Scottish Sanitary Survey Project

Sanitary Survey Report
Loch a' Chumhainn: Inner Deep Site (AB112)
and Loch A Cumhainn: Outer (AB113)
March 2010

Draft Report Distribution – Loch a' Chumhainn

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

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1. General Description

Loch a' Chumhainn is an enclosed sea loch located on the Isle of Mull, on the west coast of Scotland. The majority of the loch is enclosed and therefore fairly sheltered. The loch is 5.4 km in length, 0.07 km at its narrowest and 2.4 km at its widest point. The southern end of the loch has extensive drying areas, whilst the northern end of the loch reaches depths of up to 20 m.

This sanitary survey is being undertaken at the request of FSAS as it is included in a norovirus surveillance study.

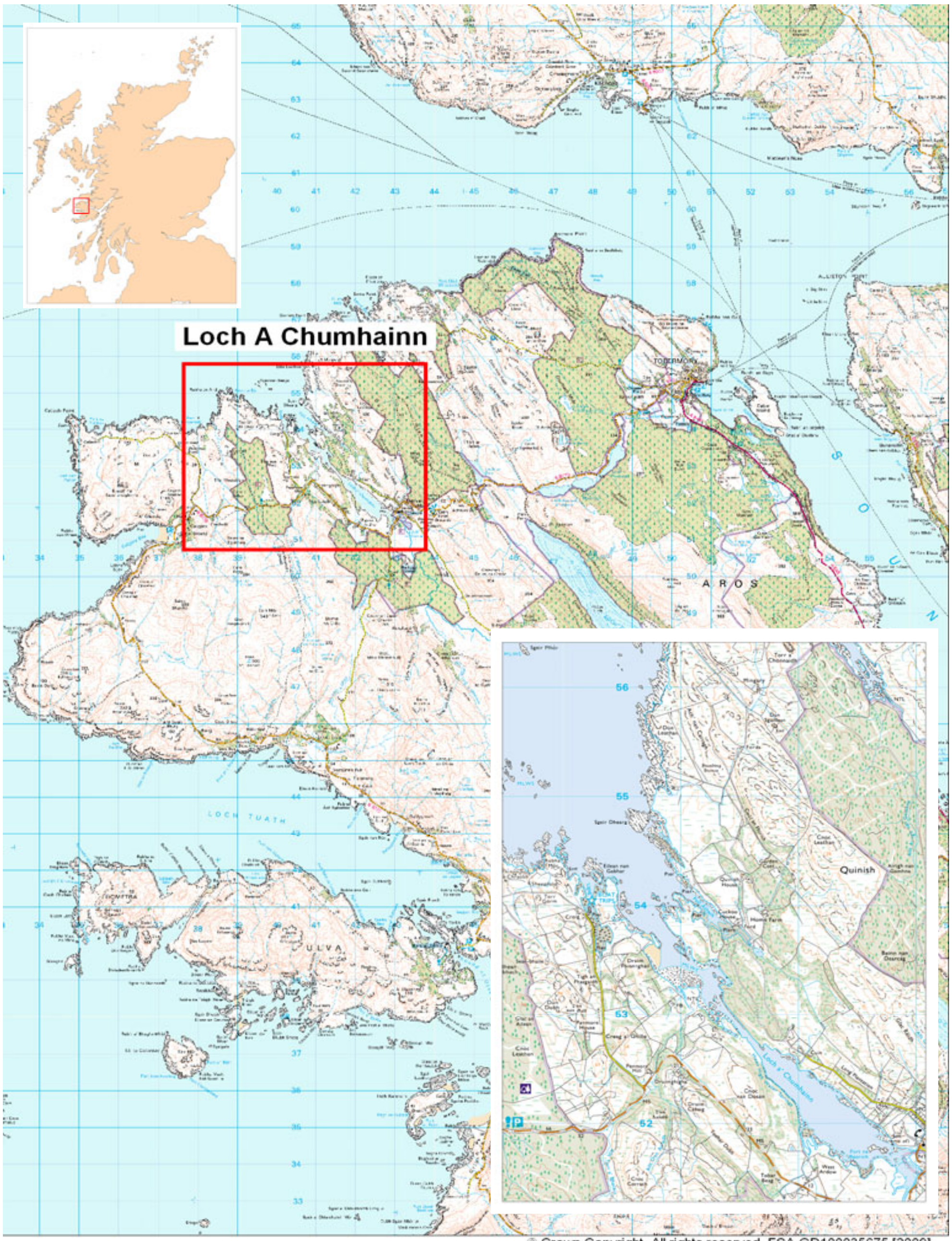


Figure 1.1 Location of Loch a' Chumhainn

2. Fishery

Loch a' Chumhainn contains two adjacent production areas, both currently classified for the harvest of Pacific oysters. There is one site in each production area, and both sites are under the same ownership.

Table 2.1 Loch a' Chumhainn shellfish sites

Production area	Site	SIN	Species
Loch a' Chumhainn: Inner Deep Site	Inner Deep Site	AB 112 017	Pacific oysters
Loch a' Chumhainn: Outer	Outer	AB 113 018	Pacific oysters

Loch a' Chumhainn: Inner Deep Site (AB 112 017) is the area to the east of a line drawn between NM 4040 5425 and NM 4095 5411. There is also a CE lease area associated with this site, and an RMP at NM 406 539. An area of trestles is located in the intertidal zone where Pacific oysters (*Crassostrea gigas)* are cultured from seed. Classification samples are taken from a cage located just to the north of the trestles that is only accessible by boat. A second dedicated sampling cage is located close to the high water mark at the southern end of the site, and is only used for biotoxin sampling. Oysters were being hardened off for market on some trestles near this cage at the time of shoreline survey. There is a storage/processing shed on the shore by this site, but no depuration facilities.

Loch a' Chumhainn: Outer (AB 113 018) is bounded by a line drawn between NM 3862 5505 (Rubha an Aird) and NM 4090 5707 (Quinish Point) and between NM 4040 5425 and NM 4095 5411. There is one Crown Estate (CE) lease area within this production area, and a Representative Monitoring Point (RMP) at grid reference NM 408 547. There is a single oyster cage at this site, which is used for classification sampling purposes and is only accessible by boat. Oysters from the Inner Deep Site are sometimes relaid here when the Inner Deep Site is classified as B, and the Outer site classified as A, to avoid the need for depuration. Both production areas have received A classifications since October 2006, so there has been little need for this site in recent years.

Stock of a range of sizes were present at the Inner Deep Site at the time of shoreline survey.

The production areas, locations of the present fisheries and the RMPs are shown in Figure 2.1.

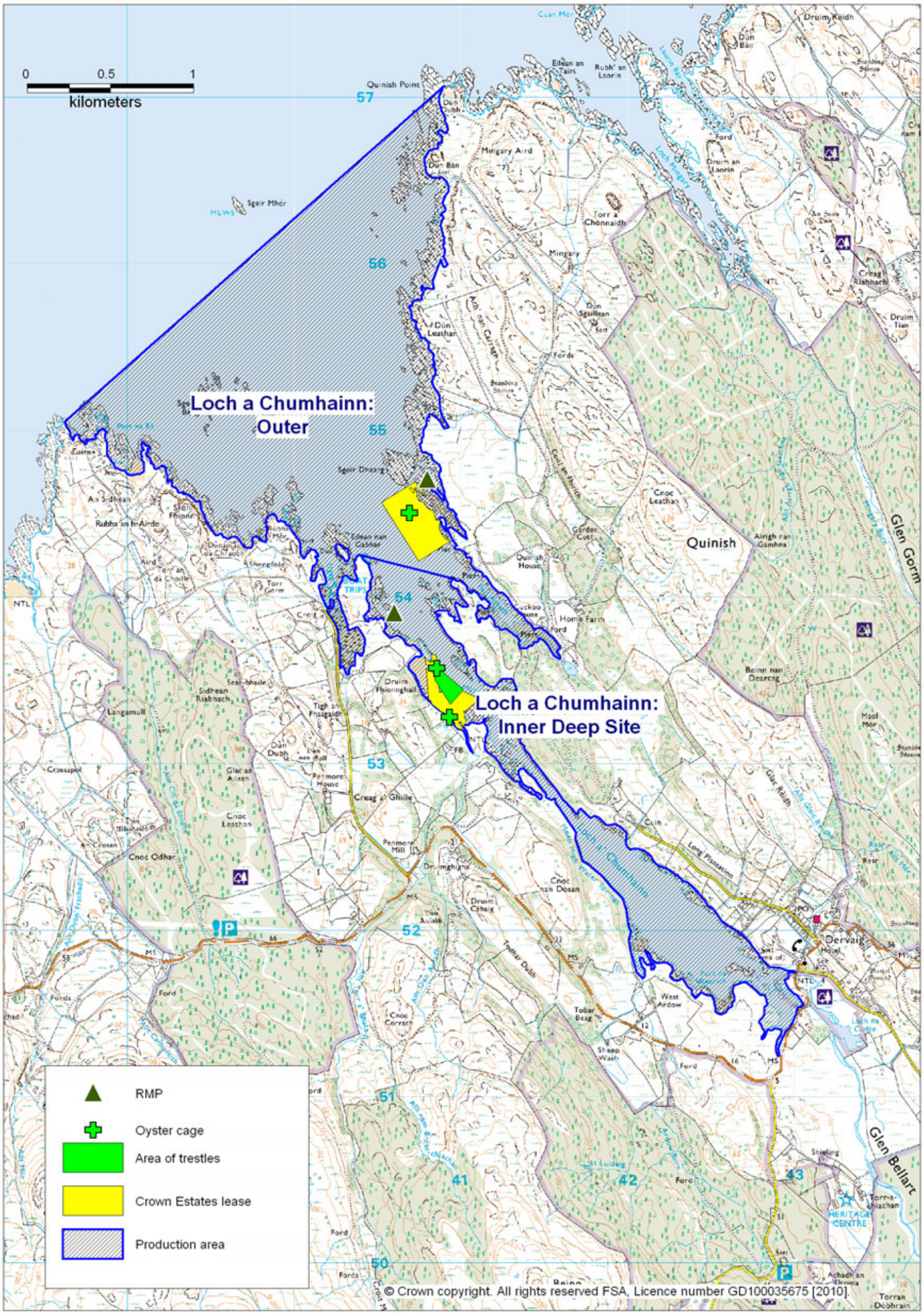


Figure 2.1 Loch a' Chumhainn fishery

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Loch a' Chumhainn. The last census was undertaken in 2001.

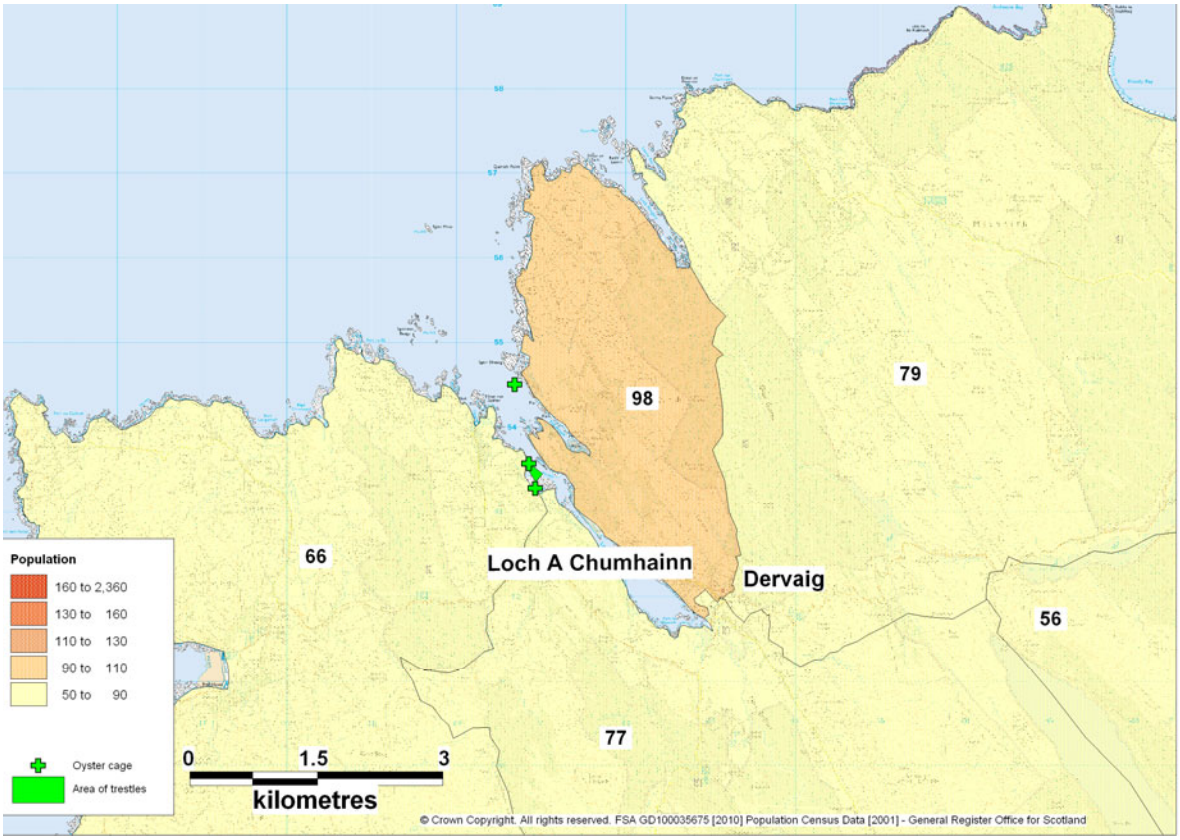


Figure 3.1 Human population surrounding Loch a' Chumhainn

Loch a' Chumhainn is bordered by four census output areas, with a population of 98 and 79 to the east, and 66 and 77 to the west and southwest. The village of Dervaig lies at the head of the loch, overlapping two of the census areas and accounting for a significant proportion of the population of the census area on the eastern side of the loch. No specific population information was available for Dervaig. Outside the village, the population is sparse with just a few scattered dwellings by the shores of the loch.

Dervaig itself is a tourist destination, with hotel, B&B and self catering accomodation. It is likely that the population in the area will be significantly larger during the summer tourist season, roughly June to September.

4. Sewage Discharges

One community septic tank was identified by Scottish Water for the area, which is consented to serve 198 people and discharges to the head of the loch at Dervaig (see Table 4.1). This system also has a. combined sewer and emergency overflow discharging at the same location, which has a predicted spill frequency of 8.8 spills of over 50 m^3 per year.

Table 4.1 Discharges identified by Scottish Water

Ref No.	NGR	Discharge Type	Level of Treatment	Consented flow (DWF) m3/d	Consent/ design PE	Discharge Name
CAR/L/1019750	NM 4283 5177	continuous	septic tank & reed bed	43.1	198	Dervaig
CAR/L/1019750	NM 4283 5177	intermittent	6mm screening		198	Dervaig PS CSO & EO

No sanitary or microbiological data is available for these discharges. Twenty-two discharge consents have been issued by SEPA within the area mapped in Figure 4.1, details of which are presented in Table 4.2.

Table 4.2 Discharge consents issued by SEPA

No.	Ref No.	NGR	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
DC1	CAR/R/1011542	NM 4017 5393	Domestic	Septic tank		15	Loch a' Chumhainn
DC2	CAR/R/1017518	NM 4149 5193	Domestic	Septic tank		14	Land via soakaway
DC3	CAR/R/1017563	NM 4355 5141	Domestic	Package plant		11	Land via soakaway
DC4	CAR/R/1018132	NM 4371 5131	Domestic	Package plant		10	Aghan Tyme Burn via partial soakaway
DC5	CAR/R/1018340	NM 4042 5207	Domestic	Septic tank		5	Land via soakaway
DC6	CAR/L/1019750	NM 4283 5177	Treated effluent / CSO and EO	Septic tank and reedbed / 6mm screen	43.1	198	Loch a' Chumhainn
DC7	CAR/R/1020514	NM 4011 5239	Domestic	Package plant	3.85	6	Unnamed watercourse via partial soakaway
DC8	CAR/S/1020919	NM 4078 5242	Treated effluent	Not stated		70	Allt Torr a Bhacain
DC9	CAR/R/1021957	NM 4331 5167	Domestic	Septic tank		16	Land via soakaway
DC10	CAR/R/1027613	NM 4130 5275	Domestic	Septic tank		5	Land via soakaway
DC11	CAR/R/1028994	NM 4366	Domestic	Septic tank		6	Land via

No.	Ref No.	NGR	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
		5139					soakaway
DC12	CAR/R/1034099	NM 4019 5395	Domestic	Package plant		8	Loch a' Chumhainn
DC13	CAR/R/1034517	NM 4302 5141	Domestic	Septic tank		10	Land via soakaway
DC14	CAR/R/1034866	NM 4035 5206	Domestic	Septic tank		6	Land via soakaway
DC15	CAR/R/1037360	NM 4038 5235	Domestic	Septic tank		6	Land via soakaway
DC16	CAR/R/1039184	NM 4300 5151	Domestic	Untreated, to be upgraded to septic tank by May 2012		5	Loch a' Chumhainn
DC17	CAR/R/1039846	NM 4319 5215	Domestic	Septic tank		5	Unnamed watercourse via partial soakaway
DC18	CAR/R/1039924	NM 4182 5147	Domestic	Septic tank		5	Land via soakaway
DC19	CAR/R/1041920	NM 40340 52070	Domestic	Septic tank		5	Land via soakaway

Of these, four discharge directly to Loch a' Chumhainn, including the Scottish Water discharge at Dervaig (DC 6), two private discharges at Croig (DC1 and DC 12), and one private discharge at Dervaig (DC 16). A further three discharge to watercourse via partial soakaway, two of these at Dervaig (DC 4 and DC 17), and one to an unnamed tributary of the watercourse named Allt Torr a Bhacain (DC 7), which is the main freshwater input in the bay in which the Inner Deep Site is located. Discharging direct to Allt Torr a Bhacain is a private discharge from a restaurant (DC 8) that has its own small treatment works consented for a maximum population of 70, although it is unlikely to be operating at this capacity for much of the time. Finally, there are 11 consents for private discharges to soakaway at Dervaig and to the west of Loch a' Chumhainn, but if these are functioning correctly they are likely to be of little impact to water quality in the loch.

As there has not historically been a requirement to register septic systems in Scotland, this list is unlikely to cover all septic tanks in the area. A physical survey of the shoreline was undertaken and observations of septic tanks and/or outfalls present along the shoreline of Loch a' Chumhainn are presented in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline survey

No.	Date	NGR	Observation	Ref No.
1	25-AUG-09	NM 39212 54646	Septic tank to soakaway, 1 cottage	
2	25-AUG-09	NM 38893 54796	Septic tank to soakaway, 2 holiday cottages	
3	25-AUG-09	NM 39535 54228	Septic tank to soakaway, 1 house	
4	25-AUG-09	NM 39496 54280	Septic tank to soakaway from B&B	
5	25-AUG-09	NM 40184 53938	Private sewer pipe to loch serving 1 house	CAR/R/1034099 CAR/R/1011542
6	25-AUG-09	NM 43052 51749	Scottish water pumping station	CAR/L/1019750
7	25-AUG-09	NM 42920 51756	Scottish Water outfall pipe to underwater.	CAR/L/1019750
8	25-AUG-09	NM 43403 51430	Scottish Water septic tank and reedbed treatment works	CAR/L/1019750
9	25-AUG-09	NM 43004 51490	Private sewer pipe to loch, 1 house	Possibly CAR/R/1039184
10	25-AUG-09	NM 42984 51419	Private sewer pipe to loch, 1 house	Possibly CAR/R/1039184
11	25-AUG-09	NM 42962 51368	Private sewer pipe to loch, 1 house & chalet	Possibly CAR/R/1039184
12	26-AUG-09	NM 42092 52594	Septic tank to soakaway	

Observations 1 to 4 and 12 were small private discharges to soakaway, and so if functioning correctly they are likely to be of little impact to water quality in the loch. Observation 5 was one of the two private discharges at Croig (Table 4.2, DC 1 and DC 12). Only one of these discharges was seen during the shoreline survey. Observations 6 to 8 apply to the Scottish Water treatment works at Dervaig and its associated pumping station and discharge pipe to the head of Loch a' Chumhainn. Observations 9 to 11 were three private discharges to Loch a' Chumhainn at Dervaig, one of which has a SEPA consent (Table 4.2, DC 16) specifying it is a raw discharge that is requiring upgrading to septic tank by May 2012.

There is limited boat traffic centred around Croig pier, where a few small boats are kept. A larger fishing boat was also observed landing here during the shoreline survey. Yachts are likely to visit the loch from time to time, but not in great numbers. Clyde Cruising Club publications indicate yacht anchorages just to the north and east of Croig. Of these boats, larger live aboard yachts are most likely to discharge waste water.

In summary, the bulk of discharges to water are at Dervaig, at the head of the loch. Also of likely significance is the restaurant discharge to Allt Torr a Bhacain, the main freshwater input to the bay in which the Inner Deep Site is located. This watercourse also receives a smaller private discharge to one of its tributaries via partial soakaway. Also, there are two private discharges at Croig which may be of significance. It is therefore possible that the Inner Deep Site is more heavily impacted by sewage discharges than the Outer site. Boat traffic centred around Croig may impact either site.

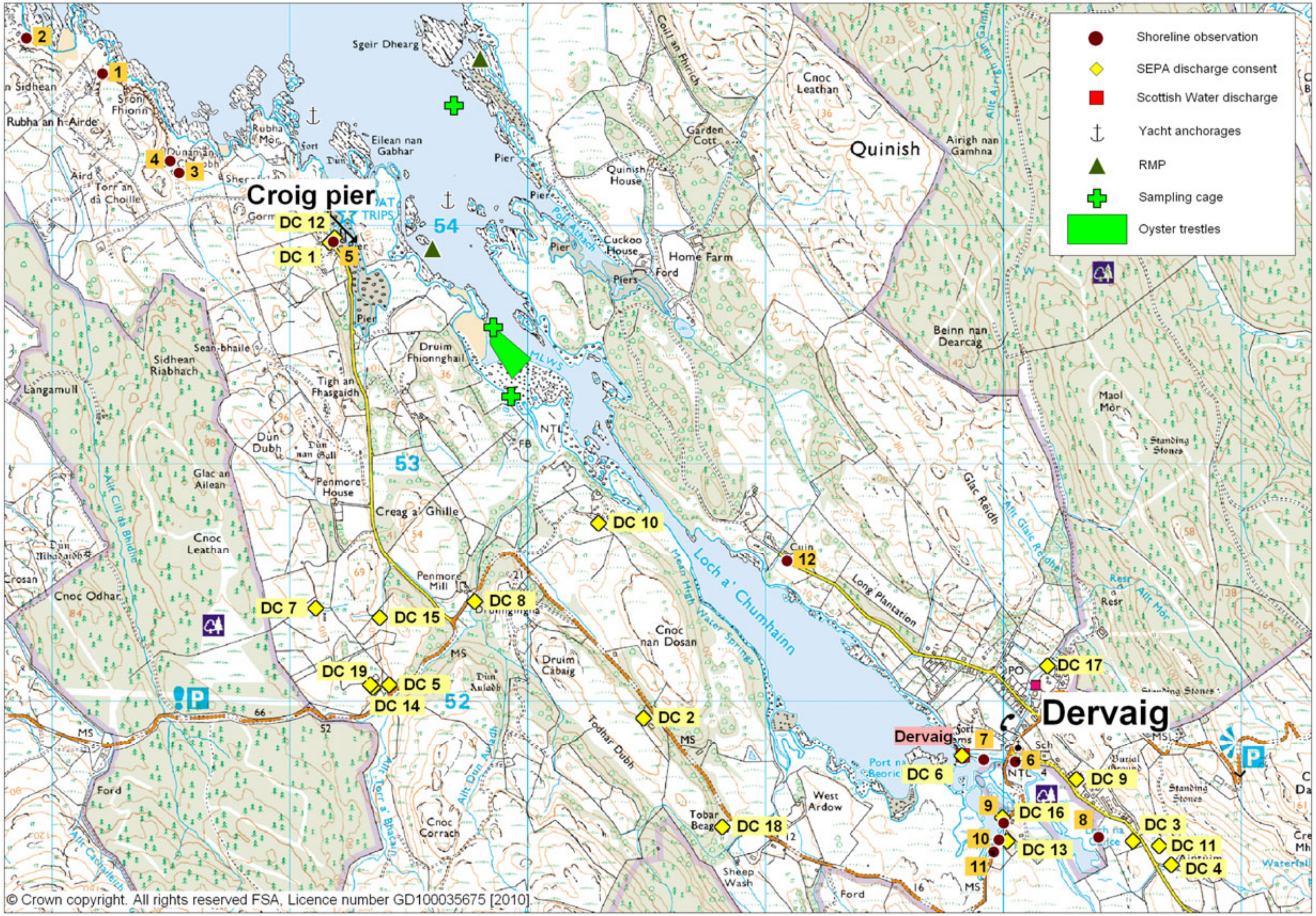


Figure 4.1 Sewage discharges at Loch a' Chumhainn

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 3. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red indicates poorly draining soils and the areas shaded blue indicate freely draining soils.

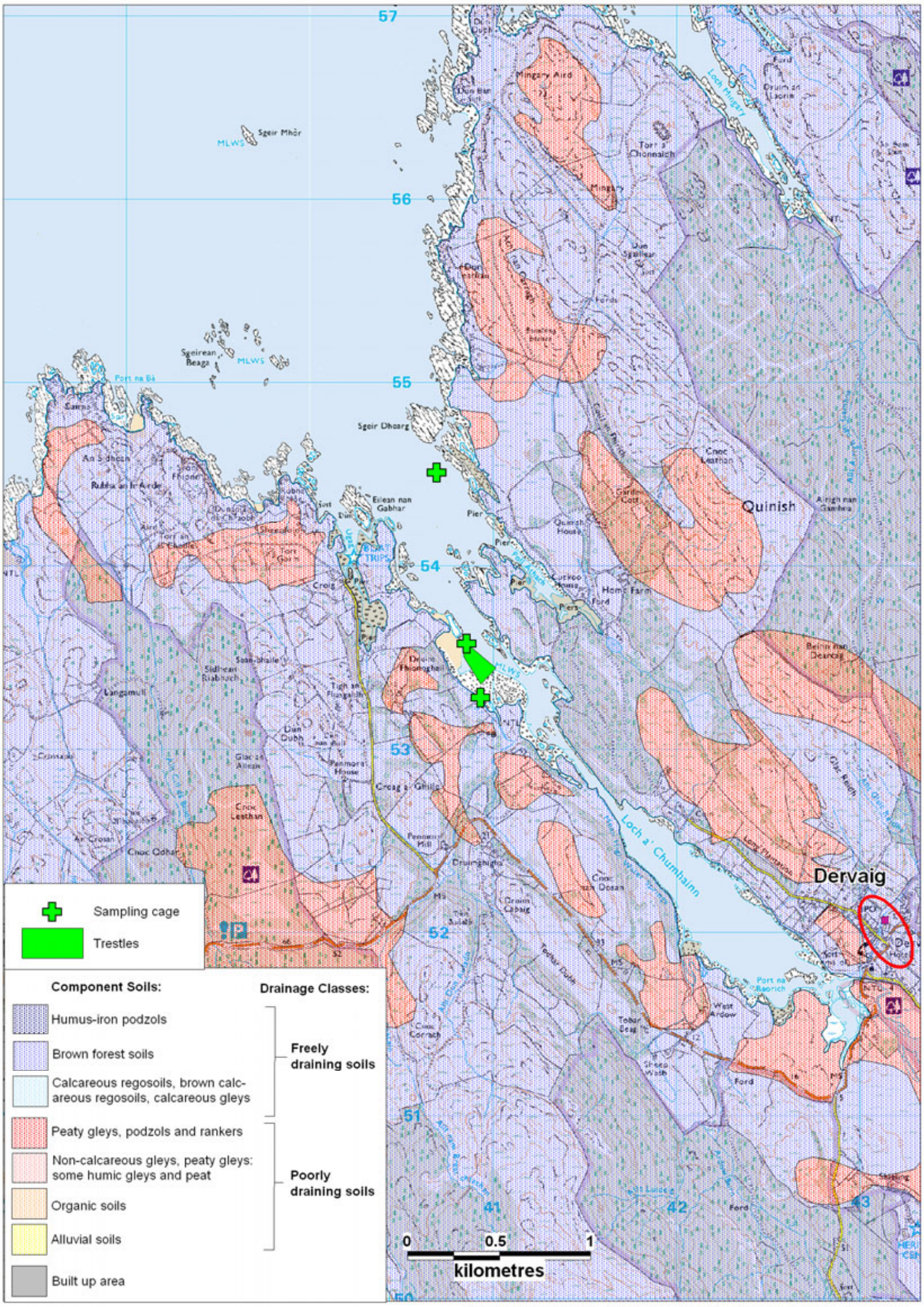


Figure 5.1 Component soils and drainage classes for Loch a' Chumhainn

Two types of component soils are are identified in the soil profile map for the area: peaty gleys, podzols and rankers and brown forest soils. The peaty gleys, podzols and rankers are poorly draining and are only found in scattered, relatively small patches around the loch including much of the shoreline at the head. The brown forest soils are freely draining and found along more of the coastline and inland. The village of Dervaig was not specifically identified as built up area in the soil map but is instead shown as brown forest soil (area outlined in red in Figure 5.1). This area should be considered built up, and as such the potential for rainfall runoff would be high from there.

Therefore, the potential for runoff contaminated with *E. coli* from human and/or animal waste is highest around the village of Dervaig and low to intermediate for much of the remaining land surrounding Loch a' Chumhainn.

6. Land Cover

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

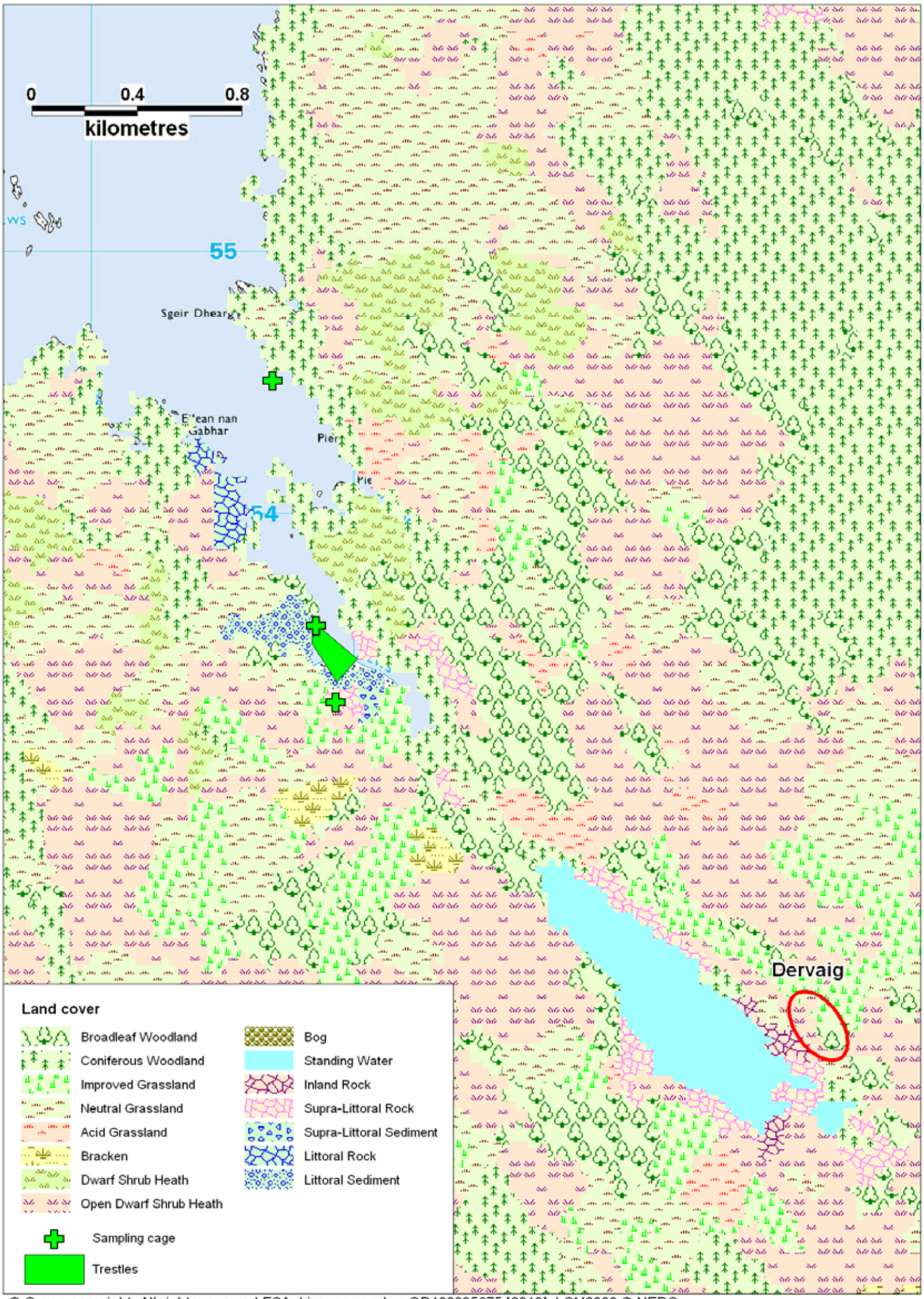


Figure 6.1 LCM2000 class land cover data for Loch a' Chumhainn

The main land cover types are coniferous and broadleaf woodland, open dwarf shrub heath, dwarf shrub heath and improved grassland. There are also several small patches of bracken and bog. The improved grassland is present in larger areas along the southern end of the loch.

The landcover map incorrectly identifies the middle portion of the loch as dry land where a narrow channel of water connects the inner and outer loch. The area at the head of the loch is noted as standing water.

As in the soil maps, the village of Dervaig has not been identified as developed area in the Landcover 2000 data. This is considered to be an oversight and the approximate location of the village has been outlined in red in Figure 6.1.

The faecal coliform contribution would be expected to be highest from developed areas (approx 1.2 – 2.8×10^9 cfu km^{-2} hr^{-1}), with intermediate contributions from the improved grassland (approximately 8.3×10^8 cfu km^{-2} hr^{-1}) and lowest from the other land cover types (approximately 2.5×10^8 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.

Therefore, the overall predicted contribution of contaminated runoff from the village of Dervaig would be highest, though this is located some distance from the fishery. Contributions from the other land cover types would be low to intermediate, and all would be expected to increase significantly following rainfall events.

Of greatest significance to the fishery would be runoff from improved grassland located to the south and west of the block of trestles at Inner Deep Site. If logging occurs at the coniferous woodland east of the cage at the outer site, this may result in a flush of contaminated runoff that could affect microbiological water quality at this site.

7. Farm Animals

Agricultural census data was received from the Scottish Government Rural and Environment Research and Analysis Directorate (RERAD) for the Kilninian and Kilmore Parish, which surrounds Loch a' Chumhainn and covers an area of 306.6 km^2. Recorded livestock populations for the parishes for 2008 are presented in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reported would have made it possible to discern individual farm data.

Table 7.1 Livestock numbers in the Kilninian and Kilmore Parish, 2007-8

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	*	*
Poultry	13	338	17	393
Cattle	23	1589	22	1373
Sheep	38	20306	38	16543
Horses used in Agriculture	*	*	*	*
Other Horses and Ponies	9	13	11	53

*Data withheld

Sheep are the predominant type of livestock kept in this parish. Due to large area of the parish, this data does not provide information on the livestock numbers in the area immediately surrounding the production areas. The only significant source of local information was therefore the shoreline survey (see Appendix), which only relates to the time of the site visit on 25-26th August 2009. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. This information should be treated with caution, as it applies only to the survey dates and is dependent upon the point of view of the observer (some animals may have been obscured from view by the terrain).

The shoreline survey identified that densities of livestock were greatest around the north end of the west shore of the loch, including pastures near the shore adjacent to the Inner Deep Site. although the majority of livestock in this area (fields of 16, 21 and 34 sheep) were in fields which would drain into the small bay northwest of Inner Deep Site where any contamination is less likely to affect the fishery. Livestock were also seen in the vicinity of Dervaig, and along the shore adjacent to the Outer site where they were fairly evenly spread.

Numbers of sheep and cattle will approximately double during May following the birth of lambs and calves, and decrease in the autumn as they are sent to market. Also, during the warmer months livestock will cool off in or drink from any watercourses they are able to access more frequently. Therefore higher contamination inputs from livestock may be expected during the summer months.

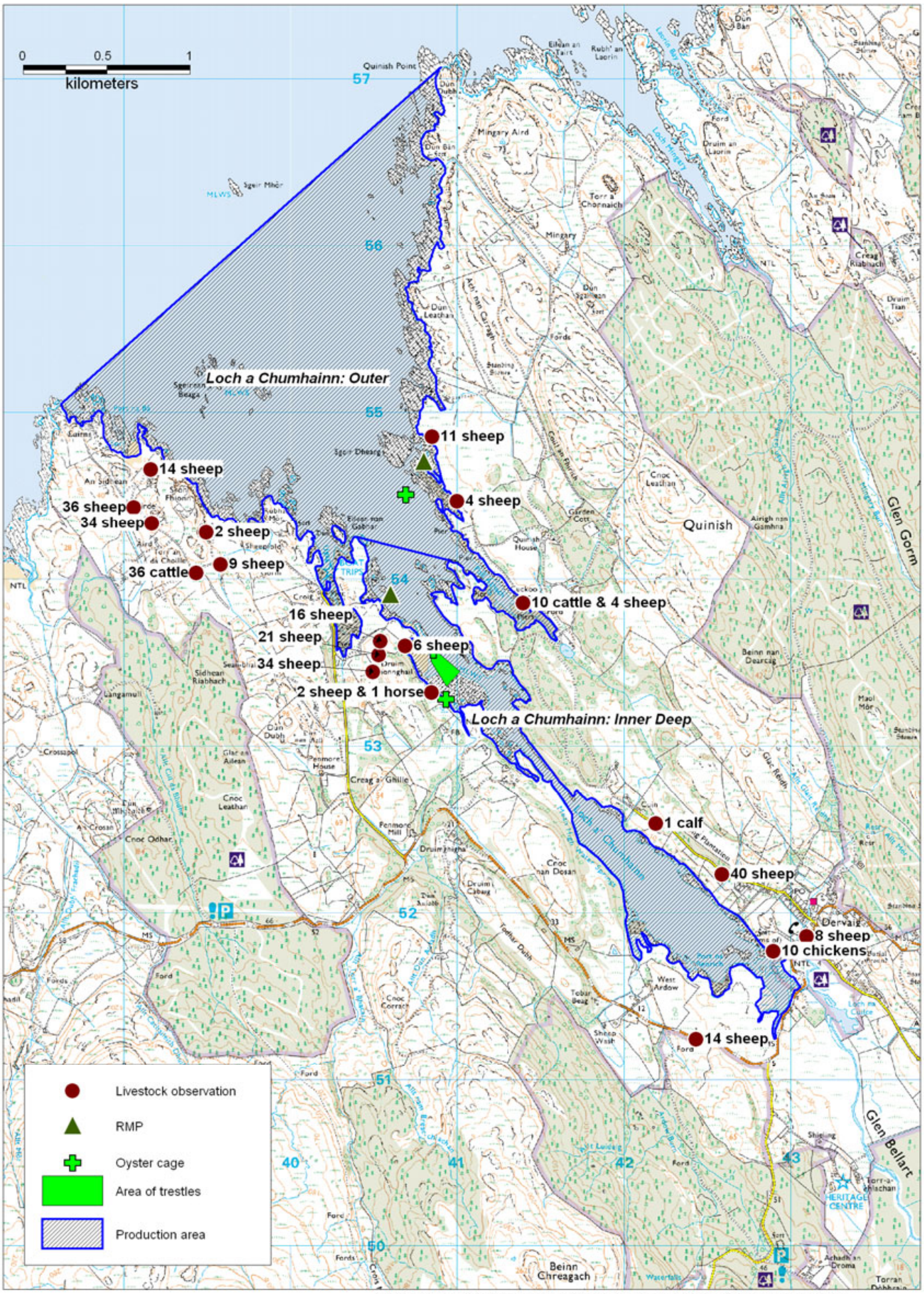


Figure 7.1 Shoreline survey livestock observations

8. Wildlife

General information related to potential risks to water quality by wildlife can be found in Appendix 4. A number of wildlife species present or likely to be present around Loch Chumhainn could potentially affect water quality around the fishery.

Seals

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*). Scotland hosts significant populations of both species.

A survey conducted by the Sea Mammal Research Unit in 2000 estimated a population of 1616 common seals on Mull (SMRU, 2007). The exact locations of the haul out sites were not specified, so it is uncertain whether they reside in the vicinity of Loch Chumhainn. Minimum grey seal pup production in the Inner Hebrides was estimated as 3461 in 2006. Adult numbers are estimated to be 3.5 times the pup population (Callan Duck, Sea Mammal Research Unit, personal communication), so it is likely this species is present in small numbers around Mull. It is uncertain whether there are any breeding colonies near the production areas.

Although no seals were seen during the course of the shoreline survey, the grower reports a substantial year round presence of seals, sometimes numbering up to 40 animals in the outer loch. Therefore, the Outer site may be more impacted by seals than the Inner Deep site.

Whales/Dolphins

A variety of whales and dolphins are routinely observed off the west coast of Scotland. It is possible that some of the smaller species of cetaceans enter the loch from time to time, although any impact of their presence is likely to be fleeting, unpredictable and confined to the outer loch.

Birds

A number of bird species are found around Loch Chumhainn, but seabirds and waterfowl are those most likely to occur around or near the fisheries in significant numbers. A number of seabird species breed in Mull. These were the subject of a detailed census carried out in the late spring of 2000 (Mitchell *et al*, 2004). Total counts of all species recorded within 5 km of the production areas are presented in Table 8.1. Where counts were of occupied sites/nests/territories, actual numbers of birds breeding in the area will be higher.

Table 8.1 Counts of breeding seabirds within 5 km of the areas

Common name	Species	Count	Method	Individual/Pair
Northern Fulmar	*Fulmarus glacialis*	243	Occupied sites	pairs
European Shag	*Phalacrocorax aristotelis*	52	Occupied nests	pairs
Herring Gull	*Larus argentatus*	45	Occupied nests	pairs
Black Guillemot	*Cepphus grylle*	15	Individuals on land	ind
Common Gull	*Larus canus*	6	Occupied nests	pairs
Razorbill	*Alca torda*	3	Individuals on land	ind

There were very few breeding seabirds recorded on the shore of Loch Chumhainn itself (6 guillemots and 6 pairs of gulls). The majority of nest sites observed were on cliffs about 4.5 km to the west of Loch Chumhainn. Therefore, these birds may feed in Loch a' Chumhainn, but not in great numbers and not in any particular area.

Waterfowl (ducks and geese) are likely to be present in the area at various times, primarily to overwinter, or briefly during migration, although some species breed on Mull in small numbers. Thirty-seven geese were observed on the east shore by the Outer site during the shoreline survey (August) suggesting there may be a small breeding population in the area.

Wading birds would be concentrated on intertidal areas, such as the area on which the trestles are located, although no aggregations were recorded during the shoreline survey.

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.

Deer will be present particularly in wooded areas where the habitat is best suited for them. Parts of the shoreline of Loch a' Chumhainn are wooded, including the shoreline opposite the Inner Deep Site. While no information was available on the population of deer in this specific area, it can be presumed that they are present. The DCS report a count of 1011 red deer and 1 roe deer for the whole of Mull, the total area of which is approximately 950 km^2.

Any impact on faecal indicator concentrations within the fisheries would be more likely at the Outer site, where significant areas of woodland are present on the adjacent shoreline. However, streams and water courses in the area may all carry at least some faecal bacteria from deer.

Otters

No otters were observed during the course of the shoreline survey, although it is believed that they are present in the area. However, the typical population densities of coastal otters are low and their impacts on the shellfishery are expected to be very minor.

Summary

In summary, the main wildlife species potentially impacting on the production areas are seals, which are present year round and more in the vicinity of the Outer site than the Inner Deep Site. Geese and seabirds may impact on the fishery to a lesser extent. However, as these animals are highly mobile, the impacts of these on the fishery will be unpredictable, and deposition of faeces by wildlife is likely to be widely distributed around the area.

9. Meteorological data

The nearest weather station is located at Ulva, approximately 12 km to the south of Loch a' Chumhainn, for which rainfall data was available for 2003-2008 inclusive apart from the months of February 2006 and June 2008. The nearest weather station for which wind data is available is Tiree, approximately 41 km to the west of the fishery. It is likely that overall wind patterns are broadly similar at Loch a' Chumhainn and at Tiree, but local topography is likely to skew these patterns in different ways, and conditions on any given day may differ due to the distance between them. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within Loch Chumhainn.

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 waste water treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003). Figures 9.1 and 9.2 present box and whisker plots which summarise the distribution of individual daily rainfall values by year and by month. 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 *.

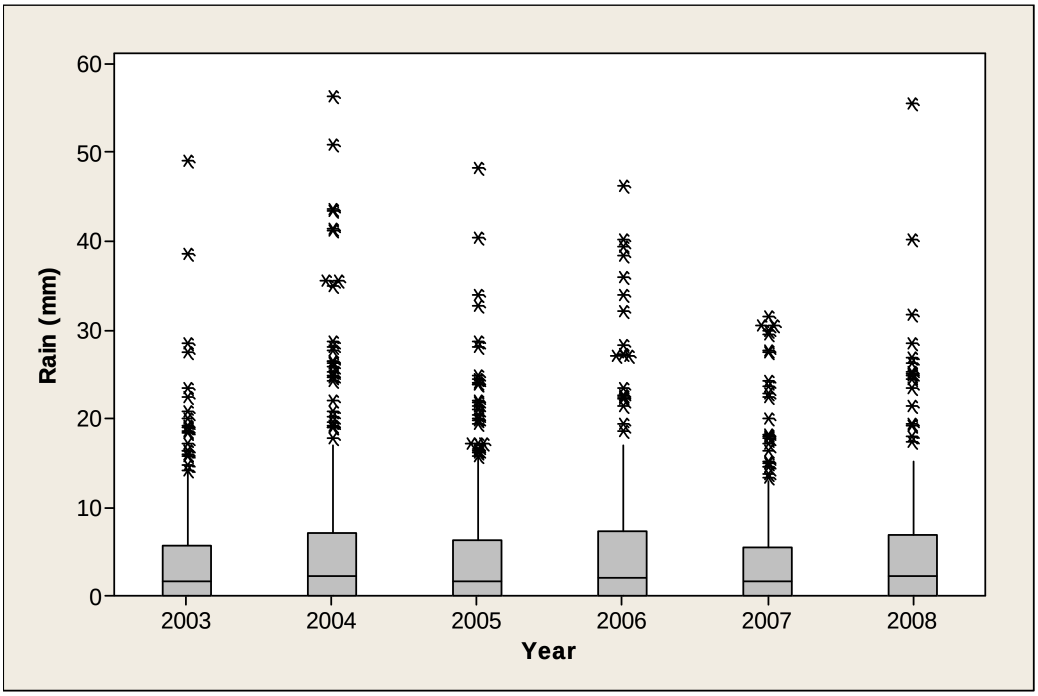


Figure 9.1 Box plot of daily rainfall values by year at Ulva, 2003-2008

Figure 9.1 shows that rainfall patterns were similar between the years presented here, although there is some variation in peak rainfall events with lower peak rainfall events observed in 2007.

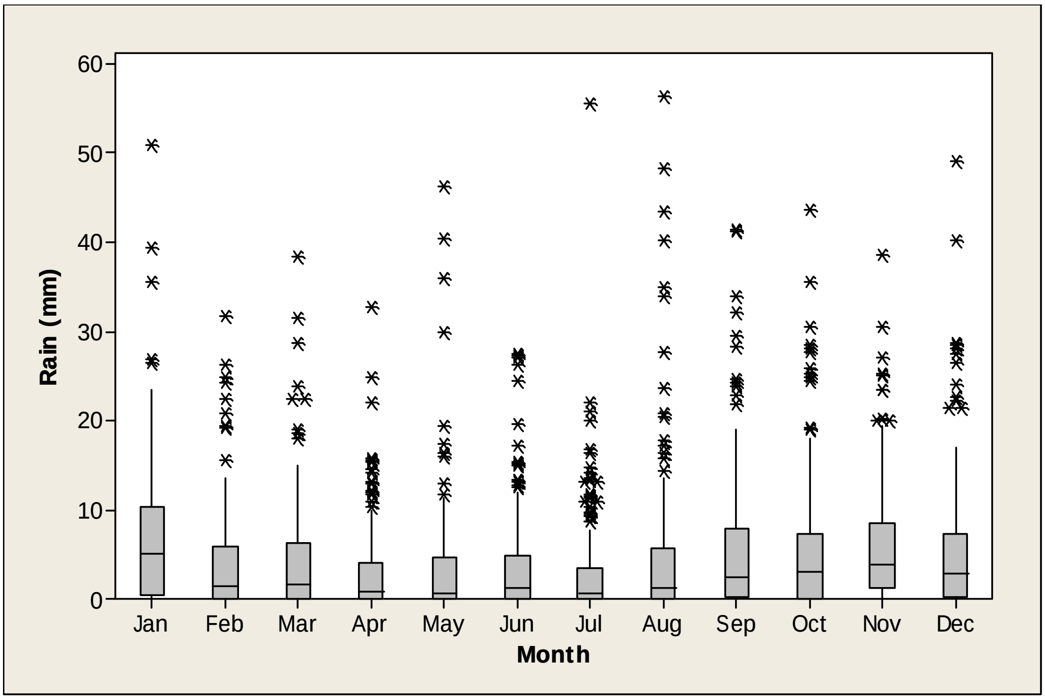


Figure 9.2 Box plot of daily rainfall values by month at Ulva, 2005-2008

The wettest month was January, and the driest month was July. A seasonal pattern is apparent with higher rainfall from September to January and lower rainfall from April to July. There is considerable variation in peak rainfall with individual events in excess of 30mm occurring in all months except June. For the period considered here (2003-2008), 42% of days experienced rainfall less than 1 mm, and 15% of days experienced rainfall of 10 mm or more.

It can therefore be expected that levels of rainfall dependent faecal contamination entering the production area from these sources will be generally be higher from September to January. High rainfall events can occur at any time of year, perhaps with the exception of July, and these may result in a 'first flush' of contaminated runoff from pastures. This effect may be particularly acute during the summer, when livestock numbers are likely to be highest, and any preceding dry periods result in a build-up of faecal contamination on pastures. High rainfall events may also result in spills of raw screened sewage at the Dervaig sewage treatment works.

9.2 Wind

Wind data collected at the Tiree weather station is summarised by season and presented in Figures 9.3 to 9.7. All wind rose figures were supplied by the Meteorological Office under license. This weather station was selected as it was the closest to Loch a' Chumhainn, and is also located within the Western Isles.

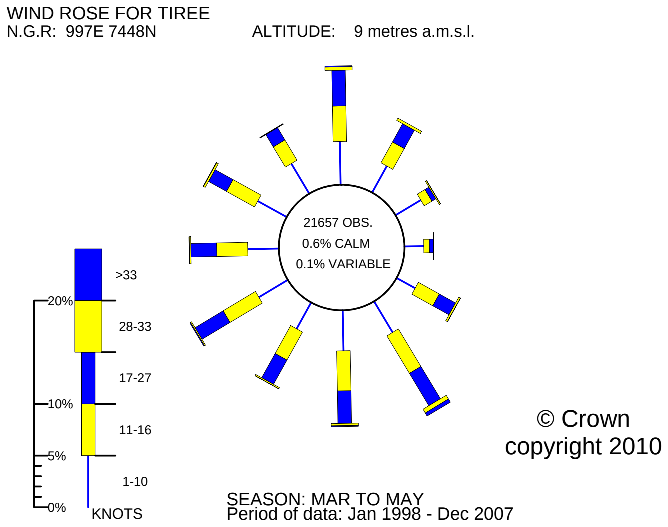


Figure 9.3 Wind rose for Tiree (March to May)

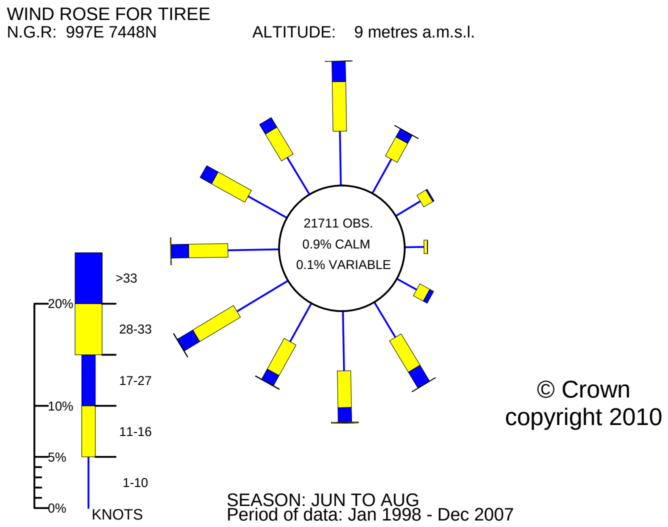


Figure 9.4 Wind rose for Tiree (June to August)

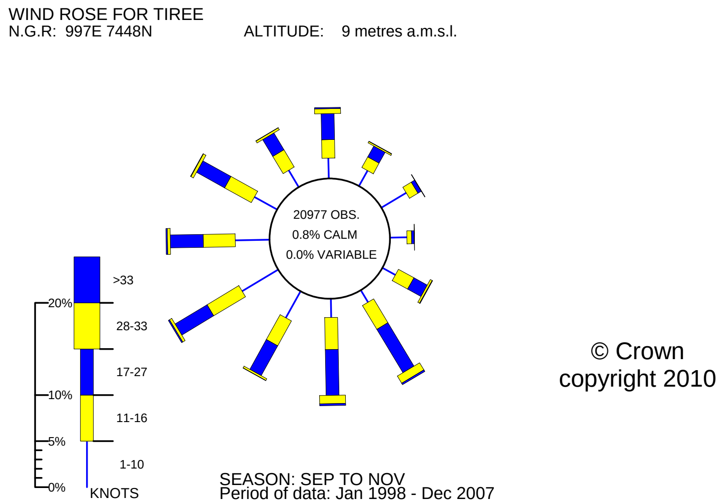


Figure 9.5 Wind rose for Tiree (September to November)

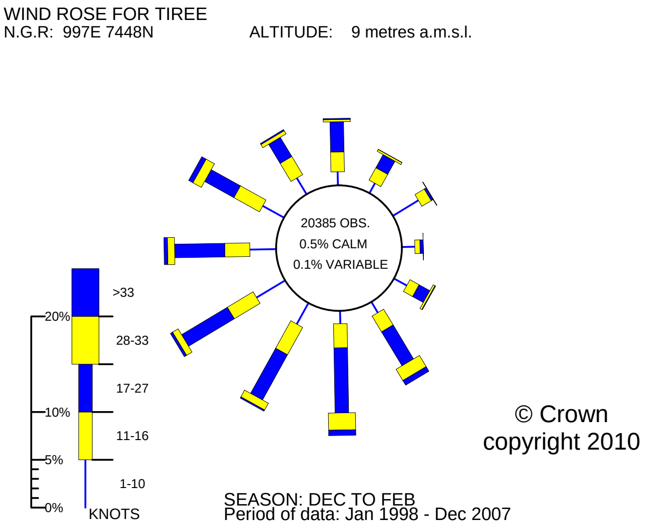


Figure 9.6 Wind rose for Tiree (December to February)

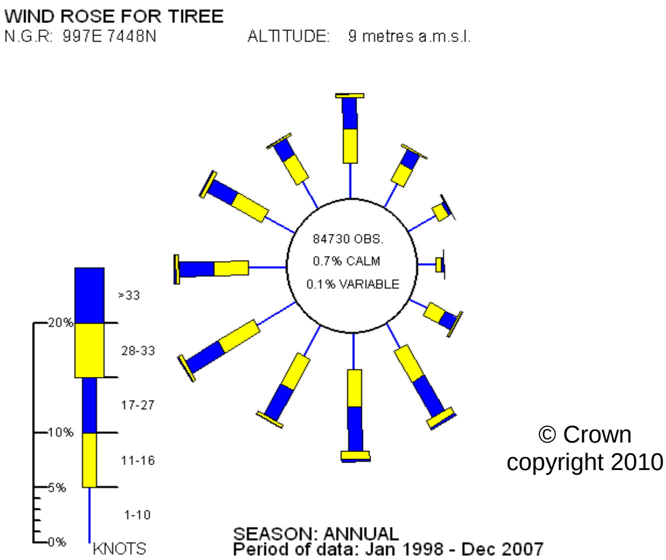


Figure 9.7 Wind rose for Tiree (All year)

Tiree is a low lying island exposed to Atlantic winds with a relatively high frequency of gales. The prevailing wind direction at Tiree is from the south and west, but wind direction often changes markedly from day to day with the passage of weather systems. Winds are generally lightest in the summer and strongest in the winter. Northerly winds are more common during the spring and summer months. Wind patterns at Tiree are likely to differ somewhat from those found at Loch a' Chumhainn. Tiree is more exposed to the open Atlantic, whereas Loch a' Chumhainnh has a north-west to south-east aspect, and is sheltered to some extent by the surrounding land which rises to over 150 m in places. Local topography is likely to channel winds up and down Loch a' Chumhainn, as well as providing some shelter. Therefore, wind patterns at Loch a' Chumhainn are likely to align more along the north-west to south-east, and may be generally lighter than at Tiree.

Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) 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. Therefore strong winds may significantly alter the pattern of surface currents within the bay and Loch a' Chumhainn, subsequently affecting the movement of freshwater-associated contamination. Strong winds may affect tide height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter from livestock, in and above the normal high water mark, into the production area. An onshore wind will result in increased wave action, which may resuspend any organic matter settled in the substrate, although the Inner Deep Site is quite sheltered from onshore winds.

10. Current and historical classification status

The two production areas considered in this report, Loch a' Chumhainn: Inner Deep Site and Loch a' Chumhainn: Outer are currently classified for the production of Pacific oysters. Their classification histories are presented in Tables 10.1 and 10.2. A map of these production areas can be found in Section 2, Figure 2.1.

Table 10.1 Classification history, Loch a' Chumhainn: Inner Deep Site, Pacific oysters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	A	A	A	A	B	B	B	B	B	B	B	A
2002	A	A	A	A	A	A	B	B	B	B	B	A
2003	A	A	A	A	A	B	B	B	B	B	A	A
2004	A	A	A	A	A	B	B	B	B	B	A	A
2005	A	A	A	A	A	B	B	B	B	A	A	A
2006	A	A	A	A	A	B	B	B	B	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
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A									

Loch a' Chumhainn: Inner Deep Site received seasonal A/B classifications from 2001 to 2006, with the exact number and timing of the B months varying from year to year but always falling between May and November. Since 2007 it has received year round A classifications.

Table 10.2 Classification history, Loch a' Chumhainn: Outer, Pacific oysters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	A	A	B	B	B	A	A	A	A	A	A	A
2003	A	B	B	A	A	A	A	A	A	A	A	A
2004	A	B	B	B	B	B	B	A	A	A	A	A
2005	A	B	B	B	B	B	B	B	B	A	A	A
2006	A	A	A	A	A	A	A	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
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A									

Loch a' Chumhainn: Outer received seasonal A/B classifications from 2002 to 2005, with the number and timing of the B months varying from year to year but always falling between February and September. Since 2006 it has received year round A classifications.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken Loch a' Chumhainn from the beginning of 2002 up to the 28th September 2009 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

One sample from the Inner Deep Site had a reported sampling location of 230 m outside the production area and was excluded from the analysis. One sample from the Outer site had a reported sampling location 14 km south of the fishery and was also excluded from the analysis. One sample from the Inner Deep Site had a reported sampling location 80 m outside of the production area, but this sample was included in the analysis as sampling locations were only recorded to 100 m accuracy at that time.

Two samples had a reported sampling location within the Outer area, but were reported as originating from the Inner Deep Site. Three samples had a reported sampling location within the Inner Deep Site area, but were reported as originating from the Outer area. These five samples were excluded from the analysis.

Two samples taken in 2004 were reported from the Loch a' Chumhainn production area (AB 111), a production area name and SIN which is no longer used. Their reported sampling location was the RMP for the Inner Deep Site, so they were reassigned to this production area (Loch a' Chumhainn: Inner Deep Site, AB 112) for the purpose of these analyses.

One sample had a reported collection time and date which was after the laboratory received time and date, so this sample was also excluded from the analysis.

Eleven samples from the Inner Deep Site and 14 samples from the Outer site had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation.

All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intravalvular fluid.

11.2 Summary of microbiological results

A summary of all sampling and results by production area are presented in Table 11.1.

Table 11.1 Summary of historical sampling and results

Sampling Summary		
Production area	Loch a' Chumhainn: Outer	Loch a' Chumhainn: Inner Deep Site
Site	Outer	Inner Deep Site
Species	Pacific oysters	Pacific oysters
SIN	AB-113-018-13	AB-112-017-13
Location	24 locations	23 locations
Total no of samples	79	83
No. 2002	10	11
No. 2003	10	10
No. 2004	11	14
No. 2005	11	11
No. 2006	10	10
No. 2007	8	8
No. 2008	11	10
No. 2009	8	9
Results Summary		
Minimum	<20	<20
Maximum	1300	2400
Median	70	70
Geometric mean	55.6	62.9
90 percentile	310	310
95 percentile	705	493
No. exceeding 230/100g	10 (13%)	12 (14%)
No. exceeding 1000/100g	2 (3%)	2 (2%)
No. exceeding 4600/100g	0 (0%)	0 (0%)
No. exceeding 18000/100g	0 (0%)	0 (0%)

The summary statistics presented in Table 11.1 indicate that the historic sampling results are similar between the two production areas.

11.3 Overall geographical pattern of results

Figure 11.1 presents a map showing geometric mean result by reported sampling locations. Since 2007, sampling locations have been recorded to nominal 1 m accuracy, and so it was not possible to plot all individual sampling locations on Figure 11.1 in a clear manner. Instead, individual samples were clustered into geographic groups where feasible and geometric mean results calculated for these locations. One result plots on land, however as it falls within 100 m of the production area boundary it was included in the overall analysis and so appears on the map. It is not considered in the geographic assessment.

From 2002 to 2007 all samples were reported from the nominal RMP at the outer site, and most were reported from the nominal RMP at the Inner Deep Site. From mid 2007 onwards, sampling locations were recorded using a GPS at the time of sampling. Samples from this period were taken from a dedicated sampling cage accessed by boat, and when this was retrieved for sampling, it was often redeployed in a slightly different position as the boat drifted, and so has moved over time. For example, the sampling cage at the Outer site appears to have moved north between 2007 and 2009. It is not clear exactly where samples were taken from before this.

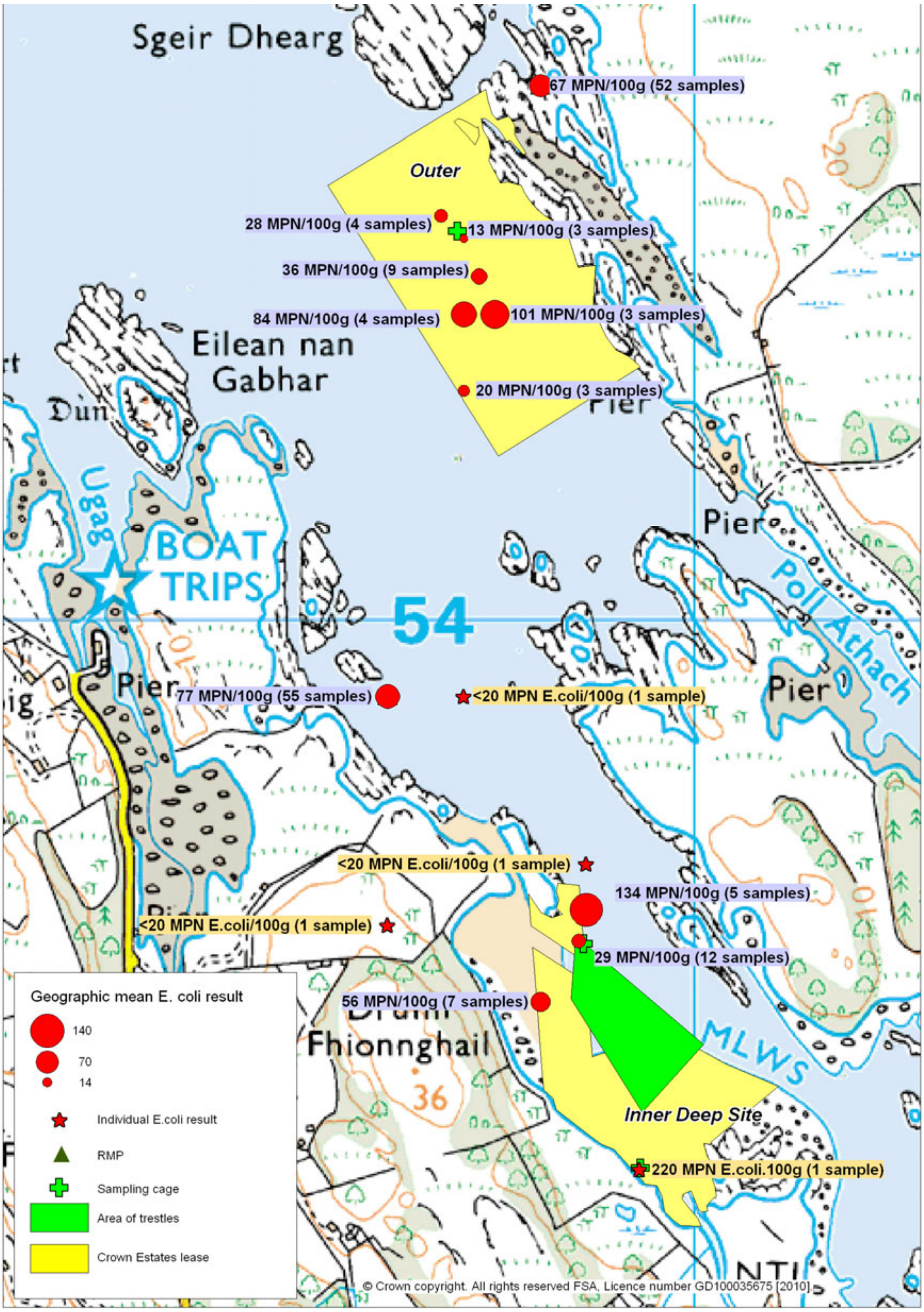


Figure 11.1 Map of sampling points and geometric mean result

The map above gives the impression of higher results toward the middle of the sampling points at the Outer site. Geographic trends within the Inner Deep site were less clear, with larger geomeans arising from locations with fewer samples.

Both the Inner Deep site and the outer site were sampled on the same day on a total of 77 occasions. Results of these samplings are presented by site in Figure 11.2. A comparison of these results reveals that there was no significant difference in average result between the sites (paired T-test, T=0.38, p=0.705). Of these samples, 11 (14%) gave results over 230 *E. coli* MPN/100g for the Inner Deep Site, and 10 (13%) gave results over 230 *E. coli* MPN/100g for the Outer site. There was no significant difference in the proportion of results over 230 *E. coli* MPN/100g between the two sites (Chi-sq=0.055, p=0.814). Nevertheless, further analyses of the microbiological data from these two sites were carried out separately as they about 1 km apart and may be subject to differing contamination sources so may differ in their relationships with various environmental variables.

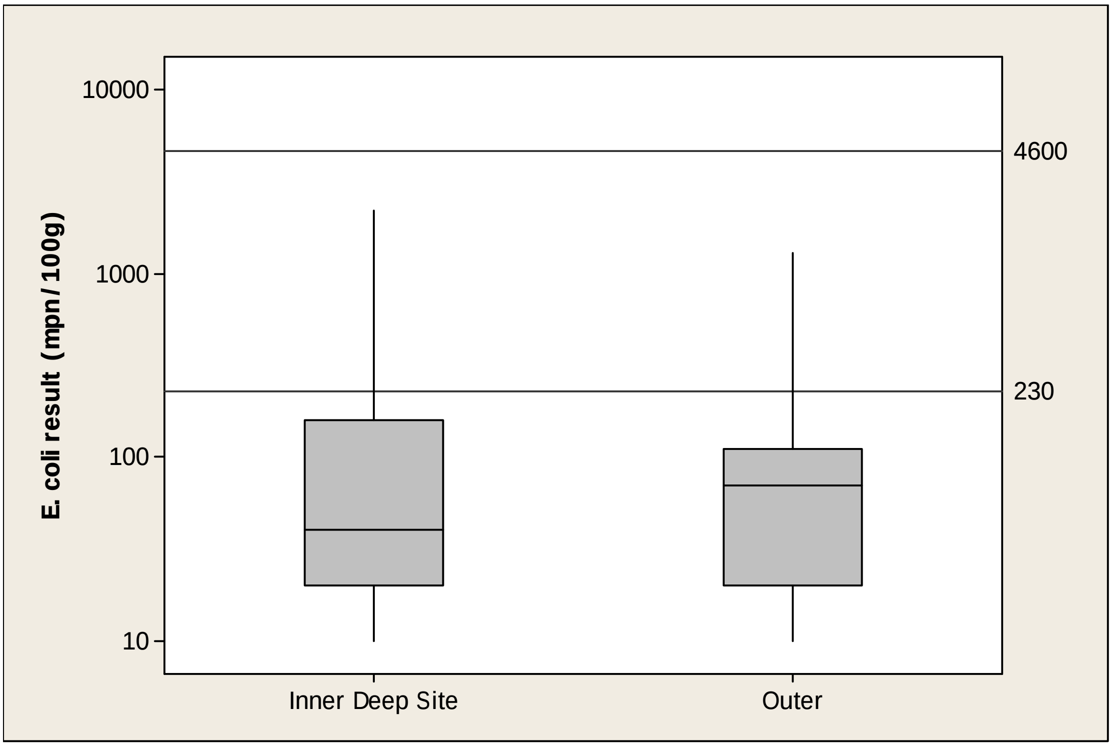


Figure 11.2 Boxplot of *E. coli* results by site, when both sites were sampled on the same day

In terms of within site variations, only samples taken by official control samplers can realistically be considered, as before their appointment exact sampling location was not recorded by GPS, and was almost always assigned to the nominal RMPs, neither of which coincide with the current fishery locations. Figure 11.1 gives the impression of higher results at the middle of the three most recent sampling points at the Outer site, although this may be a temporal effect coinciding with the northward movement of the sampling cage. Figure 11.1 also gives the impression of increased levels of contamination at sampling sites closer inshore at the Inner Deep Site.

11.4 Overall temporal pattern of results

Figures 11.3 and 11.4 present scatter plots of individual results against date for each site, fitted with trend lines calculated using two different techniques.

The first is a geometric mean of the previous 5 samples, the current sample and the following 6 samples, referred to as a rolling geometric mean (black line). The second is a loess line (blue lines), which stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away. Both lines help to highlight any underlying trends or cycles that might be obscured by shorter term variations in results.

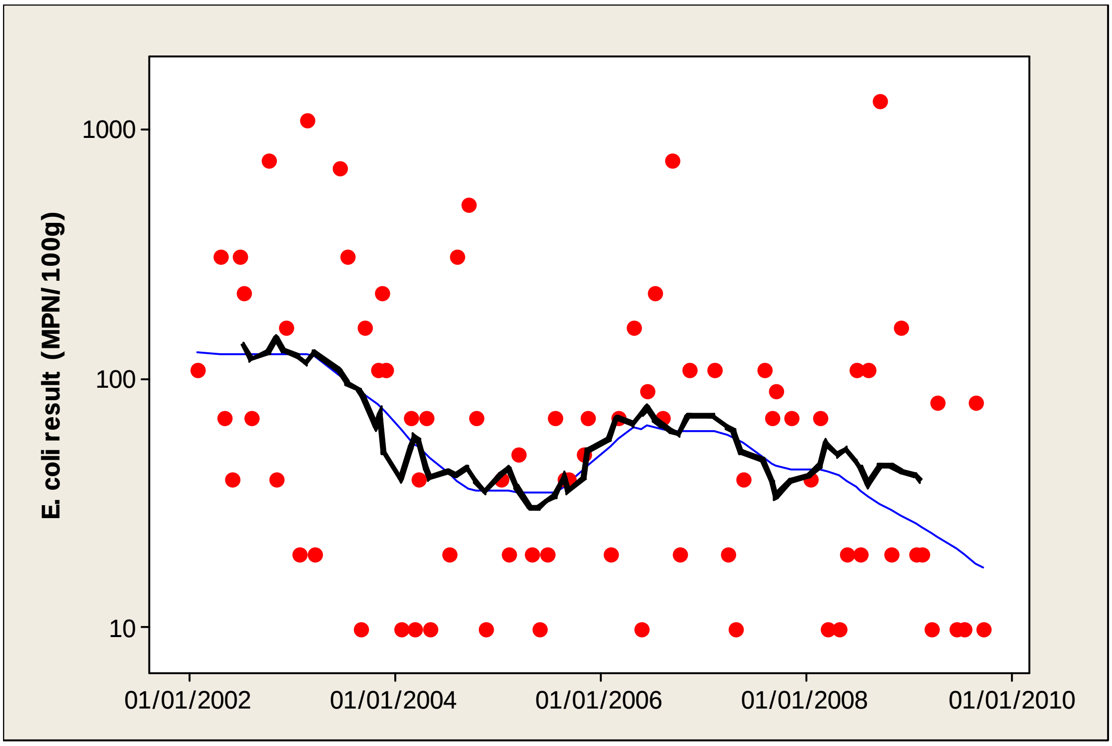


Figure 11.3 Scatterplot of *E. coli* results by date with rolling geometric mean (thick black line) and loess line (fine blue line) (Outer)

Figure 11.3 suggests a steady improvement over the years, apart from in 2006 when results appear to have deteriorated. Of the samples taken before the introduction of official control sampling officers in April 2007, 17% gave results over 230 E. coli MPN/100g, and since April 2007, only 4% of samples gave results of over 230 E. coli MPN/100g, suggesting either an improvement in water quality, or that the samples were being taken from a less contaminated part of the site. However, a peak result >1000 *E. coli* MPN/100 g has been recorded within the last two years.

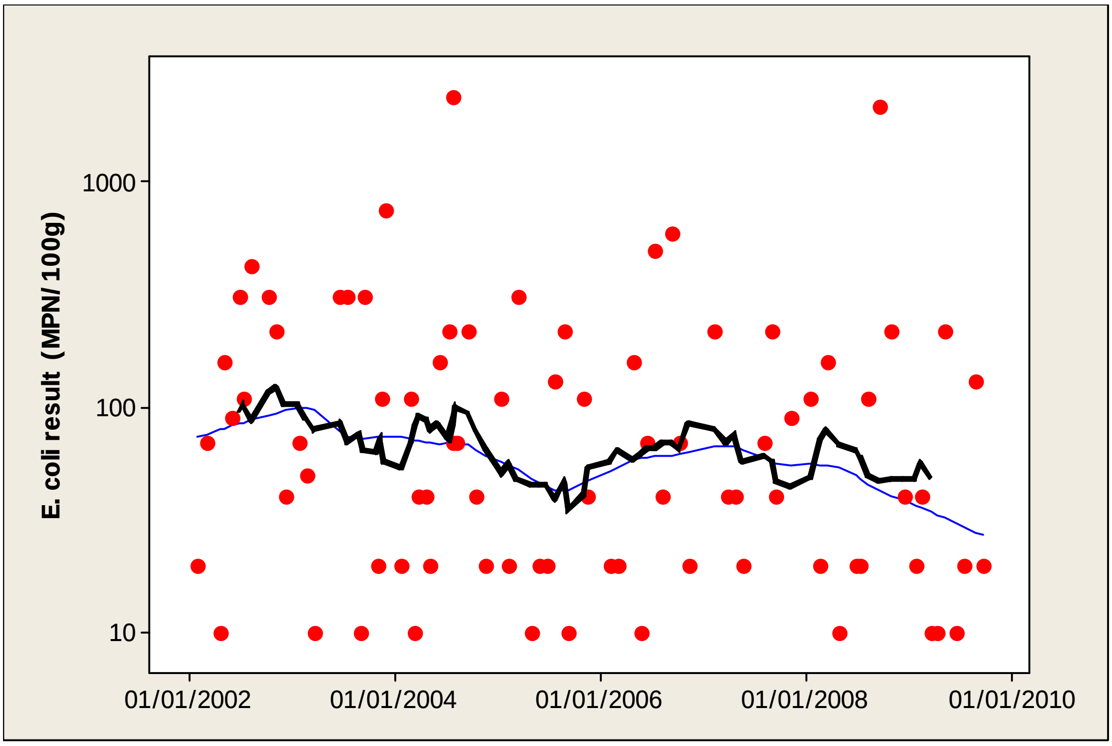
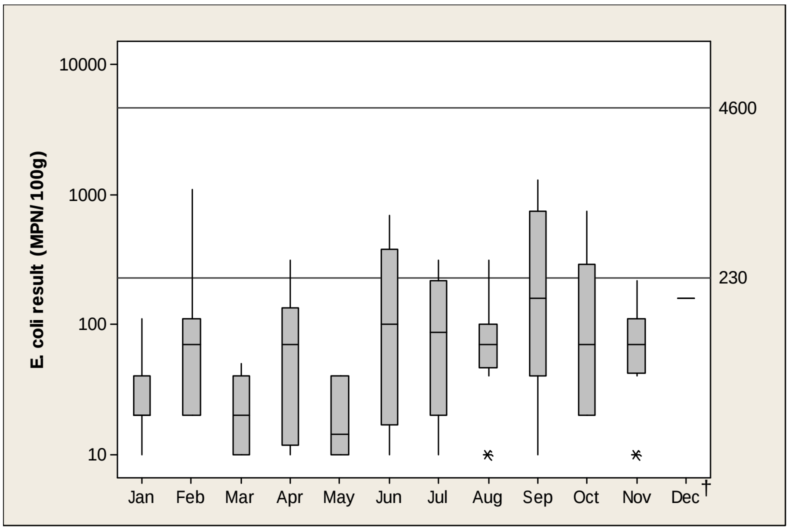


Figure 11.4 Scatterplot of *E. coli* results by date with rolling geometric mean (thick black line) and loess line (fine blue line) (Inner Deep Site)

Figure 11.4 shows a similar pattern to Figure 11.3, but the steady overall improvement and the deterioration in 2006 are less marked. Of the samples taken before the start of the official control samplers in April 2007, 19% gave results over 230 *E. coli* MPN/100g, and since April 2007, only 4% of samples gave results of over 230 *E. coli* MPN/100g, suggesting an improvement in water quality here, or that the samples were being taken from a less contaminated part of the site. However, a peak result >1000 *E. coli* MPN/100 g has been seen within the last two years.

11.5 Seasonal pattern of results

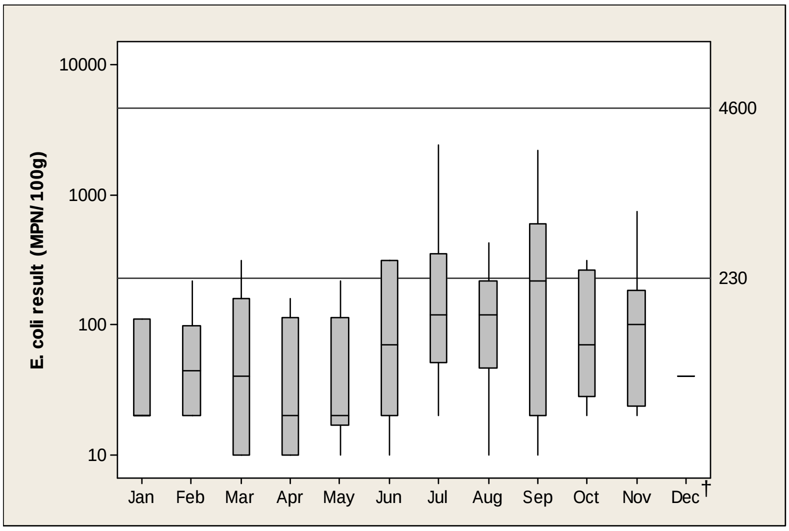
Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figures 11.5 and 11.6 present boxplots of *E. coli* result by month for the Outer and Inner Deep Sites respectively.



† - only 2 sample results in December

Figure 11.5 Boxplot of *E. coli* results by month (Outer)

Higher results generally occurred from June to November at the Outer site. Only one sample was collected in December.



† - only 2 sample results in December

Figure 11.6 Boxplot of *E. coli* results by month (Inner Deep Site)

Higher results generally occurred from June to November at the Inner Deep Site, and this pattern was slightly more distinct than observed at the Outer site. Only one sample was collected in December.

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February).

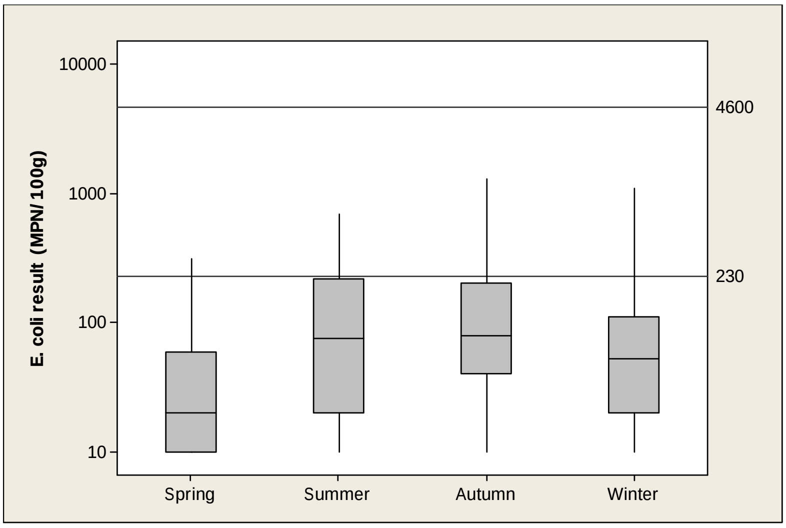


Figure 11.7 Boxplot of *E. coli* result by season (Outer)

A significant difference was found between results by season for the Outer site (One-way ANOVA, p=0.011, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the summer and autumn were significantly higher than those in the spring.

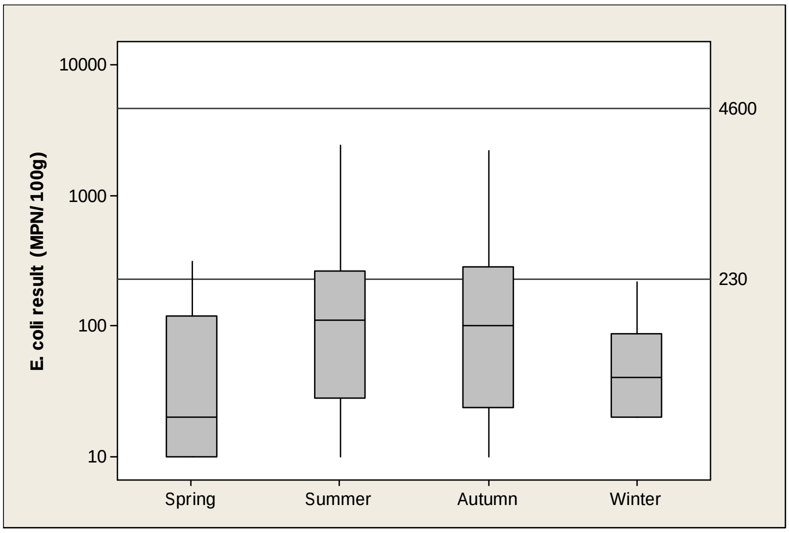


Figure 11.8 Boxplot of *E. coli* result by season (Inner Deep Site)

A significant difference was found between results by season for the Outer site (One-way ANOVA, p=0.006, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the summer and autumn were significantly higher than those in the spring, the same seasonal pattern observed at the Outer site.

11.6 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, 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. This section aims to investigate and describe the influence of these factors individually (where appropriate environmental data is available) on the sample results using basic statistical techniques.

11.6.1 Analysis of results by recent rainfall

The nearest weather station is at Ulva, approximately 12 km to the south of Loch a' Chumhainn. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2008 (total daily rainfall in mm). As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationships between rainfall in the previous 2 and 7 days and sample results were investigated and are presented below.

Two-day antecedent rainfall

Figure 11.9 presents a scatterplot of *E. coli* results against rainfall for the Outer site, whereas Figure 11.10 presents the same for the Inner Deep Site. Spearman's Rank correlations were carried out between results and rainfall.

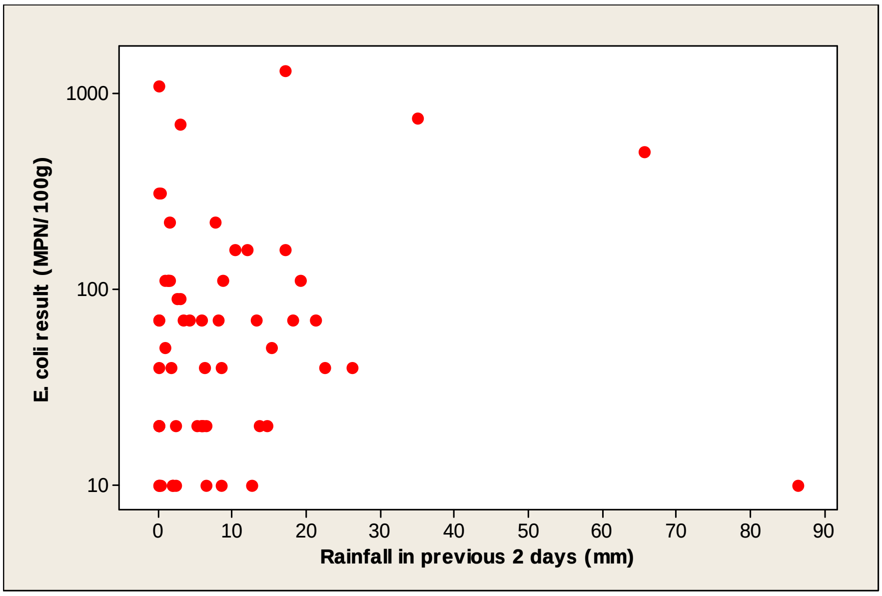


Figure 11.9 Scatterplot of *E. coli* results against rainfall in previous 2 days (Outer)

No correlation was found between *E. coli* result at the Outer site and rainfall in the previous 2 days (Spearman's rank correlation=0.123, p=0.352, Appendix 6). High *E. coli* results occurred at rainfall levels between 0 and 70 mm in the 2 days prior to sampling.

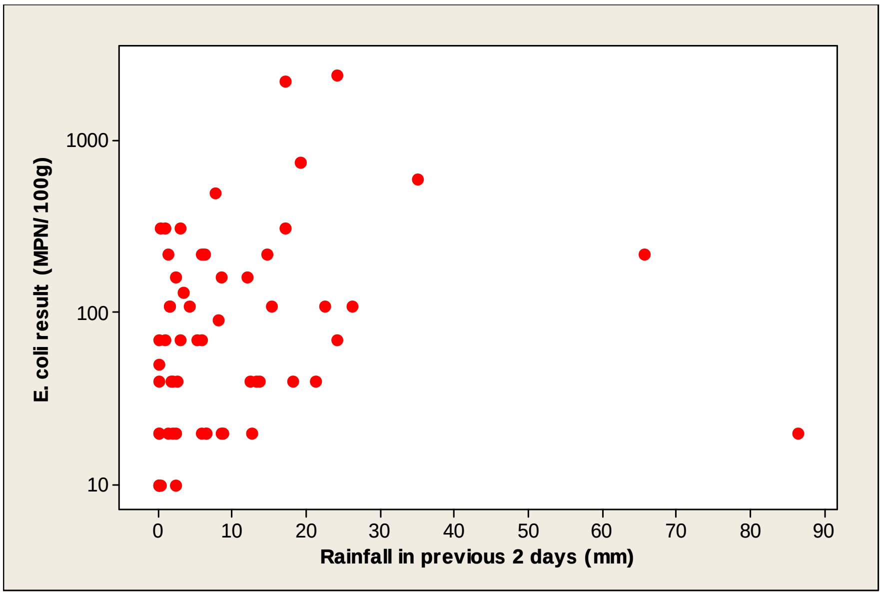


Figure 11.10 Scatterplot of *E. coli* results against rainfall in previous 2 days (Inner Deep Site)

A positive correlation was found between *E. coli* result at the Inner Deep Site and rainfall in the previous 2 days (Spearman's rank correlation=0.409, p=0.001, Appendix 6). High levels of *E. coli* in this graph are associated with rainfall totals of between approximately 10 and 40 mm. At both sites, the samples associated with the highest antecedent rainfall contained relatively low levels of *E. coli*.

Seven-day antecedent rainfall

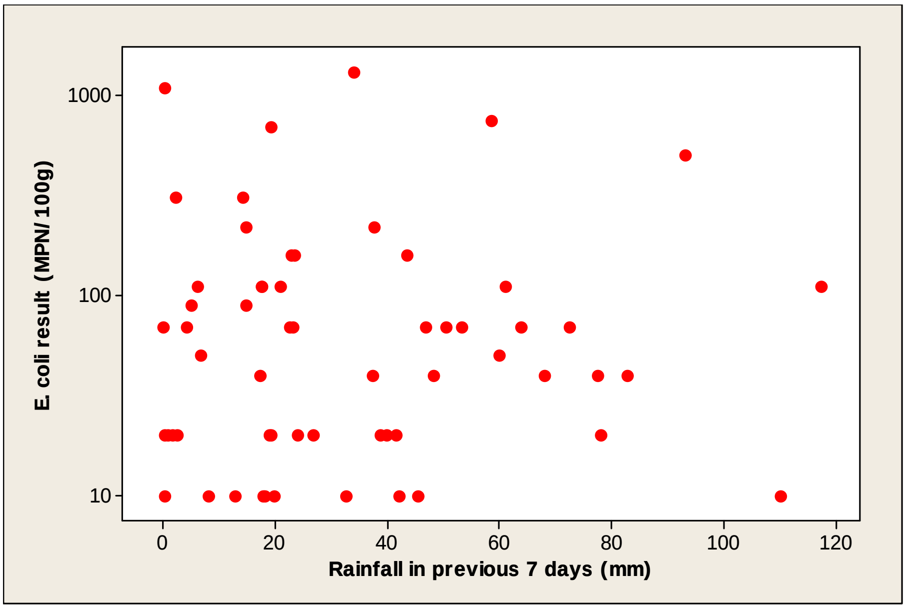


Figure 11.11 Scatterplot of *E. coli* results against rainfall in previous 7 days (Outer)

No correlation was found between *E. coli* result at the Outer site and rainfall in the previous 7 days (Spearman's rank correlation= 0.034, p=0.801, Appendix 6).

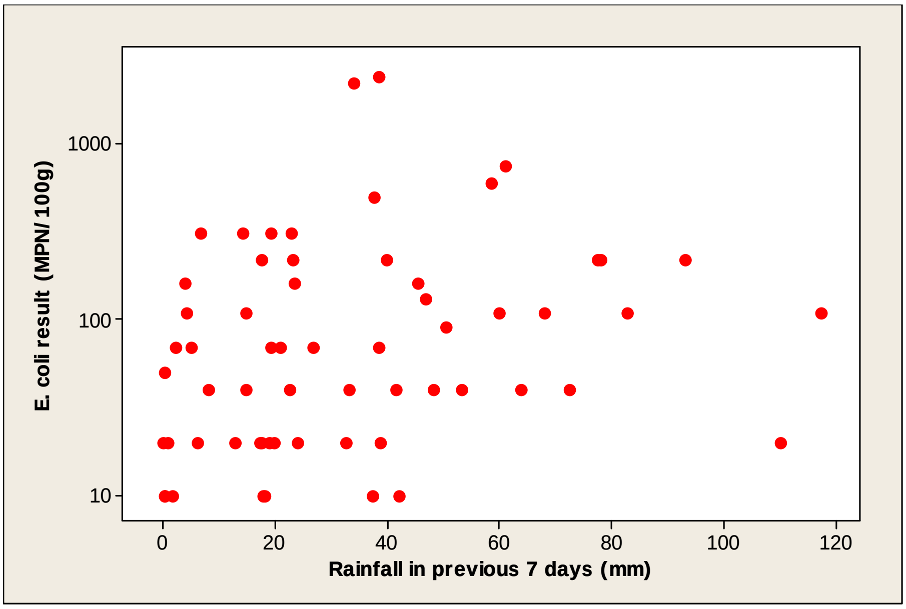


Figure 11.12 Scatterplot of *E. coli* results against rainfall in previous 7 days (Inner Deep Site)

A weak positive correlation was found between *E. coli* result at the Inner Deep Site and rainfall in the previous 7 days (Spearman's rank correlation= 0.326, p=0.010, Appendix 6).

11.6.2 Analysis of results by tidal height and state

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the loch. Figures 11.13 and 11.14 present polar plots of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle for the Outer and Inner Deep Sites respectively. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results fewer than 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *E. coli* MPN/100g are plotted in red. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides at Loch a' Chumhainn and this is not taken into account.

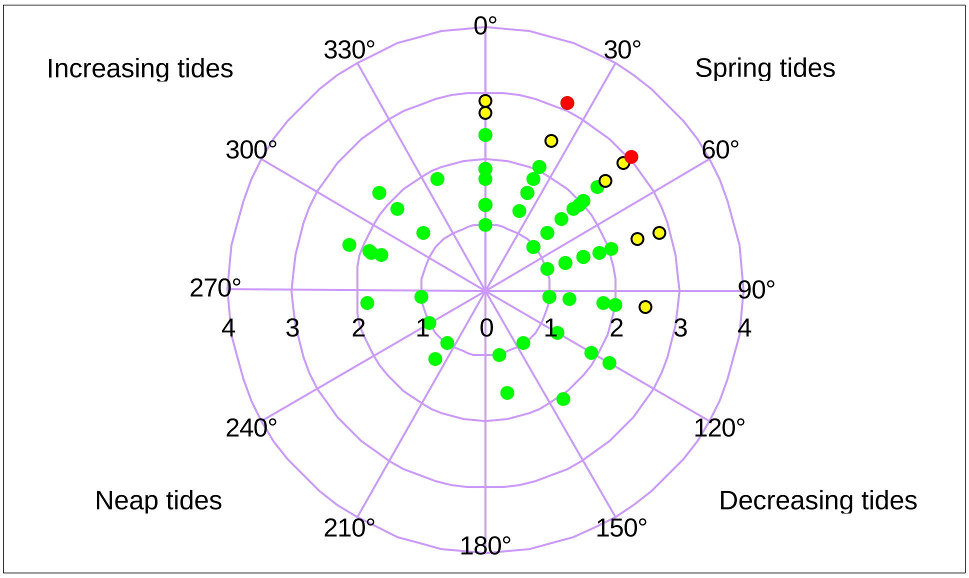


Figure 11.13 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (Outer)

A weak correlation was found between *E. coli* results and the spring/neap cycle for the Outer site (circular-linear correlation, r=0.274, p=0.003, Appendix 6), with higher results all occurring during spring tides, although it must be noted that more samples were taken during spring tides.

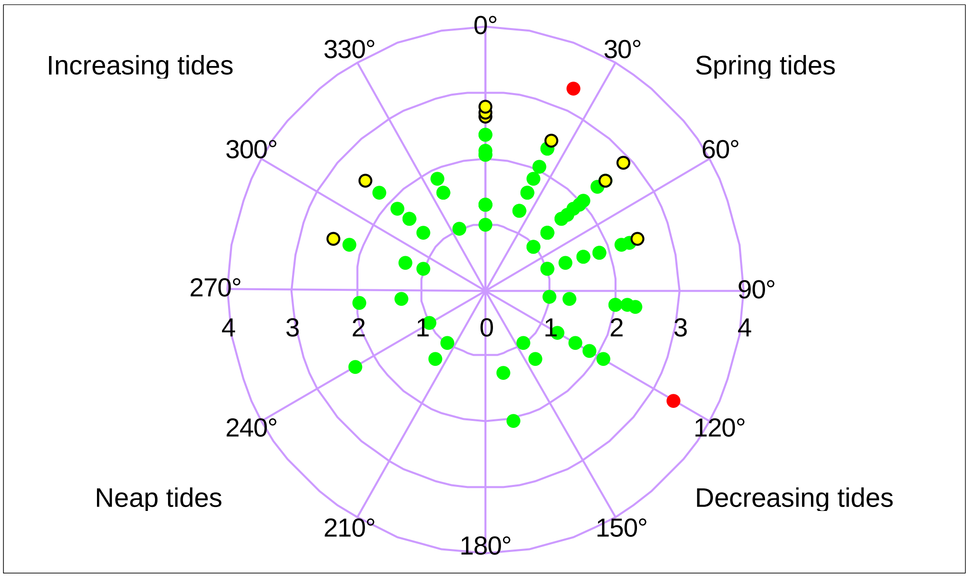


Figure 11.14 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (Inner Deep site)

No correlation was found between *E. coli* results and the spring/neap cycle for the Inner Deep Site (circular-linear correlation, r=0.186, p=0.062, Appendix 6), and no pattern in results is apparent in Figure 11.14.

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figures 11.15 and 11.16 present polar plots of $\log_{10}$ *E. coli* results on the lunar high/low tidal cycle for the Outer and Inner Deep Sites respectively. High water is at 0º, and low water is at 180º. Again, results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *E. coli* MPN/100g are plotted in red.

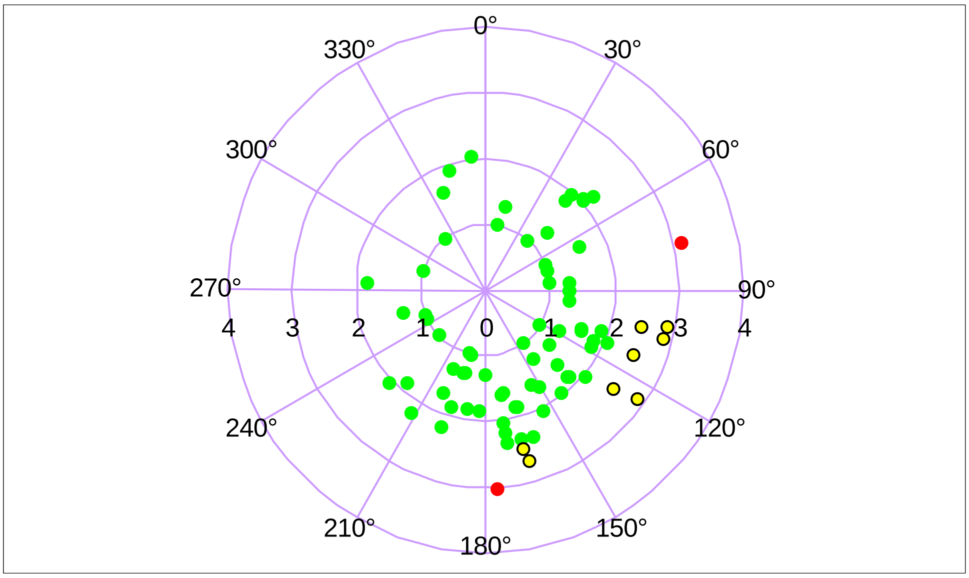


Figure 11.15 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (Outer).

A correlation was found between *E. coli* results and the high/low tidal cycle for the Outer site (circular-linear correlation, r=0.302, p<0.001, Appendix 6), with higher results generally occurring during the second half of the ebb tide.

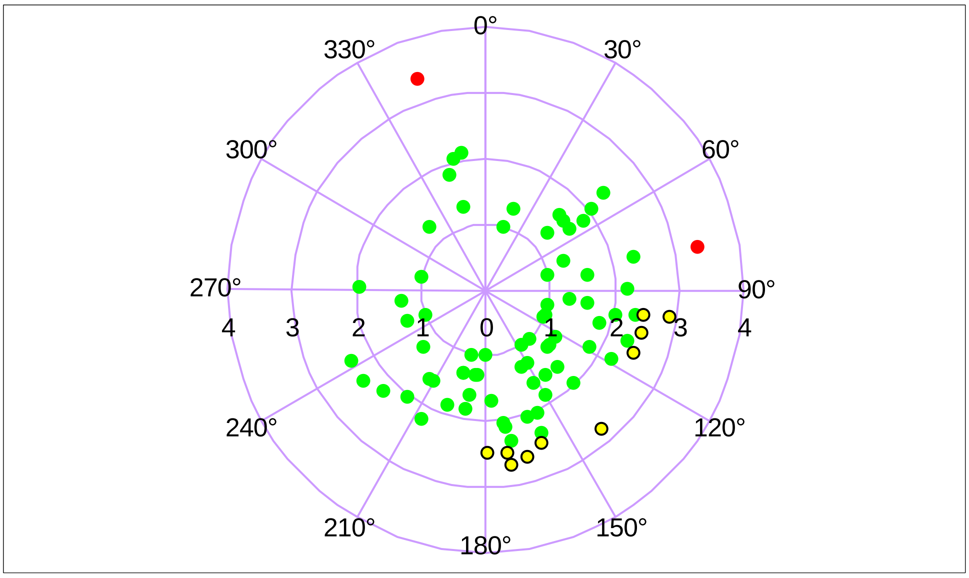


Figure 11.16 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (Inner Deep Site).

No correlation was found between *E. coli* results and the high/low cycle for the Inner Deep Site (circular-linear correlation, r=0.108, p=0.395, Appendix 6), even though Figure 11.16 shows that most results of over 230 *E. coli* MPN/100g occurred on the second half of the ebb tide.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is, of course, closely related to season and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Figure 11.17 presents a scatterplot of *E. coli* results against water temperature for the Outer site and Figure 11.18 presents the same for the Inner Deep Site.

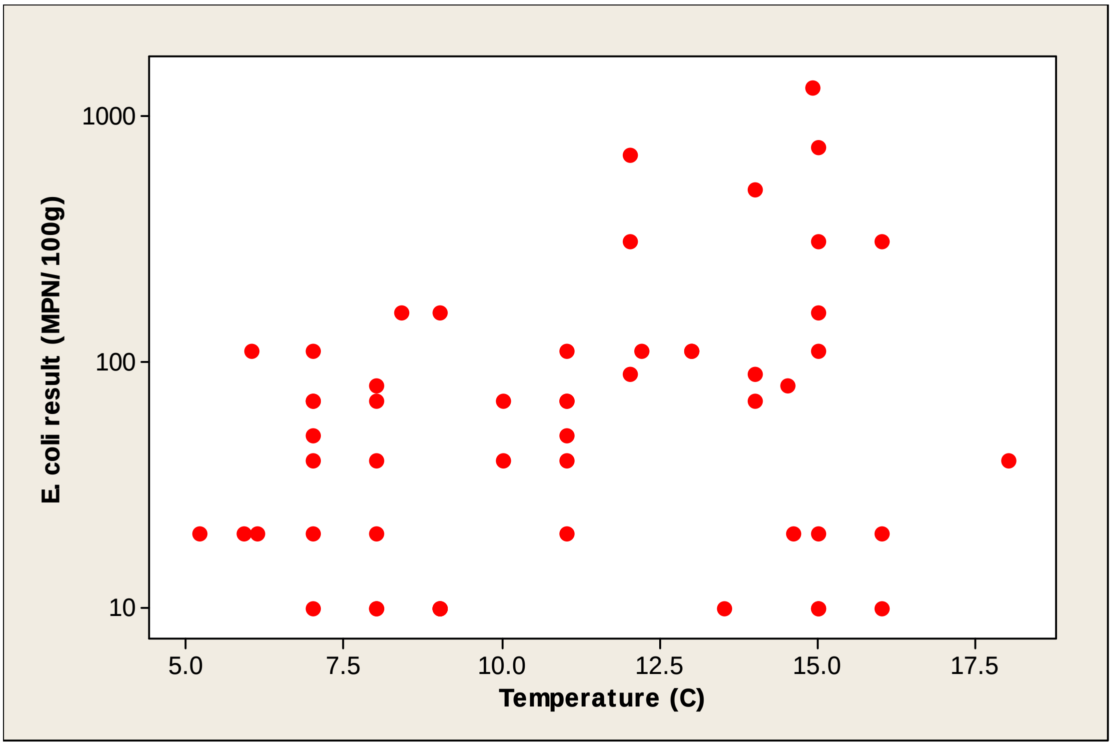


Figure 11.17 Scatterplot of *E. coli* results by water temperature (Outer)

A regression analysis of $\log_{10}$ *E. coli* result against water temperature was undertaken for each site. The coefficient of determination indicates that there was a very weak positive relationship between the *E. coli* result and water temperature for the Outer site (Adjusted R-sq=5.8%, p=0.042, Appendix 6)

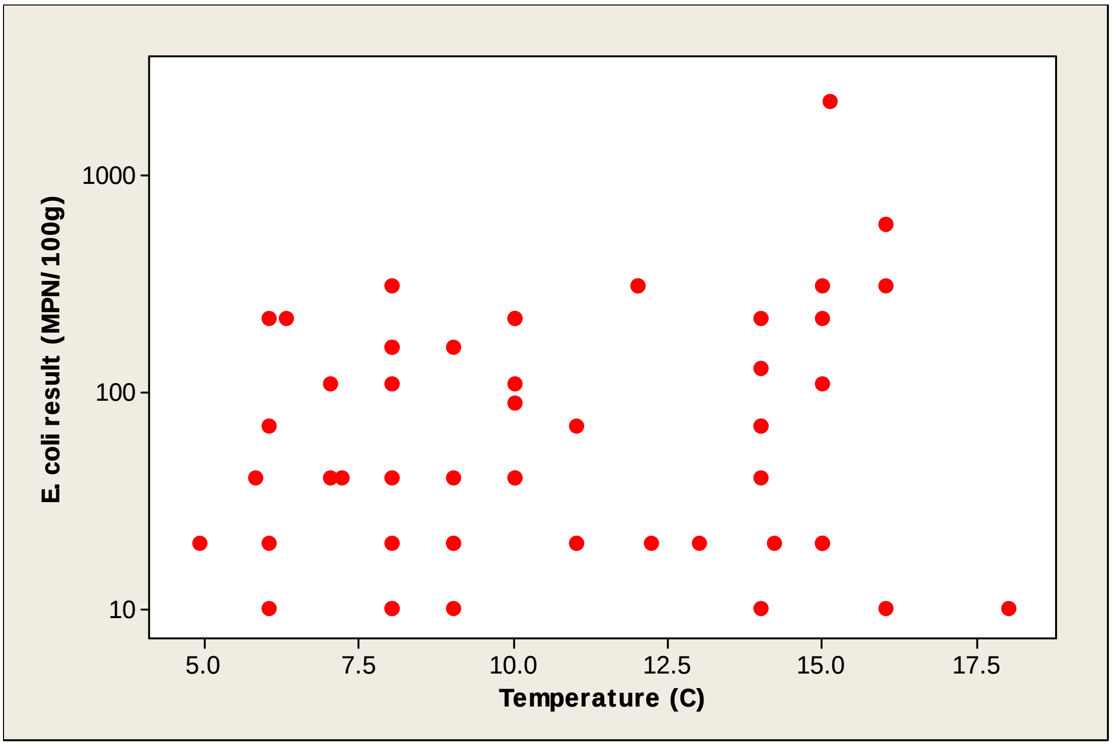


Figure 11.18 Scatterplot of *E. coli* results by water temperature (Inner Deep Site)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and water temperature for the Inner Deep Site (Adjusted R-sq=0.4%, p=0.277, Appendix 6)

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns within the production area. However, the nearest wind station for which records were available was Tiree, approximately 41 km to the west. Given the differences in local topography and distance between the two it is likely that the overall patterns of wind direction are skewed in different ways, and that the wind strength and direction may differ significantly at any given time. Therefore it was not considered appropriate to compare *E. coli* results at Loch a' Chumhainn with wind readings taken at Tiree.

11.6.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.19 and 11.20 present scatter plots of *E. coli* result against salinity for the Outer site and Inner Deep Site respectively, where salinity readings were available.

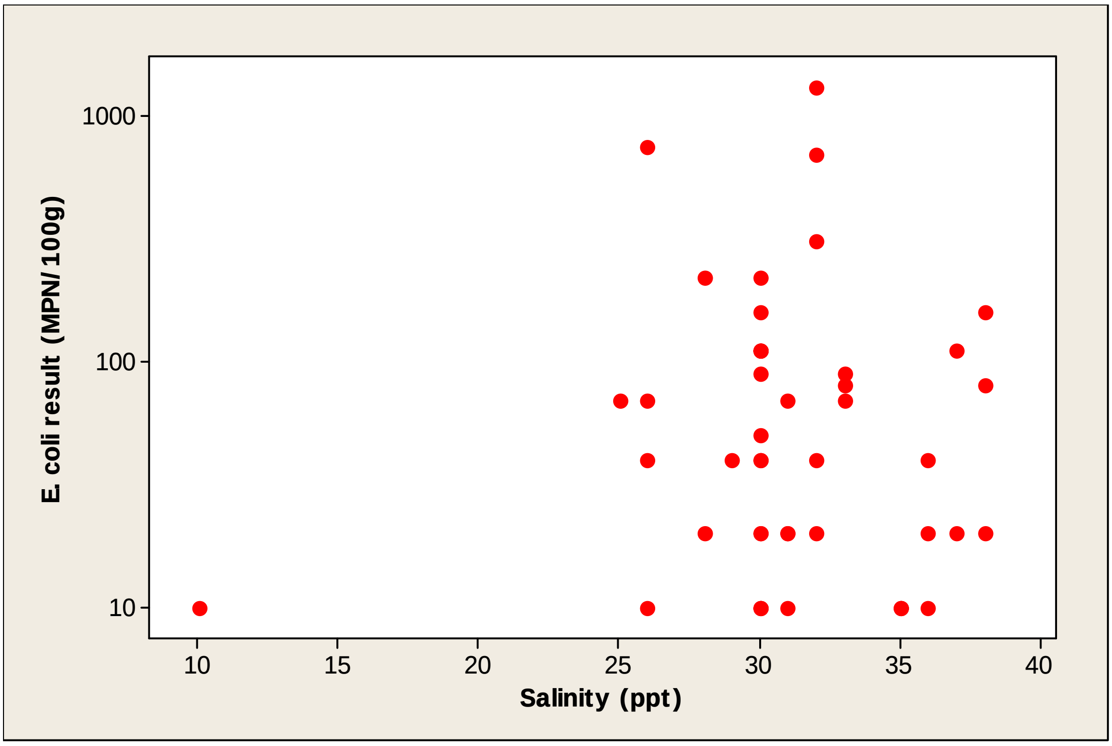


Figure 11.19 Scatterplot of *E. coli* results by salinity (Outer)

A regression analysis of $\log_{10}$ *E. coli* result against water temperature was undertaken for each site. The coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity for the Outer site (Adjusted R-sq=0.0%, p=0.885, Appendix 6).

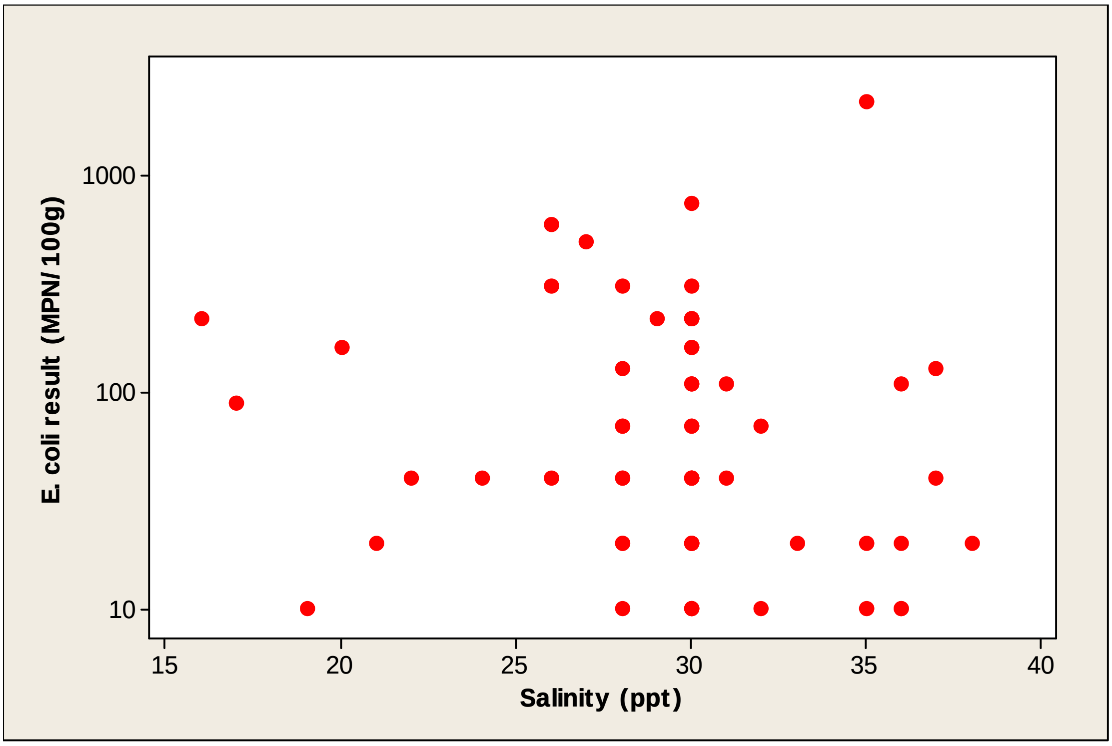


Figure 11.20 Scatterplot of *E. coli* results by salinity (Inner Deep Site)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity for the Inner Deep Site (Adjusted R-sq=0.4%, p=0.277, Appendix 6). The distribution of recorded salinities suggests greater freshwater influence at the Inner Deep Site. A salinity of 10 ppt was recorded at the Outer site on one occasion following very heavy rainfall (86.4 mm in the previous 2 days), and although an oyster sample was also take from the Inner Deep Site on this occasion, salinity was not recorded here.

11.7 Evaluation of peak results

A total of 4 samples gave results of over 1000 *E. coli* MPN/100g. The details of these are presented in Table 11.2. No sample results exceeded 4600 *E. coli* MPN/100g.

Table 11.2 Sample details of results over 1000 *E. coli* MPN/100g

Collection date	Site	NGR	*E. coli* (MPN/ 100g)	2 day rainfall (mm)	7 day rainfall (mm)	Water temp (ºC)	Salinity (ppt)	Tide (spring/ neap)	Tide (high/ low)
18/02/2003	Outer	NM 4080 5470	1100	0	0.2	*	*	spring	low water
22/07/2004	Inner Deep Site	NM 4060 5390	2400	24	38.4	*	*	spring	high water
16/09/2008	Inner Deep Site	NM 4085 5362	2200	17.1	33.8	15.1	35	spring	ebbing
16/09/2008	Outer	NM 4074 5441	1300	17.1	33.8	14.9	32	spring	ebbing

* Data unavailable

Results of over 1000 *E. coli* MPN/100g were obtained from both sites, with the highest results from the Inner Deep Site. Two samples were taken in September (on the same date, one from each site), one was taken in July, and one was taken in February. All samples had been taken on a spring tide, and three of the four were taken after significant rainfall. Water temperature and salinity were only recorded for the pair of samples taken in 2008.

11.8 Summary and conclusions

No significant difference was found between *E. coli* results between the Inner Deep Site and the Outer site either in terms of mean result or the proportion of results exceeding 230 *E. coli* MPN/100g. Within the Outer site, higher results appear to have occurred towards the middle of the site, although this may be a temporal effect coinciding with the northward movement of the sampling cage. At the Inner Deep Site there is some indication that increased levels of contamination arose at sampling sites closer inshore.

Overall, results from the Outer site appear to have improved steadily since 2002, apart from in 2006 when results appear to have deteriorated. A similar but less marked pattern was observed at the Inner Deep Site. Significant differences in results by season were found, with results for the summer and autumn significantly higher than those in the spring at both sites. A very weak positive relationship between *E. coli* results and water temperature was found at the Outer site only.

No correlations between recent rainfall and *E. coli* results were found for the Outer site. Positive correlations between both 2 and 7 day rainfall and *E. coli* result were found for the Inner Deep Site, with the correlation with 2 day rainfall slightly stronger. No relationship between *E. coli* results and salinity was found at either site. However, peak results at both sites were seen on spring tides.

Correlations between *E. coli* result tidal state on both the spring/neap and high/low tidal cycle were found at the Outer site. Higher results occurred on spring tides, and during the second half of the ebb tide. No correlations between *E. coli* results and either of these tidal cycles was found at the Inner Deep Site.

It should be noted that the relatively small amount of data precluded the assessment of the effect of interactions between environmental factors on the *E. coli* concentrations in shellfish.

11.9 Sampling frequency

When a production area has held the same (non-seasonal) classification for 3 years, and the geometric mean of the results falls within a certain range it is recommended that the sampling frequency be decreased from monthly to bimonthly (EU Working Group on the Microbioloogical Monitoring of Bivalve Mollus Harvesting Areas, 2007). As of the end of September 2009, both the the Loch a' Chumhainn: Inner Deep Site and Loch a' Chumhainn: Outer production areas had held an A classification for three years, but the geometric mean results covering the period from October 2006 to September 2009 inclusive fell above the range (a geometric mean of <13, where sample results of <20 are assigned a nominal value of 10) where sampling frequency can be reduced.

12. Designated Shellfish Growing Waters Data

The area considered in this report coincides with a shellfish growing water that was designated in 2002. The extent of the growing water and the location of monitoring point is shown on Figure 12.1.

The monitoring requires the following testing:

- Quarterly for salinity, dissolved oxygen, pH, temperature, visible oil
- Every third year for metals and organohalogens in mussels
- Quarterly for faecal coliforms in mussels

Monitoring results for faecal coliforms in shore mussels to the end of 2007 have been provided by SEPA. These are presented in Table 12.1.

Table 12.1 SEPA Faecal coliform results (faecal coliforms/100g) for shore mussels gathered from Loch a' Chumhainn

	Site	Loch a' Chumhainn	Loch a' Chumhainn
	NGR	NM 406 539	NM 4020 5400
2003	Q1	750	
	Q2	No sample	No sample
	Q3		700
	Q4		40
2004	Q1		90
	Q2		310
	Q3		24000
	Q4		160
2005	Q1		110
	Q2		2400
	Q3		13000
	Q4		750
2006	Q1		750
	Q2		310
	Q3		54000
	Q4		No sample
2007	Q1		No sample
	Q2		No sample
	Q3		No sample
	Q4		No sample

In 2003, a point within the Loch a' Chumhainn: Inner Deep Site production area, just to the north of the fishery was sampled once. After this, all samples were taken from Croig Pier, within the Loch a' Chumhainn: Outer production area. The geometric mean result of all shore mussel samples was 829 faecal coliforms / 100g. Results ranged from 40 to 54000 faecal coliforms/100g, showing that high levels of contamination are sometimes found at Croig pier. There was a significant difference between results by quarter despite the relatively low number of samples considered (One-way ANOVA, p=0.014,

Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) confirmed that results for quarter 3 were significantly higher than those for quarters 1 and 4. Levels of faecal coliforms are usually closely correlated to levels of *E. coli* often at a ratio of approximately 1:1. The ratio depends on a number of factors, such as environmental conditions and the source of contamination. Mussels tend to yield higher *E. coli* results than Pacific oysters sample from the same location (A. Younger, personal communication). Therefore, the results presented in Table 12.1 are not directly comparable with any other shellfish testing results presented in this report. Nevertheless, the levels sometimes encountered here were an order of magnitude higher than those observed in the oysters and this may partly represent the effect of the sampling location.

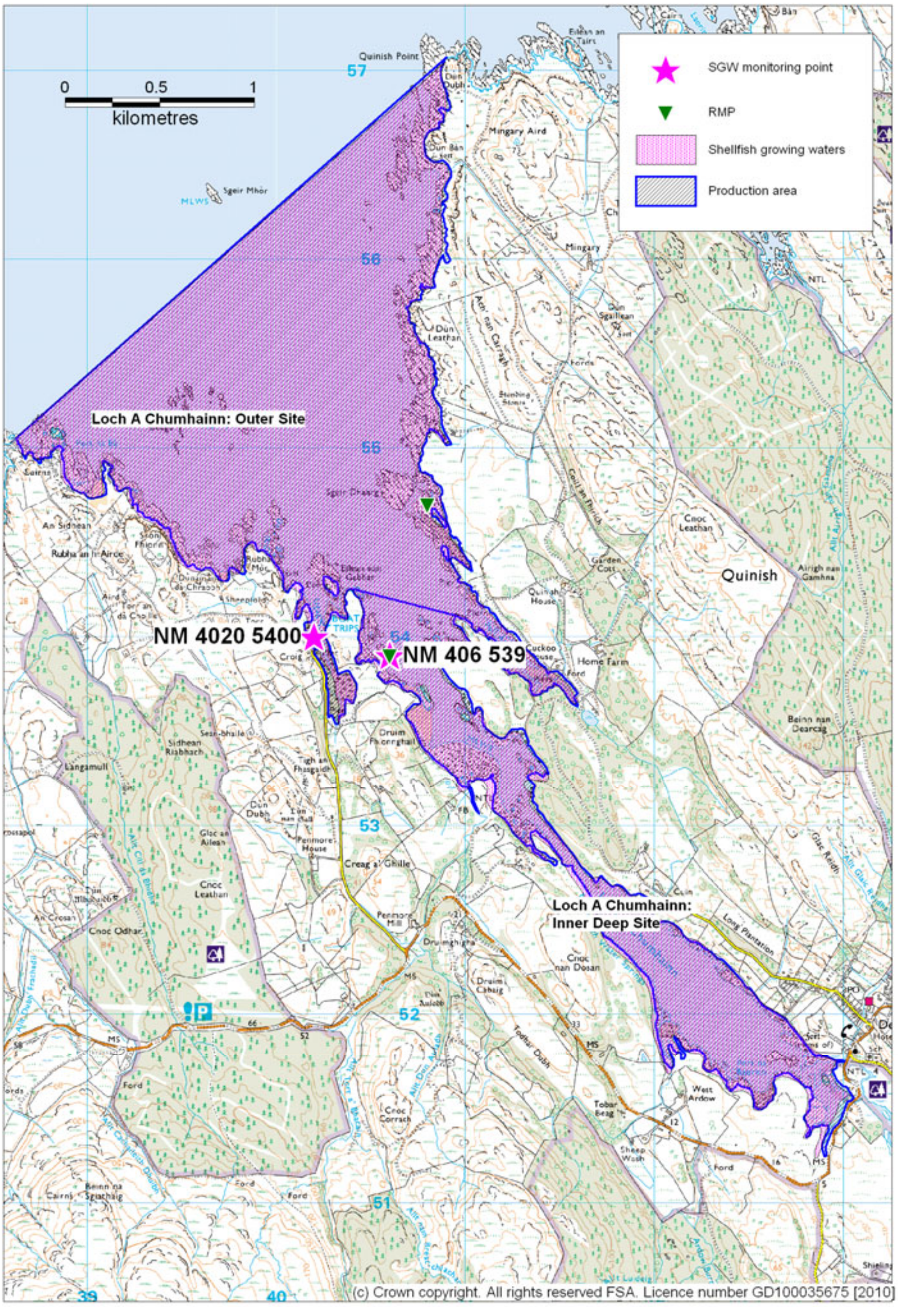


Figure 12.1 Shellfish growing waters and monitoring points

13. Rivers and streams

The following rivers and streams were measured and sampled during the shoreline survey. These represent the largest freshwater inputs into the production area. The survey was undertaken under wet conditions.

Table 13.1 River loadings for Loch a' Chumhainn

No.	Position	Width (m)	Depth (m)	Flow (m/s)	Discharge (m^3/d)	*E. coli* (cfu/100ml)	*E. coli* loading (cfu/day)
1	NM 39590 54087	0.85	0.2	0.145	2130	500	1.1×10^{10}
2	NM 39832 54101	0.43	0.08	0.614	1830	400	7.3×10^{9}
3	NM 43047 51545	0.84	0.15	0.61	6640	300	2.0×10^{10}
4	NM 43003 51740	12.6	0.45	0.604	296000	900	2.7×10^{12}
5	NM 42914 51137	0.35	0.05	2.338	3540	400	1.4×10^{10}
6	NM 42165 51335	6	0.25	1.808	234000	110	2.6×10^{11}
7	NM 40324 53510	2.65	0.1	0.554	12700	1500	1.9×10^{11}
8	NM 40726 53559	0.6	0.02	0.388	402	400	1.6×10^{9}
9	NM 40847 53320	0.2	0.05	1.189	1030	<100	$<1.0 \times 10^{9}$
10	NM 40932 53283	7	0.3	1.409	256000	330*	8.4×10^{11}
11	NM 41523 53783	0.85	0.3	0.942	20800	900	1.9×10^{11}
12	NM 40957 54549	0.45	0.18	0.898	6290	300	1.9×10^{10}
13	NM 40953 55013	2.3	0.15	0.582	17300	400	6.9×10^{10}
14	NM 41606 53630	2.25	0.17	0.713	23600	400	9.4×10^{10}
15	NM 41892 52785	0.5	0.04	0.278	480	200	9.6×10^{8}
16	NM 42066 52622	0.8	0.04	0.5	1380	1000	1.4×10^{10}

*Two samples taken giving results of 330 and 300 *E. coli* cfu/100ml. The result from the larger volume water sample was used as the result is likely to be more accurate.

Of most significance to the fishery at the Inner Deep Site is stream 10 (the Allt Tor A'Bhacain), which discharges to the southern end of the bay in which the trestles are located. It carried a loading of 8.4×10^{11} *E. coli* cfu/day at the time of survey, which is roughly equivalent to the loading that may be expected from a septic tank serving a population of 100 (based on figures published by Halcrow, 1995). It drains mainly grassland, with some forest, and there are two known private sewage discharges to this watercourse. Two other streams (8 and 9) drain into this bay, although these are much smaller, and their *E. coli* loadings were more than two orders of magnitude less than that of stream 10.

Streams 11, 12, 13 and 14 discharge to the east shore of the loch in the vicinity of the Outer site, so are likely to contribute to levels of contamination found in shellfish here. Streams 12 and 13 are closer to the site, but streams 11 and 14 had higher *E. coli* loadings, so it is unclear which of these are most significant to the site.

The highest loading of all rivers measured was that of the River Bellart (4), which drains a mixture of grassland and woodland, and discharges to the head of the loch at Dervaig. It carried a loading of 2.7×10^{12} *E. coli* cfu/day at the time of survey, contributing 61% of the total measured river borne *E. coli* loading to Loch Chumhainn. Therefore, this River is likely to make a significant contribution to levels of *E. coli* found at both sites, possibly slightly more so at the Inner Deep site as it is closer and in a narrower part of the loch.

Overall, stream inputs are likely to be a significant influence on water quality in Loch a' Chumhainn as a whole. Of particular significance is stream 10, which had a relatively high discharge and loading and discharges amongst the trestles at the Inner Deep site, and is probably the most significant identified source of contamination to this site. Due to its very close proximity to this site, it is likely to cause a noticeable gradient in levels of contamination across this site. The River Bellart is likely to affect microbiological quality of water within Loch a' Chumhainn as a whole, given its size and *E. coli* loading. Other smaller streams will also increase levels of *E. coli* within Loch A Chuhainn, and streams 11, 12, 13 and 14 may be of particular importance to the Outer site given their locations. Stream 12 lies close to the current sampling point, while streams 11 and 14 may impact the site on the falling tide. However, it is not clear whether any of these is of greater importance to contamination levels in shellfish there.

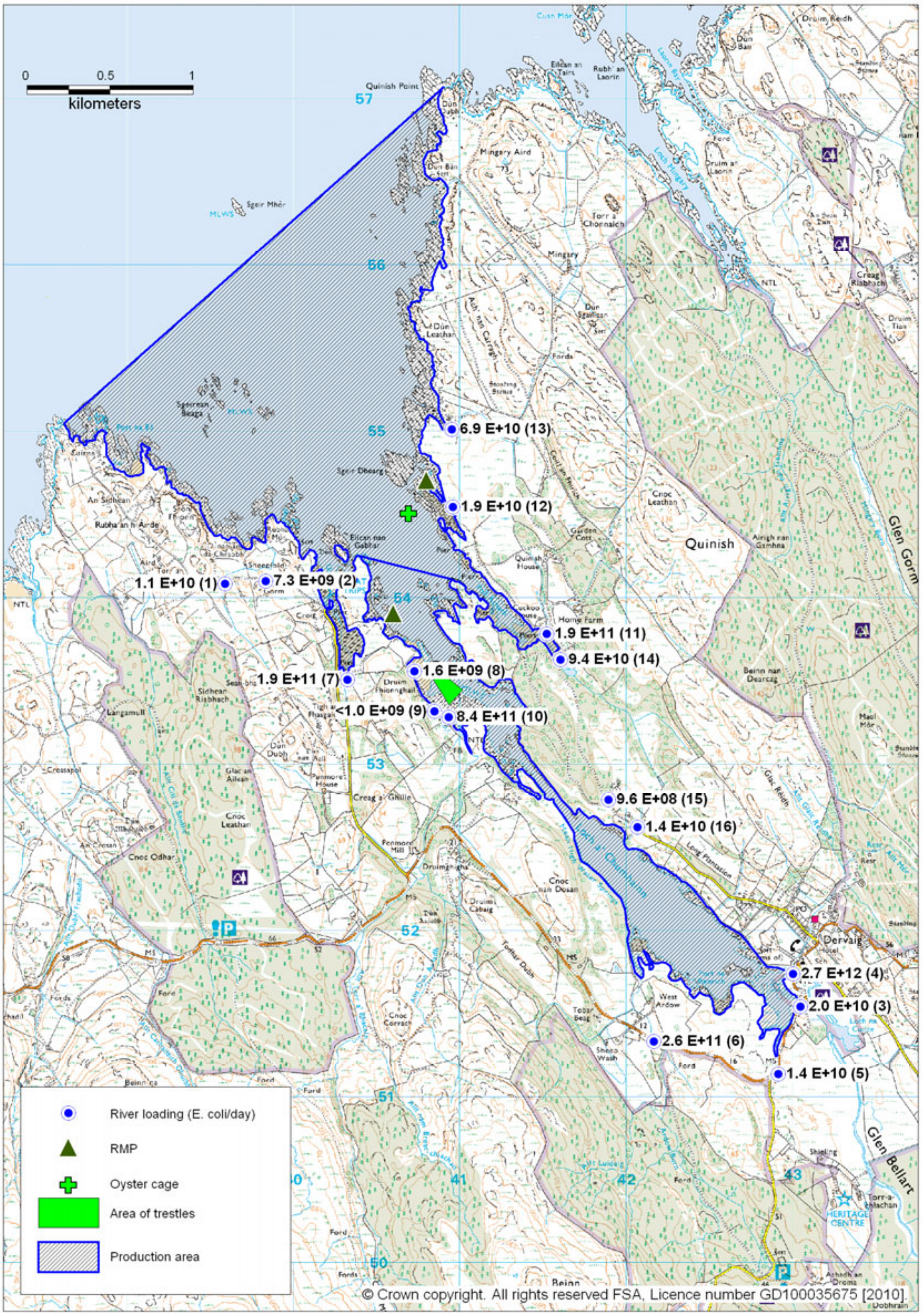


Figure 13.1 Stream loadings

14. Bathymetry and Hydrodynamics

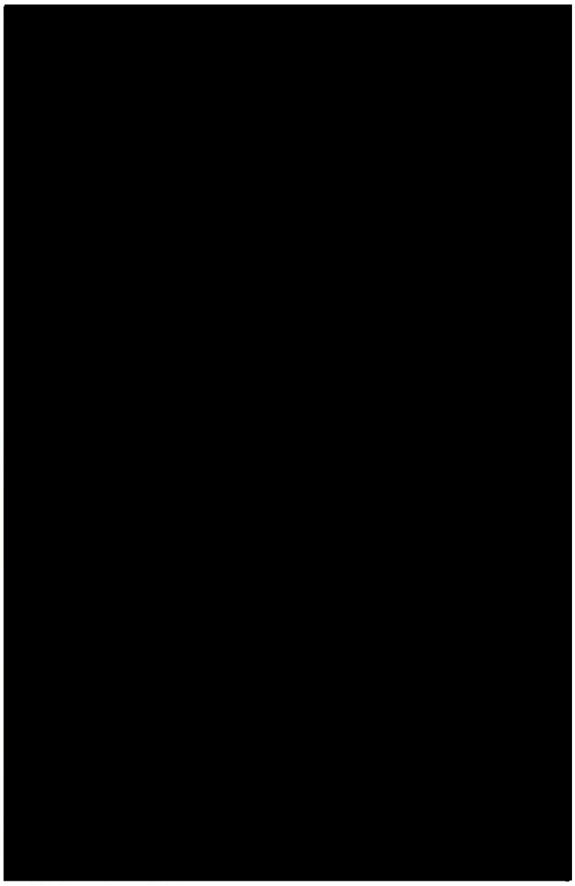


Figure 14.1 Bathymetry of Loch a' Chumhainn
Figure 14.2 Loch a' Chumhainn

Figure 14.1 shows that the loch has a wide mouth facing the north west, narrows to only 70 m in width at its midsection (referred to as ‘the narrows’), then widens slightly towards its head. There are no sills within the loch. However, the constriction within the narrows is likely to have a similar effect to a sill on surface currents and volume exchange. The bathymetry chart shows a large drying area towards the head of the loch, but the Ordnance Survey map indicates that this area is below the MLWS line. The grower indicates that the inner loch does not fully dry out inshore of the narrows. The reason for this discrepancy may be that although the actual elevation of the bed of the inner loch is consistent with it being a drying area, water from the inner loch does not get a chance to drain fully through the narrows before the tide starts flooding again. The maximum depth is 14 m at its mouth. The loch has a total area at high water of 3.9 km^2, and a mean depth at low water of 6 m. Its catchment area is 57 km^2 (Edwards and Sharples, 1986).

Tidal Curve and Description

The two tidal curves below are for Tobermory, about 11 km to the east of Loch a' Chumhainn. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 22/8/09 and the second is for seven days beginning 00.00 GMT on 29/8/09. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

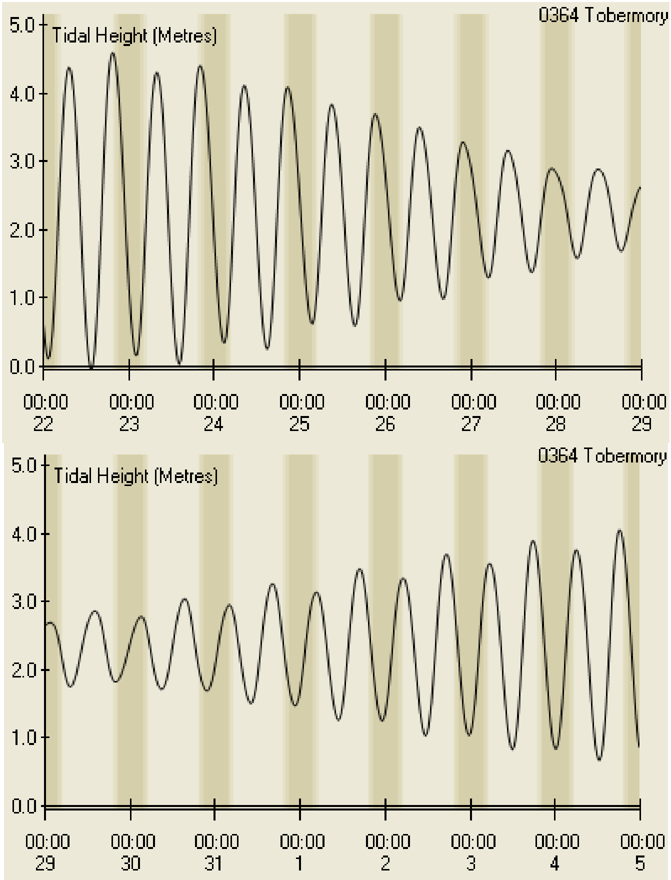


Figure 14.3 Tidal curves for Tobermory

The following is the summary description for Tobermory from TotalTide: Tobermory is a Secondary Harmonic port. The tide type is Semi-Diurnal. Predicted heights are in metres above Chart Datum.

HAT	4.9 m
MHWS	4.4 m
MHWN	3.3 m
MSL	2.38 m
MLWN	1.8 m
MLWS	0.7 m

The tidal range at spring tide is therefore approximately 3.7 m and at neap tide 1.5 m.

Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. This section aims to make a simple assessment of water movements around the area.

The nearest locations for which tidal stream information was available was for two locations off the north west coast of Mull. The locations of these stations are presented in Figure 14.4, and their tidal diamonds are presented in Tables 14.1 and 14.2. No information on tidal streams within Loch a' Chumhainn was available.

Table 14.1 Tidal streams for SN035E (taken from TotalTide)

Time	Direction	Spring rate (m/s)	Neap Rate (m/s)
-06h	275°	0.1	0.0
-05h	260°	0.1	0.1
-04h	270°	0.1	0.1
-03h	200°	0.1	0.0
-02h		0.0	0.0
-01h	050°	0.1	0.0
HW	079°	0.1	0.1
+01h	090°	0.2	0.1
+02h	106°	0.1	0.1
+03h		0.0	0.0
+04h	296°	0.1	0.1
+05h	250°	0.1	0.0
+06h	290°	0.1	0.0

Table 14.2 Tidal streams for SN035D (taken from TotalTide)

Time	Direction	Spring rate (m/s)	Neap Rate (m/s)
-06h	218°	0.3	0.1
-05h	270°	0.1	0.1
-04h	355°	0.3	0.1
-03h	011°	0.5	0.2
-02h	021°	0.6	0.2
-01h	031°	0.5	0.2
HW	047°	0.4	0.1
+01h	093°	0.2	0.1
+02h	175°	0.2	0.1
+03h	197°	0.3	0.1
+04h	202°	0.5	0.2
+05h	204°	0.5	0.2
+06h	213°	0.4	0.2

The overall pattern of tidal flows in the area appear to be an easterly flow for the last half of the flood tide and first half of the ebb tide, and a westerly flow for the second half of the ebb tide and first half of the flood tide, although there are differences between the two stations in terms of timing of peak flows, exact directions and peak rates of flow. Therefore, tidally driven currents flowing past the mouth of Loch a' Chumhainn are likely to flow in an easterly direction along the coastline on the either side of high water, flipping to a westerly direction during the ebb, then returning to an easterly direction during the flood tide.

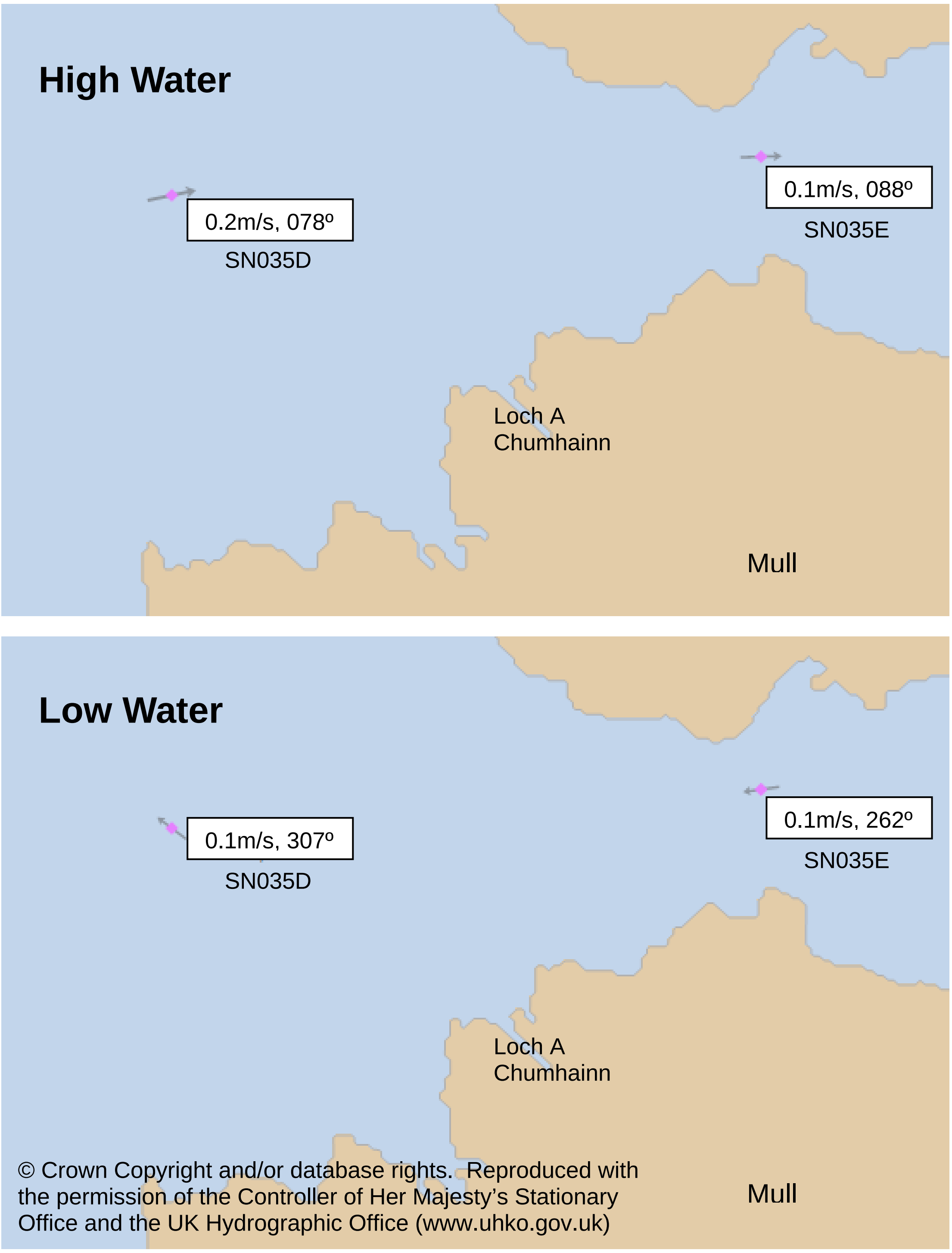


Figure 14.4 Tidal flows and direction at high and low water on a spring tide at stations SN0035D and SN035E (taken from TotalTide)

The tidal range here is fairly large, so tidally driven exchange of water is likely to be relatively important in Loch a' Chumhainn, particularly the shallower inner areas. This is reflected in its very short flushing time of 1 day (Edwards and Sharples, 1986), although this is likely to be an underestimate since it assumes the complete replacement of water on each incoming tide. Tidally driven currents within the loch would be expected in general to move in a south-easterly direction up the loch on the flood tide, and a north-westerly direction on the ebb tide back along a similar path. The shape of the loch, particularly between Croig and the narrowest part of the loch is likely to complicate this pattern. Currents are likely to speed up as they reach the narrows, and eddies may form once they have passed through here, for example at the Inner Deep site on an ebbing tide. Large eddies may form in the outer loch as the tidal stream flows past along the coast of Mull. Therefore, tidally driven currents are likely to be quite complex and difficult to predict exactly, although in general they will flow up the loch on the flood, and down the loch on the ebb, and will be fastest through the narrows.

Loch a' Chumhainn has a north west aspect and so is most exposed to winds from the north west, which could be funnelled up the loch by the surrounding land. Wind driven currents have the potential to significantly alter flows around the production area, creating surface currents flowing in the same direction as the wind which in turn generate return currents either along the sides or the bottom of the loch. Strong northerly winds and low barometric pressure may result in higher than usual tides, allowing contamination from the foreshore to be washed into the loch. These conditions can also prevent the tide from receding fully.

The catchment area of Loch a' Chumhainn is relatively small but not insignificant at about 57 km^2. The two largest freshwater inputs are the River Bellart, which discharges to the head of the loch, and the slightly smaller Allt Tor a’ Bhacain which discharges to the bay where the Inner Deep site is located. An average salinity reduction of 0.5 ppt was calculated on the basis of tidal and freshwater inflows indicating relatively low freshwater influence (Edwards and Sharples, 1986) although this will vary depending on rainfall and location within the loch. Salinity profiles taken during the shoreline survey showed that salinity near the Outer site ranged from 33.8 ppt at the surface to 33.7 ppt at the bottom (7.5m) indicating little freshwater influence. At the Inner Deep Site it ranged from 29.3 ppt at the surface to 33.7 ppt at the bottom (4m) showing higher freshwater influence at the surface. Bottom salinities were the same at both sites. All sites of salinity measurements are illustrated in Figure 14.5 overleaf. Low salinities were recorded in water samples taken from the shore during the shoreline survey near the largest freshwater inputs - at the head of the loch (2.5 ppt) and at the Inner Deep Site (8.2 ppt). As well as the sample taken at the head of the loch, two other water samples taken south of the narrows had relatively low salinities (17.4 and 21.1 ppt). All other water samples were taken north of the narrows and had salinities of over 30 ppt (aside from the one taken at the Inner Deep Site and already discussed). Therefore, at the time of shoreline survey, freshwater influence was highest to the south of the narrows. There was also considerable localised freshwater influence at the Inner Deep site in the vicinity of where the Allt Tor a’ Bhacain discharges, but there was much less freshwater influence in the Outer Loch.

Conclusions

Tidal influences will result in a bidirectional flow of water up and down the loch as the tide floods and ebbs, although this will be complicated by the shape of the loch. Large eddies may form in the outer loch as a result of the tidal stream passing the mouth of the loch along the east-west axis, and smaller

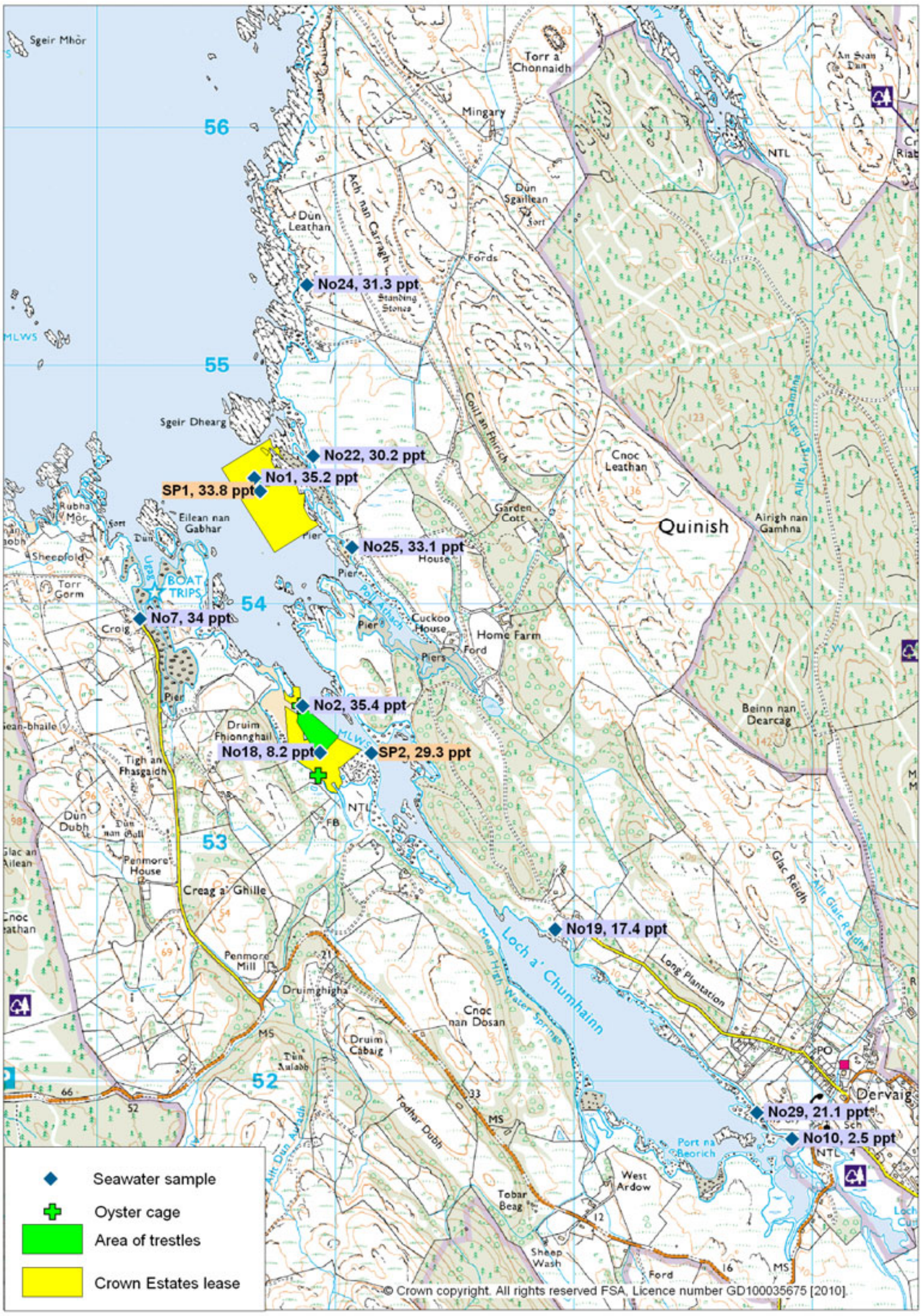


Figure 14.5 Surface salinities recorded during shoreline survey

eddies are likely to form on the downtide side of the narrows. Tidally driven currents are likely to be fastest through the narrows, which is not technically a sill but effectively divides the loch into two separate basins as suggested by salinity measurements taken during the shoreline survey. Wind driven currents are likely to change circulation patterns at times, particularly strong north westerly winds to which the loch is most exposed. These driving forces are of course superimposed on one another so a great variety of circulation patterns are likely to arise. Therefore, this simple assessment cannot realistically predict the full range of conditions that are likely to be found at Loch a' Chumhainn.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 25th and 26th August 2009 under wet conditions.

At the time of survey, the fishery consisted of two Pacific oyster sites, one in each production area, both under the same ownership. The main site is the Inner Deep Site, where oysters are cultured from seed on trestles in the intertidal zone. Oysters of a range of sizes, including market size were present. There are two dedicated sampling cages at this site, one of which is at the northern end of the site and only accessible by boat for classification sampling, the other is near the high water mark to the south of the site and only used for biotoxin sampling. There is a processing and storage shed by this site, but no depuration facilities. The Outer site consisted only of a classification sampling cage at the time of survey. Although there is no formally designated relay area, this site is used for relaying oysters from the Inner Deep Site when the Inner Deep Site has a B classification and the Outer site has an A classification, so oysters can be harvested without the need for depuration.

Few houses were observed, and they were mainly at Dervaig at the head of the loch. Five sewer pipes were seen discharging direct to the loch, one at Croig, and the other four at Dervaig. Of these, four were private sewer pipes, and one of the discharges at Dervaig was from the Scottish Water system serving this village, which consisted of a septic tank and reedbed treatment works. A further five private septic tank discharges to soakaway were recorded. Boating traffic within the loch is mainly limited to small pleasure craft operating from the pier at Croig. A large fishing boat was also observed landing its catch here.

The surrounding land is a mixture of heath, pasture and woodland. A total of 95 sheep and 36 cattle were seen on pastures to the north west of Croig. A total of 79 sheep and one horse were counted on pastures near the Inner Deep Site, including 6 sheep that had access to the shore by the trestles. Around Dervaig, 62 sheep, 10 chickens and 1 calf were seen. Although no seals were seen during the course of the shoreline survey, the grower reports a substantial year round presence of seals, sometimes numbering up to 40 animals in the outer loch. An aggregation of 37 geese was seen on the east shore near the Outer site. Locations of animals observed can be found in Figure 15.1

Of the seawater samples taken during the survey, the two taken from the boat at the location of the classification sampling cages gave the lowest results (3 and 4 *E. coli* cfu/100ml). These were taken on the falling tide. All other seawater samples were taken from the shore, and results for these ranged from 60 to 1700 *E. coli* cfu/100ml suggesting under the conditions at the time, contamination levels were much higher at the waters edge. There was no obvious spatial pattern to the *E. coli* levels found in the seawater samples. The two highest results arose on the shore adjacent to the Outer site (1700 *E. coli* cfu/100ml) and near the head of the loch (900 cfu/100ml). Salinities were markedly lower in the inner loch to the south of the narrows (range 2.5 to 21.1 ppt) than to the north of the narrows, where all but one sample had a salinity of over 30 ppt. The one exception to this was a sample taken at the Inner Deep Site next to where a significant stream discharges where the salinity was only 8.2 ppt. *E. coli* levels in freshwater samples taken from the most significant freshwater inputs ranged from <100 to 1500 cfu/100ml The two largest freshwater inputs were the River Bellart, which discharges to the head of the loch and contained 400 *E. coli* cfu/100ml, and the Allt Torr A'Bhacain which contained 330 *E. coli* cfu/100ml and discharges at the southern end of the Inner Deep Site.

Three oyster samples were taken during the survey. The two which were taken from the dedicated classification sampling cages at the Outer and Inner Deep sites both gave results of 20 *E. coli* MPN/100g, whereas the one taken from the biotoxin sampling cage, at the southern end of the Inner Deep Site and relatively high on the shoreline gave a result of 750 *E. coli* MPN/100g. The result for a seawater sample taken in this vicinity was relatively high at 210 *E. coli* cfu/100 ml.

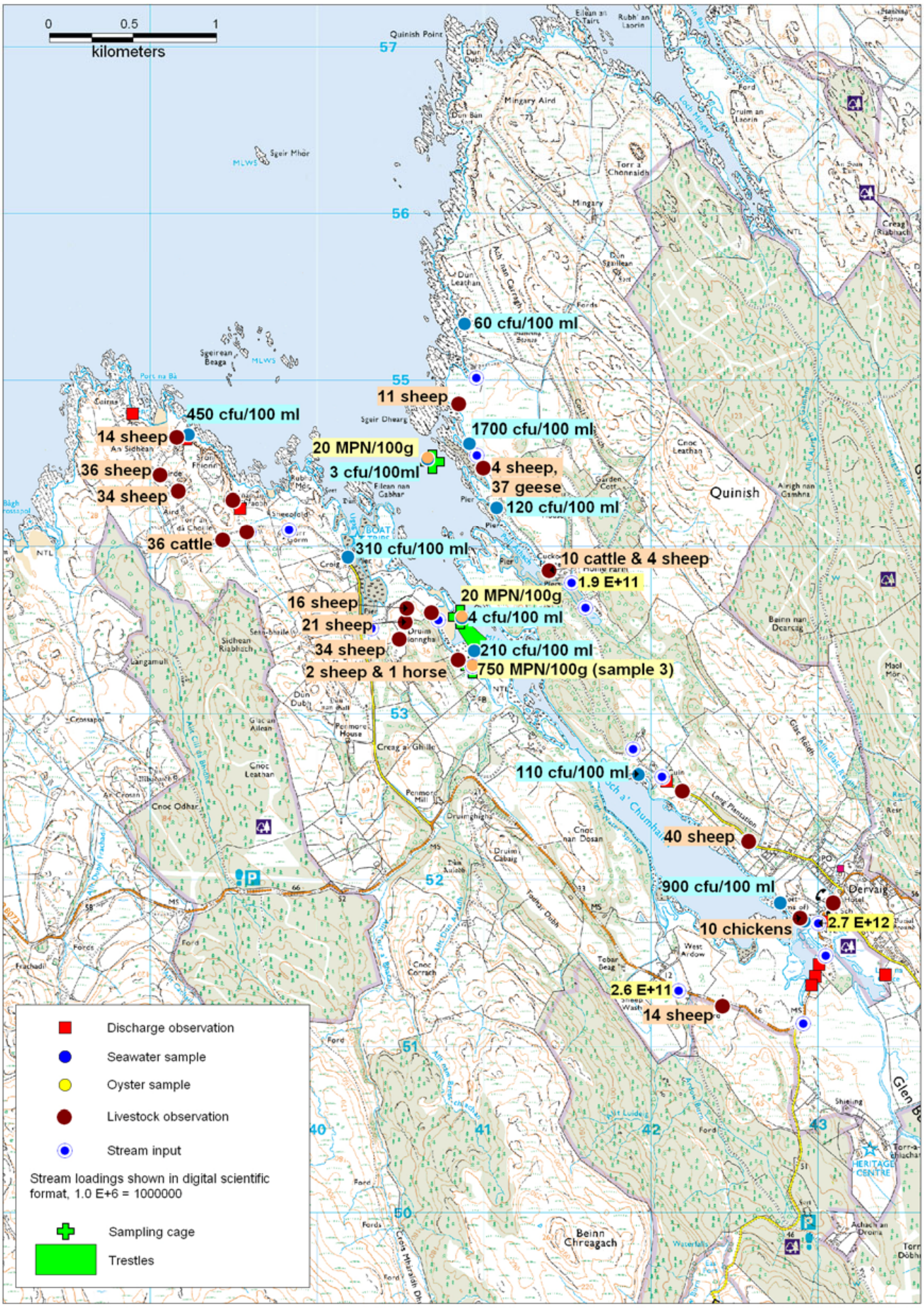


Figure 15.1 Summary of shoreline survey findings

16. Overall Assessment

Human sewage impacts

Human sewage inputs to Loch a' Chumhainn are centred around Dervaig, at the head of the loch. A Scottish Water discharge and associated CSO/EO are located near the village. The discharge serves a population of 198 and the effluent is treated by a septic tank and reed bed. Contamination will be greater when the overflow discharge is in operation when the main sewerage system is overloaded following heavy rainfall. However it is unclear how frequent this will occur.

There are three small private discharges to Loch a' Chumhainn at Dervaig, and two small private discharges to watercourses feeding into the head of the loch in the Dervaig area. These discharges are therefore likely to contribute to levels of contamination at both sites, particularly at the Inner Deep site which is closer to the head of the loch (3 km) than the Outer site (4 km).

Of probable significance to the Inner Deep site are two private discharges to the Allt Torr A' Bhacain, the watercourse discharging into the southern end of the bay where the Inner Deep Site is located. One of these is a small residential discharge, and the other is a discharge from a restaurant with a consented population of up to 70. Although this is likely to be a high estimate of its usage, this discharge is likely to be of significance to the Inner Deep Site. Two private discharges to the loch at Croig may also be of significance. Aside from these, all other discharges within the Loch a' Chumhainn area are to soakaway, and so are unlikely to impact on water quality in the loch, assuming they are functioning correctly.

There is limited boat traffic centred around Croig pier. A single fishing boat is in operation, and a few other small boats are moored in the area. Yachts are likely to visit the anchorage just to the north or east of Croig, but not in large numbers. Of these boats, visiting yachts and the fishing boat are more likely to discharge waste water overboard.

Agricultural impacts

The land surrounding Loch a' Chumhainn is a mixture of woodland, heath and improved grassland. The improved grassland is present in larger areas towards the southern end of the loch. Agricultural census data indicate that agriculture in this part of Mull is dominated by sheep production, with some cattle and small numbers of poultry, horses and pigs. The shoreline survey identified that densities of livestock were greatest around the north end of the west shore of the loch and near the Inner Deep Site, including 6 sheep which had access to the adjacent shore. Livestock were also seen in the vicinity of Dervaig, and along the shore adjacent to the Outer site. Based on their observed distribution, highest inputs from livestock may be expected on the west shore, north of the small embayment at Croig pier. Contamination from livestock will mainly be carried to the production areas via streams. Higher inputs of contamination from livestock may be expected during the summer months as stock numbers are higher, and they are likely to access streams to drink more.

Wildlife impacts

The main wildlife species potentially impacting on the production areas are seals, which are present year round and mainly in the vicinity of the Outer site, with up to about 40 animals present at times. Impacts from other wildlife species are likely to be of lesser significance. Geese were seen on the eastern shore during the shoreline survey (summer) and it is possible that they also overwinter in the area, possibly in greater numbers. Seabirds are likely to feed around the loch and deer are also likely to be present in the area. However, as these animals are highly mobile, the impacts of these on the fishery will be unpredictable, and deposition of faeces by wildlife is likely to be widely distributed around the area.

Seasonal variation

The Isle of Mull is a popular tourist destination which is served by several car ferries which sail daily from Oban. There are a few B&Bs and a number of dwellings likely to be holiday homes in the area, so there is likely to be an increase in local population during the summer months. Of specific interest to the Inner Deep Site, the restaurant that has a sewage discharge to Allt Tor A'Bhacain is likely to be busier during the summer months. More visiting yachts may also be expected during the summer.

Livestock numbers are likely to be higher in the summer, so diffuse pollution from animals may be higher during the summer, particularly following high rainfall events. Livestock are likely to access watercourses to drink more frequently during warmer weather.

Weather is wetter and windier during the autumn and winter months so an increase in rainfall dependent contamination, such as runoff from pastures and overflows from the treatment works at Dervaig, may be expected. However, heavy rainfall events may also occur during the summer months and may have a greater impact in terms of bacterial contamination. Livestock numbers will be higher, and during the longer dry periods faecal matter can build up on pastures, leading to a highly contaminated 'first flush' of runoff.

An analysis of historic *E. coli* monitoring data showed a significant seasonal effect, with results for the summer and autumn significantly higher than those in the spring at both the Outer and Inner Deep Sites. A very weak positive relationship between *E. coli* monitoring results and temperature was found at the Outer site, but not at the Inner Deep Site. Shellfish growing waters monitoring data also showed a similar seasonal effect in levels of faecal coliforms in shore mussels taken at Croig pier, with results for quarter 3 significantly higher than those for quarters 1 and 4.

Rivers and streams

Loch a' Chumhainn receives runoff from a catchment area of approximately 57 km^2, which is a mixture of moorland, woodland and some pasture. Bacterial loadings of significant freshwater inputs to the loch were calculated from measurements taken during the shoreline survey, which was undertaken during the late summer following heavy rainfall. Therefore measured loadings are likely to be towards the high end of their range. The measured *E. coli* levels were low to moderate, ranging from <100 to 1500 cfu/100ml.

The largest freshwater input is the River Bellart, which discharges to the head of the loch and delivered a calculated loading of 2.7×10^{12} *E. coli* cfu/day at the time of survey. Therefore, this river is likely to be a significant source of contamination to both sites in the same manner as the Dervaig sewage discharges, although its loading is likely to fluctuate depending on rainfall and other factors such as number and location of livestock within its catchment area.

The burn Allt Tor A'Bhacain discharges to the southern end of the bay adjacent to the Inner Deep Site, and carried a calculated loading of 8.4×10^{11} *E. coli* cfu/day at the time of survey. Given its loading and proximity to the fishery it is thought to be the most significant source of contamination at the Inner Deep Site. The close proximity of the stream to the site suggests that a gradient in levels of contamination from this source may be present across the Inner Deep Site. Allt Tor A'Bhacain receives two private sewage discharges in addition to contamination from diffuse sources, so will always carry faecal contamination irrespective of rainfall or the extent of diffuse sources within its catchment.

One stream discharges on the shore immediately adjacent to the Outer site. At the time of survey, the stream's loading was 1.9×10^{10} *E. coli* cfu/day indicating it is likely to be a significant local source of contamination. Two larger streams discharge to the east shore about 1 km to the south of this site, and these may also significant contribute to levels of contamination at this site.

Meteorology, hydrology, and movement of contaminants

Tide, wind and freshwater inputs will dictate the pattern of circulation within Loch a' Chumhainn. A weak correlation was found between historic *E. coli* monitoring results and the spring/neap cycle for the Outer site, with higher results all occurring during larger spring tides. A correlation between historic *E. coli* monitoring results and tidal state on the high/low cycle was also found for this site with higher results generally occurring during the second half of the ebb tide. Taken together, these tentatively suggest that important sources of contamination for this site lie some distance away as they impact more heavily when tidal circulation is greatest, and that they lie towards the southeast of the fishery. No effects of tide were found on historic *E. coli* monitoring results at the Inner Deep Site, although the two peak results >1000 *E.coli*/ 100 g were obtained from samples taken at spring tides.

Freshwater inputs into the head of the Loch, in particular, will result in a seaward flow of less saline water at the surface. Mixing is likely to occur at the narrows, so contamination from sources south of the narrows may be more mixed throughout the water column by the time it reaches the fishery sites. Salinity profiles taken during the shoreline survey showed slight reduction in surface salinity just off the Inner Deep site, but no reduction at the Outer site. This suggests that in the wider parts of the loch, the freshwater influence is lower.

No correlation was found between recent rainfall and historic *E. coli* monitoring results at the Outer site. At the Inner Deep site, positive correlations were found between historic *E. coli* monitoring results and total rainfall in the previous 2 and 7 days, a further indication that rainfall dependent contamination is more important at this site. The strongest of these correlations was with total rainfall 2 days previous to sampling and *E. coli* levels, which is consistent with the predicted short flushing time of the loch, and the relatively high gradient and therefore fast-draining catchment area. However, no relationship was found between historic *E. coli* monitoring results and salinity at either site.

The three most important point sources of contamination identified were the River Bellart and the Scottish Water septic tank, both of which discharge to the head of the loch, and the Allt Tor a' Bhacain which discharges at the southern end of the Inner Deep Site. Contamination from sources discharging to the inner loch may travel through the narrows to reach the outer loch. However, as the contamination reaches the wider areas of the loch, it will become more dilute. Therefore impacts of these sources on microbial contamination are likely to be slightly greater at the Inner Deep Site than at the Outer site. Impacts from the Allt Tor a' Bhacain will be much greater at the Inner Deep Site than at the Outer site. Within the Inner Deep site, the source is likely to impact most heavily at the southern inshore corner of the site and least heavily at the northernmost offshore corner where the classification sampling cage for this site is located.

Wind is likely to affect circulation patterns within the loch at times, driving a surface current in the same direction as the wind. Due to the distance between the fishery and the nearest weather station for which wind data was available no evaluation of the effects of wind on historic *E. coli* monitoring results was attempted.

Temporal and geographical patterns of sampling results

No significant difference was found between historic *E. coli* monitoring results at the Inner Deep Site and the Outer site either in terms of mean result or the proportion of results exceeding 230 *E. coli* MPN/100g. Within the Outer site, higher results appear to have occurred towards the middle of the site, although this may be a temporal effect coinciding with the northward movement of the sampling cage. At the Inner Deep Site increased levels of contamination appear to have arisen at sampling sites closer inshore. Overall, historic *E. coli* monitoring results from the Outer site appear to have improved steadily since 2002, apart from in 2006 when results appear to have deteriorated. A similar but less marked pattern was observed at the Inner Deep Site. It is not clear what factors may have contributed to this decline.

Shellfish growing waters monitoring results indicate that very high levels of contamination are sometimes found in mussels at Croig pier, suggesting there are localised water quality issues there.

Three oyster samples were taken during the shoreline survey. One taken from the sampling cage at the Outer site gave an *E. coli* result of 20 MPN/100g, as did one taken from the sampling cage at the northeastern extremity of the Inner Deep Site. A sample taken from the biotoxins sampling cage, which is located inshore from the southwestern corner of the Inner Deep site gave a result of 750 *E. coli* MPN/100g. Although based on only two samples, this does suggest levels of contamination may be higher at the southwestern corner of the Inner Deep site.

Seawater samples taken from the boat during the shoreline survey showed much lower levels of contamination than those taken from the shore, suggesting under the conditions at the time, contamination levels were much higher at the waters edge. The seawater sample taken in the vicinity of the biotoxin sample cage gave a relatively high result of 210 *E. coli* cfu/100 ml. Salinities were markedly lower in the inner loch to the south of the narrows than to the north of the narrows, where all but one sample had a salinity of over 30 ppt. The one exception to this was a sample taken at the Inner Deep Site next to the mouth of the Allt Tor a' Bhacain where the salinity was only 8.2 ppt.

Conclusions

The embayment in which Croig pier is located is impacted by discharges from septic tanks and potentially from boating traffic, as well as diffuse contamination from livestock. Shellfish growing waters monitoring has confirmed that this area is subject to high levels of contamination and so this area should be excluded from the classified areas.

The area inshore of the narrows could be considered as a distinct water body, as it has a higher level of freshwater influence and receives the bulk of human sewage and land runoff inputs. Therefore this area should also be excluded from the classified areas. Although an area around the mouth of Allt Tor a' Bhacain receives significant amounts of faecal contamination via the burn, it is not practical to exclude it from the classified area as the fishery is already established there.

Recent classification history and a straight comparison of historical *E. coli* monitoring results between the two sites suggests levels of contamination are almost identical. However, some differences were found in their response to environmental variables, with tide effects found at the Outer site, and rainfall effects at the Inner Deep Site suggesting some difference in sources and/or pathways of contamination. There is likely to be noticeable within-site variation in levels of contamination at the Inner Deep Site. Historic monitoring samples have most recently been taken from what is likely to be the least contaminated part of this site.

At the Inner Deep site, the location of the main freshwater input to this bay and shellfish sampling results suggest that the RMP should be relocated to the south western corner of the site.

At the Outer site, there is less clear evidence for the spatial assignment of the RMP, aside from a general tendency for higher levels of contamination to occur closer to the shore. Two larger streams discharge to the east shore about 1 km to the south, but another smaller stream discharges to the shoreline adjacent to the fishery. As this closer stream may result in a small hotspot of contamination around its mouth, the RMP should be relocated nearer that source.

Both sites show seasonal variation in levels of contamination and neither meets the criteria for reducing the sampling frequency from monthly to bimonthly.

17. Recommendations

Production Area

Loch a' Chumhainn: Outer

It is recommended that the production area boundaries be restricted to exclude the opposite shore and embayment at Croig in order to avoid expansion of the fishery into these more contaminated areas. It is further recommended that the southern boundary be drawn to exclude the bay at Poll Athach, due south of the fishery. Recommended production area boundaries are lines drawn between NR 4077 5486 and NR 4039 5470 and between NR 4039 5470 and NR 4076 5409 and between NR 4076 5409 and NR 4104 5423 extending to MHWS.

Loch a' Chumhainn: Inner Deep Site

It is rcommended that the production area boundaries be restricted to exclude the head of the loch and to more closely bracket the existing fishery, as higher levels of contamination have been recorded both toward the head of the loch and closer to the embayment at Croig. Recommended production area boundaries are lines drawn between NR 4084 5391 and NR 4061 5377 and between NR 4115 5327 and NR 4120 5346 extending to MHWS.

RMP

Loch a' Chumhainn: Outer

It is recommended that the RMP be relocated to NR 4080 5448, which is nearer to shore and closer to a small stream that discharges into the production area from the adjacent shoreline. The existing sampling cage could be redeployed to this location, provided that is is in place a minimum of 2 weeks prior to the first sample being taken. A sampling tolerance of 10 m is recommended to allow for variation in GPS accuracy. No sampling depth is applicable.

Loch a' Chumhainn: Inner Deep Site

It is recommended that RMP be relocated to NR 4093 5336, at the south western corner of the site nearer to where the Allt Tor a' Bhacain discharges into the bay. The existing sampling cage could be redeployed to this location, provided that is is in place a minimum of 2 weeks prior to the first sample being taken. A sampling tolerance of 10 m is recommended to allow for variation in GPS accuracy. No sampling depth is applicable.

Frequency

Both sites

Seasonality in historical monitoring results indicates that the frequency of sampling should remain at monthly.

Review

Should both sites continue to show similar levels of contamination following implementation of the recommendations of this report, then the production areas could be amalgamated with the RMP reassigned to the previous RMP which yields the highest overall *E. coli* result. However, if the Outer site is to be used as a relaying area at any point, it will need separate designation and classification.

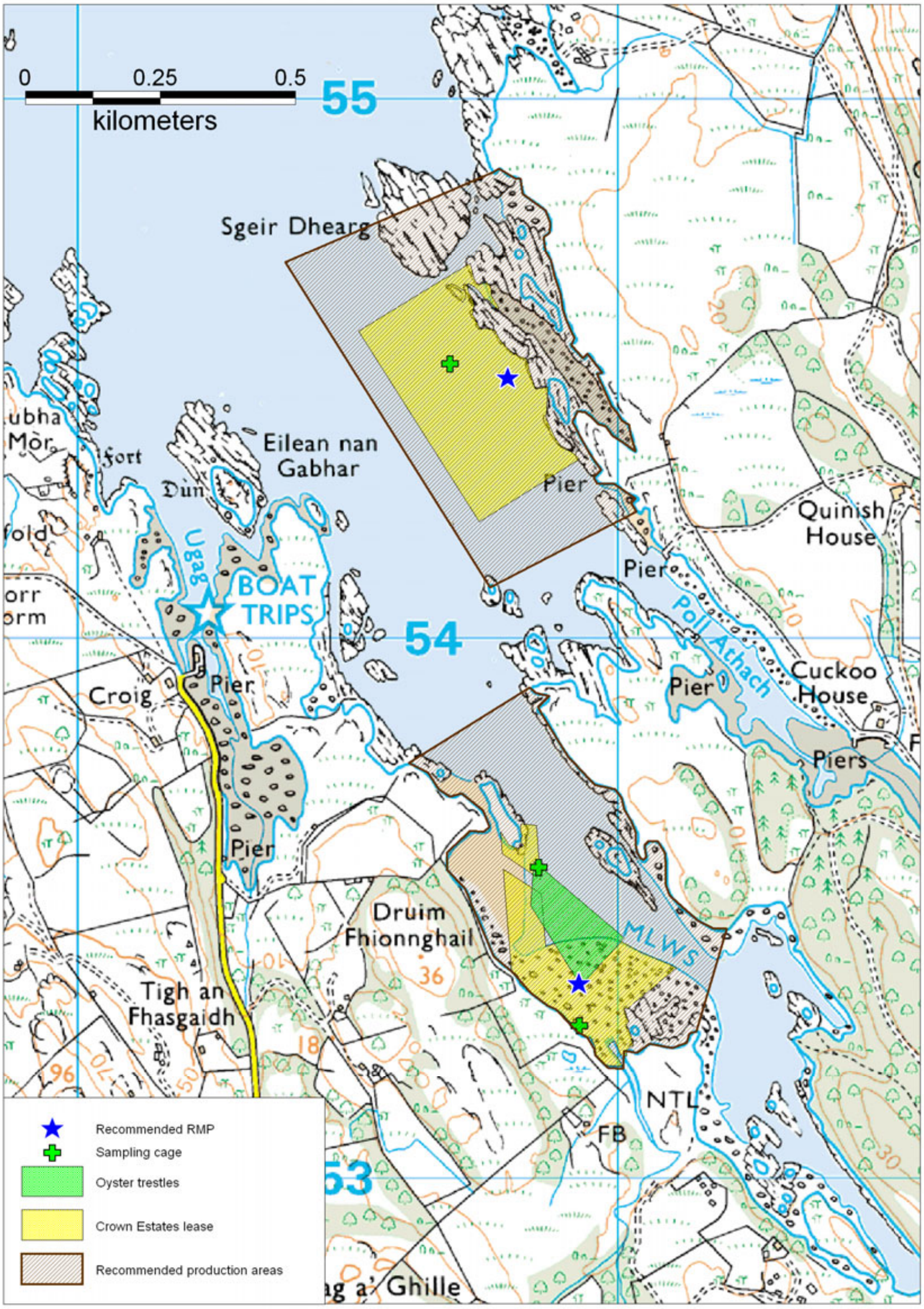


Figure 17.1 Recommendations for Loch a' Chumhainn

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Sampling Plan for Loch A Chumhainn

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISH-ERY	NGR OF RMP	EAST	NORTH	TOLER-ANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Loch A Chumhainn: Outer	Outer	AB 113 018	Pacific oyster	Cage	NR 4080 5448	140800	754480	10	N/A	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan
Loch A Chumhainn: Inner Deep Site	Inner Deep Site	AB 112 017	Pacific oyster	Trestle	NR 4093 5336	140930	753360	10	N/A	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan

Table of Proposed Boundaries and RMPs

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Loch A Chumhainn: Outer	Pacific oyster	AB 113 018 13	Area bounded by lines drawn between NM 3862 5505 and NM 4090 5707 and between NM 4040 5425 and NM 4095 5411.	NM 408 547	Area bounded by lines drawn between NR 4077 5486 and NR 4039 5470 and between NR 4039 5470 and NR 4076 5409 and between NR 4076 5409 and NR 4104 5423 extending to MHWS.	NR 4080 5448	Production area reduced to exclude more contaminated areas, RMP moved inshore.
Loch A Chumhainn: Inner Deep Site	Pacific oyster	AB 112 017 13	Area to the east of a line drawn between NM 4040 5425 and NM 4095 5411.	NM 406 539	Area bounded by lines drawn between NR 4061 5377 and NR 4084 5391 and between NR 4115 5327 and NR 4120 5346 extending to MHWS	NR 4093 5336	Production area reduced to exclude more contaminated areas, RMP moved to south west corner of site.

Geology and Soils Information

Component soils and their associations were identified using uncoloured soil maps (scale 1:50,000) obtained from the Macaulay Institute. The relevant soils associations and component soils were then investigated to establish basic characteristics. From the maps 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.

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 (Macaulay Institute, 2007).

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%.

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. They have a very high surface % runoff of between 48.4 – 60%.

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 this region have an average surface % runoff of 44.3%, so it is likely that in this case they would be poorly draining.

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and it's potential impact on runoff.

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.

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General Information on Wildlife Impacts

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 seal surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage.

According to the Scottish Executive, in 2001 there were approximately 119,000 grey seals in Scottish waters, the majority of which were found in breeding colonies in Orkney and the Outer Hebrides.

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 concentration 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).

Cetaceans

As mammals, whales and dolphins would be expected to have resident populations of *E. coli* and other faecal indicator bacteria in the gut. Little is known about the concentration of indicator bacteria in whale or dolphin faeces, in large part because the animals are widely dispersed and sample collection difficult.

A variety of cetacean species are routinely observed around the west coast of Scotland. Where possible, information regarding recent sightings or surveys is gathered for the production area. As whales and dolphins are broadly free ranging, this is not usually possible to such fine detail. Most survey data is supplied by the Hebridean Whale and Dolphin Trust or the Shetland Sea Mammal Group and applies to very broad areas of the coastal seas.

Table 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*	369
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.

It is reasonable to expect that whales would not routinely affect shellfisheries located in shallow coastal areas. It is more likely that dolphins and harbour porpoises would be found in or near fisheries due to their smaller physical size and the larger numbers of sightings near the coast.

Birds

Seabird populations were surveyed all over Britain as part of the SeaBird 2000 census. These counts are investigated using GIS to give the numbers observed within a 5 km radius of the production area. This gives a rough idea of how many birds may be present either on nests or feeding near the shellfish farm or bed.

Further information is gathered where available related to shorebird surveys at local bird reserves when present. Surveys of overwintering geese are queried to see whether significant populations may be resident in the area for part of the year. In many areas, at least some geese may be present year round. The most common species of goose observed during shoreline surveys has been the Greylag goose. Geese can be found grazing on grassy areas adjacent to the shoreline during the day and leave substantial faecal deposits. Geese and ducks can deposit large amounts of faeces in the water, on docks and on the shoreline.

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28 x 10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77 x 10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). An earlier study found that geese averaged from 5.23 to 18.79 defecations per hour while feeding, though it did not specify how many hours per day they typically feed (Bedard and Gauthier, 1986).

Waterfowl can be a significant source of pathogens as well as indicator organisms. Gulls frequently feed in human waste bins and it is likely that they carry some human pathogens.

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 will be present particularly in wooded areas where the habitat is best suited for them. Deer, like cattle and other ruminants, shed *E. coli*, *Salmonella* and other potentially pathogenic bacteria via their faeces.

Otters

The European Otter (*Lutra lutra*) is present around Scotland with some areas hosting populations of international significance. Coastal otters 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 10 m 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, which may be washed into the water during periods of rain.

References:

Alderisio, K.A. and N. DeLuca (1999). Seasonal enumeration of fecal coliform bacteria from the feces of Ring-billed gulls (*Larus delawarensis*) and Canada geese (*Branta canadensis*). *Applied and Environmental Microbiology*, 65:5628-5630.

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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 *E. coli* data was log transformed prior to statistical tests.

Section 11.3 T-test comparison of results by site

```
Paired T for log e coli inner - log e coli outer

                     N    Mean   StDev  SE Mean
log e coli inner    77  1.7672  0.5610   0.0639
log e coli outer    77  1.7451  0.5575   0.0635
Difference          77  0.0222  0.5113   0.0583


95% CI for mean difference: (-0.0939, 0.1382)
T-Test of mean difference = 0 (vs not = 0): T-Value = 0.38  P-Value = 0.705
```

Section 11.3 Chi squared comparison of proportion of results over 230 *E. coli* MPN/100g by site

```
Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

       inner  outer  Total
    1     11     10     21
       10.50  10.50
       0.024  0.024

    2     66     67    133
       66.50  66.50
       0.004  0.004

Total     77     77    154

Chi-Sq = 0.055, DF = 1, P-Value = 0.814
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (Outer)

```
Source  DF      SS     MS     F      P
Season   3   3.322  1.107  4.01  0.011
Error   75  20.708  0.276
Total   78  24.029

S = 0.5255   R-Sq = 13.82%   R-Sq(adj) = 10.38%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --+---------+---------+---------+-------
1      21  1.4285  0.4473  (--------*--------)
2      22  1.8578  0.5329                  (--------*--------)
3      20  1.9614  0.6006                      (--------*---------)
4      16  1.7361  0.5091            (---------*----------)
                           --+---------+---------+---------+-------
                           1.25      1.50      1.75      2.00

Pooled StDev = 0.5255


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season

Individual confidence level = 98.97%
```

```
Season = 1 subtracted from:

Season    Lower  Center   Upper  ----+---------+---------+---------+-----
2        0.0076  0.4293  0.8510              (--------*-------)
3        0.1011  0.5329  0.9648                (--------*-------)
4       -0.1511  0.3076  0.7662           (--------*--------)
                                 ----+---------+---------+---------+-----
                                  -0.50      0.00      0.50      1.00


Season = 2 subtracted from:

Season    Lower   Center   Upper  ----+---------+---------+---------+-----
3       -0.3234   0.1036  0.5307          (-------*--------)
4       -0.5758  -0.1217  0.3324    (---------*--------)
                                  ----+---------+---------+---------+-----
                                   -0.50      0.00      0.50      1.00


Season = 3 subtracted from:

Season    Lower   Center   Upper  ----+---------+---------+---------+-----
4       -0.6890  -0.2254  0.2382  (--------*---------)
                                  ----+---------+---------+---------+-----
                                   -0.50      0.00      0.50      1.00
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (Inner Deep Site)

```
Source  DF      SS     MS     F      P
Season   3   3.963  1.321  4.53  0.006
Error   79  23.033  0.292
Total   82  26.996

S = 0.5400   R-Sq = 14.68%   R-Sq(adj) = 11.44%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ---------+---------+---------+---------+
1      21  1.5101  0.5265  (--------*---------)
2      25  1.9966  0.5827                    (--------*-------)
3      20  1.9949  0.6269                   (---------*--------)
4      17  1.6335  0.3421      (---------*----------)
                           ---------+---------+---------+---------+
                                 1.50      1.75      2.00      2.25

Pooled StDev = 0.5400


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season

Individual confidence level = 98.96%


Season = 1 subtracted from:

Season    Lower  Center   Upper  -------+---------+---------+---------+--
2        0.0672  0.4865  0.9058                  (--------*-------)
3        0.0422  0.4848  0.9274                  (--------*--------)
4       -0.3387  0.1234  0.5855          (--------*---------)
                                 -------+---------+---------+---------+--
                                     -0.50      0.00      0.50      1.00
```

```
Season = 2 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
3       -0.4267  -0.0017  0.4232         (--------*-------)
4       -0.8084  -0.3631  0.0822   (--------*--------)
                                  -------+---------+---------+---------+--
                                      -0.50      0.00      0.50      1.00


Season = 3 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
4       -0.8287  -0.3614  0.1059  (---------*--------)
                                  -------+---------+---------+---------+--
                                      -0.50      0.00      0.50      1.00
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (Outer)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.123
P-Value = 0.352
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (Inner Deep Site)

```
Pearson correlation of 2 day rain ranked and e coli for rain ranked = 0.409
P-Value = 0.001
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (Outer)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.034
P-Value = 0.801
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (Inner Deep Site)

```
Pearson correlation of 7 day rain ranked and e coli for rain ranked = 0.326
P-Value = 0.010
```

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (Outer)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 17 November 2009 15:08:42

Variables (& observations)	r	p
Angles & Linear (79)	0.274	0.003

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (Inner Deep Site)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 17 November 2009 14:40:47

Variables (& observations)	r	p

Angles & Linear (83) 0.186 0.062

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (Outer)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 17 November 2009 14:59:10

Variables (& observations)	r	p
Angles & Linear (79)	0.302	9.63E-04

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (Inner Deep Site)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 17 November 2009 14:52:10

Variables (& observations)	r	p
Angles & Linear (83)	0.108	0.395

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (Outer)

```
The regression equation is
log e coli for temperature = 1.23 + 0.0444 temperature


Predictor       Coef  SE Coef     T      P
Constant      1.2330   0.2454  5.02  0.000
temperature  0.04442  0.02135  2.08  0.042


S = 0.534073   R-Sq = 7.5%   R-Sq(adj) = 5.8%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   1.2342  1.2342  4.33  0.042
Residual Error  53  15.1174  0.2852
Total           54  16.3516


Unusual Observations

                   log e coli
                          for
Obs  temperature  temperature     Fit  SE Fit  Residual  St Resid
  5         12.0       2.8451  1.7660  0.0752    1.0791     2.04R
 45         14.9       3.1139  1.8948  0.1103    1.2191     2.33R

R denotes an observation with a large standardized residual.
```

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (Inner Deep Site)

```
The regression equation is
log e coli for temperature = 1.57 + 0.0190 temperature
```

```
Predictor       Coef  SE Coef     T      P
Constant      1.5650   0.2496  6.27  0.000
temperature  0.01901  0.02205  0.86  0.392


S = 0.556368   R-Sq = 1.4%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.2302  0.2302  0.74  0.392
Residual Error  52  16.0964  0.3095
Total           53  16.3266


Unusual Observations

                   log e coli
                          for
Obs  temperature  temperature     Fit  SE Fit  Residual  St Resid
 43         15.1       3.3424  1.8521  0.1215    1.4903     2.74R

R denotes an observation with a large standardized residual.
```

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (Outer)

```
The regression equation is
log e coli for salinity = 1.59 + 0.0026 salinity


Predictor     Coef  SE Coef     T      P
Constant    1.5949   0.5583  2.86  0.006
salinity   0.00259  0.01781  0.15  0.885


S = 0.555477   R-Sq = 0.0%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.0065  0.0065  0.02  0.885
Residual Error  45  13.8850  0.3086
Total           46  13.8915


Unusual Observations

                 log e coli
Obs  salinity  for salinity     Fit  SE Fit  Residual  St Resid
  4      32.0        2.8451  1.6779  0.0829    1.1672     2.13R
  8      10.0        1.0000  1.6208  0.3830   -0.6208    -1.54 X
 20      26.0        2.8751  1.6623  0.1207    1.2127     2.24R
 37      32.0        3.1139  1.6779  0.0829    1.4361     2.61R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (Inner Deep Site)

```
The regression equation is
log e coli for salinity = 2.28 - 0.0175 salinity
```

```
Predictor      Coef  SE Coef      T      P
Constant     2.2826   0.4742   4.81  0.000
salinity   -0.01748  0.01593  -1.10  0.277


S = 0.561098   R-Sq = 2.1%   R-Sq(adj) = 0.4%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.3790  0.3790  1.20  0.277
Residual Error  57  17.9453  0.3148
Total           58  18.3243


Unusual Observations

                 log e coli
Obs  salinity  for salinity     Fit  SE Fit  Residual  St Resid
 10      30.0        2.8751  1.7582  0.0737    1.1169      2.01R
 40      17.0        1.9542  1.9854  0.2107   -0.0312     -0.06 X
 48      35.0        3.3424  1.6707  0.1152    1.6717      3.04R
 53      19.0        1.0000  1.9504  0.1812   -0.9504     -1.79 X
 55      16.0        2.3424  2.0029  0.2257    0.3395      0.66 X

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 12 One way ANOVA comparison of SGW sampling results by quarter

```
Source   DF      SS     MS     F      P
quarter   3   7.250  2.417  5.84  0.014
Error    10   4.138  0.414
Total    13  11.387

S = 0.6432   R-Sq = 63.67%   R-Sq(adj) = 52.77%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  ------+---------+---------+---------+---
Q1     4  2.4364  0.5077     (------*-------)
Q2     3  2.7876  0.5132        (-------*-------)
Q3     4  4.0179  0.8219                     (------*------)
Q4     3  2.2271  0.6368  (-------*--------)
                          ------+---------+---------+---------+---
                              2.0       3.0       4.0       5.0

Pooled StDev = 0.6432


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of quarter

Individual confidence level = 98.80%


quarter = Q1 subtracted from:

quarter    Lower   Center   Upper  ------+---------+---------+---------+---
Q2       -1.1530   0.3512  1.8554            (-------*------)
Q3        0.1889   1.5815  2.9741                   (------*------)
Q4       -1.7136  -0.2094  1.2948         (-------*------)
                                   ------+---------+---------+---------+---
                                       -2.0       0.0       2.0       4.0
```

```
quarter = Q2 subtracted from:

quarter    Lower   Center   Upper  ------+---------+---------+---------+---
Q3       -0.2739   1.2303  2.7345                (------*-------)
Q4       -2.1686  -0.5606  1.0475       (-------*-------)
                                   ------+---------+---------+---------+---
                                      -2.0       0.0       2.0       4.0

quarter = Q3 subtracted from:

quarter    Lower   Center    Upper  ------+---------+---------+---------+---
Q4       -3.2950  -1.7908  -0.2866  (------*-------)
                                    ------+---------+---------+---------+---
                                       -2.0       0.0       2.0       4.0
```

Hydrographic Methods

The new EU regulations require an appreciation of the hydrography and currents within a region classified for shellfish production with the aim to “determine the characteristics of the circulation of pollution, appreciating current patterns, bathymetry and the tidal cycle.” This document outlines the methodology used by Cefas to fulfil 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. A glossary at the end of the document defines commonly used hydrographic terms e.g. tidal excursion, residual flow, spring-neap cycle etc.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only. 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 consider the more basic hydrographic processes and describes the common methodology applied to all sites.

<u>Background processes</u>
Currents in estuarine and coastal waters are generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences.

Tidal flows often dominate water movement over the short term (approximately 12 hours) and move material over the length of the *tidal excursion*. Tides move water back and forth over the tidal period often leading to only a small net movement over the 12 hours tidal cycle. This small net movement is partly associated with the *tidal residual* flow and over a period of days gives rise to persistent movement in a preferred direction. The direction will depend on a number of factors including the bathymetry and direction of propagation of the main tidal wave.

Wind and density driven current also lead to persistent movement of water and are particular important in regions of relatively low tidal velocities characteristic of many of the water bodies in Scottish waters. 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.

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.

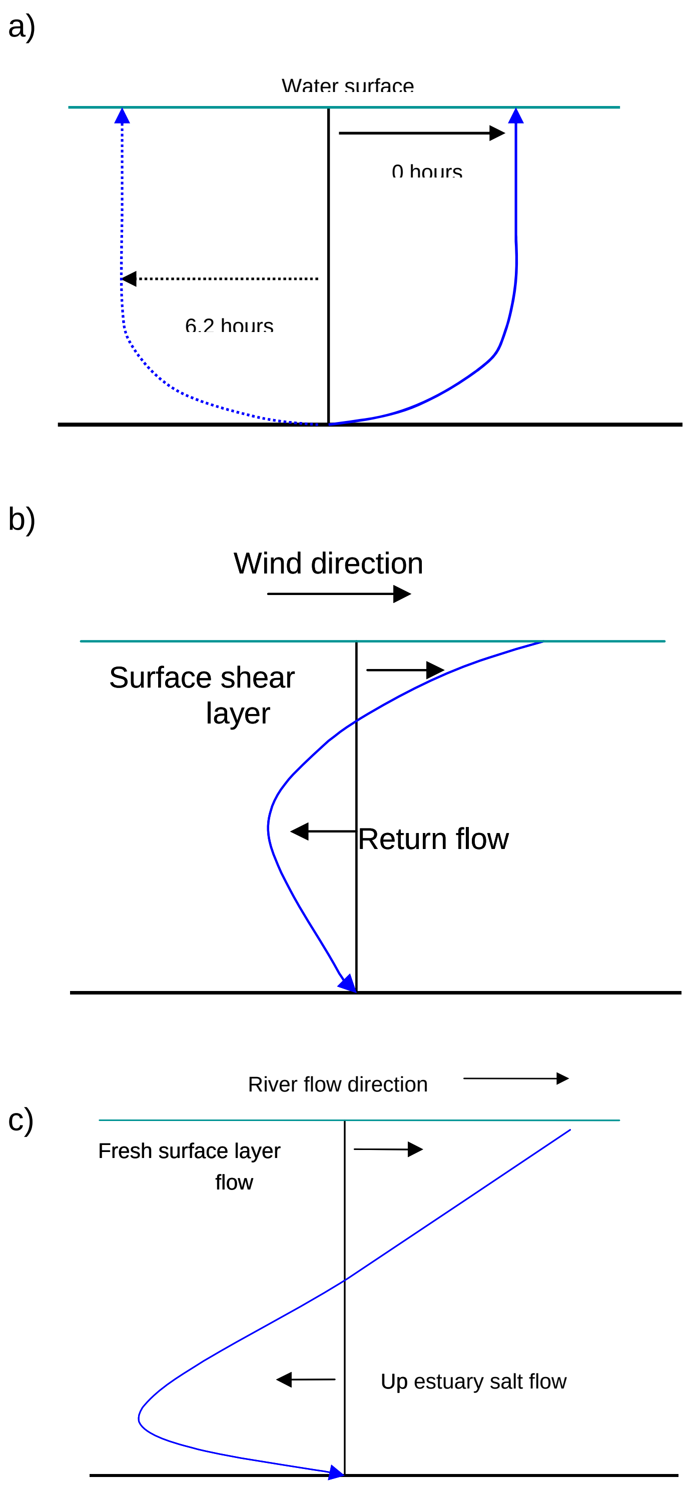

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

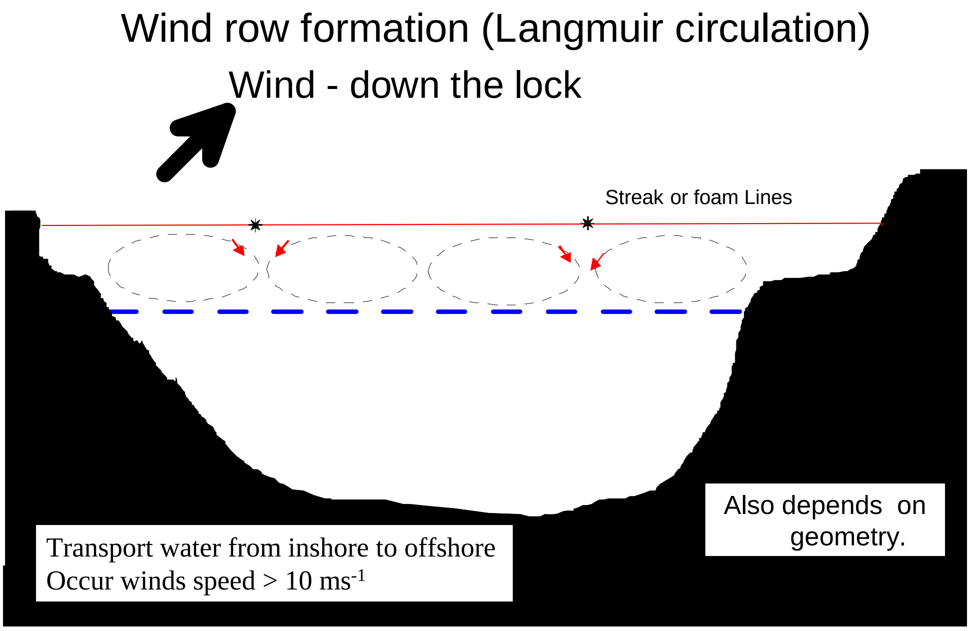

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

<u>Non-modelling Assessment</u>

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'.

Many Scottish shellfish 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.

The catalogue of Scottish Sea Loch 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 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.

References

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

The following technical terms may 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 near shore 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.

Shoreline Survey Report

Loch A Chumhainn: Inner Deep Site (AB112)
Loch A Chumhainn: Outer (AB113)

Scottish Sanitary Survey Project

Shoreline Survey Report

Prod. areas:	Loch A Chumhainn: Inner Deep Site (AB 112) & Loch A Chumhainn: Outer (AB 113)
Site names:	Inner Deep Site (AB 112 017 13) & Outer (AB 113 018 13)
Species:	Pacific oysters
Harvesters:	George Martin & Nick Turnbull (Isle of Mull Oysters)
Local Authority:	Argyll & Bute Council
Status:	Existing sites
Date Surveyed:	25-26 August 2009
Surveyed by:	Donald Campbell, Aileachd Vernon, Alastair Cook
Existing RMPs:	NM 406 539 (Loch A Chumhainn: Inner Deep Site) & NM 408 547 (Loch A Chumhainn: Outer)
Area Surveyed:	See Map in Figure 1

Weather observations

25th August: Showers. Winds S force 6. Air temp 12 °C.
26th August: Showers. Winds S force 5. Air temp 13 °C.

Site Observations

Specific observations made on site are listed in Table 1 and mapped in Figure 1.

Fishery

Both sites are under the same ownership (Isle of Mull Oysters). There is a processing shed at the Inner Deep site that serves both production areas. Harvesting may take place at any time of the year. There are no depuration facilities here.

Within Loch A Chumhainn: Inner Deep production area, there is a large area of trestles located in a sandy bay on the west shore of the loch. Pacific oysters are cultured here from seed stock, and exhibit good growth. Stock of a range of sizes are present here, including that of a harvestable size. Due to a low pressure weather system, the tides did not recede sufficiently to assess the exact extent of the fishery during the shoreline survey. These were subsequently measured on the 15th September 2009 by the sampling officer. Classification samples are taken from a dedicated sampling cage at the north east end of the site, which is accessed by boat. There is also a dedicated biotoxins sampling cage, which is left high on the shoreline to the south west of the site to allow samplers access at a greater range of tidal states. Oysters for the market are also left on trestles near this sampling cage to harden them off.

Within the Loch A Chumhainn: Outer production area the only stock is one cage of oysters which is retained for sampling purposes. The main purpose of the Outer site is that during periods when the Inner Deep Site has a B classification, and the Outer site has an A classification, oysters can be relaid from the Inner Deep Site to the Outer site and subsequently harvested without the need for depuration.

Sewage/Faecal Sources

Human – population on the shores of Loch A Chumhainn is low. A total of five sewer pipes discharging direct to the loch were recorded. One of these, serving one house, discharges by the pier at Croig. The other four discharge at Dervaig. Of these, three were private sewer pipes serving houses at the south east extremity of the village. The other was a Scottish Water treatment works serving the majority of Dervaig. Waste water from Dervaig is pumped up to a treatment works to the south of the village where it is treated by septic tank, then further treated by a reedbed. The reedbed appeared to be newly planted and not yet fully established. Final effluent is discharged to the head of the loch. A further five private septic discharges to soakaway were also recorded. One was by a house at Cuin, and the other four were by houses or holiday homes and a B&B located to the north west of Croig.

Livestock were seen on areas of pasture all round the loch. 95 sheep and 36 cattle were seen on pastures to the north west of Croig. 79 sheep and one horse were counted on pastures near the Inner Deep Site, including 6 sheep which had access to the shore by the trestles. Around Dervaig, 62 sheep, 10 chickens and 1 calf were seen. On the east shore, from Cuckoo House north a total of 19 sheep and 10 cattle were recorded.

Seasonal Population

The Isle of Mull as a whole is a popular tourist destination and there are several car ferry sailings every day to the island from Oban. There are some hotels, B&Bs, and a number of dwellings which are likely to be holiday homes in the area. Overall, there are likely to be a significant increase in population during the summer months.

Boats/Shipping

Boating activity within the loch is limited to a few pleasure craft (generally small dinghies) and is centred around the pier at Croig. A larger fishing boat was also observed landing its catch here. Yachts are likely to visit the loch from time to time, but not in great numbers.

Land Use

The surrounding land is a mixture of pastures used for extensive sheep and cattle farming, semi-natural woodland and coniferous plantation, with smaller areas of bog and rough grassland.

Wildlife/Birds

Although none was seen during the course of the shoreline survey, the grower reports a substantial year round presence of seals, sometimes numbering up to 40 animals in the outer loch. An aggregation of 37 geese was seen on the east shore by the Outer site.

Other information

Tides within Loch A Chumhainn can be affected by meteorological conditions, with low atmospheric pressure generally backing up water within the loch and preventing the tide from receding fully.

Sampling

Bacteriology results follow in Tables 2 and 3. Salinity profiles are presented in Table 4.

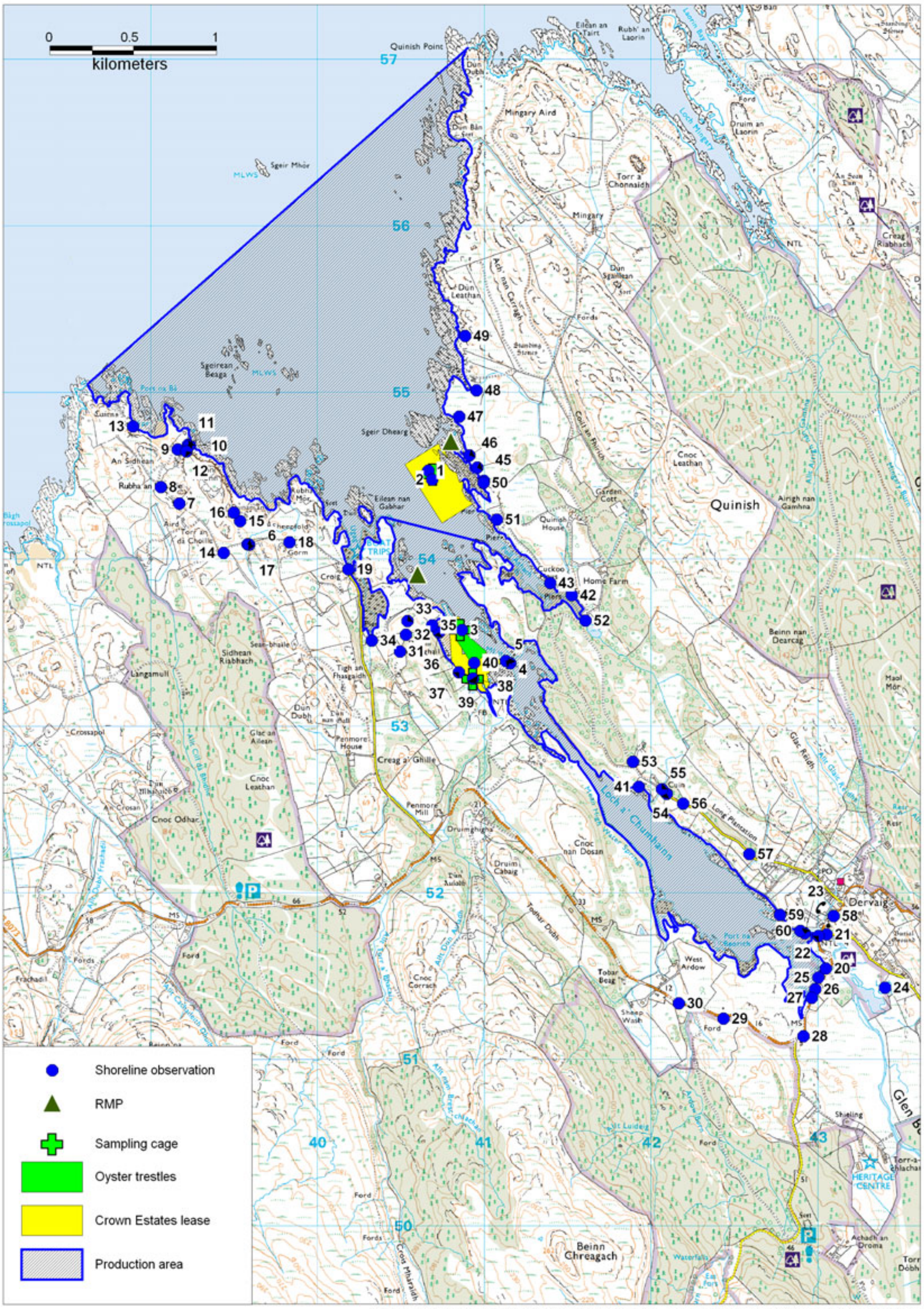

Figure 1. Map of Shoreline Observations

Table 1. Shoreline Observations

No	Date and time	Position	Photograph	Observation
1	25-AUG-09 9:29:15AM	NM 40663 54530		Water sample 1 (seawater). Oyster sample 1. Oyster norovirus sample. Only one cage of oysters held here for sampling purposes.
2	25-AUG-09 9:36:10AM	NM 40688 54476		Salinity profile 1.
3	25-AUG-09 9:43:47AM	NM 40866 53573		Outer northern corner of beach site. Oyster sample 2. Water sample 2 (seawater).
4	25-AUG-09 9:52:29AM	NM 41128 53387		Outer southern corner of site.
5	25-AUG-09 9:53:16AM	NM 41156 53375		Salinity profile 2.
6	25-AUG-09 10:39:54AM	NM 39580 54088		9 sheep
7	25-AUG-09 10:44:49AM	NM 39170 54334		34 sheep.
8	25-AUG-09 10:46:23AM	NM 39060 54431		36 sheep
9	25-AUG-09 10:52:42AM	NM 39162 54658		14 sheep
10	25-AUG-09 10:54:40AM	NM 39223 54687		Well
11	25-AUG-09 10:57:59AM	NM 39229 54678		Water sample 3 (seawater)
12	25-AUG-09 11:00:21AM	NM 39212 54646	Figure 4	Septic tank to soakaway, 1 cottage
13	25-AUG-09 11:08:56AM	NM 38893 54796		Septic tank to soakaway, 2 holiday cottages
14	25-AUG-09 11:23:25AM	NM 39436 54037		36 cattle
15	25-AUG-09 11:28:29AM	NM 39535 54228		Septic tank to soakaway, 1 house
16	25-AUG-09 11:29:22AM	NM 39496 54280		Septic tank to soakaway, B&B Aonach. 2 Sheep
17	25-AUG-09 11:33:13AM	NM 39590 54087		Stream 85cmx20cmx0.145m/s. Water sample 5 (freshwater)
18	25-AUG-09 11:46:55AM	NM 39832 54101		Stream 43cmx8cmx0.614m/s. Water sample 6 (freshwater)
19	25-AUG-09 12:00:01PM	NM 40184 53938	Figure 5	Croig pier. 12 small boats and one larger fishing boat tied up and on moorings here. Water sample 7 (seawater). Private sewer pipe serving 1 house here.
20	25-AUG-09 12:24:01PM	NM 43047 51545		Stream 84cmx15cmx0.610m/s. Water sample 8 (freshwater)
21	25-AUG-09 12:33:25PM	NM 43052 51749	Figure 6	Scottish water pumping station
22	25-AUG-09 12:41:35PM	NM 43003 51740		Stream 1260cmx45cmx0.604m/s. Water sample 9 (freshwater)
23	25-AUG-09 12:44:24PM	NM 42920 51756	Figure 7	Scottish Water outfall pipe to underwater. Water sample 10 (seawater)
24	25-AUG-09 12:59:09PM	NM 43403 51430	Figures 8 & 9	Scottish Water reedbed/septic tank treatment system.
25	25-AUG-09 1:13:39PM	NM 43004 51490		Private sewer pipe, 1 house
26	25-AUG-09 1:16:04PM	NM 42984 51419		Private sewer pipe, 1 house
27	25-AUG-09 1:17:02PM	NM 42962 51368		Private sewer pipe, 1 house & chalet
28	25-AUG-09 1:32:31PM	NM 42914 51137		Culverted stream 35cmx5cmx2.338m/s. Water sample 11 (freshwater)
29	25-AUG-09 1:38:10PM	NM 42433 51243		14 sheep

No	Date and time	Position	Photograph	Observation
30	25-AUG-09 1:45:16PM	NM 42165 51335		Stream 600cmx25cmx1.808m/s. Water sample 12 (freshwater)
31	25-AUG-09 2:08:47PM	NM 40495 53444		34 sheep.
32	25-AUG-09 2:10:22PM	NM 40529 53546		21 sheep
33	25-AUG-09 2:11:57PM	NM 40540 53628		16 sheep
34	25-AUG-09 2:18:14PM	NM 40324 53510		Stream 265cmx10cmx0.554m/s. Water sample 13 (freshwater)
35	25-AUG-09 2:27:51PM	NM 40688 53601		6 sheep with access to shore
36	25-AUG-09 2:29:06PM	NM 40726 53559		Stream 60cmx2cmx0.388m/s. Water sample 14 (freshwater)
37	25-AUG-09 2:36:01PM	NM 40847 53320		Stream 20cmx5cmx1.189m/s. Water sample 15 (freshwater). 2 sheep 1 horse
38	25-AUG-09 2:58:43PM	NM 40932 53283		Stream 700cmx30cmx1.409m/s. Water samples 16 (30ml) and 17 (200ml) (freshwater).
39	25-AUG-09 2:59:24PM	NM 40932 53282		Oyster sample 3. Stock for biotoxins sampling held here, and stock for market held here also
40	25-AUG-09 3:02:41PM	NM 40939 53377		Water sampe 18 (seawater)
41	26-AUG-09 10:06:09AM	NM 41926 52636		Water sample 19 (seawater)
42	26-AUG-09 10:29:05AM	NM 41523 53783		Stream 85cmx30cmx0.942m/s. Water sample 20 (freshwater)
43	26-AUG-09 10:35:29AM	NM 41394 53855		2 geese, 10 cattle, 4 sheep.
44	26-AUG-09 10:50:48AM	NM 40997 54470		4 sheep
45	26-AUG-09 10:56:39AM	NM 40957 54549		Stream 45cmx18cmx0.898m/s. Water sample 21 (freshwater)
46	26-AUG-09 11:01:24AM	NM 40911 54623		Water sample 22 (seawater)
47	26-AUG-09 11:08:01AM	NM 40850 54856		11 sheep
48	26-AUG-09 11:14:59AM	NM 40953 55013		Stream 230cmx15cmx0.582m/s. Water sample 23 (freshwater)
49	26-AUG-09 11:25:18AM	NM 40884 55339		Water sample 24 (seawater)
50	26-AUG-09 11:45:24AM	NM 40994 54459		37 geese
51	26-AUG-09 11:51:41AM	NM 41074 54237		Water sample 25 (seawatwer)
52	26-AUG-09 12:09:50PM	NM 41606 53630		Stream 225cmx17cmx0.713m/s. Water sample 26 (freshwater)
53	26-AUG-09 12:25:39PM	NM 41892 52785		Stream 50cmx4cmx0.278m/s. Water sample 27 (freshwater)
54	26-AUG-09 12:39:39PM	NM 42092 52594	Figure 10	Septic tank to soakaway
55	26-AUG-09 12:41:01PM	NM 42066 52622		Stream 80cmx4cmx0.500m/s. Water sample 28 (freshwater)
56	26-AUG-09 12:45:18PM	NM 42191 52535		1 calf (orphan?)
57	26-AUG-09 12:47:50PM	NM 42589 52231		40 sheep
58	26-AUG-09 12:50:42PM	NM 43096 51860		8 sheep
59	26-AUG-09 12:57:55PM	NM 42773 51866		Water sample 29 (seawater)
60	26-AUG-09 1:01:56PM	NM 42896 51770		10 chickens

Photos referenced in the table can be found attached as Figures 4-10.

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

Table 2. Water Sample Results

No.	Date and time	Position	*E. Coli* cfu / 100ml	Salinity (ppt)	Type of Sample
1	25-AUG-09 9:29:15AM	NM 40663 54530	3	35.2	Seawater
2	25-AUG-09 9:43:47AM	NM 40866 53573	4	35.4	Seawater
3	25-AUG-09 10:57:59AM	NM 39229 54678	450	30.7	Seawater
5	25-AUG-09 11:33:13AM	NM 39590 54087	500		Freshwater
6	25-AUG-09 11:46:55AM	NM 39832 54101	400		Freshwater
7	25-AUG-09 12:00:01PM	NM 40184 53938	310	34.0	Seawater
8	25-AUG-09 12:24:01PM	NM 43047 51545	300		Freshwater
9	25-AUG-09 12:41:35PM	NM 43003 51740	900		Freshwater
10	25-AUG-09 12:44:24PM	NM 42920 51756	300	2.5	Seawater
11	25-AUG-09 1:32:31PM	NM 42914 51137	400		Freshwater
12	25-AUG-09 1:45:16PM	NM 42165 51335	110		Freshwater
13	25-AUG-09 2:18:14PM	NM 40324 53510	1500		Freshwater
14	25-AUG-09 2:29:06PM	NM 40726 53559	400		Freshwater
15	25-AUG-09 2:36:01PM	NM 40847 53320	<100		Freshwater
16	25-AUG-09 2:58:43PM	NM 40932 53283	300		Freshwater
17	25-AUG-09 2:58:43PM	NM 40932 53283	330		Freshwater
18	25-AUG-09 3:02:41PM	NM 40939 53377	210	8.2	Seawater
19	26-AUG-09 10:06:09AM	NM 41926 52636	110	17.4	Seawater
20	26-AUG-09 10:29:05AM	NM 41523 53783	900		Freshwater
21	26-AUG-09 10:56:39AM	NM 40957 54549	300		Freshwater
22	26-AUG-09 11:01:24AM	NM 40911 54623	1700	30.2	Seawater
23	26-AUG-09 11:14:59AM	NM 40953 55013	400		Freshwater
24	26-AUG-09 11:25:18AM	NM 40884 55339	60	31.3	Seawater
25	26-AUG-09 11:51:41AM	NM 41074 54237	120	33.1	Seawater
26	26-AUG-09 12:09:50PM	NM 41606 53630	400		Freshwater
27	26-AUG-09 12:25:39PM	NM 41892 52785	200		Freshwater
28	26-AUG-09 12:41:01PM	NM 42066 52622	1000		Freshwater
29	26-AUG-09 12:57:55PM	NM 42773 51866	900	21.1	Seawater

No water sample 4 was taken.

Table 3. Shellfish Sample Results

No	Date and time	Position	*E. coli* result (MPN/100g)
1	25-AUG-09 9:29:15AM	NM 40663 54530	20
2	25-AUG-09 9:43:47AM	NM 40866 53573	20
3	25-AUG-09 2:59:24PM	NM 40932 53282	750

Table 4. Salinity profiles

No	Date and time	Position	Depth (m)	Salinity (ppt)	Temperature (ºC)
1	25-AUG-09 9:36:10AM	NM 40688 54476	0	33.8	14.4
			2.5	33.7	14.4
			5	33.7	14.4
			7.5	33.7	14.4
2	25-AUG-09 9:53:16AM	NM 41156 53375	0	29.3	14
			2.5	33.7	14.5
			4	33.7	14.5

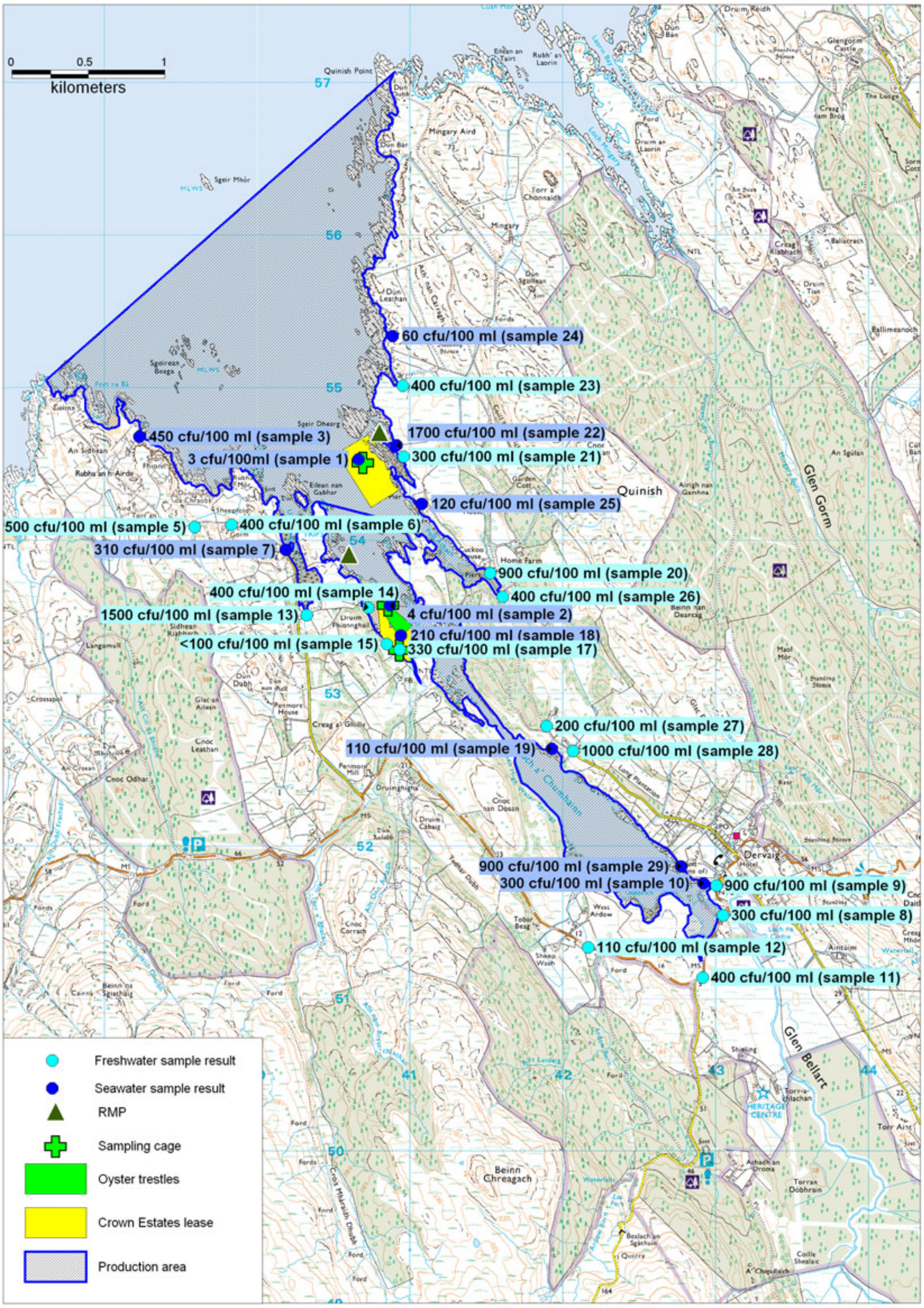

Figure 2. Water sample results map

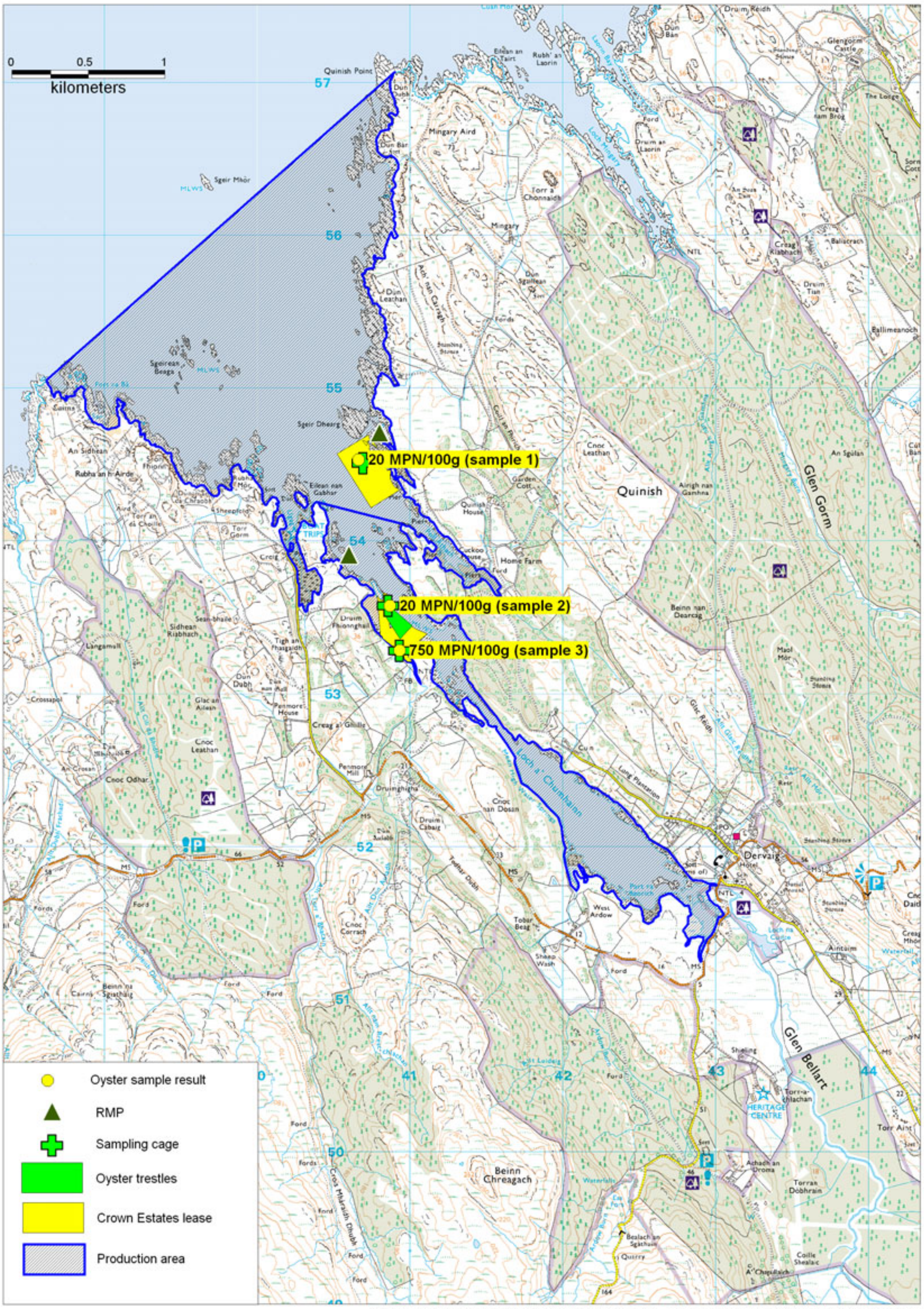

Figure 3. Oyster sample results map

Photographs

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10