Scottish Sanitary Survey Report

Sanitary Survey Report
Loch Kishorn
RC 329
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Cefas

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Report Distribution – Loch Kishorn

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Partner Organisations

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

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Appendices

I. Executive Summary

A sanitary survey was undertaken at Loch Kishorn in accordance with requirements for completion of sanitary surveys under Regulation (EC) No. 854/2004. Loch Kishorn was selected for survey at this time due to its position in a risk-based ranking of production areas that had not yet been surveyed.

Loch Kishorn is located in a relatively remote and rugged area on the northwest coast of Scotland, east of the Isle of Skye. Pacific oysters are farmed on trestles at the mouth of the River Kishorn estuary, which extends northward from the head of Loch Kishorn. At the time of survey, only a small number of trestles were in use though the harvester had plans to renew and restock the site. Although the area is classified for common mussels, no active production of this species was found at the time of survey.

The main potential sources of faecal contamination to the fishery are from diffuse source contamination from livestock and wildlife and human sewage contamination arising from Kishorn WWTW and other private septic systems associated with settlements southeast of the oyster farm.

Diffuse contamination from livestock and wildlife, as well as any emergency overflows from Kishorn Courthill pumping station, will be carried down the estuary by flow from the River Kishorn and the outgoing tide. Contamination arising from the settlements along the north shore of Loch Kishorn, including sewage effluent from the tertiary treatment works and other septic discharges, would be expected to travel mainly northwestward and across the mouth of the estuary.

Analysis of monitoring results shows a strong seasonal tendency to higher results in summer, with highest results occurring in July and August. Peak results exceeding 1000 *E. coli* MPN/100 g mainly occurred from June to September. No results exceeding this level have occurred since August 2011. No statistically significant correlation was found between recorded rainfall at the nearest Meteorological Office station and *E. coli* results at Loch Kishorn.

It is recommended that the production area boundaries by curtailed to exclude the northern part of the estuary and the Kishorn Courthill pumping station emergency overflow. The RMP should be located along the southern end of the oyster farm, high enough on the shoreline to allow monthly access for sampling. Further details on the sampling plan and recommended boundaries can be found in tabular form overleaf and on Page 72.

II. Sampling Plan & Recommended Boundaries

Production Area	Loch Kishorn North Oysters
Site Name	Loch Kishorn
SIN	RC-329-254-13
Species	Pacific oyster
Type of Fishery	Aquaculture - trestle
NGR of RMP	NG 8283 4025
East	182830
North	840250
Tolerance (m)	10
Depth (m)	NA
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	Highland – Ross & Cromarty
Authorised Sampler(s)	Hamish Spence Bill Steven
Recommended Production Area	Area bounded by lines drawn between NG 8241 4065 and NG 8301 4065 and between NG 8301 4044 and NG 8294 4022 and between NG 8293 4011 and NG 8231 4000 and between NG 8234 4027 and NG 8233 4047 extending to MHWS

III. Report

1. General Description

Loch Kishorn is a relatively short (4.1 km) south westerly facing loch which opens directly into Loch Carron, on the west coast of Scotland, east of the Isle of Skye. The area surrounding the loch is rugged, mountainous and remote, with the small settlements of Kishorn and Achintraid at the head of the loch, and the village of Lochcarron further to the east.

Pacific oysters are cultivated at the mouth of the River Kishorn estuary, which drains into the loch's north east corner and is around 1 km at its maximum width.

Loch Kishorn was selected for survey at this time due to its position in a risk-based ranking of production areas that had not yet been surveyed. The general location of the survey area is shown in Figure 1.1 overleaf.

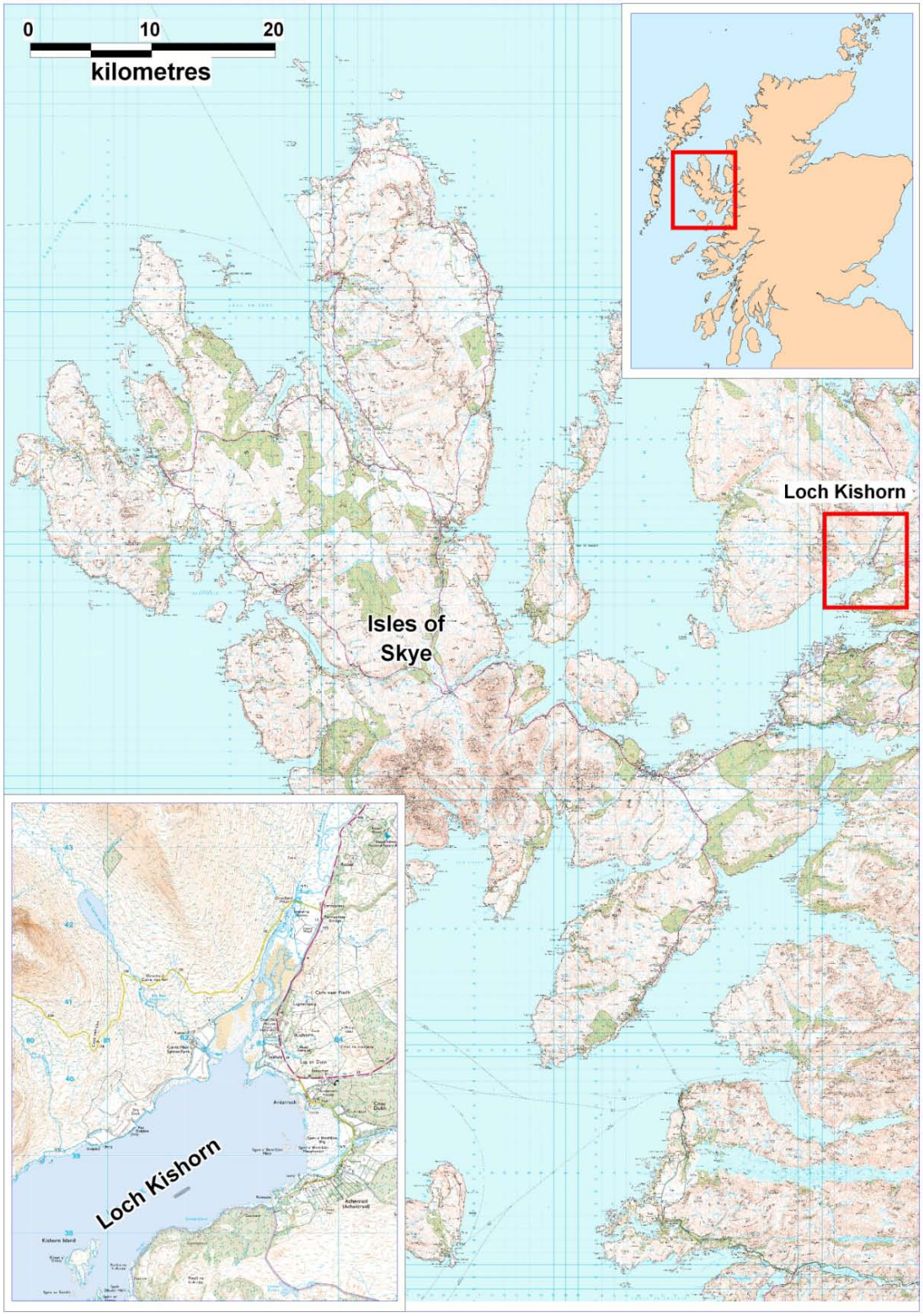


Figure 1.1 Location of Loch Kishorn survey area

2. Fishery

The fishery at Loch Kishorn North is classified for the production of Pacific oysters (*Crassostrea gigas*) and common mussels (*Mytilus edulis*), as detailed in Table 2.1 below.

Table 2.1 Shellfish farms

Production Area	Site	Site ID Number	Species	RMP*
Loch Kishorn North	Loch Kishorn	RC-329-254-08	Common mussel (*M. edulis*)	NG 8264 4052
Loch Kishorn North Oysters	Loch Kishorn	RC-329-254-13	Pacific oyster (*C. gigas*)	NG 8286 4031

*Representative Monitoring Point

The present production area limits include the entirety of the River Kishorn estuary, though bivalve mollusc production is undertaken near the estuary mouth. The production area boundary is the same for both species: the area inshore of a line drawn between NG 8231 4000 and NG 8293 4011 extending to MHWS.

Pacific oysters are grown on trestles in a small area on the east side of the estuary mouth. At the time of shoreline survey, approximately 15-20 bags of mature oysters were located in the south and centre of the trestle area. Since the shoreline survey, the harvester has stated his intention to restock the site with 100000 Pacific oysters in March 2013. The oyster RMP lies within the extent of the oyster fishery as identified during the shoreline survey.

A further area of abandoned trestles, with bags of empty shells, was identified approximately 600 m NE of the active fishery area.

In the recent past there was also common mussel production on droppers suspended from rafts. However, mussel production was discontinued due to Eider duck predation and during the shoreline survey no active production of mussels was found. The RMP for mussels is situated on the western intertidal shore of the estuary. There was also some evidence of previous mussel production in bags on the shore, though the bags appeared to have been abandoned.

The shoreline survey report noted anectodal evidence that the estuary may be used for cockle harvesting, however no harvesting activity was directly observed at the time.

Figure 2.1 shows the relative positions of the oyster farm site, the Food Standard Agency Scotland (FSAS) designated Production Area and the Crown Estates seabed lease area.

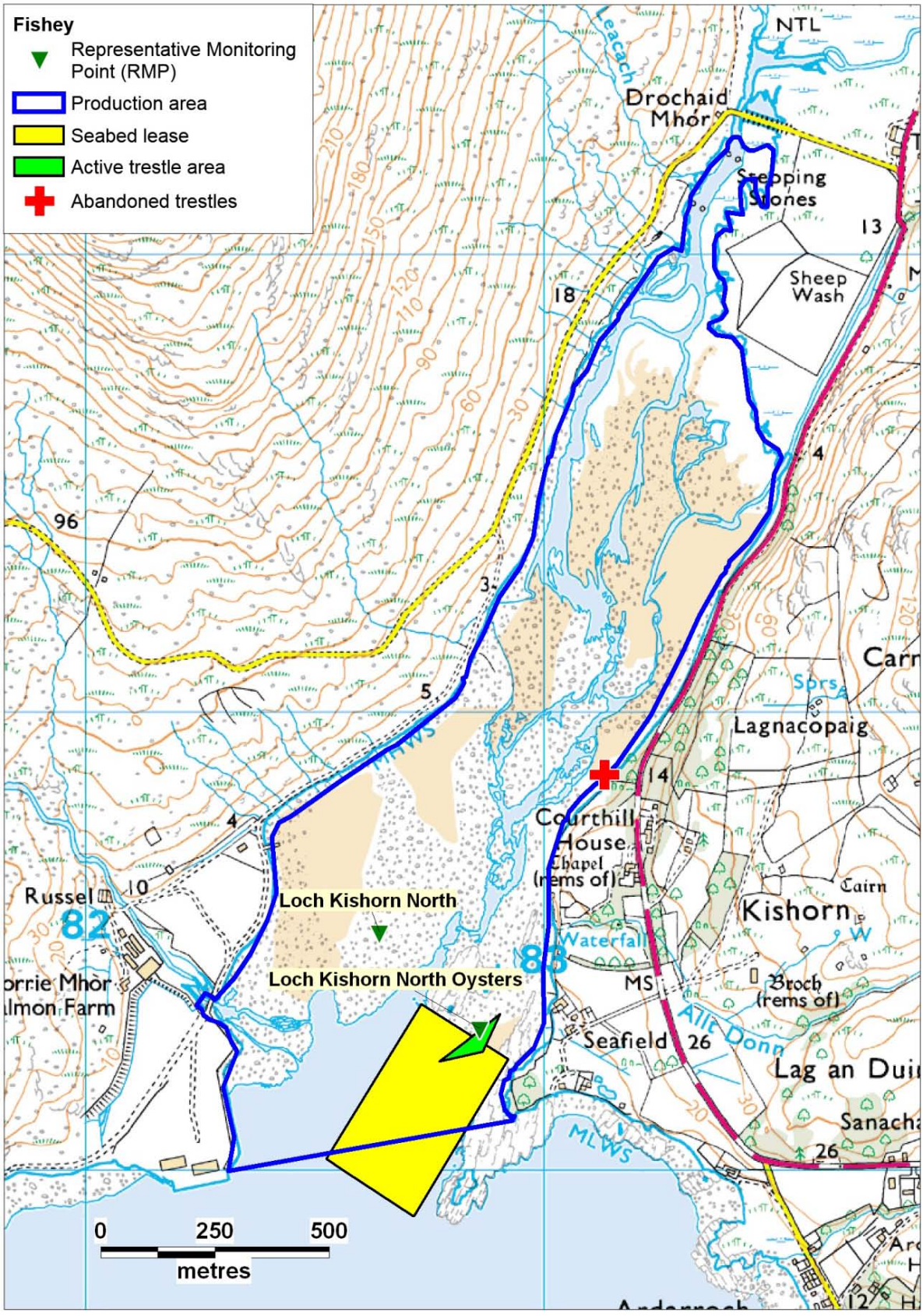


Figure 2.1 Loch Kishorn Fishery

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Loch Kishorn. The last census was undertaken in 2011. However, the 2011 census data was unavailable at the time of writing this report. Data presented below are from the 2001 census.

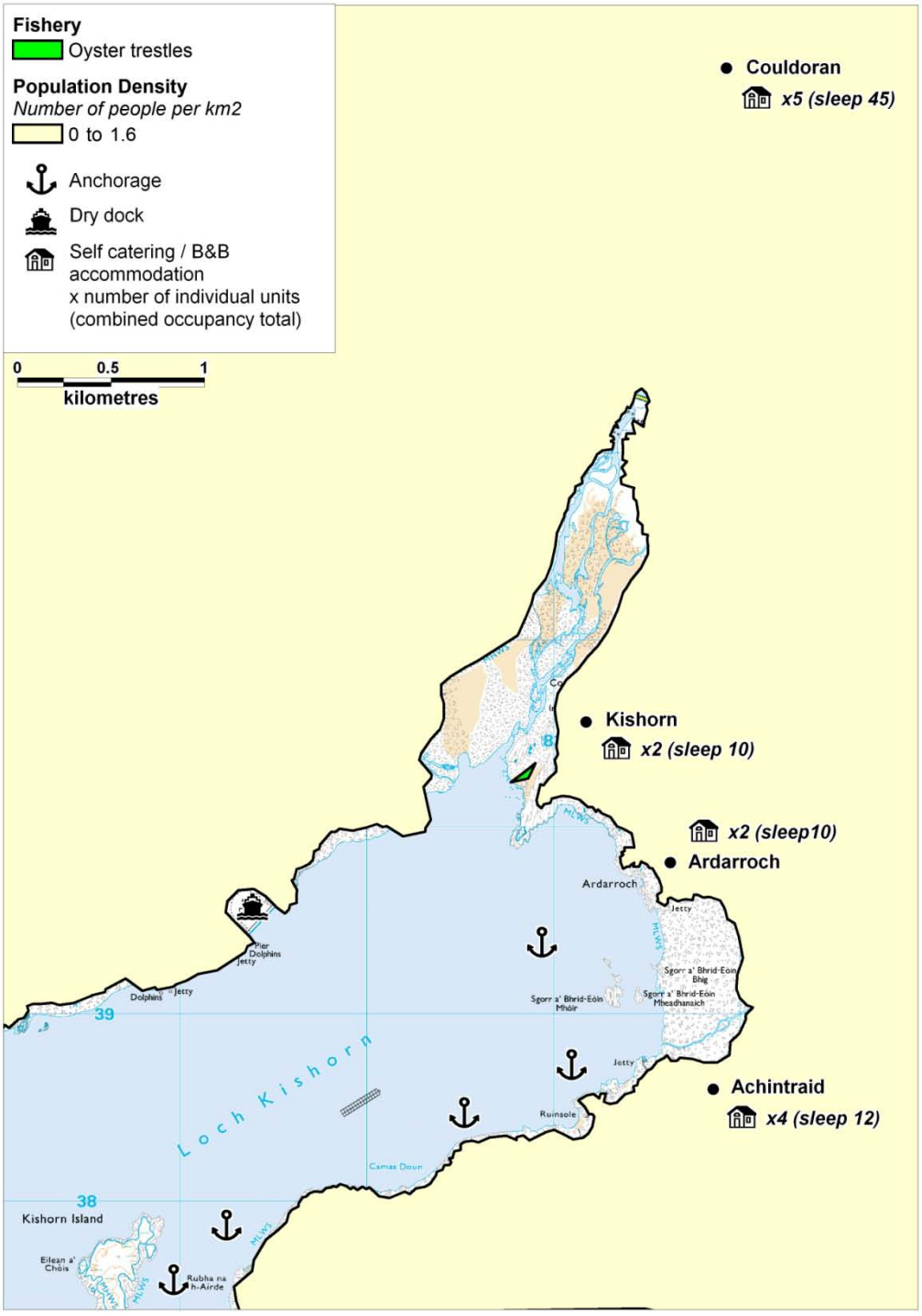


Figure 3.1 Population map of Loch Kishorn

Figure 3.1 shows that population density is low for the area surrounding Loch Kishorn. Only one census output area lies adjacent to the loch, as listed in Table 3.1.

Table 3.1 Census output areas Loch Kishorn

Output area	Population	Area (km^2)	Population Density (per km^2)
60QT000270	127	87	1.5

There are three small settlements (Kishorn, Ardarroch, Achintraid) in the vicinity of the fishery and a fourth (Couldoran) located 2.3 km north, each accommodating fewer than a dozen dwellings. A road runs along the entire south-eastern shoreline, around the estuary and along the north-western shoreline ending at the dry dock.

A relatively large proportion of the dwellings in the area are used as holiday accommodation. Self catering accommodation was identified in the following areas: Couldoran (5 units, accommodating up to 45 people), Kishorn (2 units accommodating up to 10 people), Ardarroch (2 units accommodating up to 10 people), Achintraid (4 units accommodating up to 12 people).

Occupied caravans and a house were noted adjacent to Russel Burn at the mouth of the estuary, on the west shore opposite the fishery.

There are five anchorages within Loch Kishorn. Four are located along the southern shore of the loch and the fifth is at the head of the loch. All of these lie south or southwest of the fishery. The nearest, at the head of the loch, lies approximately 800 m from the fishery. Fish farm traffic in the south of the survey area involves small and medium craft, which are site specific to the Loch.

A dry dock on the northern shore of the loch, originally forming part of the Kishorn Yard (an oil platform fabrication facility), was operating up to 1992. The site was earmarked for redevelopment by Scottish Government in 2010 “for commercial redevelopment to supply manufacturing, assembly, fabrication and other logistics for offshore renewables” (HI-energy 2010). Leiths (Scotland) Ltd operates a small quarry on the site, producing construction materials including aggregates and concretes. This lies within 250 m of the shoreline.

Kishorn Port, operated by Ferguson Transport (Spean Bridge) Ltd and located east of the dry dock, covers a 0.45 km^2 area and has a boat yard, sheltered berths and is visited by a variety of vessels including fishing barges transporting fish feed products currently stored at the port. In 2012 both companies formed Kishorn Port Ltd in joint venture in an attempt to promote the site for investment in offshore renewables.

During the shoreline survey there appeared to be few permanent moorings and little yacht traffic. However, this observation was made in winter and there may be more activity in the area during the summer months. Should activity at the port increase, this would be expected to lead to an overall increase in ship traffic in the area.

4. Sewage Discharges

Information on sewage discharges to Loch Kishorn was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Scottish Water identified sewage discharges for the area surrounding Loch Kishorn, the most significant of which are detailed in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

Ref No.	NGR	Discharge Name	Discharge Type	Level of Treatment	Flow (m^3/d)	Storage (hours)	PE
CAR/L/1081363	NG 8333 3990	Kishorn WWTW Kishorn WWTW EO	Continuous Intermittent	Tertiary 6mm screen	62.4	*	264
CAR/L/1083929	NG 8304 4082	Kishorn Courthill WWPS EO	Intermittent	6mm screen	*	46	*
CAR/L/1083924	NG 8333 3990	Kishorn Schoolhouse WWPS EO	Intermittent	6mm screen	62.4	42	*
CAR/L/1083926	NG 8355 3951	Kishorn Ardarroch WWPS EO	Intermittent	6mm screen	*	195	*
CAR/L/1083928	NG 8355 3951	Kishorn Achintraid WWPS EO	Intermittent	6mm screen	*	71	*

* Data not supplied or not applicable

Scottish Water identified five additional discharges to the south and east of the production area. However, due to their distance (>5 km) from the oyster farm, they were not considered to pose a significant risk of contamination to the fishery.

In 2011, Scottish Water installed first time sewerage provision to the communities of Kishorn and Achintraid, including a tertiary treatment works. Prior to March 2011, this area was served by private drainage (Fiona Garner, personal communication).

The Kishorn WWTW outfall discharges approximately 600 m SW of the oyster farm. The new system carries foul waste and does not incorporate surface water runoff. Scottish Water reported that the licence stipulates an end-of pipe limit for faecal coliforms for this works of 4,000 cfu/100 ml with an upper tier enforcement limit of 40,000 cfu/100 ml. UV treated effluent can vary markedly in quality, depending on the efficiency of the secondary treatment, maintenance of the UV lamps and sleeves, etc. but when operating efficiently this plant would normally produce effluent quality significantly below these limits.

Due to the level of treatment, SEPA consider this discharge to be low risk and so it is not regularly sampled. Since commissioning in 2011, SEPA have taken 3 samples which confirmed typical discharge quality of <10 cfu/100ml. Scottish Water commissioning samples showed the same quality, <10 cfu/100 ml. Provided that the works is operating as it should, given the small volume

and distance from the oyster farm the final effluent discharge is not expected to cause significant impairment to water quality at the fishery.

Four wastewater pumping stations (WWPS) carry sewage waste to the treatment works and have emergency overflows (EO). As the system does not incorporate surface water runoff, there are no combined sewer overflows from the works or pumping stations. Kishorn Schoolhouse EO uses the same outfall pipe as the WWTW. Kishorn Courthill EO outfall lies approximately 500 m N (up-estuary) of the oyster farm. The remaining EO outfalls area > 1 km from the oyster farm. All four pumping stations incorporate storage tanks for holding any spills in case of a system failure. Storage capacity of the tanks (in hours) is given in Table 4.1. The emergency overflows (EOs) would only be expected to discharge in the event of disruption to the system exceeding 42 hours at Kishorn Schoolhouse and 46 hours at Kishorn Courthill.

SEPA provided information on consented discharges to the area which are listed in Table 4.2.

Table 4.2 Discharge consents identified by SEPA

No.	Ref No.	NGR	Description/ treatment	Discharge Type	Flow (m^3/d)	PE	Discharges to
1	CAR/R/1070260	NG 8114 3943	Septic Tank	Continuous	-	-	Soakaway
2	CAR/R/1038659	NG 8203 4058	Septic Tank	Continuous	-	-	Russel Burn
3	CAR/L/1083929	NG 8304 4082	EO	Intermittent	-	-	Loch Kishorn
4	CAR/R/1034882	NG 8322 4069	Septic Tank	Continuous	-	-	Soakaway
5	CAR/L/1083924	NG 8333 3990	EO	Intermittent	-	-	Loch Kishorn
6	CAR/L/1081363	NG 8333 3990	WWTW tertiary	Continuous	-	264	Loch Kishorn
7	CAR/R/1079927	NG 8375 3996	Septic Tank	Continuous	-	-	Soakaway
8	CAR/R/1008976	NG 8379 3993	Septic Tank	Continuous	-	-	Soakaway
9	CAR/R/1070833	NG 8390 4007	Septic Tank	Continuous	-	-	Soakaway
10	CAR/R/1080846	NG 8391 4000	Septic Tank	Continuous	-	-	Soakaway
11	CAR/R/1079772	NG 8395 4004	STW tertiary	Continuous	-	-	U/T of Loch Kishorn
12	CAR/R/1023021	NG 8373 3971	Septic Tank	Continuous	-	-	Soakaway
13	CAR/L/1083926	NG 8355 3951	EO	Intermittent	-	--	Loch Kishorn
14	CAR/R/1053081	NG 8410 3916	Septic Tank	Continuous	-	-	Soakaway
15	CAR/S/1031210	NG 8403 3901	STW secondary	Continuous	3.6	20	Loch Kishorn
16	CAR/L/1083928	NG 8402 3900	EO	Intermittent	-	-	Loch Kishorn
17	CAR/R/1077410	NG 8405 3892	Septic Tank	Continuous	-	-	Soakaway
18	CAR/R/1071048	NG 8390 3885	Septic Tank	Continuous	-	-	Abhainn Cumhang
19	CAR/R/1066198	NG 8394 3878	Septic Tank	Continuous	-	-	Loch Kishorn
20	CAR/R/1052761	NG 8394 3879	Septic Tank	Continuous	-	-	Loch Kishorn
21	CAR/R/1020813	NG 8358 3875	Septic Tank	Continuous	-	-	Loch Kishorn
22	CAR/R/1025541	NG 8344 3851	STW secondary	Continuous	-	-	Land
23	CAR/R/1078791	NG 8340 3851	Septic Tank	Continuous	-	-	Soakaway
24	CAR/R/1025540	NG 8340 3850	STW secondary	Continuous	-	-	Land

25	CAR/R/1035061	NG 8321 3833	STW secondary	Continuous	-	-	U/T of Loch Kishorn

The majority of consents relate to privately owned septic tanks or small private treatment works, associated with individual properties. Of these, slightly more than half discharge either directly to Loch Kishorn or to watercourses feeding into Loch Kishorn. The remainder discharge to soakaway or to the surrounding land. Some of these homes may have subsequently been connected to mains sewerage in the area, however it is likely that some private septic tanks will remain in use.

Consents in highlighted rows in Table 4.2 relate to discharges associated with Kishorn WWTW. No attempt was made to ascertain the functional status of the septic tanks identified in the area of the fishery, as this was outside the scope of this survey. It is therefore assumed that all septic tanks were operating properly. Sewage infrastructure recorded during the shoreline survey is listed in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No	Date	NGR	Description
1	11/12/2012	NG 8337 3850	Septic tank in field, Soakaways at front of houses
2	11/12/2012	NG 8371 3876	Plastic outfall pipe, weighed down by rocks, discharging onto shore
3	11/12/2012	NG 8385 3873	Broken clay pipe on shore. Evidence of attempt to block inflow to pipe at high water mark. Presence of green algae (Ulva sp.) on foreshore parallel with broken pipe.
4	11/12/2012	NG 8404 3898	Kishorn Achintraid CSO. Running for 2 years according to the Scottish Water engineer that we spoke to.
5	11/12/2012	NG 8384 3964	Kishorn Ardarroch WWPS
6	11/12/2012	NG 8356 3966	Plastic outflow pipe not on original map. Diameter 10cm approx. No obvious discharge, end of pipe buried in the sand. Approx. 25m from property wall to where pipe is buried in sand on shore.
7	11/12/2012	NG 8358 3970	Manhole/sewage cover at top of shore. A second one was noted a few metres along the shore at the same height. Sewage line lying at top of shore.
8	11/12/2012	NG 8350 3984	Kishorn WWTW WWPS. On the shore below the station a plastic culvert was noted running under the road.
9	11/12/2012	NG 8357 3993	Sewage works.
10	11/12/2012	NG 8337 3997	Cast iron outflow pipe, running down shore, access cover at top of the shore. Diameter 7cm with very small trickle of water. Green algae present on shore near vicinity of end of pipe.
11	11/12/2012	NG 8382 4001	Manhole cover in garden. Recent manholes and earthwork in front of 5 houses indicate these may have been linked into mains sewerage.
12	12/12/2012	NG 8313 4086	Cast iron pipe. No discharge present.
13	12/12/2012	NG 8301 4031	Plastic outfall pipe visible behind fence discharging into stream. Possible septic tank at shore edge.

A possible septic tank and outflow pipe to a stream were seen on the shore adjacent to the oyster farm. A water sample taken from the stream returned a result below the limit of detection (<100 *E. coli* cfu/100 ml), suggesting very little faecal contamination at the time of survey. It was not noted whether the home was occupied at the time and it is not known whether the house has been connected to the mains sewerage system.

A water sample taken of the outflow from the cast iron pipe in observation 10 returned an exceptionally high result of 900000 *E. coli* cfu/100 ml. Although this is located near to the sewage treatment works outfall, it appears to be associated with a single property near the shoreline. No consent was received for this discharge, however historically there has been no requirement to register septic tanks in Scotland and currently registration is only required on sale or transfer of the property.

The Kishorn WWTW and one of the private discharges are reported to receive tertiary treatment, which would be expected to substantially reduce the concentration of bacterial pathogens and indicators in the effluent. However, these treatment systems are not as effective at removing enteric viruses (Thompson, et al. 2000, La Rosa, et al. 2010). This would result in a lower ratio of faecal indicator bacteria to viruses than in effluent receiving a lower level of treatment. This would therefore decrease the likelihood that faecal indicator bacteria concentrations would be representative of total enteric pathogen risk. All other reported discharges receive lower levels of treatment.

Depending on timing and duration of flow, a discharge from the intermittent outfall at Courthill could potentially impact water quality at the oyster farm. These overflows would be expected to be relatively rare, and it would be highly unlikely that any spill would be reflected in the monthly monitoring samples.

Overall, the risk to the oyster fishery from human sewage discharges is moderate.

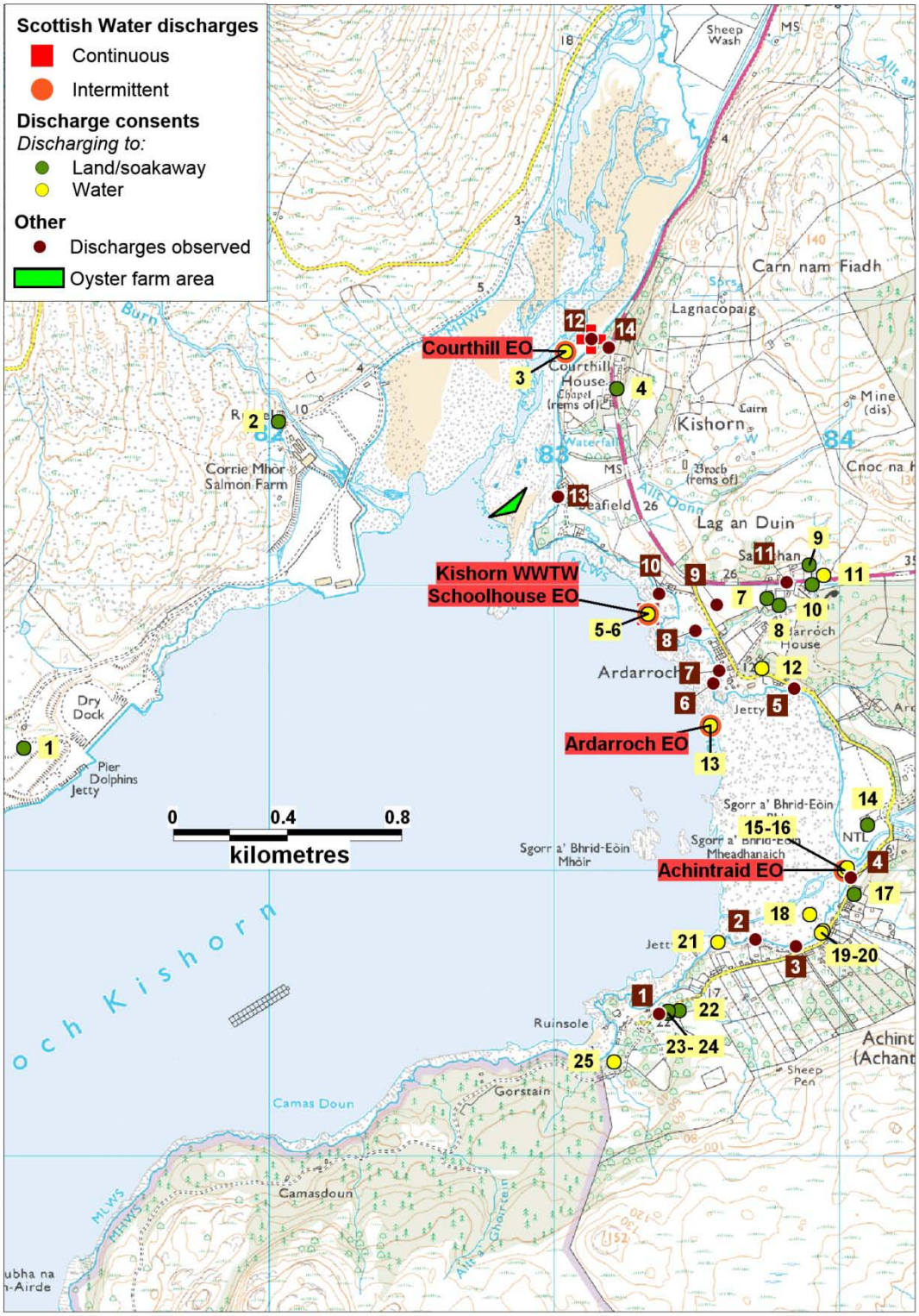


Figure 4.1 Map of discharges for Loch Kishorn

5. Agriculture

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

Table 5.1 Livestock numbers in Applecross and Lochcarron parishes 2012

	Applecross		**Lochcarron**	
	449 km^2		347 km^2	
	Holdings	Numbers	Holdings	Numbers
Pigs	7	134	6	19
Poultry	16	402	12	539
Cattle	10	192	14	173
Sheep	33	6085	37	4042
Other horses and ponies	*	*	8	21

The two agricultural parishes cover a large combined area of 796 km^2 (shown in the inset of Figure 5.1). Because the livestock numbers relate to such large parish areas, it is not possible to determine the spatial distribution of the livestock in relation to the Loch Kishorn area. Therefore the figures are of little use in assessing the potential impact of livestock contamination to the fishery; but they do give an idea of the total numbers of livestock over the broader area. Sheep are the predominant type of livestock kept in the two parishes, with an average of 184 per holding in Applecross and 109 per holding in Lochcarron. Other livestock are present in smaller numbers in both parishes.

The only significant source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 5), which only relates to the time of the site visit on 11th – 12th December 2012. Observations made during the survey are dependent upon the viewpoint of the observer and 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.

Sheep and cattle were observed along the eastern shoreline of Loch Kishorn. A flock of sixty sheep were seen at the head of the river estuary, and one

sheep was seen on land adjacent to the oyster farm, A second flock was seen adjacent to the Kishorn sewage works, at Ardarroch. No animals were seen along the western shore.

No local information was found for the area surrounding Loch Kishorn concerning the seasonal numbers of livestock; however it is expected that there would be an increase in numbers following lambing in the spring and a decrease in numbers in the autumn when the animals are sent to market.

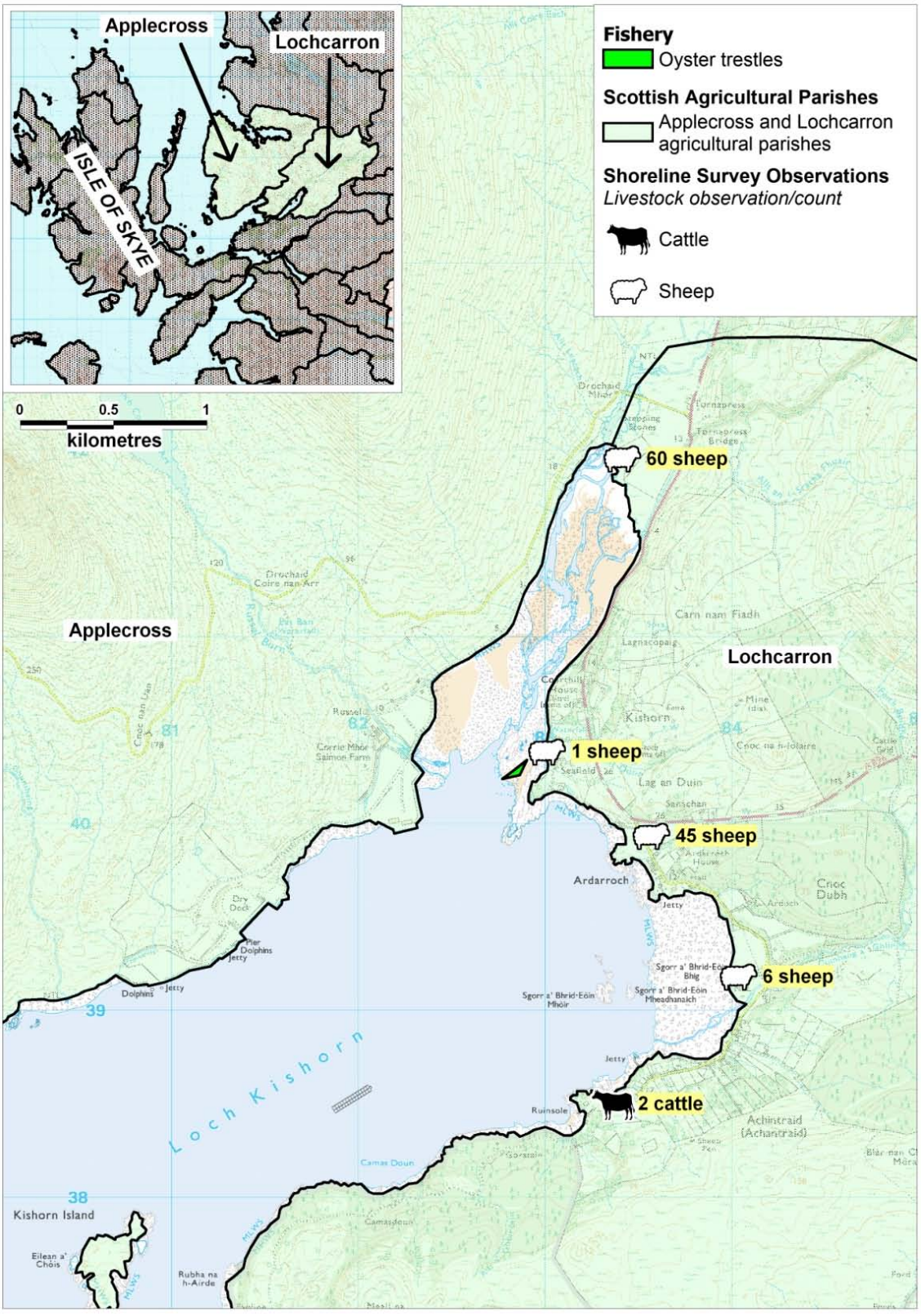


Figure 5.1 Agricultural parish boundary and livestock observations at Loch Kishorn

6. Wildlife

Pinnipeds

The common/harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*) are commonly found in the waters around Loch Kishorn.

A common seal colony exists south of Loch Kishorn, in adjoining waters around Plockton. This area offers ideal haul out habitat and anecdotal reports account for over 350 common seals within this colony. There are also unverified reports of seals around the islands just outside to the south Loch Kishorn. These seals are likely to move around within this connective water system and enter into Loch Kishorn from time to time. At the time of the shoreline survey, no seals were observed.

Cetaceans

Two species of cetacean are regularly seen to the south of Loch Kishorn in the adjoining Loch Carron. The bottlenose dolphin (*Tursiops truncatus*) and harbour porpoise (*Phocoena phocoena*) are most commonly seen during the summer months, correlating with the peak in visitors. The absence of sightings in Loch Kishorn may be due to lower numbers of visitors there than in Loch Carron. Loch Kishorn is deep enough for dolphins and porpoise and therefore these animals may be present at least from time to time. It is unlikely that they would enter the estuary or pass close to the oyster farm. At the time of the shoreline survey, no dolphins or porpoises were observed.

Birds

Seabird 2000 census data (Mitchell, *et al*., 2004) was queried for the area within a 5 km radius of Loch Kishorn and the output is summarised in Table 6.1. The recorded locations are shown in Figure 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 5km of Loch Kishorn.

Common name	Species	Count*	Method
European Herring Gull	*Larus argentatus*	4	Occupied nests
European Herring Gull	*Larus argentatus*	9	Occupied nests
Great Black Backed Gull	*Larus marinus*	9	Occupied nests
Black Guillemot	*Cepphus grylle*	10	Individuals on land

*Counts for occupied nests were doubled to reflect the number of individuals.

Relatively few seabirds are recorded as breeding in the area. There are no RSPB reserves near to Loch Kishorn, or the adjacent Loch Carron. Anecdotal reports exist for many different species of birds and seabirds, including:

Greenshanks and White- tailed Sea Eagles in the Loch Kishorn area (The Royal Society for the Protection of Birds 2012). However, no records were found of any large aggregations of birds.

During the shoreline survey an estimated 95 gulls were seen to the west and southeast of the Loch Kishorn production area. None were noted in the close vicinity of the oyster farm. Small numbers of other birds were also observed. Gulls and crows, as well as some species of shorebird, are likely to be present in the area year round and the estuary may host significant numbers of wading birds during at least some parts of the year. The locations of the sightings are shown in Figure 6.1.

Otters

The Eurasian Otter (*Lutra lutra*) population in northwest Scotland is large and is nearing the carrying capacity of the area (Strachan 2007). However there are no reports on otter populations around Loch Kishorn, though sightings are common during summer months when there is an influx of tourists to the surrounding areas. No otters were observed during the shoreline survey.

Deer

Red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*) are abundant throughout northwest Scottish Highlands. The total Scottish red deer population is estimated to be around 300,000, with the roe deer population currently unknown (Deer Commission for Scotland 2012). Sika deer are also described as present in northwest Scotland. No data on deer populations was available for the Loch Kishorn area. During the shoreline survey, droppings that may have come from deer were observed at the head of the river estuary. These droppings could be flushed into Loch Kishorn and across the shellfisheries at the mouth of the estuary on an ebb tide.

Overall

Species potentially impacting Loch Kishorn include common and grey seals, otters, deer, and birds. However, the impacts of these on the fishery will be unpredictable, and deposition of faeces by wildlife is likely to be widely distributed around the area. Significant intertidal zones within the estuary and to the southeast of the oyster farm are likely to receive droppings from a number of shore birds, including gulls, and therefore birds may have a higher impact on water quality in these areas.

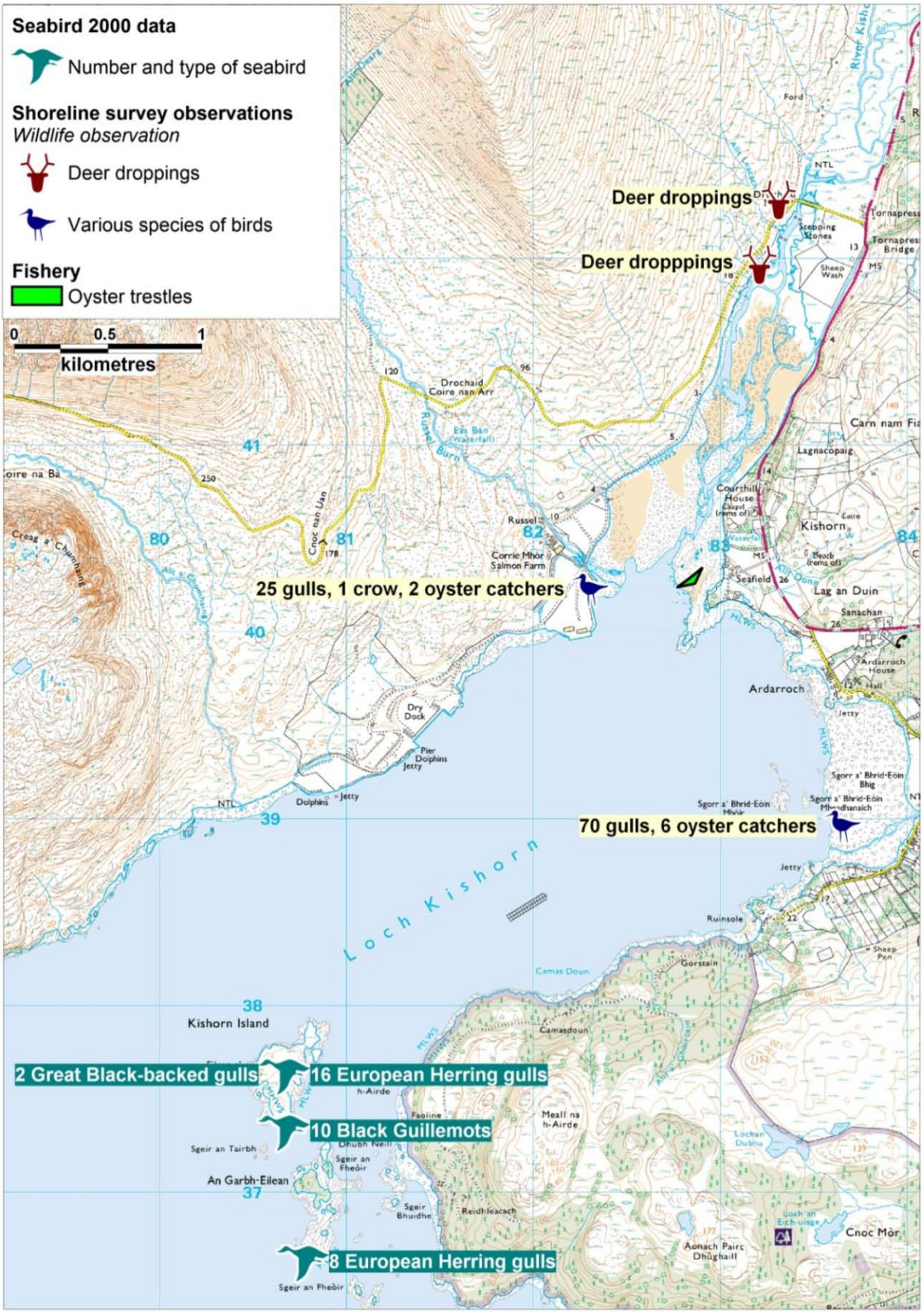


Figure 6.1 Wildlife observations around Loch Kishorn

7. Land Cover

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

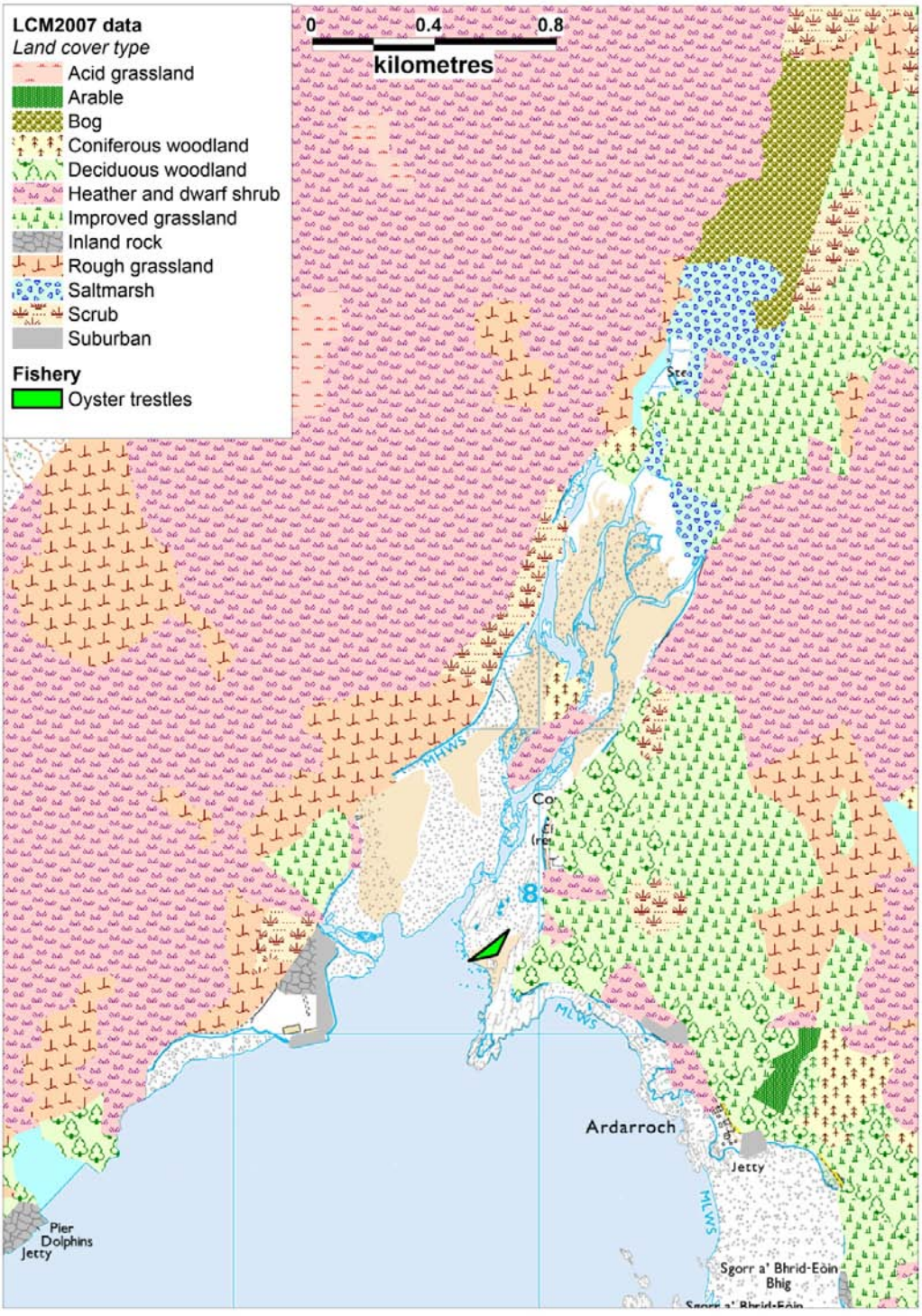


Figure 7.1 LCM2007 land cover data for Loch Kishorn

Heather and dwarf shrub heath, improved grassland, rough grassland, scrub and woodland are the predominant land cover types on the shoreline adjacent

to Loch Kishorn estuary. The shoreline adjacent to the fisheries at the southern end of the estuary is primarily composed of improved and rough grassland. Further inland, heather and dwarf shrub predominate. The small area in the centre of the estuary identified as coniferous woodland and heather and dwarf shrub heath is incorrect and the Ordnance Surveys maps and Google Earth indicate that the area is sand and shingle. Aside from some hard standing at the fish farm yard and two small areas at Ardarroch, there are no other suburban or urban areas.

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

The highest potential contribution of contaminated runoff to the Loch Kishorn shellfishery is from the areas of improved grassland at the head of the estuary and to the east of the oyster farm. Areas utilised for rough grazing would be expected to contribute significantly to faecal contaminant loading carried in watercourses and overland flow draining the area during rainfall.

8. Watercourses

There are no public river gauging stations on watercourses along the Loch Kishorn shoreline. The original shoreline survey took place on 11-12 December 2012. However, due to delayed receipt of samples at the laboratory, water samples and corresponding measurements were retaken on 13 January 2013. Watercourse measurements and sample results from 13 January are presented in Table 8.1. Moderate to heavy showers fell throughout the day of survey.

Table 8.1 Calculated spot loadings for Loch Kishorn watercourses

No	Grid Ref.	Description	Width (m)	Depth (m)	Flow (m^3/day)	*E. coli* (cfu/ 100ml)	Loading (*E. coli* per day)
1	NG 8343 3859	Watercourse	0.70	0.25	2250	< 100	$<2.3x10^9$
2	NG 8361 3875	Watercourse	0.70	0.08	4110	< 1000	$<4.1x10^{10}$
3	NG 8386 3874	Culverted watercourse	0.38	0.08	540	< 100	$<5.4x10^8$
4	NG 8394 3877	Culverted watercourse	0.50	0.10	3050	200	$6.1x10^9$
5	NG 8398 3887	Watercourse	1.30	0.12	9060	< 100	$<9.1x10^9$
6	NG 8351 3982	Watercourse	0.19	0.10	768	< 1000	$<7.7x10^9$
7	NG 8418 3916	Abhainn Cum-hang a Ghlinne	2.87	0.25	21400	< 100	$<2.1x10^{10}$
8	NG 8228 4037	Russel Burn	4.2	0.32	57700	< 100	$<5.8x10^{10}$
9	NG 8286 4120	Piped watercourse	1.10	0.15	7570	< 100	$<7.6x10^9$
10	NG 8321 4198	Watercourse	0.90	0.18	2830	< 100	$<2.8x10^9$
11	NG 8331 4216	Allt Leacach	1.20	0.25	8110	< 100	$<8.1x10^9$
12	NG 8342 4232	River Kishorn	11.5	0.58	231000	< 100	$<2.3x10^{11}$
13	NG 8360 4173	Allt Mor/Allt an t-Sratha Fhuair	3.58	0.18	46000	< 100	$<4.6x10^{10}$
14	NG 8302 4054	Allt Don	1.38	0.14	6880	200	$1.4x10^{10}$
15	NG 8301 4031	Watercourse	1.10	0.15	5920	< 100	$<5.9x10^9$

Where *E. coli* results were given as <100 or <1000, loadings were calculated based on 100 or 1000 and then presented as less than values. Watercourses with *E. coli* results of <1000 *E. coli*/100 ml were identified as contaminated by the survey team, and therefore higher dilutions were used by the laboratory. Calculated loadings are based on spot measurements and samples and therefore are only representative of the conditions at the time of sampling. It is expected that significant variation in flow will occur with variation in rainfall based on the steep terrain and relatively short length of the majority of watercourses.

Samples for most watercourses gave a value that was less than the limit of detection, showing that *E. coli* was not present in significant concentrations despite the rainfall that occurred in the day. The loadings for the two

watercourses where quantitative *E. coli* results were obtained were moderate, mainly due to the flows that were observed at the time.

The watercourse with the most direct potential impact to the fishery is No. 15 in Table 8.1. This watercourse flows past a house and then across the shore and through the area of trestles. Although there appeared to be a septic tank associated with the house and a pipe discharging into the stream, the water sample taken from this stream returned a result below the limit of detection.

The largest watercourses discharging to the area feed into the River Kishorn estuary. The River Kishorn and the combined flow of Allt Mor/Allt an t-Sratha Fhuair form the main potential sources of contamination to the oyster farm, as they flow along the east side of the estuary, carrying any contaminants southward and across the oyster farm on the way to Loch Kishorn. These watercourses drain areas of rough grassland, moor, bog, and improved grassland used for grazing sheep. Although these did not carry significant loadings of *E. coli* at the time of shoreline survey, these may carry higher loadings at times of year when more livestock are present in the area.

Seven smaller watercourses were observed to the southeast of the oyster farm, in the vicinity of Achintraid. The largest of these was the Abhainn Cum-hang a Ghlinne, the fourth largest watercourse seen in the area. The combined measured outflow of these watercourses is an order of magnitude lower than that measured for the River Kishorn. Therefore, it is anticipated that they will have a smaller effect on contamination levels at the fishery.

Figure 8.1 Map of watercourse flows and loadings to Loch Kishorn

Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1×10^3, in digital format it is written as 1E+03

9. Meteorological data

The nearest weather station for which rainfall data was available is located at Plockton, situated approximately 7 km south west of the production area. Rainfall data was available for January 2007 to August 2012. Data was missing for 10 % of this period. The nearest wind station is South Uist Range, located 105 km west of the production area. Conditions may differ between this station and Loch Kishorn due to the large distances between them. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

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

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, (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 *.

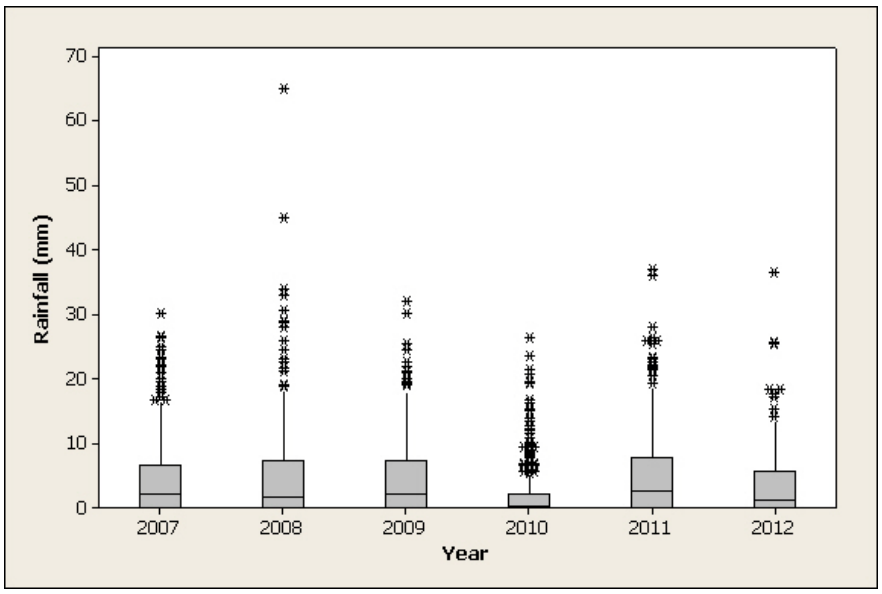


Figure 9.1 Box plot of daily rainfall values by year at Plockton (2007 – 2012)

Daily rainfall values varied somewhat from year to year. Daily rainfall was notably lower in 2010 than in the other years. In 2008, exceptionally high rainfall was recorded on two occasions.

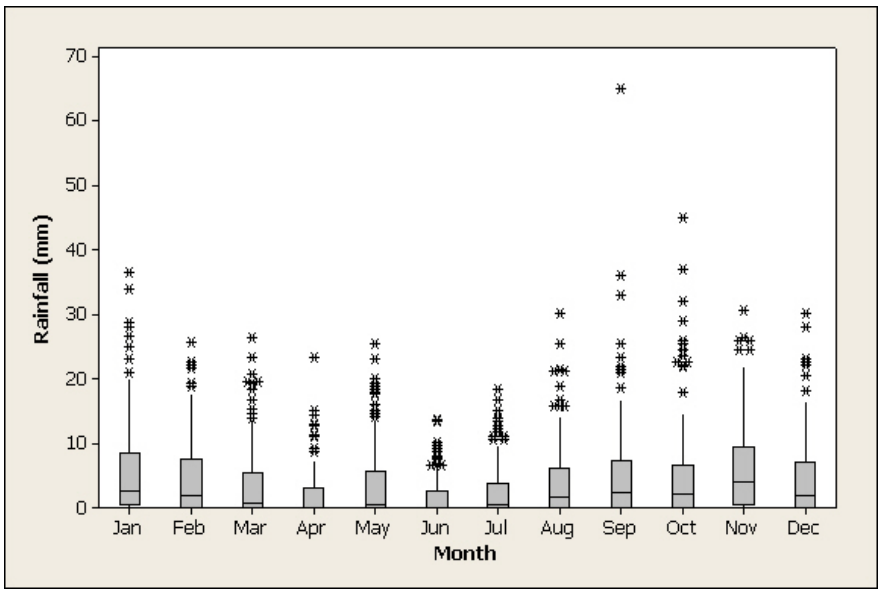


Figure 9.2 Box plot of daily rainfall values by month at Plockton (2007 – 2012)

Daily rainfall values were higher from August to March. Daily rainfall increased from August onward and was highest in November and in January. Weather was generally drier in April, June and July. Daily rainfall exceeding 20 mm was recorded in all months except June and July.

For the period considered here (2007 to 2012) 46 % of days received daily rainfall of less than 1 mm and 14 % of days received rainfall of greater than 10 mm.

Rainfall-associated runoff will tend to 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, they are likely to carry higher loadings of faecal material that can accumulate on pastures when greater numbers of livestock are 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.

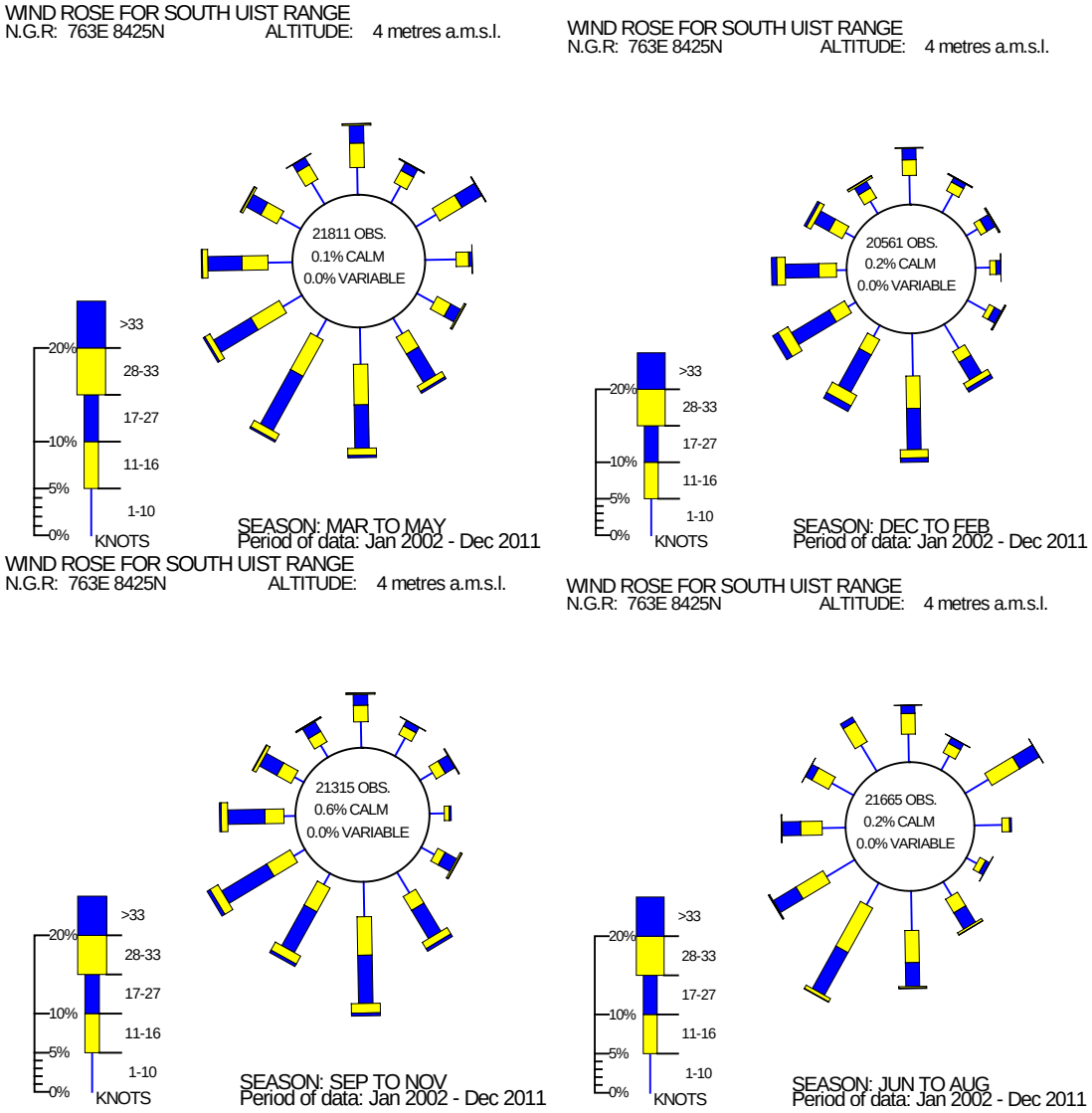


Figure 9.3 Seasonal wind roses for South Uist Range

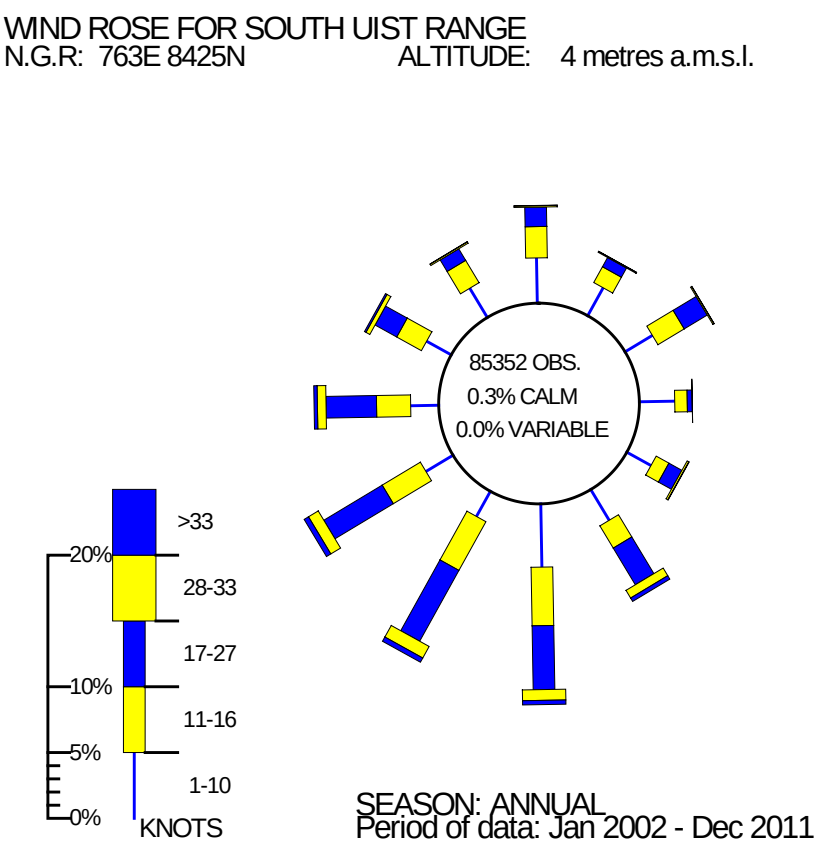


Figure 9.4 Annual wind rose for South Uist Range

Overall the annual wind direction showed that wind was stronger when coming from the west than the east, and winds from the southerly direction were stronger than those from the north. The predominant wind direction was from the southwest. Winds from the northeast were more likely to occur from March to August and winds were generally stronger from the prevailing quarter from September to February.

Wind is an important factor in the spread of contamination as it has the ability to drive surface water at about (3%) of the wind speed (Brown 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore strong winds can significantly alter the pattern of surface currents. Strong winds also have the potential to affect tide height depending on wind direction and local hydrodynamics of the site. A strong wind combined with a spring tide may result in higher than usual tides, which will carry any accumulated faecal matter at and above the normal high water mark into the production area.

10. Classification Information

The area was first classified for mussels and Pacific oysters prior to 2007. However only the classification status from 2007 onward is presented in Table 10.1 and Table 10.2 below.

Table 10.1 Loch Kishorn (commmon mussel) Classification history

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

Table 10.2 Loch Kishorn (Pacific oyster) classification history

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

Currently, the area is classified as seasonal A/B for both species. Historically, classifications for the two species have been similar with periods of B classification tending to occur in the summer.

11. Historical *E. coli* data

11.1 Validation of historical data

Results for all samples assigned against Loch Kishorn from the 01/01/2007 to the 30/08/2012 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 in October 2012. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid. All results were $\log_{10}$ transformed prior to analysis.

For common mussel samples, two samples (S02188-07-W and S02368-07-W) were recorded in the database as 'rejected' and were deleted. One sample exceeded the allowed 48hr window between sample collection and delivery, and was deleted. All samples had a box temperature of 8°C or lower. Ten samples had an *E. coli* level of < 20, so were reassigned nominal values of 10 *E. coli* MPN/100 g for the purposes of statistical evaluation and presentation. Seventeen samples had a result reported > 230 *E. coli* MPN/100 g.

For Pacific oyster samples, three samples (S02187-07-W, S02369-07-W and S00493-07-W) were recorded in the database as 'rejected' and were deleted. All samples had a collection and delivery time within 48hr, and one sample (INTEGRIN_2008_745) had a box temperature of > 8°C.

Eight samples had an *E. coli* level of < 20 *E. coli* MPN/100 g, so were reassigned nominal values of 10 *E. coli* MPN/100 g for the purposes of statistical evaluation and presentation.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results.

Sampling Summary		
Production area	Loch Kishorn	Loch Kishorn
Site	Loch Kishorn North	Loch Kishorn North Oysters
Species	Common mussels	Pacific oysters
SIN	RC-329-254-08	RC-329-254-13
Location	NG 825 405	NG 827 402
Total no of samples	59	59
No. 2007	5	5
No. 2008	11	11
No. 2009	11	11
No. 2010	12	12
No. 2011	11	11
No. 2012	9	9
Results Summary		
Minimum	< 20	< 20
Maximum	16000	5400
Median	70	110
Geometric mean	105	104
90 percentile	2400	1300
95 percentile	3500	3500
No. exceeding 230/100g	17 (28%)	14 (24%)
No. exceeding 1000/100g	7 (11%)	8 (14%)
No. exceeding 4600/100g	2 (3%)	1 (2%)
No. exceeding 18000/100g	0	0

Overall, roughly equivalent numbers of samples were taken from both species, with similar proportions of results exceeding 1000 and 4600 E.coli MPN/100 g. However, based on the proportion of results >230 MPN/100 g and on the maximum result, there appears to be a slight tendency to higher results in mussels than in Pacific oysters.

11.3 Overall geographical pattern of results

The majority of both common mussel and Pacific oyster samples were taken from locations within 200 m of the nominal RMP for Loch Kishorn North oysters. The mussel RMP is approximately 300 m NW of the oyster RMP. Only one mussel sample was recorded against a location within 100 m of the mussel RMP. Three further mussel samples were reported against locations within the production area, but up to 300 m from the RMP. Results at these four sample locations ranged from <20 to 2400 *E. coli* MPN/100 g, with the highest result reported from the northernmost sampling location.

The common mussel samples reported from near the oyster farm and RMP fell into two broad clusters: samples reported within 100 m of the oyster RMP

(Cluster 1) and samples reported within 55 m of NG 82751 40211 (Cluster 2). A summary of the results by cluster is presented in Table 11.2 below.

Table 11.2 Mussel *E. coli* results by geographic cluster

	Cluster 1	Cluster 2
n	37	16
min	<20	<20
max	16000	790
geometric mean	115	74

The geometric mean and maximum of results were higher in Cluster 1 than in Cluster 2. However, this difference was not found to be statistically significant (Two-sample T-test, p=0.373).

Only one oyster sample was reported to a location on the west side of the estuary. All others were reported within the vicinity of the oyster farm as recorded during the shoreline survey. Similarly to the mussel samples, Pacific oyster samples fell into two geographic clusters, one within 100 m of the RMP (Cluster 1) and a second to the southwest, within 50 m of NG 82755 40213 (Cluster 2). Excepting the one outlying sampling point, the reported locations for the remaining sampling points lie within 200 m of the RMP. A summary of the results by cluster is presented in Table 11.3.

Table 11.3 Pacific oyster *E. coli* results by geographic cluster

	Cluster 1	Cluster 2
n	35	20
min	<10	<10
max	3500	5400
geometric mean	93	116

Geometric mean and maximum results were slightly higher in Cluster 2 than in Cluster 1, which is opposite of what was observed in mussels. However, the difference was not found to be statistically significant (Two-sample T-test, p=0.649).

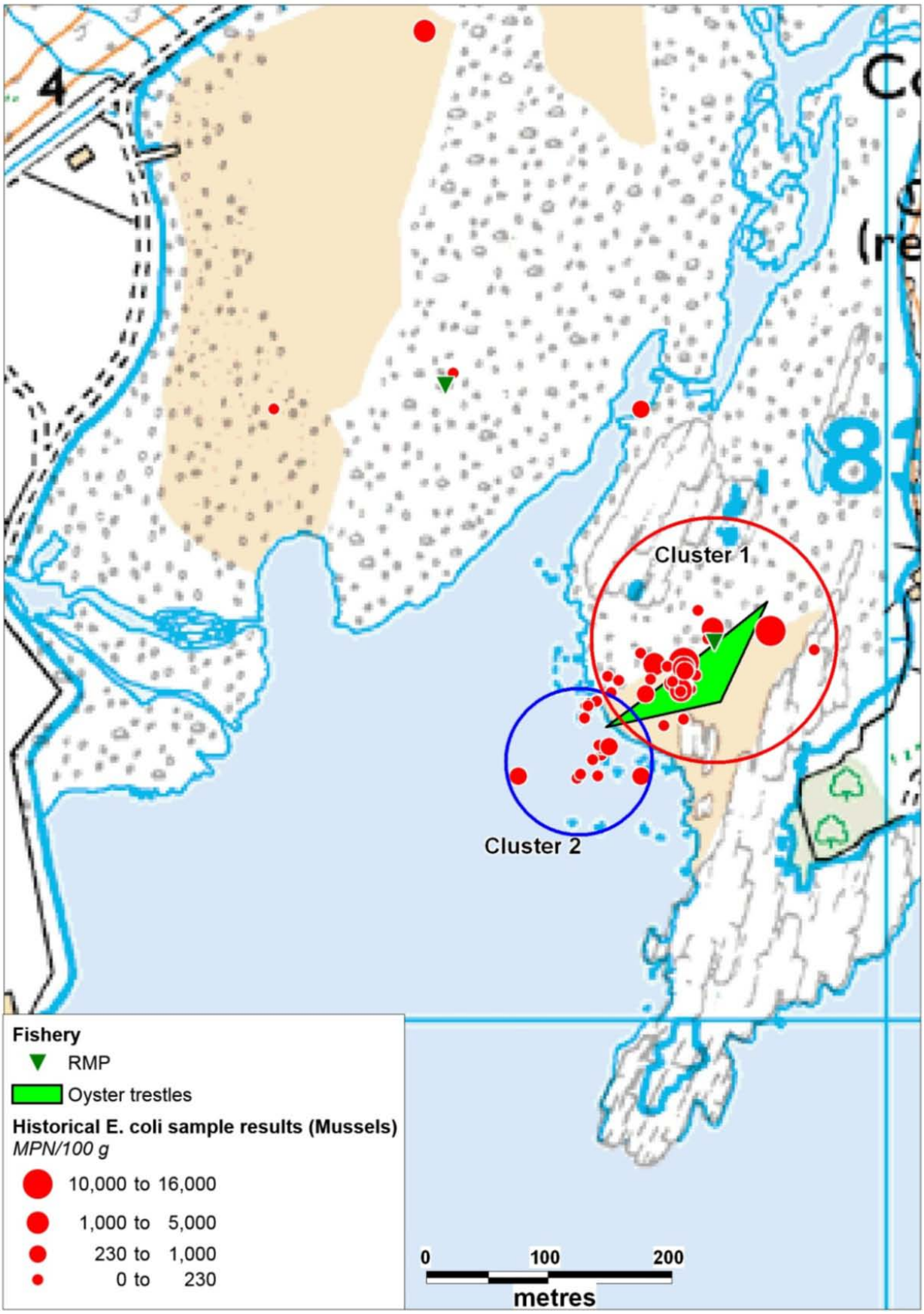


Figure 11.1 Map of historical *E. coli* sample results for common mussels at Loch Kishorn.

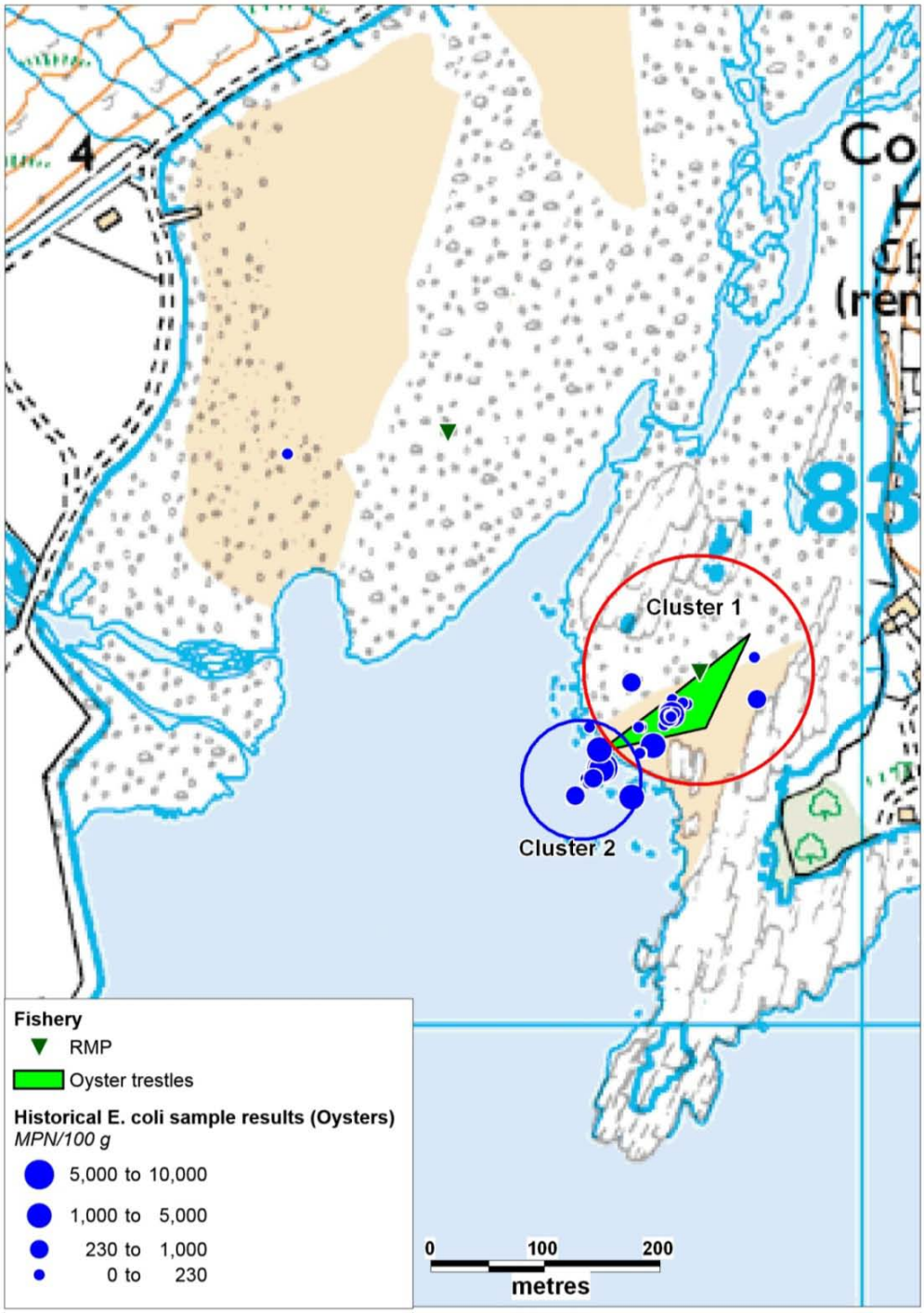


Figure 11.2 Map of historical *E. coli* sample results for Pacific oysters at Loch Kishorn.

11.4 Overall temporal pattern of results

Scatterplots of individual species *E. coli* results against date are presented below. 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. The trend line helps to highlight any apparent underlying trends or cycles.

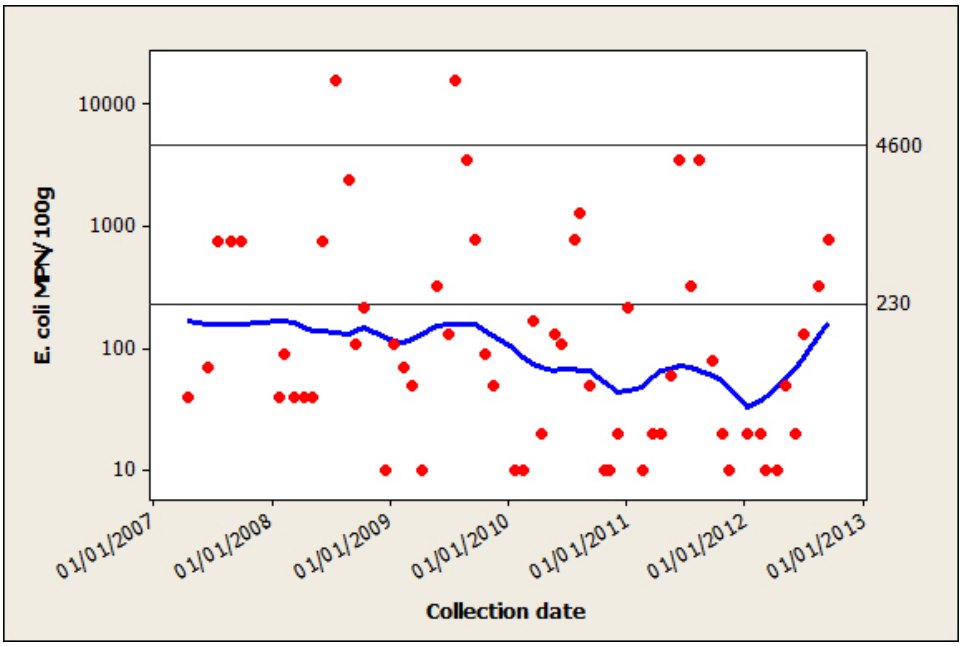


Figure 11.3 Scatterplot of mussel *E. coli* results by date with a lowess line.

Overall there is a declining trend in *E. coli* results for common mussels from 2007 to 2012, as shown by the lowess line in Figure 11.3. Two results greater than 4600 *E. coli* MPN/100 g occurred in 2008 and 2009. An increasing number of very low results appears to have occurred from 2009 onward.

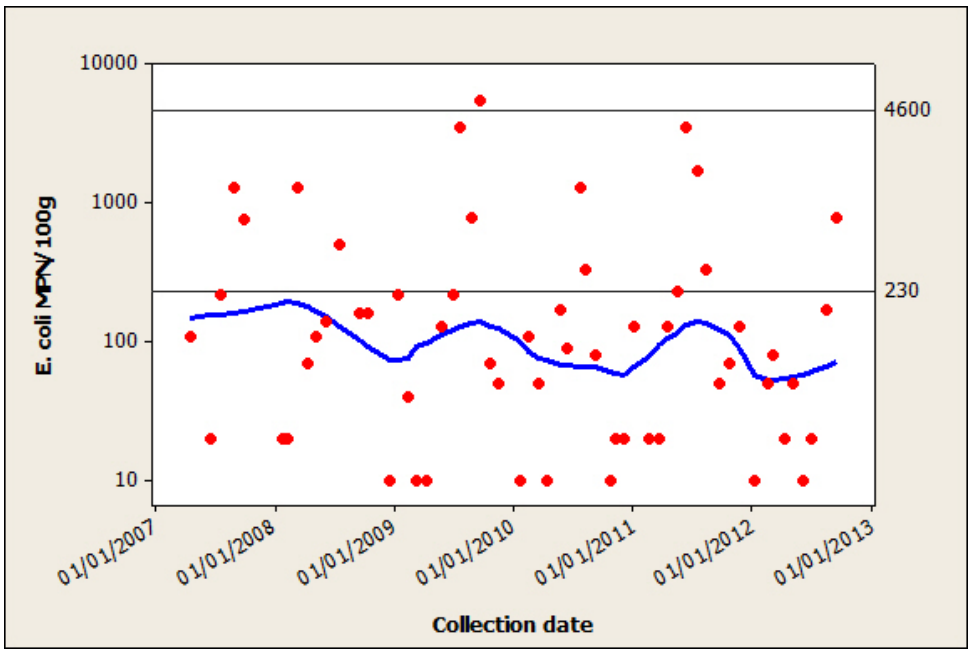


Figure 11.4 Scatterplot of Pacific oyster *E. coli* results by date with a lowess line.

The overall trend appears to be toward a slight decline in *E. coli* results over the entire period. Two clear 'peaks' in the lowess line with a trough in the intervening year suggest a cyclical trend in *E. coli* results. The majority of sampling results have been below 230 *E. coli* MPN/100 g. One result greater than 4600 *E. coli* MPN/100 g occurred in 2009. (Figure 11.4). A greater number of very low results appear to have occurred since 2009, which is likely to account for the slightly downward trend.

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. Scatterplots of individual shellfish species *E. coli* results by month, overlaid with a lowess line to highlight trends are displayed in Figures 11.5 and 11.6.

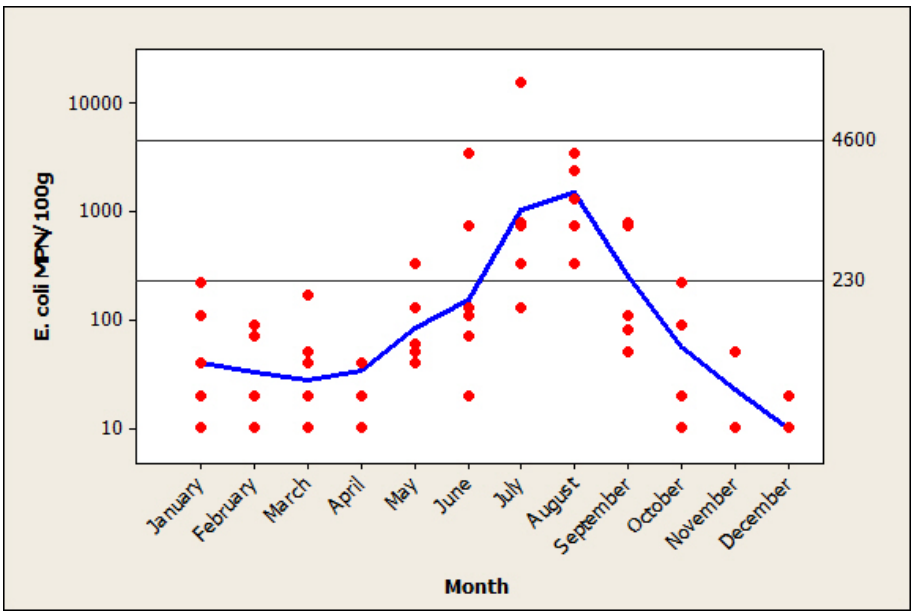


Figure 11.5 Scatterplot of mussel *E. coli* results by month with lowess line.

There is a clear peak in *E. coli* results in July and August (Figure 11.5). No results below 230 *E. coli* MPN/100g were recorded in August, and only one was recorded on July. This suggests a marked increase in the influx of faecal contamination during the summer months. Very few results were recorded in November and December, and therefore the exceptionally low results seen in these months may be misleading. However, overall results were ≤ 230 *E. coli* MPN/100 g from November to April, inclusive.

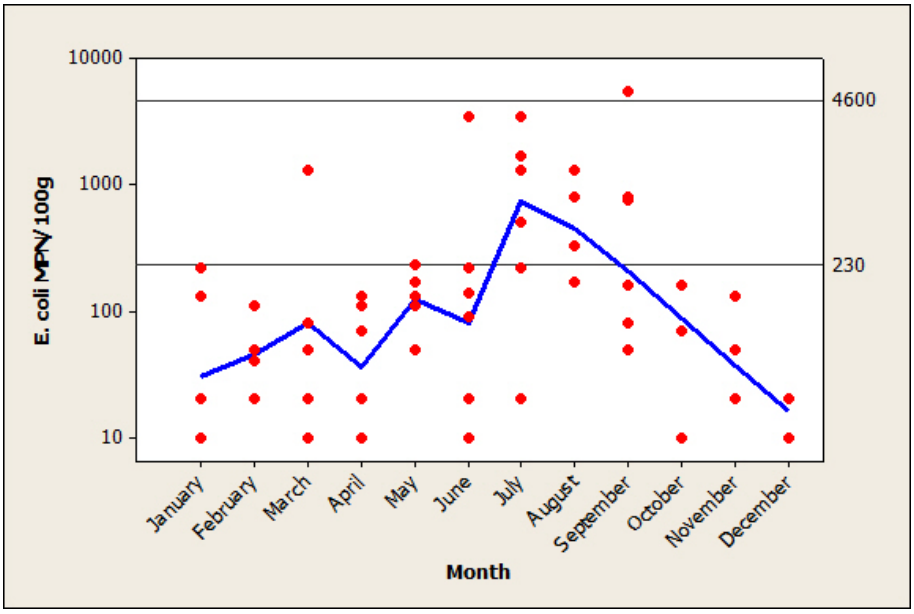


Figure 11.6 Scatterplot of Pacific oyster *E. coli* results by month with lowess line.

The same July to August peak is evident in Pacific oyster *E. coli* results. The majority of results in July and August were >230 *E. coli* MPN/100 g. A sharp decline is also evident from August-December, although only two samples were recorded in December. From November to May the majority of results were ≤230 *E. coli* MPN/100 g.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Boxplots of individual species *E. coli* results by season are presented below.

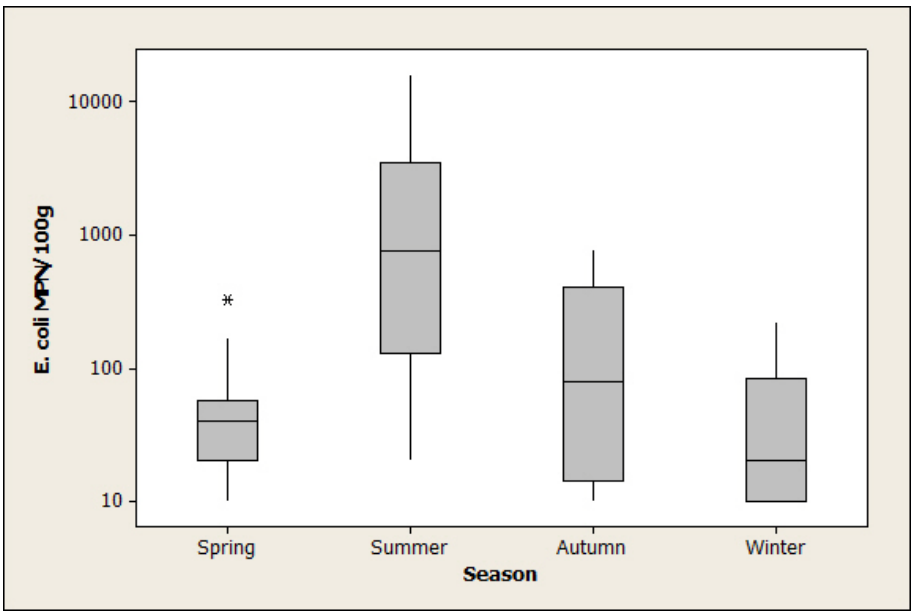


Figure 11.7 Boxplot of mussel *E. coli* results by season.

A statistically significant difference was found in mussel results by season (one-way ANOVA, p = 0.000, Appendix 4). A post-ANOVA analysis (Tukey's method) showed that the results between seasons varied significantly, with results in summer were significantly greater than those in spring, results in autumn and winter significantly lower than spring, and results in winter significantly less than autumn.

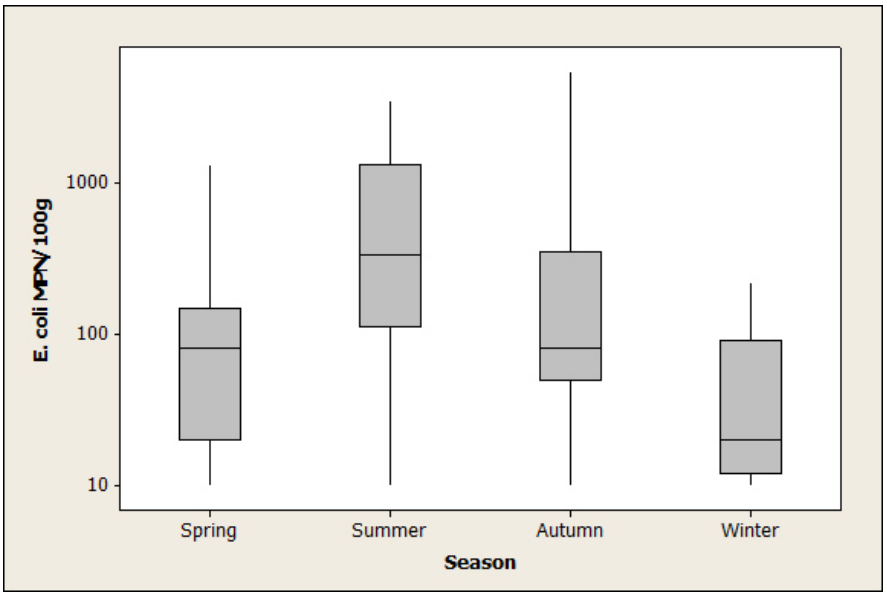


Figure 11.8 Boxplot of Pacific oyster *E. coli* results by season.

A significant difference was found between Pacific oyster results by season (one-way ANOVA, p = 0.003, Appendix 4). A post-ANOVA analysis (Tukey's method) showed that the results in summer were significantly higher than those in spring and winter, but not autumn.

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 Plockton, approximately 8km SW of the production area. Rainfall data was purchased from the Meteorological Office for the period of 01/01/07-01/09/2012 (total daily rainfall in mm). Data was extracted from this for common mussel and Pacific oysters between 16/04/07- 24/08/2012.

Two-day rainfall

Figures 11.9 and 11.10 present scatterplots of individual shellfish species *E. coli* results against total rainfall recorded on the two days prior to sampling.

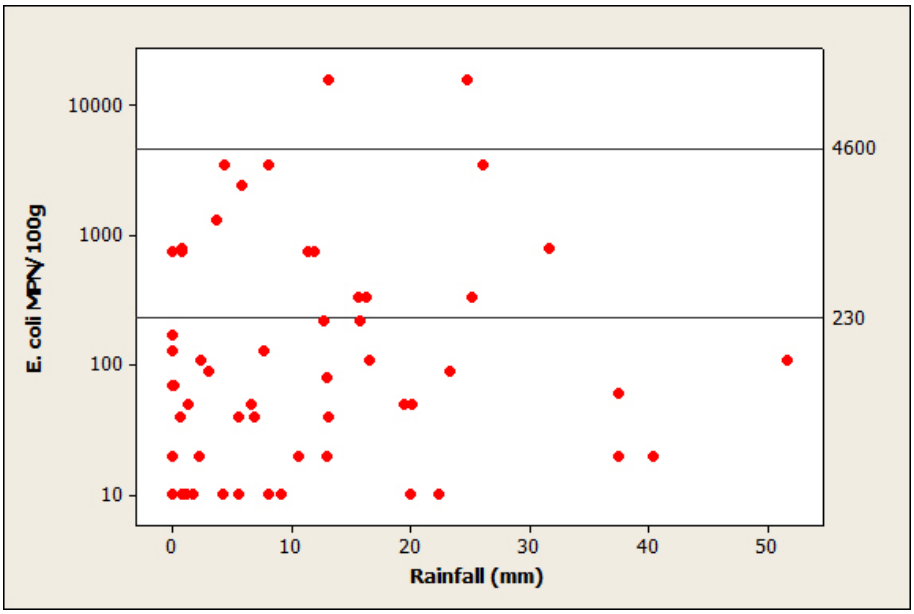


Figure 11.9 Scatterplot of mussel *E. coli* results against 2-day rainfall

No significant correlation was found between the common mussels results and the previous two day rainfall (Spearman's rank correlation r = 0.152, p = 0.260).

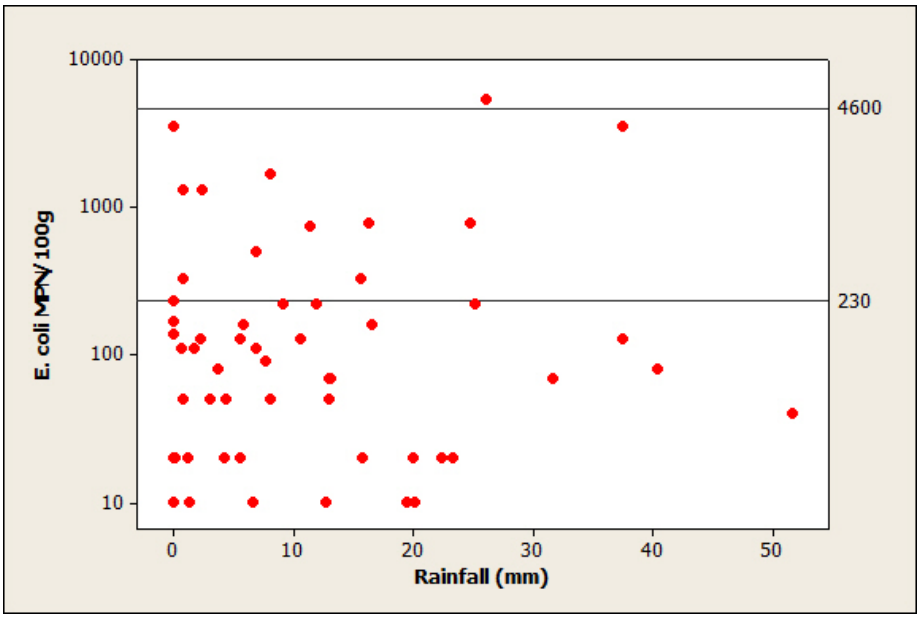


Figure 11.10 Scatterplot of Pacific oyster *E. coli* results against 2-day rainfall

No significant correlation was found between the Pacific oyster results and the previous two day rainfall (Spearman's rank correlation r = 0.071, p = 0.601).

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. Figures 11.11 and 11.12 show scatterplots of individual shellfish species *E. coli* results against total rainfall recorded for the seven days prior to sampling.

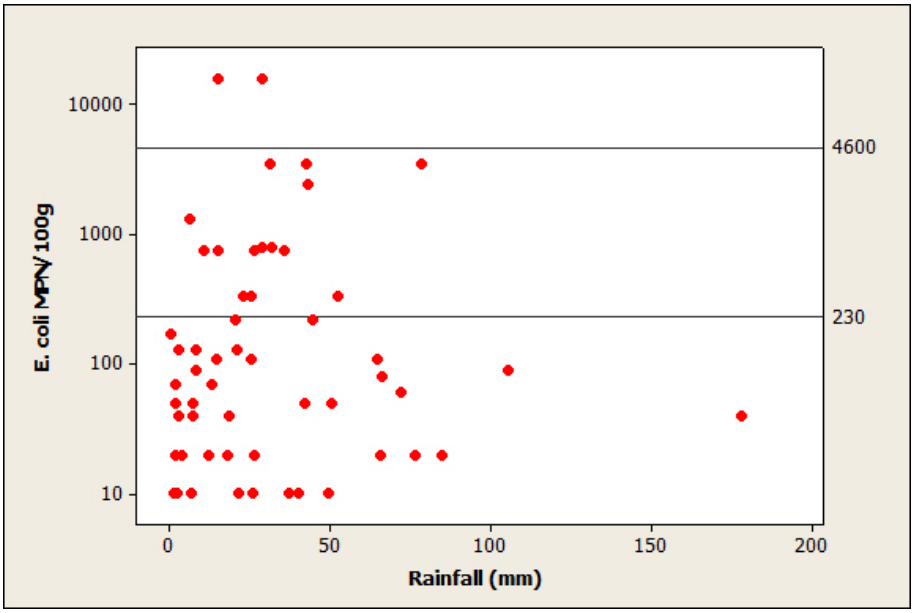


Figure 11.11 Scatterplot of mussel *E. coli* results against 7-day rainfall

No significant correlation was found between the common mussel results and the previous seven day rainfall (Spearman's rank correlation r = 0.147, p = 0.274).

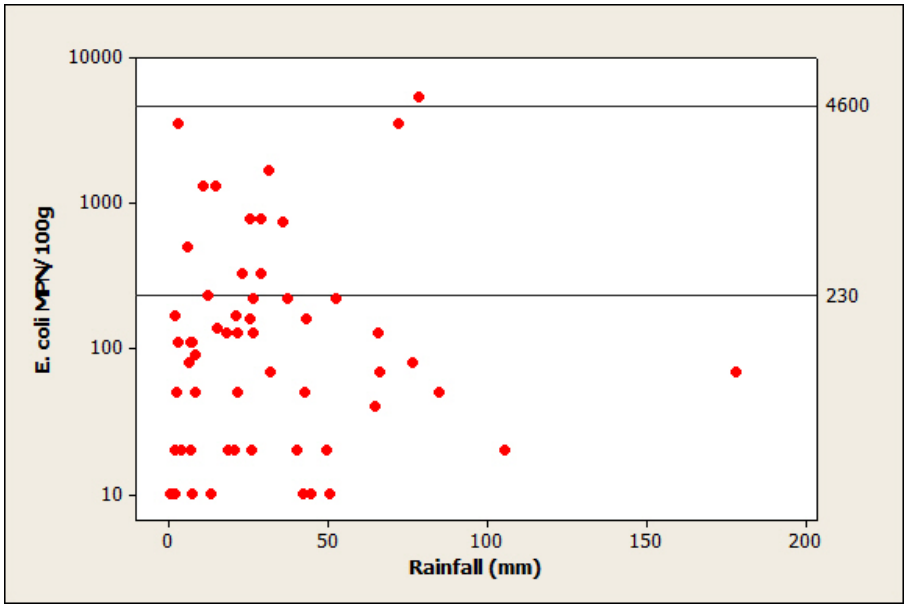


Figure 11.12 Scatterplot of Pacific oyster *E. coli* results against 7-day rainfall

No significant correlation was found between the Pacific oyster results and the previous seven day rainfall (Spearman's rank correlation r = 0.115, p = 0.392).

11.6.2 Analysis of results by tidal cycle

Spring/neap tidal cycle

Spring tides are large tides that occur fortnightly and are influenced by the state of the lunar cycle. They reach above the mean high water mark and therefore increase circulation and particle transport distances from potential contamination sources on the shoreline. The largest Spring tides occur approximately two days after the full moon about 45^{o}, then decreases to the smallest neap tides at about 225^{o}, before increasing back to spring tides 0^{o}.

Figures 11.13 and 11.14 show polar plots of *E. coli* results against the lunar cycle**.** It should be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but are not taken into account in this section.

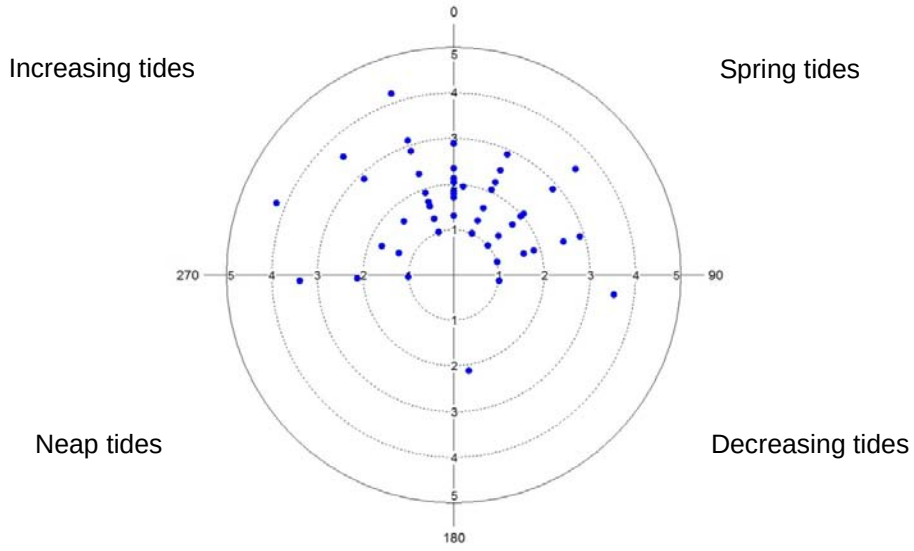


Figure 11.13 Polar plot of mussel Log$_{10}$ *E. coli* results - spring/neap tidal cycle.

A significant correlation was found between common mussel log$_{10}$ *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.232, p = 0.05). Sampling effort was heavily concentrated during increasing and spring tides and highest results occurred on increasing tides.

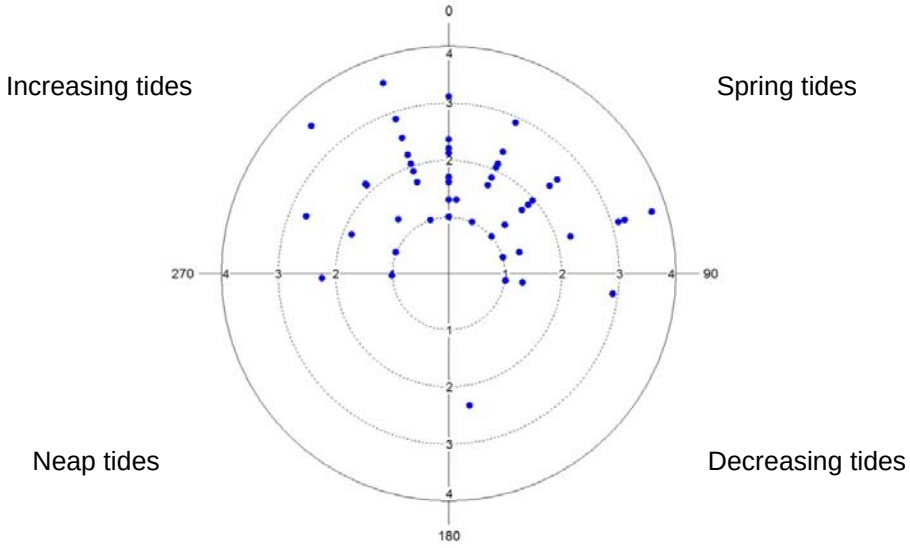


Figure 11.14 Polar plots of Pacific oyster Log_{10} *E. coli* results on the spring/neap tidal cycle.

No significant correlation was found between Pacific oyster log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.011, p = 0.993). Sampling effort was heavily concentrated during increasing and spring tides.

High/low tidal cycle

Tidal state (high/low tide) changes the direction and strength of water flow around production areas. Depending on the location of contamination sources, tidal state may cause marked changes in water quality near the vicinity of the farms. Shellfish species response time to *E. coli* levels can vary from within an hour to a few hours. High and low water data from Plockton was extracted from POLTIPS-3 in October 2012. This site was the closest to the production area and it is assumed that tidal flow will be very similar between sites. Figures 11.15 and 11.16 show polar plots of *E. coli* results against lunar tidal cycle, where high water is at 0^o and low water at 180^o.

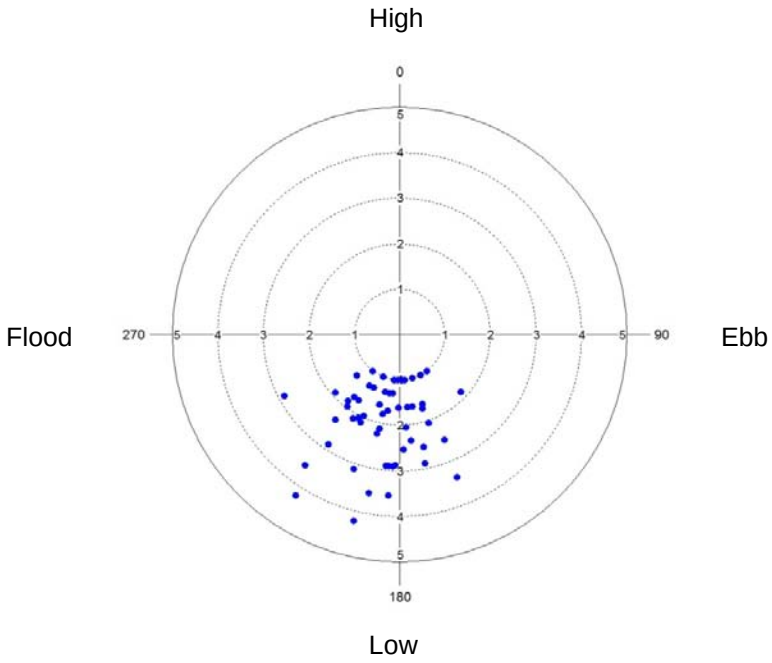


Figure 11.15 Polar plot of mussel $\log_{10}$ *E. coli* results on the high/low tidal cycle.

No significant correlation was found between common mussel $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.113, p = 0.492).

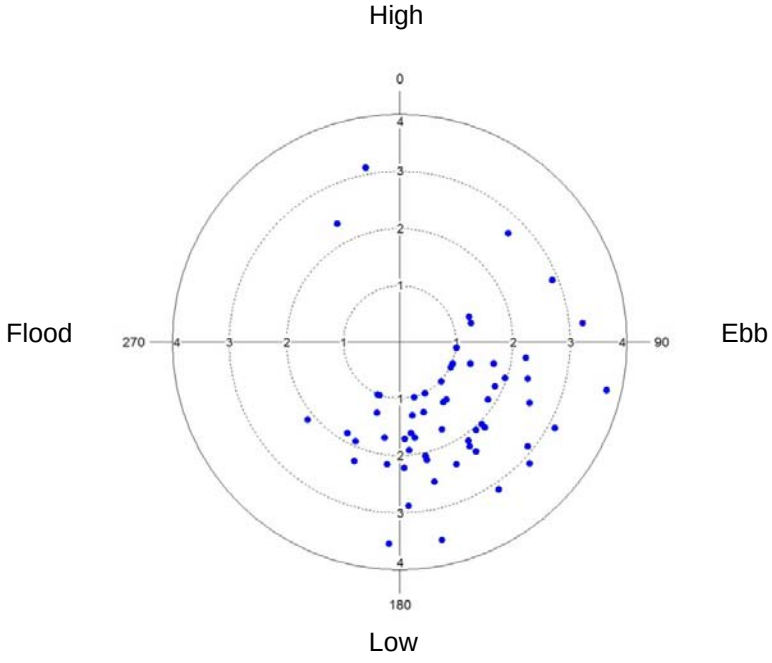


Figure 11.16 Polar plot of Pacific oyster $\log_{10}$ *E. coli* results on the high/low tidal cycle.

No significant correlation was found between Pacific oyster $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.194, p = 0.121). The majority of samples were taken just before low tide.

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 11.17 and 11.18 present individual species *E. coli* results against water temperature, with water temperature recorded for 56 of the 59 common mussel samples and 56 of the 59 Pacific oyster samples.

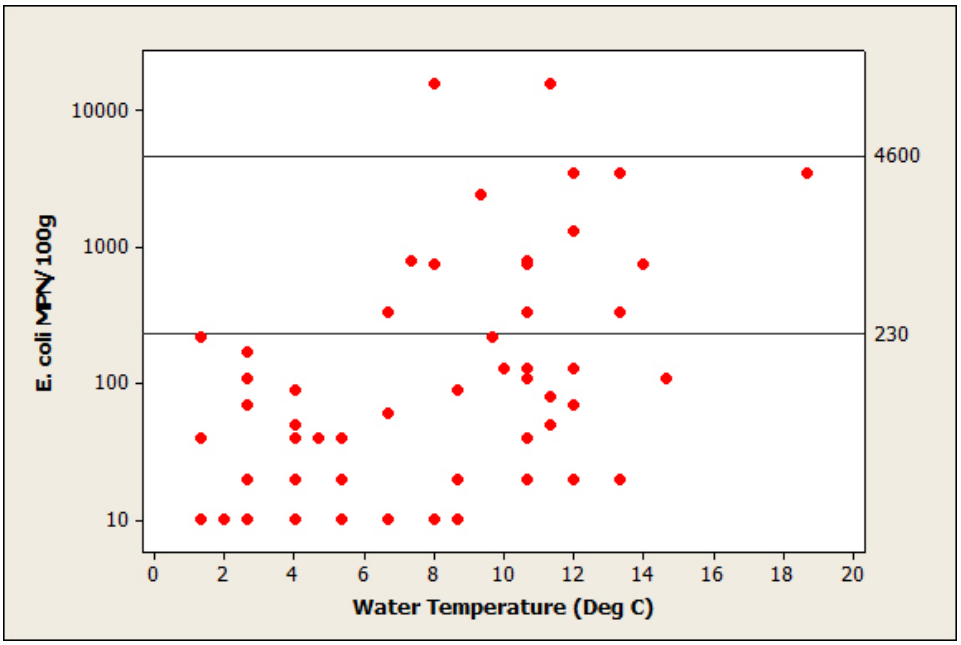


Figure 11.17 Scatterplot of mussel *E. coli* results against water temperature.

A statistically significant correlation was found between common mussel *E. coli* results and water temperature (Spearman's rank correlation r = 0.489, p = 0.000). Results >230 MPN/100 g occurred at water temperatures greater than 11°C. Low results occurred across most of the range of recorded water temperatures.

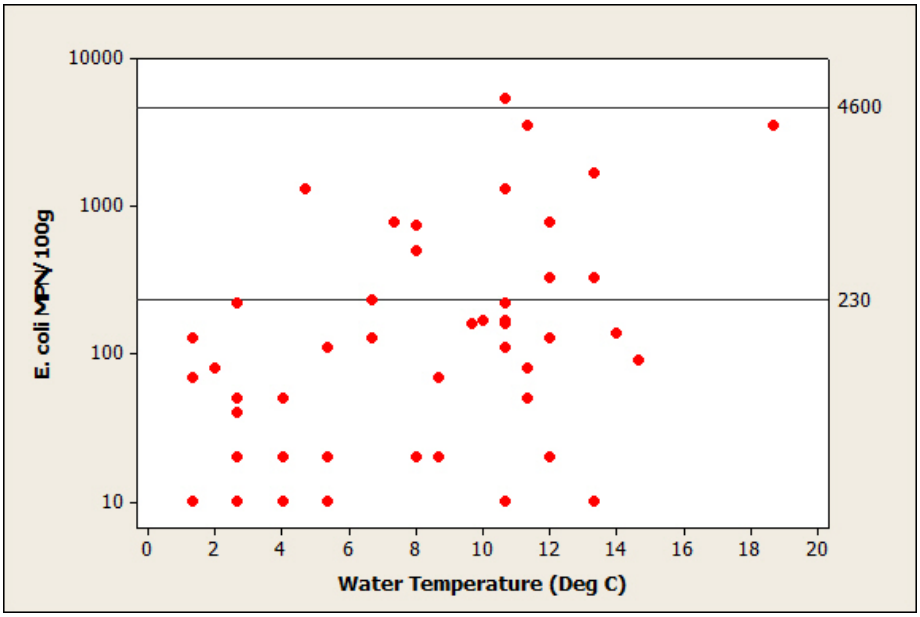


Figure 11.18 Scatterplot of Pacific oyster *E. coli* results against water temperature.

A statistically significant correlation was found between Pacific oyster *E. coli* results and water temperature (Spearman's rank correlation r = 0.403, p = 0.002). Most results >230 MPN/100 g occurred at water temperatures greater than 11°C. Low results occurred across most of the range of recorded water temperatures.

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater-borne contamination at a site. Figure 11.19 presents common mussel *E. coli* results against salinity for the 34 of 59 samples where salinity was recorded. Figure 11.20 presents Pacific oyster *E. coli* results against salinity for the 41 of 59 samples where salinity was recorded.

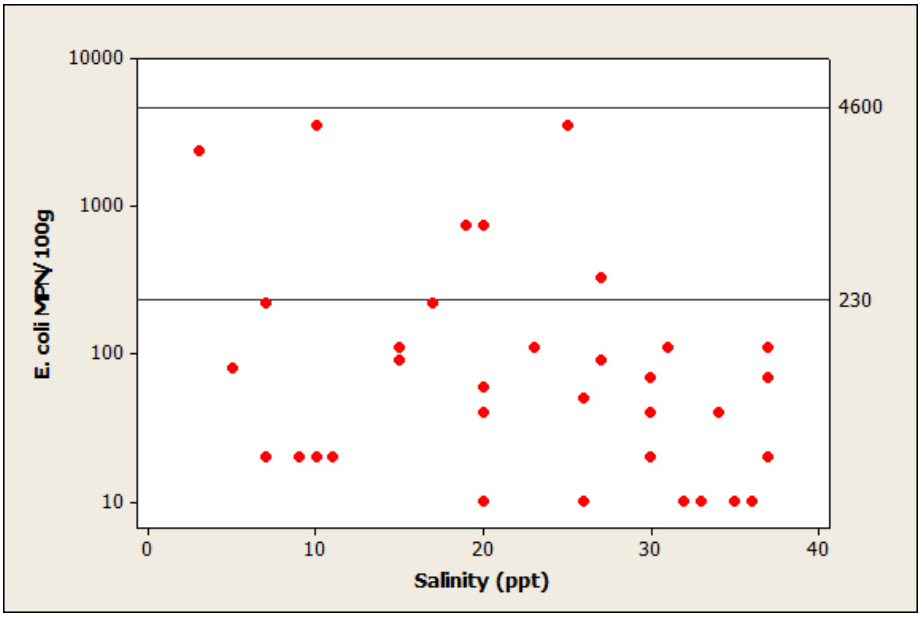


Figure 11.19 Scatterplot of mussel *E. coli* results against water salinity.

A significant negative correlation was found between common mussel *E. coli* results and salinity (Spearman's rank correlation r = -0.384, p = 0.019). There is a weak trend for E. coli sample results to correlate with lower salinities. All results >230 MPN/100 g had recorded salinities less than 30 ppt. This suggests regular and significant freshwater input to the fishery.

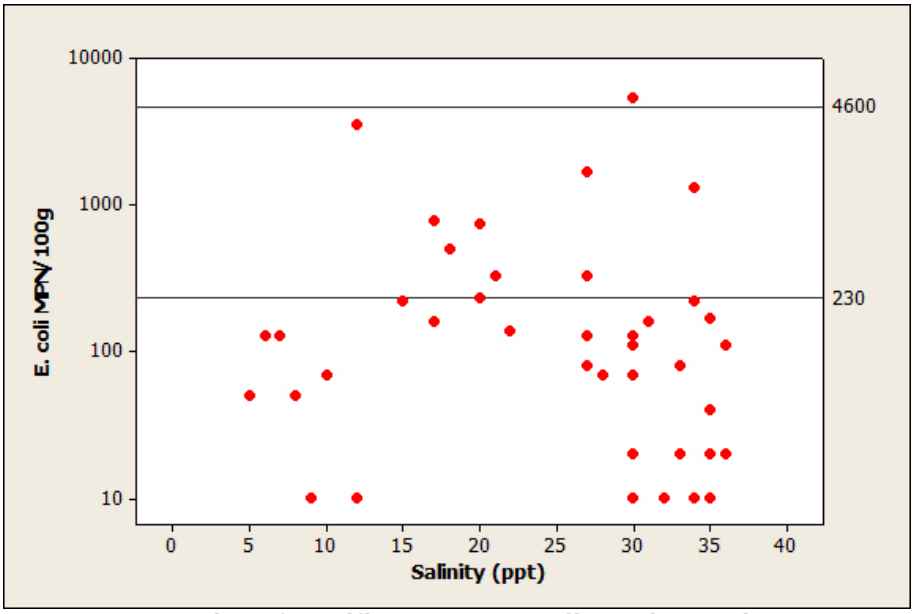


Figure 11.20 Scatterplot of Pacific oyster *E. coli* results against water salinity.

No significant correlation was found between Pacific oyster *E. coli* results and salinity (Spearman's rank correlation r = -0.174, p = 0.278).

11.7 Evaluation of results > 1000 *E. coli* MPN/100 g

Seven mussel samples yielded results > 1000 *E. coli* MPN/100 g. These are presented in Table 11.4.

Table 11.4 Mussel *E. coli* sampling results > 1000 *E. coli* MPN/100 g

Collection Date	*E. coli* (MPN/ 100 g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (^{o}C)	Salinity (ppt)	Tidal State (spring/ neap)	Tidal state (high/low)
15/07/2008	16000	NG 8291 4032	13.1	14.7	12	-	Increasing	Low
27/08/2008	2400	NG 8262 4081	5.8	42.8	13	3	Neap	Ebb
21/07/2009	16000	NG 8284 4029	24.8	28.8	14.5	-	Increasing	Low
24/08/2009	3500	NG 8286 4032	26.0	78.3	15	-	Decreasing	Low
09/08/2010	1300	NG 8281 4029	3.6	5.8	15	-	Increasing	Low
14/06/2011	3500	NG 8284 4029	8.0	31.2	20	10	Increasing	Low
15/08/2011	3500	NG 8283 4027	4.3	42.2	16	25	Spring	Low

(-) Data not available.

The high results all occurred from June to August, which is consistent with seasonal trends identified earlier in this section. All samples came from locations within Cluster 1 (see Figure 11.1) at the location of the current fishery. Results exceeding 1000 *E. coli*/100 g occurred after both high and low 2-day and preceding rainfall, but largely after moderate 7-day preceding rainfall. This suggests rainfall recorded at Plockton was not a good predictor of high results. All high results occurred at warmer water temperatures, with the lowest recorded water temperature at 12^{o}C. Salinity was only reported for three of the samples and varied widely. The majority of the elevated samples were taken as tides were increasing toward springs and at low tide. However, sampling effort was targeted at low water springs in order to facilitate access to the trestles for sampling.

Seven Pacific oyster samples had results > 1000 *E. coli* MPN/100 g. These are presented in Table 11.5.

Table 11.5 Pacific oyster *E. coli* sampling results > 1000 *E. coli* MPN/100 g

Collection Date	*E. coli* (MPN/ 100 g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (°C)	Salinity (ppt)	Tidal State (spring/ neap)	Tidal state (high/low)
28/08/2007	1300	NG 828 402	0.8	10.6	14	-	Increasing	Ebb
10/03/2008	1300	NG 8282 4025	-	-	9.5	34	Spring	Ebb
21/07/2009	3500	NG 8284 4027	0.0	2.7	14.5	-	Increasing	Ebb
21/09/2009	5400	NG 8278 4023	26.0	78.3	14	30	Spring	Ebb
26/07/2010	1300	NG 8277 4022	2.4	14.3	14	-	Increasing	Ebb
14/06/2011	3500	NG 8284 4027	37.4	72.0	20	12	Increasing	Low
18/07/2011	1700	NG 8277 4024	8.0	31.2	16	27	Spring	High

(-) Data not available.

All but one of the results exceeding 1000 *E. coli*/100 g were obtained between June and August. Locations were distributed between both clusters shown in

Figure 11.2. High results occurred after a wide range of preceding rainfall values. Two of the results occurred after very high rainfall over both the two and seven days preceding sampling. One result occurred after very low two-day and seven-day rainfall. This suggests that as with mussels, recorded rainfall at Plockton was not a good predictor of high results

Recorded water temperature varied between 9.5 and 20°C. Salinity was only recorded for four of the samples and varied between 12 and 34 ppt. Most samples were taken on an increasing to spring tide, and at ebb or low tide. However, sampling effort was targeted at these states of tide in order to facilitate access to the trestles for sampling.

11.8 Summary and conclusions

Common mussels

The majority of samples were associated with the Loch Kishorn North RMP for oysters and were all taken from the southern shoreline and not the northern shoreline, where the RMP was located. Results were spread across the present recorded area of trestles and also to the southwest of that area. Higher results appeared to be associated with the present trestle area, but analysis of the two geographical clusters of results showed no statistically significant difference.

A pronounced seasonal trend was found in mussel results. All results >230 MPN/100 g occurred from May to September, with peak contamination levels occurring in July and August. Only one result <230 MPN/100 g occurred in July, and none occurred in August. This was confirmed by statistical analysis of results by season, which showed significantly higher results in summer than in other seasons.

There was no significant correlation with either previous two or seven day rainfall. A significant correlation was found between *E. coli* results and spring/neap tidal state, with highest results coinciding with an increasing tide. However, nearly all samples were taken on either increasing or spring tides. Although the majority of elevated results were collected on low/ebb tides state, no statistically significant correlation was found between *E. coli* results and high/low tidal state. A significant positive correlation found between water temperature and *E. coli* results, and a significant negative correlation with salinity. Results greater than 230 *E. coli* MPN/100 g occurred at temperatures greater than 11°C and salinities below 30 ppt.

Pacific oysters

The majority of samples were taken from around the Loch Kishorn North RMP for oysters, with a cluster of results from locations to the southwest of the

present trestle area, in common with the mussel results. Analysis of the results by cluster showed no significant difference in *E. coli* results between the two.

A clear seasonal trend was found in oyster results, though this trend was less pronounced than in mussels. The majority of results >230 MPN/100 g occurred from June to September. The less pronounced trend appeared to be partly driven by the lower peak results and partly by the occurrence of results <230 MPN/100 g in all months.

There was no significant correlation with either previous two or seven day rainfall. No significant correlation was found between tidal state with respect to spring/neap tides or high/low tides. Positive correlations were found between *E. coli* results and water temperature, where increasing contamination was associated with increasing water temperature. No correlation was found between *E. coli* and salinity.

12. Designated Shellfish Growing Waters Data

The Loch Kishorn production area lies within the Loch Kishorn North West designated shellfish growing water. Under the Shellfish Waters Directive (European Communities 2006), designated waters must be monitored quarterly for faecal coliforms in shellfish flesh and intervalvular fluid. SEPA is responsible for ensuring that this monitoring is undertaken, and have used common mussels for this purpose.

The relative positions of the SGW boundary, the Loch Kishorn production area, shellfish farm, RMP and the SGW monitoring point are shown in Figure 12.1. Since 2007, SEPA have based the SGW assessment on FSAS *E. coli* results. These *E. coli* results have been reviewed in Section 11 of this report. Monitoring results obtained prior to 2007 were not considered.

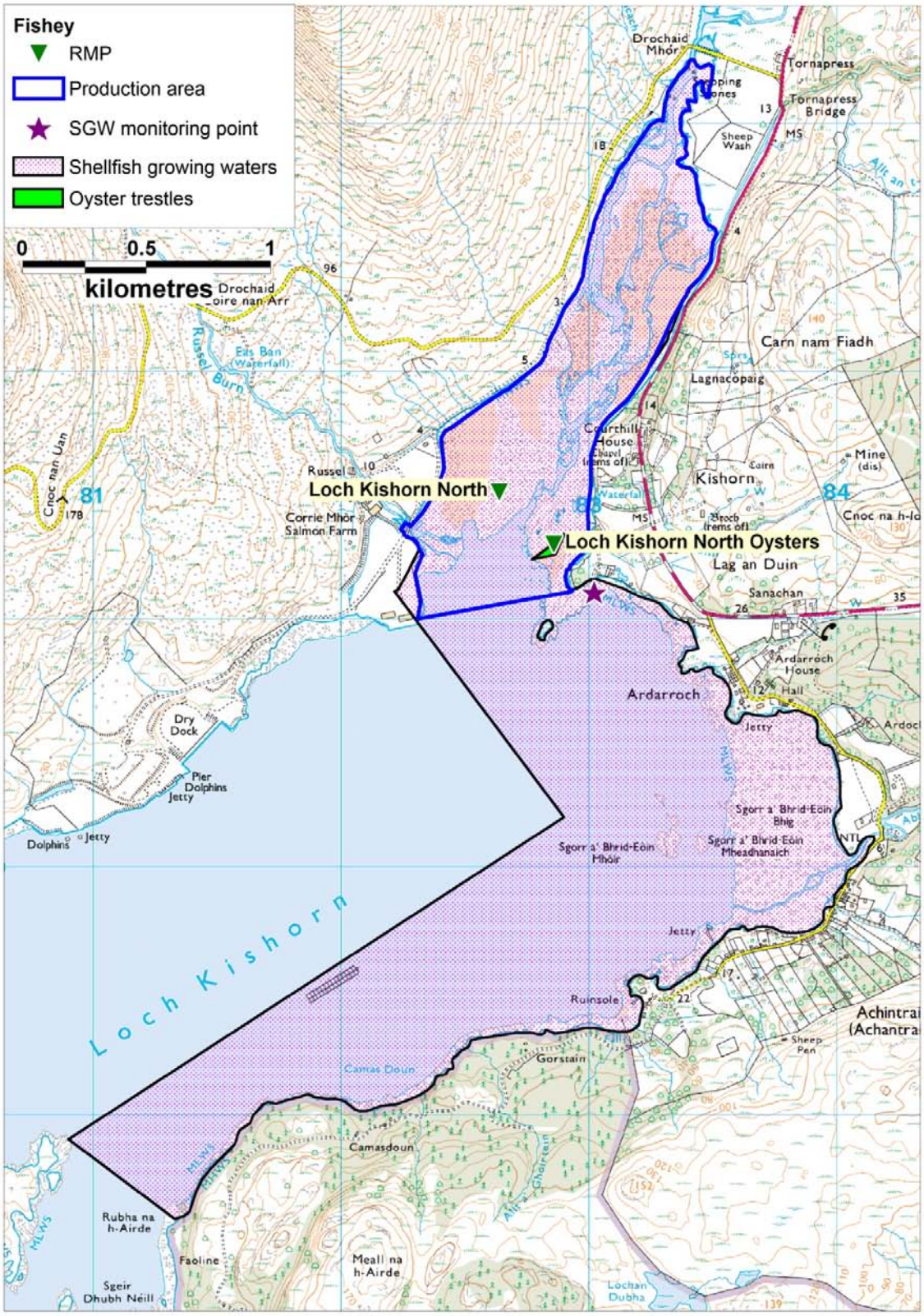


Figure 12.1 Designated shellfish growing water – Loch Kishorn, North West

13. Bathymetry and Hydrodynamics

13.1 Introduction

The Study Area

Loch Kishorn, Wester Ross, is situated adjacent to the north of Loch Carron. There is freshwater input from the surrounding land and rivers and large amounts of rainfall transporting material into the loch (Karayusel and Karayucel 1999). To the north and west, Loch Kishorn is surrounded by the Applecross peninsula. A headland to the east partially separates it from upper Loch Carron. To the west of this headland lies the Garra Islands which denote the mouth of the Loch the largest being Kishorn Island. The River Kishorn flows into the head of the loch with other small rivers including Russel Burn, Abhainn Cumhang a Ghlinne and Allt a' Chumhaing. The study area is shown in Figure 13.1 and the assessment area is contained within the red line.

Coordinates for the deepest part of Loch Kishorn:
57° 22.3' N 005° 38.5' W
NG 805 385

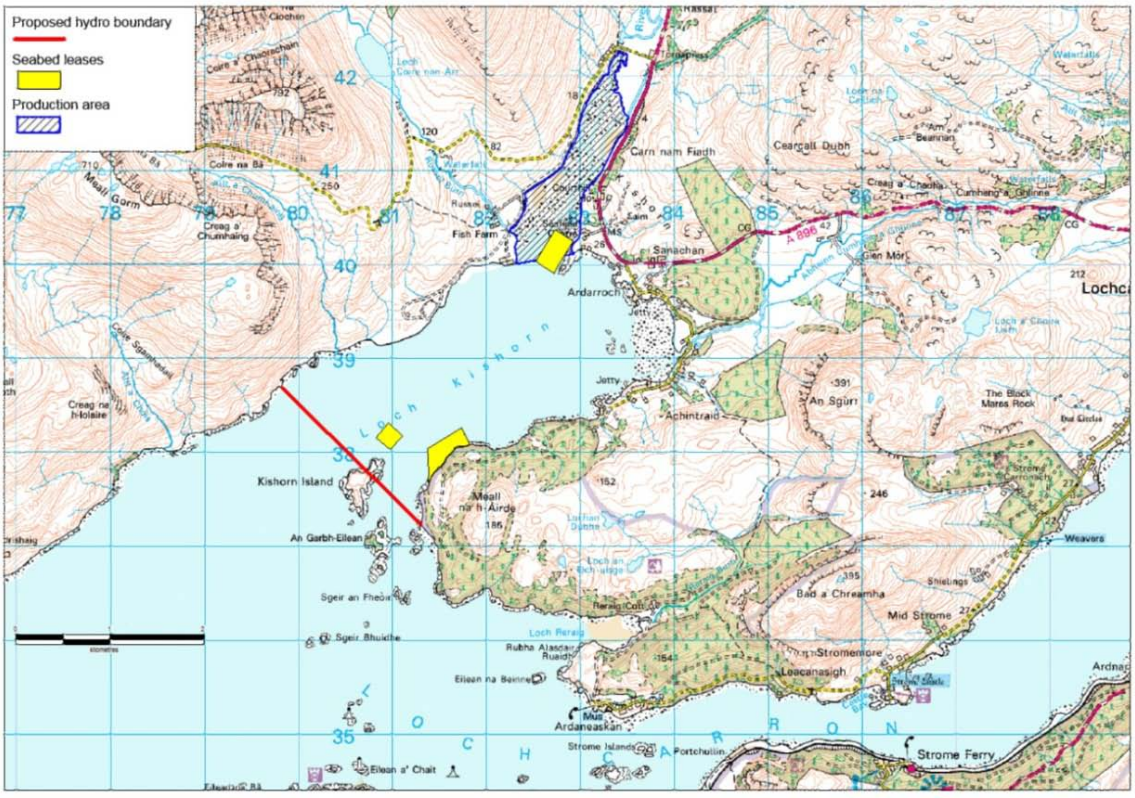


Figure 13.1 Extent of hydrographic study area

13.2 Bathymetry and Hydrodynamics

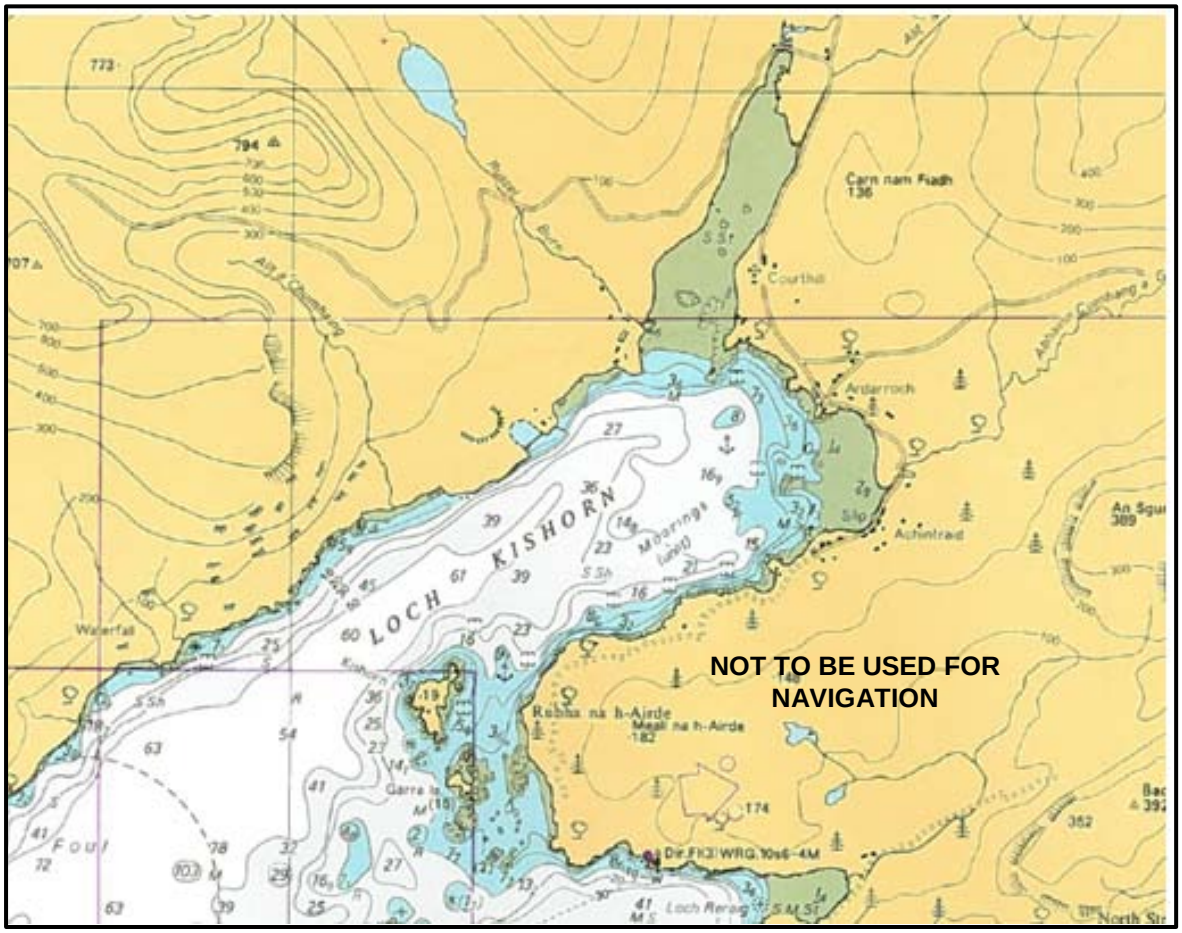


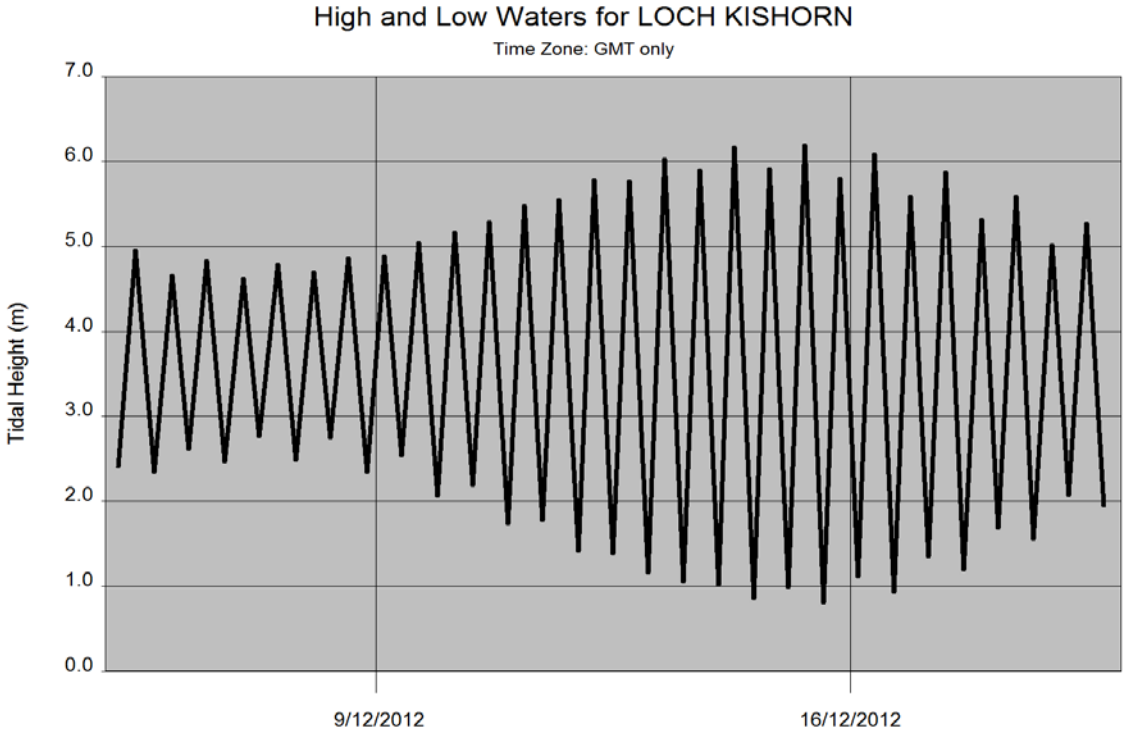
Figure 13.2 Admiralty chart extract for Loch Kishorn

Figure 13.2 shows the bathymetry of Loch Kishorn, one of the smallest lochs in Scotland and relatively bathymetrically simple. It is short (4.1 km), with no sills or major basins. The maximum charted depth is 63 m and there is no shallow sill at the entrance which would impede exchange. The consequence of this is that interaction between Loch Carron and Loch Kishorn is relatively high and therefore the formation of isolated deep water is restricted (Russel, *et al*., 2011; Mente, *et al*., 2010). The loch covers an area of around 4.1 km x 1.3 km with an estimated mean low water depth of 22.2 m and the proportion of intertidal areas in Loch Kishorn is comparatively high at 24% (Russel, *et al*., 2011; Mente, *et al*., 2010). The estimated low water volume is 1.2×10^8 m^3. The bay is generally steep sided on the northwest side of the loch with depths increasing to > 20 m within about 100 - 150 m of the shore although at the head of the loch and around the Garra Islands to the southeast, the gradient is less. River Kishorn flows into the head of the loch which is a shallow estuarine area of length 2.5 km and width of 1 km. The current shellfishery is located in this estuarine area.

Tides

Loch Kishorn has a typical semi-diurnal tidal characteristic. Data on tidal information is given from local pilot books or charted information. The nearest location for tidal predictions is Plockton [http://easytide.ukho.gov.uk].

Standard tidal data for Loch Kishorn are given below (Laurence 1990) and the spring/neap cycle of tidal height around the time of the survey (11-13 December 2012) is shown in figure 13.3:



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

Figure 13.3 Two week tidal curve for Loch Kishorn.

Tidal Heights:

Mean High Water Springs = 5.1 m
Mean Low Water Springs = 0.7 m
Mean High Water Neaps = 3.8 m
Mean Low Water Neaps = 2.0 m

Tidal Ranges:

Mean Spring Range = 4.4 m
Mean Neap Range = 1.8 m

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

Springs: 2.3×10^7 m^3
Neaps: 9.6×10^6 m^3

Tidal Streams and currents

There are no tidal diamonds for this area. Enhancement of tidal streams caused by straights and channels are negligible in Loch Kishorn due to its relatively simple bathymetric topography. However, there may be some localised effects around the Garra Islands. There are a number of sources of current meter data available from previous surveys. Current data were obtained from SEPA which were collected from two sites in north and south Loch Kishorn (Anderson, 2006a; Anderson, 2009; Black, *et al*., 2005). They typically span 15 days; being the half-lunar period to capture a spring-neap cycle. In these reports sub-surface typically refers to a depth of approximately 8m, mid-depth is typically 14m and near-bottom is typically 2-3m above the sea bed. There is one other reported value of current speed by Karayucel and Karayucel (1998) of 0.05 m/s with a reported range of 0.01 to 0.18 m/s but no direction is given.

Data from the north of Loch Kishorn were collected in 1997 and 2002 (Anderson, Kishorn North - site and hydrographic survey report. Report to Scottish Sea Farms. AMSL Report No 06/08.1 2006a) summarised in Table 13.1. Semi-diurnal periodicity along with some spring-neap variation was displayed throughout the velocity readings. In general, the currents were of a moderate velocity and whilst the tabulated mean and maximum velocities are greatest in the sub-surface Anderson reports that overall “there was similarity between current velocity and direction at all depths, with relatively little current shear” (Anderson, Kishorn North - site and hydrographic survey report. Report to Scottish Sea Farms. AMSL Report No 06/08.1 2006a). The data in 1997 has rather little technical narrative accompanying it. Anderson also reports (2006a) that the directions of the currents in mid-water and sub-surface areas are highly asymmetric with the flow out of the Loch being of greater duration than the inflow with a pronounced residual to the south-west. The near-bed current residual was negligible in comparison. Overall, the 2002 survey suggested that the Allt a’ Chrois site in north Loch Kishorn was “moderately-flushed”.

Table 13.1 Allt a’ Chrois current data measured in 1997 (*in italics*) and in 2002.

	Near-bed	Mid	Sub-surface
Mean Speed (ms^{-1})	*0.016* 0.046	*0.040* 0.060	*0.040* 0.083
Maximum Speed (ms^{-1})	0.269	0.229	0.568
Principal Axis Amp & Dir (ms^{-1}) & (°M)	0.072 (085)	0.082 (245)	0.122 (245)
Eccentricity Ratio	2.32	1.86	2.35
Residual speed (ms^{-1})	*0.016* 0.003	*0.028* 0.030	*0.032* 0.028
Residual direction (°M)	*252* 151	*257* 267	*255* 257

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

Data from the south of Loch Kishorn were collected at Camus Doun Point in 1997 and 2009 (Anderson, Kishorn South - site and hydrographic survey report. Report to Scottish Sea Farms. AMSL Report No 09/04.1 2009), summarised in Table 13.2. Semi-diurnal periodicity along with some spring-neap variation was displayed throughout the velocity readings. In general, the currents were of a moderate velocity with the sub-surface consistently showing the greatest maximum velocity. The data in 1997 has rather little technical narrative accompanying it. Anderson reports (2009) that the current direction was asymmetric in all depths with the surface and mid-water current vectors generally flowing north-east and the current vectors near the bed were flowing in a south-west direction. Overall, the 2009 survey suggested that the Camus Doun site in south Loch Kishorn was “moderately to weakly-flushed”.

Table 13.2 Camas Doun Point current data measured in 1997 (marked in italics) and in 2009.

	Near-Bed	Mid	Sub-Surface
Mean Speed (ms^{-1})	*0.039* 0.035	*0.035* 0.057	*0.029* 0.061
Maximum Speed (ms^{-1})	*0.200* 0.256	*0.160* 0.303	*0.230* 0.412
Principal Axis Amp & Dir (ms^{-1}) & (^{o}M)	0.078 (235)	0.087 (060)	0.108 (065)
Eccentricity Ratio	2.36	1.61	2.40
Residual speed (ms^{-1})	*erratic* 0.012	*0.015* 0.009	*0.017* 0.012
Residual direction (^{o}M)	*270* 203	*045* 026	*045* 035

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

A more complete current meter record is found in Black *et al* (2005) who made 3 consecutive current meter deployments between August and November 2001 at the Camus Doun site on the southern side of Loch Kishorn near the village of Achintraid. They used a combination of profiling and single point meters to collect a data record of 168 days duration. Table 13.3 shows the data from Camas Doun gathered in 2001 (Black, *et al*., 2005). Data from each current meter deployment is reported separately in Black *et al* (2005)

and Table 13.3 shows the data from each deployment. The maximum current speeds are higher than those reported in table 13.2, and this was also noted by Black *et al* (2005). No obvious explanation can be given and it may reflect the difference in record length to some extent. Using the lower limit of residual surface current of 0.03 m/s gives an estimated maximum transport of around 1.3 km over a tidal cycle.

Table 13.3 Camas Doun current data 2001 from Black *et al* (2005). Principal Axis amplitude and direction not reported.

	Near Bed	Sub-Surface
Mean Speed (ms^{-1})	0.089 0.092 0.029	0.143 0.092 0.076
Maximum Speed (ms^{-1})	0.502 0.183 0.355	0.553 0.437 0.355
Residual speed (ms^{-1})	0.009 0.012 0.002	0.036 0.036 0.029
Residual direction (^{o}M)	242 187 121	223 223 230

Using a typical surface principal current amplitude of 0.1 m/s (Tables 13.1 and 13.2) and the assumption of a uniform sinusoidal tide, the cumulative transport that might be expected during each phase of the tide has been estimated as approximately 1.5 km. No distinction is made here for springs and neaps.

Additional work was done by Black *et al* (2005) using surface drifters around the Camas Doun site to measure the horizontal dispersion coefficients. They report "reasonable dispersion" in the area, at a time of neap tides. In all cases the dispersion coefficients were higher than the default value of 0.1 $m^2 s^{-1}$ recommended by SEPA for sea lice medicine consent modelling. However, there is a clear caveat that the values are highly dependent upon tidal and wind conditions at the time of any dispersion survey. Such data is therefore only a general indicator of dispersion potential. Using a median value of 0.05 m/s from the reported values for the drifter speed, this gives a potential maximum transport distance of around 2 km over a tidal cycle.

The residual current vectors are shown in Figure 13.4 to capture the key features of the circulation within Loch Kishorn. The principle observation is that there is a broadly cyclonic circulation of the surface waters, with the most dominant residual occurring along the north side towards the south west. However, there are records (Black, *et al*., 2005) showing a south westward flow of surface water on the south side. This variability in circulation could be linked to the amount of freshwater run-off during the measurement period. The general pattern of circulation near the bed is less clear although in most

cases there is a degree of vertical sheer with the near bed flow in a different direction to the surface or mid water.

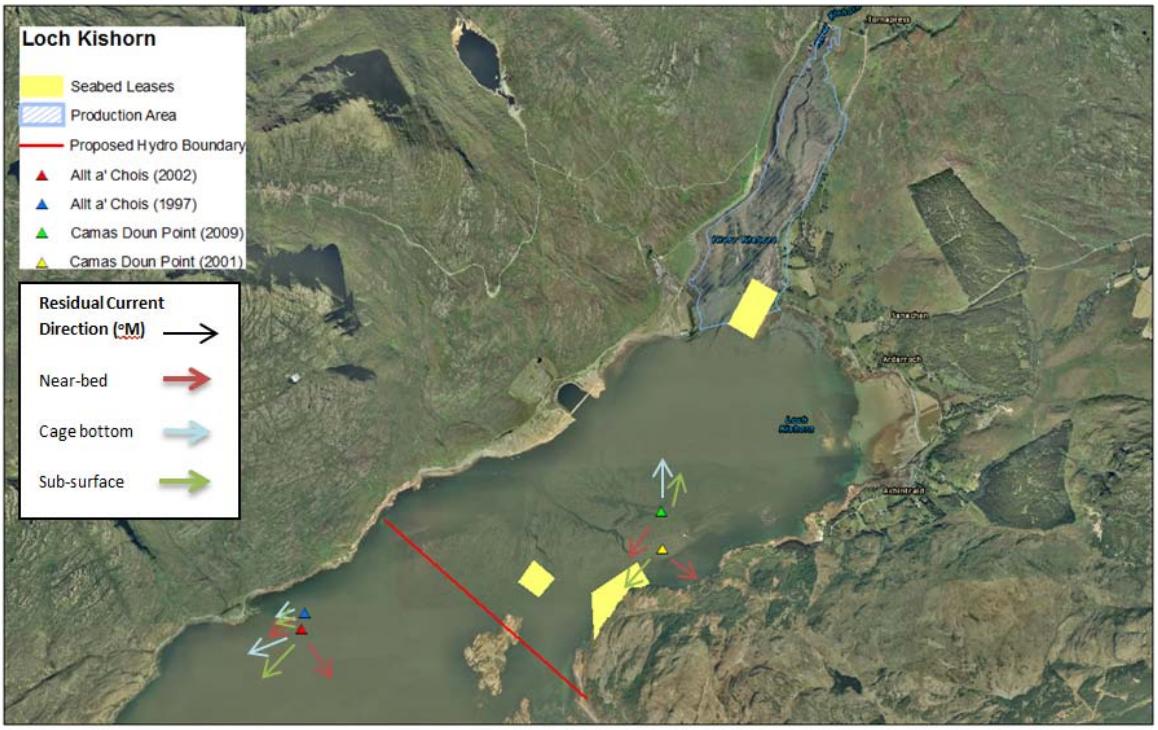


Figure 13.4 Map showing residual current directions for the current meter deployments that are reported.

The principal current directions reported in Anderson (2006a, 2009) are shown in Figure 13.5. It should be noted that these show a 180° shift between north and south which is rather unlikely based on the nature of tidal forcing for this system. During flood and ebb one would expect the principal current on both sides of the loch to behave similarly. It is possibly indicative of a 180° error in the reporting of the direction of the principal axis.

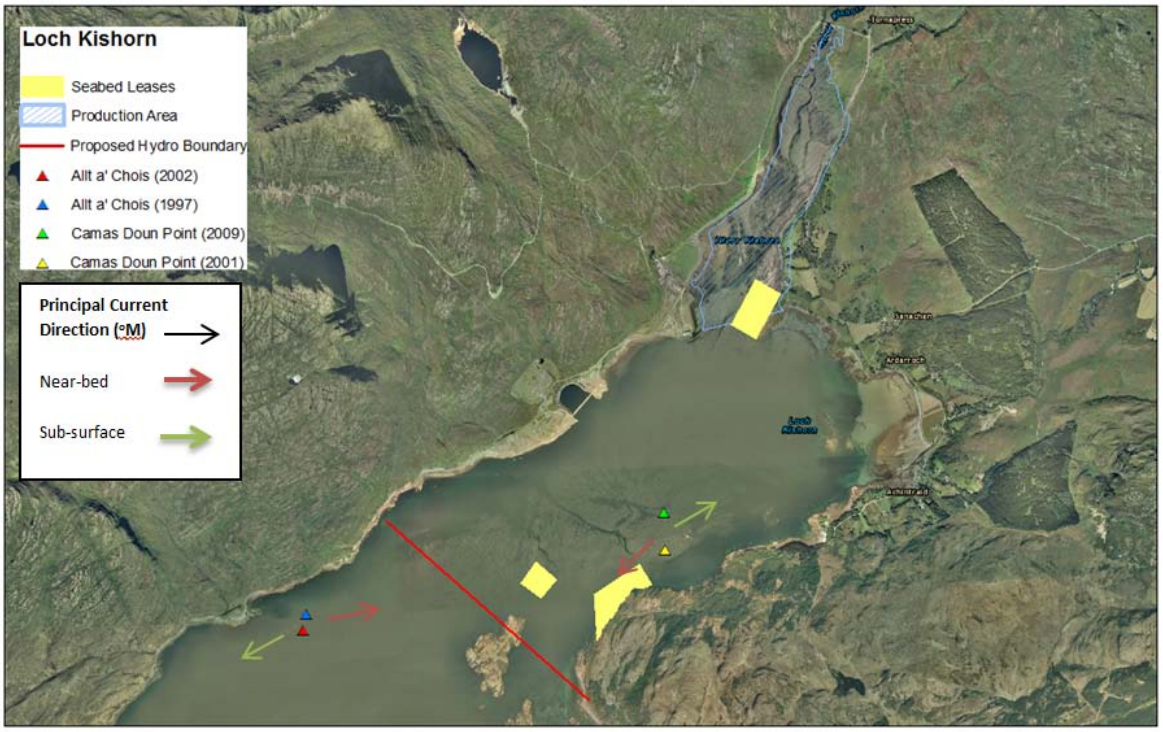


Figure 13.5 Map showing principal current directions for the current meter deployments that are reported in Anderson (2006a, 2009). Note the caveats on direction given in the text.

13.3 River/Freshwater Inflow

The source of river inflow into Loch Kishorn is primarily from the River Kishorn which is situated to the north and feeds into the substantial estuary. This river is not gauged. Other negligible rivers which may not flow in drier weather are Russel Burn, Allt a' Chumhaing and Abhainn Cumhang a Ghlinne. The annual precipitation in the area is approximately 2000 mm and the annual freshwater runoff is estimated as 115.2 mm^3yr^{-1} (Edwards and Sharples 1986). The ratio of fresh water flow to tidal flow is low at approximately 1:125(Edwards and Sharples 1986), though of course this will have considerable seasonal variability.

13.4 Meteorology

The meteorological section of this report indicates that the prevailing winds and the strongest winds are found in the south west quadrant during all seasons. It must be noted that the data is taken from a meteorological station some 105 km west of Loch Kishorn on South Uist. However, the topography of the land at this site is likely to promote the occurrence of dominant wind forcing from the south west.

The pattern of rainfall follows a typical seasonal pattern, being highest in autumn and winter. Clearly the resulting run-off will also show a seasonal dependence and be larger in the autumn and winter months. It must be noted

however, that rainfall can be high in this area regardless of season. In the period from 2007 – 2012, Plockton received daily rainfall of less than 1mm over 46% of days and for 14% of days, the area received over 10 mm.

13.5 Model Assessment

The exchange characteristics of Loch Kishorn were assessed using a layered box model approach. The model represents the Loch as a box made up of three layers and was formulated according to the method of Gillibrand *et al* (2012). The box layers are forced with surface wind stress, estimates of fresh water discharge, surface heat flux parameters and, at the open coastal boundary, profiles of temperature and salinity are prescribed from climatology compiled by the UK Hydrographic Office. This sets the model with climatological boundary conditions to represent an 'average' year. The model has been tuned and validated for Lochs Creran and Etive. A full validation for Kishorn has not been done due to lack of seasonal data.

The box model quantifies the primary exchange mechanisms. The key outputs from the model with respect to this hydrographic assessment is a series of annual mean values that describe the relative importance of the estuarine (gravity) exchange, tidal exchange, exchange between the layers and the flushing time, which is the inverse of the exchange rate. These values are given in Table 13.4.

Table 13.4 Summary of annual mean parameter values from the box modelling exercise.

Parameter	Value
Tidal Volume Flux ($m^3 s^{-1}$)	460
Estuarine Circulation Volume Flux ($m^3 s^{-1}$)	62
Wind Driven Entrainment between upper and lower layer ($m^3 s^{-1}$)	17
Tidal and Density driven entrainment between upper and lower layers ($m^3 s^{-1}$)	0.1
Median Flushing Time (days)	3.0
95%-ile Flushing Time (days)	4.8

The ratio of Tidal volume flux to estuarine circulation volume flux is 7.4. Values greater than 2 indicate a system that is strongly tidal in its exchange characteristics (Gillbrand, *et al*., 2012).

13.6 Hydrographic Assessment

Surface flow

The site and the meteorological data indicate that there is likely to be a rather persistent freshwater discharge into the surface waters of the loch, though the absolute value of discharge would be seasonally varying. It is expected that this would manifest itself as a weak estuarine flow with surface residual flows, certainly on the northern side, directed towards the south west further supported by the observations of asymmetry in the tidal flow. The weak current shear that is reported (Anderson, Kishorn North - site and hydrographic survey report. Report to Scottish Sea Farms. AMSL Report No 06/08.1 2006a) also implies a weak estuarine flow.

The principal current direction of the surface water has, from rather short surveys of currents, been shown to flow in alignment with the shore line. Cumulative transport during each phase of the tide is estimated to be around 1.5 km.

Net transport of contaminants is related to the residual flow presented in Figure 13.4. The residual surface flow measured in previous surveys varies in its direction between the north and the south shores. On the north shore the surface residual is to the south west whilst on the south shore the residual is often to the north east. This can be interpreted as a weakly cyclonic circulation of surface waters. With the measured surface residuals of order 0.02 m/s, the transport over a tidal cycle of approximately 12 hours would be less than 1 km (consistent with the strong asymmetry of the flow), or a quarter of the loch length. It is therefore likely that any surface contaminant would follow the contours of the loch and disperse effectively via the surface estuarine flow. Characteristics of surface flow will show some seasonality related to the run-off.

The dominance of the south west winds is likely to retard the surface flow during periods of strong wind. However, under those conditions, the loch is likely to become more uniformly mixed, breaking down surface stratification. Further, any retardation of flow will be relaxed as the wind decreases. This will give rise to non-steady estuarine circulation in the Loch.

There is only one study that measures dispersion in the Loch (Black, *et al*., 2005), but this shows the rate of dispersion in the surface waters would be rather high compared to other sea loch sites. We expect this to be a rather characteristic feature of the loch given the observed horizontal shear in the surface currents across the loch set up from the freshwater discharge and the tidal flow. Dispersion could be further enhanced by strong winds.

The tidal flow would appear to be rather straightforward at this site, with rather little opportunity for generating dispersive eddies. However, there may be areas of enhanced dispersion around the islands.

Exchange Properties

The key aspect of the model output in terms of the exchange is that the tidal volume flux dominates the estuarine (or gravitational) volume flux by a factor of 7.4. This means that exchange of waters in Loch Kishorn is principally a tidally driven process. Hence there is likely to be rather little seasonal variation in the flushing time of the Loch. The model predicts that 95% of the time the flushing time will be 4.8 days or less. This is consistent with the "moderately" flushed assessments given by Anderson (2006a, 2009). However, this is a shorter flushing time than that reported by Anderson, (2006b) of 7.6 days. The current box model is a development of that used by Anderson and includes additional processes that enhance exchange, notably the density driven circulation.

It is expected that Loch Kishorn would be a moderately-well flushed system throughout most of the year with surface contaminants being effectively dispersed in the residual flow.

There are a number of current meter data series available for Kishorn and there is sufficient ancillary data to set up a layered box model. However, long term hydrographic data coverage for this area is low; particularly data sets with seasonal resolution. Therefore the confidence level of this assessment is MEDIUM.

14. Shoreline Survey Overview

The shoreline survey was undertaken from the 11th-13th December 2012, with a second survey conducted on the 13th January 2013. This second survey was necessary because samples taken during the initial survey arrived for analysis outside the 48 hr processing limit. Shellfish, freshwater and seawater samples were therefore re-sampled on the 13th January 2013 and the results of these were used in the assessment.

No rainfall fell on the two days prior to the initial survey or during the survey days, though a light snow fell on the 3rd day (13th December 2012). Air temperatures were low between 0 to -1°C and the ground remained frozen. There was little or no wind. Moderate to heavy rainfall fell throughout the day of re-sampling on the 13th January 2013, with an air temperature of 3.5°C at the start of the day.

The fishery at Loch Kishorn North is situated on a mixed area of rock and sand to the very south-east of the tidal estuarine part of upper Loch Kishorn. It currently consists entirely of Pacific oyster production. At the time of shoreline survey, there were 15-20 bags of mature oysters (> 3 yrs) located in the south-central part of the site. The harvester indicated that he planned to undertake a renewal of stock and hardware in 1-2 years time.

In the recent past, common mussels were produced on 'Galician' style rafts. This was discontinued due to problems with Eider duck predation. An area of abandoned trestles with bags of empty shells was found north along the shore from the present fishery.

Many of the properties in the area were reported to be connected to the relatively new waste water treatment system, which was installed around 2 years ago. This replaced the existing septic tank storage and direct discharge to shore. There were still a number of discharge pipes running onto the shore, but according to a Scottish Water operative met during the survey, at least some of these would be redundant. Recent ground/earth works and new man holes were observed by the road in front of the houses at Achantraid, which seemed to corroborate this account.

Numerous watercourses were observed and recorded. The largest of these was the River Kishorn, which discharged to the head of the estuary. Numerous small streams and burns were seen to discharge into the bay, with areas of seepage through rocks/boulders also present. During the initial shoreline survey watercourses were not flowing rapidly due to the dry weather that persisted prior and during the survey. On the re-sampling survey watercourses were running high from the heavy rainfall experienced on the day of the survey. The majority of freshwater samples taken returned results

below the level of detection for the dilutions tested (<100 or <1000 *E. coli* cfu/100 ml depending on whether the sample was identified as potentially contaminated). Two samples returned results of 200 *E. coli* cfu/100 ml, and one of contaminated effluent returned a result of 900000 *E. coli* cfu/100 ml.

Very little livestock was observed in the southern survey area due to the location of the houses on the seafront which blocked the view inland. No livestock was observed on the western side of the loch. A large flock of sheep was seen near the head of the estuary, in a fenced area above the shore near Tornapress Bridge. A second smaller flock was seen near the Kishorn WWTW at Ardarroch. Droppings were noted intermittently along the shore walk but were difficult to distinguish between deer and/or sheep.

The majority of the coast around Loch Kishorn is rural, with farming, plantation/wild forestry and private house/crofting on the foreshore alternating with wild, undeveloped shoreline. There has been an upsurge in industry around the old fabrication yard area to the west of the loch, with haulage companies, renewable energy firms, boat fabrication/ repair companies all utilising the space. A boat yard and pier were observed on the west shore of the estuary, north west of the fishery.

Sea birds were noted during the survey, especially on the first day when seagulls were seen resting on the water in the main part of the Loch. There were fewer birds noted on the following two days, although oystercatchers were noted.

Seawater E. coli results showed moderate levels of contamination on the southwest side of the estuary and lower levels of contamination at the head of the estuary and near Achintraid, south of the estuary. Seawater samples taken from near the trestles were the least contaminated. Pacific oyster and wild shore mussel samples taken from the area of the fishery showed very low contamination levels.

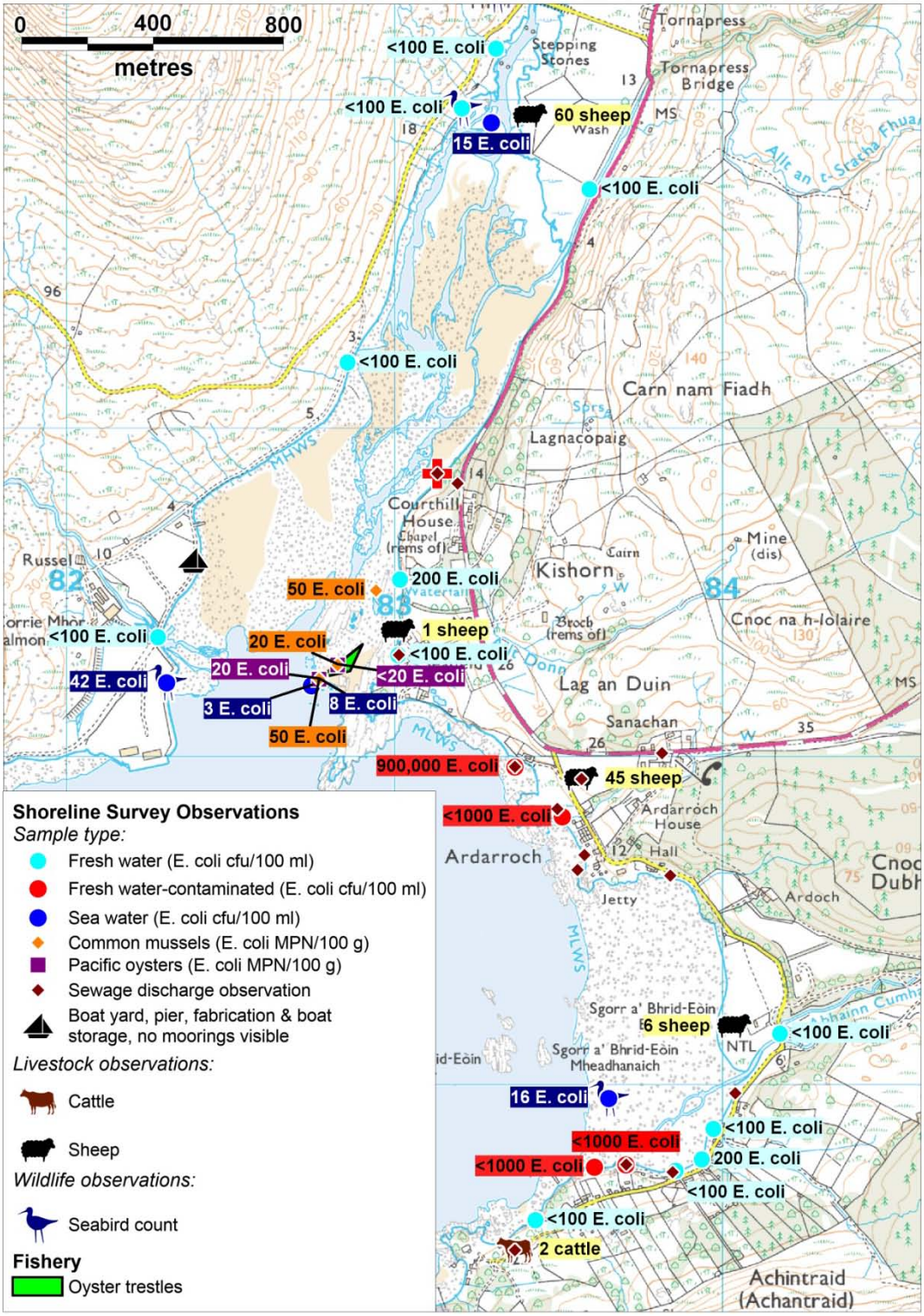


Figure 14.1 Summary of shoreline survey findings for Loch Kishorn

15. Overall Assessment

Human sewage impacts

Although a remote area in general, the discharge of final effluent from Kishorn WWTW and overflows from two pumping stations are situated within 1 km of the Pacific oyster farm. The Kishorn WWTW was upgraded to UV treatment within the last two years. A slight improvement in shellfish *E. coli* monitoring results from 2010 onward appears to coincide with the upgrade. Although tertiary treatment would be expected to significantly reduce bacterial load in the effluent, it may not be as effective at removal of viruses. As long as the works is operating efficiently it is not expected to significantly impact water quality at the fishery.

Intermittent overflows from the Kishorn sewerage system are emergency overflows incorporating between 42 and 195 hours storage. Overflows would only occur in event of equipment failure or blockage and spills to the environment would only occur once the storage capacity was exceeded.

As the oyster farm is relatively near to the Kishorn Corthill (500 m) and Kishorn Schoolhouse EOs (600 m), any significant overflows from these may have an impact on water quality at the fishery. The impact of any spills from these overflows is unlikely to be reflected in monthly shellfish monitoring results due to their expected rarity.

Athough the treatment works is reported to serve houses along much of the shoreline southeast of the fishery, a significant number of individual consents for both septic tanks and small treatment works were registered in the same area. During the shoreline survey, an active septic discharge was recorded from a private property in the vicinity of the sewage treatment works. A water sample taken from the effluent confirmed that it was septic effluent (900000 *E. coli* cfu/100 ml). Although only a small volume, it is anticipated that this could contribute significantly to faecal contamination levels in the near vicinity and to background contamination levels further afield. A possible septic tank and outlet pipe to a stream were seen adjacent to the fishery, and though a water sample taken from the stream was not found to be contaminated it was not known whether the house was occupied at the time of survey.

Due to the presence of continuous sewage discharges and overflows within 1 km of the fishery (including those from private septic systems), the overall risk from sewage contamination to the oyster fishery location is considered to be moderate.

Agricultural impacts

Flocks of sheep were observed on areas of improved pasture at the head of the estuary and along the shore southeast of the oyster farm. A single sheep was seen on land east of the oyster farm. Total numbers were modest (112) though it is possible that not all animals in the area were observed. Only a very small number of cattle were seen. A small area of arable land near Ardarroch was identified in the landcover data, and this may also contribute faecal contaminants to the bay via nearby watercourses.

The majority of land around the fishery is mountainous or used for coniferous plantation, and therefore poses a lower risk of faecal contamination to the fishery than the improved pasture and arable lands.

Highest potential impacts to the oyster farm are likely to be from any animals on fields on the adjacent shore and from sheep kept on land to the north around the estuary. Impacts from these sources may be carried to the fishery in freshwater flow whenever the trestles are submerged. Sources arising on shore around Ardarroch and Kishorn, to the south of the oyster farm, may only impact the fishery on the flood tide.

Overall risk to the fishery from agricultural impacts is considered moderate.

Wildlife impacts

Little information on numbers and locations of wildlife relative to the fishery was available. Seals, gulls and other wading birds, otters and deer are all likely to contribute to background levels of faecal contamination in Loch Kishorn and around the fishery. Any faecal contamination from deer and from otters is likely to be carried via watercourses feeding into the loch. Impacts from gulls and wading birds may be more direct where they rest and feed on the intertidal areas around the fishery. Seals are not known to haul out at the fishery, although they are present elsewhere in the loch. Overall, the risk from these sources is expected to be low.

Seasonal variation

There is clear evidence of seasonal variation in human population around the fishery, with a relatively high proportion of seasonal accommodation. The peak tourist season in much of Scotland is July and August. Seasonal variation is likely to occur in livestock numbers, as lambs are born in spring and remain until autumn. Historical monitoring results show a very marked trend toward higher results in July and August, which coincides with an expected peak in visitor population in the area. Recorded daily rainfall during the study period was lowest in July, and higher from August to April.

There was insufficient data upon which to make an assessment of seasonal variation in wildlife impacts. Overall the likelihood of seasonal variation in sources and impacts is high.

Rivers and streams

The oyster farm, being situated in an estuary, is subject to significant freshwater flow and high variation in water salinity. This is reflected in the data provided with the monitoring results, which show salinity varying from 4 to over 35 ppt. The majority of watercourses in the area drain areas of rough moorland and grassland, though the River Kishorn also passes through an area of improved pasture used for grazing sheep.

Rivers discharging to the upper end of Loch Kishorn, southeast of the oyster farm, pass through inhabited areas and where small numbers of livestock are also kept. Some of these receive septic tank effluent, and therefore may be subject to higher contamination levels particularly during summer when more dwellings are occupied.

During the shoreline survey sampling undertaken in January 2013, none of the recorded and sampled watercourses was found to be notably contaminated. Theoretical upper loadings were highest for the larger rivers, and are more reflective of the flow recorded at the time than of relative contamination levels.

Movement of contaminants

A weak estuarine flow was predicted, particularly for the upper parts of Loch Kishorn and this would be expected to be more pronounced at the fishery, which is located at the mouth of the River Kishorn estuary. There is likely to be continual, but seasonally varying freshwater flow southward over the oyster farm from discharges from the river and larger watercourses to the north.

Analysis of current data indicates the presence of a weakly cyclonic circulation of surface waters, with surface flow toward the northeast on the south side of the loch. This may carry contamination arising from sewage discharges and watercourses in the vicinity of Andarroch northward toward the fishery. It is not clear, however, how this would react upon reaching the outer part of the estuary. Net flow is southwestward on the north side of Loch Kishorn, suggesting that outflow from the estuary moves mainly along the north side of the loch.

Maximum transport distance attributable to tidal flow only is predicted to be 1.5 km or less in the north end of Loch Kishorn. There is evidence of some

stratification, though it is expected that wind effects would lead to this becoming largely mixed.

Temporal and geographical patterns of sampling results

Results from monitoring in both oysters and mussels at Loch Kishorn have shown a slight trend toward improvement since 2010. More low results have occurred since the installation of the improved sewerage works and though occasional higher results still occur these are lower than were seen previously. Geographical variation in results seems to suggest higher results may occur toward the southern end of the trestle area for mussels, though high results in Pacific oysters did not show any clear spatial trend.

Seawater samples taken during the shoreline survey showed potentially higher levels of faecal contamination around the area of Kishorn Yard, on the southwest side of the estuary. It is not clear whether the source is arixing from the yard itself or whether this represents effluent from the WWTW as well as diffuse source contamination from the River Kishorn and Russel Burn being swept westward across the mouth of the estuary.

Seawater samples taken from the top of the estuary and from the shore at Achintraid showed very similar levels of contamination, which were consistent with modest levels of faecal contamination. Both these areas were influenced by significant watercourses. Mussel and Pacific oyster samples taken during the shoreline survey showed similar very low levels of faecal contamination, with no clear geographic variation.

Environmental Factors

No statistically significant correlation was found between *E. coli* results and rainfall or high/low tidal cycle in either mussels or oysters. Higher *E. coli* results were found to be significantly correlated with increasing tides in mussels only. However, the reason for this is not clear. Rainfall-dependent contamination, such as that associated with CSO operation or diffuse runoff from land-based sources such as livestock, does not appear to be a significant cause of variation in shellfish *E. coli* results at this fishery. A statistically significant correlation was found between temperature and results, with higher results occurring at higher temperatures. However, low results occurred across the range of recorded temperatures suggesting that the driver was not simply temperature but possibly other factors that coincided with higher temperatures.

A statistically significant correlation was found between *E. coli* results and salinity in mussels, though this was not seen in Pacific oyster results. A wide

range of salinities was observed in the data, which was consistent with the estuarine location of the fishery.

Conclusions

The shellfishery at Loch Kishorn is subject to moderate human and livestock-source contamination with a strong seasonal variation. Due to its proximity to intermittent sewage outfalls, there is a risk that any overflows from these will not be reflected in the monitoring data. A high influx of visitors relative to the permanent population during the summer months would mean greater risk from human source contamination at this time. Livestock populations are likely to be highest in summer, and therefore there is higher potential input from livestock sources at this time as well.

The predicted movement of contaminants suggests arising in close proximity to the south of the fishery might impact water quality there, while any discharges from the north would be expected to have the greatest impact.

Overall Risk Table

Factor	Risk
Sewage discharges from WWTW	Medium
Rainfall-dependent diffuse sources	Medium
Wildlife sources	Low
Seasonal variability	High

16. Recommendations

Loch Kishorn North – Pacific oysters

Production area

Due to the presence of sewage discharges within the estuary, it is recommended that the production area boundaries be curtailed to exclude these sources. Although the southern boundary does not extend far enough to include the entire extent of the seabed lease associated with the oyster farm, due to the continuous outfall from Kishorn WWTW and nearby private sewage discharges it is not recommended that this boundary be extended. Therefore, the recommended production area is the Area bounded by lines drawn between NG 8241 4065 and NG 8301 4065 and between NG 8301 4044 and NG 8294 4022 and between NG 8293 4011 and NG 8231 4000 and between NG 8234 4027 and NG 8233 4047 extending to MHWS. This area also excludes the mouth of the Russel Burn above the bridge.

RMP

It is recommended that the RMP be placed along the southern end of the active fishery in order to reflect contamination arising from sources both up and downstream along the main channel of the estuary. The RMP should be set high enough up the shore, however, to allow for monthly access. Therefore, it is recommended that the RMP be relocated to NG 8283 4025.

Frequency

Due to strong variation in results across months, monthly sampling is recommended.

Depth of sampling

This fishery is intertidal, therefore sampling depth is not applicable

Tolerance

A sampling tolerance of 10 m is recommended. The oyster trestles are fixed and a bag should be identified specifically for collection of monitoring samples. Shellfish added to the bag must be in situ for at least 14 days to ensure they are representative of water conditions at that location.

Loch Kishorn North – common mussels

No commercial production of mussels is undertaken within this production area, therefore it is recommended that monitoring of this species be discontinued.

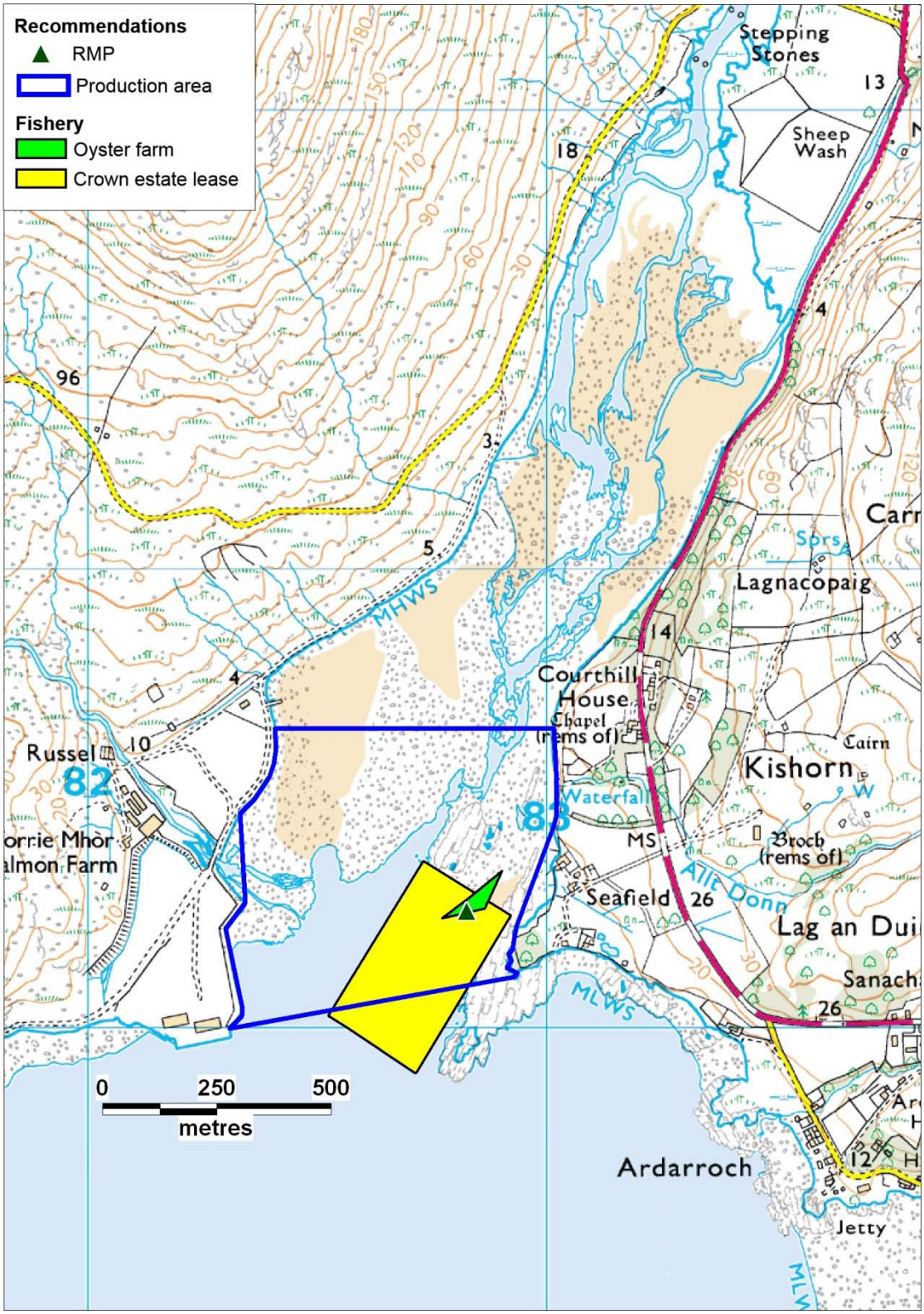


Figure 16.1 Map of recommendations at Loch Kishorn

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2. **Tables of Typical Faecal Bacteria Concentrations**
3. **Statistical Data**
4. **Hydrographic Section Glossary**
5. **Shoreline Survey Report**

1. General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

The concentration of *E. coli* and other faecal indicator bacteria contained in seal faeces has been reported as being similar to that found in raw sewage, with counts showing up to 1.21×10^4 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 treams, which may be washed into the water during periods of rain.

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2. Tables of Typical Faecal Bacteria Concentrations

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

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

Source: (Kay, Crowther, et al., Faecal indicator organism in concentration sewage and treated effluents 2008b)

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

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

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

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

Source: (Kay, Crowther, et al., Faecal indicator organism concentrations and catchment export coefficients in the UK 2008a)

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

Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^8
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 and Bedard 1986)

3. Statistical Data

Loch Kishorn Oysters

One-way ANOVA: logec versus season

```
Source  DF      SS     MS     F      P
season   3   6.956  2.319  5.20  0.003
Error   55  24.530  0.446
Total   58  31.485

S = 0.6678   R-Sq = 22.09%   R-Sq(adj) = 17.84%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  --------+---------+---------+---------+-
1      17  1.8752  0.6433          (------*-----)
2      17  2.4587  0.7627                    (-----*------)
3      13  2.1015  0.7224               (------*------)
4      12  1.5002  0.4610  (-------*-------)
                          --------+---------+---------+---------+-
                                1.50      2.00      2.50      3.00

Pooled StDev = 0.6678

Grouping Information Using Tukey Method

season   N    Mean  Grouping
2       17  2.4587  A
3       13  2.1015  A B
1       17  1.8752  A B
4       12  1.5002    B

Means that do not share a letter are significantly different.

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

Individual confidence level = 98.96%

season = 1 subtracted from:

season    Lower   Center   Upper  ------+---------+---------+---------+---
2       -0.0239   0.5835  1.1909                  (-----*-----)
3       -0.4262   0.2263  0.8787              (-----*------)
4       -1.0427  -0.3750  0.2927        (-----*------)
                                ------+---------+---------+---------+---
                                   -1.0       0.0       1.0       2.0

season = 2 subtracted from:

season    Lower   Center    Upper  ------+---------+---------+---------+---
3       -1.0096  -0.3572   0.2953        (-----*------)
4       -1.6261  -0.9585  -0.2908  (-----*------)
                                  ------+---------+---------+---------+---
                                     -1.0       0.0       1.0       2.0

season = 3 subtracted from:

season    Lower   Center   Upper  ------+---------+---------+---------+---
4       -1.3102  -0.6013  0.1076     (------*------)
                                ------+---------+---------+---------+---
                                   -1.0       0.0       1.0       2.0
```

Loch Kishorn Mussels

One-way ANOVA: logec versus season

```
Source  DF      SS     MS      F      P
season   3  19.573  6.524  16.16  0.000
Error   55  22.210  0.404
Total   58  41.784

S = 0.6355   R-Sq = 46.84%   R-Sq(adj) = 43.95%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  --+---------+---------+---------+-------
1      16  1.5844  0.4398     (----*-----)
2      18  2.8617  0.7982                          (----*----)
3      13  1.8931  0.7088          (-----*----)
4      12  1.4740  0.4719  (------*-----)
                          --+---------+---------+---------+-------
                          1.20      1.80      2.40      3.00

Pooled StDev = 0.6355

Grouping Information Using Tukey Method

season   N    Mean  Grouping
2       18  2.8617  A
3       13  1.8931    B
1       16  1.5844    B
4       12  1.4740    B

Means that do not share a letter are significantly different.


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

Individual confidence level = 98.96%


season = 1 subtracted from:

season    Lower   Center   Upper  -------+---------+---------+---------+--
2        0.6983   1.2773  1.8562                          (----*---)
3       -0.3205   0.3087  0.9379                (-----*----)
4       -0.7539  -0.1104  0.5331             (----*----)
                                  -------+---------+---------+---------+--
                                      -1.2       0.0       1.2       2.4

season = 2 subtracted from:

season    Lower   Center    Upper  -------+---------+---------+---------+--
3       -1.5819  -0.9685  -0.3552      (----*----)
4       -2.0156  -1.3876  -0.7597  (----*-----)
                                   -------+---------+---------+---------+--
                                       -1.2       0.0       1.2       2.4

season = 3 subtracted from:

season    Lower   Center   Upper  -------+---------+---------+---------+--
4       -1.0936  -0.4191  0.2555          (-----*----)
                                  -------+---------+---------+---------+--
                                      -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 Neep, The highest level that tides reach on average during neep tides.

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

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

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

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

Tidal period. The dominant tide around the UK is the twice daily one generated by the moon. It has a period of 12.42 hours. For near shore so-called rectilinear tidal currents then roughly speaking water will flow one way for 6.2 hours then back the other way for 6.2 hours.

Tidal range. The difference in height between low and high water. Will change over a month.

Tidal excursion. The distance travelled by a particle over one half of a tidal cycle (roughly~6.2 hours). Over the other half of the tidal cycle the particle will move in the opposite direction leading to a small net movement related to the tidal residual. The excursion will be largest at Spring tides.

Tidal residual. For the purposes of these documents it is taken to be the tidal current averaged over a complete tidal cycle. Very roughly it gives an idea of the general speed and direction of travel due to tides for a particle over a period of several days.

Tidal prism. The volume of water brought into an estuary or sea loch during half a tidal cycle. Equal to the difference in estuary/sea loch volume at high and low water.

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

Neep tides occur during the first or last quarter of the moon when the tide-generating forces of the sun and moon oppose each other. The tidal range is smallest and tidal currents are weakest during neep tides.

Tidal diamonds. The tidal velocities measured and printed on admiralty charts at specific locations are called tidal diamonds.

Wind driven shear/surface layer. The top metre or so of the surface that generally moves in the rough direction of the wind typically at a speed that is a few percent (~3%) of the wind speed.

Return flow. A surface flow at the surface may be accompanied by a compensating flow in the opposite direction at the bed.

Stratification. The splitting of the water into two layers of different density with the less dense layer on top of the denser one. Due to either temperature or salinity differences or a combination of both.

5. Shoreline Survey Report

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

Document Number	B0067_Shoreline 0003
Revision	03
Date	01/02/2013

Revision History

Revision	Changes	Date
A	Draft issue for internal review	20/12/12
01	First draft issue to Cefas, incorporating comments at rev A	07/01/13
02	Second draft issue to Cefas, incorporating re-sampling results and Cefas comments on revision 01.	25/01/13
03	Final draft issued to CEFAS, resolving comments issued on revision 02.	01/02/2013

	Name & Position	Date
Author	**Andrea Veszelovszki**	01/02/2013
Checked	**John MacDonald**	01/02/2013
Approved	**John MacDonald**	01/02/2013

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Shoreline Survey Report

Production area: Loch Kishorn North/Loch Kishorn North Oysters

Site name: Loch Kishorn

SIN: RC-329-254-08/RC-329-254-13

Species: Pacific Oyster (*Crassostrea gigas)* & Common mussel (*Mytilus sp.*)

Harvester: Mr Mark Pattinson

Local Authority: Highland (Ross & Cromarty)

Status: Existing area

Date Surveyed: 11 – 13th December 2012

Surveyed by: Lars Brunner (Team Leader), Eilidh Cole, Alison Clarke, Gail Twigg. The Sampling Officer, Bill Steven was met during the sampling, but was not present for the majority of the exercise.

Date Re-sampled: 13th January 2013

Surveyed by: Lars Brunner (Team Leader) and Andrea Veszelovszki.

Existing RMP: NG82864031

Area Surveyed: From Corrie Mhor Salmon Farm, situated on the South West of Loch Kishorn, to the north and head of the loch at Drochaid Mhor. From Drochaid Mhor to the south east limit of the Production Area. This part of the survey route covers the shallow estuarine area of the Loch which includes the Production Area. Southwards from the farm towards the jetty which lies just NE of Runisole Cove.

Sampling Notes

The initial samples collected during December 2012, did not reach the laboratory in sufficient time for testing. As such, a further re-sampling exercise

was undertaken in January 2013. Observations are presented from both survey visits, with sample results only presented for the latter visit.

Weather

11th December: Dry for 48 hours prior to survey. 15% scattered cloud cover; no wind; temperature -1°C; sea state calm. Very cold overnight with temperatures between -3/-5°C (inferred from forecast). Frosty start, remaining cold throughout the day. Ground frozen.

12th December: No rain; 20% cloud cover; wind 2.5 knots; wind direction NE; temperature -1°C; sea state calm. Very cold overnight with temperatures between -4/-6°C. Frosty start, remaining cold throughout the day. Ground frozen.

13th December: Light snow falling. Overcast with 100% cloud cover; wind 1.5 knots; wind direction SW; temperature 0°C; sea state calm.

13th January: Overcast with heavy grey clouds. Temperature at start of survey, 3.5°C with moderate to heavy showers throughout the day.

Fishery

The site at Loch Kishorn North is situated on a mixed area of rock and sand to the very south-east of the tidal estuarine part of upper Loch Kishorn. It currently consists entirely of Pacific Oyster (*Crassostrea gigas*) production, although there are very small quantities present of this usually abundant species.

In the recent past there was also common mussel production (*Mytilus* sp.), growth of which was carried out on 'galician' style rafts. This was discontinued when predation from Eider ducks proved problematic. There is some evidence of previous bag culture of *Mytilus* sp. on site, but this has been discontinued, and only a few bags of empty shells remain.

The Pacific Oyster cultivation is currently limited to around 15-20 bags of mature oysters (> 3yrs) which are located to the South, and to the centre of the site. The site harvester has indicated that he plans to undertake a renewal of stock and hardware in the coming 1-2 years.

The Survey team met with the harvester on Thursday the 13th of December in order to survey and take samples at the fishery, and then again on the 13th of January, when re-taking samples.

Sewage Sources

The Loch Kishorn area acquired a new waste water treatment system around 2 years ago (information from talking to a Scottish Water operative while on site) that replaced the existing septic tank storage and direct discharge to shore. The limit of the system extends from near the southern limit of the shore survey at Achintraid to Kishorn Courthill CSO (combined sewage overflow) in the North. There are still many discharge pipes running onto the shore, but it may be assumed that many, if not all, of these are now disused as the houses themselves have been connected into the new treatment system. This assumption is made on the basis of information provided when talking to a Scottish Water operative met during the survey, and on the evidence of recent ground/earth works and new man holes observed by the road in front of the houses at Achantraid.

On the west side of the Loch, by the Russel Burn, the old fabrication yard is currently seeing an upsurge of industrial activity, although no new discharge sources were observed, it is worth noting that access to the main part of the yard (to the south of the bridge over the Russel Burn) is restricted, and we were not able to enter the area for a closer examination.

Seasonal Population

Loch Kishorn is a lightly populated area, with the highest density of housing occurring in the Achintraid area. The area is likely to experience a slight increase in population during the summer months, due to a rise in B&B residents, self-catering property occupation, and seasonal occupation of second homes. In addition there is likely to be sporadic visits by campers and camper vans, although there are no designated caravan parks or campsites. During the survey we noted a small population of travelling people residing in caravans by the area near Russel Burn (NG 8235 4056). It was indicated to us that travelling people in the past have used the bay for cockle (*Cerastoderma edule*) harvesting, although this was not observed during this survey.

Boats/Shipping

The commercial facilities on the west side of Loch Kishorn attract a variety of vessels, the most frequent of which are medium sized landing craft that use the site as a hub for transport of aquaculture feeds and materials to Skye and the Outer Hebrides (up to several times a week). In addition there are

intermittent visits from other small to medium commercial vessels. Though out-with the remit of this report, it is worth noting that this traffic will likely grow in the future as use of the Kishorn site increases by the renewable energy industry.

Fish farm traffic in the south of the survey area involves small and medium craft, which are site specific to the Loch. There will likely be occasional visits from larger boats. There appeared to be few permanent moorings in the bay, and little yacht traffic, although due to the time of the year this was difficult to verify and may increase during the summer.

Of note is a fabrication and ship repair yard which is located at NG 8236 4072. This site is not noted on current maps or by SEPA as a potential discharge point. The yard is located on an area with a high tidal range, and there are no moorings or a permanent slipway. All vessels present are presumably beached on a HWS tide and worked on during low tidal periods. There are also many boats ranging from yachts to commercial vessels in land-based storage ashore. No discharges were noted from the site during the survey.

Farming and Livestock

Very little livestock was observed in the southern survey area, or on the western side of the Loch. The former was due to the location of the houses on the seafront blocking the view further back up the hill, although the latter was a direct observation as from most areas there was a good view to the hillside flanks to the west. Of the livestock seen, there were some cattle noted in a field behind Achintraid, and two large flocks of sheep were seen. The first was adjacent to the WWTW (waste water treatment works) at Ardarroch, and the second in a fenced area above the shore near Tornapress Bridge (NG 8355 4196)

Droppings were noted intermittently along the shore walk but were difficult to distinguish between deer and/or sheep.

Land Use

Upper Loch Kishorn has a fairly unusual mix for the Northern Highlands of rural/heavy industry/aquaculture. The majority of the coast around the loch is rural use, with farming, plantation/wild forestry and private house/crofting foreshore alternating with wild, undeveloped shore. There are small areas in use for aquaculture, one as a shore base for instillations offshore, the other as a salmon hatchery. There is heavy industry based around the old fabrication yard area to the west of the loch, with haulage companies, renewable energy

firms, boat fabrication and the boat fabrication and repair yard (see Boats/Shipping above).

Land Cover

The survey zone from Ruinsole in the south to Seafield in the centre is situated around a wide bay with mixed forest and crofting on the hillside behind running down to detached houses fronting the shore. Some areas of this land are used for agriculture, although exactly how much was not possible to verify within this survey. In the centre of this area there is a large open, grass covered area used for recreation.

The survey zone in the upper Loch, from Seafield to the bridge at Drochaid Mhor is an enclosed glen, with hillsides rising steeply on either side of the loch and a land cover of rough grazing land on the east side of the Loch, and open moorland on the west. At the very head of the upper loch there is some low-lying, improved grassland that is used for grazing.

Watercourses

Many watercourses of different size discharge into Loch Kishorn. The largest is the River Kishorn at the head of the upper Loch followed by the Abhainn Cumhang a Ghilinne in the east and the Russel Burn in the west. There are numerous small streams and burns running into the bay, and areas of seepage through rocks/boulders as well.

Wildlife/Birds

Sea birds were noted during the survey, especially on the first day when seagulls were seen resting on the water in the main part of the Loch. There were fewer birds noted on the following two days, although oystercatchers were noted. There was no concentration of birds in any particular location (i.e. outfalls).

Shoreline Maps

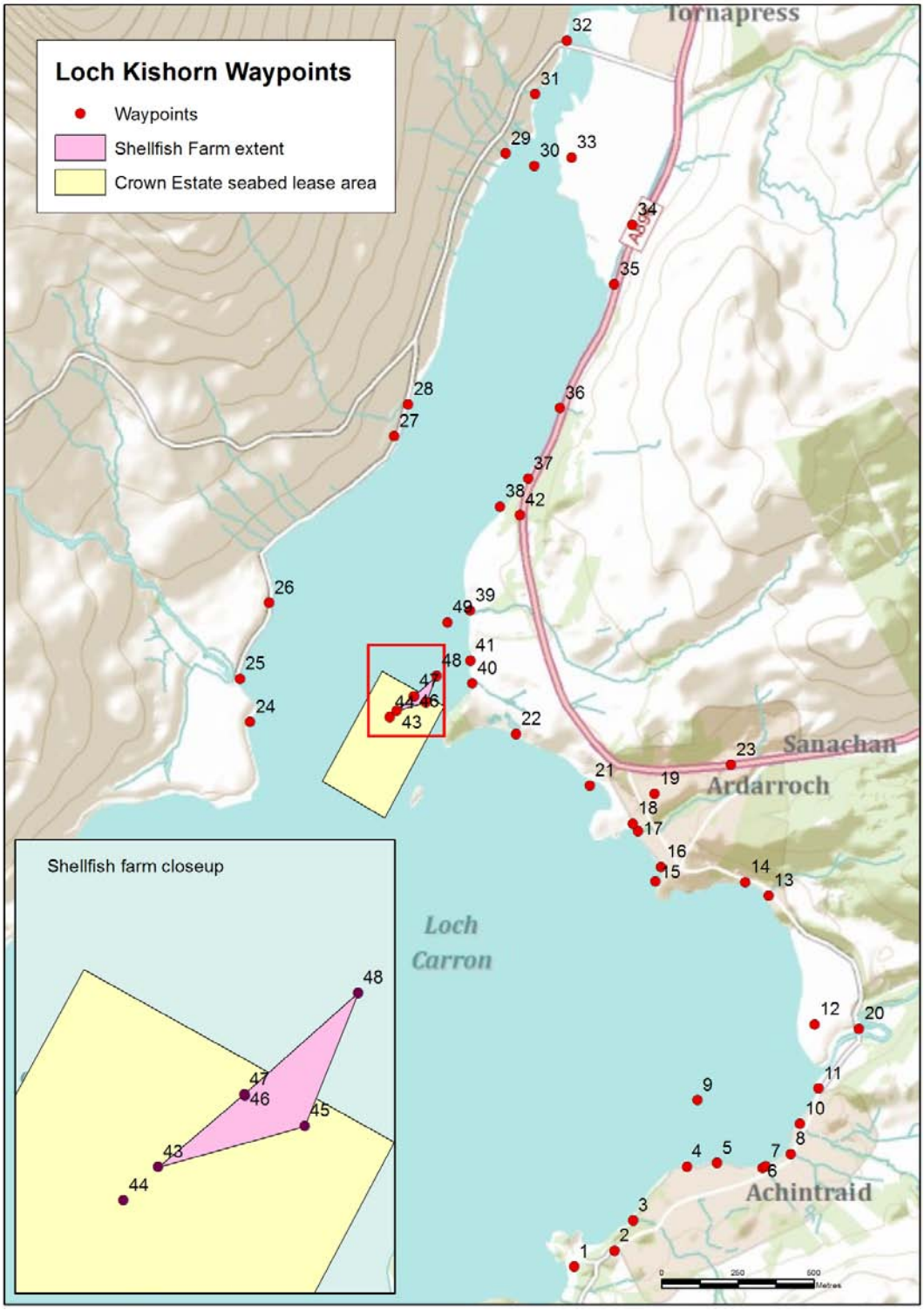

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Figure 1: Map of shoreline observations marked as waypoints.

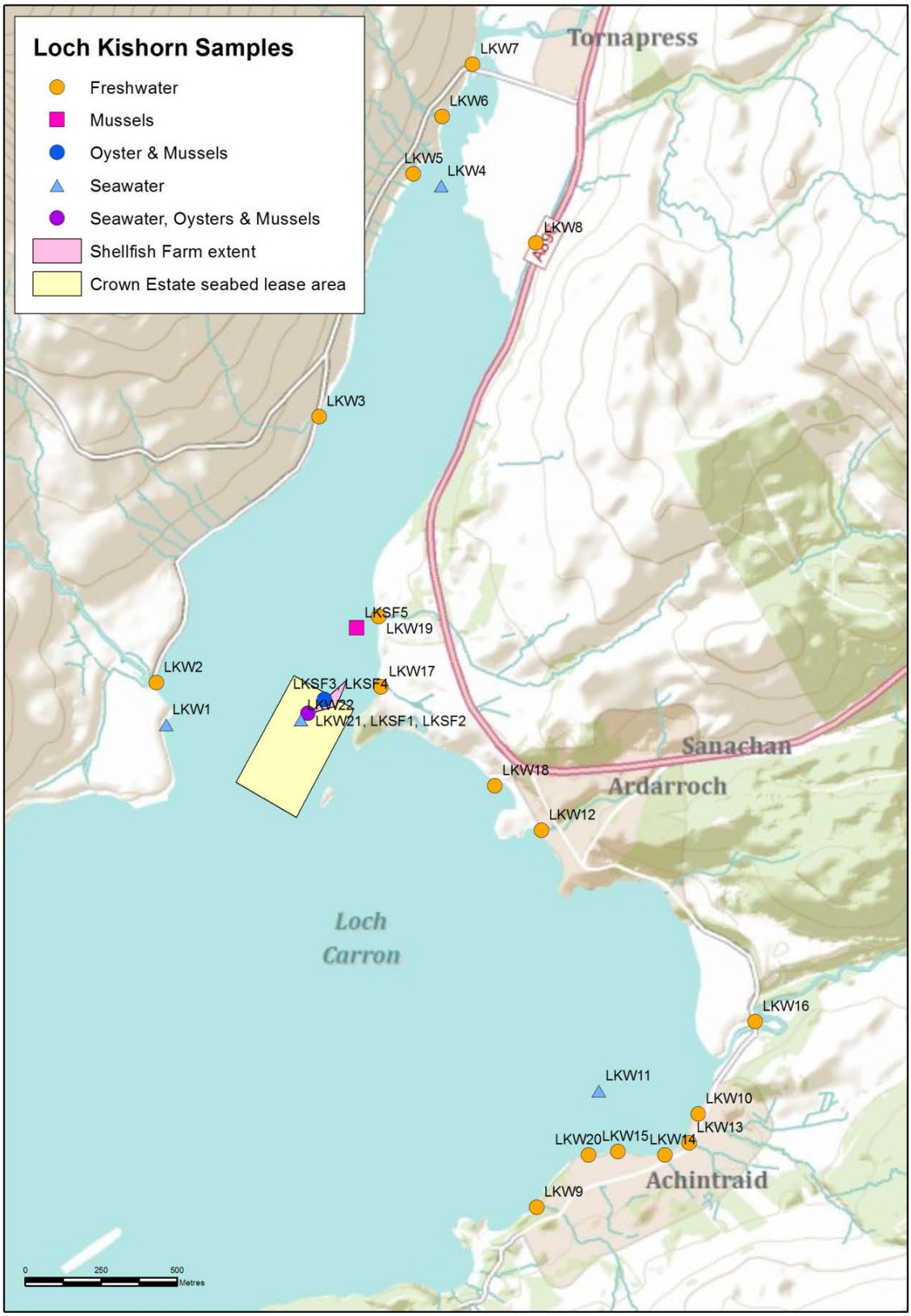

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Figure 2: Map showing locations of samples taken during shoreline survey.

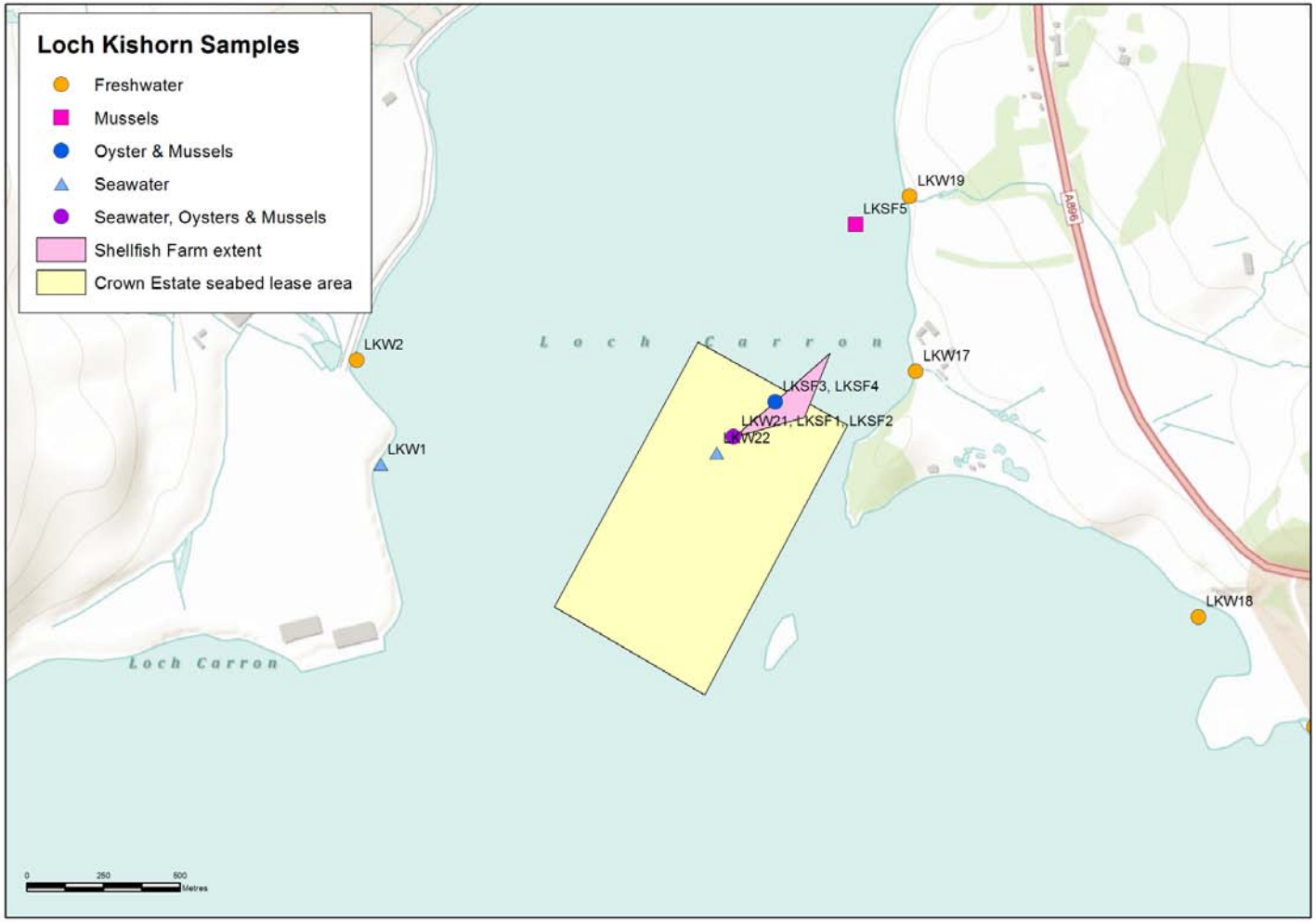

Figure 3: Close-up of harvest area, showing samples taken in the vicinity.

Table 1. Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	11/12/2012	9:42	NG 83238 38454	183238	838454	Fig. 4,5		Jetty for Scottish Sea Farms. House behind on hill but no visible sign of any discharge. Further house situated on right of road leading to the fish farm jetty. Fish farm can be seen from the shore.
2	11/12/2012	9:58	NG 83368 38498	183368	838498	Fig. 6		Septic tank in field. 2 cows in field at back of house. Soakaways at front of houses. Houses appear to be new builds
3	13/01/2013	9:58	NG 83432 38589	183432	838589		LKW09 (FW)	Steam running down through rocks into loch. Width - 70 cm; Depth - 25 cm; Flow - 0.149 m/s; SD - 0.071.
4	13/01/2013	12:40	NG 83611 38751	183611	838751		LKW20 (FW)	Small burn running off hillside by farmhouse, across shore into loch, possibly contaminated. Width - 70 cm; Depth - 8 cm; Flow - 0.849 m/s; SD - 0.019. Three houses on roadside.
5	13/01/2013	11:10	NG 83707 38758	183707	838758	Fig. 7	LKW15 (FW)	Contaminated. 12 cm plastic pipe (orange), weighed down by rocks, discharging onto shore. Two houses visible up near road. Flow, approx. 0.080-0.100 m/s.
6	11/12/2012	10:44	NG 83849 38734	183849	838734	Fig. 8		Broken clay pipe on shore. Evidence of attempt to block inflow to pipe at high water mark. Presence of green algae (*Ulva* sp.) on foreshore parallel with broken pipe.
7	13/01/2013	11:01	NG 83860 38739	183860	838739		LKW14 (FW)	Burn running under road through culvert onto shore. Culvert width 50cm. Burn: Width - 38 cm; Depth - 8 cm; Flow - 0.207 m/s; SD - 0.090. Outfall pipe on shore - little to nothing coming from pipe.
8	13/01/2013	10:30	NG 83940 38774	183940	838774	Fig. 9	LKW13 (FW)	Double open culvert running under road onto shore. Water course: Width - 50 cm; Depth - 10 cm; Flow - 0.706 m/s; SD - 0.014.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
9	13/01/2013	10:15	NG 83655 38960	183655	838960		LKW11 (SW)	Sample taken on foreshore. Observed 70 gulls, 6 oyster catchers at water's edge during first survey.
10	13/01/2013	10:05	NG 83975 38867	183975	838867		LKW10 (FW)	Stream running under road across rough scrub land to shore. Width - 1.3 m; Depth - 12cm; Flow - 0.672 m/s; SD - 0.003. Close to houses and road.
11	11/12/2012	11:55	NG 84040 38976	184040	838976	Fig. 10		Kishorn Achintraid CSO. Running for 2 years according to the Scottish Water engineer spoken to while on site.
12	11/12/2012	12:05	NG 84038 39179	184038	839179			Playing fields. House with 12 covered hay (?) bales in adjacent field. 6 sheep are visible in field on higher ground in a NE facing position.
13	11/12/2012	12:34	NG 83914 39593	183914	839593			Small stream running off hill through woodland then through rough grassland on to shore through a corrugated metal culvert. No obvious signs of pollution.
14	11/12/2012	12:37	NG 83843 39639	183843	839639			Kishorn Ardarroch WWPS CSO.
15	11/12/2012	12:50	NG 83559 39656	183559	839656	Fig. 11		Plastic outflow pipe not on original map. Diameter 10cm approx. No obvious discharge, end of pipe buried in the sand. Approx. 25m from property wall to where pipe is buried in sand on shore.
16	11/12/2012	12:52	NG 83580 39701	183580	839701			Manhole/sewage cover at top of shore. A second one was noted a few metres along the shore at the same height. Sewage line lying at top of shore.
17	13/01/2013	10:20	NG 83513 39818	183513	839818		LKW12 (FW)	Contaminated. Burn running under road, across rough grassland, across shore into loch. Width 19cm; Depth 10cm; Flow 0.468m/s; s.d. 0.007. 3 houses in close proximity to shore.
18	11/12/2012	13:10	NG 83497 39842	183497	839842			Kishorn WWTW EO CSO. On the shore below the station a plastic culvert was noted running under the road. Appeared to be water run-off from hills.
19	11/12/2012	13:15	NG 83571 39933	183571	839933			Sewage works. Sheep droppings outside gate of sewage works. Field opposite containing approx. 45 sheep.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
20	13/01/2013	11:20	NG 84178 39157	184178	839157		LKW16 (FW)	River running under concrete road bridge. Total width of river 11.5m. Four readings taken, reading from south to north bank. Depth 1 - 15 cm; Flow 1 - 0.274 m/s; SD 1 - 0.017. Depth 2 - 19 cm; Flow 2 - 0.350 m/s; SD 2 - 0.016. Depth 3 - 23 cm; Flow 3 - 0.407 m/s; SD 3 - 0.023. Depth 4 - 44 cm; Flow 4 - 0.350 m/s; SD 4 - 0.033.
21	13/01/2013	11:50	NG 83368 39970	183368	839970		LKW18 (FW)	Contaminated. Cast iron outflow pipe, running down shore, access cover at top of the shore. Diameter 7cm with very small trickle of water. Green algae present on shore near vicinity of end of pipe.
22	11/12/2012	14:01	NG 83144 40145	183144	840145	Fig. 12, 13		Large fibre glass/plastic reservoir in fenced off field above shore. Inflow turned off at tap, outflow pipe coming from bottom of tank onto rough grassland at top of shore. Large pond above and behind not visible from shore.
23	11/12/2012	15:05	NG 83817 40011	183817	840011			Manhole cover in garden. Houses numbered 7, 8, 9, 10, 11 on shoreline survey plan map appear to be linked, couldn't find any septic tank discharges, recent manholes and earthwork indicate these may have been linked into mains Kishorn Sewage Works, (possible gravity fed), no pumping station present.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
24	13/01/2013	8:10	NG 82306 40227	182306	840227		LKW1 (SW)	It should be noted that access further west to Kishorn Yard was impossible due to a high security fence. Access to the fish farm was obviously restricted and would have required a change of clothing as advised by a site worker. Access to point marked on shoreline survey plan map was difficult to reach due to steep rocky shore and icy conditions. The seawater sample was taken as near to point as safety allowed. 25 gulls, 1 crow, 2 oyster catchers noted on shore during first survey.
25	13/01/2013	8:25	NG 82281 40365	182281	840365	Fig. 14, 15, 16,17	LKW2 (FW)	Sample taken just down from bridge next to restricted site. Width 4.2m. Depth 1 - 33 cm; Flow 1 - 0.282 m/s; SD 1 - 0.018. Depth 2 - 30 cm; Flow 2 - 0.727 m/s; SD 2 - 0.031. House situated further up river, access restricted. Mixed industrial land e.g. haulage depot and small scale industrial activities. 4 traveller's caravans with accompanying vehicles (4 x 4 and vans) parked on shore.
26	12/12/2012	10:03	NG 82387 40600	182387	840600	Fig. 18, 19		Boat yard, pier, fabrication and boat storage not marked on map. No moorings visible.
27	12/12/2012	10:20	NG 82809 41104	182809	841104	Fig. 20		2 metal tanks at side of roadway. Manhole covers with SV written on them. Pipes coming out of tanks but no visible discharge. Sampling officer indicated that they were relics of oil rig construction.
28	13/01/2013	9:05	NG 82859 41202	182859	841202	Fig. 21	LKW3 (FW)	Sample taken by concrete pipe; Width - 1.10 m; Depth - 15 cm; Flow - 0.531 m/s; SD - 0.027
29	13/01/2013	9:15	NG 83208 41977	183208	841977		LKW5 (FW)	Width - 90 cm; Depth - 18 cm; Flow - 0.202 m/s; SD - 0.045. Stream running down hill and running under road. Droppings present next to stream, possibly deer or sheep.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
30	13/01/2013	9:15	NG 83297 41933	183297	841933		LKW4 (SW)	Taken at head of loch at low tide.
31	13/01/2013	9:25	NG 83312 42159	183312	842159	Fig. 22	LKW6 (FW)	Two concrete pipes running under road. Stream: Width - 1.2 m; Depth - 25 cm; Flow - 0.313 m/s; SD - 0.030. Deer and/or sheep droppings noted near to stream.
32	13/01/2013	9:35	NG 83420 42323	183420	842323	Fig. 23	LKW7 (FW)	Width of river 11.5m. Measurements taken from west to east bank. House next to river on west bank. Second house further upstream. Depth 1 - 75 cm; Flow 1 - 0.375 m/s; SD 1 - 0.016. Depth 2 - 41 cm; Flow 2 - 0.428 m/s; SD 2 - 0.017.
33	12/12/2012	12:35	NG 83415 41953	183415	841953			Approx. 60 sheep in lower field. House noted in upper field.
34	13/01/2013	9:45	NG 83597 41730	183597	841730		LKW8 (FW)	River running parallel to road. Width 3.58m. Depth 1 - 20 cm; Flow 1 - 0.777 m/s; SD 1 - 0.030. Depth 2 - 16 cm; Flow 2 - 0.877 m/s; SD 2 - 0.058.
35	12/12/2012	12:55	NG 83529 41546	183529	841546	Fig. 24		Water running down from hill and under road culvert.
36	12/12/2012	13:05	NG 83337 41165	183337	841165			Water running down from hill and under road culvert.
37	12/12/2012	13:10	NG 83225 40947	183225	840947	Fig. 25		Mystery building at shore-side with 2 s and 1 SCV markers. Met sampling officer and had quick discussion about the current status of oyster fishery.
38	12/12/2012	13:25	NG 83132 40864	183132	840864	Fig. 26, 27,28		Cast iron pipe Dia. 19cm. No discharge present. Old oyster trestles overgrown with abandoned bags containing empty shells. Site appears to be abandoned.
39	13/01/2013	12:30	NG 83019 40541	183019	840541		LKW19 (FW)	River sampled below waterfall. Continues through scrubland onto shore. Width - 138 cm; Depth - 14 cm; Flow - 0.412 m/s; Sd - 0.018.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
40	13/01/2013	11:40	NG 83014 40311	183014	840311	Fig. 29,30	LKW17 (FW)	Stream running past house and sheds directly into cultivation zone. Width - 1.1m; Depth - 15 cm; Flow - 0.415 m/s; SD - 0.008. Possible septic tank at shore edge. Plastic outfall pipe visible behind fence discharging into stream. Large plastic reservoir tank, no outfall obvious at time of survey.
41	12/12/2012	13:51	NG 83012 40384	183012	840384			Disused broken pipe lying on shore. 1 solitary sheep on hill just above shore.
42	12/12/2012	14:17	NG 83193 40834	183193	840834			Kishorn Courthill CSO
43	13/01/2013	12:56 – 13:18	NG 82771 40238	182771	840238		LKW21 (SW), LKSF1, LKSF2	Oyster sample and mussels (14 of) collected from most southerly waypoint marker of farm.
44	13/01/2013	13:04	NG 82748 40218	182748	840218	Fig. 31	LKW22 (SW)	Seawater sample collected at oyster fishery.
45	13/12/2012	13:05	NG 82865 40259	182865	840259	Fig. 32, 33		Overgrown trestles, empty shells in bags. Most easterly waypoint marker of farm.
46	13/12/2012	13:10	NG 82828 40280	182828	840280			Harvest area
47	13/01/2013	13:25-13:33	NG 82828 40281	182828	840281		LKSF3/LKSF4	Oyster and mussel (20 of) samples collected. Western edge of farm.
48	13/12/2012	13:20	NG 82903 40341	182903	840341			Northerly point of farm.
49	13/01/2013	13:45	NG 82945 40508	182945	840508	Fig. 34	LKSF5	Mussel sample collected from northern section

Photographs referenced in the table can be found attached as Figures 4 – 34.

*Indicates flow rate measured using volume of water collected over a specific time.

**Waypoint missed at time of survey therefore taken later.

Sampling

Water and shellfish samples were collected at sites marked on the map shown in Figure 2. Samples were transferred to either Biotherm 10 or Biotherm 25 boxes with ice packs and shipped to Glasgow Scientific Services (GSS) for *E.coli* analysis. All samples were shipped on the day of collection. All samples were received and analysed by GSS the day following collection. Temperatures for samples on arrival at GSS ranged between 4.1ºC and 4.4ºC. As stated above, only samples from the re-survey in January 2013 are reported, with those taken in December 2012 discarded due to the delay in transporting them to the lab for analysis. The results are presented in Tables 2 and 3.

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:

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

As the oyster fishery was at an intertidal zone, shellfish samples were taken at low tide and no boat was required. No salinity profiles were taken.

Table 2: Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	13/01/2013	LKW1	NG 82306 40227	Sea Water	42	33.2
2	13/01/2013	LKW2	NG 82281 40365	Fresh water clean	< 100	
3	13/01/2013	LKW3	NG 82859 41202	Fresh water clean	< 100	
4	13/01/2013	LKW4	NG 83297 41933	Sea Water	15	7
5	13/01/2013	LKW5	NG 83208 41977	Fresh water clean	< 100	
6	13/01/2013	LKW6	NG 83312 42159	Fresh water clean	< 100	
7	13/01/2013	LKW7	NG 83420 42323	Fresh water clean	< 100	
8	13/01/2013	LKW8	NG 83597 41730	Fresh water clean	< 100	
9	13/01/2013	LKW9	NG 83432 38589	Fresh water clean	< 100	
10	13/01/2013	LKW10	NG 83975 38867	Fresh water clean	< 100	
11	13/01/2013	LKW11	NG 83655 38960	Sea Water	16	32.9
12	13/01/2013	LKW12	NG 83513 39818	Fresh water contaminated	< 1000	
13	13/01/2013	LKW13	NG 83940 38774	Fresh water	200	

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
				clean		
14	13/01/2013	LKW14	NG 83860 38739	Fresh water clean	< 100	
15	13/01/2013	LKW15	NG 83707 38758	Fresh water contaminated	< 1000	
16	13/01/2013	LKW16	NG 84178 39157	Fresh water clean	< 100	
17	13/01/2013	LKW17	NG 83014 40311	Fresh water clean	< 100	
18	13/01/2013	LKW18	NG 83368 39970	Fresh water contaminated	900,000	
19	13/01/2013	LKW19	NG 83019 40541	Fresh water clean	200	
20	13/01/2013	LKW20	NG 83611 38751	Fresh water contaminated	< 1000	
21	13/01/2013	LKW21	NG 82771 40238	Sea Water	8	28.4
22	13/01/2013	LKW22	NG 82748 40218	Sea Water	3	16

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	Location on Line	E. coli (MPN/100 g)
1	13/01/2013	LKSF1	NG 82771 40238	Oysters	N/A	20
2	13/01/2013	LKSF2	NG 82771 40238	Mussels	N/A	50
3	13/01/2013	LKSF3	NG 82828 40281	Oysters	N/A	< 20
4	13/01/2013	LKSF4	NG 82828 40281	Mussels	N/A	20
5	13/01/2013	LKSF5	NG 82945 40508	Mussels	N/A	50

*Mussel samples taken are wild mussels from the area of the fishery, noting that the fishery does not currently produce mussels commercially.

Where watercourses were too small or impractical to measure using the flow meter, flow rate was measured using a bucket where a measured volume of water was collected over a specific time.

Photographs

Figure 4: Scottish Sea Farms Site (Waypoint 1)

Figure 5: Fish farm as seen from shore. (Waypoint 1)

Figure 6: Septic tank in field with 2 cows in adjacent field (Waypoint 2)

Figure 7: Plastic pipe discharging on to shore (Waypoint 5)

Figure 8: Broken clay pipe and green algae (*Ulva* sp.) on shore (Waypoint 6)

Figure 9: Culvert running under road (Waypoint 8)

Figure 10: Kishorn Achintraid CSO (Waypoint 11)

Figure 11: Plastic outflow pipe not on original map with no obvious discharge (Waypoint 15)

Figure 12: Large fibre glass/plastic reservoir in fenced off field (Waypoint 22)

Figure 13: Large pond above and behind reservoir in field above shore (Waypoint 22)

Figure 14: Road bridge leading to restricted site with river running beneath (Waypoint 25)

Figure 15: Road bridge leading to restricted site (Waypoint 25)

Figure 16: Road bridge leading to restricted site (Waypoint 25)

Figure 17: Corrie Mhor Salmon Farm from road bridge (Waypoint 25)

Figure 18: Boat storage with fabrication units behind (Waypoint 26)

Figure 19: Boat yard and pier (Waypoint 26)

Figure 20: Decommissioned storage tanks. Possible relic of oil rig construction (Waypoint 27)

Figure 21: Outflow from concrete pipe (Waypoint 28)

Figure 22: Two concrete pipes running under road and discharging on to shore (Waypoint 31)

Figure 23: River Kishorn feeding into the estuarine area at the north of Loch Kishorn (Waypoint 32)

Figure 24: Concrete culvert running under road (Waypoint 35)

Figure 25: Mystery building at shore side (Waypoint 37)

Figure 26: Cast iron pipe on shore with no evident outflow (Waypoint 38)

Figure 27: Old overgrown oyster trestles (Waypoint 38)

Figure 28: Old abandoned oyster bags containing empty shells (Waypoint 38)

Figure 29: Large plastic reservoir tank (Waypoint 40)

Figure 30: Plastic outfall pipe visible behind fence discharging into stream. (Waypoint 40)

Figure 31: The oyster fishery (Waypoint 44)

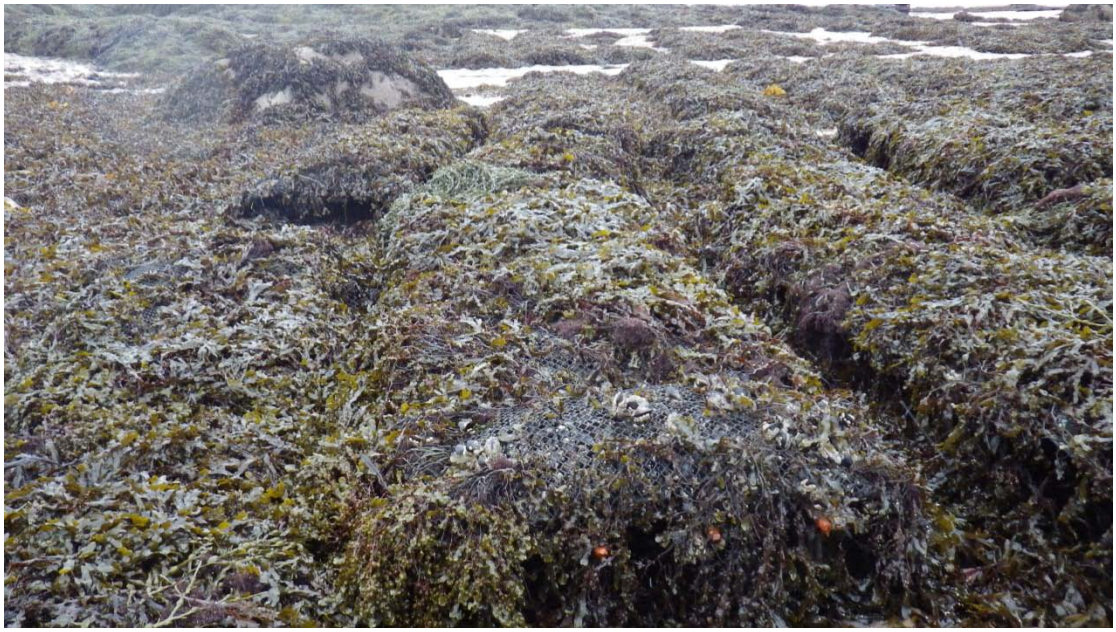

Figure 32: Overgrown oyster bags at oyster fishery (Waypoint 45)

Figure 33: Overgrown oyster trestles at oyster fishery (Waypoint 45)

Figure 34: Shore mussels collected at oyster fishery (Waypoint 49)