 2006

The wettest months were September, October, November, December and January. For the period considered here (2003-2006), only 9.9% of days experienced no rainfall. 12.6% of days received only a 'trace', and 46.9% of days experienced rainfall of 1mm or less.

A comparison of Stornoway rainfall data with Scotland average rainfall data for the period of 1970-2000 is presented in Table 9.1 (Data from Met office website © Crown copyright). This indicates that rainfall in Stornoway was lower than the average for the whole of Scotland for every month of the year, but there were fewer dry days in Stornoway during the autumn, winter and spring.

Table 9.1 Stornoway mean monthly rainfall vs Scottish average 1970-2000

Month	Scotland rainfall (mm)	Stornoway rainfall (mm)	Scotland - days of rainfall >= 1mm	Stornoway - days of rainfall >= 1mm
Jan	170.5	141.1	18.6	20.3
Feb	123.4	104.5	14.8	16.0
Mar	138.5	112.7	17.3	19.7
Apr	86.2	70.7	13	14.5
May	79	57.3	12.2	11.6
Jun	85.1	63.8	12.7	12.7
Jul	92.1	72.5	13.3	14.1
Aug	107.4	81.7	14.1	13.7
Sep	139.7	113.4	15.9	17.0
Oct	162.6	134.5	17.7	20.3
Nov	165.9	143.8	17.9	20.6
Dec	169.6	135.8	18.2	20.9
Whole year	1520.1	1231.7	185.8	201.4

It can therefore be expected that levels of rainfall dependant faecal contamination entering the production area from these sources will be higher during the autumn and winter months. As there are few dry days, it is likely that a steady flow contaminated of runoff from pastures is to be expected throughout the wetter months. It is possible that there is a build-up of faecal matter on pastures during the drier summer months when stock levels are at their highest which results in more significant faecal runoff in the autumn at the onset of the wetter months.

9.2 Wind

Wind data collected at the Stornoway weather station is summarised by season and presented in Figures 9.5 to 9.8.

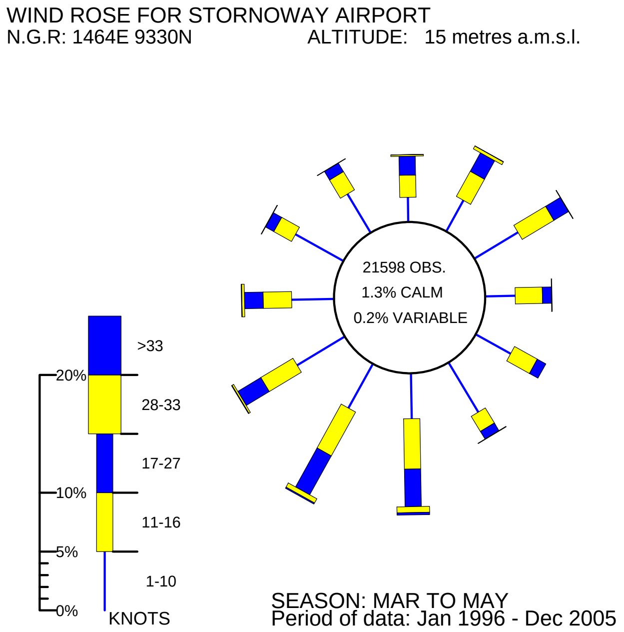


Figure 9.5 Wind rose for Stornoway March to May

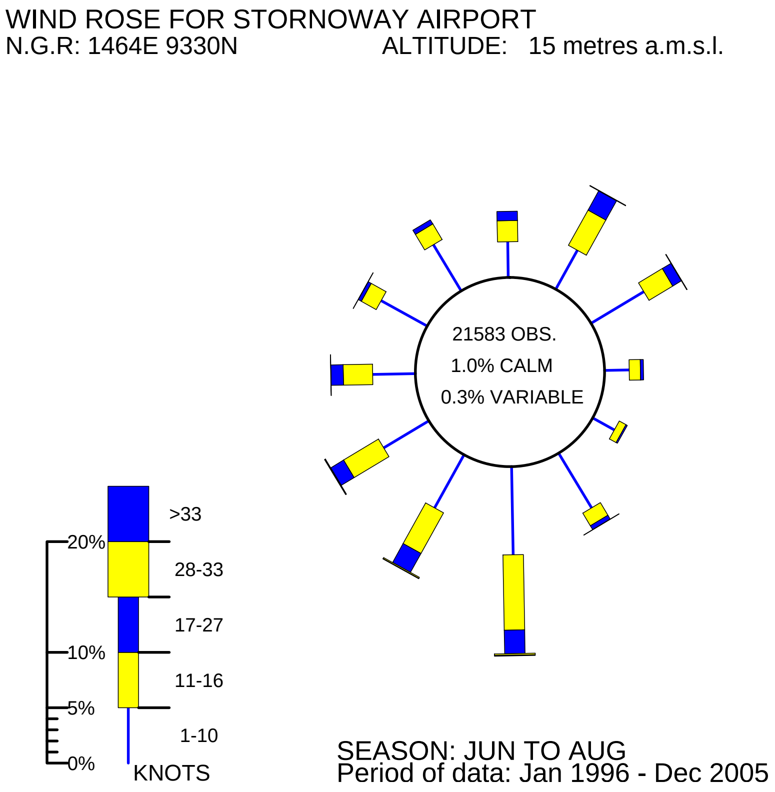


Figure 9.6 Wind rose for Stornoway June to August

WIND ROSE FOR STORNOWAY AIRPORT
N.G.R: 1464E 9330N ALTITUDE: 15 metres a.m.s.l.

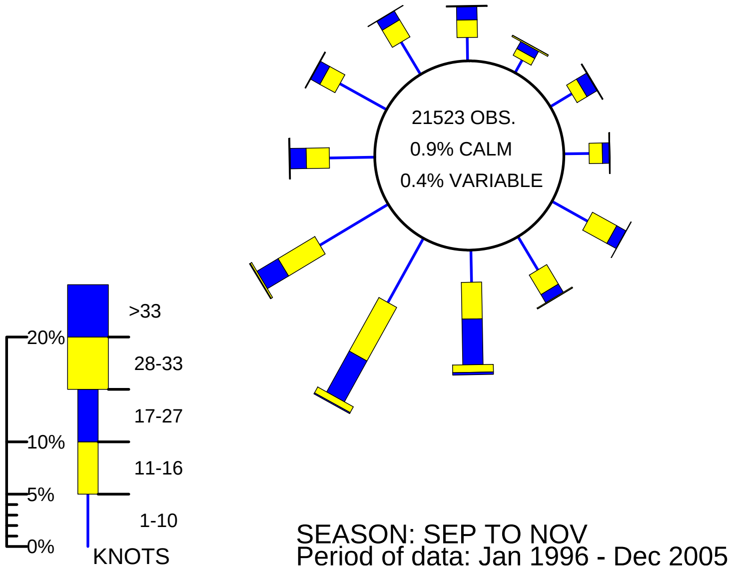


Figure 9.7 Wind rose for Stornoway September to November

WIND ROSE FOR STORNOWAY AIRPORT
N.G.R: 1464E 9330N ALTITUDE: 15 metres a.m.s.l.

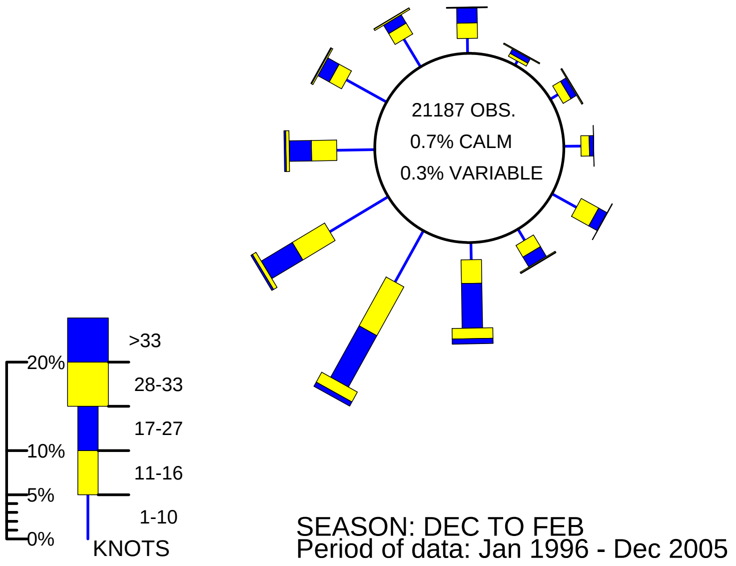


Figure 9.8 Wind rose for Stornoway December to February

Stornoway is one of the more windy areas of Scotland with a much higher frequency of gales than the country as a whole. The wind roses show that the overall prevailing direction of the wind is from the south and west, and the strongest winds come from this direction. Winds are generally lighter during the summer months and strongest in the winter.

Loch Roag as a whole faces the open Atlantic to the northwest. The Loch Roag: Eilean Chearstaigh production area and the nearby Ceabhagh site are totally sheltered from the open sea by the surrounding low hills and small islands. These will also give limited shelter from winds coming from all directions.

A strong north westerly wind combined with a spring tide may result in higher than usual tides which will carry accumulated faecal matter from livestock, above the normal high water mark, into the loch.

Although tidally driven circulation of water in the Loch is important, wind effects are likely to cause significant changes in water circulation. Winds typically drive surface water at about 3% of the wind speed (J. Aldridge, pers. comm.) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s in the direction of the wind. These surface water currents create return currents which may travel along the bottom or sides of the loch depending on bathymetry. Either way, strong winter winds will increase the circulation of water and hence dilution of contamination from point sources within the loch. The complex bathymetry and hydrodynamics of the loch will make the effects of winds combined with tides difficult to accurately predict, but there may be some instances where contamination from settlements may be carried more effectively to production sites by wind driven currents. An example may be a strong westerly wind carrying contamination from the settlement of Circebost towards the production site at Ceabhagh.

10. Current and historical classification status

The Loch Roag: Eilean Chearstaigh production area (LH 344) was first classified for production under this name with the existing boundaries in 2006. These boundaries encompass three production sites (Eilean Scarastaigh, Aerd Beag Lundale and Buckle Point). Only two of these, Eilean Scarastaigh and Buckle Point, are currently in use. There is a discrepancy in the designation of the Eilean Scarastaigh site as the actual location of the farm lies nearest the seabed lease for Aerd Baeg Lundale. To the north, the new Ceabhagh site currently lies in unclassified waters.

A map of the current production area is presented in Figure 10.1. The classification history is presented in Table 10.1. Currently, the area is classified as an 'A' throughout the entire year (2007/8).

Table 10.1 Classification history Loch Roag: Eilean Chearstaigh

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	A	A	A	A	A	B	B	A	A	A	A	A
2007	A	A	A	A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A

Of the 15 samples taken from the current reported RMP at Eilean Scarastaigh, only one exceeded 230 *E. coli* / 100g, a sample taken in March 2006 which returned a result of 310 *E. coli* / 100g, so what few results are available support the current classification.

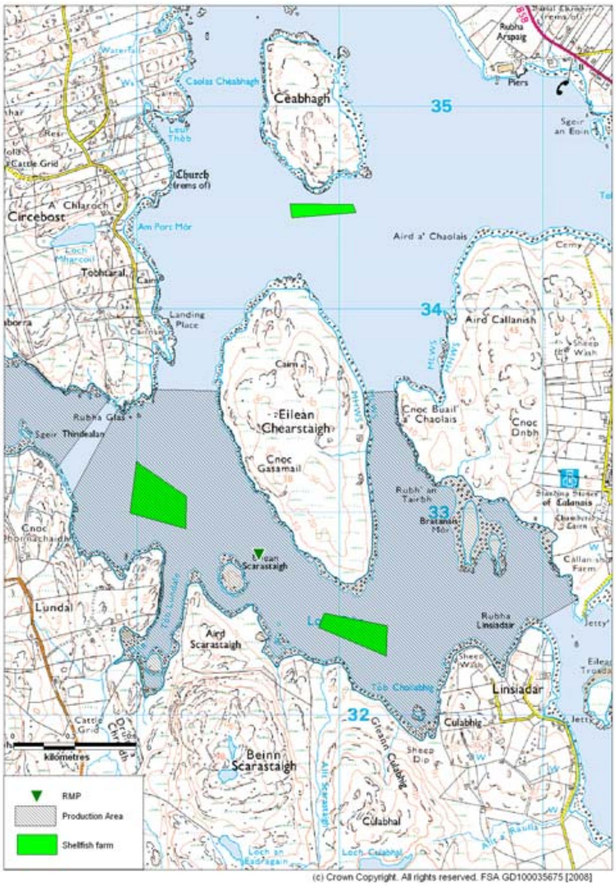


Figure 10.1 Current production area

11. Historical *E. coli* data

11.1 Validation of historical data

All samples were taken from Loch Roag: Eilean Chearstaigh up to the end of 2006 were extracted from the database and validated according to the criteria described in the standard operating procedure for validation of historical *E. coli* data. 8 samples were discarded from the analysis due to geographical discrepancies, and two samples were discarded as although they plotted within the production area, they were reported as coming from a different production area. In the three instances where the result was reported as <20, it was adjusted to 10. All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intervalvular fluid.

11.2 Summary of microbiological results by sites

Common mussels were sampled from 2 sites within the Loch Roag: Eilean Chearstaigh production area. At the Eilean Scarastaigh site all samples were collected from the RMP which falls within the production area and the crown estate lease area, though it does not fall within the actual farm boundaries as measured on the shoreline survey. At the Eilean Chearstaigh site all samples were collected from a point which falls within the production area and a crown estate lease. Only 3 samples were collected from here, and they were all collected in 1999, prior to the Loch Roag area boundaries and site numbering being changed to their present form.

Table 11.1 Summary of results from all sites within Loch Roag: Eilean Chearstaigh

Sampling summary			
Production area	Loch Roag: Eilean Chearstaigh	Loch Roag	Loch Roag: Eilean Chearstaigh
Site	Eilean Scarastaigh	Eilean Kearstay	All sites (2)
Species	Common mussels	Common mussels	Common mussels
SIN	LH 34469708	LH 18411508	LH 344 / LH 184
Location of RMP	NB196328	None at present	NB196328 and NB201324
Location sampled	NB196328	NB190330	All locations (2)
Total no of samples	15	3	18
n 1999	0	3	3
n 2000	0	0	0
n 2001	0	0	0
n 2002	0	0	0
n 2003	0	0	0
n 2004	0	0	0
n 2005	3	0	3
n 2006	12	0	12
Results Summary			
Minimum	<20	250	<20
Maximum	310	500	500
Median	110	-	120
Geometric mean	64.3	-	83.8
90 percentile	220	-	268
95 percentile	247	-	338.5
n exceeding 230/100g	1 (7%)	3 (100%)	4 (22%)
n exceeding 1000/100g	0 (0%)	0 (0%)	0 (0%)
n exceeding 4600/100g	0 (0%)	0 (0%)	0 (0%)
n exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)

Due to the small number of results, and the large amount of time between when the different sites were sampled, no statistical evaluation of differences in results between the two sites was undertaken.

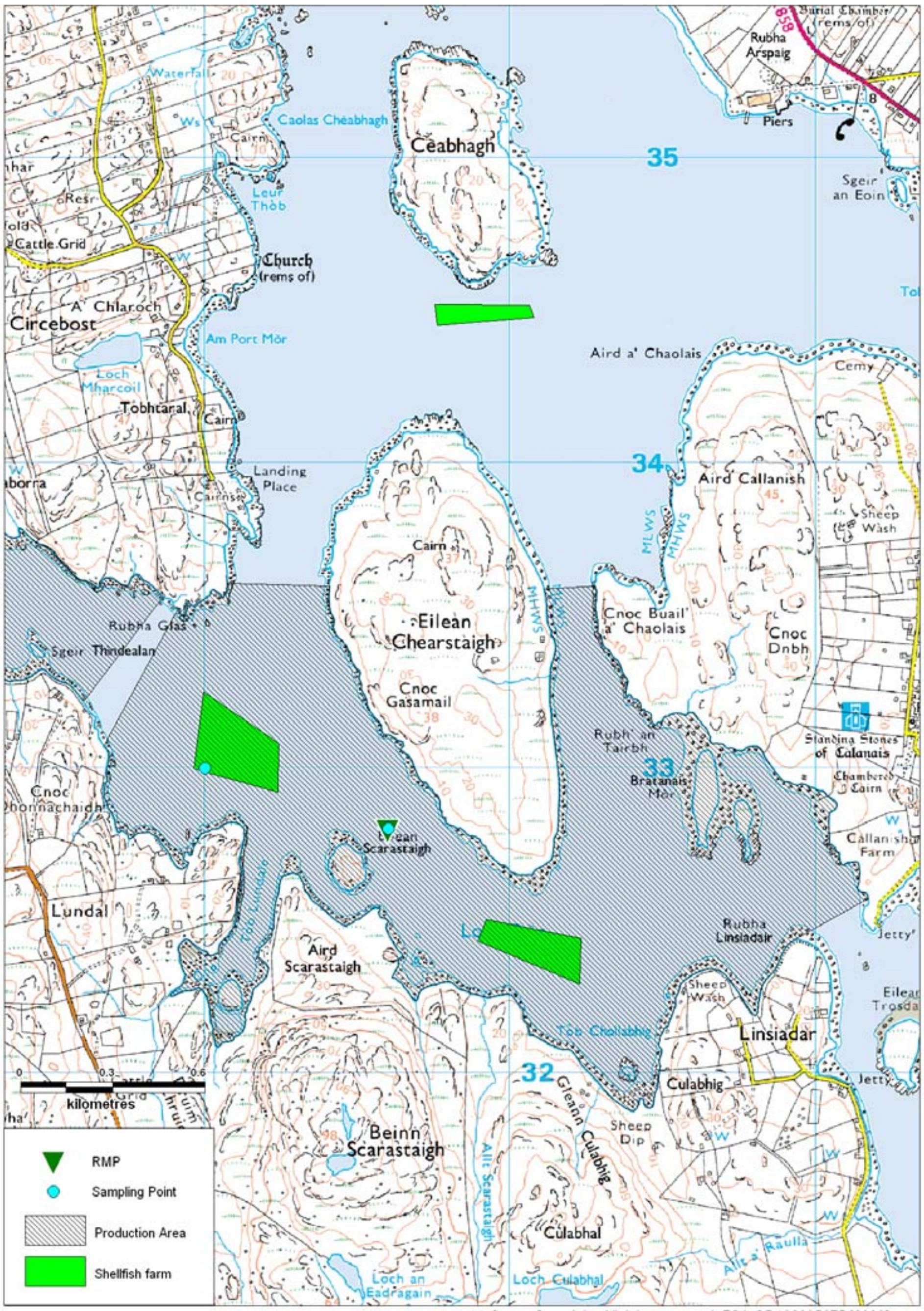


Figure 11.1 Location of sampling points

11.3 Temporal pattern of results

Figure 11.2 presents a scatter plot of individual results against date for all samples taken from within the Loch Roag: Eilean Chearstaigh boundaries.

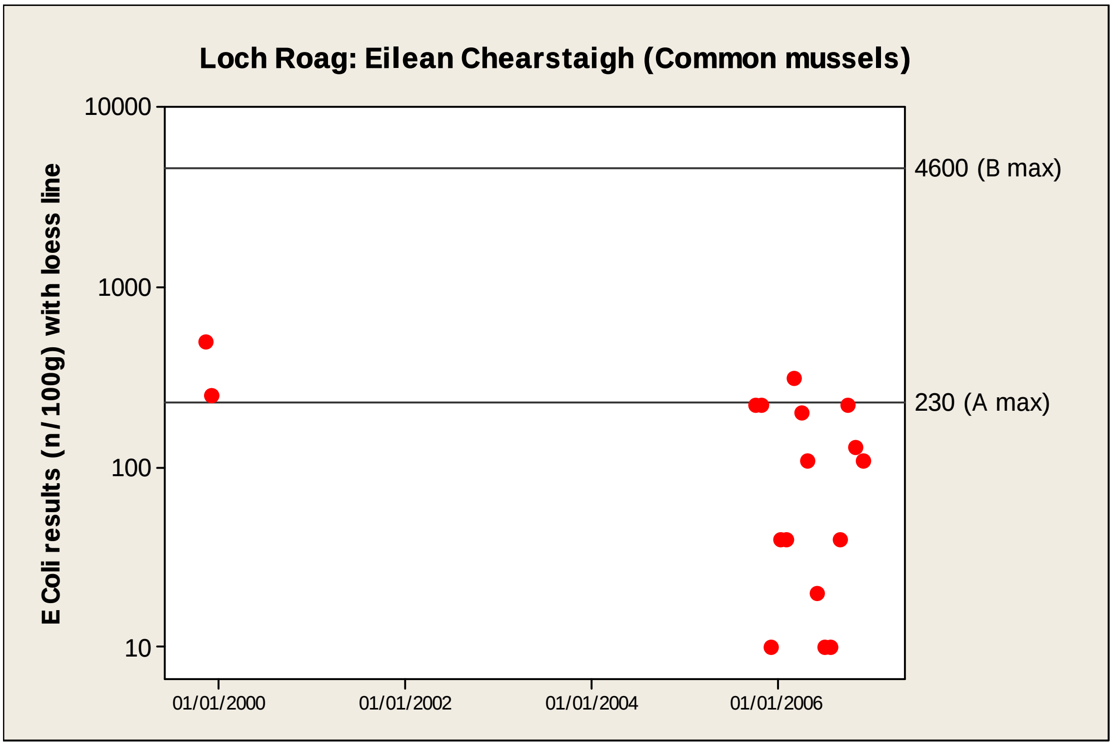


Figure 11.2 Scatterplot of results by date

No monitoring was undertaken between 2000 and late 2005 and there are insufficient results from which to discern a trend from Figure 11.2.

There are insufficient results to present mean result by month sampled, but a seasonal breakdown is presented in Figure 11.3. Results were significantly lower during the summer months (ANOVA, p=0.007), however this was based on a very limited data set comprising essentially one year and is not necessarily representative of what might be observed over a period of several years.

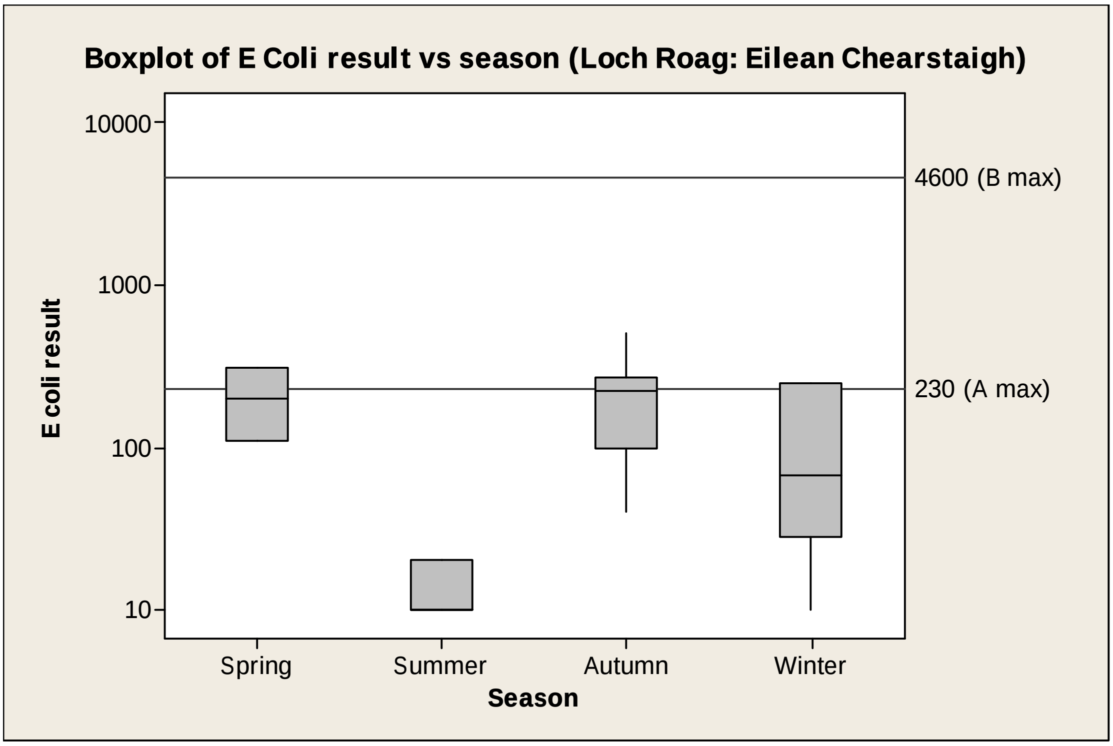


Figure 11.3 Boxplot of *E.coli* result vs season

11.4 Analysis of results against environmental factors

Environmental factors such as rainfall, tide state and size, winds, sunshine and temperatures can all influence the flux of faecal contamination into growing waters (e.g. Mallin et al, 2001; Lee & Morgan, 2003). The effects of these influences can be complex and difficult to interpret even with large datasets. In this case there is insufficient data available to undertake any meaningful analyses to investigate the relationship between environmental factors and sampling results.

12. Designated Shellfish Growing Waters Data

Neither Eilean Chearstaigh nor Ceabhagh lie within a designated shellfish growing water. However, there is a designated water beginning at Loch Barraglom, 1 km to the west of the Eilean Chearstaigh production area boundary. The monitoring point for this site is reported as NB16000 34000, and is located approximately 3.4 km west of the shellfish farm at Eilean Scarastaigh. The relative positions of the mussel farms, production area and shellfish growing water are illustrated in Figure 12.1.

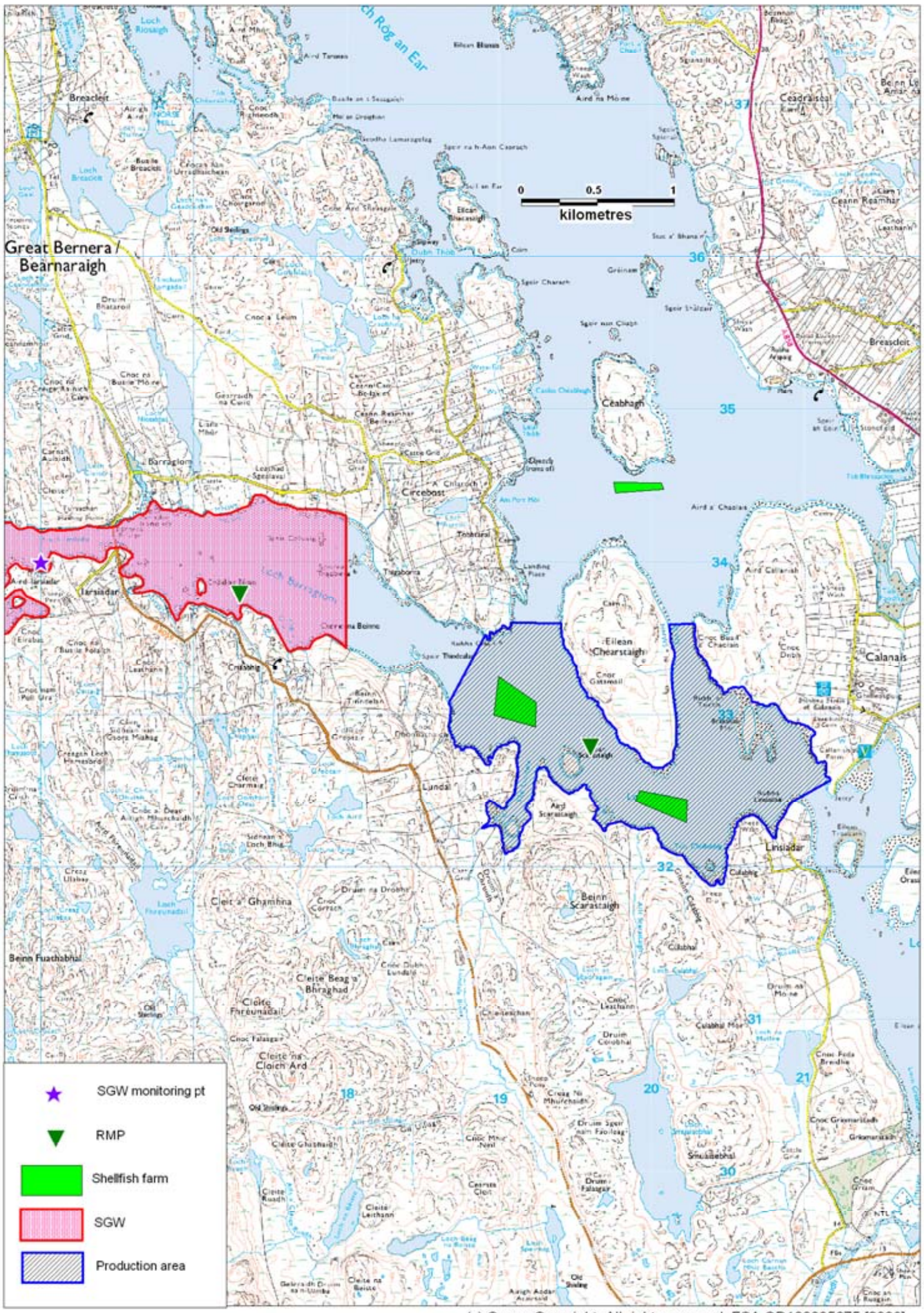


Figure 12.1 Designated shellfish growing water

The monitoring regime requires the following testing:

- Quarterly for salinity, dissolved oxygen, pH, temperature and visible oil
- Twice yearly for metals in water
- Annually for metals and organohalogens in mussels
- Quarterly for faecal coliforms in mussels

Due to the remote location, SEPA were not able to implement a full and compliant sampling regime until 2003. Quarterly faecal coliform monitoring has been undertaken since 2003. Faecal coliform results follow in the table below.

Table 12.1 SEPA faecal coliform results (FC/100g)

	Site	Loch Roag	Loch Roag
	OS Grid Ref.	NB 148 335	NB 16000 34000
2003	Q1	20	-
	Q2	-	-
	Q3	-	200
	Q4	-	110
2004	Q1	-	20
	Q2	-	40
	Q3	-	290
	Q4	-	70
2005	Q1	-	<20*
	Q2	-	<20*
	Q3	-	18000
	Q4	-	50
2006	Q1	-	20
	Q2	-	<20*
	Q3	-	<20*
	Q4	-	750
2007	Q1	-	20
	Q2	-	
	Q3	-	
	Q4	-	

* Assigned a nominal value of 10 for calculation of geometric mean.

All but one sample was collected from a location just to the west of the bridge between Great Bearnaraigh and Iarsiadar. The geometric mean result of all samples was 59 FC/100 g with results ranging from <20 to 18000. Results were generally well below guideline levels, though 2 out of 16 results (12.5%) were above 300 FC/100 g. All results over 100 FC/100 g were confined to Q3 or Q4, which seems to fit in with seasonal contamination patterns observed in other Scottish mussel production areas, though with such a limited number of samples is difficult to draw firm conclusions.

Levels of faecal coliforms are usually closely correlated to levels of *E. coli*, often at a ratio of approximately 1:1. The ratio depends upon a number of factors such as environmental conditions and the source of contamination. As a consequence, the results in Table 12.1 are not directly comparable with other shellfish testing results presented in this report.

13. Bathymetry and Hydrodynamics

This site was chosen for a full hydrodynamic modelling study using the Hydrotrack model described in the Hydrography Methods Document. This document can be consulted for background information on the model and the methods applied. The area of interest is shown in Figure 13.1.

13.1 Physical Characteristics

Primary data comes from Spurway (2001). The loch is approximately 16.78 km long and covers an area of 36.6 km^2. Average depth is 20.0 m with a maximum depth of 30 m at the entrance. The total volume of East Loch Roag is 7.39 x 10^8 m^3. The loch is connected to West Loch Roag via a narrow strait at Earshader. The maximum cross-sectional area of this strait is ~1295 m^3, allowing a maximum of 0.1% of the combined tidal flux into both East and West Loch Roag to be exchanged between the two lochs. The two basins can therefore be considered as hydrographically separate (Tyrer and Bass, 2005). The loch is further characterised by a series of islands inside the loch, including Keava, Eilean Kearstay and Oresay, creating a complex geometry with sills and fast-flowing straits. The southern end of East Loch Roag is formed by Loch Ceann Hulavig, a sub-basin with a narrow connection to the main Loch at Callanish. Further to the south the system of Langavat is found, which drains through the Grimersta river into Loch Ceann Hulavig.

Measurements by SEPA in 2001 are presented in Spurway (2001), and include temperature and salinity measurements along 5 stations on the main axis of East Loch Roag. The study cautiously concludes that the waters of Loch Roag are well mixed and not subject to vertical stratification (only small temperature and salinity differences were found between surface and bottom waters). Nevertheless, a fresh water influence is clear in the shallow sub-basin of Loch Ceann Hulavig, due to the large influx of water from the Grimersta river and Langavat system.

<u>Tides</u>

Spring tidal range is given as 3.8m at Little Bernera, with neap tidal range at 2.5m (Admiralty Chart). Admiralty Chart information gives peak tidal velocities in the straits as 0.75 knots (~0.4 ms^{-1}) between Great Bernera and Keava, during both ebb and flood; 1.5 knots (0.75 ms^{-1}) between Great Bernera and Eilean Kearstay, during flood and 0.8/0.75 knots (0.4 ms^{-1}) between Eilean Kearstay and Callanish, during flood/ebb.

<u>Wind driven flows</u>

Wind statistics measured at Tiree (Figure 13.2) were judged to be representative of the wind speed and directions experienced at East Loch Roag. The annual average shows a relatively uniform distribution with respect to winds having a westerly component and doesn't show the clear predominance of south-westerly winds seen at other stations. The proportion of time winds blow from the east and northeast is significantly less than for other directions. The significant proportion of time that south-easterly winds occur could be of influence on East Loch Roag, as this direction aligns with the main axis of the loch.

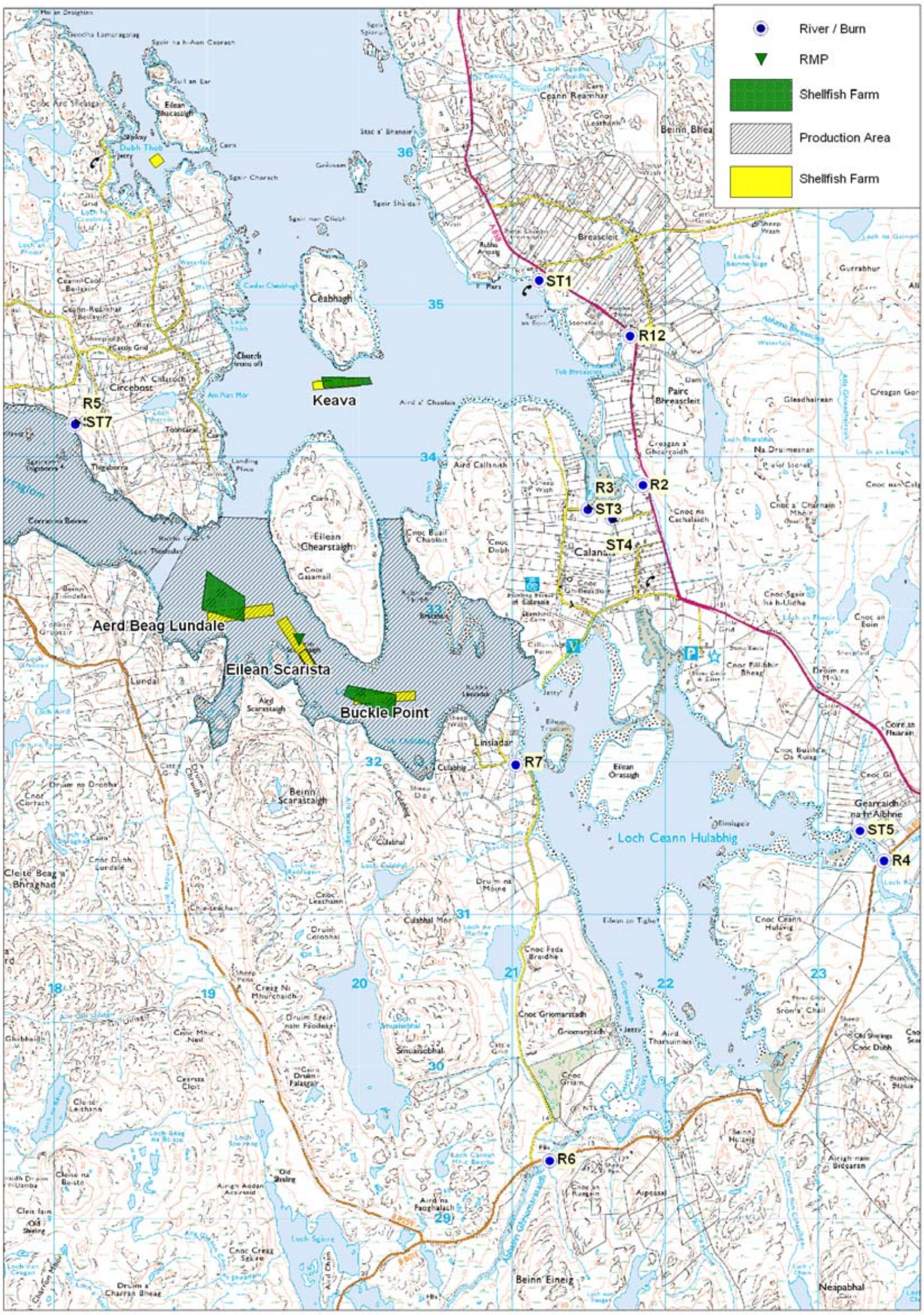


Figure 13.1: East Loch Roag contamination sources as identified by the shoreline survey and the production areas.

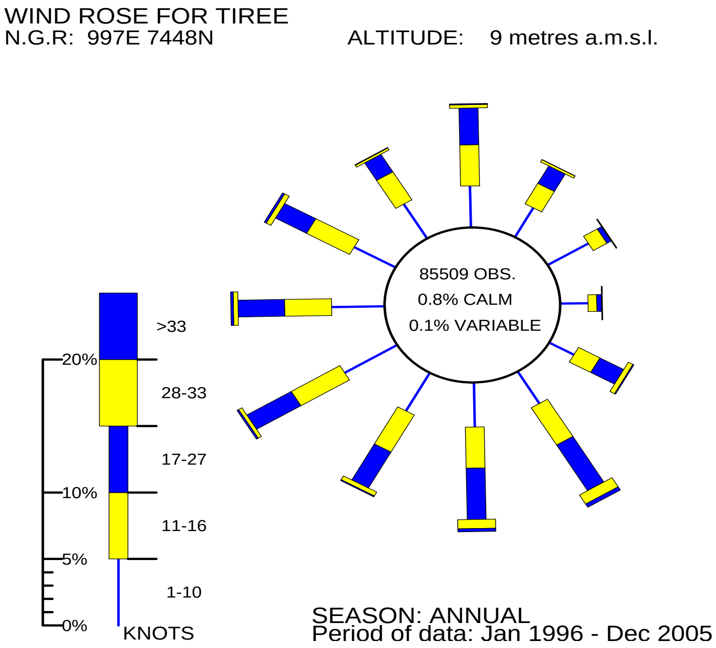


Figure 13.2: Annual wind rose for Tiree.

Density driven flows

Over the entire loch freshwater inputs are estimated to be small compared to tidal inputs. The shoreline survey revealed 7 rivers entering the loch (see Figure 13.1) in to the modelled area (depicted in Figure 13.3), of which the largest are the Breasclete, Abhainn Dhubh and Grimersta rivers (daily flow > 1000 m^3/day). The Abhainn Dhubh and Grimersta rivers discharge into the shallow basin of Loch Ceann Hulavig, and are therefore expected to have a high local impact (possible saline stratification, causing surface flows) but a minor overall impact, as this basin has a restricted exchange with the main loch and the rivers are not located near the connecting strait. The Breasclete river discharges into the main loch, but is considerable smaller than the other two. Measurements reported in Spurway (2001) show limited influence of fresh water in East Loch Roag proper, with increasing influence in Loch Ceann Hulavig although waters appear to be well mixed inside the basin.

Protected areas

The East Loch Roag area comprises two designated Special Area of Conservation sites: SAC UK 0017074 (Tob Valasay and Loch Shader, East Loch Roag, just north of modelled area on the eastern side of East Loch Roag) and SAC UK 0030255 (Langavat, East Loch Roag, discharges into modelled area via Grimersta river). The Langavat area is a protected site due to its stocks of wild Atlantic salmon (Salmo salar), who travel through East Loch Roag en route to their natal waters.

Related studies

The Loch Roag area has been the subject of a few studies regarding commercial mariculture operations. Spurway (2001) applied a box model to Loch Roag to study the modifications in dissolved available inorganic nitrogen due to fish farms activities. The study concludes that the then consented biomass was unlikely to cause hypernutrification (excess of nutrients) in the loch. Tyrer and Bass (2005) report on the Site Optimisation Plan for salmon farming in Loch Roag, following the Strategic Framework for Scottish Aquaculture. They also report on marine farm nutrient discharges, which they consider to be well within the carrying capacity of the loch.

13.2 Model study

Set-up

The area covered by the model is shown in Figure 13.3 and represents approximately the lower half of East Loch Roag proper and the southward-connected basin of Loch Ceann Hulavig. The resolution of the model (the grid spacing) was 50m and variations in currents down to this lengthscale can be represented. A single semi-diurnal (12.4 hour period) tidal flow was applied to the open boundaries in the north (connection to the Atlantic, maximum values of 10 cm./s) and west (inside Loch Barraglom, which forms the connection to West Loch Roag, maximum values of 5 cm/s). This resulted in tidal amplitudes of approximately 2.7 metres at both locations. The open boundary inside Loch Barraglom was used to represent the flow inside this loch better, as the strait at Earshader lies outside the model domain. Experiments with a closed boundary here were also performed, but showed very similar results. Water inputs from the 3 largest rivers identified during the shoreline survey were included: the Breasclete (R1), the Abhainn Dhubh (R4) and the Grimersta (R6).

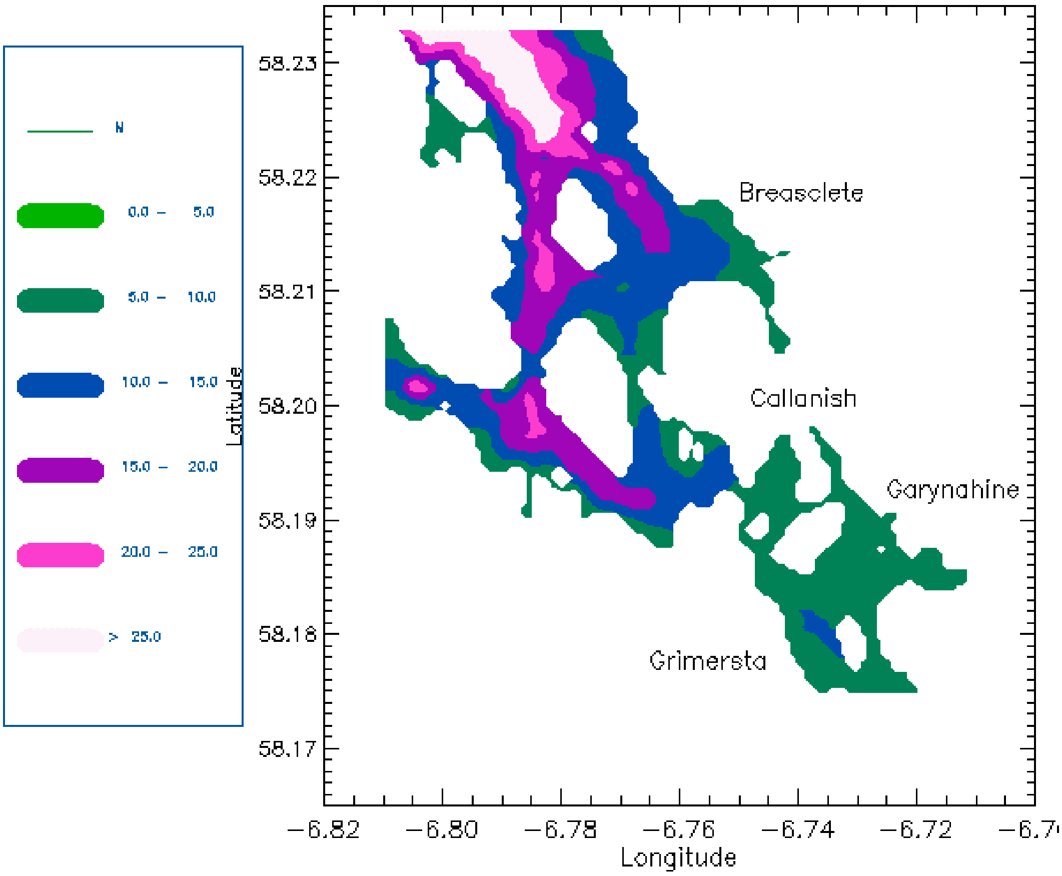


Figure 13.3: Model domain with depths (m). With permission SeaZone Ltd.(put points to show actual locations)

In addition to the tidal and river forcing, the model response to constant winds blowing from the north, south, east and west directions at a speed of 5 m/s (gentle to moderate breeze) was calculated. The effect of the surrounding topography is likely to cause alignment of winds along the axis of the loch and so south-easterly and north-westerly winds were also simulated. In all scenarios, the forcing was applied for 4 tidal cycles (49 hours and 36 minutes) so that a constant (equilibrium) wind driven current pattern was attained. Particles were released into the combined tidal and wind generated currents from locations identified as potential sources during the shoreline survey. Particles were released at hourly intervals during a complete tidal cycle and were then followed for 2 days.

Limitations of using a depth-integrated model are discussed in the hydrography methods document. These concern the inability of the model to describe the vertical structure within the water column and will affect the modelling of wind and density driven flows in particular. In the case of East Loch Roag, this limitation is deemed to be mainly important in the sub-basin of Loch Ceann Hulavig. Measurements reported in Spurway (2001) indicate the freshwater inputs forming a less dense surface layer a few metres thick near the entrance while the interior of the shallow basin is characterised by mixed, less saline waters. The present model includes riverine inflow but assumes the incoming flow has the same salinity as the marine waters and that it is mixed over the entire depth. Thus, surface flows are not reproduced in the model, but these are expected to be of minor importance due to the shallow nature of Loch Ceann Hulavig (causing the water column to be mixed in a large part of the basin) and the distance of the three major rivers discharging into the modelled area to the production sites. Nevertheless, surface flows are likely to carry the majority of a bacterial load, so that the present model results may not give a good indication of the movement of contaminants within the Loch Ceann Hulavig basin.

<u>Results</u>

Apart from flows through the various narrow straits, modelled tidal currents (both residual and principle) were found to be weak. Peak tidal current values in the straits calculated by the model were 0.35 m/s (Great Bernera-Keava), 0.68 m/s (Great Bernera-Eilean Kearstay) and 0.52 m/s (Eilean Kearstay-Callanish). This corresponds reasonably well to peak currents indicated on the Admiralty Chart of 0.385 m/s (0.75 knots), 0.77 m/s (1.5 knots) and 0.41 m/s (0.8 knots) respectively.

Typical residual (time-independent) current speeds from the model were 5 cm/s or less. However, much larger velocities were found in the narrow straits, with peak residual currents up to 15 cm/s in the strait between Linshader and Callanish for example.

The shoreline survey indicated potential point sources of contamination within the lower reaches of East Loch Roag associated with the settlements of Breasclete, Callanish and Garynahine, as well as some on the north side of Loch Barraglom on Great Bernera. The main sources of contamination in the vicinity of the production areas south of Eilean Kearstay and Great Bernera are the rivers at Linshader (R7) and Great Bernera (R5) and the septic tanks at Great Bernera (ST6, ST7). All identified sources (shown in Figure 13.1) were included in the particle tracking analysis.

The bay at Breasclete contains several contaminant sources and is characterised by a residual current eddy filling the bay (see Figure 13.5 for the residual current field under the different forcings). This gyre keeps particles released at ST2, R1 and the sources inside the shallow estuary northwards of Callanish (ST3, ST4, R3, R4) trapped inside the bay for the modelled period of 2 days (see Figures 13.4 b,c). Note that the particles from sources on Callanish were released well inside Breasclete Bay in a worst case scenario: experiments with particles released inside the estuary showed that these particles did not leave the estuary. Particles released at ST1 can under north and east winds leave the gyre and reach the northwest side of the headland of Callanish (see Figure 13.4a). This would allow further travel southwards towards the production area south of Eilean Kearstay, but the process would take several days.

Similar behaviour (circulation within a residual gyre) was found for particles released inside Loch Barraglom (R5, ST6, ST7, see Figure 13.4 g), irrespective of whether an open or closed boundary was used. The particles showed southward motion coinciding with the underlying residual flow field in the loch. However, we have less confidence in the results for this source as the boundary will have a large influence on the modelled results, due to its close proximity to the release point. These sources are located inside a production area.

Particles released at the other three locations (all inside loch Ceann Hulavig) showed considerable movement (Figures 13.4 d,e,f). The residual current appears to confine particles released near the Abhainn Dhubh river (ST5, R4) to the bay in which the river discharges. However, particles released at the sources R6 and R7 show the ability to leave the loch Ceann Hulavig basin and reach East Loch Roag proper, accumulating on the southwest side of the Callanish headland. Details of the residual circulation around the strait at Linshader (Figure 13.6), show a residual eddy to the southwest of the Callanish headland causing all particles which leave loch Ceann Hulavig to gather in this small bay. Note that the release point of particles for source R7 was chosen to be in front of the Linshader strait, thus representing a worst case scenario. Release of particles at the original location (between Linshader and the small island) gave similar spatial results under all forcing conditions (tides only and all wind directions) as those presented in Figure 13.4f.

Experiments including lower peak currents were found to be more responsive to wind driven flows, and exhibited particles released from Grimersta river (R6) travelling into East Loch Roag proper under forcing with south-easterly winds (again, travelling to the bay southwest of Callanish). Particles released from source R7 in front of the strait at Callanish showed similar behaviour in these experiments to those presented in Figure 13.4f, i.e. travel in the northward direction once inside East Loch Roag.

13.3 Discussion

Riverine input into the model was based on flow rates observed during the shoreline survey that may not be representative of conditions more generally. Also, the model results only represent the depth averaged effect of river inputs. As discussed above the freshwater inputs in reality are confined to a surface layer. It is difficult to know how this will modify the results. From general principals it might be expected that flows from the rivers Grimersta and Abhainn Dhubh at the southern end of Loch Ceann Hulavig will mainly move within this sub-basin. Nevertheless, the Grimersta river has already been identified as a possible source of contamination for the production areas.

It should also be emphasised that the wind driven flows are set up as a consequence of persistent winds from a given direction. At any particular time winds will vary dynamically in strength and direction and so the results shown correspond to an idealised situation. For this reason the possibility cannot be excluded that particles released at R6 and R7 will impact on the production site Buckle Point, entering the production site from the northeast. Particles released at R6 and R7 have been shown to enter East Loch proper south of the Callanish headland, and model results shown in Figure 13.6 indicate a westward circulation in the area west of the Linshader strait, which could potentially transport contaminants to the production site.

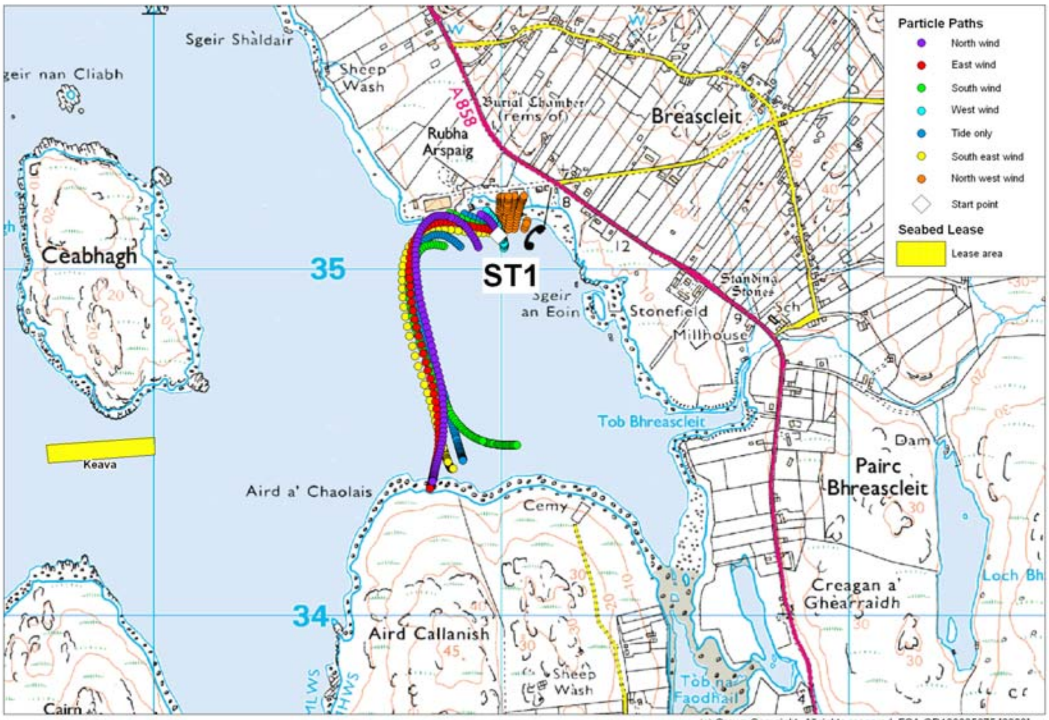


Figure 13.4 a: particles paths of particles released at sources ST1. Particles released at every hour and under different wind directions (no wind, north, east, south, west, northwest and southeast winds).

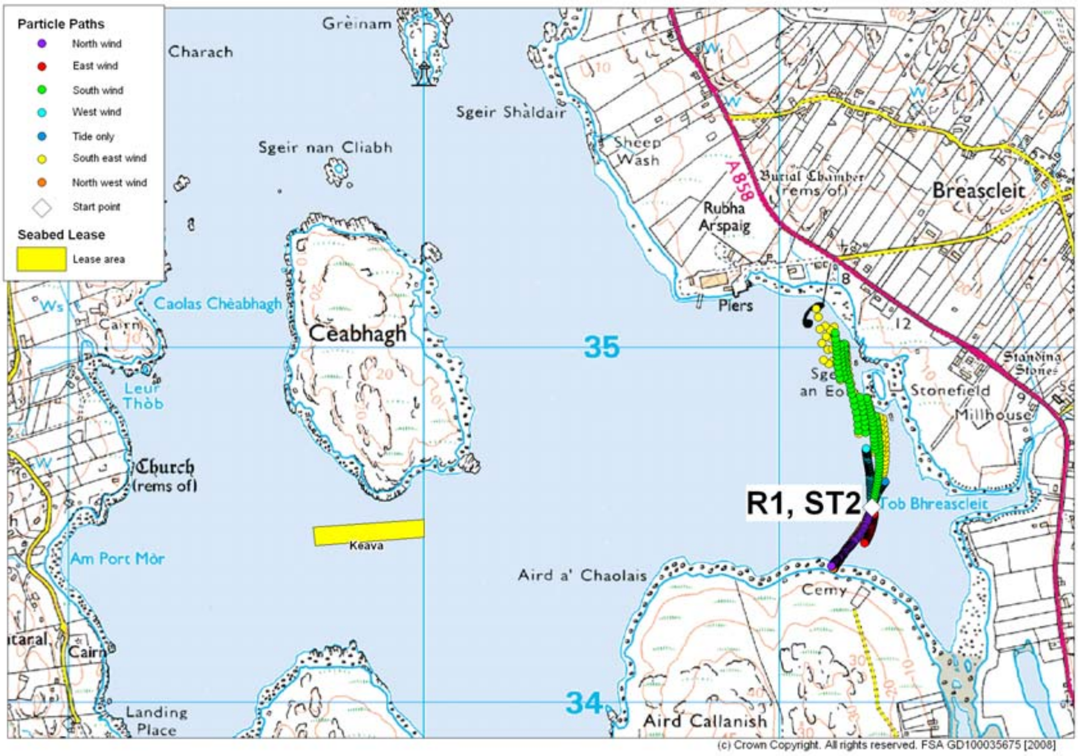


Figure 13.4 b: particles paths of particles released at sources ST2 and R1. Particles released at every hour and under different wind directions (no wind, north, east, south, west, northwest and southeast winds).

Figure 13.4 c: particles paths of particles released at sources ST3, ST4 and R2, R3. Particles released at every hour and under different wind directions (no wind, north, east, south, west, northwest and southeast winds).

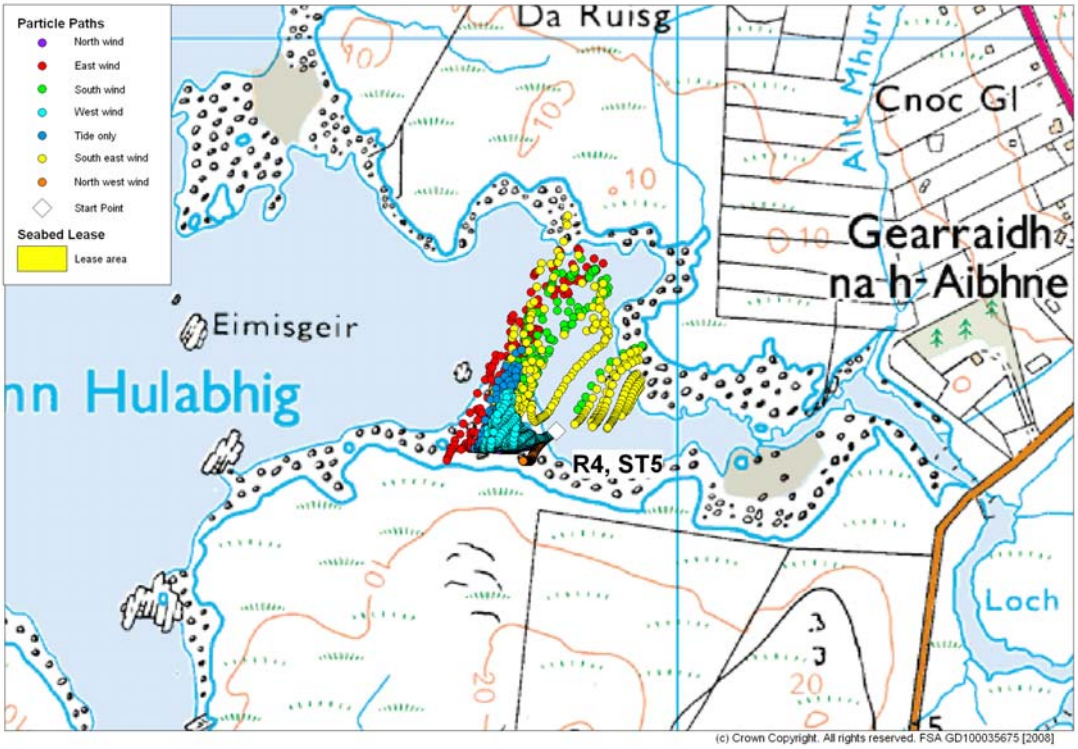


Figure 13.4 d: particles paths of particles released at sources ST5 and R4. Particles released at every hour and under different wind directions (no wind, north, east, south, west, northwest and southeast winds).

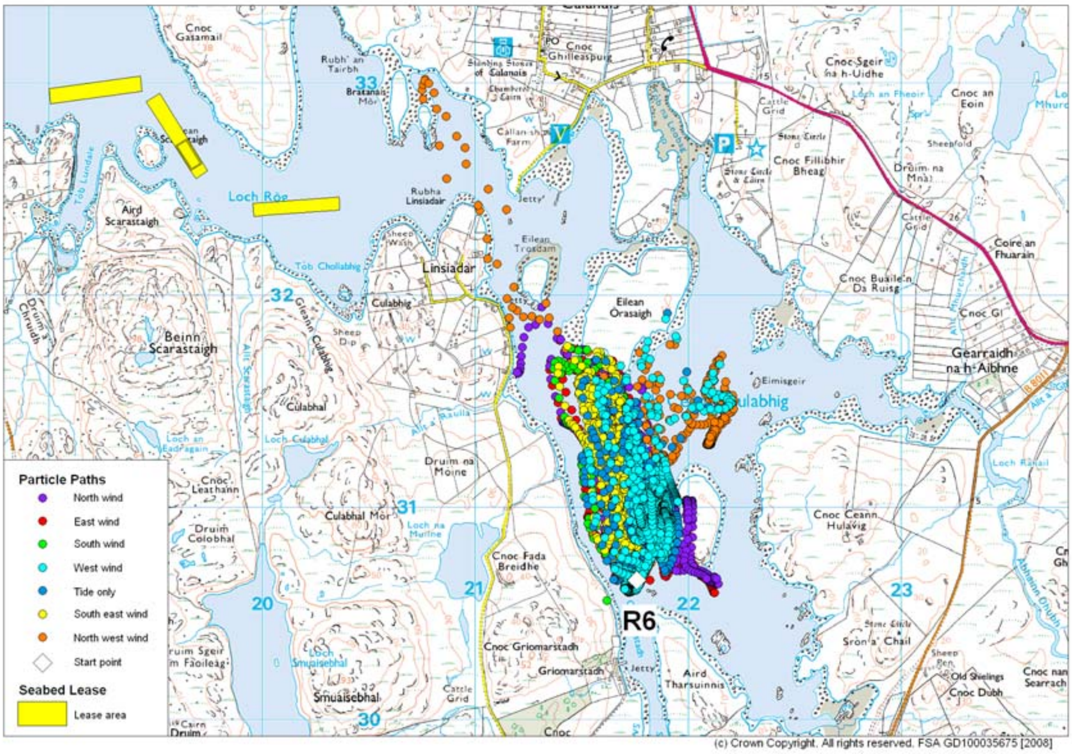


Figure 13.4 e: particles paths of particles released at source R6 (Grimersta river). Particles released at every hour and under different wind directions (no wind, north, east, south, west, northwest and southeast winds).

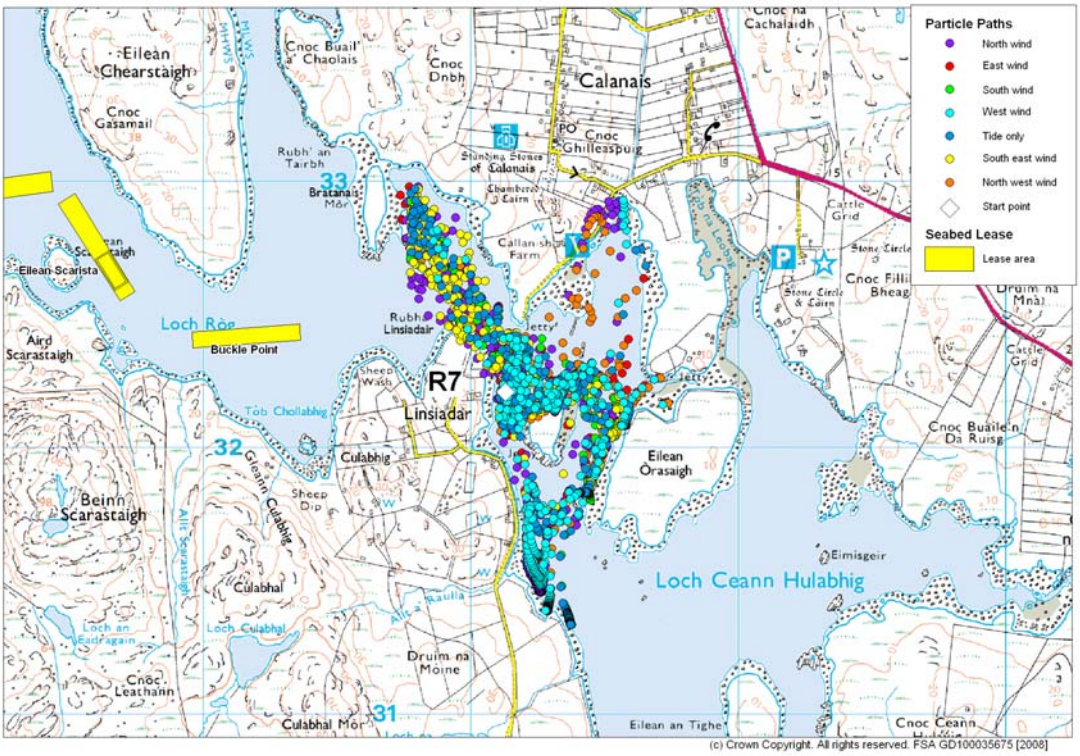


Figure 13.4 f: particles paths of particles released at source R7. Particles released at every hour and under different wind directions (no wind, north, east, south, west, northwest and southeast winds).

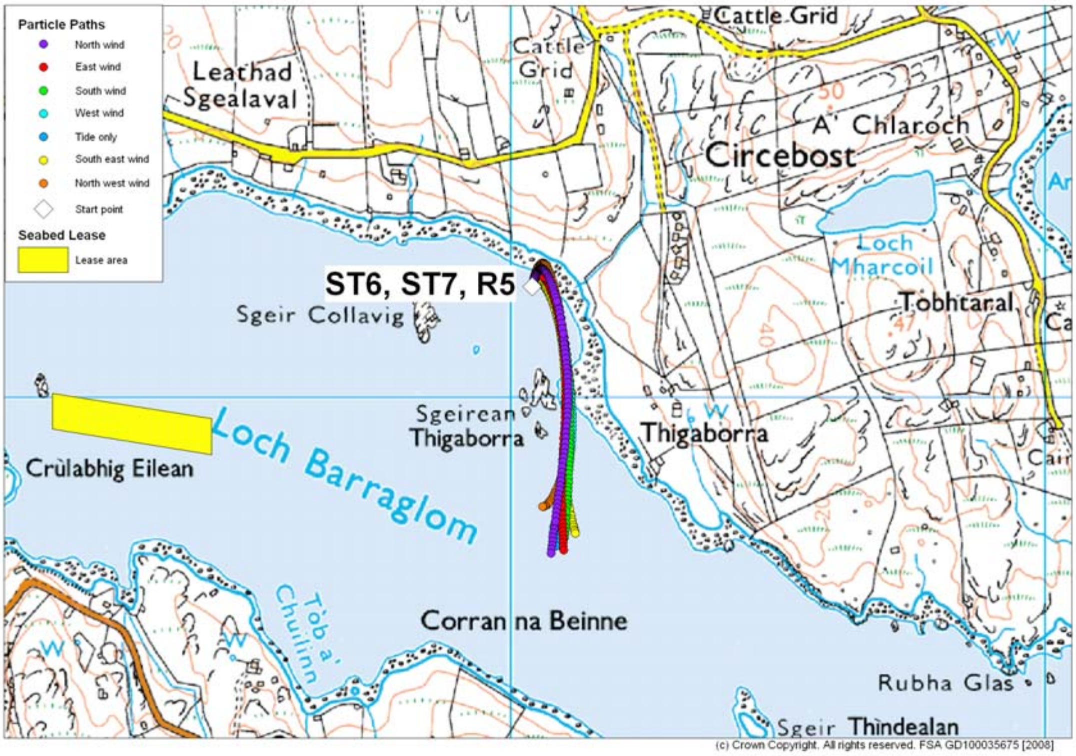


Figure 13.4 g: particles paths of particles released at sources ST6, ST7 and R5. Particles released at every hour and under different wind directions (no wind, north, east, south, west, northwest and southeast winds).

Experiments with different release locations of the particles (results not shown) indicated that contamination from the source ST1 could potentially reach the production area east and south of Eilean Kearstay if released into the main channel between Keava and Breasclete Bay. Transport of particles outside of Breasclete Bay is possible under certain wind directions (see Figure 13.5), e.g. under south winds. Under changing conditions particles from ST1 could impact on the production site Buckle Point from the northeast side.

13.4 Summary

Particle pathways can be complex due to the complex geography and bathymetry of East Loch Roag. Transport distances due to tides vary with source, but can be up to 1 km. Basin exchange of particles (between Loch Ceann Hulavig and East Loch Roag) is possible under all wind forcing conditions as well as with tides alone. Wind generated currents have an important influence as they can significantly enhance this exchange of particles when the wind direction aligns with the orientation of the loch (north-westerly or south-easterly).

It is concluded that particles released from sources ST6, ST7, R5, R6 and R7 (Great Bernera, Grimersta and Linshader sources) impact on existing production areas. Particles released from other sources are confined to their local regions as the particles get trapped in local circular gyres. Impact on existing production sites was not found in these experiments, but cannot always be excluded for the production site Buckle Point (see the discussion section above).

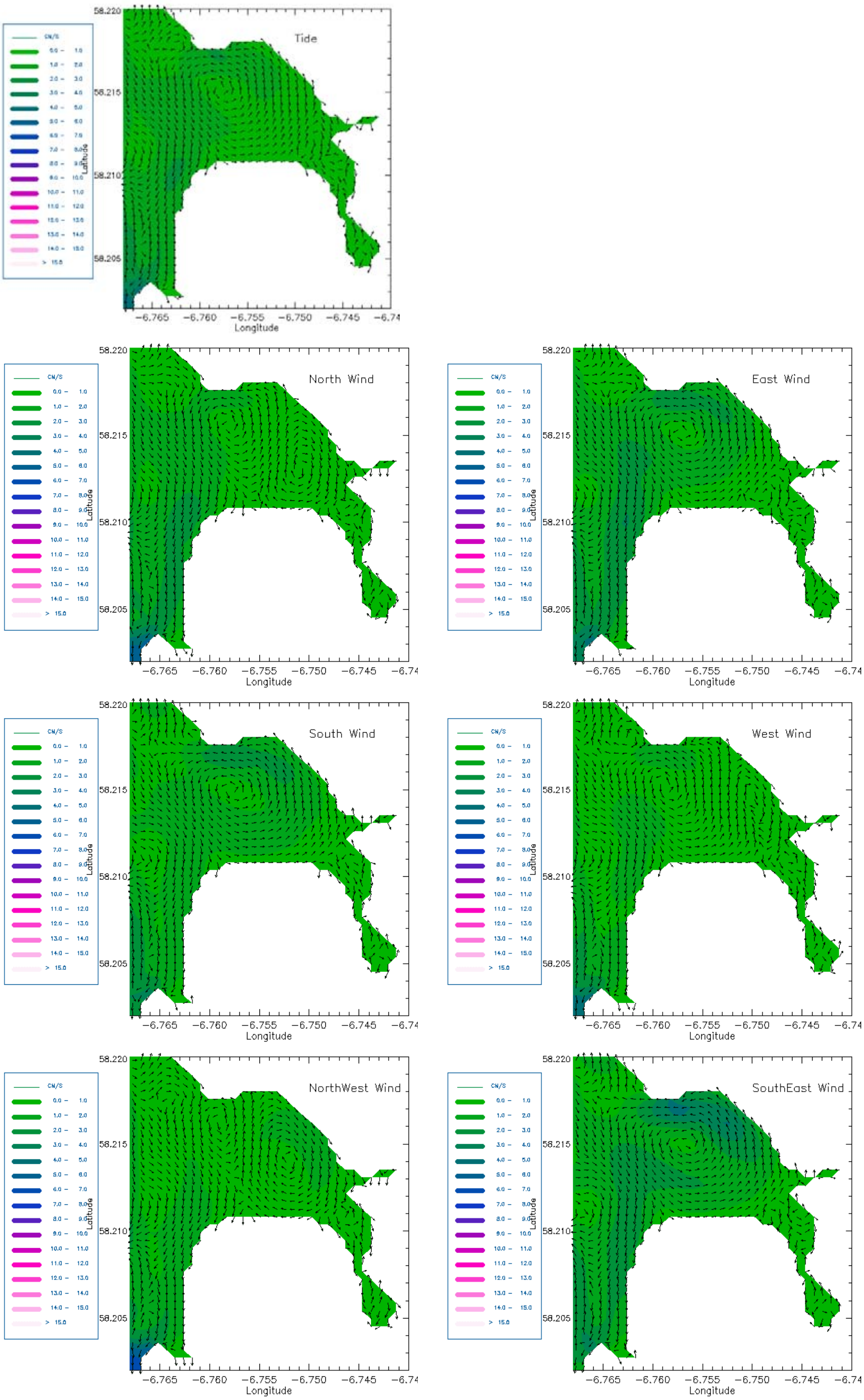


Figure 13.5: Residual currents in Breasclete Bay for tidal forcing only and with imposed wind directions. Colour distribution indicates residual current speed and arrows give the direction. Arrows plotted at every model grid point.

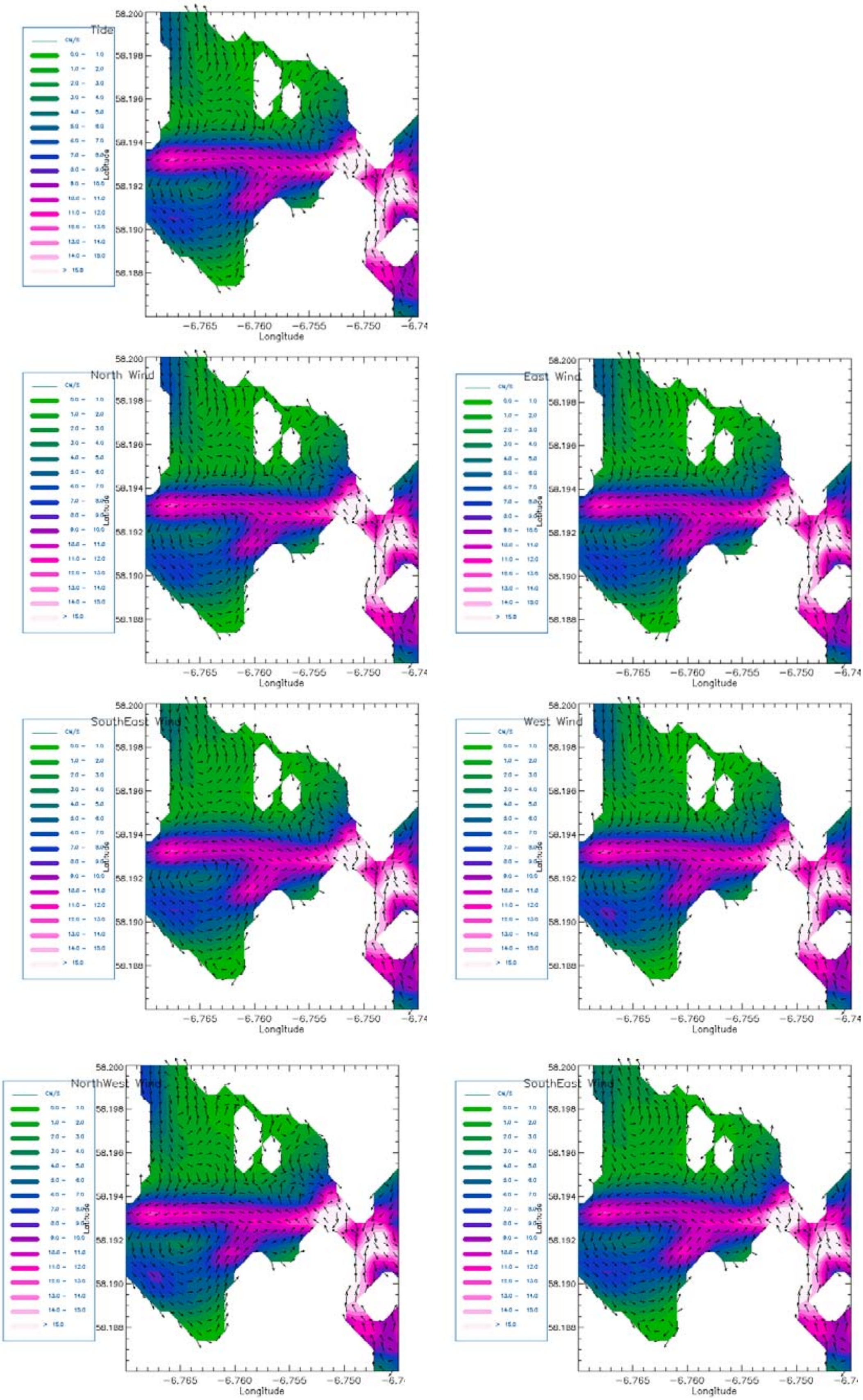


Figure 13.6: Residual currents in the southern end of East Loch Roag for tidal forcing only and with imposed wind directions. Geographically induced strong currents limit wind effects on the residual current pattern. Colour distribution indicates residual current speed and arrows give the direction. Arrows plotted at every model grid point.

14. River Flow

There are no river gauging stations on rivers or burns feeding into Loch Roag Ceabhagh.

The following watercourses were measured and sampled during the shoreline survey. These represented the largest freshwater inputs to Loch Roag Ceabhagh.

Table 14.1 River flows and loadings – Loch Roag Ceabhagh

No	Grid Ref	Description	Width (m)	Depth (m)	Meas. Flow (m/s)	Flow in m3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per m3)
1	NB 21768 34795	Abhainn Bhreascleit	3.8	0.04	1.8	23639	100	2.4×10^{10}
2	NB 21853 33819	Stream	1.6	0.06	0.2	1659	200	3.3×10^{9}
3	NB 21491 33658	Stream	0.2	0.01	1.0	173	<100*	8.7×10^{7}
4	NB 23433 31352	Abhainn Dhubh	4.5	0.4	1.5	233280	100	2.3×10^{11}
5	NB 18137 34218	Stream	1.0	0.03	0.4	1037	>100000**	1.6×10^{11}
6	NB 21244 29384	Abhainn Ghriomarstaidh	17.9	1†	4†	6186240	100	6.2×10^{12}
7	NB 21021 31983	Stream	0.4	0.04	0.15	207	97000	2×10^{11}

* Assigned a nominal value of 50 for the calculation of loading
** Assigned a nominal value of 150000 for the calculation of loading
† These values were estimated

Of these, none directly discharge into the shellfish farms. However, stream numbers 1, 5 and 7 empty into the bay at points closest to the shellfish farms, as shown on the map in Figure 14.1.

Combined loadings from sources 1-3 could potentially impact the site at Keava, however this site is less likely to be affected by bacterial loadings from any of the other streams.

The mussel farms at Eilean Scarastaigh and Buckle Point lie closer to rivers with higher loadings and would be more likely than Keava to be impacted by river sources of bacterial contamination with Eilean Scarastaigh most likely to receive contamination from source 5 and Buckle Point by

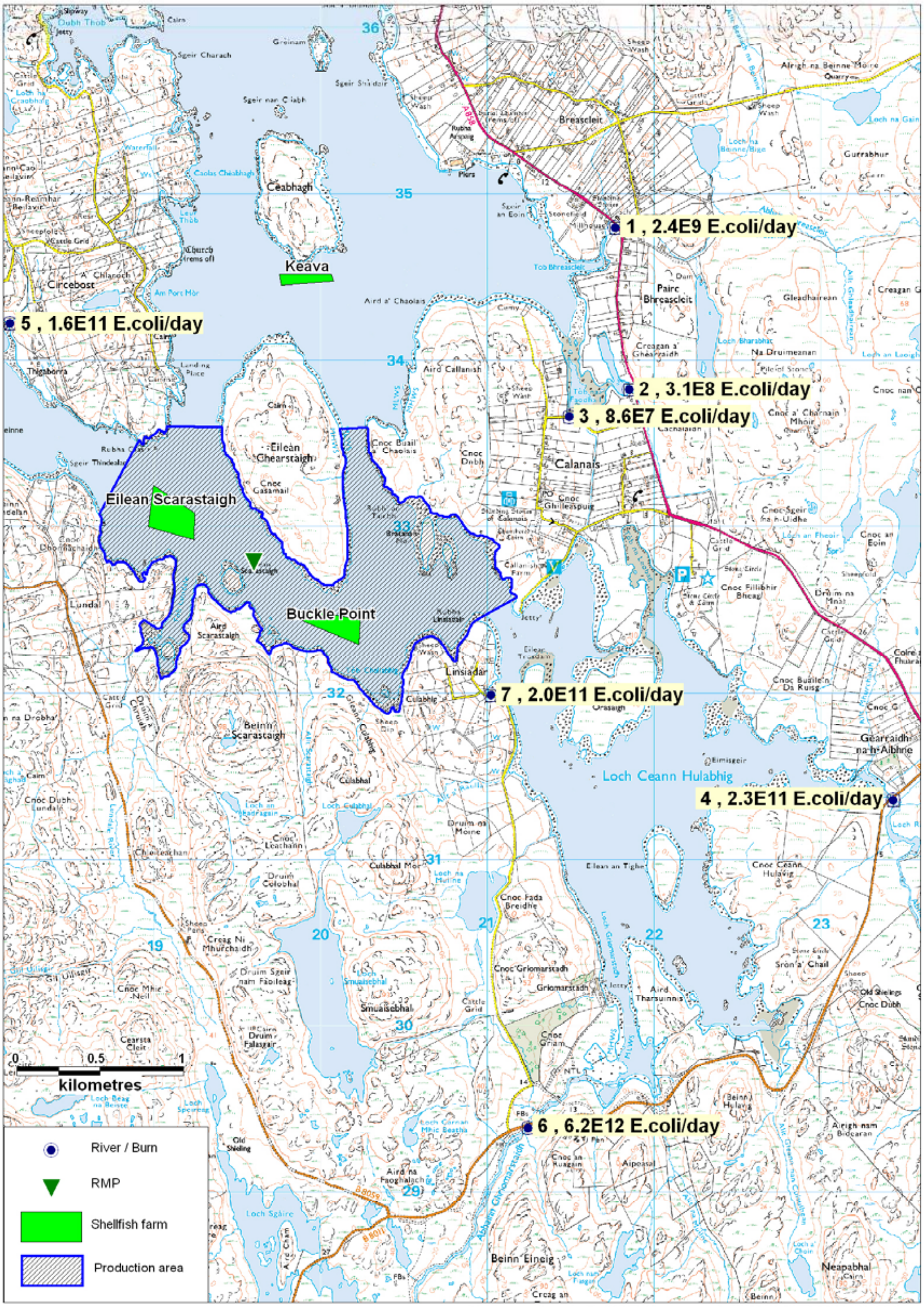


Figure 14.1 Location of significant streams and loadings

15. Shoreline Survey Overview

The shoreline survey confirmed locations of the majority of community septic discharges in the area and that most homes appeared to be connected to the public system. Two septic tanks were observed to be malfuntioning, one of which was discharging solid waste onto the shoreline.

Agricultural use of land in the area was restricted to grazing, predominantly of sheep. Over 700 sheep were observed during the survey, as well as 60 cattle and small numbers of pigs and chickens. No arable agriculture was observed.

Two rivers, the Ghriomarstaidh and the Dhubh discharge into the loch.along the southern shore 3 km or more from the nearest shellfish farm. It was not possible to measure adequately the Ghriomarstaidh during the shoreline survey as it was flowing too deeply and swiftly to safely enter so the depth and flow were estimated.

Water samples were taken from fresh-water sources around the area as well as from sea water at the fishery and around the shoreline, especially near discharges.

Seawater samples collected on or near the shellfish farms had between 0 and 2 *E. coli* cfu/100 ml, indicating relatively low levels of faecal contamination. Fresh and seawater samples taken nearer to the shoreline and adjacent discharges showed concentrations ranging from 0 to >100000 *E.coli* cfu/100 ml. In general, samples taken from near discharges were highly contaminated, as might be expected. These concentrations diminished rapidly with distance from the source. Observed levels of contamination were highest around Circebost, to the west of the Eilean Chearstaigh production area, where a septic tank was observed overflowing at the shoreline. A further seawater sample collected approximately 0.5 km along the shoreline to the south showed no *E.coli* and one collected from the end of the point nearest the Eilean Chearstaigh shellfish farm contained 1 *E.coli* cfu/100 ml.

Streams throughout the area contained evidence of faecal contamination, most likely from livestock as sheep were grazed throughout the area.

Houses associated with crofts were concentrated in Calanais and Breascleit on the eastern shore of the loch and Circebost on the island of Bearnaraigh.

Shellfish samples collected from the mussel farms showed levels of contamination within the range allowed for Class A shellfish waters. Shore mussel samples collected from near the septic tank discharge at Calanais, however, contained 16000 *E. coli* (mpn/100 ml) and indicated much higher levels of contamination. The area from which these were collected is a small inlet that is cut off from the main body of the loch during low water and so would be poorly flushed, allowing bacteria levels to become more concentrated.

The most contaminated areas based on water sample results were 1 km or more from the shellfish farms.

Figure 15.1 illustrates the most significant shoreline survey observations.

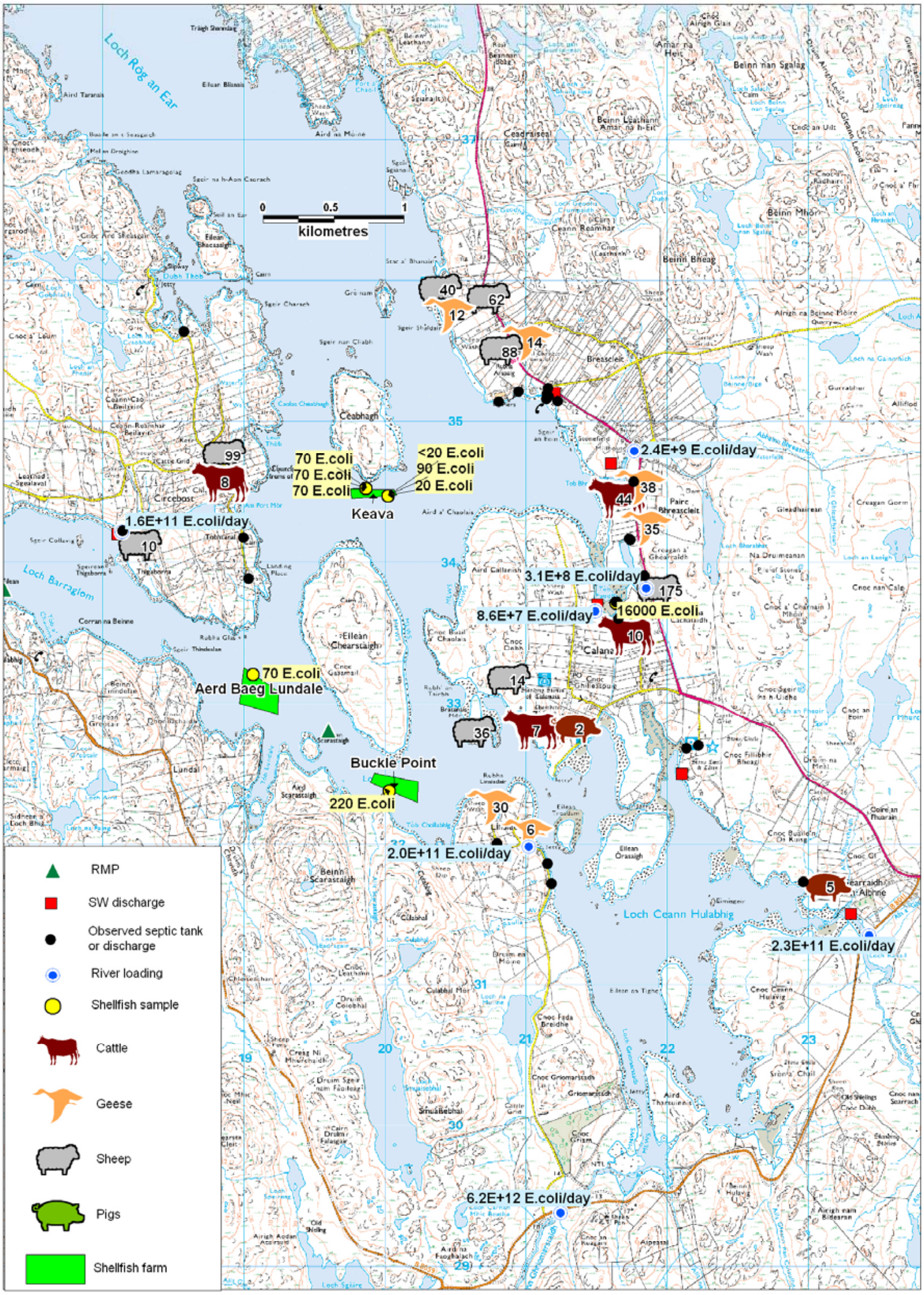


Figure 15.1 Summary of shoreline survey findings

16. Overall Assessment

Human Sewage Inputs

Human sewage inputs to the south-eastern section of Loch Roag are relatively low as the human population in the area at the last census was 565 and it is not likely to have increases significantly since. The largest sewage discharges are from the settlements of Breascleit and Calanais to the east of the shellfish farms. Hydrodynamic modelling indicates, however, that these contaminants from these discharges are likely to circulate within local gyres and are not likely to impact any of the shellfish farms.

Discharges from sources on Great Bearnariagh, including the septic tank at Kirkibost dun Innes, may impact the shellfish farms particularly those in the Eilean Chearstaigh production area.

Agricultural Impacts

There was no arable agriculture in the vicinity of the production areas though there was grazing of livestock. Livestock were more numerous on along the eastern shoreline where hydrodynamics would indicate that pollutants aren't likely to travel far to the west. However, livestock found around Circebost on Great Bearnaraigh and Linsiadar to the south of the production area could both contribute contaminants that may impact the shellfisheries.

In addition, diffuse faecal contaminants carried into the production area via the rivers Ghriomarstaidh and Dhubh and an unnamed stream at Linsiadar carry relatively high loadings of *E.coli* onto the production areas and may affect the site at Buckle Point first. A further unnamed stream on Great Bearnaraigh contributes significant loadings to the area north and west of the mussel farm at Aerd Baeg Lundale and would affect that site most acutely.

The combined effect of improved grassland on top of poorly draining base soils at both Linsiadar and in the vicinity of Callanish Farm across the narrows separating Loch Ceann Hulabhig would be to increase the concentration of faecal bacteria found in runoff from these areas. Diffuse pollution entering the loch waters here would be swept by the current running though the constriction and possibly affect the all the musself farms but particularly that at Buckle Point.

Wildlife Impacts

It is difficult to determine what impacts wildlife will have on the shellfishery in East Loch Roag. It is unlikely that larger marine mammals will enter this section of the loch, and though seals and otters may be present in the area their impacts are likely to be highly localised and unpredictable.

Greylag geese were observed on the shoreline and droppings observed around the loch indicating a significant presence. Their impact to the fisheries is likely to be diffuse and is assumed to be randomly distributed. Other seabirds may impact the mussel farms when roosting on the floats and lines but this is also localised and unpredictable.

Deer are present in the area though their numbers are not known. Faecal bacteria from deer are likely to be carried via rivers and streams as diffuse pollution and so their impact will be considered with other riverine inputs. Direct impact to the fisheries is unlikely as lack of an opposable thumb prevents the deer from stealing boats and dropping trou on the mussel farms.

Seasonal Variation

The settlement of Calanais has a tourist attraction, a visitor's centre and some accomodation in B&Bs. The main tourist season is July, when schools in Scotland are on summer holiday and August when English and Welsh schools are on break. Winter is likely to see fewest visitors as access to the island can be disrupted for days at a time due to weather conditions.

Seasonal varioations in livestock population are to be expected with an increase in numbers after the birth of lambs and calves in late spring.

Rainfall as recorded at Stornoway is lower than the Scottish average in all months, though it is higher during September through January when compared to February through August.

Rivers and Streams

A number of streams and rivers discharge into East Loch Roag, carrying estimated *E. coli* loadings of between 8.7×10^{7} to 6.2×10^{12} per day. Highest loadings were for the river Ghriomarstaidh, which enters the loch at the southern end via Loch Ceann Hulabhig.

The Allt Scarastaigh discharges into the loch near the farm at Buckle Point, though it wasn't possible to sample it during the shoreline survey.

Generally, outside of Loch Ceann Hulabhig freshwater inputs are likely to be mixed by the time they reach the fisheries.

Meteorology and Movement of Contaminants

While there was insufficient historical data to compare the interrelation of environmental factors with *E.coli* results in shellfish, there did appear to be significantly lower contamination levels observed during the summer months.

Rainfall in the area is generally lower than in Scotland on the whole, with wettest months occurring in winter. Soils and landcover in the area indicate that the potential for runoff is high in many areas around the loch, and the presence of grazing livestock indicates that this runoff may contain elevated *E.coli* levels from faecal waste deposited on fields.

Hydrographic analysis indicates that freshwater input to the loch is likely to be well mixed by the time it reaches the fisheries and that corresponding contaminants are not as likely to be entrained in surface waters except in Loch Ceann Hulabhig. Particle tracking modelling indicates that sources on the eastern shoreline at Calanais and Bhreascleit are unlikely to travel far enough westward to impact the fisheries.

However, sources from the vicinity of Linsiadar and waters moving from Loch Ceann Hulabhig into Loch Roag are likely to carry contaminants across the eastern side of the Eilean Chearstaigh production area, impacting at Buckle Point first.

Analysis of Results

Analysis of historical results was rendered difficult by discrepancies within the dataset and the resulting low number of useable datapoints.

Monitoring results were reported against the stated RMP, which though it lies on a Crown Estate seabed lease area it does not correspond with measured farms observed during the shoreline survey.

Of the useable monitoring results, all samples tested in the Eilean Chearstaigh production area returned *E.coli* concentrations of 500 or fewer mpn/100 g. Of those collected from the current RMP, only 1 exceed 230/100g.

Results obtained on the day of the shoreline survey also fell within this range with one notable exception being the shore mussel sample collected from near the septic tank outfall north of Calanais (16000/100g). Shoreline survey results showed higher levels of contamination in the mussel sample collected from the Buckle Point farm than from the one near Aerd Baeg Lundale.

At Keava, shellfish samples collected returned *E.coli* concentrations ranging from <20/100 g to 90/100 g. It is difficult to draw broad conclusions from such limited sampling, however the highest result was observed on the eastern end of the shellfish farm, with greater variation with depth. On the western side of the farm, results were the same for all depths, indicating that the concentration of contaminants in the water was fairly consistent.

17. Recommendations

Eilean Chearstaigh

It is recommended that the boundaries of the current Loch Roag: Eilean Chearstaigh be retained as the area bounded by lines drawn between NB 1891 3352 and NB 1867 3308 and between NB 2094 3244 and NB 2114 3260 and between NB 2028 3360 and NB 2011 3360 and between NB 1941 3360 and NB 1908 3360.

The site farmed as Eilean Scarastaigh actually lies on the lease for Aerd Baeg Lundale and it is recommended that the site name be updated to reflect this.

The RMP for this production area is currently reported as NB 196 328. This does not lie on either shellfish farm. It is recommended that the RMP be relocated to the southeast end of the Buckle Point farm as higher *E.coli* results were obtained here and hydrographic assessment reveals that this end of the production area may be more acutely impacted by sources of faecal contamination to the south and east. The recommended new RMP is NB 2020 3240. Sampling depth is recommended to be 3 metres as the waters are well mixed.

Sampling frequency is recommended to remain monthly due to variability observed in historical monitoring results.

Ceabhagh

It is recommended that the production area boundaries for the new Loch Roag: Ceabhagh production area be set as the area bounded by lines drawn between NB 1941 3460 and NB 1983 3460 and between NB 2014 3465 and NB 2073 3438 and between NB 2027 3360 and NB 2011 3359 and between NB 1939 3361 and NB 3361 extending to MHWS.

It is recommended that the RMP be placed at NB 2005 3450. Sampling depth is recommended to be 3 metres as the waters are well mixed and higher levels of *E.coli* were observed at that depth.

Sampling frequency is recommended to be monthly as the site is new and has little monitoring history.

For both production areas, production area boundaries and new RMPs are illustrated in Figure 17.1.

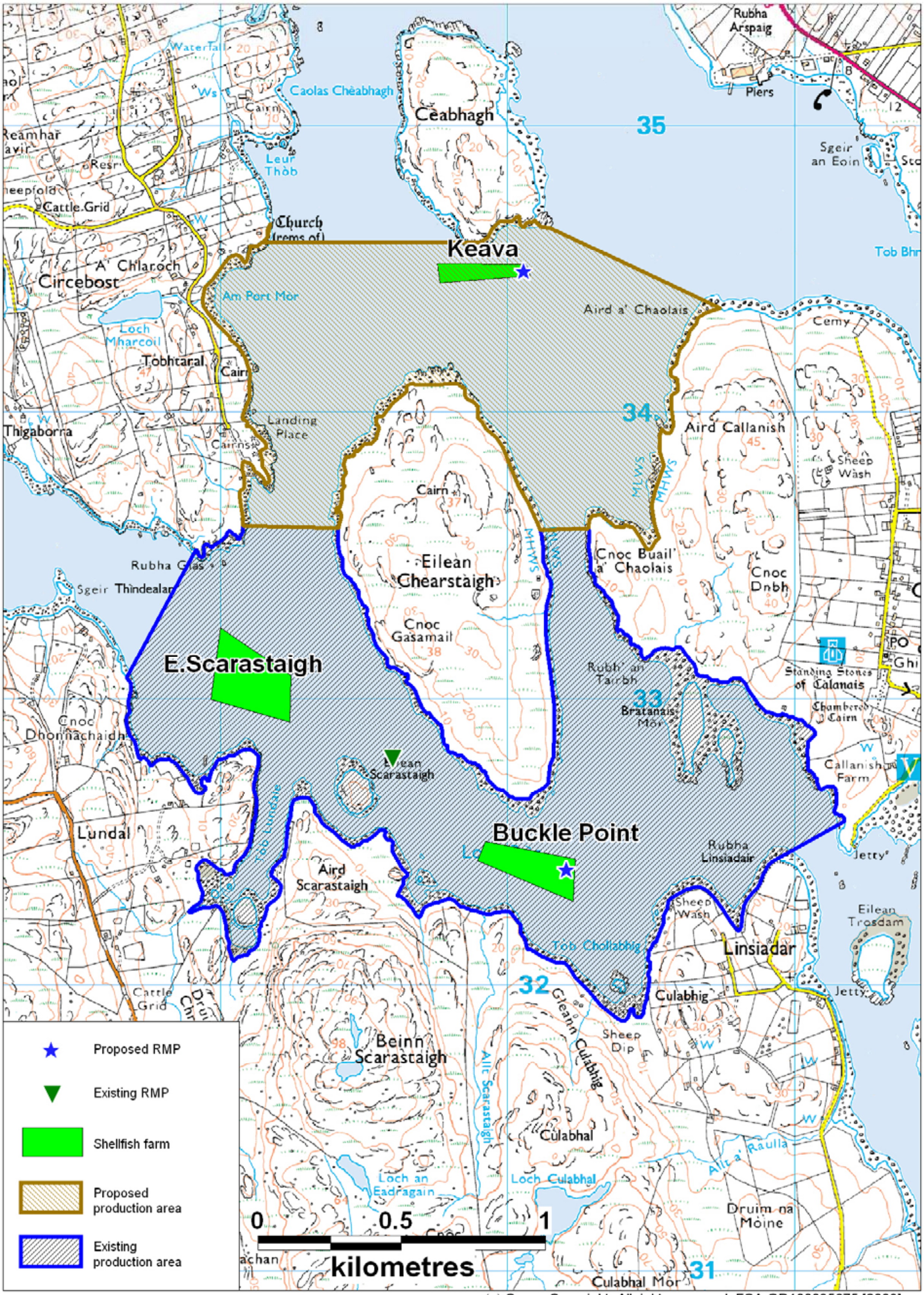


Figure 17.1 Recommendations for Loch Roag

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19. List of Figures and Tables

Appendices

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Shoreline Survey Report

Loch Roag: Ceabhagh
Loch Roag: Eilean Chearstagh
LH 381 and LH 344

Scottish Sanitary Survey Project

Prod. area:	Loch Roag: Ceabhagh and Loch Roag: Eilean Chearstagh
Site name:	Keava and Eilean Chearstagh
Species:	Common mussels
Harvester:	Hebridean Mussels Ltd
Local Authority:	Comhairle nan Eilean Siar
Status:	Keava: New Application Eilean Scarastaigh: Classified A year round
Date Surveyed:	21-24 August
Surveyed by:	Michelle Price-Hayward and Alastair Cook
Existing RMP:	Eilean Scarastaigh: LH34469708
Area Surveyed:	See map in Figure 1

Weather observations
Sunny and dry, 18-22ºC. Winds Force 1-3, westerly.

Fishery
There are two mussel farms within the existing Eilean Chearstaigh production area: Buckle Point and Eilean Scarista. These are illustrated in the map found in Figure 1. Each contained 3 double-headed long lines with 7m pegged drop ropes. The locations of the lines, Crown Estate lease areas and designated RMP coordinates are mapped in Figure 1.

There is only one mussel farm within the proposed new production area at Ceabhagh. At the time of survey, two double-headed long lines were in place on the site.

Harvest may take place at any time of year, with stock of different maturity present on each site for harvest in rotation.

Sewage/Faecal Sources
The following discharges were identified by Scottish Water:

Table 1: Scottish Water Discharges

Discharge Name	Discharge Type	Level of Treatment	Consented flow m3/day	NGR of discharge	East	North
Breasclete B	Continuous	Septic Tank	42	NB21203520	121200	935200
Breasclete C&D	Continuous	Septic Tank	27	NB21603470	121600	934700
Callanish A	Continuous	Septic Tank	25	NB21503370	121500	933700
Callanish B	Continuous	Septic Tank	PE 400			
Callanish C	Continuous	Septic Tank		NB221325	122100	932500
Callanish D						
Garrynahine	Continuous	Septic Tank	10.5	NB23303150	123300	931500
Kirkibost dun Innes	Continuous	Septic Tank	10.8	NB18103420	118100	934200

The following locations were confirmed during the shoreline survey:

Breasclete B:
An inspection cover was located on the shoreline at grid reference NB 2116 3517. A discharge pipe was observed at NB21143 35154 that ran out to below the tide line.

Breasclete C&D:
An inspection cover was found next to a small stream after some direction from a local crofter, who indicated that the discharge pipe was further around the point. This pipe was not observed during the shoreline survey.

Callanish A:
A community septic tank was located at grid reference NB 21654 33598, which was some distance from the location reported for this discharge. No pipe was confirmed.

Callanish B:
No grid reference was given for this discharge.

Callanish C:
Inspection covers were found at NB 22072 33071, NB 22221 32697, and NB 22136 32677 with the last being located on the shoreline. No associated discharge pipe was observed and was presumed to be underwater.

Callanish D, Garynahine:
No evidence of tank or inspection covers found in vicinity of reported location.

Kirkibost dun Innes:
A round, overflowing tank was observed adjacent to a stream at NB 18142 34219. There appeared to be an associated pipe leading into the loch beneath a pile of rocks, however it may have been blocked given the flow running down the sides of the tank.

In addition to the Scottish Water assets, private septic tanks were observed, one of which appeared to be malfunctioning as there was human waste on the shoreline around the discharge pipe. For the most part, groups of houses seemed to be on the community septic systems.

Seasonal Population
Tourism is important to the island economy, with the largest influx of visitors occurring during the Scottish school holidays in July (personal communication, visitor’s centre and B&B owner). Archaeological sites and outdoor activitities such as hunting and fishing draw the most visitors. There were guest houses and hotels in Stornoway as well as in the small settlements strung out along the A road through Breasclete and Calanais.

Boats/Shipping
Workboats were observed in the area during the survey. These were a mix of day boats and liveaboard fishing vessels.

Land Use

Land use on North Lewis is predominantly croft grazing of sheep. Over 700 sheep were observed during the survey. Though other livestock was observed (5 pigs, 8 chickens and 60 cattle) only cattle were present in what might be considered locally significant numbers. The land is very poor and rocky, with deep peat predominating. There is no arable agriculture in the area.

Wildlife/Birds

Significant numbers (135) of Greylag Geese were observed around the area with goose droppings abundant on the shoreline as well as in the fields around the loch. (see Table 3). Goose droppings were observed in many fields. Some gulls were observed, but not in significant aggregations. These were not specifically recorded.

Specific observations taken on site are mapped in Figures 1 and 2 and listed in Tables 2 and 3.

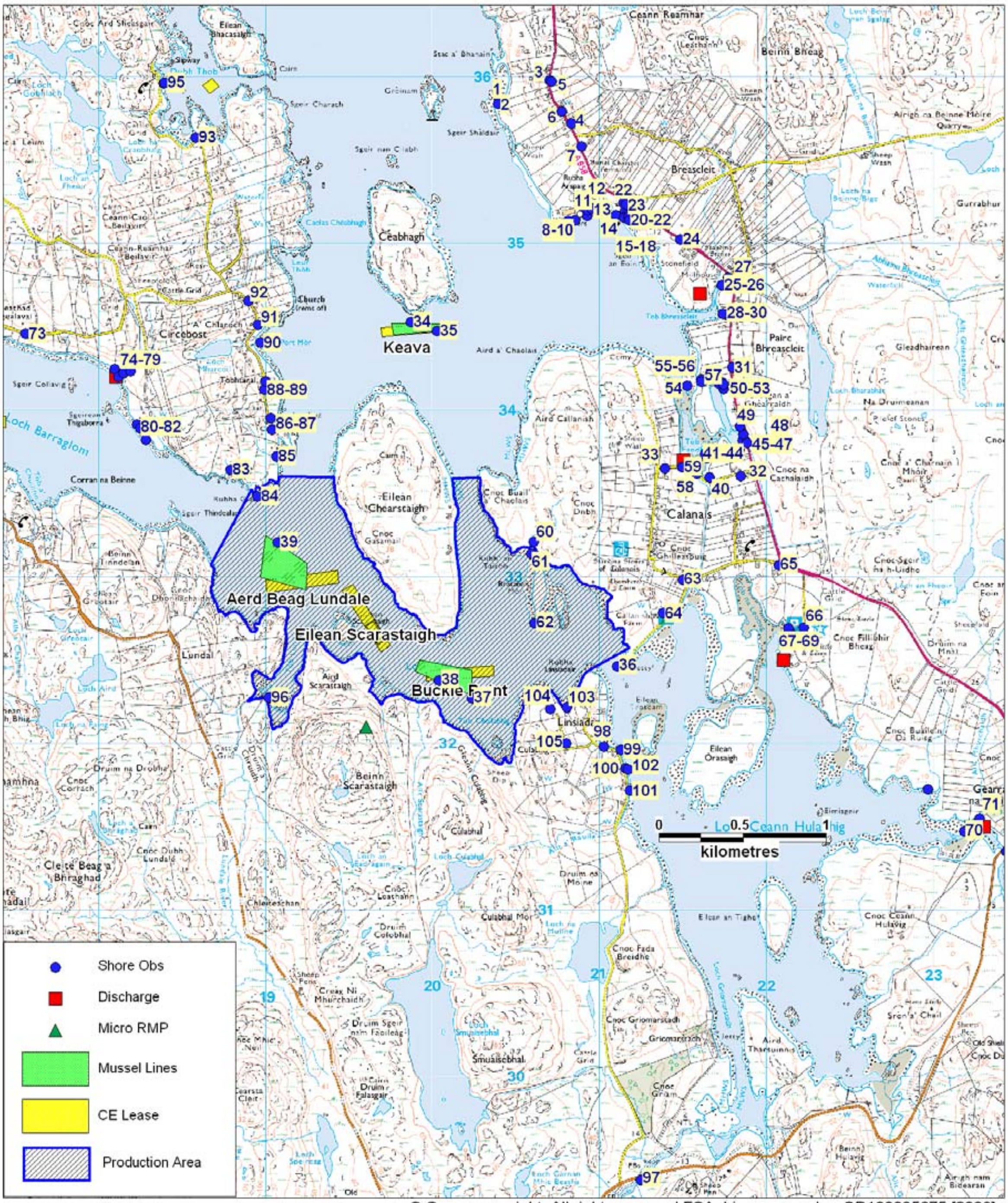


Figure 1. Map of shoreline observations

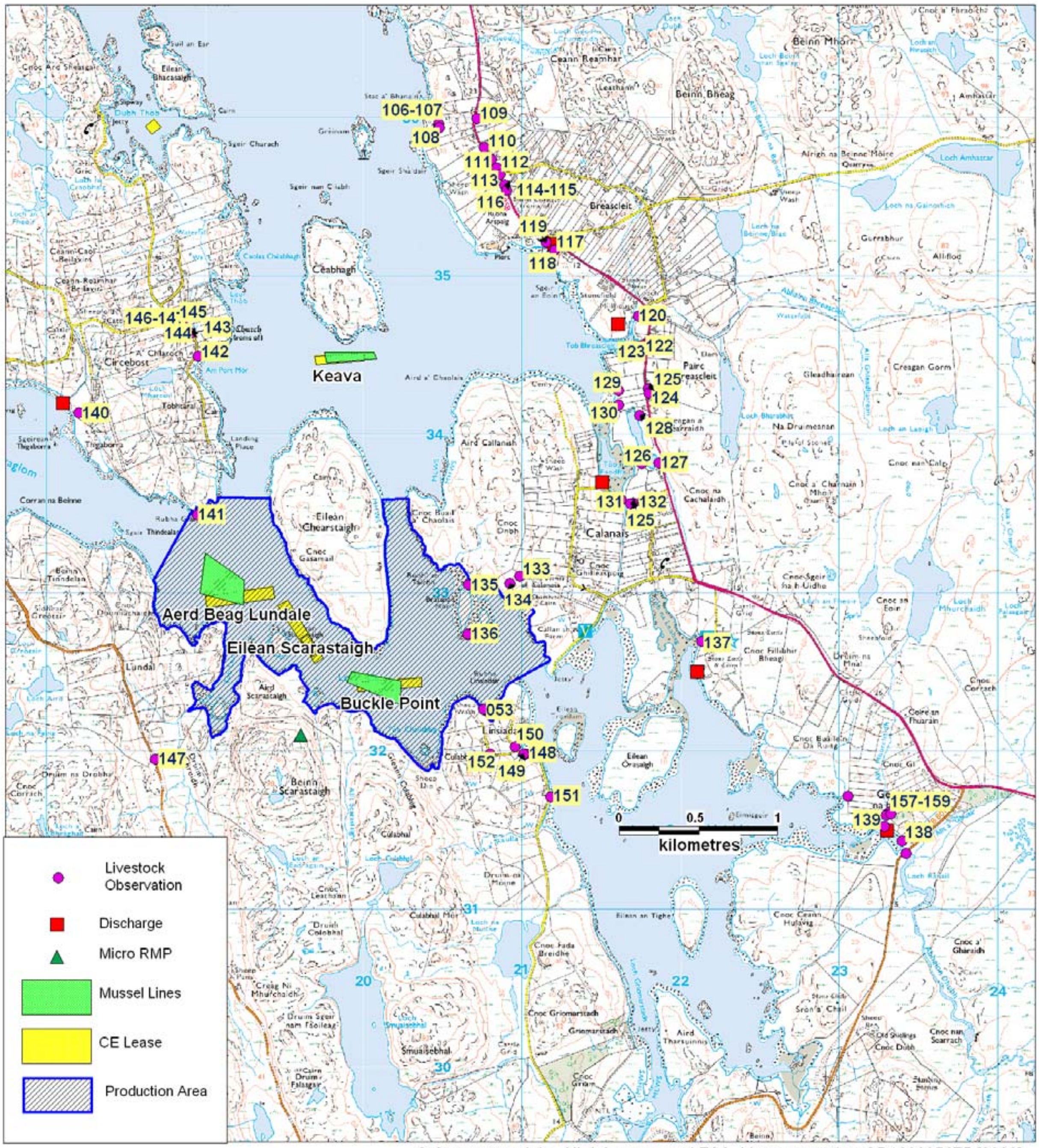


Figure 2. Map of livestock observations

Table 2. Shoreline Observations

No.	Date	NGR	East	North	Description	Photograph of area
1	21-AUG-07 10:07:08AM	NB 20393 35866	120393	935866	water sample 1, salinity 32 ppt.	
2	21-AUG-07 10:09:47AM	NB 20390 35836	120390	935836	salmon farm and barge seen from here immediately south of small island with lighthouse, more cages to the north.	
3	21-AUG-07 10:24:08AM	NB 20697 35976	120697	935976	8 houses around here.	
4	21-AUG-07 10:29:23AM	NB 20827 35718	120827	935718	7 more houses, sheep washing pen.	
5	21-AUG-07 10:23:00AM	NB 20708 35972	120708	935972	house	
6	21-AUG-07 10:34:00AM	NB 20771 35791	120771	935791	drainage channel	
7	21-AUG-07 10:52:58AM	NB 20888 35580	120888	935580	3 more houses on landward side of road.	
8	21-AUG-07 11:02:31AM	NB 20909 35211	120909	935211	Equateq factory, jetty, 3 moorings.	
9	21-AUG-07 11:07:39AM	NB 20850 35137	120850	935137	30cm orange plastic pipe from factory, not flowing.	
10	21-AUG-07 11:09:34AM	NB 20807 35134	120807	935134	3 x 22cm plastic pipes, 1 flowing circa 10L per second, water sample 2 taken from flowing pipe, salinity 33 ppt.	
11	21-AUG-07 11:19:54AM	NB 20924 35165	120924	935165	Water sample 3, salinity 33ppt.	
12	21-AUG-07 11:24:42AM	NB 20928 35200	120928	935200	very small stream not sampled.	
13	21-AUG-07 11:25:42AM	NB 20949 35206	120949	935206	septic overflow 110mm pipe dripping (1.5 mL per second), water sample 4 presumed fresh.	
14	21-AUG-07 11:35:44AM	NB 21094 35170	121094	935170	stream braided 20cmx2cmx0.3m/s and 8cmx2cmx0.5m/s.	
15	21-AUG-07 11:40:18AM	NB 21160 35170	121160	935170	inspection cover on beach.	Figures 5 & 6
16	21-AUG-07 11:41:23AM	NB 21143 35154	121143	935154	concrete encased pipe to below water level.	
17	21-AUG-07 11:43:46AM	NB 21150 35190	121150	935190	septic tank cover in back garden.	
18	21-AUG-07 11:45:00AM	NB 21204 35166	121204	935166	recycling skip/container	Figure 7
19	21-AUG-07 11:46:38AM	NB 21173 35160	121173	935160	stream 35cmx5cmx0.7m/s, water sample 5 fresh.	
20	21-AUG-07 11:50:54AM	NB 21175 35139	121175	935139	3 moorings and work boat in bay, water sample 6, salinity 33ppt.	
21	21-AUG-07 11:53:28AM	NB 21223 35139	121223	935139	septic tank cover.	Figure 8
22	21-AUG-07 12:00:23PM	NB 21142 35240	121142	935240	29 houses, 1 caravan, 2 sheds.	
23	21-AUG-07 12:04:31PM	NB 21157 35234	121157	935234	3 inspection covers.	
24	21-AUG-07 12:14:34PM	NB 21482 35025	121482	935025	12 houses.	
25	21-AUG-07 12:25:00	NB 21730 34750	121730	934750	stream	Figures 11-13
26	21-AUG-07 12:32:05PM	NB 21766 34796	121766	934796	43 houses.	
27	21-AUG-07 12:32:14PM	NB 21768 34795	121768	934795	stream 380cmx4cmx1.8m/s water sample 7 fresh (advised there was a septic tank downstream which discharges around the point somewhere).	Figure 10
28	21-AUG-07 12:47:11PM	NB 21763 34568	121763	934568	inspection cover next to very small stream.	
29	21-AUG-07 12:52:40PM	NB 21735 34577	121735	934577	line of rocks (covering pipe?), water sample 8, salinity 7ppt.	Figures 15-16

No.	Date	NGR	East	North	Description	Photograph of area
30	21-AUG-07 1:02:01PM	NB 21804 34572	121804	934572	farmyard next to stream.	
31	21-AUG-07 1:06:09PM	NB 21794 34257	121794	934257	10 houses.	
32	21-AUG-07 1:09:14PM	NB 21841 33605	121841	933605	9 houses.	
33	21-AUG-07 1:11:16PM	NB 21390 33651	121390	933651	17 houses and 13 cattle.	
-	21-AUG-07 2:23:55PM	NB 20063 34518	120063	934518	Keava mussel lines corner (water is 12m deep, lines are 7m long).	Figures 17-19
-	21-AUG-07 2:24:36PM	NB 20077 34477	120077	934477	Keava mussel lines corner.	
-	21-AUG-07 2:27:18PM	NB 19761 34453	119761	934453	Keava mussel lines corner.	
-	21-AUG-07 2:28:13PM	NB 19752 34520	119752	934520	Keava mussel lines corner.	
34	21-AUG-07 2:34:37PM	NB 19867 34528	119867	934528	water sample 9, salinity profile taken, mussel samples Keava 1 (top) Keava 2 (middle) Keava 3 (bottom).	
35	21-AUG-07 3:02:57PM	NB 20022 34475	120022	934475	water sample 10, salinity profile taken, mussel samples Keava 4 (top) Keava 5 (middle) Keava 6 (bottom).	
36	21-AUG-07 3:29:55PM	NB 21101 32464	121101	932464	water sample 11, salinity profile taken.	
-	21-AUG-07 3:35:54PM	NB 20233 32441	120233	932441	Buckle Point mussel lines corner.	Figures 20-21
-	21-AUG-07 3:37:10PM	NB 20227 32292	120227	932292	Buckle Point mussel lines corner.	
37	21-AUG-07 3:37:45PM	NB 20232 32272	120232	932272	loose rope, hazard to navigation.	
-	21-AUG-07 3:40:04PM	NB 19893 32433	119893	932433	Buckle Point mussel lines corner.	
-	21-AUG-07 3:40:36PM	NB 19921 32502	119921	932502	Buckle Point mussel lines corner.	
38	21-AUG-07 3:50:17PM	NB 20032 32378	120032	932378	mussel sample Buckle Point 1 (top), water sample 12, salinity profile taken.	
-	21-AUG-07 4:04:14PM	NB 19242 33081	119242	933081	Scarista mussel lines corner.	Figure 22
-	21-AUG-07 4:05:28PM	NB 19239 32920	119239	932920	Scarista mussel lines corner.	
-	21-AUG-07 4:06:31PM	NB 18964 32997	118964	932997	Scarista mussel lines corner.	
-	21-AUG-07 4:07:53PM	NB 18996 33249	118996	933249	Scarista mussel lines corner.	
39	21-AUG-07 4:10:08PM	NB 19068 33207	119068	933207	mussel sample Scarista 1 (top), water sample 13, salinity profile taken.	
40	22-AUG-07 9:26:31AM	NB 21654 33598	121654	933598	communal septic tank, some animal droppings.	Figure 23
41	22-AUG-07 9:33:46AM	NB 21640 33712	121640	933712	end of sewer pipe, 15cm diameter, flowing 0.5 L/s. Wild mussel sample Calanais 1.	Figures 24-25
42	22-AUG-07 9:39:34AM	NB 21629 33739	121629	933739	water sample 14, salinity 29ppt.	
43	22-AUG-07 9:54:29AM	NB 21682 33720	121682	933720	sewage related debris.	
44	22-AUG-07 9:55:53AM	NB 21703 33722	121703	933722	sewage related debris.	
45	22-AUG-07 10:03:11AM	NB 21853 33819	121853	933819	stream 160cmx6cmx0.2m/s, water sample 15, fresh water.	Figure 26
46	22-AUG-07 10:08:14AM	NB 21880 33801	121880	933801	18cm metal pipe over stream heading towards waypoint 48.	Figure 27
47	22-AUG-07 10:09:58AM	NB 21874 33810	121874	933810	sewage related debris.	Figure 28
48	22-AUG-07 10:11:13AM	NB 21858 33854	121858	933854	very small stream not sampled.	

No.	Date	NGR	East	North	Description	Photograph of area
49	22-AUG-07 10:13:19AM	NB 21840 33902	121840	933902	possible pumping station (silent).	Figure 29
50	22-AUG-07 10:22:13AM	NB 21741 34125	121741	934125	sewage related debris.	
51	22-AUG-07 10:23:43AM	NB 21733 34164	121733	934164	inspection covers.	
52	22-AUG-07 10:25:29AM	NB 21726 34159	121726	934159	very small stream not sampled.	
53	22-AUG-07 10:25:46AM	NB 21714 34156	121714	934156	very small stream not sampled.	Figure 30
54	22-AUG-07 10:31:39AM	NB 21524 34146	121524	934146	water sample 16, salinity 31ppt.	
55	22-AUG-07 10:40:18AM	NB 21608 34170	121608	934170	sheep faeces.	
56	22-AUG-07 10:44:38AM	NB 21738 34154	121738	934154	septic tank cover, no overflow to shore.	
57	22-AUG-07 11:00:50AM	NB 21581 33620	121581	933620	very small stream not sampled	
58	22-AUG-07 11:08:56AM	NB 21491 33658	121491	933658	stream 20cmx1cmx1m/s, water sample 17, fresh water.	
59	22-AUG-07 11:56:33AM	NB 20602 33212	120602	933212	very small stream not sampled.	
60	22-AUG-07 11:59:43AM	NB 20589 33139	120589	933139	water sample 18, salinity 21ppt.	
61	22-AUG-07 12:14:39PM	NB 20605 32722	120605	932722	water sample 19, salinity 24ppt.	
62	22-AUG-07 12:52:56PM	NB 21495 32983	121495	932983	3 houses.	
63	22-AUG-07 12:54:27PM	NB 21376 32783	121376	932783	house and visitor centre, 3 hogs.	
64	22-AUG-07 1:10:58PM	NB 22072 33071	122072	933071	2 hogs, inspection cover.	
65	22-AUG-07 1:17:20PM	NB 22221 32697	122221	932697	inspection cover.	
66	22-AUG-07 1:20:09PM	NB 22136 32677	122136	932677	inspection cover on beach associated discharge pipe must be underwater.	Figure 33
67	22-AUG-07 1:21:50PM	NB 22136 32677	122136	932677	water sample 20, salinity 3ppt.	
68	22-AUG-07 1:26:00PM	NB 22129 32693	122129	932693	pottery shards.	
69	22-AUG-07 1:50:52PM	NB 23181 31474	123181	931474	water sample 21, salinity 1ppt.	
70	22-AUG-07 1:53:36PM	NB 23274 31551	123274	931551	stream 250cmx10cmx0.8m/s.	
71	22-AUG-07 2:01:59PM	NB 23433 31352	123433	931352	river 450cmx40cmx1.5m/s, water sample 22 fresh.	
72	22-AUG-07 5:05:40PM	NB 17556 34458	117556	934458	6 houses.	
73	22-AUG-07 5:25:54PM	NB 18091 34246	118091	934246	10 sheep on shore side of fence.	
74	22-AUG-07 5:28:29PM	NB 18142 34219	118142	934219	septic tank overflowing into small stream also line of rocks leading into sea covering pipe which might be blocked.	Figure 34
75	22-AUG-07 5:32:10PM	NB 18137 34218	118137	934218	stream 100cmx3cmx0.4m/s, water sample 23 fresh, d/s septic tank.	
76	22-AUG-07 5:35:17PM	NB 18116 34201	118116	934201	water sample 24, salinity 20ppt.	
77	22-AUG-07 5:39:45PM	NB 18146 34222	118146	934222	water sample 25, fresh water, u/s septic tank.	
78	22-AUG-07 5:45:49PM	NB 18188 34233	118188	934233	8 houses circa 50m back from here, 20 sheep in field.	
79	22-AUG-07 5:56:47PM	NB 18225 33914	118225	933914	1 house about 50m back from beach.	
80	22-AUG-07 5:57:48PM	NB 18244 33892	118244	933892	very small stream not sampled.	
81	22-AUG-07 6:00:57PM	NB 18277 33823	118277	933823	water sample 26, salinity 30ppt .	
82	22-AUG-07 6:20:13PM	NB 18786 33641	118786	933641	stream 40cmx3cmx0.2m/s.	

No.	Date	NGR	East	North	Description	Photograph of area
83	22-AUG-07 6:26:10PM	NB 18947 33482	118947	933482	water sample 27, salinity 34ppt.	
84	22-AUG-07 6:34:35PM	NB 19060 33722	119060	933722	small stream 10cmx2cmx1m/s.	
85	22-AUG-07 6:40:51PM	NB 19033 33881	119033	933881	septic tank and 4 cows.	
86	22-AUG-07 6:43:55PM	NB 19026 33951	119026	933951	5 houses.	
87	22-AUG-07 6:46:19PM	NB 18988 34124	118988	934124	3 houses, 2 dogs, 1 rabbit hutch.	
88	22-AUG-07 6:47:03PM	NB 18997 34171	118997	934171	septic tank in field, 4 geese.	
89	22-AUG-07 6:53:56PM	NB 18967 34406	118967	934406	water sample 28, 29ppt.	
90	22-AUG-07 6:59:30PM	NB 18951 34513	118951	934513	5 houses.	
91	22-AUG-07 7:01:40PM	NB 18893 34654	118893	934654	7 houses.	
92	23-AUG-07 10:12:55AM	NB 18577 35636	118577	935636	septic outflow from 2 houses, human waste evident, water sample 29, salinity 26ppt.	Figure 35
93	23-AUG-07 10:22:18AM	NB 18387 35958	118387	935958	fishing pier 6 boats processing shed with outflow.	Figure 36
94	23-AUG-07 10:27:06AM	NB 18390 35964	118390	935964	water sample 30, salinity 32ppt.	
95	23-AUG-07 11:15:40AM	NB 19013 32274	119013	932274	water sample 31, salinity 28ppt.	
96	23-AUG-07 11:47:12AM	NB 21244 29384	121244	929384	River Grimestra, estimated flow 3-5 m3/s, water sample 32 fresh.	Figure 37
97	23-AUG-07 11:59:52AM	NB 21021 31983	121021	931983	3 houses behind, stream 40x4x0.15m/s, water sample 33 fresh.	
98	23-AUG-07 12:08:33PM	NB 21124 31961	121124	931961	water sample 34, 21ppt.	
99	23-AUG-07 12:11:58PM	NB 21152 31854	121152	931854	septic tank on beach probably for 3 houses.	
100	23-AUG-07 12:14:02PM	NB 21179 31717	121179	931717	septic pipe to shore probably 1 house 15cm ceramic flowing <1L per minute.	Figure 38
101	23-AUG-07 12:20:10PM	NB 21168 31843	121168	931843	water sample 35, salinity 20ppt.	
102	23-AUG-07 12:31:23PM	NB 20800 32218	120800	932218	water sample 36, salinity 25ppt.	
103	23-AUG-07 12:46:34PM	NB 20701 32206	120701	932206	sheep wash.	
104	23-AUG-07 12:51:08PM	NB 20796 32001	120796	932001	septic tank to ditch.	
105	23-AUG-07 1:20:02PM	NB 22966 31727	122966	931727	inspection cover in field 10m back from shore, pipe not visible, water sample 37, salinity 2ppt.	

Table 3. Livestock observations

No.	Date	NGR	East	North	Description
106	21/08/2007 10:02	NB 20471 35963	120471	935963	30 Sheep - Fenced
107	21/08/2007 10:08	NB 20471 35939	120471	935939	10 Sheep - Fenced
108	21/08/2007 10:16	NB 20476 35937	120476	935937	Dog faeces
109	21/08/2007 10:30	NB 20758 35812	120758	935812	12 Greylag Geese, 2 Sheep
110	21/08/2007 10:43	NB 20802 35739	120802	935739	60 Sheep, 1 cow, 2 dogs
111	21/08/2007 10:47	NB 20834 35683	120834	935683	26 Sheep
112	21/08/2007 10:48	NB 20855 35642	120855	935642	25 Sheep
113	21/08/2007 10:51	NB 20886 35577	120886	935577	No stock
114	21/08/2007 10:52	NB 20887 35578	120887	935578	13 Sheep NE of road
115	21/08/2007 10:55	NB 20900 35542	120900	935542	14 Greylag Geese, 24 Sheep
116	21/08/2007 11:59	NB 21147 35216	121147	935216	3 Sheep
117	21/08/2007 12:47	NB 21767 34570	121767	934570	38 Geese to sw
118	21/08/2007 12:58	NB 21757 34566	121757	934566	14 Cow
119	21/08/2007 13:05	NB 21793 34289	121793	934289	5 Cattle
120	21/08/2007 13:07	NB 21797 34260	121797	934260	35 Geese
121	21/08/2007 13:10	NB 21699 33565	121699	933565	100 Sheep 3 Cows + 5 from Al
122	22/08/2007 09:58	NB 21752 33818	121752	933565	animal and goose droppings in tideline, 2 sheep in fenced field
123	22/08/2007 10:04	NB 21859 33822	121859	933822	4 Sheep se of this point
124	22/08/2007 10:34	NB 21607 34276	121607	934276	5 Cows
125	22/08/2007 10:38	NB 21607 34185	121607	934185	20 Cows
126	22/08/2007 11:14	NB 21621 33587	121621	933587	47 Sheep, 2 Cows TODHSS
127	22/08/2007 11:17	NB 21680 33564	121680	933564	22 Sheep on rt
128	22/08/2007 11:40	NB 20983 33103	120983	933103	14 Sheep this+adj field
129	22/08/2007 11:43	NB 20919 33058	120919	933058	7 Cows
130	22/08/2007 12:03	NB 20659 33052	120659	933052	Goose dropings 5/m
131	22/08/2007 12:15	NB 20653 32737	120653	932737	36 Sheep across water from this point
132	22/08/2007 13:45	NB 23394 31430	123394	931430	Sheep and cow faeces appr 1/M2
133	22/08/2007 13:53	NB 23282 31524	123282	931524	24 Sheep, 1Cow
134	22/08/2007 17:49	NB 18199 34137	118199	934137	10 Sheep in this field
135	22/08/2007 18:27	NB 18945 33492	118945	933492	3 Photos
136	22/08/2007 18:53	NB 18950 34494	118950	934494	5 Cows
137	22/08/2007 19:01	NB 18904 34638	118904	934638	22 Sheep
138	22/08/2007 19:02	NB 18877 34672	118877	934672	24 Sheep
139	22/08/2007 19:03	NB 18861 34685	118861	934685	3 Sheep uphill from here

No.	Date	NGR	East	North	Description
140	22/08/2007 19:05	NB 18838 34704	118838	934704	50 Sheep, 3 Cows OP
141	23/08/2007 11:02	NB 18680 31947	118680	931947	14 Sheep
142	23/08/2007 12:01	NB 21017 31982	121017	931982	6 Cows in field ne of this point
143	23/08/2007 12:06	NB 21008 31982	121008	931982	6 Geese, 2 Sheep
144	23/08/2007 12:08	NB 20953 32029	120953	932029	5 Sheep
145	23/08/2007 12:16	NB 21177 31709	121177	931709	1 Sheep
146	23/08/2007 12:27	NB 20795 31980	120795	931980	6 Sheep
147	23/08/2007 12:34	NB 20757 32258	120757	932258	30 Geese
148	23/08/2007 12:35	NB 20753 32263	120753	932263	2 Sheep on opposite shore
149	23/08/2007 13:00	NB 23421 31353	123421	931353	35 Sheep
150	23/08/2007 13:07	NB 23295 31594	123295	931594	5 Pigs
151	23/08/2007 13:09	NB 23325 31604	123325	931604	8 Chickens
152	23/08/2007 13:11	NB 23314 31613	123314	931613	45 Sheep
153	23/08/2007 13:19	NB 23053 31715	123053	931715	50 Sheep

As in other parts of Scotland where crofting and sheep husbandry are the predominant agricultural activity of the area, sheep populations generally double during lambing. Ewes and lambs are grazed through the summer and in September the lambs are shipped to the mainland for finishing. There was an anecdotal account of crofters abandoning sheep to roam the island as feral because it was not economical to send them to market. It was not possible to verify whether this was the case.

Recorded observations apply to the date of survey only. Animal numbers were recorded on the day from the point of observer's view. This does not necessarily equate to total numbers present as natural features may obscure individuals from view.

Dimensions and flows of watercourses are estimated at the most convenient point of access and not necessarily at the point at which the watercourses enter the loch.

Sampling
Water and shellfish samples were collected at sites marked on the maps shown in Figures 3 and 4. All samples were transferred to cool boxes for transport and shipped to the laboratory via air courier for *E. coli* analysis. Water sampled at the site was tested for salinity using a hand-held refractometer. These readings are recorded in Table 1 as salinity in parts per thousand (ppt).

Samples were also tested for salinity by the laboratory under more controlled conditions. These results are more precise than the field measurements and are shown in Table 3, given in units of grams chloride per litre of water. In sea water, six ions contribute over 99% of the dissolved salts and are present in essentially constant proportions. Of these six, chloride is the most easily measured. The following formula is used to convert lab readings in milligrams chloride ion per litre to salinity in parts per thousand (ppt): g Cl/1000 * 1.80655.

Bacteriology results follow in Tables 4 and 5.

Table 4. Water Sample Results

No.	Date	Sample	Type	NGR	E. coli (cfu /100g)	Salinity(ppt)
1	21/08/2007	Roag 1	Sea	NB 20393 35866	0	34.3
2	21/08/2007	Roag 2	Sea	NB 20807 35134	0	33.8
3	21/08/2007	Roag 3	Sea	NB 20924 35165	2	33.6
4	21/08/2007	Roag 4	Fresh	NB 20949 35206	200	na
5	21/08/2007	Roag 5	Fresh	NB 21173 35160	100	na
6	21/08/2007	Roag 6	Sea	NB 21175 35139	60	34.0
7	21/08/2007	Roag 7	Fresh	NB 21768 34795	100	na
8	21/08/2007	Roag 8	Sea	NB 21735 34577	35	10.2
9	21/08/2007	Roag 9	Sea	NB 19867 34528	0	31.8
10	21/08/2007	Roag 10	Sea	NB 20022 34475	0	31.6
11	21/08/2007	Roag 11	Sea	NB 21101 32464	8	21.0
12	21/08/2007	Roag 12	Sea	NB 20032 32378	2	25.5
13	21/08/2007	Roag 13	Sea	NB 19068 33207	0	30.6
14	21/08/2007	Roag 14	Sea	NB 21629 33739	720	30.4
15	21/08/2007	Roag 15	Fresh	NB 21853 33819	200	na
16	21/08/2007	Roag 16	Sea	NB 21524 34146	48	30.4
17	21/08/2007	Roag 17	Fresh	NB 21491 33658	<100	na
18	21/08/2007	Roag 18	Sea	NB 20589 33139	2	25.5
19	21/08/2007	Roag 19	Sea	NB 20605 32722	6	22.4
20	21/08/2007	Roag 20	Sea	NB 22136 32677	300	20.1
21	21/08/2007	Roag 21	Sea	NB 23181 31474	54	0.49
22	23/08/2007	Roag 22	Fresh	NB 23433 31352	100	na
23	23/08/2007	Roag 23	Fresh	NB 18137 34218	>100000	na
24	24/08/2007	Roag 24	Sea	NB 18116 34201	1300	27.3
25	24/08/2007	Roag 25	Fresh	NB 18146 34222	200	na
26	24/08/2007	Roag 26	Sea	NB 18277 33823	0	30.7
27	24/08/2007	Roag 27	Sea	NB 18947 33482	1	30.4
28	24/08/2007	Roag 28	Sea	NB 18967 34406	8	28.9
29	24/08/2007	Roag 29	Sea	NB 18577 35636	36	30.5
30	24/08/2007	Roag 30	Sea	NB 18390 35964	0	33.6
31	24/08/2007	Roag 31	Sea	NB 19013 32274	19	28.5
32	24/08/2007	Roag 32	Fresh	NB 21244 29384	100	na
33	24/08/2007	Roag 33	Fresh	NB 21021 31983	97000	na
34	24/08/2007	Roag 34	Sea	NB 21124 31961	9	22.0
35	24/08/2007	Roag 35	Sea	NB 21168 31843	31	19.1
36	24/08/2007	Roag 36	Sea	NB 20800 32218	52	25.3
37	24/08/2007	Roag 37	Sea	NB 22966 31727	54	1.1

Table 5. Shellfish Sample Results

No.	Date	Sample	Type	NGR	E. coli (mpn/ 100g)	Depth
1	21/08/2007	Keava 1	Mussel	NB 19867 34528	70	<1m
2	21/08/2007	Keava 2	Mussel	NB 19867 34528	70	3m
3	21/08/2007	Keava 3	Mussel	NB 19867 34528	70	7m
4	21/08/2007	Keava 4	Mussel	NB 20022 34475	<20	<1m
5	21/08/2007	Keava 5	Mussel	NB 20022 34475	90	3m
6	21/08/2007	Keava 6	Mussel	NB 20022 34475	20	7m
7	21/08/2007	Buckle Point 1	Mussel	NB 20032 32378	220	<1m
8	21/08/2007	Scaristaigh 1	Mussel	NB 19068 33207	70	<1m
9	21/08/2007	Calanais 1	Mussel	NB 21640 33712	16000	shore

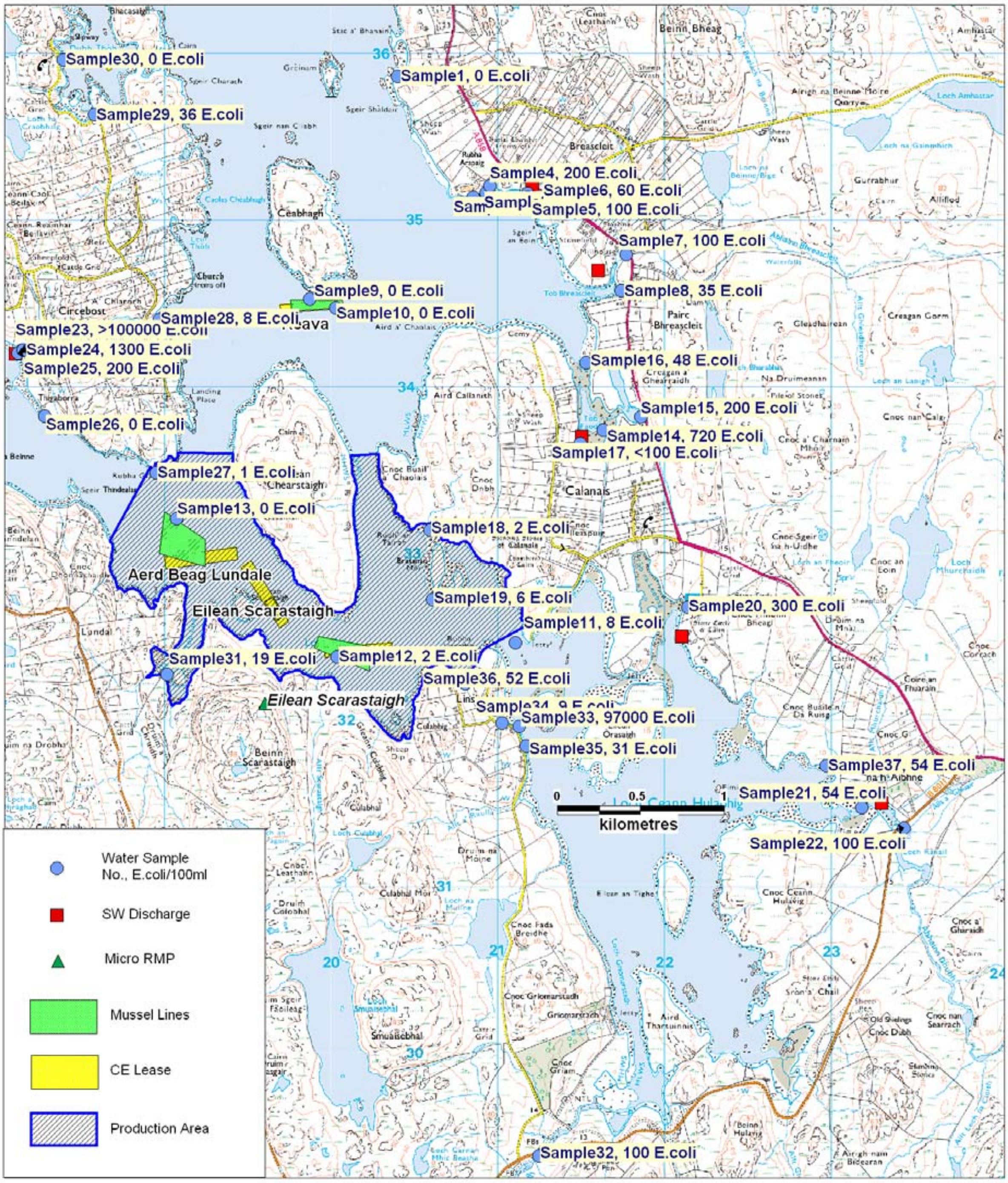


Figure 3. Map of water sample results

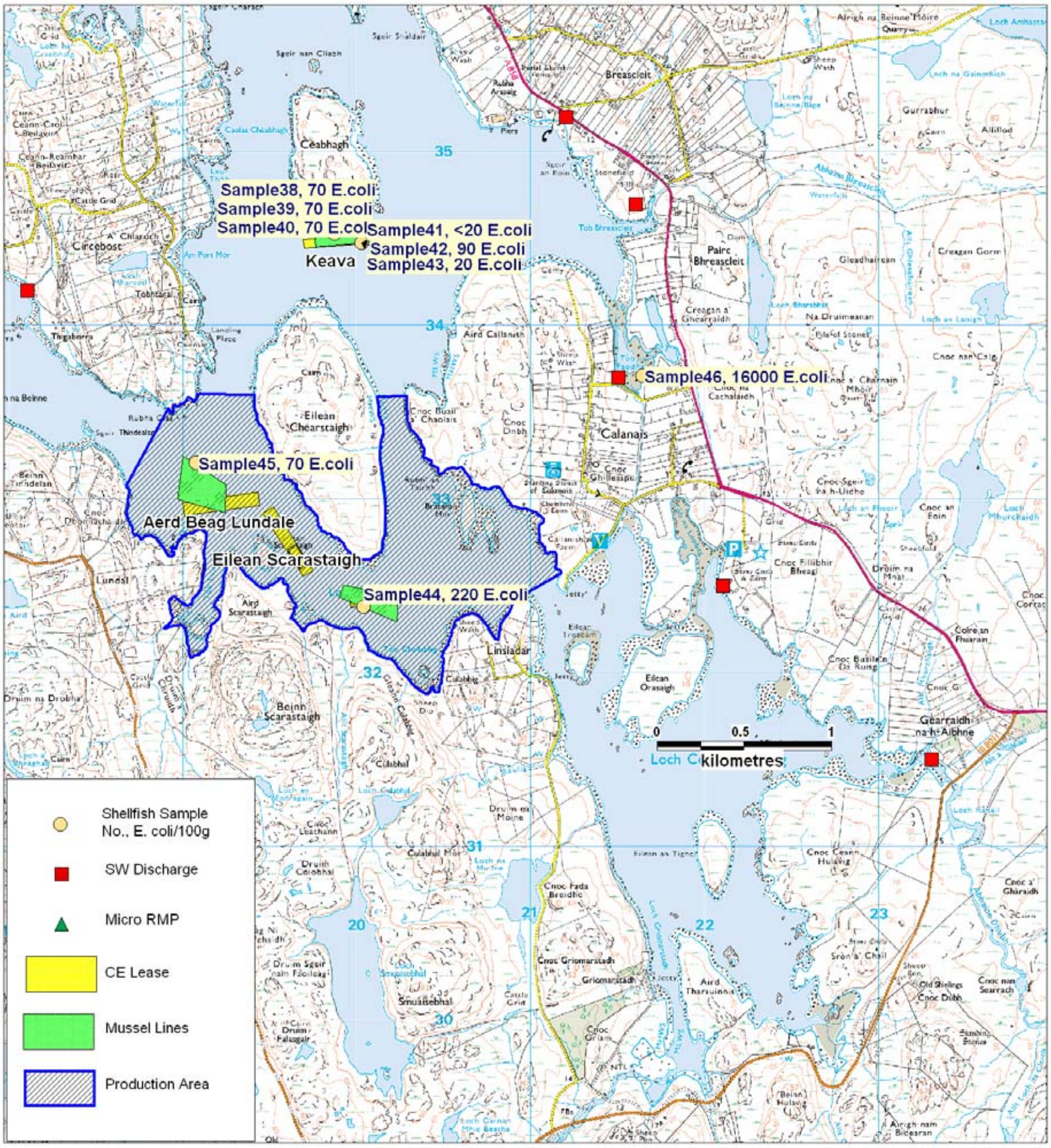


Figure 4. Map of shellfish sample results

Photos

Figure 5. Roag080702 Discharge pipe from Breasclete A (north) septic tank.

Figure 6. Roag080703 Inspection cover for Breasclete B septic tank.

Figure 7. Roag080704 Recycling centre container near shoreline.

Figure 8. Roag080706 Apparent septic tank, to south of recycling centre.

Figure 9. Roag080707 Slipway - N. Breasclete.

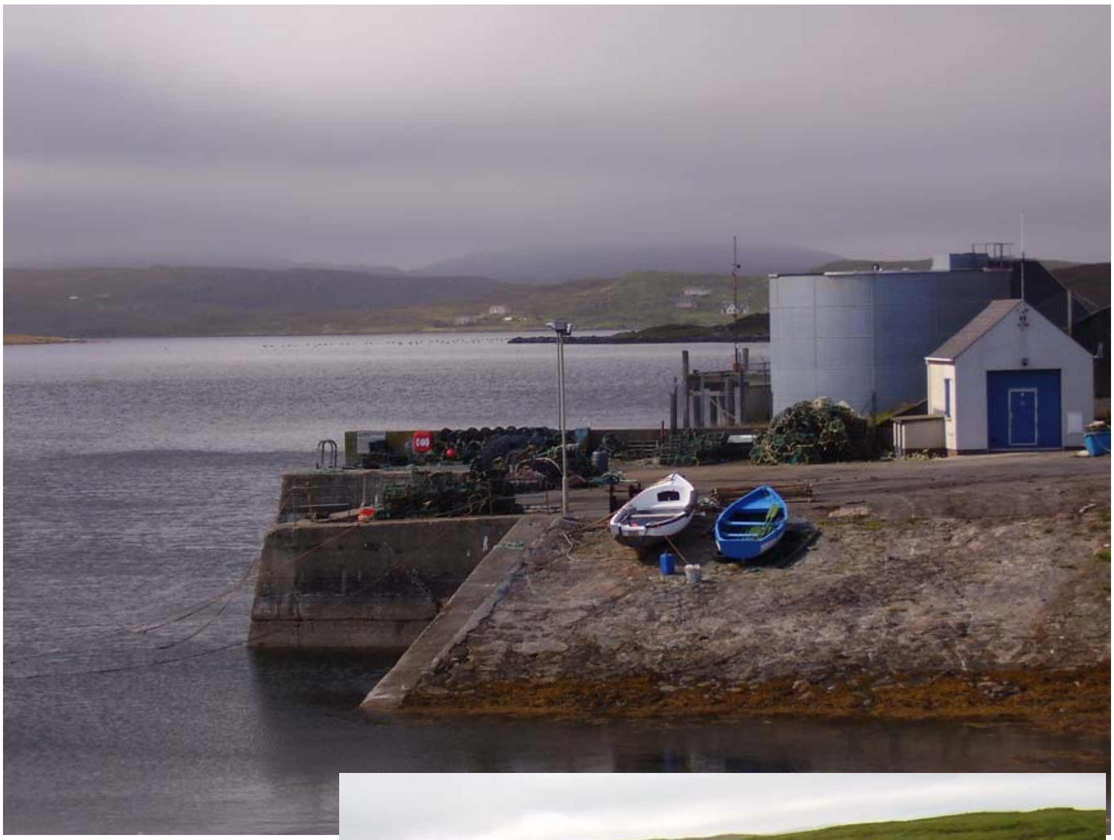


Figure 10.
Roag080708
Abhainn Bhreascleit
looking sw as it passes
under A858.

Figure 11. Roag080709 Pipe running across burn SW of road.

Figure 12. Roag080710 Inspection covers Breasclete C&D septic tanks.

Figure 13.
Roag080711
Small stream
feeding into burn
above from North

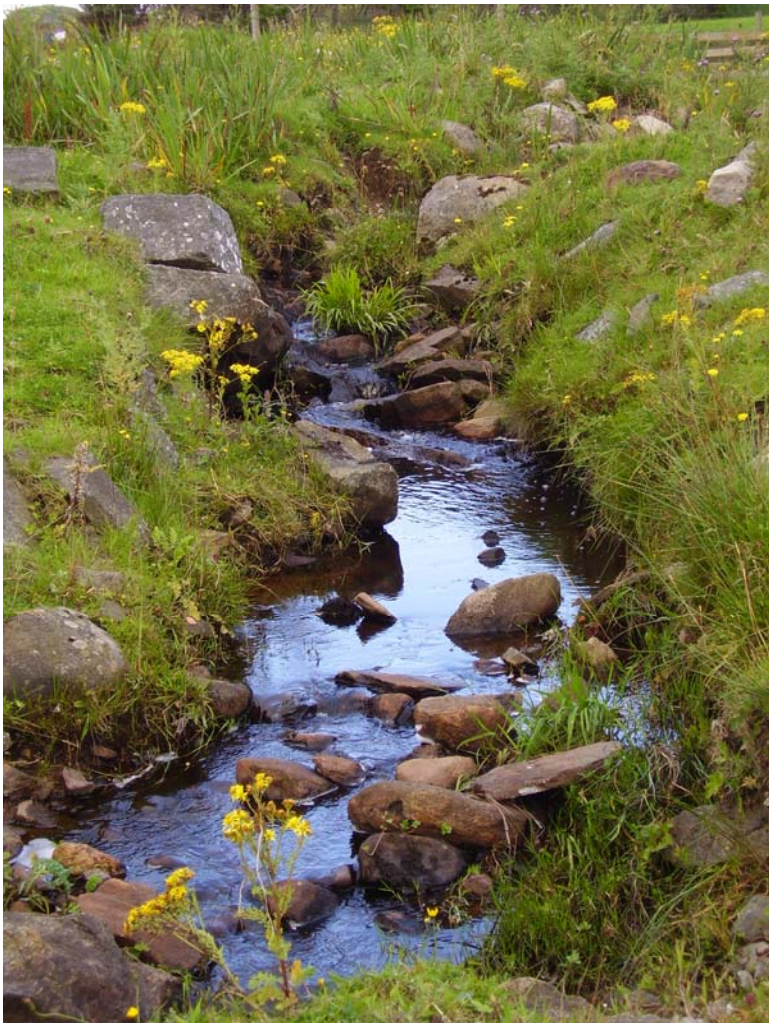


Figure 14. Roag080714 Straw waste plus cow faeces next to stream.

Figure 15. Roag080716 Discharge pipe from Breasclete C&D into Tob Breasclete.

Figure 16. Roag080717 Float appears to mark end of discharge pipe.

Figure 17. Roag080719 Keava looking East along the lines.

Figure 18. Roag080720 Keava looking North, disused salmon barge in background.

Figure 19. Roag080721 Sampling at Keava.

Figure 20. Roag080726 Buckle Point looking E toward gap between Linsiadar and Calanais.

Figure 21. Roag080728 Buckle Point long lines.

Figure 22. Roag080730 Eilean Scarista long lines.

Figure 23. Roag080733
Community septic tank.

Figure 24. Roag080735
Discharge pipe from septic tank in Fig. 23.

Figure 25. Roag080736
Discharge from end of pipe.

Figure 26. Roag080742
Unnamed stream passing under A848

Figure 27. Roag080743 Pipe running from South Calanais septic tank.

Figure 28. Roag 080744 Sanitary debris

Figure 29. Roag080746.
Possible pumping station.

Figure 30. Roag080747 Microbial growth in stream

Figure 31. Roag080756 Exposed soil profile.

Figure 32. Roag080759 Workboat on Buckle Point site.

Figure 33. Roag080760 Septic tank discharge inspection cover.

Figure 34. Roag080792 Septic tank discharging into stream.

Figure 35. Roag080765 Septic discharge with human waste on shoreline, N of Circebost.

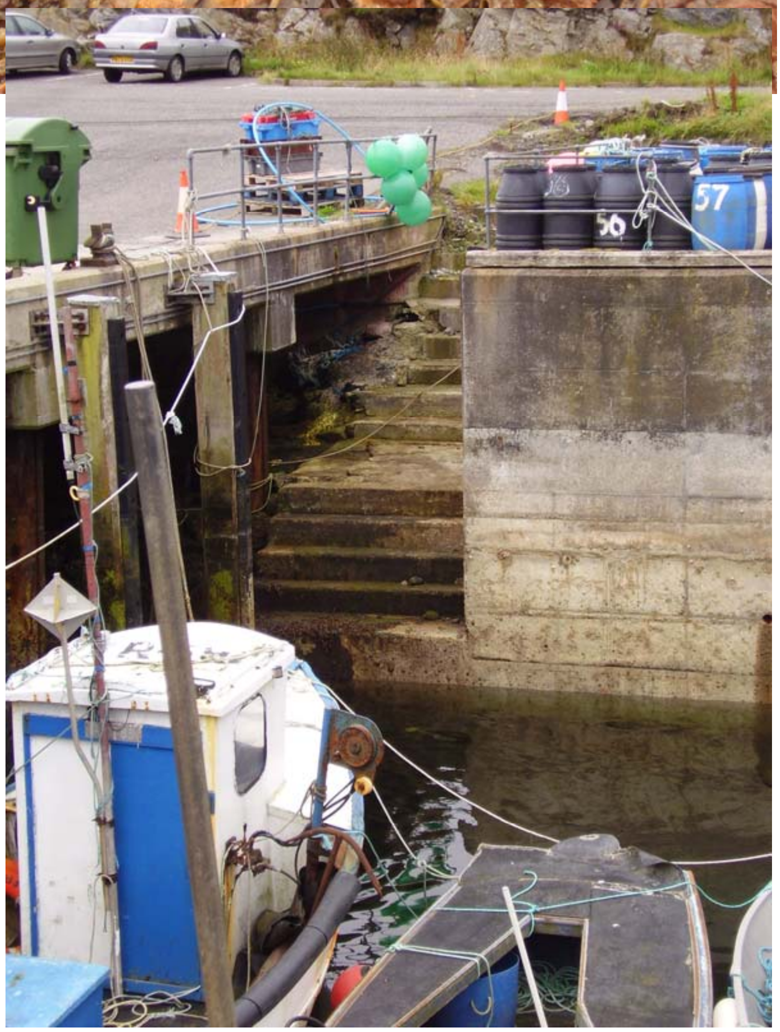


Figure 36.
Roag080771
Pier at Circebost.

Figure 37. Roag080776 Grimista River.

Figure 38. Roag080782 Septic tank along shoreline.

Sampling Plan for Loch Roag: Eilean Chearstaigh and Ceahbagh

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISHERY	NGR OF RMP	EAST	NORTH	TOLERANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER	OTHER INFO
Loch Roag: Ceahbagh	Keava	LH 381 772	Common mussel	Long Line	NB 2005 3450	12005	93450	10	3	Hand	Monthly	Comhairle nan Eilean Siar	Paul Tyler	Alan Yates	
Loch Roag: Eilean Chearstaigh	Buckle Point	LH 344 791	Common mussel	Long Line	NB 2020 3240	12020	93240	10	3	Hand	Monthly	Comhairle nan Eilean Siar	Paul Tyler	Alan Yates	

Tables of Typical Faecal Bacteria Concentrations

Summary of faecal coliform concentrations (cfu 100ml-1) for different treatment levels and individual types of sewage-related effluents under different flow conditions: geometric means (GMs), 95% confidence intervals (Cis), and results of t-tests comparing base- and high-flow GMs for each group and type.

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	282	$2.8 \times 10^{6*}$ (-)	2.3×10^6	3.2×10^6
Crude sewage discharges	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	79	$3.5 \times 10^{6*}$ (-)	2.6×10^6	4.7×10^6
Storm sewage overflows					203	2.5×10^6	2.0×10^6	2.9×10^6
Primary	127	$1.0 \times 10^{7*}$ (+)	8.4×10^6	1.3×10^7	14	4.6×10^6 (-)	2.1×10^6	1.0×10^7
Primary settled sewage	60	1.8×10^7	1.4×10^7	2.1×10^7	8	5.7×10^6		
Stored settled sewage	25	5.6×10^6	3.2×10^6	9.7×10^6	1	8.0×10^5		
Settled septic tank	42	7.2×10^6	4.4×10^6	1.1×10^7	5	4.8×10^6		
Secondary	864	$3.3 \times 10^{5*}$ (-)	2.9×10^5	3.7×10^5	184	$5.0 \times 10^{5*}$ (+)	3.7×10^5	6.8×10^5
Trickling filter	477	4.3×10^5	3.6×10^5	5.0×10^5	76	5.5×10^5	3.8×10^5	8.0×10^5
Activated sludge	261	$2.8 \times 10^{5*}$ (-)	2.2×10^5	3.5×10^5	93	$5.1 \times 10^{5*}$ (+)	3.1×10^5	8.5×10^5
Oxidation ditch	35	2.0×10^5	1.1×10^5	3.7×10^5	5	5.6×10^5		
Trickling/sand filter	11	2.1×10^5	9.0×10^4	6.0×10^5	8	1.3×10^5		
Rotating biological contactor	80	1.6×10^5	1.1×10^5	2.3×10^5	2	6.7×10^5		
Tertiary	179	1.3×10^3	7.5×10^2	2.2×10^3	8	9.1×10^2		
Reedbed/grass plot	71	1.3×10^4	5.4×10^3	3.4×10^4	2	1.5×10^4		
Ultraviolet disinfection	108	2.8×10^2	1.7×10^2	4.4×10^2	6	3.6×10^2		

Source: Kay, D. et al (2008) Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42, 442-454.

Comparison of faecal indicator concentrations (average numbers/g wet weight) excreted in the faeces of warm-blooded animals

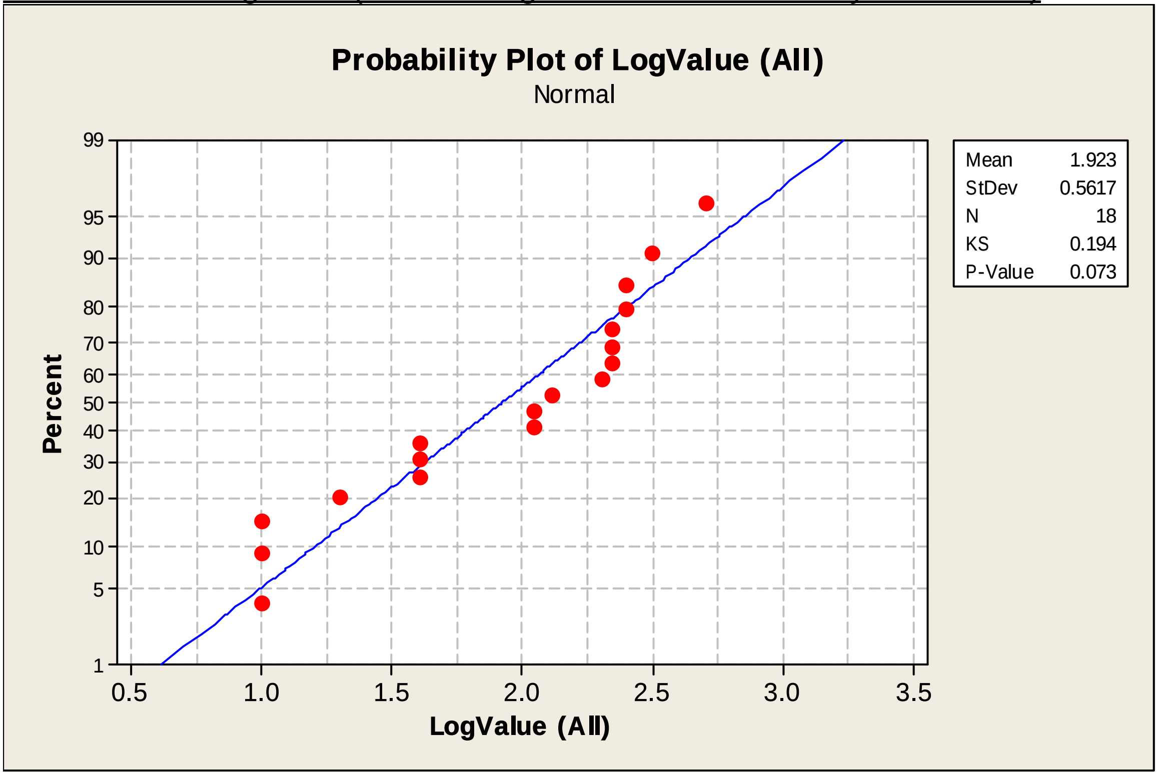
Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^8
Cow	230,000	23,600	5.4×10^9
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^8
Pig	3,300,000	2,700	8.9×10^8
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^8
Human	13,000,000	150	1.9×10^9

Source: Adapted from Geldreich 1978 by Ashbolt et al in World Health Organisation (WHO) Guidelines, Standards and Health. 2001. Ed. by Fewtrell and Bartram. IWA Publishing, London.

Statistical Data

All analyses were undertaken using log transformed results as this gives a more normal distribution.

Distribution on log scale (with Kolmogorov-Smirnov normality test results)



Section 11.3 ANOVA comparison of results by season

```
Source                DF     SS     MS     F      P
Season (all results)   3  3.054  1.018  6.17  0.007
Error                 14  2.309  0.165
Total                 17  5.363

S = 0.4062   R-Sq = 56.94%   R-Sq(adj) = 47.71%


                          Individual 95% CIs For Mean Based on Pooled StDev
Level  N    Mean   StDev    +---------+---------+---------+---------
1      3  2.2779  0.2259                        (-------*-------)
2      3  1.1003  0.1738    (-------*--------)
3      6  2.2404  0.3647                         (-----*-----)
4      6  1.8402  0.5444                   (-----*-----)
                            +---------+---------+---------+---------
                          0.60      1.20      1.80      2.40

Pooled StDev = 0.4062


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season (all results)

Individual confidence level = 98.85%


Season (all results) = 1 subtracted from:
```

```
Season
(all
results)    Lower   Center    Upper  --------+---------+---------+---------+-
2         -2.1413  -1.1776  -0.2138  (-------*-------)
3         -0.8722  -0.0376   0.7971            (------*------)
4         -1.2723  -0.4377   0.3969        (------*------)
                                     --------+---------+---------+---------+-
                                          -1.2       0.0       1.2       2.4
```

Season (all results) = 2 subtracted from:

```
Season
(all
results)    Lower  Center   Upper  --------+---------+---------+---------+-
3          0.3054  1.1400  1.9747                      (------*-----)
4         -0.0948  0.7399  1.5745                  (------*------)
                                   --------+---------+---------+---------+-
                                        -1.2       0.0       1.2       2.4
```

Season (all results) = 3 subtracted from:

```
Season
(all
results)    Lower   Center   Upper  --------+---------+---------+---------+-
4         -1.0816  -0.4001  0.2813           (-----*----)
                                    --------+---------+---------+---------+-
                                         -1.2       0.0       1.2       2.4
```

Hydrographic Methods Document

1.0 Introduction

This document outlines the methodology used by Cefas to fulfill the requirements of the sanitary survey procedure with regard to hydrographic evaluation of shellfish production areas. It is written as far as possible to be understandable by someone who is not an expert in oceanography or computer modelling. This document collects together information common to all hydrographic assessments avoiding the repetition of information in each individual report.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only and is not discussed in any detail in this document. Selected sites will be assessed in more detail using either: 1) a hydrodynamic model, or 2) an extended consideration of sources, available field studies and expert assessment. This document will focus on this more detailed hydrographic assessment and describes the common methodology applied to all sites.

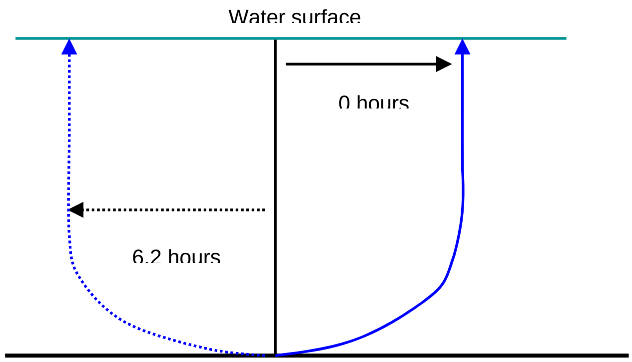
The regulations require an appreciation of the hydrography and currents within a region classified for shellfish production.

2.0 Background processes

This section gives an overview of the hydrographic processes relevant to sanitary surveys.

Movement in the estuarine and coastal waters is generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences. Unless tidal flows are weak they usually dominate over the short term (~12 hours) and move material over the length of the tidal excursion. The tidal residual flow acts over longer time scales to give a net direction of transport. Whilst tidal flows generally move material in more or less the same direction at all depths, wind and density driven flows often move material in different directions at the surface and at the bed. Typical vertical profiles are depicted in figure 1. However, it should be understood that in a given water body, movement will often be the sum of all three processes.

a)



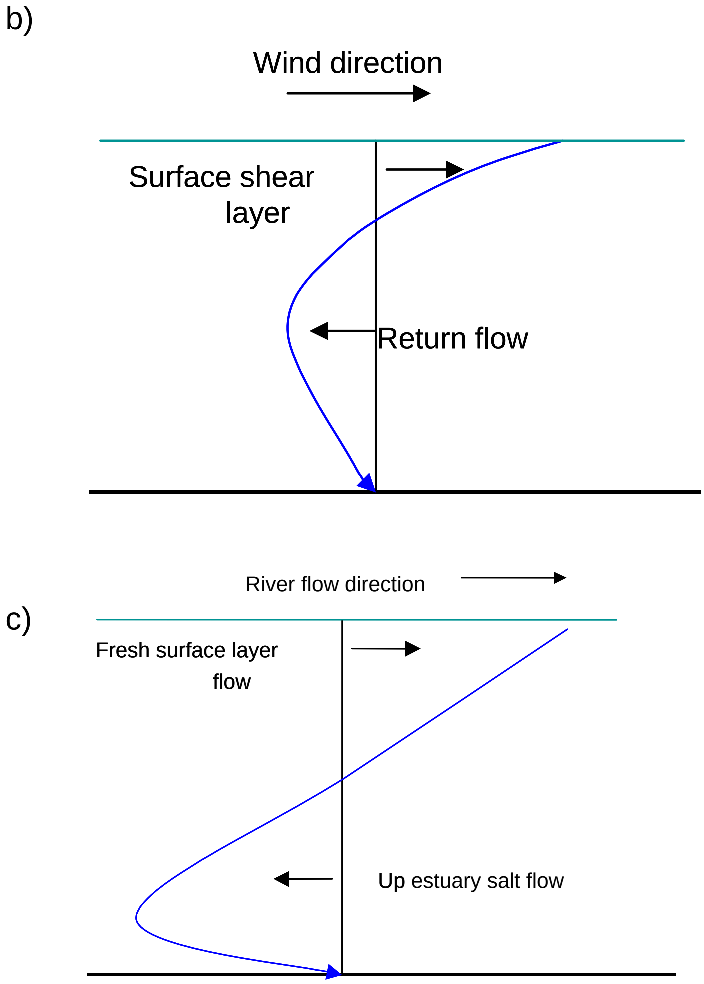


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction over a period of 6.2 hours. b) wind driven current profile, c) density driven current profile.

In sea lochs, mechanisms such as “wind rows” can transport sources of contamination at the edge of the loch to production areas further offshore. Wind rows are generated by winds directed along the main length of the loch. An illustration of the waters movements generated in this way is given in Figure 2. As can be seen the water circulates in a series of cell that draw material across the loch at right angles to the wind direction. This is a particularly common situation for lochs with high land on either side as these tend to act as a steering mechanism to align winds along the water body.

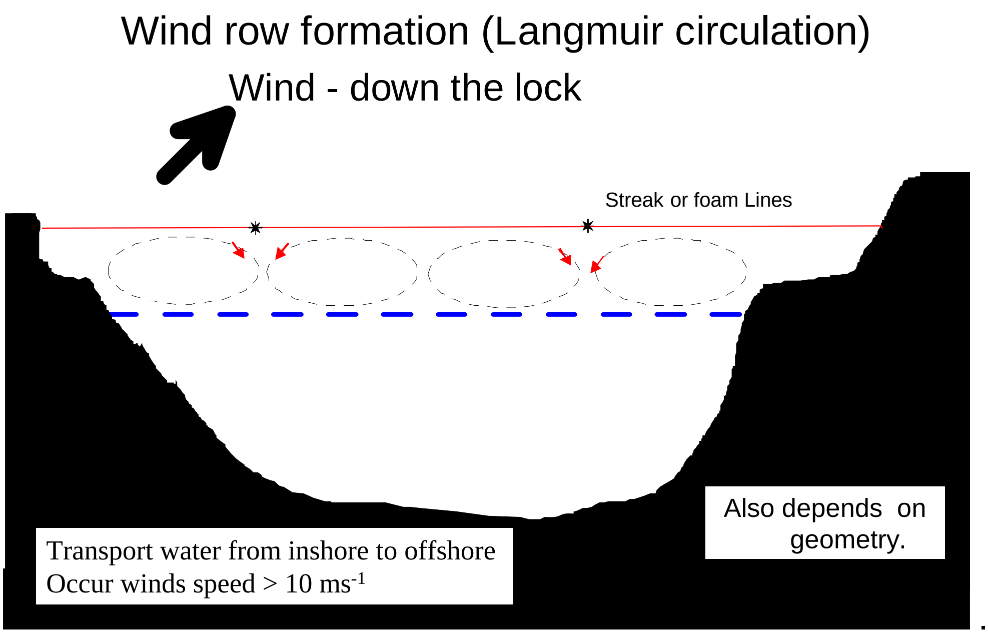


Figure 2: Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

3.0 Basic Assessment

This will be applied to most sites and consists of a description of bathymetry and the tidal regime obtained from admiralty charts and tidal diamonds and is not described in detail here.

4.0 More Detailed Assessment

This is applied at the request of the regulator (FSAS) when particular circumstances apply. Typically this will be at sites where production areas regular fail or where unusual results have been reported.

3.1 Modelling approach

The Hydrotrack computer model is used. This is able to simulate depth averaged tidal currents and give some indication of wind driven currents. Model output from the model is analysed to provide information on:

- Particle paths due to tides and winds.
- Residual current patterns due to tide and winds.

Tidal forcing is a simple sinusoidal current applied at the model boundary. Where possible the assumption is made that the change in tidal phase across the boundary is negligible. Basic checking of the model is limited to the available data. In most cases this is limited to reproducing the observed tidal range. If tidal diamond or current meter observations are available, model results are checked against these.

Model calculations are carried out for five cases: tides only and tides plus winds from north, south east and west directions. The resulting winds patterns are for winds blowing constantly for 48 hours so that a steady current pattern is produced. In reality of course winds are highly variable. For each of these cases the results over the last two tidal periods are analysed to provide tidal phase and amplitude and the residual current. The paths of particles moving with the water and starting from known sources of contamination are calculated using the analysed currents. For point sources very near the shore, model release points may be moved slightly offshore out to ensure particles are caught by the prevailing current and not trapped at the release point.

For a given water body, the strength of the applied wind is chosen to ensure wind driven currents are large relative to the tidal currents so that particle paths clearly show the wind driven movement.

Although Hydrotrack calculates currents over the spatial area of a water body, it cannot calculate the vertical profile of currents. Although adequate for tidal flows this has limitations for wind and density driven systems characteristic of many sea lochs. Therefore the modelling approach is more usefully applied to tidally dominated systems or shallow regions where vertical structure may be less significant.

3.2 Non-modelling approach

In this approach the assessment requires a certain amount of expert judgment and subjectivity enters in. For all production areas, the following general guidelines are used:

1. Near-shore flows will generally align parallel to the shore.
2. Tidal flows are bi-directional, thus sources on either side of a production area are potentially polluting.
3. For tidal flows, the tidal excursion gives an idea of the likely main ‘region of influence’ around an identified pollutant source.
4. Wind driven flows can drive material from any direction depending on the wind direction. Wind driven current speeds are usually at a maximum when the wind direction is aligned with the principle axis of the loch.
5. Density driven flows generally have a preferred direction.
6. Material will be drawn out in the direction of current, often forming long thin ‘plumes’.
7. Estimates of flow speed combined with T_{90} will give a ‘region of influence’.
8. The ratio of river run-off to tidal prism gives an indication of the importance of density effects.

Many Scottish shell fish production areas occur within sea lochs. These are fjord like water bodies consisting of one or more basins, deepened by glacial activity and having relatively shallow sills that control the mixing and flushing processes.

The sills are often regions of relatively high currents, while the basins are much more tranquil often containing higher density water trapped below a fresh lower density surface layer. Tidal mixing primarily occurs at the sills.

For the more detailed assessment of sea loch regions, the “Sea Loch catalogue” produced by the SMBA is used to quantify sills, volume fluxes and likely flow velocities. Because the flow is so constrained by the rapidly varying bathymetry, care has to be used in the extrapolation of direct measurements of current flow. Mean flow velocities can be estimated at the sills by using estimates of the sill area and the volume change through a tidal cycle. This in turn can be used to estimate the maximum distance travelled in a tidal cycle in the sill area. Away from the sill area, tidal velocities are general low and transport events are dominated by wind or density effects. Sea Lochs generally have a surface layer of fresher water, the extent of this depends, on freshwater input, sill depth and quantity of mixing.

In addition to movement of particles by currents, dilution is also an important consideration. Dilution reduces the effect of an individual point source although at the expense of potentially contaminating a larger area. Thus class A production areas can be achieved in water bodies area with significant faecal coliform inputs if no transport pathway exists and little mixing can occur. Conversely a poor classification might occur where high mixing causes high and permanent background concentrations arising from many weak diffuse sources.

Dilution calculations in regions with steep and variable bathymetry typical of sea lochs are extremely difficult. The following methods are applied.

For class A and B classifications, correlation with data (European Commission 1996) suggest the following water concentration need to be achieved:

Class A: 1 bacterium per 100 ml = 10^4 m^{-3}
Class B: 100 bacterium per 100 ml = 10^6 m^{-3}

3.2.1 Integrated inputs

Given *E. coli* loadings and estimates of water body volume and flushing time, the E. coli concentration averaged over the entire water body can be estimated from

$$C = S T_f / V$$

C = number *e-coli* m^{-3}
S = Sum of all loadings (number of *e-coli* per day)
T_f = Flushing time (days)
V = Water body volume (m^3)

This can then be compared with the Class A and B requirements.

3.2.2 Individual inputs

For a source with a loading M *E. coli* per second, discharging into water flowing at speed u (ms^{-1}), the number of *E. coli* per meter in the flow direction is given by M/u (*E. coli* m^{-1}). To achieve a target concentration of T, the cross sectional area that the material needs to be mixed over is given by

$$A = M/(u\ T)$$

Assuming an average depth for the water body this can be converted to a distance offshore. A subjective judgement can then made as to whether this is likely to occur over the relevant time scales (< 3 days). That is, will the required dilution occur quickly enough that only localised impacts would be expected? For sea lochs the assumption is made that away from the sills, mixing is likely to be quite weak.

Reference:

European Commission 1996. Report on the equivalence of EU and US legislation for the Sanitary Production of Live Bivalve Molluscs for Human Consumption. EU Scientific Veterinary Committee Working Group on Faecal Coliforms in Shellfish, August 1996.

Glossary of terms

The following technical terms appear in the hydrographic assessment.

Bathymetry. The underwater topography given as depths relative to some fixed reference level e.g. mean sea level.
Hydrography. Study of the movement of water in navigable waters e.g. along coasts, rivers, lochs, estuaries.
Tidal period. The dominant tide around the UK is the twice daily one generated by the moon. It has a period of 12.42 hours. For nearshore so-called rectilinear tidal currents then roughly speaking water will flow one way for 6.2 hours then back the other way for 6.2 hours.
Tidal range. The difference in height between low and high water. Will change over a month.
Tidal excursion. The distance travelled by a particle over one half of a tidal cycle (roughly~6.2 hours). Over the other half of the tidal cycle the particle will move in the opposite direction leading to a small net movement related to the tidal residual. The excursion will be largest at Spring tides.
Tidal residual. For the purposes of these documents it is taken to be the tidal current averaged over a complete tidal cycle. Very roughly it gives an idea of the general speed and direction of travel due to tides for a particle over a period of several days.
Tidal prism. The volume of water brought into an estuary or sea loch during half a tidal cycle. Equal to the difference in estuary/sea loch volume at high and low water.
Spring/Neap Tides. The strongest tides in a month are called spring tides and the weakest are called neap tides. Spring tides occur every 14 days with neaps tides occurring 7 days after springs. Both tidal range and tidal currents are strongest at Spring tides.
Tidal diamonds. The tidal velocities measured and printed on admiralty charts at specific locations are called tidal diamonds.
Wind driven shear/surface layer. The top metre or so of the surface that generally moves in the rough direction of the wind typically at a speed that is a few percent (~3%)of the wind speed.
Return flow. Often a surface flow at the surface is accompanied by a compensating flow in the opposite direction at the bed (see figure 1).
Stratification. The splitting of the water into two layers of different density with the less dense layer on top of the denser one. Due to either temperature or salinity differences or a combination of both.