Scottish Sanitary Survey Programme

Sanitary Survey Report
Loch Nevis: Ardintigh Point
HL 180
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Cefas

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The hydrographic assessment and the shoreline survey and its associated report were undertaken by SRSL, Oban.

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Appendices

I. Executive Summary

Under (EC) Regulation 854/2004, which sets forth specific rules for the organisation of official controls on products of animal origin intended for human consumption, sanitary surveys of production areas and their associated hydrological catchments and coastal waters are required in order to establish the appropriate representative monitoring points (RMPs) for the monitoring programme.

The purpose of the sanitary survey is to demonstrate compliance with the requirements stated in Annex II (Chapter II Paragraph 6) of Regulation (EC) 854/2004. The sanitary survey results in recommendations on the location of RMPs, the frequency of sampling for microbiological monitoring, and the boundaries of the production areas deemed to be represented by the RMPs.

A sanitary survey was undertaken on the mussel fishery at Loch Nevis on the basis recommended in the European Union Reference Laboratory publication: “Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application” (http://www.crlcefas.org/gpg.asp). This production area was selected for survey at this time based on a risk-based ranking of the area amongst those in Scotland that have yet to receive sanitary surveys.

Loch Nevis is a 17 km long sea loch southeast of the Isle of Skye, on the west coast of Scotland. The mouth opens westward to the Sound of Sleat, which separates the Skye from the mainland. The two main settlements on the loch, Tarbet and Inverie, are accessible by ferry only.

At the time of the shoreline survey, the fishery comprised two 200 m mussel long lines east of Ardintigh Point. This site was to be used for spat collection only and therefore the production area was declassified in April 2013, subsequent to initiation of this survey. A previous mussel farm in Ardintigh Bay had been sold for conversion to salmon farming, though scallop ranching was reported to be undertaken on a second lease area southwest of Ardintigh Point.

The primary sources of faecal contamination to the fishery are:

- Discharges from septic tanks associated with the holiday accommodation in Ardintigh Bay and Tarbet Bay
- Diffuse contamination from livestock and wildlife sources

One septic tank outfall was observed at the outdoor centre at Ardinitigh Bay, and two further probable outfalls to Tarbet Bay were seen where the only consented discharges were to soakaway. Diffuse faecal contamination is most likely to be carried via watercourses from land to the loch, however some contamination could be directly deposited (i.e. droppings from birds or seals and overboard discharges from boats). Some soakaway systems were located relatively near the high tide line (MHWS) and

therefore the effectiveness of these systems may be affected by proximity to the water table and high tide line, particularly during the larger spring tides.

Livestock, mainly sheep, were present in low numbers near Ardintigh and Tarbet. Watercourses discharging to the loch from these areas are likely to carry faecal contamination from these animals, as well as from wildlife animals.

Historical monitoring results suggested that contamination levels were slightly higher at the Ardintigh Bay mussel farm than at the Ardintigh Point farm. Significant seasonality was seen at Ardintigh Point, with highest results occurring during the summer and early autumn which is consistent with the seasonal operation of visitor accommodation.

Low predicted current speeds suggest that faecal contamination sources very near the fishery (within 1 km) will be most significant. Therefore the most significant sources at Ardintigh Bay will be the outdoor education centre and Ardintigh Burn, while at the Ardintigh Point site the Allt Raineach and sources arising from both Ardintigh Bay and Tarbet Bay may be significant.

Summary of recommendations

As the area is currently declassified, it is not recommended that monitoring recommence unless the Ardintigh Point site becomes active or the scallop farm is deemed to require classification.

If the area containing the present mussel lines were to be reclassified, then it is recommended that the production area be curtailed to exclude Tarbet Bay and Ardintigh Bay and the monitoring point established at the Ardintigh Point site, at the end nearest Tarbet Bay. Fuller details of the recommendations can be found in Section 16.

II. Sampling Plan

No sampling plan is included as the area is not currently classified and no current classification application has been received. If the present mussel lines at Ardintigh Point are brought into commercial production, a sampling plan can be established on the basis of the Recommendations (see Section 16).

III. Report

1. General Description

Loch Nevis is a 17 km long sea loch southeast of the Isle of Skye, on the west coast of Scotland. The survey area is shown in Figure 1.1. The mouth opens westward to the Sound of Sleat, which separates the Skye from the mainland. Though the loch has no road access, there are two settlements accessible by ferry: Tarbet, which is located at the head of Tarbet Bay on the south shore of the loch, and Inverie located on the north shore just inside the mouth of the loch. Kylesmorar and Kylesknoydart are located at the narrows to the east of Tarbet.

To the southwest of the mouth lies Mallaig, where there are ferry services to Tarbet and Inverie.

The loch begins at the southern part of the Sound of Sleat running from northwest to southeast. It extends eastward a short distance before turning southward toward Tarbet and then eastwards again toward a narrows and then on to the head of the loch. The loch is bounded to the north by the Knoydart peninsula, often referred to as “Scotland’s last wilderness” due to its inaccessibility and North Morar to the south. The surrounding country is mountainous and virtually uninhabited.

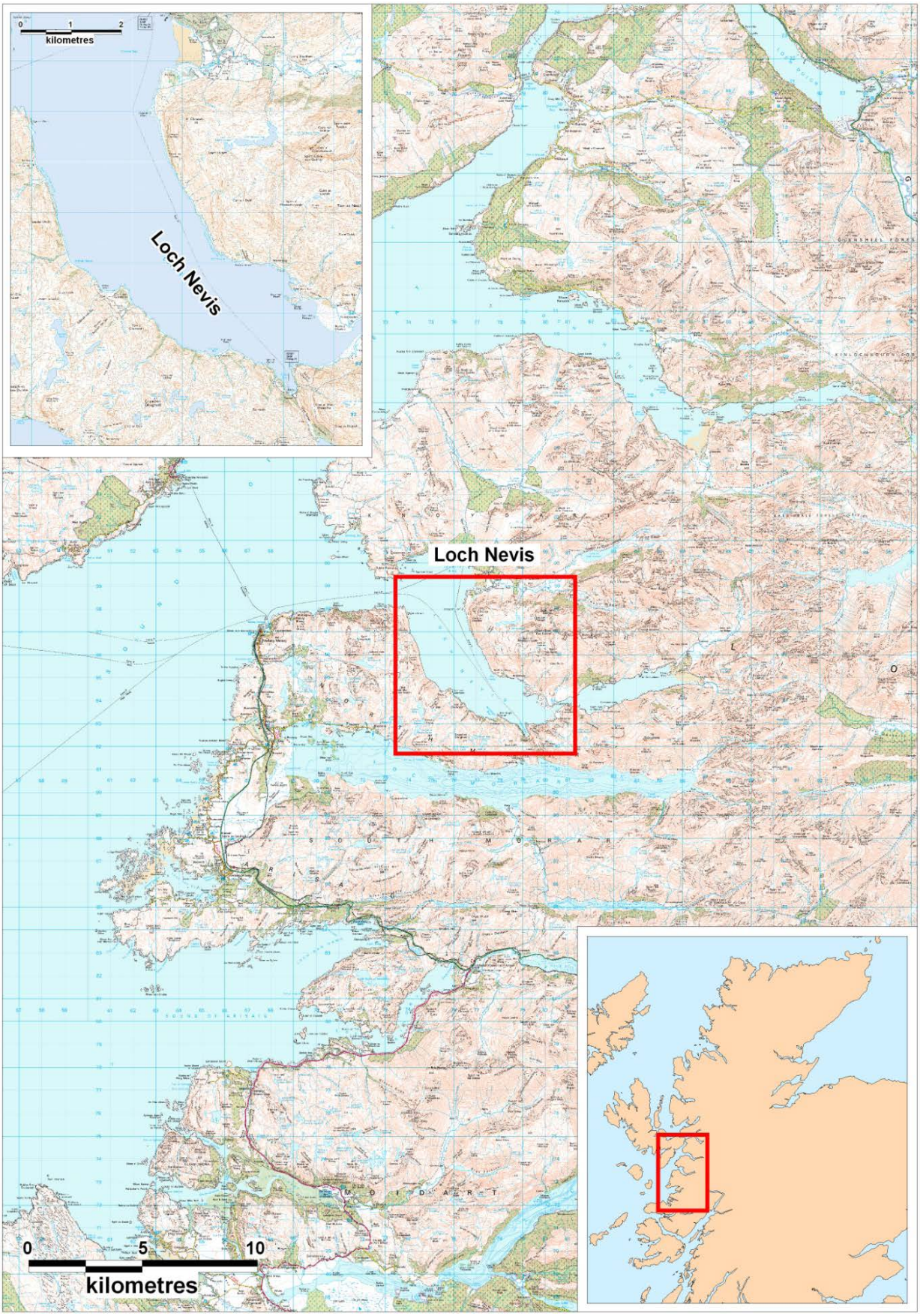


Figure 1.1 Location of Loch Nevis

2. Fishery

Loch Nevis has previously been classified for long-line culture of common mussels. The two most recently classified sites are listed in Table 2.1.

Table 2.1 Loch Nevis shellfish farms

Production area	Site	SIN	Species
Loch Nevis: Ardintigh Point	Ardintigh Bay	HL-180-725-08	Common Mussels
Loch Nevis: Ardintigh Point	Ardintigh Point	HL-180-228-08	Common Mussels

The Loch Nevis: Ardintigh Point production area boundaries were defined as lying within lines drawn between NM 7700 9334 to NM 7700 9400 and the line between NM 7700 9400 to NM 8000 9300 extending to Mean High Water springs (MHWS). The RMP was located at NM 7749 9345.

At the time of the shoreline survey the Ardintigh Bay site was in the process of being dismantled and had little infrastructure left with only a few buoys remaining. The sampling officer reported that this site had been sold to a salmon farming company and would no longer be used for shellfish aquaculture.

Two 200m longlines were present at the Ardintigh Point site appearing to be in good condition. Fishery observations from the shoreline survey are shown in Figure 2.1. These were reported to be used for spat collection only, and hence the area was declassified in early 2013 subsequent to the initiation of the sanitary survey.

An application was submitted for classification of a mussel site on the north side of the loch at Braomisaig in May 2012. This application was later withdrawn.

It was also noted during the shoreline survey that an area of seabed was being used for scallop ranching (presumably *Pecten maximus*) in the Crown Estate lease area east of the Ardintigh Bay site. The area has not been classified for the production of scallops.

The Kylesmorar cottages website (http://www.kylesmorar.com/) identified that guests could collect shellfish from the shore, indicating there is likely to be a low level of casual gathering of various intertidal species for personal consumption.

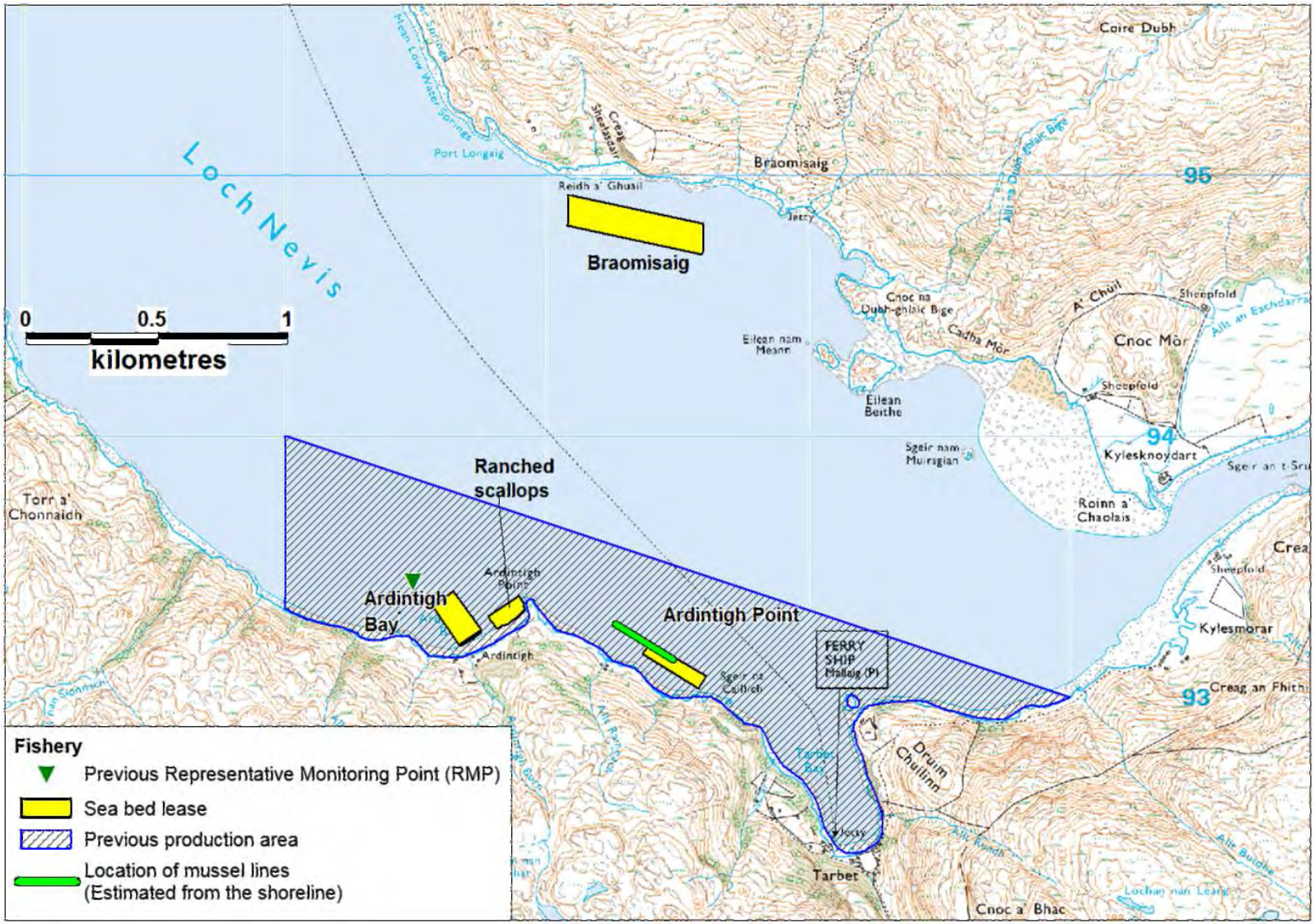


Figure 2.1 Loch Nevis fishery area

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Loch Nevis. The last census was undertaken in 2011. However, the 2011 census data was unavailable at the time of writing this report. Data presented in Figure 3.1 is from the 2001 census. The immediate population surrounding the Loch Nevis area is contained within one large census output area with a total area of 250 km^2.

In the vicinity of the previous production area on the southwestern coastline of the loch there are the small settlements of Tarbet, Kylesmorar and Kylesknoydart. All three settlements are only accessible by boat or on foot. The Outdoor Centre on the shores of Ardintigh Bay has accommodation consisting of 5 bunkhouses spread over the 10 acre site, sleeping 24 people in total. There is also additional room for camping. Kylesmorar has four self catering cottages sleeping 14 people in total. An old inn at Kylesmorar provides accommodation for staff who look after the cottages. There are several buildings at Kylesknoydart near the shoreline assumed to be residential dwellings. The self catering accommodation in the area indicates the area is likely to be popular with tourists, and an increase in population is likely to occur from April to September inclusive.

A private ferry operates all year from Mallaig to Tarbet, visiting Tarbet five times a week from May to the end of September (http://www.knoydart-ferry.co.uk/knoydart-ferry-timetable.html) and two days a week the rest of the year. There is also an anchorage in Tarbet Bay.

During the shoreline survey it was observed that there was a small jetty for the Outdoor Centre at Ardintigh Bay, a small jetty and pier (currently damaged) in Tarbet Bay and two moorings for small vessels in Ardintigh Bay. Seven moorings were observed in Tarbet Bay and three small vessels were present.

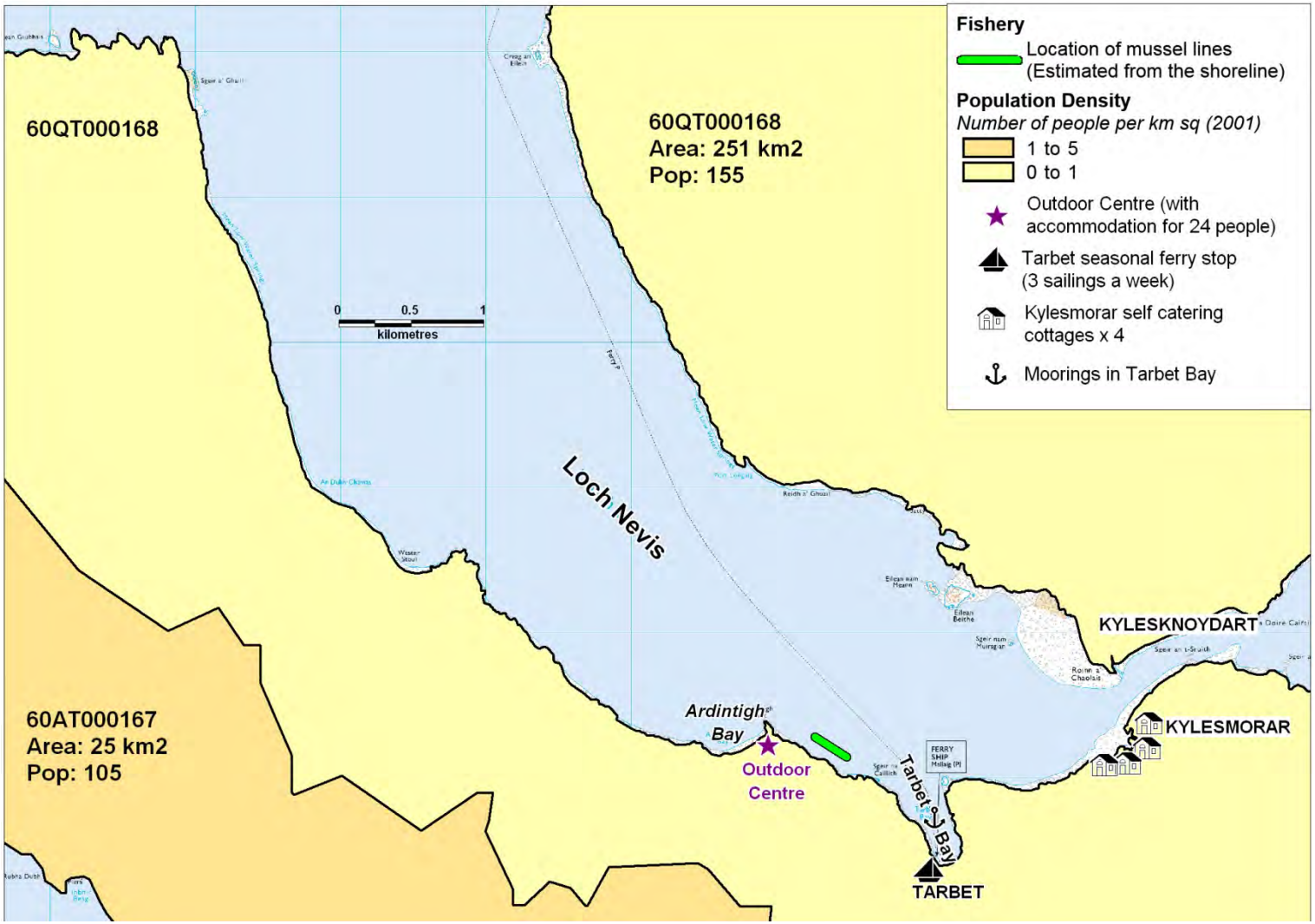


Figure 3.1 Population map of Loch Nevis

4. Sewage Discharges

Information on sewage discharges to the area around Loch Nevis was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Data requested included the name, location, type, size (in either flow or population equivalent), level of treatment, sanitary or bacteriological data, spill frequency, discharge destination (to land or to waterbody or to sea), any available dispersion or dilution modelling studies, and whether improvements were in work or planned.

Scottish Water reported no assets in the area. SEPA provided information on 7 sewage discharges consents. These are listed in Table 4.1 and mapped in Figure 4.1

Table 4.1 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented/ design PE	Discharges to
1	CAR/R/1078225	NM 79061 92441	Continuous	Septic Tank	5	Soakaway
2	CAR/R/1078218	NM 79070 92410	Continuous	Septic Tank	5	Soakaway
3	CAR/R/1078220	NM 79085 92409	Continuous	Septic Tank	5	Soakaway
4	CAR/R/1078185	NM 79262 92402	Continuous	Septic Tank	5	Soakaway
5	CAR/R/1078175	NM 79283 92455	Continuous	Septic Tank	5	Soakaway
6	CAR/R/1078166	NM 79230 92880	Continuous	Septic Tank	5	Soakaway
7	CAR/R/1078204	NM 79241 92959	Continuous	Septic Tank	7	Soakaway

Reported discharge data was also compared to information presented in the SEPA shellfish growing report for Loch Nevis. The report confirmed no public sewage discharges in the area. A further consent, CAR/L/1002353, related to the Ardintigh marine cage fish farm (Site C), located west of Ardintigh Point. Although no specific information related to sewage discharge associated with this permit was received in the initial data provided by SEPA, subsequent comment received after draft consultation identified that there would be intermittent discharge of sewage from a feed barge toilet at this farm.

All discharge consents reported by SEPA pertained to small, private septic tanks serving single dwellings located on the shore around Tarbet and Tarbet Bay. All discharges are recorded as discharging to soakaway. The majority are within are within 30 m of MHWS, and one is within 10 m of MHWS. Those soakaways closest to the high water mark may be subject to poor function and overland flow if used during periods of high soil saturation, such as during very high tides or periods of high rainfall and therefore may impact water quality in the adjacent receiving waters.

No consents were received for dwellings at Kylesmorar, Kylesknoydart or for the outdoor adventure centre at Ardintigh therefore the list above is anticipated to significantly underrepresent the likely number of septic tanks in the area.

The shoreline survey (Appendix 5) notes that there is only one permanent resident of Tarbet, with the remaining dwellings in seasonal occupation. Effectiveness of septic tanks can be reduced when they are used infrequently as the biological treatment requires regular input of nutrients to function properly.

Three discharge pipes were identified during the shoreline survey. These are listed in Table 4.2 below.

Table 4.2 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	22/04/2013	NM 77733 93171	Manhole (septic tank) and discharge pipe running into bay. 10cm PVC pipe. No discharge visible as pipe heads underwater.
2	22/04/2013	NM 79110 92426	Discharge pipe 10cm PVC pipe below houses. Not flowing.
3	22/04/2013	NM 79272 92443	Discharge pipe, 10cm PVC, not flowing, assumed discharge pipe from old church and bothy.

Observation 1 appeared to relate to septic discharges from the outdoor adventure centre, which accommodates up to 24 people. No discharge consent was identified for this property.

Observation 2 and 3 are both near Tarbet and could represent outfalls from septic tanks. No records of discharges to sea were provided by SEPA.

Summary

Although the shoreline around Loch Nevis is very sparsely populated, there are a number of cottages and other dwellings very near the shoreline, only some of which have septic tanks registered with SEPA. While all of the discharges relating to consents provided by SEPA were stated as discharging to land, observations from the shoreline survey suggest that some septic tanks discharge directly to Loch Nevis. Any discharges from the feed barge at the fish farm would be direct to the loch, but as these are over 1 km from the mussel farm they are not expected to pose a significant source of contamination there.

There is likely to be seasonal variation in sewage input, as Section 3; Human Population and the shoreline survey all indicate almost all dwellings are used as holiday accommodation.

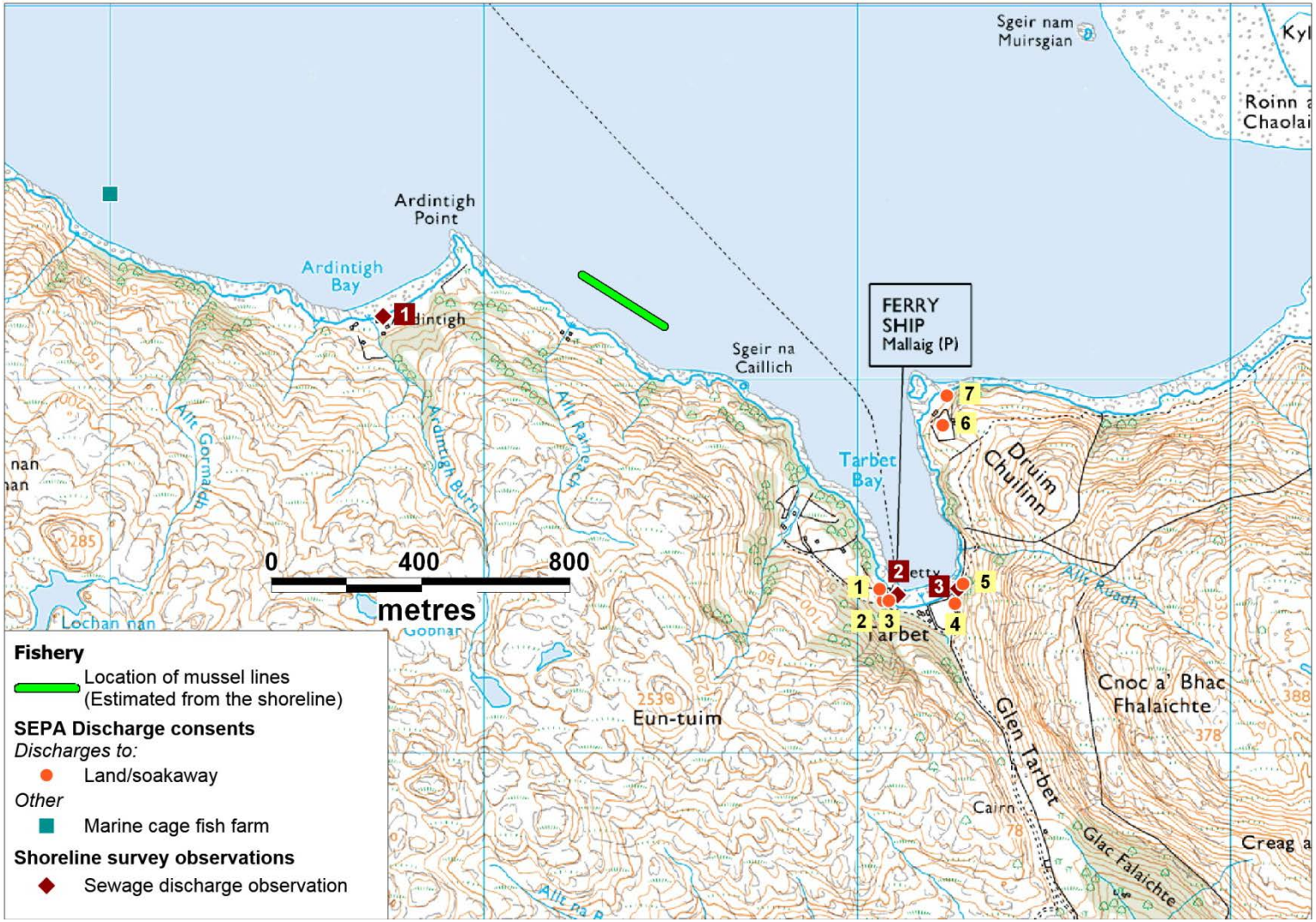


Figure 4.1 Map of sewage discharges for Loch Nevis

5. Agriculture

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish production area. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Glenelg parish. Reported livestock populations for the parish in 2012 are listed in Table 5.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 5.1 Livestock numbers for the Glenelg agricultural parish along the Loch Nevis coastline 2012

	Glenelg	
	550 km^2	
	Holdings	Numbers
Pigs	*	*
Poultry	9	125
Cattle	19	346
Sheep	49	10837
Other horses and ponies	*	*

The agricultural parish of Glenelg borders the production area, encompassing a total land area of approximately 550 km^2 (shown in the inset Figure 5.1). The number of pigs and other horses and ponies were not reported due to the small number of holdings. Pigs are kept at Kylesmorar, based on photographs posted on estate website (http://www.kylesmorar.com/). Relatively small numbers of cattle were reported. Sheep are the predominant type of livestock kept in the area, with an average of approximately 221 animals per holding. Because the livestock numbers relate to a large geographic area, it is not possible to determine the spatial distribution of the livestock in relation to the Loch Nevis fishery. Therefore the figures are of limited use in assessing the potential impact of livestock contamination to the fishery; however they do give an idea that the total numbers of livestock kept in the parish area are relatively low.

The SEPA Loch Nevis Growing Waters report (2011) identifies that as the area is predominantly moorland and mountains with limited farming.

An additional significant source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 5) which only relates to the time of the site visit on the 22nd April 2013 (see Table 5.1). Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been obscured by the terrain. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 5.1.

During the survey a single sheep was observed grazing near Ardintigh Bay and a further 30 sheep and a horse were recorded near Tarbet Bay.

In general, numbers of sheep are expected to be approximately double during May following the birth of lambs, and to decrease in the autumn as they are sent to market.

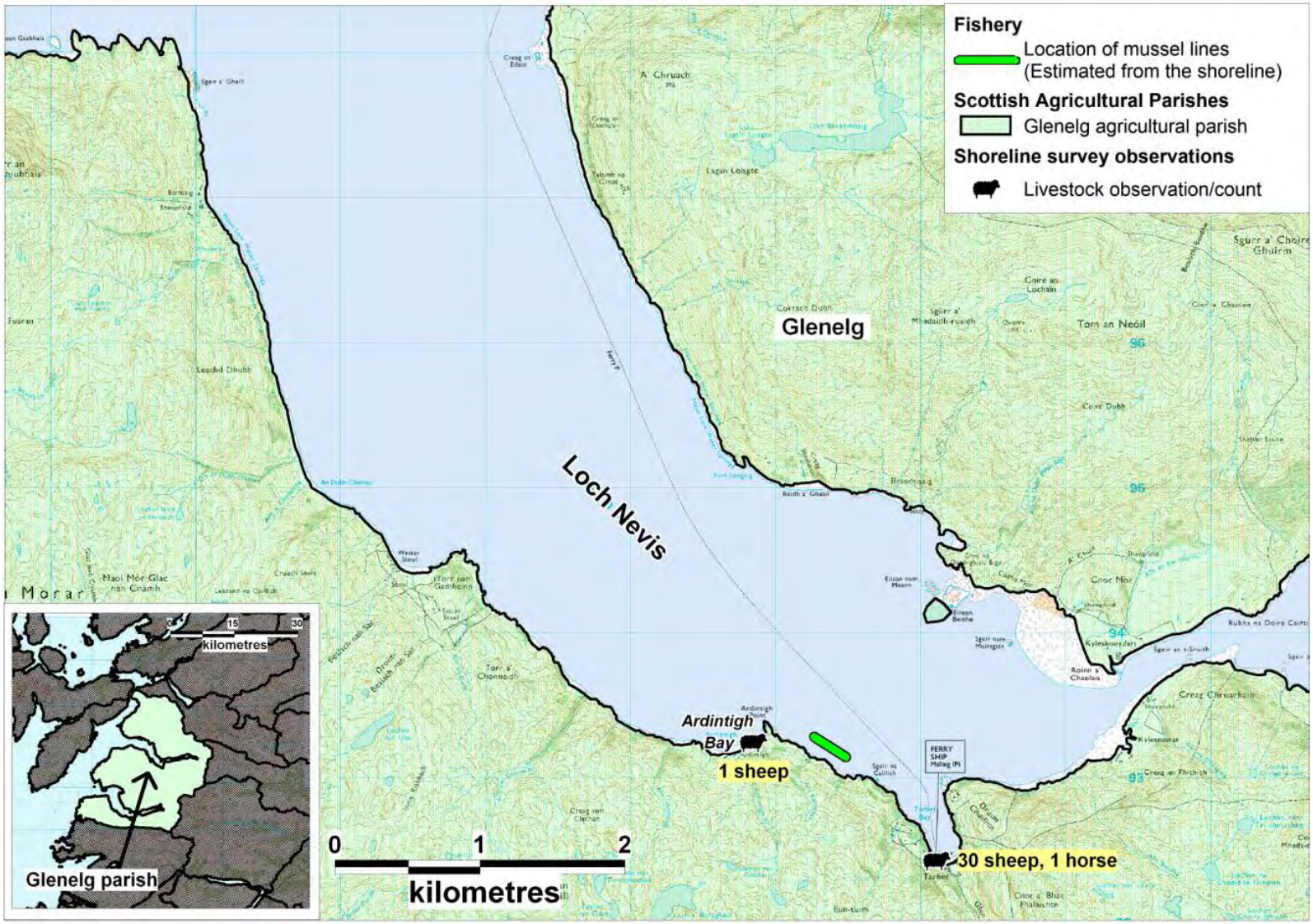


Figure 5.1 Livestock observations at Loch Nevis

6. Wildlife

Pinnipeds

Two species of seal are found in the waters of Loch Nevis. These are the common/harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*). There are accounts of seal colonies at Sandaig Bay, near the mouth of Loch Nevis, and at Kylesknoydart (The Highland Council, 2008). No seals were seen during the shoreline survey.

Birds

Seabird2000 data was queried for a 5km area around the fishery near Tarbet. No records of breeding seabirds were identified within this area.

During the shoreline survey, 21 gulls and one oyster catcher were observed adjacent to the scallop ranching site to the west of Ardintigh Bay.

Some of the larger intertidal areas are likely to attract wading birds, however no specific records were found for the loch.

Cetaceans

There are anecdotal accounts of cetaceans such as Harbour porpoise in Loch Nevis. The topography of the loch means that the first sill is relatively deep at 20 m deep which may allow small cetaceans such as dolphins and porpoise to enter. However the shallowness of the second sill at 4 m deep is likely to prevent even small cetaceans from entering into this area.

The Hebridean Whale and Dolphin Trust have reports of larger cetaceans in the waters outside of Loch Nevis, with minke whales observed from the Loch Nevis and Kilchoan ferry (Hebridean Whale and Dolphin Trust, 2008).

Deer

No population data was found for deer in the area surrounding Loch Nevis. However there are anecdotal reports of both Roe and Red deer in the moorland surrounding Loch Nevis (Trekking Britain, 2012). Deer stalking is offered on local estates and the restaurant at Inverie serves hill venison, suggesting that a significant population of deer may be present in the area.

Otters

No population data on the Eurasian otter (*Lutra lutra*) was available at the time of this report. However there were anecdotal accounts of otters around Loch Nevis (Highland Outdoor Centre, 2013).

Overall

Wildlife are likely to contribute a significant proportion of the faecal indicator bacteria load to the area, however their total impacts are likely to be relatively minor. Although birds were only identified in Ardintigh Bay, there is no other evidence to suggest that this was a favoured location for them and thus no evidence that they would contribute to a consistent spatial variation in contamination across the fishery.

Locations of wildlife identified during the shoreline survey are shown in Figure 6.1.

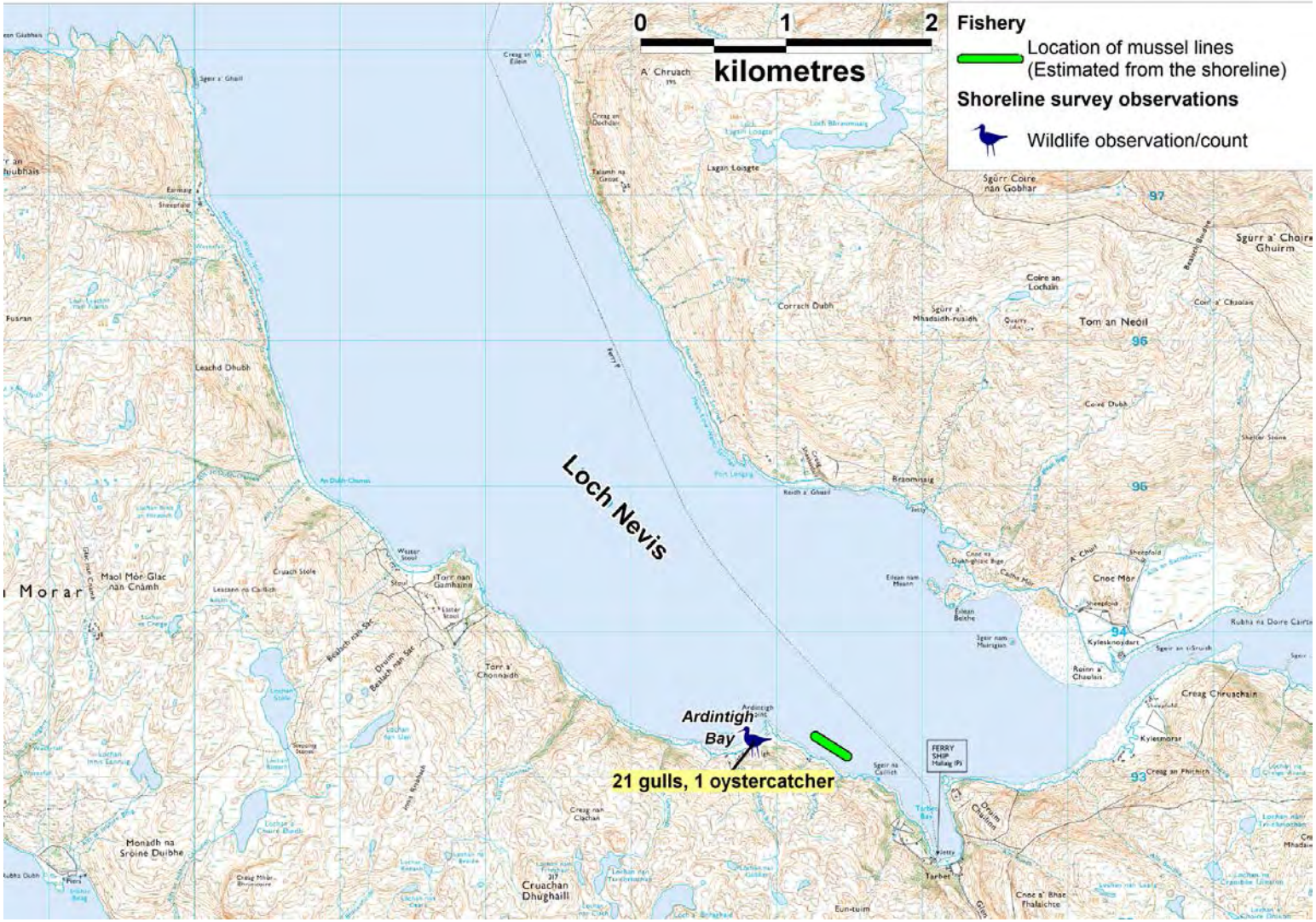


Figure 6.1 Map of wildlife around Loch Nevis.

7. Land Cover

The Land Cover Map 2007 data for the area is shown in Figure 7.1 . Dwarf shrub heath, acid grassland, rough grassland, improved grassland and both coniferous and broad leaved woodland are all present on the coastline surrounding Loch Nevis. Inland there are additional areas of bog, inland water and inland rock. There are no areas of suburban or urban development and only very small and scattered areas of improved grassland, with small areas west of Ardintigh Point and around the head of Tarbet Bay nearest the fishery. The SEPA Loch Nevis Growing Waters report (2011) confirmed that as the land cover in the area is predominantly heather moorland.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately $8.3x10^8$ cfu km^{-2} hr^{-1} for areas of improved grassland and approximately $2.5x10^8$ cfu km^{-2} hr^{-1} for rough grazing (Kay, et al., 2008a). The contributions from all land cover types would be expected to increase significantly after rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay, et al., 2008a).

The potential contribution of contaminated run-off to Loch Nevis as a result of land cover would be low overall. The highest risk of diffuse contamination from this source is for the area around the head of Tarbet Bay. In addition, the small area of improved grassland west of Ardintigh would contribute diffuse contamination to the nearshore waters in the near vicinity. Areas utilised for rough grazing would be expected to contribute significantly to faecal contaminant loading carried in watercourses and overland flow draining the area during rainfall.

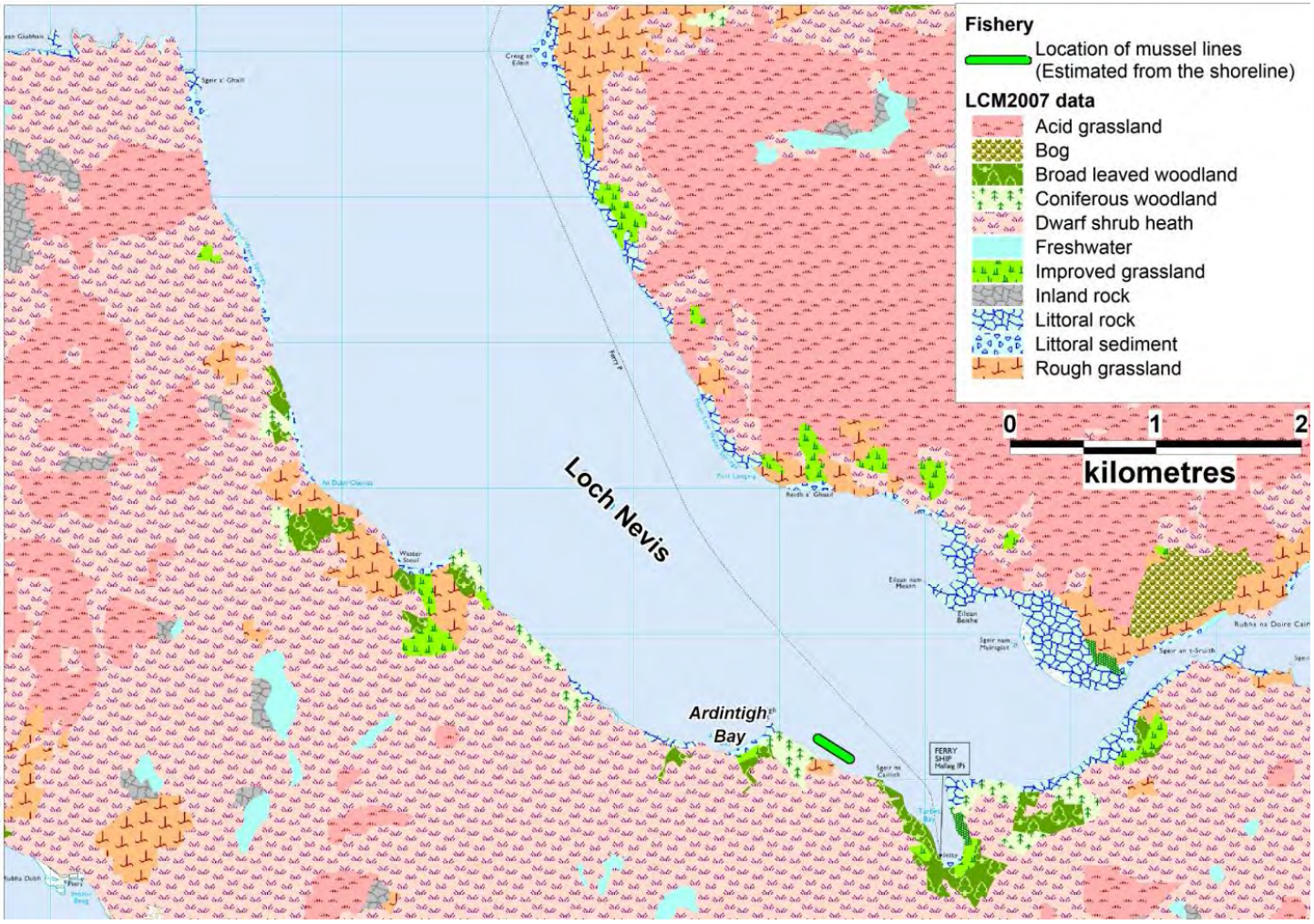


Figure 7.1 LCM2007 class land cover data for Loch Nevis

8. Watercourses

There are no river gauging stations on watercourses along the Loch Nevis coastline. In the Sea Lochs Catalogue by Edwards and Sharples (1986), Loch Nevis is shown to have a relatively high freshwater input. Rainfall is measured at 2500 mm/yr, which equates to 367.4 m m^3/yr.

The shoreline survey was conducted on the 22nd April, 2013. In the 48 hours preceding the survey, short heavy showers fell and there was rain on the day survey. Six watercourses were noted during the shoreline survey.

Table 8.1 Watercourse flows to Loch Nevis

No.	Description	NGR	Width (m)	Depth (m)	Flow (m^3/d)
1	Ardintigh Burn	NM 7772 9313	1.00	0.25	1500
2	Allt Raineach	NM 7822 9313	1.20	0.20	2000
3	Stream	NM 7886 9273	1.30	0.22	800
4	Allt Ruadh	NM 7933 9256	1.00	0.17	2000

The observed watercourses were located along the southern shoreline of Loch Nevis, with four out of the six located to the east in Tarbet Bay. Only the four watercourses listed in Table 8.1 were measured during the survey. Of those, samples were taken for bacteriological analysis from numbers 1, 2 and 4: all of these yielded results of <100 *E. coli*/100 ml. No comparative loading information could therefore be estimated.

To the west of Ardintigh Point, Ardintigh Burn (watercourse 1) enters into Ardintigh Bay where the scallop ranching site is located. Watercourse 2 (Allt Raineach) enters Loch Nevis directly adjacent to the estimated location of Ardintigh Point mussel lines. If that watercourse does contain higher *E. coli* concentrations from time to time, it could impact at the southwest extent of the mussel lines. The locations of the observed watercourses are shown in the map in Figure 8.1.

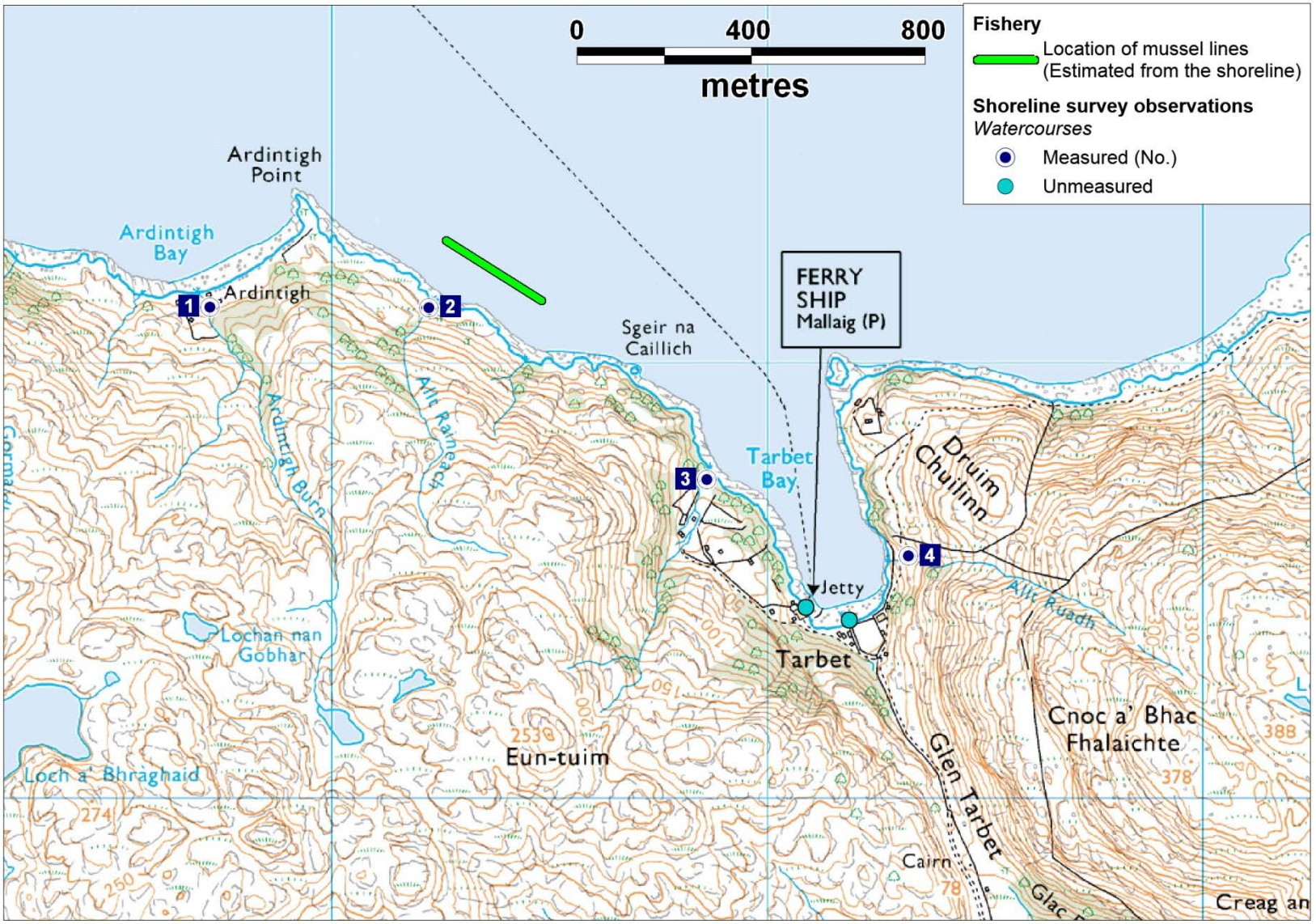


Figure 8.1 Map of watercourse loadings at Loch Nevis

9. Meteorological Data

The nearest weather station is located at Rhubana, situated approximately 10 km west of the fishery; however data for this station consisted mostly of estimates rather than measurements and so have not been used. The nearest weather station with the most complete rainfall data history is located at Skye; Lusa, situated approximately 32 km north north west of the fishery. Rainfall data was available for January 2007 – August 2012 at the time of writing this report. The nearest wind station is also situated at Tiree, approximately south west of the fishery. Conditions may differ between this station and the fishery due to the distances between them. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

Data for these stations was purchased from the Meteorological Office. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas. This section aims to describe the local rain and wind patterns in the context of the bacterial quality of shellfish at Loch Nevis.

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). The box and whisker plots in Figures 9.1 and 9.2, present a summary of 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 *.

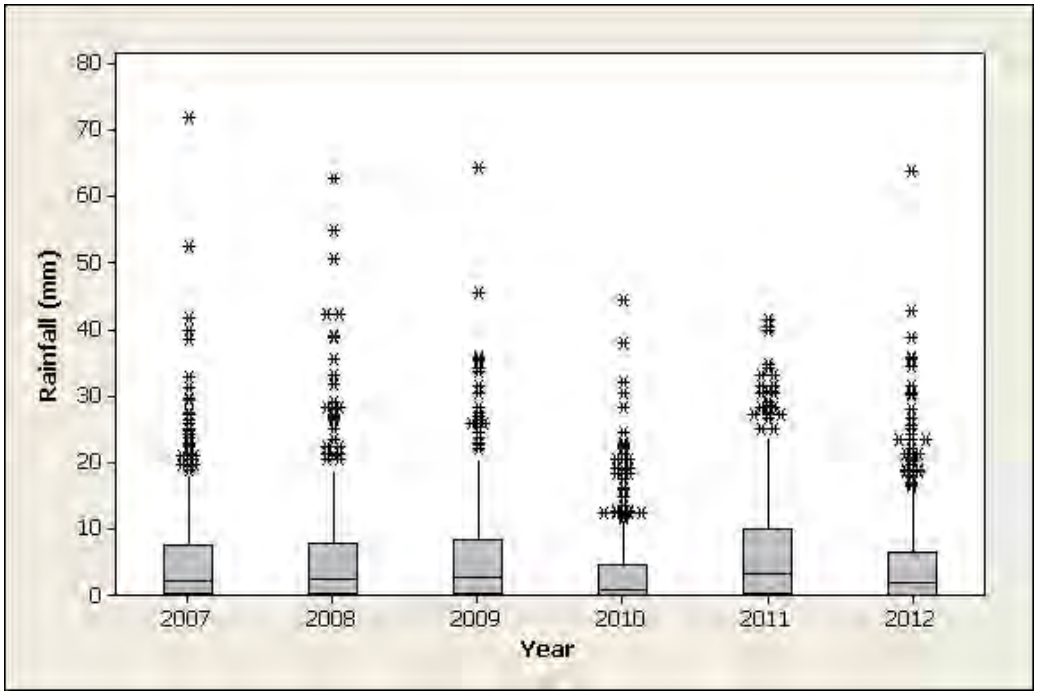


Figure 9.1 Box plot of daily rainfall values by year at Skye; Lusa (2007 – 2012)

Daily rainfall values varied from year to year, with 2010 being the driest year. The wettest year was 2011. High rainfall values of more than 30 mm/d occurred in all years and extreme rainfall events of more than 60 mm/d were seen in 2007, 2008, 2009 and 2012.

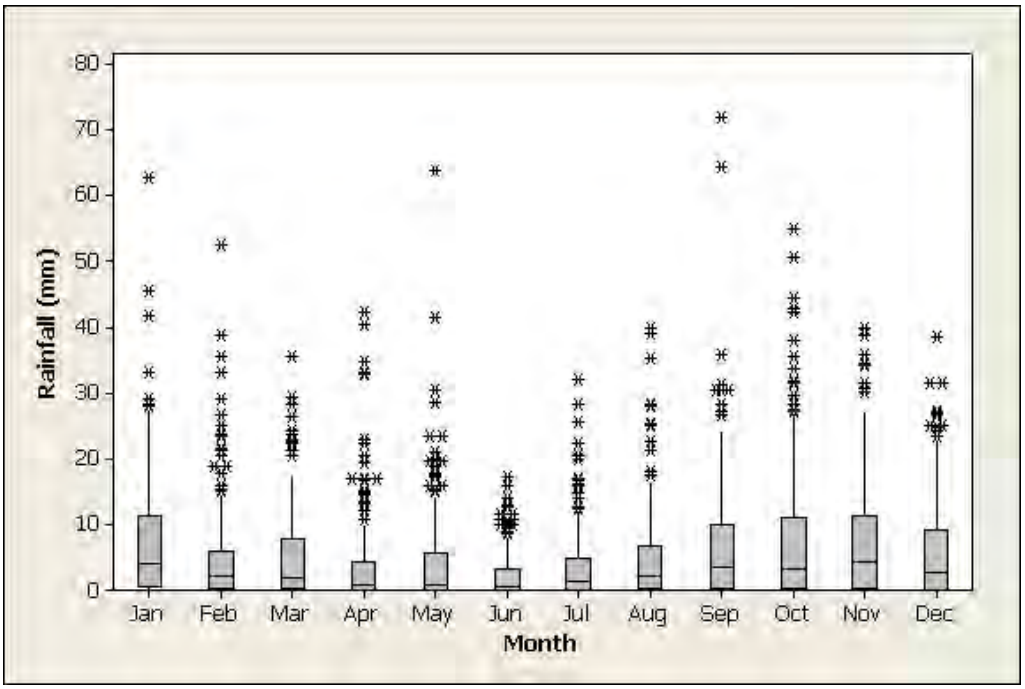


Figure 9.2 Box plot of daily rainfall values by month at Skye; Lusa (2007 – 2012)

Daily rainfall values were higher overall during the winter. Rainfall was highest between September and January. Rainfall values exceeding 30 mm/d were seen in all months apart from June.

For the period considered here (2007 – 2012) 40 % of days received daily rainfall of less than 1 mm and 19 % of days received rainfall of over 10 mm.

It is therefore expected that run-off due to rainfall will be higher during the autumn and winter months. However, extreme rainfall events leading to episodes of high run-off can occur in most months and when these occur during generally drier periods, they are likely to carry higher loadings of faecal material that has accumulated on pastures when greater numbers of livestock were present.

9.2 Wind

Wind data was collected from Tiree and summarised in seasonal wind roses in Figure 9.3 and annually in Figure 9.4.

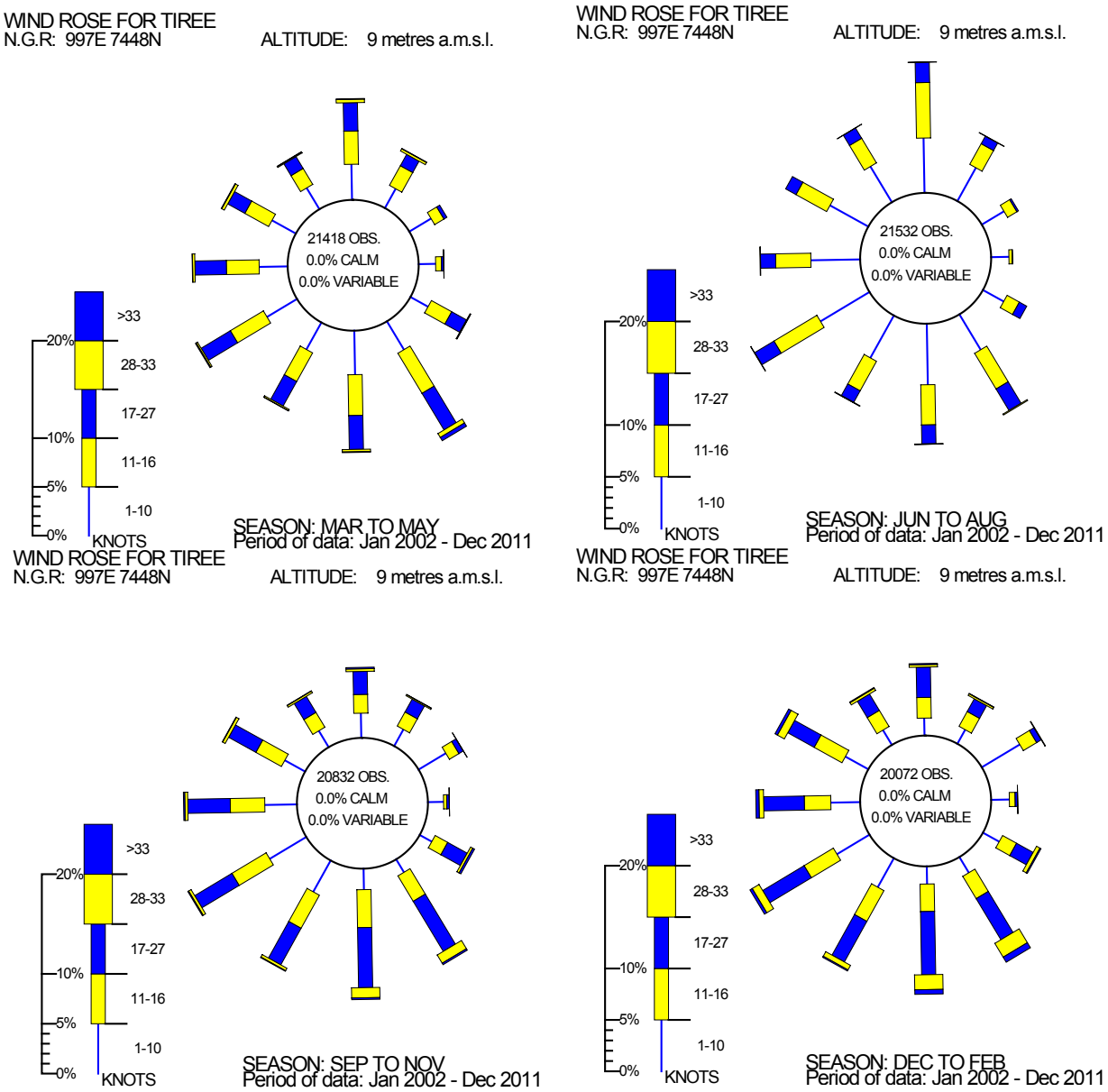


Figure 9.3 Seasonal wind roses for Tiree

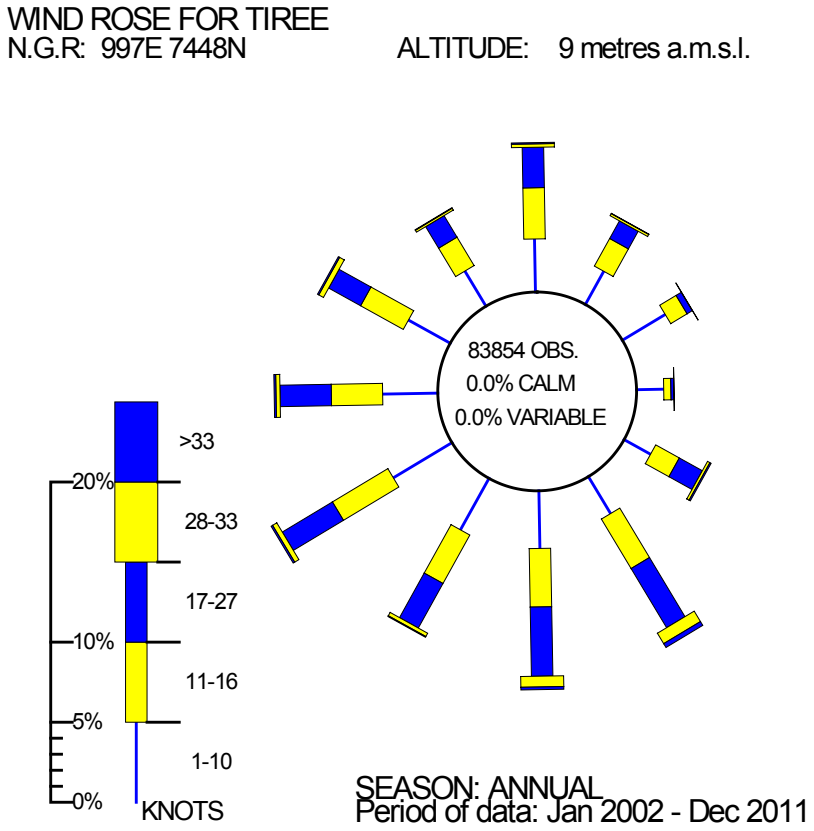


Figure 9.4 Annual wind rose for Tiree

Overall the predominant winds ranged between west southwest and south southeast. Winds were least likely to blow from the east. Northerly winds occurred relatively frequently during spring and summer.

Wind is an important factor in the spread of contamination as it has the ability to 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 can significantly alter the pattern of surface currents. Strong winds also have the potential to affect tide height depending on wind direction and local hydrodynamics of the site. A strong wind combined with a spring tide may result in higher than usual tides, which will carry any accumulated faecal matter at and above the normal high water mark into the production area.

10. Classification Information

The area has been classified for mussel production since 2003. The classification history since 2006 is listed in Table 10.1. The area was declassified in April 2013, after the initiation of this survey.

Table 10.1 Loch Nevis: Ardintigh Point classification history

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	A	A	A	A	A	A	A	A	A	A	A	A
2007	A	A	A	A	B	B	B	B	B	A	A	A
2008	A	A	A	A	A	A	A	B	B	A	A	A
2009	A	A	A	A	A	A	A	B	B	A	A	A
2010	A	A	A	A	A	A	A	B	B	A	A	A
2011	A	A	A	A	A	A	A	B	B	B	B	B
2012	A	A	A	A	A	A	A	A	A	A	A	A
2013	A	A	A									
2014												

Historically the site had generally held a seasonal A/B classification with B classifications tending to occur during August and September.

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned against the two sites in Loch Nevis production area; Ardintigh Bay and Ardintigh Point for the period 01/01/2007 to the 07/05/2013 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted from the database on 08/05/2013. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

All *E. coli* results of < 20 *E. coli* MPN/ 100 g were reassigned results of 10 *E. coli* MPN/ 100 g for the purposes of graphical representation and statistical analysis. The one result of > 18000 *E. coli* MPN/ 100 g was reassigned a result of 36000 *E. coli* MPN/ 100 g for the same purposes.

All 34 samples from Ardintigh Bay were reported as valid and were collected and delivered within the 48 hr permitted time window. All samples had box temperatures of < 8^{o}C.

All 20 samples from Ardintigh Point were reported as valid and were collected and delivered within the 48 hr permitted time window. All samples had box temperatures of < 8^{o}C.

11.2 Summary of microbiological results

A summary of historical monitoring results by location is shown in Table 11.1.

Table 11.1 Summary of historical sampling and results

Sampling Summary		
Production area	Loch Nevis	
Site	Ardintigh Bay	Ardintigh Point
Species	common mussels	
SIN	HL-180-725-08	HL-180-228-08
Location	Various	Various
Total no of samples	34	20
No. 2008	6	6
No. 2009	7	6
No. 2010	5	5
No. 2011	8	3
No. 2012	8	-
Results Summary		
Minimum	< 20	< 20
Maximum	> 18000	1100
Median	40	20
Geometric mean	53	44
90 percentile	800	447
95 percentile	11100	1068
No. exceeding 230/100g	5 (15%)	4 (20%)
No. exceeding 1000/100g	3 (9%)	1 (5%)
No. exceeding 4600/100g	1 (3%)	0 (0%)
No. exceeding 18000/100g	1 (3%)	0 (0%)

Sampling at both locations has not been monthly, with between 5 to 8 samples taken at Ardintigh Bay and fewer samples taken at Ardintigh Point before its declassification in 2013. The maximum result recorded at Ardintigh Bay was markedly higher than that recorded at Ardintigh Point.

11.3 Overall geographical pattern of results

The geographical locations of sample results for both the common mussel sites are displayed below in Figure 11.1.

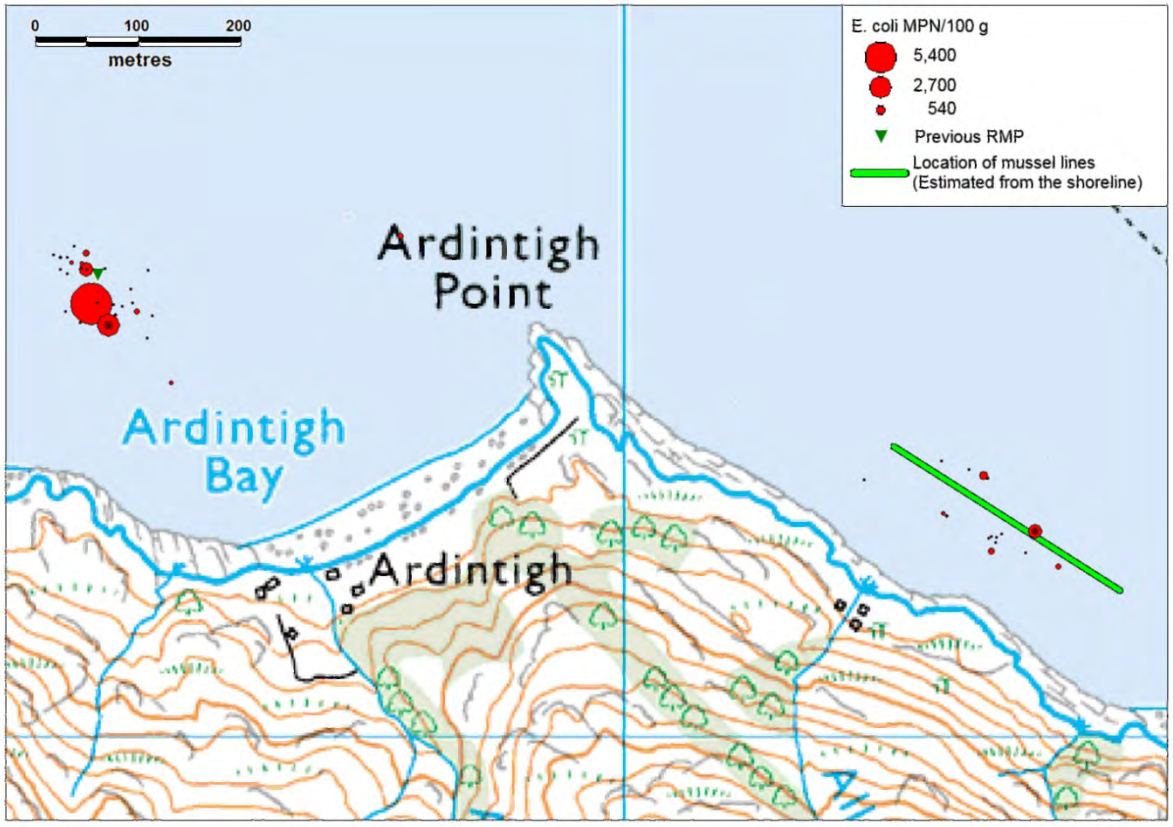


Figure 11.1 Map of reported sampling locations for common mussels at Loch Nevis

Historical samples at Ardintigh Bay have mostly been recorded as being taken within < 150 m of the RMP. One sample was recorded against a location on the Ardintigh Point site, and this was included in the analysis for Ardintigh Bay. The highest *E. coli* results were from samples taken to the south of the RMP

The general tendency to lower results at the Ardintigh Point site is evident in Figure 11.1. There appears to be some trend towards higher results at that site occurring towards the middle of the spread of sampled locations.

11.4 Overall temporal pattern of results

Scatterplots of common mussel *E. coli* results against date for Ardintigh Bay and Ardintigh Point are presented in Figures 11.2 and 11.3 respectively. The datasets are fitted with a lowess trend line. Lowess trendlines allow for locally weighted regression scatter plot smoothing. At each point in the dataset an estimated value is fitted 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 lowess line is influenced more by the data close to it (in time) and less by the data further away. A trend line helps to highlight any apparent underlying trends or cycles.

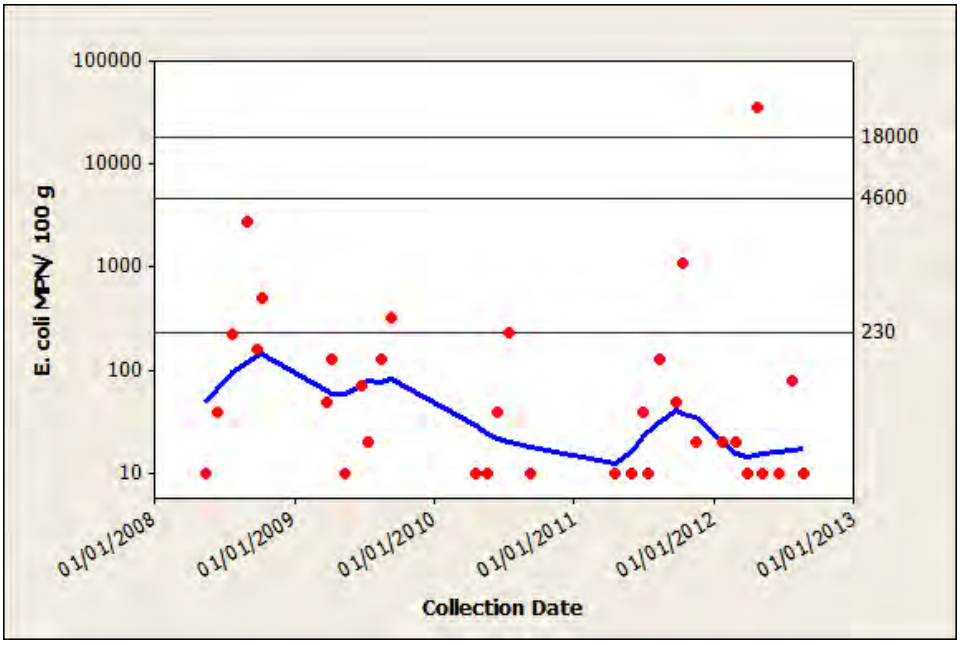


Figure 11.2 Scatterplot of common mussel *E. coli* results by collection date at Ardintigh Bay, fitted with a lowess line

Contamination levels in results from Ardintigh Bay have shown a gradual decrease over the sampling years 2008 to 2012, as displayed by the lowess line in Figure 11.2. This is caused by an increasing number of results at < 20 *E. coli* MPN/100 g and fewer > 230 *E. coli* MPN/100 g. However, the highest result recorded at > 18000 *E. coli* MPN/100 g occurred in 2012.

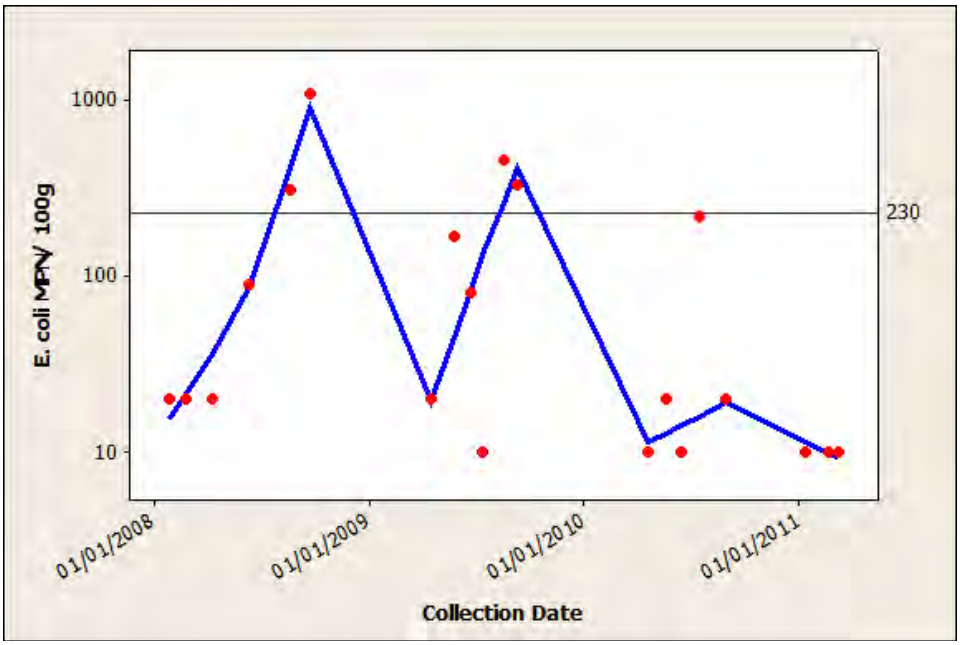


Figure 11.3 Scatterplot of common mussel *E. coli* results by collection date at Ardintigh Point, fitted with a lowess line

Contamination levels from results taken at Ardintigh Point are shown to peak sharply in 2008 and 2009, with a much smaller peak again in 2011. The peaks appear to follow a seasonal pattern.

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 in human distribution. All of these can affect levels of microbial contamination, causing seasonal patterns in results. Figures 11.4 and 11.5 display scatterplots of common mussel *E. coli* results by month, overlaid with a lowess line to highlight trends for Ardintigh Bay and Ardintigh Point respectively. In both scatterplots the points have been subject to a jitter of 0.02 on the x-axis and 0.001 on the y-axis in order to ensure that all of the data points are visible.

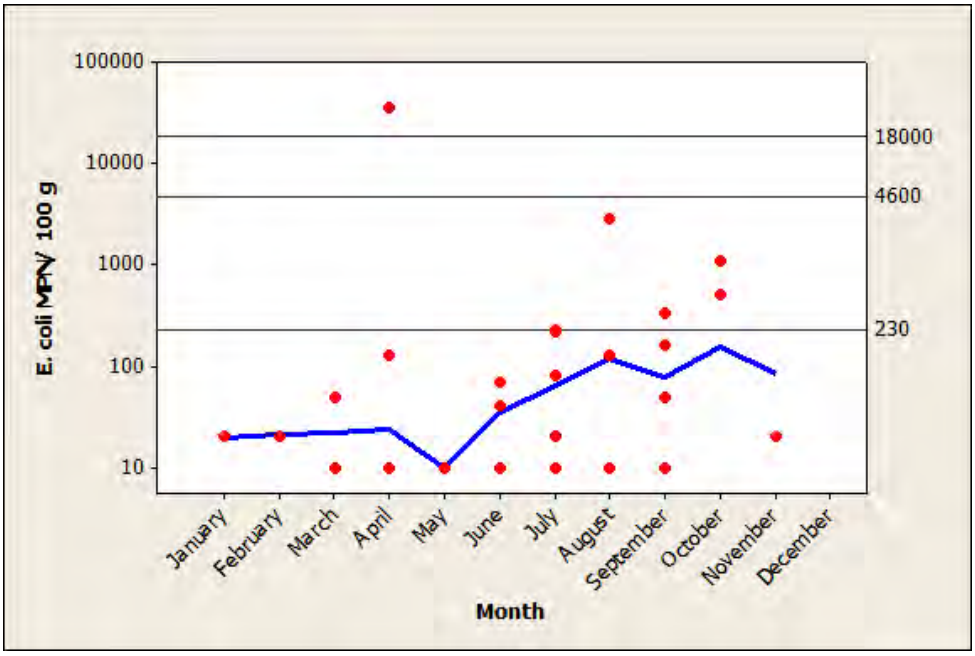


Figure 11.4 Scatterplot of common mussel *E. coli* results by month at Ardintigh Bay, fitted with a lowess line

There is a general trend for *E. coli* results at Ardintigh Bay to increase from May to October. However, uneven sampling across months may contribute to this apparent trend. No samples were taken in December, and only one sample was taken in months January, February, May and November. The highest *E. coli* result was seen with a sample taken in April.

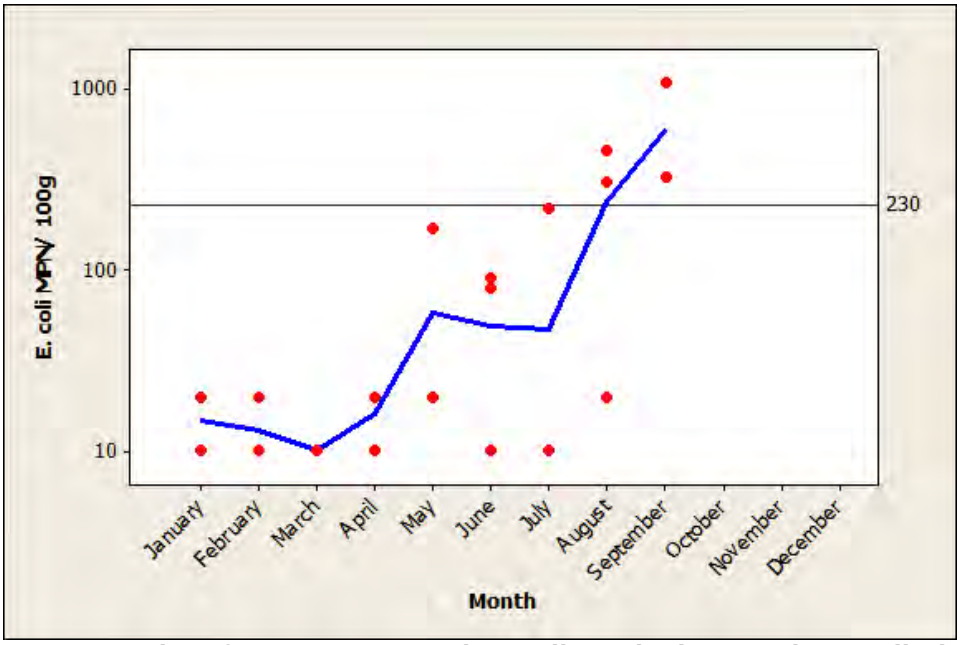


Figure 11.5 Scatterplot of common mussel *E. coli* results by month at Ardintigh Point, fitted with a lowess line

There is a marked upward trend in *E. coli* results at Ardintigh Point peaking at the end of the summer/beginning of autumn. However, it is not possible to determine the pattern in late autumn/early winter as no samples were taken between October and December.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Boxplots of common mussel *E. coli* results by season are presented for Ardintigh Bay and Ardintigh Point in Figures 11.6 and 11.7 respectively.

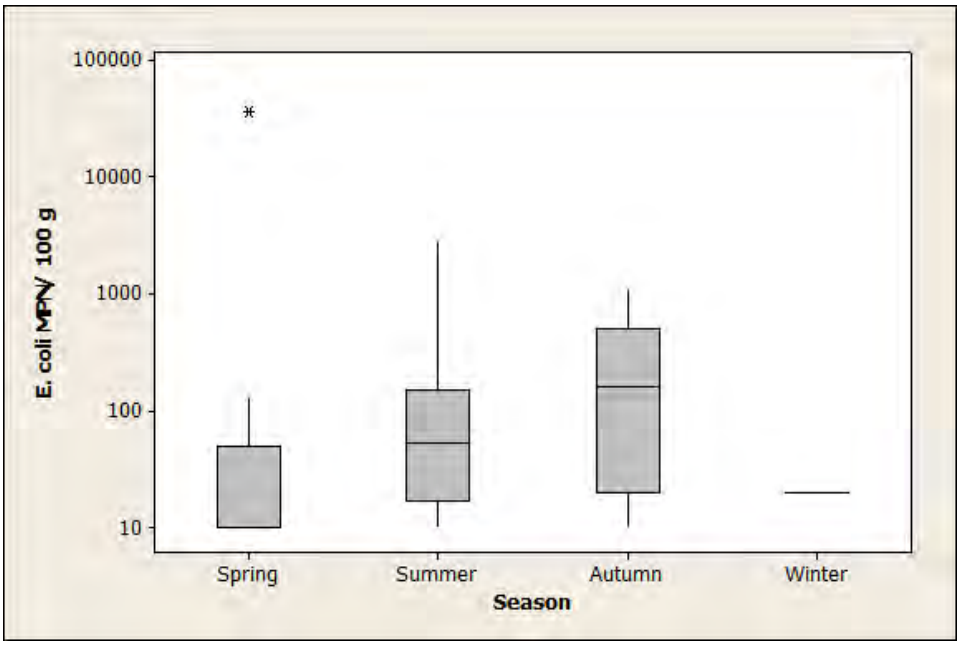


Figure 11.6 Boxplot of common mussel *E. coli* results by season at Ardintigh Bay

No significant difference was found between Ardintigh Bay common mussel *E. coli* results by season (one-way ANOVA, p = 0.456, Appendix 4).

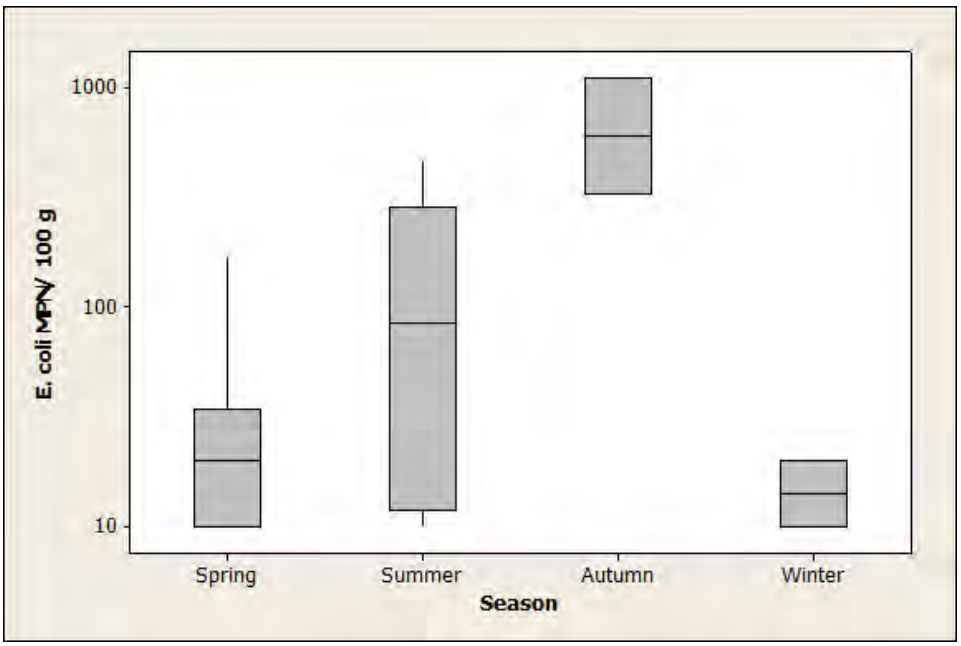


Figure 11.7 Boxplot of common mussel *E. coli* results by season at Ardintigh Point

A significant difference was found between common mussel results by season (one-way ANOVA, p = 0.010, Appendix 4). Results showed that samples in spring had lower results than those in autumn, and autumn had higher results than those taken in winter. It should be noted that no samples were taken in late autumn or early winter.

11.5.1 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, wind, sunshine and temperature can all influence the flux of faecal contamination into growing waters (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.

11.5.2 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Skye; Lusa approximately 32 km NNW of the Loch Nevis production area. Rainfall data was purchased from the Meteorological Office for the period of 01/01/07 - 31/12/2012 (total daily rainfall in mm). Data was extracted from this for relevant periods prior to the dates of samples at Ardintigh Bay and Ardintigh Point.

Two-day rainfall

Scatterplots of common mussel *E. coli* results against total rainfall recorded on the two days prior to sampling are displayed in Figures 11.8 and 11.9, for Ardintigh Bay and Ardintigh Point respectively. The points on both scatterplots have been subject to a jitter of 0.003 on the x-axis and 0.001 on the y-axis.

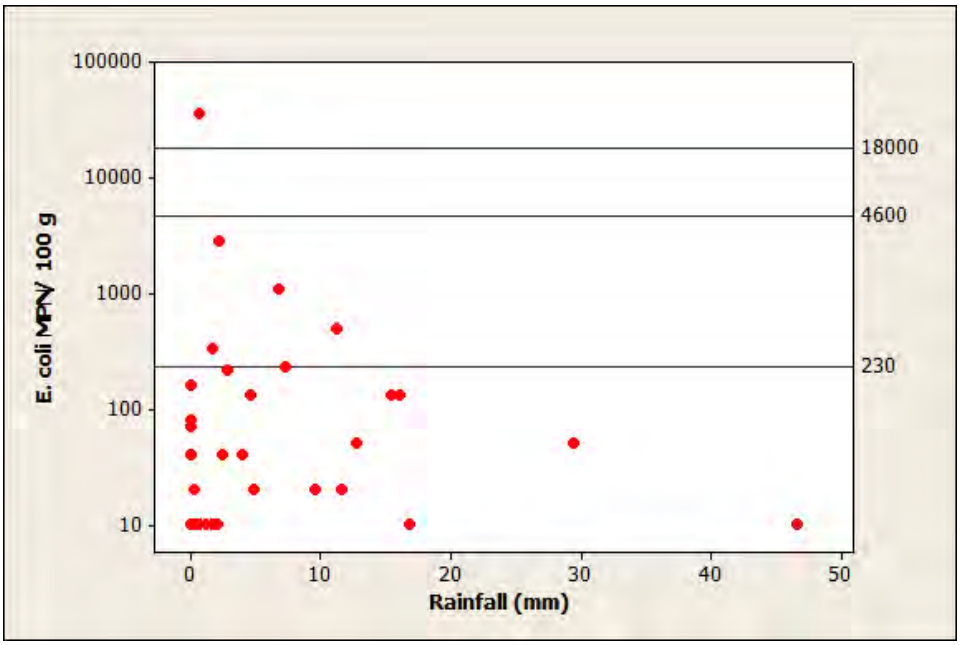


Figure 11.8 Scatterplot of common mussel *E. coli* results against rainfall in the previous two days at Ardintigh Bay

No significant correlation was found between the Ardintigh Bay common mussel *E. coli* results and the previous two day rainfall (Spearman's rank correlation $r = 0.234$, $p = 0.182$). However, the highest *E. coli* results occurred after relatively low levels of rainfall.

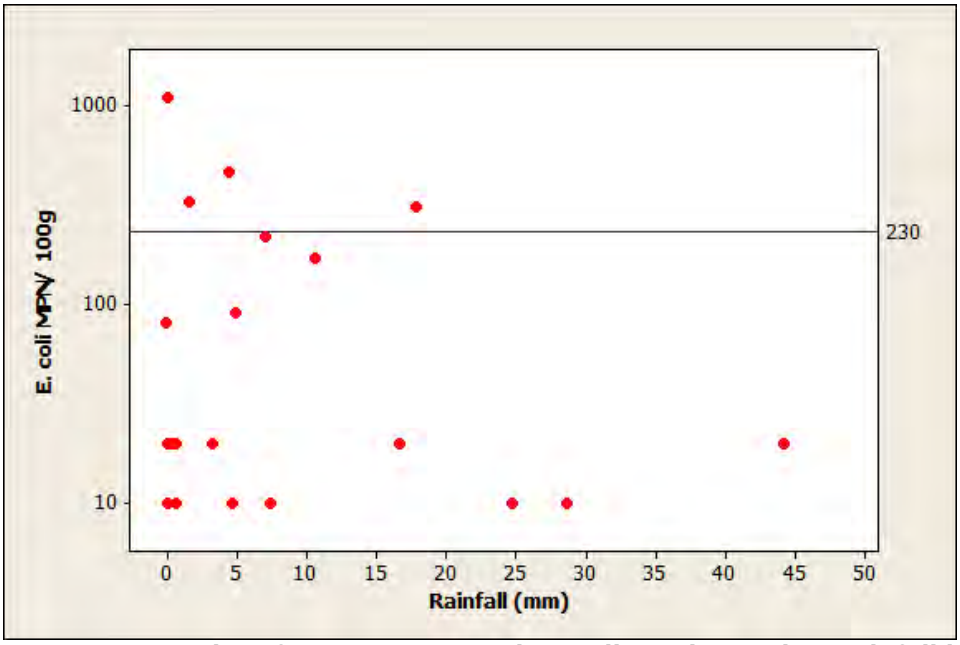


Figure 11.9 Scatterplot of common mussel *E. coli* results against rainfall in the previous two days at Ardintigh Point.

No significant correlation was found between the Ardintigh Point common mussel *E. coli* results and the previous two day rainfall (Spearman's rank correlation r = -0.139, p = 0.559). The highest results occurred after no or low to moderate amounts of rainfall.

Seven-day rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different system, the relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. Scatterplots of common mussel *E. coli* results against total rainfall recorded for the seven days prior to sampling at Ardintigh Bay and Ardintigh Point are shown in Figures 11.10 and 11.11 respectively. The points on the scatterplot in Figure 11.10 have been subject to a jitter of 0.025 on the x-axis and 0.025 on the y-axis and those in Figure 11.11 to a jitter of 0.002 on the x-axis and 0.001 on the y-axis .

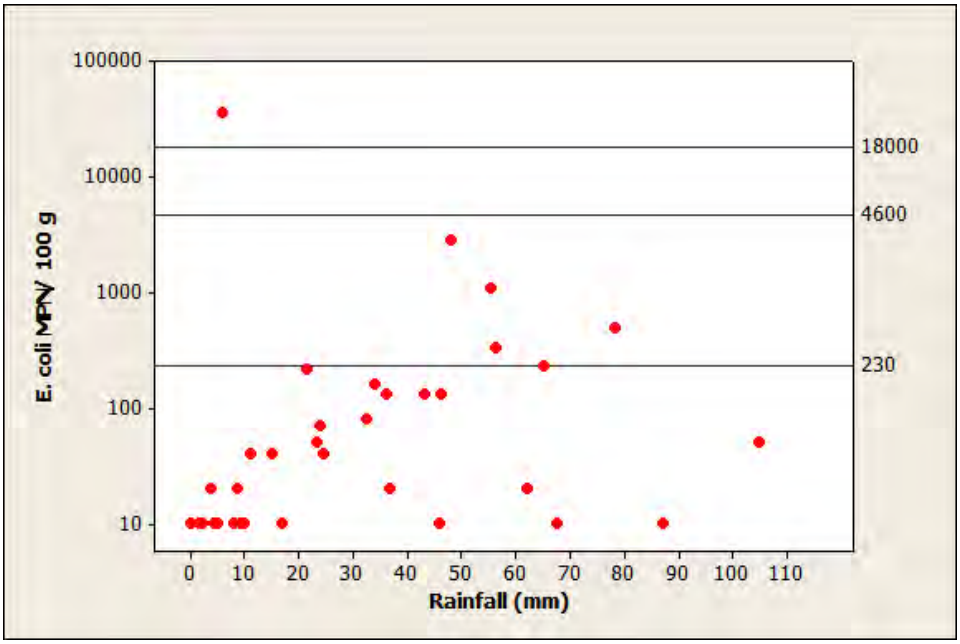


Figure 11.10 Scatterplot of common mussel *E. coli* results against rainfall in the previous seven days at Ardintigh Bay

A significant correlation was found between the Ardintigh Bay common mussel *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.449, p = 0.008). The majority of high results > 230 *E. coli* MPN/ 100 g were taken when there had been moderate amounts of rainfall over the previous seven days. However, the highest result coincided with rainfall of < 10 mm.

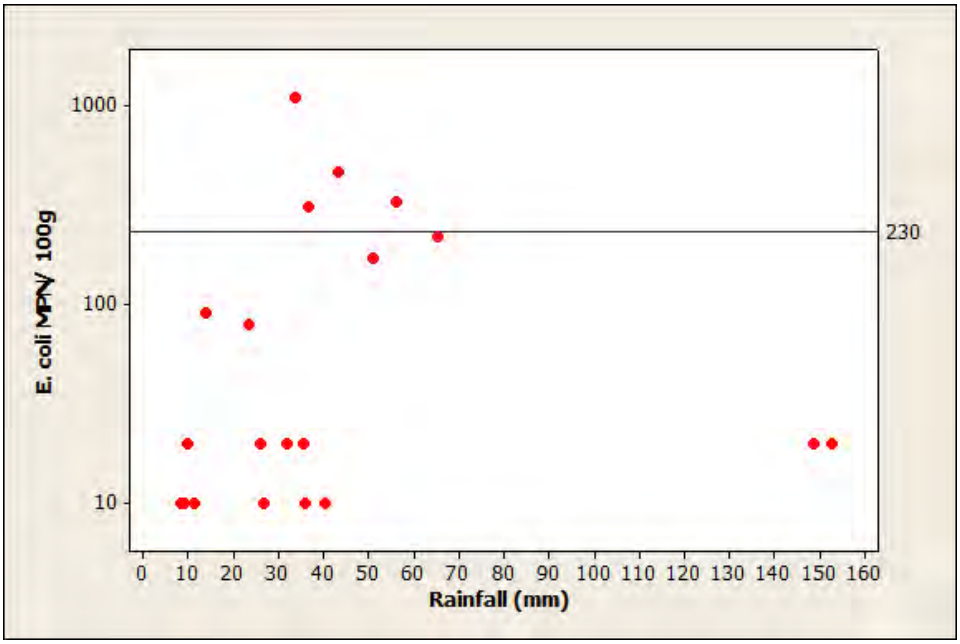


Figure 11.11 Scatterplot of common mussel *E. coli* results against rainfall in the previous seven days at Ardintigh Point

No significant correlation was found between the Ardintigh Point common mussel *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.440, p = 0.052).

11.5.3 Analysis of results by tidal height

Spring/neap tidal cycle

Spring tides are large tides that occur fortnightly and are influenced by the state of the lunar cycle. They reach above the mean high water mark and therefore increase circulation and particle transport distances from potential contamination sources on the shoreline. The largest spring tides occur approximately two days after the full moon about 45°, then decreases to the smallest neap tides at about 225°, before increasing back to spring tides 0°. Figures 11.12 and 11.13 present polar plots of common mussel *E. coli* results against the lunar cycle for Ardintigh Bay and Ardintigh Point respectively**.** It should be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but is not taken into account in this section.

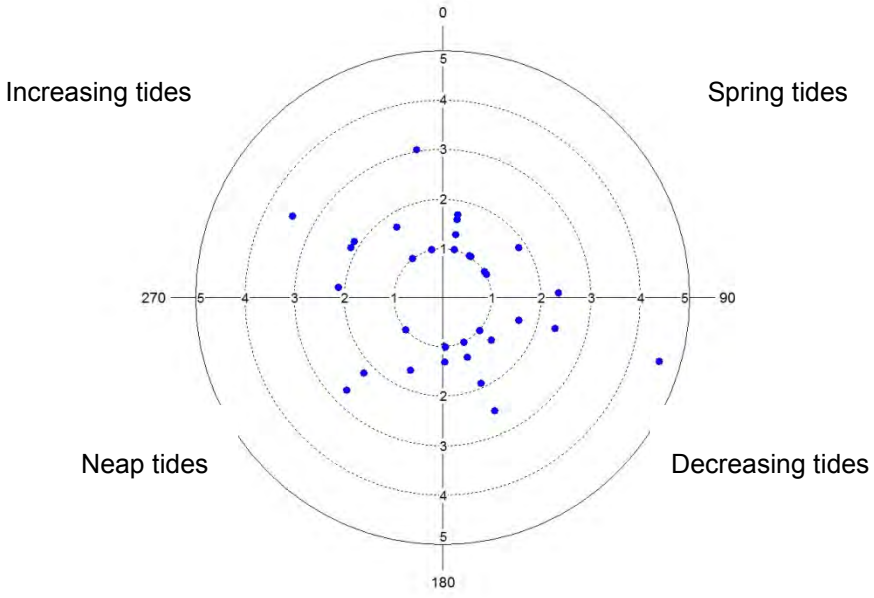


Figure 11.12 Polar plots of common mussel Log_{10} *E. coli* results on the spring/neap tidal cycle at Ardintigh Bay

No significant correlation was found between common mussel log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.136, p = 0.565). High results are shown to have been taken during all tidal states.

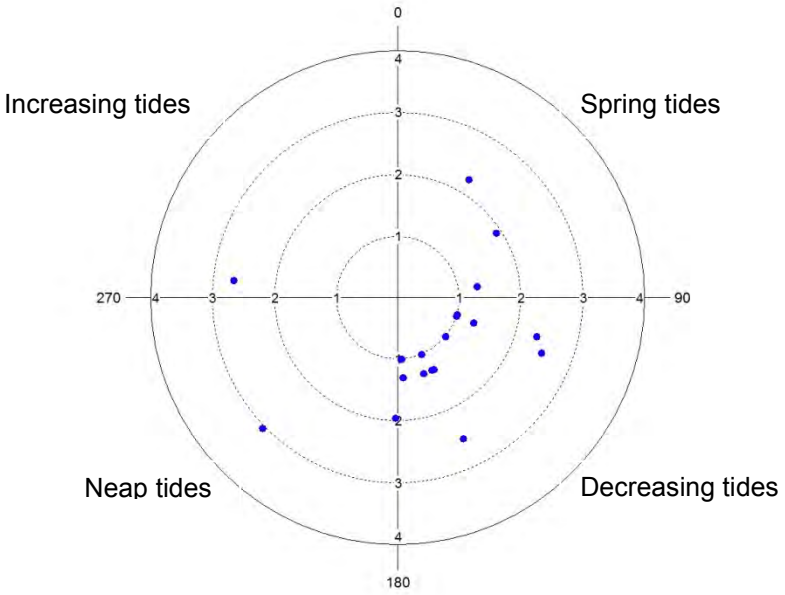


Figure 11.13 Polar plots of common mussel Log_{10} *E. coli* results on the spring/neap tidal cycle at Ardintigh Point

A significant correlation was found between common mussel log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.59, p = 0.002). The majority of samples yielding low results were taken during a decreasing tide, though high results were taken during all tidal states. Sampling effort was concentrated on decreasing tides, with only one sample taken at neap tide and one on an increasing tide.

High/low tidal cycle

Tidal state (high/low tide) changes the direction and strength of water flow around production areas. Depending on the location of contamination sources, tidal state may cause marked changes in water quality near the vicinity of the farms. Shellfish species response time to changing *E. coli* levels in the surrounding water can vary from within an hour to a few hours. Figure 11.14 and 11.15 present polar plots of common mussel *E. coli* results against the high/low tidal cycle for Ardintigh Bay and Ardintigh Point respectively. High water is at located at 0^o and low water at 180^o.

High and low water data from Mallaig was extracted from POLTIPS-3 in May 2013. This site was the closest to the production area (approximately 14 km to the west): the timing of low and high tides are likely to occur later at Ardintigh than at Mallaig but it is assumed that the differences will be approximately constant.

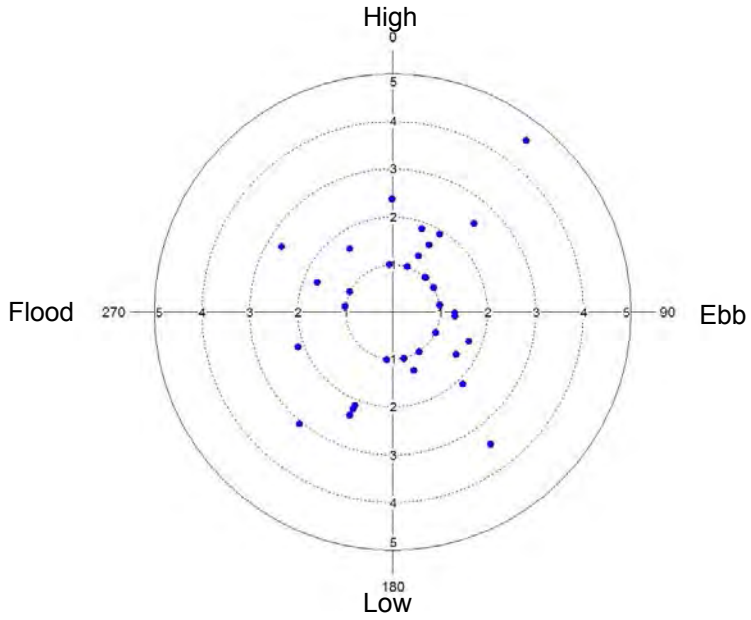


Figure 11.14 Polar plots of common mussel log_{10} *E. coli* results on the high/low tidal cycle at Ardintigh Bay.

No significant correlation was found between common mussel log_{10} *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.142, p = 0.536). High results are shown to have been taken during all tidal states, though the majority of samples were taken during a high/ebb tidal state.

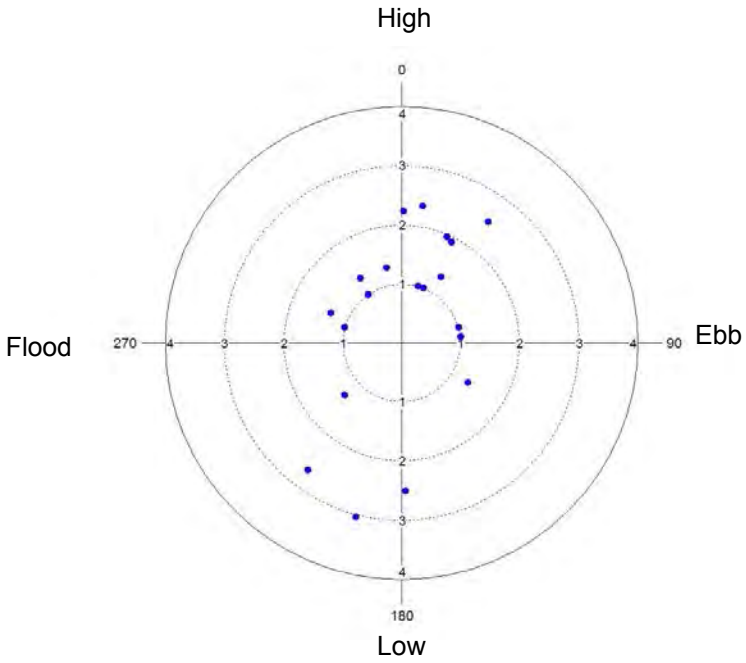


Figure 11.15 Polar plots of common mussel log_{10} *E. coli* results on the high/low tidal cycle at Ardintigh Point.

No significant correlation was found between common mussel log_{10} *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.356, p = 0.115). High

results were seen with samples taken at both high and low tidal states The majority of samples were taken during a high tidal state.

11.5.4 Analysis of results by water temperature

Water temperature can affect survival time of bacteria in seawater (Burkhardt, et al., 2000). It can also affect the feeding and elimination rates in shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. Water temperature is obviously closely related to season. Any correlation between temperatures and *E. coli* levels in shellfish flesh may therefore not be directly attributable to temperature, but to the other factors e.g. seasonal differences in livestock grazing patterns. Figure 11.16 and 11.17 present common mussel *E. coli* results against water temperature for Ardintigh Bay and Ardintigh Point respectively. Water temperature was recorded for 20 out of the 34 samples for Ardintigh Bay and nine out of the 20 samples for Ardintigh Point. The points on the scatterplot in Figure 11.16 have been subject to a jitter of 0.01 on the x-axis and 0.001 on the y-axis and those in Figure 11.17 to a jitter of 0.019 on the x-axis and 0.001 on the y-axis.

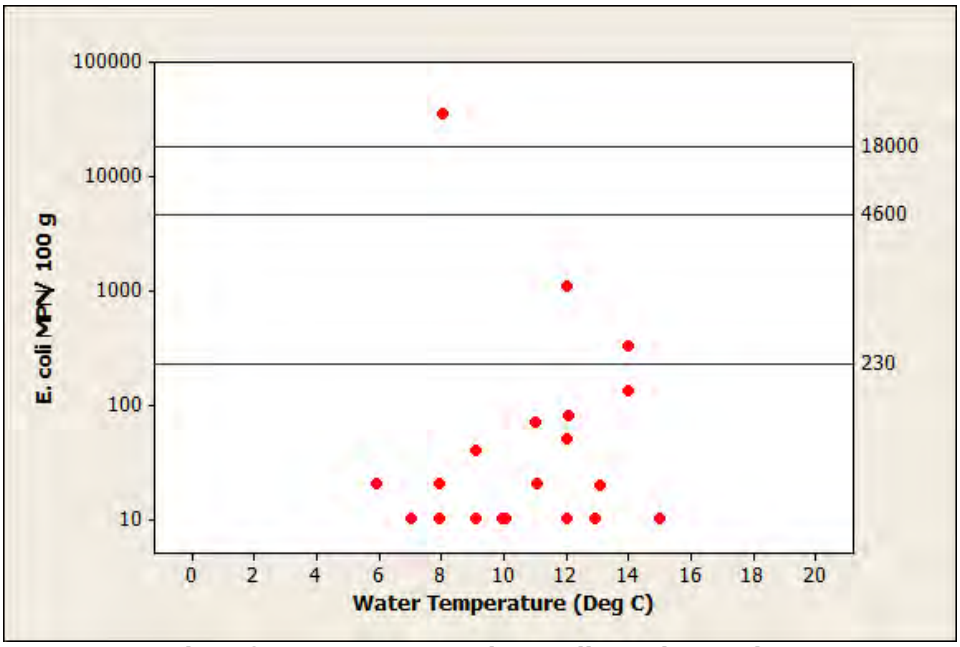


Figure 11.16 Scatterplot of common mussel *E. coli* results against water temperature at Ardintigh Bay

No significant correlation was found between common mussel *E. coli* results and water temperature (Spearman's rank correlation r = 0.427, p = 0.188). The majority of samples were taken when water temperatures were between 8 and 13^{o}C.

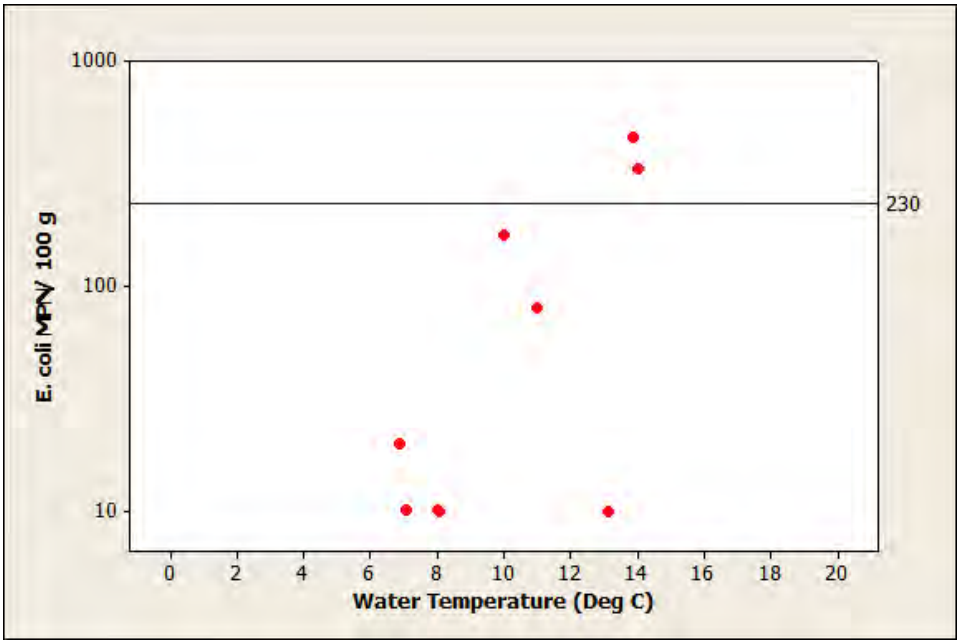


Figure 11.17 Scatterplot of common mussel *E. coli* results against water temperature at Ardintigh Point

A significant correlation was found between common mussel *E. coli* results and water temperature (Spearman's rank correlation r = 0.648, p = 0.059). Few samples had waster temperatures taken, though higher results are correlated well with water temperatures > 9^{o}C.

11.5.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater borne contamination at a site. Salinity was recorded for 25 out of the 34 of the Ardintigh Bay samples, and for all 20 samples taken at Ardintigh Point. Scatterplots of common mussel *E. coli* results against salinity for Ardintigh Bay and Ardintigh Point are shown in Figures 11.18 and 11.19 respectively. The points on the scatterplot in Figure 11.18 have been subject to a jitter of 0.019 on the x-axis and 0.001 on the y-axis and those in Figure 11.19 to a jitter of 0.05 on the x-axis and 0.001 on the y-axis.

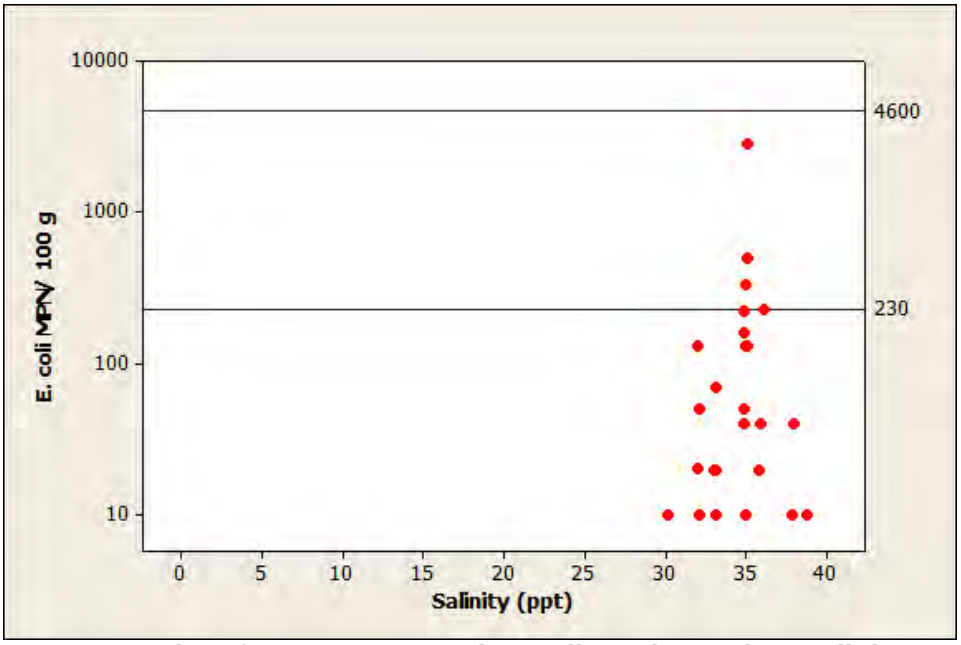


Figure 11.18 Scatterplot of common mussel *E. coli* results against salinity at Ardintigh Bay

No significant correlation was found between common mussel *E. coli* results and salinity (Spearman's rank correlation r = 0.119, p = 0.570). The majority of samples were taken during when water salinity was between 32 and 36 ppt.

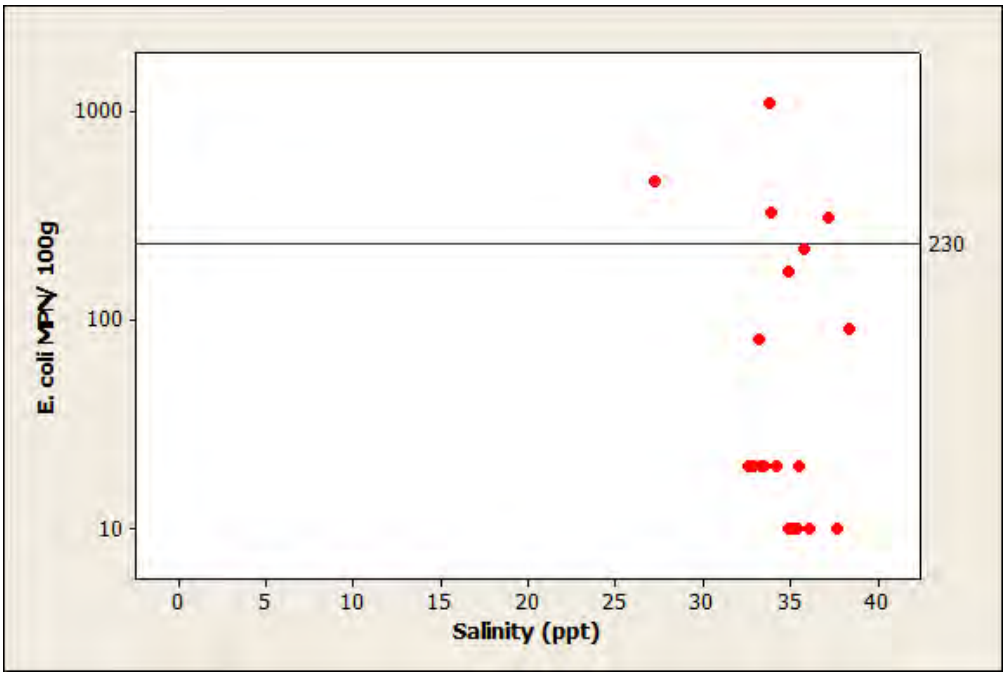


Figure 11.19 Scatterplot of common mussel *E. coli* results against salinity at Ardintigh Point

No significant correlation was found between common mussel *E. coli* results and salinity (Spearman's rank correlation r = -0.204, p = 0.308). The majority of samples were taken when water salinity was between 32 and 37 ppt.

11.6 Evaluation of Ardintigh Bay results over 1000 *E. coli* MPN/100g

In the results from Loch Nevis Ardintigh Bay, five common mussel samples had results > 1000 *E. coli* MPN/ 100 g and are listed below in Table 11.2.

Table 11.2 Ardintigh Bay common mussel *E. coli* sampling results over 1000 *E. coli* MPN/100g

Collection Date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (°C)	Salinity (ppt)	Tidal State (high/low)	Tidal state (spring/neap)
28/08/2008	2800	NM 775 934	2.2	48.0	-	35	Ebb	Increasing
11/10/2011	1100	NM 7748 9345	6.8	55.4	12	-	Low	Increasing
25/04/2012	> 18000	NM 7748 9342	0.6	5.8	8	-	High	Decreasing

The three recorded sampling locations were close to each other although one was only recorded to 100 m accuracy. Samples were taken in different years. Two were taken in late autumn and one in April. All were taken after low amounts of rainfall. Samples were taken during various high/low and spring/neap tidal states.

11.7 Evaluation of Ardintigh Point results over 230 *E. coli* MPN/100g

In results from Loch Nevis Ardintigh Point, four common mussel samples had results > 230 *E. coli* MPN/ 100 g, and are listed in Table 11.3.

Table 11.3 Historic at Ardintigh Point common mussel *E. coli* sampling results over 230 *E. coli* MPN/100g

Collection Date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (°C)	Salinity (ppt)	Tidal State (high/low)	Tidal state (spring/neap)
20/08/2008	310	NM 784 932	17.8	36.8	-	37	Ebb	Decreasing
24/09/2008	1100	NM 784 932	0.0	34.0	-	34	Low	neap
17/08/2009	460	NM 7835 9325	4.6	43.2	14	27	Low	Increasing
10/09/2009	330	NM 7836 9318	1.6	56.2	14	34	High	neap

(-) No data available

The four sampling recorded locations were close to each other although two were only recorded to 100 m accuracy. Elevated sample results varied between 310 and 1100 *E. coli* MPN/ 100 g. Samples were only taken in years 2008 and 2009, with two samples taken in August and two in September.

Rainfall levels in the two days prior to sampling varied between 0.0 and 17.8 mm, and in seven days prior varied between 34.0 and 56.2 mm. The highest result corresponded to the lowest two and seven day rainfall levels.

Water temperature was only recorded for two of the four samples and was relatively high at 14°C. Samples were taken during various high/low and spring/neap tidal states.

11.8 Summary and conclusions

Average and peak *E. coli* levels were higher at Ardintigh Bay than at Ardintigh Point.

Ardintigh Bay

There appeared to be a tendency for higher results to occur at locations south of the previous RMP. There was no statistical association between *E. coli* results and season. However, few samples had been taken during the winter period. There was no significant correlation between 2-day rainfall and *E. coli* but there was between 7-day rainfall and *E. coli*, although the highest result (>18000 *E. coli* MPN/100 g) occurred after very low rainfall.

No significant correlation was found between the *E. coli* results and either the spring/neap tidal or high/low tidal cycle.

Ardintigh Point

There appeared to be some tendency for the highest *E. coli* results to occur in samples taken towards the centre of the historically sampled locations. There was a significant association between *E. coli* results and season, with the highest results occurring in September. However, no samples had been taken from October to December inclusive.

There was no significant correlation between 2-day rainfall and *E. coli* but there was between 7-day rainfall and *E. coli*, although very low results were associated with the two highest rainfall values.

A significant correlation was found between the *E. coli* results and the spring/neap tidal cycle, but not the high/low tidal cycle. The majority of low results occurred in samples taken during decreasing tides although sampling was skewed towards this state.

A correlation was found between results and seawater temperature: higher results were from samples taken at water temperatures > 9^{o}C. This conforms to the observed seasonal effect.

12. Designated Waters Data

The Loch Nevis production area falls within the Loch Nevis designated Shellfish Waters Growing Water (SGW) (shown in Figure 12.1). The SGW was originally designated in 2002 and, under the current Shellfish Waters Directive, must be monitored quarterly for faecal coliforms in the shellfish flesh and intervalvular fluid. SEPA is responsible for ensuring that this monitoring is undertaken. The designated monitoring point is situated in Ardintigh Bay, east of the RMP.

The relative positions of the production area, RMP, SGW boundary and the SGW monitoring point are shown in Figure 12.1. Since 2007, SEPA have based the SGW assessment on FSAS *E. coli* results. The *E. coli* results have been reviewed in Section 11 of this report and therefore are not reconsidered here.

The shellfish growing water report for the area identified the land bordering Loch Nevis is predominantly moorland and mountains with limited farming activity. The area does not have any settlements of significant size. Since monitoring began in 2002 of the six samples analysed for faecal coliforms in 2003 and 2004, two gave results above the guideline standard and in 2005, two samples gave results above the Guideline standard. The waters failed to comply with the Guideline standard for faecal coliforms in 2008 but passed in 2007, 2009 and 2010.

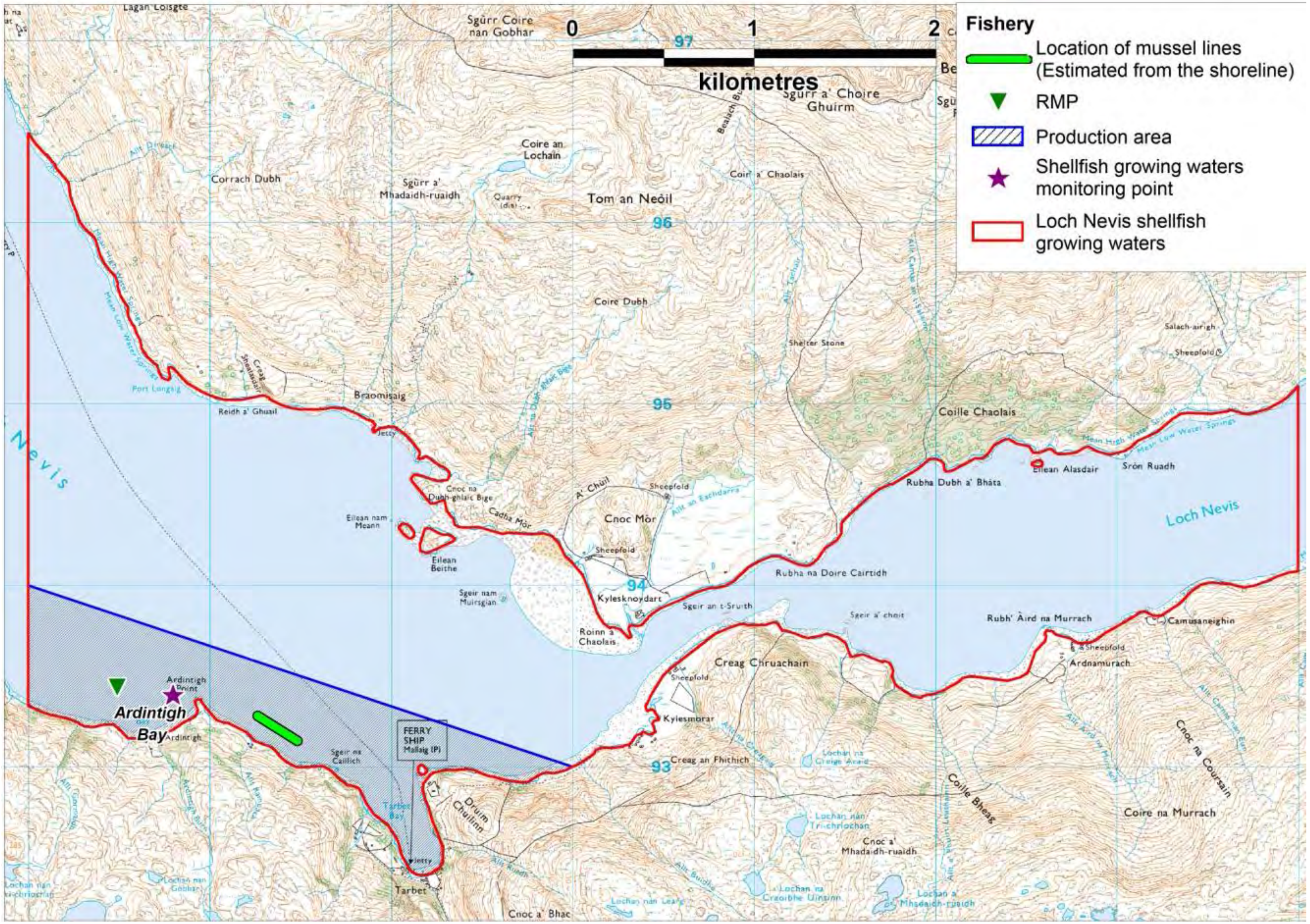


Figure 12.1 Designated shellfish growing water – Loch Nevis

13. Bathymetry and Hydrodynamics

13.1 Introduction

13.1.1 The Study Area

Loch Nevis is situated in the Lochaber region of the west coast of Scotland. It lies in a remote region away from industrial activity and the few houses in the area can only be accessed by boat. It is mostly surrounded by mountains and moorlands. It begins at the southern part of the Sound of Sleat running from northwest to southeast to Camusrory at the head of the loch. The busy fishing town of Mallaig lies to the extreme west of the loch and it is bounded to the north by the Knoydart peninsula with its southerly boundary being North Morar. The main township on Loch Nevis is Inverie which can be reached by ferry from Mallaig and it stretches around the coast from Rubha Roanuill to Creag an Eilein. Tarbet is another smaller township which consists of a collection of houses but has restricted access.

Coordinates for the middle of Loch Nevis:

56° 59.54’ N 005° 40.47’ W

NM 76894 95022

The extent of the hydrography study area is shown in Figure 13.1.

Figure 13.1 Extent of hydrographic study area

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

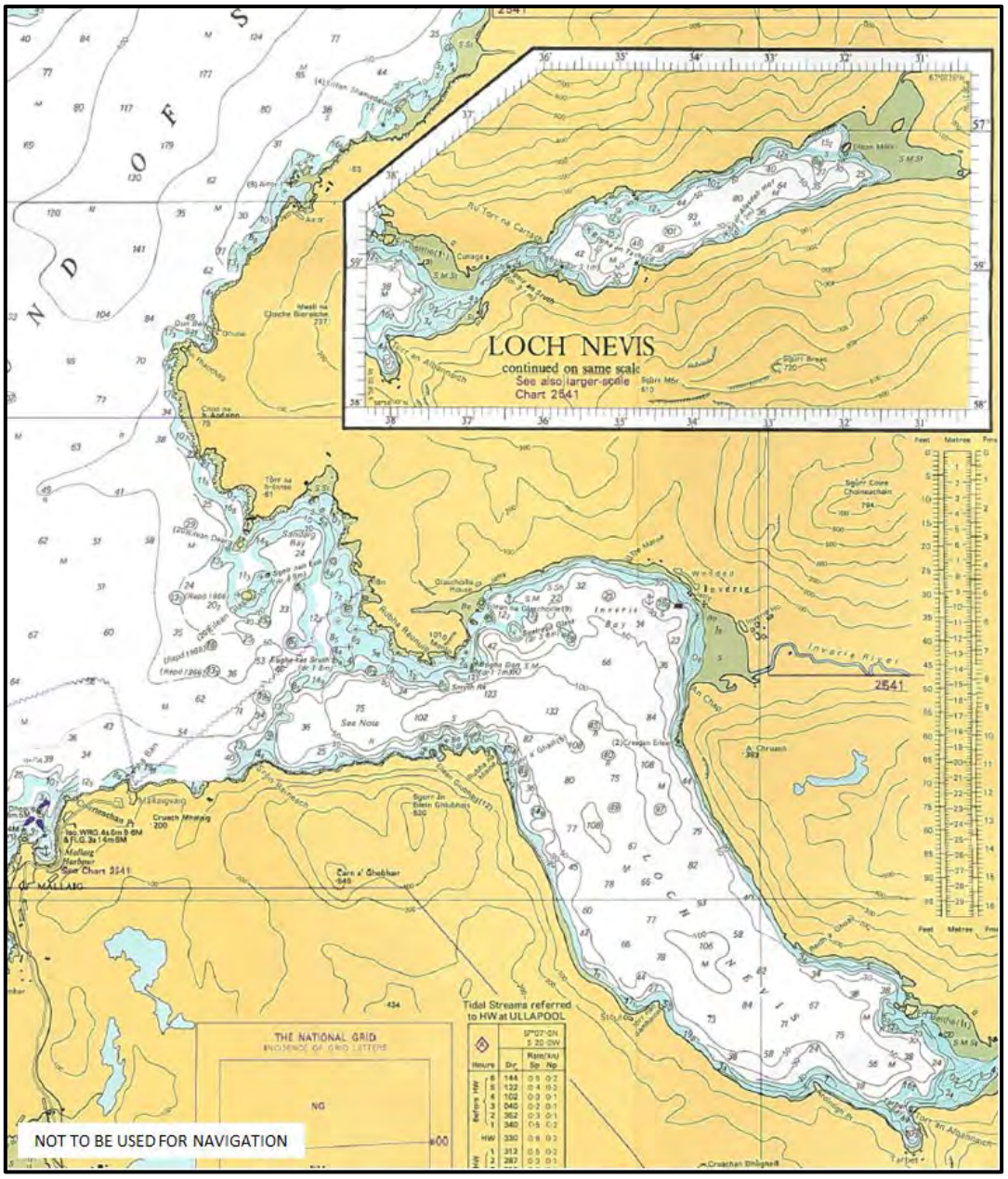


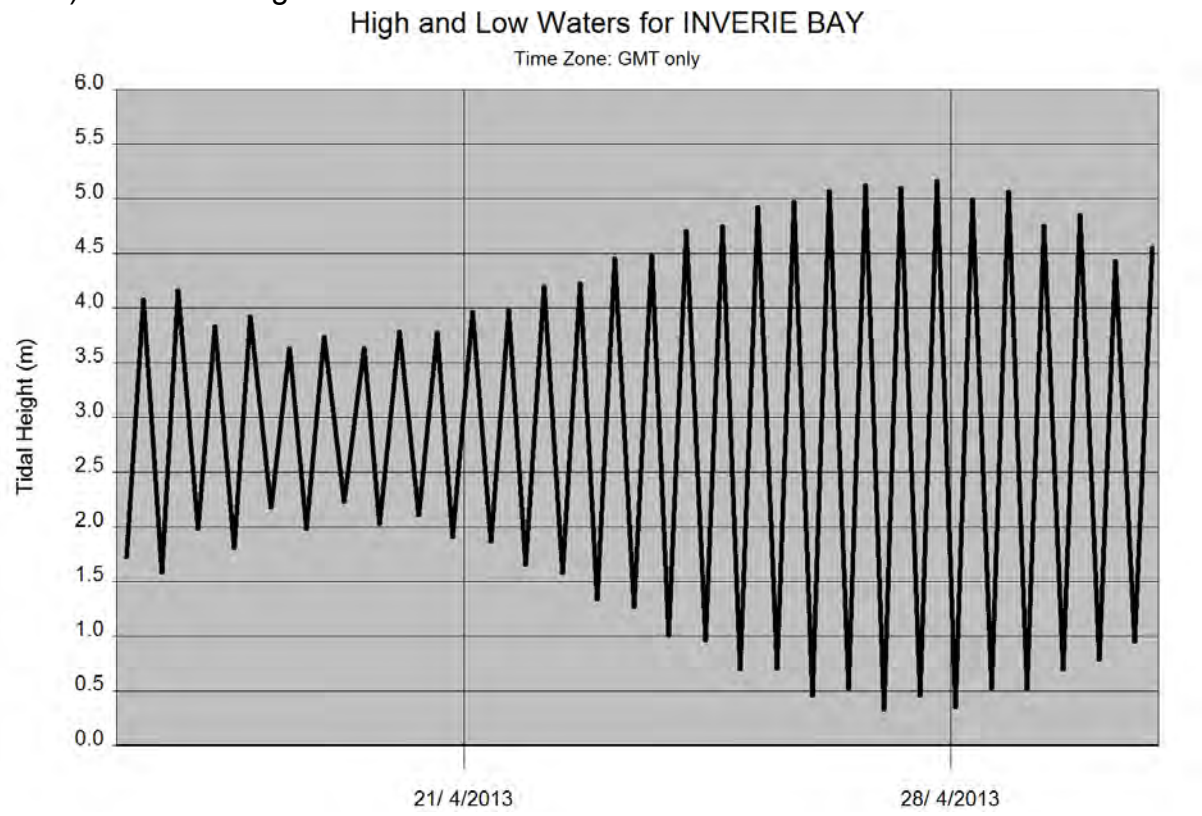
Figure 13.2 Admiralty chart (2208) extract for Loch Nevis

Figure 13.2 shows the bathymetry of Loch Nevis. The maximum charted depth from Admiralty chart 2541 (not shown) is 161 m near the narrowed channel to the north of the loch. Loch Nevis contains two sills, one 200 m and the other 1700 m in length and with maximum sill depths of 20 and 4 m respectively. The loch has a total length of 17.2 km and an average width of approximately 1.6 km with an estimated mean low water depth of 52.3 m (Edwards & Sharples, 1986). Therefore the estimated low water volume is approximately 1.5 x 10^9 m^3. The loch, however has a rather complex bathymetry with two deep, wide basins separated by a narrow passage between Kylesknoydart and Kylesmorar. At the head of the loch there is an extensive intertidal zone of approximately 1 km^2. Loch Nevis is generally steep sloping with strong bathymetric gradients into the middle reaches of the loch within < 50 m from the shore.

13.2.2 Tides

Loch Nevis has a typical semi-diurnal tidal characteristic. Data on tidal information is given from charted information. The nearest location for tidal predictions is Inverie Bay, Loch Nevis [http://easytide.ukho.gov.uk].

Standard tidal data for Loch Nevis are given below (from Admiralty Surveys) and the spring/neap cycle of tidal height around the time of the planned survey (22 – 25 April 2013) is shown in figure 13.3:



Reproduced from Poltips3 [www.pol.ac.uk/appl/poltips3]

Figure 13.3 Two week tidal curve for Inverie Bay, Loch Nevis.

Tidal Heights at Inverie Bay, Loch Nevis:

Mean High Water springs = 5.0 m
Mean Low Water springs = 0.7 m
Mean High Water neaps = 3.8 m
Mean Low Water neaps = 2.0 m

Tidal Ranges:

Mean spring Range = 4.3 m
Mean neap Range = 1.8 m

This gives a tidal volume of water during each tidal cycle of approximately:

springs: 1.2×10^8 m^3
neaps: 5.2×10^7 m^3

13.2.3 Tidal Streams and currents

There are no published tidal diamonds for this area. Enhancement of tidal streams caused by straights and shallow channels will be important near the mouth of the loch where it opens into the Sound of Sleat and between Kylesknoydart and Kylesmorar to the south where the loch is at its most narrow. Here the tide is reported to run at up to 1.5 m/s (Laurence, 1990) with a mean speed of 0.6 m/s (Edwards & Sharples, 1986). There are numerous small islands doted around the loch, for example, Eilean Glas, Sgeirean Glasa, Bogha Don, Eilean nam Meann, Eilean Maol and Eilean Tioram which may cause localised effects. Close to the outer sill, the loch is wide and therefore the exchange potential for this area is high. Contrastingly, the innermost basin is comparatively narrow and long with a width of approximately 200 m and a maximum sill depth of 4 m (Edwards & Sharples, 1986) which significantly reduces the capacity for tidal flushing of the inner basin. There are a number of sources of current meter data available from previous surveys. Current data were obtained from SEPA which were collected from three sites in Loch Nevis (MacFarlane, 2006; MacFarlane, 2008; MacFarlane, 2009). Figure 13.4 shows the location of these sites. The Hydrographic surveys typically span 15 days; being the half-lunar period to capture a spring-neap cycle.

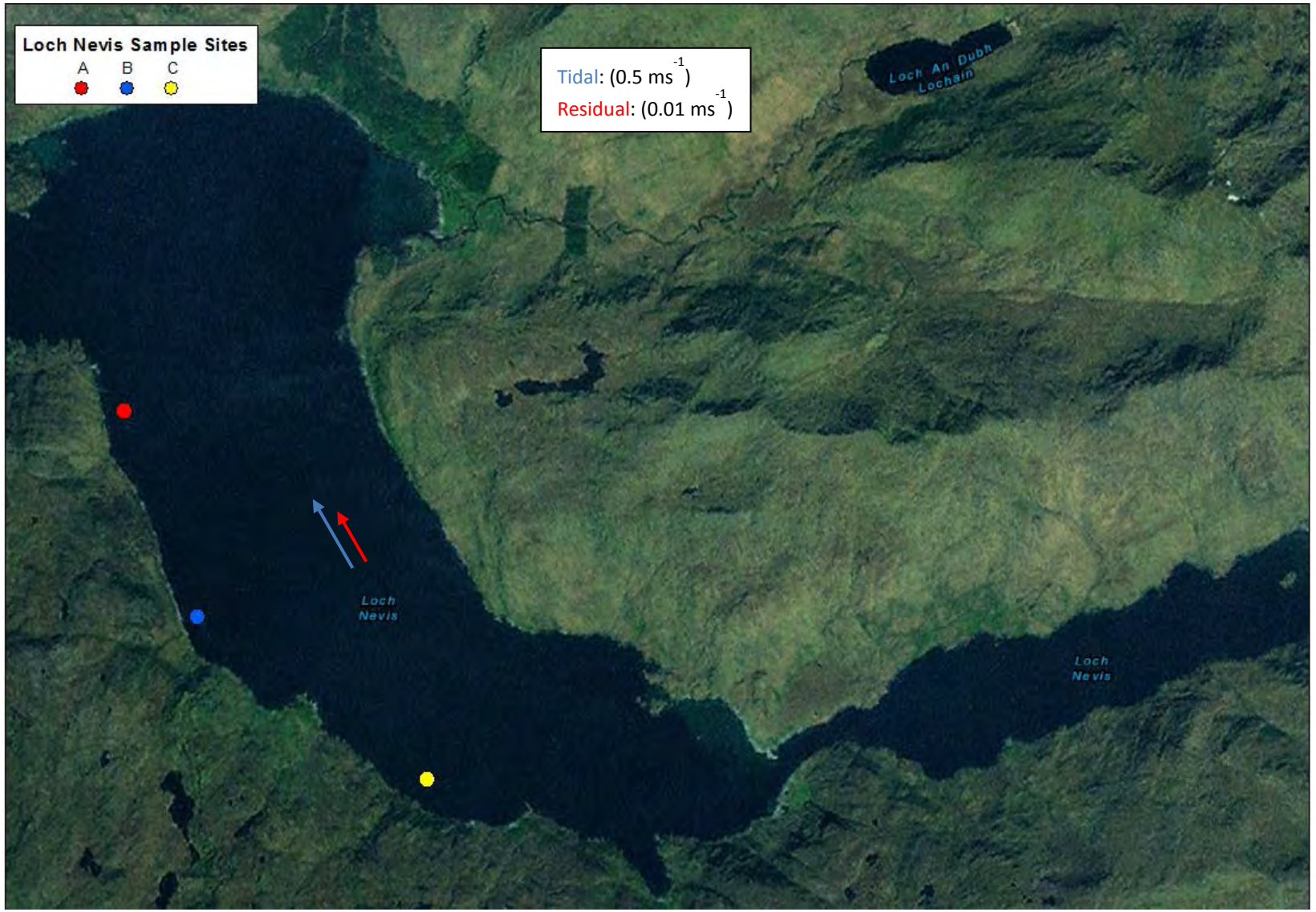


Figure 13.4 Map showing Loch Nevis sample sites. Net cumulative displacement through tidal flow (ebb) and residual flow are shown

Data from Site A which is in the north of the outer basin of Loch Nevis were collected in 2006 (MacFarlane, 2009), summarised in Table 13.1. Semi-diurnal periodicity along with some spring-neap variation was displayed throughout the velocity readings. In general, the currents were of a moderate velocity and whilst the tabulated mean velocity was greatest in the sub-surface, it is notable that there were similarities in current velocities throughout all the depths. The alignment of the current axis generally follows the bathymetry with greatest anisotropy in the surface. There is rather little technical narrative accompanying the report for Site A in Loch Nevis and no assessment from that survey of the flushing properties at that location.

Table 13.1 Loch Nevis Site A current data measured in 2006

Height above seabed	Near-bed (3m)	Mid (21m)	Sub-surface (27m)
Mean Speed (ms-1)	0.04	0.05	0.06
Maximum Speed (ms-1)	0.13	0.13	0.15
Principal Axis Amp & Dir (ms-1) & (oM)	0.047 (295)	0.052 (345)	0.061 (345)
Eccentricity Ratio	1.08	2.20	2.16
Residual speed (ms-1)	0.02	0.03	0.04
Residual direction (oM)	275	348	341

Data from Site B which is approximately 2km south of Site A in Loch Nevis were collected in 2006 (MacFarlane, 2008), summarised in Table 13.2. Semi-diurnal periodicity along with some spring-neap variation was displayed throughout the velocity readings. In general, the currents were of a moderate to low velocity with the sub-surface and mid depth showing similarities in both velocities and direction with the current directed along the axis of the Loch with moderate anisotropy. Again, there is rather little technical narrative accompanying the report for Site B in Loch Nevis.

Table 13.2 Loch Nevis Site B current data measured in 2006

Height above seabed	Near-bed (3m)	Mid (29m)	Sub-surface (35m)
Mean Speed (ms^{-1})	0.019	0.026	0.028
Maximum Speed (ms^{-1})	0.10	0.18	0.17
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.026 (160)	0.037 (320)	0.040 (320)
Eccentricity Ratio	1.2	1.4	1.5
Residual speed (ms^{-1})	0.002	0.004	0.004
Residual direction (^oM)	095	312	281

It is important to note that the principal directions show an approximate 180° shift between the near bed and the mid and sub-surface levels. Given the nature of tidal forcing this is rather unlikely as the currents will tend to flow in the same direction at the same time. It is possibly indicative of a 180° error in the reporting of the direction of the principal axis for the near bed.

Data from Site C which is approximately 4km south-east of Site B in Loch Nevis were collected in 2000 (MacFarlane, 2006), summarised in Table 13.3. Semi-diurnal periodicity along with some spring-neap variation was displayed throughout the velocity readings. In general, the currents were of a moderate to low velocity with the currents getting weaker from surface to bed. The surface currents showed greatest anisotropy with the current axis directed north-south. In mid and bottom currents there was almost isotropic current flow with no clear major axis.

The three sites described above show rather similar characteristics; notably mean and maximum current speeds in all depths with the same order of magnitude. Further, the principle current in most cases is directed along the axis of the loch. Most of the variability between sites is within the residual flow and this is entirely expected given the rather short deployments and inter-seasonal variation.

Using a typical surface principal current amplitude of 0.5 m/s (Tables 13.1-3) and the assumption of a uniform sinusoidal tide, the cumulative transport that might be expected during each phase of the tide has been estimated as approximately 0.7 km, illustrated in Figure 13.4. No distinction is made here for springs and neaps.

Dispersion is an important property of a water body with respect to redistribution of contaminants over time. There are no measurements or published data relating to dispersion in Loch Nevis. Without such data it is difficult to judge what the dispersive environment might be like, but the rather shallow sills and exposure of the entrance to prevailing westerly winds might enhance dispersion in the Loch.

Table 13.3 Loch Nevis Site C current data measured in 2000

Height above seabed	Near-bed (2m)	Mid (27m)	Sub-surface (51.5m)
Mean Speed (ms-1)	0.016	0.025	0.038
Maximum Speed (ms-1)	0.166	0.312	0.187
Principal Axis Amp & Dir (ms-1) & (oM)	0.02 (280)	0.03 (280)	0.06 (170)
Eccentricity Ratio	1.0	1.2	1.7
Residual speed (ms-1)	0.001	0.008	0.01
Residual direction (oM)	033	243	183

13.2.4 River/Freshwater Inflow

There are several rivers surrounding Loch Nevis which may or may not flow depending on the season. The main watercourses are Poll Ailein which flows into Inverie Bay in the North of Loch Nevis. This area has a number of small rivers flowing into the bay including Allt Coir A' Chip and Allt a' Mhuilinn. The other main watercourse, River Carnach, is situated at the head of the loch and stems from Lochan nam Breac in the north. Other smaller rivers of note are Allt Gormaidh, Allt Buidhe, Allt, Camas an t-Salainn and Allt Ruadh. There are other unnamed watercourses on the OS map. The annual precipitation in the area is approximately 2500 mm and the annual freshwater run-off is estimated as 367 Mm^3yr^{-1} (Edwards & Sharples, 1986). The ratio of freshwater flow to tidal flow in Loch Nevis is low at approximately 1:175 (Edwards & Sharples, 1986) and therefore the input of freshwater near the surface has rather little influence on the overall salinity of the loch which is generally around 34 psu (Steele & Baird, 1962). The fresh input, at most, would reduce the salinity by around 0.2 ppt (SEPA, 2011). This will likely have substantial seasonal variability.

13.2.5 Meteorology

Several meteorological surveys have been completed in three different locations in Loch Nevis (see figure 13.4). Surveys compiled by TransTech Ltd (formerly Dalriada Solutions Ltd) have been utilised here (MacFarlane, 2006; MacFarlane, 2008; MacFarlane, 2009). Meteorological data were recorded at each cage site.

Table 13.4 Loch Nevis wind data measured at 3 different sites.

Measurement date	Site A (11 day period 2006)	Site B (20 day period 2006)	Site C (15 day period 2000)
Mean Speed (ms^{-1})	2.85	4.0	4.9
Maximum Speed (ms^{-1})	9.70	11.3	10.5

The nearest reporting weather station with wind records is Tiree therefore the wind rose statistics should only be considered as indicative and not suited to direct comparison with any data measured locally in Loch Nevis. The data from Tiree merely confirms a predominantly south-westerly airflow year round for the western isles. It is highly likely that the wind direction will be strongly influenced in Loch Nevis by the morphology of the surrounding high ground and winds will tend to blow along the axis of the loch. With winds predominantly in the western quadrant, the implication is that winds will probably blow towards the head of the loch.

13.2.6 Model Assessment

The exchange characteristics of Loch Nevis were assessed using a layered box model approach. The model represents the Loch as a box made up of three layers and was formulated according to the method of Gillibrand et al (2013). The box layers are forced with surface wind stress, estimates of fresh water discharge, surface heat flux parameters and, at the open coastal boundary, profiles of temperature and salinity are prescribed from climatology compiled by the UK Hydrographic Office. This sets the model with climatological boundary conditions to represent an 'average' year. The model was tuned and validated for Lochs Creran and Etive though a full validation for Loch Nevis has not been done due to lack of seasonal data.

The box model quantifies the primary exchange mechanisms. The key outputs from the model with respect to this hydrographic assessment are a series of annual mean values that describe the relative importance of the estuarine (gravity) exchange, tidal exchange, exchange between the layers and the flushing time (inverse of the exchange rate) of the surface and intermediate layers. These values are given in Table 13.5.

Table 13.5 Summary of annual mean parameter values from the box modelling exercise.

Parameter	Value
Tidal Volume Flux ($m^3 s^{-1}$)	268.4
Estuarine Circulation Volume Flux ($m^3 s^{-1}$)	107.3
Wind Driven Entrainment between upper and lower layer ($m^3 s^{-1}$)	60.6
Tidal and Density driven entrainment between upper and lower layers ($m^3 s^{-1}$)	15.7
Median Flushing Time (days)	30.7
95%-ile Flushing Time (days)	51

The ratio of tidal volume flux to estuarine circulation volume flux is 2.5. Values greater than 2 indicate a system that is strongly tidal in its exchange characteristics (Gillibrand, et al., 2012).

The flushing time for Loch Nevis is estimated at around 30 days which is bigger than the value for the simplified tidal prism model (9) suggesting that the exchange environment is less efficient than can be captured by simple volume tidal exchanges. This may be linked to the rather shallow sills within the Loch system.

13.3 Hydrographic Assessment

13.3.1 Surface flow

The site and the meteorological data indicate that there is likely to be a rather small freshwater discharge into the surface waters of the loch, though the absolute value of discharge would have moderate seasonal variation.

The Loch is divided into two very distinct basins and so there is likely to be significant variation in surface properties between the basins of the loch, with the inner basin being less saline than that which opens into the coastal waters. The relatively small freshwater discharge would suggest that stratification might dominate only under calm conditions and most likely in the upper basin, but would most likely be well mixed in most cases.

Surface flows would be enhanced/retarded by winds blowing out of/into the loch. The winds would be generally funnelled by the surrounding hills creating winds blowing along the axis of the loch which would further enhance the mixing of the waters through the full depth.

Underlying the estuarine flow is the tidal flow running approximately SE on the flood and NW on the ebb in the outer basin where it has been measured. The principal current direction of the surface water has, from rather short surveys of the local currents, been shown to flow in broad alignment with the shoreline. Cumulative transport during each phase of the tide is estimated to be around 0.7 km based on a typical surface principal current amplitude of 0.5 m/s, section 13.2.3.

Net transport of contaminants is related to the residual flow presented in Figure 13.1 and documented in Table 13.1-3. The residual surface flows measured in the surface waters of the outer basin are very weak and have been reported as flowing in a variety of directions. With the surface residuals at the three sites of order 0.01 m/s, the net transport over a tidal cycle of approximately 12 hours would be less than 0.5 km, compared to the loch length of 17 km. It is likely that residual flow alone would not flush surface contaminants effectively.

Given the current meter measurements in Loch Nevis it is likely that any surface contaminant would be transported primarily along the axis of the loch. The dispersive characteristics of the site are unknown but there will be enhanced dispersion as the flow encounters promontories along the path of the flow and in periods of strong wind.

13.3.2 Exchange Properties

The key aspect of the model output in terms of the exchange is that the tidal volume flux dominates the estuarine (or gravitational) volume flux by a factor of 2.5. This means that exchange of waters in Loch Nevis is principally a tidally driven process. Hence there is likely to be rather little seasonal variation in the flushing time of the Loch. The model predicts that 95% of the time the flushing time will be 50 days or less which is rather long compared to other lochs where it is typically less than 20 days.

One might describe the flushing characteristics of Loch Nevis as being 'weakly flushed', however orographic winds (where the direction is steered by the shape of the adjacent high ground) funnelling wind along the axis of the loch may enhance surface flushing rates. Exchange rates in the outer part of the Loch may be faster than in the inner basin due to the presence of a long shallow sill.

There is a limited amount of available current meter data for Loch Nevis and there is a paucity of any measured hydrographic data. However, there is a simple model assessment of exchange available and some current meter measurements. Therefore the confidence level of this assessment is MEDIUM.

14. Shoreline Survey Overview

The shoreline survey at Loch Nevis was conducted on the 22nd April 2013. In the preceding 48 hrs prior to the survey, short heavy showers fell, with showers falling throughout most of the survey day, increasing later in the day. Wind was WSW at 11.2km/hr, increasing later and gusty.

The fishery at Loch Nevis consisted of one common mussel site at Ardintigh Point centred on the RMP of NM 7749 9345. The farm consisted of a series of two, roughly 200 m mussel longlines, and belong to the harvester Mr Andrew MacLean of Moidart Shellfish. It was not possible to ascertain from the shore the state of the lines, although they appear in good condition. To the west of Ardintigh Point, lays the old Loch Nevis Mussels site at Ardintigh Bay. The infrastructure has largely been removed, with remaining buoys expected to be removed soon. To the immediate east of this site is another lease area centred on NM 7788 9331, and this is currently used as a scallop ranch by Mr McClean and some local fishermen.

A cottage and several bunkhouses were located at Ardintigh which are used by holiday makers and visitors. There was reported to be only one full-time resident in the area. To the east of Tarbet Bay lay a total of seven dwellings. One jetty is located in Ardintigh Bay and services the outdoor centre. A small jetty is also located in Tarbet Bay, which services the surrounding houses and a small, damaged pier also served the holiday home at the NE corner of Tarbet Bay. None of these has permanent boats moored. Two moorings for small vessels is located in Ardintigh Bay, though no vessels were present at the time of this survey. There were seven moorings in Tarbet Bay, with three small vessels present.

The land around the area of survey is mostly rough hill moorland, with small areas of native woodland. This ground was seemingly used for rough grazing by sheep. The only two exceptions were the area around Ardintigh Bay, which was improved ground with habitation and recreational use, and the area around the head of Tarbet Bay, which consisted of some improved fields used for agriculture.

Approximately 30 sheep and a horse were seen along Tarbet Bay, and one sheep was seen grazing at Ardintigh Bay. The surrounding area is used for wild grazing, and other sheep were seen going to and from the shoreline survey route.

Three watercourses were sampled during the survey, with Ardintigh Burn having the highest flow and which discharges at NM 7771 9318. Allt Raineach discharges adjacent to the mussel lines. Four other watercourses were noted to the east, in Tarbet Bay.

Little in the way of wildlife was observed during the survey, with only 30 gulls and 1 oystercatcher observed in Ardintigh Bay. A map of the most significant observations is shown in Figure 14.1.

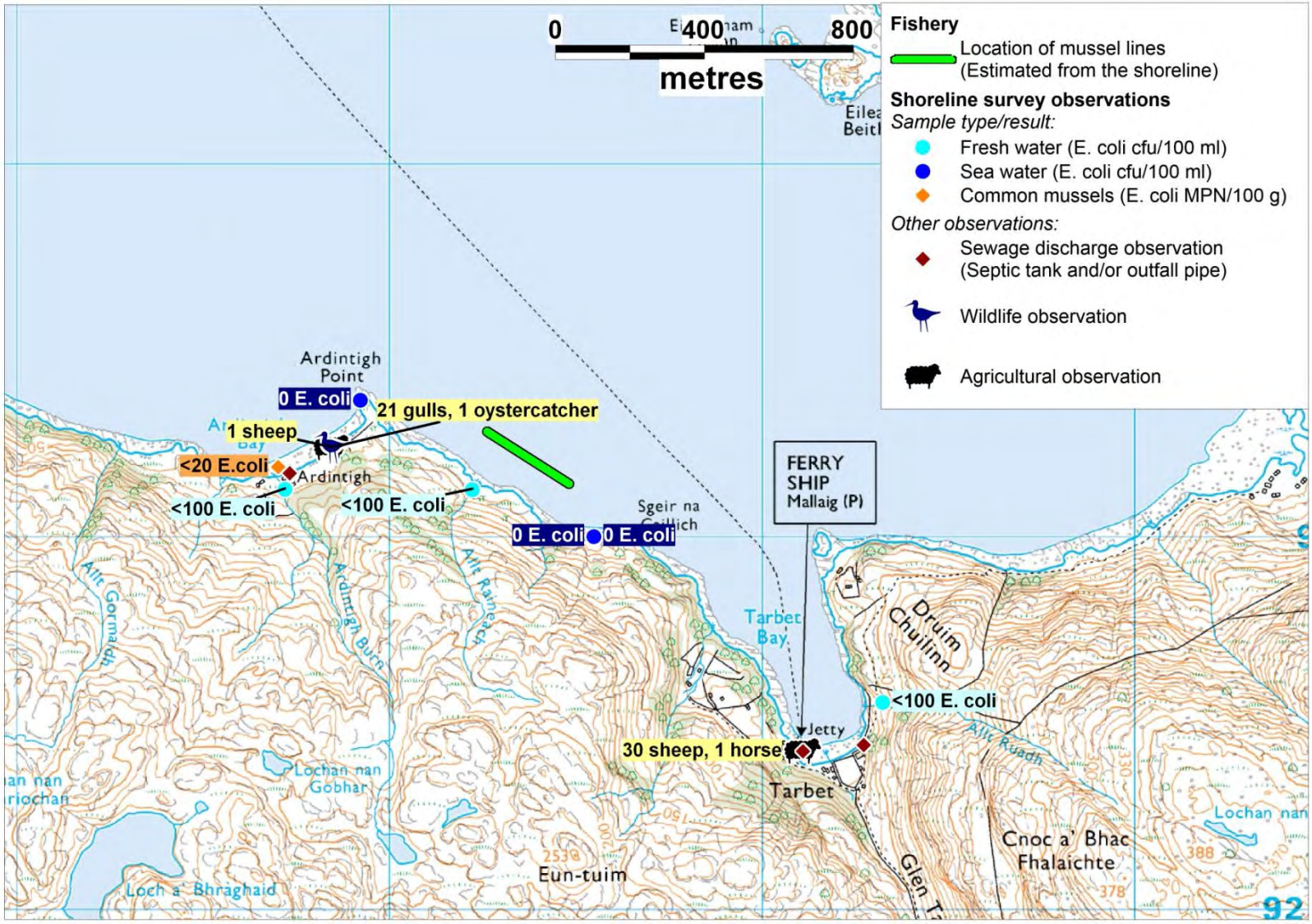


Figure 14.1 Map of significant shoreline survey findings - Loch Nevis

15. Overall Assessment

Human sewage impacts

Although the area is very lightly populated, there is holiday accommodation near the shore. The highest impact from human sewage is to Ardintigh Bay, where the presumed discharge from the outdoor adventure centre and camp was found during the shoreline survey. This is likely to be in greatest use in summer, when there are more frequent ferry services to the area. There is also an anchorage at Tarbet, and overboard discharges from boats in this area would contribute to faecal contamination in the bay.

The Ardintigh Point site is more remote from sources of human faecal contamination, though it may receive impacts from Ardintigh Bay on a flood tide and from Tarbet on an ebb tide.

Agricultural impacts

There is very little agricultural activity in the area. Only a small number of farm animals were observed during the shoreline survey, and most of these were seen around Tarbet. There are likely to be further livestock to the east, around Kylesmorar where there is a working croft on the estate. However, this is more remote from the fisheries and therefore any impacts would be subject to significant dilution before reaching the Ardintigh Point fishery.

One sheep was seen at Arditigh Bay, where there is a small area of improved grassland noted in Landcover 2007 data. Any sheep kept in this area would be likely to contribute significantly to any faecal loadings carried in freshwater runoff to the waters of the bay and would be most likely to impact at the Ardintigh Bay shellfish site.

Wildlife impacts

Little information was found on the numbers and distribution of wildlife species around the fishery. It is likely that seals, deer, otters, and seabirds make the largest contribution to background faecal contamination levels in the loch. However, there is no evidence to suggest one area of the fishery may be more affected than another.

Seasonal variation

Significant seasonal variation is likely in the local human population, with the majority visiting the area during the holiday season, primarily April to September, inclusive. Therefore, sewage impacts to the area are expected to be higher during this period. There may be a short additional loading at the beginning of the season when septic tanks receive a sudden increase in material after a period of disuse.

The impact of seasonal variation is likely to be most acute in Ardintigh Bay, where the outdoor education centre and livestock were seen.

There is likely to be seasonal variation in livestock numbers, with the numbers of sheep likely to be higher in summer. However, given the low numbers in the area, this may not be significant to the fishery.

Seasonal variation was seen in historical monitoring results with a marked effect at Ardintigh Bay.

Rivers and streams

Few watercourses discharge to the loch in the vicinity of the fishery. The majority discharge to Tarbet Bay. All watercourses measured during the shoreline survey were of similar size, and all sample results were below the limit of detection of the test used. The two watercourses of greatest significance to the Ardintigh shellfish farms are the Ardintigh Burn which discharges to the head of Ardintigh Bay and the Allt Raineach, which discharges to the loch near the northwest end of the Ardintigh Point mussel line. Of these, the Ardintigh Burn has a larger catchment and passes through a campsite and area of improved grassland and therefore may potentially carry human and/or livestock source faecal contamination.

Movement of contaminants

Current meter records from the Ardintigh Bay site suggest relatively little residual tidal movement, suggesting that contamination reaching this area may tend to persist. Generally, surface flows are expected to be along the axis of the loch, with recorded current speeds in the outer basin at less than 0.2 ms^{-1} (0.4 kt). Overall transport distance over a single tidal cycle is estimated to be in the order of 1 km. Therefore, contamination sources very close to the shellfish farms are likely to be of greatest significance to contamination levels found in shellfish.

Temporal and geographical patterns of sampling results

At both monitored sites, an increase in results was seen through the year, and this was most pronounced at the Ardintigh Point site. At Ardintigh Bay, higher results occurred from May to October. Although geographic mean results were similar between the two sites, the more results >1000 *E. coli*/100 g, as well as the highest result overall, occurred at the Ardintigh Bay site. The peak result of >18000 *E. coli*/100 g at this site suggests that it was subject to a contamination event in late April 2012.

No clear geographic pattern was seen in the Ardintigh Point results. Highest results at Ardintigh Bay were seen further south and nearer identified sources of contamination at the head of the bay.

Conclusions

Although the area has fallen out of classification, there are mussel lines used for spat collection at Ardintigh Point and there is an area used for scallop production west of the point in Ardintigh Bay. This area has not been classified or monitored for scallops, and it should be ascertained whether the scallop operation is still active and then a decision taken whether classification monitoring should be undertaken.

Contamination levels seen in historical monitoring results suggest that observed sources at Ardintigh Bay are more likely to accumulate in the water of the bay and lead to higher levels of faecal contamination in shellfish grown there. A significant seasonal variation in results is also seen at this site, coinciding with seasonal increases in tourist numbers.

Seasonal variation was also seen at Ardintigh Point, though this was markedly more variable that seen at Ardintigh Bay. Results were largely below 230 *E. coli*/100 g and there was only 1 result > 1000 *E. coli*/100 g.

Both areas are likely to receive some diffuse contamination from land based sources via watercourses discharging nearby. However, the watercourse discharging to Ardintigh Bay is likely to carry more livestock and potentially human faecal contamination that the watercourse discharging near the Ardintigh Point site, which is likely to carry predominantly wildlife source faecal contamination.

As the area is currently declassified, it is not recommended that monitoring recommence unless the Ardintigh Point site becomes active or the scallop farm is deemed to require classification.

Overall Risk Table

Risk	
Septic tank discharges	Seasonally moderate
Rainfall-dependent diffuse sources	Low
Wildlife sources	Low
Seasonal variability	High

16. Recommendations

If the area containing the present mussel lines were to be reclassified, then the following production area, and sampling plan is recommended.

Production area

It is recommended that the previous production area boundaries be redrawn to exclude Ardintigh Bay, as this contains the most significant pollution source and has shown higher *E. coli* results than Ardintigh Point, and Tarbet Bay as this contains additional sources of pollution. The recommended boundaries would then be the area bounded by lines drawn from NM 7800 9330 to NM 7800 9336 to NM 8000 9300 and from NM 7881 9289 to NM 7916 9289 and extending to MHWS.

RMP

The RMP be relocated to NM 7848 9314, at the eastern end of the current mussel line and nearer sources arising from the vicinity of Tarbet. Should the fishery be extended this should be re-evaluated.

Tolerance

Should sampling recommence, a tolerance of 40 m is recommended to allow for some movement of the lines.

Frequency

Due to the seasonal variability seen in results, any classification monitoring in the area should continue to be undertaken on a monthly basis.

Depth of sampling

For monitoring of suspended culture of mussels at the point identified above, the recommended sampling depth is 1 m as the identified sources of contamination are likely to be carried to the mussel farm at or near the surface.

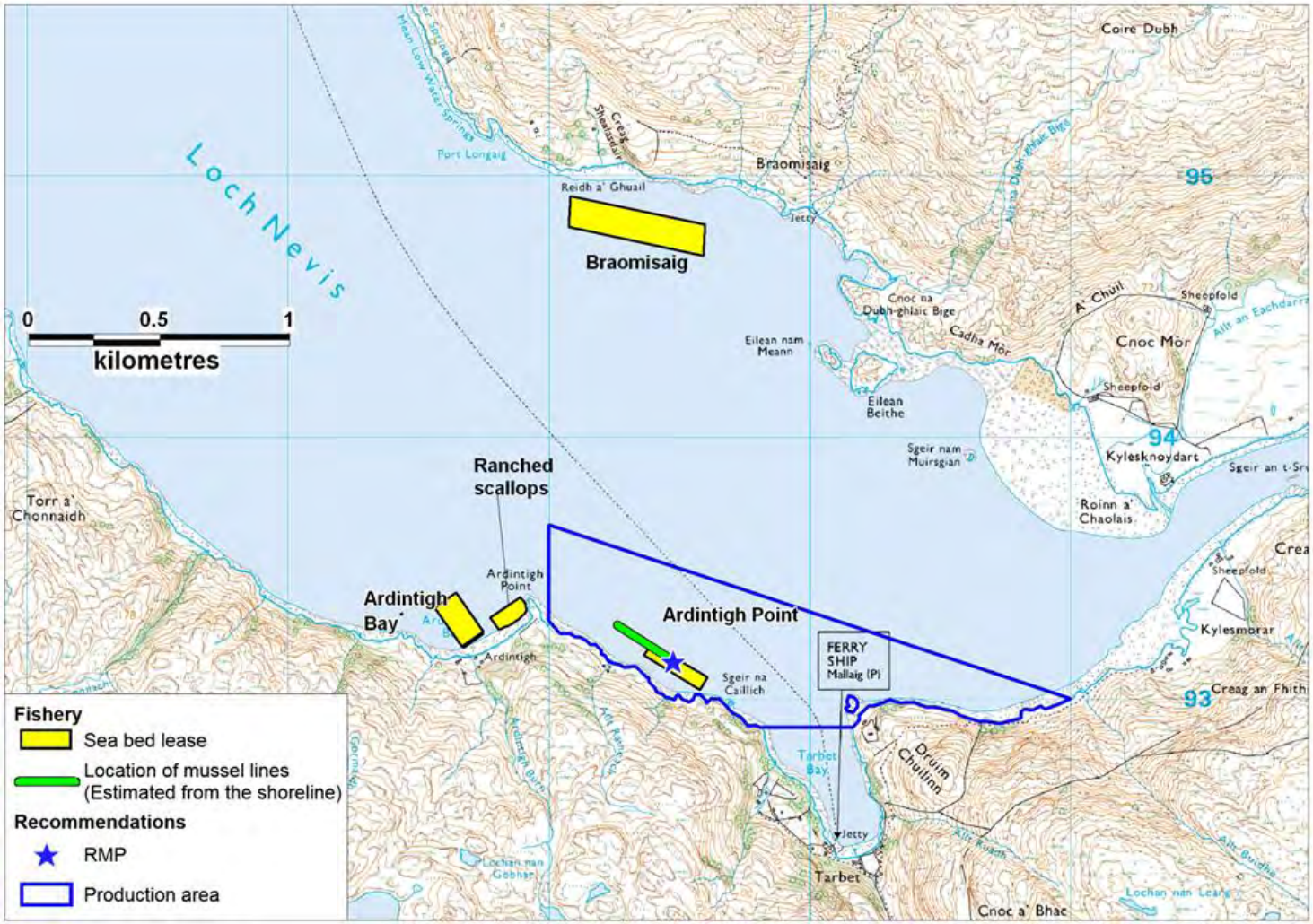


Figure 16.1 Map of recommendations at Loch Nevis

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18. List of Figures and Tables

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1. **General Information on Wildlife Impacts**
2. **Tables of Typical Faecal Bacteria Concentrations**
3. **Statistical Data**
4. **Hydrographic Section Glossary**
5. **Shoreline Survey Report**

1. 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 50-170 kg. 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 x 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.

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 & 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 (Gauthier & Bedard, 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.

Other

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 National Heritage, n.d.). 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 treams, which may be washed into the water during periods of rain.

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2. 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	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	282	2.8×10^{6} * (-)	2.3×10^{6}	3.2×10^{6}
Crude sewage discharges	252	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	79	3.5×10^{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	1.0×10^{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	3.3×10^{5} * (-)	2.9×10^{5}	3.7×10^{5}	184	5.0×10^{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	2.8×10^{5} * (-)	2.2×10^{5}	3.5×10^{5}	93	5.1×10^{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}		
Reed bed/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, et al., 2008)

Table 3 – Geometric mean (GM) and 95% confidence intervals (CIs) of the GM faecal indicator organism (FIO) concentrations (cfu $100ml_{-1}$) under base- and high-flow conditions at the 205 sampling points and for various subsets, and results of paired t-tests to establish whether there are significant elevations at high flow compared with base flow

FIO	*n*	Base Flow			High Flow		
Subcatchment land use		Geometric mean	Lower 95% CI	Upper 95% CI	Geometric mean[a]	Lower 95% CI	Upper 95% CI
Total coliforms							
All subcatchments	205	5.8×10^{3}	4.5×10^{3}	7.4×10^{3}	7.3×10^{4}**	5.9×10^{4}	9.1×10^{4}
Degree of urbanisation							
Urban	20	3.0×10^{4}	1.4×10^{4}	6.4×10^{4}	3.2×10^{5}**	1.7×10^{5}	5.9×10^{5}
Semi-urban	60	1.6×10^{4}	1.1×10^{4}	2.2×10^{4}	1.4×10^{5}**	1.0×10^{5}	2.0×10^{5}
Rural	125	2.8×10^{3}	2.1×10^{3}	3.7×10^{3}	4.2×10^{4}**	3.2×10^{4}	5.4×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	6.6×10^{3}	3.7×10^{3}	1.2×10^{4}	1.3×10^{5}**	1.0×10^{5}	1.7×10^{5}
≥75% Rough Grazing	13	1.0×10^{3}	4.8×10^{2}	2.1×10^{3}	1.8×10^{4}**	1.1×10^{4}	3.1×10^{4}
≥75% Woodland	6	5.8×10^{2}	2.2×10^{2}	1.5×10^{3}	6.3×10^{3}*	4.0×10^{3}	9.9×10^{3}
Faecal coliform							
All subcatchments	205	1.8×10^{3}	1.4×10^{3}	2.3×10^{3}	2.8×10^{4}**	2.2×10^{4}	3.4×10^{4}
Degree of urbanisation							
Urban	20	9.7×10^{3}	4.6×10^{3}	2.0×10^{4}	1.0×10^{5}**	5.3×10^{4}	2.0×10^{5}
Semi-urban	60	4.4×10^{3}	3.2×10^{3}	6.1×10^{3}	4.5×10^{4}**	3.2×10^{4}	6.3×10^{4}
Rural	125	8.7×10^{2}	6.3×10^{2}	1.2×10^{3}	1.8×10^{4}**	1.3×10^{4}	2.3×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	1.9×10^{3}	1.1×10^{3}	3.2×10^{3}	5.7×10^{4}**	4.1×10^{4}	7.9×10^{4}
≥75% Rough Grazing	13	3.6×10^{2}	1.6×10^{2}	7.8×10^{2}	8.6×10^{3}**	5.0×10^{3}	1.5×10^{4}
≥75% Woodland	6	3.7×10	1.2×10	1.2×10^{2}	1.5×10^{3}**	6.3×10^{2}	3.4×10^{3}
Enterococci							
All subcatchments	205	2.7×10^{2}	2.2×10^{2}	3.3×10^{2}	5.5×10^{3}**	4.4×10^{3}	6.8×10^{3}
Degree of urbanisation							
Urban	20	1.4×10^{3}	9.1×10^{2}	2.1×10^{3}	2.1×10^{4}**	1.3×10^{4}	3.3×10^{4}
Semi-urban	60	5.5×10^{2}	4.1×10^{2}	7.3×10^{2}	1.0×10^{4}**	7.6×10^{3}	1.4×10^{4}
Rural	125	1.5×10^{2}	1.1×10^{2}	1.9×10^{2}	3.3×10^{3}**	2.4×10^{3}	4.3×10^{3}
Rural subcatchments with different dominant land uses							
≥75% Imp. pasture	15	2.2×10^{2}	1.4×10^{2}	3.5×10^{2}	1.0×10^{4}**	7.9×10^{3}	1.4×10^{4}
≥75% Rough Grazing	13	4.7×10	1.7×10	1.3×10^{2}	1.2×10^{3}**	5.8×10^{2}	2.7×10^{3}
≥75% Woodland	6	1.6×10	7.4	3.5×10	1.7×10^{2}**	5.5×10	5.2×10^{2}

[a] Significant elevations in concentrations at high flow are indicated: **po0.001, *po0.05.

[b] Degree of urbanisation categorised according to percentage built-up land: 'Urban' (X10.0%), 'Semi-urban' (2.5–9.9%) and 'Rural' (o2.5%).

Source: (Kay, et al., 2008a)

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 x 108
Cow	230,000	23,600	5.4 x 109
Duck	33,000,000	336	1.1 x 1010
Horse	12,600	20,000	2.5 x 108
Pig	3,300,000	2,700	8.9 x 108
Sheep	16,000,000	1,130	1.8 x 1010
Turkey	290,000	448	1.3 x 108
Human	13,000,000	150	1.9 x 109

Source: (Gauthier & Bedard, 1986)

3. Statistical Data

One-way ANOVA: logec versus season Ardintigh Point

```
Source  DF     SS     MS     F      P
season   3  4.336  1.445  5.35  0.010
Error   16  4.326  0.270
Total   19  8.662

S = 0.5200   R-Sq = 50.06%   R-Sq(adj) = 40.69%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  ---+---------+---------+---------+------
1      6  1.3556  0.4533      (-----*-----)
2      8  1.8319  0.6624             (----*----)
3      2  2.7800  0.3697                   (---------*--------)
4      4  1.1505  0.1738  (------*------)
                          ---+---------+---------+---------+------
                           0.80      1.60      2.40      3.20

Pooled StDev = 0.5200

Grouping Information Using Tukey Method

season  N    Mean  Grouping
3       2  2.7800  A
2       8  1.8319  A B
1       6  1.3556    B
4       4  1.1505    B

Means that do not share a letter are significantly different.

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

Individual confidence level = 98.87%

season = 1 subtracted from:

season    Lower   Center   Upper  ---------+---------+---------+---------+
2       -0.3280   0.4763  1.2805                   (----*-----)
3        0.2085   1.4244  2.6403                      (-------*--------)
4       -1.1663  -0.2051  0.7562             (------*-----)
                          ---------+---------+---------+---------+
                                -1.5       0.0       1.5       3.0


season = 2 subtracted from:

season    Lower   Center   Upper  ---------+---------+---------+---------+
3       -0.2292   0.9481  2.1254                   (-------*-------)
4       -1.5933  -0.6813  0.2306          (-----*------)
                          ---------+---------+---------+---------+
                                -1.5       0.0       1.5       3.0


season = 3 subtracted from:

season    Lower   Center    Upper  ---------+---------+---------+---------+
4       -2.9191  -1.6294  -0.3398  (-------*--------)
                                  ---------+---------+---------+---------+
                                        -1.5       0.0       1.5       3.0
```

One-way ANOVA: logec versus Season Ardintigh Bay

```
Source  DF      SS     MS     F      P
Season   3   1.875  0.625  0.89  0.456
Error   30  21.007  0.700
Total   33  22.883

S = 0.8368   R-Sq = 8.20%   R-Sq(adj) = 0.00%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  ---------+---------+---------+---------+
1      11  1.4881  1.0842              (------*-------)
2      14  1.8025  0.6690                   (------*-----)
3       7  2.0661  0.7563                    (---------*--------)
4       2  1.3010  0.0000  (-----------------*----------------)
                          ---------+---------+---------+---------+
                                 0.70      1.40      2.10      2.80

Pooled StDev = 0.8368

Grouping Information Using Tukey Method

Season   N    Mean  Grouping
3        7  2.0661  A
2       14  1.8025  A
1       11  1.4881  A
4        2  1.3010  A

Means that do not share a letter are significantly different.

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

Individual confidence level = 98.93%

Season = 1 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
2       -0.6035   0.3144  1.2322              (-----*-----)
3       -0.5234   0.5780  1.6795               (------*------)
4       -1.9383  -0.1871  1.5641     (-----------*----------)
                                  -------+---------+---------+---------+--
                                      -1.5       0.0       1.5       3.0

Season = 2 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
3       -0.7909   0.2637  1.3182             (------*------)
4       -2.2235  -0.5014  1.2206   (-----------*----------)
                                  -------+---------+---------+---------+--
                                      -1.5       0.0       1.5       3.0

Season = 3 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
4       -2.5916  -0.7651  1.0614  (-----------*-----------)
                                  -------+---------+---------+---------+--
                                      -1.5       0.0       1.5       3.0
```

4. Hydrographic Assessment 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.

MHW. Mean High Water, The highest level that tides reach on average.

MHWN. Mean High Water Neep, The highest level that tides reach on average during neep tides.

MHWS. Mean High Water Spring, The highest level that tides reach on average during spring tides

MLW. Mean Low Water, The lowest level that tides reach on average.

MLWN. Mean Low Water Neep, The lowest level that tides reach on average during neep tides.

MLWS. Mean Low Water Spring, The lowest level that tides reach on average during spring tides.

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. Spring tides occur during or just after new moon and full moon when the tide-generating force of the sun acts in the same direction as that of the moon, reinforcing it. The tidal range is greatest and tidal currents strongest during spring tides.

Neep tides occur during the first or last quarter of the moon when the tide-generating forces of the sun and moon oppose each other. The tidal range is smallest and tidal currents are weakest during neep 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. A surface flow at the surface may be accompanied by a compensating flow in the opposite direction at the bed.

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.

5. Shoreline Survey Report

Report Title	Loch Nevis Shoreline Survey Report
Project Name	Shellfish Sanitary Surveys
Client/Customer	Cefas
SRSL Project Reference	00561_B0067

Document Number	B0067_Shoreline 0010
Revision	Issue 01
Date	16/05/2013

Revision History

Revision	Changes	Date
A	Issue for internal review	30/04/2013
01	First formal issue to CEFAS for comments	16/05/2013

	Name & Position	Date
Author	Alison Clarke & Lars Brunner	30/04/13
Checked	Andrea Veszelovszki, Ray Leakey	16/05/2013
Approved	Andrea Veszelovszki	16/05/2013

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Shoreline Survey Report

Production area:	Loch Nevis: Ardintigh Point
Site name:	Ardintigh Bay Ardintigh Point
SIN:	Ardintigh Bay HL-180-725-08 Ardintigh Point HL-180-228-08
Species:	Common Mussels
Harvester:	Andrew MacLean (Moidart Shellfish)
Local Authority:	Highland Council: Lochaber
Status:	Declassified
Date Surveyed:	22nd April 2013
Surveyed by:	Lars Brunner & Alison Clarke
Existing RMP:	NM 7749 9345
Area Surveyed:	From Ardintigh Bay E and SE around coast to the NE tip of Tarbet Bay

Weather

There was mixed rainfall in the week prior to the survey. In the 48 hrs preceding the survey there had been a mix of dry spells and short, heavy showers.

Mon 22nd April 2013: 95% cloud cover, wind WSW 11.2km/hr, temp 6.1°C, weather showery to start, rain increasing later with wind increasing – gusty.

Stakeholder engagement during the survey

Despite repeated attempts prior to the survey, we were unable to contact the harvester. During the survey, we were transported by vessel by Tom McClean, who has been a resident of the area since the 1970's, and previously ran Loch Nevis mussels, which utilised the lease area to the western end of Arditigh Bay (NM 7752 9337). Mr McClean was very helpful in providing us with information about the current state of cultivation in the Loch, as well as general background information.

Due to the site's remote location and its declassified status, it was not possible to meet the local authority sampling officer on this survey; however he was very helpful in giving useful information about the area.

Fishery

The fishery at Ardintigh consisted of cultivated lines of common mussels, but as of the 1st April 2013, is declassified. There are still lines in the water in the

loch and although it was not possible to access the lines, a summary of what remains is provided below.

The survey plan records three areas of crown estate lease in the survey area – two leases in Ardintigh Bay itself, and one between Ardintigh Bay and Tarbet Bay. The area of lease to the west of Ardintigh Bay (centred on NM 7752 9337) was the site of common mussel longlines belonging to Loch Nevis Mussels, but the longlines and associated infrastructure have largely been removed, and the few buoys that remain are to be removed soon. To the immediate east of this site is another lease area centred on NM 7788 9331, and this is currently used as a scallop ranch by Mr McClean and some local fishermen.

Around Ardintigh Point, the third lease site (centred on the RMP of NM 7749 9345) is a series of two, roughly 200m mussel longlines which are the responsibility of the harvester noted in the survey plan, Mr Andrew MacLean of Moidart Shellfish. It was not possible to ascertain from the shore the state of the lines, although they appear in good condition.

Sewage Sources

The survey area is very sparsely inhabited. There is a cottage and several bunkhouses at Ardintigh, which is occupied periodically with visiting groups. The only other habitation in the area is in Tarbet Bay, which consists of a total of seven dwellings, all with septic tanks. One of the dwellings, the old church, is used as a bunkhouse. It was not possible to obtain access to one area of the shore at the NE side of Tarbet Bay as doing so would have meant disturbing private property, although an examination of the shore from the vessel that picked us up did not indicate any shore discharges.

Seasonal Population

There are no designated campsites, B&B's, hotels or caravan parks in the survey area. As noted above, the property in Ardintigh Bay is used as an outdoor centre and is only inhabited part-time. Some of the properties in Tarbet Bay are let as self-catering, and there is only one full time resident in the area. The property at the north-east corner of Tarbet Bay is a holiday house.

Boats/Shipping

There is one jetty in Ardintigh Bay which services the outdoor centre, a small jetty in Tarbet Bay, which services the houses there, and a small pier at the holiday home at the NE corner of Tarbet Bay (which is currently damaged). All of these are tidal so have no permanent mooring. There are 2 moorings

for small vessels in Ardintigh Bay, with no vessels present. There were seven moorings in Tarbet Bay, with three small vessels present.

Farming and Livestock

One sheep was observed grazing at Ardintigh Bay during the survey, although others had been seen prior to the survey but not recorded. No more livestock was seen on survey until Tarbet Bay where 30 sheep and 1 horse were recorded.

Land Use

Most of the land around the area of survey is rough hill moorland, with small areas of native woodland. This ground was seemingly used for rough grazing by sheep. The only two exceptions were the area around Ardintigh Bay, which was improved ground with habitation and recreational use, and the area around the head of Tarbet Bay, which consisted of some improved fields used for agriculture.

Land Cover

As noted above, the dominant land cover is rough hill moorland, with small areas of native woodland closer to the shore in all areas of survey. The areas around Ardintigh Bay and the head of Tarbet Bay have small fields of improved grassland.

Watercourses

There are no major watercourses in the survey area – the watercourse with the largest flow is the Ardintigh Burn, which discharges at NM 7771 9318. There are several other, smaller streams in the survey area.

Wildlife/Birds

30 gulls and 1 oystercatcher were observed in Ardintigh Bay, there were no birds observed around Tarbet Bay. Other than the farmed animals noted above, no other wildlife was observed on survey.

Shoreline Survey Maps

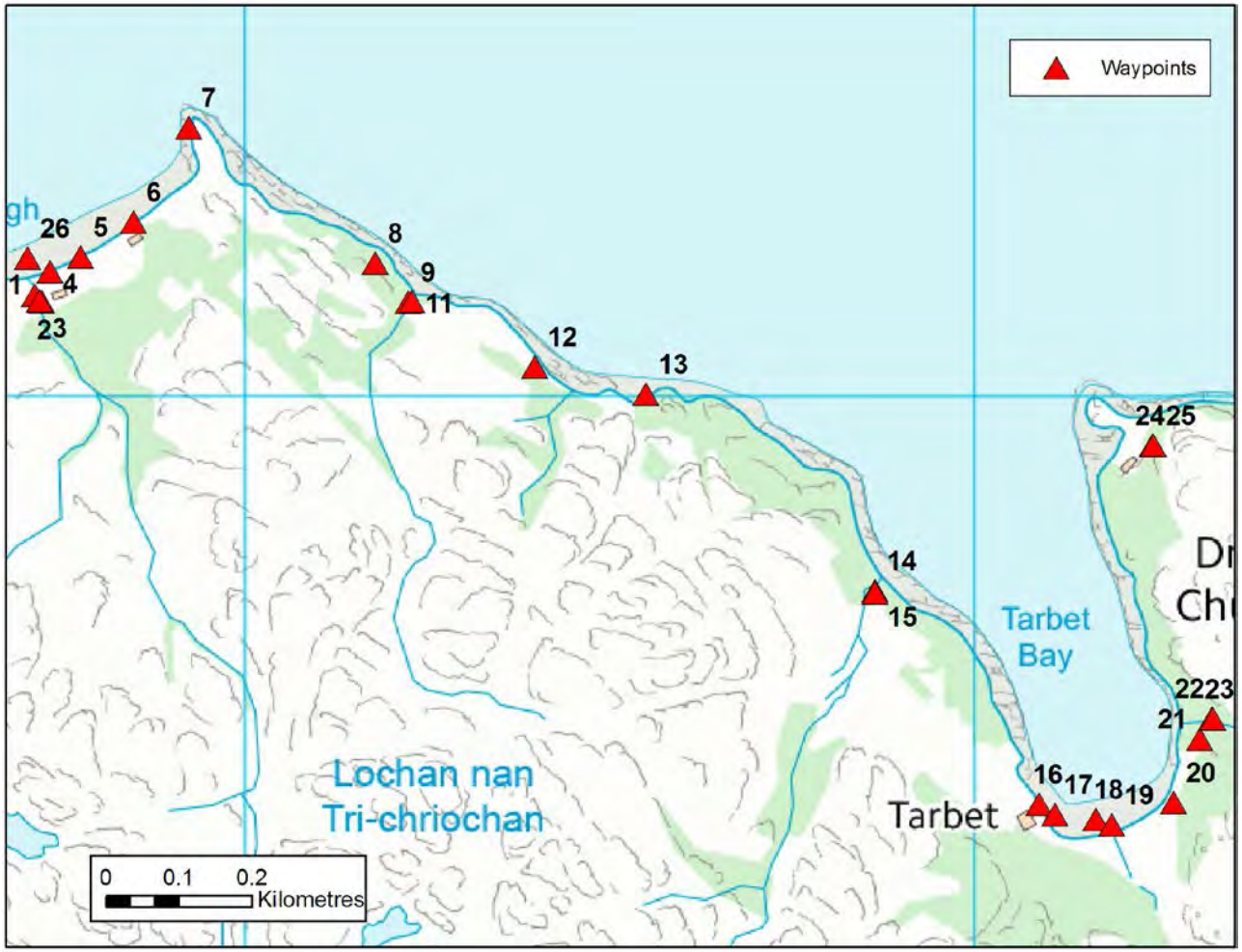

Figure 1. Loch Nevis waypoints

Shoreline Survey Maps

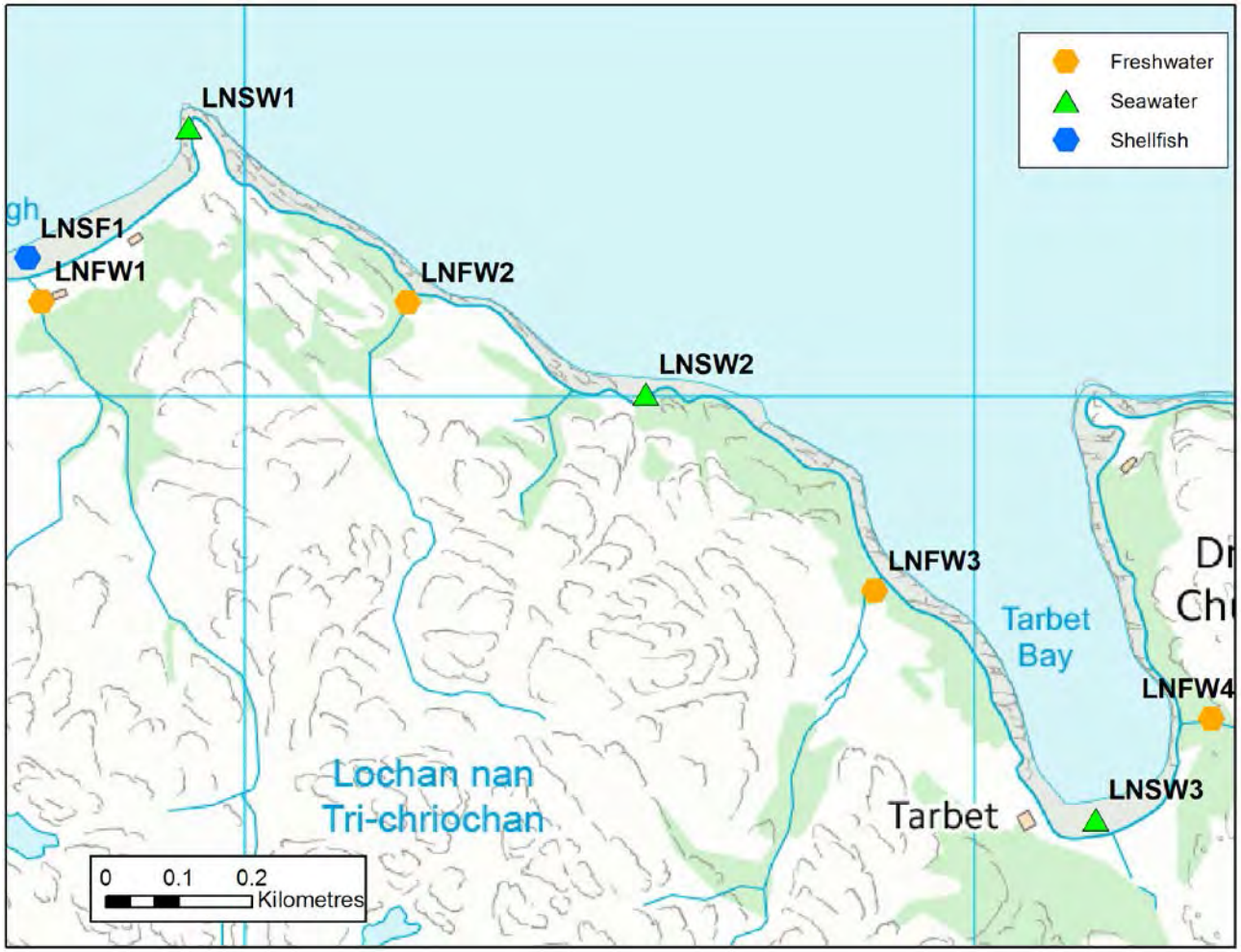

Figure 2. Loch Nevis samples

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	22/04/2013	6:37	NM 77711 93139	177711	793139			Start of survey.
2	22/04/2013	6:40	NM 77721 93130	177722	793130	Fig. 3	LNFW1	Freshwater sample LNFW1.
3	22/04/2013	6:41	NM 77718 93131	177719	793132			Stream measurement associated with waypoint 2; Width 1m; depth 25cm; flow 0.068m/s SD 0.020
4	22/04/2013	6:47	NM 77733 93171	177733	793172			Manhole (septic tank) and discharge pipe running into bay. 10cm PVC pipe. No discharge visible as pipe heads underwater. Not sampled as property has been unoccupied over-winter (from first hand evidence) so unlikely to be running.
5	22/04/2013	6:50	NM 77774 93191	177775	793191	Fig. 4		Whale vessel moored on shore - unoccupied, no discharge
6	22/04/2013	6:54	NM 77847 93239	177847	793240	Fig. 5		Bird count - 21 gulls, 1 oystercatcher. Photo of salmon farm and associated cage mooring buoys. Also corner of scallop ranch (not visible due to tide level). 1 sheep on hillside.
7	22/04/2013	7:02	NM 77923 93369	177923	793369		LNSW1	Seawater sample LNSW1.
8	22/04/2013	7:10	NM 78178 93183	178178	793184			Start of mussel line section - two standard 200m lines present.
9	22/04/2013	7:13	NM 78223 93129	178224	793129		LNFW2	Freshwater sample LNFW2.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
10	-	-	-	-	-		-	Deleted waypoint.
11	22/04/2013	7:26	NM 78229 93130	178229	793131			Stream measurement associated with WP9; Width 1.2m; depth 20cm; flow 0.099m/s SD 0.011. There is no WP10 as this was deleted due to being taken incorrectly.
12	22/04/2013	7:29	NM 78397 93041	178397	793041			End of mussel line section.
13	22/04/2013	7:36	NM 78549 93003	178550	793004		LNSW2	Seawater sample LNSW2.
14	22/04/2013	7:55	NM 78863 92733	178863	792733		LNFW3	Freshwater sample LNFW3.
15	22/04/2013	7:55	NM 78863 92730	178864	792731			Stream measurement associated with WP14. Width 1.3m; depth 22cm; flow 0.031m/s SD 0.009.
16	22/04/2013	8:14	NM 79088 92440	179088	792440			Stream running into bay by side of houses - no sample taken.
17	22/04/2013	8:18	NM 79110 92426	179110	792426			Discharge pipe 10cm PVC pipe below houses. No discharge present. Observation made of seven moorings in bay, with three occupied by small boats. 30 sheep & 1 horse present in bay area.
18	22/04/2013	8:26	NM 79166 92419	179167	792420		LNSW3	Seawater sample LNSW3.
19	22/04/2013	8:29	NM 79188 92412	179188	792412			Stream running down off hillside into bay. Not sampled.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
20	22/04/2013	8:36	NM 79272 92443	179273	792443			Discharge pipe, 10cm PVC, no discharge - assumed discharge pipe from old church and bothy.
21	22/04/2013	8:42	NM 79308 92530	179309	792530	Fig. 6 Fig. 7		Two overall photos of Tarbet Bay taken from hillside path above, as shoreline below inaccessible due to shear rocks.
22	22/04/2013	8:46	NM 79325 92558	179325	792558		LNFW4	Freshwater sample LNFW4. Taken from hill path above shore due to difficult shoreline.
23	22/04/2013	8:46	NM 79326 92557	179327	792557			Stream measurement associated with LNFW4. Width 1m; depth 17cm; flow 0.137 m/s SD 0.013.
24	22/04/2013	9:03	NM 79243 92933	179244	792933	Fig. 8		Shore access and view made adjacent to Sir Cameron MacIntosh's house. Two dwellings - access to the shore impossible without going onto private property. From quick observation, there is no discharge pipe on shore or manhole cover. 2 photos taken of general area.
25	22/04/2013	9:06	NM 79245 92933	179245	792933			End of survey track.
26	22/04/2013	11:31	NM 77702 93189	177702	793190		LNSF1	On return to survey start point, due to state of the tide, wild mussel sample able to be collected - LNSF1.

Photographs referenced in the table can be found attached as Figures 3 – 7.

Sampling

Water samples were collected at the sites marked on the Loch Nevis samples map shown in Figure 2.

At some point between collecting the sample and organising the samples into the Biotherm box for postage, sample LNFW3 (taken at NM 78863 92733, waypoint no. 14) was lost and was therefore not analysed.

All the samples were transferred to a Biotherm 10 box with ice packs and posted to the Glasgow Scientific Services (GSS) for *E.coli* analysis. All the samples were posted on the day of collection and all the samples were received the following day. The sample temperatures on arrival at the laboratory were recorded at 3.2°C.

Seawater samples were tested for salinity by GSS and the results were reported in mg Chloride per litre. These results have been converted to parts per thousand (ppt) using the formula:

$$\text{Salinity (ppt)} = 0.0018066 \times Cl \ \text{(mg/L)}$$

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	22/04/2013	LNFW1	NM 77721 93130	Fresh Water	<100	
2	22/04/2013	LNFW2	NM 78223 93129	Fresh Water	<100	
3	22/04/2013	LNFW4	NM 79325 92558	Fresh Water	<100	
4	22/04/2013	LNSW1	NM 77923 93369	Sea Water	0	34
5	22/04/2013	LNSW2	NM 78549 93003	Sea Water	0	30.5
6	22/04/2013	LNSW3	NM 78549 93003	Sea Water	0	34.3

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (MPN/100g)
1	22/04/2013	LNSF1	NM 77702 93189	Mussels	<20

Photographs

Figure 3: General view of bunkhouse and outdoor centre, Ardintigh. Site of sample LNFW1 (waypoint 2)

Figure 4: Vessel beached ashore at Ardintigh (waypoint 5)

Figure 5: View W down Loch Nevis. Vessel moored is used by the outdoor centre and not permanently moored. Remains of mussel farm (in process of dismantling) in middle left of picture. Fish Farm located further down loch, out of survey area. Waypoint 6.

Figure 6: General view of Tarbet Bay (1), taken from WP21 looking west. The houses in centre right and building/bothy to left are the only residences present.

Figure 7: General view of Tarbet Bay (2), taken from WP 21, looking towards W. Photo shows moorings and vessels present in bay.

Figure 8: Private residence at NE end of Tarbet Bay to which land access could not be obtained. No sign of discharge pipes on the shore. This photo did not have a waypoint, but was taken from grid reference NM 790 928, looking east.