Scottish Sanitary Survey Report

Sanitary Survey Report
Loch Bay
SL-117-275-04
April 2014

Cefas

Food Standards Agency
food.gov.uk
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Report Title	Loch Bay Sanitary Survey Report
Project Name	Scottish Sanitary Survey
Client/Customer	Food Standards Agency Scotland
Cefas Project Reference	C5792C
Document Number	C5792C_2013_15
Revision	V1.0
Date	07/04/2014

Revision History

Revision number	Date	Pages revised	Reason for revision
0.1	24/01/2014	All	Draft for external consultation
1.0	07/04/2014	2,10, 11	Correction/clarification of text in accordance with consultation response

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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 classified mussel fishery at Loch Bay 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). The area was selected for survey at this time based on a risk-based ranking amongst those Scottish production areas that had yet to receive a survey.

Loch Bay lies west of the Waternish peninsula, northern Isle of Skye, off the west coast of Scotland. The production area lies at the southeast end of the loch, at the mouth of the Bay River.

The classified fishery is for harvesting of wild common cockles (*Cerastoderma edule*), however it is not currently actively fished due to poor stock levels.

Overall, the fishery is subject to moderate levels of faecal contamination. The main sources of contamination to the fishery are:

Diffuse faecal contamination from livestock and wildlife sources carried via the Bay River across the centre of the cockle bed and an unnamed watercourse at the west end of the cockle bed.

Potential diffuse livestock and human contamination carried via intermittent land drainage to the east end of the cockle bed.

Diffuse agricultural and human source pollution associated with the crofting communities located along the east shore, 1 to 2 km north of the fishery.

Potential discharges arising from yachts anchoring north of the fishery.

The majority of contamination sources in the area are diffuse in nature and therefore most will be transported via rainfall runoff to watercourses draining the local catchment. A small number of septic tanks along the east shore of the loch are

consented to discharge to watercourses, however more may have been diverted to water after clogging or failure of soakaway fields. Once they reach the loch, faecal contaminants are predicted to be carried as much as 700 m on the tide. Sources arising from the east side of the loch are further likely to be subject to significant dilution due to the depth of the loch and therefore may only contribute to background levels of contamination around the head of the loch.

There is likely to be significant seasonal variation in both human and livestock populations present around the fishery, with peaks predicted in both during the summer months. Analysis of historical *E. coli* monitoring data found statistically highly significant variation in results by season, with results in summer significantly higher than in spring and winter and results in autumn significantly higher than in winter.

Summary of recommendations

No material changes are recommended to the production area boundaries, which already exclude potential sources of faecal contamination to the NE of the cockle bed. It is recommended, however, that the production area boundaries be specified to extend to MHWS.

RMP

Based on the observed location of mature cockles during the shoreline survey, and the reported inactivity of the fishery, there does not appear to be reason to continue monitoring until such time as commercial interest in the fishery resumes. The current RMP is located where there are currently sufficient cockles, but also near the channel of the Bay River, and would be expected to adequately reflect the contamination status of the bed. Should FSAS wish to continue to monitor this site, no change is recommended to the RMP.

Frequency

Should classification monitoring continue, monthly sampling is recommended due to expected and observed seasonal variations in inputs and contamination levels.

II. Sampling Plan

Production Area	Loch Bay
Site Name	Loch Bay
SIN	SL-117-275-04
Species	Common cockles
Type of Fishery	Wild
NGR of RMP	NG 2637 5415
East	126370
North	854150
Tolerance (m)	50 m
Depth (m)	Not applicable
Method of Sampling	Hand raked
Frequency of Sampling	Monthly
Local Authority	Highland Council
Authorised Sampler(s)	Allan MacDonald Stephen Cox
Local Authority Liaison Officer	Alan Yates
Production area boundaries	The area within the lines drawn from NG 2586 5450 to NG 2664 5470 and NG 2633 5404 to NG 2638 5408 and extending to MHWS

III. Report

1. General Description

Loch Bay lies west of the Waternish peninsula, northern Isle of Skye, off the west coast of Scotland. The location of the area is shown in Figure 1.1. The Loch opens to the NW into outer Loch Dunvegan and the Little Minch. It is part of the Skye and Lochalsh area of the Highland Council.

This sanitary survey has been undertaken on the classified fishery at Loch Bay 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.

Figure 1.1 Location of Loch Bay

2. Fishery

The Loch Bay fishery is a wild common cockle (Cerastoderma edule) bed which has been classified for production since 2004. Details of the site are presented in table 2.1.

Table 2.1 Loch Bay Area shellfish farms

Production area	Site	SIN	Species	RMP
Loch Bay	Loch Bay	SL-117-275-04	Common cockles	NG 2637 5415

The current production boundaries are defined as the area within the lines drawn from NG 2586 5450 to NG 2664 5470 and NG 2633 5404 to NG 2638 5408. This area is not specified as extending to MHWS, however an area marked out by these grid references and not extending to MHWS would exclude most of the intertidal area at the head of the loch. Therefore, it has been presumed that the production area extends to MHWS.

The production area is located in the SE corner of the loch, at the mouth of the Bay River. No information was found on the precise extent of the cockle bed. It is anticipated that cockles would be present (and harvested) throughout the intertidal sands within the production area. However, no information was found on cockle densities in the area. Locations of the cockle bed, production area and RMP are shown in Figure 2.1.

The shoreline survey team were told by the harvester that the area had been out of use for some time and was not actively worked. He noted there were few cockles, and those present were small. The sampling officer also indicated that there had been no commercial harvest from this area during 2013.

Few cockles were found during the shoreline survey, and these were small in size. Cockle numbers were reported to be lower toward the west side of the sands and highest numbers seen to the east of the Bay River, where the RMP is located.

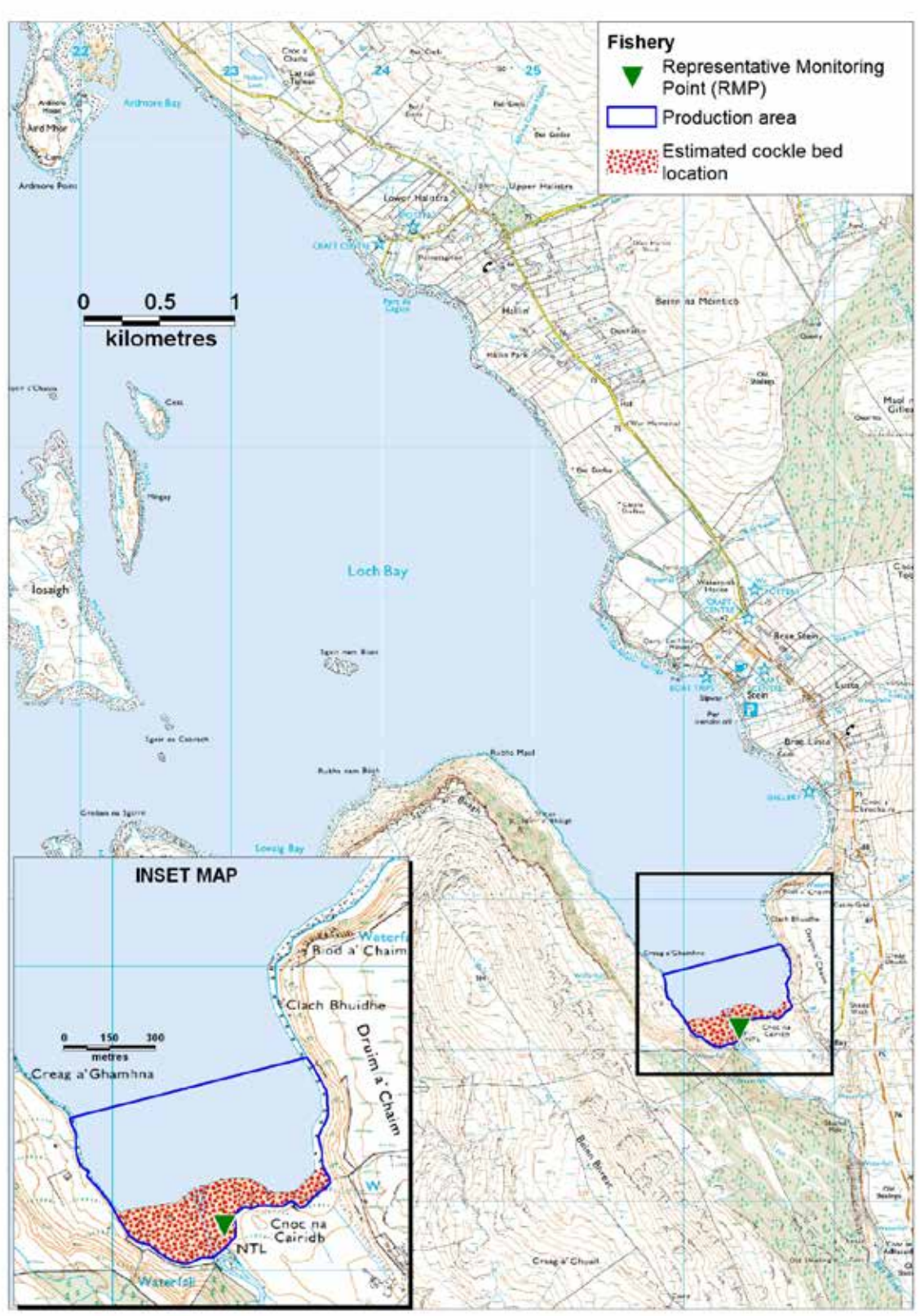


Figure 2.1 Loch Bay Area Fishery

3. Human Population

Information on the 2011 population census data for the area around Loch Bay was obtained from the General Register Office for Scotland. The census output areas are shown thematically mapped by densities in Figure 3.1. Overall population density for the area is low, with the majority of resident population concentrated around crofting townships along the eastern shore. The west shore of the loch is inaccessible and uninhabited.

The B886 road runs along the eastern side of the loch; the majority of dwellings in the area are located along this road. The main settlements are Stein, Brae Stein and Lusta (approximately 2 km NE of the cockle bed) and Hallin, Upper Halistra and Lower Halistra (approximately 5 km NNW of the cockle bed).

Facilities for boats, including moorings, pier and slipway are present at Brae Stein. A further mooring was seen during the shoreline survey to the south of Brae Stein. There are three identified anchorages in the area (Clyde Cruising Club, 2007).

The area has a number of facilities for tourists including boat tours, tourist attractions and visitor accommodation. As with the resident population, these facilities are concentrated along the east shore around identified population centres. Together, these suggest that the local population may increase significantly during the tourist season, roughly from April to September.

The closest habitation to the fishery is likely to be associated with a cluster of buildings and farm at Bay, near the head of the loch.

Overall, impacts from human sources to the water quality of the shellfish bed are likely to be low due to the low population density of the overall area, with any effects predominately to the north east of the fishery where the settlement of Brae Stein is located. A seasonal increase in human population and activity is expected during the spring and summer, and therefore any potential impact to the fishery would be higher at this time.

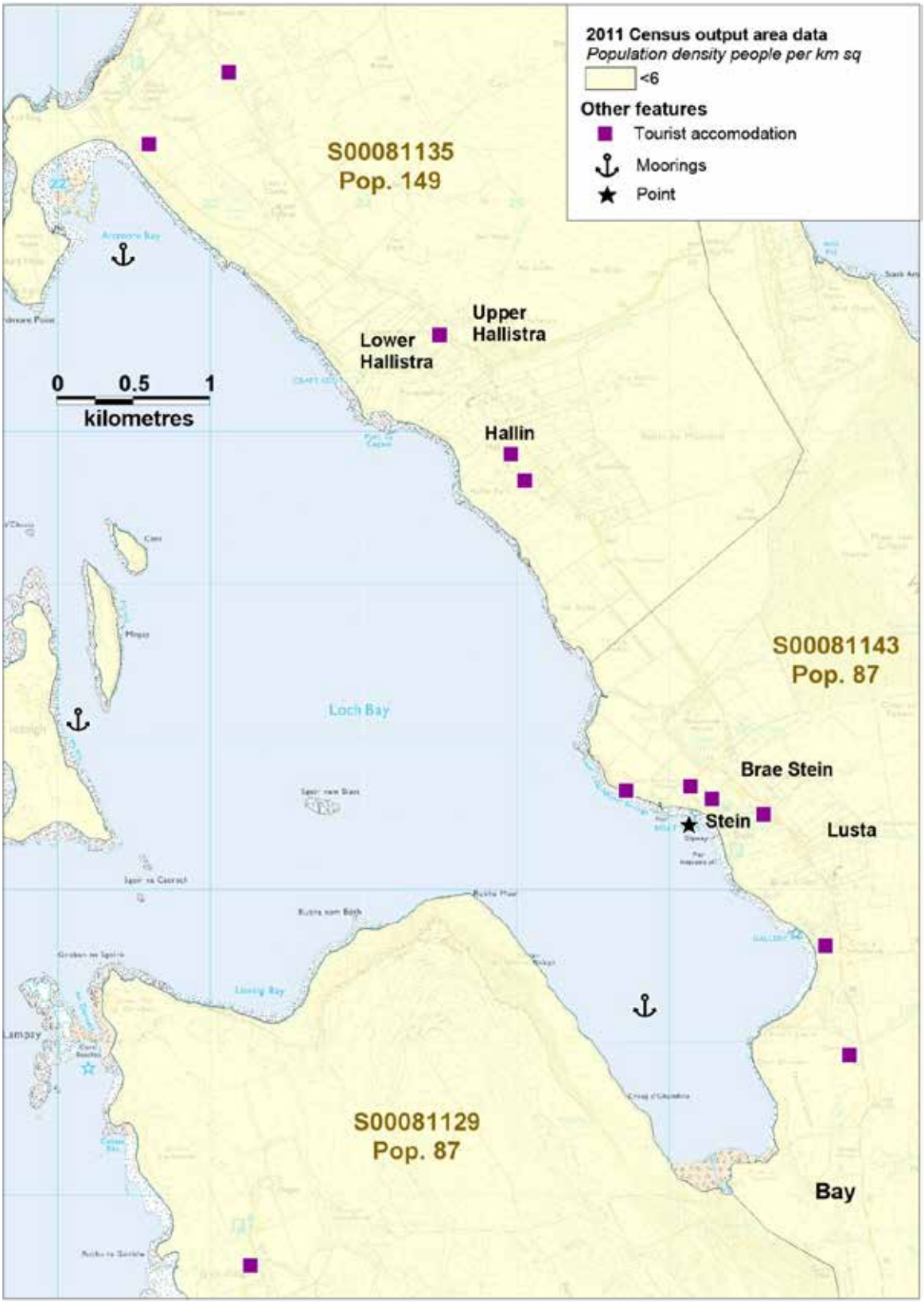


Figure 3.1 Population map for the area in the vicinity of Loch Bay

4. Sewage Discharges

Information on sewage discharges within a 5 km radius around point NG 2467 5786 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, watercourse or sea), any available dispersion or dilution modelling studies, and whether improvements were in work or planned.

4.1 Community Discharges – Scottish Water

Scottish Water reported one community sewage discharge within the area requested. This is shown in Table 4.1 below:

Table 4.1 Scottish Water discharges

Licence Number	Site Name	Discharge Type	Treatment Level	DWF (m^3/d)	PE
I/B10/128/94	Waternish WwTW	FE	Secondary	-	10

WwTW = Waste Water Treatment Works FE = Final Effluent DWF = Dry Weather Flow, PE = Population Equivalent, - = No data provided

This treatment works serves four houses. It was not specified whether the outfall discharges to soakaway or to a nearby watercourse.

4.2 Consented Discharges - SEPA

SEPA provided information on consented discharges within the request area identified above. Discharges not in the area immediately adjacent to Loch Bay have been excluded from assessment as they are considered far enough removed to have little impact on the fishery.

The consented discharges assessed in this report are given in Appendix 6.

Historically, there has been no requirement to register septic tanks in Scotland and Currently, registration is required for all new properties and upon sale of existing properties, therefore there are likely to be unconsented septic tank discharges in addition to the consented discharges listed.

SEPA provided information of 85 discharge consents within the Loch Bay catchment. A subset of these, shown in Figure 4 was identified as being located nearest to Loch Bay. These included one marine cage fish farm (CAR/L/1002357) and one tannery effluent discharge (CAR/L/1002091).

The composition of the tannery effluent was not specified. The information from the consent document indicates that effluent does undergo some settlement of suspended solids and may not contain more than 750 mg/l suspended solids and 2.5

mg/l total chromium. It is consented to discharge a maximum of 10 m^3/day for a maximum of 62 days in a year.

The large majority of consents were for discharge to soakaway. The effectiveness of soakaway systems depends on location and maintenance, and SEPA have identified previously that in remote areas, consents originally registered as discharging to land may have been diverted to sea or watercourses upon failure of the soakaway fields.

The majority of discharges to sea are located at the small settlement of Stein, which lies closer to the coast than the other settlements in the area.

Three consents relate to properties at Bay, less than 400 m uphill of the production area. While all are recorded as discharging to soakaway, they are all within 50 m of a watercourse that flows into the production area, and may represent a source of contamination via the watercourse.

Shoreline Survey Discharge Observations

Three observations of sewage infrastructure were noted during the shoreline survey. These are listed in Table 4.3 below.

Table 4.2 Discharge-associated observations made during the shoreline survey

No.	Date	Associated Photograph (Appendix 5)	*E. coli* (cfu/100ml)	Description
1	22/10/2013	Fig14	-	Manhole cover above shore, below Stein Inn. No observed discharges onto shore below.
2	22/10/2013	Fig15	5000	Sample taken from 10cm UPVC pipe draining onto foreshore (contaminated).

Observation 1 reports a manhole cover above the shore at Stein. No discharge was noted but several consents plot in the vicinity and this probably serves as an inspection point for one of them.

Observation 2 reports a 10 cm plastic pipe discharging at 15 ml/s onto the shore of Loch Bay. A sample taken returned a value of 5000 *E. coli* cfu/100 ml (estimated loading: 6.5×10^7 *E. coli*/day). The E. coli concentration is low for a septic tank discharge. The location of this discharge does not coincide with that of any of the identified consents, however several consented discharges are located in the vicinity.

Summary

Although SW reported one WWTW for the area, it only serves four homes. The large majority of homes in the area are connected to private septic tanks and most of these are reported to discharge to soakaway. Discharges from septic tanks

associated with properties at Bay and at Stein are nearest to the cockle bed. Most of the impact will be via diffuse runoff rather than direct discharge to sea.

Three consented discharges were identified to Loch Bay at Stein and two to watercourses between Stein and the production area. The only discharge observed during the shoreline survey was recorded at Stein.

List of Acronyms

MDF=	Mean daily flow	DWF=	Dry weather flow
PE=	Population Equivalent	ST=	Septic Tank
WWTW=	Wastewater Treatment Work	CSO=	Combined Sewer Overflow

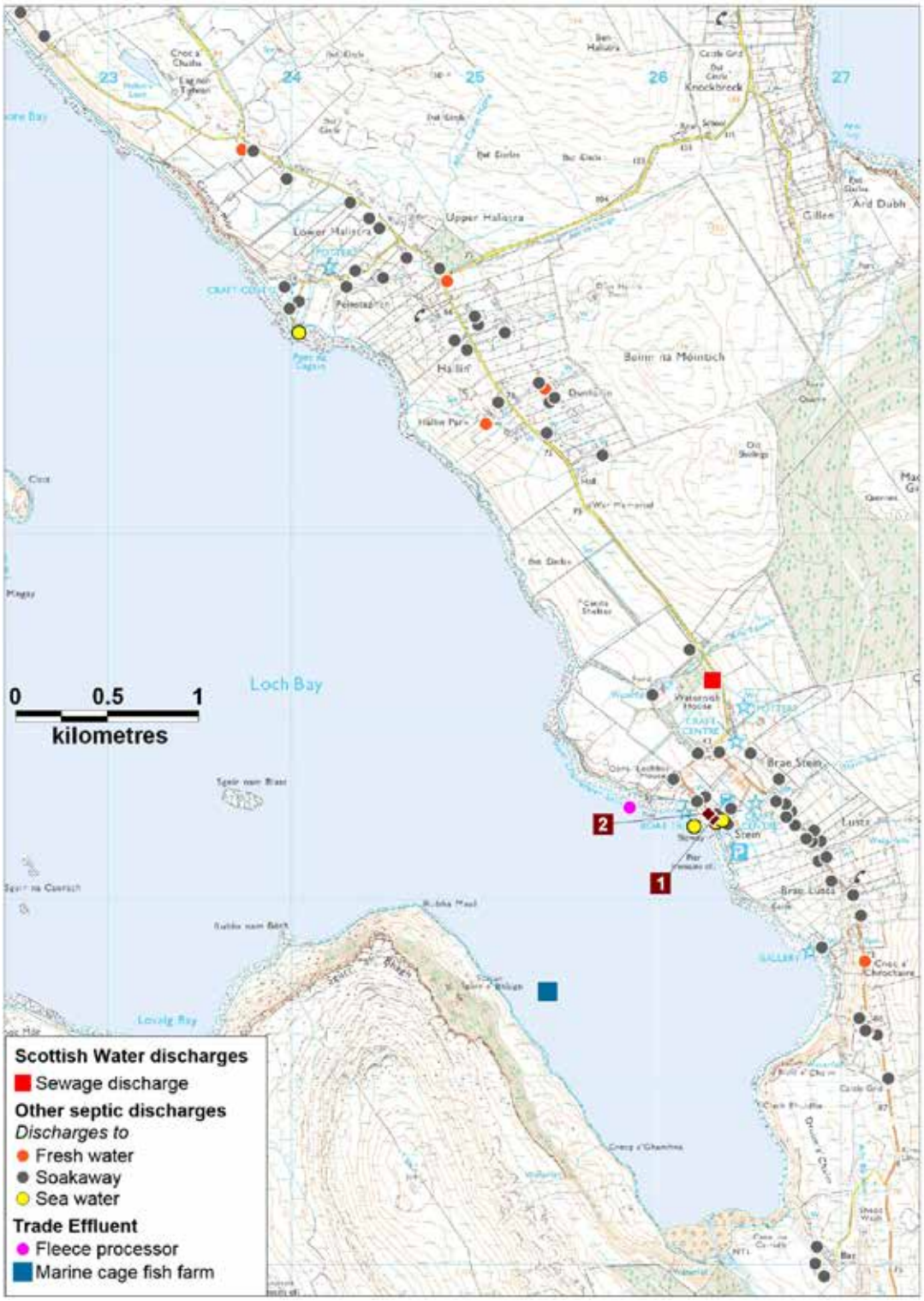


Figure 4.1 Map of discharges for Loch Bay

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. Parish-level data from the 2012 Agricultural Census was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for Duirinish. Reported livestock populations are listed in Table 5.1.

Table 5.1 Livestock numbers in the Duirinish agricultural parish 2012

	Duirinish	
	326 km^2	
	Holdings	Numbers
Pigs	8	50
Poultry	58	1781
Cattle	46	942
Sheep	123	22213
Other horses and ponies	21	41

The Duirinish parish covers a very large area of 326 km^2 and therefore it is not possible to determine the spatial distribution of the livestock in relation to the Loch Bay area or identify how many animals are likely to impact the catchment around the fishery. Sheep production is the predominant activity in the parish, with significant numbers of cattle and smaller numbers of other livestock also present.

A 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 21st and 22nd October 2013. 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 shoreline survey 10 cattle and 20 sheep in total were observed in the fields south of the fishery. On the eastern shoreline approximately 35 sheep were observed in fields inland from the survey route. The Ordnance Survey map identifies a cattle shelter on the eastern shoreline; however it was not confirmed during the shoreline survey whether this was still in use. Two sheep dips were located by SEPA in the area; the closest is located inland south of the production area, close to where the livestock were observed during the shoreline survey.

Numbers of sheep will be approximately double during late spring following the birth of lambs, and decrease again in the autumn when they are sent to market.

Any contributions of faecal contamination from livestock grazing in the area would be most likely to affect the areas of shellfish bed closest to the shoreline. Although few

livestock were present during the survey, the sheep and cattle were in close range of the fishery and any impact would be greatest on the southern side of the shellfish bed: however, the distribution of animals around the area may change with time.

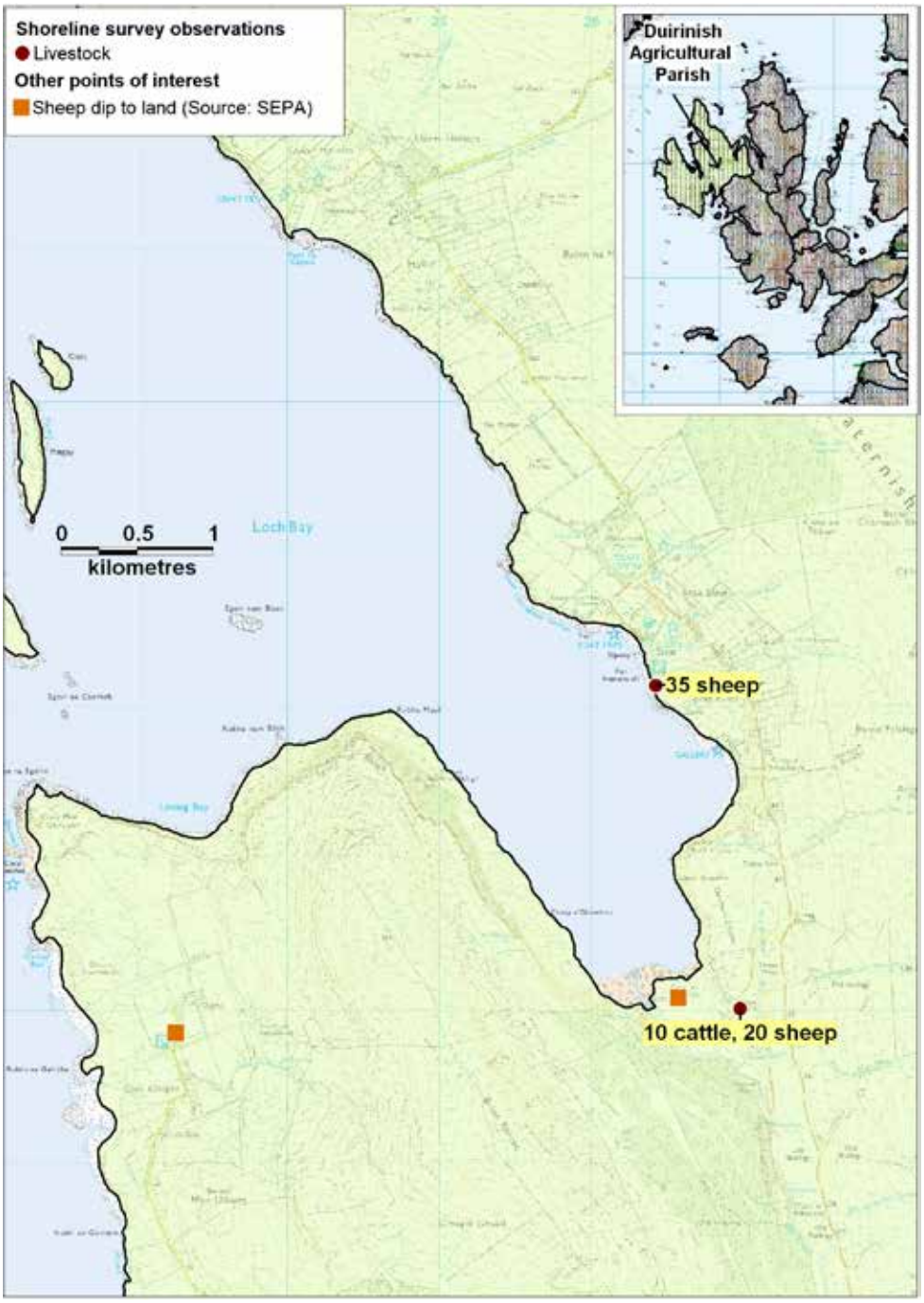


Figure 5.1 Livestock observations at Loch Bay

6. Wildlife

Wildlife species present in and around the production area will contribute to background levels of faecal contamination at the fishery, and large concentrations of animals may constitute significant sources when they are present. Seals, cetaceans and some seabirds may deposit faeces directly into the sea, while birds and mammals present on land will contribute a proportion of any faecal indicator loading carried in diffuse run-off or watercourses.

The species most likely to contribute to faecal indicator levels at the Loch Bay common cockle fishery are considered below.

Pinnipeds

In a recent report by the Special Committee on Seals (SCOS, 2012) numbers of harbour seals around Loch Bay were stated to vary between 20 and 100 seals. Comparatively the number of grey seals was approximately 100 seals. The Inner Hebrides supports a stable grey seal population, with over 3000 pups born in 2010. Comparatively the harbour seal population is just starting to return from a sharp decline in the population (SCOS, 2012). The area in Loch Bay around the Islands of Ascrib, Isay and Dungvegan is designated a special area of conservation for its breeding colony of harbour seals, the largest in the UK (JNCC, 2013; SNH, 2006).

Cetaceans

The waters between the Isle of Skye and the Isles of Lewis are important for many cetaceans including minke and sperm whales, orcas, common and bottlenose dolphins and Harbour porpoise. The majority of sightings are made at Neist Point, southwest of Loch Bay, (glendaleskye.com, 2013). Whale and dolphin sightings are most common during June-September when they are migrating back north following their breeding season. These animals are less likely to be present near the intertidal shore at Loch Bay, however they may contribute to background levels of faecal contamination in the wider area if present in large numbers.

Birds

Seabird 2000 census data (Mitchell, et al., 2004) for the area within a 5 km radius of Loch Bay was obtained and is summarised in Table 6.1. This census, undertaken between 1998 and 2002 covered twenty five species of seabird that breed regularly in Britain and Ireland.

Table 6.1 Seabird counts within 5 km of the Loch Bay

Common name	Species	Count	Method
Razorbill	*Alca torda*	23	Individuals on land
Black Guillemot	*Cepphus grylle*	69	Individuals on land
Northern Fulmar	*Fulmarus glacialis*	78	Individuals on sea
European Herring Gull	*Larus argentatus*	136	Occupied sites
Common Gull	*Larus canus*	18	Occupied nests
Lesser Black-backed Gull	*Larus fuscus*	4	Occupied nests
Great Black-backed Gull	*Larus marinus*	26	Occupied nests
European Shag	*Phalacrocorax aristotelis*	74	Occupied nests
Great Cormorant	*Phalacrocorax carbo*	28	Occupied nests
Black-legged Kittiwake	*Rissa tridactyla*	2	Occupied nests

*The counts have been adjusted where the method used was occupied nests, territory or sites to reflect the probable number of individual birds (i.e. counts were doubled).

There are breeding colonies of various species of seabirds on the islands, and on the small peninsula at the head of Loch Bay. The nearest colonies to the fishery are two on the small islands and skerries in Loch Bay which are about 5.5 km from the production area. Four gulls were observed at the head of the loch and three cormorants at Stein during the shoreline survey. Common seabirds such as gulls and cormorants are considered likely to be present in and around the area through much of the year.

Although no specific counts were found of wading birds in the area, it is likely that the cockle bed would attract wading birds that feed on small cockles and other infauna. The large amount of improved grassland around the loch is also likely to attract geese, particularly during winter. However, no record of the presence or numbers of these birds was found.

Otters

Anecdotal reports were found of otters in the area around Loch Bay (The Cottage Guide, 2013) and the National Biodiversity Network has records in the surrounding areas. No otters were observed during the shoreline survey.

Deer

Red deer and roe deer are reported as present throughout Skye (The Skye Guide, 2013; Aebisher, et al., 2011). No information was found on populations in the vicinity of Loch Bay, however these animals are likely to contribute to faecal contamination carried in watercourses discharging to the loch.

Overall, wildlife species likely to contribute to background levels of contamination at the cockle fishery include seals, deer and seabirds. Wading birds, if present, would be expected to have a more direct impact at the cockle bed. However, no evidence was found of potentially significant concentrations of wildlife using the area.

Figure 6.1 Map of wildlife around Loch Bay

7. Land Cover

The Land Cover Map 2007 data for the area is shown in Figure 7.1 below:

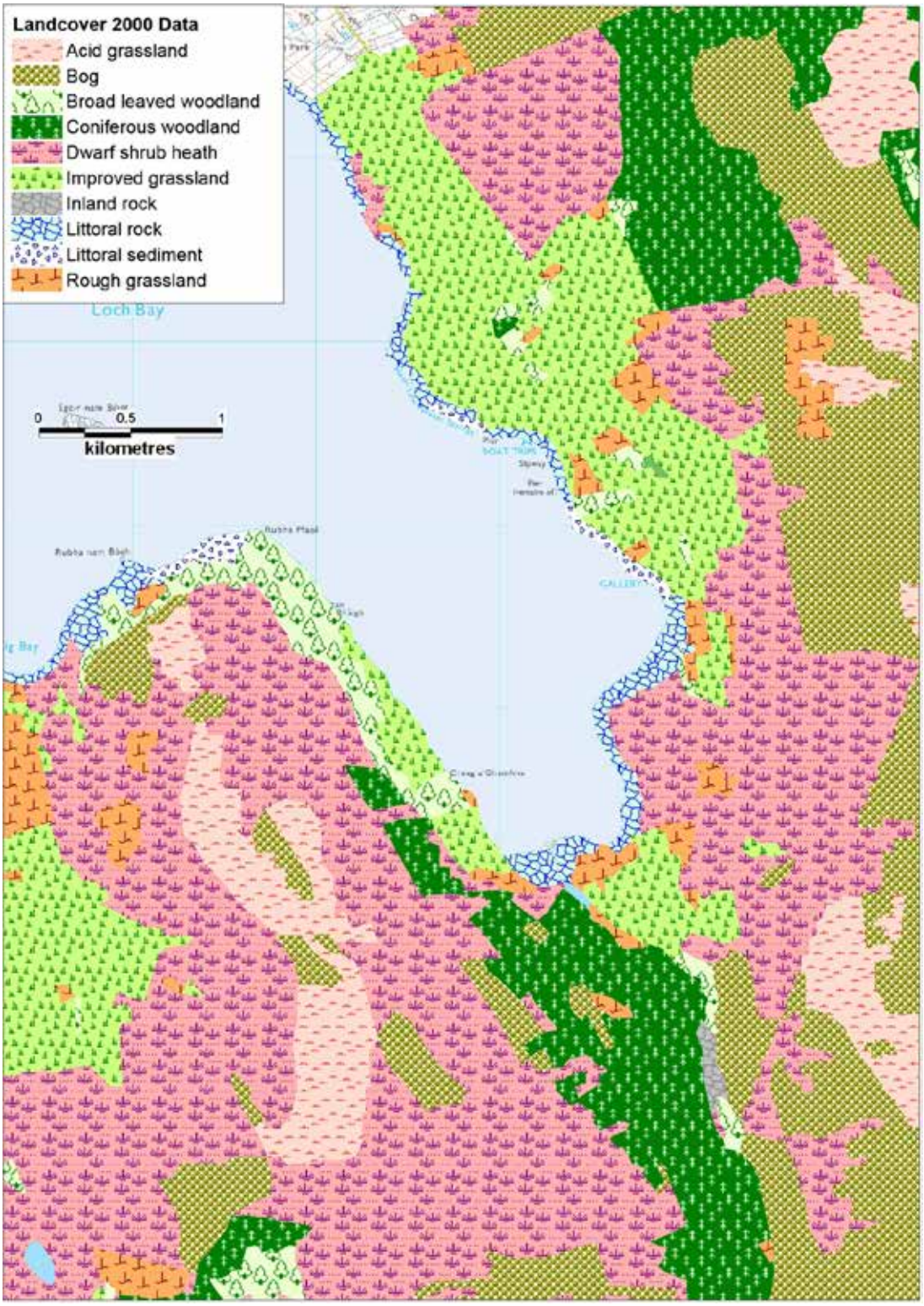


Figure 7.1 LCM2007 land covers data for the area around Loch Bay

Landcover type around Loch Bay is varied. Much of the shoreline is improved grassland associated with farms and/or crofts. Inland, large tracts of heath and bog predominate, with some coniferous plantation extending southward from the head of the loch along the Bay River and also inland to the NW of the loch.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately $8.3x10^8$ cfu/km^2/hr for areas of improved grassland and approximately $2.5x10^8$ cfu/km^2/hr for rough grazing (Kay, et al., 2008). 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., 2008).

The highest potential contribution of contaminated run-off to the Loch Bay shellfish bed is from the areas of improved grassland located along the western shoreline and inland south of the shellfish bed. The potential contribution of contaminated run-off to the shellfish bed would be highest in these areas.

8. Watercourses

There are no gauging stations on watercourses entering into Loch Bay

Spot measurements of size and samples for microbial content were taken during the shoreline survey conducted on the 21st and 22nd September 2013. Weather conditions were dry on the 21st; there were intermittent heavy showers on the 22nd. No weather observations were provided for the 24 hrs prior to the survey. The watercourses listed in Table 8.1 are noted to be the most significant freshwater inputs to the area around the fishery in Loch Bay.

There three further areas of land drainage were observed during the survey: one at the east end of the cockle bed, the second approximately 90 m south of watercourse 4, and the third approximately 150 m north of watercourse 7. Flow from these was not sufficient to measure. An unnamed watercourse was also noted approximately 100 m north of watercourse 3, but was not sampled as the surveyor observed no potential sources of contamination (dwellings, livestock and/or outfalls) entering the watercourse or in the surrounding catchment area.

Table 8.1 Watercourses entering Loch Bay

No.	NGR	Description	Width (m)	Depth (m)	Flow (m^3/d)	Loading (*E. coli* per day)
1	NG 26340 54064	Bay River	4.23	0.23*	17274*	5.2×10^9
2	NG 26104 54081	Unnamed watercourse	0.60	0.15	933	$<9.3 \times 10^7$
3	NG 26922 55353	Allt a' Chaim	1.00	0.16	22575	8.1×10^{10}
4	NG 26917 55676	Unnamed watercourse	0.80	0.12	10841	1.0×10^{11}
5	NG 26675 55861	Unnamed watercourse	0.75	0.07	2127	5.1×10^{10}
6	NG 26422 56140	Lusta Burn	1.11	0.50	11413	1.8×10^{10}
7	NG 26345 56345	Stein Burn	1.90	0.14	13008	2.7×10^{11}
8	NG 25871 56579	Unnamed watercourse	1.00	0.15	10018	4.2×10^{10}

*Average taken from two measurements

Most of the recorded watercourses had significant flows. Although there are a number of watercourses identified along the western shore on the OS 1:25000 base maps, due to difficulties with access the shoreline survey did not extend along this area. Therefore, all the watercourses for which flows and loadings were calculated were located around the head and east side of the loch.

Two watercourses flow directly across the Loch Bay shellfish bed, and therefore will have the most direct impact on water quality there. The Bay River flows across the

centre of the cockle bed and had an moderate estimated loading. An unnamed watercourse flows across the west end of the cockle bed and had an estimated loading two orders of magnitude lower than that of the Bay River. The Bay River drains a significantly larger catchment area that includes improved pasture area, which may explain the higher loading. The area of land drainage noted on shoreline adjacent to the eastern extent of the shellfish bed may represent a significant contamination source when flowing, as it drains an area that includes the houses identified at Bay and therefore could potentially carry diffuse contamination from human sources under very wet conditions.

Watercourses that flowed through the crofted areas around Stein were found to have the moderately to high loadings, with the highest loadings recorded from Stein Burn (2 km north of the cockle bed) and a small, unnamed watercourse adjacent to houses approximately 1.5km NE of the cockle bed.

The locations and loadings of measured watercourses as well as noted areas of land drainage are shown in Figure 8.1.

Overall, freshwater inputs are expected to provide moderate levels of contamination to the shellfish bed in Loch Bay, with the highest impact expected from the watercourses and land drainage that discharge directly to the shellfish bed. Of these, the highest loading was observed from the Bay River.

Figure 8.1 Map of watercourse loadings at Loch Bay.

9. Meteorological Data

The nearest weather station for which a nearly complete rainfall data set was available is located at Harris: Quidnish, situated approximately 37 km to the north of Loch Bay fishery. Rainfall data was available for January 2007 – December 2012, with only 3 days of data missing. The nearest wind station is South Uist Range located 51 km west of the fishery. Conditions may differ between these stations and the fishery due to the distances between them. However, the data is still presented as it can be useful in identifying overall trends and seasonal variation in rainfall and wind direction.

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 Bay.

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 *.

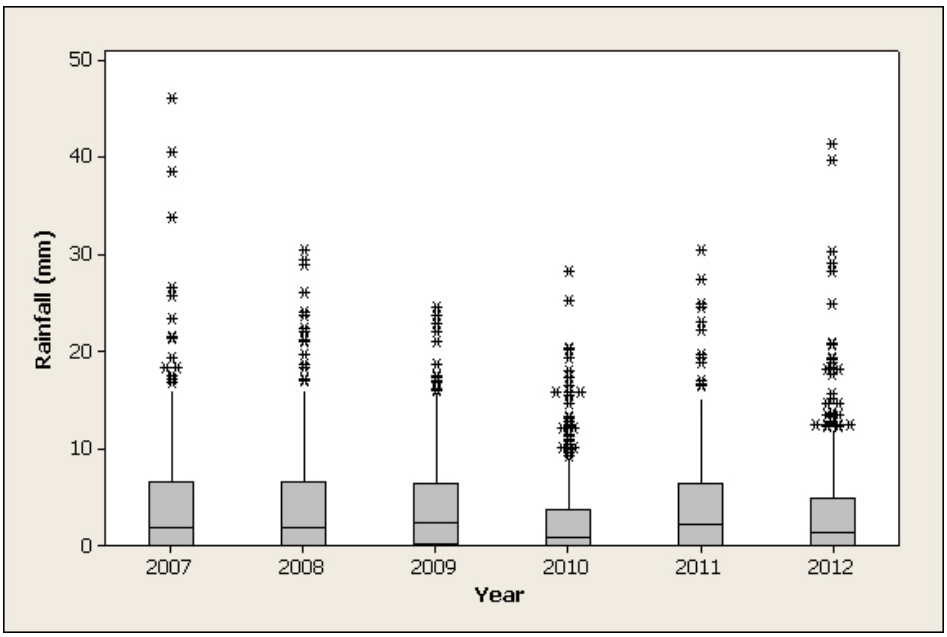


Figure 9.1 Box plot of daily rainfall values by year at Harris: Quidnich (2007 – 2012)

Total rainfall varied from year to year, with 2010 being markedly drier than the others, with a total of 977 mm rainfall during the year. The wettest year was 2007

(1633 mm total rainfall). High daily rainfall values (greater than 30 mm/d) did not occur in all years and overall the highest exceptional event was less than 50 mm/d.

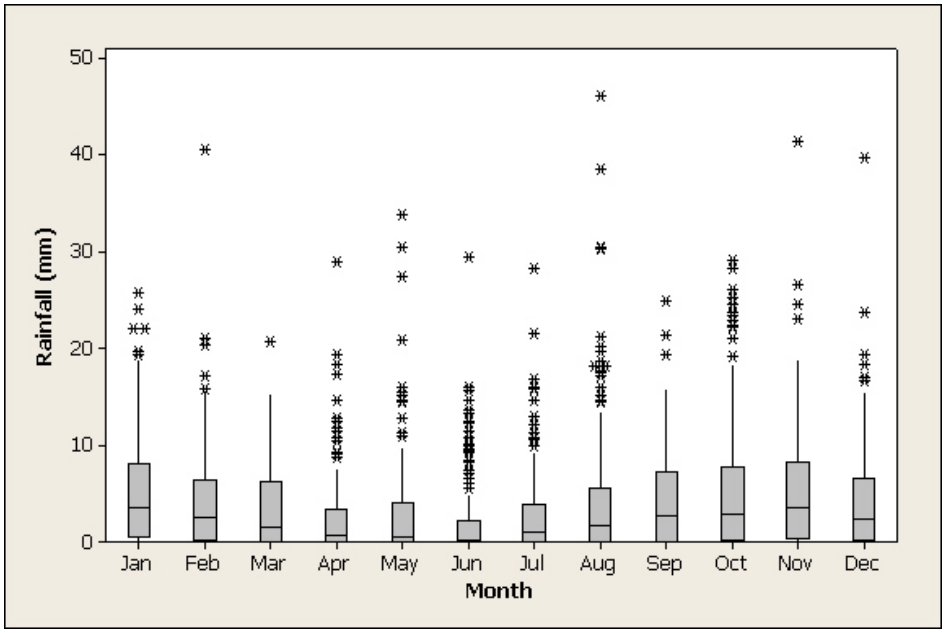


Figure 9.2 Box plot of daily rainfall values by month at Harris: Quidnich (2007 – 2012)

Recorded daily rainfall values were lower between April and July and higher from August to March. For the period considered here (2007 – 2012) 43 % of days received daily rainfall of less than 1 mm and 12 % of days received rainfall of over 10 mm.

It is expected that run-off due to rainfall will generally be higher during the autumn and winter months. However, extreme rainfall events leading to episodes of high runoff can occur in most months and when these occur during generally drier periods in summer and early autumn, 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 South Uist Range and summarised in seasonal wind roses in Figure 9.3 and annually in Figure 9.4.

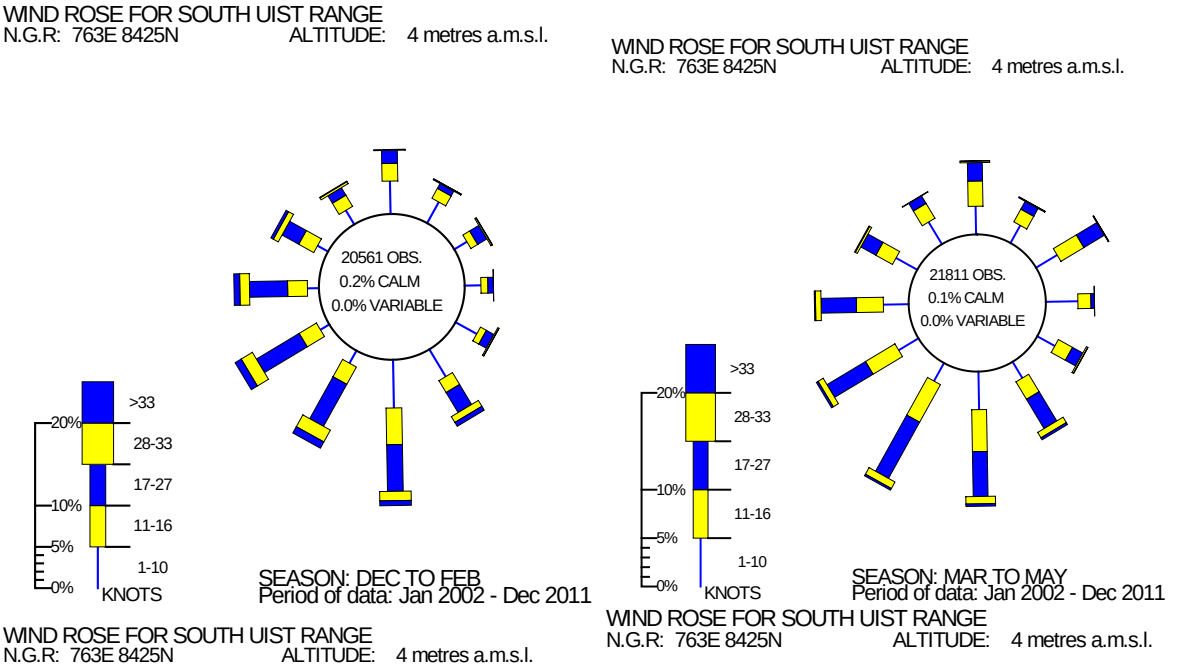


Figure 9.3 Seasonal wind roses for South Uist Range

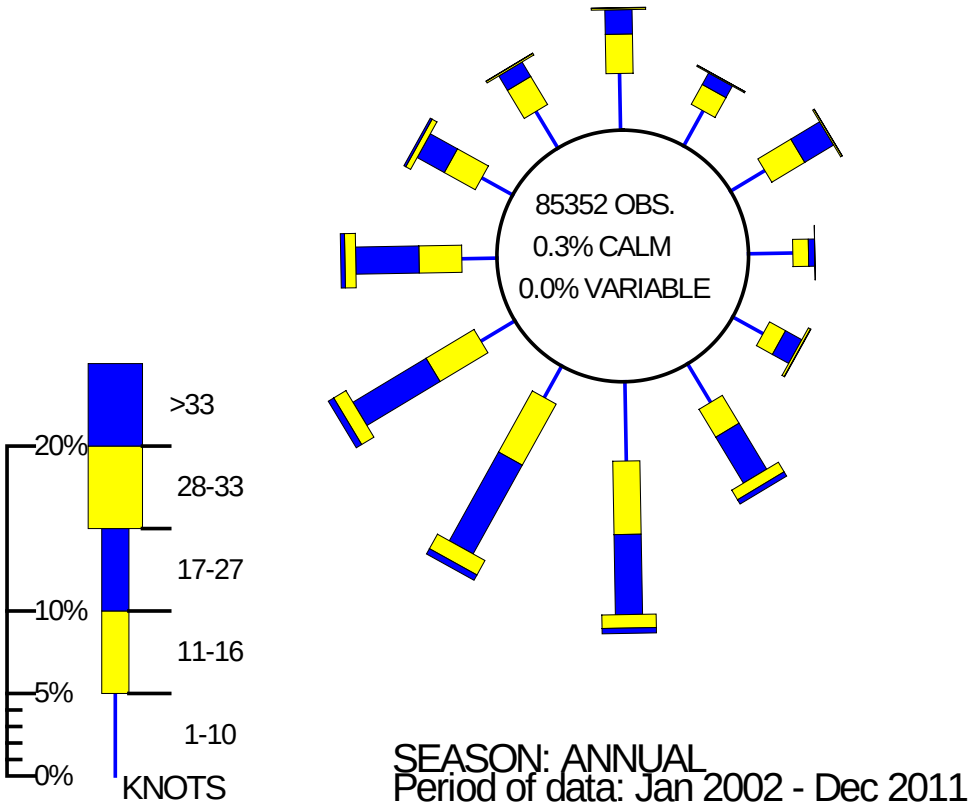


Figure 9.4 Annual wind rose for South Uist Range

Overall the predominant winds were from the SW quadrant. Winds were least likely to blow from the east. Winds from the NE occurred more 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

Loch Bay has been classified for harvest of common cockles (*Cerastoderma edule*) since 2004. The classification history since 2008 is listed in Table 10.1.

Table 10.1 Loch Bay classification history

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

In general, class A has been assigned to the period January to April and class B to the period May to December.

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned against the Loch Bay site for the period 01/01/2008 to the 02/12/2013 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 02/12/2013. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

All sample results reported as <20 *E. coli* MPN/100 g were reassigned a value of 10 *E. coli* MPN/100 g for the purposes of statistical evaluation and graphical representation.

Two samples were reported in the database as rejected and were omitted from further analysis in this report. Three results were omitted from further analysis as the samples were recorded as having been taken >100 m from the production area (one sample on land 33.9 km to the southwest and two samples in Loch Harport 26.1 km to the southeast). One record was missing the two letter prefix to its NGR, which was corrected and a further three records had the letters ‘BNG’ removed from the middle of stated grid reference. After correction, the results were included in these analyses. The remaining 49 samples were all received at the laboratory within 48 hours of collection.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Loch Bay
Site	Loch Bay
Species	Common cockles
SIN	SL-117-275-04
Location	Various
Total no of samples	49
No. 2008	6
No. 2009	7
No. 2010	6
No. 2011	8
No. 2012	12
No. 2013	10
Minimum	<20
Maximum	16000
Median	310
Geometric mean	212
90 percentile	3500
95 percentile	12600
No. exceeding 230/100g	25 (51%)
No. exceeding 1000/100g	12 (24%)
No. exceeding 4600/100g	4 (8%)
No. exceeding 18000/100g	0

Sampling has increased over the sampling period. Over half the sample results had contamination levels >230 *E. coli* MPN/100 g, with four results also >4600 *E. coli* MPN/100 g.

11.3 Overall geographical pattern of results

The geographical locations of all 49 samples assigned to Loch Bay are mapped in Figure 11.1, with the size of the symbol shown proportionate to the magnitude of the *E. coli* result. Over half the samples (28/49) were recorded against a single grid reference with 1 m accuracy (NG 26377 54155). These samples spanned the years from 2008 to 2012. A further 11 samples were recorded at the nominal RMP with 10 m accuracy, all in 2012 and 2013. The remaining samples were reported against locations mainly within 50 m of the RMP, however one sample was taken from the west side of the river in early 2012.

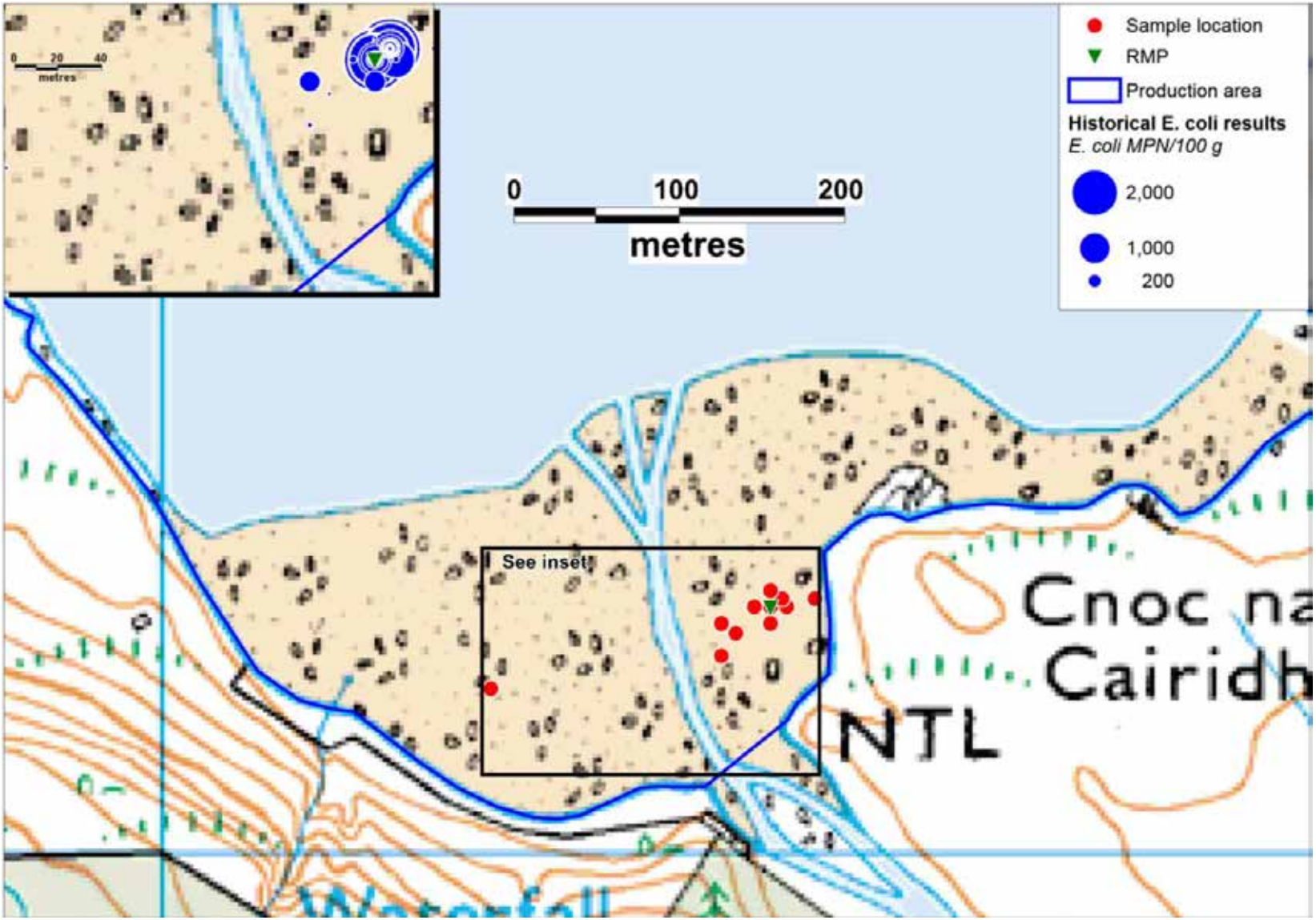


Figure 11.1 Map of reported sampling locations for common cockles at Loch Bay

11.4 Overall temporal pattern of results

A scatterplot of *E. coli* results against date for Loch Bay is presented in Figure 11.2. The dataset is 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.

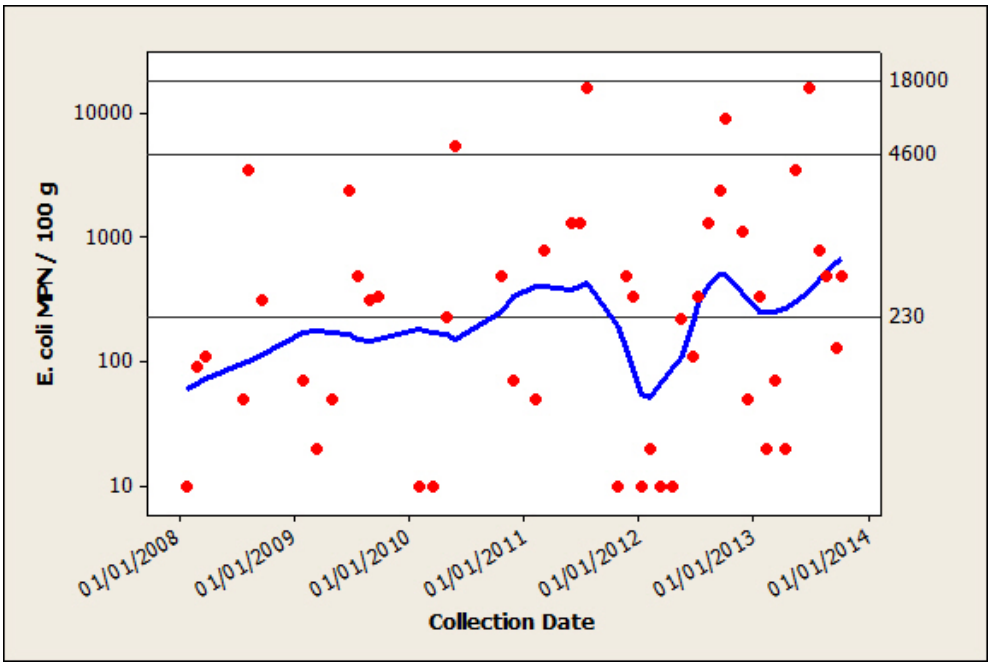


Figure 11.2 Scatterplot of *E. coli* results by collection date at Loch Bay, fitted with a lowess line

Overall there was a gradual increasing trend in *E. coli* results between 2008 and 2013. A brief dip in the trend occurred at the beginning of 2012, when there was a cluster of very low results. Results greater than 4600 *E. coli* MPN/100 g have occurred from 2010 onward.

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. A scatterplot of *E. coli* results by month, overlaid by a lowess line to highlight trends is displayed in Figure 11.3. Jittering was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

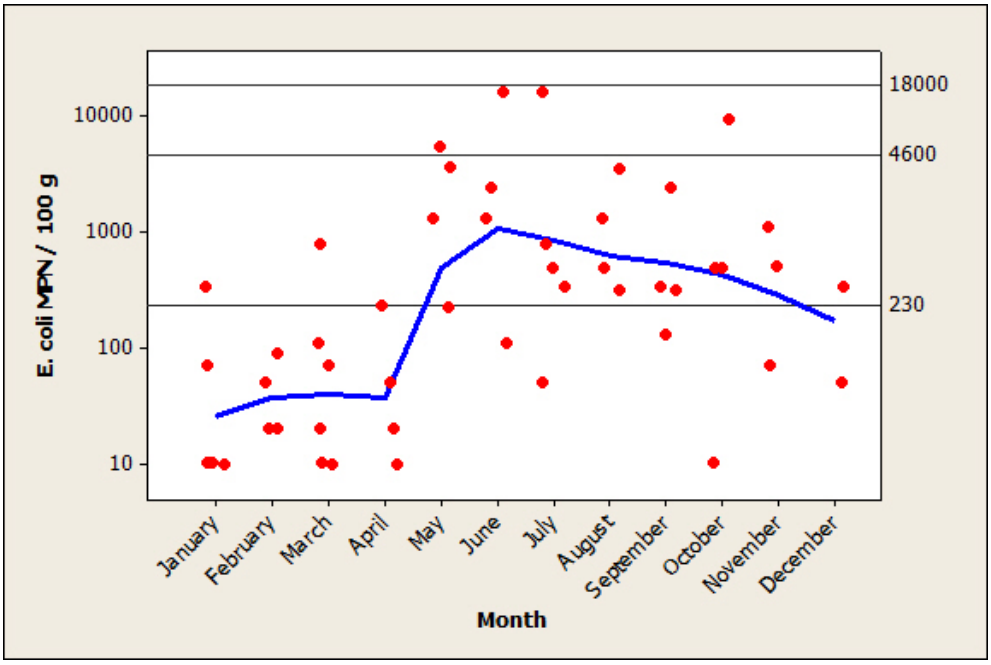


Figure 11.3 Scatterplot of *E. coli* results by month at Loch Bay, fitted with a lowess line

A sharp increase in contamination levels is shown between April and May, when all results were >230 *E. coli* MPN/100 g. The highest results have occurred in June and July, after which results trended downward gradually for the remaining months of the year.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). A boxplot of *E. coli* results by season is presented in Figure 11.4.

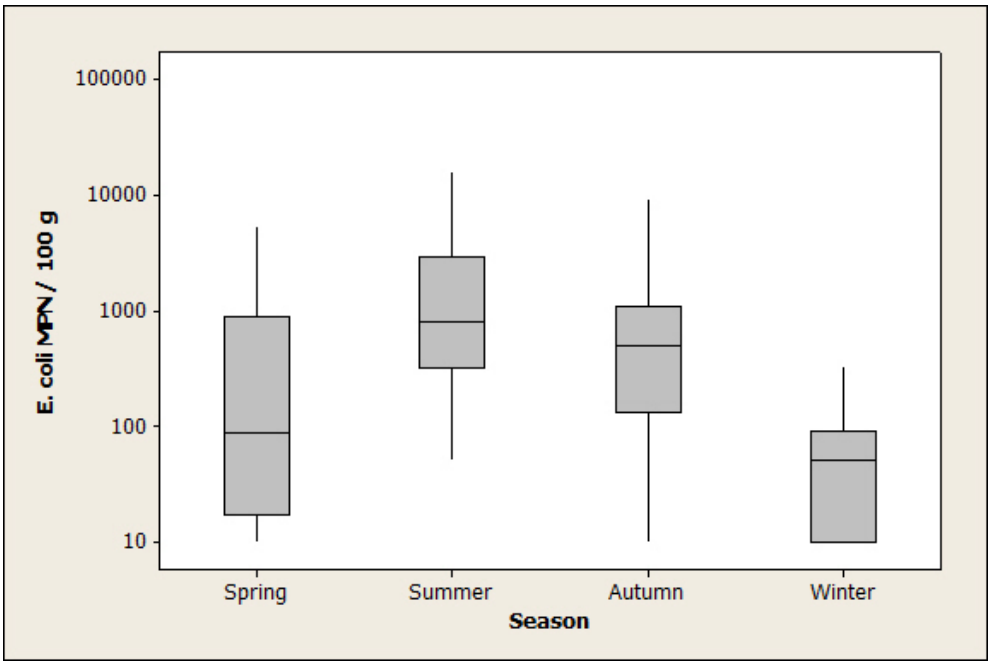


Figure 11.4 Boxplot of *E. coli* results by season at Loch Bay

A very highly statistically significant difference was found between *E. coli* results by season (one-way ANOVA, p = 0.001, Appendix 4). Using Tukey's method, results in

summer were found to be significantly higher than in spring and winter, and results in autumn were also found to be significantly higher than those in winter.

11.6 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.

11.6.1 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Harris Quidnich approximately 37 km north of Loch Bay. Rainfall data was purchased from the Meteorological Office for the period of 01/01/08 - 31/12/2012 (total daily rainfall in mm). Data was extracted from this for all sample results at Loch Bay between 01/01/2008 – 31/12/2012. Due to the large distance between the recording station and the fishery, caution should be used in interpreting rainfall associations based on this data.

Two-day rainfall

A scatterplot of *E. coli* results against total rainfall recorded on the two days prior to sampling is displayed in Figure 11.5. Jittering was applied to results at 0.02 (x-axis) and 0.001 (y-axis) respectively.

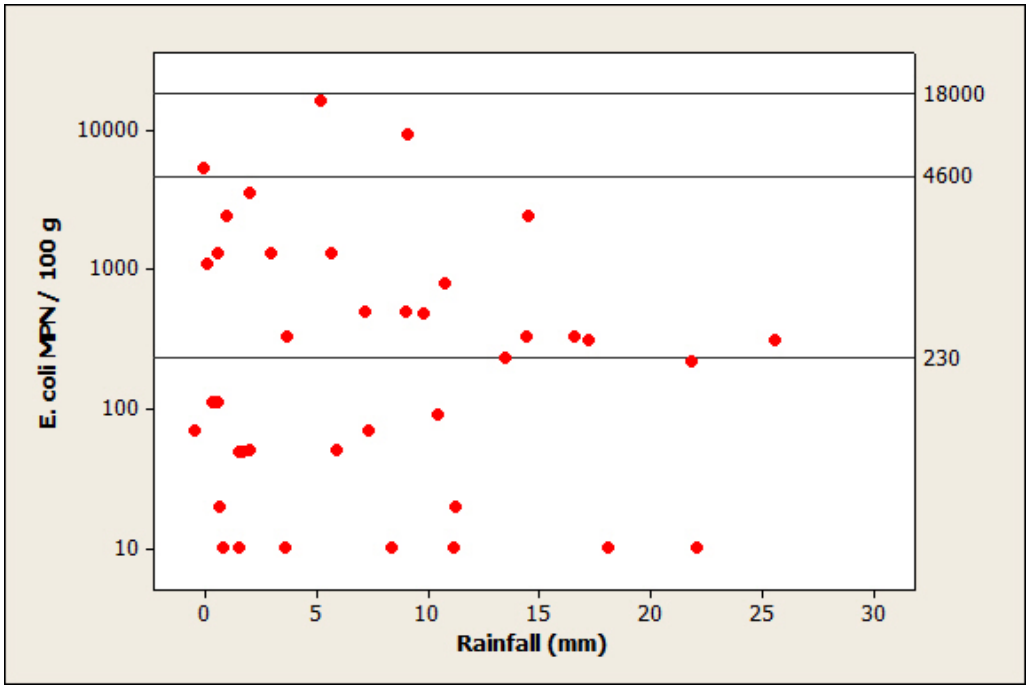


Figure 11.5 Scatterplot of *E. coli* results against rainfall in the previous two days at Loch Bay

No significant correlation was found between *E. coli* results and the previous two day rainfall (Spearman's rank correlation r = -0.091, p = 0.583).

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. A scatterplot of *E. coli* results against total rainfall recorded for the seven days prior to sampling at Loch Bay is shown in Figure 11.6. Jittering was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

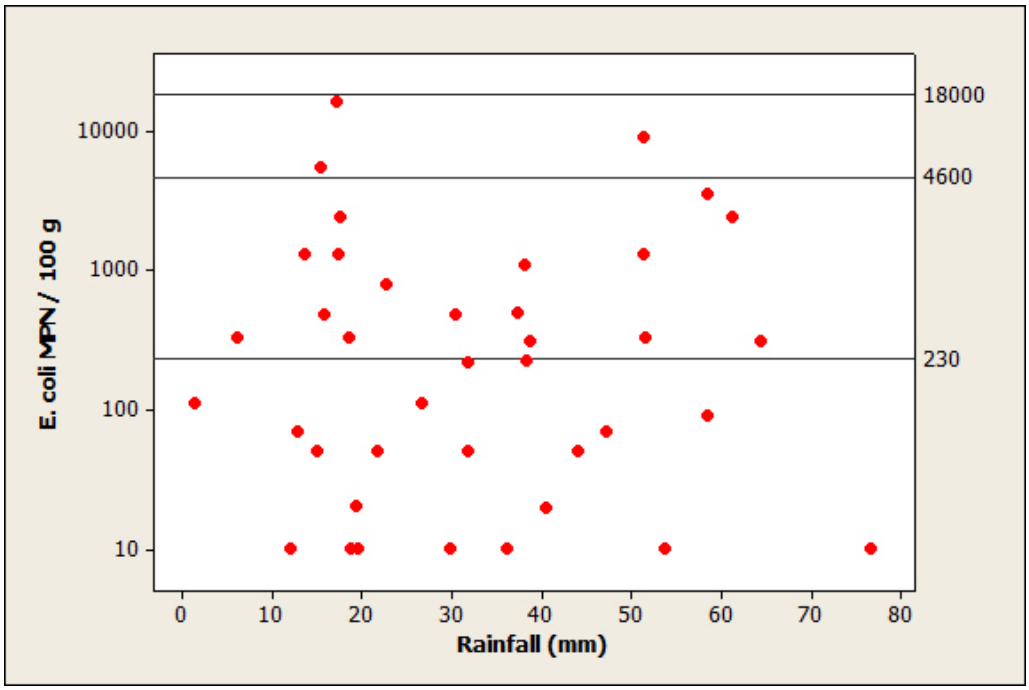


Figure 11.6 Scatterplot of *E. coli* results against rainfall in the previous seven days at Loch Bay

No significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = -0.008, p = 0.960), with the highest rainfall level of >70 mm associated with a low result of <20 *E. coli* MPN/100 g.

11.6.2 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/new moon, at about 45^{o} on a polar plot. The tides then decrease to the smallest (neap) tides, at about 225^{o}, before increasing back to spring tides. A polar plot of *E. coli* results against the lunar cycle is shown for Loch Bay in Figure 11.7**.** It should be noted that local meteorological

conditions (e.g. wind strength and direction) can also influence tide height, but are not taken into account in this section.

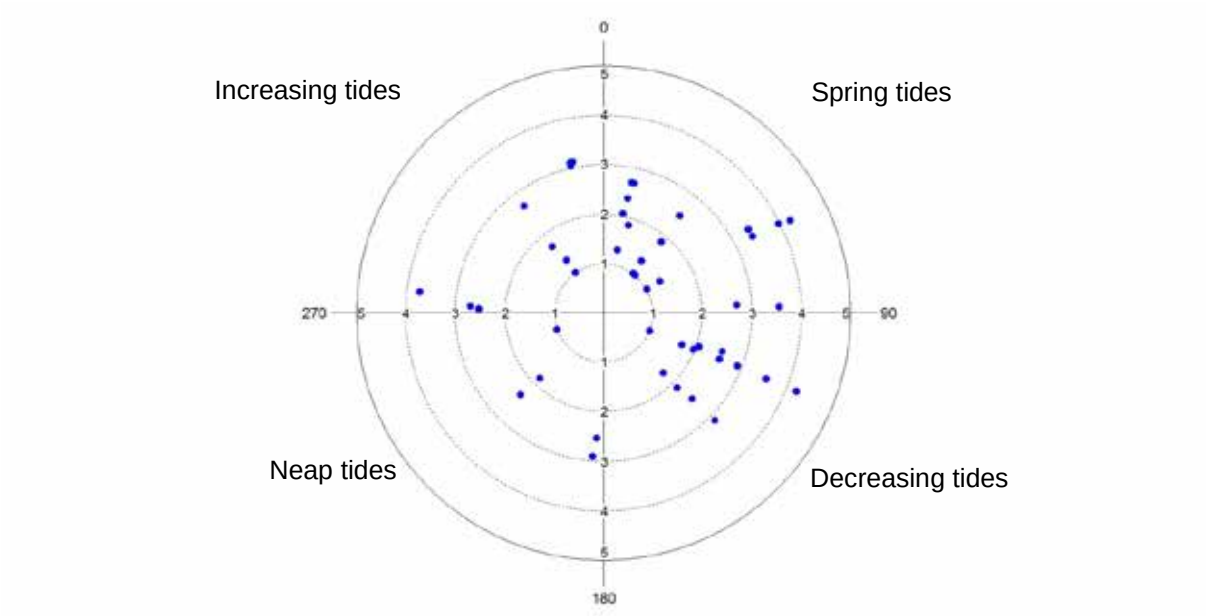


Figure 11.7 Polar plots of log_{10} *E. coli* results on the spring/neap tidal cycle at Loch Bay

No significant correlation was found between log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.148, p = 0.367).

11.6.2.1 Tidal state by high/low water

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 *E. coli* levels can vary from within an hour to a few hours. A polar plot of *E. coli* results against the high/low tidal cycle for Loch Bay is shown in Figure 11.8. High water is located at 0^o on the polar plot and low water at 180^o.

High and low water data from West Loch Dunvegan was extracted from POLTIPS-3 in December 2013. This site was the closest to the production area (approximately 6 km to the southwest as the bird flies) and it is assumed that tidal state will be similar between sites.

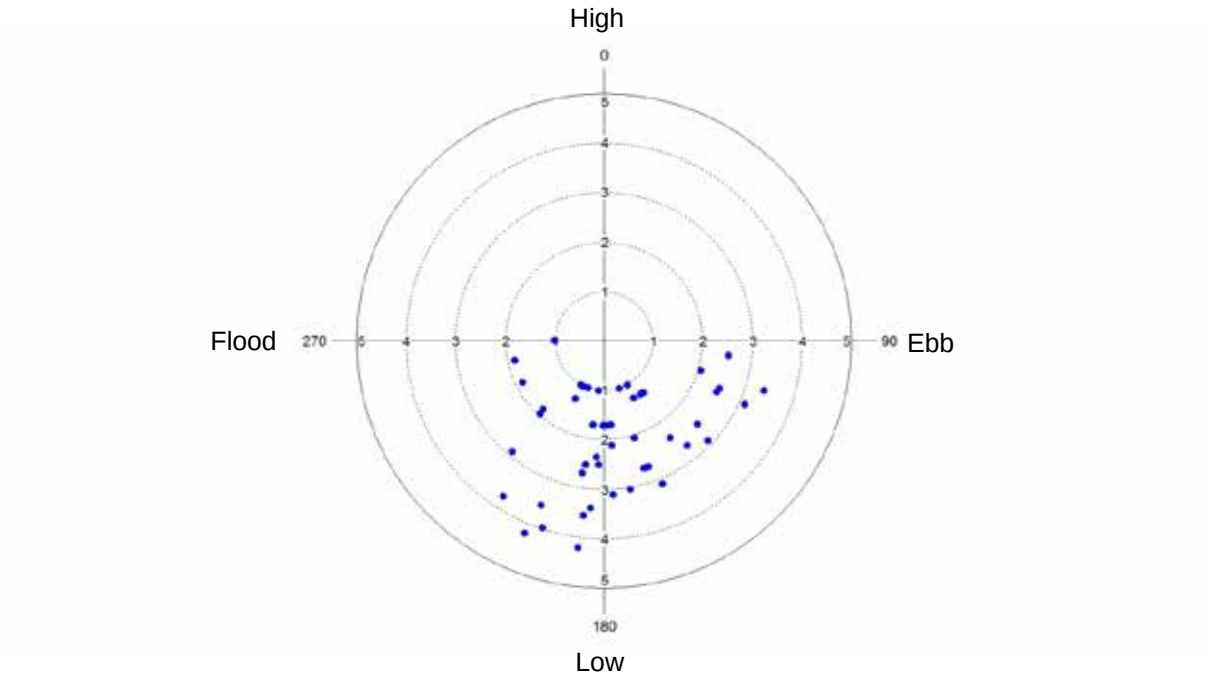


Figure 11.8 Polar plots of log_{10} *E. coli* results on the high/low tidal cycle at Loch Bay

No significant correlation was found between log_{10} *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.138, p = 0.417). Samples were only taken around low tides, when the cockle bed would be accessible.

11.6.3 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 11.9 presents *E. coli* results against water temperature. Water temperature was recorded for 39 out of the 49 samples. Jittering of results was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

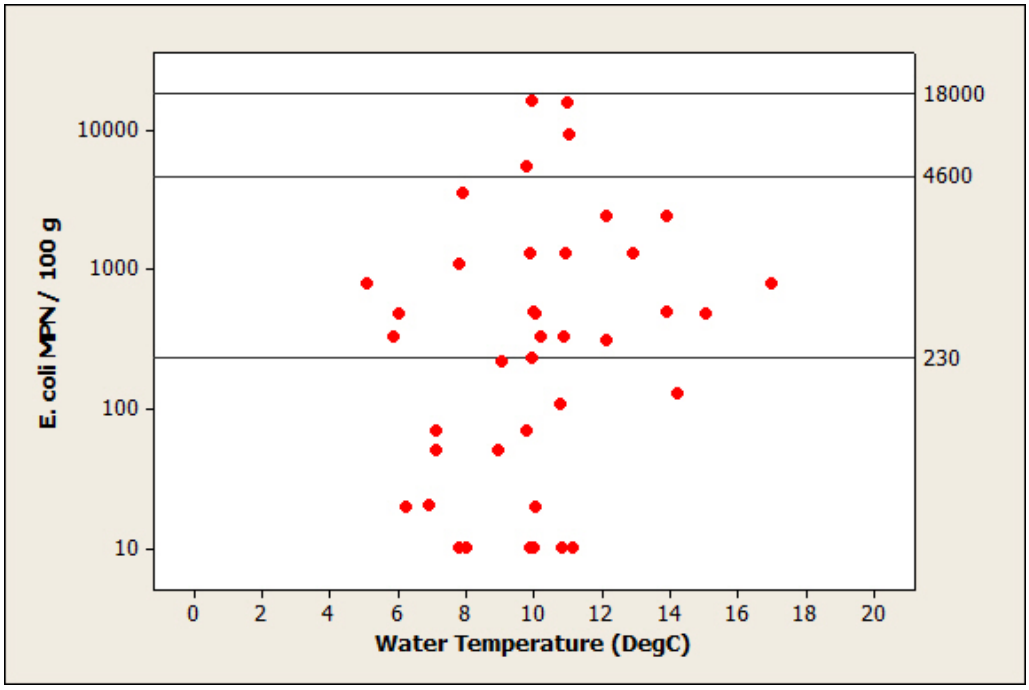


Figure 11.9 Scatterplot of *E. coli* results against water temperature at Loch Bay

No significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = 0.283, p = 0.081).

11.7 Evaluation of results > 4600 *E. coli* MPN/100g

In the results from Loch Bay, four samples had results greater than 4600 *E. coli* MPN/100 g ; these are listed below in Table 11.2.

Table 11.2 Loch Bay historic *E. coli* sampling results over 4600 *E. coli* MPN/100g

Collection Date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (°C)	Tidal State (high/low)	Tidal state (spring/neap)
25/05/2010	5400	NG 26377 54155	0.0	14.2	10	Low	Increasing
19/07/2011	16000	NG 26377 54155	5.0	18.6	11	Low	Decreasing
02/10/2012	9200	NG 2637 5415	8.6	50.4	11	Low	Spring
25/06/2013	16000	NG 2637 5415	-	-	10	Low	Spring

-No data available

All samples were reported against either the RMP or within 10 m of it. Samples were reported to have been taken in each year since 2010, all in different months. Rainfall over the previous two days varied. Reported water temperature was relatively stable at 10 and 11°C. All samples were taken at low tide which is consistent with the nature of the fishery. No trend was apparent in spring/neap tidal state.

11.8 Summary and conclusions

Overall contamination levels at Loch Bay have been increasing since 2008. Over 50% of sample results were >230 *E. coli* MPN/100 g and nearly a quarter (24%) >1000 *E. coli* MPN/100 g. The highest results were 16000 *E. coli* MPN/100 g, in samples reported from

the vicinity of the RMP in 2011 and 2013. A strong seasonal increase in results was found, with highest results in summer and lowest results in winter. Reported sampling locations were nominally at the RMP, with the majority of results reported to a single NGR stated to 1m accuracy. No statistically significant correlations were found between results and rainfall levels in the previous two or seven days prior to sampling. No correlation was found between results and water temperature. No statistically significant correlations were found between results and high/low tidal state or spring/neap tidal state.

12. Designated Waters Data

The Loch Bay production area does not coincide with either a designated shellfish water protected area or a designated bathing water.

13. Bathymetry and Hydrodynamics

Loch Bay is situated in the northwest of Skye on the west coast of Scotland lying on the west side of the Waternish peninsula which runs northwest between Loch Snizort to the east and Loch Dunvegan to the west. The mouth of Loch Bay opens into the Little Minch to the northwest. At the mouth, there is a cluster of islands the largest being Isay Island along with the smaller islets of Mingay and Clett. The study area extends from the head of Loch Bay to the northwest where the outer boundary is between Oans Point and Rubha Maol. The study area includes a number of townships all on the northeast shore. The most northerly of these is the crofting township of Stein and moving southwards there are Lusta and finally Waternish.

Coordinates for the middle of Bay:

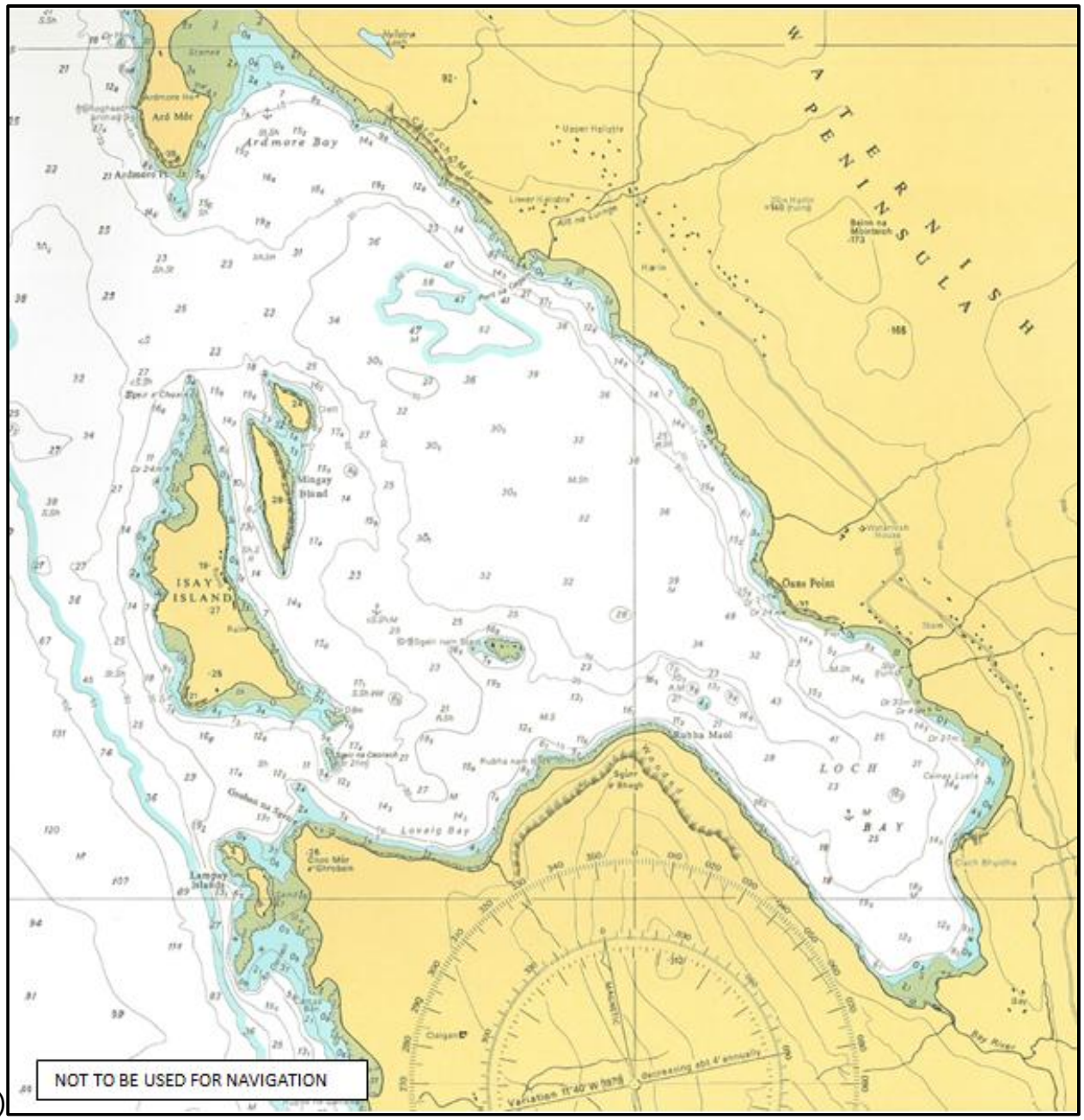
57° 30.40’ N 006° 34.60’ W
NG 25980 55526

Figure 13.1 Extent of hydrographic study area

13.1 Bathymetry and Hydrodynamics

13.1.1 Bathymetry

(a)



(b)

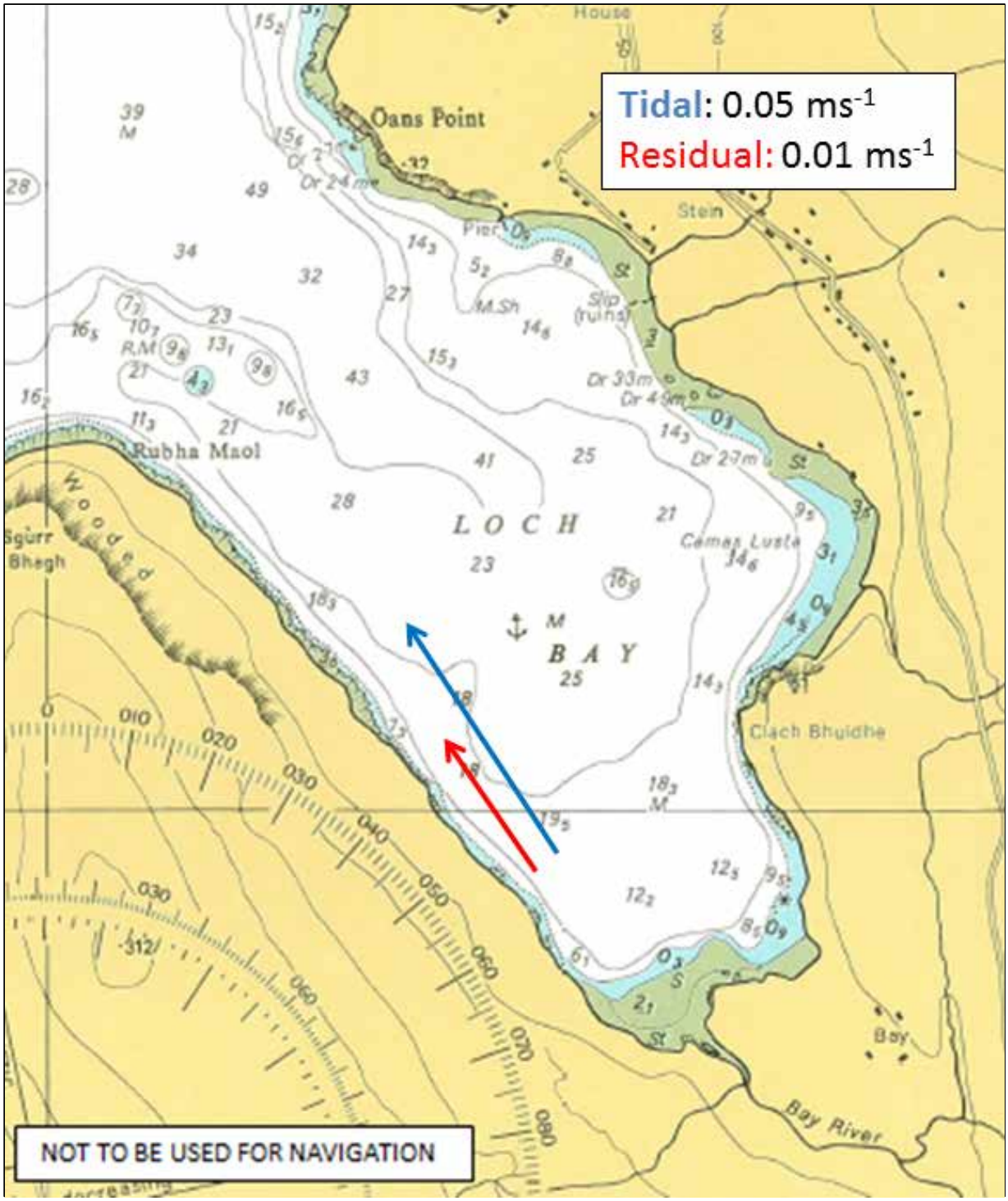


Figure 13.2 Admiralty chart (2533) extract for Loch Bay showing (a) the wider area to the west of Waternish Peninsula and (b) the detail of the study area. Net cumulative displacement by tidal flow (ebb) and the estimated cumulative displacement through residual flow over a full tidal cycle are shown.

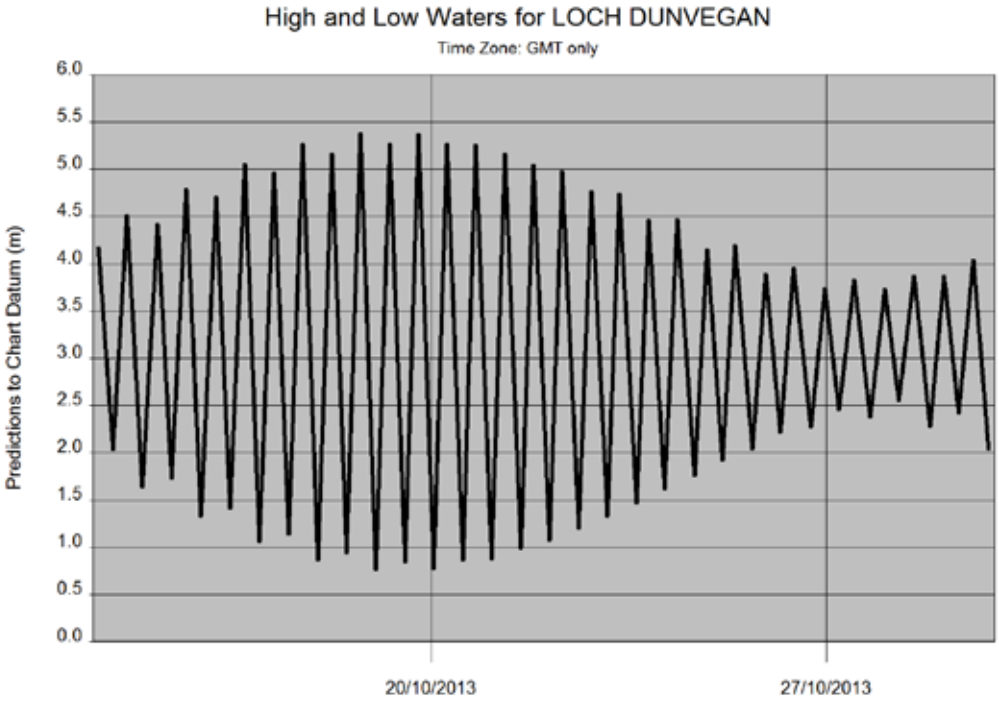
Figure 13.2(a) shows the bathymetry of Loch Bay and of the immediate vicinity. From Admiralty Chart 2533 we see that in this wider area, the maximum charted depth is 58 m, some 3 km to the northwest of the assessment area. The whole loch has a total length of 6.9 km and an average width of 2.25 km with an estimated mean low water depth of

23.4 m (Edwards & Sharples, 1986). Therefore the estimated low water volume is approximately 3.6 x 10^8 m^3. Loch Bay contains one sill which is located between Isay Island and Ard Mór at the mouth of the loch and has a length of 1944 m with a maximum depth of 26 m. The loch has relatively simple bathymetry with the exception of the islands at the mouth. The hydrographic study area consists of the southeast portion of the loch and is approximately 2.25 km in length and a maximum charted depth of 49 m near the outer limit of the assessment boundary. Again, the bathymetry in this portion of the loch is relatively simple with no significant bathymetric features. The southwestern shore is steep-sided whilst the head of the loch and the northeast shore have more extensive intertidal areas.

13.1.2 Tides

Loch Bay has a typical semi-diurnal tidal characteristic. Data on tidal information is given from charted information. The nearest location for tidal predictions is Loch Dunvegan, approximately 5 km from the middle of the assessment area [http://easytide.ukho.gov.uk].

Standard tidal data for Loch Dunvegan are given below (from Admiralty Surveys) and the spring/neap cycle of tidal height around the time of the planned survey (21 – 22 October 2013) is shown in figure 13.3:



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

Figure 13.3 Two week tidal curve for Loch Dunvegan.

Tidal Heights at Loch Dunvegan:

Mean High Water Springs = 5.2 m
Mean Low Water Springs = 0.7 m
Mean High Water Neaps = 3.8 m
Mean Low Water Neaps = 2.1 m

Tidal Ranges:

Mean Spring Range = 4.5 m
Mean Neap Range = 1.7 m

This gives the volume of water added to Loch Bay during each tidal cycle as being approximately:

Springs: 7.0×10^7 m^3
Neaps: 2.6×10^7 m^3

13.1.3 Tidal Streams and currents

There are no published tidal diamonds for this area. Enhancement of tidal flow caused by narrow straights and shallow channels is probably negligible for the assessment area but may be more important near the mouth of the loch, particularly in the vicinity of Isay Island, Mingay Island and Clett, and the channels between them.

Current meter data was available from SEPA for a previous survey in Loch Bay (Marine Harvest (Scotland) Ltd, 2006). Figure 13.4 shows the location of this site. The hydrographic survey spans 15 days; being the half-lunar period to capture a spring-neap cycle.

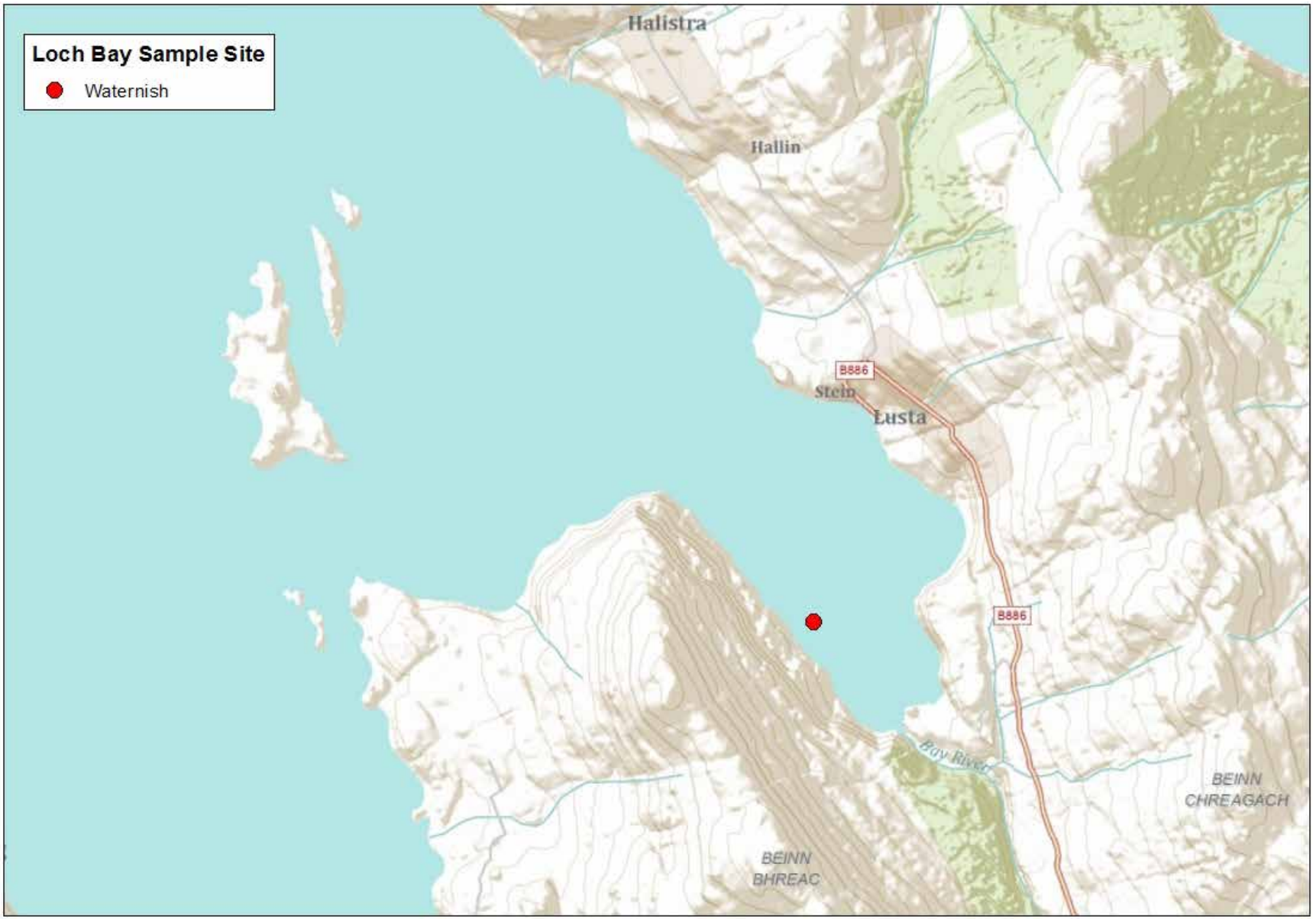


Figure 13.4 Map showing Loch Bay sample site.

Data from Waternish, Loch Bay were collected between 12 April and 1 May 2006 (Marine Harvest (Scotland) Ltd, 2006),and are summarised in Table 13.1. Semi-diurnal periodicity along with spring-neap variation in speed was displayed throughout the record. In general, the currents were of a moderate speed and whilst the tabulated mean speed was greatest in the sub-surface, the values were similar throughout all the depths. The tidal flow was aligned along the direction of the shore. Residual flows in the surface and mid water were approximately south with an order of magnitude smaller than the tidal flow. The wind statistics during the period confirm that there was a dominant wind from the northwest which would drive a southerly residual flow.

Table 13.1 Loch Bay current data measured in 2006

Height above seabed	Near-bed (3.7 m)	Mid (12.1 m)	Sub-surface (19.1 m)
Mean Speed (ms^{-1})	0.029	0.034	0.037
Principal Axis Amp (ms^{-1}) & Dir	0.057 (330°)	0.064 (330°)	0.054 (330°)
Residual speed (ms^{-1})	0.007	0.009	0.007
Residual direction (^{o}M)	060	178	176

Another data set from Loch Bay (no precise position data or depth available) was collected between 24 June and 10 July 1997 which is summarised in Table 13.2. In general, the mean current speed was less than that measured in 2006 but with similarities between the sub-surface and mid depth. The tidal component of the flow is a similar order of magnitude as 2006 (to be expected), though aligned to the NE. The residual speeds were small and directed north. It is likely the residual flow is driven by either freshwater or wind from the south.

Table 13.2 Loch Bay current data measured in 1997

Height above seabed	Near-bed	Mid	Sub-surface
Mean Speed (ms^{-1})	0.017	0.023	0.021
Principal Axis Amp (ms^{-1}) & Dir			0.04 (037°)
Residual speed (ms^{-1})			0.002
Residual direction (^{o}M)			000

Using a mean surface principal current amplitude of 0.05 m/s (derived from a mean of 0.058 m/s from Table 13.1 and the value of 0.04 m/s in Table 13.2) and the assumption of a uniform sinusoidal tide, the cumulative transport that might be expected during each phase of the tide (approximately 6 hours) has been estimated as approximately 700 m. 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 Bay. Without such data it is difficult to judge what the dispersive environment might be like. However, flow round the islands at the mouth of the loch might enhance dispersion.

Dispersion of surface contaminants may be enhanced by wave energy within Loch Bay. Sources of wave energy are from both short period waves that are created within the Bay itself and The Minch.

13.1.4 River/Freshwater Inflow

There are several rivers surrounding Loch Bay whose flow may vary depending on the season. The main watercourse is Bay River which is situated at the head of the loch. On the northeast shore the Lusta Burn and Stein Burn flow into the loch. However, these may or may not flow depending on the season. Just outside the study area, north of Oans Point, Allt Fasach flows into Loch Bay. There are other unnamed watercourses on the OS map which, again, may or may not flow depending on season.

The annual precipitation in the area is approximately 1800 mm and the annual freshwater runoff is estimated as 76 Mm^3yr^{-1} (Edwards & Sharples, 1986). This will likely have substantial seasonal variability.

13.1.5 Meteorology

Rainfall data were taken from Quidnish located in the Isle of Harris which is approximately 37 km to the north of Loch Bay and spanned the time frame from January 2007 – December 2012 (although 3 days of data are missing).

The year with the highest rainfall was 2007 and the least rain fell in 2010. In 2007, an unusual maximum of approximately 50 mm/d occurred but generally high rainfall values (>30 mm/d) were seen in all years. The highest daily rainfall values occurred throughout the autumn and winter seasons where rainfall increased from August onwards. The highest recorded rainfall was in October, November and January. Rainfall was lower in the months April to July. There was rainfall of >30 mm/d in February, May, August, November and December with the 2007 extreme rainfall event occurring in August. For the duration of the data set, daily rainfall of below 1 mm occurred 43% of the time and daily rainfall of above 10 mm occurred 12% of the time.

It can be surmised from these data that run-off due to rainfall is expected to be higher in the autumn and winter months but it must also be noted that high rainfall and consequently high run-off can occur in most months.

Data about wind conditions were collected from South Uist Range which is located 51 km west of Loch Bay. Due to the distance between the two areas, the wind rose statistics may not be directly transferrable to the specific production area in Loch Bay but they can be used to give a general pattern of the seasonal wind conditions in the northwest Inner Hebrides area. The data from South Uist Range shows that overall westerly winds and southerly winds were stronger than northerly or easterly winds. There is a predominant south-westerly airflow year round for the area. However,

north easterly winds were present during the spring and summer seasons. It is highly likely that the wind direction will be strongly influenced in Loch Bay by the morphology of the surrounding high ground.

13.1.6 Model Assessment

There is rather little data available for this location to prepare a refined, three-layer box model for Loch Bay. However, simple modelling techniques based on tidal prism methods (Edwards & Sharples, 1986) have been employed by others to establish flushing times (Marine Scotland, 2012). The flushing time was estimated at 3.7 days although this method is known to overestimate exchange and therefore under-predict flushing time (Gillibrand, et al., 2002). Further, there will be variations about this value due to wind forcing and freshwater flow.

13.2 Hydrographic Assessment

13.2.1 Surface flow

The site and meteorological data indicate that there is likely to be a well distributed freshwater discharge into the surface waters around the perimeter of the Loch Bay; though the distribution of fresh water sources is concentrated at the head of Loch Bay. The meteorological data indicate a moderate seasonal variation in freshwater discharge.

The loch is relatively small such that there is unlikely to be much variation in properties of flow across the loch. Further, it is rather a shallow loch with moderate tidal flow so is likely to be well mixed.

From the single current meter record it shows that on the west side of the assessment areas the tidal flow appears to be aligned with the shore. We anticipate that that the tidal flow would be similar on the east side, flowing into the loch on the flood and out of the loch on the ebb. The cumulative transport distance on each phase (flood/ebb) of the tide has been estimated at around 700m.

Surface flows would be enhanced/retarded by winds blowing out of/into the loch, as seen in some of the residual flows. Winds will also further enhance the mixing of the waters through the full depth. The topography of the land is likely to steer the wind along the axis of the Loch enhancing the in/out flow of surface waters.

From the rather limited current meter measurements in Loch Bay it is likely that any surface contaminant in the inner part of the loch would be transported primarily along the shoreline. Once beyond the entrance there is likely to be effective transport and dispersal into The Minch, except in periods of onshore winds.

Net transport of contaminants is related to the residual flow documented in Table 13.1 and 13.2. The residual surface flow measured in the surface waters of Loch Bay

is likely to be a weak flow out of the Bay in general, through the discharge of freshwater, but is seen to also respond to onshore winds. With the measured surface residual of order 0.01 m/s or less, the net transport over a tidal cycle of approximately 12 hours would be around 400 m. The implication is that the cumulative transport on the ebb is greater than on the flood phase of the tide.

13.2.2 Exchange Properties

The simple modelling study (Marine Scotland, 2012) indicates a flushing time for Loch Bay of 3.7 days. Given the volume of the loch and the relatively big tidal range, the exchange is likely to be dominated by the tidal volume flux meaning that the exchange of waters in Loch Bay is principally a tidally driven process. Hence there is likely to be rather little seasonal variation in the flushing time of the Loch.

One might describe the flushing characteristics of Loch Bay as being ‘well flushed’, with the potential for additional enhancement from the fresh water discharge and from winds. Effective vertical mixing in this shallow system and a relatively deep sill across the mouth means that subsurface exchange will probably have similar exchange characteristics as the surface water.

Although it would appear that Loch Bay is a simple tidal system, there is rather little current meter data available for Loch Bay and a paucity of any measured hydrographic data by which to check the assessment. Further, there is no published scientific literature for this location to aid the assessment. Therefore the confidence level of this assessment is LOW.

14. Shoreline Survey Overview

The shoreline survey at Loch Bay was carried out on the 21st and 22rd October 2013. No rainfall was recorded on the first day of the survey but intermittent heavy rainfall was recorded on the second survey day. Wind was F1-2 S/SE on the first day and F3-4 S/SE on the second day.

The fishery consists of a wild cockle bed in the area of sand and shingle at the mouth of the Bay River. At the time of the shoreline survey few adult sized cockles were noted in the areas sampled. The highest density of cockles was east of Bay River and the lowest density in the west and central parts of the bay.

Three shellfish samples were taken for testing; two east of the river mouth and one west. Due to a paucity of cockles, mussels were taken in place of cockles for two of the samples. The cockle sample and mussel samples (LBSF1 & LBSF2) taken east of the river both returned a result of <20 *E. coli* MPN/100 g. The mussel sample to the west (LBSF3) returned 50 *E. coli* MPN/100 g. A sea water sample (LBSW1), taken at the head of the loch, returned a value of 2 *E. coli* (cfu/100 ml).

The harvester (Mr Sturrock) advised the site has not been harvested for some time.

The majority of the human population is mainly located high along the eastern shore except at Camus Lusta and Stein where properties were found directly on the shore. A few houses are also located in Bay at the head of the loch. An inn is located at Stein and several bed and breakfast and self catering properties were found in Stein and Lusta. A manhole cover was noted above the shore in Stein and one possible discharge was noted further along to the north. A sample (LBFW8) taken from this discharge returned a value of 5000 *E. coli* (cfu/100ml). A sea water sample taken off Stein returned a value of 160 *E. coli* (cfu/100ml).

A public slipway is located at the village of Stein, with several small vessels stored at the top. Several moorings at were located off the slipway, with one small pleasure craft anchored.

At the head of the loch 10 cows and 20 sheep were noted and approximately 35 sheep were recorded in the fields above the eastern shore. Not all the land surrounding the survey route was visible to the surveyors, so the actual number of animals may have been greater. Land use around the loch wass split between forestry and crofting/small scale farming. Forestry was located on the bank of the River Bay and much of the land between the shore and road on the eastern shore is split into crofting land.

One large watercourse, Bay River, enters Loch bay. Several small streams and burns also feed into the loch. Freshwater contamination varied between <10 and 2400 *E. coli* (cfu/100ml)

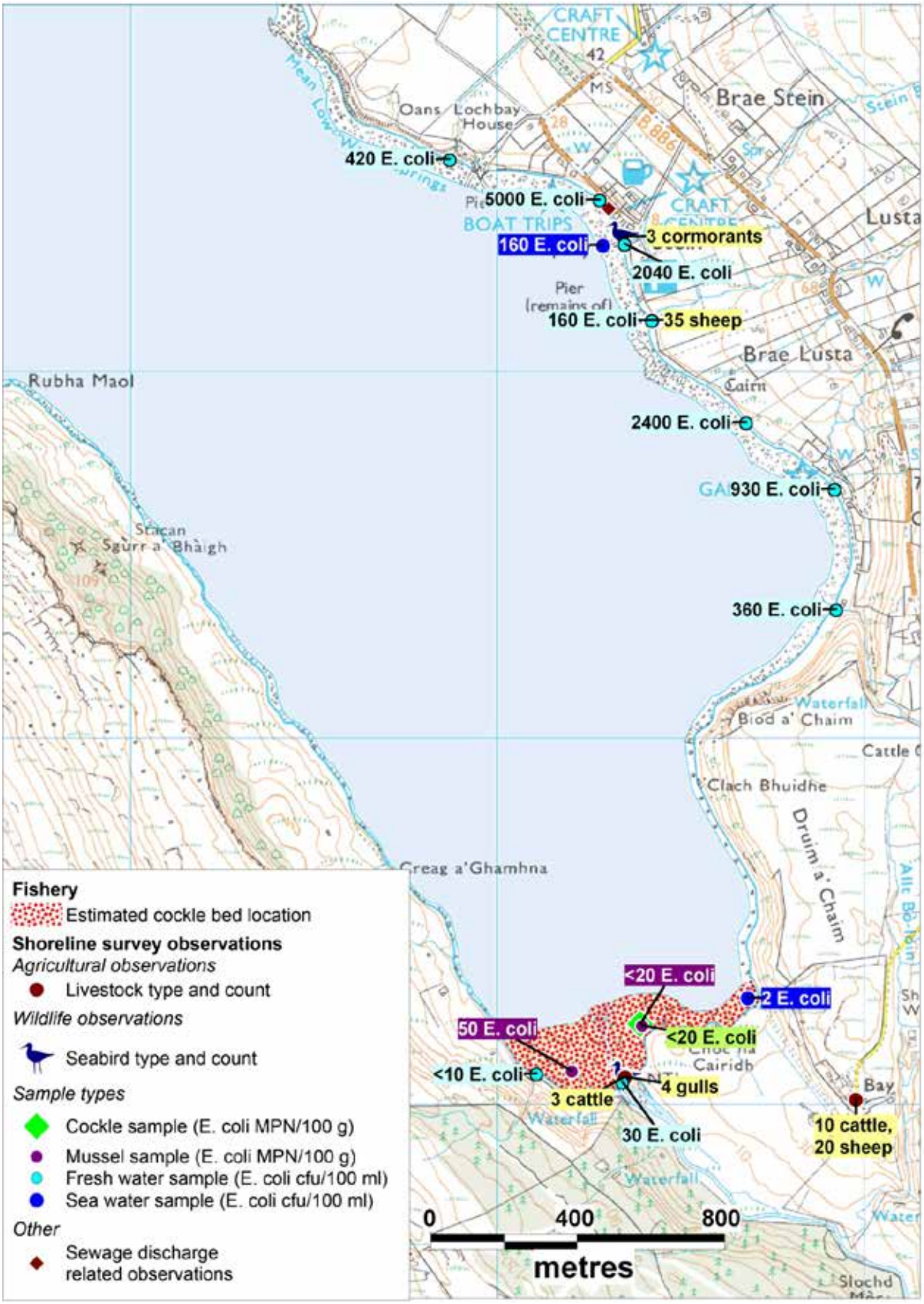


Figure 14.1 Map of shoreline survey observations at Loch Bay

15. Bacteriological Survey

As the area had significant monitoring history, and was reported to have low stock levels, no bacteriological survey was conducted.

16. Overall Assessment

Human sewage impacts

The human population around the shoreline at Loch Bay is limited to a farm near the head of the loch and dwellings associated with crofting townships along the east side of the loch. Facilities for tourists are present along the east side of the loch, and therefore seasonal variation in population is likely as visitor numbers augment the number of permanent residents during the tourist season from April to September.

All dwellings in the area are connected to private septic tanks except for four homes in the vicinity of Stein, which are connected to a Scottish Water WWTW. Although the large majority of septic tanks are reported to discharge to soakaway, there is the strong possibility that at least some may have been rerouted to watercourses. No discharges to sea were seen during the shoreline survey, which only covered the head of the loch and did not extend north of Stein. The majority of impact from human sewage from homes in the area will be from diffuse runoff or direct discharge to watercourses.

Yachts are likely to be present in the area, particularly during the summer cruising season. When in use, the anchorage identified at the head of the loch and visitor moorings at Stein may be significant sources of overboard sewage discharges. Though not directly over the cockle bed, effluent may be carried southward either on the tide or on wind-driven currents.

The highest risk of contamination to the fishery is from septic tank discharges and a trade discharge associated with a fleece processor at Stein. These lie over 1 km north of the fishery.

Agricultural impacts

Agricultural diffuse faecal contamination from sheep and cattle rearing is expected to be significant at the fishery. Improved pasture associated with the farm at Bay and crofts along the east shore of the loch are expected to contribute contaminated runoff during and after rainfall. No livestock were noted on the shoreline, and therefore rainfall runoff is likely the be the predominant transport mechanism for faecal contamination from livestock sources. Highest impacts are expected from improved pasture area near Bay, along the Bay River where any accumulated faecal contaminants would be carried across the centre of the cockle bed via the river. Crofting activities along the east shore around Stein would be expected to contribute to observed faecal indicator loadings in watercourses discharging along that area. Contaminants arising from these sources may be carried toward the cockle bed on the flood tide and could contribute to overall contamination levels there.

Wildlife impacts

Among species likely to contribute to faecal contamination at the fishery are seals, seabirds, wading birds, deer and otters. Little specific evidence was found regarding populations of these animals around the production area. Seabirds are known to breed on the islands in the outer loch, but not in very large numbers. Common seals breed in the area, but it is not known whether they access beach at the head of the loch. They are likely to forage within the loch for food, and therefore may contribute to background levels of faecal contamination within the loch in general. There is no known concentration of wildlife sources at or around the fishery. However, it is likely that watercourses will be likely to carry contamination from deer and other land mammals and therefore the Bay River may pick up contamination from these animals as it passes through suitable habitat upstream.

Seasonal variation

Tourism appeared to be significant in the area, with attractions and facilities for visitors found in and around Stein. A tour boat operator in Stein operates roughly from Easter to September, and elsewhere in Scotland peak season in terms of accomodation rates runs from April to October. Therefore, seasonal variation in human population is expected during this period.

Statistically significant seasonal variation was seen in shellfish hygiene monitoring results, with results highest during the summer and lowest in winter. A very sharp rise in *E. coli* results was seen between April and May, and then tailed off slowly over the remaining months of the year.

Seasonal variation is also expected in farming and farm animals, with lambs driving an increase in livestock numbers during the late spring and summer months.

Rivers and streams

Watercourses discharging below the crofted areas at Stein were found to carry moderate estimated *E. coli* loadings. It is not clear what proportion of faecal contamination is attributable to agricultural activities, however. The watercourses discharging to the head of the loch, which drain the catchment including the forested area and the farm at Bay, were found to carry the least *E. coli* of those watercourses sampled during the shoreline survey. The Bay River discharges across the centre of the cockle bed and therefore although it carried a moderate estimated loading it will directly impact at the cockle bed. The smaller, unnamed watercourse discharging to the west of the river had a much lower estimated loading and would impact most directly on the western end of the cockle bed. An area of land drainage on the east side of the cockle bed may be significant, particularly under heavier rainfall conditions, as this appeared to drain land on which three septic tanks were identified.

No correlations were found between rainfall and *E. coli* results, however the station from which rainfall data was obtained was a long distance from the fishery and therefore may not have accurately reflected rainfall levels within the catchment of the loch.

Movement of contaminants

Overall, the predicted transport distance for contaminants within the southeast section of the loch, where the fishery is located, is 700m or less. Therefore, it is likely that sources arising relatively near to the fishery are likely to have the greatest impact on contamination levels there. Contamination arising from the eastern shore is likely to be subject to significant dilution due to the depth of water in the vicinity. Distances between the sources along this shore and the cockle bed at the head of the loch exceed the predicted 700 m tidal excursion, suggesting that contaminants arising from these sources are not likely to significantly impact the shellfishery considering simple tidal movement only.

Temporal and geographical patterns of sampling results

There was, overall, an upward trend in sampling results over the period 2008 to 2013. The highest recorded sample results all occurred from 2010 onward. However, it should be noted that sampling effort also increased during this period and therefore it is possible that eposides of higher contamination are now being detected where there may have been missed in the past.

Most of the samples were recorded against two grid references, one of which was the RMP and the other a nearby point within 10 m of the RMP. The highest sample results were all recorded against these two locations. Few cockles were found away from these locations during the shoreline survey.

Conclusions

The fishery was reported to be largely inactive at the time of shoreline survey. Stock present did not appear sufficient to support commercial fishing, though small cockles were found.

The main sources of faecal contamination to the area are:

Diffuse contamination from livestock located around Bay and within the River Bay catchment.

Diffuse contamination from livestock and, potentially, human sources associated with crofts along the east shore at Stein.

Potential overboard discharges from boats using anchorages at the head of the loch and moorings at Stein.

Diffuse contamination from wildlife sources.

There was a strong association between historical *E. coli* results and season, which appeared to be consistent with predicted seasonal variation in human and livestock populations.

17. Recommendations

Production area

No material changes are recommended to the production area boundaries, which already exclude potential sources of faecal contamination to the NE of the cockle bed. It is recommended that the production area boundaries be specified to extend to MHWS, as this area would encompass the full extent of any cockle bed within it.

RMP

Based on the observed location of mature cockles during the shoreline survey, and the reported inactivity of the fishery, there does not appear to be reason to continue monitoring until such time as commercial interest in the fishery resumes. The current RMP is located where there are currently sufficient cockles, but also near the channel of the Bay River, and would be expected to adequately reflect the contamination status of the bed. Should FSAS wish to continue to monitor this site, no change is recommended to the RMP.

Frequency

Should classification monitoring continue, monthly sampling is recommended due to expected and observed seasonal variations in inputs and contamination levels.

Depth of sampling

Sampling depth is not applicable in this case.

Tolerance

A sampling tolerance of 50 m is considered adequate to allow for sufficient animals to be gathered for sampling purposes.

Figure 17.1 Map of recommendations at Loch Bay

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4. **Hydrographic Section Glossary**
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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 1.21×10^4 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 1.28×10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77×10^8 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 streams, 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

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}		

comparing base- and high-flow GMs for each group and type.

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

Table 3 – Geometric mean (GM) and 95% confidence intervals (CIs) of the GM faecal indicator organism (FIO) concentrations (cfu/100ml) 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)

Table 4 - Comparison of faecal indicator concentrations (average numbers/g wet weight) excreted in the faeces of warm-blooded animals

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

Source: (Gauthier & Bedard, 1986)

References

Gauthier, G. & Bedard, J., 1986. Assessment of faecal output in geese. *Journal of Applied Ecology,* 23(1), pp. 77-90.

Kay, D. et al., 2008a. Faecal indicator organism concentrations and catchment export coefficients in the UK. *Water Research,* 42(10/11), pp. 2649-2661.

Kay, D. et al., 2008b. Faecal indicator organism in concentration sewage and treated effluents. *Water Research,* 42(1/2), pp. 442-454.

3. Statistical Data

One-way ANOVA: LogEC versus Season

```
Source  DF      SS     MS     F      P
Season   3  12.375  4.125  6.74  0.001
Error   45  27.548  0.612
Total   48  39.922

S = 0.7824   R-Sq = 31.00%   R-Sq(adj) = 26.40%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev   -+---------+---------+---------+--------
1      14  2.0843  0.9476           (------*------)
2      13  2.9684  0.7449                      (------*-------)
3      11  2.5841  0.7791                 (-------*-------)
4      11  1.6215  0.5609   (-------*-------)
                           -+---------+---------+---------+--------
                          1.20      1.80      2.40      3.00

Pooled StDev = 0.7824

Grouping Information Using Tukey Method

Season   N    Mean  Grouping
2       13  2.9684  A
3       11  2.5841  A B
1       14  2.0843    B C
4       11  1.6215      C

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 = 98.94%


Season = 1 subtracted from:

Season    Lower   Center   Upper  --------+---------+---------+---------+-
2        0.0807   0.8841  1.6875                    (-----*------)
3       -0.3406   0.4998  1.3402                (------*------)
4       -1.3032  -0.4628  0.3776         (------*------)
                                --------+---------+---------+---------+-
                                     -1.2       0.0       1.2       2.4


Season = 2 subtracted from:

Season    Lower   Center    Upper  --------+---------+---------+---------+-
3       -1.2388  -0.3843   0.4702          (------*------)
4       -2.2013  -1.3469  -0.4924  (------*------)
                                  --------+---------+---------+---------+-
                                       -1.2       0.0       1.2       2.4


Season = 3 subtracted from:

Season    Lower   Center    Upper  --------+---------+---------+---------+-
4       -1.8520  -0.9626  -0.0732     (------*------)
                                  --------+---------+---------+---------+-
                                       -1.2       0.0       1.2       2.4
```

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 Neap, The highest level that tides reach on average during neap 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 Neap, The lowest level that tides reach on average during neap 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.

Neap 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 neap 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 Bay (Skye) Shoreline Survey Report
Project Name	Shellfish Sanitary Surveys
Client/Customer	Cefas
SRSL Project Reference	00561_B0067

Document Number	B0067_Shoreline 0023

Revision History

Revision	Changes	Date
A	Issue for internal review	28/10/2013
01	First formal issue to Cefas	31/10/2013

	Name & Position	Date
Author	Lars Brunner & Eilidh Cole	23/10/2013
Checked	Andrea Veszelovszki, John Hausrath	29/10/2013
Approved	Andrea Veszelovszki	31/10/2013

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Shoreline Survey Report

Production area: Loch Bay

Site name: Loch Bay

SIN: SL-117-275-04

Species: Common cockle

Harvester: Mr Andrew Sturrock

Local Authority: Highland Council: Skye & Lochalsh

Status: Existing site

Date Surveyed: 21st & 22nd October 2013

Surveyed by: Eilidh Cole, Lars Brunner

Existing RMP: NG 2637 5410

Area Surveyed:

Section 1: The southernmost part of Loch Bay, covering an area to the immediate E & W of the discharge of the Bay River.

Section 2: An area of the E shoreline of the bay, extending from south of Camuslusta to immediately NW of the village of Stein.

19.1.1 Weather

21st October: 15% cloud cover, wind S/SE, f1-2. Sea state calm. Good visibility, weather sunny.

22nd October: 100% cloud cover, wind S/SE, f3-4, occasionally gusting. Sea state slight. Poor visibility, intermittent heavy showers through the day.

19.1.2 Stakeholder engagement during the survey

It was not possible to meet with the harvester, Mr Andrew Sturrock, on either of the survey days due to other commitments that he had, although he provided information prior to the survey that is included in the Fishery section below.

Contact was also made with Mr Stephen Cox and Mr Allan MacDonald, the sampling officers for Highland Council, prior to the survey. He was not able to meet us on either of the survey days due to prior commitments, but provided helpful information which is included in the fishery section below.

19.1.3 Fishery

The Loch Bay fishery consists of hand harvest of common Cockles (*Cerastoderma edule)* from the area of sand and shingle around the mouth of the Bay River at the south end of Loch Bay. No fixed facilities for harvest handling (i.e. shore base or storage facilities) were noted during the survey.

From observation while on survey, there were few adult size cockles present in the areas sampled. There were some smaller cockles (sub 1cm diameter), and several dead, whole shells contained within the sand. The numbers of cockles seemed at their lowest on the west and central parts of the bay, with the highest quantities seen in the area to the east of the Bay River, where a sample was obtained.

Mr Andrew Sturrock, the harvester, contacted the team prior to the survey, where he stated that the site had been out of use for some time, and had not been actively worked. He also stated that there were few cockles present, and those that were present were of a small size.

Mr Stephen Cox, the sampling officer for Highland Council, indicated that there had been no commercial harvest on site during 2013, and reiterated what the harvester had told us about the low numbers of cockles present on site.

19.1.4 Sewage Sources

Most of the population around Loch Bay is found on its eastern shore. The houses present form a typical township layout, with individual houses surrounded by small areas of crofting land. There is no population on the western shore, and a few isolated houses in Bay, which sits above the southern shore of the loch.

The majority of housing sits high above the shore, the exception being small areas of southern Camuslusta and Stein, where property sits adjacent to the shore. In Stein manhole covers were noted in the grass above the shoreline but only one discharge pipe was noted on the shore. Farming is undertaken in the survey area, but no other industry was noted. No public toilets were seen in the survey area.

19.1.5 Seasonal Population

No campsites or caravan parks were noted in the survey area. There is an inn in the village of Stein, and several B&Bs and self-catering properties in Stein and Lusta.

19.1.6 Boats/Shipping

There is a slipway available for public use in the village of Stein, with a collection of small vessels (dinghy, canoe and pleasure craft) stored at the top of the slipway. There were a total of 11 moorings off the public slipway, with one small pleasure craft at mooring.

One small dinghy was noted stored at the top of the beach below the village of Bay (NG 26693 54239) and there were small personal craft stored at several locations along the survey path on the eastern shore. No fishing vessels were noted in the loch.

Farming and Livestock

Livestock were noted in the fields above the production area at the head of the Loch (10 cows & 20 sheep in total – although noted in two different waypoints (7&16), they are the same animals), and in the fields above the survey route on the eastern shore of the loch (approx. 35 sheep). It was not possible to view other areas of land above the shoreline clearly, so this may be an underestimate of the total number of animals present.

19.1.7 Land Use

Land use around Loch Bay is entirely rural in nature and is split between forestry and crofting/small scale farming. There is an area of plantation forestry in the bank of the Bay River at the south of the bay, and much of the land between the shoreline and B886 road is split into grazing plots of a size and style consistent with crofting.

Land Cover

On the western side of Loch Bay, the land cover is wild with heath, scrub trees and moorland. The area to the south around Bay River comprises plantation spruce forestry to the west of the river, with a mix of agricultural grazing and unimproved land to the east. The eastern side of Loch Bay consists of crofts running from the road to the shore, with small areas of shrub wood on steep slopes to the south and north of the survey route.

Watercourses

The major watercourse encountered on the survey was Bay River, which discharges at NG 2634 5409. Several smaller streams were encountered, the largest of which was the Lusta Burn (NG 2643 5613) and the Allt a Chaim discharging at NG 2693 5534.

19.1.8 Wildlife/Birds

Few birds were seen on survey, with 4 gulls observed at the mouth of the Bay River and 3 cormorants seen on the second day of survey. No other wildlife was observed on the survey.

Shoreline Survey Maps

Figure 1. Loch Bay waypoints

Figure 2. Loch Bay samples

Table 1 Shoreline Observations – Link your notes to GPS points and add to table below

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	21/10/2013	15:08	NG 26684 54291	126685	854292			Start of survey day one.
2	21/10/2013	15:14	NG 26683 54293	126684	854293	Figure 3	LBSW1	Seawater sample from the head of Loch Bay on the east shore.
3	21/10/2013	15:15	NG 26669 54285	126670	854285			East beach of the head of Loch Bay, very shingly and no evidence of cockles present. No cockle shells present either. Attempted shellfish sample but none collected as no cockles found. Freshwater discharge on lower beach but not sampled as too shallow and appears to be just run-off.
4	21/10/2013	15:18	NG 26661 54273	126662	854273	Figure 4		Rigid Inflatable Boat (RIB) on upper shore.
5	21/10/2013	16:12	NG 26390 54221	126391	854221		LBSF1	Cockle sample. Cockles were very difficult to find and those that were found were predominantly small.
6	21/10/2013	16:13	NG 26395 54216	126396	854216	Figure 5	LBSF2	Extra shellfish sample taken from shore mussels as cockles very small and sparse. This was taken in case cockle sample was insufficient. Mussels were plentiful.
7	21/10/2013	16:22	NG 26348 54076	126348	854077	Figure 6		Attempted search for cockles at mouth of river. None found. Four seagulls on shore. Three cows on grassland above shore.
8	21/10/2013	16:24	NG 26360 54088	126361	854088			Attempted search for cockles. None found.
9	21/10/2013	16:27	NG 26341 54062	126341	854063		LBFW1	Planned freshwater sample from Bay River at head of Loch Bay. Sample associated with waypoint 10.
10	21/10/2013	16:31	NG 26340 54064	126340	854065			Watercourse Width - 4.23 m. East shore measurements: Depth - 21 cm; Flow - 0.291 m/s; SD - 0.010. West shore measurements: Depth - 25 cm; Flow - 0.120 m/s; SD - 0.008.
11	21/10/2013	16:43	NG 26318 54140	126318	854140	Figure 7		Site of attempted cockles search (20 mins). No cockles found.
12	21/10/2013	16:46	NG 26346 54073	126346	854073			Site of attempted cockles search. No cockles found.
13	21/10/2013	17:01	NG 26203 54092	126204	854092		LBSF3	Mussel sample taken in absence of cockle samples on west shore of Loch Bay.
14	21/10/2013	17:09	NG 26107 54085	126107	854085		LBFW2	Planned freshwater sample from unnamed river. Sample Associated with waypoint 15.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
15	21/10/2013	17:10	NG 26104 54081	126105	854082			River measurements: Width - 60 cm; Depth - 15 cm; Flow - 0.085 m/s; SD - 0.022.
16	21/10/2013	17:30	NG 26976 54015	126977	854015			Houses above bay. Five houses altogether with sheepfold and some small sheds/agricultural buildings. Ten cows and twenty sheep present in fields immediately below village. No septic tanks or discharge pipes were seen in immediate area. End of survey day 1.
17	22/10/2013	10:55	NG 26924 55351	126925	855351	Figure 8	LBFW3	Start of survey day 2. Planned freshwater sample taken from river (Allt a' Chaim) running next to house. Sample associated with waypoint 18.
18	22/10/2013	10:56	NG 26922 55353	126923	855354			Allt a' Chaim river measurements: Width - 1 m; Depth - 16 cm; Flow - 1.633 m/s; SD - 0.077. River runs next to house on shore. No pipes visible.
19	22/10/2013	11:02	NG 26936 55404	126936	855404	Figure 9		Boat above shore and one mooring in bay.
20	22/10/2013	11:07	NG 26963 55461	126963	855461			Stream running down from hillside, not sampled as hillside clear of housing and livestock and the property next to watercourse had no pipe running into it.
21	22/10/2013	11:11	NG 26956 55598	126956	855598			Very shallow ground drainage running from hillside, not sampled.
22	22/10/2013	11:14	NG 26920 55679	126921	855680	Figure 10	LBFW4	Planned freshwater sample from unnamed burn. Sample associated with waypoint 23.
23	22/10/2013	11:14	NG 26917 55676	126918	855677			Burn measurements: Width - 80 cm; Depth - 12 cm; Flow - 1.307 m/s; SD - 0.025. Houses adjacent to burn, no pipes visible on foreshore. No birds or wildlife.
24	22/10/2013	11:27	NG 26678 55861	126678	855861		LBFW5	Planned freshwater sample from small unnamed burn running off hillside. Sample associated with waypoint 25.
25	22/10/2013	11:39	NG 26675 55861	126676	855862			Burn measurements: Width - 75 cm; Depth - 7 cm; Flow - 0.469 m/s; SD - 0.012.
26	22/10/2013	11:49	NG 26422 56140	126422	856140		LBFW6	Planned freshwater sample from Lusta Burn. Sample associated with waypoint 27.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
27	22/10/2013	11:50	NG 26422 56140	126422	856140	Figure 11		Lusta Burn measurements: Width - 1.11m; Depth - 50 cm; Flow - 0.238 m/s; SD - 0.013. Approximately thirty five sheep in field immediately above burn.
28	22/10/2013	12:00	NG 26347 56348	126348	856348	Figure 12	LBFW7	Unplanned freshwater sample from Stein Burn, taken due to proximity of houses and livestock in fields above. Sample associated with waypoint 29.
29	22/10/2013	12:00	NG 26345 56345	126345	856345			Stein Burn measurements: Width - 1.9 m; Depth - 14 cm; Flow - 0.566 m/s; SD - 0.018.
30	22/10/2013	12:06	NG 26288 56345	126288	856346		LBSW2	Planned seawater sample taken from end of slipway.
31	22/10/2013	12:10	NG 26341 56367	126341	856368	Figure 13		Eleven moorings in bay, access to slipway, one pleasure craft moored, twelve smaller vessels on shore. Three cormorants on mooring buoys.
32	22/10/2013	12:15	NG 26303 56445	126304	856445	Figure 14		Manhole cover above shore, below Stein Inn. No discharges onto shore below.
33	22/10/2013	12:19	NG 26279 56469	126279	856469	Figure 15	LBFW8	Unplanned freshwater sample taken from 10cm UPVC pipe draining onto foreshore (contaminated). 15 ml / sec flow estimate, measured by vial and timer. Village on shore behind this pipe.
34	22/10/2013	12:22	NG 26264 56480	126265	856480			Water running under road and then as a trickle over shore, not sampled.
35	22/10/2013	12:30	NG 26005 56535	126005	856536	Figure 16		Three cm diameter blue plastic pipe running from above shore into water. Runs at least 20 - 30 m offshore under the sea. Not sampled as too far out to sea to access.
36	22/10/2013	12:36	NG 25871 56579	125871	856579	Figure 17	LBFW9	Planned freshwater sample from unnamed burn. Sample associated with waypoint 37.
37	22/10/2013	12:36	NG 25871 56579	125871	856579			Burn measurements: Width - 1 m; Depth - 15 cm; Flow - 0.773 m/s; SD - 0.013.
38	22/10/2013	12:39	NG 25862 56578	125863	856579			End of survey.

Sampling

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

All samples were transferred to Biotherm 10 or Biotherm 30 boxes with ice packs and posted to Glasgow Scientific Services (GSS) for *E. coli* analysis. All samples were received and analysed two days after sample collection. A forty eight hour extension was granted due to the time of low tide being too late in the day to meet the post office deadline for next day delivery. The sample temperatures on arrival to the laboratory ranged between 1.8˚C and 5˚C.

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

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

One cockle sample was collected by the survey team from the shore at the head of Loch Bay during low tide. As stated in the observation table above, cockles were extremely sparse and the majority of cockles that were found were predominantly small. Therefore it was only possible to take one cockle sample instead of the planned three. Due to the scarcity of cockles, two common mussel samples were also collected. These were taken from rocks on the shore at the east and west side of the head of Loch Bay as illustrated in Figure 2.

LBFW7 was an extra sample acquired which was not on the sample plan. It was taken from an Stein Burn and was sampled due to the proximity of houses and livestock in fields above. LBFW8 was also an extra, unplanned sample and was taken from a discharging pipe which had several houses behind it and was therefore classified as 'contaminated'.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	21/10/2013	LBSW1	NG 26683 54293	Seawater	2	33.06
2	22/10/2013	LBSW2	NG 26288 56345	Seawater	160	23.67
3	21/10/2013	LBFW1	NG 26341 54062	Freshwater	30	-
4	21/10/2013	LBFW2	NG 26107 54085	Freshwater	<10	-
5	22/10/2013	LBFW3	NG 26924 55351	Freshwater	360	-
6	22/10/2013	LBFW4	NG 26920 55679	Freshwater	930	-
7	22/10/2013	LBFW5	NG 26678 55861	Freshwater	2400	-
8	22/10/2013	LBFW6	NG 26422 56140	Freshwater	160	-
9	22/10/2013	LBFW7	NG 26347 56348	Freshwater	2040	-
10	22/10/2013	LBFW8	NG 26279 56469	Freshwater	5000	-
11	22/10/2013	LBFW9	NG 25871 56579	Freshwater	420	-

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (MPN/100g)
1	21/10/2013	LBSF1	NG 26390 54221	Cockles	<20
2	21/10/2013	LBSF2	NG 26395 54216	Mussels	<20
3	21/10/2013	LBSF3	NG 26203 54092	Mussels	50

Photographs

Figure 3. Seawater sample LBSW1 from the head of Loch Bay on the east shore. Associated with waypoint 2.

Figure 4. Inflatable RIB on upper shore. Associated with waypoint 4.

Figure 5. Extra shellfish sample LBSF2 taken from shore mussels as cockles were very small and sparse. Associated with waypoint 6.

Figure 6. Site of attempted search for cockles at mouth of river. Associated with waypoint 7.

Figure 7. Site of attempted search for cockles. Associated with waypoint 11.

Figure 8. Planned freshwater sample LBFW3 taken from river (Allt a' Chaim) running next to house. Associated with waypoint 17.

Figure 9. One mooring in bay. Associated with waypoint 19.

Figure 10. Planned freshwater sample LBFW 4 from unnamed burn. Associated with waypoint 22.

Figure 11. Approximately thirty five sheep in field immediately above Lusta Burn. Associated with waypoint 27.

Figure 12. Unplanned freshwater sample LBFW7 from Stein Burn. Associated with waypoint 28.

Figure 13. Eleven moorings in bay, access to slipway, one pleasure craft moored, twelve smaller vessels on shore. Associated with waypoint 31.

Figure 14. Manhole cover above shore, below Stein Inn. No discharges onto shore below. Associated with waypoint 32.

Figure 15. Unplanned freshwater sample LBFW 8 taken from 10cm UPVC pipe draining onto foreshore (contaminated). Associated with waypoint 33.

Figure 16. Three centimetre diameter blue plastic pipe running from above shore into water. Associated with waypoint 35.

Figure 17. Planned freshwater sample LBFW9 from unnamed burn. Associated with waypoint 36.

6. Consented discharges for Loch Bay area (SEPA)

No.	Licence No.	NGR	Effluent type	Treatment level	Discharges to	PE
1	CAR/L/1002091	NG 2585 5650	Tannery Effluent	N/A	Loch Bay	-
2	CAR/L/1002357	NG 2540 5550	MCFF	N/A	-	-
3	CAR/R/1008953	NG 2570 5843	Sewage effluent	Primary	Soakaway	5
4	CAR/R/1009259	NG 2620 5640	Sewage effluent	Primary	Soakaway	5
5	CAR/R/1010686	NG 2345 6105	Sewage effluent	Primary	Soakaway	5
6	CAR/R/1012115	NG 2689 5632	Sewage effluent	Primary	Soakaway	6
7	CAR/R/1015095	NG 2635 5645	Sewage effluent	Primary	Soakaway	5
8	CAR/R/1018733	NG 2485 5938	Sewage effluent	Primary	Allt na Luinge	6
9	CAR/R/1019768	NG 2715 5527	Sewage effluent	Primary	Soakaway	5
10	CAR/R/1021824	NG 2634 5681	Sewage effluent	Primary	Soakaway	10
11	CAR/R/1025497	NG 2481 5945	Sewage effluent	Primary	Soakaway	5
12	CAR/R/1036203	NG 2720 5526	Sewage effluent	Primary	Soakaway	8
13	CAR/R/1036566	NG 2715 5528	Sewage effluent	Secondary	U/T Allt a Chaim	6
14	CAR/R/1037126	NG 2609 5666	Sewage effluent	Primary	Soakaway	5
15	CAR/R/1037571	NG 2506 5860	Sewage effluent	Secondary	U/W	6
16	CAR/R/1038303	NG 2541 5872	Sewage effluent	Primary	Soakaway	5
17	CAR/R/1040484	NG 2396 5935	Sewage effluent	Primary	Soakaway	5
18	CAR/R/1042998	NG 2489 5906	Sewage effluent	Primary	Soakaway	5
19	CAR/R/1043352	NG 2404 5927	Sewage effluent	Primary	Soakaway	5
20	CAR/R/1045161	NG 2252 6085	Sewage effluent	Primary	Soakaway	8
21	CAR/R/1045867	NG 2398 5994	Sewage effluent	Primary	Soakaway	5
22	CAR/R/1045917	NG 2430 5935	Sewage effluent	Primary	Soakaway	5
23	CAR/R/1045918	NG 2435 5944	Sewage effluent	Primary	Soakaway	5
24	CAR/R/1046471	NG 2496 5901	Sewage effluent	Primary	Soakaway	5
25	CAR/R/1047983	NG 2688 5621	Sewage effluent	Primary	Soakaway	5
26	CAR/R/1048698	NG 2673 5648	Sewage effluent	Primary	Soakaway	5
27	CAR/R/1048865	NG 2502 5914	Sewage effluent	Primary	Soakaway	5
28	CAR/R/1049900	NG 2632 5647	Sewage effluent	Primary	Soakaway	5
29	CAR/R/1050235	NG 2684 5632	Sewage effluent	Primary	Soakaway	5
30	CAR/R/1051051	NG 2626 5656	Sewage effluent	Primary	Soakaway	10
31	CAR/R/1053530	NG 2399 5923	Sewage effluent	Primary	Soakaway	5
32	CAR/R/1055006	NG 2691 5394	Sewage effluent	Primary	Soakaway	5
33	CAR/R/1063325	NG 2710 5535	Sewage effluent	Secondary	Soakaway	10
34	CAR/R/1064446	NG 2285 6150	Sewage effluent	Primary	Soakaway	5
35	CAR/R/1064562	NG 2448 5967	Sewage effluent	Primary	Soakaway	10
36	CAR/R/1064655	NG 2443 5973	Sewage effluent	Primary	Soakaway	5
37	CAR/R/1064933	NG 2443 5973	Sewage effluent	Primary	Soakaway	5
38	CAR/R/1065361	NG 2463 5951	Sewage effluent	Primary	Soakaway	5
39	CAR/R/1067164	NG 2692 5623	Sewage effluent	Primary	Soakaway	5
40	CAR/R/1067456	NG 2622 5680	Sewage effluent	Primary	Soakaway	5
41	CAR/R/1067487	NG 2618 5737	Sewage effluent	Primary	Soakaway	5
42	CAR/R/1067490	NG 2597 5712	Sewage effluent	Primary	Soakaway	5
43	CAR/R/1068595	NG 2686 5638	Sewage effluent	Primary	Soakaway	5
44	CAR/R/1068823	NG 2299 6157	Sewage effluent	Primary	Soakaway	8
45	CAR/R/1069346	NG 2695 5610	Sewage effluent	Primary	Soakaway	5
46	CAR/R/1069527	NG 2500 5919	Sewage effluent	Primary	Soakaway	6

No.	Licence No.	NGR	Effluent type	Treatment level	Discharges to	PE
47	CAR/R/1069801	NG 2538 5879	Sewage effluent	Primary	U/T of Loch Dunvegan	6
48	CAR/R/1071466	NG 2638 5641	Sewage effluent	Primary	Loch Bay	11
49	CAR/R/1071539	NG 2632 5642	Sewage effluent	Primary	Loch Bay	5
50	CAR/R/1071571	NG 2635 5643	Sewage effluent	Primary	Loch Bay	5
51	CAR/R/1072689	NG 2432 5981	Sewage effluent	Primary	Soakaway	5
52	CAR/R/1074851	NG 2666 5666	Sewage effluent	Primary	Soakaway	5
53	CAR/R/1076210	NG 2713 5528	Sewage effluent	Primary	Soakaway	6
54	CAR/R/1076536	NG 2670 5652	Sewage effluent	Primary	Soakaway	5
55	CAR/R/1076797	NG 2321 6124	Sewage effluent	Primary	Soakaway	5
56	CAR/R/1076799	NG 2251 6093	Sewage effluent	Primary	Soakaway	7
57	CAR/R/1076834	NG 2711 5591	Sewage effluent	Primary	Soakaway	10
58	CAR/R/1076948	NG 2690 5574	Sewage effluent	Primary	Soakaway	5
59	CAR/R/1077001	NG 2651 5680	Sewage effluent	Primary	Soakaway	6
60	CAR/R/1077019	NG 2274 6160	Sewage effluent	Primary	Soakaway	5
61	CAR/R/1077084	NG 2675 5641	Sewage effluent	Primary	Soakaway	5
62	CAR/R/1077130	NG 2517 5910	Sewage effluent	Primary	Soakaway	5
63	CAR/R/1077290	NG 2444 5974	Sewage effluent	Primary	Soakaway	5
64	CAR/R/1077299	NG 2621 5654	Sewage effluent	Primary	Soakaway	11
65	CAR/R/1077777	NG 2681 5633	Sewage effluent	Primary	Soakaway	5
66	CAR/R/1077878	NG 2640 5650	Sewage effluent	Primary	Soakaway	5
67	CAR/R/1078017	NG 2707 5602	Sewage effluent	Primary	Soakaway	5
68	CAR/R/1078019	NG 2626 5657	Sewage effluent	Primary	Soakaway	5
69	CAR/R/1078095	NG 2686 5401	Sewage effluent	Primary	Soakaway	5
70	CAR/R/1078549	NG 2670 5645	Sewage effluent	Primary	Soakaway	5
71	CAR/R/1078588	NG 2665 5654	Sewage effluent	Primary	Soakaway	5
72	CAR/R/1078736	NG 2535 5883	Sewage effluent	Primary	Soakaway	5
73	CAR/R/1079018	NG 2450 5940	Sewage effluent	Primary	Soakaway	5
74	CAR/R/1079408	NG 2687 5410	Sewage effluent	Primary	Soakaway	5
75	CAR/R/1079715	NG 2331 6103	Sewage effluent	Primary	Soakaway	5
76	CAR/R/1088457	NG 2726 5502	Sewage effluent	Secondary	Soakaway	5
77	CAR/R/1090473	NG 2539 5855	Sewage effluent	Primary	Soakaway	12
78	CAR/R/1090480	NG 2513 5872	Sewage effluent	Primary	Soakaway	12
79	CAR/R/1091118	NG 2373 6010	Sewage effluent	Primary	U/W	5
80	CAR/R/1093606	NG 2404 5910	Sewage effluent	Secondary	Loch Bay	6
81	CAR/R/1098578	NG 2544 5874	Sewage effluent	Primary	Soakaway	5
82	CAR/R/1100140	NG 2379 6009	Sewage effluent	Primary	Soakaway	5
83	CAR/R/1101995	NG 2265 6072	Sewage effluent	Primary	Soakaway	8
84	CAR/R/1114881	NG 2713 5566	Sewage effluent	Secondary	U/W	6
85	I/B10/128/94	NG 263 572	Sewage effluent	Package plant (un-specified)	U/W	10

- No data provided; PE= Population Equivalent; DWF=Dry Weather Flow; MCFF=Marine Cage Fish Farm; U/T=unnamed tributary; U/W=unnamed watercourse