Scottish Sanitary Survey Project

Sanitary Survey Report
Colonsay (AB 041) and East of the Strand (AB 422)
April 2010

Cefas

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Report Distribution – Colonsay and East of the Strand

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

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1. General Description

Colonsay is a relatively small, low lying island in the Inner Hebrides situated between Islay and Mull. The island is sparsely populated and remote, with access by small aircraft and ferry only. It is home to a well-established Pacific oyster fishery and also has exploitable razor clam beds. The area examined in this survey was principally a classified Pacific oyster production area at the south end of the island on an expanse of intertidal sands called The Strand. This is actually located between Colonsay and Oronsay. These are illustrated in Figure 1.1.

The Strand is orientated east-west, and is open to the sea through narrow channels at either end. The widest part of The Strand is approximately 3.4km, west-east and 1.3km at the widest part north to south. The main area of sands is well protected by the islands to the north and south.

This sanitary survey was triggered by the risk matrix score achieved for Colonsay, which was driven by changes in the classification in recent years, the number of results outwith the classification, and the species involved. The razor clam beds at East of the Strand were also included in this survey due to the receipt of applications for full and fast track classification of this area, which is within 2km of the Pacific oyster fishery. The razor clam area lies off the east coast of the southern part of Colonsay and the northern part of Oronsay.

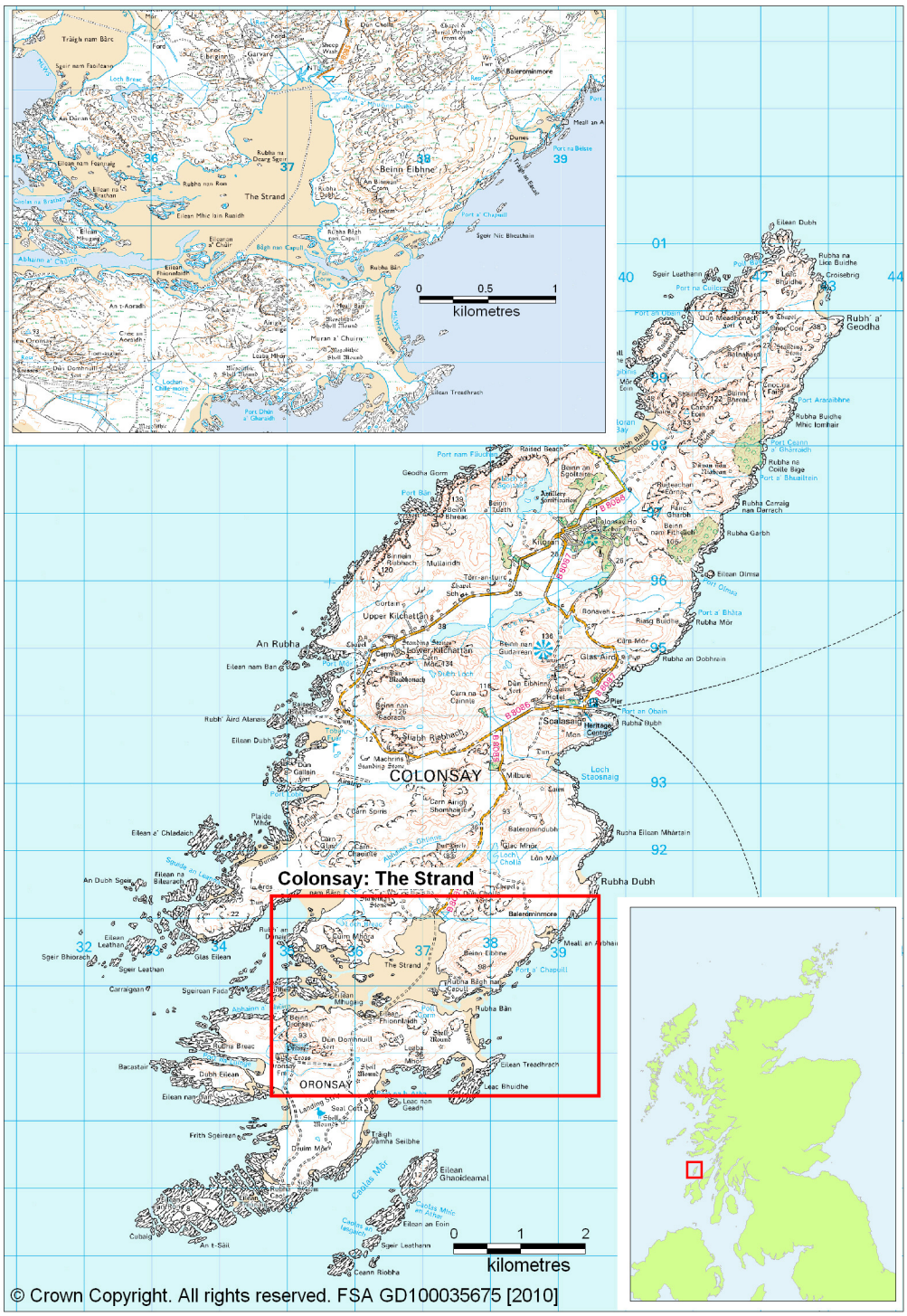

Figure 1.1 Location of Colonsay and Oronsay

2. Fishery

There are two separate fisheries at Colonsay, which are listed in Table 2.1. The Pacific oyster fishery is located on an extensive intertidal area known as The Strand, which separates the island of Colonsay from neighbouring Oronsay. The razor beds also considered in this report lie in the coastal waters just to the east of The Strand, and extend about 1 km from the coast.

Table 2.1 Production areas in Colonsay

Production Area	Site	SIN	Species
Colonsay	The Strand	AB 041 009 13	Pacific oysters
East of the Strand	Islands of Colonsay and Oronsay	AB 422 826 16	Razor clams

Colonsay Pacific Oysters

The production area for Colonsay (AB 041 009) is an area bounded by lines drawn between NR 3400 9075 and NR 3400 8945 and between NR 3511 9139 and NR 3540 9096 and between NR 3600 9028 and NR 3600 8959. The Representative Monitoring Point (RMP) is at NR 355 903.

Three Crown Estate (CE) lease areas fall within this production area. The lease area at the south western end of The Strand supports the main growing area, where there are two blocks of about 400 trestles along the north and south sides of the channel. Juvenile Pacific oysters are purchased and rotated through this area as they grow.

A second, smaller area of oyster trestles is found within the second CE lease area at the eastern end of The Strand, outside of the production area. This area is used to hold mature stock from the main site for ease of access during poor weather, and stock may be held here for extended periods. There is a processing shed with depuration facilities uphill from this area. The grower advises that the oysters are now always depurated post harvest, even during periods of class A classification.

The third CE lease area lies at the north western end of The Strand. In the past this has been used to raise very small seed stock, as it is more sheltered than the other areas. Currently seed stock is bought in at sufficient size to be laid straight on the main growing area. The north-western lease area may be used if small seed is purchased in the future. The area would not require classification because the seed will be transferred to the main growing area for on-growing, upon reaching a weight of 5-10 g.

East of the Strand Razor Clams

Applications for both fast track and standard classifications for harvesting of razor clams were received from a harvester operating out of Oban for the area to the east of The Strand, which had not yet been classified. The proposed area indicated on the applications was the area bounded by lines drawn

between NR 3800 8980 to NR 3900 8980 and between NR 3900 8980 to NR 3900 8900 and between NR 3800 8900 to NR 3800 8980, and it is believed this covers most of the exploitable beds. Razor clams will be harvested by hand using divers in an area up to 20m depth (Figure 2.1 'Likely razor area'), possibly extending further ashore to 30m depth (Figure 2.1 'Possible razor area'). Harvesting of razor clams is planned to take place year-round, although due to the remoteness of the site it will be highly weather dependent.

Figure 2.1 shows the relative positions of the production areas, oyster trestles, razor clam beds, Crown Estate seabed lease areas and nominal representative monitoring point (RMP).

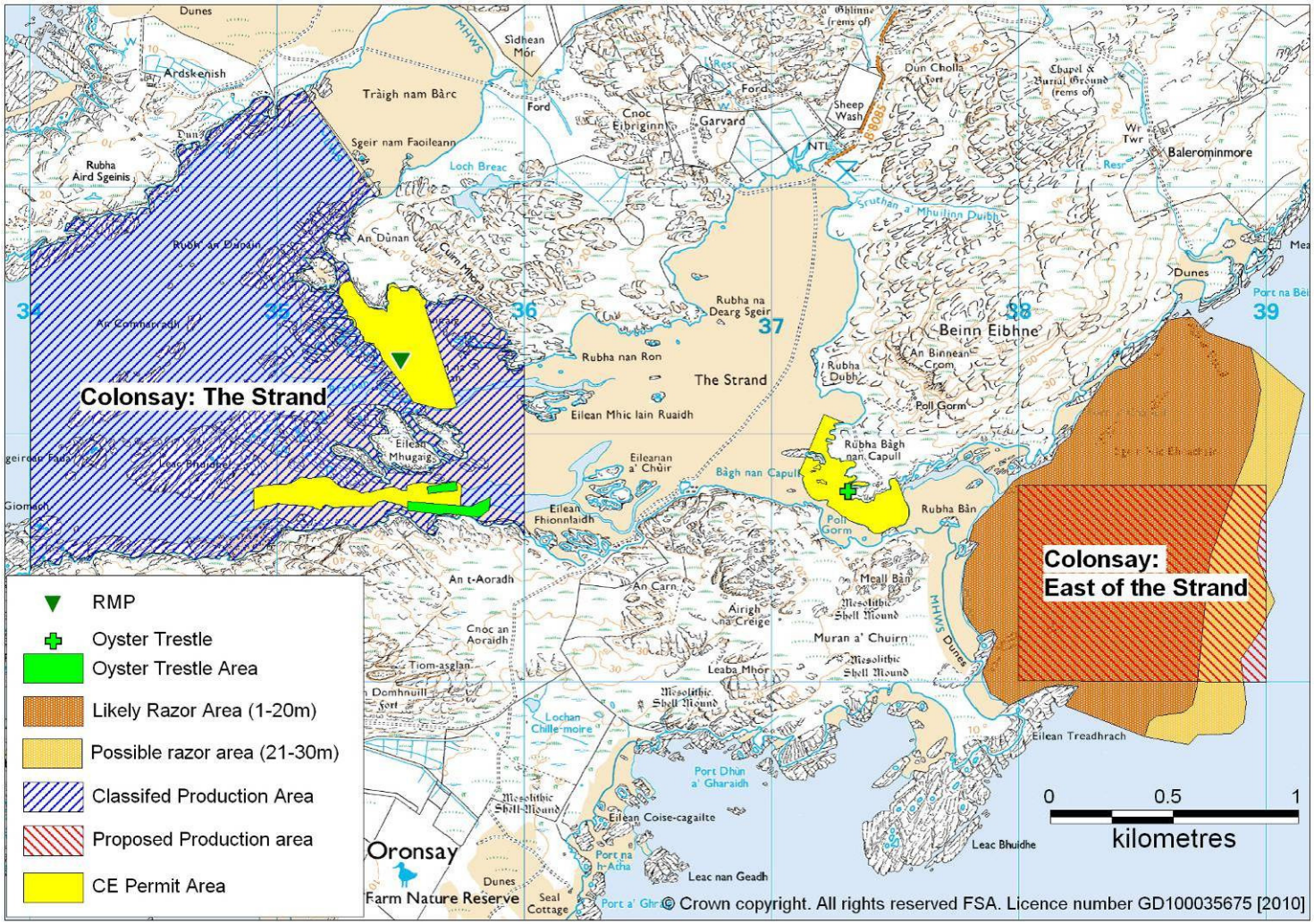

Figure 2.1 Colonsay Pacific Oyster and Razor Clam Fisheries

3. Human Population

The population census in 2001 by the General Register Office for Scotland showed that the combined population for the area of Colonsay and Oronsay (the boundary of which is shown in figure 3.1) is only 113 people. The largest settlements are in the northern part of Colonsay at Scalasaig and Kiloran.

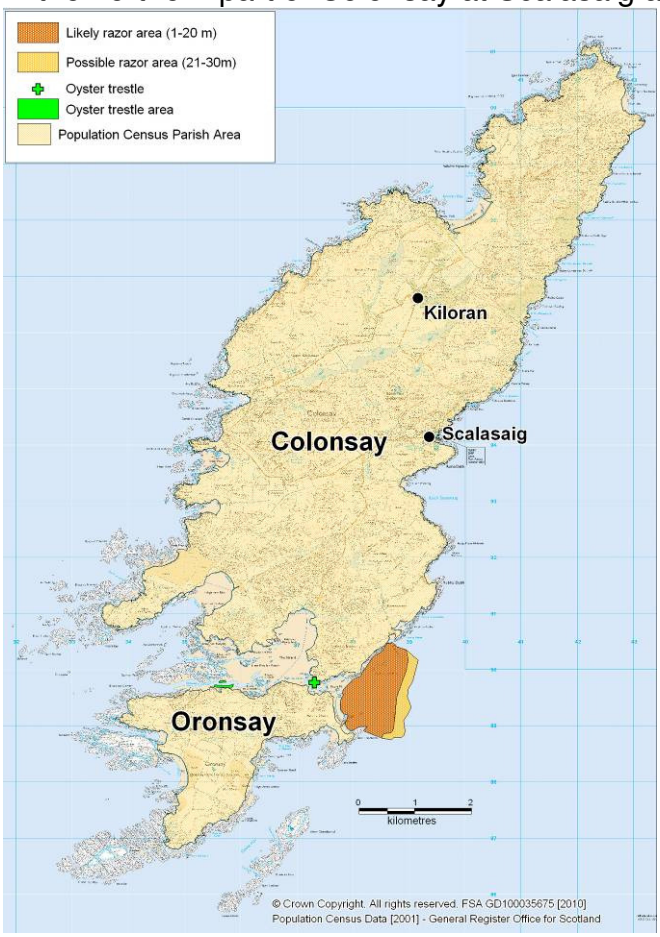

Figure 3.1 Human population on Colonsay and Oronsay

The shoreline adjacent to The Strand has a minimal population, with only two dwellings. There is only one dwelling on Oronsay, and this does not lie within the catchment area for The Strand. Therefore human sewage inputs to the area are expected to be very low.

Colonsay receives influxes of tourists during the summer months so the population on the island will be higher at this time of year. Camping is not permitted on the island and there is no tourist accommodation in the vicinity of the fisheries. Therefore, there is unlikely to be a change in water quality in the vicinity of the razor clam beds as a result of increased human impacts, other than a possible increase in yacht traffic.

Oronsay attracts tourists and there is a public park with picnic facilities at the north end of the strand. Vehicles may drive across the strand between Colonsay and Oronsay at low tide. This activity is unlikely to have any significant affect on bacterial quality of water at the fisheries.

4. Sewage Discharges

A total of 19 discharge consents have been issued by SEPA on Colonsay, details of which are presented in Table 4.1.

Table 4.1 Domestic discharges identified by SEPA

No.	Ref No.	NGR of discharge	Level of Treatment	Population equivalent (PE)	Discharges to
5	CAR/R/1009872	NR 3581 9318	Septic Tank	10	Land
6	CAR/R/1013634	NR 3759 9577	Septic Tank	9	Land
7	CAR/R/1014761	NR 3713 9536	Septic Tank	5	Land
8	CAR/R/1018567	NR 3965 9462	Septic Tank	5	Land via soakaway
9	CAR/R/1020665	NR 3776 9530	Septic Tank	5	Loch Fada
10	CAR/R/1020877	NR 3880 9816	Septic Tank	6	Land via soakaway
11	CAR/R/1021944	NR 3607 9511	Septic Tank	6	Land via soakaway
12	CAR/R/1022079	NR 3660 9509	Septic Tank	6	Land via soakaway
13	CAR/R/1025743	NR 3627 9479	Septic Tank	5	Land via soakaway
14	CAR/R/1029695	NR 3758 9568	Septic Tank	6	Land via soakaway
15	CAR/R/1029696	NR 3689 9525	Septic Tank	5	Land via soakaway
16	CAR/R/1031201	NR 3975 9463	Septic Tank	5	Land via soakaway
17	CAR/R/1032077	NR 3647 9484	Septic Tank	5	Land via soakaway
18	CAR/R/1033213	NR 3649 9527	Septic Tank, package treatment plant and constructed sub-base to Puraflo Modules	6	Unnamed tributary of Port Mor via partial soakaway
19	CAR/R/1033214	NR 3655 9517	Septic Tank, package treatment plant and constructed sub-base to Puraflo Modules	6	Unnamed tributary of Port Mor via partial soakaway
20	CAR/R/1033215	NR 3645 9526	Septic Tank, package treatment plant and constructed sub-base to Puraflo Modules	6	Unnamed tributary of Port Mor via partial soakaway
21	CAR/R/1035706	NR 3822 9323	Package treatment plant and Puraflo modules	5	Unnamed tributary of Allt Staosnaig via partial soakaway
22	CAR/R/1037650	NR 3973 4616	Septic Tank	6	Land via soakaway
23	CAR/R/108044	NR 3692 9551	Septic Tank	8	Land via mound soakaway

All of the discharges listed in table 4.1 are located greater than 3km north of the fishery, and the majority of them discharge to soakaway. Therefore, no impact on water quality in the fishery is expected as a result of these discharges. Historically, there has been no requirement to register septic systems in Scotland, and so this list is unlikely to cover all septic tanks in the area. A physical survey the shoreline was undertaken at The Strand and at Scalasaig, and observations of septic tanks and/or outfalls present along the shoreline are presented in Table 4.2.

Table 4.2 Discharges and septic tanks observed during shoreline survey

No.	Date	NGR	Observation
1	22/06/2009	NR 39027 94128	Discharge pipe, grey plastic, runs across ditch, under road and toward stream noted above.
2	24/06/2009	NR 38972 94153	Septic tank for hotel, 9 rooms plus toilets for bar and restaurant.
3	24/06/2009	NR 39461 94111	Drainage pipe coming out of concrete in bank adjacent to pier.
4	23/06/2009	NR 39498 94219	Iron discharge pipe with concrete supports.

The shoreline survey identified a few small private discharges to coastal waters at Scalasaig. This small settlement lies about 4 km to the north of the razor beds, so there is the possibility of some very minor impacts on the razor beds from these, depending on water circulation in the area. There is a small harbour at Scalasaig from which the ferry sails daily during the summer. At the time of shoreline survey, 12 boats were observed here, including 5 visiting yachts. Boats are likely to regularly pass over the razor clam beds east of The Strand, but it is unlikely that boat traffic passes through The Strand.

There are only two dwellings in the immediate area of either fishery, both on the north shore of The Strand. The harvester's house is one of these, and this is served by a septic tank discharging to soakaway about 200 metres from the high water mark so this is unlikely to impact on the fisheries. The other dwelling is located at Garvad, about 350 metres from the high water mark. No discharge pipe to the shore was seen here during the shoreline survey, so it is very likely that this property is also served by a septic tank to soakaway. Assuming that both the septic tank and soakaway are correctly functioning, they are unlikely to have an impact on the water quality of the fishery.

However, norovirus testing results (see note in Section 16 and Appendix 9) indicated that human sewage does reach the fishery at times.

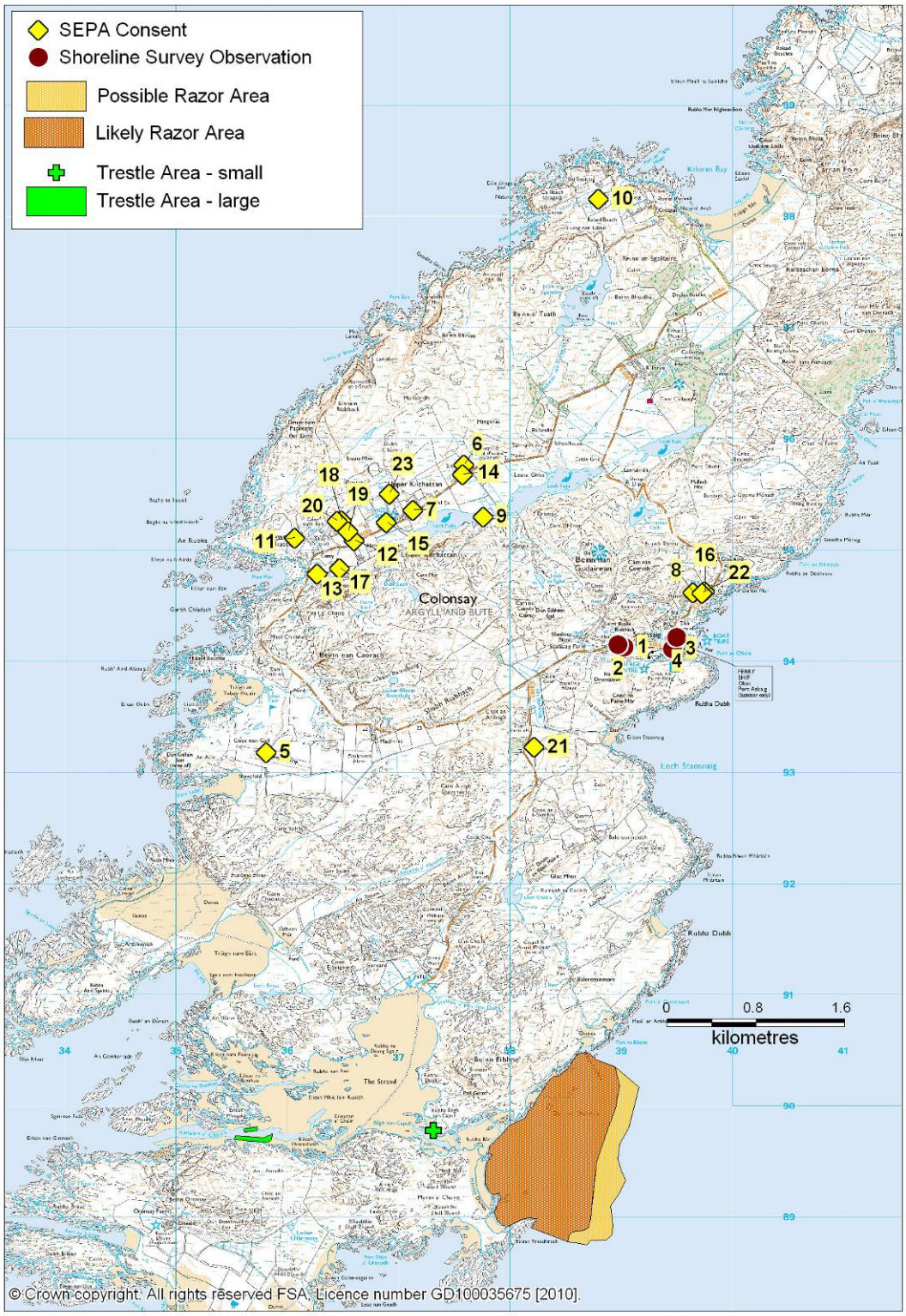

Figure 4.1 Sewage discharges at Colonsay (see tables 4.1 and 4.2 for details)

5. Geology and Soils

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

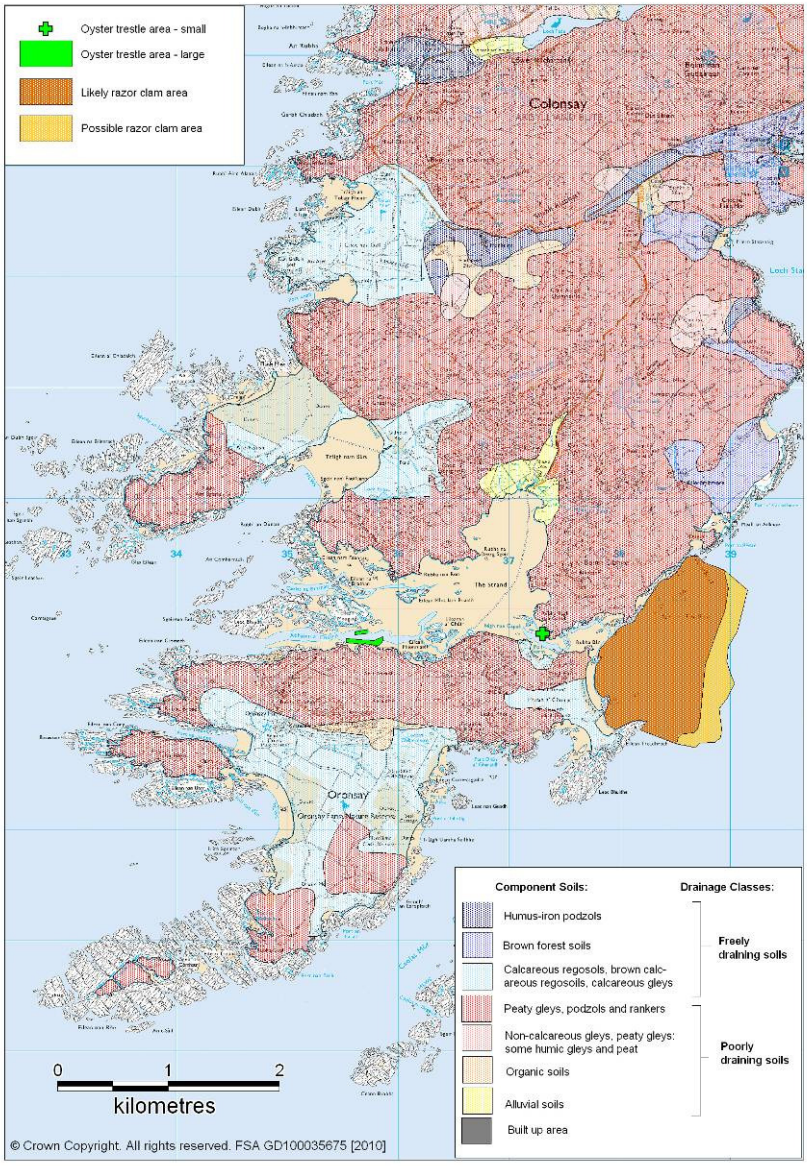

Figure 5.1 Component soils and drainage classes for Colonsay

Soils in the vicinity of the fisheries are predominantly poor draining. There are areas of freely draining soils located to the north of the Strand and on Oronsay to the south. In general, therefore, all of the land surrounding the areas of the fisheries will be subject to land run-off after rainfall.

6. Land Cover

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

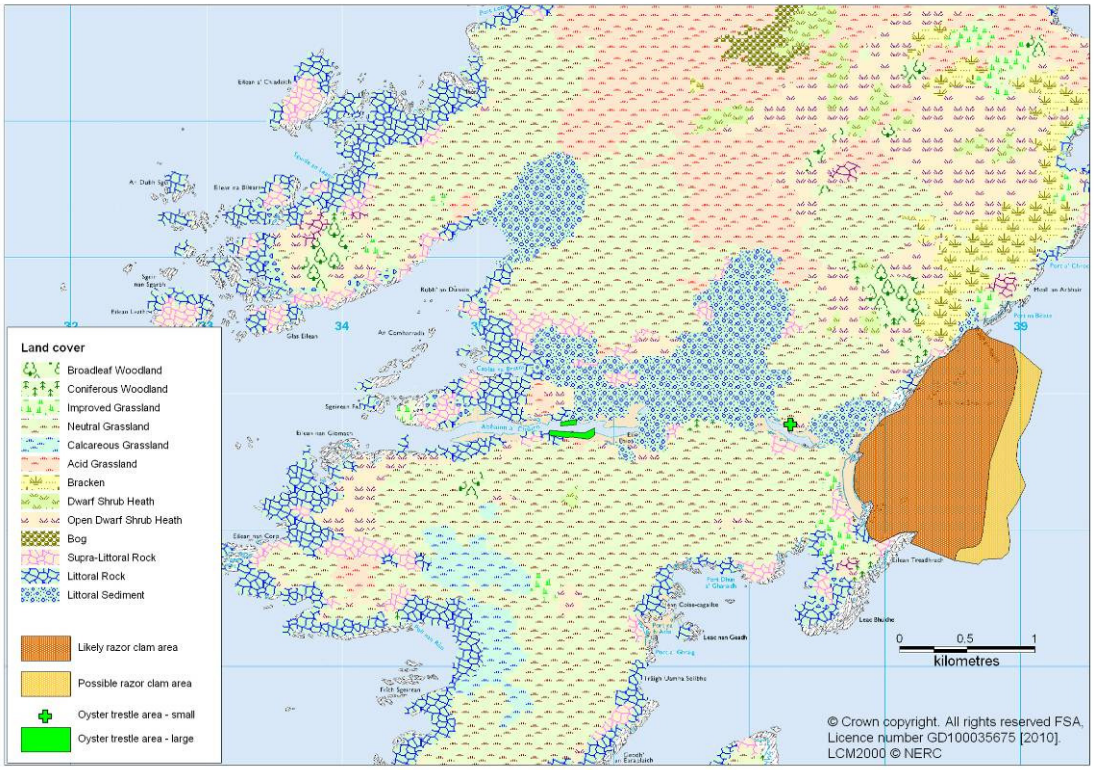

Figure 6.1 LCM2000 class land cover data for Colonsay

Landcover in the vicinity of the Colonsay fisheries is predominantly grassland with small areas of heath and woodland. North of the razor clam fishery are more extensive areas of heath and bracken. The land surrounding the Colonsay production area is mostly supra-littoral and littoral rock adjacent to large areas of neutral grassland.

The faecal coliform contribution would be expected to be highest from developed areas (approx 1.2 – 2.8x10^9 cfu km^{-2} hr^{-1}), with intermediate contributions from the improved grassland (approximately 8.3x10^8 cfu km^{-2} hr^{-1}) and lowest from the other land cover types (approximately 2.5x10^8 cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, this being expected to be highest, at more than 100-fold, for the improved grassland.

Therefore, the overall predicted contribution of contaminated runoff from these land cover types is low, but would be expected to increase significantly following rainfall events.

7. Farm Animals

With regard to potential sources of pollution of animal origin, agricultural census data to parish level was requested from the Scottish Government. Agricultural census data was provided by the Rural Environment, Research and Analysis Directorate (RERAD) for the parish of Colonsay, encompassing a land area of 45.32 km^2 which covers both Colonsay and Oronsay. Reported livestock populations for the parishes in 2007 and 2008 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 Colonsay parish 2007 - 2008

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	*	*
Poultry	5	189	*	*
Cattle	6	391	6	415
Sheep	13	5357	12	5332
Horses and ponies	*	*	*	*

* Data withheld for reasons of confidentiality

The RERAD data shows that there are predominantly sheep, and some cattle and poultry in the Colonsay parish. Pigs are kept, but no data on numbers could be provided. Sheep outnumber people within this parish at a ratio of about 50:1. However, due to the large area; this data does not provide information on the livestock numbers immediately surrounding the oyster trestles and razor clam bed. The only significant source of local information was therefore the shoreline survey (see Appendix), which relates to the time of the site visit on 23-24 June 2009. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. This information should be treated with caution, as it applies only to the survey dates and is dependent upon the point of view of the observer (some animals may have been obscured from view by the terrain).

Sheep and some cattle are grazed on the surrounding pastures. A total of 184 sheep and 39 cattle were directly observed, mainly on the north shore of The Strand. The grower advised that some of these sheep were gathered for lamb marking, and more typically about 100-150 sheep are grazed in the area. Sheep and cattle droppings were numerous in most places. There were no fences preventing livestock from accessing the shore, and cattle were recorded on the beach by Garvad. A flock of 34 sheep was recorded on Oronsay by the main area of trestles, and 16 sheep were recorded in the vicinity of the small area of trestles by the processing shed. The grower reports that a group of about 25-30 cattle regularly gather in warm weather on a beach on the north shore of Oronsay, just to the south of the processing shed. It was not possible to survey the east coast of Colonsay and Oronsay

adjacent to the razor beds at the time of the shoreline survey due to the limited time available for the surveying and the restrictions related to sample submission from such a remote island. It is likely that livestock is present on the grassland there at least part of the time.

Contamination from livestock will be carried to the fishery via direct deposition in the intertidal area and subsequent tidal transport, or via land runoff. The widespread distribution of livestock observed during the shoreline survey indicates that contamination will be fairly evenly spread, thus impacting both the main oyster trestle area and the area by the processing shed. It is likely that the distribution of sheep and cattle within the area is likely to change over time. The western part of the razor clam bed will be at higher risk of contamination from animal faeces than the part further offshore.

Numbers of sheep and cattle will approximately double during spring following the birth of lambs and calves, and decrease in the autumn as animals are sent to market. Livestock will access streams to drink more frequently during warmer weather, so it is likely that impacts from livestock sources will be greater during the summer months.

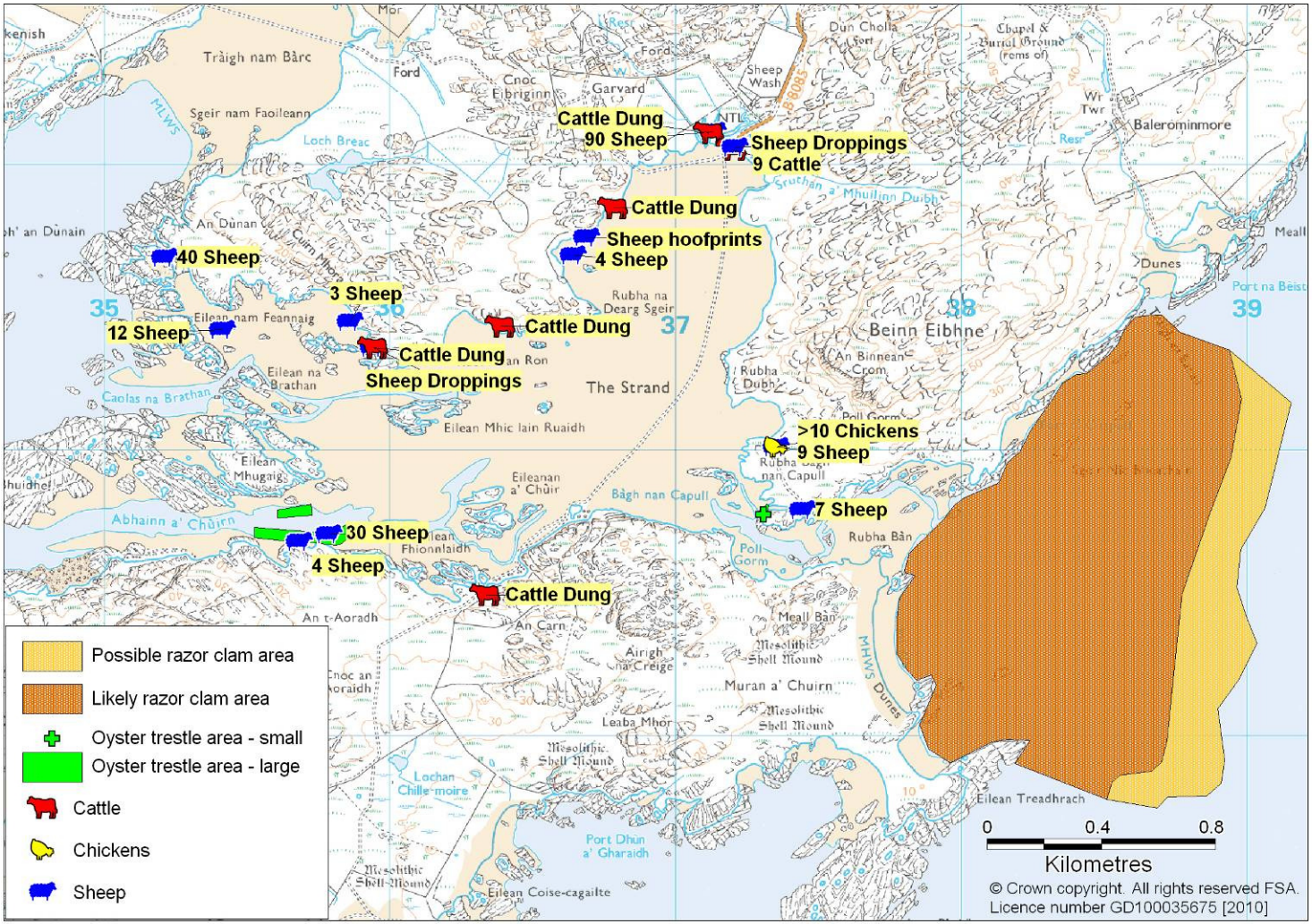

Figure 7.1 Livestock Observed in Colonsay during the Shoreline Survey

8. Wildlife

General information related to potential risks to water quality by wildlife can be found in Appendix 4. A number of wildlife species present or likely to be present around Colonsay could potentially affect water quality around the fishery.

Seals

Two species of seals 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*). Scotland hosts significant populations of both species.

A survey conducted by the Sea Mammal Research Unit in 2007 estimated a population of 4732 common seals from Appin to Mull of Kintyre (SMRU, 2008) indicating they are present in the region. Grey seal pup production at Oronsay Strand (presumably The Strand) was estimated at 47 in 2007 indicating that this species is present in the vicinity of the fisheries. Adult numbers are estimated to be 3.5 times the pup population (Callan Duck, Sea Mammal Research Unit, personal communication), so it is likely this species is present in quite large numbers.

Four seals (species uncertain) were observed in the vicinity of the main area of oyster trestles at The Strand. The grower indicated that they are a regular presence by this area of trestles. Therefore, although they are likely to forage widely throughout the area, it appears that the main block of trestles is a favoured haulout site so higher impacts from seals may potentially be felt here compared to the smaller block of trestles located by the processing shed.

Whales/Dolphins

A variety of whales and dolphins are routinely observed off the west coast of Scotland. It is possible that some of the species of cetaceans pass over the razor beds on occasion, although any impact of their presence is likely to be fleeting and unpredictable. It is much less likely that they enter the extensive and enclosed intertidal area in which the oyster fishery is located.

Birds

A number of bird species are found around Colonsay, but seabirds and waterfowl are those most likely to occur around or near the fisheries in significant numbers. Breeding seabirds were the subject of a detailed census carried out in the late spring of 1999, 2000 and 2001 (Mitchell *et al.*, 2004). Total counts of all species recorded within 5 km of the production areas are presented in Table 8.1. Where counts were of sites/nests/territories occupied by breeding pairs actual numbers of birds breeding in the area will be higher.

Table 8.1 Counts of breeding seabirds within 5 km of the cage sites

Common name	Species	Count	Method	Individual /pair
Northern Fulmar	*Fulmarus glacialis*	36	Occupied sites	Pairs
Great black-backed gull	*Larus marinus*	55	Occupied nests	Pairs
Herring gull	*Larus argentatus*	347	Occupied nests	Pairs
European shag	*Phalacrocorax aristotelis*	1	Occupied nests	Pairs
Black Guillemot	*Cepphus grylle*	57	Individuals on land	Individuals
Common gull	*Larus canus*	48	Occupied nests	Pairs
Lesser black-backed gull	*Larus fuscus*	168	Occupied nests	Pairs
Black-headed gull	*Larus ridibundus*	5	Occupied nests	Pairs
Little Tern	*Sterna albifrons*	2	Occupied nests	Pairs
Common Tern	*Sterna hirundo*	30	Occupied nests	Pairs
Arctic Tern	*Sterna paradisaea*	188	Occupied nests / Occupied territory	Pairs

The location of these breeding sites is thematically mapped in Figure 8.1, with each recorded pair counted as two birds in the represented count.

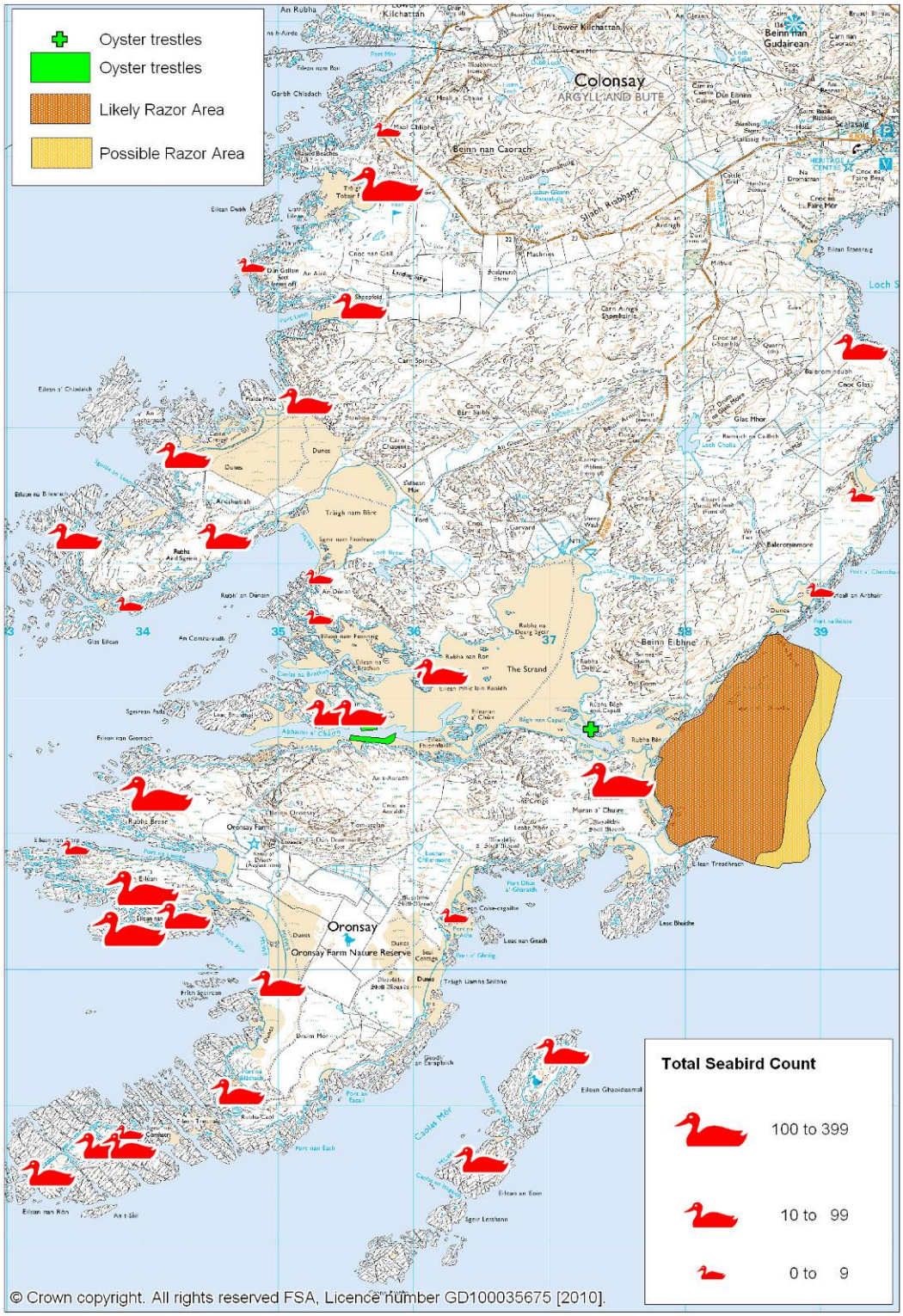

Figure 8.1 Breeding seabird counts within 5 km of the shellfisheries

Figure 8.1 indicates that significant numbers of seabirds breed all around the area, including in close proximity to both areas of trestles. Contamination from seabirds may be carried to the fishery via runoff from the area where they nest, or through direct deposition in the intertidal area. Impacts may therefore be felt at either block of trestles, and possibly to a lesser extent at the razor beds. The impact at the razor bed may be greatest on the south

western side. Some species disperse outside of the spring/summer breeding season, whereas others are likely to be resident year round, so overall seabird population levels are likely to be highest during the breeding season.

Waterfowl (ducks and geese) are likely to be present in the area at various times, either to overwinter, or briefly during migration, or to breed. Three geese were observed during the shoreline survey, and goose droppings were recorded at various points around The Strand during the shoreline survey.

Wading birds would be concentrated on intertidal areas such as The Strand. About 45 oystercatchers were recorded on The Strand during the shoreline survey.

Oronsay and South Colonsay is a Special Protected Area (SPA) as it hosts small but nationally significant populations of chough (4 breeding pairs) and corncrake (16 breeding pairs) but it is not anticipated that these birds would have any significant impact on the fisheries.

Deer

There are no deer on Colonsay or Oronsay.

Otters

No otters were observed during the course of the shoreline survey, although it is likely that they are present in the area. However, the typical population densities of coastal otters are low and their impacts on the shellfishery are expected to be very minor.

Summary

In summary, the main wildlife species potentially impacting on the production areas are seals, which are present year round and appear to favour the area by the main group of oyster trestles at The Strand, so may be expected to impact most here.

Seabirds and geese may impact on the fishery to a lesser extent. It is likely that all parts of the Pacific oyster fishery are affected to a similar extent but the south western part of the razor clam bed may be affected more than the rest.

There may be more seabirds present in the area during the breeding season but whether there is any seasonality in waterfowl numbers is uncertain.

9. Meteorological data

The nearest weather station is located at Colonsay: Homefield, approximately 4 km to the north of the production area, for which rainfall data was available for 2003-2008 inclusive apart from October and part of December 2006. The nearest weather station for which wind data is available is Tiree, approximately 63 km to the north-west of the fishery. It is likely that overall wind patterns are broadly similar at Colonsay and at Tiree, as they are both low lying islands exposed to the Atlantic, but local topography may skew these patterns in different ways, and conditions at any given time are likely to 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 Colonsay.

Rainfall and wind data were supplied to Cefas/FSAS by the Meteorological Office under licence. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas.

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 at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

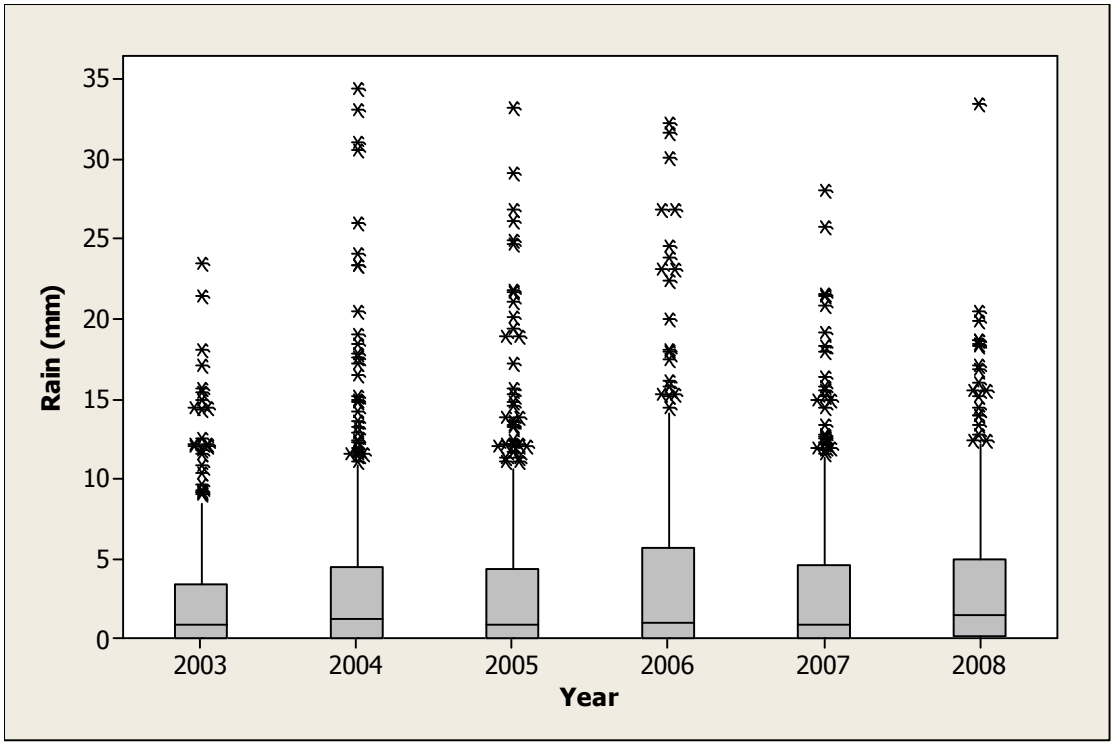

Figure 9.1 Box plot of daily rainfall values by year at Colonsay: Homefield, 2003-2008

Figure 9.1 shows that rainfall patterns were similar between the years presented here, with 2003 the driest and 2006 the wettest.

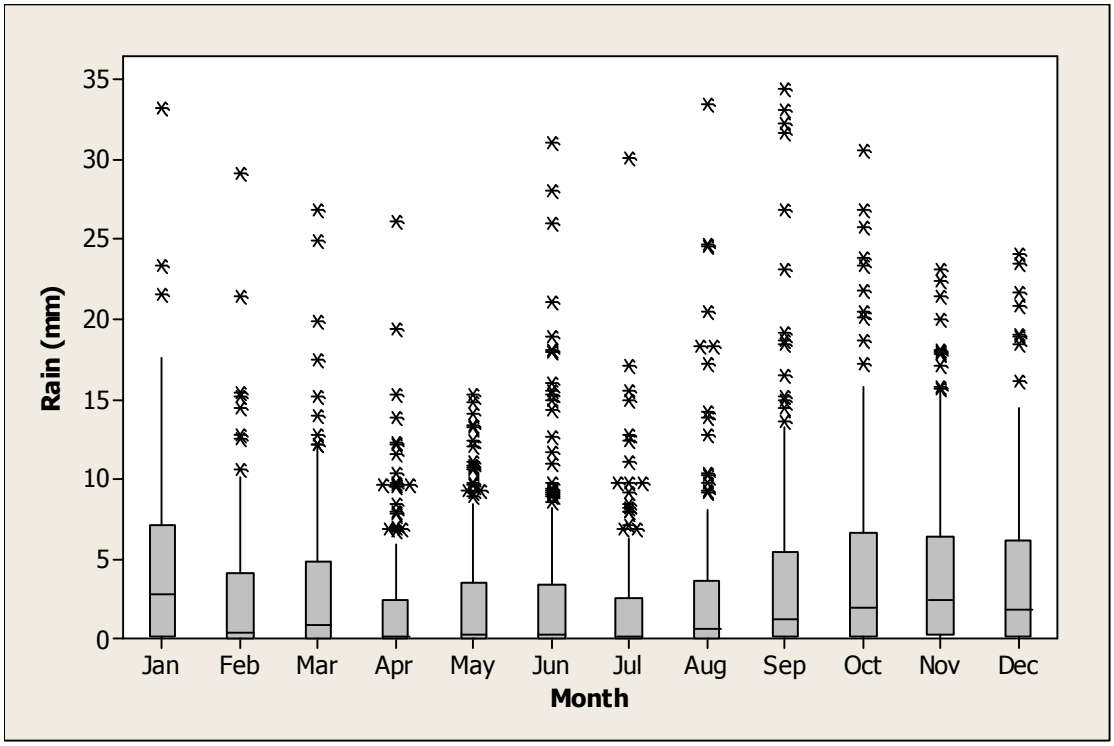

Figure 9.2 Box plot of daily rainfall values by month at Colonsay: Homefield, 2003-2008

The wettest months were September to March and April to July were the driest months. Days with high rainfall greater than 20 mm occurred during all months except May. For the period considered here (2003-2008), 49% of days experienced rainfall less than 1 mm, and 9% of days experienced rainfall of 10 mm or more.

It can therefore be expected that levels of rainfall dependent faecal contamination entering the production area from these sources will be higher on average during the autumn and winter months. High rainfall events can occur at any time of the year, and these may result in a contaminated 'first flush' of pasture runoff which may be particularly acute during the summer when livestock numbers are likely to be highest and preceding dry periods may result in a buildup of faecal matter on pastures.

9.2 Wind

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

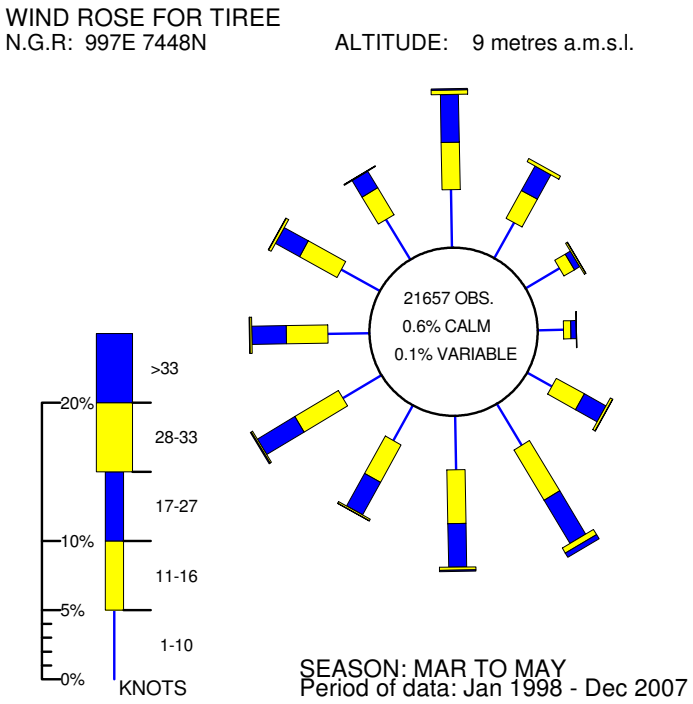

Figure 9.3 Wind rose for Tiree (March to May)

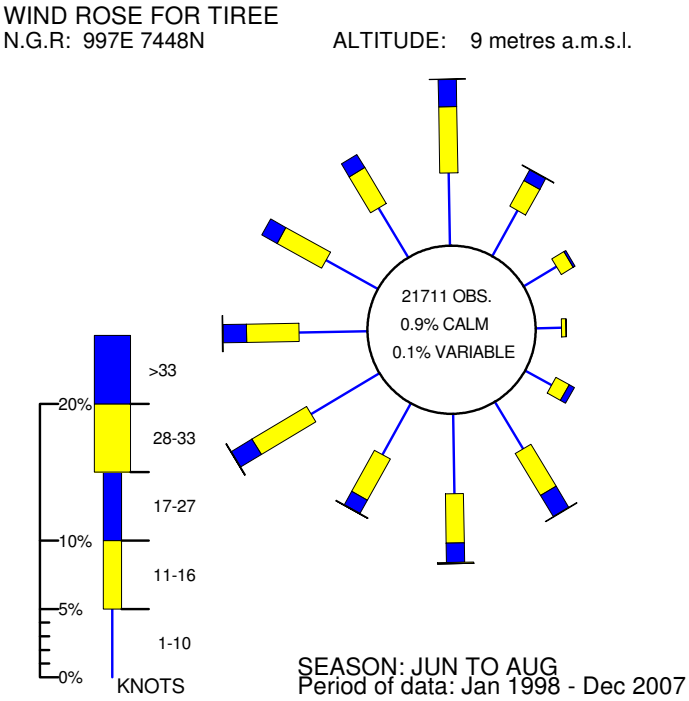

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Figure 9.4 Wind rose for Tiree (June to August)

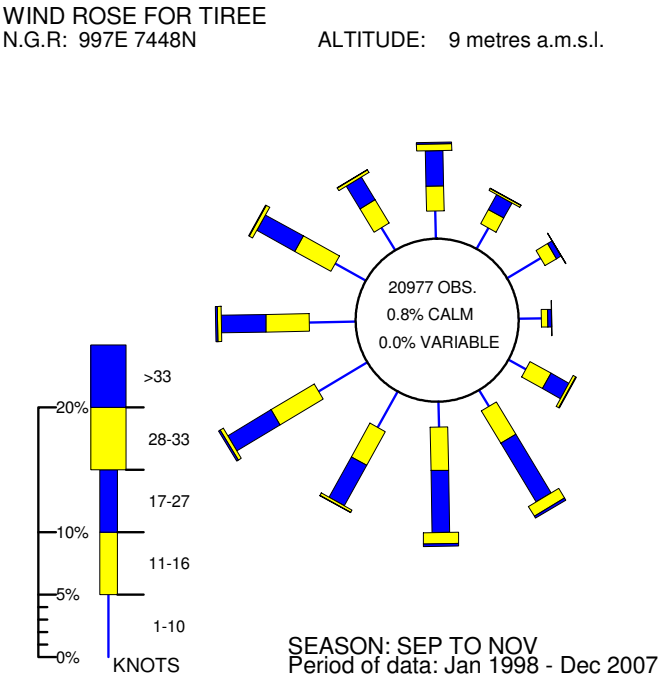

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Figure 9.5 Wind rose for Tiree (September to November)

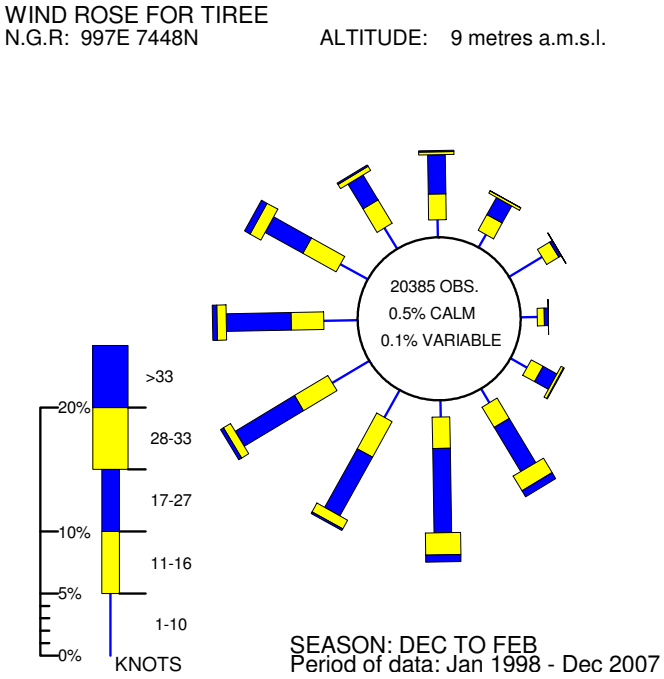

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Figure 9.6 Wind rose for Tiree (December to February)

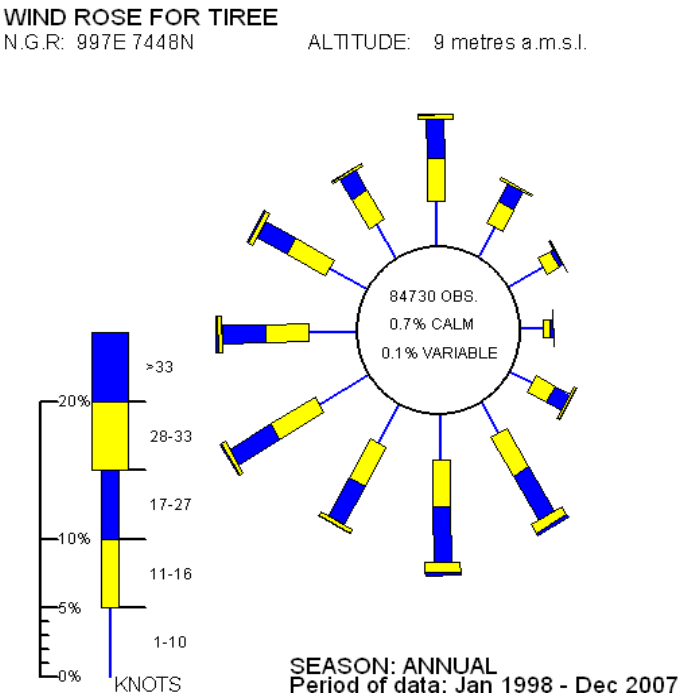

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Figure 9.7 Wind rose for Tiree (All year)

The prevailing wind direction at Tiree is from the south and west, but wind direction often changes markedly from day to day with the passage of weather

systems. There is a higher occurence of northerly winds during the first half of the year. Tiree is a low lying island exposed to Atlantic winds with a relatively high frequency of gales. Winds are generally lightest in the summer and strongest in the winter. The fishery at Colonsay is located in a west facing bay which receives some shelter from wave action from some small rocky islands within the bay. The land to the south and north is generally low lying, although it dose rise to over 90 m at one point. Therefore, wind patterns at The Strand while similar to those at Tiree, may be more skewed to the west.

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 alter the pattern of surface currents at Colonsay at times. 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 accumulated faecal matter from livestock, in and above the normal high water mark, into the production area. An onshore wind will result in increased wave action, which may resuspend any organic matter settled in the substrate.

10. Current and historical classification status

Colonsay is currently classified for the production of Pacific oysters. Its classification history presented in Table 10.1. A map of the current production area can be found in Section 2, Figure 2.1.

Table 10.1 Classification history, Colonsay, 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	A	A	A	A	A	B	B	B	B	B	A
2003	A	A	A	A	A	B	B	B	B	B	B	A
2004	A	A	A	A	A	B	B	B	B	B	B	A
2005	B	A	A	A	A	A	A	A	A	A	B	B
2006	B	B	B	B	B	B	B	B	B	B	B	B
2007	B	B	B	A	B	B	B	B	B	B	B	B
2008	A	A	A	A	A	B	B	B	B	B	B	B
2009	A	A	A	A	A	B	B	B	B	B	B	B
2010	A	A	A									

The area received a B classification in 2001. Since then it has held seasonal A/B classifications, with the timing of varying from year to year, aside from in 2006 when it held a B classification all year. Months receiving A classifications have generally fallen in the winter and spring.

East of the Strand is yet to be classified for the harvest of razor clams.

11. Historical *E. coli* data

11.1 Validation of historical data

Results for shellfish samples taken at Colonsay from the beginning of 2002 up to the 29th September 2009 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. No sample records from the razor beds at East of The Strand were found.

One result had no reported grid reference and so was rejected from the analysis. One result had the wrong two letter prefix to the reported grid reference and this was corrected. Ten results were recorded as being from NR 3731 8979 and 1 result was recorded as being from NR 373 897. Both of these locations fall outside the production area, but they do fall close to an area of trestles by the oyster shed where the grower sometimes keeps stock, so these were included in the analysis as these locations are likely to be accurate. One sample was reported from NR 358 896 which is 45 m outside the production area, and one sample was reported from NR 356 896 which is 10 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.

Three samples had a reported collection date and time which fell after the date and time which they were received by the laboratory, so these were not included in the analysis.

Nine 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 are reported in most probable number per 100g 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 the three distinct clusters of reported sampling locations. Geometric mean results by individual sampling locations are presented in Figure 11.1. A total of 29 samples were taken in 2002, with multiple samples reported from the same location on several sampling occasions.

Table 11.1 Summary of historical sampling and results

Sampling Summary			
Production area	Colonsay	Colonsay	Colonsay
Site	The Strand	The Strand	The Strand
Cluster	At the RMP	At/by the trestles	By the processing shed
Species	Pacific oysters	Pacific oysters	Pacific oysters
SIN	AB-041-009-13	AB-041-009-13	AB-041-009-13
Location	NR355903	6 NGRs	2 NGRs
Total no of samples	80	11	11
No. 2002	29	0	0
No. 2003	10	0	0
No. 2004	11	0	0
No. 2005	12	0	0
No. 2006	13	0	0
No. 2007	5	2	1
No. 2008	0	5	6
No. 2009	0	4	4
Results Summary			
Minimum	<20	20	<20
Maximum	16000	2400	310
Median	120	170	70
Geometric mean	150	193	77.3
90 percentile	1340	500	310
95 percentile	3590	1450	310
No. exceeding 230/100g	27 (34%)	5 (45%)	2 (18%)
No. exceeding 1000/100g	13 (16%)	1 (9%)	0 (0%)
No. exceeding 4600/100g	4 (5%)	0 (0%)	0 (0%)
No. exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)

11.3 Overall geographical pattern of results

Figure 11.1 presents a map showing geometric mean result by reported sampling locations. Before mid 2007, all samples were reported from NR 355 903 (the nominal RMP). Although this falls within a Crown Estates lease area, the grower advises that this area has only ever been used for cultivation of seed stock so the samples must have actually been taken from the other two lease areas. Figure 11.2 presents a boxplot of results by the clusters of sampling locations identified in Table 11.1.

Due to uncertainty of the actual sampling location of all samples attributed to the RMP, and the actual location of the fishery, only comparisons of results at the main blocks of trestles and at the processing shed are considered in detail here. Although results were higher on average at the main block of trestles, a comparison of mean result showed no significant difference (T-test, T=-1.81, p=0.087, Appendix 6). A higher proportion of values exceeding 1000 and 4600 *E. coli* MPN/100 g were seen at the nominal RMP than at the other location.

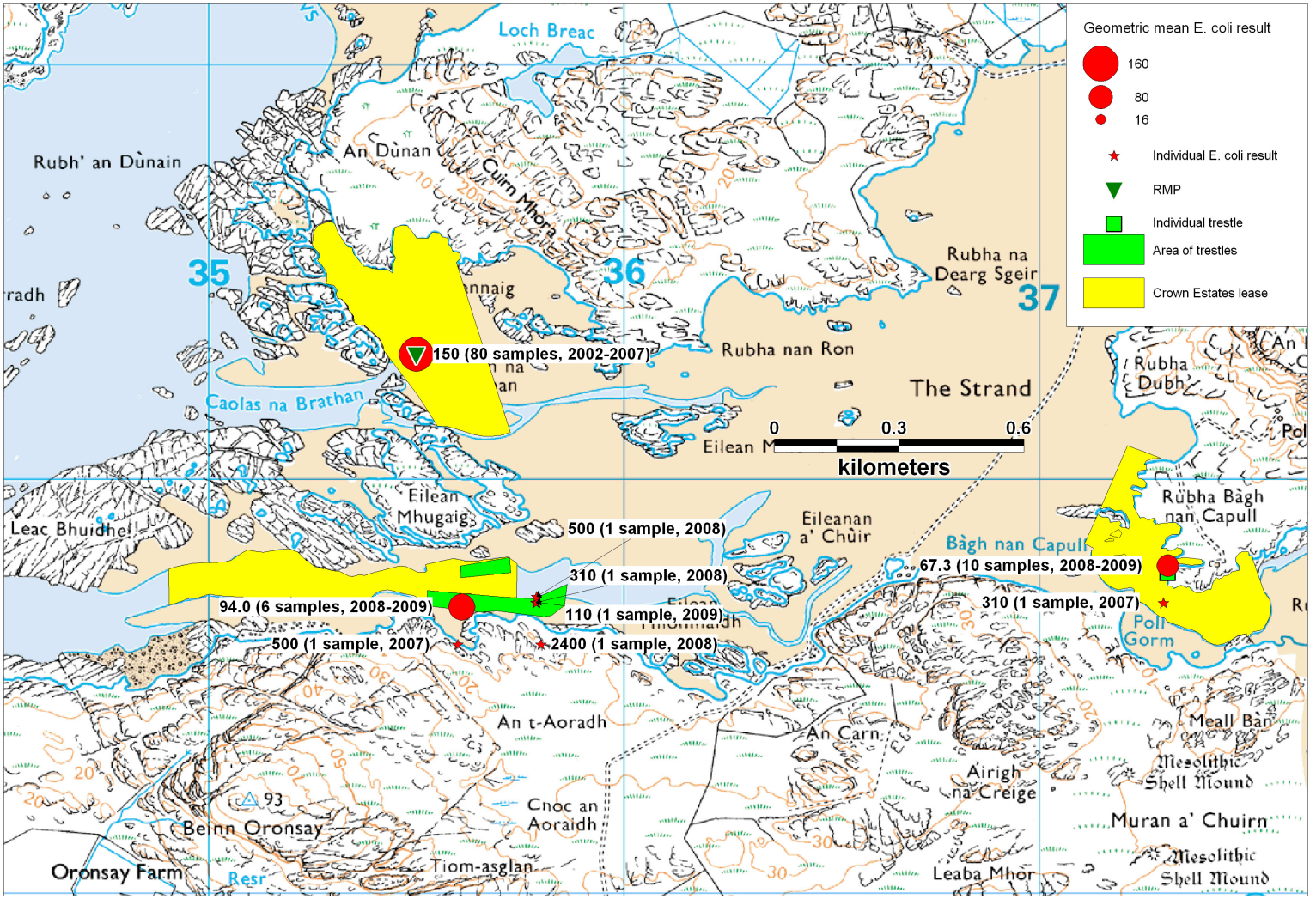

Figure 11.1 Map of sampling points and geometric mean result

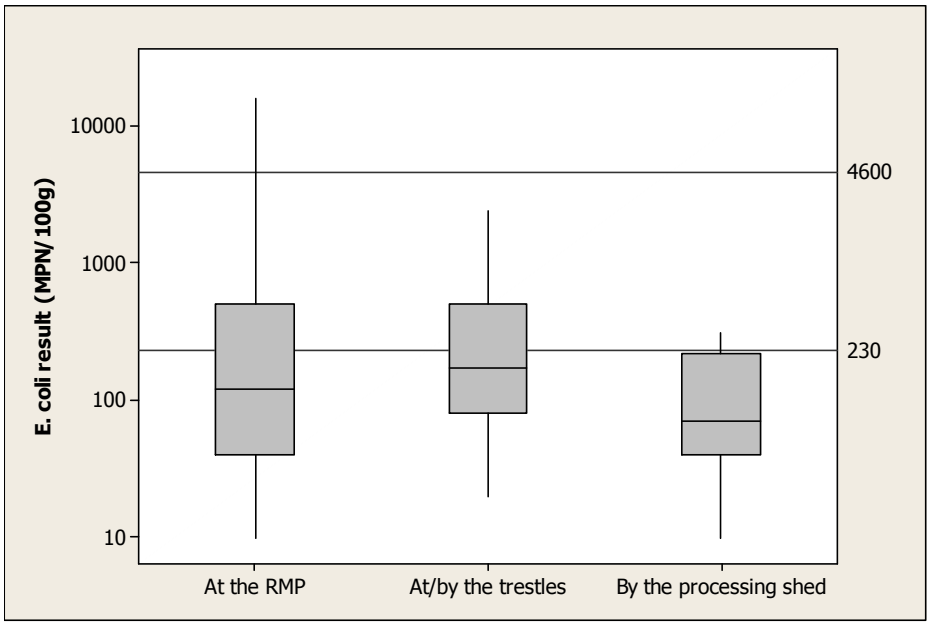

Figure 11.2 Boxplot of result by area sampled

Of results identified as being from the current fishery location, the highest overall result was recorded at the main block of trestles.

In Figure 11.1 it is apparent that samples were taken from the western end of the main area of trestles on seven occasions, and from the eastern end on four occasions. A comparison of these results reveals that the geometric mean *E. coli* result was higher at the eastern end compared to the western end of the trestles (450 and 119 MPN/100g respectively), but this difference was not statistically significant (T-test, t=1.75, p=0.141).

Samples were not taken from multiple locations on any occasion. Therefore, any apparent geographical differences in levels of contamination in shellfish presented here may be a result of temporal rather than spatial effects.

11.4 Overall temporal pattern of results

Figure 11.3 presents a scatter plot of individual results against date for Colonsay The Strand. The points are fitted with trend lines calculated using two different techniques. These trend lines help to highlight any apparent underlying trends or cycles.

One of the trend lines joins the values representing the geometric mean of the previous 5 samples, the current sample and the following 6 samples and is referred to as a rolling geometric mean (black line). The other is a loess line (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 loess line 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 will be influenced more by the data close to it (in time) and less by the data further away.

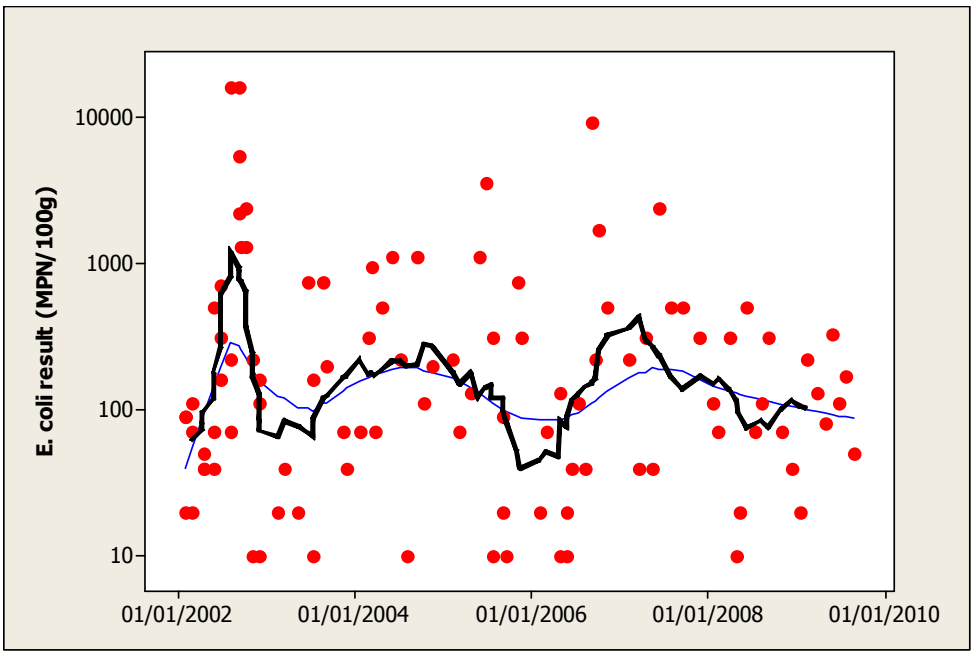

Figure 11.3 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line)

Figure 11.3 shows a sharp peak in 2002, although this was accentuated by the collection of multiple samples from the same location on most sampling occasions in 2002. Smaller peaks in results appeared to occur in late 2004 and early 2007. No results over 1000 *E. coli* MPN/100g occurred from mid 2007 onwards.

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 11.4 presents a boxplot of *E. coli* result by month.

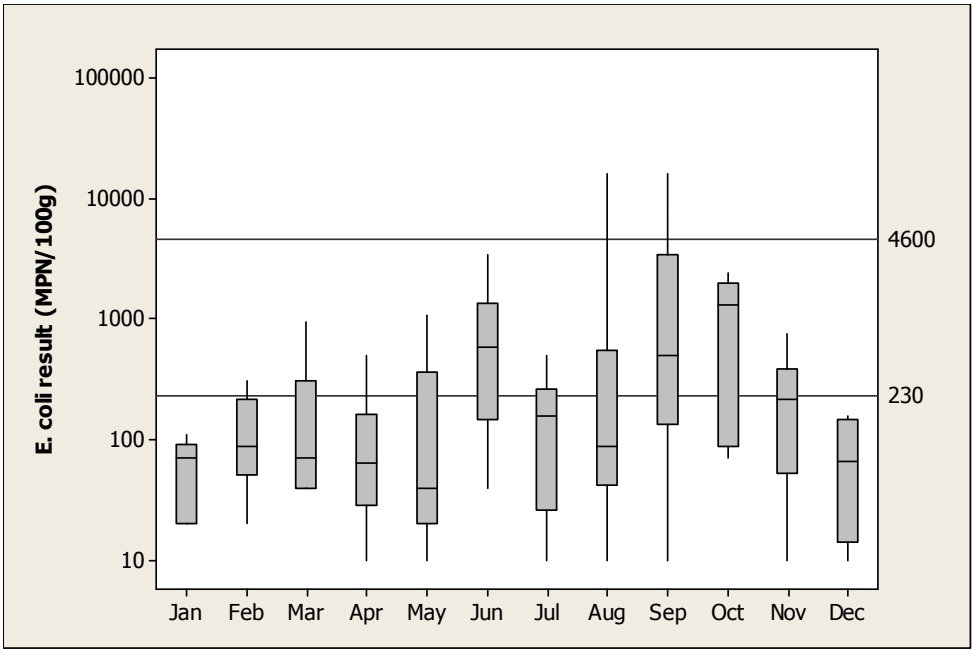

Figure 11.4 Boxplot of results by month

Results greater than 230 *E. coli* MPN/100 g occurred during all months except December and January and results greater than 4600 *E. coli* MPN/100 g occurred only during August and September during the period in question. Results were generally lower in December and January

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

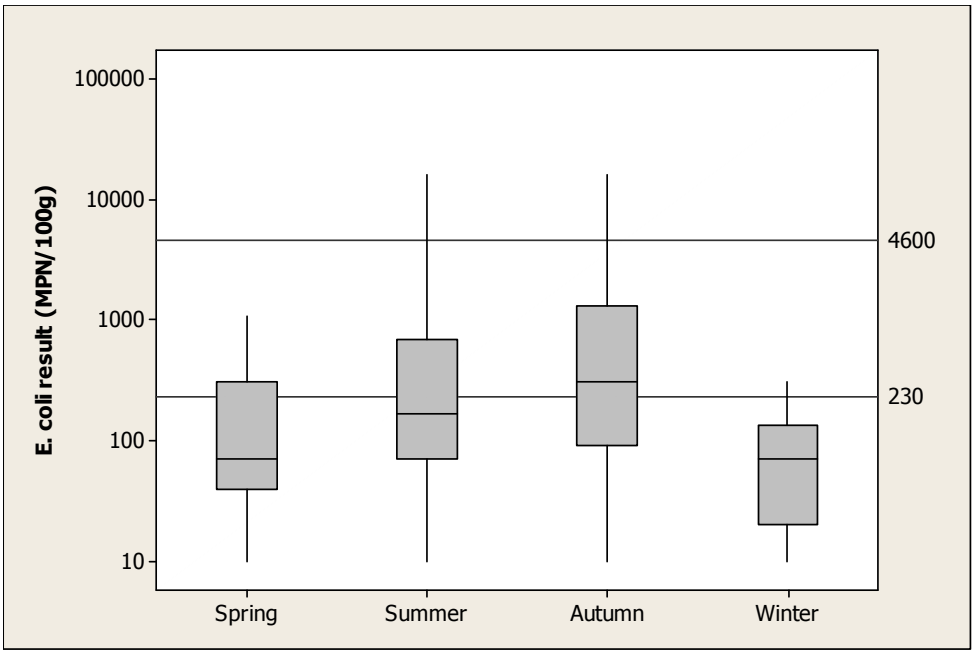

Figure 11.5 Boxplot of result by season

A significant difference was found between results by season (One-way ANOVA, p=0.001, Appendix 6). A post ANOVA test (Tukeys comparison,

Appendix 6) indicates that results for the autumn were significantly higher than those in the winter and spring.

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 Colonsay: Homefield, approximately 4 km to the north of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2008 (total daily rainfall in mm).

Two-day antecedent rainfall

Figure 11.6 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.

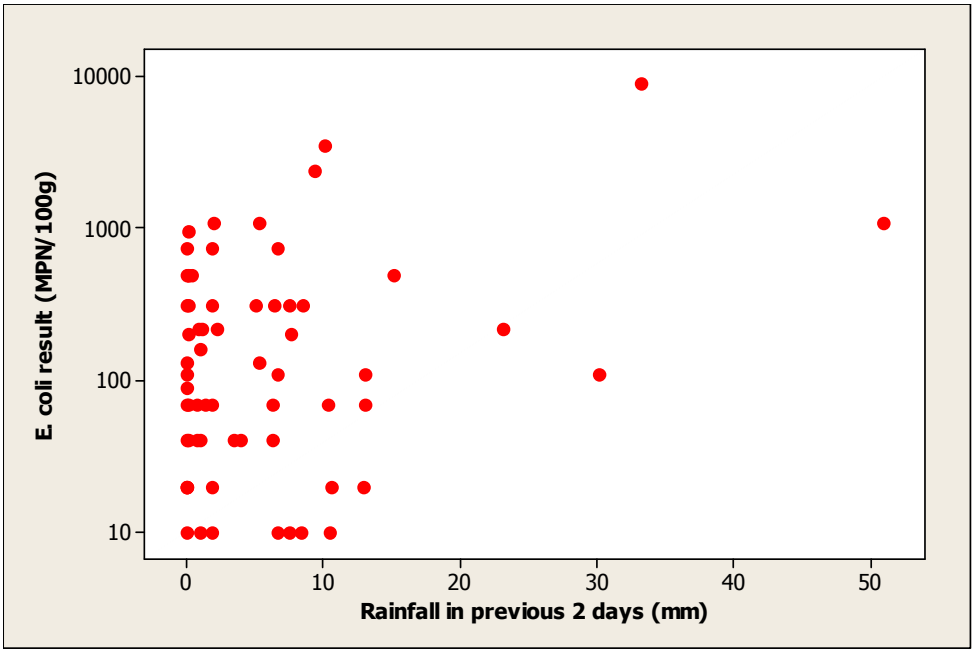

Figure 11.6 Scatterplot of result against rainfall in previous 2 days

No correlation was found between *E. coli* result and rainfall in the previous 2 days (Spearman's rank correlation=0.111, p=0.384, Appendix 6). However,

results greater than 2400 *E. coli* MPN/100 g were only seen after more than 10 cm rainfall over the preceding 2 days.

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.

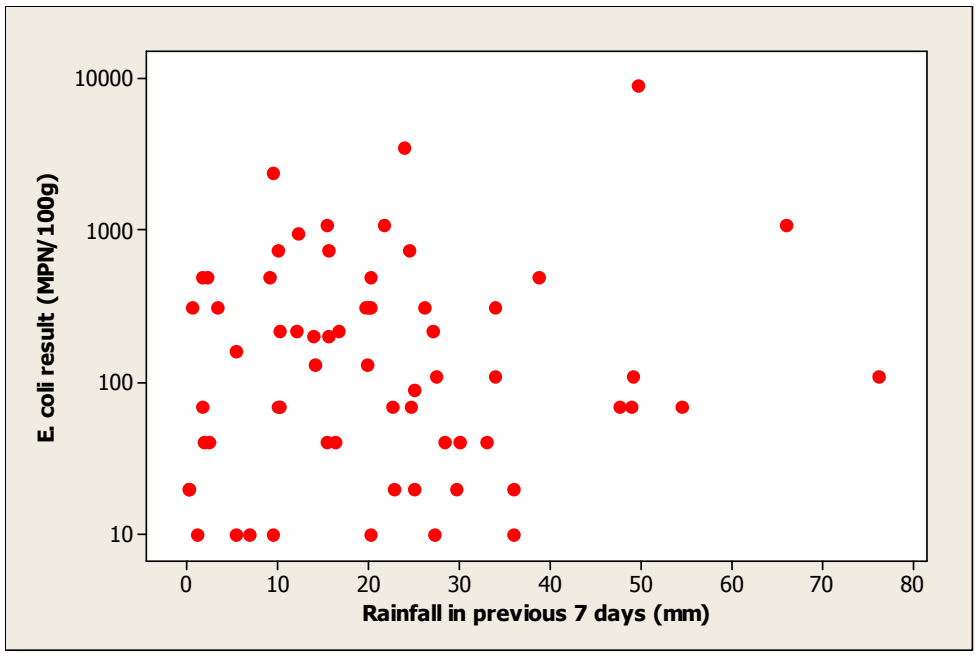

Figure 11.7 Scatterplot of result against rainfall in previous 7 days

No correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation= 0.025, p=0.847, Appendix 6). Results greater than 2400 E. coli MPN/100 g were seen only after more than 10 mm of rainfall in the preceding 7 days and not after rainfall exceeding 50 mm in 7 days.

11.6.2 Analysis of results by tidal height and state

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the area. Figure 11.8 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 are located 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 of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 4600 *E. coli* MPN/100g are plotted in yellow, and those over 4600 *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.

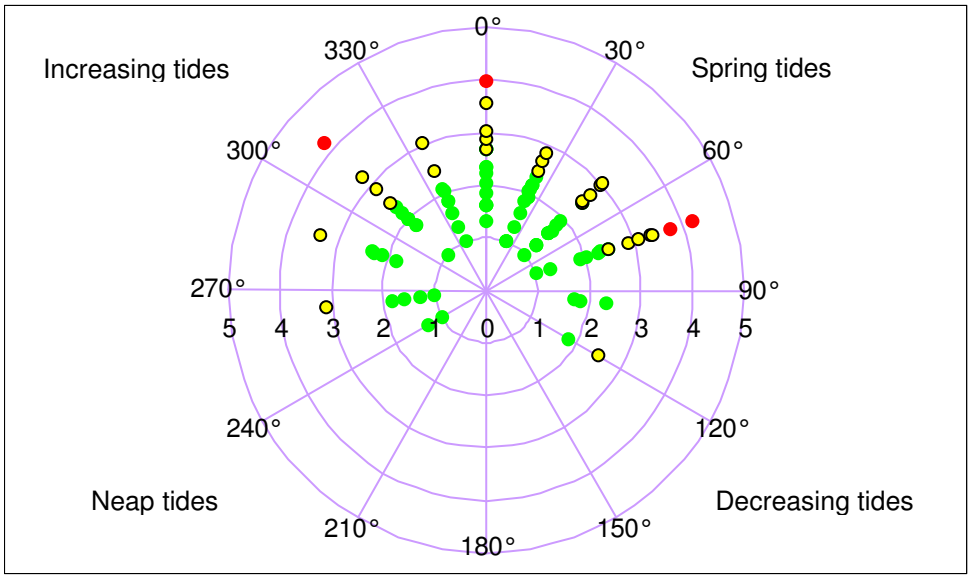

Figure 11.8 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle

No correlation was found between *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.077, p=0.554, Appendix 6). Sampling was targeted towards spring tides.

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figure 11.9 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 is located at 180º. Again, results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 4600 *E. coli* MPN/100g are plotted in yellow, and those over 4600 *E. coli* MPN/100g are plotted in red.

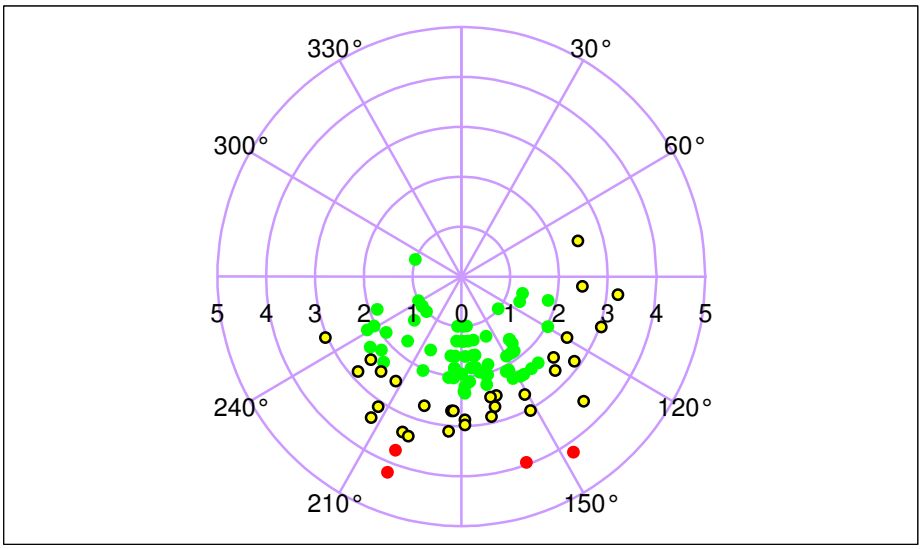

Figure 11.9 Polar plot of log-10 *E. coli* results on the high/low tidal cycle

No correlation was found between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.091, p=0.441, Appendix 6). Sampling was targeted towards low water.

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 11.10 presents a scatterplot of *E. coli* results against water temperature.

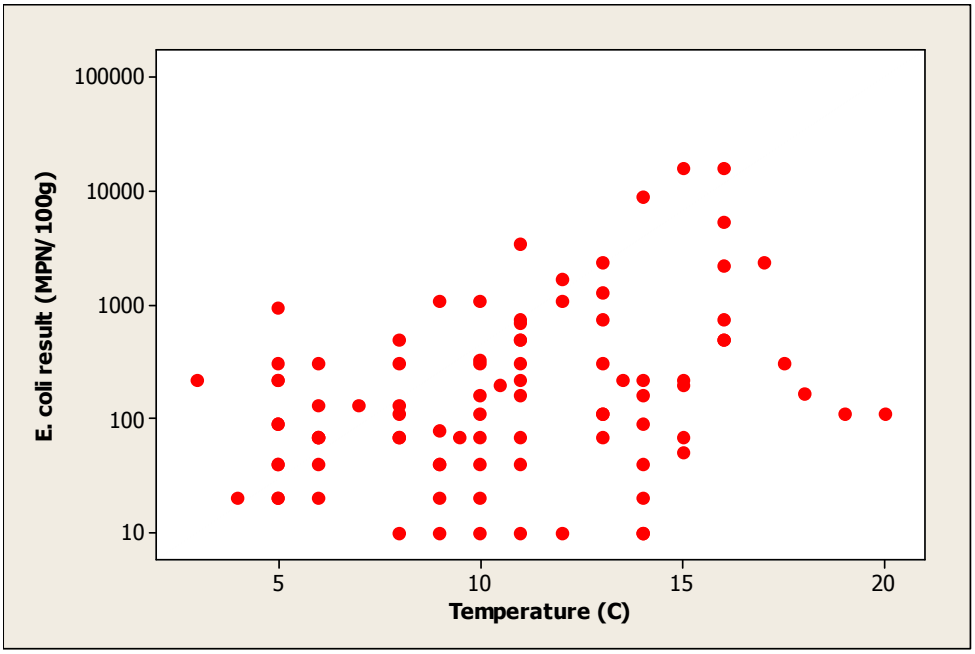

Figure 11.10 Scatterplot of result by water temperature

The coefficient of determination indicates that there was a weak positive relationship between the *E. coli* result and water temperature (Adjusted R-sq=9.9%, p=0.001, Appendix 6)

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns within the production area. However, the nearest wind station for which records were available was Tiree, approximately 63 km to the north-west of the fishery. Given the differences in local topography and distance between the two it is likely that the overall patterns of wind direction differ, and that the wind strength and direction may differ significantly at any given time. Therefore it was not considered appropriate to compare *E. coli* results at Colonsay with wind readings taken at Tiree.

11.6.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.11 presents a scatter plots of *E. coli* result against salinity.

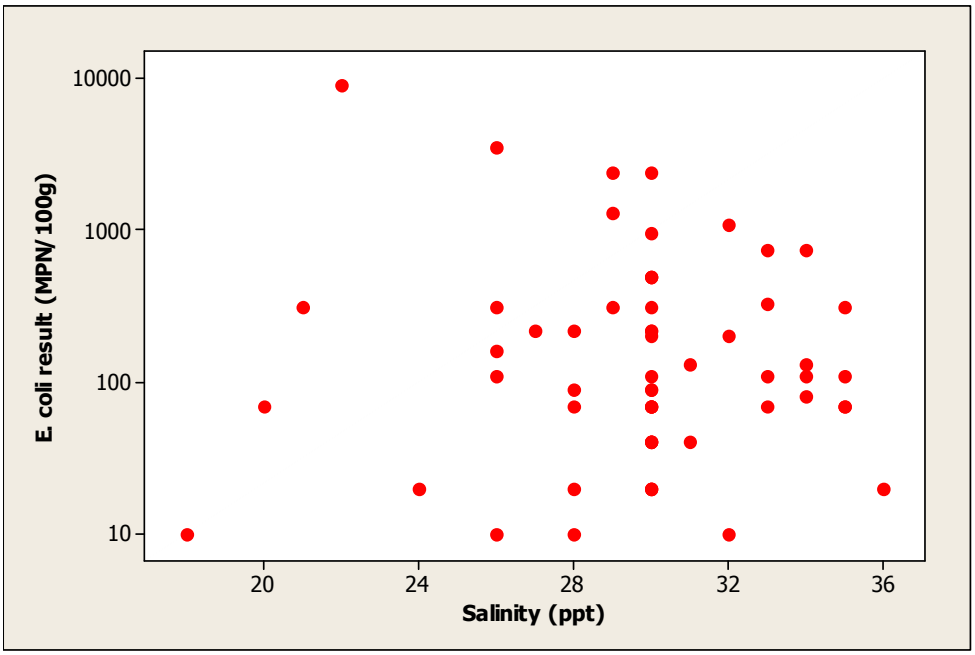

Figure 11.11 Scatterplot of result by salinity

The coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity (Adjusted R-sq=0.0%, p=0.946, Appendix 6).

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

A total of 4 samples gave a result of over 4600 *E. coli* MPN/100g, and these are listed in Table 11.2.

Table 11.2 Historic *E. coli* sampling results over 4600 *E. coli* MPN/100g

Collection date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
06/08/2002	16000	NR355903	*	*	15	*	Low	Increasing to spring
10/09/2002	5400	NR355903	*	*	16	*	Low	Spring
10/09/2002	16000	NR355903	*	*	16	*	Low	Spring
07/09/2006	9100	NR355903	33.2	49.6	14	22	Low	Spring

* Data unavailable

All samples were reported from the RMP (NR 255 903), but as already discussed must have originated from the other two lease areas. Three of these results arose in September, and one arose in August, when water temperatures were warm. Three of these arose in 2002, two of which arose on the same occasion. On the 6/8/2002, an additional two samples were reported from the same sampling location, and these samples gave results of 70 and 220 *E. coli* MPN/100g indicating that very large variations in *E. coli* levels may occur even at the same time and place. On the 10/9/2002 a third sample was taken from the same location, and this gave a result of 2200 *E. coli* MPN/100g.

Salinity and rainfall data was only available for one of these samples, and this sampe was collected following high rainfall and at relatively low 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 samples were taken from the razor beds at East of The Strand. Samples were reported from three distinct clusters at The Strand, one at the RMP, one at the main area of trestles recorded during the shoreline survey, and one by the processing shed. Stock has never been kept at the RMP, so any samples attributed to this location must have actually be taken at one of the other two lease areas. Results were on average highest at the main area of trestles and lowest at the processing shed, but the difference between these clusters was not statistically significant. All results of over 4600 *E. coli* MPN/100g were attributed to the RMP. At the other two clusters, the highest peak results arose at the main area of trestles.

The main area of trestles was sampled at either end on several occasions with higher results on average at the eastern end, although again this difference was not significant. It must be noted that samples were not taken from multiple locations on any occasion, so any apparent geographical differences in levels of contamination may be a result of temporal rather than spatial effects.

In terms of overall temporal trends, a peak in results arose in 2002, although this was accentuated by the collection of multiple samples from the same

location on most sampling occasions in 2002. Smaller peaks in results appeared to occur in late 2004 and early 2007. No results over 1000 *E. coli* MPN/100g occurred from mid 2007 onwards. A strong seasonal pattern was found, with results in the autumn significantly higher than those in the winter and spring. A weak positive relationship was also found with temperature.

Highest E. coli results were found to occur at rainfall in excess of 10 mm in both the 2 and 7 days preceding sampling.

No correlation between levels of *E. coli* in shellfish and tidal state on either the spring/neap or high/low tidal cycles was found, although sampling was strongly targeted towards low water on spring tides, so the full range of tidal conditions were not represented.

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 either area as The Strand has held seasonal classifications within the last three years and the razor beds are yet to be classified.

12. Designated Shellfish Growing Waters Data

The area considered in this report coincides with a shellfish growing water that was designated in 2002. The growing waters boundaries are the same as for the current Pacific oyster production area. The extent of the growing water and the location of monitoring points is shown on Figure 12.1.

The monitoring requires the following testing:

- Every third year for metals and organohalogens in mussels
- Quarterly for faecal coliforms in mussels

Monitoring results for faecal coliforms in shore mussels from 2002 to mid 2007 have been provided by SEPA, which discontinued monitoring of most harvesting areas in 2007. These results are presented in Table 12.1.

Table 12.1 SEPA Faecal coliform results (faecal coliforms/100g) for shore mussels gathered from Colonsay.

	Site	Colonsay	Colonsay
	OS Grid Ref.	NR 355 903	NR 35675 90301
	Q1	40	
	Q2		
	Q3		3500
2003	Q4		40
	Q1		90
	Q2		500
	Q3		750
2004	Q4		110
	Q1		310
	Q2		110
	Q3		2200
2005	Q4		1300
	Q1		220
	Q2		310
	Q3		405
2006	Q4		170000
	Q1		160
	Q2		
	Q3		
2007	Q4		

Two points were sampled, one at the nominal RMP and the other a short distance to the east.

The geometric mean result of all shore mussel samples was 433 faecal coliforms / 100g. Results ranged from 40 up to one exceptionally high result of 170000 faecal coliforms/100g. Results were highest on average for quarter 3, and lowest for quarter 1, but differences between results by quarter were not significant (One-way ANOVA, p=0.336, Appendix 6). Levels of faecal coliforms are usually closely correlated to levels of *E. coli* often at a ratio of

approximately 1:1. The ratio depends on a number of factors, such as environmental conditions and the source of contamination. As a consequence of this and species differences, the results presented in Table 12.1 are not directly comparable with other shellfish testing results presented in this report. Nevertheless, the SGW results show periodically very high levels of faecal contamination are present in the area.

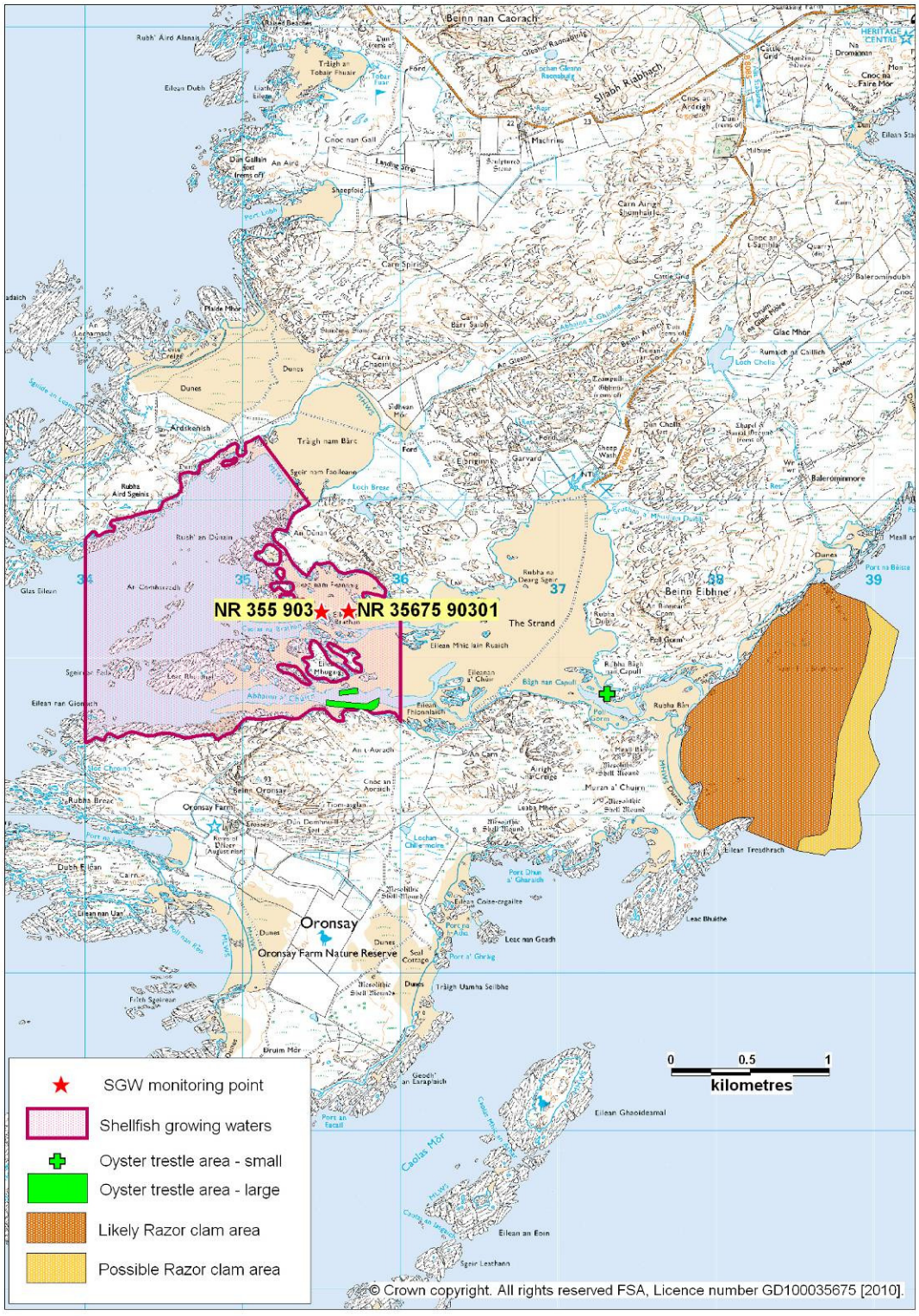

Figure 12.1 Shellfish growing waters and monitoring points

13. Rivers and streams

There are no river gauging stations on rivers or burns along the coastline in the Colonsay area.

The following streams were measured and sampled during the shoreline survey. These represent the largest freshwater inputs into the survey area in the vicinity of the Pacific oyster fishery. There was no rainfall on the days of the survey during which the streams were measured and sampled.

Table 14.1 Stream loadings for Colonsay

No	Grid Reference	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	NR 36336 89493	0.14	*	*	-	100	-
2	NR 37190 91101	0.15	0.02	0.004	1.0	700	$7.3x10^6$
3	NR 37293 90914	0.40	0.02	0.001	0.7	2600	$1.8x10^7$
4	NR 39418 94169	0.12	0.23	0.012	28.6	700	$2.0x10^8$

*Too shallow to measure

The points where the streams were measured and sampled are shown in Figure 14.1 together with the calculated loadings.

Stream 4 was located near the ferry terminal at Scalasaig, approximately 4 km north of the razor bed, and so is not displayed on the map. This was the only stream that was flowing significantly at the time of the survey and the loading from this, $2.0x10^8$, was relatively low. It is therefore unlikely that any contamination from this source will significantly impact on the microbiological quality of the razor (or oyster) fisheries.

Stream 1 was too small to measure and had a relatively low *E. coli* level at the time of the survey – no loading could be calculated. Streams 2 and 3, located at the north end of The Strand, were barely flowing at the time of the survey but had relatively high *E. coli* levels. Due to the very low flows, the calculated loadings were small. If the flows increased significantly after rainfall, the loadings from these streams would be likely to increase and there would be some possibility of impact on the microbiological quality of the oysters.

It should be noted that the shoreline adjacent to the razor bed was not included in the survey and therefore there could be additional streams located there. The only one that is evident on the 1:25,000 OS map enters the sea at Port na Béiste, a short distance to the north of the razor bed.

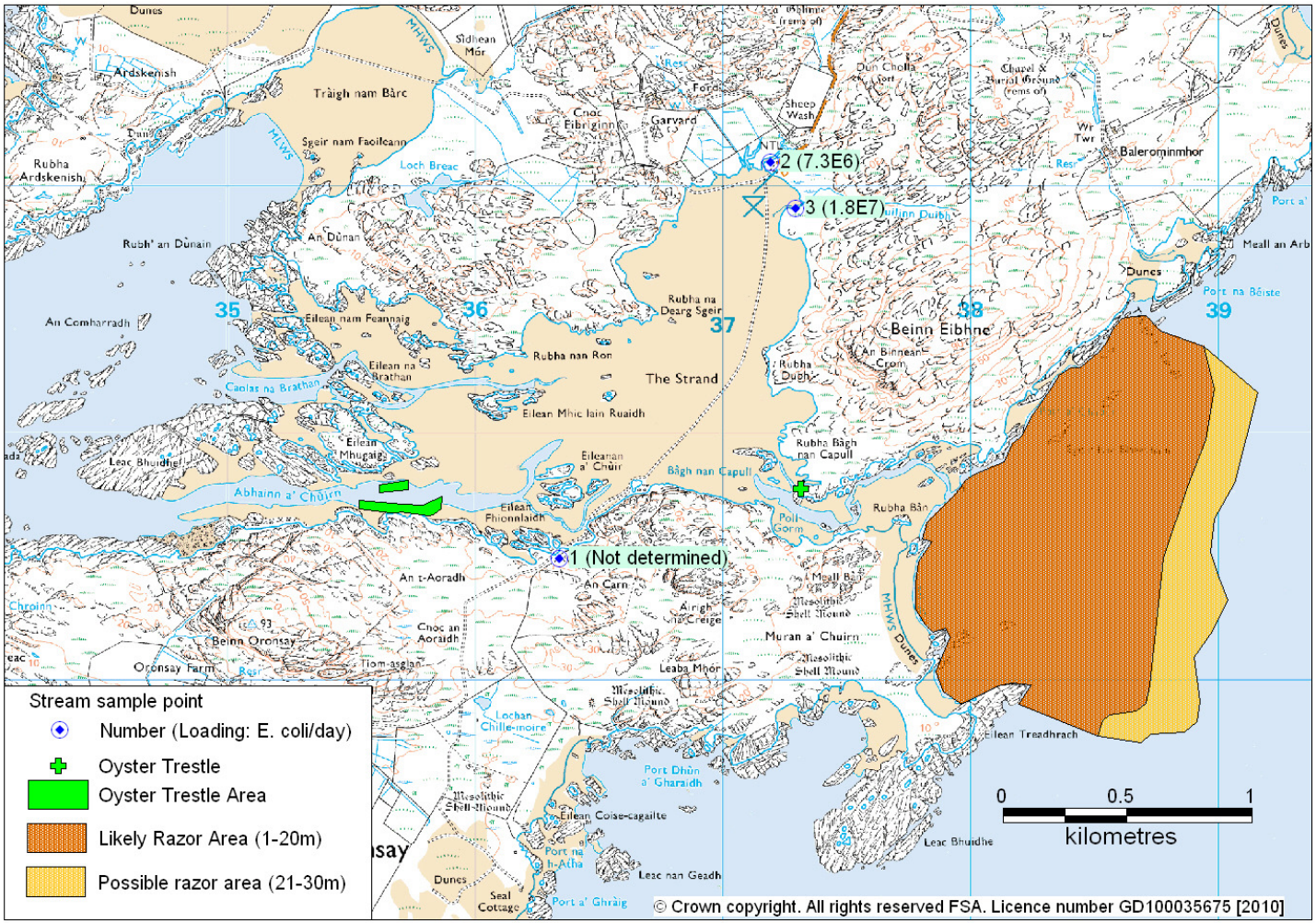

Figure 13.1 Stream loadings at Colonsay: The Strand

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

14. Bathymetry and Hydrodynamics

Currents in coastal waters and estuaries are driven by a combination of tide, wind and freshwater inputs. This section aims to make a simple assessment of water movements around the area. Figure 14.1 shows the OS map of Colonsay/Oronsay and Figure 14.2 shows the bathymetry of the area. The oyster harvesting area is located in the channel between the islands of Colonsay and Oronsay and the razor harvesting area is located immediately to the east. The channel between the islands is more constricted at the eastern end than the western. The area between the islands in the vicinity of the oyster fishery largely dries out at low tide with the trestles located towards the channel (there is a causeway between the islands at low tide). To the east of the islands, the sea floor shelves relatively steeply and reaches 50 m approximately 1 to 1.5 km from shore. Razors will be found from mean low water springs (MLWS) to about 50 m, but the harvesting method will constrain the exploitable area to depths of 20 m or possibly up to 30 m at the very most.

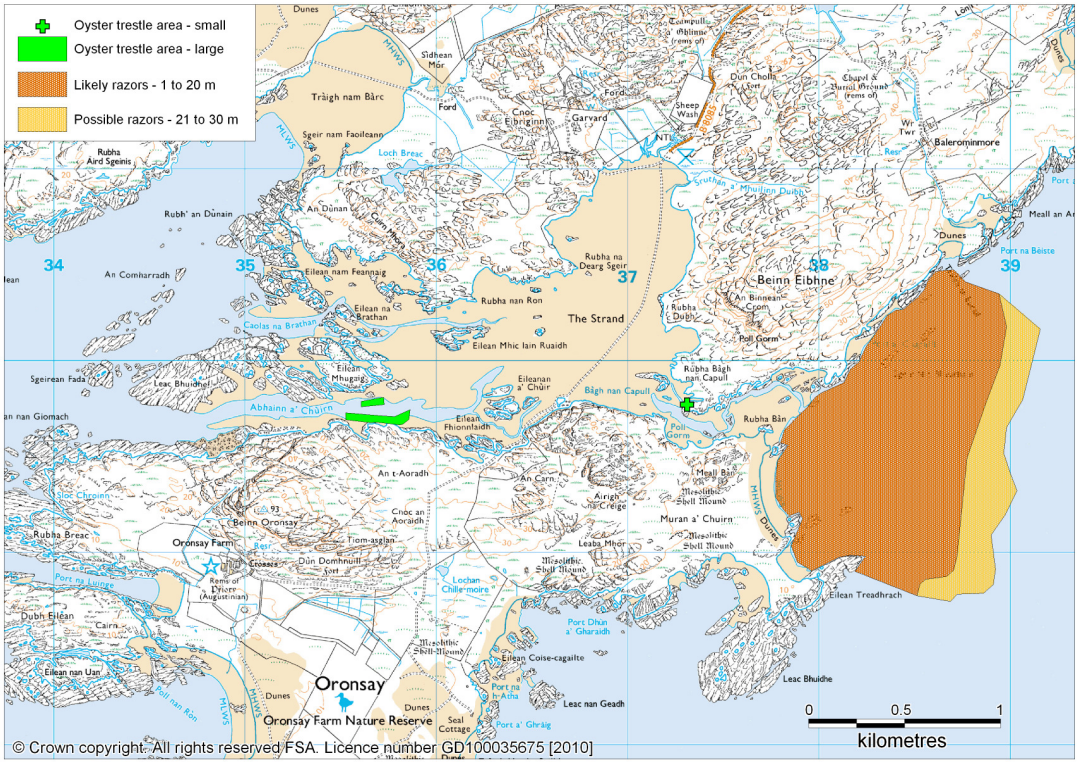

Figure 14.1 OS map of Colonsay/Oronsay

Figure 14.2 Bathymetry of Colonsay/Oronsay

14.1 Tidal Curve and Description

The two tidal curves presented in Figure 14.3 are for Scalasaig. This secondary port is located on the east side of the island of Colonsay, approximately 4 km north of the razor bed. The first tidal curve is for seven days beginning 00.00 BST on 22/06/09 and the second is for seven days beginning 00.00 BST on 30/06/09. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

The following is the summary description for Scalasaig from TotalTide:

> 0374 Scalasaig is a Secondary Non-Harmonic port.
> The tide type is Semi-Diurnal.
>
> | | |
> |---|---|
> | HAT | 4.1 m |
> | MHWS | 3.7 m |
> | MHWN | 2.7 m |
> | MSL | 2.15 m |
> | MLWN | 1.5 m |
> | MLWS | 0.7 m |
> | LAT | 0.2 m |
>
> Predicted heights are in metres above Chart Datum

The tidal range at spring tide is therefore approximately 3.0 m and at neap tide 1.2 m.

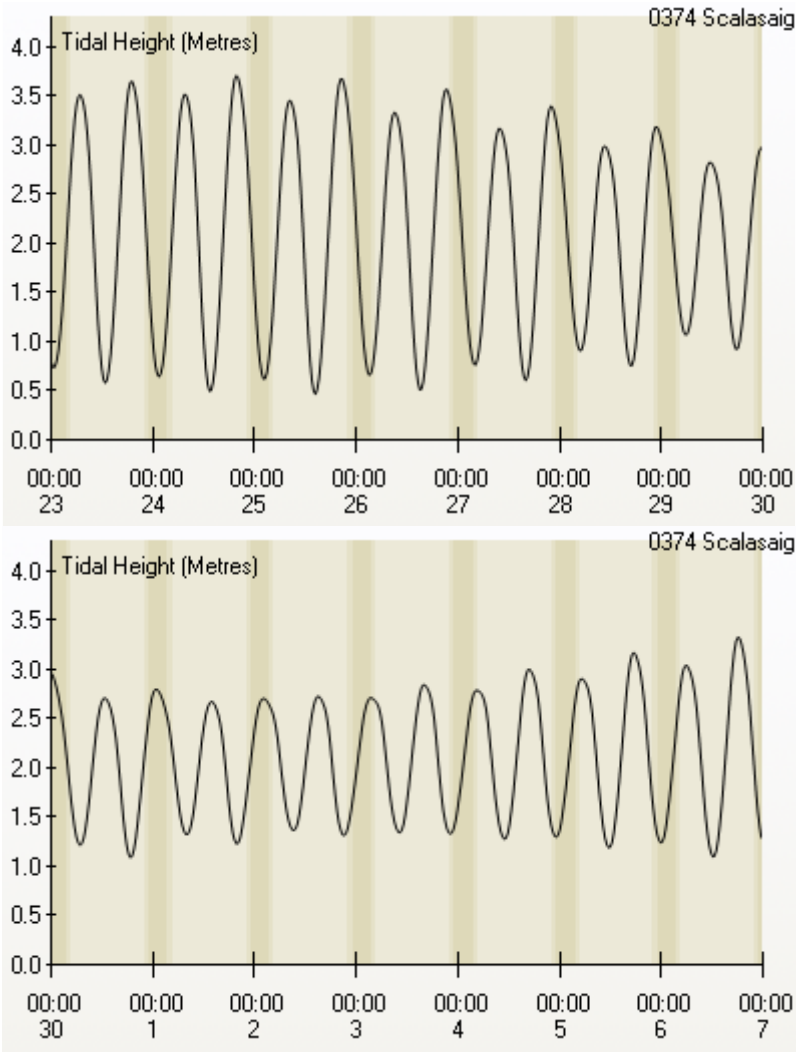

Figure 14.3 Tidal curves at Scalasaig

14.2 Currents

The only tidal stream information which was available from TotalTide was for a tidal diamond between Oronsay and Jura. The tidal diamond information is given below in Table 14.1. The associated spring tidal streams are shown in Figure 14.4 (flood tide) and Figure 14.5 (ebb tide).

Table 14.1 Tidal diamond for station SN038A (55° 59.50'N 6° 05.50'W)

Time	Direction	Spring rate	Neap Rate
-06h	291°	0.21 m/s	0.10 m/s
-05h	330°	0.21 m/s	0.10 m/s
-04h	357°	0.31 m/s	0.10 m/s
-03h	012°	0.36 m/s	0.10 m/s
-02h	044°	0.21 m/s	0.10 m/s
-01h	092°	0.26 m/s	0.10 m/s
HW	114°	0.26 m/s	0.10 m/s
+01h	140°	0.26 m/s	0.10 m/s
+02h	167°	0.21 m/s	0.10 m/s
+03h	197°	0.26 m/s	0.10 m/s
+04h	220°	0.26 m/s	0.10 m/s
+05h	247°	0.26 m/s	0.10 m/s
+06h	278°	0.21 m/s	0.05 m/s

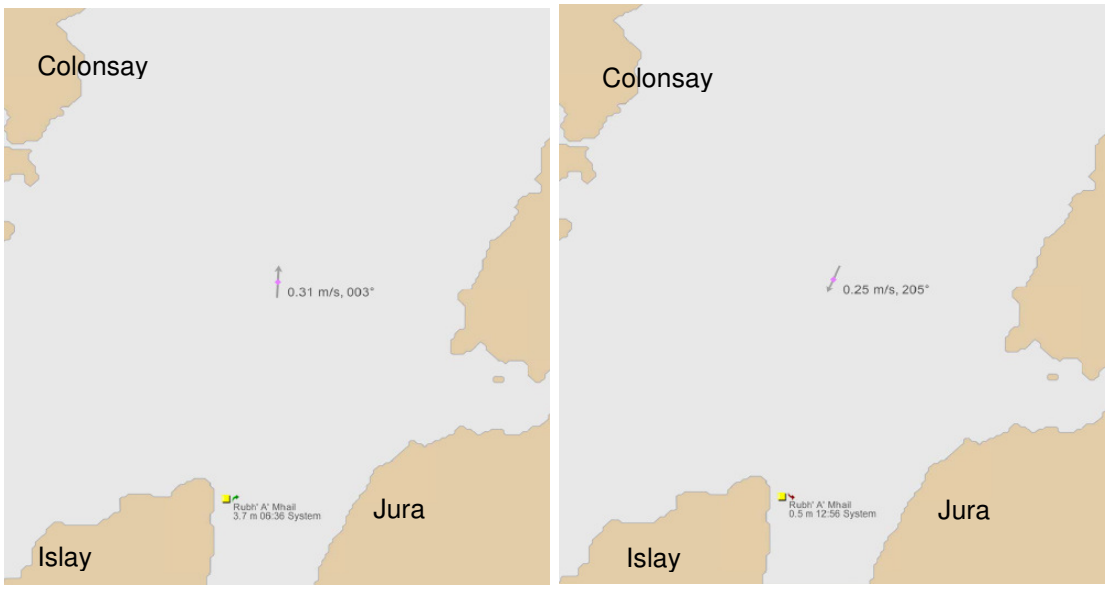

Figure 14.4 Spring flood tide at **Station 038A**
Figure 14.5 Spring ebb tide at **Station 038A**

Despite a moderate tidal range, the indicated tidal streams are relatively weak compared to those elsewhere in the general area, e.g. in the Sound of Jura and to the south and west of Islay. Based on the tidal diamond, the particle transport distance at this station would be in the order of 5-6 km on spring tides and 2-3 km on neap tides. Therefore on this basis it is possible that contamination from sources at Scalasaig (about 4 km to the north) may reach the razor beds around low water on spring tides only, albeit in a highly dilute form, and it is possible that flows are weaker closer to the coast.

The tidal stream information gives an indication of the currents that may apply at the razor bed but not at the oyster trestles between the islands. For the

former, it will be expected that currents will flow northwards along the coast during the flood tide and southwards along the coast during the ebb tide.

The flows within the channel between the two islands are expected to be complex, with water flooding from both direction on the rising tide and also ebbing in both directions on the falling tide. However, given the greater restriction at the eastern end, it would be expected that the main exchange of water will arise from the western part of the channel and that these should impact on the two larger areas of trestles. The location of the smaller area of trestles towards the eastern end means that it would be expected to be influenced by ebbing and flooding through the eastern part of the channel.

Currents flowing near the shore along the eastern coast of the islands would be expected to be sheltered from prevailing westerly/south-westerly winds by the islands themselves. However, those winds would be expected to influence the tides and currents within the channel between the islands and would increase the effect of the tide flooding from the western end and reduce the effect of the tide ebbing in that direction.

Given the large body of water surrounding the islands, the low levels of freshwater input, and the fact that the channel largely dries out on each tidal cycle, it is not expected that there will be any density driven flows in the area. Salinities recorded at The Strand during *E. coli* classification monitoring averaged 29.7 ppt and ranged from 18 to 36 ppt. This is a surprisingly large range given the low levels of freshwater input to the area. The low salinities recorded on occasion may be a consequence of the samples being taken at low water following significant rainfall, so salinity may be expected to rise rapidly as the tide floods.

14.3 Conclusions

The part of the razor clam bed nearest shore will be subject to local sources of contamination, potentially including any within the eastern part of the channel between the islands, which will be transported along the shore with the currents. The part of the razor bed further from shore should not be impacted by these sources – the dilution will markedly increase away from shore given the depth in the area. Contamination from Scalasaig may reach the razor beds low water on spring tides only, but this will be subject to high levels of dilution.

The larger areas of oyster trestles will be exposed to contamination arising at the western end of the channel during the flooding tide and to local sources to the east of the trestles during the ebbing tide. On the latter, it is likely that they will also be impacted by any contamination arising at the northern end of The Strand.

The small area of trestles at the eastern end of the channel will be exposed to contamination arising from outside the channel on the flooding tide and to local sources within the channel on the ebbing tide – as with the other trestles, this could include contamination arising at the northern end of The Strand.

15. Shoreline Survey Overview

The shoreline survey was conducted from the 23-24 June 2009 under warm, dry and settled conditions. Additional sampling of the razor fishery was undertaken on the 2 September 2009 under calm but wet conditions.

The Pacific oyster fishery at The Strand consisted of three distinct blocks of trestles where oysters are grown in bags. Two large blocks of trestles were located at the western end of the strand just off the north coast of Oransay, and a third smaller block of trestles was located by the oyster processing shed at the eastern end of The Strand. Juvenile oysters are bought in and grown on the two larger blocks of trestles to the west. Mature stock is held at the smaller site by the shed so they can be processed and despatched during periods when it is not possible to access the main growing area by tractor. Harvesting occurs year round. There are depuration facilities at the processing shed.

The razor beds lie to the east of The Strand. Razors would be hand gathered by divers, thereby limiting the harvestable area to a depth of about 20 m. Harvesting may occur at any time of the year, but would be highly weather dependent.

No sewage discharges were seen at either The Strand or the shore adjacent to the oyster trestles. Some small sewage discharges were observed at Scalasaig, which is on the east coast of Colonsay about 4 km to the north of the razor beds. Some boats (including 5 visiting yachts and a ferry) were also observed at Scalasaig, some of which may discharge overboard. Significant seasonal increases in population are expected on Colonsay, with holiday accommodation mainly at Scalasaig, and none in the vicinity of either fishery.

The majority of the surrounding land is rocky with heather scrub and natural grassland. A total of 184 sheep and 39 cattle were recorded on pastures adjacent to The Strand, mainly on the north shore but also on the south shore near the main block of trestles. Large amounts of sheep and cattle droppings were noted at various points within the survey area. Livestock were not fenced from the shore, and some cattle were observed resting on The Strand at low tide.

Seals are reported to haul out near the main area of trestles, and 4 were observed here during the shoreline survey. Three geese were observed during the shoreline survey, and goose droppings were recorded at various points around The Strand during the shoreline survey. About 45 oystercatchers were also recorded on The Strand during the shoreline survey.

Seawater samples taken at The Strand contained low levels of *E. coli* ranging from 1 to 18 cfu/100ml. The two seawater samples taken at the main block of trestles contained 1 and 4 *E. coli* cfu/100ml, and the sample taken at the trestles by the processing shed contained 4 *E. coli* cfu/100ml. A seawater sample taken from the Strand near Garvad was more contaminated (18 *E. coli*

cfu/100ml) than those taken at the trestles. Two seawater samples taken at the razor beds both contained 1 *E. coli* cfu/100ml. The salinities of all samples taken from The Strand and the razor bed were indicative of full strength seawater. The two seawater samples taken at Scalasaig harbour contained the highest levels of contamination (230 and 760 *E. coli* cfu/100ml).

Freshwater samples and discharge measurements were taken, where possible, at streams draining into the survey area. Flows were very low at the time of survey, and *E. coli* levels ranged from 100 to 2600 cfu/100 ml. Two streams drained to the north shore of The Strand just over 1 km from the trestles by the processing shed, and one drained to the south shore of The Strand about 500 m to the east of the main blocks of trestles.

Four oyster samples were taken from the main block of trestles, and results ranged from 110 to 220 *E. coli* MPN/100g, and a sample taken from the trestles by the processing shed contained 3500 *E. coli* MPN/100g. Norovirus was not detected in a sample taken from the main block of trestles. Two razor samples were taken from the razor beds and both contained <20 *E. coli* MPN/100g.

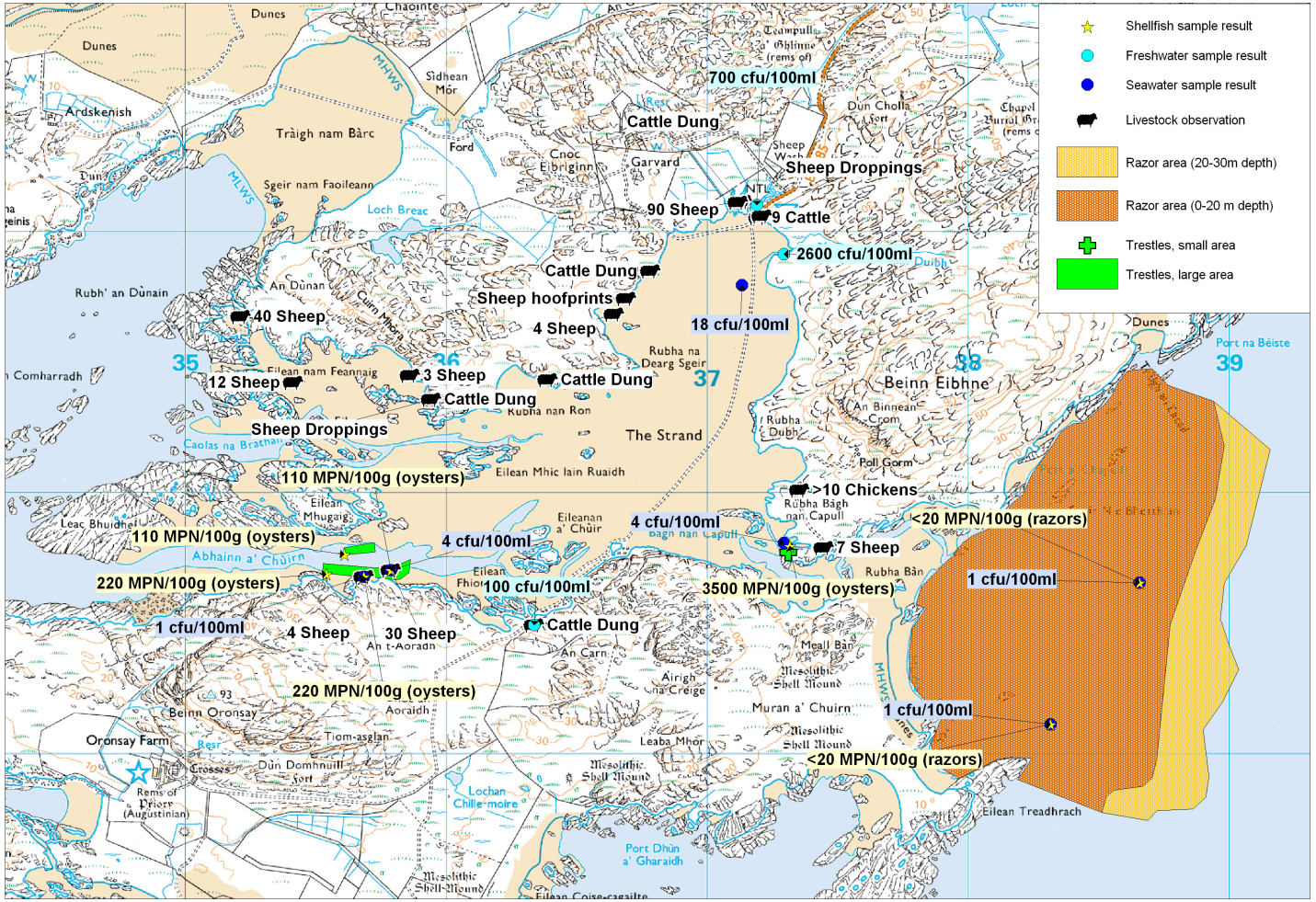

Figure 15.1 Summary of shoreline observations

16. Overall Assessment

Human sewage impacts

No direct impacts from human sewage are anticipated at The Strand as there are no discharges to water here and the area is not navigable by boat. There are a few small private discharges to coastal waters at Scalasaig. This small settlement lies about 4 km to the north, so there is the possibility of minor impacts from these, depending on patterns of water circulation in the area. There is a small harbour at Scalasaig from which the ferry sails daily during the summer, where a few visiting yachts were seen during the shoreline survey. Boats are likely to regularly pass over the razor beds so occasional minor impacts are possible from overboard discharges. Quarterly norovirus testing (see Summary in Appendix 9) results were negative in all but one sample, which was taken in February 2010. This sample was positive at the limit of detection for norovirus Genogroup II. The primers used to detect this genogroup are not thought to cross react significantly with viruses from any of the animal species known to be present in the vicinity. Therefore, this result is indicative of the presence of human sewage contamination in the waters overlying the oyster trestles.

Agricultural impacts

Sheep and some cattle are grazed on the pastures surrounding The Strand, and are likely to be responsible for the majority of contamination observed at the oyster fishery. Based on census data, the ratio of sheep to humans on Colonsay and Oronsay is about 50:1. A total of 184 sheep and 39 cattle were recorded during the shoreline survey, mainly on the north shore of The Strand, but livestock droppings were widely distributed around the whole area. There were no fences preventing livestock from accessing the shore, and cattle were recorded on the beach by Garvard, and are reported to frequent a beach just to the south of the processing shed during warm weather. The east coast of Colonsay and Oronsay adjacent to the razor beds were not surveyed, but it is probable that livestock are also grazed on the grassland, although livestock impacts here will be lower as the shellfish beds are located in deeper water and are much less enclosed.

Contamination from livestock will be carried to the fishery via direct deposition in the intertidal area and subsequent tidal transport, or via land runoff. Given the distribution of livestock observed during the shoreline survey, contamination from livestock will be fairly evenly spread around The Strand, impacting at both the main area of trestles and those by the processing shed.

Wildlife impacts

Seals are present year round and appear to favour the area by the main group of oyster trestles at The Strand as a haulout site, so impacts from seals are likely to be greatest in this area.

Seabirds and geese, both of which are present in the area are likely to impact the fisheries to some extent. As there was no information available regarding spatial distribution of these animals, impacts on water quality are assumed to be evenly distributed.

Seasonal variation

Human population will be higher during the summer, but this is unlikely to result in increased impacts at the Pacific oyster fishery. An increase in boating activity during the summer could result in overboard discharges from yachts passing near the razor beds.

Numbers of sheep and cattle will approximately double during spring following the birth of lambs and calves, and decrease in the autumn as animals are sent to market. They will also access streams to drink more frequently during warmer weather, so it is likely that impacts from livestock sources will be greater during the summer months. There may be more seabirds present in the area during the breeding season but whether there is any seasonality in waterfowl numbers is uncertain.

A strong seasonal pattern in historic *E. coli* monitoring results was found at The Strand, with results in the autumn significantly higher than those in the winter and spring. A weak positive relationship was found with temperature. A seasonal pattern was also seen in shellfish growing waters monitoring results from The Strand, where results were highest on average for quarter 3, and lowest for quarter 1, although differences between results by quarter were not statistically significant.

Rivers and streams

Only three small streams draining to The Strand were found during the shoreline survey, which was undertaken during a dry spell. Flows and hence *E. coli* loadings were low and so at the time of survey these streams would have had a minimal impact on the fishery. *E. coli* levels ranged from 100 to 2600 cfu/100ml suggesting they are subject to faecal contamination. The two larger streams discharge about 1 km to the north of the area of trestles by the shed, and the smallest stream discharges about 500 m to the east of the main blocks of trestles. However, it is likely that their flows and loadings increase following significant rainfall and salinity readings, and they may be an important pathway carrying contamination from livestock into the area at times.

The shoreline adjacent to the razor bed was not included in the survey and the OS map indicates that a small stream enters the sea at Port na Béiste, a short distance to the north of the razor bed. Again, this is likely to carry contamination of livestock origin and may, in the absence of other sources, be of significance to the razor beds at times.

Meteorology, hydrology, and movement of contaminants

Tidal streams at the razor beds are bi-directional, travelling in a northerly direction on the flood tide and a southerly direction on the ebb tide. Tidal stream information suggests that contamination from Scalasaig may reach the razor beds around low water on spring tides only, albeit in a highly dilute form. The flows across The Strand are expected to be complex, with water flooding from both direction on the rising tide and also ebbing in both directions on the falling tide. However, given the greater restriction at the eastern end, a greater exchange of water through the western end of the Strand would be expected. No correlation was found between historical *E. coli* monitoring results at The Strand and tidal state either on the high low or spring neap cycle, although this may be expected as sampling was strongly targeted towards low water on spring tides.

Tidal currents flowing along the shore at the razor bed would be expected to be sheltered from prevailing westerly/south-westerly winds by the islands themselves. However, those winds would be expected to influence the tides and currents at The Strand and would increase the effect of the tide flooding from the western end and reduce the effect of the tide ebbing in that direction, thereby increasing the importance of sources to the west of the fishery.

There is little in the way of freshwater inputs either to The Strand or on the shoreline adjacent to the razor bed so stratification and density driven flows are not expected at either. No relationship was found between historical *E. coli* monitoring results at The Strand and recent rainfall or salinity suggesting that rainfall dependent pathways are not the primary mechanism by which contamination is carried into the area and possibly implying that direct deposition in the intertidal area is of most importance.

Temporal and geographical patterns of sampling results

Historical *E. coli* classification monitoring results show a peak in 2002, although this was accentuated by the collection of multiple samples on most sampling occasions in 2002. Smaller peaks in results appeared to occur in late 2004 and early 2007. No results over 1000 *E. coli* MPN/100g have occurred since mid 2007.

Historical *E. coli* results from before mid 2007 were all reported from the nominal RMP, where mature stock has never been held so it is uncertain where these samples actually were taken and as a consequence they could not be used in the geographical analysis. After this they were taken from either the main block of trestles or from the trestles near the processing shed, with the sampling location recorded by GPS. Results were higher on average at the main block of trestles, a higher proportion of results here were over 230 *E. coli* MPN/100g, and of these two clusters the highest overall results also arose at the main block of trestles. Within the main area of trestles results were higher on average at the eastern end. None of these differences was statistically significant. It must be noted that samples were not taken from multiple locations on any occasion, so any apparent geographical differences in levels of contamination may be a result of temporal rather than spatial

effects, although these findings do support the location of an RMP at the eastern end of the main area of trestles.

During the shoreline survey four oyster samples were taken from the main block of trestles at The Strand and results ranged from 110 to 220 *E. coli* MPN/100g, and a sample taken from the trestles by the processing shed contained 3500 *E. coli* MPN/100g. This is the opposite pattern to that observed in the historic monitoring results but only represents one sampling occasion. Norovirus was not detected in a sample taken from the main block of trestles, which is consistent with the absence of sewage sources. Two razor samples taken from different points within the razor bed both contained <20 *E. coli* MPN/100g.

Seawater samples taken at The Strand contained low levels of *E. coli* ranging from 1 to 18 cfu/100ml, with the highest result recorded by Garvard. Two seawater samples taken at the razor beds both contained 1 *E. coli* cfu/100ml suggesting that the levels of contamination are lower than those experienced within The Strand.

Overall conclusions

The Strand

The main source of contamination at The Strand is diffuse contamination from livestock. This appears to impact all areas of The Strand, but at the time of shoreline survey was perhaps heaviest on the north shore in the vicinity of Garvad. Diffuse contamination from wildlife (birds and seals) is also likely to make a contribution. Seals favour the area where the main block of trestles is located as a haulout area but their numbers are small relative to the numbers of livestock potentially present in the area. A comparison of historic *E. coli* monitoring results from the two distinct areas where shellfish stock are kept suggests levels of contamination are generally higher at the main block of trestles than at the smaller block of trestles near the processing shed.

East of The Strand

Potential sources impacting on the razor beds include diffuse contamination originating from The Strand and carried out across the beds on an ebbing tide, and a very small stream discharging to the shore just north of the beds. It is also possible that contamination originating from Scalasaig reaches the razor beds around low water on spring tides, but this will be in a highly diluted form. Also, any diffuse contamination from livestock and wildlife along the adjacent shoreline will tend to travel up and down the coast with the tides, with greatest impacts nearest the shore.

Large volumes of water will be carried from The Strand on the ebbing tide, and based on water samples taken on the shoreline survey this will only be lightly contaminated, but will be more contaminated than that from the open sea. It will be carried in a southerly direction across the beds on an ebbing tide, rapidly becoming diluted with time and distance. As this is probably the main contaminating influence on the beds, the RMP should be set as close to

the shore as possible, just to the south of the eastern end of The Strand to best capture contamination from this source. This should also adequately capture any diffuse contamination originating from the adjacent shoreline due to its nearshore location.

17. Recommendations

The Strand

Production Area
The production area boundaries need to be extended to include the smaller area of trestles near the processing shed. The lease area at the north west end of The Strand is not currently in use, and if it were to be used in the future it would only be to raise small seed stock to a size of about 5-10 g, so this area need not be classified. As the northern half of The Strand may be subject to slightly higher levels of contamination, and the fishery does not lie here, this part should be excluded from the production area.

Recommended production area boundaries are lines drawn between NR 3483 8949 and NR 3483 9015 and between NR 3483 9015 and NR 3720 9015 and between NR 3751 8981 and NR 3759 8962 extending to MHWS.

RMP
Within the main block of trestles, historic *E. coli* monitoring results suggested that levels of contamination may be higher at the eastern end. Taken together, these suggest that the RMP should be set at the eastern end of the main growing area. It is therefore recommended that the RMP be set at NR 3585 8971.

Sampling Tolerance
As this is a well established aquaculture site, a standard 10 m sampling tolerance is recommended as it should be possible to place a dedicated sampling bag at this location. As stock to be used for sampling purposes is replenished, care should be taken to ensure that it is in place at least two weeks prior to sampling so that it has time to take on the microbiological character of the RMP.

Frequency
As an element of seasonality has been identified in local livestock numbers, and corresponding seasonal variations in historic *E. coli* monitoring results have been identified, monthly monitoring should be continued.

East of The Strand

Production Area
Boundaries should be set to include the entire exploitable area, and therefore should be extended slightly from those indicated by the harvester on the application for classification. This still allows the small stream input to the north to be excluded from the production area, so that any localised hotspot of contamination arising from this source would lie outside the boundaries.

Recommended production area boundaries are lines drawn between NR 3876 9054 and NR 3939 9054 and between NR 3939 9054 and NR 3939 8870 and between NR 3939 8870 and NR 3791 8870 extending to MHWS.

RMP
It is recommended that the RMP be set at NR 3792 8962.

Sampling Tolerance
A 100 m tolerance is recommended to allow for variation in stocking density and to allow sufficient area from which to reliably obtain samples.

Frequency
As the razor fishery at East of the Strand has no classification history, monthly monitoring is recommended until sufficient monitoring history has been obtained to permit evaluation of stability.

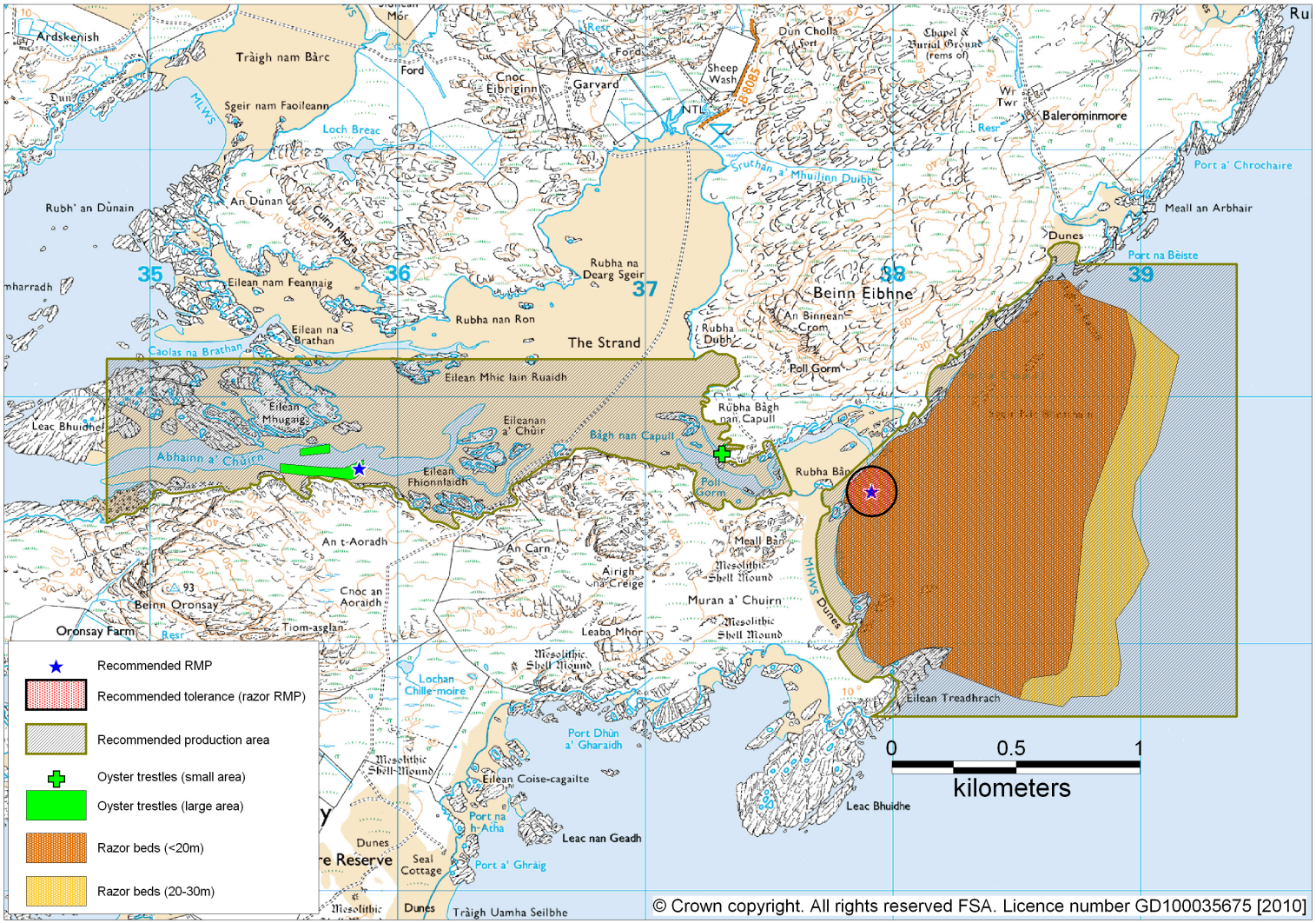

Figure 17.1 Recommendations for Colonsay

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Sampling Plan for Colonsay and East of The Strand

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISH-ERY	NGR OF RMP	EAST	NORTH	TOLER-ANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Colonsay	The Strand	AB 041 009 13	Pacific oyster	Trestle	NR 3585 8971	135850	689710	10	N/A	Hand	Monthly	Argyll & Bute Council	Andrew Abrahams	Christine McLachlan
East of The Strand	Islands of Colonsay and Oronsay	AB 422 826 16	Razors	Wild	NR 3792 8962	137920	689620	100	NA	Diver	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan

Table of Proposed Boundaries and RMPs for Colonsay and East of The Strand

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Colonsay	Pacific oyster	AB 041 009 13	Area bounded by lines drawn between NR 3400 9075 and NR 3400 8945 and between NR 3511 9139 and NR 3540 9096 and between NR 3600 9028 and NR 3600 8959	NR 355 903	Area bounded by lines drawn between NR 3483 8949 and NR 3483 9015 and between NR 3483 9015 and NR 3720 9015 and between NR 3751 8981 and NR 3759 8962 extending to MHWS	NR 3585 8971	RMP shifted to east end of trestles. Production area boundaries redrawn to better represent current fishery.
East of The Strand	Razors	AB 422 826 16	NA	NA	Area bounded by lines drawn between NR 3876 9054 and NR 3939 9054 and between NR 3939 9054 and NR 3939 8870 and between NR 3939 8870 and NR 3791 8870 extending to MHWS	NR 3792 8962	Boundary set to cover likely extent of shellfish bed. RMP set near shore.

Geology and Soils Information

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.

References

Macaulay Institute. http://www.macaulay.ac.uk/explorescotland. Accessed September 2007.

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 x 10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al* 2004).

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

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

Cetaceans

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

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

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

Table 1 Cetacean sightings in 2007 – Western Scotland.

Common name	**Scientific name**	**No. sighted***
Minke whale	*Balaenoptera acutorostrata*	28
Killer whale	*Orcinus orca*	183
Long finned pilot whale	*Globicephala melas*	14
Bottlenose dolphin	*Tursiops truncatus*	369
Risso's dolphin	*Grampus griseus*	145
Common dolphin	*Delphinus delphis*	6
Harbour porpoise	*Phocoena phocoena*	>500

*Numbers sighted are based on rough estimates based on reports received from various observers and whale watch groups. Source: Hebridean Whale and Dolphin Trust.

It is reasonable to expect that whales would not routinely affect shellfisheries located in shallow coastal areas. It is more likely that dolphins and harbour porpoises would be found in or near fisheries due to their smaller physical size and the larger numbers of sightings near the coast.

Birds

Seabird populations were surveyed all over Britain as part of the SeaBird 2000 census. These counts are investigated using GIS to give the numbers observed within a 5 km radius of the production area. This gives a rough idea of how many birds may be present either on nests or feeding near the shellfish farm or bed.

Further information is gathered where available related to shorebird surveys at local bird reserves when present. Surveys of overwintering geese are queried to see whether significant populations may be resident in the area for part of the year. In many areas, at least some geese may be present year round. The most common species of goose observed during shoreline surveys has been the Greylag goose. Geese can be found grazing on grassy areas adjacent to the shoreline during the day and leave substantial faecal deposits. Geese and ducks can deposit large amounts of faeces in the water, on docks and on the shoreline.

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28 x 10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77 x 10^8 FC per faecal deposit to a local

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

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

Deer

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

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

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

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

Otters

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.

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Stoddard, R. A., Gulland, F.M.D., Atwill, E.R., Lawrence, J., Jang, S. and Conrad, P.A. (2005). Salmonella and Campylobacter spp. in Northern elephant seals, California. *Emerging Infectious Diseases* www.cdc.gov/eid 12:1967-1969.

Tables of Typical Faecal Bacteria Concentrations

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

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

```
Two-sample T for log result

place      N   Mean  StDev  SE Mean
shed      11  1.888  0.476     0.14
trestles  11  2.286  0.554     0.17

Difference = mu (shed) - mu (trestles)
Estimate for difference:  -0.398
95% CI for difference:  (-0.859, 0.063)
T-Test of difference = 0 (vs not =): T-Value = -1.81  P-Value = 0.087  DF = 19
```

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

```
Source   DF      SS     MS     F      P
Season    3   9.019  3.006  6.40  0.001
Error    98  46.017  0.470
Total   101  55.036

S = 0.6852   R-Sq = 16.39%   R-Sq(adj) = 13.83%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  ------+---------+---------+---------+---
1      27  1.8857  0.5898    (-------*------)
2      27  2.3032  0.7668                (-------*------)
3      27  2.5460  0.8325                       (-------*------)
4      21  1.8211  0.4283  (-------*--------)
                          ------+---------+---------+---------+---
                              1.75      2.10      2.45      2.80
Pooled StDev = 0.6852

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

Individual confidence level = 98.97%

Season = 1 subtracted from:

Season    Lower   Center   Upper  --------+---------+---------+---------+-
2       -0.0704   0.4175  0.9055                   (------*------)
3        0.1724   0.6603  1.1482                      (------*------)
4       -0.5862  -0.0646  0.4571            (------*-------)
                          --------+---------+---------+---------+-
                               -0.70      0.00      0.70      1.40
Season = 2 subtracted from:

Season    Lower   Center   Upper  --------+---------+---------+---------+-
3       -0.2452   0.2427  0.7307                (------*------)
4       -1.0037  -0.4821  0.0395      (------*-------)
                          --------+---------+---------+---------+-
                               -0.70      0.00      0.70      1.40

Season = 3 subtracted from:

Season    Lower   Center    Upper  --------+---------+---------+---------+-
4       -1.2465  -0.7249  -0.2032  (-------*------)
                          --------+---------+---------+---------+-
                               -0.70      0.00      0.70      1.40
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.111
P-Value = 0.384
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.025
P-Value = 0.847
```

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 23 November 2009 14:01:56

Variables (& observations)	r	p
Angles & Linear (102)	0.077	0.554

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 23 November 2009 14:01:03

Variables (& observations)	r	p
Angles & Linear (102)	0.091	0.441

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature

```
The regression equation is
log e coli for temperature = 1.54 + 0.0622 temperature

Predictor       Coef  SE Coef     T      P
Constant      1.5394   0.2156  7.14  0.000
temperature  0.06221  0.01895  3.28  0.001

S = 0.700255   R-Sq = 10.9%   R-Sq(adj) = 9.9%

Analysis of Variance

Source          DF       SS      MS      F      P
Regression       1   5.2832  5.2832  10.77  0.001
Residual Error  88  43.1514  0.4904
Total           89  48.4346

Unusual Observations

                  log e coli
                         for
Obs  temperature  temperature     Fit  SE Fit  Residual  St Resid
 12         15.0       4.2041  2.4725  0.1101    1.7316      2.50R
 15         16.0       4.2041  2.5347  0.1248    1.6694      2.42R
 27         14.0       1.0000  2.4103  0.0969   -1.4103     -2.03R
 40         14.0       1.0000  2.4103  0.0969   -1.4103     -2.03R
 63         14.0       3.9590  2.4103  0.0969    1.5488      2.23R
 79         20.0       2.0414  2.7835  0.1913   -0.7421     -1.10 X

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 11.6.5 Regression analysis – *E. coli* result vs salinity

The regression equation is
log e coli for salinity = 2.16 - 0.0016 salinity

Predictor	Coef	SE Coef	T	P
Constant	2.1647	0.7115	3.04	0.004
salinity	-0.00161	0.02379	-0.07	0.946

S = 0.664945 R-Sq = 0.0% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0020	0.0020	0.00	0.946
Residual Error	58	25.6448	0.4422		
Total	59	25.6468			

Unusual Observations

Obs	salinity	log e coli for salinity	Fit	SE Fit	Residual	St Resid
19	20.0	1.8451	2.1325	0.2459	-0.2874	-0.47 X
29	26.0	3.5441	2.1229	0.1227	1.4212	2.17R
35	18.0	1.0000	2.1357	0.2909	-1.1357	-1.90 X
39	22.0	3.9590	2.1293	0.2020	1.8297	2.89R
47	21.0	2.4914	2.1309	0.2237	0.3604	0.58 X

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.

Section 12 One way ANOVA comparison of SGW sampling results by quarter

Source	DF	SS	MS	F	P
q	3	2.844	0.948	1.25	0.336
Error	12	9.126	0.761		
Total	15	11.970			

S = 0.8721 R-Sq = 23.76% R-Sq(adj) = 4.70%

Level	N	Mean	StDev	Individual 95% CIs For Mean Based on Pooled StDev
Q1	5	2.1188	0.3501	(----------*----------)
Q2	3	2.4106	0.3362	(----------*----------)
Q3	4	3.0923	0.4278	(----------*----------)
Q4	4	2.9970	1.6187	(----------*----------)
				1.40 2.10 2.80 3.50

Pooled StDev = 0.8721

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.

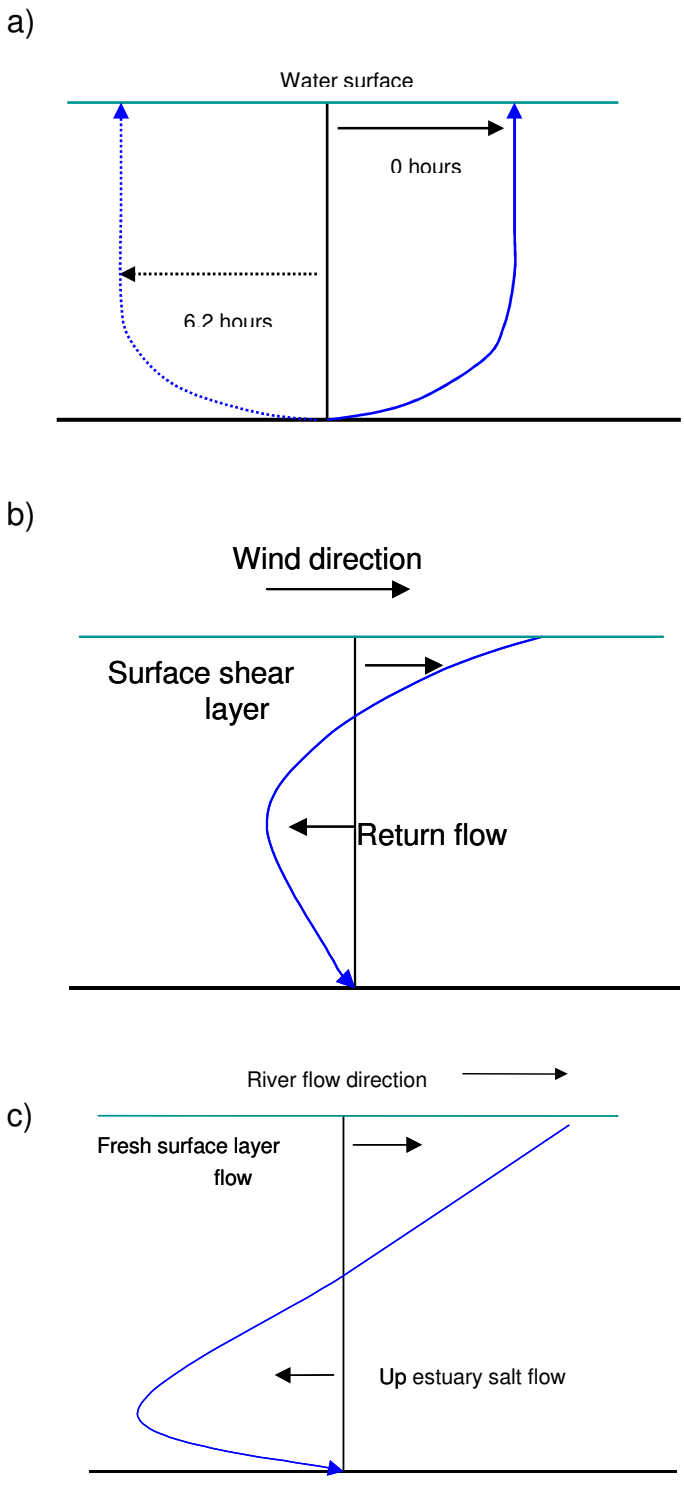

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

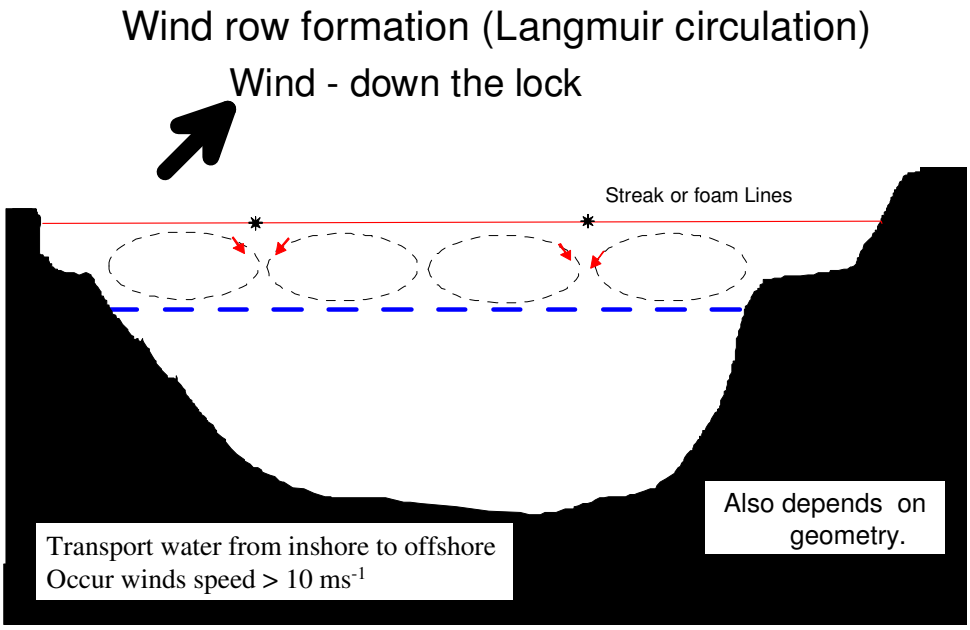

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

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

Colonsay: The Strand (AB 041)
and
East of The Strand (AB422)

Scottish Sanitary Survey Project

Shoreline Survey Report

Prod. area:	Colonsay; East of the Strand
Site name:	The Strand (AB 041 009 13)
	The Islands of Colonsay and Oronsay (AB 422 826 16)
Species:	Pacific oysters, razor clams
Harvester:	A. Abrahams, D. Leadbetter
Local Authority:	Argyll & Bute Council
Status:	Existing site (AB 041)
	New wild harvest site (AB422)
Date Surveyed:	23-24 June 2009
	02 September 2009 (AB 422 shellfish sampling only)
Surveyed by:	Michelle Price-Hayward, Christine McLachlan
Existing RMP:	NR 355 903 (oysters only)
Area Surveyed:	See Map in Figure 1

Weather observations
23 June: Dry, partly cloudy to sunny. Winds SE force 2. Air temp ~16C.
24 June: Dry, partly cloudy to sunny. Winds NE force 3. Air temp ~15C.
02 September: Light showers, Winds S force 1. Air temp unknown. Seawater temp 15C. Rain 48 hours previous - moderate.

Site Observations
The locations of the two production areas is mapped in Figure 1. Specific observations made on site are listed in Tables 1 and mapped in Figure 2. The locations of the oyster trestles were noted using a hand-held GPS receiver and the waypoints used to create the mapped trestle areas are listed in Table 2. Accuracy recorded by the unit was to within 7 meters. The location of the razor clam bed was estimated using information provided by harvester via Argyll & Bute Council and approximate depth areas.

Fishery
Pacific oyster (*C. gigas*)
Pacific oysters are grown here in bags on approximately 400 trestles. Juvenile oysters are purchased in and rotated through the area as they grow. Bags are turned on a regular basis to keep oysters from adhering to each other. Stock is harvested year round, as demand warrants. Bags are collected from the trestles and then taken by tractor to an on-shore grading unit. A depuration unit is located near the harvester's residence and the harvester reports that all outgoing batches of oysters are depurated, even during periods of A classification.

The oyster trestles are located in three distinct blocks. Two large blocks of trestles are located just above MLWS to either side of a water channel called Abhainn a' Chùirn, along the northern shore of Oronsay near The Strand. This area lies in a remote part of the island and is accessible only during low tide and parts of it only during a low spring tide.

A third, smaller area of trestles is located approximately 1.5km east of the other two blocks in a more sheltered cove nearer to the harvester's home and sorting shed on Colonsay. Stock is moved up here from the main areas of trestles for ease of access during poor weather. Stock may stay on this site for extended periods of time.

The harvester reported that he may consider expanding the fishery at some point in the future but had no immediate plans to do so.

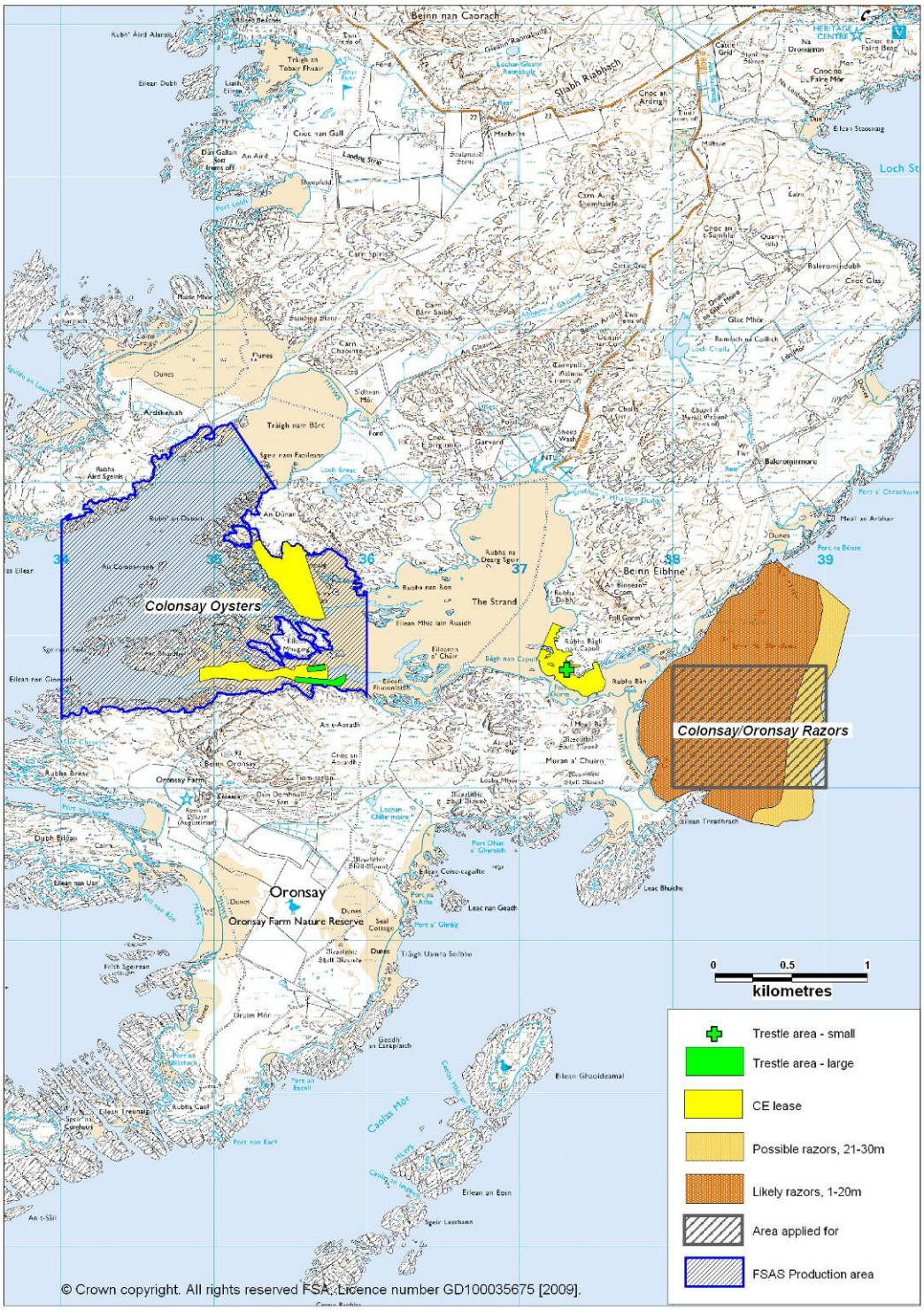

Figure 1. Location of Colonsay production areas and fisheries

Razor clam (*Ensis* spp.)

An application for classification was also submitted by a separate harvester for razor clams to be gathered from a subtidal area east of the Strand. As this was within 2km of the Colonsay Pacific oyster fishery, the two surveys were combined. As no boat was available during the June survey dates for collecting razor clam samples, a separate sampling trip was scheduled by Christine McLachlan of Argyll & Bute Council, and samples were gathered on 02 September 2009. The harvester reported that the razor clam bed essentially comprised the entire area specified in the application (See Figure 2.) Harvesting could occur at any time of year, though due to the remote and exposed nature of the location would be highly weather dependent. Razors would be hand gathered by divers, practically limiting the operation to the subtidal seabed area up to approximately 20 m depth.

Sewage/Faecal Sources

Human

There are few sources of human faecal contamination in the vicinity. The harvester at Colonsay oysters lives up a steep hill above the sorting shed east of the main area of trestles. He reports that his septic tank discharges to soakaway about 200 m back from the shoreline.

A septic tank outfall was observed at Scalasaig. Additionally, there was septic discharge to the stream flowing through the town from the hotel and possibly other residences along it. Boats moored in the harbour may be a further source of human sewage waste if the toilets are discharged overboard in the harbour. The ferry docks overnight in Scalasaig and presumably crew stay aboard if they are not normally resident on the island. The ferry has an onboard sewage treatment system.

Livestock

Sheep and some cattle are grazed on the surrounding hills. A total of 184 sheep and 39 cattle were directly observed, and both sheep and cattle droppings were commonly encountered. Cattle were observed wading in the stream and lying on the sand at low tide near the car park at the crossing to Oronsay. The grower reports that at the time of survey, the some of the large numbers of sheep observed were recently gathered for lamb marking, and more usual sheep numbers in the vicinity are in the order of 100-150 animals. He also reports that about 25-30 cattle regularly gather on the north east corner of Oronsay on a beach just opposite the processing shed in warm weather.

A few small streams, ground seeps and drains were observed along the shoreline that would provide a means for carrying waste to the sea. Many of these streams had very little water flow on the day due to the lack of rain during the previous fortnight.

The largest stream observed flowing in the area discharged discharged adjacent to the ferry pier at Scalasaig, which is approximately 4km north of the proposed razor clam production area.

Seasonal Population
Seasonal increases in population are significant in Colonsay. However, camping and caravans are not permitted on the island so the numbers of visitors are restricted by the availability of overnight accommodation. During the summer, a ferry brings day visitors from Islay on Wednesdays. Otherwise, ferries deliver visitors to the island only once daily during the summer. There is one hotel, as well as several B&B and self catering cottages. The hotel has only 9 rooms. There are one restaurant, one bar and one café on the island, all near the town of Scalasaig.

Boats/Shipping
There is a small harbour at Scalasaig, where the ferry docks overnight. On the day of survey there were 12 boats observed in the harbour, including 5 visiting yachts of which at least one had crew aboard.

Land Use
Land use in the area is predominantly sheep grazing. The terrain on the island is rocky with heather scrub and some natural grassland.

Wildlife/Birds
Seals are known to haulout near the main area of oyster trestles and 4 were observed during the survey. Others could be heard in the distance, but were not directly observed. The harvester reported that seals could regularly be seen near to where the main area of oyster trestles is located.

Geese and shorebirds were observed during the survey, and large numbers of goose droppings were present along the shoreline. A total of 44 wild geese, ducks and shorebirds were observed on the day and goose droppings were observed in some areas.

Sampling
Water and shellfish samples were collected at sites marked on the map. Due to limitations of tide and transport schedules, all oyster and some water samples were collected on the 23rd and then held in cool boxes until received by the laboratory on the morning of the 25th. The remaining water samples were collected on the 24th and submitted in the same cool boxes as the other samples on the 25th.

Freshwater samples showed moderate to high levels of contamination, with the highest result (2600 *E. coli* cfu / 100 ml) obtained from the stream in which cattle were observed. The lowest result (100 *E. coli* cfu / 100 ml) was obtained from the small stream on Oronsay nearest the main area of oyster trestles.

Seawater sample results were highest at Scalasaig harbour (760 *E. coli* cfu/ 100 ml) and lowest (1 *E. coli* cfu / 100 ml) at the oyster fishery itself.

Pacific oyster samples collected from the main areas of trestles at Oronsay contained between 110 and 220 *E. coli* MPN / 100 g, while a sample collected

from the small cluster of trestles at Colonsay contained 3500 *E. coli* MPN / 100g.

A separate Pacific oyster sample was taken from the same location as Oyster sample 1 and submitted for norovirus testing. Results were negative for both genogroup I and genogroup II.

Razor clam and seawater samples were collected by the harvester and the local authority on 02/09/2009. Results for seawater samples were both 1 *E.coli* cfu / 100 ml and for the razor clam samples <20 *E.coli* MPN / 100 g.

Bacteriology results follow in Tables 3 and 4 and are mapped in Figures 3 and 4.

Photos referenced in the table can be found attached as Figures 5-14.

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 sea.

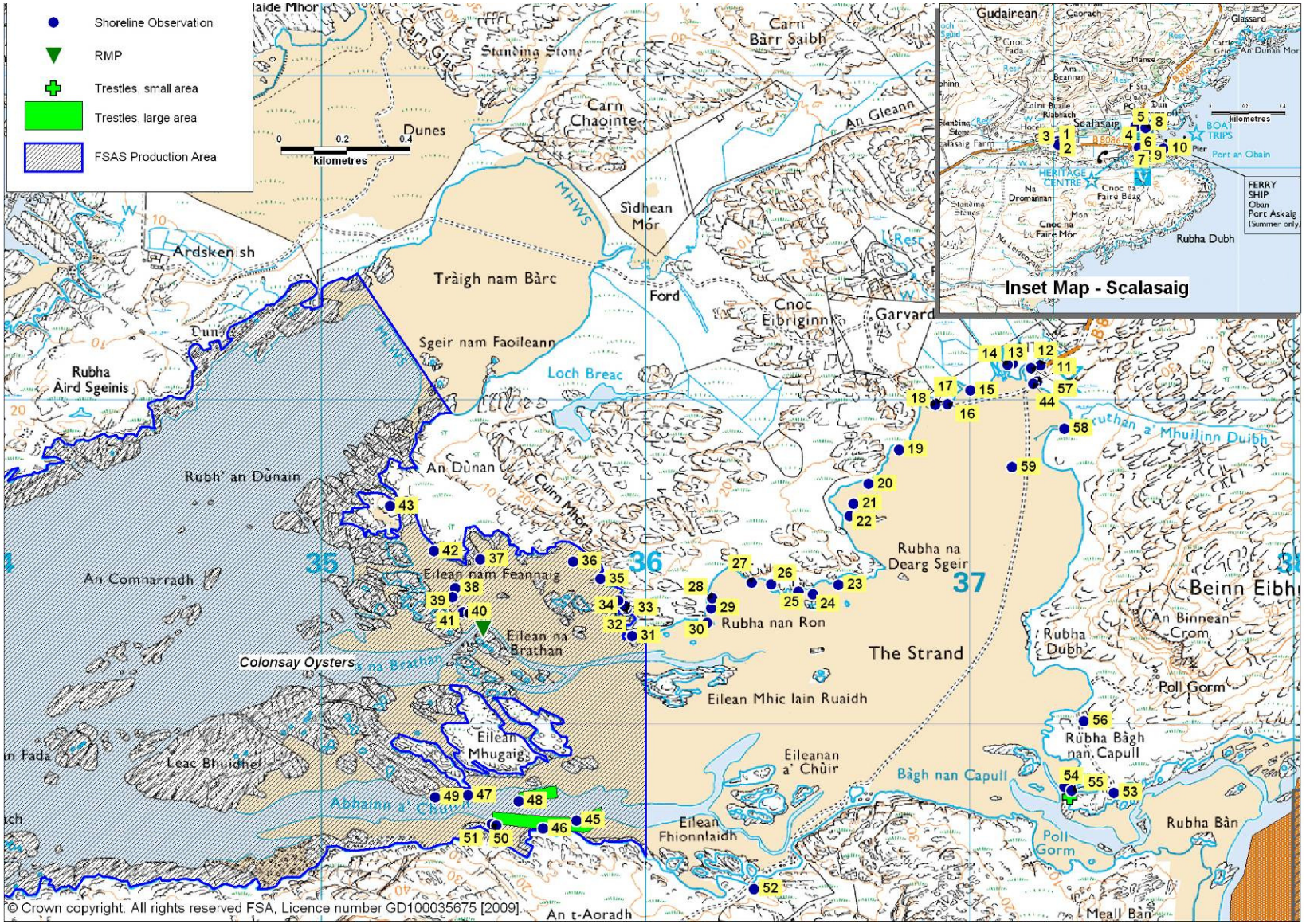

Figure 1. Map of Shoreline Observations

Table 1. Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Description
1	22/06/2009	20:36:03	NR 39022 94146	139022	694146		Stream running downhill from hotel, odourous, sewage fungus on stream bed.
2	22/06/2009	21:03:56	NR 39027 94128	139027	694128		Discharge pipe, grey plastic, runs across ditch, under road and toward stream noted above.
3	24/06/2009	07:30:00	NR 38972 94153	138972	694153		Septic tank for hotel, 9 rooms plus toilets for bar and restaurant.
4	24/06/2009	10:20:25	NR 39418 94169	139418	694169		Stream at ferry pier, 120cm x 23cm x 0.012 m/s. Salinity 0ppt. Freshwater sample 4.
5	23/06/2009	16:21:14	NR 39444 94228	139444	694228		Iron manhole cover.
6	24/06/2009	10:27:43	NR 39461 94111	139461	694111		Drainage pipe coming out of concrete in bank adjacent to pier.
7	24/06/2009	10:31:45	NR 39476 94068	139476	694068		Seawater sample 6 taken from harbour next to ferry pier. Salinity 33 ppt.
8	23/06/2009	16:17:15	NR 39498 94219	139498	694219	Figure 6	Iron discharge pipe with concrete supports. Seawater sample 4.
9	22/06/2009	20:45:49	NR 39510 94100	139510	694100		12 boats in harbour, no people observed.
10	22/06/2009	20:53:39	NR 39594 94107	139594	694107		5 cruising yachts side-tied to pier, at least one person staying aboard plus 1 dayboat on a mooring.
11	23/06/2009	08:17:11	NR 37209 91060	137209	691060	Figure 7	Car park and picnic area at strand, 20 oystercatchers on island across sand, sheep and old cattle dung.
12	23/06/2009	08:21:50	NR 37219 91110	137219	691110		Stream noted.
13	23/06/2009	08:25:42	NR 37133 91115	137133	691115	Figure 8	90 sheep toward the shore from this point.
14	23/06/2009	08:26:22	NR 37118 91112	137118	691112		Fresh cow dung, small stream.
15	23/06/2009	08:30:40	NR 37004 91032	137004	691032		Small stream, odourous, appears to flow past house viewed uphill from this point.
16	23/06/2009	08:36:39	NR 36933 90989	136933	690989		Cockles noted on shore.
17	23/06/2009	08:38:18	NR 36901 90989	136901	690989	Figure 9	Photo of bay looking NE.
18	23/06/2009	08:38:45	NR 36895 90988	136895	690988		Small stream, too shallow to measure.
19	23/06/2009	08:43:09	NR 36783 90849	136783	690849	Figure 10	Area of shoreline with scum on water. Large amounts of livestock dung noted all along shoreline.
20	23/06/2009	08:47:38	NR 36689 90744	136689	690744		Sheep hoofprints noted in the sand.
21	23/06/2009	08:49:20	NR 36643 90683	136643	690683		Stream, too shallow to sample. 4 sheep.
22	23/06/2009	08:50:41	NR 36630 90645	136630	690645		Pair of oystercatchers on island.
23	23/06/2009	09:04:59	NR 36596 90432	136596	690432		Seals audible from here, likely hauled out somewhere to the east.
24	23/06/2009	09:11:41	NR 36518 90403	136518	690403		Thousands of tiny flat winkle shells, numerous cockle shells.
25	23/06/2009	09:14:11	NR 36473 90411	136473	690411		Goose droppings found. Sheep droppings still frequent.
26	23/06/2009	09:17:50	NR 36389 90433	136389	690433		Fewer livestock droppings found here.
27	23/06/2009	09:20:14	NR 36329 90439	136329	690439		2 gulls.

No.	Date	Time	NGR	East	North	Associated photograph	Description
28	23/06/2009	09:26:11	NR 36206 90390	136206	690390		Goose droppings, no sheep droppings. Landcover rock, bracken, heather and some grass.
29	23/06/2009	09:28:59	NR 36203 90360	136203	690360		Goose and sheep droppings.
30	23/06/2009	09:30:54	NR 36192 90314	136192	690314		Seal hauled out on rock in channel.
31	23/06/2009	09:41:08	NR 35959 90274	135959	690274		Goose droppings. 5 oystercatchers.
32	23/06/2009	09:47:06	NR 35943 90358	135943	690358		Sheep, goose and cattle droppings too numerous to avoid.
33	23/06/2009	09:48:05	NR 35938 90366	135938	690366		Freshwater seep, flag iris and low spot in ground. No flow.
34	23/06/2009	09:49:34	NR 35916 90383	135916	690383	Figure 11	Water mucky, algal mat present on surface.
35	23/06/2009	09:54:36	NR 35861 90450	135861	690450		3 sheep, nesting herons (3 birds observed).
36	23/06/2009	09:58:17	NR 35778 90504	135778	690504		Mussels found on small rock.
37	23/06/2009	10:09:22	NR 35490 90511	135490	690511		20 oystercatchers, 1 duck and 2 seals off shore, 3 greylag geese.
38	23/06/2009	10:12:12	NR 35414 90422	135414	690422		12 sheep on rocks.
39	23/06/2009	10:13:46	NR 35405 90393	135405	690393		Clam shells observed here, 8 gulls.
40	23/06/2009	10:17:35	NR 35437 90348	135437	690348		2 seals.
41	23/06/2009	10:20:08	NR 35459 90344	135459	690344		Clump of seaweed moving approx 1 m/s westward through gap in island.
42	23/06/2009	10:36:38	NR 35348 90536	135348	690536	Figure 12	Area of stagnant ponded water between two rock groins.
43	23/06/2009	10:43:20	NR 35212 90675	135212	690675		Top of hill, photos taken looking NE and S. To the north is a stone wall bounding a field, with the top of a farm house just visible. Approximately 40 sheep observed on fields.
44	23/06/2009	11:32:34	NR 37197 91053	137197	691053	Figure 13	9 highland cattle.
45	23/06/2009	12:21:46	NR 35788 89704	135788	689704		Oyster sample 1, taken for classification and sent to integrin. Norovirus sample also taken from here. Seawater sample 1. Salnity 30 ppt. 30 sheep visible.
46	23/06/2009	12:40:47	NR 35684 89679	135684	689679	Figure 14	Oyster sample 2, shoreward side of trestles, about mid farm. Seawater sample 2. 4 sheep.
47	23/06/2009	13:09:32	NR 35453 89782	135453	689782		Harvester reports seals haulout here.
48	23/06/2009	13:10:00	NR 35609 89764	135609	689764		Oyster sample 3.
49	23/06/2009	13:15:11	NR 35352 89776	135352	689776		Seals also often observed here.
50	23/06/2009	13:19:27	NR 35526 89693	135526	689693		Current observed running at rapid pace, water less than knee deep. Harvester reported trestles here often buried by sand in winter.
51	23/06/2009	13:23:00	NR 35540 89689	135540	689689		Oyster sample 4.
52	23/06/2009	14:09:25	NR 36336 89493	136336	689493	Figure 15	Stream too shallow to measure, 140cm wide. Bed covered in red-brown biofilm. Animal droppings numerous. Fresh water sample 1.
53	23/06/2009	14:38:19	NR 37447 89790	137447	689790		Grading shed for oyster farm. 7 sheep.
54	23/06/2009	14:42:42	NR 37293 89808	137293	689808		Sea water sample 3, salinity 30 ppt.

No.	Date	Time	NGR	East	North	Associated photograph	Description
55	23/06/2009	14:43:00	NR 37316 89796	137316	689796	Figure 16	Oyster sample 5.
56	23/06/2009	15:14:37	NR 37353 90011	137353	690011		House. 9 sheep and >10 chickens.
57	24/06/2009	09:17:34	NR 37190 91101	137190	691101		Stream 150cm x 20cm x 0.004 m/s (essentially no flow), salinity 14 ppt. Freshwater sample 2.
58	24/06/2009	09:34:53	NR 37293 90914	137293	690914		Stream 400cm x 20 cm x 0.001 m/s (no flow), salinity 15 ppt. Freshwater sample 3.
59	24/06/2009	09:50:48	NR 37132 90795	137132	690795		Seawater sample 5, salinity 32 ppt.
60	02/09/2009	18:50:00	NR 38656 89656	138656	689656		Razor sample 1, seawater sample R3
61	02/09/2009	17:10:00	NR 38315 89113	138315	689113		Razor sample 2, seawater sample R4

Table 2 Trestle location waypoints

Waypoint	Date	Time	Grid Reference	Eastings	Northings	Observation
293	23/06/2009	12:21:46	NR 35788 89704	135788	689704	Corner of trestles.
294	23/06/2009	12:40:47	NR 35684 89679	135684	689679	Shoreward side of trestles, about mid farm.
295	23/06/2009	13:04:04	NR 35608 89761	135608	689761	Corner of trestles.
296	23/06/2009	13:06:57	NR 35607 89789	135607	689789	Corner of trestles.
299	23/06/2009	13:18:53	NR 35527 89729	135527	689729	Corner of trestles.
300	23/06/2009	13:19:27	NR 35526 89693	135526	689693	Corner of trestles.
301	23/06/2009	13:44:45	NR 35655 89678	135655	689678	Corner of trestles.
302	23/06/2009	13:46:41	NR 35692 89701	135692	689701	Corner of trestles.
303	23/06/2009	13:47:20	NR 35703 89714	135703	689714	Corner of trestles.
304	23/06/2009	13:48:02	NR 35694 89680	135694	689680	Corner of trestles.
305	23/06/2009	13:50:00	NR 35809 89666	135809	689666	Corner of trestles.
306	23/06/2009	13:50:56	NR 35826 89669	135826	689669	Corner of trestles.
307	23/06/2009	13:51:45	NR 35857 89694	135857	689694	Corner of trestles.
308	23/06/2009	13:53:01	NR 35863 89745	135863	689745	Corner of trestles.

Table 3. Water Sample Results

Obs No.	Date	Time	Sample	Grid Ref	Type	*E. coli* (cfu/ 100ml)
52	23/06/2009	14:09:25	FW1	NR 36336 89493	Fresh water	100
57	24/06/2009	09:17:34	FW2	NR 37190 91101	Fresh water	700
58	24/06/2009	09:34:53	FW3	NR 37293 90914	Fresh water	2600
4	24/06/2009	10:20:25	FW4	NR 39418 94169	Fresh water	700
45	23/06/2009	12:21:46	SW1	NR 35788 89704	Sea water	4
46	23/06/2009	12:40:47	SW2	NR 35684 89679	Sea water	1
54	23/06/2009	14:42:42	SW3	NR 37293 89808	Sea water	4
8	23/06/2009	16:17:15	SW4	NR 39498 94219	Sea water	230
59	24/06/2009	09:50:48	SW5	NR 37132 90795	Sea water	18
7	24/06/2009	10:31:45	SW6	NR 39476 94068	Sea water	760
60	02/09/2009	18:50:00	SWR3	NR 38656 89656	Sea water	1
61	02/09/2009	17:10:00	SWR4	NR 38315 89113	Sea water	1

Table 4. Shellfish Sample Results

Obs No.	Date	Time	Sample	Grid Ref	Type	*E. coli* (MPN/ 100g)
45	23/06/2009	12:21:46	Oyster 1	NR 35788 89704	*C. gigas*	110
46	23/06/2009	12:40:47	Oyster 2	NR 35684 89679	*C. gigas*	220
48	23/06/2009	13:10:00	Oyster 3	NR 35609 89764	*C. gigas*	110
51	23/06/2009	13:23:00	Oyster 4	NR 35540 89689	*C. gigas*	220
55	23/06/2009	14:43:00	Oyster 5	NR 37316 89796	*C. gigas*	3500
60	02/09/2009	18:50:00	Razor 1	NR 38656 89656	*Ensis* spp.	<20
61	02/09/2009	17:10:00	Razor 2	NR 38315 89113	*Ensis* spp.	<20

Table 5. Norovirus Results

Obs No.	Ref No.	Date	Grid Ref	Genogroup I	Genogroup II
45	09/163	23/06/09	NR 35788 89704	Not detected	Not detected

Figure 3. Water sample results map

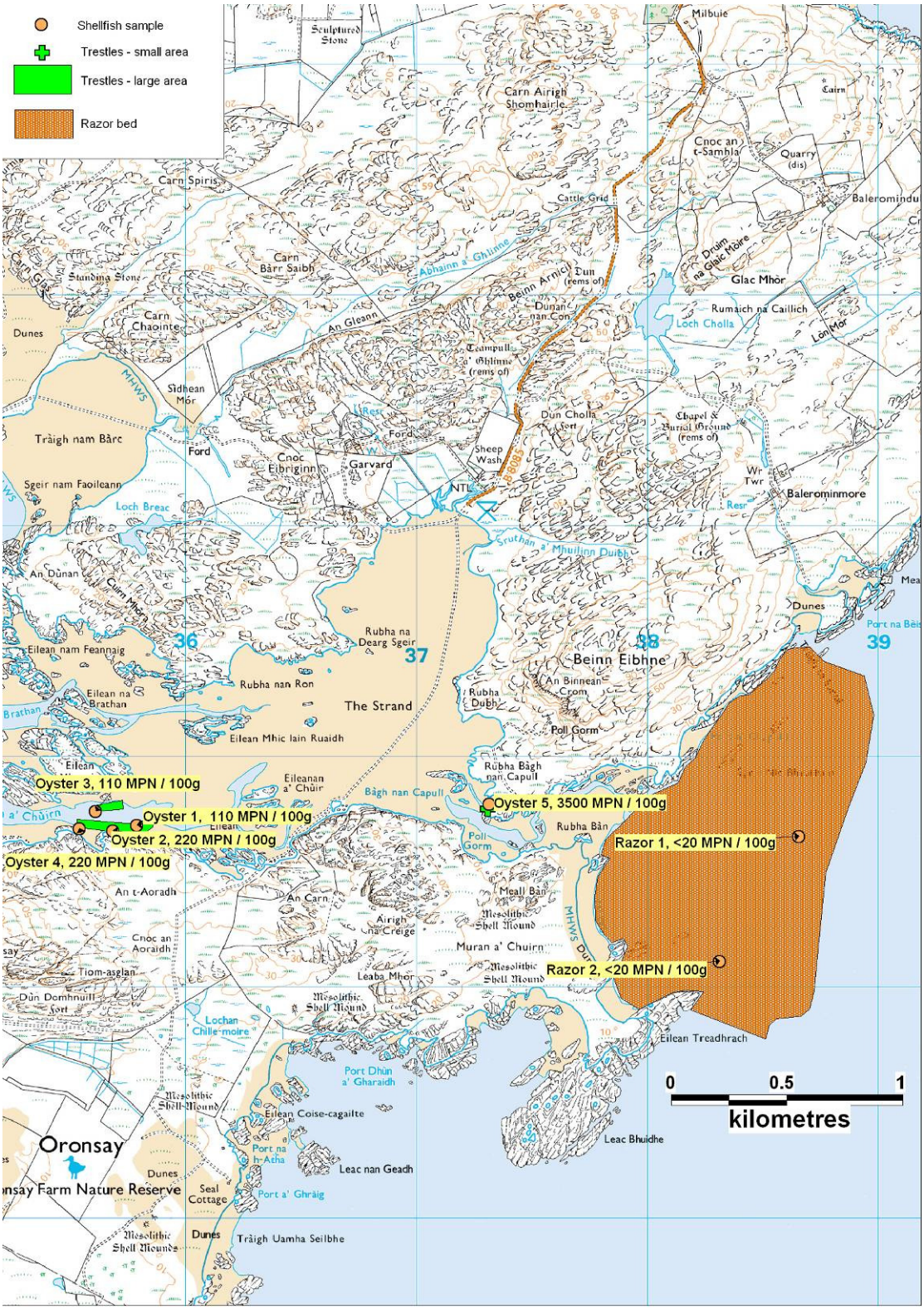

Figure 4. Shellfish sample results map

Photographs

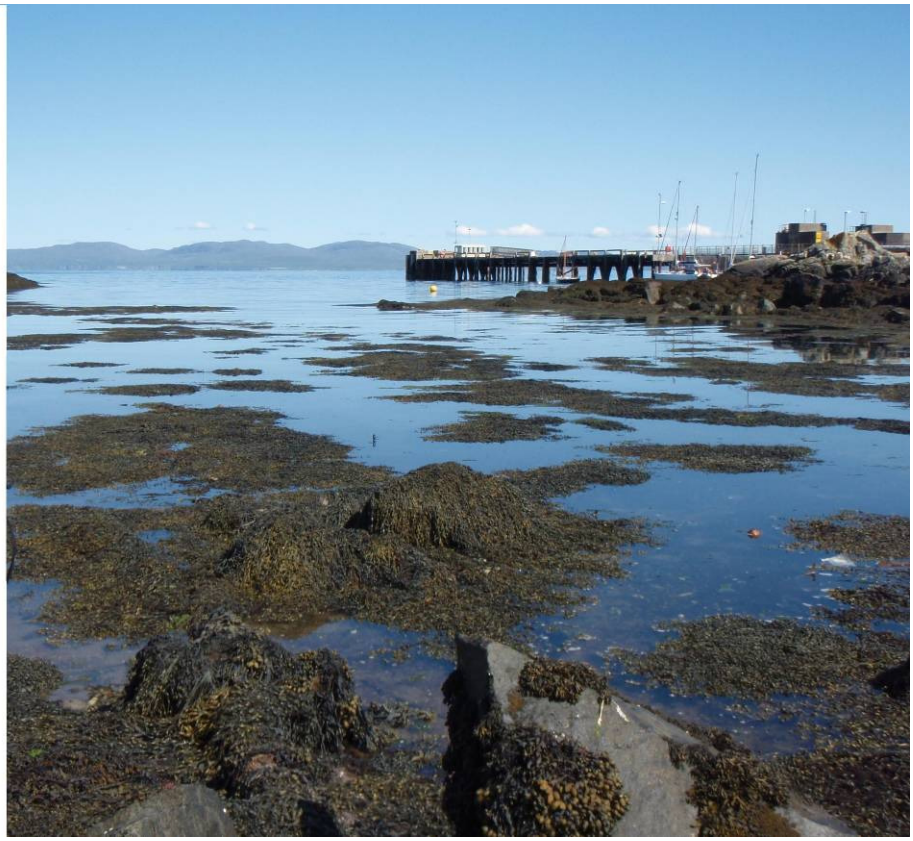

Figure 5. Looking toward ferry pier from shoreline at Scalasaig

Figure 6. Iron discharge pipe from Scalasaig

Figure 7. Car park at Colonsay end of strand

Figure 8. Some of the sheep on shore north of car park at strand

Figure 9. Bay looking northeast from strand

Figure 10. Scum on water surface

Figure 11. Algal mat, detail in inset

Figure 12. View from hill showing area of stagnant water between two rock groins (red arrow)

Figure 13. Cattle on shore, droppings in foreground

Figure 14. Oyster trestles at shore of Oronsay

Figure 15. Stream near fishery

Figure 16. Area of trestles near grading shed

Norovirus Testing Summary

Colonsay (AB 041)

Pacific oyster samples were taken from Colonsay on a quarterly basis and submitted for Norovirus analysis beginning with the date of the shoreline survey.

Results are tabulated below.

Ref No.	Date	NGR	GI	GII
09/163	23/06/2009	NR 3579 8970	Not detected	Not detected
09/328	22/09/2009	NR 3731 8979	Not detected	Not detected
09/466	30/11/2009	NR 3731 8979	Not detected	Not detected
10/120	28/02/2010	NR 3731 8979	Not detected	Positive at limit of detection