Scottish Sanitary Survey Project

Sanitary Survey Report
Fairlie
NA 065
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Cefas

Food Standards Agency
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Buidheann Inbhe-Bìdhe

Report Distribution – Fairlie

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

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1. General Description

Fairlie is a small village on the North Ayrshire coast within the outer reaches of the Firth of Clyde, and approximately 40 km southwest of Glasgow. To the west of Fairlie, across Fairlie Roads, is Great Cumbrae Island. Hunterston, which is an area of heavy industry including a nuclear power station, lies to the southwest of Southannan Sands. The sanitary survey was initiated based on the high ranking obtained by the Fairlie production area on a risk matrix. Its placement near the top of the rankings was based on scores received for a high population in the immediate area, the species involved, and recent changes in classification.

Figure 1.1 Location of Fairlie study area

2. Fishery

The fishery at Fairlie is comprised of a single site classified for the production of Pacific oysters, as identified in Table 2.1.

Table 2.1 Fairlie shellfish farms

Production Area	Site	SIN	Species	RMP
Fairlie	Southannan Sands	NA 065 332	Pacific oysters	NS 1980 5420

The production area at Fairlie is defined as an area bounded by lines drawn between NS 2083 5500 and NS 1974 5442 and between NS 2063 5465 and NS 2040 5438, and coincides with a designated Shellfish Growing Water of the same name (see Section 12). The site is currently classified class A from April 2010 to March 2011.

Juvenile Pacific oysters are purchased from a hatchery and grown on in bags on trestles. The trestles are located on intertidal sands adjacent to the ore terminal pier at the southwestern corner of Fairlie Sands and not on Southannan Sands, as the name suggests. The production cycle from purchase of juvenile stock to harvest takes approximately 3 years. Harvest may occur at any time of year, dependent upon demand and availability. Part of the site is located below Mean High Water Springs and access for harvesting and sampling is restricted to low tide.

The boundaries of the existing trestle layout were recorded during the shoreline survey in August 2010 and are represented in Figure 2.1. At the time, the harvester identified that the farm was being renovated and that the exact trestle layout was likely to differ somewhat from that recorded.

The nominal RMP is located above MHWS, approximately 90 m west of the recorded trestle area and 13 m outside the production area boundaries. Actual sample locations are recorded by the sampling officer, and these are represented in Section 11.

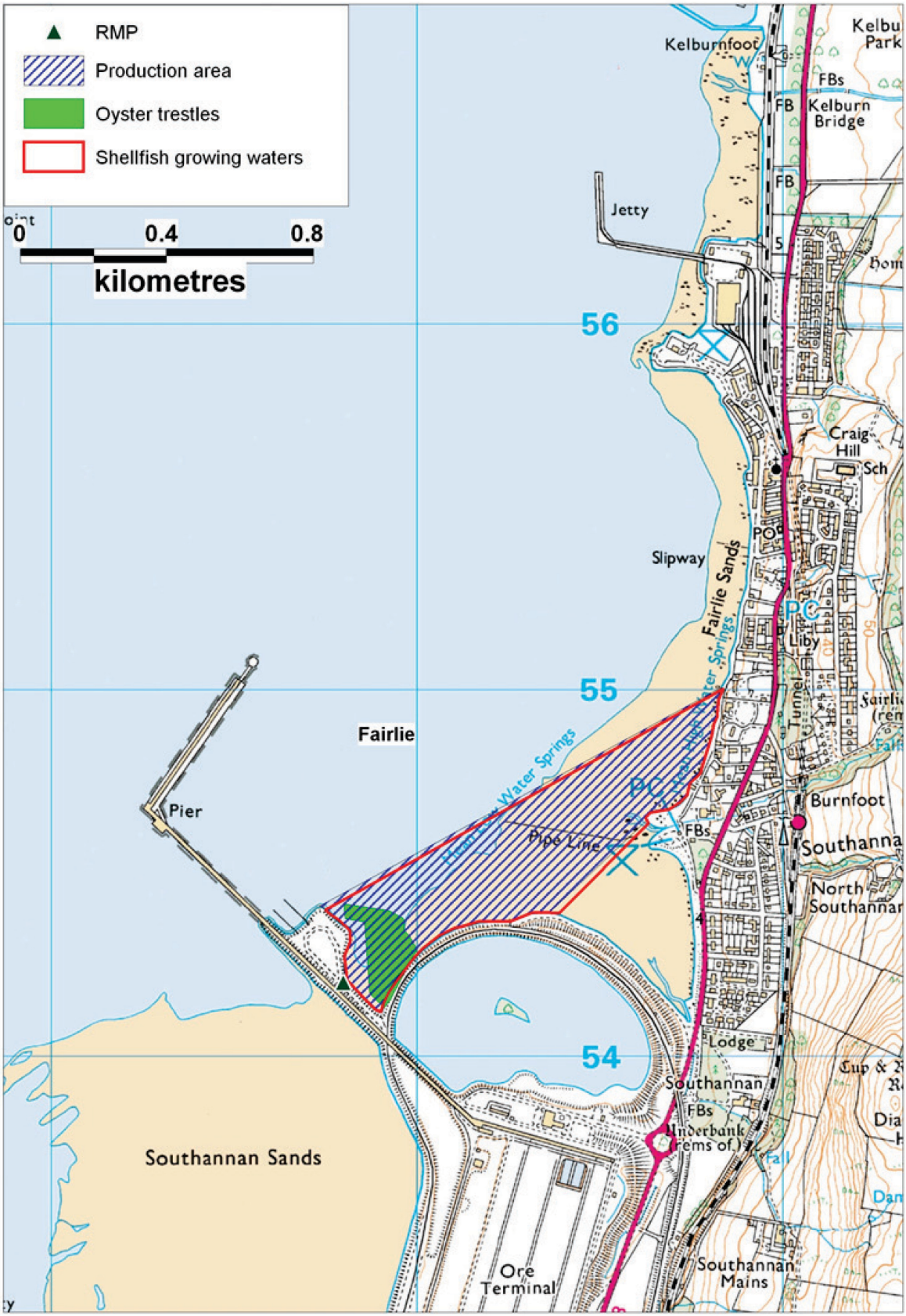

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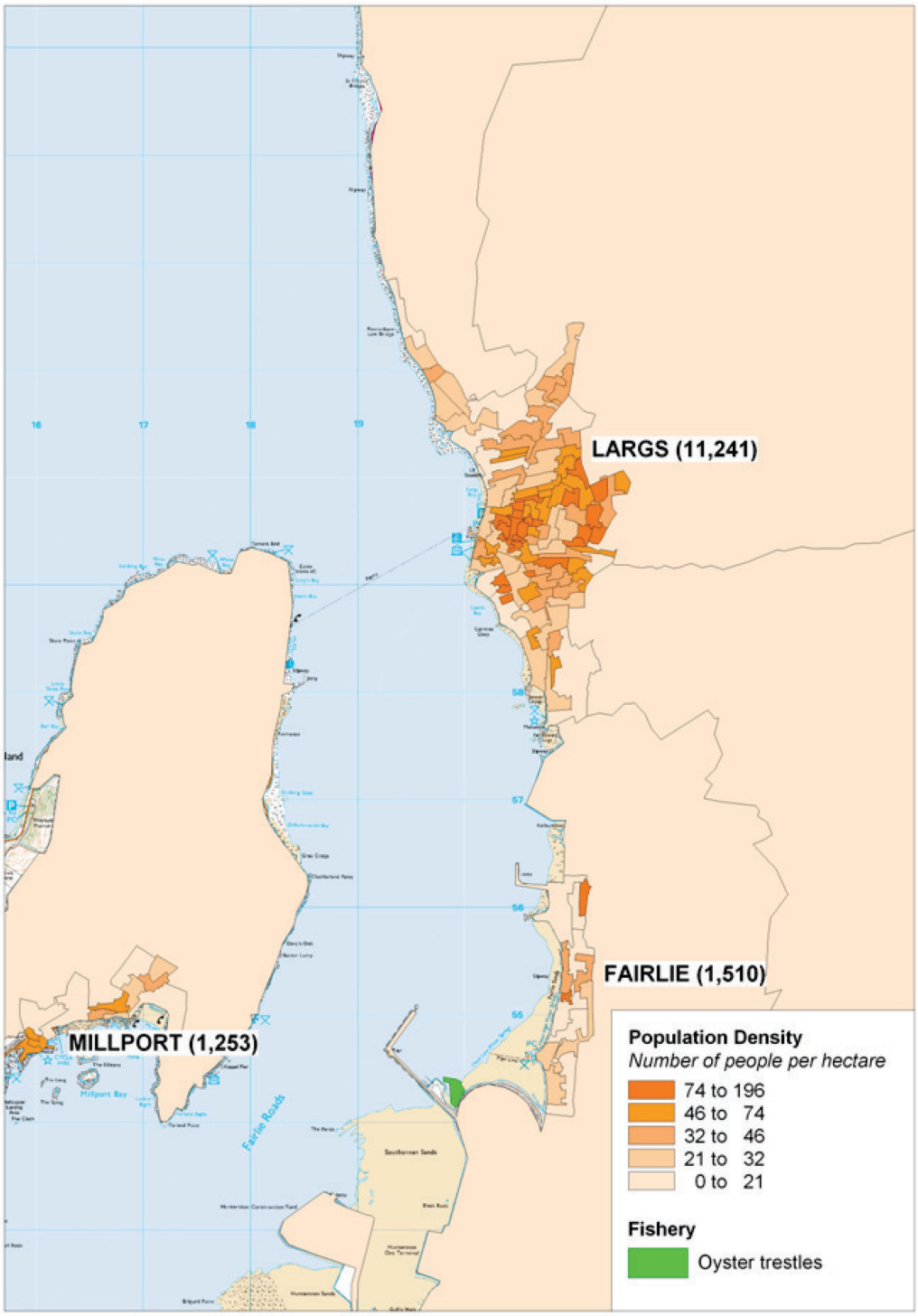
Figure 2.1 Fairlie oyster fishery

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of the Fairlie production area. The data pertain to the last census undertaken in 2001.



2001 Population Census Data, General Register Office, Scotland.

Figure 3.1 Population map for Fairlie

Figure 3.1 shows the population density for the census output areas surrounding the Fairlie production area. There are three main population centres in near the fishery. The village of Fairlie lies directly adjacent to the production area and has a population of 1510. Largs is located approximately 5 km north of the oyster farm and has a population of 11241. Millport, population 1253, is on the south coast Great Cumbrae Island approximately 3.5 km from the oyster farm.

A ferry operates between Largs and Great Cumbrae Island all year, with more frequent sailings during the peak summer holiday season from the end of May to the end of August. The area is popular with tourists and day visitors due to its proximity to Glasgow. There is a large marina south of Largs (Largs Yacht Haven) which operates year-round and has berthing for over 700 yachts, and there are further moorings to the north of the fishery off Fairlie and at Millport, on the southern end of Great Cumbrae Island. Therefore, yacht traffic is likely to be busy particularly during summer.

Given the human population and industrial development in the area, it is highly likely that contamination from human sewage will affect the waters around the fishery. Tourism is likely to cause a significant seasonal increase in population during the summer months.

4. Sewage Discharges

Scottish Water identified the following community septic tanks and sewage discharges for the Fairlie area. These are detailed in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

Consent Ref No.	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow m^3/day	Consented Design PE
CAR/L/1008728	NS 2041 5606	FAIRLIE WWTW 1998 NS207559	Continuous	Septic Tank	484	2200
RP/1129	NS 2076 5536	FAIRLIE, FAIRLIE NO1 CSO	Intermittent	N/K	N/A	Not stated
RP/1130	NS 2018 5470	FAIRLIE, FAIRLIE NO2 CSO	Intermittent	N/K	N/A	Not stated
CD11738	NS 207 559	FAIRLIE WWPS 1	Intermittent	6mm Screen	N/A	Not stated
CD11739	NS 207 559	FAIRLIE WWPS 2	Intermittent	20mm Bar Screen	N/A	Not stated

N/A = Not applicable N/K = Not known

No microbiological data were available for these discharges. All but one related to intermittent discharges from combined sewage system overflows or emergency overflows associated with sewage pumping stations serving the Fairlie WWTW. Intermittent discharges from Fairlie WWPS 1 and 2 are recorded against the same national grid reference, therefore it is not clear whether these are one or two discharges.

A total of 44 discharge consents were provided by SEPA for the area around Fairlie. Only those discharging to sea or watercourses within 5km along the coast from the oyster farm are listed in Table 4.2.

Table 4.2 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
1	CAR/L/1004819	NS 2007 5945	Intermittent	Storm overflow/EO	1856	N/A	Firth of Clyde
2	CAR/L/1008728	NS 2041 5606	Continuous	Treated Sewage Effluent	484	not stated	Firth of Clyde
3	CAR/L/1003319 (CD11738)	NS 2056 5600	Intermittent	CSO/EO	up to 500 l/s	N/A	Firth of Clyde
4	CAR/L/1000437 (CD11739)	NS 2069 5462	Intermittent	EO	200 l/s	N/A	Fairlie Burn
5	CAR/R/1000706	NS 1960 5440	Continuous	Sewage effluent Surface water (industrial)	not stated	not stated	Firth of Clyde
6	CAR/L/1040509	NS 1773 5177	Continuous	Treated sewage effluent	85	not stated	Firth of Clyde
7	CAR/L/1003329	NS 1765 5165	Continuous	Secondary EO	not stated	not stated	Firth of Clyde
8	CAR/L/1023168	NS 1725 5125	Continuous	Treated sewage effluent	141.8	not stated	Firth of Clyde

Item 2 above relates to the Fairlie WWTW discharge, and items 3 and 4 relate to Fairlie pumping stations 1 and 2 respectively. There is some disagreement between the location of the Fairlie No 2 CSO as identified by Scottish Water and the corresponding licence as identified by SEPA, therefore it is not clear whether the CSO discharges into Fairlie Burn or via an extended pipe to the Firth of Clyde. Item 5 relates to discharge of surface water and secondary

treated sewage associated with a commercial/industrial source south of Hunterston sands. No information was given regarding the volume of flow or proportion of the sewage component.

Item 1 was the only consent associated with sewage infrastructure at Largs, which has roughly 10 times the population of Fairlie. Information from the SEPA bathing water report for Largs: Pencil Beach identified ten Scottish Water assets that may affect the bathing water beach immediately north of the marina. The report mentions that four CSOs discharge to Gogo Water, and that an EO discharges immediately to the north of where Gogo Water joins Fairlie Roads. A further CSO is reported to discharge approximately 250 m north of the bathing water and an EO is reported south of the bathing water. A new treatment works was reported to be located north of town at Quarter Farm. The location of the works was confirmed using satellite imagery freely available on the internet, however the date of the image was unknown and the works appeared to still be partly under construction at the time. The outfall location was not identified.

Largs Yacht Haven provides a free sewage pumpout service for yachts with holding tanks and encourages visitors to use toilet facilities on shore whilst at the marina.

Sewage infrastructure and observations of sewage-related debris recorded during the shoreline survey are listed in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	24-Aug-10	NS 2094 5626	Sanitary debris - 2 cotton buds in tideline.
2	24-Aug-10	NS 2080 5587	Sanitary debris - cotton buds in tideline.
3	24-Aug-10	NS 2075 5591	Fairlie WWTW.
4	24-Aug-10	NS 2090 5558	Manhole cover on shore.
5	24-Aug-10	NS 2090 5558	Manhole cover on shore.
6	24-Aug-10	NS 2091 5534	Manhole cover on shore.
7	24-Aug-10	NS 2091 5531	Manhole cover on shore.
8	24-Aug-10	NS 2090 5526	Manhole cover on shore.
9	24-Aug-10	NS 2084 5494	Small amount of foul water leaking from metal plate.
10	24-Aug-10	NS 2082 5488	Manhole cover on beach.
11	24-Aug-10	NS 2075 5474	Manhole cover on shore.
12	25-Aug-10	NS 2002 5365	Sanitary debris - cotton bud.
13	25-Aug-10	NS 1991 5328	Sanitary debris.
14	25-Aug-10	NS 1951 5267	Sanitary debris.

Sanitary (sewage-related) debris was identified along the shoreline to the north and south of the oyster farm, but not on the sands immediately adjacent to it. Seven manhole covers were found along the shoreline, and foul water was found leaking from a metal plate roughly mid-way along the shore between Fairlie CSO 1 and 2. These are presumed to be sewerage infrastructure related to Fairlie WWTW and associated discharges. The

discharges identified in Tables 4.1 and 4.2 and the observations in Table 4.3 are shown mapped in Figure 4.1, with the location of the oyster trestles shown for reference. The approximate locations of CSO/EO discharges identified as discharging directly to coastal waters in the bathing waters report have been included on the map. The information available was insufficient to determine approximate locations for upstream discharges to Gogo Water.

The shoreline survey identified an area of yacht moorings located immediately offshore of Fairlie (see Section 15). Discharges from yachts using this mooring area would also be expected to affect water quality in the general area and potentially at the fishery.

Two discharges lie within 500 metres of the fishery: Fairlie CSO No. 2 and a continuous sewage and industrial discharge of unknown size and treatment. The CSO would be expected to markedly affect water quality in the area when it operates, however the discharge associated with CAR/R/1000706 would be expected to have a greater overall impact as it is a continuous discharge located only 200 m from the northern end of the trestles. The pier at this location is used by ships used for the bulk transport of coal. All of the Fairlie WWTW discharges lie within 2 km of the oyster farm and therefore would be expected to impact water quality to some degree within this area. Discharges from further north could potentially lead to elevated levels of faecal contaminants present in waters at the fishery, particularly if spills from CSOs or EOs are of a long duration.

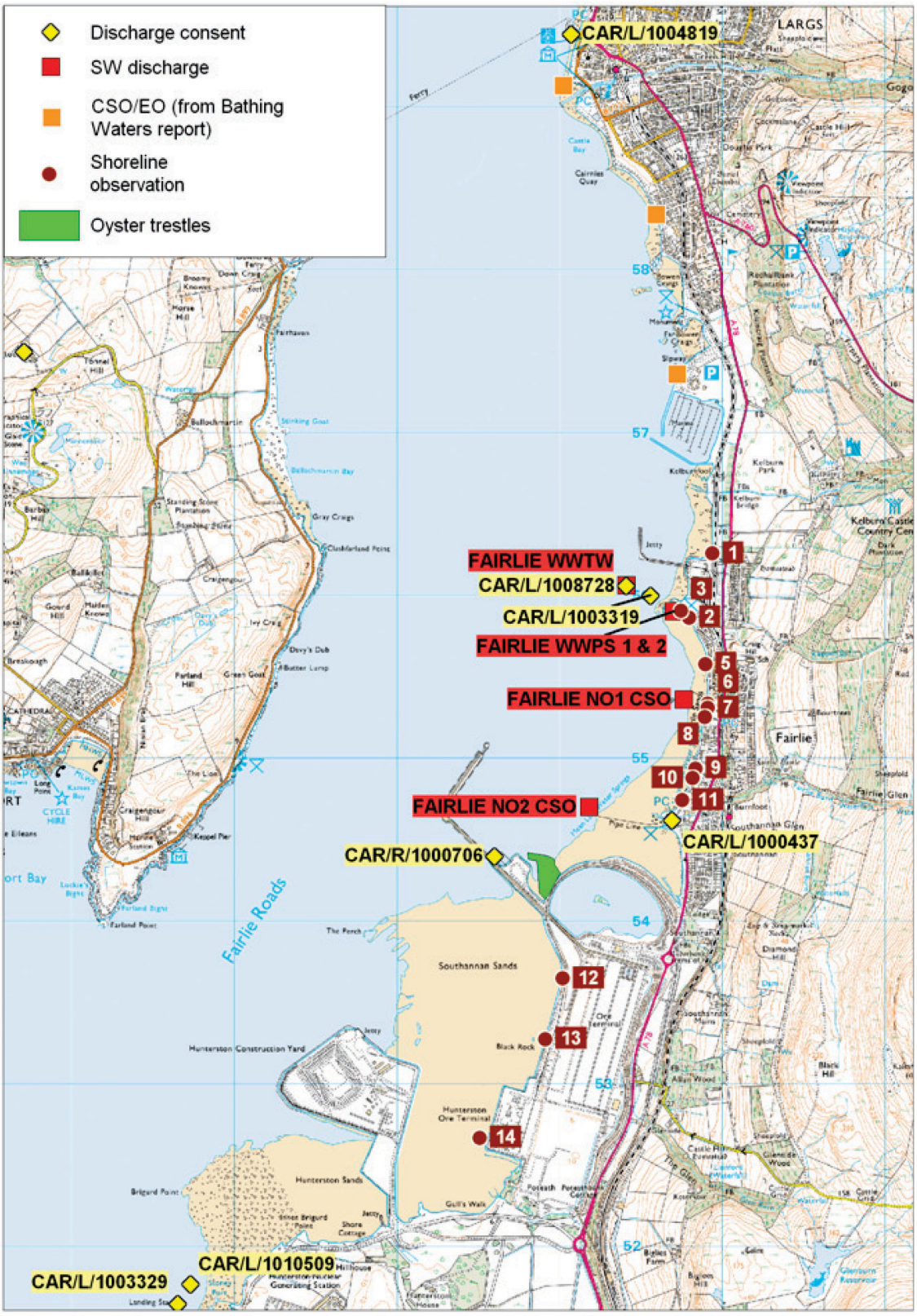


Figure 4.1 Map of discharges for Fairlie

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 3. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red indicate poorly draining soils while areas shaded blue indicate more freely draining soils. Solid grey areas indicate predominantly impermeable surfaces on built-up areas.

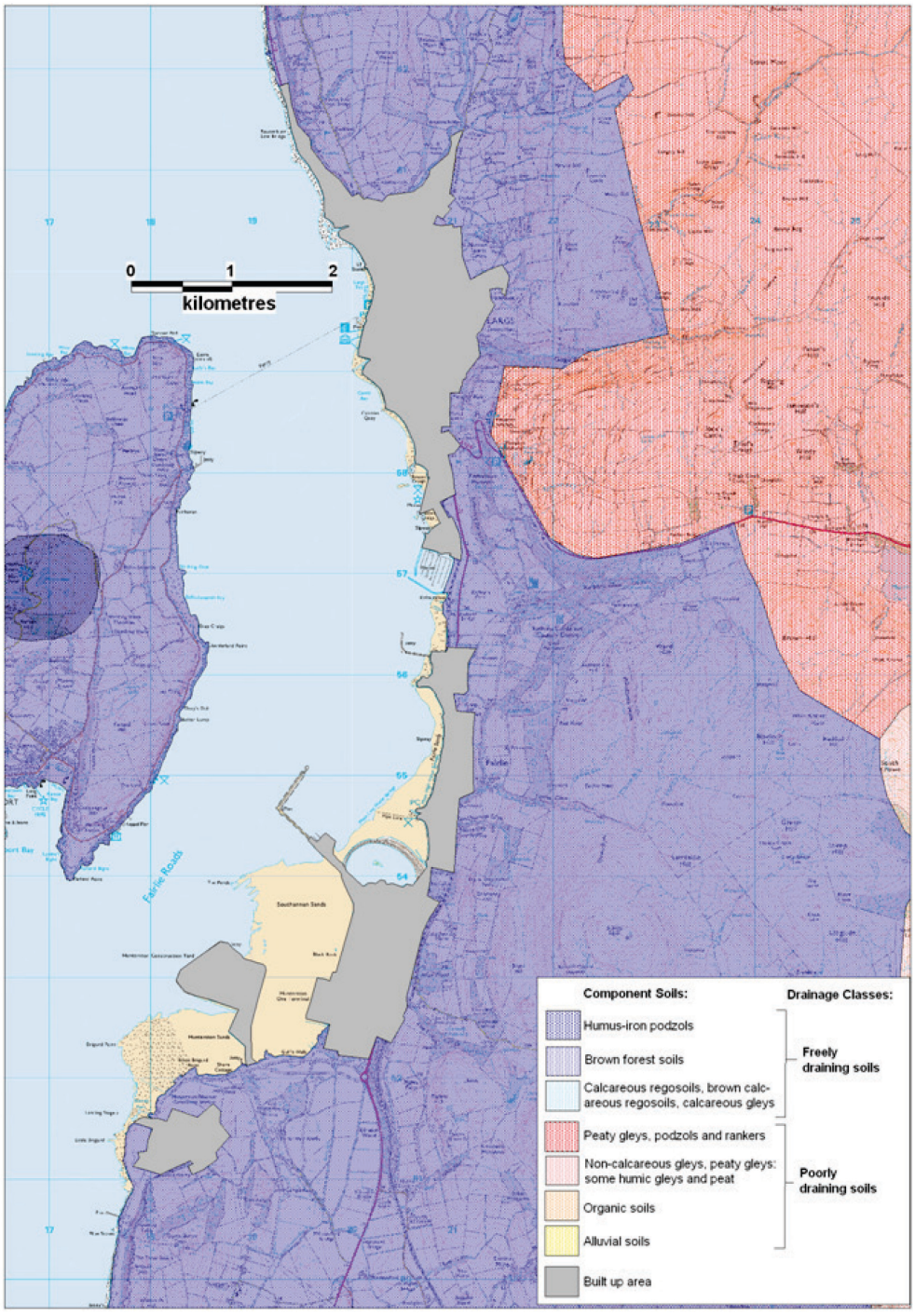


Figure 5.1 Component soils and drainage classes for Fairlie.

There are four types of component soils present in the area: peaty gleys, podzols and rankers, non-calcareous gleys, brown forest soils and humus-iron podzols. Built up areas along the coast relate to populated and industrial areas around Fairlie and Largs. The peaty gleys, podzols and rankers and non-calcareous gleys inland from the fishery are poorly draining and the brown forest soils that cover the stretch of coastline adjacent to the fishery and on Great Cumbrae Island are freely draining. Therefore, the potential for runoff contaminated with *E. coli* from human and/or animal waste will be higher along the built up shoreline and for watercourses draining the less permeable soils inland of the coastal strip.

6. Land Cover

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

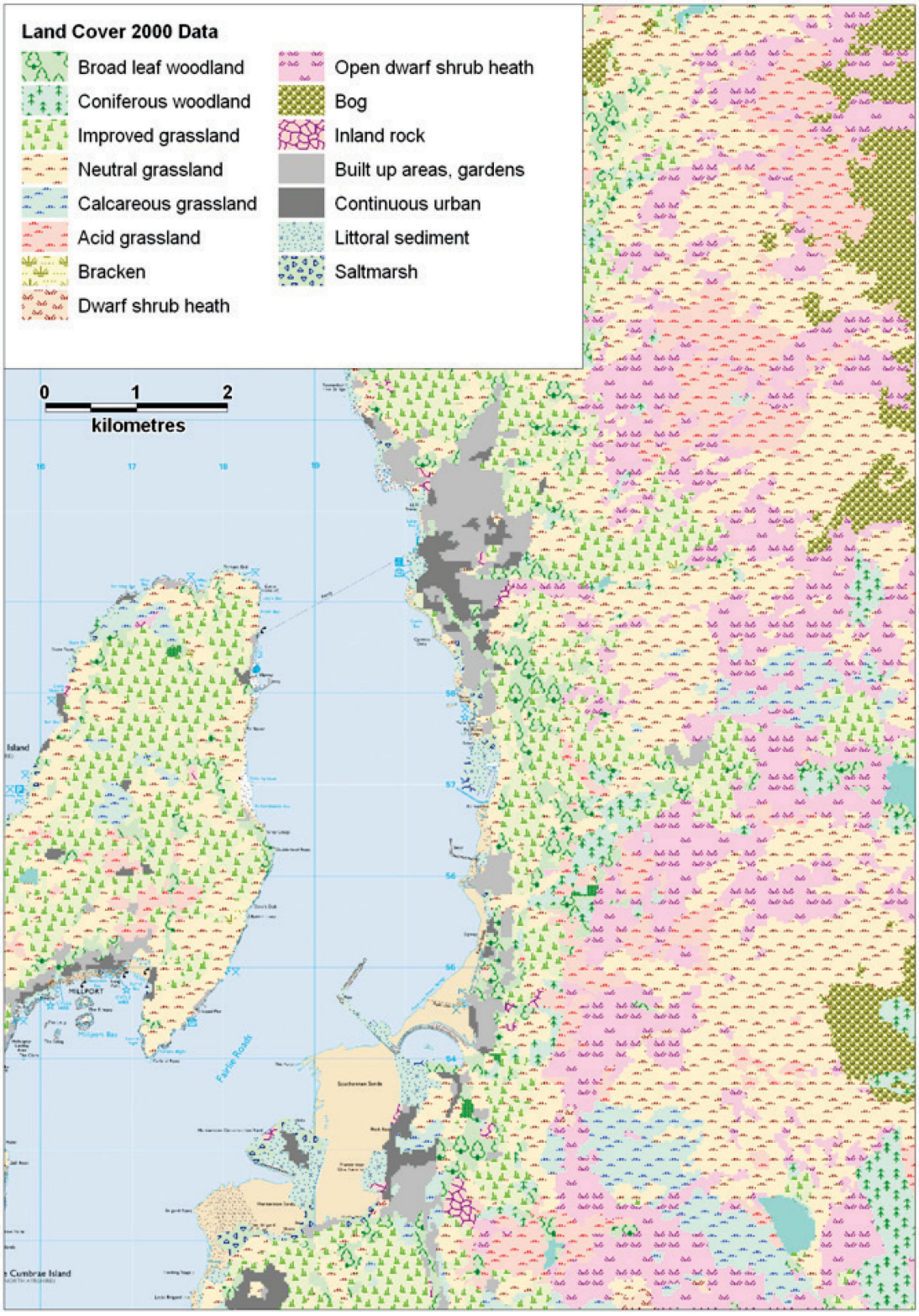


Figure 6.1 LCM2000 class land cover data for Fairlie

A variety of land cover types are found in the Fairlie area. Urban and built up areas shown along the eastern shoreline roughly correspond with those identified in the soil profile map and the villages of Fairlie and Largs. The urban area noted at the southern boundary of the map is the Hunterston Nuclear Generating Station. A small fringe of urban and built up area is identified at the south end of Great Cumbrae Island, which corresponds with the village of Millport. Improved grassland covers much of the island and is also found along the mainland shore east of the built up areas. Substantial areas of acid, calcareous and neutral grassland cover much of the rest of Great Cumbrae Island and a large portion of the land east of the villages. These landcover types may be used for rough grazing. Small areas of woodland can be found interspersed amongst the improved grassland and built up areas, as well as further inland.

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 $1.2 – 2.8x10^9$ cfu km^{-2} hr^{-1}) and lower for areas of improved grassland (approximately $8.3x10^8$ cfu km^{-2} hr^{-1}) and rough grazing (approximately $2.5x10^8$ cfu km^{-2} hr^{-1}) areas. Lowest contributions would be expected from areas of woodland (approximately $2.0x10^7$ 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 these land cover types would be intermediate to high, and would be expected to increase significantly following rainfall events. It is likely that the areas of shoreline immediately adjacent to the villages of Fairlie and Largs and areas of improved grassland will be subject to higher levels of contamination.

7. Farm Animals

Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the parishes Cumbrae, Largs and West Kilbride. Reported livestock populations for the parishes in 2008 and 2009 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 Cumbrae, Largs and West Kilbride parishes 2008 - 2009

	Cumbrae (14.24 km^2)				Largs (88.28 km^2)				West Kilbride (42.75 km^2)			
	2008		2009		2008		2009		2008		2009	
	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers
Pigs	0	0	0	0	0	0	0	0	0	0	0	0
Poultry	0	0	*	*	*	*	*	*	6	96	6	87
Cattle	5	1,228	5	1,067	9	1,207	9	1,196	14	1,929	14	1,720
Sheep	*	*	*	*	15	14,964	14	13,827	13	14,130	12	13,738
Horses and ponies	*	*	0	0	7	126	6	92	11	55	10	53

* Data withheld for reasons of confidentiality

Cattle, sheep, and poultry are farmed in all three parishes and horses are kept in both Largs and West Kilbride. No pig farms were reported for any of the parishes. In every category for which data were provided, numbers of animals declined from 2008 to 2009. 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. However, due to the large geographic areas of the parishes, and the missing data from Cumbrae and Largs, the only information available regarding the numbers of animals present near the fishery is that recorded during the shoreline survey (Section 15 and Appendix 7). This information relates only to the time of the site visit on the 24th and 25th August 2010 and is dependent upon the point of view of the observer. During the shoreline survey approximately 30 sheep were recorded in a field behind the yacht marina at Fairlie. Pastures interspersed with woodlands were observed east of Fairlie, but no livestock were seen there. The location of the livestock observed and noted during the shoreline survey is illustrated in Figure 7.1.

In addition to the farm census data above, there is a large equestrian centre with stables, grazing fields and paddocks at the Kelburn Estate, east of the marina. The website for the facility identifies 3,000 acres of land for riding

with nearby beaches (Kelburn Estate, 2011). It is likely, therefore, that at least some diffuse pollution from horse manure and bedding would be carried via Kelburn to the sea just south of the marina.

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Figure 7.1 Livestock observations at Fairlie

8. Wildlife

The oyster fishery at Fairlie lies within the Portencross Coast SSSI, which was notified for its aggregations of non-breeding birds. Although the area is predominantly developed, there are significant open areas where wildlife congregate.

Birds
Seabird 2000 counts for seabirds within 5km of the site are listed in Table 8.1 below.

Table 8.1 Seabird counts within 5km of the site.

Common name	Species	Count	Method
Northern Fulmar	*Fulmarus glacialis*	59	Occupied sites or nests
Common Gull	*Larus canus*	144	Occupied nests
Black Guillemot	*Cepphus grylle*	20	Individuals on sea
Common tern	*Sterna hirundo*	12	Occupied nests

A survey of birds in the Portencross Coast SSSI had been undertaken on behalf of Scottish Natural Heritage that indicated significant numbers of wading birds, gulls and ducks present within the SSSI (Craigton Ecological Services 2006). This showed that the Hunterston Lagoon and the island within the lagoon were used by a variety of seabirds. A colony of approximately 20 breeding pairs of common and black-headed gulls was identified on land approximately 100m southwest of the northern end of the oyster trestles.

Over 400 birds were recorded during the shoreline survey. The majority of these were observed on Hunterston Sands, south of the fishery. Eight ducks were seen near the northern end of the fishery.

On occasions, the sampling officer has identified on the sample submission form that birds were notably present at or very near the trestles at the time of sampling. This occurred in summer and autumn only, suggesting that birds might be more prevalent in the area at these times.

Moderate numbers of wading birds, gulls and ducks are present in the area, with some breeding in the lagoon and on land adjacent to the oyster fishery during the summer months. No data on seasonal variation in numbers were available, however breeding sites near the fishery are likely to be consistently occupied during the summer months.

Deer
Roe deer are known to be present in the area, and are likely to be present in significant numbers in woodland east of the fishery. Two deer were observed during the Scottish Natural Heritage survey (Craigton Ecological Services 2006). Wooded areas along streams and inland from the fishery are likely to host significant deer populations, though no information on population numbers was available. Deer are therefore anticipated to contribute to the faecal loading in local streams.

Other

A single otter and a seal were also observed during the 2006 survey, confirming the presence of these animals in the area. Whilst both grey and harbour seals have been observed in the Firth of Clyde, there are no known breeding colonies and few animals have been observed around Fairlie. Therefore, it is anticipated that while these animals may contribute to background levels of faecal indicator bacteria when present, their presence is likely to be limited and therefore of no significance to microbiological water quality at oyster fishery.

Summary

The most significant potential wildlife source of faecal contamination to the fishery is likely to be from birds, particularly gulls, wading birds and ducks. The northwestern end of the oyster farm, which lies adjacent to the gull colony and, is likely to be most impacted from avian sources.

Figure 8.1 Map of wildlife observations near Fairlie

9. Meteorological data

The nearest weather station for which the majority of records are available is located at Hunterston, approximately 3 km to the south of the production area. Rainfall data was available for 2003-2009 inclusive apart from the months of July and September 2009, April 2008, February and November 2005, and 5 individual days in 2006. The nearest weather station for which wind data is available is Glasgow Bishopton, 27 km to the north east. However, data from the Prestwick: Gannet wind station, approximately 30 km to the south of the fishery was used in preference as this is also located on the Ayrshire coast, whereas the Glasgow Bishopton station is located further inland within the Clyde valley. Overall wind patterns are likely to be broadly similar at Prestwick and Fairlie, but local topography may result in some differences and conditions on any given day may differ due to the distance between them. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish at Fairlie.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003). Figures 9.1 and 9.2 present box and whisker plots summarising the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median noted by 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 *.

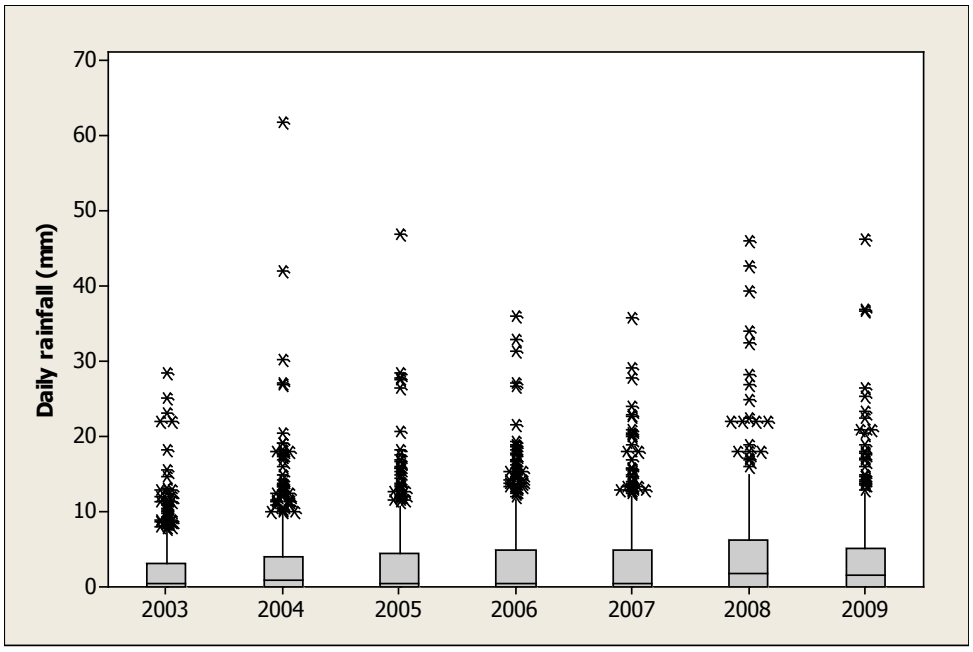

Figure 9.1 Box plot of daily rainfall values by year at Hunterston, 2003-2009

Figure 9.1 shows that rainfall appeared to increase gradually over the period presented here, with 2003 the driest and 2008 the wettest.

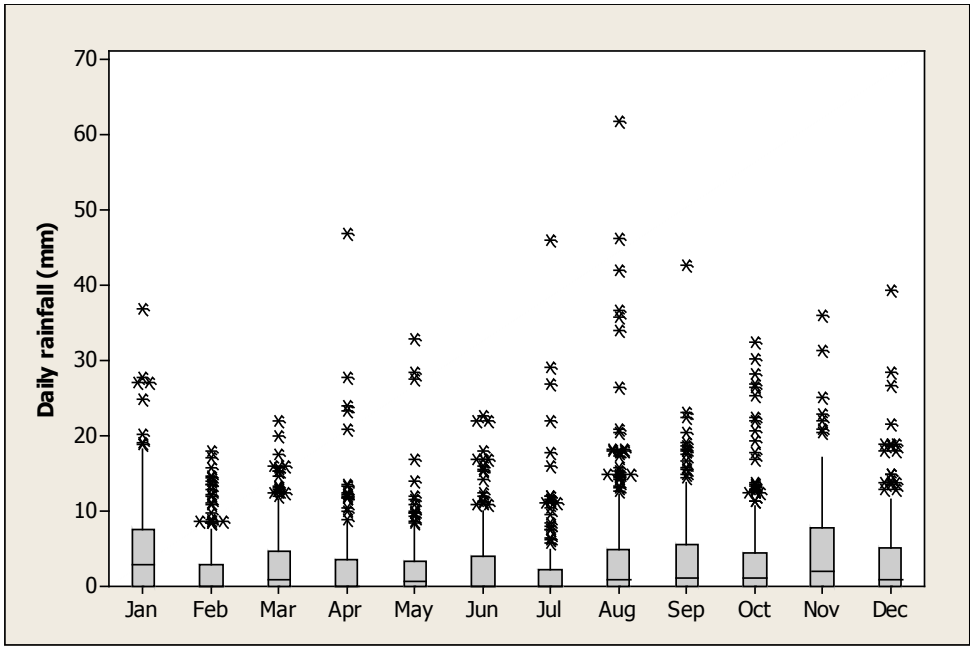

Figure 9.2 Box plot of daily rainfall values by month at Hunterston, 2003-2009

Weather was generally wetter from August through January, with the wettest months being November and January. Days with very high rainfall (over 20 mm) have occurred in all months aside from February. For the period considered here (2003-2009), 51% of days experienced rainfall less than 1 mm, and 11% of days experienced rainfall of 10 mm or more.

It can therefore generally be expected that levels of run-off will be higher during the autumn and winter months. However, it is likely that associated faecal contamination entering the production area will be greatest when extreme rainfall events occur during summer or early autumn after a build-up of faecal matter on pastures during the drier summer months when stock levels are at their highest.

9.2 Wind

Wind data collected at the Prestwick: Gannet weather station is summarised by season and presented in Figures 9.3 to 9.7.

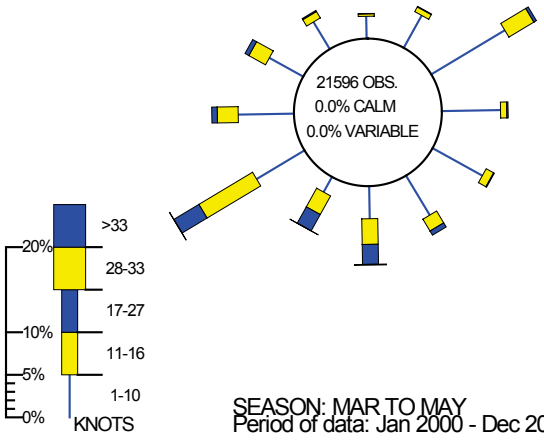

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Figure 9.3Wind rose for Location (March to May)

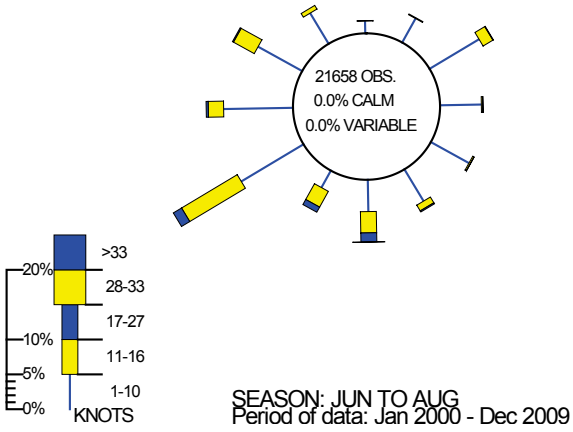

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Figure 9.4 Wind rose for Location (June to August)

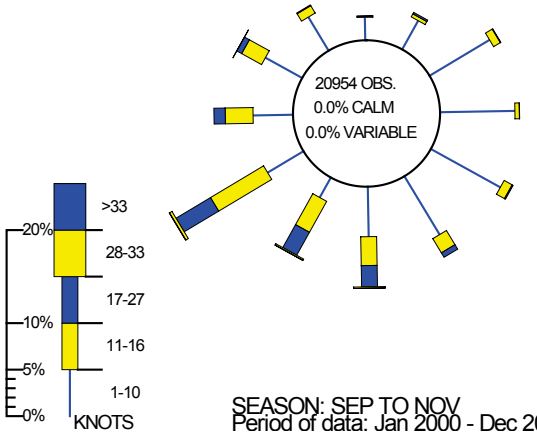

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Figure 9.5 Wind rose for Location (September to November)

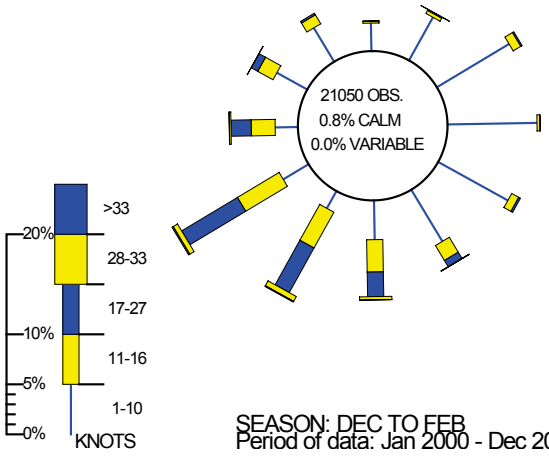

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Figure 9.6 Wind rose for Location (December to February)

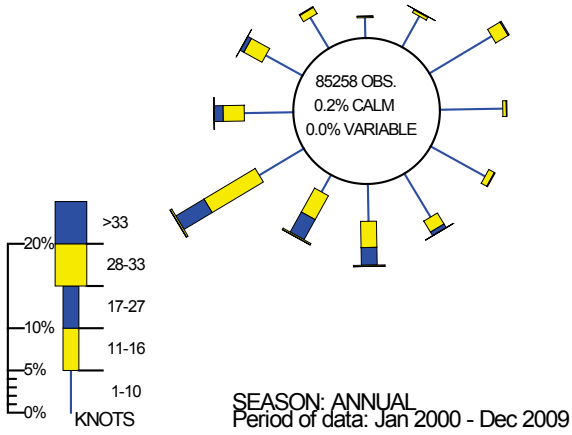

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Figure 9.7 Wind rose for Location (All year)

The prevailing wind direction at Prestwick is from the southwest, but wind direction often changes markedly from day to day with the passage of weather systems. There is a higher occurrence of north easterly winds during the spring, although these tend to be light to moderate. Winds are generally lightest in the summer and strongest in the winter. Both the fishery and the weather station are located on the Ayrshire coast, and so are most exposed to winds from a westerly direction, although Fairlie may receive some limited shelter from these winds from Great Cumbrae island, which lies about 2 km to the west. The pier at Fairlie may also provide some shelter from westerly winds and waves.

Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore strong winds may significantly alter the pattern of surface currents at Fairlie. Strong winds may affect tide

height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry deposited faecal matter at or above the normal high water mark into the production area. A strong northerly wind could cause increased wave action at the site, which may resuspend any organic matter settled in the substrate.

10. Current and historical classification status

Classification records for both Pacific and native oysters produced at Fairlie were available from 2001. The native oyster fishery was no longer classified after 2003.

Table 10.1 Classification history, Fairlie Pacific oysters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	B	B	B	B	B	B	B	B	B	B	B	B
2002	A	B	A	A	A	A	A	A	A	A	A	A
2003	B	B	A	A	A	A	A	A	B	B	B	B
2004	B	B	A	A	A	A	A	A	A	B	B	B
2005	B	B	B	B	B	B	B	B	B	B	B	B
2006	B	B	B	B	A	A	A	B	B	B	B	B
2007	B	B	B	B	A	A	A	A	A	A	A	A
2008	B	B	B	A	A	A	A	A	A	A	B	B
2009	B	B	B	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									

Table 10.2 Classification history, Fairlie native oysters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	a	a	a	a	a	a	a	a	a	a	a	a
2002	B	A	A	A	A	A	A	A	A	B	B	B
2003	B	B	B	A	A	A	A	A	B	B	B	B

Lower case denotes provisional classification

Both species tended to receive B classification during the winter months, though the history for native oysters is far more limited. The Pacific oyster fishery was classed year-round B in 2001 and 2005, and year-round A from April 2009 to March 2011.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken Fairlie from the beginning of 2002 up to the 16th April 2010 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

One Pacific oyster sample had no reported grid reference and so was rejected from the analysis. Most samples were reported from the nominal RMP, which falls about 13 m outside the production area. Two other samples fell between 20 and 30 m outside the production area. As 100 m is the level of accuracy to which sampling locations were historically specified, these samples fell within that tolerance and so were included in the analysis.

All samples were received by the testing laboratory within two days of collection. One native oyster and four Pacific oyster samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation.

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

11.2 Summary of microbiological results

A summary of all sampling and results is presented in Table 11.1 by species.

Table 11.1 Summary of historical sampling and results

Sampling Summary		
Production area	Fairlie	Fairlie
Site	Southannan Sands	Southannan Sands
Species	Pacific oysters	Native oysters
SIN	NA-065-332-13	NA-065-332-12
Location	19 locations	NS198542 (RMP)
Total no of samples	72	8
No. 2002	6	6
No. 2003	9	2
No. 2004	11	0
No. 2005	11	0
No. 2006	12	0
No. 2007	7	0
No. 2008	7	0
No. 2009	8	0
No. 2010	1	0
Results Summary		
Minimum	<20	<20
Maximum	3500	1300
Median	185	75
Geometric mean	147	90.2
90 percentile	700	607
95 percentile	998	954
No. exceeding 230/100g	20 (28%)	3 (38%)
No. exceeding 1000/100g	4 (5%)	1 (13%)
No. exceeding 4600/100g	0 (0%)	0 (0%)
No. exceeding 18000/100g	0 (0%)	0 (0%)

Only 8 native oyster samples were taken within this period, so sample numbers were insufficient to carry out a more detailed evaluation of results for this species.

Subsequent to the initial analysis undertaken in May 2010, a further 10 Pacific oyster sample results were reported for Fairlie. These are summarised in the table below, but have not been included in the subsequent statistical analyses.

Table 11.2 Additional sample results, 2010-11

Date	NGR	Result	Date	NGR	Result
11/01/2010	NS 1986 5431	260	14/09/2010	NS 1997 5431	700
12/04/2010	NS 1992 5432	110	13/10/2010	NS 1993 5431	230
19/05/2010	NS 1993 5432	230	10/11/2010	NS 1995 5431	9200
16/06/2010	NS 1988 5428	130	14/12/2010	NS 1995 5431	490
25/08/2010	NS 1988 5428	230	11/01/2011	NS 1995 5431	220

Four results exceeded 230 *E. coli* MPN/100 g, one of which was the highest result seen to date from this site (9200 MPN/100 g).

11.3 Overall geographical pattern of results

Until mid 2007, all samples were reported from the nominal RMP. After this time, sampling officers were equipped with GPSs with which sampling

location was recorded at the time of collection. Results of these latter samples, all of which were Pacific oyster samples taken from 2007 onward, are thematically mapped by sampling location in Figure 11.1.

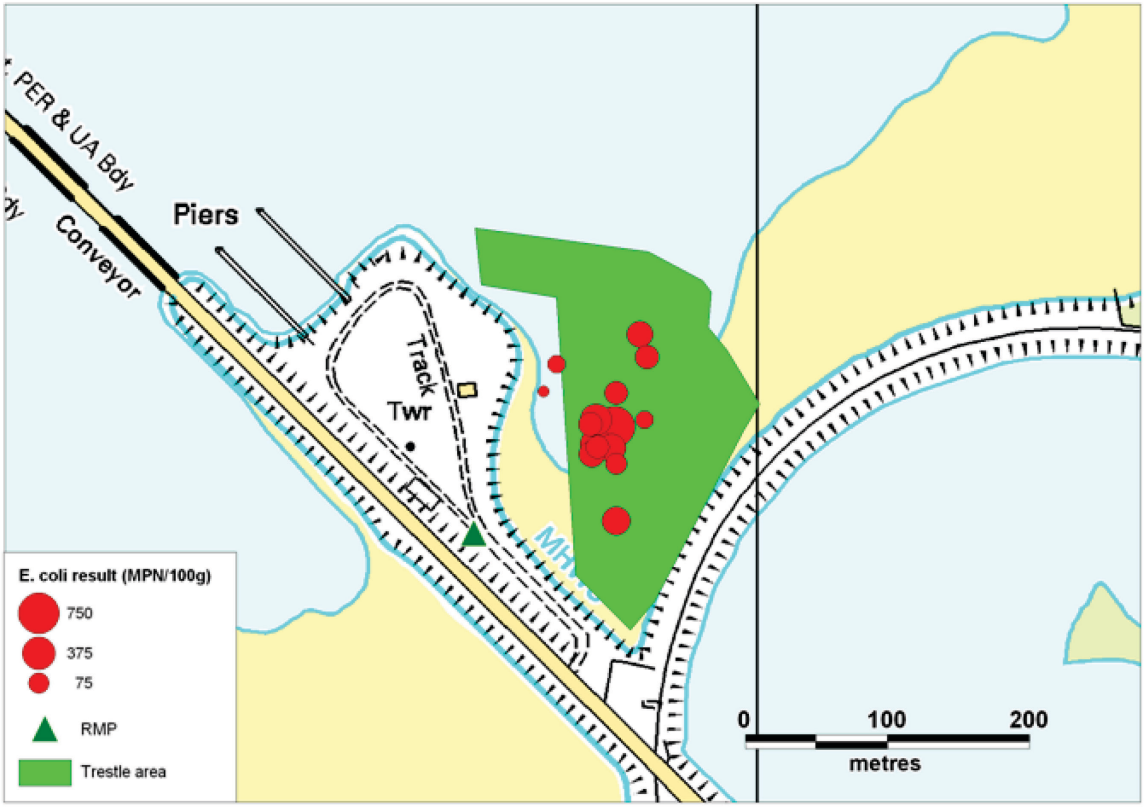

Figure 11.1 Map of gridded *E. coli* results (Pacific oysters)

Sampling effort was mostly concentrated near or below MLWS and no samples were taken from northern or eastern extents of the trestle area. There appeared to be a tendency toward higher results along the eastern side of the sampled area.

11.4 Overall temporal pattern of results

Figure 11.2 presents a scatter plot of individual Pacific oyster results against date, fitted with trend lines calculated using two different techniques. It is fitted with a line indicating the geometric mean of the previous 5 samples, the current sample and the following 6 samples, referred to as a rolling geometric mean (black line). It is also fitted with loess lines (blue line), which stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away. These trend lines help to highlight any apparent underlying trends or cycles.

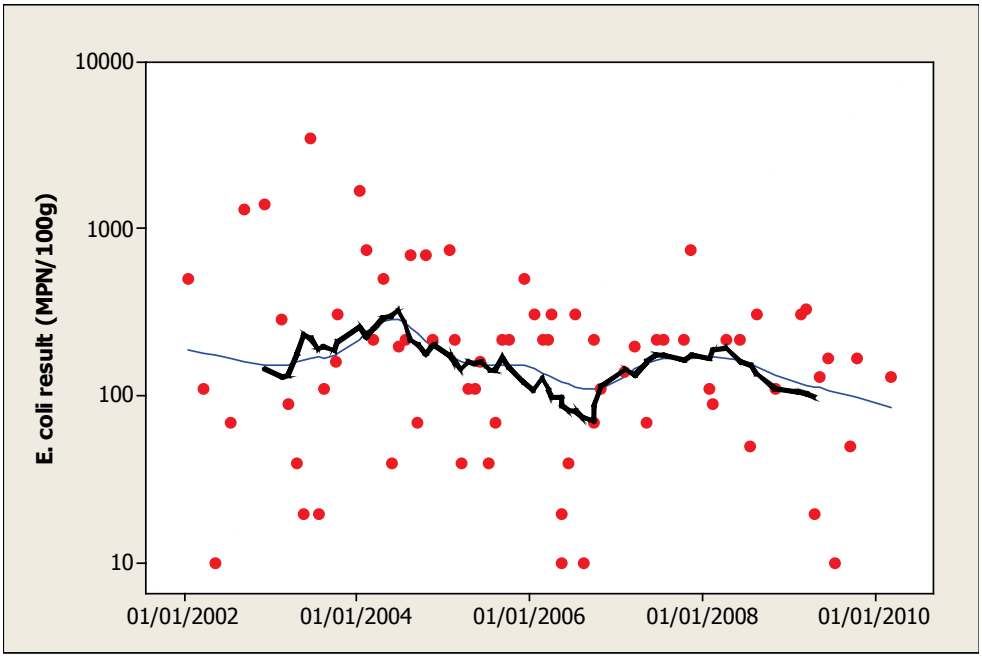

Figure 11.2 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line)

Figure 11.2 suggests an overall slight improvement in results, and a gradual decline in peak levels over years. However, it should be noted that the more recent results presented in Table 11.2 show that this trend has been reversed.

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 boxplot of *E. coli* result by month.

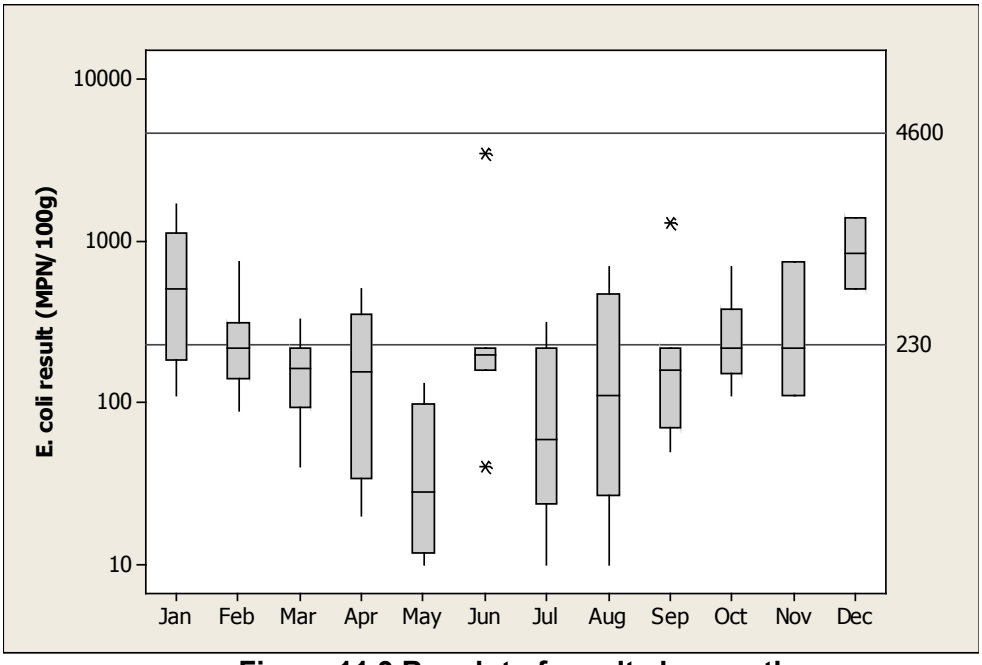

Figure 11.3 Boxplot of results by month

Higher results generally arose during the colder months of the year, although the highest individual result arose in June. The monthly pattern of results appears to roughly coincide with day length, which is shortest in December and longest in June. Five or more samples were taken during all months except November and December, when three and two samples respectively were taken.

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

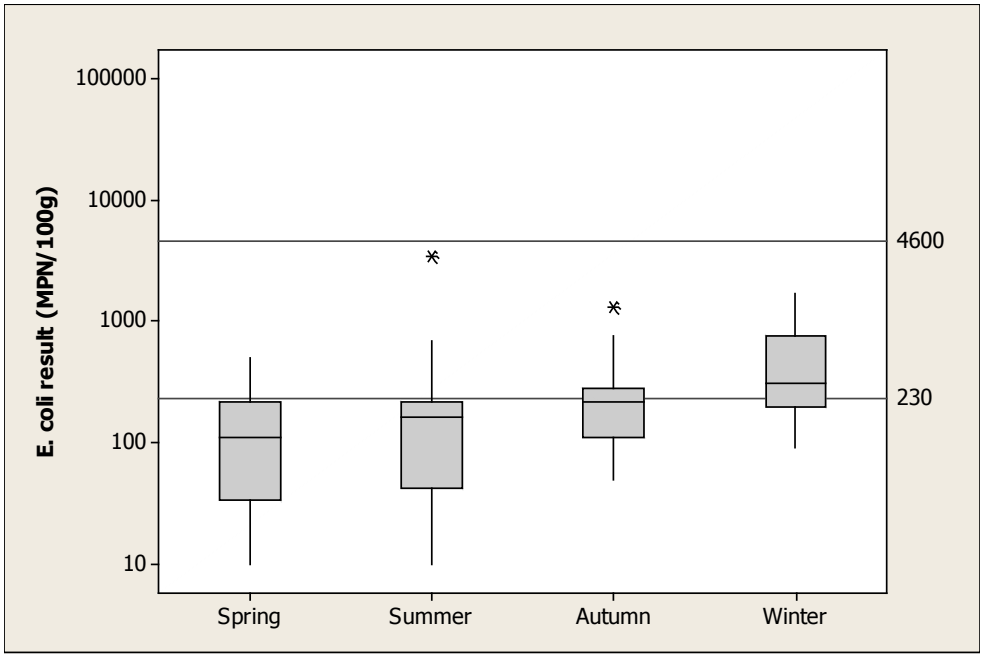

Figure 11.4 Boxplot of result by season

A significant difference was found between results by season (One-way ANOVA, p=0.002, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the winter were significantly higher than those in the spring and summer. This is a fairly unusual pattern for Scottish shellfish sites, where more typically if a pattern is observed at all, results are higher during late summer/early autumn.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station is at Hunterston, just to the south of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2009 (total daily rainfall in mm).

Two-day antecedent rainfall

Figure 11.5 presents a scatterplot of *E. coli* results against rainfall in the previous two days. A Spearman's Rank correlation was carried out between results and rainfall.

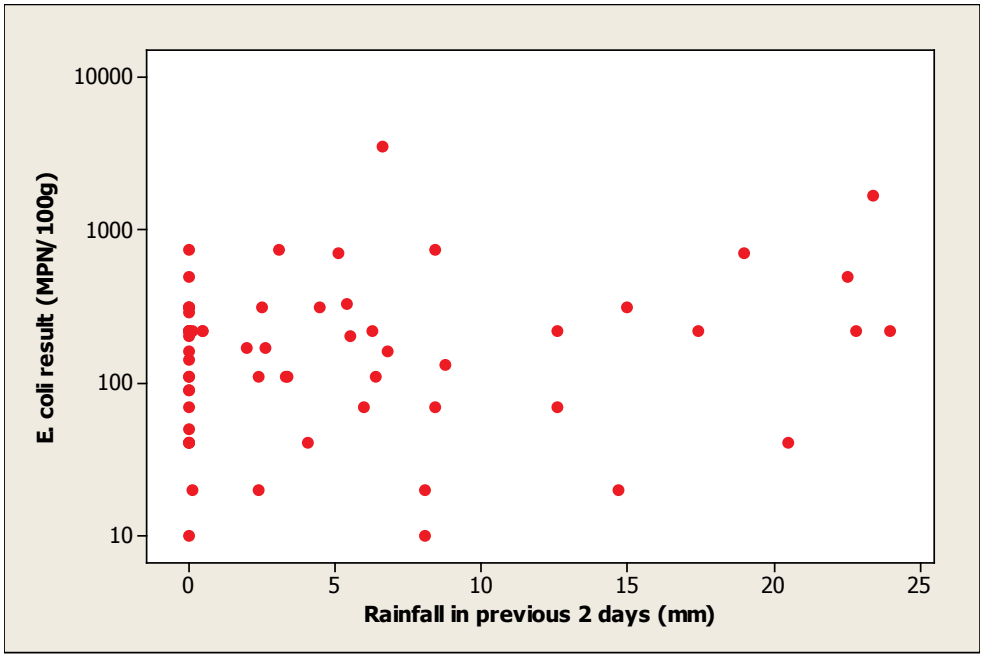

Figure 11.5 Scatterplot of result against rainfall in previous 2 days

No statistically significant correlation was found between *E. coli* result and rainfall in the previous 2 days (Spearman's rank correlation=0.125, p>0.10, Appendix 6). A large number of samples were obtained after no rainfall in the two days prior to sampling, and these exhibited a wide range of results, from <20 to 750 MPN/100 g.

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.

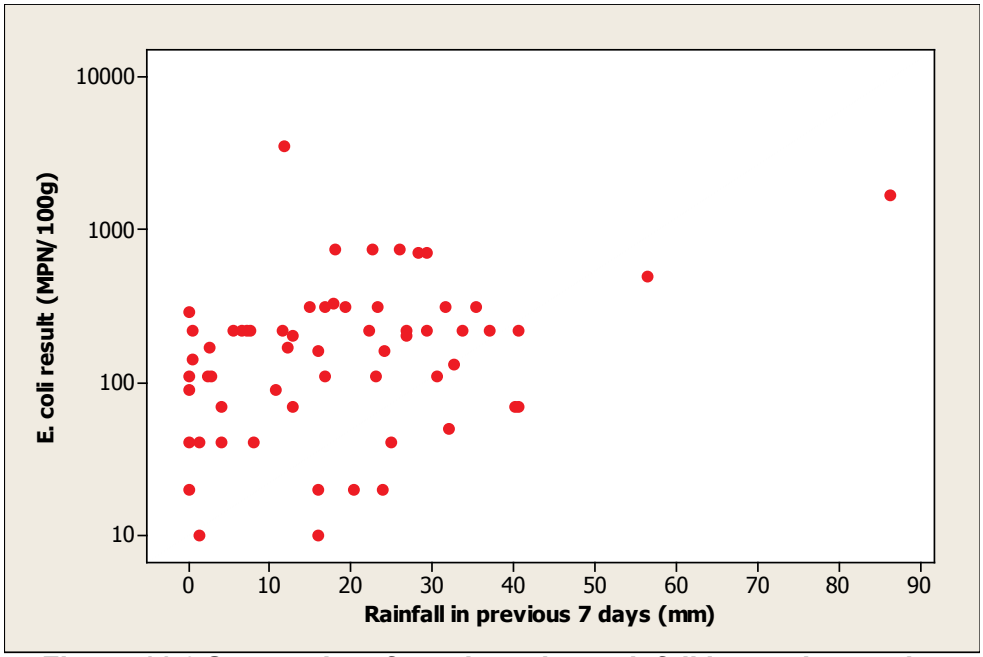

Figure 11.6 Scatterplot of result against rainfall in previous 7 days

A positive correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation= 0.328, $p<0.01$, Appendix 6). However, the highest result occurred after moderate rainfall and results >230 occurred at all rainfall levels.

11.6.2 Analysis of results by tidal height and state

Spring/Neap Cycle

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. Results under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *E. coli* MPN/100g are plotted in red. 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.

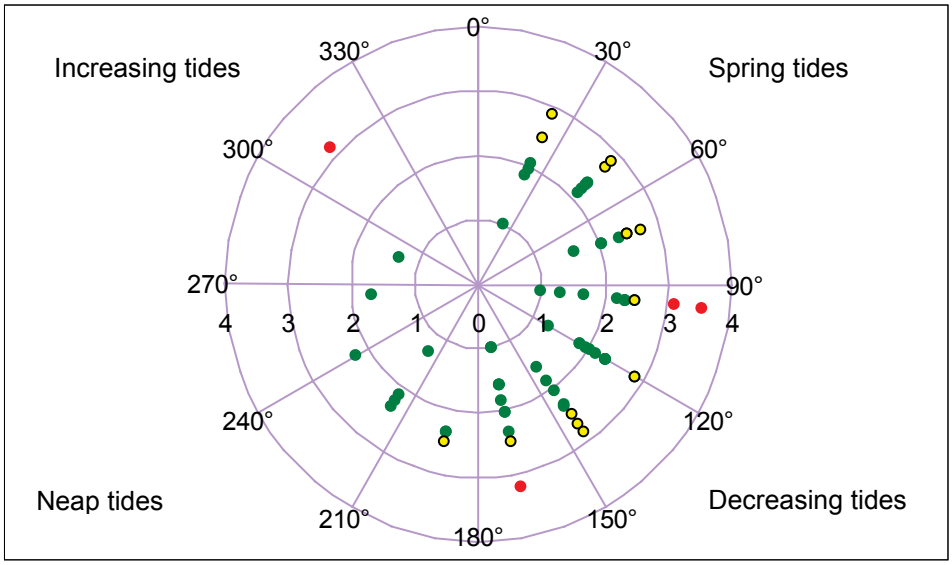

Figure 11.7 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle

No statistically significant correlation was found between *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.172, p=0.129, Appendix 6). Sampling was targeted towards spring tides.

High/Low Cycle

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* concentrations in some shellfish species can respond within a few hours or less to changes in *E. coli* concentrations 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. Again, results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *E. coli* MPN/100g are plotted in red.

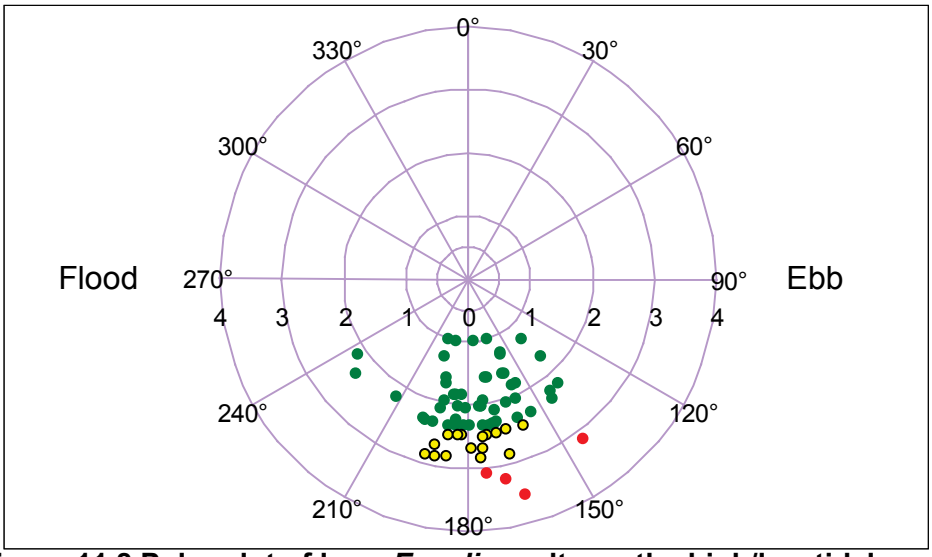

Figure 11.8 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle

No statistically significant correlation was found between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.107, p=0.455, Appendix 6). However, sampling was undertaken at or near low water on all occasions.

11.6.3 Analysis of results by water temperature

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

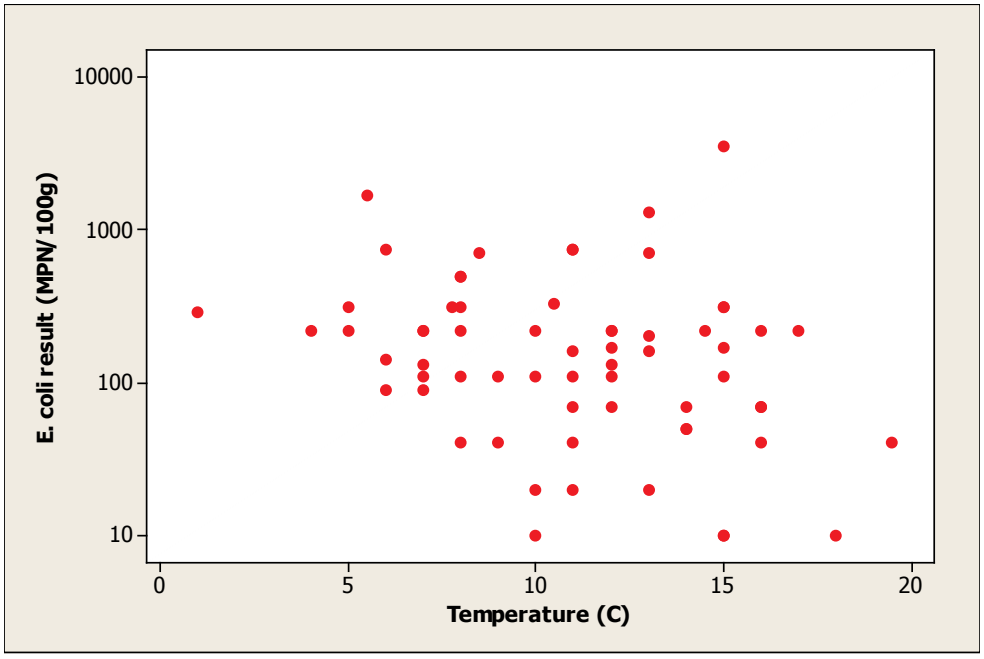

Figure 11.9 Scatterplot of result by water temperature

A negative correlation was found between *E. coli* result and water temperature (Spearman's rank correlation= -0.286, p<0.025, Appendix 6). Although the highest results occurred at temperatures between 5 and 15ºC, no low results occurred at temperatures below 10ºC.

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.10 presents a scatter plots of *E. coli* result against salinity.

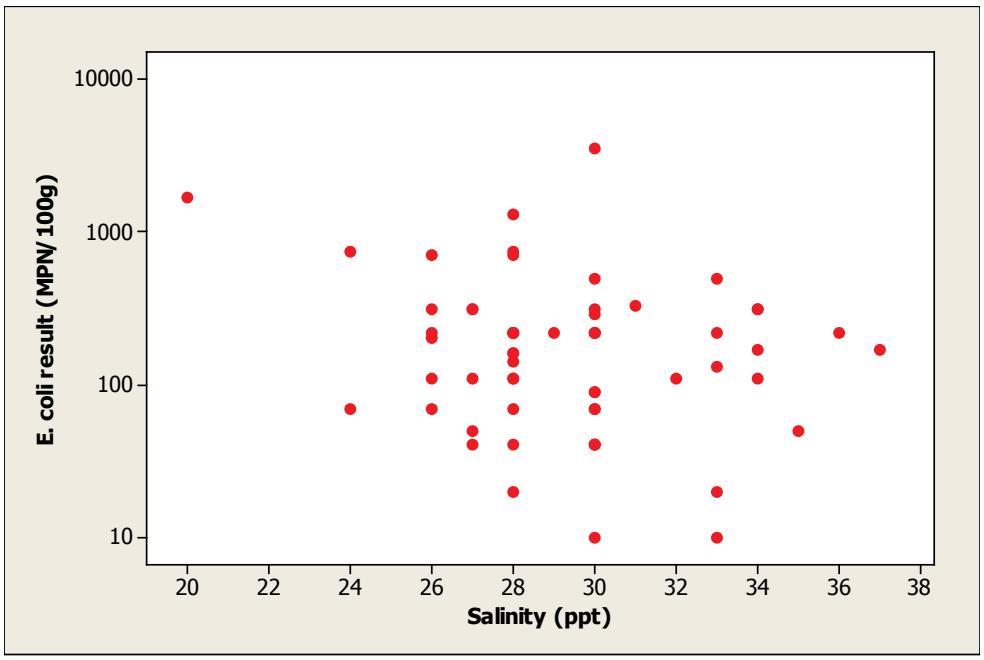

Figure 11.10 Scatterplot of result by salinity

No correlation was found between the *E. coli* result and salinity (Spearman's rank correlation= -0.122, p>0.10, Appendix 6).

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

A total of 5 samples gave a result of over 1000 *E. coli* MPN/100g, details of which are presented in Table 11.2.

Table 11.3 Historic *E. coli* sampling results over 1000 *E. coli* MPN/100g

Collection date	Species	*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)
11/09/2002	Native oysters	1300	NS198 542	*	*	13	28	Low	Spring
11/09/2002	Pacific oysters	1300	NS198 542	*	*	13	28	Low	Spring
03/12/2002	Pacific oysters	1400	NS198 542	*	*	*	*	Low	Increasing
18/06/2003	Pacific oysters	3500	NS198 542	6.6	11.8	15	30	Low	Spring
14/01/2004	Pacific oysters	1700	NS198 542	23.4	86.2	5.5	20	Low	Decreasing
10/11/2010	Pacific oysters	9200	NS1995 5431	*	*	10	35	Low	

* Data unavailable

All samples were reported from the RMP (NS 198 542). The first two results arose on the same day in September 2002, when samples of both species contained 1300 *E. coli* MPN/100 g. The three other high results arose in December, June and January. The highest result obtained to date was 9200 *E. coli* MPN/100 g, in November 2010. Rainfall data was only available for two of the occasions, one of which was after moderate rain, the other after heavy rain. Salinities in most cases were toward the low end of the reported range, however the highest result also had the highest salinity. Sampling was targeted towards low water on spring tides for access reasons, so the tidal states at which these samples were taken are typical for all samples.

11.8 Summary and conclusions

No clear geographic patterns were seen when sample results for samples for which the sampling location was recorded accurately by GPS were plotted.

In terms of overall temporal patterns in levels of contamination, a slight improvement in results was seen since 2002, with a gradual decline in peak levels. A seasonal pattern was apparent, with results for the winter significantly higher than those in the spring and summer. A negative correlation was also found between *E. coli r*esults and water temperature. This is a fairly unusual pattern for Scottish shellfish sites, where more typically if a pattern is observed at all, results are higher during late summer/early autumn, and may be due to the less livestock-orientated nature of the contaminating sources in the area. This pattern does not appear to coincide with seasonal rainfall values in the area.

No correlation was found between *E. coli* results and rainfall in the previous 2 days, but a positive correlation was found between *E. coli* results and rainfall in the previous 7 days. No correlation was found between *E. coli* results and salinity however. No correlation was found between *E. coli* results and either the spring/neap or high/low tidal cycle, but sampling was strongly targeted towards low water on spring tides.

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

11.9 Sampling frequency

When a production area has held the same (non-seasonal) classification for 3 years, and the geometric mean of the results falls within a certain range it is recommended that the sampling frequency be decreased from monthly to bimonthly. This is not appropriate for this production area as it has held seasonal classifications within the last three years.

12. Designated Water Data

Shellfish Waters

The production area at Fairlie coincides with the designated Shellfish Growing Water of the same name. It was designated in 2002, and monitoring began in the Q4 of that year. The sampling point is at NS 2061 5467. Monitoring results for faecal coliforms in mussels through Q1 2007 were provided by SEPA and are presented in Table 12.1. Since 2007, SEPA have obtained shellfish classification monitoring results (*E. coli*) under an agreement with FSAS for the purposes of SGW monitoring. Those results have been used in the analysis in Section 11 of this report and so are not repeated here.

The extent of the area and the location of the relevant monitoring points are shown on Figure 12.1.

Figure 12.1 Map of Fairlie Shellfish Growing Water

Table 12.1 SEPA monitoring for shore mussels gathered from Fairlie

Year	Quarter	Faecal coliform results (FC/100g)
		NS 2061 5467
2002	Q4	<20*
2003	Q1	140
	Q2	-
	Q3	5400
	Q4	11000
2004	Q1	750
	Q2	220
	Q3	320
	Q4	2400
2005	Q1	160
	Q2	70
	Q3	40
	Q4	220
2006	Q1	1200
	Q2	40
	Q3	>18000**
	Q4	16000
2007	Q1	310

* Assigned a nominal value of 10 for calculation of the geometric mean
** Assigned a nominal value of 36000 for calculation of the geometric mean

All samples were collected from the same location. The geometric mean result for all samples is 500 FC/100 g. Results ranged from <20 to >18000 faecal coliforms/100 g indicating large fluctuations in microbial contamination at this monitoring point, with highest results usually occurring in Q3 and Q4.

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. Consequentially, the results presented in Table 12.1 are not directly comparable with the other shellfish testing results presented in this report.

The overall level of contamination observed in shore mussels taken from the SEPA monitoring point indicate episodically high levels of contamination are present in the vicinity.

Bathing Waters

Largs (Pencil Beach) is a designated bathing water under the EU Bathing Water Directive (76/160/EEC). It lies approximately 3 km northeast of the oyster trestles. Although it has been monitored by SEPA since 2000, it was first formally designated as bathing water in 2006. The monitoring point for this area is NS 209 577. Under the bathing waters programme, water samples are taken throughout the summer bathing season and tested for a variety of water quality parameters, including faecal coliforms. The mandatory standard for faecal coliforms at bathing beaches is <2000 cfu/100 ml in 95% of samples. A tighter guideline standard is set at <100 cfu/100 ml in 80% of

samples. Largs has complied with the mandatory standard in all years except 2002, when it failed to meet the mandatory standard. However, it was noted in the 2009 Bathing Water Report that one sample result taken after very heavy rainfall exceeded the mandatory standard for faecal coliforms (Scottish Environment Protection Agency 2009). An improvement plan produced in 2008 () identified that sewage discharges had a significant impact on the bathing water and assessed that the beach posed a medium risk of failure for the 2008 season.

An EU report on the equivalence of monitoring results in shellfish flesh and water samples identified that in Pacific oysters, the predicted geometric mean *E. coli* concentration in water required for Class A compliance in shellfish (required for direct live sale) was 3 cfu/100 ml. Compliance with Class B was predicted with a geometric mean of 585.9 cfu/100 ml (EU Scientific Veterinary Committee Working Group on Faecal Coliforms in Shellfish 1996). Therefore, compliance with only the bathing waters mandatory standard is unlikely to result in compliance with Class A in bivalve molluscs.

13. River Flow

There are no gauging stations on burns or streams along the Fairlie coastline.

The burns and streams listed in Table 13.1 were measured and sampled during the shoreline survey. The locations are shown on the map presented in Figure 13.1. These watercourses were deemed to represent the potentially most significant freshwater inputs into the survey area in the vicinity of the shellfisheries. Other dry, or slightly flowing, culvert and possible land drains were seen during the shorelines survey: these are included in Table 1 of the shoreline survey report. The weather was dry at the time of the survey but there had been significant rain in the preceding two days.

Table 13.1 Stream loadings at Fairlie

No	Grid Reference	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	NS 2089 5765	Coalpit Burn	1.9	0.08	0.902	11800	600	$7.1x10^{10}$
2	NS 2096 5661	Kel Burn	5.5	0.15	0.044	3140	6400	$2.0x10^{11}$
3	NS 2084 5579	Keppen Burn	0.95	0.15	0.243	2990	280	$8.4x10^{9}$
4	NS 2091 5535	Stream	0.95	0.03	0.094	230	530	$1.2x10^{9}$
5	NS 2070 5463	Fairlie Burn	5.7	0.16	0.133	10500	600	$6.3x10^{10}$
6	NS 2075 5411	Stream	2.2	0.17	0.403	13000	1700	$2.2x10^{11}$
7	NS 1964 5231	Burn Gill	2.8	0.17	0.31	12700	1000	$1.3x10^{11}$
8	NS 1978 5299	Stream[1]	0.8	0.02	0.129	178	>10000	$>1.8x10^{10}$

Note: Outfall marked at this location on the OS 1:10000 map

A flowing pipe that could have been a land drain was also measured and sampled. However, this only yielded an *E. coli* result of 10 cfu/100 ml and a calculated loading of $6.2x10^{5}$ *E. coli*/day.

All streams had moderate to high loadings of *E. coli*. This is likely to have been due in part to the rainfall on the days preceding the survey. Streams 5 and 6 had relatively high loadings and discharge in the immediate vicinity of the trestles: these are likely to affect the microbiological quality of the oysters. Streams 3 and 4 are further north and had lower loadings, but may also contribute to the *E. coli* levels at the fishery. The actual loading for stream 8 could not be calculated due to the E. coli concentration exceeding the upper limit of detection for the test used. The fishery may be protected from the impact from the effects of this and some of the other watercourses due to the physical barriers presented by the constructions and jetties projecting from the shore.

The microbiological loadings from the watercourses would be expected to be lower after periods of dry weather.

Figure 13.1 Map of stream loadings at Fairlie

14. Bathymetry and Hydrodynamics

The OS map and Hydrographic Chart for the area are shown in Figures 14.1 and 14.2 respectively.

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Figure 14.1 OS map of Fairlie
Figure 14.2 Bathymetry at Fairlie

Fairlie is located on the mainland coast of Hunterston Channel (Fairlie Roads; note the location of Fairlie Roads differs between the OS map and the UKHO chart) which itself lies between the mainland and the island of Great Cumbrae. Depths in the main channel exceed 40 m. There are extensive drying areas on the eastern shore in the vicinity of Hunterston and Fairlie. From the edge of the drying area, the seabed shelves steeply towards the main channel. There are a number of jetties and constructions which project into the sea and which will create a barrier to currents that would otherwise flow parallel to the shore. The oyster trestles are located on the north side of the construction at the landward end of Hunterston Jetty.

The chart notes that the discharge of hot water from Hunterston Power Station Outfalls causes considerable turbulence off Little Brigurd Point. It is not expected that the effects of the turbulence, or any impact of the

temperature on microbes, will be significant in terms of the present assessment.

14.1 Tidal Curve and Description

The two tidal curves below are for Millport, approximately 3 km south of the oyster farm. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 24/08/10 and the second is for seven days beginning 00.00 BST on 31/08/10. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle, including the dates of the shoreline survey.

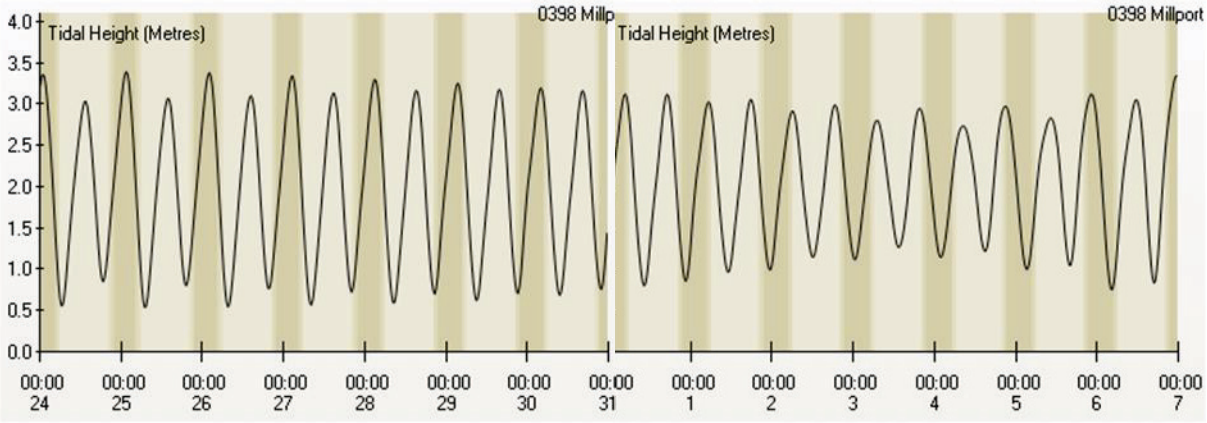

Figure 14.3 Tidal curves for Millport

The following is the summary description for Millport from TotalTide:
0398 Millport is a Secondary Harmonic port.
The tide type is Semi-Diurnal.

HAT	3.9 m
MHWS	3.4 m
MHWN	2.7 m
MSL	1.99 m
MLWN	1.0 m
MLWS	0.4 m
LAT	-0.1 m

Predicted heights are in metres above Chart Datum. The tidal range at spring tide is 3.0 m, and at neap tide 1.7 m, and so tidal ranges in the area are moderate.

14.2 Currents

Tidal stream information was available for a station in Hunterston Channel between the mainland and Great Cumbrae. The location of this station, together with the tidal streams for peak flood and ebb tide, are presented in Figures 14.4 and 14.5, and the tidal diamond is presented in Table 14.1.

Figure 14.4 Spring tidal flows in Fairlie Roads

Table 14.1 Tidal streams for station SN040E (55°44.60'N 4°54.07'W) (TotalTide)

Time	Direction	Spring rate (m/s)	Neap rate (m/s)
-06h	052°	0.41	0.26
-05h	048°	0.57	0.36
-04h	044°	0.51	0.31
-03h	052°	0.41	0.31
-02h	053°	0.41	0.26
-01h	050°	0.31	0.21
HW	035°	0.05	0.05
+01h	231°	0.31	0.21
+02h	237°	0.67	0.41
+03h	229°	0.72	0.46
+04h	229°	0.67	0.41
+05h	230°	0.41	0.26
+06h	119°	0.31	0.21

From Figures 14.1 and 14.2, and Table 14.1, the tidal currents flow directly up and down the main Hunterston Channel, flowing north-easterly on the flood tide and south-westerly on the ebb tide. The peak spring flow, at approximately 0.7 m/s (1.4 knots), is not fast for such a narrow channel. The currents will be modified by the various obstructions projecting from shore. On the flood tide, the landward end of the causeway south of the oyster farm will

cause the currents to bend around from the main channel over the south end of Fairlie Sands while on the ebb tide, water from the northern end of the sands will curve round towards the main channel. Water will flow under the outer portions of the conveyor where it is on pilings and this may moderate flows somewhat on the down current side. The Clyde Club Cruising Guide identifies that the channel at Largs is "exposed to winds from the north through west to south" (Clyde Cruising Club, 2004). These winds will therefore potentially modify the surface currents: in particular, a westerly wind will tend to accentuate high tide over Fairlie Sands. Winds from the north may also accentuate high tide over the oyster farm.

14.3 Ayrshire Multi-fuelled Power Station Assessments

There are plans to build a multi-fuel power station at Hunterston. A number of studies contributed to the planning application (http://www.ayrshirepower.co.uk/planning-application) submitted in June 2010. The application contains a number of elements relevant to the consideration of the movement and fate of microbial contaminants. A coastal and marine model was setup and run by EnviroCentre Ltd using Mike21 software. The example model outputs in the technical appendix to the planning application shows that the tide fills in over the area of the oyster trestles between two and one hours before high tide and recedes from the trestles between three and four hours after high tide. The modelling shows that during operation of the proposed plant, temperatures at the outer edge of Fairlie Sands, including over the oyster trestles, will be approximately 1°C warmer than background at certain states of tide. The latter results would imply that temperature effects from the current power station outfall could also be seen at the oyster farm. Seawater salinities measured off the ore terminal at Southannan Sands (the nearest of monitoring sites to the oyster farm) were between 25 and 35 ppt, with the value varying with date. In general, the salinity of water within the sediment in the area was between 5 and 15 ppt. However, on some monitoring dates, and more often at some locations than others, the measured salinities in the sediment reached those of the overlying seawater: this effect was seen off the Ore Terminal. The seawater salinity results compare well to those obtained from shore sampling during the shoreline survey where results ranged from 17.6 to 35.6 ppt.

14.4 Conclusions

Contamination arising from south of Hunterston Jetty and north of Fairlie Quay will tend to be taken into the main channel due to the various obstructions projecting from the eastern shore. They will therefore be subject to significant dilution. Contamination arising from sources at, or near the shore between those two points will be subject to much less dilution in the shallower water within the embayment (when the drying area is covered). The direction of the currents around the landward end of the jetty and within the embayment will mean that, for all but any sources immediately in the area of the oyster farm, the north-western end of the trestles will be impacted by contamination to a greater extent than the rest of the farm. Salinity data indicates that significant localised impact of freshwater in the intertidal area.

15. Shoreline Survey Overview

The shoreline survey was undertaken on 24-25 August under calm conditions, though significant rain was reported to have fallen in the two days prior to survey.

The boundaries of the Pacific oyster farm were recorded to at least 10 m accuracy using a hand-held GPS. Juvenile oysters are bought in and grown in bags on trestles on or near the intertidal shore. At the time of survey, the site was being renovated and therefore exact layout may change from that recorded.

The outfall from the sewage treatment works at Fairlie was not visible at the time of survey. The pipeline between the town and the sewage works was observed to run along the shoreline below the high water mark. A small sewage leak was observed at one location along the pipeline and some of the manhole covers were observed to be slightly damaged, but not leaking. Sanitary-related debris was recorded at several locations along the shore of Fairlie and Southannan Sands.

There is a deepwater port immediately adjacent to the oyster site which handles bulk movements of coal. Large vessels of the type used for this type of transport are not permitted to discharge sewage waste to inshore waters. However, they may discharge either effluent or sludge to onshore facilities. The ore terminal pier immediately south of the oyster farm is on pilings, allowing the flow of water underneath it.

There are numerous hotels and B&Bs in the area and a large marina (700 berths) with restaurants, bars, and a spa at the northern end of Fairlie. At the time of survey, a large number of these berths were occupied, principally by yachts and cruisers of a size which would be likely to have onboard toilets.

There is a boatyard to the south of the marina and an area of swinging moorings at the southern end of Fairlie, where about 60 yachts were observed.

A small flock of sheep (30 animals) was observed in a field near the yacht marina. Areas of pasture interspersed with woodland were observed above the town of Fairlie, however no livestock were seen on these areas. The oyster site is located within a large industrial port. The Hunterston Nuclear Power Station is located to the south.

A large number of gulls and other water birds were observed, with the largest concentrations at the south end of Fairlie and at Southannan Sands. Most were gulls and wading birds.

Levels of *E. coli* found in watercourses draining into the survey area were found to be low to moderate in general, though one small stream draining from the Clydeport terminal to Southannan Sands was found to be highly

contaminated (>10000 *E. coli* cfu/100 ml). Seawater samples taken from the northern end of Fairlie showed higher levels of faecal contamination (280 to 2900 *E. coli* cfu/100 ml) than those taken from near the oyster farm and further south (<10 to 30 *E. coli* cfu/100 ml).

Four oyster samples contained from 230 to 790 *E. coli* MPN/100 g, with highest results from the eastern and northern corners of the site.

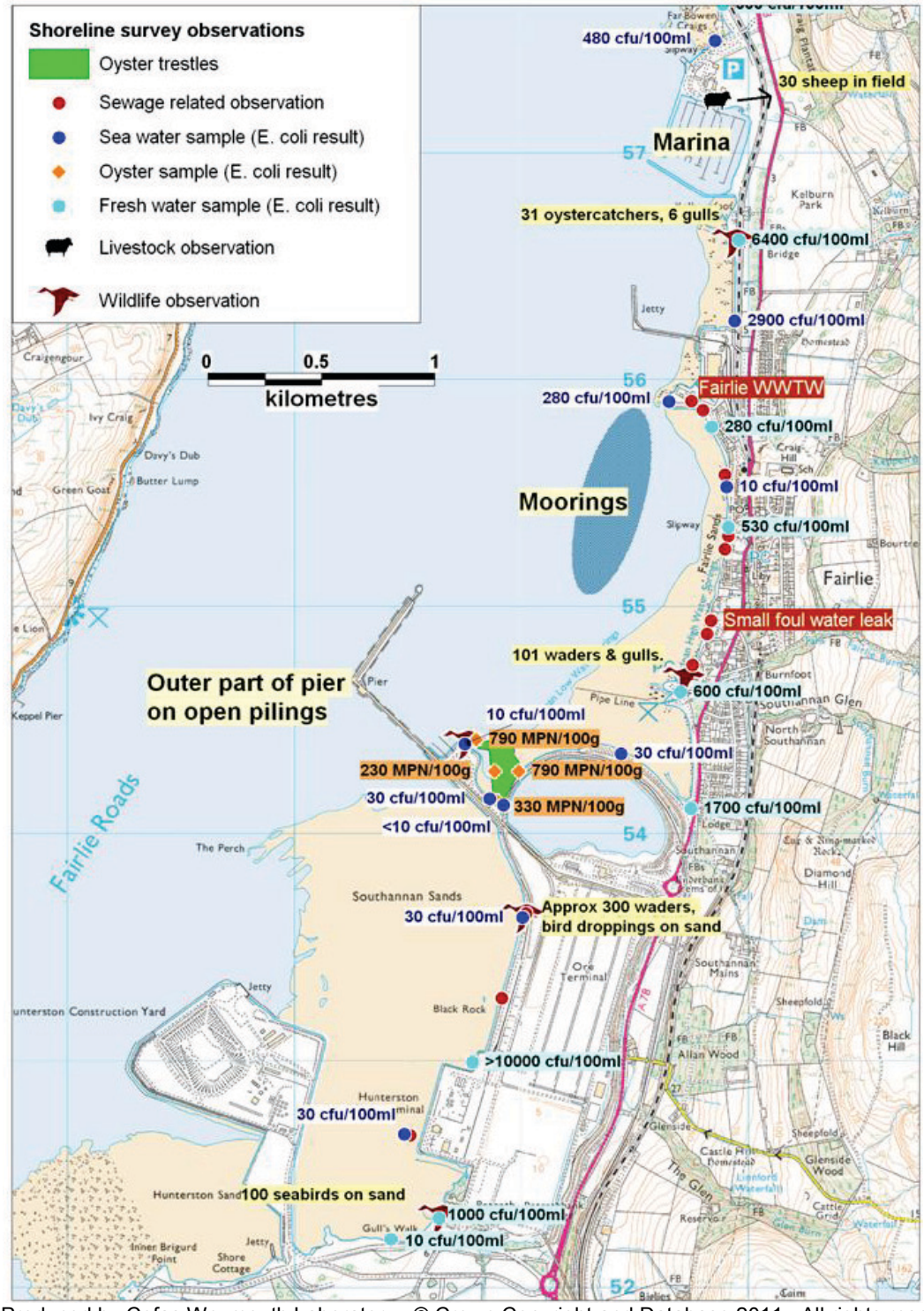

Figure 15.1 Summary of shoreline survey findings for Fairlie

16. Overall Assessment

Human sewage impacts

There is a substantial human population in the Fairlie area, the majority of which is served by Scottish Water treatment works at Fairlie and Largs. The final effluent discharged from the Fairlie works enters the firth of Clyde approximately 1.7 km north of the oyster farm and one of the associated overflows discharges within 500 m of the fishery. Industrial discharges with septic content also affect waters in the area, with the closest of these identified approximately 200m west of the northern end of the oyster trestles.

A large marina is located to the north of Fairlie and though it provides pumpout service for yachts with holding tanks, and users are encouraged to make use of toilet facilities on shore, yachts without holding tanks may discharge sewage overboard in or around the marina. Discharges from yachts, particularly those moored off Fairlie, would be likely to affect water quality in the area primarily in summer.

Whilst the volume of discharge from the Fairlie treatment works may be higher in summer due to higher summer occupancy of hotels and B&Bs in the area, industrial discharges to the area are likely to be more consistent year round. SEPA identified that sewage discharges had a significant impact on bathing waters monitoring results at the Largs beach, and that high results tended to follow heavy rainfall which may cause CSOs to discharge.

Given the proximity of both continuous and intermittent sewage discharges to the oyster farm at Fairlie, it is likely that sewage discharges will have a significant impact on water quality. It is also likely that impact of intermittent discharges from the CSOs in the area will not be adequately represented in a monthly monitoring regime at this site.

There is likely to be an increase in human population and activity in the area during the summer months, as well as higher rainfall during the late summer and early autumn, both of which would be considered likely to increase pollution levels in area waters. However, the historical monitoring results run counter to this trend, peaking during the winter months. Bacteria are likely to survive longer in winter, when cooler temperatures and lower levels of UV light provide favourable conditions for survival (REF) and possibly this is leading to the higher winter results observed at this site. Sewage discharges from the resident population at Fairlie and from the industrial operations nearer to the oyster farm are more likely to be stable year-round and may represent a greater proportion of the overall level of contaminants entering fishery waters, therefore permitting survivability to become a more important predictor of faecal indicator concentrations in shellfish.

Agricultural impacts

Few farms and livestock were recorded in the area, with only 30 sheep observed during the shoreline survey. The sheep were observed on a field near the marina, and the Kelburn equestrian centre is also located to the southeast of the marina. A water sample taken from Kelburn during the shoreline survey was found to contain a relatively high concentration of *E. coli* (6400 cfu/100 ml), indicating that it may be subject to diffuse pollution from the stables upstream. Faecal contamination from livestock is anticipated to contribute to background levels of contamination entering the sea north of the fishery and this may be carried toward the trestles on the southbound (ebb) tide.

Wildlife impacts

A significant number of wading birds and seabirds are present in the area for at least part of the year. Summer surveys of breeding birds identified a gull colony immediately west of the oyster farm and further breeding sites around the lagoon adjacent the southern end of the oyster farm. Large numbers of wading birds and seabirds were observed on Southannan sands and Fairlie sands, with a smaller number observed south of the marina at Largs. The official control sampling officer noted bird activity observed at the fishery on some summer sampling occasions, indicating that birds may be more active around the site during the summer breeding season.

Seasonal variation

Seasonal variation was observed in historical sampling results, with higher *E. coli* results seen during the winter months. Seasonal increases in human population and seabird populations are likely to occur in summer, which is counter to the trend observed in monitoring results. The most significant source of faecal contamination to the area is human sewage from both continuous and storm-related discharges. Daily rainfall was observed on average to be higher from August to January, though individual daily rainfall amounts in excess of 20 mm occurred during most months of the year in the data set considered. Interrelationships between different seasonal factors may complicate the seasonal pattern in results, making it difficult to predict seasonal variation.

Rivers and streams

A total of eight significant watercourses were observed and measured during the shoreline survey. Sample results and flow measurements taken on the day showed these watercourses contributing a calculated total of approximately 55000 m^3 of freshwater with a combined loading of 7.1×10^{11} *E.coli* per day at the time of survey. Three of the watercourses contributed 77% of the total loading: Kel Burn, Burn Gill, and an unnamed watercourse discharging approximately 800 m southeast of the oyster farm. Two of these, Kel Burn and Burn Gill, are situated over 2.5 km north and south of the oyster farm, respectively and man-made obstructions lie between the discharge points and the fishery. These obstructions may constrain flow toward the fishery, and so these burns may be less likely to have a large impact on water

quality at the fishery. Fairlie Burn, though it had a lower loading at the time of survey, discharges within 800 m of the oyster farm and so there will be less opportunity for dilution of the flow before reaching the fishery. Therefore, the unnamed burn and Fairlie Burn are most likely to affect water quality at or near the oyster farm.

Movement of contaminants

The direction of tidal flow is along the channel at Fairlie Roads and generally north or northeasterly on the flood tide and south or southwesterly on the ebb, with the ebb flow slightly stronger. Tidal currents are relatively weak with a peak spring rate of only 0.8 m/s. Current movements closer to the shore will be significantly affected by constructed piers and jetties and wind, and so are difficult to predict. Modelling studies undertaken on discharges of cooling water from the nuclear generating station suggest that water temperatures at the fishery may be elevated by up to 1ºC, thereby suggesting significant northward flow of discharged water. This may result in higher feeding rates and consequently greater uptake of contaminants than in colder waters outside this area of influence. It should likewise be presumed that other discharges to the shoreline north of the nuclear facility would also reach the fishery, albeit in a diluted state.

Contaminants arising from the shoreline between the ore terminal jetty and Fairlie jetty to the north are likely to be subject to much less dilution than those from further south or north and so will be of greater concern to water quality at the oyster farm. For all sources but those immediately adjacent to the oyster farm (for example the gull colony), the movement of currents around the end of the solid jetty at the ore terminal and within the embayment north of it will mean that the northwestern end of the trestles will be impacted more greatly than the rest of the farm.

Temporal and geographical patterns of sampling results

Analysis of historical monitoring data back to 2002 did not suggest any clear geographic trends in contamination around the fishery. Samples were taken from locations toward the centre of the farm, primarily. The highest result obtained to date was taken slightly further east than the bulk of the samples, however it is not clear whether this would have been due to a temporal rather than a geographic effect.

No clear trend in results over time were observed, though the high result obtained in November 2010 was the first result greater than 1000 *E. coli* MPN/100 g since 2004. Although this result is exceptional when compared with the monitoring history, it is likely that the monitoring history does not adequately reflect the risk to the fishery from short term contamination events related to combined sewer overflows in the vicinity.

Seasonal variation in results was observed, with results in winter higher than those in spring and summer. Analysis of results by month showed that

lowest results (<20 MPN/100 g) were confined to May, July and August while results greater than 230 MPN/100 g occurred during all months but May.

Conclusions

The oyster farm at Fairlie is subject to contamination from nearby point and diffuse sources of faecal contamination, most notably the Fairlie WWTW final effluent and CSO discharges, Fairlie Burn and the unnamed watercourse on the eastern side of the ore terminal lagoon (aka Hunterston Lagoon), as well as from the gull colony on land immediately adjacent to the terminal. Each of these sources is likely to have a slightly different seasonal variation based on population presence and activity and rainfall. The CSOs are most likely to overflow in response to heavy rainfall and this may occur at any time of year, although the wettest months overall are November to January.

In addition to the most immediate sources, there are further sewage discharges both to the south and north of the fishery, as well as effluent from the Hunterston Nuclear Power Station, which is predicted to cause a moderate increase in seawater temperature at the fishery though the effect of this, if any, on the bacteriological quality of the oysters is not known.

There are significant numbers of both wading birds and seabirds in the area, with a gull colony on land immediately adjacent to the area of trestles.

Current speeds in the Fairlie Roads channel are not particularly high, and a number of man-made structures on the shoreline are likely to further affect the flow of water along the coast in the area therefore contaminants arising from the shoreline east of the fishery may not dilute sufficiently prior to passing over the shellfish.

Given the close proximity of a CSO discharge, it is likely that the monthly sampling regime does not adequately reflect the risk from short term contamination events and so is not sufficiently protective of public health.

The incidence of high *E. coli* results in the winter is of marked significance at the site given the expected impact from human sewage and the shellfish species involved: they may indicate a risk from contamination by norovirus during the winter months. Results of quarterly norovirus sampling to date are shown in Appendix 9.

17. Recommendations

Production area

Much of the area around Fairlie Sands is subject to contamination from sewage sources and so would not be appropriate for cultivation of oysters, which are frequently consumed raw. Therefore, it is recommended that the production area boundaries be curtailed to exclude as much as possible areas nearer to the CSO and stream sources arising from the Fairlie shore. Therefore, it is recommended that the production area be amended to the area bounded by lines drawn between NS 1973 5441 to NS 2000 5446 to NS 2000 5428 extending to MHWS.

RMP

It is recommended that the RMP be relocated to reflect likely higher levels of contamination coming from north and east of the fishery. However, it is recognised that the monitoring point must be accessible to facilitate sampling at least monthly. The recommended RMP is NS 1997 5437.

Frequency

Normally, monthly sampling would be recommended for this type of site. However, it should be noted that given the proximity of an intermittent untreated sewage discharge to the fishery, monthly sampling may not necessarily reflect the risk from sewage overflows. Higher *E. coli* results, indicative of higher levels of faecal contamination, have historically been found to occur from November to January. Therefore, the increased risk from pathogens may warrant increased sampling frequency during these months.

Tolerance

Sampling tolerance is recommended to be 20 metres in order to allow for variation in low tides. It is recommended that a dedicated sampling bag be placed at the location for sampling use in order to ensure that mature stock is available for sampling. Stock must be in place for a minimum of two weeks prior to sampling to ensure that it equilibrates to the local water quality.

Figure 17.1 Map of recommendations at Fairlie

18. Acknowledgements

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Sampling Plan for Fairlie

PRODUCTION AREA	Fairlie
SITE NAME	Southannan Sands
SIN	NA 065 332 13
SPECIES	Pacific oyster
TYPE OF FISHERY	Trestle aquaculture
NGR OF RMP	NS 1997 5437
EAST	219970
NORTH	654370
TOLERANCE (M)	20
DEPTH (M)	Not applicable
METHOD OF SAMPLING	Hand
FREQUENCY OF SAMPLING	Monthly*
LOCAL AUTHORITY	North Ayrshire Council
AUTHORISED SAMPLER(S)	William Murray
LOCAL AUTHORITY LIAISON OFFICER	William Murray

* Due to an increased risk of contamination with pathogens during November to January, an increase in sampling frequency during these months should be considered.

Table of Proposed Boundaries and RMPs

PRODUCTION AREA	**Fairlie**
SPECIES	**Pacific oyster**
SIN	**NA 065 332 13**
EXISTING BOUNDARY	**Area bounded by lines drawn between NS 2083 5500 and NS 1974 5442 and between NS 2063 5465 and NS 2040 5438**
EXISTING RMP	**NS 1980 5420**
RECOMMENDED BOUNDARY	**Area bounded by lines drawn between NS 1973 5441 to NS 2000 5446 to NS 2000 5428 extending to MHWS**
RECOMMENDED RMP	**NS 1997 5437**
COMMENTS	**Boundary amended to eliminate more contaminated areas to the northeast - RMP relocated to eastern side of the fishery near MLWS**

Geology and Soils Assessment

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 droppings in particular are known to contain human pathogenic bacteria such as *Salmonella* and *Campylobacter* as some species commonly feed around refuse tips and sewage works. The prevalence of *Salmonella* spp in herring gulls was found to be 10 times higher in birds obtained from the Clyde area than those from a less populated area in North East Scotland (Girdwood *et al.* 1985). Carriage rates in the Clyde birds were found to be highest from August to November, during which time between

13% and 30% of birds were found to be carrying Salmonella, depending on the month. Although direct transmission from birds to humans is not thought likely under most circumstances, there is a strong possibility that shellfish may concentrate any pathogens present in seawater contaminated with significant amounts of gull faeces.

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.

References:

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

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

Lisle, J.T., Smith, J.J., Edwards, D.D., andd McFeters, G.A. (2004). Occurrence of microbial indicators and *Clostridium perfringens* in wastewater, water column samples, sediments, drinking water and Weddell Seal feces collected at McMurdo Station, Antarctica. *Applied and Environmental Microbiology*, 70:7269-7276.

Scottish Natural Heritage. http://www.snh.org.uk/publications/on-line/wildlife/otters/biology.asp. Accessed October 2007.

Tables of Typical Faecal Bacteria Concentrations

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

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

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

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

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

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

Statistical Data

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

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

```
Source  DF      SS     MS     F      P
Season   3   4.153  1.384  5.70  0.002
Error   68  16.528  0.243
Total   71  20.681

S = 0.4930   R-Sq = 20.08%   R-Sq(adj) = 16.56%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  ----+---------+---------+---------+-----
1      22  1.9044  0.4994  (------*------)
2      20  2.0706  0.6105        (------*------)
3      16  2.3090  0.3879               (-------*-------)
4      14  2.5569  0.3874                      (--------*--------)
                          ----+---------+---------+---------+-----
                            1.80      2.10      2.40      2.70

Pooled StDev = 0.4930


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

Individual confidence level = 98.95%


Season = 1 subtracted from:

Season    Lower  Center   Upper  ------+---------+---------+---------+---
2       -0.2345  0.1662  0.5669              (------*-----)
3       -0.0215  0.4046  0.8307                 (------*------)
4        0.2091  0.6524  1.0958                    (-------*------)
                         ------+---------+---------+---------+---
                            -0.60      0.00      0.60      1.20


Season = 2 subtracted from:

Season    Lower  Center   Upper  ------+---------+---------+---------+---
3       -0.1966  0.2384  0.6733              (------*------)
4        0.0343  0.4862  0.9381                  (------*-------)
                         ------+---------+---------+---------+---
                            -0.60      0.00      0.60      1.20


Season = 3 subtracted from:

Season    Lower  Center   Upper  ------+---------+---------+---------+---
4       -0.2267  0.2479  0.7225             (-------*-------)
                         ------+---------+---------+---------+---
                            -0.60      0.00      0.60      1.20
```

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 2 day rainfall

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.125
```
n=61, p>0.10

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 7 day rainfall

Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.328
n=61, p<0.01

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 20 April 2010 12:12:34

Variables (& observations)	r	p
Angles & Linear (72)	0.172	0.129

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 20 April 2010 12:13:40

Variables (& observations)	r	p
Angles & Linear (72)	0.107	0.455

Section 11.6.3 Spearman's rank correlation for *E. coli* result and water temperature

Pearson correlation of ranked temperature and ranked E coli for temperature =-0.286
n=64, p<0.025

Section 11.6.5 Spearman's rank correlation for *E. coli* result and salinity

Pearson correlation of ranked e coli for salinity and ranked salinity = -0.122
n=59, p>0.10

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.

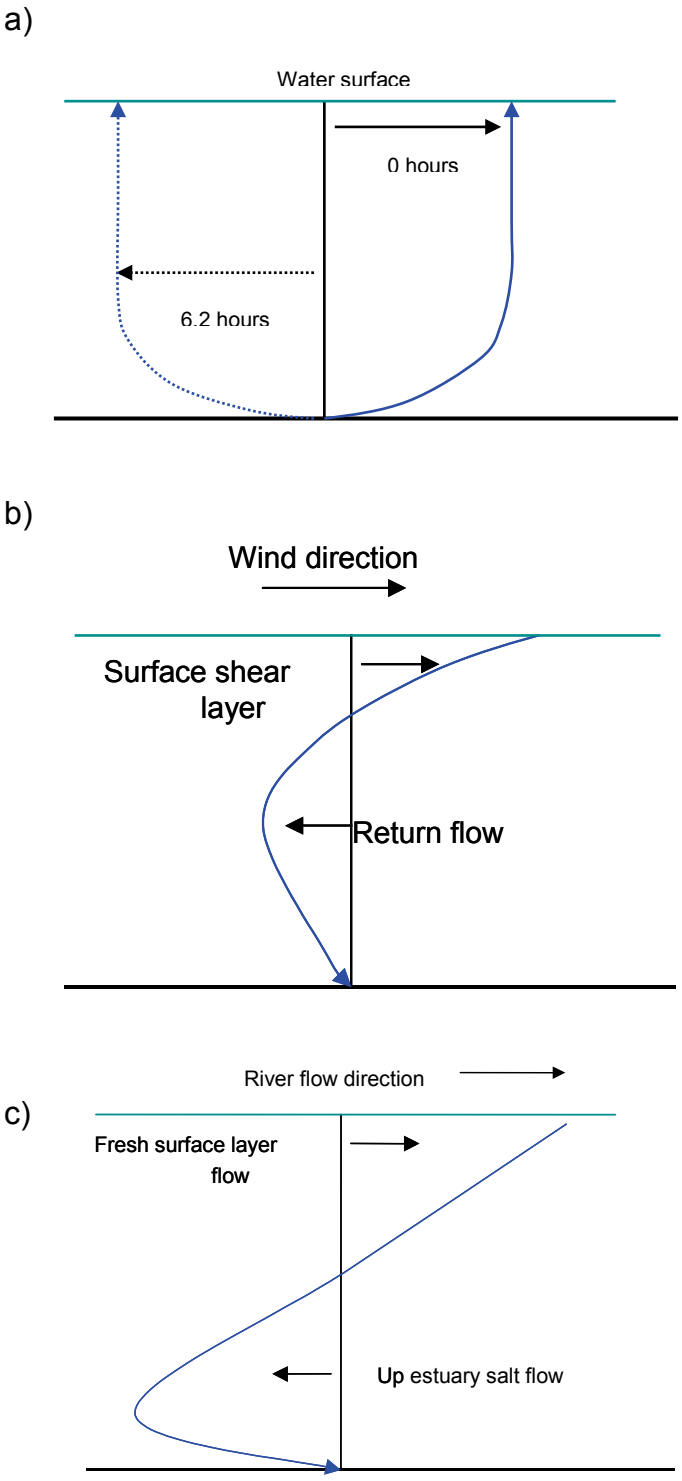


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

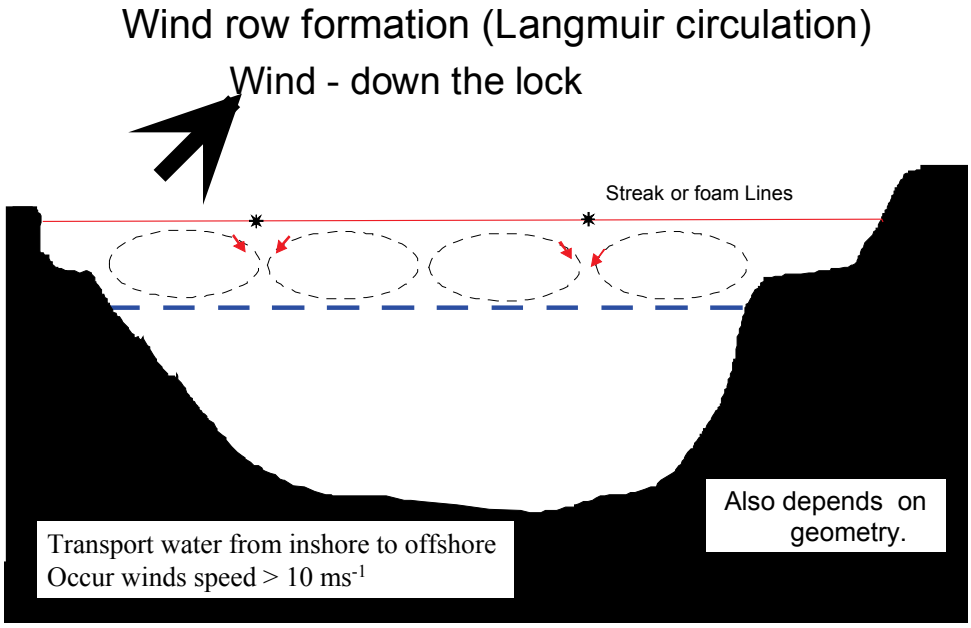


Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

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

Production Area:

Production Area	Site	SIN	Species
Fairlie	Southannan Sands	NA 065 662 13	Pacific Oysters

Harvester: Cumbrae Oysters
Status: Existing site
Date Surveyed: 24 & 25 August 2005
Surveyed by: William Murray & Alastair Cook
Area Surveyed: See Figure 1.

Monitoring Points:

Site	Nominal RMP	Sampling Point
Southannan Sands	NS 198 542	NS 1988 5423

Weather Observations

24/08/2010 Showers, light westerly breeze, air temperature 15°C.
25/08/2010 Cloudy, very light westerly breeze, air temperature 14°C, water temperature 14°C.
Significant rain had fallen in the two days prior to the survey.

Specific observations made on site are mapped in Figure 1 and listed in Table 1. Water and shellfish samples were collected at sites marked on Figures 2 and 3. Bacteriology results are given in Tables 2 and 3. Photographs are presented in Figures 4-13.

Fishery

The fishery is an oyster trestle fishery. Juvenile Pacific oysters are bought in and grown on to market size, a process which takes around 3 years. Harvest may occur at any time of the year. There was little in the way of mature stock on the site at the time of survey but larger amounts of juvenile stock. The site is currently being renovated so the exact layout is likely to change. The company has depuration facilities near West Kilbride. To maintain regular supplies to their customers, oysters are bought in from a grower in Poole Harbour, depurated and sold on without ever being laid at the Fairlie site.

Sewage/Faecal Sources

Human – The town of Fairlie lies to the north of the site. This is served by a sewage treatment works at the northern end of the town the outfall of which is somewhere offshore from the works but was not visible at the time of survey. Running along the Fairlie shoreline below the high water mark is the sewage pipeline which carries waste water from the town to the treatment works. At the time of survey a small leak of unscreened sewage was observed at one location, and some of the manhole covers were slightly damaged but did not appear to be leaking. Presumably there are some overflow discharges associated with this system, but none was seen during the shoreline walk.

Sanitary debris was recorded at several locations along the Fairlie shore. No sewage discharges were seen to Southannan Sands, but fresh sanitary debris was seen here.

Livestock – A flock of 30 sheep was recorded in a field behind the yacht marina at Fairlie. Behind the town of Fairlie lie areas of pastures interspersed with woodlands but no livestock were seen here.

Significant watercourses draining to the survey area were sampled and measured. Levels of *E. coli* within these watercourses were generally low to moderate, although one small stream draining from the Clydeport terminal to Southannan Sands contained >10000 *E. coli* cfu/100 ml. When the oyster site was visited at low tide a number of what appeared to be streams were issuing from the surrounding rocks. Further investigation revealed that these were seawater carried in by the tide draining from the rocks as the salinity was 35 ppt (water sample F14).

E. coli levels in seawater samples taken from the vicinity of the oyster site and south of it contained relatively low levels of *E. coli* (<10 to 30 cfu/100 ml). Seawater samples taken from the northern end of Fairlie had considerably higher levels of contamination (280 to 2900 *E. coli* cfu/100 ml).

The four oyster samples contained from 230 to 790 *E. coli* MPN/100 g, with highest results at the northern and eastern corners of the site.

Seasonal Population

There are numerous hotels or B&B's in the area and a large marina (Largs Yacht Haven) with restaurants, bars and a spa at the northern end of Fairlie. Other attractions in the area include golf courses and other outdoor activities. It is therefore likely that there are significant increases in population levels in the area during the summer months.

Boats/Shipping

There is a deepwater port (Clydeport Hunterstone) immediately adjacent to the oyster site which handles bulk movements of coal. Large commercial vessels of the type used for the transport of such material are not permitted to discharge to inshore waters.

Fairlie hosts a large yacht marina (Largs Yacht Haven) which has about 700 berths. At the time of survey a large number of these berths were occupied, mainly by liveaboard yachts and cruisers of a size which would be likely to have onboard toilets. It is quite possible that yachts leaving this marina discharge their tanks in the general area. Additionally there is a boat yard to the south of the yacht marina, and an area of swinging moorings extending along the southern end of Fairlie where about 60 yachts were moored at the time.

Land Use

The oyster site is located within a large industrial port. To the north the shore is lined by the town of Fairlie, behind which there is a mixture of woodland and pasture. To the south is another industrial site (Hunterstone Nuclear Power Station). Around the power station there is a mixture of pasture and woodlands.

Wildlife/Birds

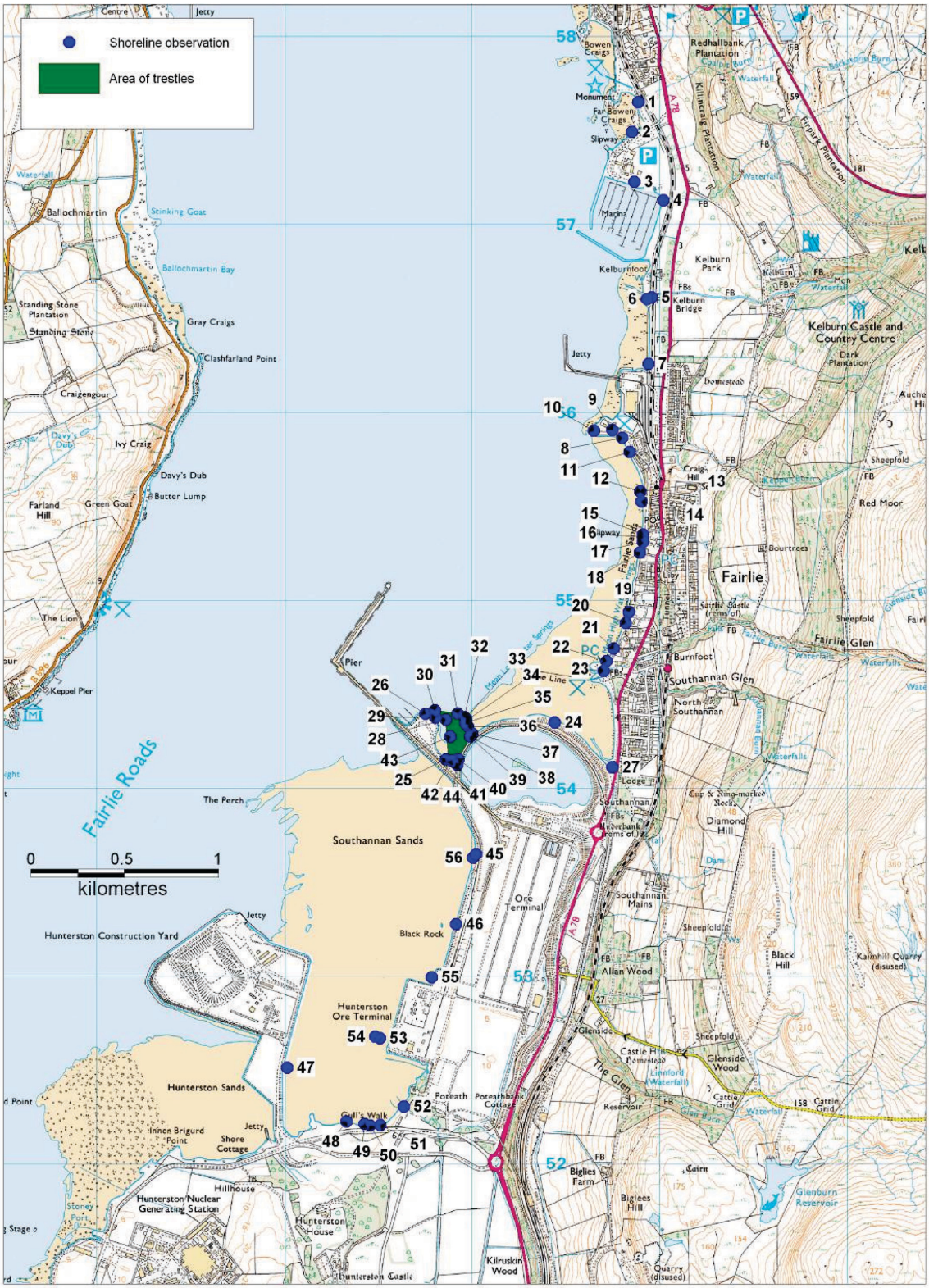
Waterbirds were common along this stretch of coast. Six seagulls and thirty oystercatchers were recorded just south of Largs Yacht Haven. Around 100 waders and gulls were recorded at the south end of Fairlie. Eight ducks were seen at high water in the vicinity of the oyster trestles. A flock of 100 waders and gulls, and a high tide roost with 300 waders and gulls were recorded on Southannan Sands, but it is likely that the former were seen again amongst the latter.

Other observations

Of relevance to the patterns of water circulation in the area, the ore terminal pier immediately adjacent to the fishery is on pilings rather than of solid construction allowing a flow of water underneath it.

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

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



Produced by Cefas Weymouth Laboratory. C

Figure 1. Shoreline Observations

Table 1. Shoreline observations

No.	Description	Position	Photograph	Observation
1	24-AUG-10 9:38:26AM	NS 20886 57653		Stream 190cmx8cmx0.902m/s. Freshwater sample 1. 5 dog walkers in area.
2	24-AUG-10 9:49:34AM	NS 20853 57495	Figure 4	20 cm black plastic pipe, possible surface drain. Seawater sample 2.
3	24-AUG-10 10:01:48AM	NS 20864 57228	Figure 5	Marina 700 berths (Largs Yacht Haven). 30 sheep in field behind.
4	24-AUG-10 10:06:05AM	NS 21019 57131	Figure 6	Small culvert not flowing.
5	24-AUG-10 10:21:38AM	NS 20957 56614		Stream 550cm wide, 15cmx0.043m/s at 1m across, 15cmx0.045m/s at 4m across. Freshwater sample 3.
6	24-AUG-10 10:31:22AM	NS 20931 56604		30 oystercatchers and 6 seagulls.
7	24-AUG-10 10:38:32AM	NS 20940 56260		Seawater sample 4. 2 cotton buds in tideline.
8	24-AUG-10 11:11:48AM	NS 20799 55866	Figure 7	Cotton buds in tideline.
9	24-AUG-10 11:13:40AM	NS 20748 55907	Figure 8	Fairlie WWTW.
10	24-AUG-10 11:16:53AM	NS 20650 55903	Figure 9	Seawater sample 5. About 60 yachts on moorings extending south towards fishery.
11	24-AUG-10 11:23:14AM	NS 20839 55791		Stream 95cmx15cmx0.243m/s. Freshwater sample 6.
12	24-AUG-10 11:33:48AM	NS 20896 55580		Manhole cover on shore.
13	24-AUG-10 11:34:25AM	NS 20897 55581		Manhole cover on shore.
14	24-AUG-10 11:36:15AM	NS 20903 55527		Seawater sample 7.
15	24-AUG-10 11:41:14AM	NS 20911 55351		Stream 95cmx3cmx0.094m/s. Freshwater sample 8.
16	24-AUG-10 11:44:26AM	NS 20910 55336		Manhole cover on shore.
17	24-AUG-10 11:45:35AM	NS 20911 55311	Figure 10	Manhole cover on shore.
18	24-AUG-10 11:47:11AM	NS 20895 55255		Manhole cover on shore.
19	24-AUG-10 11:53:57AM	NS 20836 54939	Figure 11	Small amount of foul water leaking from metal plate.
20	24-AUG-10 11:59:57AM	NS 20818 54880		Manhole cover on beach. Area of moorings end off from here. Dog walkers.
21	24-AUG-10 12:02:39PM	NS 20753 54744		Manhole cover on shore.
22	24-AUG-10 12:04:52PM	NS 20717 54676	Figure 12	100 waders and gulls.
23	24-AUG-10 12:07:25PM	NS 20701 54625		Stream 570cmx16cmx0.133m/s. Freshwater sample 9.
24	24-AUG-10 12:30:19PM	NS 20439 54351		Seawater sample 10.
25	24-AUG-10 1:01:38PM	NS 19860 54153		Seawater sample 11.
26	24-AUG-10 1:21:27PM	NS 19751 54396		Seawater sample 12. 8 ducks on water.
27	25-AUG-10 6:36:00AM	NS 20747 54111		Stream 220cmx17cmx0.403m/s. Freshwater sample 13.
28	25-AUG-10 6:56:46AM	NS 19859 54366		Corner of area of trestles.
29	25-AUG-10 6:57:27AM	NS 19806 54376		Corner of area of trestles.

No.	Description	Position	Photograph	Observation
30	25-AUG-10 6:58:09AM	NS 19801 54416		Corner of area of trestles. Oyster sample 1.
31	25-AUG-10 7:09:32AM	NS 19923 54399		Corner of area of trestles.
32	25-AUG-10 7:10:42AM	NS 19959 54380		Corner of area of trestles.
33	25-AUG-10 7:10:53AM	NS 19967 54371		Corner of area of trestles.
34	25-AUG-10 7:11:13AM	NS 19966 54356		Corner of area of trestles.
35	25-AUG-10 7:11:24AM	NS 19965 54346		Corner of area of trestles.
36	25-AUG-10 7:12:25AM	NS 19978 54330		Corner of area of trestles.
37	25-AUG-10 7:13:00AM	NS 20001 54292		Corner of area of trestles.
38	25-AUG-10 7:13:32AM	NS 19989 54275		Oyster sample 2.
39	25-AUG-10 7:18:20AM	NS 19989 54274		Corner of area of trestles.
40	25-AUG-10 7:28:45AM	NS 19927 54153		Corner of area of trestles.
41	25-AUG-10 7:29:06AM	NS 19912 54133		Corner of area of trestles.
42	25-AUG-10 7:39:37AM	NS 19892 54147		Oyster sample 3.
43	25-AUG-10 8:25:10AM	NS 19882 54276		Oyster sample for norovirus (taken from RMP which was also sampled for classification purposes around this time).
44	25-AUG-10 8:37:07AM	NS 19921 54125	Figure 13	Sample of water (14) draining from rocks on shore, has appearance of stream but salinity by refractometer was 35ppt so was just seawater draining away.
45	25-AUG-10 9:25:33AM	NS 20020 53649		Cotton bud.
46	25-AUG-10 9:32:28AM	NS 19914 53276		Fresh sanitary debris.
47	25-AUG-10 9:52:50AM	NS 19014 52512		3 concrete culverts, not flowing.
48	25-AUG-10 10:04:59AM	NS 19331 52225		50 cm diameter concrete pipe, not flowing. Likely to be land drain.
49	25-AUG-10 10:11:07AM	NS 19426 52213		50 cm diameter concrete pipe, flowing, 15cmx1cmx0.048m/s, freshwater sample 15.
50	25-AUG-10 10:17:30AM	NS 19455 52204		50 cm diameter concrete pipe, trickling.
51	25-AUG-10 10:19:08AM	NS 19511 52206		50 cm diameter concrete pipe, trickling.
52	25-AUG-10 10:22:06AM	NS 19636 52306		Stream 280cmx17cmx0.310m/s. Freshwater sample 16. 100 birds on sand further out.
53	25-AUG-10 10:32:46AM	NS 19509 52670		Sanitary debris.
54	25-AUG-10 10:33:43AM	NS 19484 52677		Seawater sample 17.
55	25-AUG-10 10:43:52AM	NS 19784 52994		Stream 80cmx2cmx0.129m/s. Freshwater sample 18.
56	25-AUG-10 10:56:32AM	NS 20005 53630		Seawater sample 19. High tide roost for about 300 wading birds, lots of bird droppings on sand.

Sampling

Water and shellfish samples were collected at sites marked on the maps in Figures 2 and 3 respectively. Bacteriology results follow in Tables 2 and 3.

Samples of seawater were tested for salinity by the laboratory using a salinity meter under controlled conditions. These results are shown in Table 2, given in units of grams salt per litre of water. Note that this is equivalent to ppt.

Table 2. Water sample *E. coli* results

Sample Ref.	Date and time	Position	Type	*E. coli* (cfu/100 ml)	Salinity (g/L)
F1	24-AUG-10 9:38:26AM	NS 2089 5765	Freshwater	600	
F2	24-AUG-10 9:49:34AM	NS 2085 5750	Seawater	480	17.6
F3	24-AUG-10 10:21:38AM	NS 2096 5661	Freshwater	6400	
F4	24-AUG-10 10:38:32AM	NS 2094 5626	Seawater	2900	24.2
F5	24-AUG-10 11:16:53AM	NS 2065 5590	Seawater	280	32.3
F6	24-AUG-10 11:23:14AM	NS 2084 5579	Freshwater	280	
F7	24-AUG-10 11:36:15AM	NS 2090 5553	Seawater	10	27.8
F8	24-AUG-10 11:41:14AM	NS 2091 5535	Freshwater	530	
F9	24-AUG-10 12:07:25PM	NS 2070 5463	Freshwater	600	
F10	24-AUG-10 12:30:19PM	NS 2044 5435	Seawater	30	35.6
F11	24-AUG-10 1:01:38PM	NS 1986 5415	Seawater	30	34.7
F12	24-AUG-10 1:21:27PM	NS 1975 5440	Seawater	10	35.1
F13	25-AUG-10 6:36:00AM	NS 2075 5411	Freshwater	1700	
F14	25-AUG-10 8:37:07AM	NS 1992 5413	Seawater	<10	35*
F15	25-AUG-10 10:11:07AM	NS 1943 5221	Freshwater	10	
F16	25-AUG-10 10:22:06AM	NS 1964 5231	Freshwater	1000	
F17	25-AUG-10 10:33:43AM	NS 1948 5268	Seawater	30	30.9
F18	25-AUG-10 10:43:52AM	NS 1978 5299	Freshwater	>10000	
F19	25-AUG-10 10:56:32AM	NS 2001 5363	Seawater	30	33.4

* Not measured by lab, tested by refractometer on site.

Table 3. Mussel sample *E. coli* results

Sample Ref.	Date and time	Position	Result (*E. coli* MPN/100 g)
Oyst1	25-AUG-10 6:58:09AM	NS 1980 5442	790
Oyst2	25-AUG-10 7:13:32AM	NS 1999 5428	790
Oyst3	25-AUG-10 7:39:37AM	NS 1989 5415	330
Oyst4*	25-AUG-10 7:16:00AM	NS 1988 5428	230

*Taken by the sampling officer as a classification sample during the same visit.

Figure 2. Water sample results

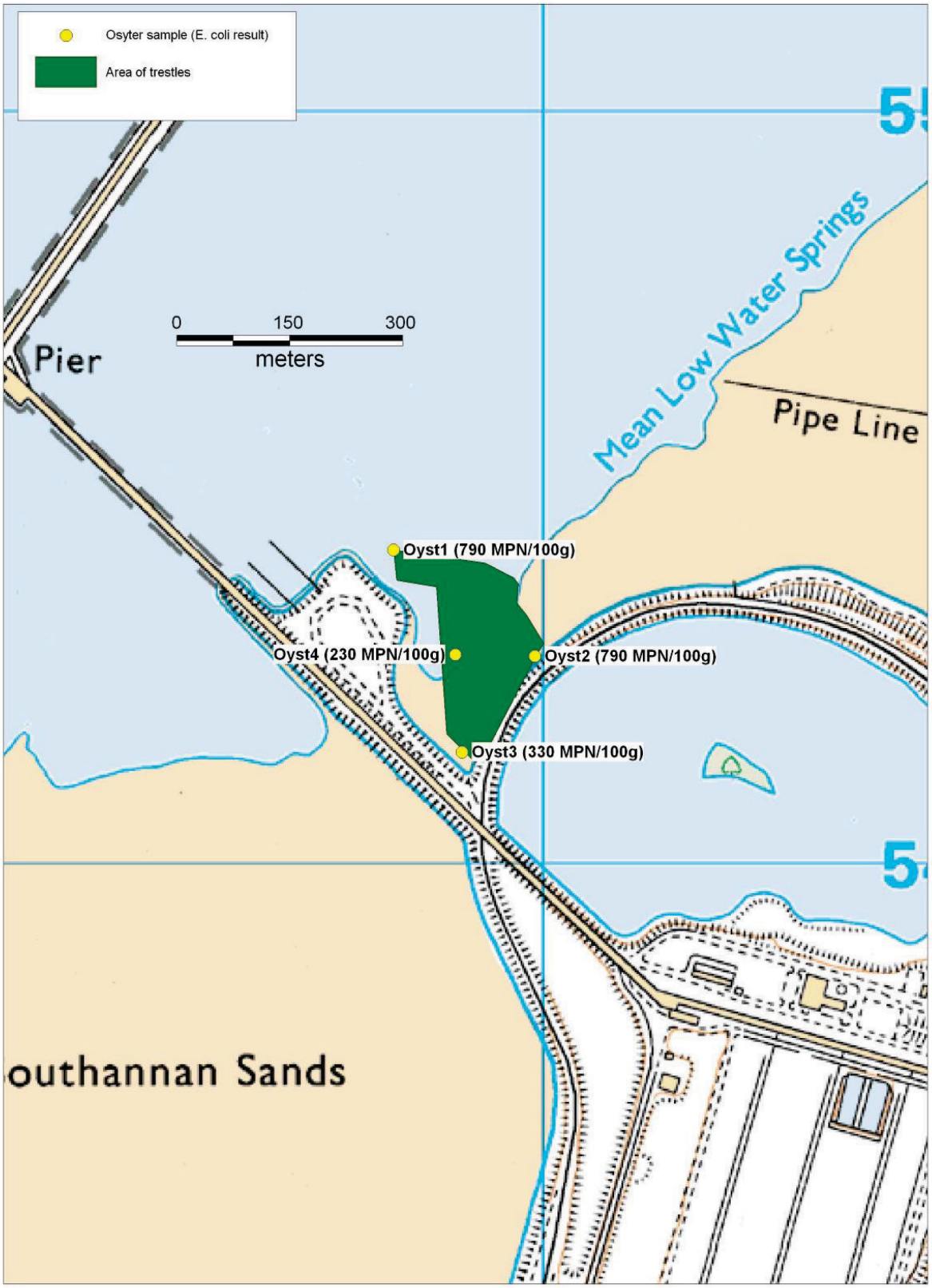


Figure 3. Shellfish sample results

Photographs

Figure 4. Possible surface drain

Figure 5. Largs Yacht Haven marina

Figure 6. Small culvert

Figure 7. Cotton buds in tideline

Figure 8. Fairlie WWTW

Figure 9. Area of yacht moorings

Figure 10. Manhole cover on shore

Figure 11. Foul discharge from metal plate

Figure 12. Gulls and wading birds

Figure 13. Location of seawater sample 14 and oyster trestles.

Norovirus Testing Summary

Fairlie

Oyster samples taken from the oyster farm at Fairlie were submitted for Norovirus analysis quarterly from August 2010. The sample for quarters 1 and 2 of 2011 have yet to be submitted.

Ref No.	Date collected	NGR	GI	GII
10/384	25/08/10	NS 19882 54277	not detected	not detected
10/583	14/12/10	NS 19945 54309	positive	positive