Scottish Sanitary Survey Programme

Sanitary Survey Report

Production Area: Ulva: Loch Tuath

SIN: AB 285

February 2012

Cefas

Food Standards Agency
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Buidheann Inbhe-Bìdhe

Report Distribution – Ulva: Loch Tuath

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I. Executive Summary

The sanitary survey at Ulva: Loch Tuath was undertaken based on a failure assessment to examine areas which had received results that outwith their normal classification. The Ulva: Loch Tuath fishery is located on the north side of the island of Ulva in the Inner Hebrides off the west coast of the island of Mull. The fishery is located in Soriby Bay which is situated at the southeastern end of Loch Tuath. Pacific oysters are grown in mesh bags on metal trestles. Oysters from the farm are only supplied to the restaurant on the island. The restaurant is open from Easter to the end of October.

The island of Ulva is very sparsely populated, with no roads or motor vehicles. It attracts visitors during the summer with a visitor centre, wild camping, walking trails and a cafe. There are two small hamlets on the opposite shoreline on the Isle of Mull. There are no point sources of human faecal contamination direct to the production area and the impact of human sewage from further afield is limited. Other potential sources of faecal contamination include wildlife, a limited number of livestock and anchored or passing yachts. Deer are the most likely source of faecal contamination to the fishery due to a deer fence inland of the shoreline, keeping the deer toward the shoreline. Three streams were seen at the head of the inlet where the fishery is located. These were measured and sampled but despite the heavy rainfall during the preceding night *E. coli* concentrations were below the limit of detection of the test used for the samples.

Historical monitoring results have suggested that generally the level of contamination of the oysters is low with intermittent results greater than 230 *E. coli* MPN/100 g. Although no statistically significant variation in results was found, they did appear to vary by month with the lowest results in March and highest peak results tending to occur July-September. The active fishery only pertains to a very small area along the eastern shore of the bay, and within that area higher results tended to occur among the more northerly observations.

It is recommended that the southern boundary of the fishery be drawn to exclude the mouths of the streams where they discharge to the bay. The recommended boundaries are the area described by lines drawn between NM 4249 4047 to NM 4308 4071 and between NM 4281 4010 to NM 4305 4011 and extending to MHWS.

It is recommended that the RMP be set on the northernmost of the trestles at NM 4295 4022.

II. Sampling Plan

PRODUCTION AREA	Ulva: Loch Tuath
SITE NAME	Soriby Bay
SIN	AB 285 081 13
SPECIES	Pacific oyster
TYPE OF FISHERY	Trestle
NGR OF RMP	NM 4295 4022
EAST	142950
NORTH	740220
TOLERANCE (M)	10
DEPTH (M)	Not applicable
METHOD OF SAMPLING	Hand
FREQUENCY OF SAMPLING	Monthly, during season February to October
LOCAL AUTHORITY	Argyll & Bute Council
AUTHORISED SAMPLER(S)	
LOCAL AUTHORITY LIAISON OFFICER	

III. Report

1. General Description

The Ulva: Loch Tuath production area is located on the north east shore of the island of Ulva off the west coast of the island of Mull in the Inner Hebrides. The production area is located in Soriby Bay which is situated at the southeastern end of Loch Tuath. Soriby Bay is 580 m at its widest point and measures approximately 480 m from the mouth to the head of the bay. The bay is shallow with depths of up to 10 m. Although Loch Tuath is open to seas from the west, Soriby Bay is sheltered from this direction and opens to the north, where it receives protection from the Isle of Mull.

The sanitary survey at Ulva: Loch Tuath was undertaken based on its placement in a failure assessment performed on historical monitoring results. This was a statistical assessment undertaken to identify areas for which the geometric mean of *E. coli* results for 2010 was significantly higher than that of the previous three years.

The location of Loch Tuath is shown in Figure 1.1.

Figure 1.1 Location of Ulva: Loch Tuath

2. Fishery

The area considered in this survey is summarised in Table 2.1 and shown on the map in Figure 2.1.

Table 2.1 Ulva: Loch Tuath production area and site

Production Area	Site	SIN	Species	Nominal RMP
Ulva: Loch Tuath	Soriby Bay	AB 285 081 13	Pacific oysters	NM 429 404

Current production area boundaries are given as the “area inshore of a line drawn between NM 4248 4048 and NM 4308 4071”. The nominal RMP lies 186 metres north of the northernmost trestle recorded during the shoreline survey.

Pacific oysters are grown in mesh bags on metal trestles. Oysters from the farm are supplied to the restaurant on the island only. The restaurant is open from Easter to the end of October.

According to the local authority, the active part of the fishery is a pair of trestles high on the eastern shore, represented by the most northerly of the two red crosses in Figure 2.1. Monitoring samples are taken from this location. At the time of the shoreline survey only one bag was in place on these trestles and there were insufficient oysters in this bag to provide a sample. More oysters were put down at this location after the shoreline survey.

A larger area of trestles was present in deeper water towards the head of the bay, south and west of the sampling trestle. The local authority has reported that this block of trestles is no longer active. At the time of the shoreline survey many of the trestles were empty, and some bags were lying on the seabed. Some of these bags had a mixture of empty oyster shells and wild mussels inside. However, some bags still contained very large, live Pacific oysters.

At the time of the shoreline survey a significant number of native oysters were observed on the seabed, and some had attached to the exterior of trestles or oyster bags.

Figure 2.1 shows the location of the production area, nominal RMP and the location of the oyster trestles as recorded during the shoreline survey.

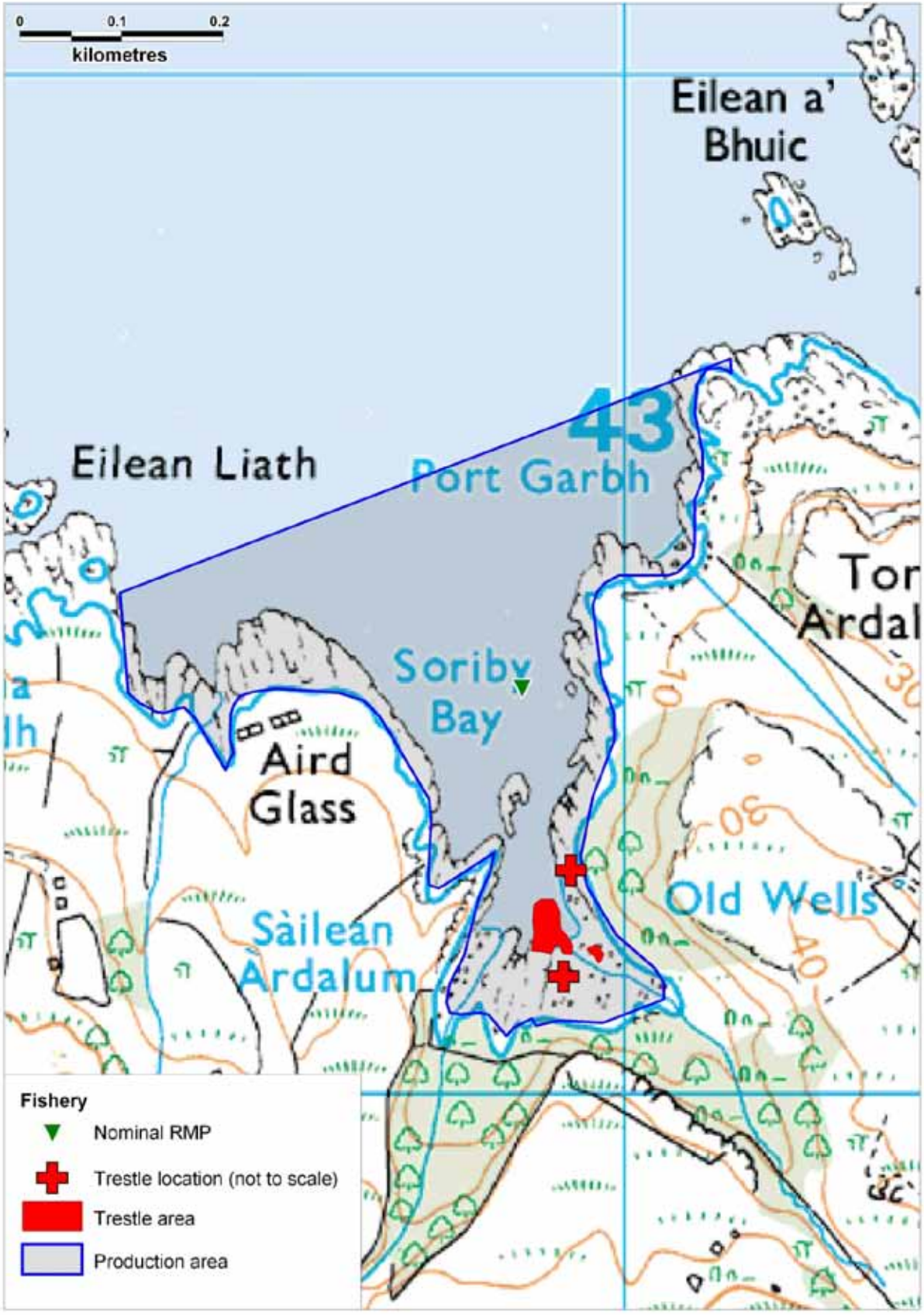

Figure 2.1 Ulva- Loch Tuath Fishery

3. Human Population

Information on the human population of the area around Ulva was obtained from the General Register Office for Scotland. Data was provided for the 2001 census by output area. The population density for the output areas nearest the fishery is shown thematically mapped in Figure 3.1.

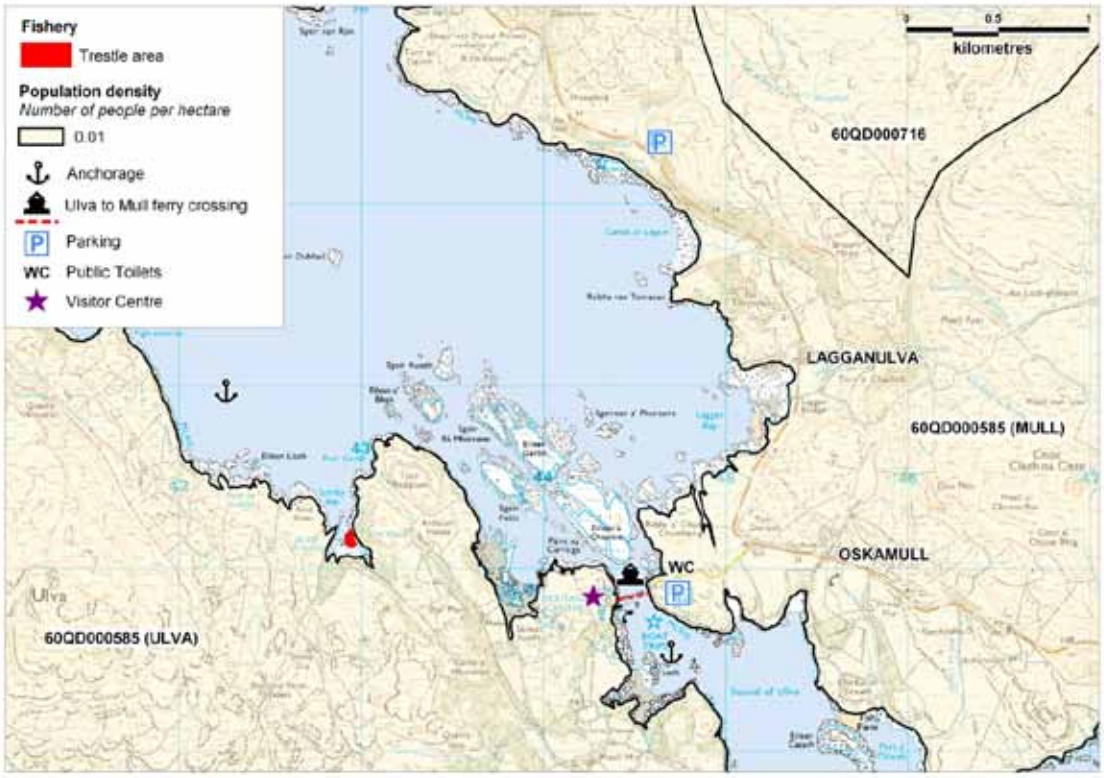

Figure 3.1 Population map of Ulva: Loch Tuath

The island of Ulva is very sparsely populated, with no roads or motor vehicles. Access to the island is via on-demand ferry for foot and bicycle traffic only. The island has a permanent population of 16, the majority of which live on the eastern side of the island. The island attracts visitors during the summer with a visitor centre, wild camping, walking trails and a cafe (open April – October). There is a self catering cottage one mile inshore from the ferry terminal. There are no specific campsites on the island however wild camping is allowed in permitted areas. There are no dwellings on the shores of Soriby Bay, and the nearest marked footpath ends approximately 300 metres from the shore. The population in the surrounding area is spread amongst two census output areas, as listed in Table 3.1. The census output area 60QD000585 covers both the island of Ulva and part of the island of Mull. As the approximate population of Ulva is known to be 16 (http://www.isleofulva.com/), the population density for Ulva has been calculated separately and the population density of the remainder of the census output area adjusted accordingly. The population density for both sections of the census output area are thematically mapped in Figure 3.1 and listed in Table 3.1.

Table 3.1 Census output areas: Loch Tuath

Output area	Population	Area (km^2)
60QD000585 (ULVA)	16	18
60QD000585 (MULL)	97	67
60QD000716	77	55
Total	**190**	**140**

On the opposite coastline on the Isle of Mull two small hamlets, Lagganulva and Oskamull, are located on the road running close to the shoreline. At the ferry pier there is a car park with public toilets. There is another parking area further west along the coastline with no facilities.

Two anchorages are identified on the Admiralty chart for the area (see Figure 14.1), one is located north west of Soriby Bay and the second to the east of the ferry crossing at the head of the Sound of Ulva. Commercial tour boats occasionally utilise the anchorage in Soriby Bay (http://www.northernlight-uk.com/news/may_2011.htm). Any overboard discharges from yachts anchored in Soriby Bay could potentially impact water quality at the fishery depending on the number of people onboard, whether the discharges are treated and the predicted movement of contaminants for the area (Section14).

4. Sewage Discharges

Information on sewage discharges in the vicinity of the fishery was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). No Scottish Water community septic tanks or sewage discharges were identified for the area surrounding the fishery.

Discharge consents provided by SEPA are listed in Table 4.1. There are no intermittent discharges in the area.

Table 4.1 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented/ design PE	Discharges to
1	CAR/R/1041565	NM 46060 39850	STE	Septic tank	6	Soakaway
2	CAR/R/1037758	NM 46110 39940	STE	Septic tank	5	Soakaway
3	CAR/R/1040278	NM 45800 40100	STE	Septic tank	6	Land
4	CAR/R/1037610	NM 43040 43580	STE	Septic tank	5	Soakaway
5	CAR/R/1030179	NM 42900 43640	STE	Septic tank	6	Soakaway
6	CAR/R/1040165	NM 41973 44321	STE	Septic tank	15	Soakaway
7	CAR/R/1046309	NM 41683 44533	STE	Septic tank	5	Soakaway
8	CAR/R/1087653	NM 41610 44610	STW FE	unknown	8	Soakaway
9	CAR/R/1028030	NM 41553 44579	STW FE	unknown	7	Unnamed watercourse
10	CAR/R/1039436	NM 41520 44650	STE	Septic tank	5	Soakaway
11	CAR/R/1079308	NM 41369 44751	STW FE	unknown	15	Unnamed watercourse

No sewage discharge consents were provided for the island of Ulva. Eleven of the provided consents related to septic tanks along the shore of Mull. During the shoreline survey, it was observed that there were a small number of homes and a cafe on the island, between the ferry pier and the fishery. Although no consents were provided for these, they are presumed to have private septic tanks as there is no public sewerage provision on the island. The nearest potential septic tank discharge is approximately 400 metres inland from the fishery and outwith its catchment area.

Sewage infrastructure recorded during the shoreline survey is listed in Table 4.2.

Table 4.2 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	30/08/2011	NM 44590 39898	Septic tank and public toilets near car park

Given the limited population living in proximity to the fishery, and the lack of significant numbers of discharges further afield, it is unlikely that the oyster fishery at Loch Tuath is significantly impacted by human sewage and any impact would be greater on the western side of Soriby Bay than the eastern side.

Figure 4.1 Map of discharges for Ulva: Loch Tuath

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 2. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red indicate poorly draining soils while areas shaded blue indicate more freely draining soils.

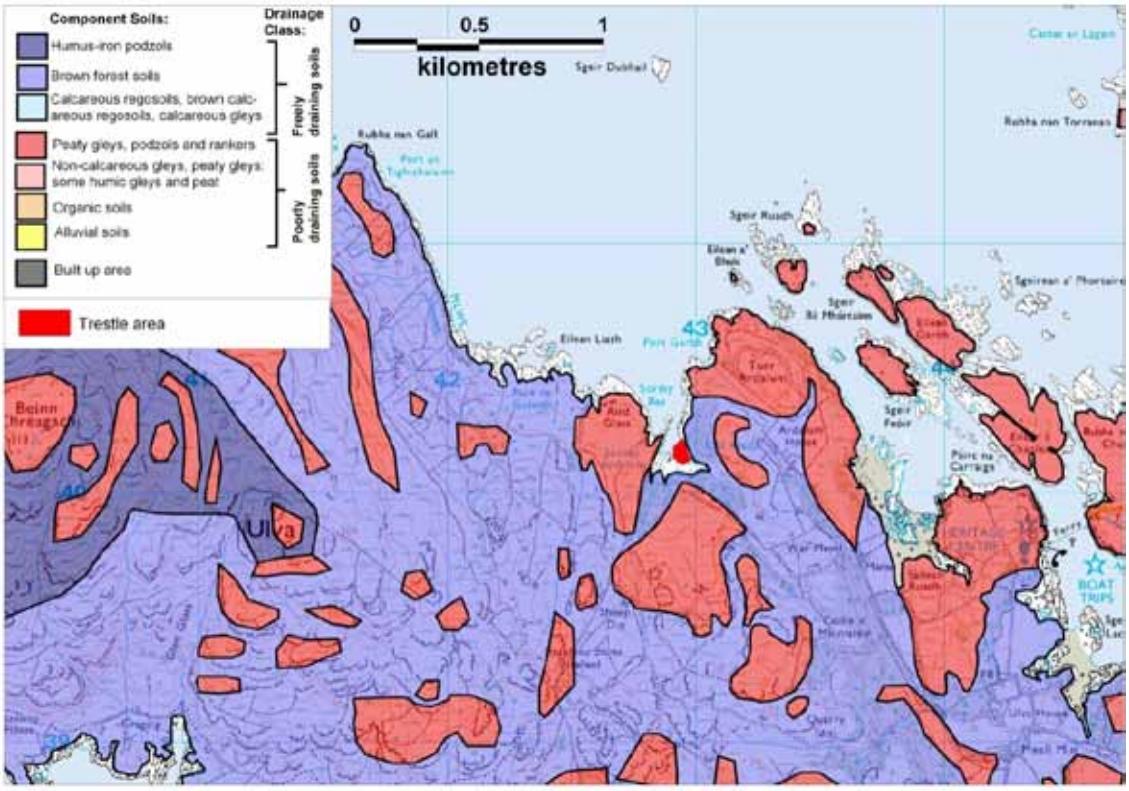

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Figure 5.1 Component soils and drainage classes for Ulva: Loch Tuath.

Three types of component soil are found in this area. Freely-draining humus-iron podzols and brown forest soils predominate with areas of poorly draining peaty gleys podzols and rankers interspersed throughout. The land drainage in the vicinity of the fishery is mixed, with the catchment of the two streams draining into the head of Soriby Bay passing through both freely and poorly draining soil types.

The potential for runoff, attributable to soil drainage, which may be contaminated with *E. coli* from animal waste, is moderate, and greater on the western side of Soriby Bay than the eastern side.

6. Land Cover

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

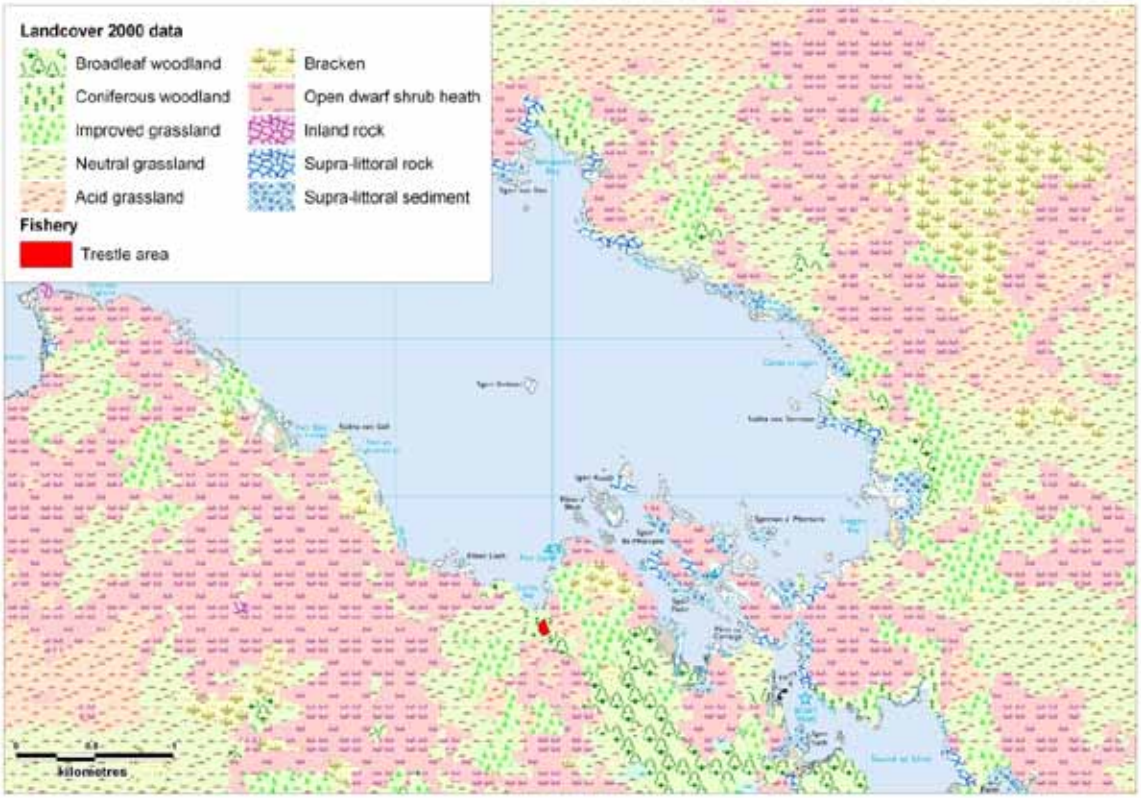


Figure 6.1 LCM2000 class land cover data for Ulva: Loch Tuath

A variety of land cover types are found in the Loch Tuath area. On the southern shoreline of Loch Tuath the most common land cover type is open dwarf shrub heath, which is scattered along the majority of the shoreline. Interspersed between the areas of open dwarf shrub heath are patches of improved grassland, neutral grassland, acid grassland and bracken. There are patches of improved grassland inland to the west of Soriby Bay and on the direct shoreline to the east of the fishery. There is a large area of broadleaf woodland located west of the Sound of Ulva. On the eastern shoreline of Loch Tuath there is acid grassland, neutral grassland and open dwarf shrub heath. Interspersed between these land cover types are patches of improved grassland, bracken and broadleaf woodland. The improved grassland is scattered in patches close to but not directly on the shoreline of the loch. There are no urban or built up areas.

Studies undertaken by Kay et al (2008) found that faecal indicator organism export coefficients for faecal coliform bacteria were highest for urban catchment areas (approx 1.2 – 2.8×10^9 cfu km^{-2} hr^{-1}) and lower for areas of improved grassland (approximately 8.3×10^8 cfu km^{-2} hr^{-1}) and rough grazing (approximately 2.5×10^8 cfu km^{-2} hr^{-1}) areas. Lowest contributions would be expected from areas of woodland (approximately 2.0×10^7 cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to

increase significantly after rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay *et al*. 2008).

Therefore, the overall predicted contribution of contaminated runoff from the area around the Ulva: Loch Tuath fishery would be moderate and would be expected to increase significantly following rainfall events.

7. Farm Animals

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 Kilninian and Kilmore parish. Reported livestock populations for the parish in 2009 and 2010 are listed in Table 7.1. 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 7.1 Livestock numbers in Kilninian and Kilmore parish 2009 - 2010

	Kilninian and Kilmore 307 km^2			
	2009		2010	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	*	*
Poultry	17	408	17	409
Cattle	22	1271	24	1399
Sheep	39	17150	37	16048
Horses used in Agriculture	*	*	*	*
Other horses and ponies	9	35	9	35

The Kilninian and Kilmore agricultural parish encompasses the entire northern half of the Isle of Mull and the Isle of Ulva. The fishery lies in Soriby Bay on the north eastern coastline of the Isle of Ulva. Table 7.1 indicates there were over 1390 cattle and 16000 sheep reported in the parish in 2010. It also indicates that there are less than five holdings of pigs and of horses used for agricultural purposes within the parish. Although large numbers of livestock are reported, it is the number of animals kept within the catchment and near the shore of the fishery that will be most likely to affect water quality there; such spatial information cannot be obtained from the census data.

The only source of spatially relevant information regarding livestock was the shoreline survey (see Appendix 6), which only relates to the time of the site visit during the 30th August 2011. The only sign of livestock was horse manure observed close to an abandoned farm house inland to the east of the fishery (see Figure 7.1). No sheep or cattle or signs of other livestock were observed during the shoreline survey. Both the harvester and local wildlife ranger reported that livestock are no longer kept on Ulva. However, subsequent to the survey it was reported that a flock of Hebridean sheep was introduced to the island sometime between September and December 2011 (http://www.isleofulva.com/news-archive/). There are also reportedly wild

goats on the island (http://www.isleofulva.com/visitor-information/os-map-of-ulva/), though no specific records on numbers and range could be found. Therefore, livestock are present in presumably small numbers and the majority of the animals reported in the agricultural census data are kept on Mull.

The area surrounding Soriby Bay has been fenced off as part of a woodland restoration project and grazing animals excluded from an area including much of the catchment of the bay. Therefore, these animals would be unlikely to contribute to faecal coliform loadings in the bay.

Figure 7.1 Livestock observations at Ulva: Loch Tuath

8. Wildlife

Wildlife may also contribute to faecal contamination observed at the fishery. General information on the impacts of wildlife species can be found in Appendix 2. Wildlife species most likely to contribute to faecal contamination of the waters of Soriby Bay are considered below.

Birds

Seabird 2000 census data (Mitchell *et al*. 2004) was queried for the area within a 5 km radius of the Ulva: Loch Tuath production area. This census, undertaken between 1998 and 2002, covered the 25 species of seabird that breed regularly in Britain and Ireland. The majority of records pertained to breeding areas around the south side of the island, which due to the local topography is actually more than 6 km by sea from the fishery. Only one record was found for the immediate vicinity of Soriby Bay and that was for two occupied territories of herring gulls (*Larus argentatus*), relating to approximately 4 birds.

The ranger at Ulva identified during the shoreline survey that there were no significant populations of seabirds, geese or wading birds present at Soriby Bay, and none of these birds were seen during the shoreline survey.

Therefore, these animals are not expected to contribute significantly to levels of faecal contamination found within the bay.

Seals

Both grey seals (*Halichoerus grypus*) and common or harbour seals (*Phoca vitulina vitulina*) are recorded in western Scotland. However, no records were found for the Isle of Ulva. Seals are recorded at the Treshnish Isles, which lie approximately 5 km northwest of the western tip of Ulva. As these animals may range widely for food, and may be attracted by the marine cage fish farm located in the outer loch, it should be presumed that they may be present in the area from time to time. No seals were observed during the shoreline survey.

Deer

Deer are present throughout much of Scotland in significant numbers. The Isle of Mull has an estimated deer population of approximately 9000, which equates to almost 3 deer to every person on the island (http://madeonmull.co.uk/about-mull/). A survey was undertaken on Ulva in July 2011 and 200 red deer were counted at that time (Jamie Howard, personal communication). Deer and livestock are excluded by fencing from two areas as part of a woodland restoration project. The easternmost of these areas includes Soriby Bay, and the fence is located inland of the shoreline.

During the shoreline survey deer droppings and hoof prints were seen along the eastern shore of Soriby Bay indicating that deer are present in the area. Shoreline observations are listed in Table 8.1. Faecal indicator bacteria

arising from deer droppings are likely to be carried via rainfall runoff to streams or directly into the sea.

Table 8.1 Wildlife observations recorded during shoreline survey

No	Date	NGR	Shoreline observation
1	30/08/2011	NM 43007 40263	Deer fence
2	30/08/2011	NM 43011 40333	Hoof prints
3	30/08/2011	NM 43015 40356	Deer hoof prints
4	30/08/2011	NM 43010 40369	Deer droppings and hoofprints
5	30/08/2011	NM 42984 40188	Deer droppings

Otters

Otters have been recorded in the area in the past, however no specific records of otter numbers were available. A wildlife survey was undertaken on Ulva in July 2011, and otters were mentioned, however it is not known whether they were found in Soriby Bay. No otters were seen during the shoreline survey.

Otters typically defecate in established latrines adjacent to freshwater courses. Ulva has a number of streams and burns that may host otters, and any faecal contamination from these animals is likely to be carried in the streams. Typical population densities of coastal otters are low and therefore any impact is expected to be minor and most likely to occur at the head of the bay.

Wild goats

There is some record of wild goats on the island, however no specific information was found on their numbers or range. Therefore, it is not known whether these animals may contribute to faecal contamination found at the fishery. No goats or evidence of their recent presence was seen during the shoreline survey.

Conclusions

Overall, due to the relative lack of other inputs wildlife are expected to be a predominant source of faecal contamination reaching the oyster fishery. The deer fence along the shore of the bay serves to keep deer toward the shore. Birds, seals, and otters may also contribute to background levels of contamination found in the bay. No information on seasonal variation in wildlife presence was found, however the two most likely sources to Soriby Bay, deer and otters, are likely to have a year-round presence.

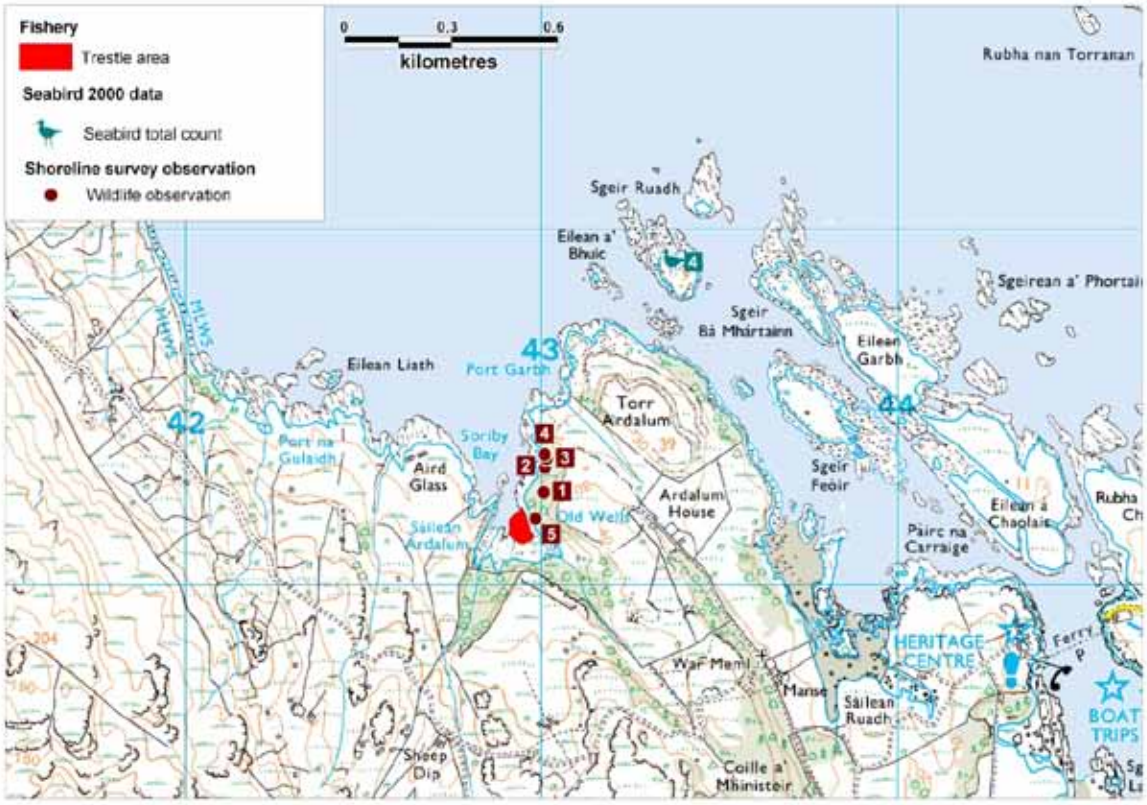


Figure 8.1 Map of wildlife distributions and observations

9. Meteorological data

The nearest weather station is located at Mull: Gruline which lies 12.8 km to the east of the fishery. Rainfall data was available for 2003-2010 but data were missing for September 2004, and October to December 2006. The nearest station with wind data available was Tiree, 42 km west of the fishery.

Total daily rainfall data 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 Ulva: Loch Tuath.

9.1 Rainfall

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

Figures 9.1 and 9.2 are box and whisker plots that summarise individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median shown as a line within the box. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

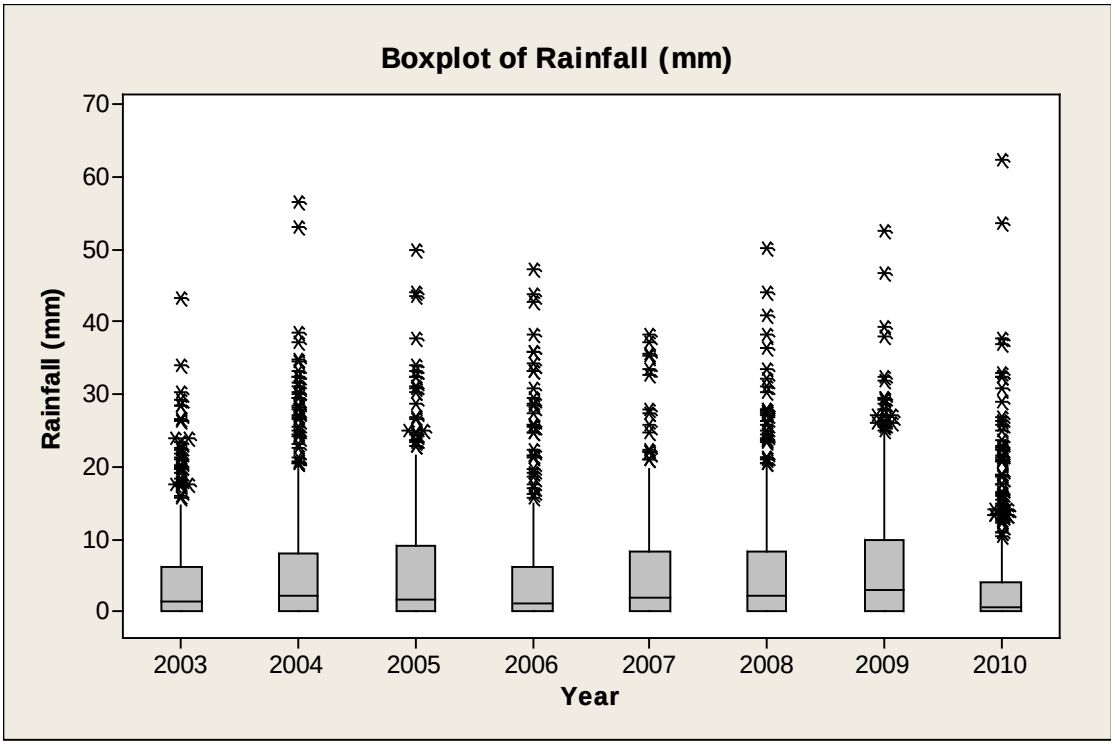


Figure 9.1 Box plot of daily rainfall values by year at Ulva:Loch Tuath (2003 – 2010)

Rainfall varied from year to year, with 2009 being the wettest and 2010 the driest. However, care must be taken in interpreting the plot due to missing data in 2004 and 2006.

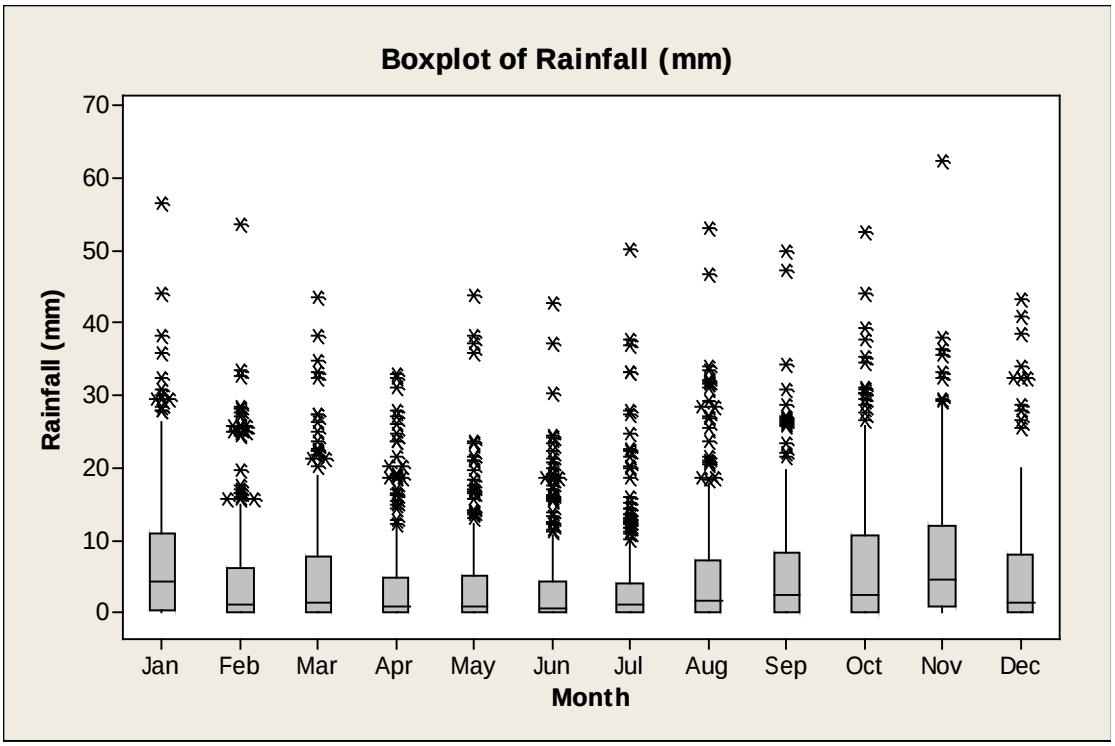


Figure 9.2 Box plot of daily rainfall values by month at Ulva: Loch Tuath (2003 – 2010)

Weather was wettest in January, October and November and driest from April to August, when there is a marked increase in daily rainfall. Extreme rainfall events exceeding 30 mm in a day occurred during all months with no obvious seasonal pattern which indicated that these could occur at any point throughout the year. For the period considered here (2003-2010) 44% of days received rainfall of 1mm or less and 19% of days received rainfall of 10mm or more.

The potential for increased run-off is therefore highest in late summer, autumn and winter. However, the amount of contamination in any run-off will depend on the higher rainfall levels occurring when faecal contamination is present on the land. This is most likely in the late summer and early autumn periods.

9.2 Wind

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

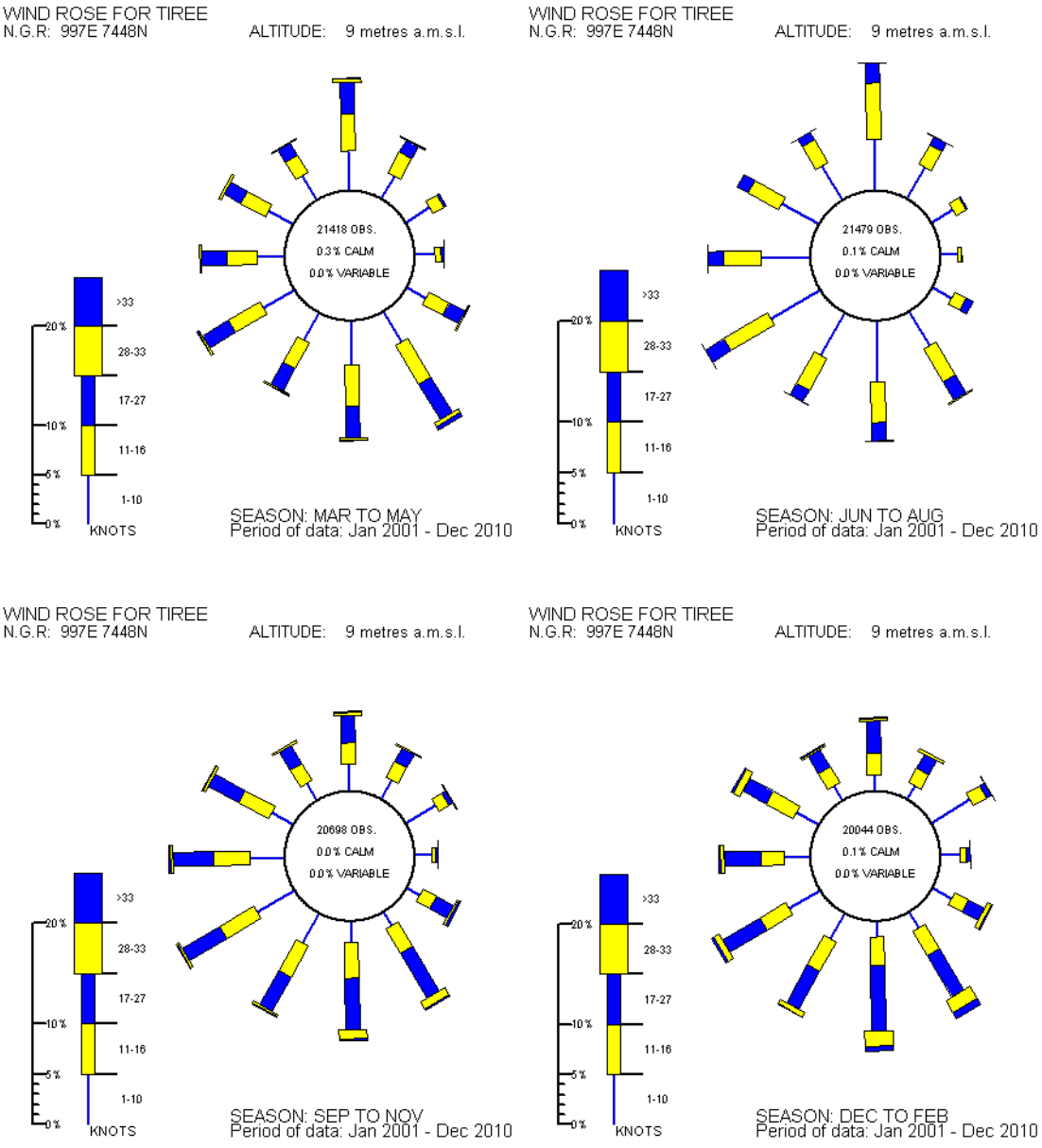


Figure 9.3 Seasonal wind roses for Tiree

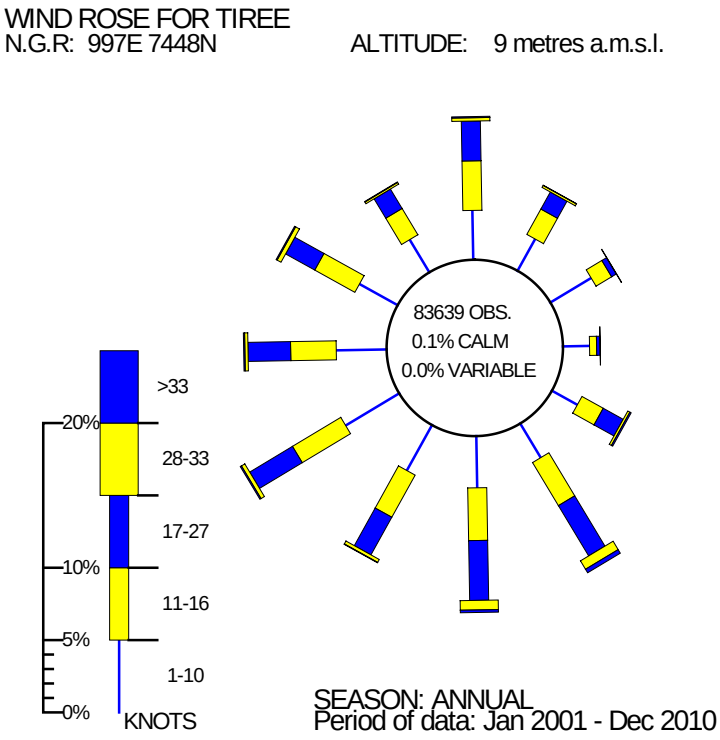


Figure 9.4 Wind rose for Tiree (All year)

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. There was no marked change in wind direction throughout the months; however winds were much stronger in the winter months than in the summer months. Wind is an important factor in the spread of contamination into a production area 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, particularly those from the north will significantly alter the pattern of surface currents at Ulva: Loch Tuath. 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. Current and historical classification status

Ulva Loch Tuath: Soriby Bay was first classified in 2003 for Pacific Oysters (*Crassostrea gigas*). The historical and current classifications for the area are shown below in Table 10.1.

Table 10.1 Ulva Loch Tuath, Pacific Oysters

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
2003	A	A	A	A	A	A	A	A	A	A	A	A
2004	A	A	A	A	A	A	A	A	A	A	A	A
2005	A	A	A	A	A	A	A	A	A	A	A	A
2006	A	A	A	A	A	A	A	A	A	A	A	A
2007	A	A	A	A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A									

All months for all years up until March 2012 have consistently been classified as A.

11. Historical *E. coli* data

11.1 Validation of historical data

The results for all samples assigned against Ulva: Loch Tuath Soriby Bay from 1 January 2007 up to the 31st December 2011 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 February 2012. All *E. coli* results were reported in most probable number per 100g of shellfish flesh and intravalvular fluid.

One sample, dated 27/11/07, was recorded on the database as “Rejected” and was deleted. Two samples were recorded as being collected on 02/02/10, at different times: it was subsequently confirmed by FSAS that one of these was not valid and the record was deleted. Five of the remaining samples were received at the laboratory more than 24 hours after collection but none was received more than 48 hours after collection. The reported coolbox temperatures were all <8°C.

The locations given for two samples fell outside the production area. In one case, this appeared to be a simple transposition of two digits and, when this was corrected, the location fell within the production area. The location for the other sample plotted on land approximately 1 km to the south of the production area. However, this did not appear to be due to a transposition of digits and the result was deleted from the data set for the purposes of the present analyses.

Twenty-one samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. No sample had a result reported as >18000.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Ulva: Loch Tuath Soriby Bay
Site	Loch Tuath Soriby Bay
Species	Pacific oysters
SIN	AB-285-081-13
Location	Various
Total no of samples	50
No. 2007	7
No. 2008	11
No. 2009	11
No. 2010	11
No. 2011	10
Results Summary	
Minimum	<20
Maximum	2400
Median	20
Geometric mean	31
90 percentile	768
95 percentile	2400
No. exceeding 230/100g	5 (10%)
No. exceeding 1000/100g	1 (2%)
No. exceeding 4600/100g	0
No. exceeding 18000/100g	0

11.3 Overall geographical pattern of results

Prior to 2008, sampling locations were recorded on the database to 100 m accuracy: 6 of the samples taken in 2007 were reported against one location and 1 against a second. The latter coincided with the location of the nominal RMP. After that period, sampling locations were recorded to 1 m accuracy: the 44 samples were recorded against 29 different locations. The sampling locations are shown in Figure 11.1. It should be noted that with the GPS units used by the sampling officers, the true accuracy is unlikely to be better than 5 m. The locations that were recorded to 1 m accuracy all lay within a rectangular area that measured approximately 21 m by 8 m (and thus potentially on a single trestle). Due to the close proximity of these locations, a formal spatial analysis was not undertaken. However, all of the 5 samples that gave results >230 *E. coli* MPN/100 g, and had been taken from 2008 onwards, had recorded sampling locations that lay on the northern half of that area.

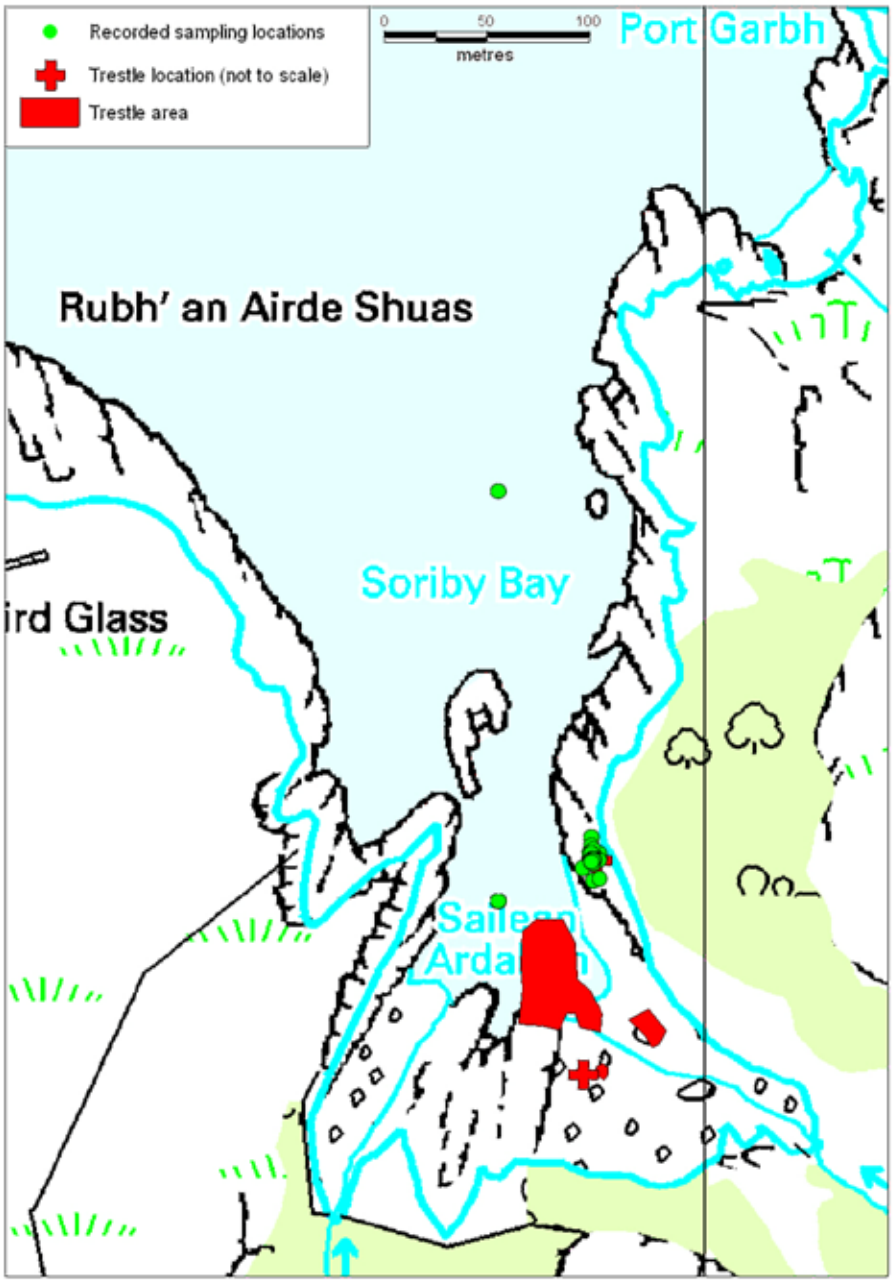


Figure 11.1 Map of reported sampling locations

11.4 Overall temporal pattern of results

Figure 11.2 presents a scatter plot of individual oyster results against date, fitted with a loess trend line. Loess stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away. The trend line helps to highlight any apparent underlying trends or cycles.

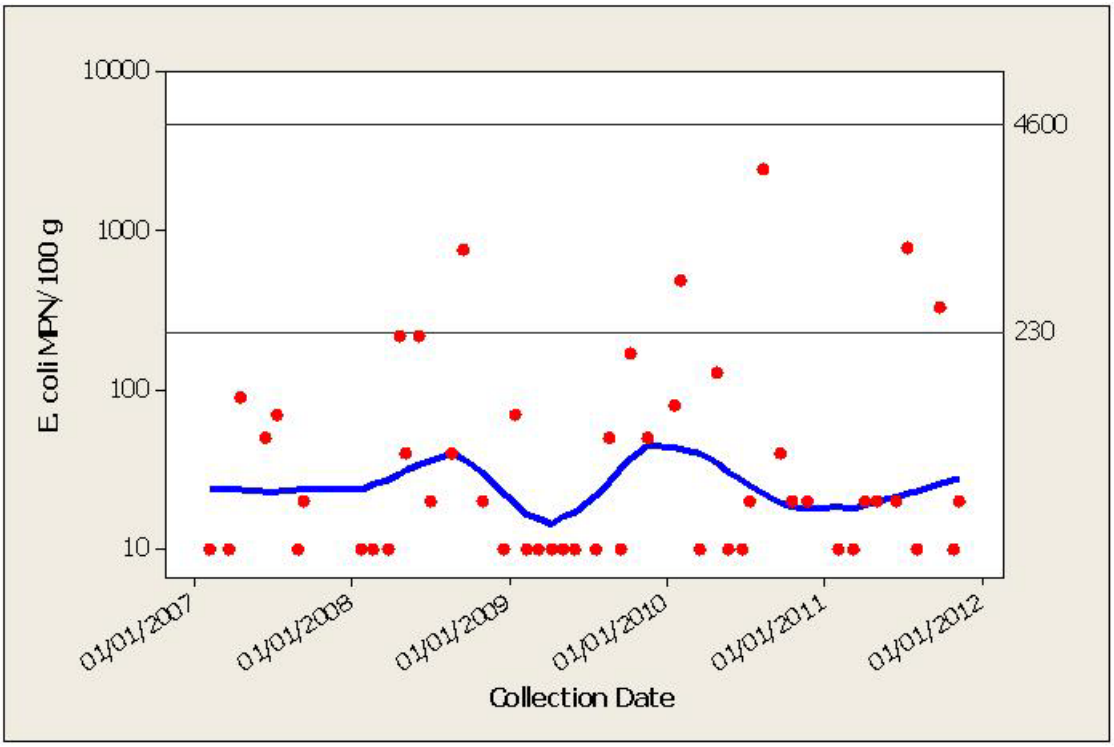


Figure 11.2 Scatterplot of *E. coli* results by date with loess line

The general level of contamination of the oysters is low with intermittent results greater than 230 *E. coli* MPN/100 g. The underlying level of contamination appears to be stable across the period of this assessment but, in 2009 there was a general increase in results in summer/autumn and in 2010 there was a general increase around winter time.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figure 11.3 presents a scatterplot of *E. coli* result by month, overlaid with a loess line to highlight any trends. It should be noted that the points on the graph have been "jittered" (randomly moved a small distance in the X and Y directions) to allow otherwise superimposed points to be seen separately.

The lowest results were seen in March and this is reflected by the trend line at that point. Otherwise, there is no marked trend across the months. However, four of the five samples yielding results exceeding 230 *E. coli* MPN/100 g were taken between July and September. It should be noted that fewer samples were taken in winter with only one sample having been taken in December.

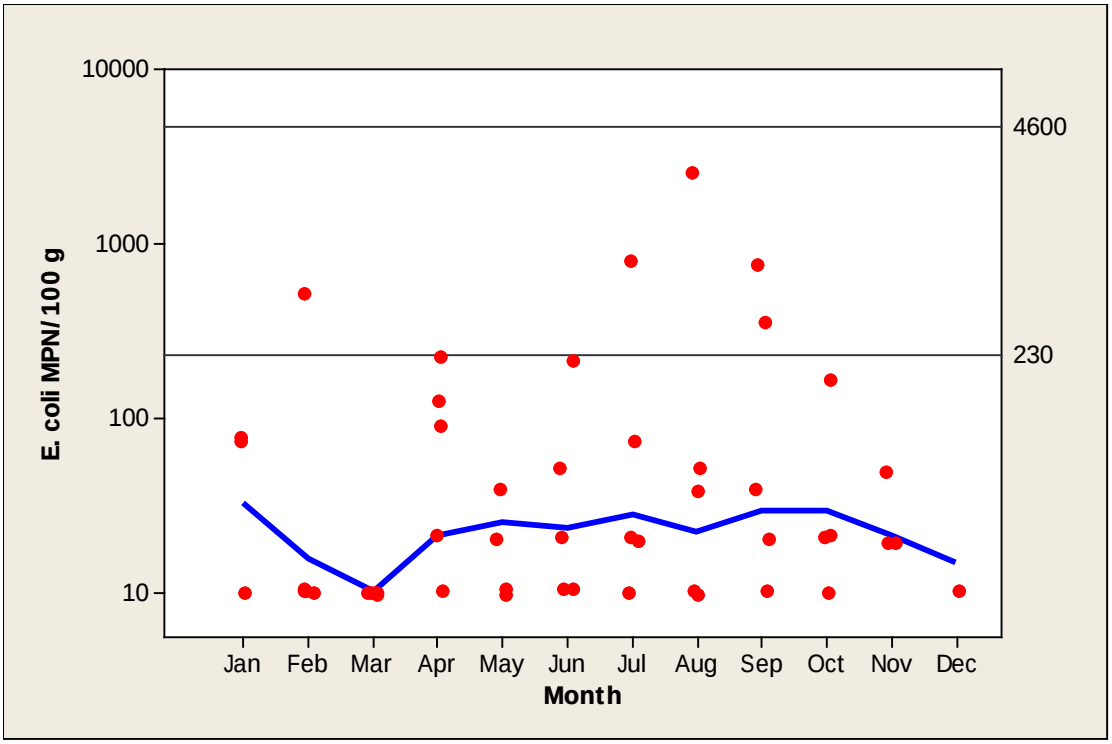


Figure 11.3 Scatterplot of results by month

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February). Boxplots of results by season are shown in Figure 11.4.

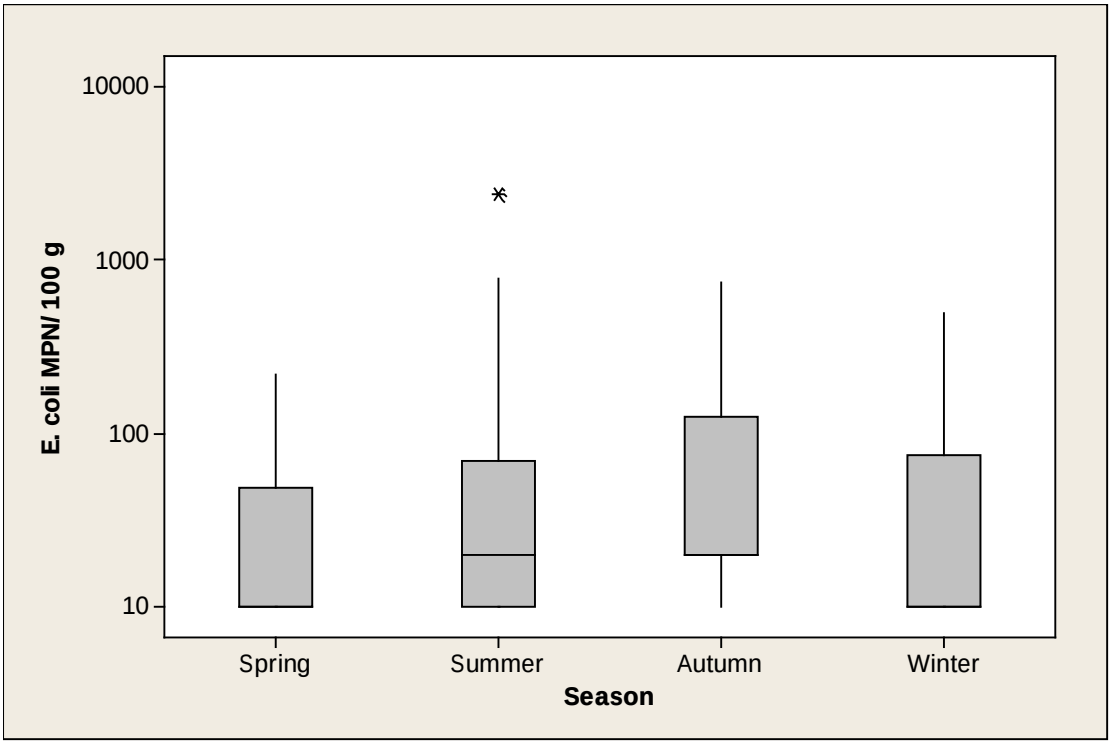


Figure 11.4 Boxplot of result by season

No significant difference was found between results by season (One-way ANOVA, p=0.493, Appendix 4).

11.6 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, winds, sunshine and temperatures can all influence the flux of faecal contamination into growing waters (e.g. Mallin *et al*, 2001; Lee & Morgan, 2003). The effects of these influences can be complex and difficult to interpret. This section aims to investigate and describe the influence of these factors individually (where appropriate environmental data is available) on the sample results using basic statistical techniques.

11.6.1 Analysis of results by recent rainfall

The nearest weather station for which rainfall was available was at Ulva itself, very close to the production area. However, there was a significant amount of missing data and so rainfall data for Mull: Gruline was used instead (see Section 9 for details). Rainfall data was purchased from the Meteorological Office for the period 1/1/2002 to 31/12/2010 (total daily rainfall in mm). Data was extracted from this for the period 1/1/2007 to 31/12/2010.

Two-day antecedent rainfall

Figure 11.5 presents a scatterplot of *E. coli* results against total rainfall recorded on the two days prior to sampling.

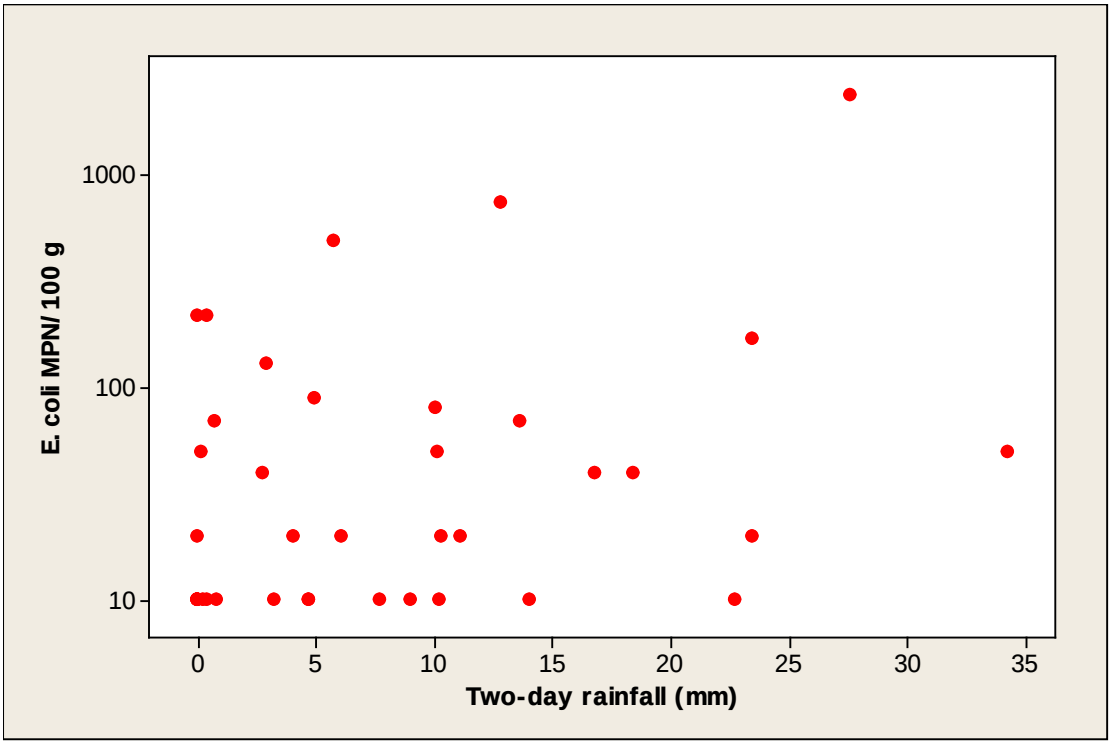


Figure 11.5 Scatterplot of result against rainfall in previous 2 days

A Spearman's Rank correlation was carried out between the results and the two day rainfall. A weak but significant correlation was found between *E. coli* result and rainfall in the previous 2 days (Spearman's rank correlation=0.323, p=0.042).

Seven-day antecedent rainfall

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results was investigated in an identical manner to the above. Figure 11.6 presents a scatterplot of *E. coli* results against total rainfall recorded on the seven days prior to sampling.

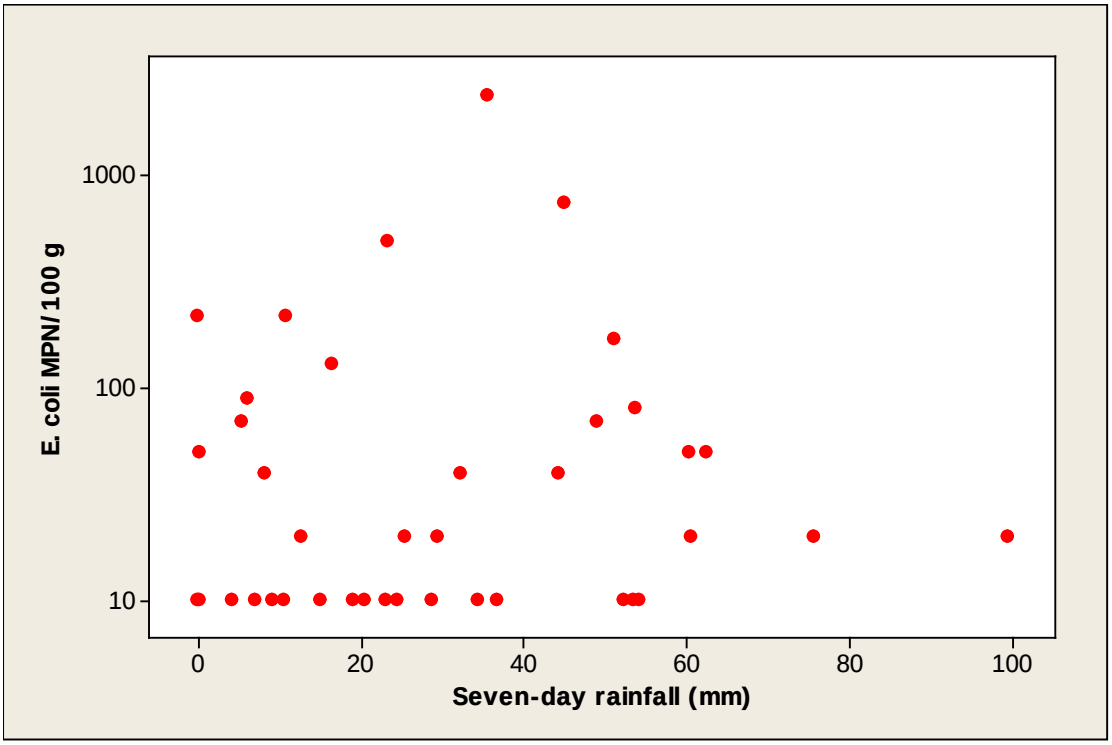


Figure 11.6 Scatterplot of result against rainfall in previous 7 days

A significant correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation= 0.705, p<0.001). However, the highest results occurred after moderate levels of rainfall.

11.6.2 Analysis of results by tidal height and state

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the area. Figure 11.7 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle. Full/new moons are located at 0º, and half moons at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

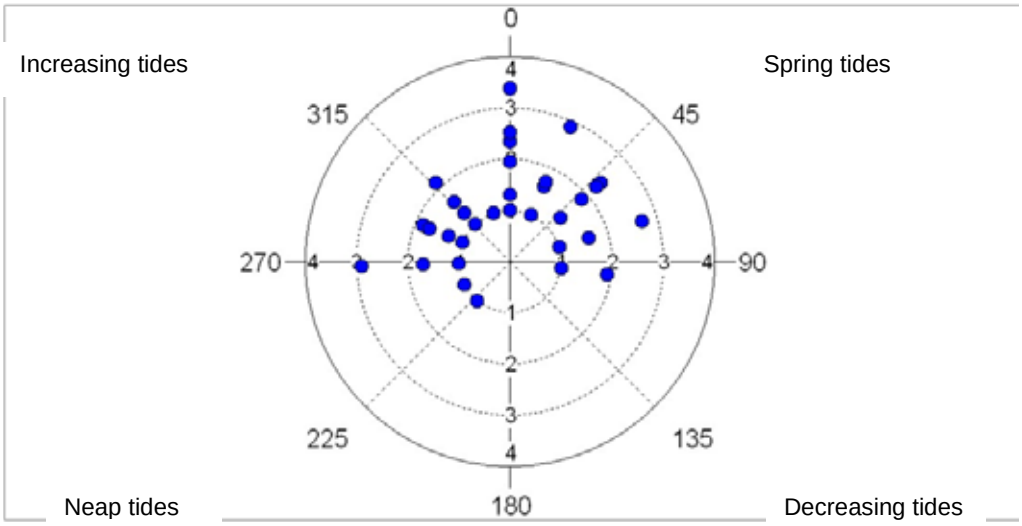


Figure 11.7 Polar plot of log_{10} *E. coli* results on the spring/neap tidal cycle

No significant correlation was found between log_{10} *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.246, p=0.058). Most samples had been taken on an increasing tide or around spring tide.

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figure 11.8 presents a polar plot of log_{10} *E. coli* results on the lunar high/low tidal cycle. High water is located at 0º, and low water at 180º.

No significant correlation was found between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.106, p=0.589). Most samples had been taken around low water.

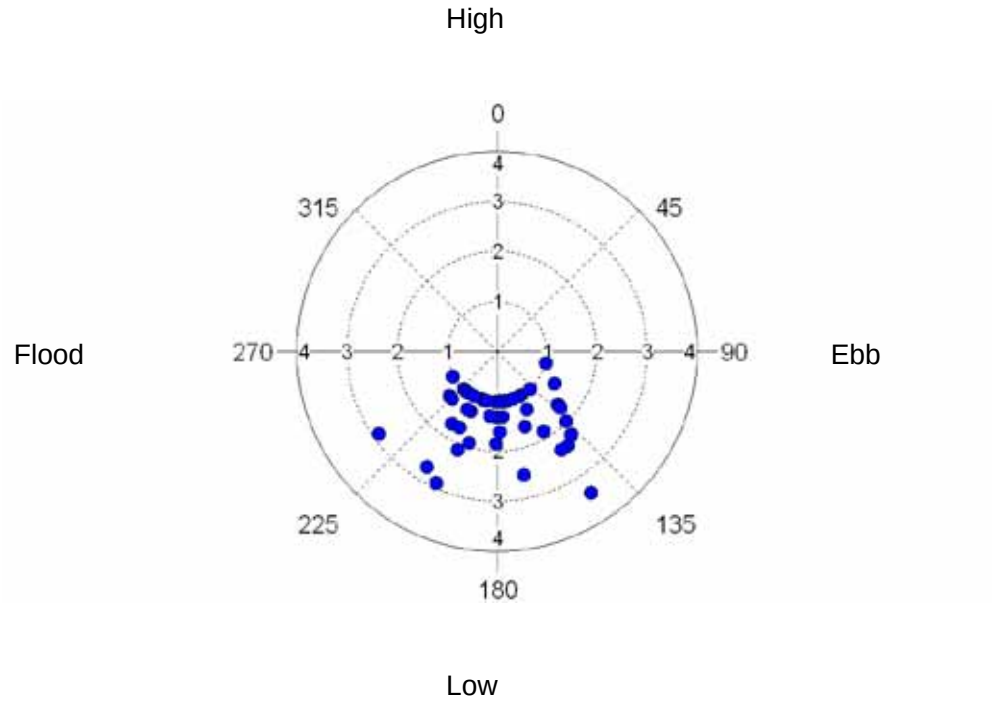


Figure 11.8 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Water temperature was recorded against 49 of the sampling occasions. Figure 11.9 presents a scatterplot of *E. coli* results against water temperature recorded at the time of sampling.

No significant correlation was found between *E. coli* result and water temperature (Spearman's rank correlation= 0.237, p=0.101).

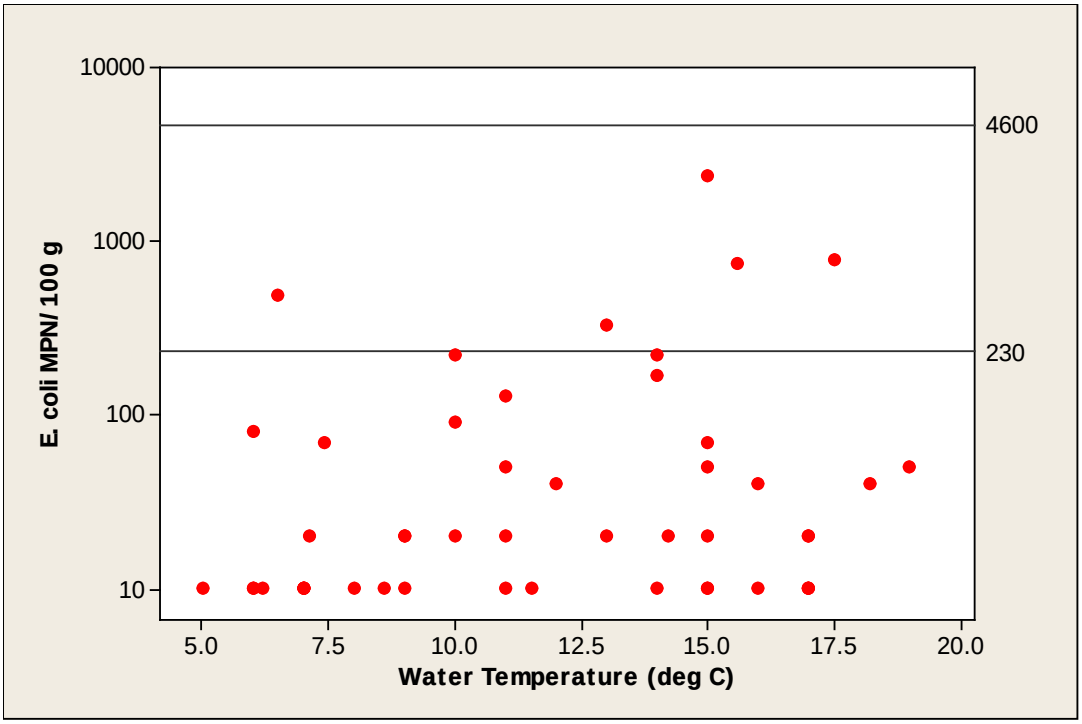


Figure 11.9 Scatterplot of *E. coli* results against water temperature

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence the potential for freshwater borne contamination, at the site. A scatterplot of *E. coli* results against salinity is shown in Figure 11.10.

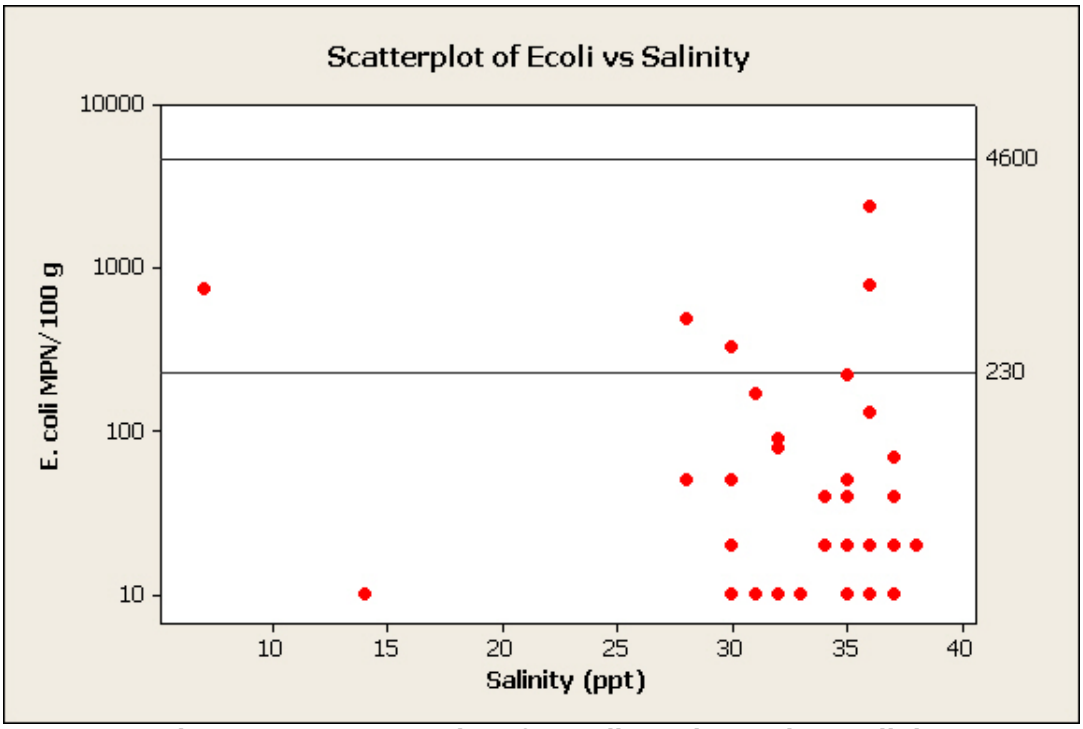


Figure 11.10 Scatterplot of E. coli results against salinity

Salinity was recorded for 46 of the 50 oyster sampling occasions for the data analysed. No significant correlation was found between *E. coli* result and salinity (Spearman's rank correlation = -0.161, p=0.284). Most of the recorded salinities exceeded 30 ppt.

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

Five of the oyster samples gave results greater than 230 *E. coli* MPN/100g. Details of these samples are presented in Table 11.2. All of those samples had been taken in the northern half of the area sampled on the eastern shore.

Four of the five samples had been taken between July and September. The other had been taken in February. All had been taken from the main sample trestle on the eastern shore of the production area. For the three samples for which rainfall data was available, light to moderate rain had occurred in the two days prior to sampling. Four of the samples had been taken at relatively high seawater temperatures for Scotland (≥13°C) while the February sample had naturally been taken at a much lower temperature. Four of the samples had been taken at moderate to high seawater salinities while one was taken at relatively low salinity. This sample had been taken after relatively high seven-day rainfall.

It was noted above that sampling had been concentrated around the run up to, and at spring tides, and around low water. Within those general tendencies, there appeared to be no additional pattern to the tidal state under which the high results had been obtained.

Table 11.2 Historic *E. coli* sampling results over 230 *E. coli* MPN/100g

Collection date	*E. coli* (MPN/ 100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
16/09/2008	750	NM 42945 40231	12.8	44.8	15.6	7	Spring	Flood
02/02/2010	490	NM 42947 40221	5.7	23.2	6.5	28	Spring	Low
10/08/2010	2400	NM 42946 40222	27.6	35.5	15.0	36	Increasing	Ebb
12/07/2011	790	NM 42947 40223	*	*	17.5	36	Increasing	Low
27/09/2011	330	NM 42946 40221	*	*	13.0	30	Increasing	Low

*Data not available

11.8 Summary and conclusions

Most of the samples had been taken from a small area on the eastern shore. The samples yielding results greater than 230 *E. coli* MPN/100 g were all recorded as having been taken from the northern half of that area. No overall change in the extent of contamination was evident over time. No significant difference was found in *E. coli* concentrations between seasons although 4 out of the 5 samples yielding results greater than 230 *E. coli* MPN/100 g were

taken between July and September. Further to this, no overall significant correlation was found between *E. coli* results and seawater temperature but 4 of the 5 high results occurred at temperatures ≥13°C.

A weak correlation was found between *E. coli* results and 2-day rainfall and a stronger correlation was found with 7-day rainfall. For the 3 samples for which rainfall data was available, all had occurred after moderate to heavy rain in the previous 7-days. However, no significant correlation was found between *E. coli* in the oysters and salinity of the seawater.

No association was seen between *E. coli* results and either the spring/neap or high/low tidal cycles. However, most samples had been taken under a restricted state of tides.

Therefore, there may be a tendency towards higher results at the northern end of the area and high results may be influenced by both season (summer/early autumn) and rainfall.

11.9 Sampling frequency

When a production area holds a non-seasonal classification and the geometric mean of the results falls within a certain range, the EURL Good Practice Guide (GPG) recommends that consideration be given to the sampling frequency being decreased from monthly to bimonthly. The production area currently holds a year-round A classification. However, the geometric mean of the 32 results obtained between 1/01/2009 and 31/12/2011 is 30.9 *E. coli* MPN/100g. This is higher than the upper limit of 13 *E. coli*/100 g given in the GPG for class A stability assessment.

12. Designated Shellfish Growing Waters Data

The production area at Loch Tuath lies within the Isle of Ulva, Mull (Loch Tuath) designated shellfish growing water. The area was designated under the European Community Shellfish Waters Directive (2006/113/EC) in 2000. SEPA is responsible for ensuring that monitoring is undertaken for a variety of parameters, including faecal coliforms in mussels. The most recent sampling point used by SEPA for SGW monitoring is at Laggan Bay, NM 45292 40955. This lies along the shore of Mull, approximately 2.5 km northeast of the Loch Tuath Pacific oyster site.

Results of shellfish monitoring to 2006 were provided by SEPA and are presented in Table 12.1. From 2000 to early 2003, samples were reported from NM 454 397, which lies approximately 1.2 km south of the more recent location. The relative positions of the SGW boundaries, the Ulva: Loch Tuath production area, and both the shellfish hygiene and SGW monitoring points are shown in Figure 12.1.

Table 12.1 SEPA monitoring results for shore mussels – Loch Tuath

Year	Quarter	Faecal coliform results (FC/100g)	
		NM 454 397	NM 45292 40955
2000	Q1	-	
	Q2	16000	
	Q3	110	
	Q4	430	
2001	Q1	<20	
	Q2	<20	
	Q3	140	
	Q4	-	
2002	Q1	200	
	Q2	40	
	Q3	5400	
	Q4	310	
2003	Q1	20	
	Q2	-	-
	Q3		500
	Q4		310
2004	Q1		320
	Q2		160
	Q3		16000
	Q4		110
2005	Q1		20
	Q2		3500
	Q3		3500
	Q4		16000
2006	Q1		-
	Q2		20
	Q3		68
	Q4		380

- No result reported

The results reported above indicate occasionally very high levels of faecal contamination in shore mussels at the monitoring points on the coast of Mull. The geometric mean result from the Laggan Bay site was 447 faecal coliforms/ 100 ml flesh and intervalvular fluid, compared 167 for the other site, which indicates either a substantial increase in contamination over time or that the levels of contamination at the Laggan Bay site were higher than those at the other location.

Since 2007, SEPA have obtained shellfish classification monitoring results (*E. coli*) under an agreement with FSAS for the purposes of SGW monitoring. The Shellfish Growing Waters Report for the area (SEPA, 2011) identified the shellfish hygiene RMPs at Loch Na Keal and Loch Na Keal West, both of which are for common mussels. As these lie even further from the fishery at Loch Tuath, these results are not considered further here as they are unlikely to be representative of conditions at the oyster fishery.

Although levels of faecal coliforms are usually correlated to levels of *E. coli* at a ratio of roughly 1:1, the ratio depends on a number of factors, such as environmental conditions and the source of contamination. Comparison is further complicated by differences in accumulation between the different species of shellfish.

Due to the distance between the monitoring point and the fishery in Soriby Bay, and to a lesser extent the other factors identified above, the results presented in Table 12.1 are not directly comparable with the other shellfish testing results presented in this report.

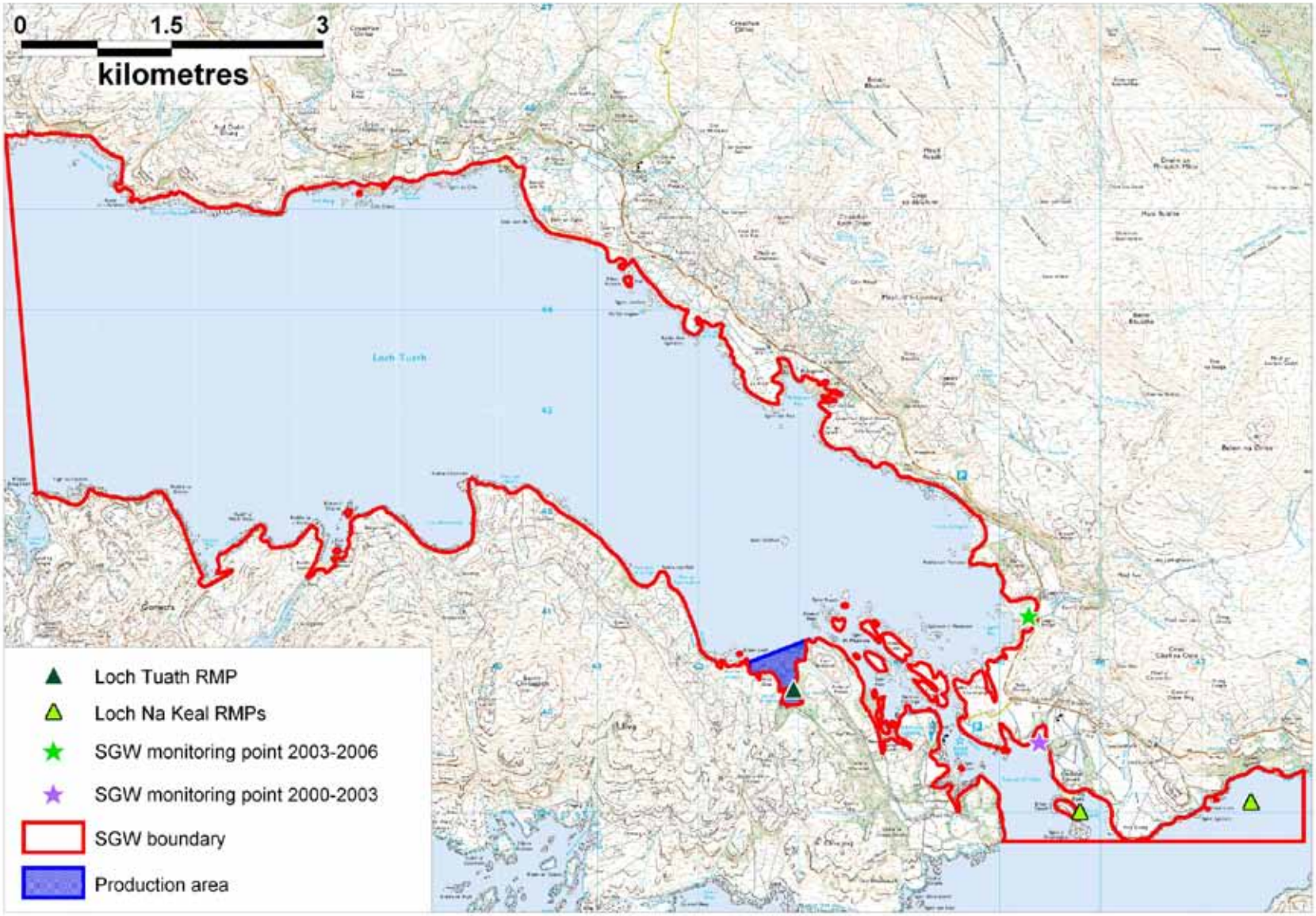


Figure 12.1 Isle of Ulva, Mull (Loch Tuath) Shellfish Growing Water

13. River Flow

There are no river gauging stations on rivers or burns along the Loch Tuath coastline.

During the shoreline survey, three streams were seen at the head of the inlet where the fishery is located. These were measured and sampled. Rainfall had been heavy the night before the survey and there was intermittent rain on the day. The results are shown in Table 13.1.

Table 13.1 River (or stream) loadings for Ulva: Loch Tuath

No,	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	NM 43070 40058	Stream	0.115	0.04	0.41	160	<100	$<1.6 \times 10^8$
2	NM 42905 40035	Stream	0.68	0.035	0.31	630	<100	$<6.3 \times 10^8$
3	NM 42823 40037	Stream	1.0	0.065	0.09	520	<100	$<5.2 \times 10^8$

The locations and estimated *E. coli* loadings are shown in Figure 13.1.

Figure 13.1 Map of river/stream loadings at Ulva: Loch Tuath

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+3.

Despite the heavy rainfall during the night preceding the survey, *E. coli* concentrations were below the limit of detection of the test used for the samples. The survey was undertaken in August when faecal contamination from animals would be expected to be high. This would indicate that the streams do not carry a high level of faecal contamination to the fishery. Areas of direct land run-off were also noted during the survey but, given the results from the streams, it would be expected that the level of contamination in such run-off would be generally low. Other minor watercourses are shown along the adjacent coastline on the Ordnance Survey map of the area but, unless there were localised significant sources of contamination, these would not be expected to affect the water quality within the inlet where the fishery is located.

14. Bathymetry and Hydrodynamics

The hydrographic chart of Loch Tuath is shown in Figure 14.1.

Loch Tuath is located between the islands of Mull (to the north and east) and Ulva and Geometra (to the south). The outer loch lies east-west with the mouth to the west. The inner loch lies south-east to north-west. The total length of the loch is approximately 10.5 km. The width varies from 3.4 km at the mouth to 1.8 km at the head. At the south-eastern end the inner loch joins to Loch na Keal via Ulva Sound. There is also a narrow, drying channel between Geometra and Ulva. Soriby Bay lies on the southern shore of the inner loch.

The loch does not contain any sills. The seabed in outer Loch Tuath shelves rapidly from shore and reaches depths of 20 – 40 m at the centre. The seabed in the inner loch shelves somewhat less steeply and reaches depths of approximately 20 m. Depths within Soriby Bay reach a maximum of approximately 17 m. On the chart a small, shallow area of only 8.2 m depth is marked at the mouth of the bay. A narrow drying area that consists mainly of rocky outcrops lies around much of the loch, including Soriby Bay. To the east of Soriby Bay, at the head of the loch and the channel to Ulva Sound, there is a shallow area with several islands and more extensive drying areas.

The fishery is located in an inlet on the south-east of Soriby Bay. There is a sandy drying area at the head of the inlet where the area of trestles is located. On the eastern side, at the site of an individual trestle, there is a drying area consisting of a mix of sand and rock.

14.1 Tidal Curve and Description

The two tidal curves shown in Figure 14.2 are for Ulva Sound, approximately 3 km from the production area. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 30/08/11 and the second is for seven days beginning 00.00 BST on 06/09/11. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

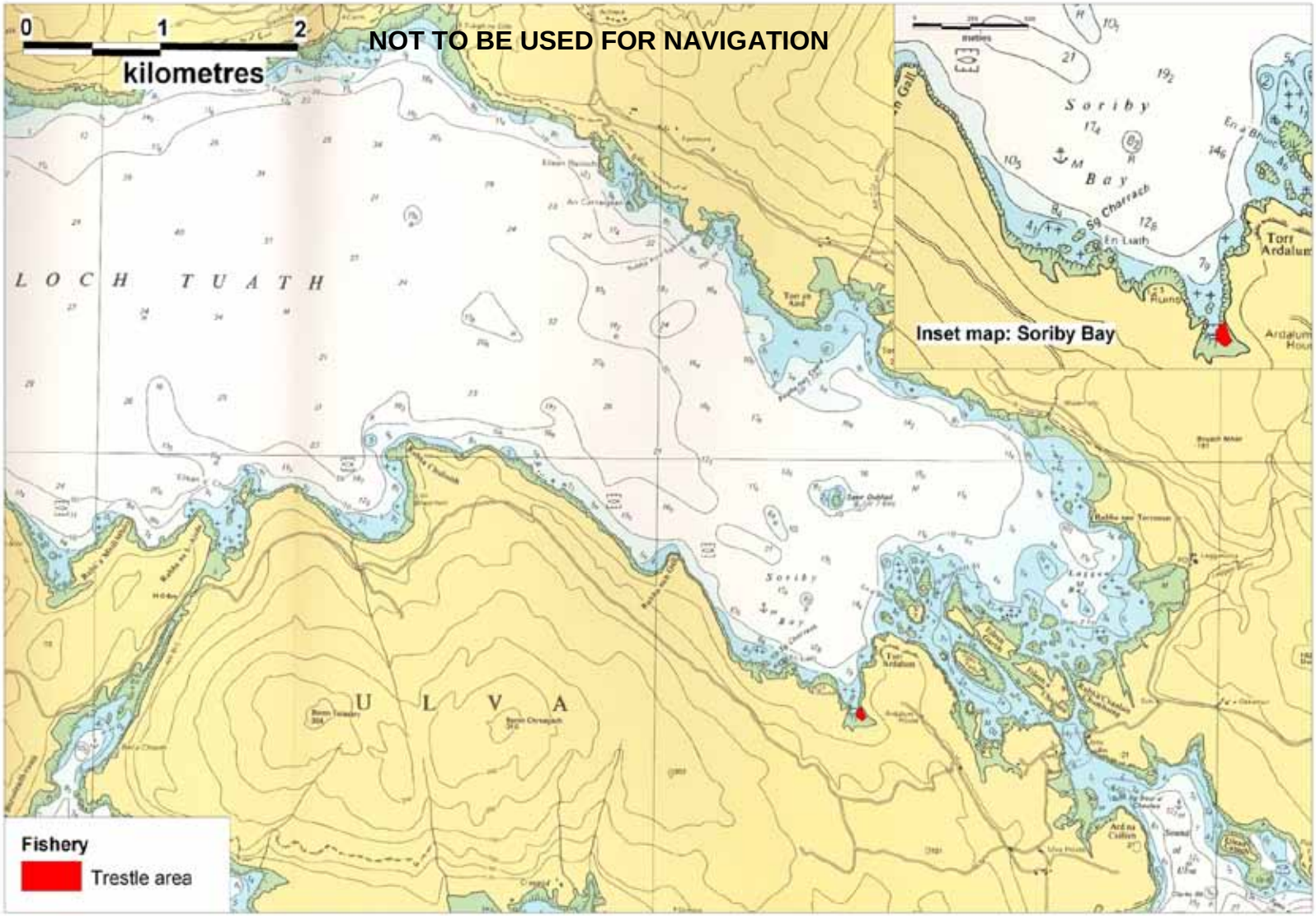


Figure 14.1 Bathymetry at Loch Tuath

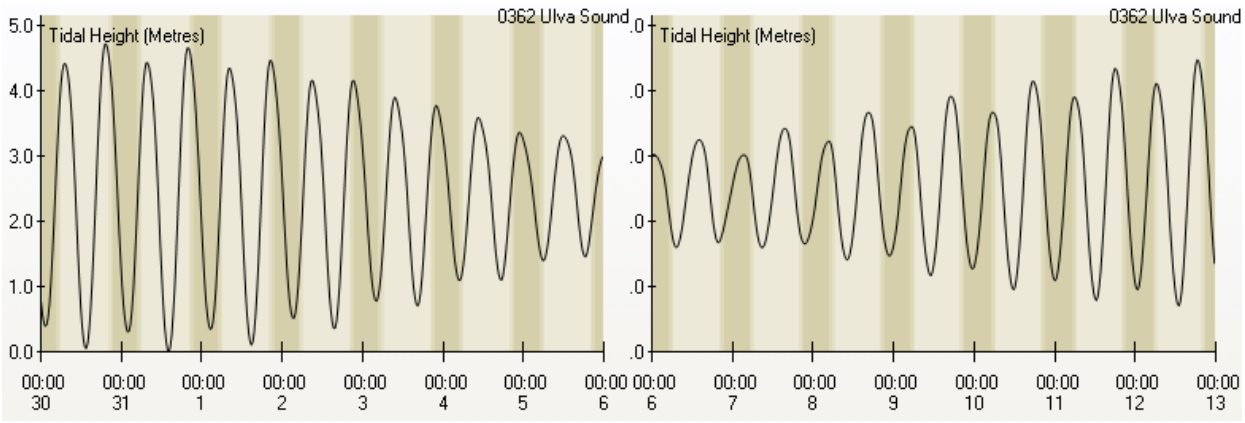


Figure 14.2 Tidal curves for Ulva Sound

The following is the summary description for Ulva Sound from TotalTide: 0362 Ulva Sound is a Secondary Non-Harmonic port. The tide type is Semi-Diurnal.

HAT	4.9 m
MHWS	4.4 m
MHWN	3.2 m
MLWN	1.8 m
MLWS	0.6 m
LAT	-0.1 m

Predicted heights are in metres above chart datum. The tidal range at spring tide is therefore 3.8 m and at neap tide it is 1.4 m, so the area is mesotidal (moderate tidal range).

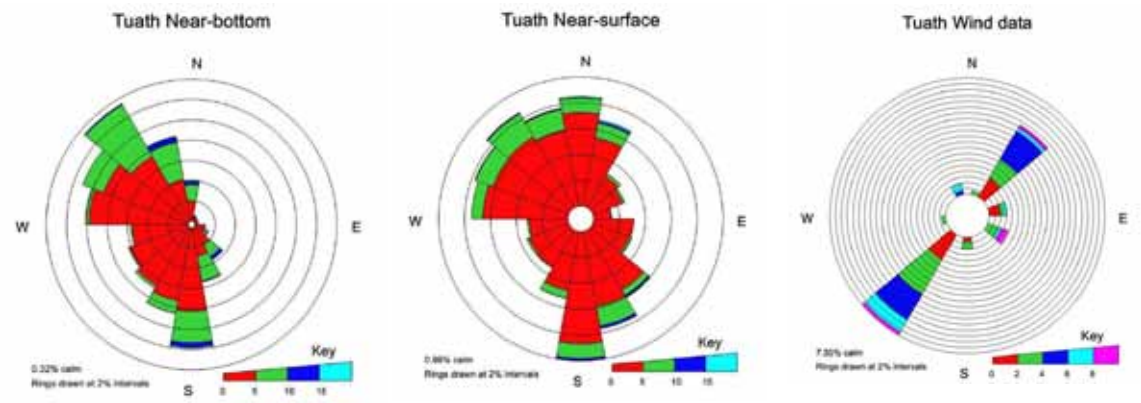
14.2 Currents

There is no tidal stream information for the immediate vicinity of Loch Tuath: the nearest tidal diamond is off the west cost of Mull. SEPA supplied data from a current meter study that had been undertaken in Loch Tuath for a site a short distance to the north-west of Soriby Bay. Summary information on the site is given in Table 14.1 and the position is shown on the map in Figure 14.3. Plots of the current directions and speeds, together with the wind direction and speeds over the relevant period, are shown in Figure 14.4. The wind direction appeared to have only been recorded to an accuracy of the cardinal and intermediate points of the compass.

Table 14.1 Survey period for the current meter study

Location	NGR	Survey period
Tuath	NM 4189 4135	08/12/2000 – 05/01/2001

Figure 14.3 Current meter location



Currents measured in cm/s. Wind measured in m/s. As per convention, currents are plotted against the direction towards which they are travelling while winds are plotted against the direction from which they are travelling. The length of each segment in a plot relates to the proportion of observations lying in that direction. The speed relates to the colour key beneath each plot. The proportion that each colour takes up in an individual segment relates to the proportion of observations in that direction having speed in that range. Directions are in degrees true.

Figure 14.4 Current and wind plots for the Ness of Copister current meter study

Flows at near-bottom approximately followed the coastline while those near the surface showed greater variability. Wind directions during the study were approximately north-easterly and south-westerly most of the time (with the latter predominating) and these winds may have been at least part of the reason for the greater variability in current flow near the surface. Table 14.2

shows the median and maximum current flows at the two depths. Current directions within Soriby Bay will tend to follow the coast but may form a gyre due to the curve of the bay. Within the inlet where the fishery is located, the predominant current direction will be north on the ebb tide and south on the flood tide.

Table 14.2 Median and maximum current speeds

Depth	Current speed (cm/s)	
	Median	Maximum
Near-bottom	3.3	19.4
Near-surface	2.3	19.7

At a maximum current speed of just under 20 cm/s, the distance that contaminants would be transported over an ebb or flood tide, ignoring any effects of dilution or dispersion, is approximately 3 km. In general, the distance would be expected to be significantly less than this. Current speeds over the drying area within the inlet where the fishery is located may be higher than those further out.

14.3 Conclusions

While the tides in Loch Tuath are moderate, currents are generally weak. Transport distances are expected to be small with the implication that the effect of local sources of pollution is likely to dominate. Within the inlet where the fishery is located, the impact from sources towards the head (south end) of the inlet will predominate on the ebb tide and those further out, and outside the inlet will predominate on the flood tide.

15. Shoreline Survey Overview

The shoreline survey was carried out on 30 August 2011. There was heavy rain the previous night and intermittent rain showers on the day of survey.

Pacific oysters were grown in poches on wire trestles. The sampling point is high up the east shore of the bay, where the active part of the fishery is located. At the time of survey, there was one poche present with insufficient oysters for sampling. However, a subsequent visit by the official control sampling officer on 27 September 2011 confirmed that 12 bags of oysters had been placed on the trestles.

A larger area of trestles was found in deeper water toward the head of the bay, south and west of the sampling trestle. The local authority reported that this block of trestles was no longer active. Many of the trestles were empty, and some bags were lying on the seabed. Some of the bags had very large, live oysters inside and a sample taken from one of these returned a result of 700 *E. coli* MPN/100g.

Pacific oysters from the farm are supplied to the restaurant on the island only. The restaurant is open from Easter to the end of October.

No dwellings were present around the shore of Soriby Bay. A restaurant is situated near the ferry landing on Ulva, though no discharge was directly observed. A septic tank was observed at Mull ferry landing, where there was an outbuilding with public toilets near the car park. There is no visitor accommodation on the island, though camping is permitted. Small boats were observed outside the bay, and there was a marine cage fish farm in the outer part of the bay.

Both the harvester and a wildlife ranger reported that livestock were no longer kept on the island. However, horse droppings were observed on the track when returning to the ferry. Land in the area is no longer used for grazing livestock. Native trees were being restored in an area east of the bay and a deer fence was in place to protect the new seedlings. Deer prints and droppings were observed along the east shore outside the deer fence. No geese, seabirds or wading birds were observed. The ranger reported that there were likely to be otters in the area.

Three watercourses were observed at the head of the bay and areas of direct runoff from land were seen along the east shore. Samples taken from the streams all returned results of <100 *E. coli* cfu/100 ml indicating little faecal contamination. A sample of wild mussels was taken from the eastern side of the bay, nearest the stream and this yielded a result of 130 *E. coli* MPN/100 g. A seawater sample taken near this location contained 7 *E. coli* cfu/100 ml, while one taken further north along the east shore of the bay contained no detectable *E. coli*.

Figure 15.1 shows a map of the most significant findings from the shoreline survey.

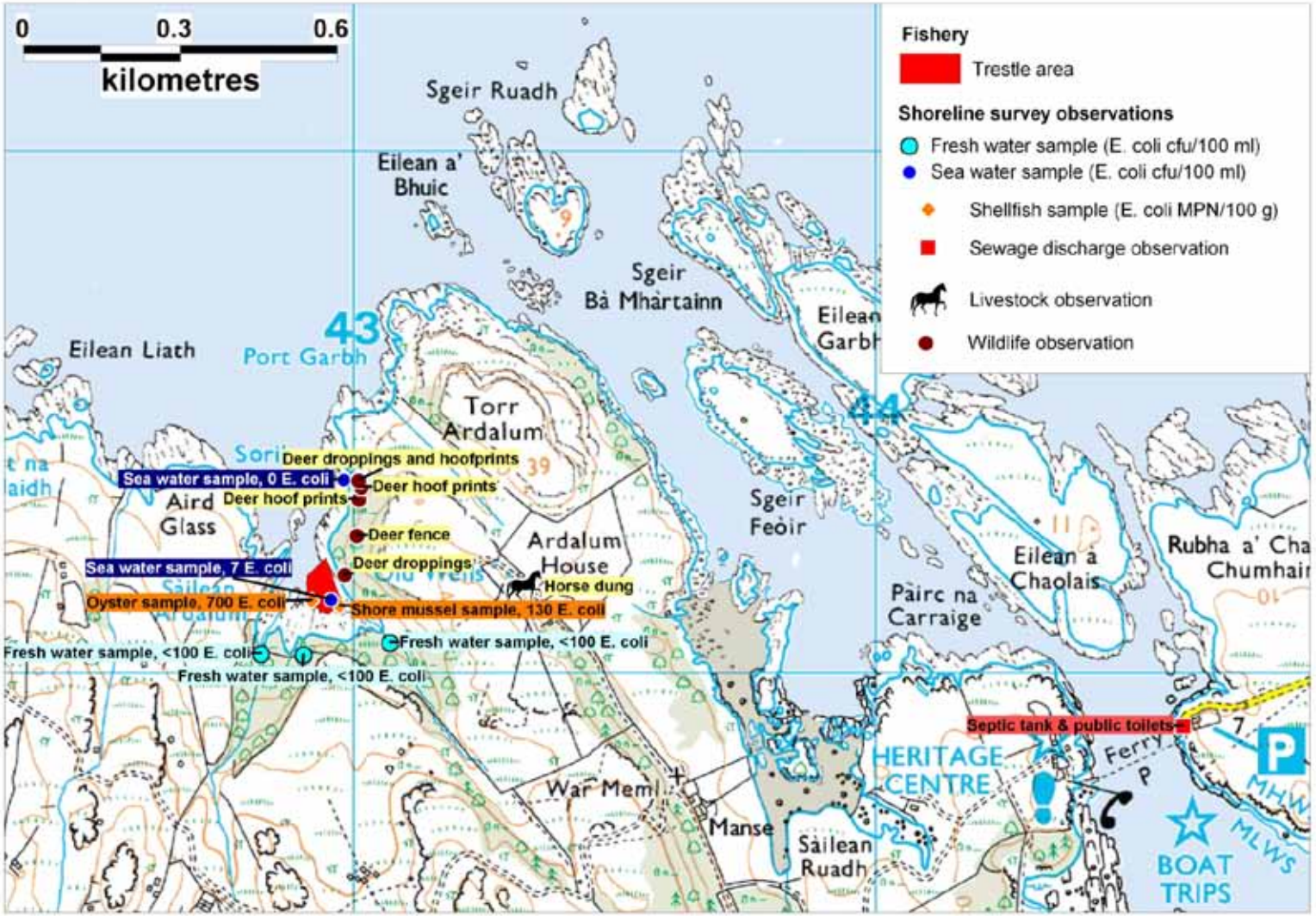


Figure 15.1 Summary of shoreline survey findings for Ulva: Loch Tuath

16. Overall Assessment

Human sewage impacts

No direct discharges of sewage to Soriby Bay were identified. There is no human habitation along the shores of the bay and the nearest occupied dwelling lies outwith the catchment area of the bay. The permanent population of the island is 16. Although there is no visitor accommodation on the island, wild camping is permitted. There is therefore the possibility of contamination from improper disposal of human waste from wild campers. However no evidence of this, and no campers, were observed during the survey.

Given the limited population living in proximity to the fishery, and the further lack of significant numbers of private discharges further afield, it is unlikely that the oyster fishery at Loch Tuath is significantly impacted by human sewage on a continuing basis. Intermittent impact from wild camping is possible and most likely during the peak holiday months of July to September.

Agricultural impacts

The island was previously used for grazing livestock, however the majority of livestock were reported to have been removed from the island. Horse droppings were observed along the road to the ferry. There is no arable farm land on the island. Subsequent to the shoreline survey, a flock of sheep was re-established on the island, though it is not known exactly where these animals are grazed. There is no arable agriculture on the island.

Overall, the fishery is unlikely to receive significant impacts from agricultural sources of faecal contamination on a continuing basis.

Wildlife impacts

No seabirds or geese were seen during the shoreline survey, and the ranger reported there were no significant populations of these birds in the area.

Evidence of deer was seen along the shore and a deer fence was in place just inland of the shoreline to keep deer away from newly replanted trees further to the east. Given the restriction in their movements, deer are likely to be kept toward the shoreline and leave droppings along this area. Therefore, these animals are the most likely source of faecal contamination to the fishery.

Seasonal variation

The island hosts visitors from roughly April to October, when the restaurant is open. Discharges from the restaurant and from the toilets at the ferry pier are likely to be in use during this period, and may get little or no use outside this period. Wild camping is permitted and most likely to occur during the peak holiday months of July to September.

The flock of sheep moved onto the island in late 2011 are likely to have lambs in spring 2012. This would roughly double the sheep population, and therefore increase any impacts from this source during the summer months and until lambs are sold off.

No statistically significant difference was seen in historical sampling results by season. In 2009 there was a general increase in results in summer/autumn and in 2010 there was a general increase around winter time. Four of the five sample results exceeding 230 *E. coli* MPN/100 g occurred in 2010 and 2011. The lowest results were seen in March.

Otherwise, there is no marked trend across the months. However, four of the five samples yielding results exceeding 230 *E. coli* MPN/100 g were taken between July and September. Fewer samples were taken in winter with only one sample having been taken in December.

Rivers and streams

The three streams seen at the head of Soriby Bay were measured and sampled. Despite the heavy rainfall during the night preceding the survey, *E. coli* concentrations were below the limit of detection of the test used for the samples. The survey was undertaken in August when faecal contamination from animals would be expected to be high. This would indicate that the streams do not carry a high level of faecal contamination to the fishery.

Areas of direct land run-off were also noted during the survey but, given the results from the streams, it would be expected that the level of contamination in such run-off would be generally low. Other minor watercourses are shown along the adjacent coastline on the Ordnance Survey map of the area but, unless there were localised significant sources of contamination, these would not be expected to affect the water quality within the inlet where the fishery is located.

Movement of contaminants

While the tides in Loch Tuath are moderate, currents are generally weak. Transport distances are expected to be small with the implication that the effect of local sources of pollution is expected to dominate. Within the inlet where the fishery is located, the impact from sources towards the head (south end) of the inlet will predominate on the ebb tide and those further out, and outside the inlet will predominate on the flood tide.

Temporal and geographical patterns of sampling results

The large majority of samples taken since 2007 were recorded within a rectangular area measuring approximately 21m by 8m. Due to the close proximity of the reported sampling locations, a formal spatial analysis was not undertaken. However, all of the 5 samples that gave results >230 *E. coli* MPN/100 g had recorded sampling locations that lay on the northern half of that area. Samples taken nearer the head of the bay, and consequently

closer to the potential watercourse sources of contamination, during the shoreline survey showed markedly different results, with a result of 700 *E. coli* MPN/100 g in Pacific oysters and 130 *E. coli* MPN/100g in shore mussels. A seawater sample taken in the vicinity was found to contain 7 *E. coli* cfu/100 ml, which indicates relatively light contamination with faecal material. The Pacific oyster sample was of large, old animals left in the abandoned part of the fishery, and it is not clear what effect age would have on their uptake and retention of faecal contaminants.

The general level of contamination of the oysters is low with intermittent results greater than 230 *E. coli* MPN/100 g. The underlying level of contamination appears to be stable across the period of this assessment but, in 2009 there was a general increase in results in summer/autumn and in 2010 there was a general increase around winter time.

Conclusions

The fishery at Soriby Bay is generally lightly impacted by sources of faecal contamination. Potential sources include wildlife, a limited number of livestock, anchored or passing yachts and occasional wild campers. Historical monitoring results have suggested generally low levels of faecal contamination, though there have been four results exceeding 230 *E. coli* MPN/100 g in 2010 and 2011. Samples taken during the shoreline survey suggested relatively high levels of contamination in the oyster sample, though water samples were relatively clean and did not suggest a likely source of the contamination.

Although no statistically significant variation in results was found, there did appear to vary by month with the lowest results in March and highest peak results tending to occur July-September.

The active fishery only pertains to a very small area along the eastern shore of the bay, and within that area higher results tended to occur among the more northerly observations.

17. Recommendations

Production area

There are no point sources of faecal contamination to the production area. The existing fishery lies within 80 m of the head of the bay and the diffuse contamination sources there. Therefore, it is recommended that the southern boundary of the fishery be drawn to exclude the mouths of the streams where they discharge to the bay. The recommended boundaries are the area described by lines drawn between NM 4249 4047 to NM 4308 4071 and between NM 4281 4010 to NM 4305 4011 and extending to MHWS.

RMP

As the existing RMP is located on the trestle currently in use, and there are only two trestles in use, it is recommended that the RMP be set on the northernmost of these at NM 4295 4022.

Tolerance

A 10 metre tolerance is recommended as it is possible to collect the sample from a fixed location on the trestle.

Depth of sampling

Not applicable

Frequency

The stability assessment did not indicate that the area was suitable for a reduced sampling frequency. However, it is noted that the fishery only serves the local restaurant, which is only open from Easter to the end of October. Fewer samples have been taken in winter anyway due to access and timing issues. Consideration could therefore be given to sampling, and classifying, the production area for part of the year. The EURL Good Practice Guide recommends that for seasonal classification of Class A areas, sampling be initiated one month prior to the harvesting season. As Easter may fall in March or April, it is therefore recommended that monitoring commence in February to ensure that it occurs one month prior to harvesting, and that samples then be taken monthly up to and including October. This would allow for a closed season of November to February and the classified period would run from March to October inclusive.

Figure 17.1 Map of recommendations at Soriby Bay

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19. List of Figures and Tables

Appendices

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Geology and Soils Assessment Method

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

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

Brown forest soils are characteristically well drained with their occurrence being restricted to warmer drier climates, and under natural conditions they often form beneath broadleaf woodland. With a very low surface % runoff of between 2 – 29.2%, brown forest soils can be categorised as freely draining (Macaulay Institute, 2007).

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

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

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

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

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

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website

and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and it's potential impact on runoff.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

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

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

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

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

General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

One of the *Salmonella* species isolated from the elephant seals, *Salmonella typhimurium*, is carried by a number of animal species and has been isolated from cattle, pigs, sheep, poultry, ducks, geese and game birds in England and Wales. Serovar DT104, also associated with a wide variety of animal species, can cause severe disease in humans and is multi-drug resistant (Poppe et al 1998).

Cetaceans

As mammals, whales and dolphins would be expected to have resident populations of *E. coli* and other faecal indicator bacteria in the gut. Little is known about the concentration of indicator bacteria in whale or dolphin

faeces, in large part because the animals are widely dispersed and sample collection difficult.

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

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 and DeLuca, 1999). An earlier study found that geese averaged from 5.23 to 18.79 defecations per hour while feeding, though it did not specify how many hours per day they typically feed (Bedard and Gauthier, 1986).

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

Deer

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

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

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

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

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 Natural Heritage website). Otters primarily forage within the 10 m depth contour and feed on a variety of fish, crustaceans and shellfish (Paul Harvey, Shetland Sea Mammal Group, personal communication).

Otters leave faeces (also known as spraint) along the shoreline or along streams, which may be washed into the water during periods of rain.

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Tables of Typical Faecal Bacteria Concentrations

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

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

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

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

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

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

Statistical Data

One-way ANOVA: Log_EC versus Season

```
Source  DF      SS     MS     F      P
Season   3   0.934  0.311  0.81  0.493
Error   46  17.631  0.383
Total   49  18.566

S = 0.6191   R-Sq = 5.03%   R-Sq(adj) = 0.00%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  --------+---------+---------+---------+-
1      14  1.3296  0.4785   (----------*----------)
2      15  1.6246  0.7340             (----------*----------)
3      12  1.6192  0.6060            (-----------*-----------)
4       9  1.3820  0.6198  (-------------*-------------)
                          --------+---------+---------+---------+-
                                1.20      1.50      1.80      2.10

Pooled StDev = 0.6191


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

Individual confidence level = 98.94%


Season = 1 subtracted from:

Season    Lower  Center   Upper  ---------+---------+---------+---------+
2       -0.3184  0.2949  0.9082              (-----------*-----------)
3       -0.3597  0.2896  0.9388             (------------*------------)
4       -0.6527  0.0524  0.7575       (-------------*-------------)
                                 ---------+---------+---------+---------+
                                       -0.50      0.00      0.50      1.00


Season = 2 subtracted from:

Season    Lower   Center   Upper  ---------+---------+---------+---------+
3       -0.6446  -0.0054  0.6338       (------------*------------)
4       -0.9384  -0.2425  0.4533  (-------------*-------------)
                                 ---------+---------+---------+---------+
                                       -0.50      0.00      0.50      1.00


Season = 3 subtracted from:

Season    Lower   Center   Upper  ---------+---------+---------+---------+
4       -0.9649  -0.2371  0.4906  (-------------*-------------)
                                 ---------+---------+---------+---------+
                                       -0.50      0.00      0.50      1.00
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Hydrographic Methods

The new EU regulations require an appreciation of the hydrography and currents within a region classified for shellfish production with the aim to "determine the characteristics of the circulation of pollution, appreciating current patterns, bathymetry and the tidal cycle." This document outlines the methodology used by Cefas to fulfil the requirements of the sanitary survey procedure with regard to hydrographic evaluation of shellfish production areas. It is written as far as possible to be understandable by someone who is not an expert in oceanography or computer modelling. A glossary at the end of the document defines commonly used hydrographic terms e.g. tidal excursion, residual flow, spring-neap cycle etc.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only. Selected sites will be assessed in more detail using either: 1) a hydrodynamic model, or 2) an extended consideration of sources, available field studies and expert assessment. This document will consider the more basic hydrographic processes and describes the common methodology applied to all sites.

Background processes

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

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

Wind and density driven current also lead to persistent movement of water and are particular important in regions of relatively low tidal velocities characteristic of many of the water bodies in Scottish waters. Whilst tidal flows generally move material in more or less the same direction at all depths, wind and density driven flows often move material in different directions at the surface and at the bed. Typical vertical profiles are depicted in Figure 1. However, it should be understood that in a given water body, movement will often be the sum of all three processes.

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

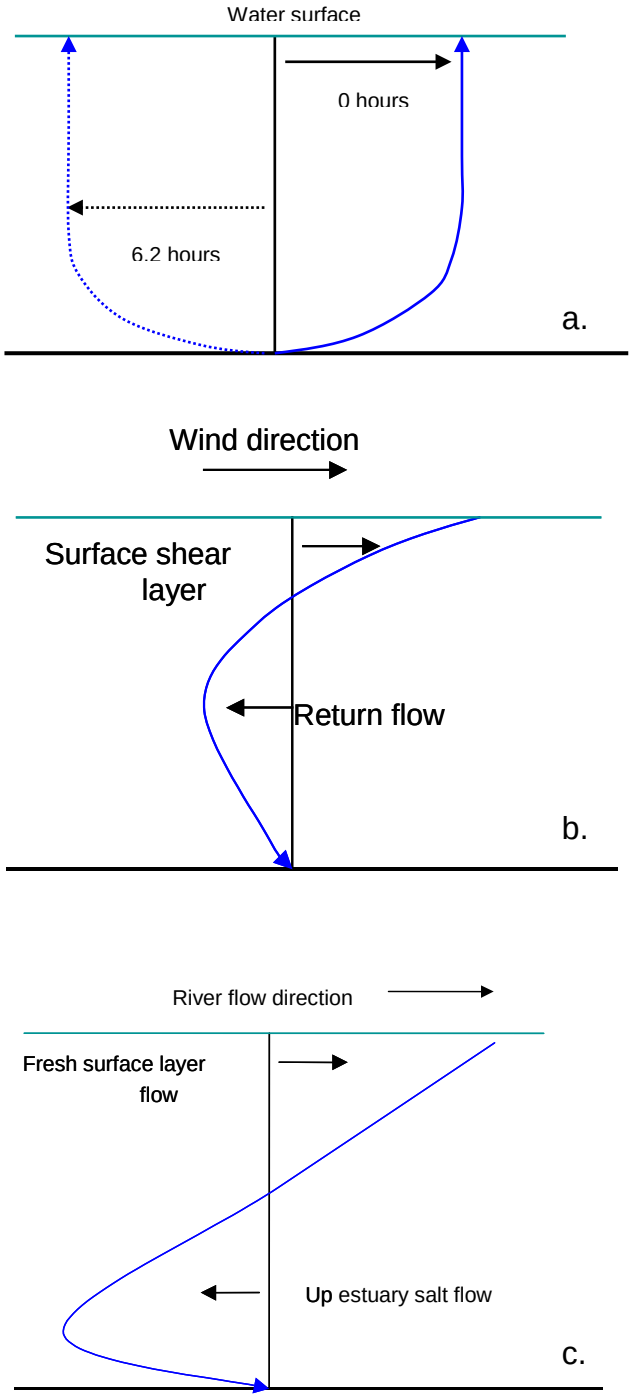

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

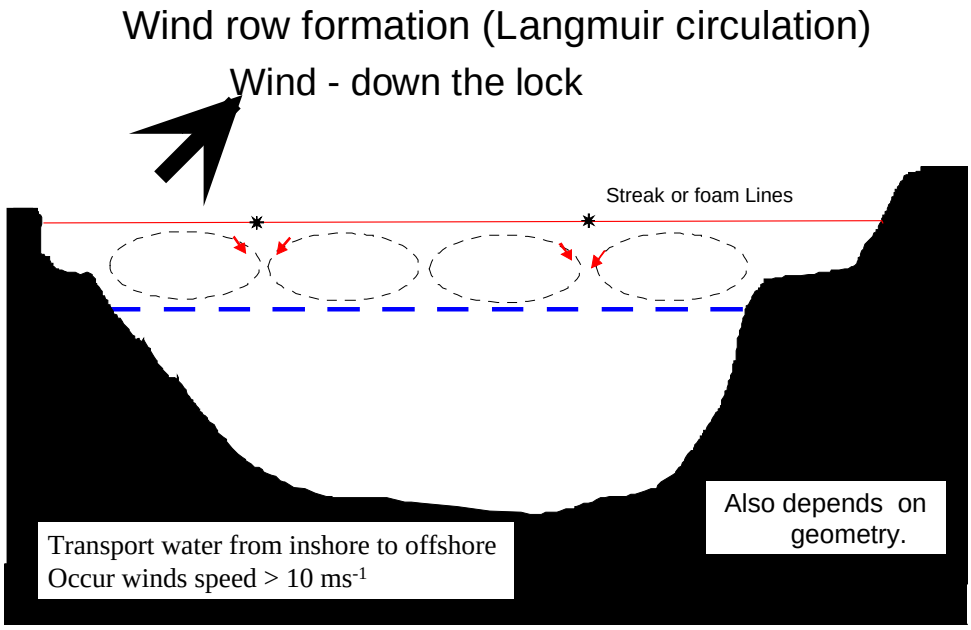

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

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

1. Near-shore flows will generally align parallel to the shore.
2. Tidal flows are bi-directional, thus sources on either side of a production area are potentially polluting.
3. For tidal flows, the tidal excursion gives an idea of the likely main 'region of influence' around an identified pollutant source.
4. Wind driven flows can drive material from any direction depending on the wind direction. Wind driven current speeds are usually at a maximum when the wind direction is aligned with the principle axis of the loch.
5. Density driven flows generally have a preferred direction.
6. Material will be drawn out in the direction of current, often forming long thin 'plumes'.

Many Scottish shellfish production areas occur within sea lochs. These are fjord-like water bodies consisting of one or more basins, deepened by glacial activity and having relatively shallow sills that control the mixing and flushing processes. The sills are often regions of relatively high currents, while the basins are much more tranquil often containing higher density water trapped below a fresh lower density surface layer. Tidal mixing primarily occurs at the sills.

The catalogue of Scottish Sea Loch produced by the SMBA is used to quantify sills, volume fluxes and likely flow velocities. Because the flow is so constrained by the rapidly varying bathymetry, care has to be used in the extrapolation of direct measurements of current flow. Mean flow velocities can be estimated at the sills by using estimates of the sill area and the volume change through a tidal cycle. This in turn can be used to estimate the maximum distance travelled in a tidal cycle in the sill area. Away from the sill area, tidal velocities are general low and transport events are dominated by wind or density effects. Sea Lochs

generally have a surface layer of fresher water; the extent of this depends on freshwater input, sill depth and quantity of mixing.

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

Bathymetry. The underwater topography given as depths relative to some fixed reference level e.g. mean sea level.

Hydrography. Study of the movement of water in navigable waters e.g. along coasts, rivers, lochs, estuaries.

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

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

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

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

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

Spring/Neap Tides. The strongest tides in a month are called spring tides and the weakest are called neap tides. Spring tides occur every 14 days with neaps tides occurring 7 days after springs. Both tidal range and tidal currents are strongest at Spring tides.

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

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

Return flow. Often a surface flow at the surface is accompanied by a compensating flow in the opposite direction at the bed (see figure 1).

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

Shoreline Survey Report

Prod. area:	Ulva: Loch Tuath
Site name:	Soriby Bay (AB 285 081 13)
Species:	Pacific oyster
Harvester:	James Howard
Local Authority:	Argyll & Bute
Status:	Existing
Date Surveyed:	30 August 2011
Surveyed by:	Michelle Price-Hayward, Allison Hardie
Nominal RMP:	NM 429 404
Area Surveyed:	East shore and head of Soriby Bay, Loch Tuath

Weather observations
Overcast, intermittent rain showers with heavy rain previous night. Temp 16C, Winds NW F2-3.

Site Observations

Fishery
Pacific oysters are grown in mesh bags on metal trestles. Only one bag was in place on the trestle normally used for sampling, which the local authority reported is the only currently active part of the fishery. There were insufficient oysters in this bag at the time of survey to provide a sample.

A larger area of trestles was found in deeper water toward the head of the bay, south and west of the sampling trestle. The local authority reported that this block of trestles was no longer active. Many of the trestles were empty, and some bags were lying on the seabed. Some of the bags had a mixture of empty oyster shells and wild mussels inside. However, some bags had very large, live oysters inside and a sample was taken from one of these.

A significant number of native oysters were present on the seabed, and some had attached to the exterior of trestles or oyster bags.

A sample of wild mussels was taken from the eastern side of the main bock of trestles, nearest the stream.

Pacific oysters from the farm are supplied to the restaurant on the island only. The restaurant is open from Easter to the end of October.

Sewage/Faecal Sources
No dwellings were present around the shore of Soriby Bay. The nearest occupied dwelling was Ardalum House, along a track away from the bay. A restaurant is situated near the ferry landing on Ulva, though no discharge was directly observed. The nearest observed septic tank was at Mull ferry landing, where there was an outbuilding with public toilets near the car park.

Farming and livestock
Both the harvester and a wildlife ranger reported that livestock were no longer kept on the island. No livestock tracks or droppings were observed along the shoreline and no

livestock animals were seen on either shore. However, horse droppings were observed on the track when returning to the ferry. The land along the west side of the bay is rough grassland, and along the east side and head of the bay is deciduous woodland.

Seasonal Population
There are no hotels or accommodation for visitors on the island, though there are walking trails, a church, a restaurant and visitor's centre and camping is permitted on the island. On the day of survey, a carpark at the Mull end of the ferry had 12 cars and further vehicles were parked along the verge of the road. Picnic benches outside the restaurant at the Ulva side of the ferry were occupied by restaurant diners.

Boats/Shipping
There was a marine cage fish farm located in the outer part of the bay, with empty cages moored just inside the production area boundary. An automated feeding barge was in place at the farm. A number of small boats were moored in bays and inlets around the ferry pier, however these were mostly open boats and some distance from the fishery.

Land Use
Land in the area is no longer used for grazing livestock and has no human occupation. Native trees were being restored in an area east of the bay. A deer fence was in place to protect the inland areas which had been planted with new seedlings.

Watercourses
The only watercourses observed flowing were at the head of the bay. Smaller areas of land runoff were observed along the east shore. Three streams were measured and sampled.

Wildlife/Birds
Deer droppings and hoofprints were observed along the east shore, on the shore side of the deer fence. The fence was presumably installed to protect an area recently planted with tree seedings further inshore along the east side of the bay.

No geese, wading birds or seabirds were observed. The ranger reported that there were not known to be any large populations of any of these birds present on the bay, although there were likely to be otters in the area.

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

Figure 1. Map of Shoreline Observations

Table 1. Shoreline Observations

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
1	30/08/2011	10:10:38	NM 43182 40281	143182	740281		New tree seedlings planted along both sides of path
2	30/08/2011	10:36:41	NM 42970 40260	142970	740260	Figure 3	Photo toward west side of bay. Cage fish farm visible in outer bay
3	30/08/2011	10:39:06	NM 42988 40248	142988	740248		Area of land drainage, wet but not flowing
4	30/08/2011	10:40:17	NM 43007 40263	143007	740263		Deer fence
5	30/08/2011	10:43:07	NM 43011 40333	143011	740333		Hoof prints
6	30/08/2011	10:44:18	NM 43015 40356	143015	740356		Deer hoof prints
7	30/08/2011	10:45:16	NM 43008 40368	143008	740368		Area of land drainage, wet but not flowing
8	30/08/2011	11:00:28	NM 42982 40370	142982	740370		Seawater sample UVW1
9	30/08/2011	11:02:09	NM 43010 40369	143010	740369		Deer droppings and hoofprints
10	30/08/2011	11:10:46	NM 42984 40188	142984	740188		Deer droppings
11	30/08/2011	11:14:59	NM 42981 40137	142981	740137		Disused area of trestles, shore mussels here
12	30/08/2011	11:20:20	NM 42948 40220	142948	740220	Figure 4	RMP - 2 racks with only one bag of trestles, not enough to sample
13	30/08/2011	11:32:43	NM 43063 40086	143063	740086		Land drainage. Jellyfish washed ashore in area
14	30/08/2011	11:36:21	NM 42974 40129	142974	740129	Figure 5	Shore mussel sample
15	30/08/2011	11:43:08	NM 42958 40141	142958	740141		Seawater sample UVW2
16	30/08/2011	11:54:53	NM 43010 40137	143010	740137	Figure 6	Sorting shed with empty bags. Dog and wildlife ranger
17	30/08/2011	12:07:48	NM 43070 40058	143070	740058	Figure 7	Stream 11.5 cm x 4 cm, flow 0.408 m/s, SD 0.007. Freshwater sample UVW3
18	30/08/2011	12:18:20	NM 42905 40035	142905	740035		Stream, 68 cm x 3.5 cm, flow 0.305 m/s, SD 0.012. Freshwater sample UVW4
19	30/08/2011	12:26:57	NM 42876 40028	142876	740028	Figure 8	Land drainage, seeping. View overlooking trestles from head of bay
20	30/08/2011	12:29:49	NM 42823 40037	142823	740037		Stream, 100 cm x 6.5 cm, flow 0.093, SD 0.010. Freshwater sample UVW5
21	30/08/2011	12:47:55	NM 42939 40114	142939	740114		1 rack with oysters and mussels in bags, some empty shells
22	30/08/2011	12:49:35	NM 42948 40115	142948	740115		Corner of larger area of trestles, few bags, some mussels and native oysters around
23	30/08/2011	12:58:47	NM 42909 40140	142909	740140		Corner of trestle area, native oysters growing on rack
24	30/08/2011	13:00:41	NM 42920 40139	142920	740139		Oyster sample
25	30/08/2011	13:56:16	NM 43062 40355	143062	740355	Figure 10	View across bay - no apparent access, buildings or livestock
26	30/08/2011	14:06:22	NM 43326 40165	143326	740165		Abandoned farm house, inhabited house a little further along track, horse droppings
27	30/08/2011	14:41:59	NM 44590 39898	144590	739898	Figure 11	Septic tank and public toilets near ferry car park
Trestle areas only (not individually plotted on map)							
-	30/08/2011	11:15:13	NM 42978 40130	142978	740130		Trestle area boundary
-	30/08/2011	11:15:22	NM 42975 40128	142975	740128		Trestle area boundary
-	30/08/2011	11:15:37	NM 42971 40134	142971	740134		Trestle area boundary
-	30/08/2011	11:16:09	NM 42963 40142	142963	740142		Trestle area boundary
-	30/08/2011	11:16:42	NM 42973 40147	142973	740147		Trestle area boundary
-	30/08/2011	12:50:02	NM 42951 40112	142951	740112		Trestle area boundary

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
-	30/08/2011	12:50:13	NM 42953 40115	142953	740115		Trestle area boundary
-	30/08/2011	12:50:22	NM 42953 40119	142953	740119		Trestle area boundary
-	30/08/2011	12:50:29	NM 42950 40121	142950	740121		Trestle area boundary
-	30/08/2011	12:50:38	NM 42947 40119	142947	740119		Trestle area boundary
-	30/08/2011	12:52:28	NM 42949 40136	142949	740136		Trestle area boundary
-	30/08/2011	12:52:40	NM 42950 40145	142950	740145		Trestle area boundary
-	30/08/2011	12:53:28	NM 42944 40156	142944	740156		Trestle area boundary
-	30/08/2011	12:53:47	NM 42938 40162	142938	740162		Trestle area boundary
-	30/08/2011	12:54:14	NM 42937 40180	142937	740180		Trestle area boundary
-	30/08/2011	12:54:45	NM 42931 40191	142931	740191		Trestle area boundary
-	30/08/2011	12:55:16	NM 42918 40191	142918	740191		Trestle area boundary
-	30/08/2011	12:57:05	NM 42911 40185	142911	740185		Trestle area boundary
-	30/08/2011	12:57:28	NM 42910 40169	142910	740169		Trestle area boundary
-	30/08/2011	12:57:56	NM 42911 40170	142911	740170		Trestle area boundary
-	30/08/2011	12:58:22	NM 42911 40157	142911	740157		Trestle area boundary
-	30/08/2011	13:10:54	NM 42929 40137	142929	740137		Trestle area boundary
-	30/08/2011	13:11:07	NM 42933 40145	142933	740145		Trestle area boundary
-	30/08/2011	13:11:13	NM 42937 40145	142937	740145		Trestle area boundary
-	30/08/2011	13:11:23	NM 42939 40138	142939	740138		Trestle area boundary

Photographs referenced in the table can be found attached as Figures 3-13.

Sampling

Water and shellfish samples were collected at sites marked on the map. Where indicated in Table 1, salinity was recorded in the field using a refractometer. Samples were transferred to a Coleman coolbox with ice packs and shipped to Glasgow Scientific Services on 30 August via courier for *E. coli* analysis. Samples were received by the laboratory on 31 August. The sample temperature on arrival was 6.6ºC, which was within the recommended temperature range of 2-8ºC. These results have been included in Tables 2 and 3.

Seawater samples were tested for salinity by the laboratory and results reported in mg Cloride per litre. These results have been converted to parts per thousand (ppt), and are shown in Table 2.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	30/08/11	UVW1	NM 4298 4037	Seawater	0	35.6
2	30/08/11	UVW2	NM 4296 4014	Seawater	7	30.5
3	30/08/11	UVW3	NM 4307 4006	Freshwater	<100	
4	30/08/11	UVW4	NM 4291 4004	Freshwater	<100	
5	30/08/11	UVW5	NM 4282 4004	Freshwater	<100	

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (MPN/100g)
1	30/08/11	Ulva Mussel	NM 4297 4013	Mussel	130
2	30/08/11	Ulva Oyster	NM 4292 4014	Pacific oyster	700

Results are displayed geographically in Figure 2 on the following page.

Figure 2. Sample results map

Photographs

Figure 3. Photo toward west side of bay

Figure 4. Trestles at RMP with bag of oysters

Figure 5. Location of shore mussel sample

Figure 6. Sorting shed

Figure 7. Stream at eastern end of bay

Figure 8. View across trestle area from head of bay

Figure 9. View along western shore from head of bay

Figure 11. View across bay to fish farm

Figure 12. Septic tank from toilets at ferry