Scottish Sanitary Survey Project

Sanitary Survey Report

Seil Sound: Balvicar &
Seil Sound: Kilbrandon
AB247 & AB248
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Cefas

FOOD STANDARDS AGENCY
SCOTLAND
Buidheann Inbhe-Bìdhe an Alba

Report Distribution – Seil Sound

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1. General Description

Seil Sound is located 12 miles south of Oban on the west coast of Scotland. It is separated from the Firth of Lorn by the islands of Seil and Luing. The sound is oriented roughly north and south, and is sheltered by islands to the west and south and the mainland to the east. It is 9 km in length and 1.25 km at its widest point and is very shallow at the northern end (0-5 m) while at the southern end this increases to up to100 m.

Figure 1.1 Location of Seil Sound

2. Fishery

There are seven sites in two adjacent production areas within the survey area, as listed in Table 2.1 and shown on Figure 2.1.

Table 2.1 Seil Sound production areas and sites

	SIN	Species	Description
Seil Sound: Balvicar			
Ardshellach	AB 247 071 13	Pacific oysters	1 area of trestles
Balvicar North	AB 247 735 13	Pacific oysters	2 areas of trestles
East of Balvicar	AB 247 703 08	Common mussels	Lines and rafts
Rubha nan Ron South	AB 247 728 13	Pacific oysters	2 areas of trestles
Rubha nan Ron South	AB 247 728 08	Common mussels	Listed in classification document but no mussel fishery at this site
Balvicar	AB 247 072 13	Pacific oysters	Trestles belonging to two different owners
Seil Sound: Kilbrandon			
Island Site	AB 248 784 13	Pacific oysters	No stock
Kilbrandon	AB 248 073 13	Pacific oysters	Stock for sampling only

Seil Sound: Balvicar

The Seil Sound: Balvicar production area is currently defined as the area bounded by lines drawn between NM 7851 1969 and NM 7854 1968 and NM 7707 1534 and NM 7821 1534. Both mussels and Pacific oysters are cultured within this production area. The production area is large, with several active oyster sites spread around it, and many potential sources of contamination. To better capture contamination within this area, and hence be better protective of public health, two RMPs were set at two different representative locations. These are located at NM 775 173 and NM 773 158. The RMP for mussels is located at NM 779 169. All observations relate to the positions of the farms at the time of shoreline survey.

Ardshellach (AB 247 071 13). This is the northernmost of the sites in the Balvicar production area. At the time of shoreline survey, this site consisted of an area of Pacific oyster trestles on the east shore of Seil Sound at Ardshellach. Stock of a range of sizes was present, including harvestable stock.

Balvicar North (AB 247 735 13). This site consisted of two separate areas of Pacific oyster trestles, one on an island in the middle of Seil Sound where trestles are spread out at low density over a large area (Island), and one on the eastern shore at Craig Ulian (Craig Ulian). Stock of a range of sizes was present, including those of harvestable size.

Rubha nan Ron South (AB 247 728 13 and AB 247 728 08). This site consisted of two separate blocks of Pacific oyster trestles at the time of shoreline survey. The main block of trestles was located on the west shore of Seil Sound, just south of the town of Balvicar (Main Site). A processing shed was located on the shoreline above this site, where depuration facilities may be installed at some point in the future. Stock of a range of sizes was present including those of harvestable size.

In addition to the main block of trestles, the grower also has 2 trestles just to the east of the boatyard at Balvicar (Boatyard). Planning permission had been granted for a further 300 trestles to be deployed here. At the time of a second visit to the site on 24 April 2009, there were still just the two racks in place here.

This site is also listed in the classification document for 2009 as a mussel site, but mussels have never been cultured here, so there is no requirement for it to be classified for this species.

Balvicar (AB 247 072 13). This site has Pacific oyster trestles belonging to two different harvesters and extends along 350 meters of coastline. The smaller of the two, owned by Ewen McAskill, consisted of a few areas of trestles, some of which had old stock on but most of which were empty. According to the harvester, the farm has been inactive for over a year, but would normally be harvested during the autumn. These were primarily confined to the southern end of the site.

The larger portion of the trestles, ending to the north, belonged to Caledonian oysters and was in active production. Stock of a range of sizes was present including of a harvestable size.

East of Balvicar (AB 247 703 08). This mussel site consisted of two lines with 10 m droppers, and 5 rafts with 10m droppers. Stock of a range of sizes was present on site, including of a harvestable size. Harvesting usually occurs during the summer months, but is dependent on demand.

Seil Sound: Kilbrandon

The Seil Sound: Kilbrandon production area is currently defined as the area bounded by lines drawn between NM 7707 1534 and NM 7821 1534 between NM 7644 1470 (Rubha na Moine) and NM 7791 1470. Only Pacific oysters are cultured within this production area, and the RMP is located at NM 764 153

Island Site (AB 248 784 13). This site consisted of an area of 114 oyster trestles. There was no stock on this site at the time of the shoreline survey. The grower intends to start restocking either in autumn of 2009 or spring 2010, with harvesting planned from 2012 or 2013.

Kilbrandon (AB 248 073 13). This site consisted of a small area of Pacific oyster trestles that are relatively high on the shoreline. It is not in commercial production at present, and a few bags of mature oysters are held here to allow sampling to maintain classification. The grower intends to start restocking in the spring of 2010, with harvesting planned from 2012 or 2013.

Figure 2.1 shows the production areas, mussel lines, oyster trestles, RMPs,and Crown Estates sea bed leases.

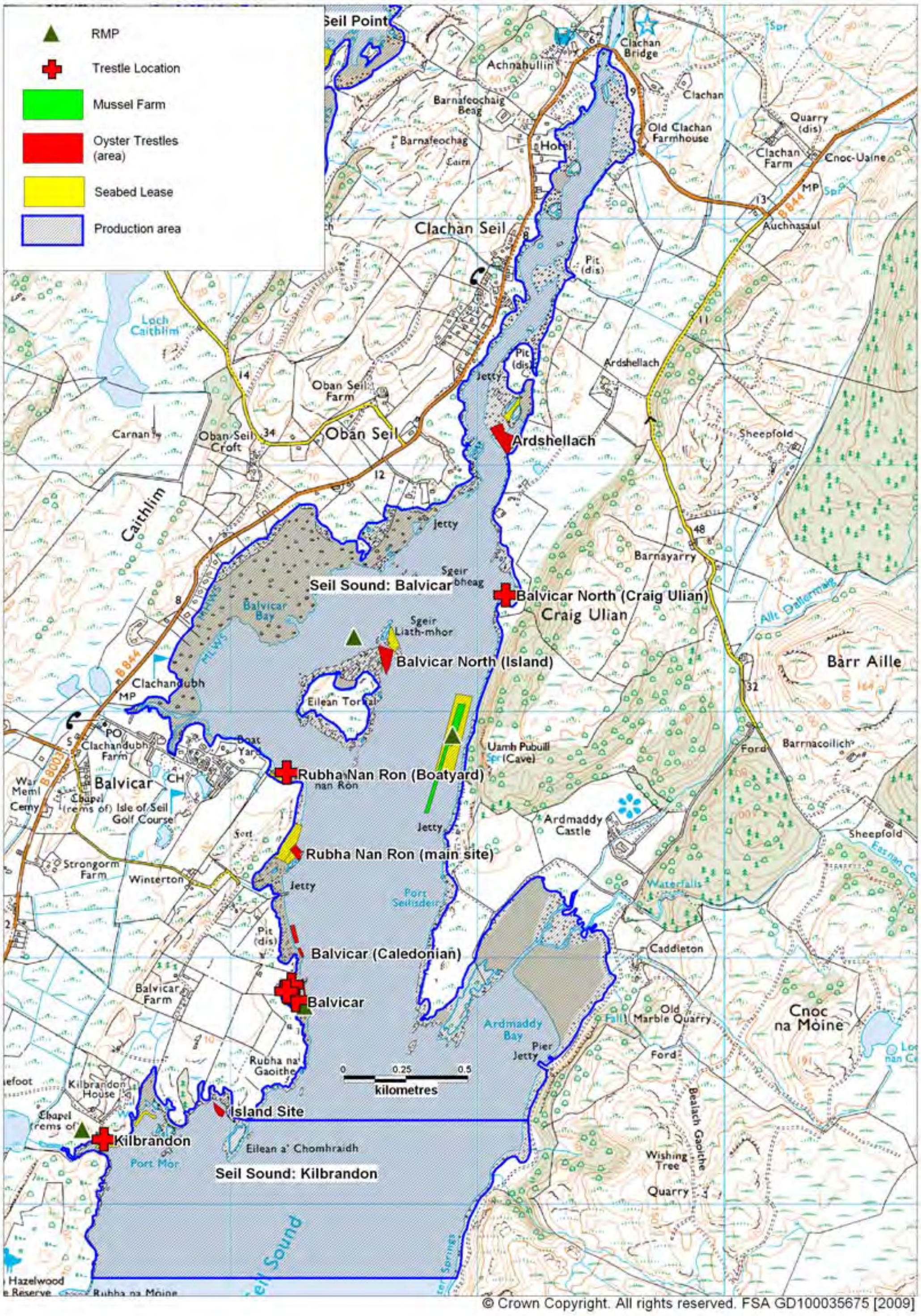


Figure 2.1 Seil Sound: Balvicar and Kilbrandon shellfish farms

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Seil Sound.

Six census output areas bordering immediately on Seil Sound and their populations are:

Area	Population
60QD000080	98
60QD000079	105
60QD000078	112
60QD000077	144
60QD000081	125
60QD000570	109
Total	693

Only 60QD000077, with a population of 144, lies completely within the survey area. The remaining census areas cover larger areas with more dispersed populations. Along the western side of Seil Sound are the settlements of Balvicar and Clachan Seil, where the majority of the area's population is located. A further settlement, Clachan, is located at the northeastern end of the sound. The remainder of the area is sparsely populated. Any associated faecal pollution from human sources will be concentrated along the western side of the sound between Balvicar and the northern end of the sound. Therefore, shellfish farms located within the Balvicar production area are likely to be more impacted by human faecal pollution than those in the Kilbrandon production area.

A few dwellings in the area may be holiday homes, and the ‘Atlantic Bridge’ at Clachan Seil is a popular tourist attraction, so it is likely that the population is higher during the summer months.

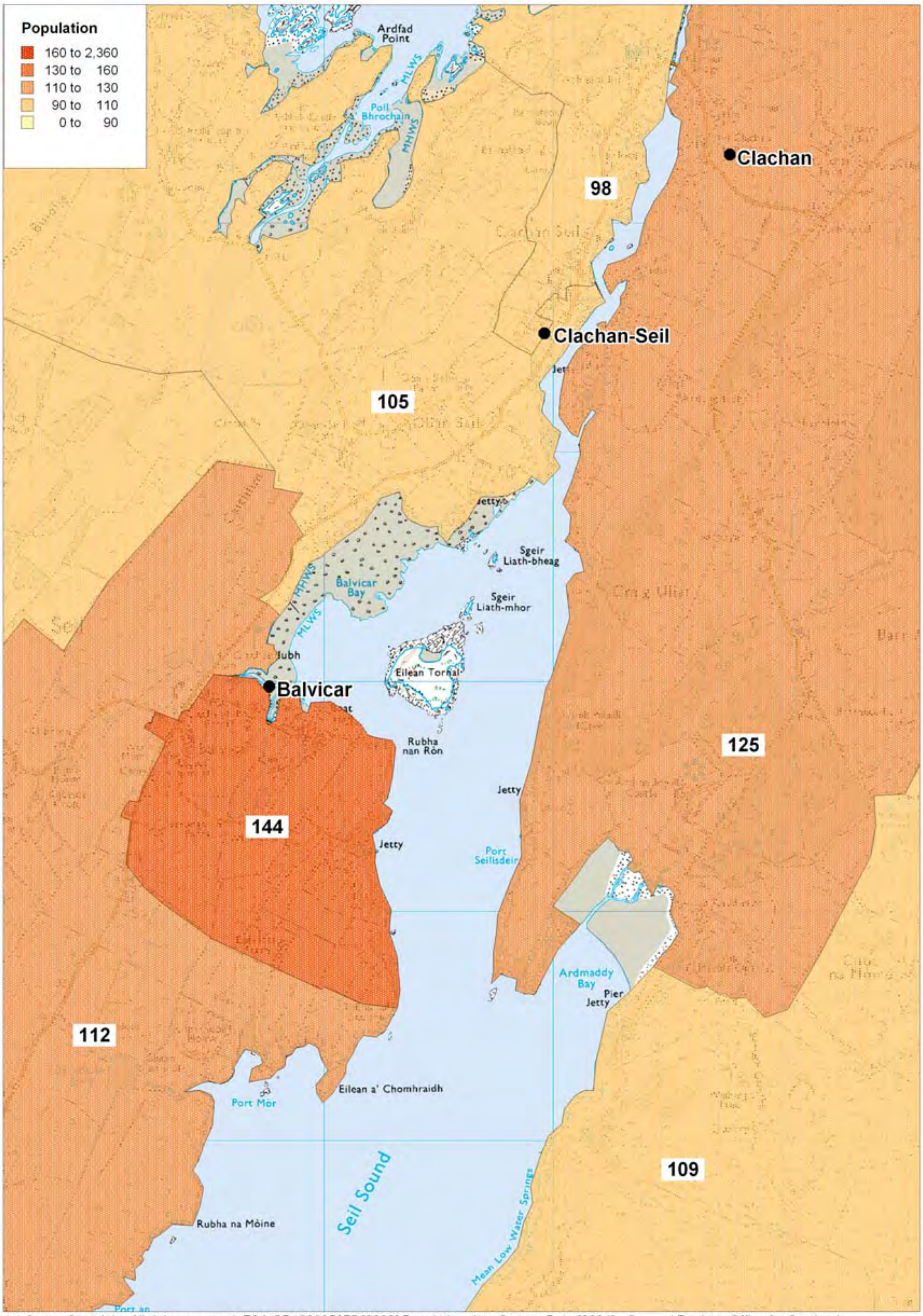


Figure 3.1 Population of Seil Sound

4. Sewage Discharges

Community septic tanks were initially identified by Scottish Water for the Seil Sound area. Details are presented in Table 4.1, and a map indicating their positions is presented in Figure 4.1.

Table 4.1 Discharges identified by Scottish Water

Discharge Name	NGR	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design pop	Q&S III Planned improvement?
Clachan Seil	NM 7830 1900	Continuous	Septic tank	24.12	-	Yes
Clachan Seil CSO & EO	NM 7820 1880	Intermittent	6mm mesh screening	-	-	Yes
Clachan Seil Upper	NM 7805 1874	Continuous	Septic tank	-	51	Yes
Balvicar	NM 7645 1692	Continuous	Septic tank	-	-	Yes
Balvicar ST	NM 768 168	Continuous	Septic tank	-	-	Yes

No sanitary or microbiological data is available for these discharges, and the predicted spill frequency of the Clachan Seil overflow is not known. These details applied to the sewage infrastructure at the time of shoreline survey. Subsequent changes to the sewerage at Balvicar are addressed in detail later in this section.

A number of discharge consents were identified by SEPA for this area. Details of those consents provided to us by SEPA are presented in Table 4.2. As there was historically no requirement to register private sewage and septic tank discharges in Scotland, this list is unlikely include all the discharges that may be present in the area. None of these appear to relate to any of the Scottish Water discharges listed above. All but two discharge to land/soakaway.

Table 4.2 Discharge consents provided by SEPA

Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
CAR/R/1015858	NM 7842 1940	Continuous	Septic tank	-	12	Clachan Sound
CAR/R/1020304	NM 7827 1937	Continuous	Septic tank	-	5	Land (via soakaway)
CAR/R/1013702	NM 7826 1896	Continuous	Septic tank	-	7	Seil Sound
CAR/R/1016103	NM 7658 1701	Continuous	Septic tank	-	10	Land
CAR/R/1020115	NM 7642 1683	Continuous	Septic tank	-	7	Land (via soakaway)
CAR/R/1020066	NM 7657 1688	Continuous	Septic tank	-	5	Land (via soakaway)
CAR/R/1019075	NM 7663 1686	Continuous	Septic tank	-	10	Soakaway
CAR/R/1020297	NM 7651 1545	Continuous	Septic tank	-	13	Soakaway

A large number of septic tanks and/or outfalls were recorded during the shoreline survey, confirming that SEPA consents only cover a small number of discharges in the area. As only the shoreline was walked in most areas, septic tanks with soakaways set back from the shore were not observed. Details are presented in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline survey

No.	Date	Grid Reference	Observation
1	19/08/2008	NM 78491 19674	110mm orange sewer pipe to underwater on shore below
2	19/08/2008	NM 78486 19594	110mm black plastic sewer pipe to shore, sweetcorn and toilet paper around end
3	19/08/2008	NM 78409 19400	150mm metal sewer pipe, trickle coming from end, possibly SEPA consent no CAR/1015858
4	19/08/2008	NM 78283 19074	150mm metal sewer pipe to underwater, possibly the Scottish Water Clachan Seil septic tank discharge
5	19/08/2008	NM 78193 18880	110mm orange sewer pipe, trickling, excrement and toilet paper around end
6	19/08/2008	NM 78162 18797	150mm metal sewer pipe to underwater, possibly a Scottish Water asset (Clachan Seil septic tank or CSO & EO)
7	19/08/2008	NM 78175 18643	110mm orange sewer pipe, not flowing but odour detected
8	19/08/2008	NM 78101 18560	120mm broken ceramic sewer pipe not flowing
9	19/08/2008	NM 78048 18466	120mm metal sewer pipe to underwater and 110mm orange plastic pipe alongside it
10	19/08/2008	NM 77983 18366	110mm orange plastic sewer pipe to underwater
11	19/08/2008	NM 77973 17963	Broken 120mm ceramic sewer pipe
12	19/08/2008	NM 77870 17833	100mm metal sewer pipe
13	19/08/2008	NM 78133 18824	Scottish water Clachan Seil Upper communal septic tank (outflow not visible, serves about 20 houses)
14	20/08/2008	NM 77162 17791	Septic pipe, presumably to soakaway as not visible on shore
15	20/08/2008	NM 76861 17346	110mm orange plastic sewer pipe to underwater
16	20/08/2008	NM 76932 17484	110mm orange plastic sewer pipe not flowing
17	20/08/2008	NM 76970 17554	110mm orange plastic sewer pipe trickling
18	20/08/2008	NM 76617 16983	3 sewer pipes to burn (serving about 10 houses), one of these is probably the Scottish Water Balvicar septic tank discharge.
19	20/08/2008	NM 76762 16908	120mm ceramic broken sewer pipe and 120mm cast iron sewer pipe which is probably the Scottish Water Balvicar ST septic tank discharge.
20	20/08/2008	NM 76801 16868	110mm orange plastic sewer pipe not flowing
21	20/08/2008	NM 76855 16946	110mm orange plastic sewer pipe, excrement around the end
22	20/08/2008	NM 76991 16880	110mm orange plastic sewer pipe
23	20/08/2008	NM 77187 16165	110mm orange plastic sewer pipe not flowing
24	21/08/2008	NM 77899 16515	110mm cast iron sewer pipe, dripping and paper around end
25	21/08/2008	NM 78623 19303	110mm plastic sewer pipe not flowing but grey around end

Most of the observed discharges in the area were small private septic tanks, although there are small Scottish Water septic tanks at both Clachan Seil and Balvicar. Not all were functioning correctly, with raw unscreened waste being discharged in some cases. The majority were spread along the west shore with highest concentrations around Clachan Seil and Balvicar. Of the 25 discharge observations listed, totalling 27 discharge pipes and one Scottish Water septic tank with no visible discharge pipe (presumably buried), only two private septic tank discharges (24 & 25) were seen on the east shore. Discharge observation 24 was located about 130 m to the south east of the East of Balvicar mussel site and so would be expected to impact upon this site, particularly at its southern end. On the shore south of Balvicar, where a large proportion of the oyster sites were located, only one small private discharge pipe was seen (23). This was not flowing at the time of the survey, but when in operation would be expected to impact on the Balvicar and Rubha nan Ron South sites.

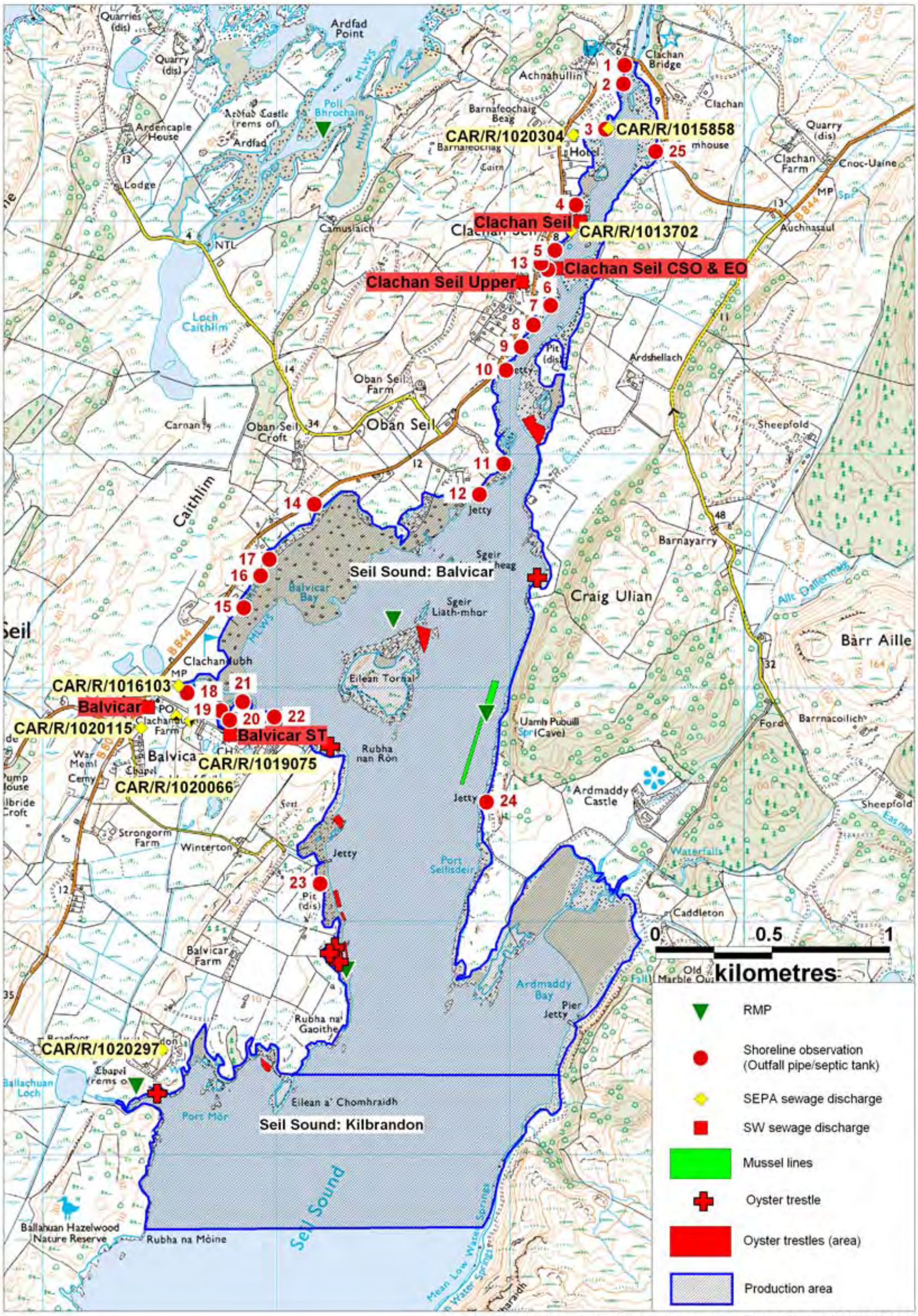


Figure 4.1 Existing discharges at Seil Sound

At the time of survey, Scottish Water were undertaking a major overhaul of sewage treatment in the area. This was substantially complete when the site was revisited in April 2009. A map of the discharges associated with the new scheme is presented in Figure 4.2. The catchment area includes the majority of houses in Clachan Seil and Balvicar, and only discharge observations 23, 24 and 25 fall outside of this. Although it is not compulsory for households to be connected, a high level of connection is reported (166 households). This should greatly reduce the amount of septic tank outfalls to Seil Sound, although it is probable that a small number of private septic discharges will remain within the catchment area. Observations made in June 2009 confirmed that the scheme was virtually complete, and the discharges were located as illustrated in Figure 4.2.

The new treatment works is a membrane bioreactor (MBR) plant. MBRs combine activated sludge with a low-pressure ultrafiltration step, and due to the small pore size in the membrane they are very effective at removing bacteria. MBR plants typically achieve a > 5 log reduction in bacteria, but are slightly less effective for removing viruses due to their smaller size (typically > 4 log reduction). Therefore, the effluent will be almost free of bacteria, and contain only low levels of virus. Scottish Water report that final effluent samples taken from the plant contained no faecal coliforms. Even using an estimate of 50 *E. coli* cfu/100ml of final effluent, and assuming a population of 1000 each using 200 l of water per head per day, an estimate of the total loading discharged would be 1×10^8 *E. coli* per day. This is equivalent to about 0.01 population equivalents of septic tank treated waste water, and is likely to be an overestimate as levels of *E. coli* in the treated waste are much lower, and the population used is higher than that resident in the area.

The treated water will be discharged towards the north end of Balvicar Bay. This is just under 300 m from the Balvicar North (Island) site, so although an overall improvement in water quality in Seil Sound should result from the scheme, it is possible that a localised deterioration around the new outfall in the vicinity of the outfall may occur. Given the reported efficiency of bacterial removal by MBR plants, this localised effect on the bacteriological quality of the shellfish here may be minor. The impact of virus contamination at this site, however, may no longer be adequately represented by bacteriology results obtained at this site.

In addition to the treatment works, there will be 6 pumping stations along the pipelines that will have emergency overflows, four of these are at Clachan Seil, and two are at Balvicar, and there will be a combined sewer overflow at the treatment works. All overflows have a 6 mm screen. There is also a storage tank at the sewage works which has the capacity to store 24 hours worth of dry weather flow to the works. Modelling works undertaken by Scottish Water predict a very low frequency and volume of spills (1.6 per year and 17.2 m^3 per year respectively), and that spills will only occur at the treatment works overflow. Some surface water will enter the system through domestic sources only, such as roof runoff from some properties. Spills will contain screened raw sewage, so are likely to have a significant localised impact on water quality. Should the system not perform as anticipated, it is possible that spills may also occur at the pumping stations.

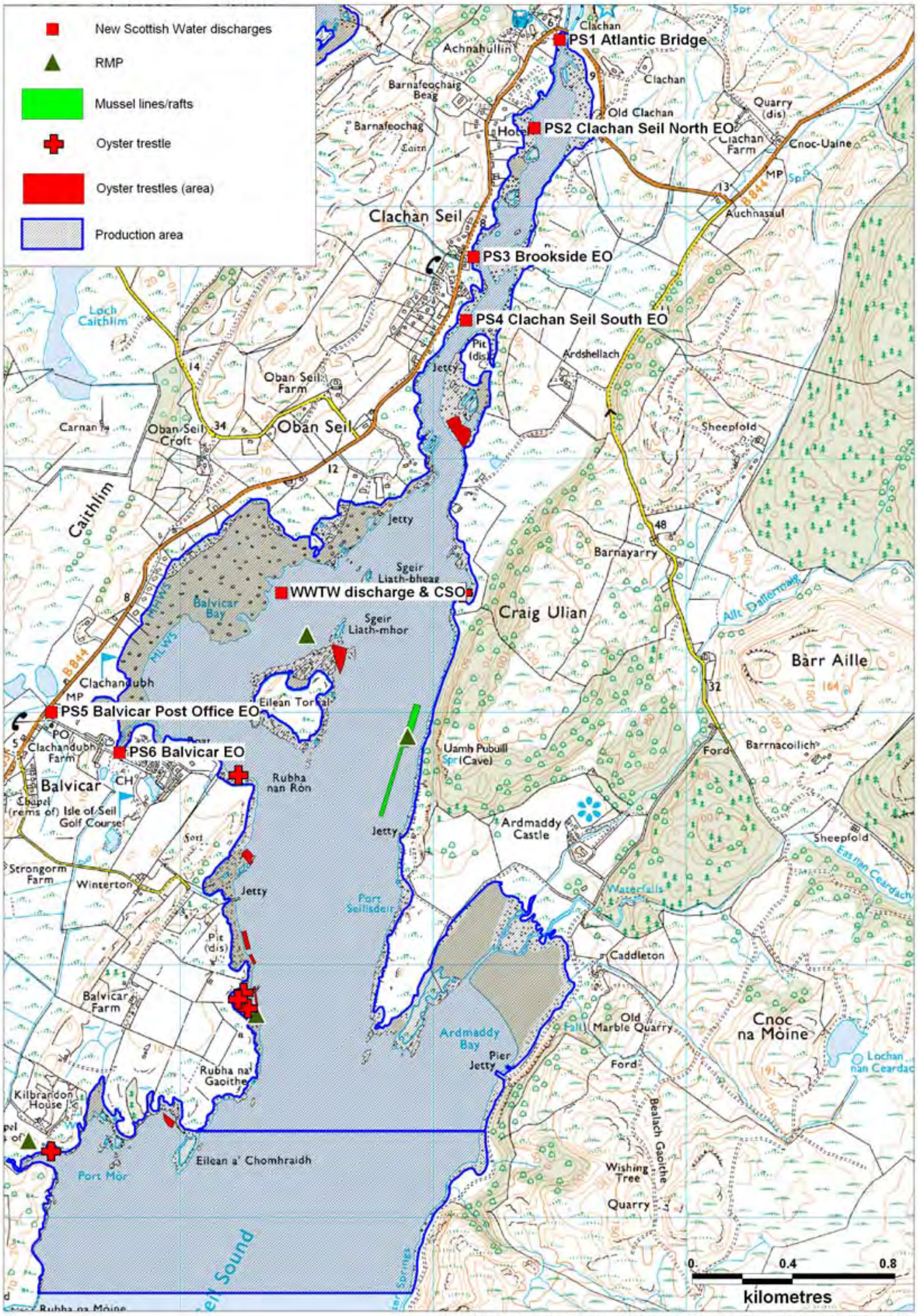


Figure 4.2 Location of discharges for the new Scottish Water scheme

Overall, the new scheme should result in a considerable decrease in the amount of indicator bacteria being discharged to Seil Sound from human sources. Broadly speaking improvements may be expected at most sites, particularly those closest to Clachan Seil (Ardshellach) and Balvicar (Rubha nan Ron South (Boatyard)), whereas some deterioration may be possible at the site closest to the discharge (Balvicar North (Island)), and very occasionally this site may be significantly impacted by spills from the treatment works. Also, a significant increase in viral contamination may occur at this site that may be underrepresented by monitoring of faecal indicator bacteria in this case.

Some dwellings in the area may be holiday homes, and the ‘Atlantic Bridge’ at Clachan Seil is a popular tourist attraction, so it is likely that human inputs are higher during the summer months. A popular yacht anchorage lies 0.8 km by footpath from the ‘Atlantic Bridge’, bringing visitors to the pub and B&Bs at Clachan.

Seil Sound also receives significant boat traffic. Several areas of moorings were seen during the shoreline survey, mainly around Clachan Seil and Balvicar. A total of 43 yachts and smaller boats were counted, with one larger vessel at the Balvicar boatyard. Some of these were of sufficient size for people to live on board, and most appeared to be pleasure craft. A tour boat operates from a base in the northern end of the sound and has marine toilet that discharges directly to the sea. It is not possible to predict timing and amount of use of this near the fisheries, however the boat is busy during the summer tourist season. Therefore, higher inputs around Clachan Seil and Balvicar may be anticipated during the summer months from these sources, although it is difficult to be precise about potential impacts from this source.

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 or yellow indicate poorly draining soil while areas shaded blue indicate more freely draining soils.

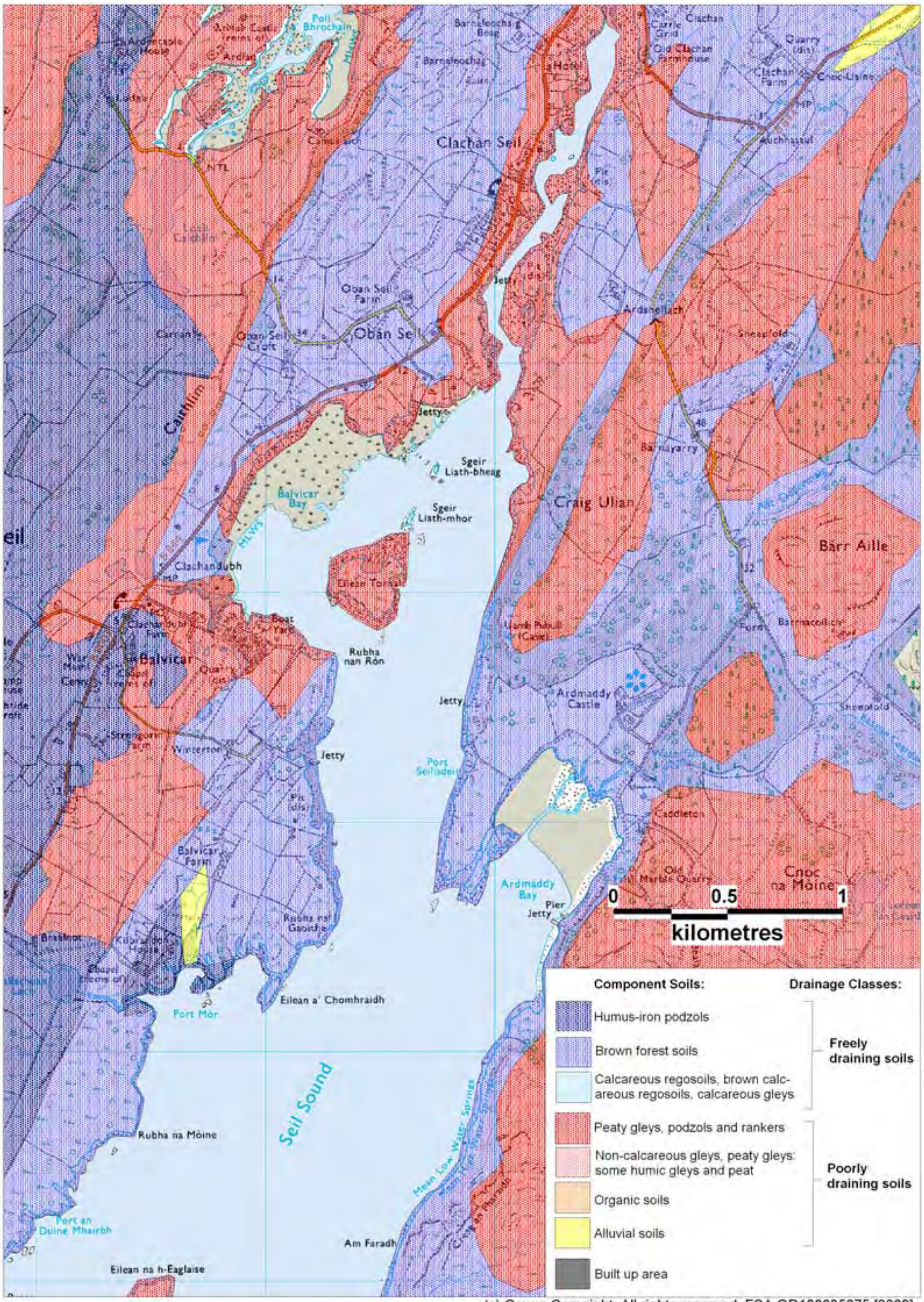


Figure 5.1 Component soils and drainage classes for Seil Sound.

Three main types of component soils are predominant in this area: brown forest soils, peaty gleys, podzols and rankers, and humus-iron podzols. A fourth type, alluvial soils, are found in two small areas.

Brown forest soils are freely-draining and line much of the coastline of Seil Sound as well as some inland areas to the north.

Peaty gleys, podzols and rankers are poorly-draining soils and line much of the coast of the sound from Balvicar northwards. These soils are also found in patches inland of the shoreline on the east side of the sound.

Humus-iron podzols are found largely on Seil Island inland of the shoreline and are classed as freely-draining soils.

Two small areas of alluvial soils are found in the area, the most significant of which, due to its location, lies on the western coastline of Seil Sound just north of Port Mor. This lies in a line between Kilbrandon Farm and the shoreline near the unused trestles at Kilbrandon Island Site, and may indicate an area of stream runoff.

Highest potential for runoff contaminated with *E. coli* from human and/or animal waste exists at the northern end of the sound south to Balvicar, where poorly draining soils line the shore. This includes the areas of highest human population, where there may be are a number of septic tanks which discharge to soakaway. Correctly installed soakaways should not fail, but the chances of soakaway failure will increase with decreasing soil permeability.

6. Land Cover

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

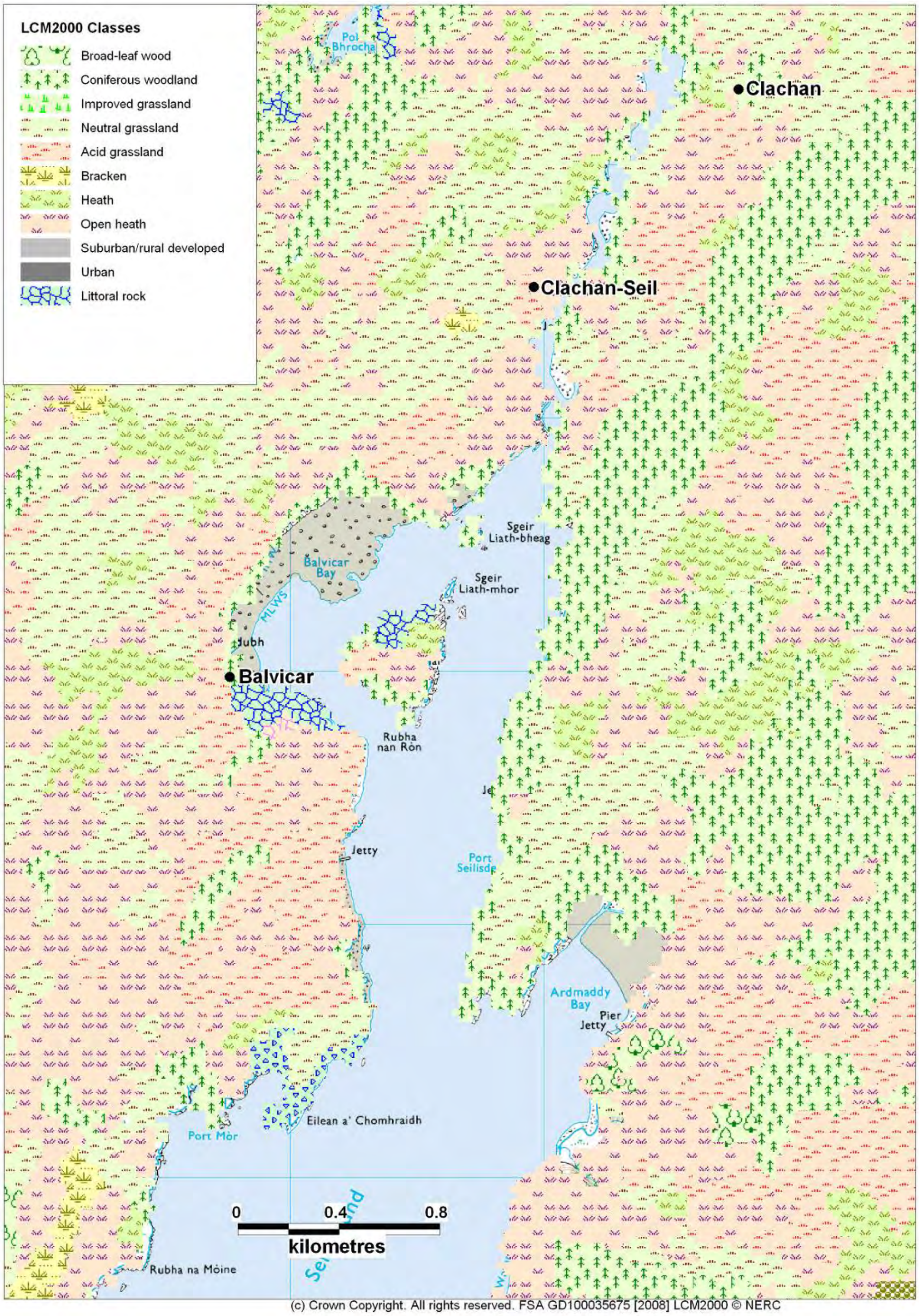


Figure 6.1 LCM2000 class land cover data for Seil Sound: Balvicar and Kilbrandon

Land cover along the western side of the sound is predominantly heath and grassland, with scattered stands of mainly coniferous woodland.

The land cover on the eastern side of the sound is predominantly heath and natural grassland interspersed with larger areas of coniferous forest than are found on the western side.

Although the LCM2000 class data does not identify any urban/suburban land, there is some surrounding the settlements of Balvicar and Clachan Seil. The map indicates that there is no improved grassland in the area.

The faecal coliform contribution would be expected to be highest from developed areas (approx 1.2 – 2.8×10^9 cfu km^{-2} hr^{-1}), with intermediate contributions from the improved grassland (approximately 8.3×10^8 cfu km^{-2} hr^{-1}) and lowest from the other land cover types (approximately 2.5×10^8 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.

The developed area around Balvicar, would contribute the highest loading of faecal contaminants of all the landcover types in the area and is located close to the oyster farms at Balvicar North and Rubha nan Ron. However, this covers a relatively small amount of the land area in the vicinity of the fishery. As the majority of the land surrounding the production areas aside from the developed areas at Balvicar and Clachan Seil is unimproved grassland, heath or forest, the potential for contaminated runoff from much of the land area is relatively low.

Contributions from grassland used for grazing livestock, such as those by the Ardshellach, Balvicar and Rubha Nan Ron South sites may be higher than predicted above, particularly after a heavy rainfall.

7. Farm Animals

With regard to potential sources of pollution of animal origin, agricultural census data was requested from the Scottish Government. Agricultural census data was provided by RERAD for the parishes of Kilbrandon & Kilchattan, and Kilninver & Kimelford. These parishes cover a total land area of 54 and 131 km^2 respectively. The parish of Kilbrandon & Kilchattan covers the islands of Seil, Luing, Shuna and Torsa as well as a portion of the mainland east of the sound. The larger parish of Kilninver & Kilmelford only borders on approximately 2.5 km of the northeastern coastline of the sound and so may be less significant in terms of livestock contributions to pollution in Seil Sound. Reported livestock populations for these parishes in 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.

Table 7.1 Livestock census data for Kilchattan and Kilninver & Kimelford Parishes 2008

	Kilbrandon &Kilchattan		Kilninver & Kilmelford	
	Holdings	Numbers	Holdings	Numbers
Total Pigs	0	-	0	-
Total Poultry	*	*	*	*
Total Cattle	8	1584	7	562
Total Sheep	16	7950	14	11597
Horses and Ponies	*	*	*	*

* Data withheld on confidentiality basis.

Both poultry and horses/ponies are farmed within these parishes, however specific data on numbers could not be provided. Due to the large area of the parishes, this data does not provide detailed information on the livestock numbers in the area immediately surrounding Seil Sound. The only information specific to the area near the shellfishery was therefore the shoreline survey (see Appendix 8), which only relates to the time of the site visit on 19th – 21st August 2008. The spatial distribution of animals observed during the shoreline survey is illustrated in Figure 7.1.

There are several areas of pasture on the shores of Seil Sound upon which livestock were observed at the time of the shoreline survey. Contamination from these animals will be carried into the sound either by direct deposition on the shore below the high water mark, or through land runoff. At Balvicar Farm, a total of 82 sheep were seen, some of which were on the shore. Therefore, diffuse inputs may be expected all along the shore where the Balvicar site is located. Eighteen cattle were seen on the shore at Craig Ulian, next to the Balvicar North (Craig Ulian) site so some faecal contamination may be expected here. At Ardmaddy Castle, 52 cattle and 36 sheep were seen, and these were fenced from the shore so it is likely that streams draining this area will be the most important pathway by which contamination from these is carried into the sound. There are no fisheries within Ardmaddy Bay, but the fishery most likely to be affected by sources in Ardmaddy bay may be the East of Balvicar site. Just south of Oban Seil, 40 sheep and 4 cattle were seen, and 4 sheep were seen near the Kilbrandon oyster trestles. These may be expected to impact most on the Balvicar North (Island site) by virtue of their proximity.

Livestock populations in the area will increase during the spring as lambs and calves are born, then decrease from the autumn as animals are sent to market.

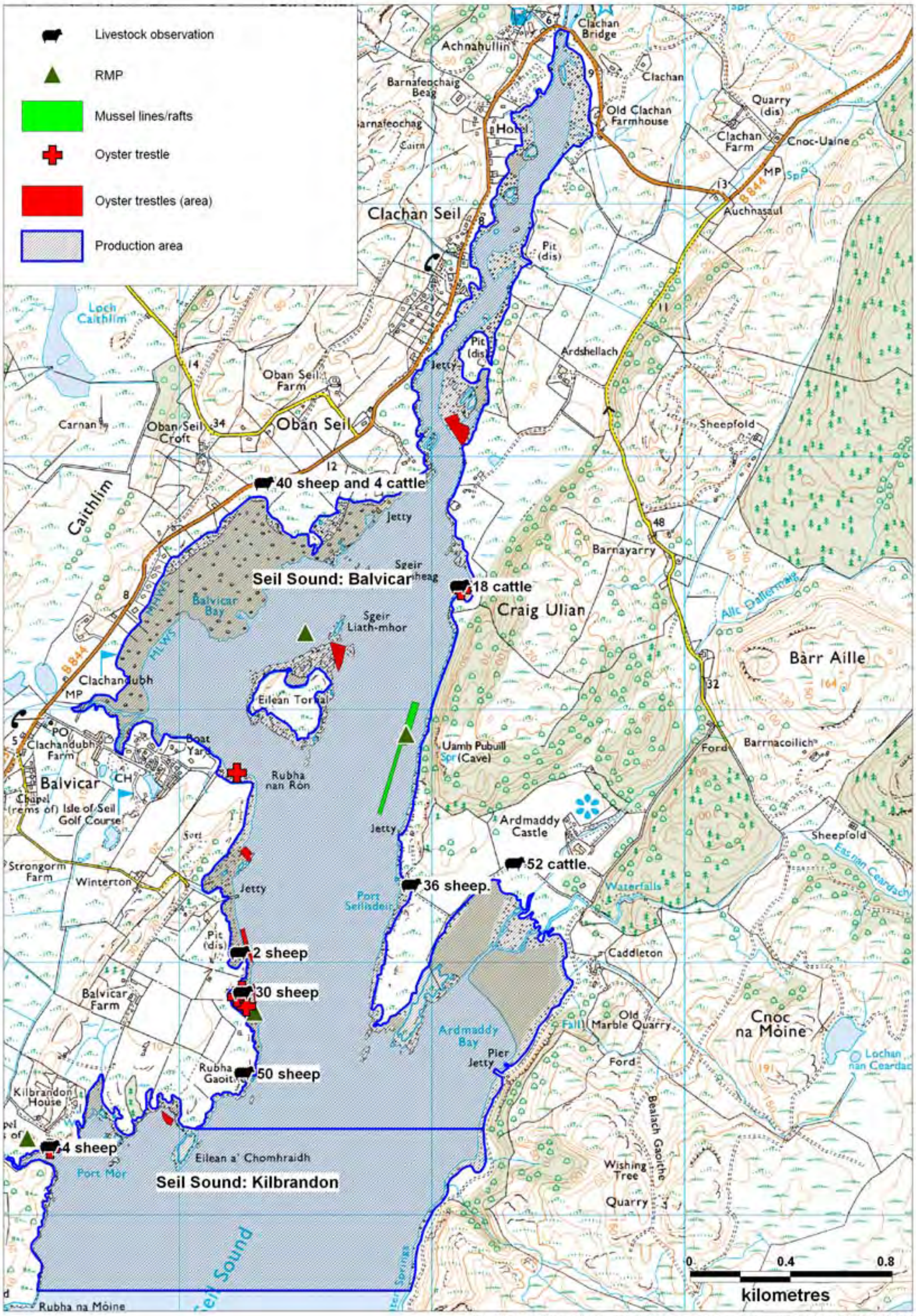


Figure 7.1 Livestock observations at Seil Sound

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 at Seil Sound could potentially affect water quality around the fishery.

Seals

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*). Scotland hosts significant populations of both species.

A survey conducted by the Sea Mammal Research Unit in 2000 estimated a population of 527 common seals in the Firth of Lorn from Craignish Point to Dunstaffnage. The exact locations of the haul out sites were not specified. No seals were seen during the course of the shoreline survey. The local sampling officer, a resident of Clachan Seil, advises that a small colony of seals (6-8 animals) haul out on the small rocky islets of Sgeir Liath Mhor and Beag, near the Balvicar North (Island) site during the summer months.

Seals will forage widely for food so it is likely that seals will feed near all sites at some point in time, although their haulout location near the Balvicar North (Island) site suggests their impacts may be greatest here at times when they are resident in the area.

Whales/Dolphins

Whales and dolphins are relatively common off the west coast of Scotland and sightings are recorded by the Hebridean Whale and Dolphin trust. These are reported to the trust by ferry skippers, whale watch boats and other observers and are listed in Appendix 4.

It is possible that cetaceans may enter Seil Sound from time to time. As the sound is shallow and enclosed, particularly towards its northern end, it is likely that only the smaller species visit the sound, and that they are unlikely to occur as far north as Clachan Seil. Their presence is likely to be fleeting and so any impact is likely to be localised, short-term and unpredictable.

Birds

A number of bird species are found around Seil Sound, but seabirds and waterfowl are most likely to occur around or near the fisheries in significant numbers.

Seabird populations were investigated all over Britain as part of the SeaBird 2000 census (Mitchell *et al*, 2004). The area was surveyed in sections on various dates in late spring of 1999, 2000 and 2001. Total counts of all species recorded within 5 km of the trestles are presented in Table 8.1.

Counts were mainly of occupied nests or territories, so actual numbers of seabirds breeding in the area will be higher.

Table 8.1 Seabird counts within 5 km of the production areas

Common name	Species	Count	Method
Herring Gull	Larus argentatus	238	Occupied territory/nests
Common Tern	Sterna hirundo	119	Occupied nests
Black-headed Gull	Larus ridibundus	100	Occupied nests
Arctic Tern	Sterna paradisaea	74	Occupied nests
European Shag	Phalacrocorax aristotelis	65	Occupied nests
Lesser Black-backed Gull	Larus fuscus	37	Occupied territory
Common Gull	Larus canus	24	Occupied territory/nests
Great Black-backed Gull	Larus marinus	19	Occupied territory/nests
Black Guillemot	Cepphus grylle	2	Individuals on land

None of these observations were within Seil Sound or on adjacent land. Nevertheless, it is likely that seabirds will be found in the area even if they are not nesting there in large numbers. An aggregation of 100 gulls was seen in Ardmaddy bay during the shoreline survey, and during a second survey both gulls and cormorants were noted on the mussel floats. Though nesting occurs in early summer after which some species disperse, gulls are likely to be present in the area throughout the year.

Waterfowl (ducks and geese) are likely to be present in the area at various times, primarily to overwinter, or briefly during migration, although some species breed in Argyll and Bute in small numbers. No geese seen during the course of the shoreline survey, although they are often found on coastal pastures such as those found around Seil Sound. The local sampling officer advised that large concentrations of geese (over 100 birds at times) are seen year round but more often during the winter on the golf course just north of Balvicar, around Balvicar farm, and on the mainland around Ardshellach. Therefore, greatest impacts from geese may be expected at the Ardshellach, Balvicar, and Rubha Nan Ron sites, although as these animals are highly mobile their presence in any given area will be unpredictable. An aggregation of 33 ducks and one swan was seen on the shore at Clachan Seil during the shoreline survey, but this is not particularly close to any of the sites.

Wading birds would be concentrated on intertidal areas, such as the areas where the trestles are located. No aggregations of wading birds were noted during the shoreline survey.

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.

Deer will be present particularly in wooded areas where the habitat is best suited for them. Parts of the eastern shoreline of Seil Sound are wooded, including the shoreline adjacent to the Balvicar North (Craig Ulian) site. While no population data were available for this specific area, it can be presumed that deer are present in the area. It is therefore possible that some of the indicator organisms detected in the streams feeding into Seil Sound will be of deer origin, although their contribution relative to other sources is not known.

Otters

No otters were observed during the course of the shoreline survey, although otters are likely to be 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

Potential wildlife impacts to the fisheries at Seil Sound include seals, waterfowl, seabirds, deer and otters. Given their preferred haunts, seal impacts might be greatest at the Balvicar North (Island) site, mainly during the summer months, and geese impacts may occur at the Ardshellach, Balvicar and Rubha Nan Ron South sites at any time of the year. Any impacts from other species will be unpredictable, and relatively minor.

9. Meteorological data

The nearest weather station is located at Kimelford, approximately 5 km to the east of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily rainfall in mm). No data was available for November 2004 or October 2006. It is likely that the rainfall experienced at Kimelford is similar to that experienced at the production area due to their close proximity.

The nearest major weather station where wind is measured is located at Glasgow: Bishopton, approximately 77 km to the south east of the production area. Wind direction was recorded at 3 hourly intervals for the majority of the period 1/1/1996 to 31/12/2007. It is likely that the wind patterns may differ between the production area and the weather station, given the distance between the two and differences in local topography.

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 wastewater treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003).

Total annual rainfall and mean monthly rainfall were calculated, and are presented in Figures 9.1 and 9.2.

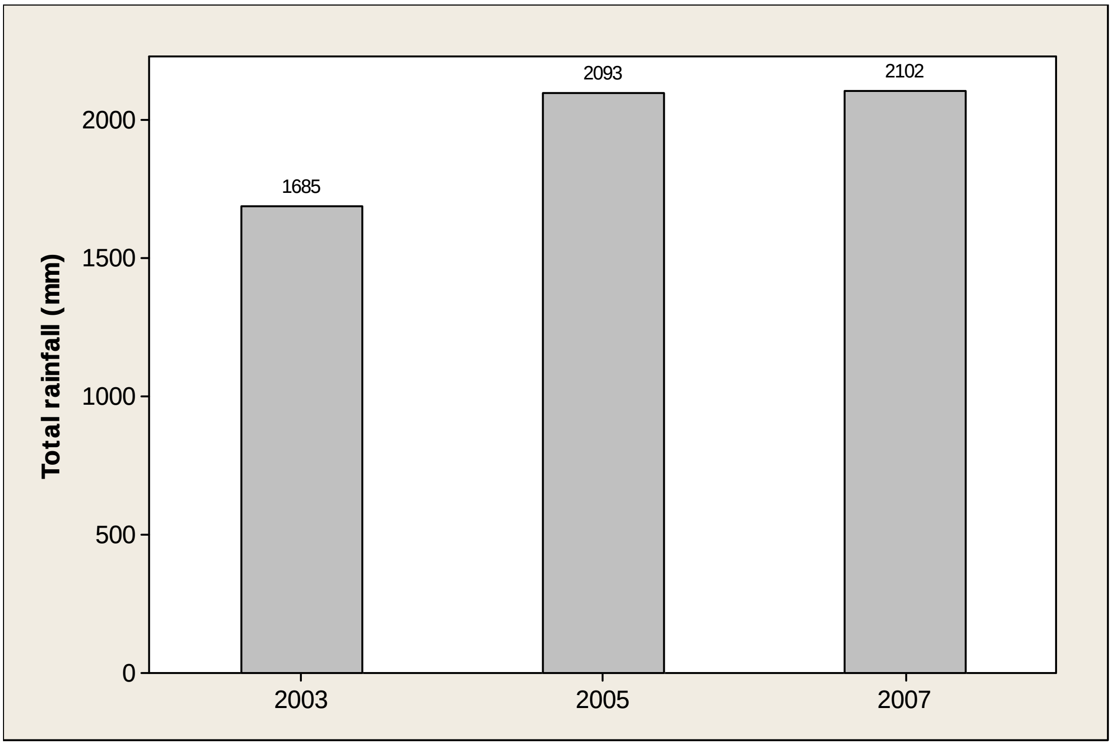


Figure 9.1 Total annual rainfall at Kimelford, 2003 – 2007 (not calculated for 2004 or 2006 due to incomplete data)

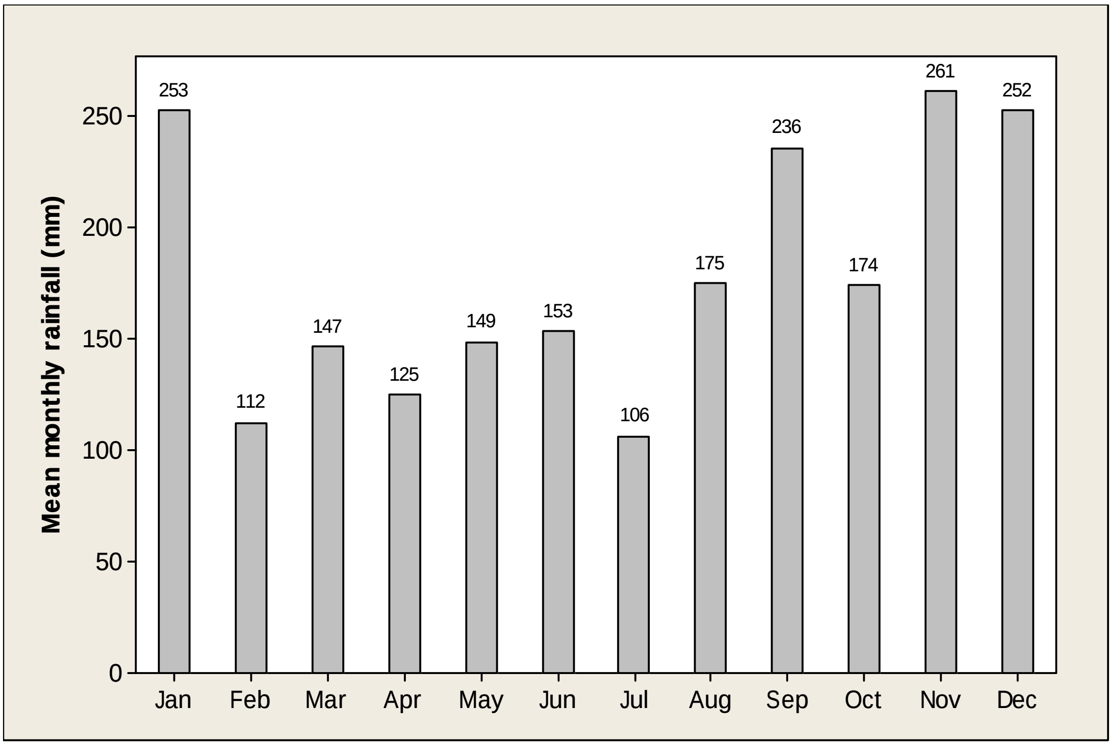


Figure 9.2 Mean total monthly rainfall at Kimelford, 2003 - 2007

The wettest months were January, September, November, and December. For the period considered here, only 26% of the days experienced no rainfall. 21% of days experienced rainfall of 10 mm or more.

It can therefore be expected that levels of faecal contamination entering the production area from rainfall dependant sources may be higher during the autumn and winter months. It is possible that faecal matter can build up on pastures during the drier summer months when stock levels are at their highest, leading to more significant faecal contamination of runoff during summer storms, or at the onset of the wetter weather in the autumn.

9.2 Wind

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

WIND ROSE FOR GLASGOW, BISHOPTON
N.G.R: 2417E 6710N ALTITUDE: 59 metres a.m.s.l.

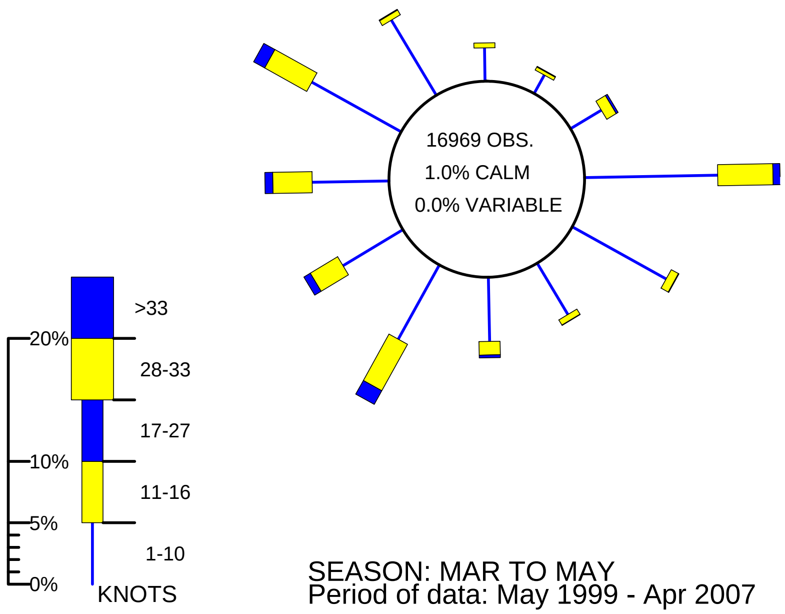


Figure 9.3 Wind rose for Glasgow: Bishopton (March to May)

WIND ROSE FOR GLASGOW, BISHOPTON
N.G.R: 2417E 6710N ALTITUDE: 59 metres a.m.s.l.

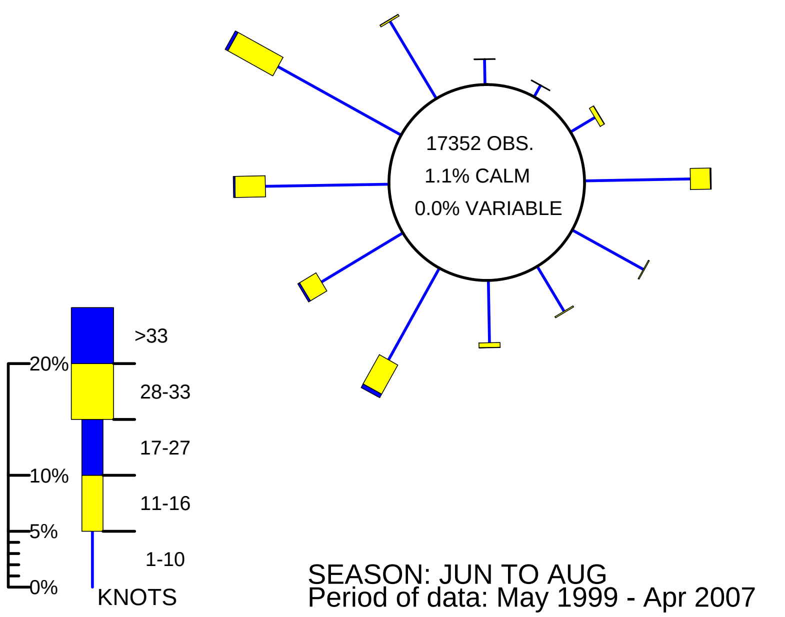


Figure 9.4 Wind rose for Glasgow: Bishopton (June to August)

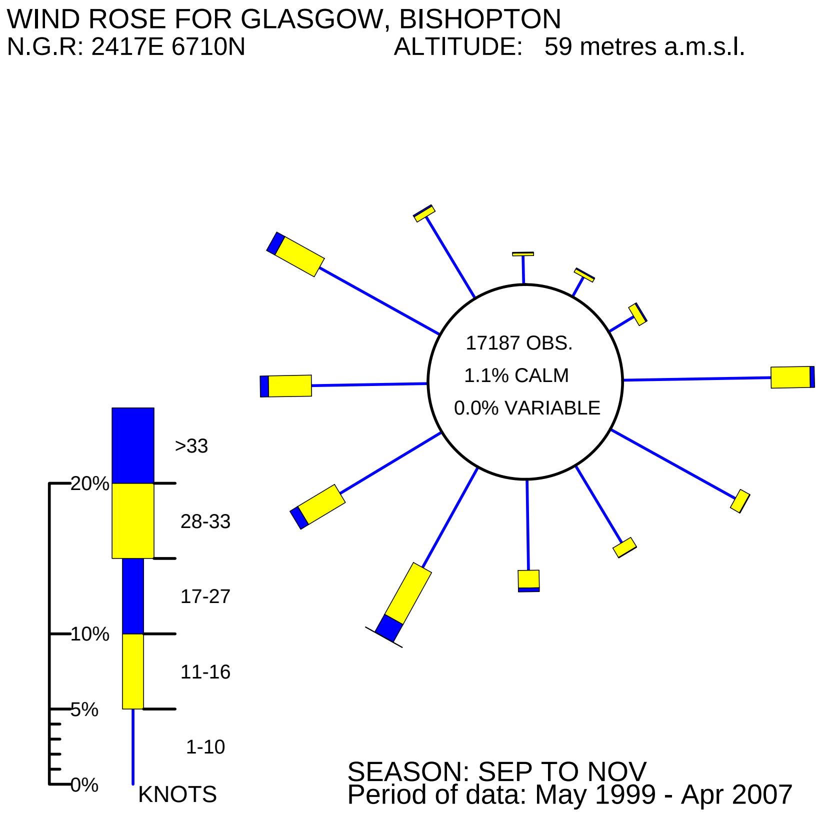


Figure 9.5 Wind rose for Glasgow: Bishopton (September to November)

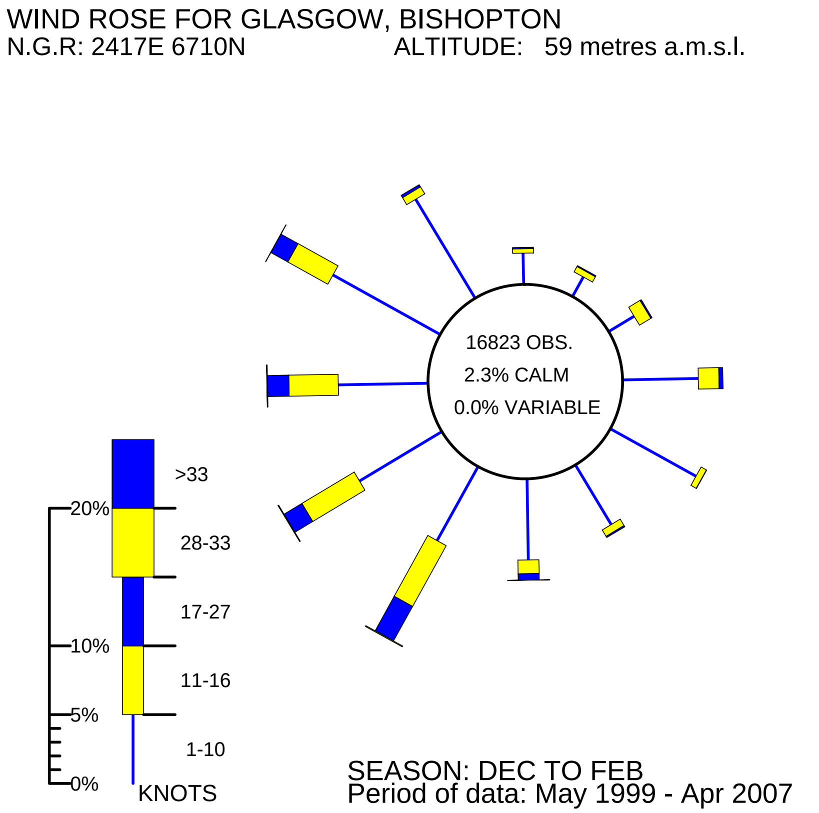


Figure 9.6 Wind rose for Glasgow: Bishopton (December to February)

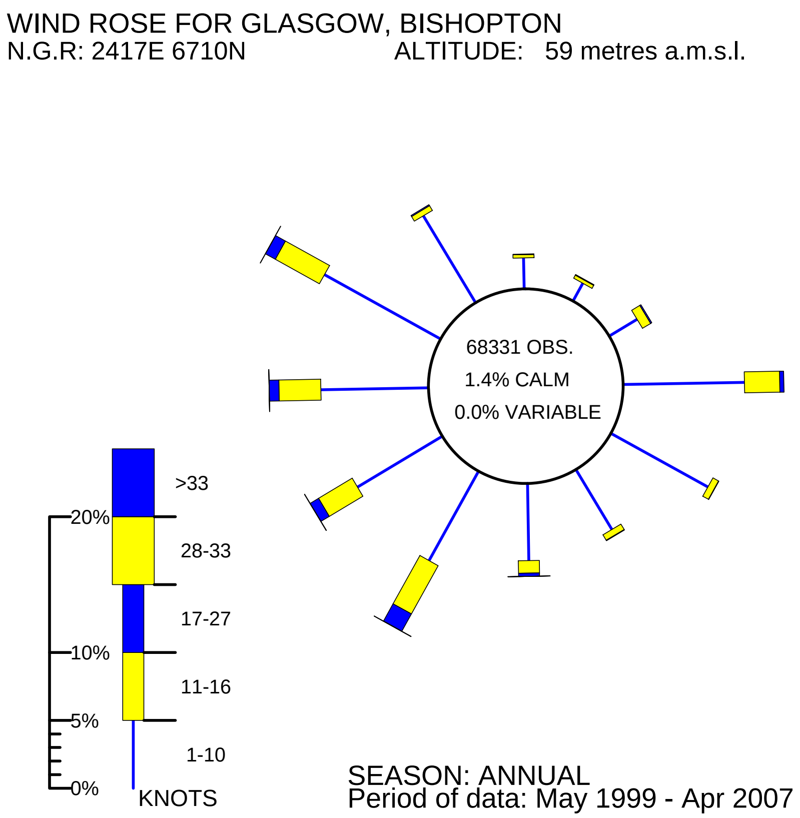


Figure 9.7 Wind rose for Glasgow: Bishopton (All year)

Glasgow is not one of the windier areas of Scotland, with a low frequency of gales compared to places such as the Western Isles and the Shetlands. The wind roses show that the overall prevailing direction of the wind is from the west, and the strongest winds come from this direction. Stronger winds are also experienced from the east, presumably due in part to local topography - Bishopton is in the Clyde Valley, which has a west to east aspect. Winds are generally lighter during the summer months and stronger in the winter.

Seil Sound has a SSW to NNE aspect, opening out at its southern end. It is about 6 km long and up to 1.5 km. To the west lies the island of Seil which rises to almost 150 m, and to the east lies the mainland, which rises to 200 m in places. It is partly sheltered from the south by the island of Torsa and the mainland. It is more exposed to south and southwesterly winds than from other directions.

A strong southerly or southwesterly wind combined with a spring tide may result in higher than usual tides which will carry accumulated faecal matter from livestock, above the normal high water mark, into the loch.

Although tidally driven circulation of water in the Sound is likely to be important due to its relatively large tidal range, wind effects are likely to cause significant changes in water circulation. 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 in the direction of the wind. These surface water currents create return currents which may travel along the bottom or sides of the loch depending on bathymetry. Strong winds will increase the circulation of water and hence dilution of contamination from point sources within the loch. There may be some instances where contamination from point sources may be carried to production sites by wind driven currents when the wind is blowing from a particular direction.

10. Current and historical classification status

The survey area consists of two adjacent production areas: Seil Sound Balvicar (classified for mussels and Pacific oysters) and Seil Sound Kilbrandon (classified for Pacific oysters only). A map of the production areas is presented in Figure 10.1.

Seil Sound Balvicar

Seil Sound Balvicar has been classified with its current boundaries for the production of Pacific oysters since 2002. Prior to this the production area had different boundaries and was referred to as Seil Sound. The classification history from 2002 is presented in Table 10.2. Up to 2005, the area was classified as a seasonal A/B, but since 2006 it has been classified as a year round B. There are two RMPs identified for this production area: one falls 5 m away from the trestles at the Balvicar site, and the other falls about 100 m away from the trestles at the Balvicar North (Island) site so both fall within the 100 m level of accuracy which can be expected when estimating the grid reference from and Ordnance Survey map.

Table 10.1 Classification history, Seil Sound Balvicar, Pacific oysters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	A	A	A	A	A	A	B	B	B	B	B	B
2003	A	A	A	A	B	B	B	B	B	B	B	A
2004	A	A	A	B	B	B	B	B	B	B	B	B
2005	A	A	B	B	B	B	B	B	B	B	B	B
2006	B	B	B	B	B	B	B	B	B	B	B	B
2007	B	B	B	B	B	B	B	B	B	B	B	B
2008	B	B	B	B	B	B	B	B	B	B	B	B
2009	B	B	B	B	B	B	B	B	B	B	B	B
2010	B	B	B									

Seil Sound Balvicar was first classified for the production of mussels in 2006. The classification history is presented in Table 10.2. Throughout the period of classification, it was classified as B. The RMP for this production area falls on both the Crown Estates lease and one of the mussel rafts.

Table 10.2 Classification history, Seil Sound Balvicar, mussels

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	B	B	B	B	B	B	B	B	B	B	B	B
2007	B	B	B	B	B	B	B	B	B	B	B	B
2008	B	B	B	B	B	B	B	B	B	B	B	B
2009	B	B	B	B	B	B	B	B	B	B	B	B
2010	B	B	B									

Seil Sound Kilbrandon

Seil Sound Kilbrandon has been classified with its current boundaries for the production of Pacific oysters since 2002. Prior to this the production area had different boundaries and was referred to as Seil Sound. The classification history is presented in Table 10.3. Throughout the period of classification, it was classified as a seasonal A/B aside from in 2005 when it was a B all year. Class A periods fell during the winter and spring. The RMP lies about 100 m away from the trestles at the Kilbrandon site which is within the 100 m level of accuracy which can be expected when estimating the grid reference from and Ordnance Survey map.

Table 10.3 Classification history, Seil Sound Kilbrandon, Pacific oysters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	B	B	B	B	B	B	B	B	B	B	B	B
2003	A	A	A	A	B	B	B	B	B	B	B	A
2004	A	A	A	A	B	B	B	B	B	B	B	A
2005	B	B	B	B	B	B	B	B	B	B	B	B
2006	A	A	A	B	B	B	B	B	B	B	B	B
2007	A	A	A	B	B	B	B	B	B	B	B	B
2008	A	A	A	A	B	B	B	B	B	B	B	B
2009	B	A	A	B	B	B	B	B	B	B	A	A
2010	A	A	B									

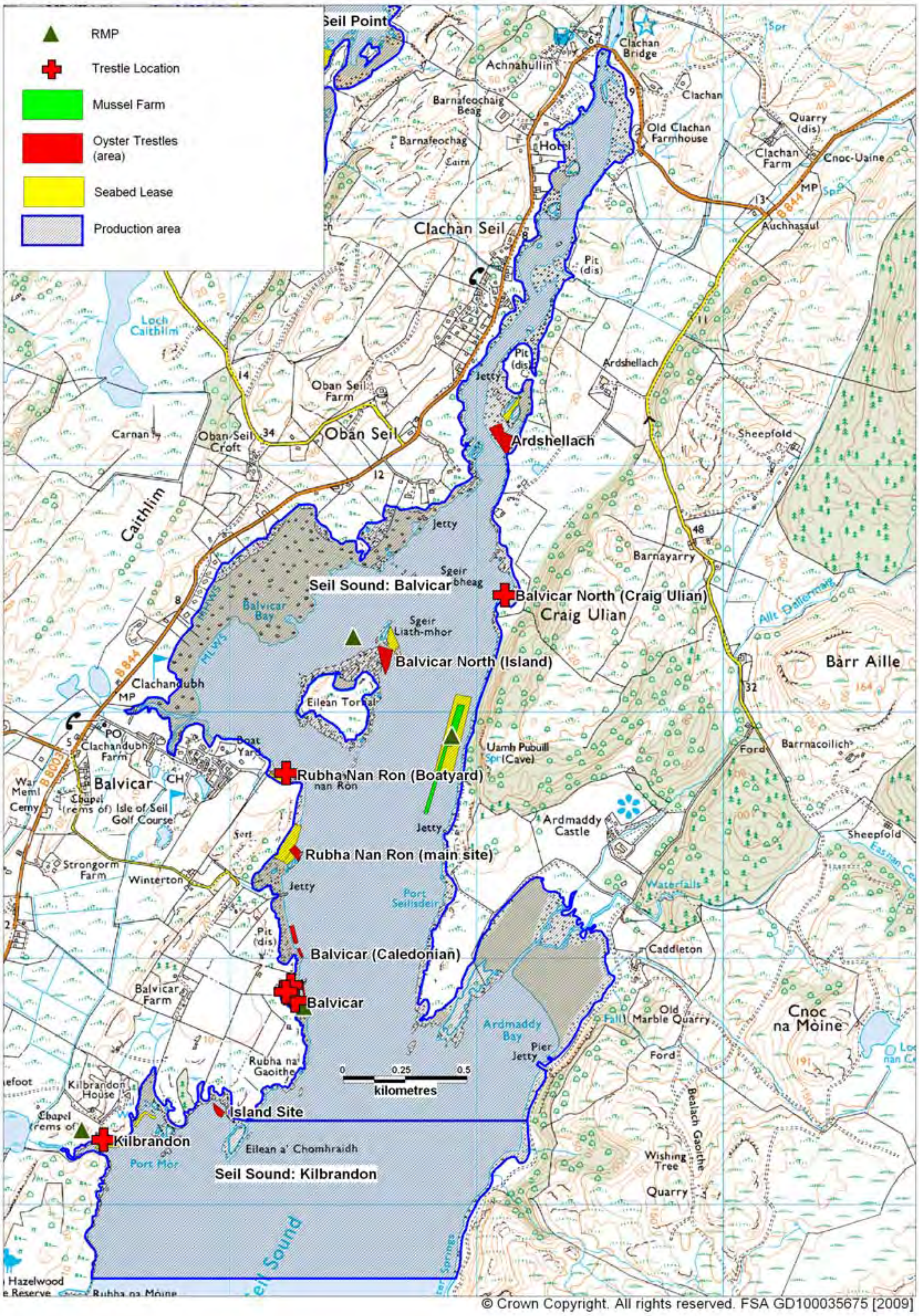


Figure 10.1 Map of current production areas

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken from Seil Sound Balvicar and Seil Sound Kilbrandon from the beginning of 2002 up to the end of 2007 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

One oyster sample reported as originating from Seil Sound Balvicar (Rubha nan Ron South) had a reported sampling location 5.3 km east of the production area, and was removed from the analysis. One oyster sample reported as originating from Seil Sound Kilbrandon (Kilbrandon) had a reported sampling location 4 km north of the area and was also removed from the analysis. Six samples reported as originating from Seil Sound Kilbrandon (Kilbrandon) had a reported sampling location at NM774153, 1 km to the east of the RMP and in the middle of Seil Sound. It was assumed that a one-digit error was made when the sampling location was reported, and the sampling location for these six samples was adjusted to NM764153.

19 oyster samples had the result reported as <20, and these were assigned a nominal value of 10 for statistical assessment and graphical presentation. Two oyster samples had a reported result of >18000, which were assigned a nominal value of 36000 for statistical assessment and graphical presentation.

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

11.2 Summary of microbiological results

A summary of all sampling and results by is presented in Table 11.1. Reported sampling locations for samples taken before the start of the official control samplers in April 2007 were reported to an accuracy of 100 m, generally from one grid reference only per site. After the start of the official control samplers, sampling locations were recorded to 1 m accuracy using a GPS, and these sampling locations were generally clustered around a small area within each site sampled. As a consequence, results were presented by site rather than by reported sampling location in Table 11.1, and no attempt was made to investigate small scale geographical trends within individual sites in Section 11.3.

Table 11.1 Summary of results from Seil Sound Balvicar and Seil Sound Kilbrandon

Sampling Summary						
Production area	Seil Sound: Balvicar	Seil Sound: Balvicar	Seil Sound: Balvicar	Seil Sound: Balvicar	Seil Sound: Balvicar	Seil Sound: Kilbrandon
Site	Ardshellach	Balvicar North	East of Balvicar	Rubha nan Ron South	Balvicar	Kilbrandon
Species	Pacific oysters	Pacific oysters	Common mussels	Pacific oysters	Pacific oysters	Pacific oysters
SIN	AB-247-71-13	AB-247-735-13	AB-247-703-8	AB-247-728-8	AB-247-72-13	AB-248-73-13
Location	NM782182 only	9 grid references	9 grid references	NM772164 only	9 grid references	8 grid references
Total no of samples	34	41	29	12	65	64
No. 2002	0	0	0	0	12	12
No. 2003	0	0	0	0	12	12
No. 2004	11	10	0	0	12	12
No. 2005	12	12	9	3	11	12
No. 2006	10	10	11	8	9	9
No. 2007	1	9	9	1	9	7
Results Summary						
Minimum	<20	<20	20	<20	<20	<20
Maximum	5400	5400	16000	3500	>18000	16000
Median	405	700	220	265	220	160
Geometric mean	356	448	334	246	271	120
90 percentile	1930	1700	3880	1660	2980	995
95 percentile	2400	3500	5400	2510	14600	2295
No. exceeding 230/100g	23 (68%)	29 (71%)	14 (48%)	6 (50%)	32 (49%)	22 (34%)
No. exceeding 1000/100g	9 (26%)	15 (37%)	7 (24%)	3 (25%)	14 (22%)	7 (11%)
No. exceeding 4600/100g	1 (3%)	2 (5%)	3 (10%)	0 (0%)	6 (9%)	2 (3%)
No. exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (3%)	0 (0%)

11.3 Overall geographical pattern of results

Figure 11.1 presents a map of geometric mean *E. coli* result by site.

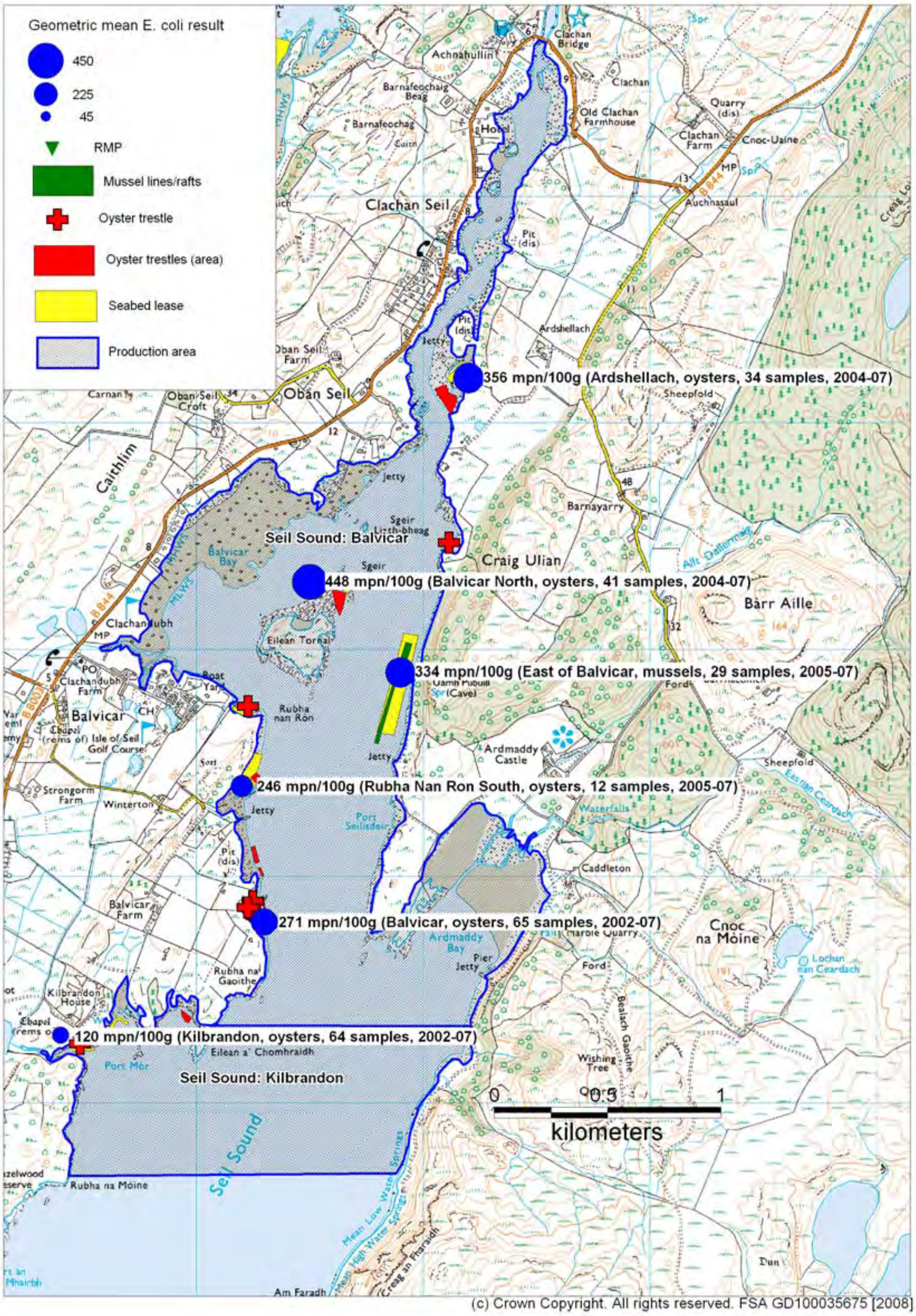


Figure 11.1 Geometric mean E. coli result by site

Of the eight discrete areas of Pacific oyster trestles identified in Section 2, three had no *E. coli* monitoring history (Island site, Balvicar North (Craig Ulian), and Rubha Nan Ron (Boatyard)). Therefore, all samples referred to in this section as originating from Balvicar North originate from the Balvicar North (Island) site, and all referred to as originating from Rubha nan Ron South originate from the main Rubha nan Ron South site. Also, no samples were taken from the Balvicar (Caledonian) trestles, but these are located in close proximity to the Balvicar site, so could be considered an extension of the same site.

As there was only one site sampled for mussels, and as it is not appropriate to compare results obtained for different shellfish species, geographic analysis will be confined to a comparison of results obtained at the five oyster sites. Figure 11.2 presents a boxplot of all oyster results by site. 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 *. These results are not directly comparable however, as they were often taken on different occasions for the different sites, and hence under different conditions.

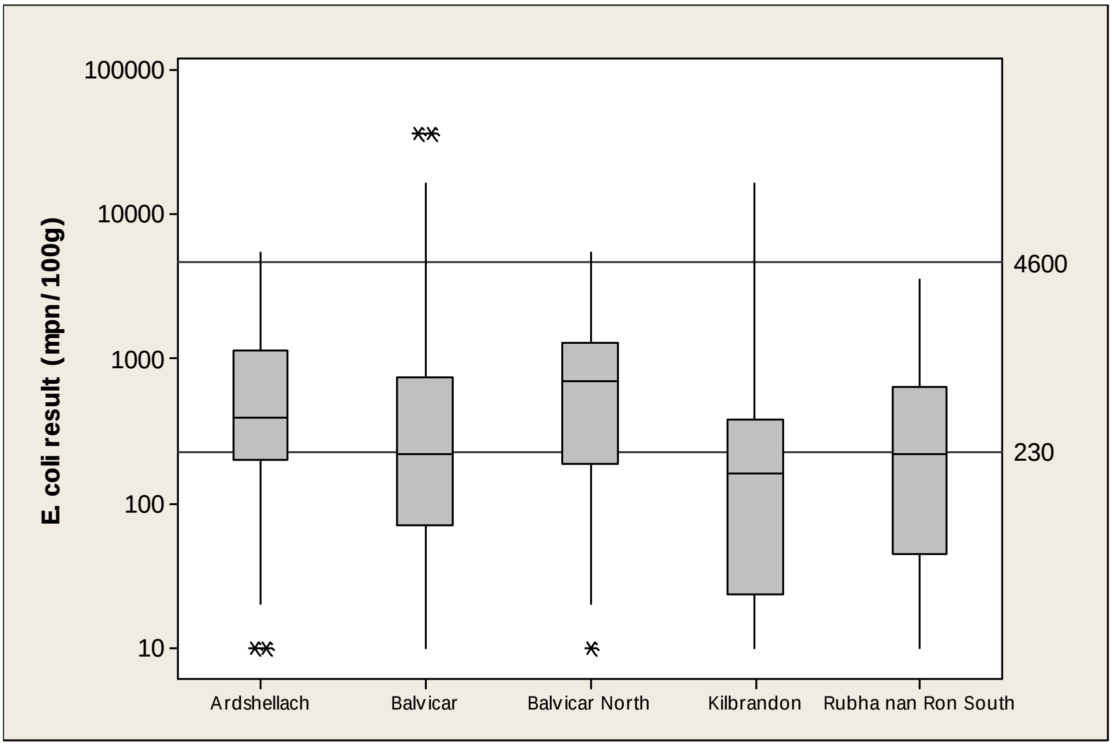


Figure 11.2 Boxplot of all Pacific oyster E. coli results by site

These five oyster sites were all sampled on the same day on only 8 occasions, all between September 2005 and August 2006. A comparison of these results showed a significant difference in results between sites (2-way ANOVA, p=0.003, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicated that results were significantly lower for Balvicar than Ardshellach and Balvicar North.

It was possible to use a much larger dataset of 26 occasions when multiple sites were sampled if the Rubha Nan Ron South site was excluded from the analysis, allowing a more robust comparison between the other four sites. A comparison of these results again showed a significant difference between sites (2-way ANOVA, p=0.000, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicated that results were significantly lower for Balvicar and Kilbrandon compared to Balvicar North, and significantly lower for Kilbrandon compared to Ardshellach.

Table 11.2 Proportion of all Pacific oyster results exceeding 230 *E. coli* MPN/100g

Site	Ardshellach	Balvicar North	Rubha nan Ron South	Balvicar	Kilbrandon
No. exceeding 230 *E. coli* MPN /100g	23 (68%)	29 (71%)	6 (50%)	32 (49%)	22 (34%)
No. less than 230 *E. coli* MPN /100g	11 (32%)	12 (29%)	6 (50%)	33 (51%)	42 (66%)

A significant difference was found in the proportion of oyster results over 230 *E. coli* MPN/100g between sites (Chi-Square, p=0.001, Appendix 6). The proportion of results over 230 *E. coli* MPN/100g was greater than expected on the basis of the overall average at Balvicar North and Ardshellach, and lower than expected on the basis of the overall average at the other three sites. These results are not directly comparable however, as they were taken on different occasions for the different sites, and hence under different conditions.

Table 11.3 Proportion of oyster results exceeding 230 *E. coli* MPN/100g for the 26 occasions when Ardhshellach, Balvicar, Balvicar North and Kilbrandon were sampled on the same day.

Site	Ardshellach	Balvicar North	Balvicar	Kilbrandon
No. exceeding 230 *E. coli* MPN /100g	20 (77%)	22 (85%)	14 (54%)	9 (35%)
No. less than 230 *E. coli* MPN /100g	6 (23%)	4 (15%)	12 (46%)	17 (65%)

A significant difference was found in the proportion of oyster results over 230 *E. coli* MPN/100g between the four sites when they were sampled on the same occasions (Chi-Square, p=0.001, Appendix 6). The proportion of results over 230 *E. coli* MPN/100g was greater than expected on the basis of the overall average at Balvicar North and Ardshellach, and lower than expected on the basis of the overall average at Balvicar and Kilbrandon.

11.4 Overall temporal pattern of results

Figures 11.3 to 11.6 present scatter plots of individual results against date for each site, fitted with trend lines calculated using two different techniques. They are fitted with lines indicating the geometric mean of the previous 5 samples, the current sample and the following 6 samples, referred to as a rolling geometric mean (black line). They are also fitted with loess lines (blue lines), which stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away. These trend lines help to highlight any apparent underlying trends or cycles. Too few samples were collected to assess any overall temporal trends at Rubha na Ron South and so a scatterplot is not included here.

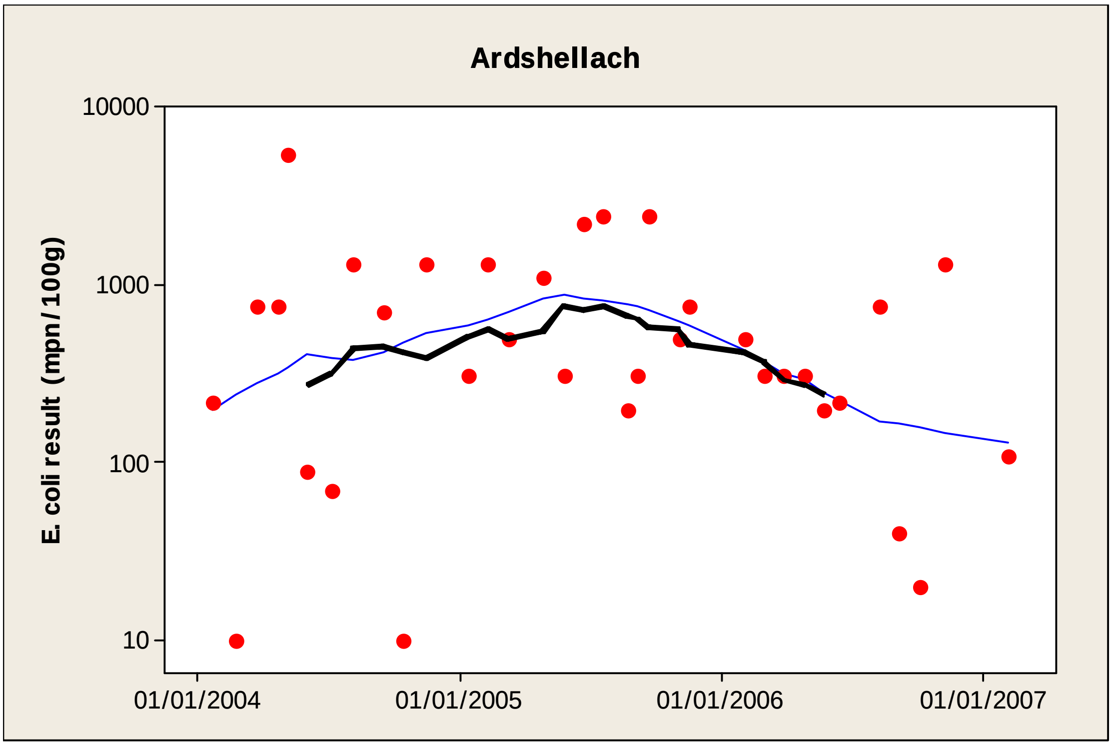


Figure 11.3 Scatterplot of E. coli results by date with rolling geometric mean (black line) and loess line (blue line) (Ardshellach oysters)

Figure 11.3 suggests a deterioration in results from 2004 to 2005, followed by an improvement from 2005 at Ardshellach.

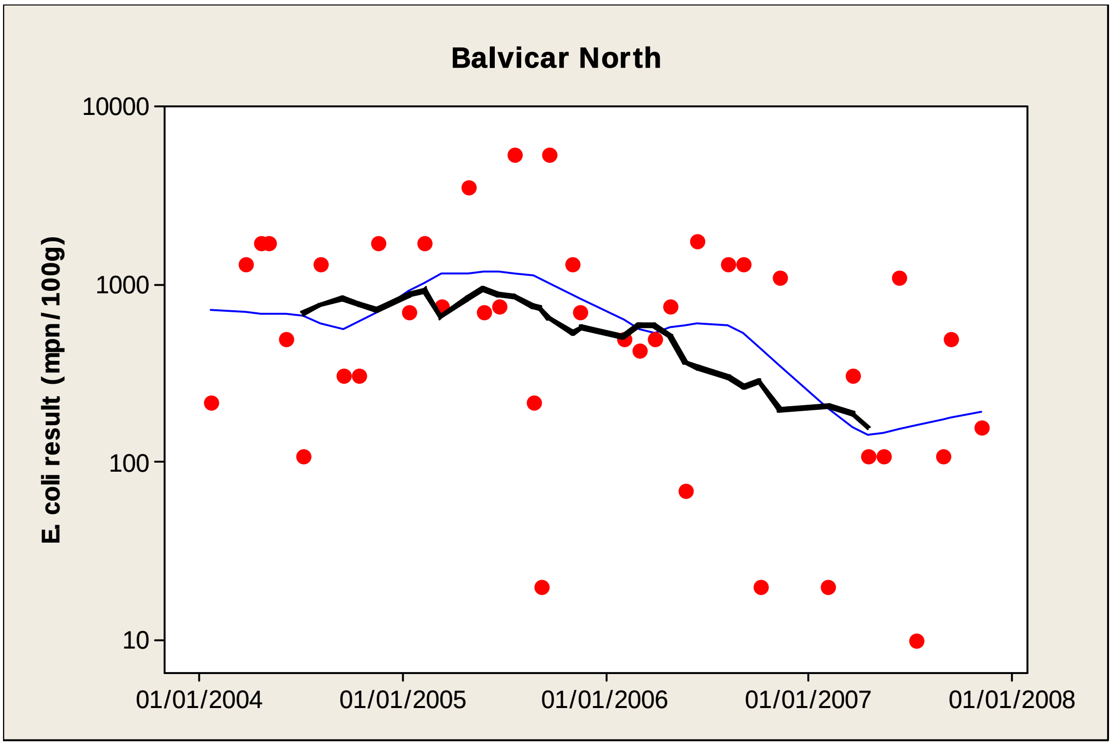


Figure 11.4 Scatterplot of E. coli results by date with rolling geometric mean (black line) and loess line (blue line) (Balvicar North oysters)

Figure 11.4 suggests an improvement in results since 2005 for Balvicar North.

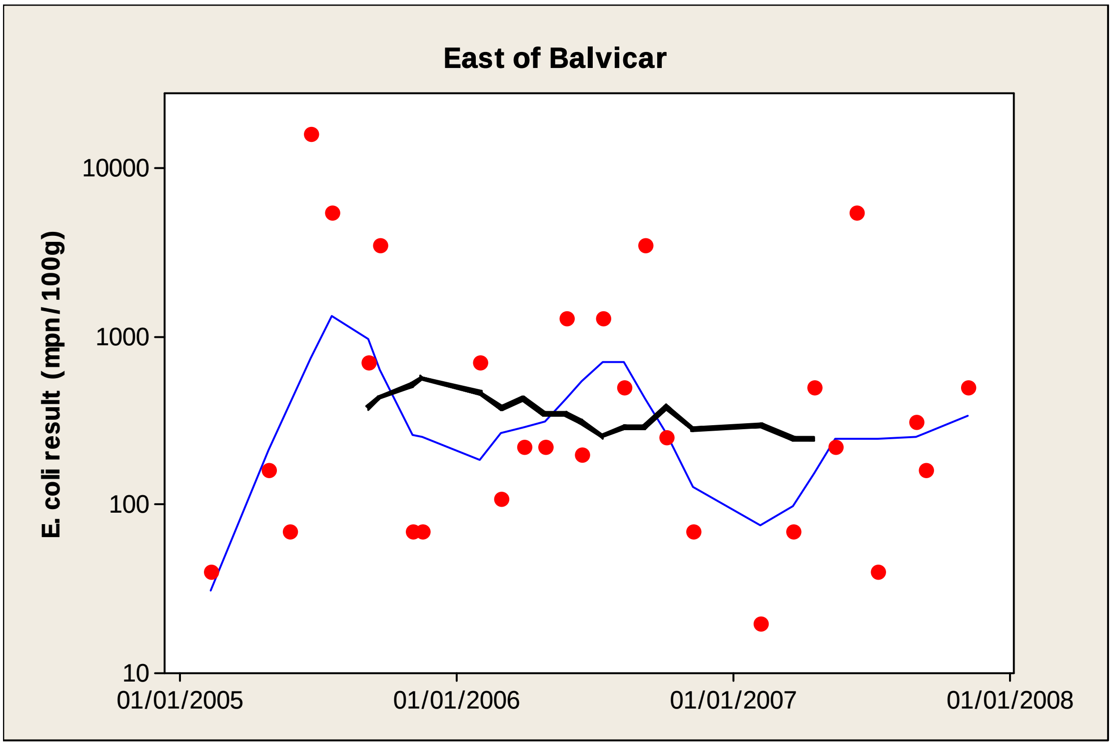


Figure 11.5 Scatterplot of E. coli results by date with rolling geometric mean (black line) and loess line (blue line) (East of Balvicar mussels)

Figure 11.5 suggests a slight improvement in results from 2005 and that results peak in the summer months at East of Balvicar.

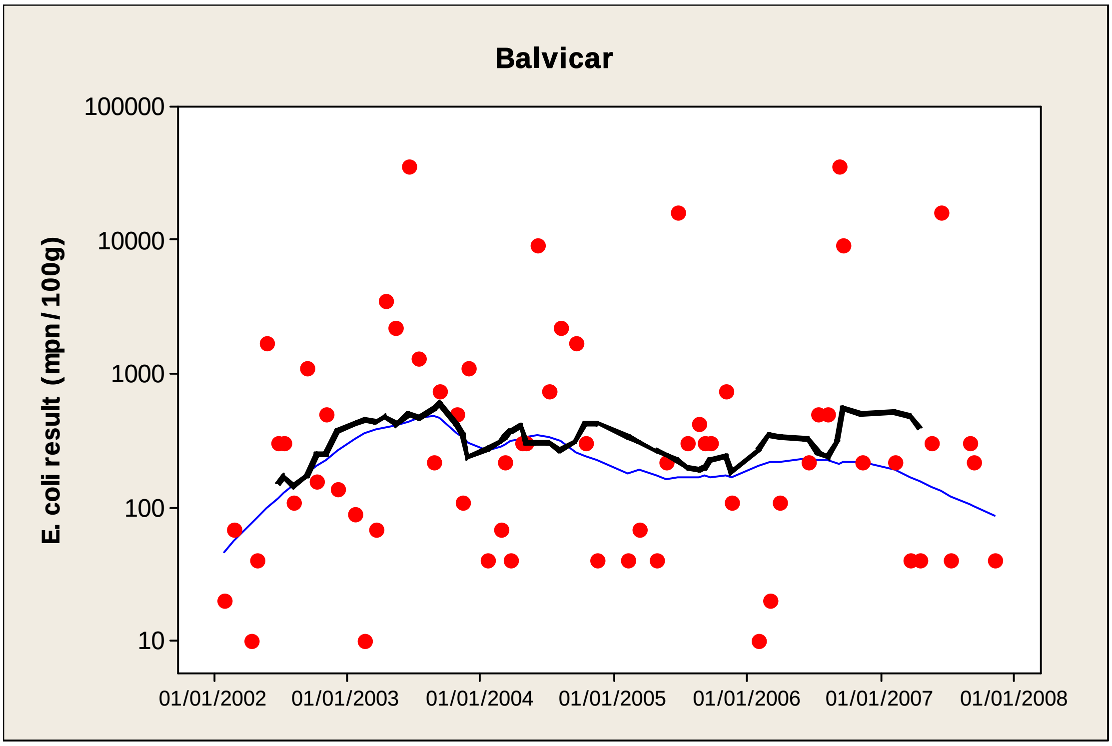


Figure 11.6 Scatterplot of E. coli results by date with rolling geometric mean (black line) and loess line (blue line) (Balvicar oysters)

Figure 11.6 suggests a deterioration in results peaking in 2003 and general improvement since, but peak results remain high.

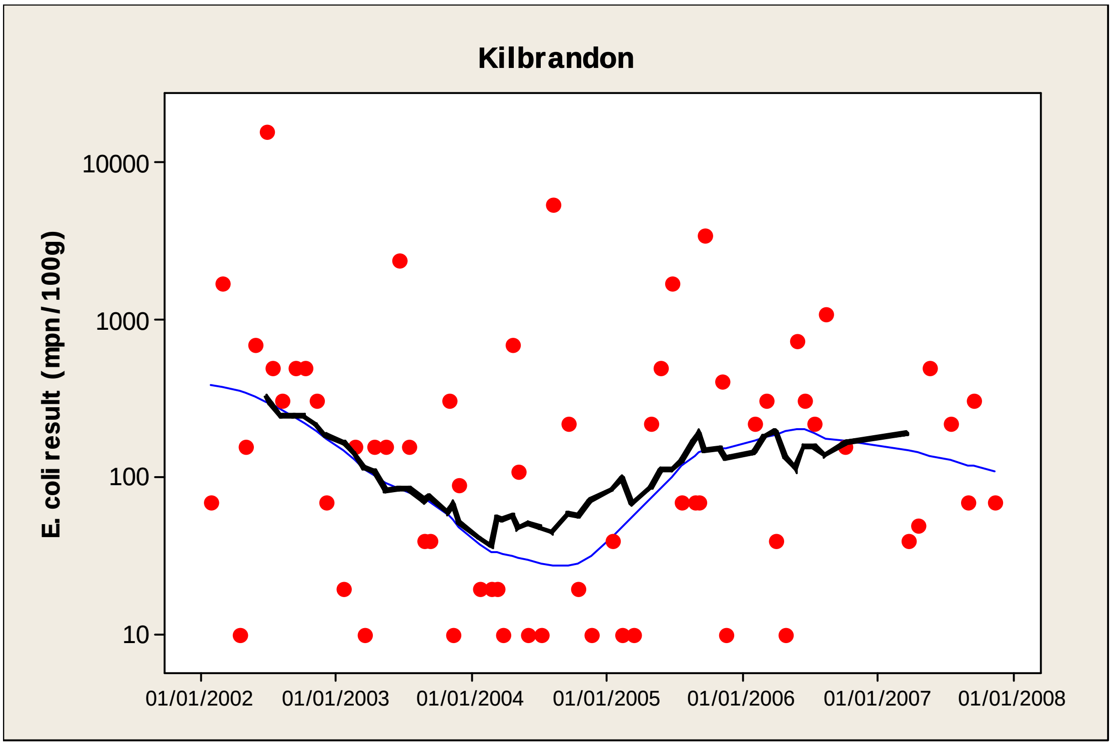


Figure 11.7 Scatterplot of E. coli results by date with rolling geometric mean (black line) and loess line (blue line) (Kilbrandon oysters)

Figure 11.7 suggests that results improved from 2002 to 2004, then deteriorated from 2005 to 2007 at Kilbrandon.

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. Figures 11.8 to 11.12 present geometric mean *E. coli* result by month for each site. Very few samples have been taken in December. Too few samples were taken from Rubha nan Ron South for a meaningful analysis of seasonality at this site.

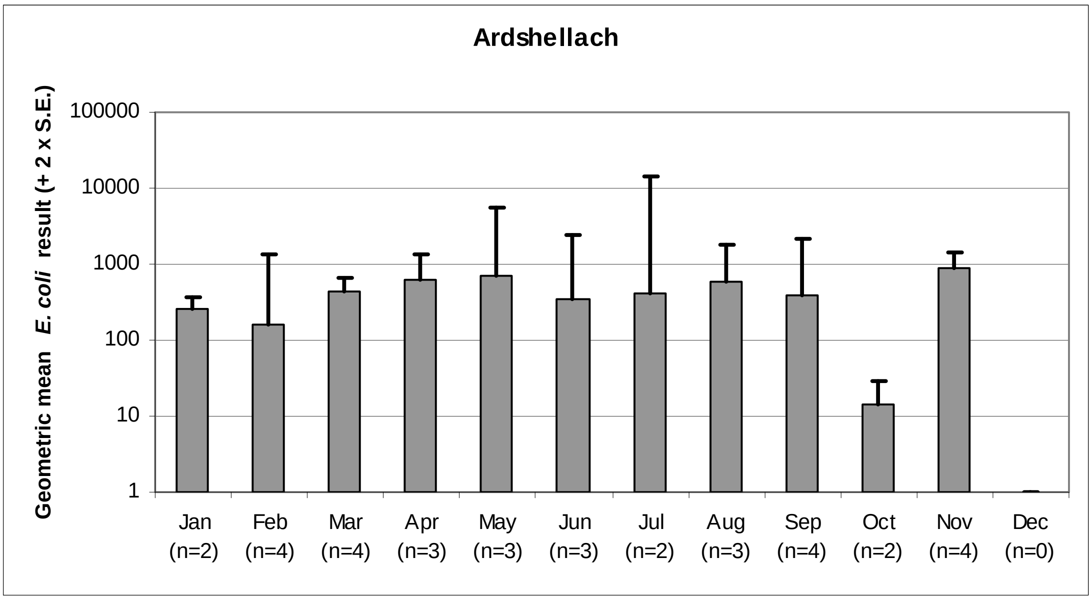


Figure 11.8 Geometric mean E. coli result by month (Ardshellach oysters)

No particular monthly pattern is apparent at Ardshellach.

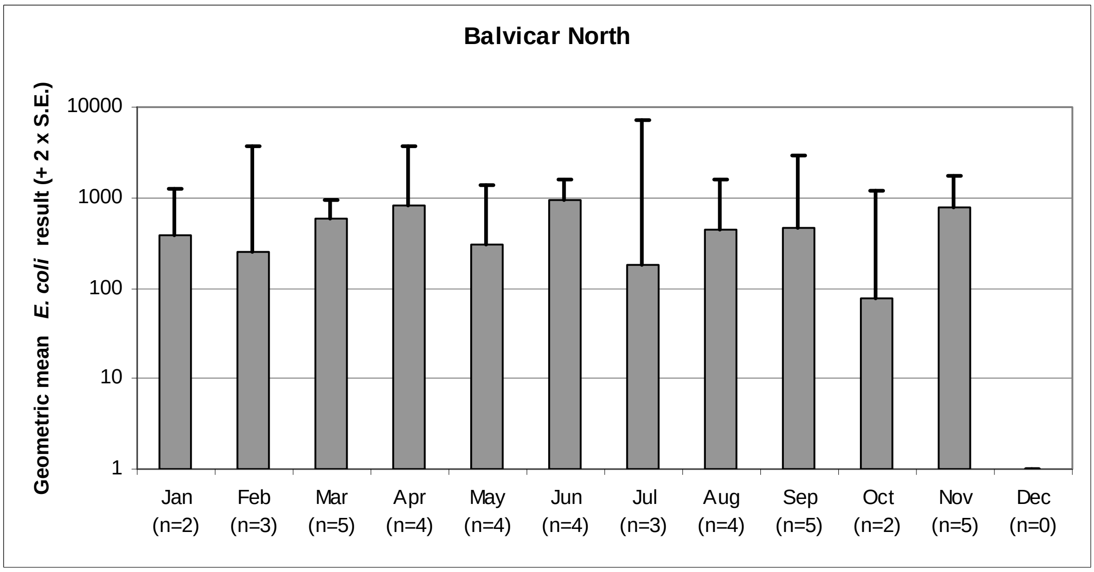


Figure 11.9. Geometric mean E. coli result by month (Balvicar North oysters)

No particular monthly pattern is apparent at Balvicar North.

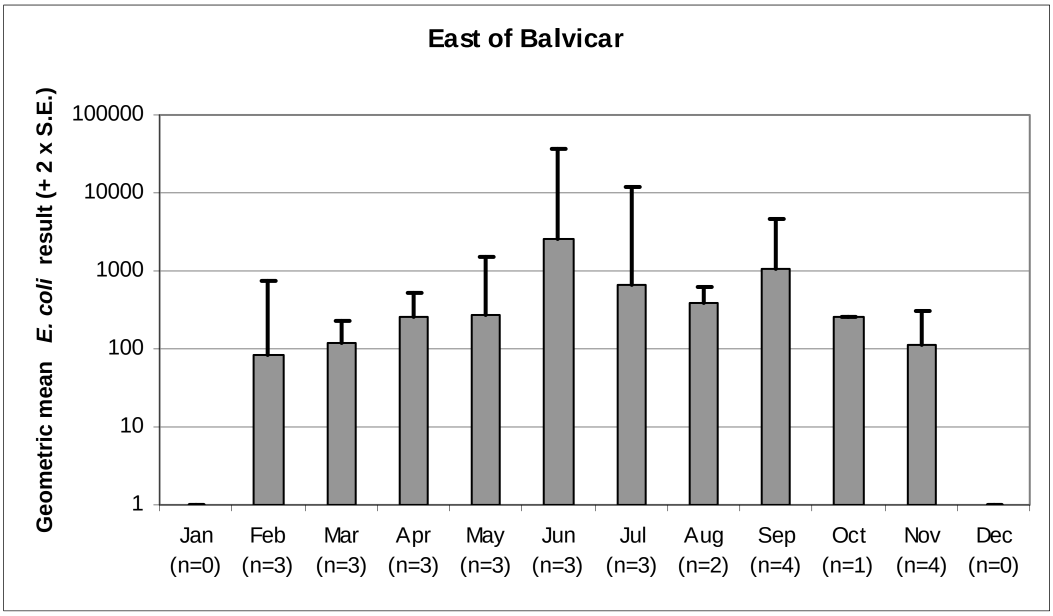


Figure 11.10 Geometric mean E. coli result by month (East of Balvicar mussels)

Sample numbers were low, but higher results occurred during the warmer months at East of Balvicar.

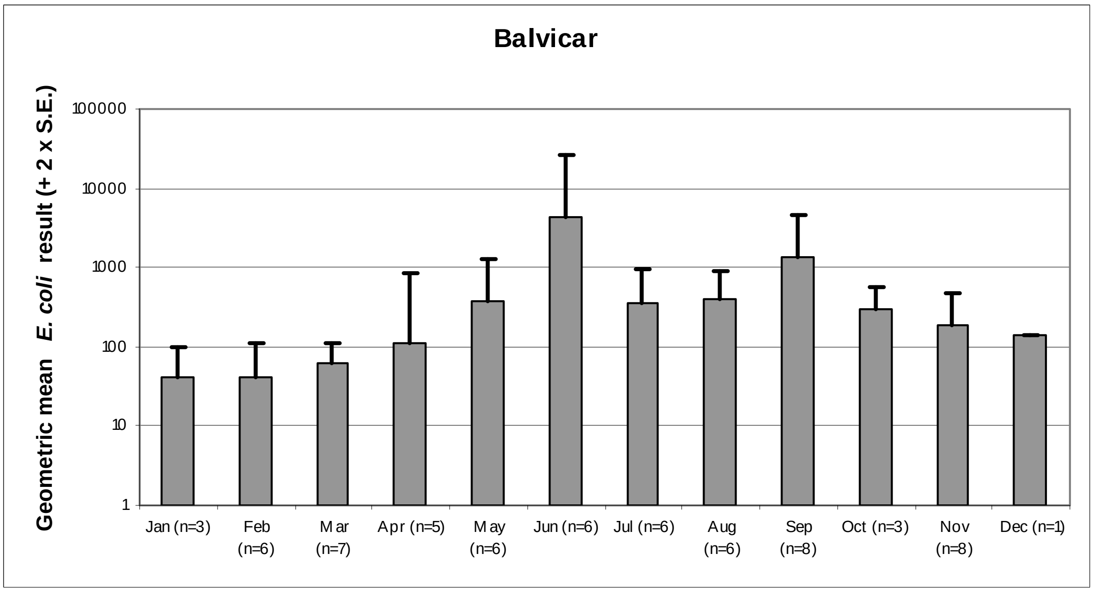


Figure 11.11 Geometric mean E. coli result by month (Balvicar oysters)

Higher results occurred during the warmer months at Balvicar.

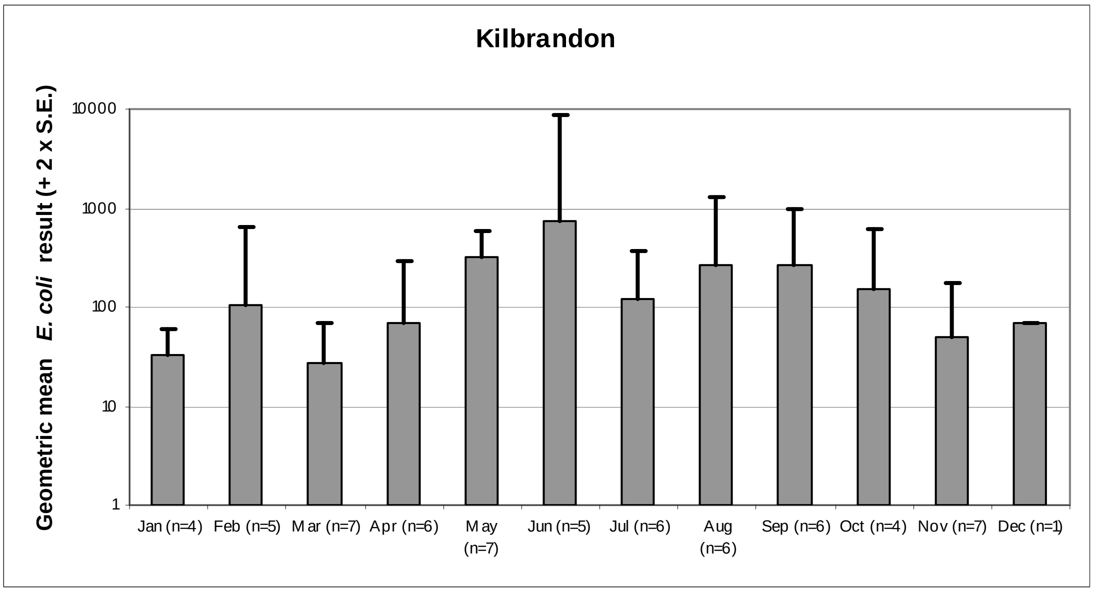


Figure 11.12 Geometric mean E. coli result by month (Kilbrandon oysters)

Higher results occurred during the warmer months at Kilbrandon.

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

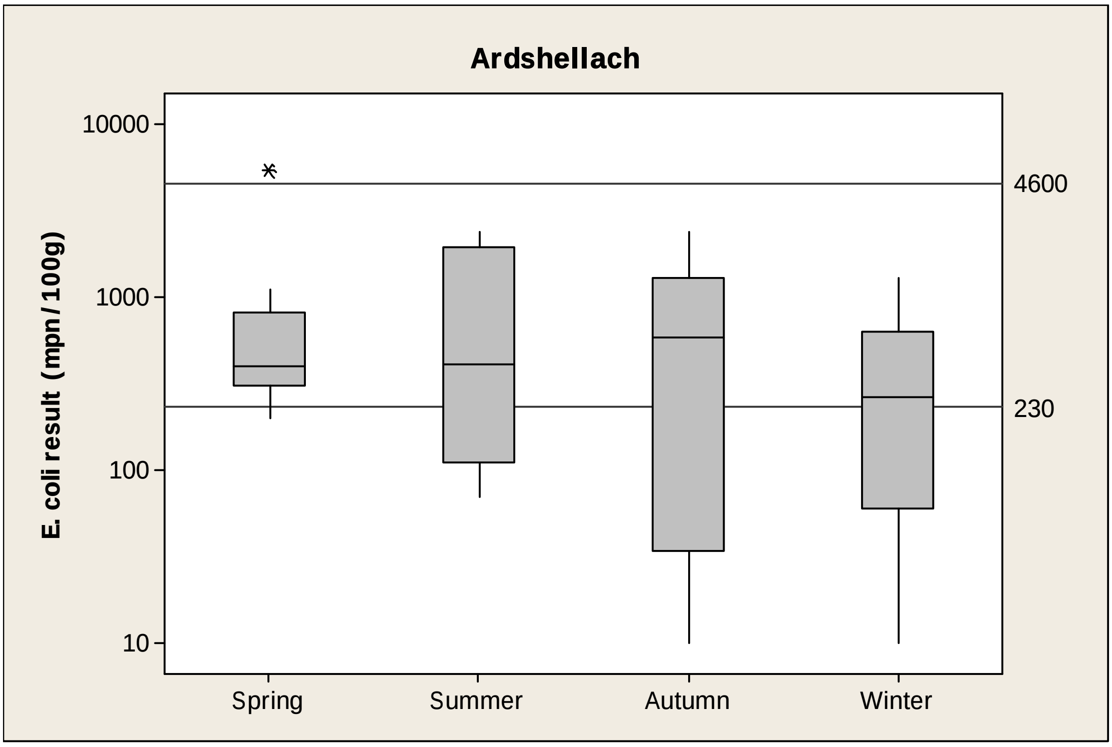


Figure 11.13 Boxplot of E. coli result by season (Ardshellach oysters)

No significant difference was found between results by season for Ardshellach (One-way ANOVA, p=0.516, Appendix 6).

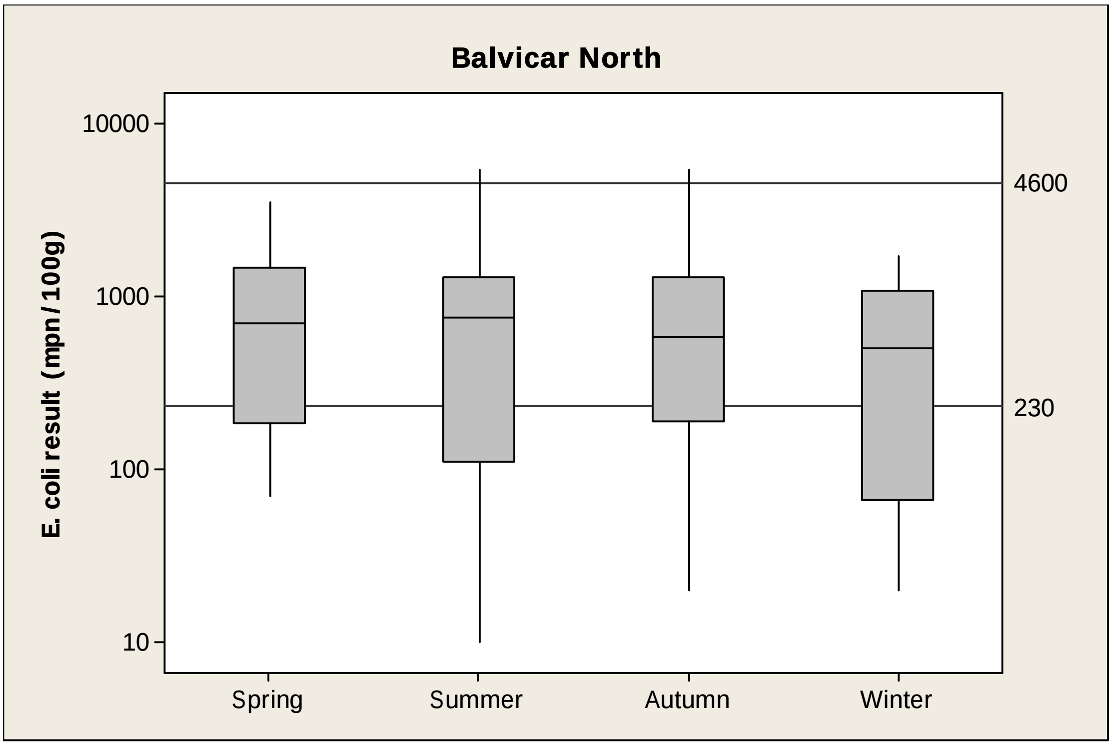


Figure 11.14 Boxplot of E. coli result by season (Balvicar North oysters)

No significant difference was found between results by season for Balvicar North (One-way ANOVA, p=0.922, Appendix 6).

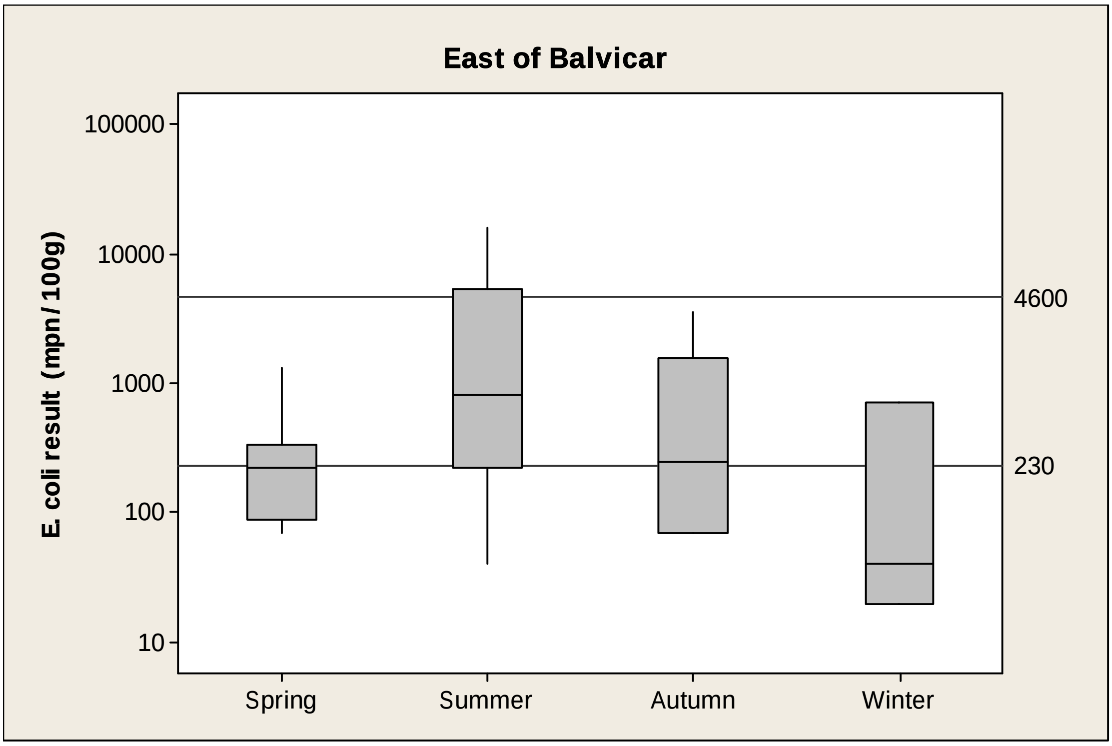


Figure 11.15 Boxplot of E. coli result by season (East of Balvicar mussels)

No significant difference was found between results by season for East of Balvicar (One-way ANOVA, p=0.102, Appendix 6).

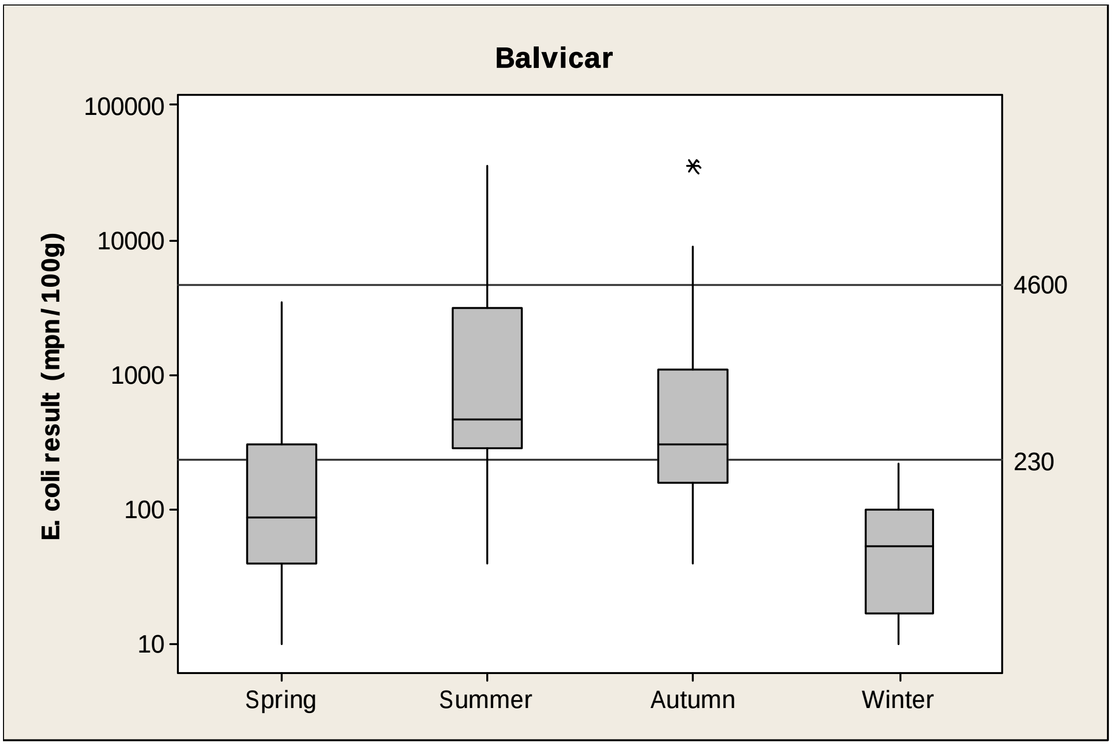


Figure 11.16 Boxplot of E. coli result by season (Balvicar oysters)

A significant difference was found between results by season for Balvicar (One-way ANOVA, p=0.000, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results in the summer were significantly higher than those in the winter and spring, and results in the autumn were significantly higher than in the winter.

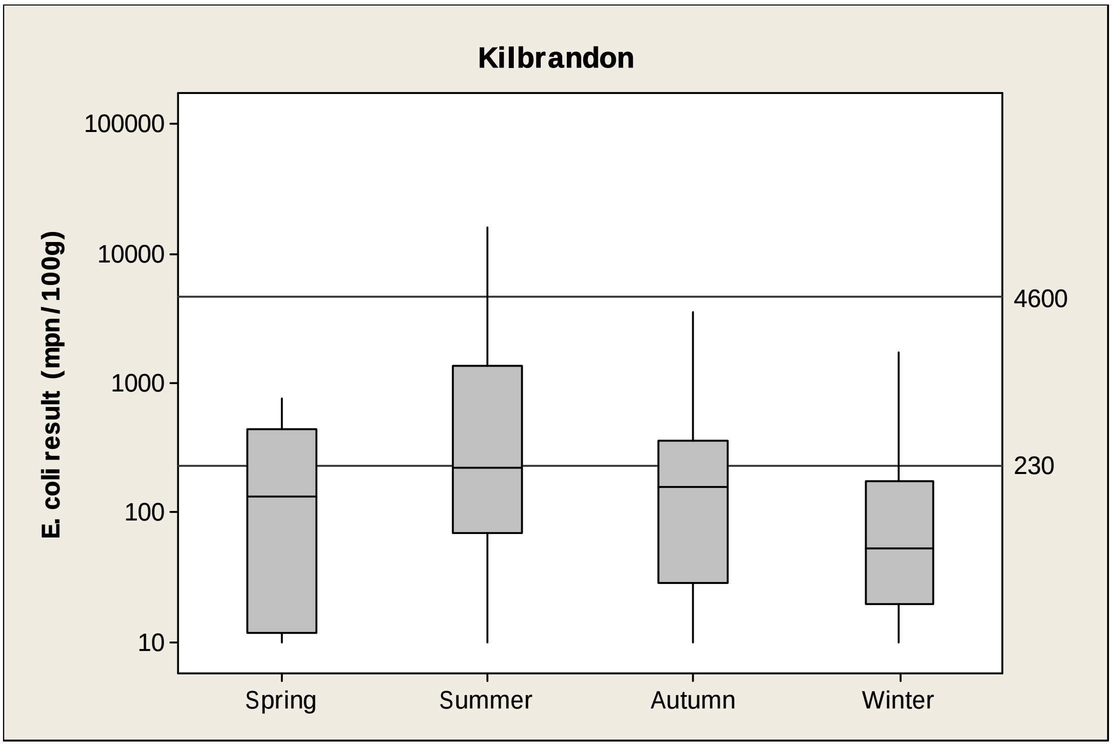


Figure 11.17 Boxplot of E. coli result by season (Kilbrandon oysters)

No significant difference was found between results by season for Kilbrandon (One-way ANOVA, p=0.135, Appendix 6).

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. Too few samples were taken from Rubha nan Ron South for meaningful analyses of results from this site to be carried out.

11.6.1 Analysis of results by recent rainfall

The nearest weather station is Kimelford, approximately 5 km to the east of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily rainfall in mm). No data was available for November 2004 or October 2006. Figures 11.18 to 11.22 present scatterplots of *E. coli* results against rainfall for each site. A Spearman's rank correlation of *E. coli* against rainfall was carried out for each site.

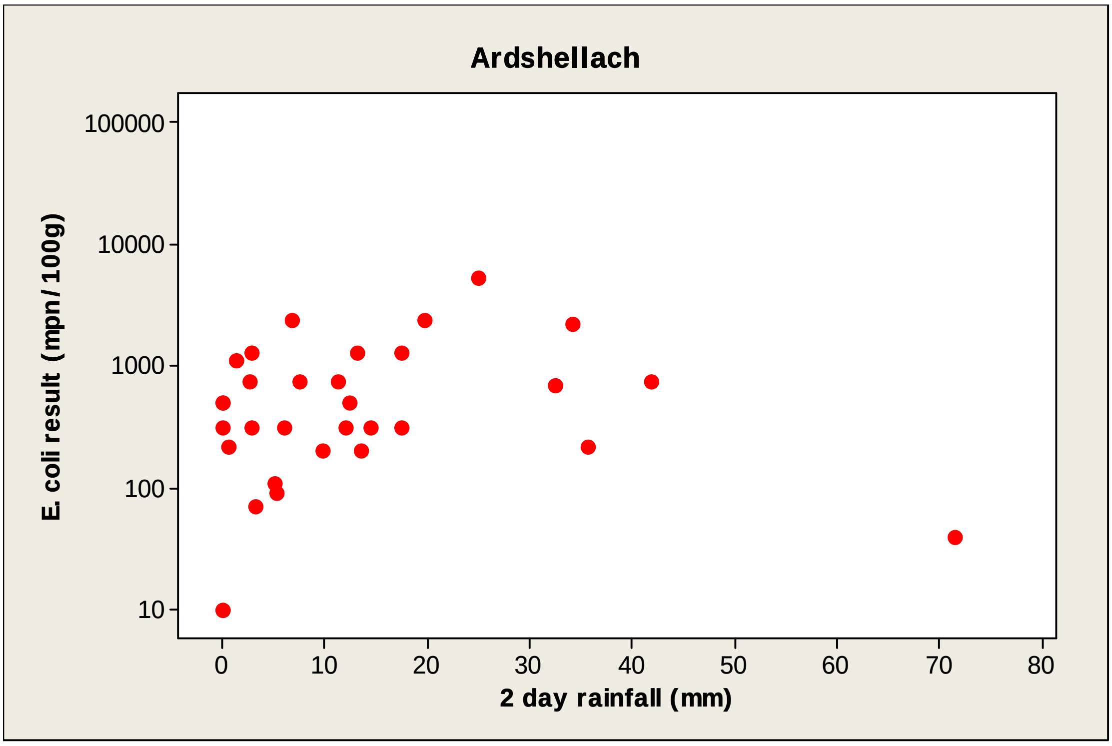


Figure 11.18 Scatterplot of E. coli result against rainfall in previous 2 days (Ardshellach oysters)

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous two days for Ardshellach (Spearman's rank correlation=0.284, p=0.116, Appendix 6).

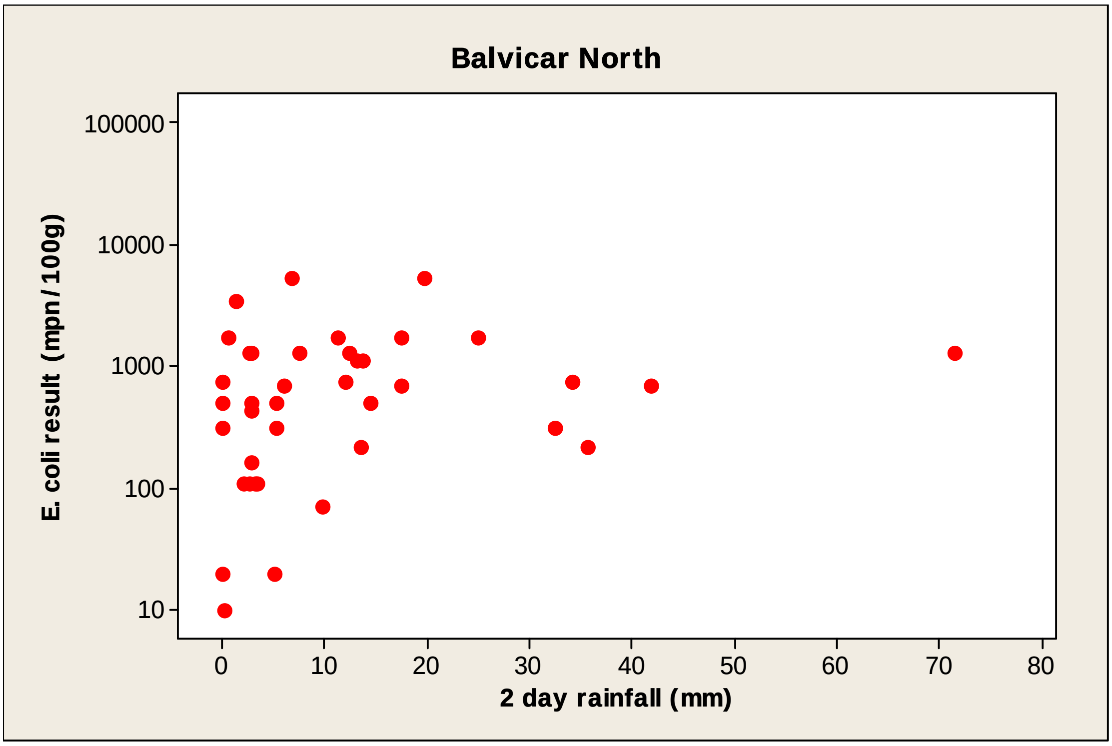


Figure 11.19 Scatterplot of E. coli result against rainfall in previous 2 days (Balvicar North oysters)

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous two days for Balvicar North (Spearman's rank correlation=0.289, p=0.074, Appendix 6).

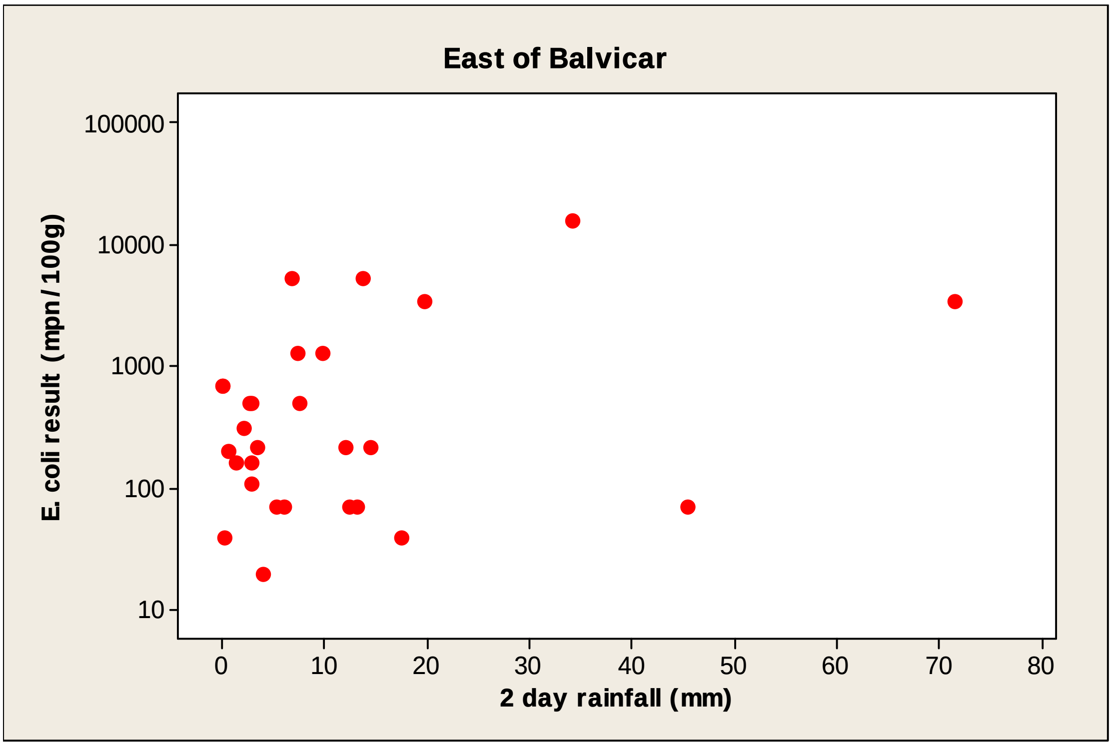


Figure 11.20 Scatterplot of E. coli result against rainfall in previous 2 days (East of Balvicar mussels)

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous two days for East of Balvicar (Spearman's rank correlation=0.171, p=0.383, Appendix 6).

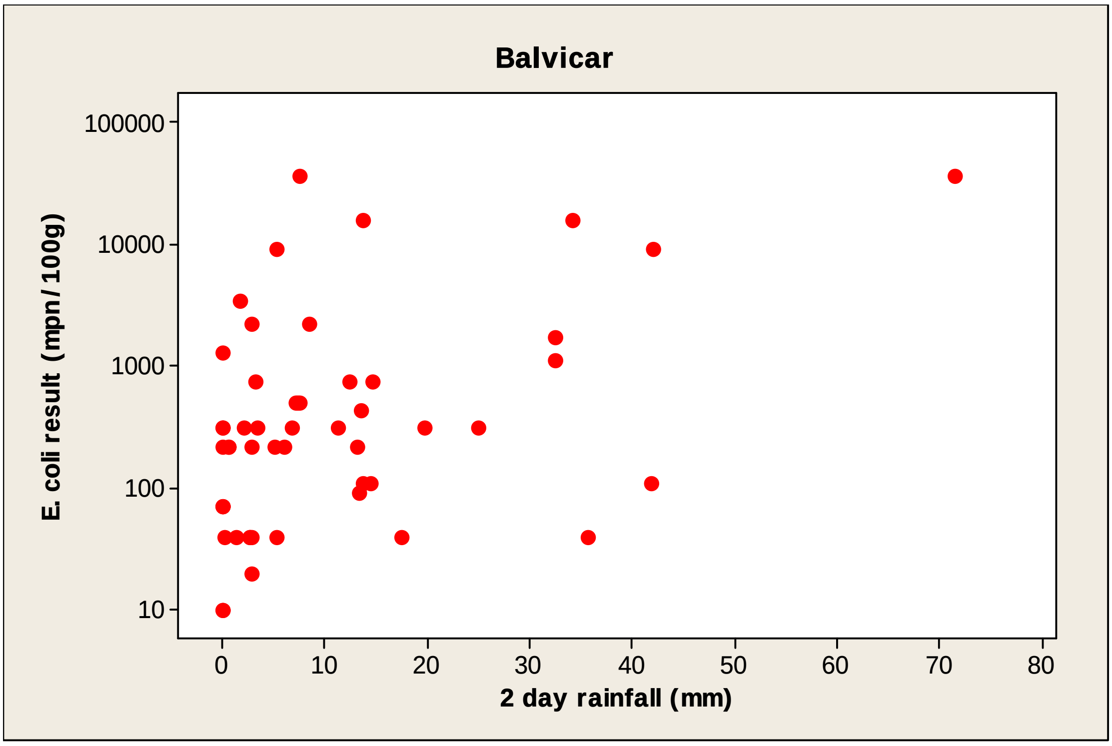


Figure 11.21 Scatterplot of E. coli result against rainfall in previous 2 days (Balvicar oysters)

A significant positive correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous two days for Balvicar (Spearman's rank correlation=0.384, p=0.005, Appendix 6).

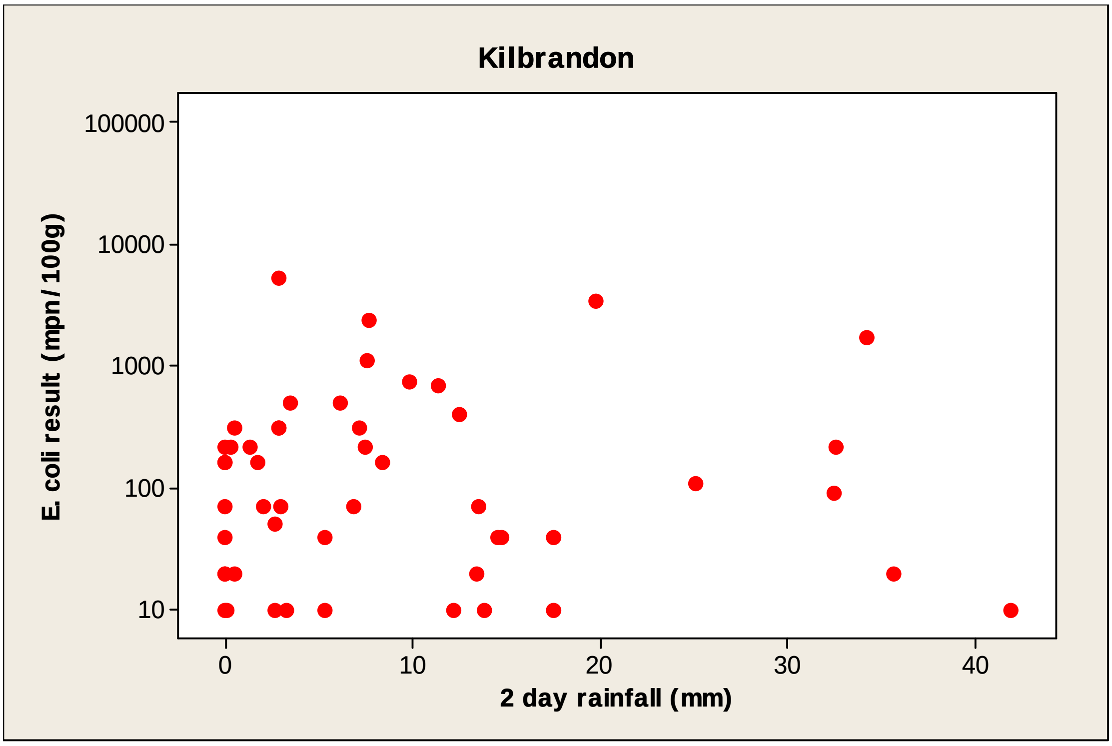


Figure 11.22 Scatterplot of E. coli result against rainfall in previous 2 days (Kilbrandon oysters)

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous two days for Kilbrandon (Spearman's rank correlation=0.060, p=0.677, Appendix 6).

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationships between rainfall in the previous 7 days and sample results were investigated in an identical manner to the above.

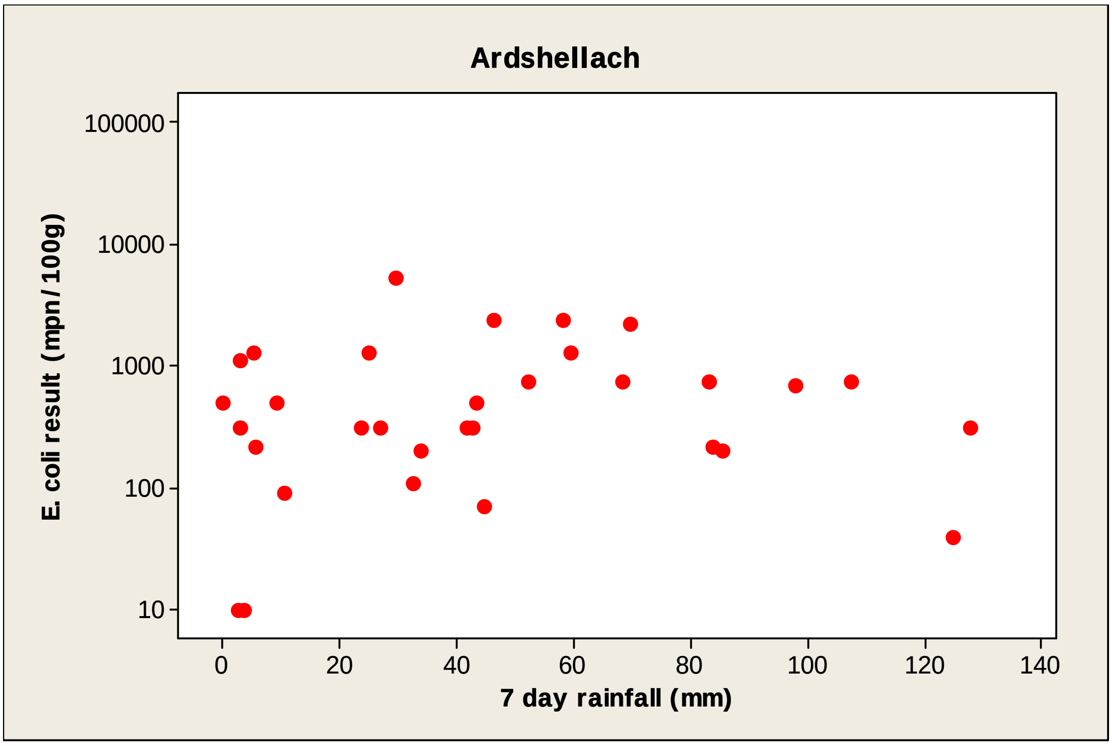


Figure 11.23 Scatterplot of E. coli result against rainfall in previous 7 days (Ardshellach oysters)

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous 7 days for Ardshellach (Spearman's rank correlation=0.142, p=0.437, Appendix 6).

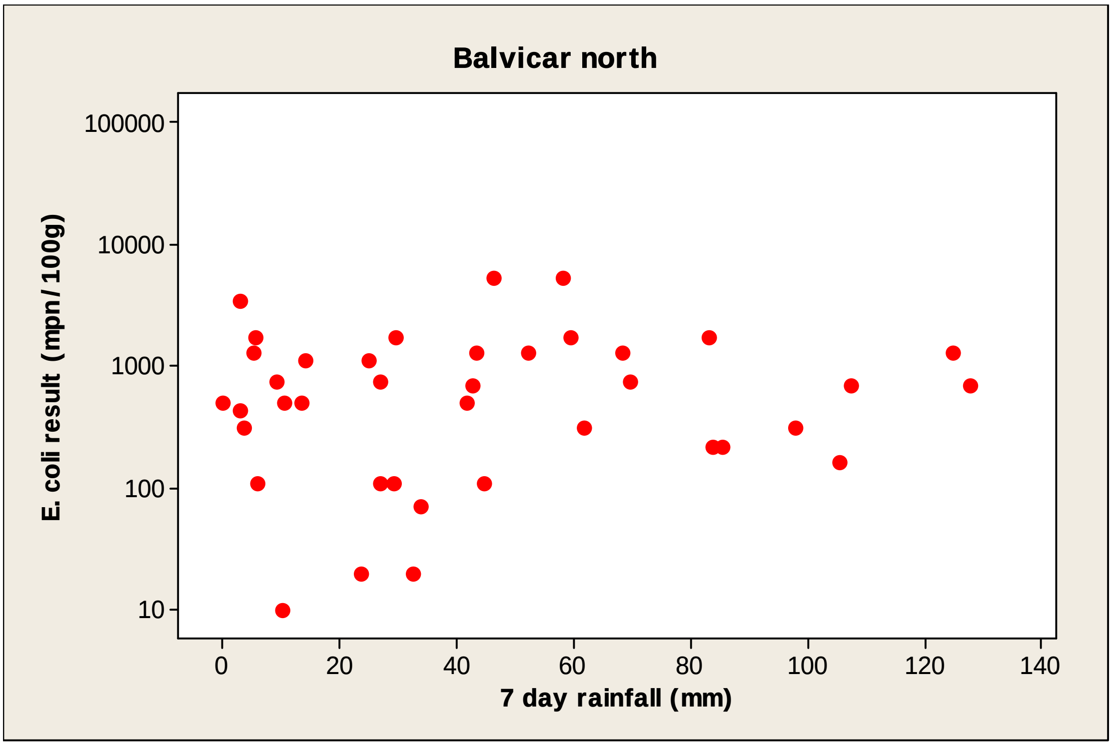


Figure 11.24 Scatterplot of E. coli result against rainfall in previous 7 days (Balvicar North oysters)

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous 7 days for Balvicar North (Spearman's rank correlation=0.073, p=0.660, Appendix 6).

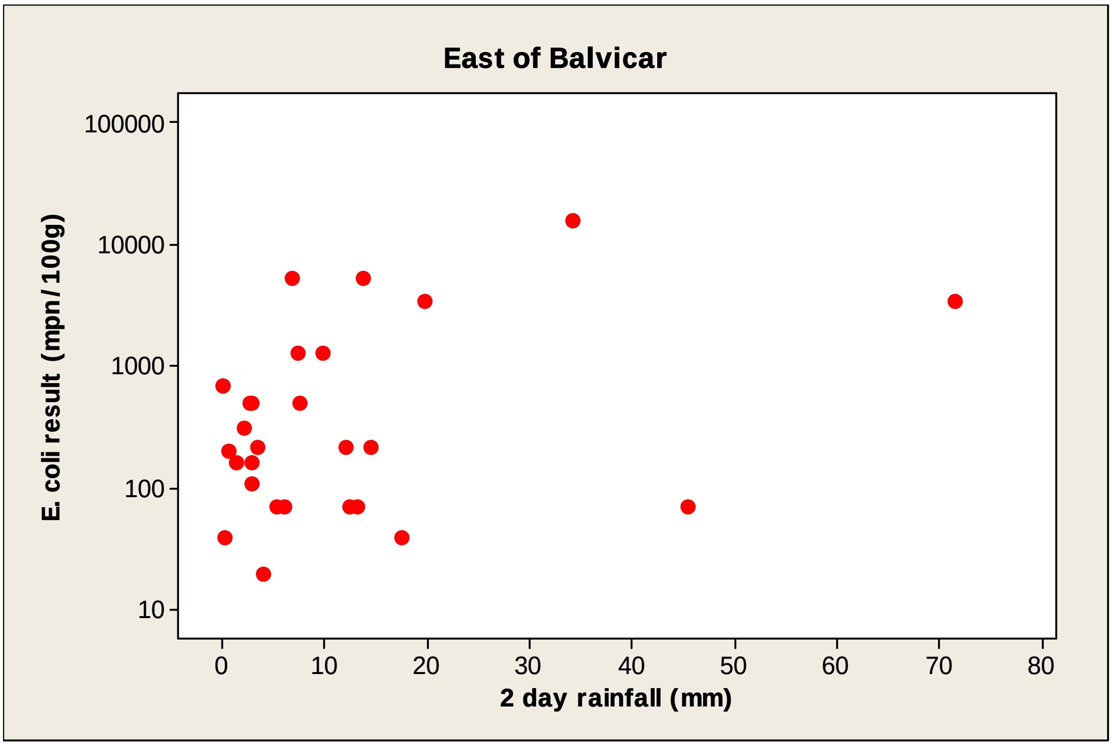


Figure 11.25 Scatterplot of E. coli result against rainfall in previous 7 days (East of Balvicar mussels)

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous 7 days for East of Balvicar (Spearman's rank correlation=0.148, p=0.451, Appendix 6).

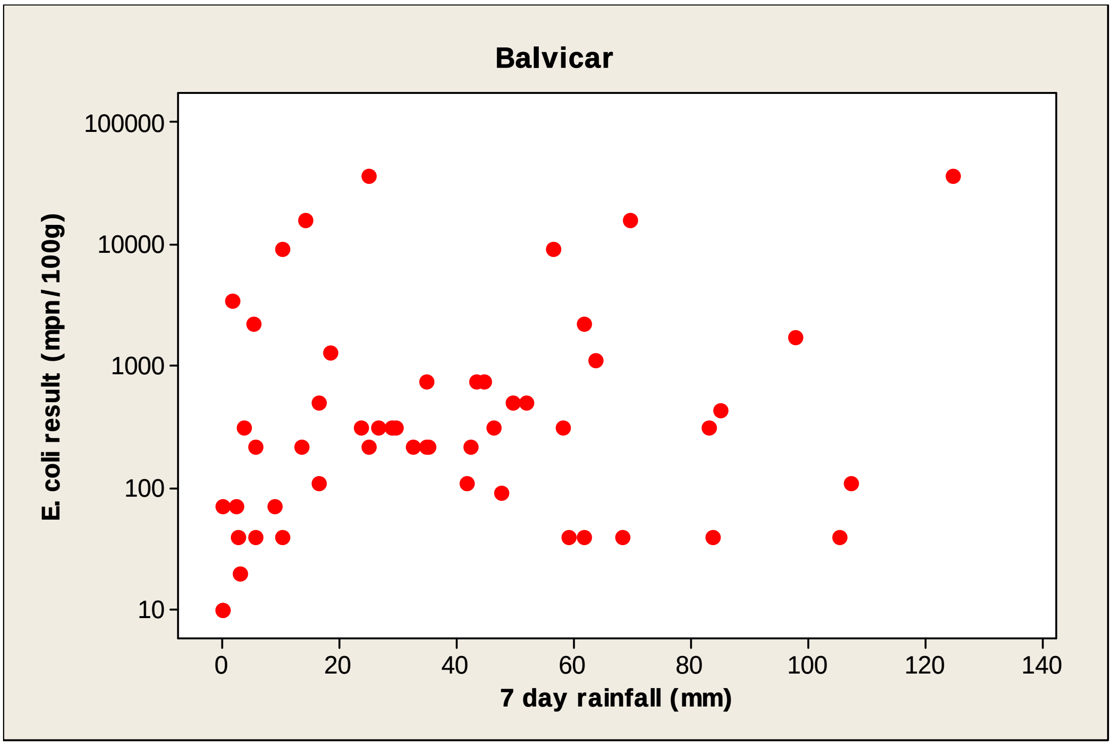


Figure 11.26 Scatterplot of E. coli result against rainfall in previous 7 days (Balvicar oysters)

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous 7 days for Balvicar (Spearman's rank correlation=0.234, p=0.094, Appendix 6).

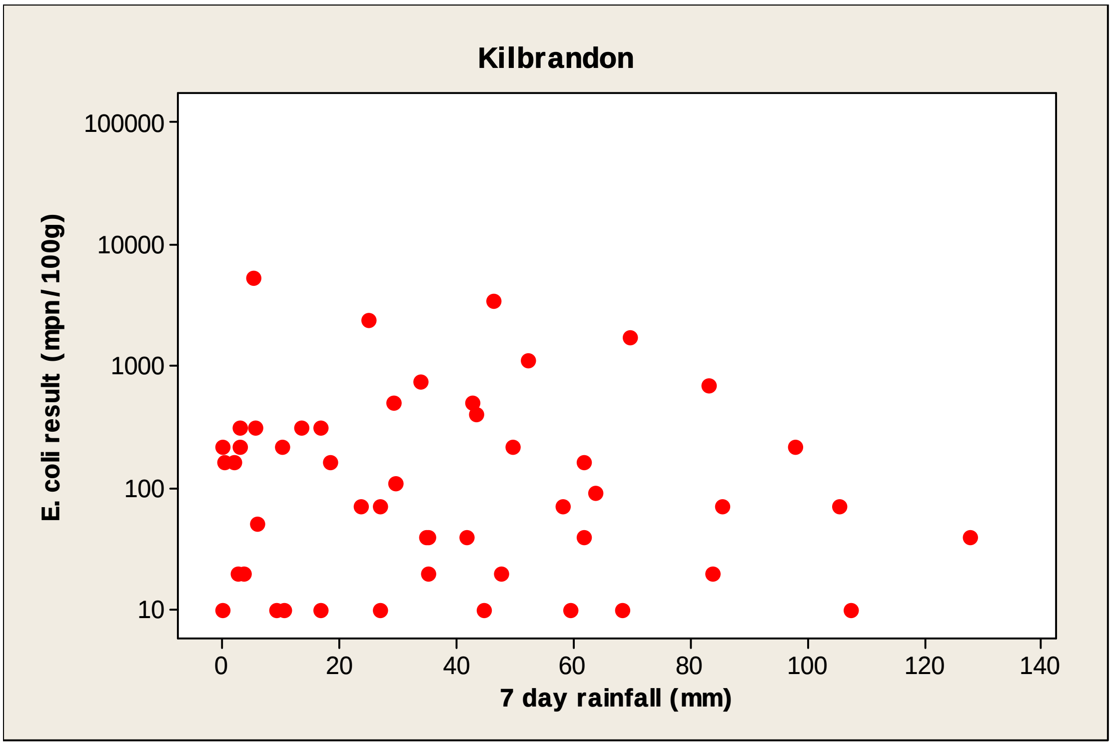


Figure 11.27 Scatterplot of E. coli result against rainfall in previous 7 days (Kilbrandon oysters)

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous 7 days for Kilbrandon (Spearman's rank correlation=-0.056, p=0.698, Appendix 6).

11.6.2 Analysis of results by spring/neap and high/low tidal cycles

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 coastal waters. Also, 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. However, as the sampling visits were usually conducted over low water during spring tides these factors could not be investigated.

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. Figures 11.28 to 11.32 present scatter plots of results against water temperature for each site.

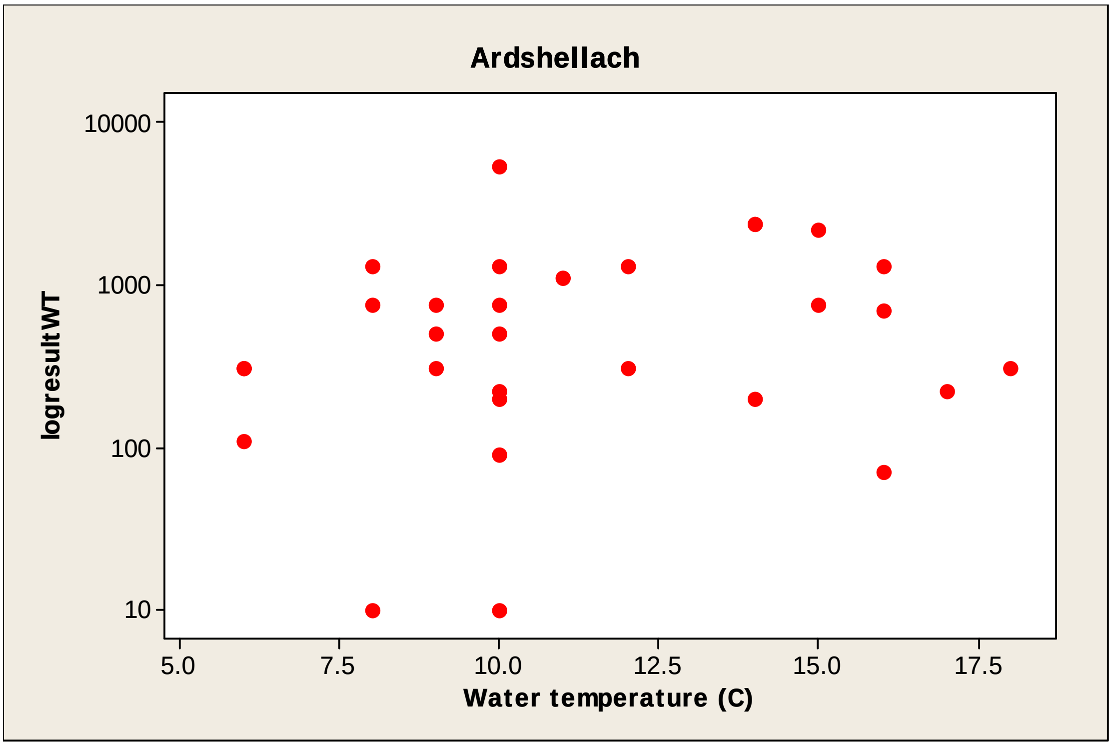


Figure 11.28 Scatterplot of E. coli result by water temperature (Ardshellach oysters)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and water temperature for Ardshellach (Adjusted R-sq=0.5%, p=0.295, Appendix 6).

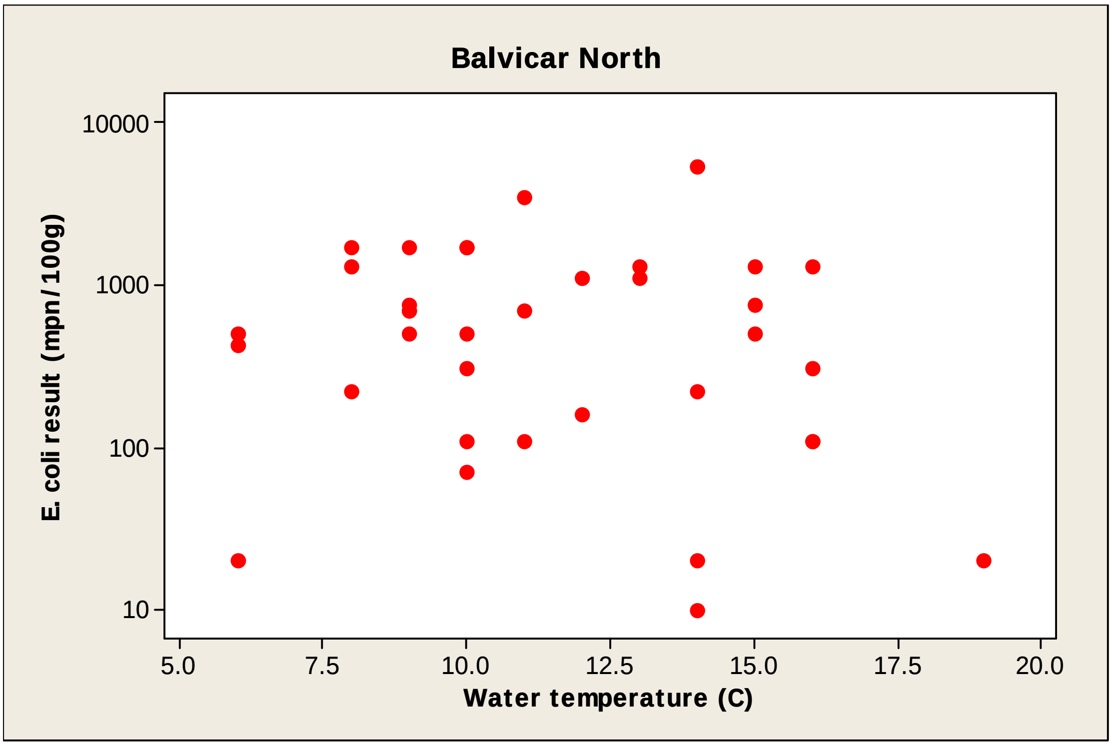


Figure 11.29 Scatterplot of E. coli result by water temperature (Balvicar North oysters)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and water temperature for Balvicar North (Adjusted R-sq=0.0%, p=0.402, Appendix 6).

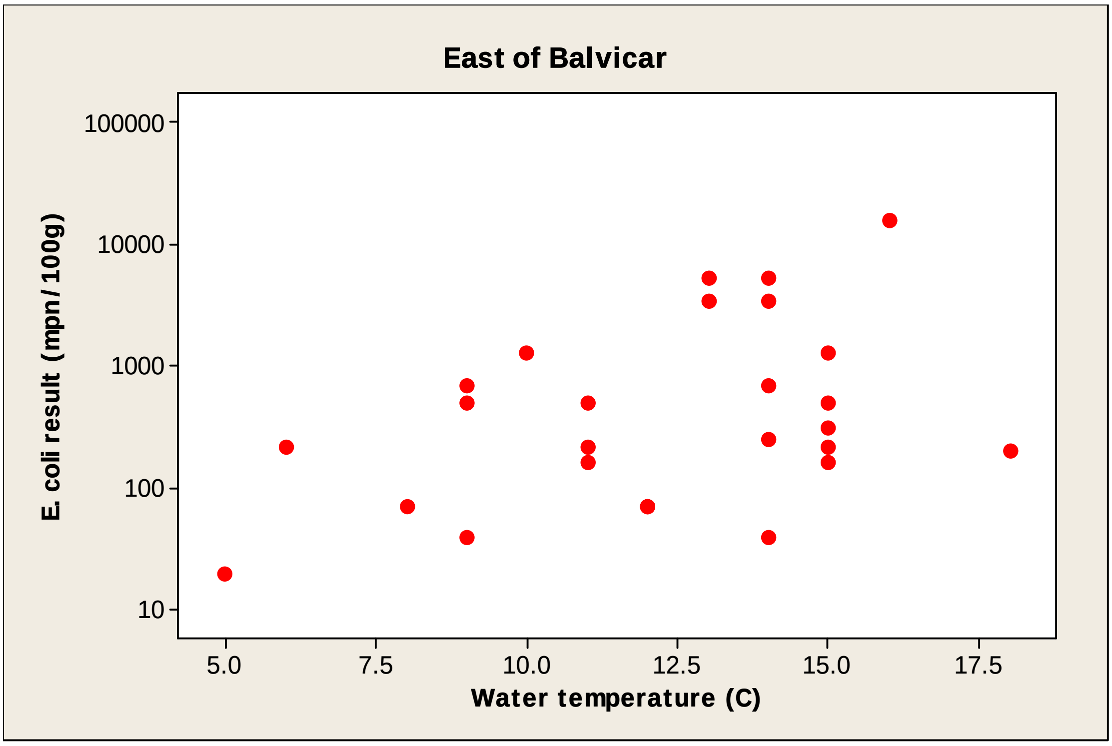


Figure 11.30 Scatterplot of E. coli result by water temperature (East of Balvicar mussels)

The coefficient of determination indicates that there was a very weak positive relationship between the *E. coli* result and water temperature for East of Balvicar (Adjusted R-sq=12.5%, p=0.040, Appendix 6).

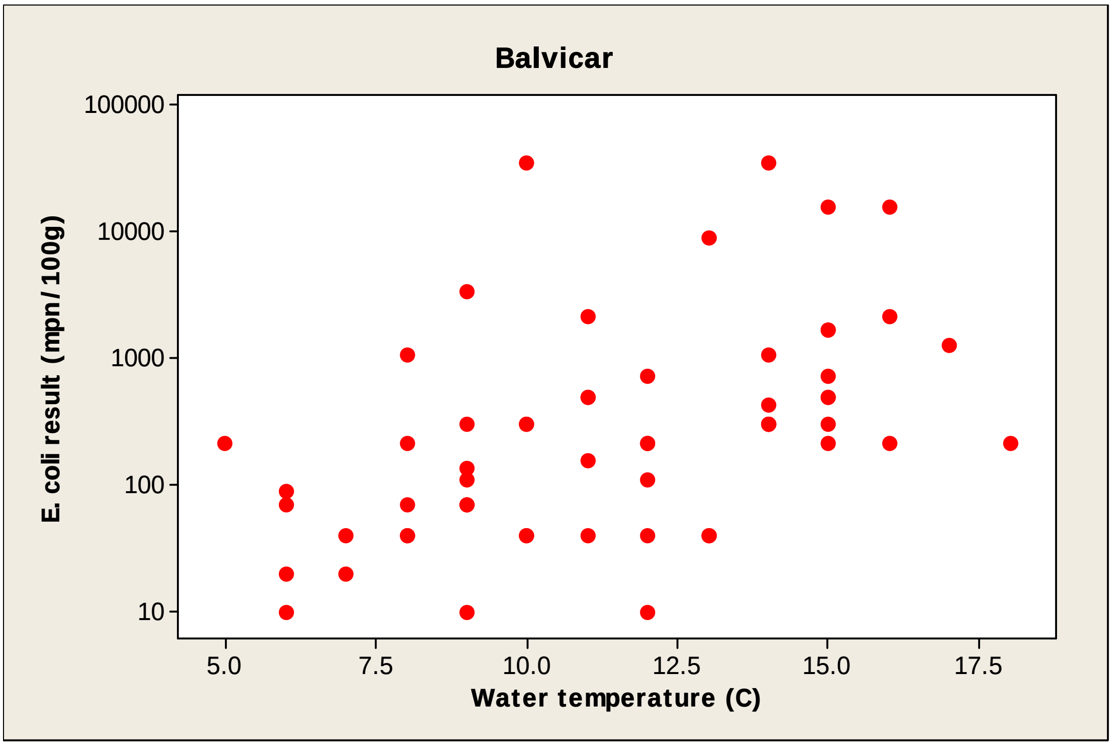


Figure 11.31 Scatterplot of E. coli result by water temperature (Balvicar oysters)

The coefficient of determination indicates that there was a weak positive relationship between the *E. coli* result and water temperature for Balvicar (Adjusted R-sq=22.1%, p=0.000, Appendix 6).

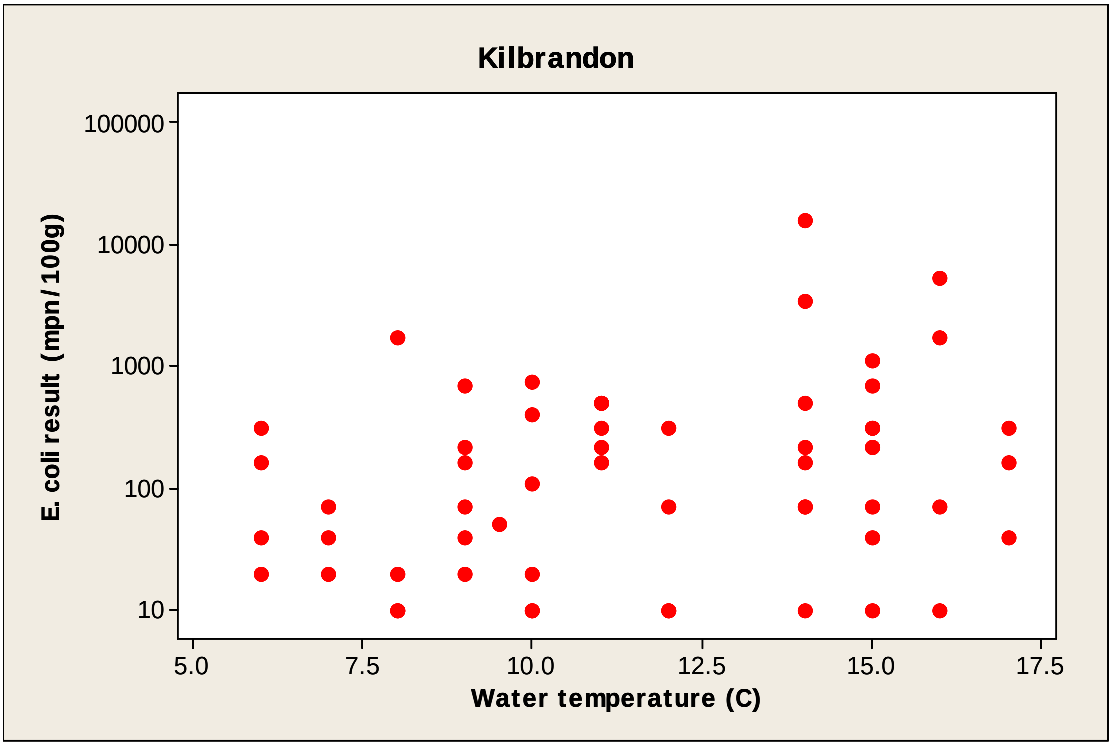


Figure 11.32 Scatterplot of E. coli result by water temperature (Kilbrandon oysters)

The coefficient of determination indicates that there was an extremely weak positive relationship between the *E. coli* result and water temperature for Kilbrandon (Adjusted R-sq=5.3%, p=0.046, Appendix 6).

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns in the production area. Mean wind direction for the 7 days prior to each sample being collected was calculated from wind data recorded at the Glasgow: Bishopton weather station 77 km to the south east of the production area, where available. Polar plots of log10 *E. coli* result by mean wind direction in the previous 7 days is plotted in Figures 11.32 to 11.37 for each site. It must be noted that the weather station used was a considerable distance from Seil Sound, so although they may broadly reflect wind patterns in the area, they are likely to vary on any given day. The effects of variation in wind direction and wind speed were not taken into account.

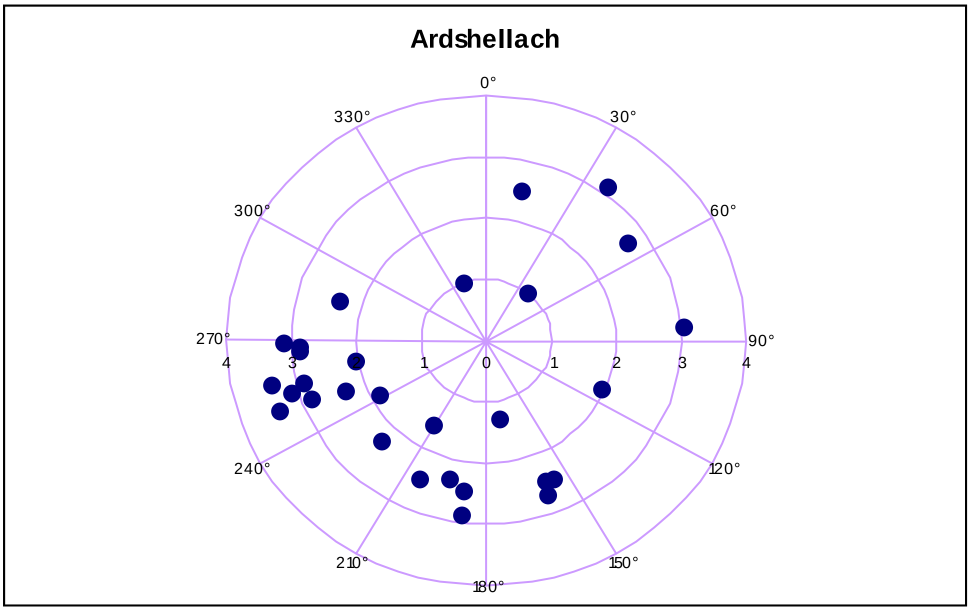


Figure 11.33 Polar plot of log10 E. coli result by wind direction (Ardshellach oysters)

No correlation was found between wind direction and *E. coli* result for Ardshellach (circular-linear correlation, r=0.225, p=0.268, Appendix 6).

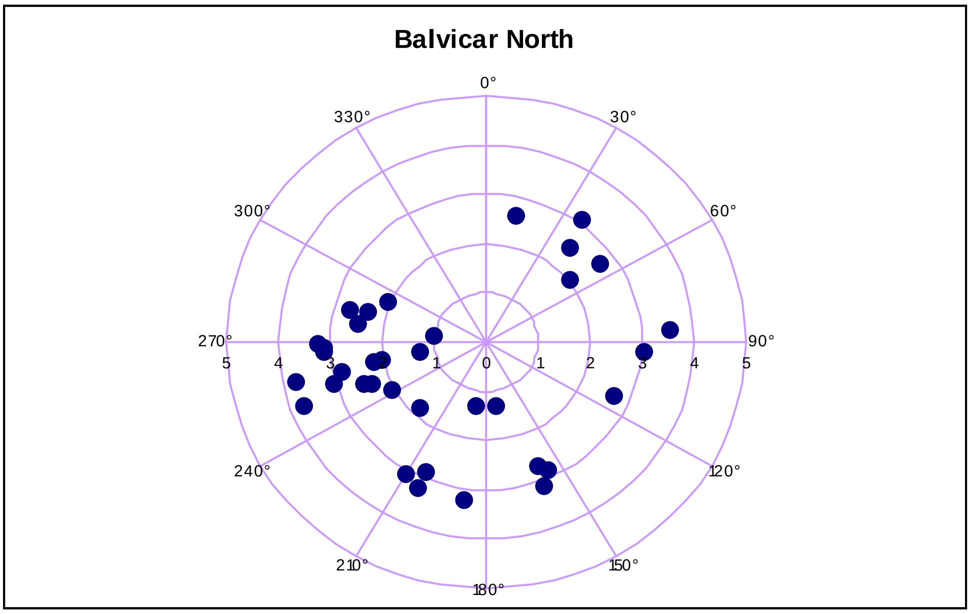


Figure 11.34 Polar plot of log10 E. coli result by wind direction (Balvicar North oysters)

No correlation was found between wind direction and *E. coli* result for Balvicar North (circular-linear correlation, r=0.137, p=0.537, Appendix 6).

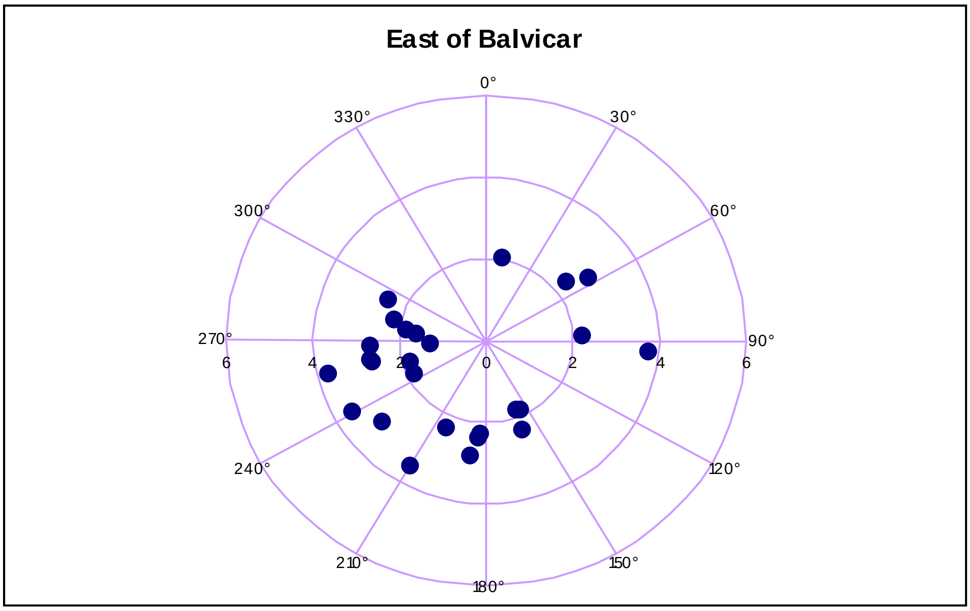


Figure 11.35 Polar plot of log10 E. coli result by wind direction (East of Balvicar mussels)

No correlation was found between wind direction and *E. coli* result for East of Balvicar (circular-linear correlation, r=0.133, p=0.664, Appendix 6).

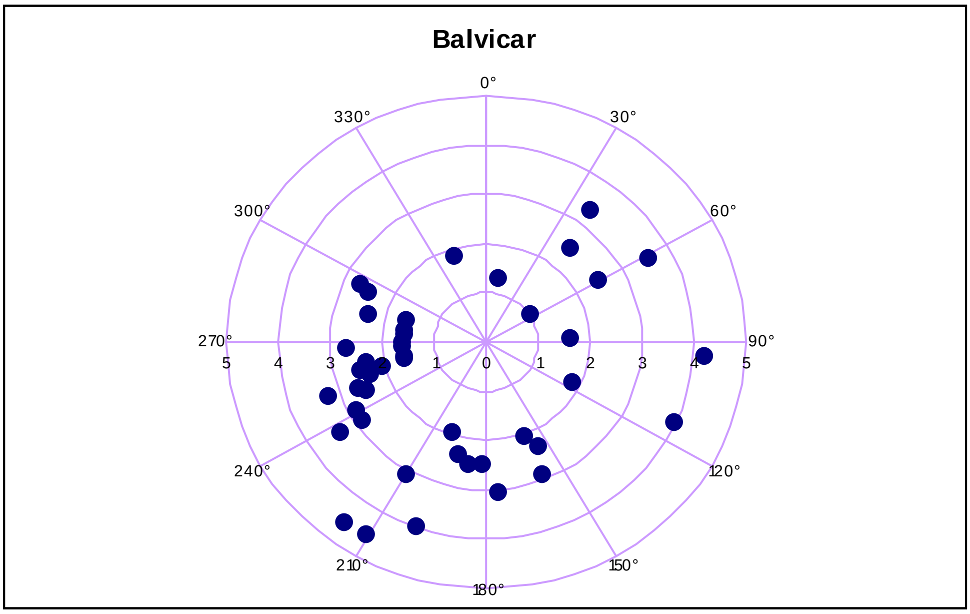


Figure 11.36 Polar plot of log10 E. coli result by wind direction (Balvicar oysters)

A significant correlation was found between wind direction and *E. coli* result for Balvicar (circular-linear correlation, r=0.395, p=0.001, Appendix 6). Results appear to be lowest when the wind was blowing from the north and west.

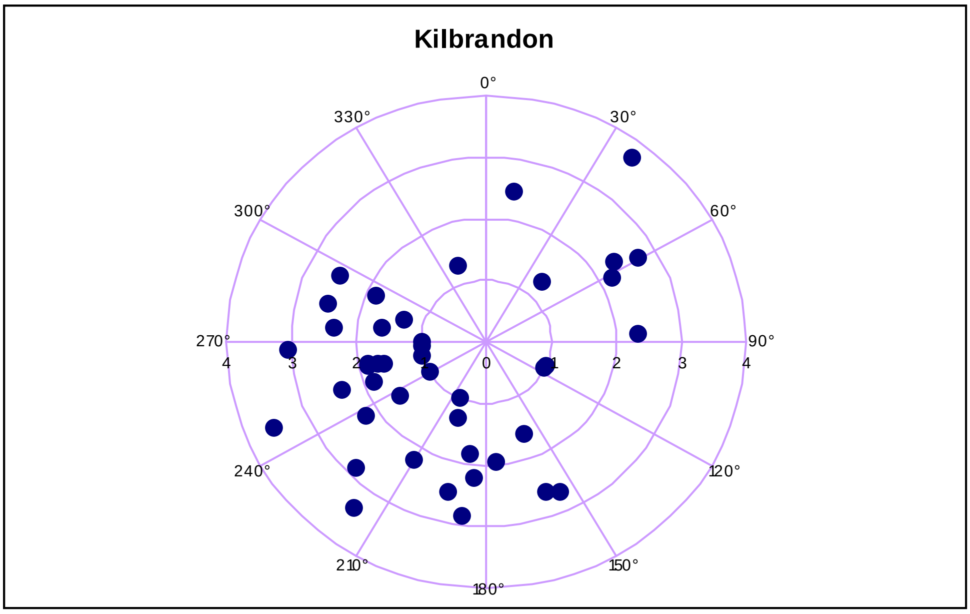


Figure 11.37 Polar plot of log10 E. coli result by wind direction (Kilbrandon oysters)

No correlation was found between wind direction and *E. coli* result for Kilbrandon (circular-linear correlation, r=0.111, p=0.612, Appendix 6).

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 11.38 to 11.42 present scatter plots of *E. coli* result against salinity, for each site.

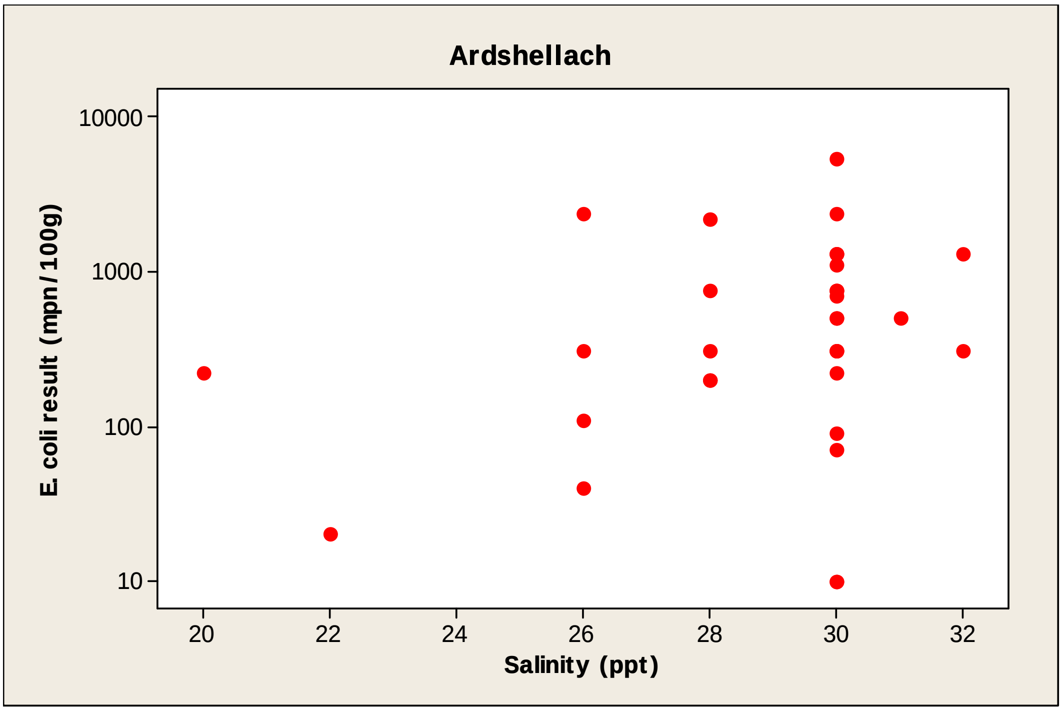


Figure 11.38 Scatterplot of E. coli result by salinity (Ardshellach oysters)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity for Ardshellach (Adjusted R-sq=4.5%, p=0.119, Appendix 6).

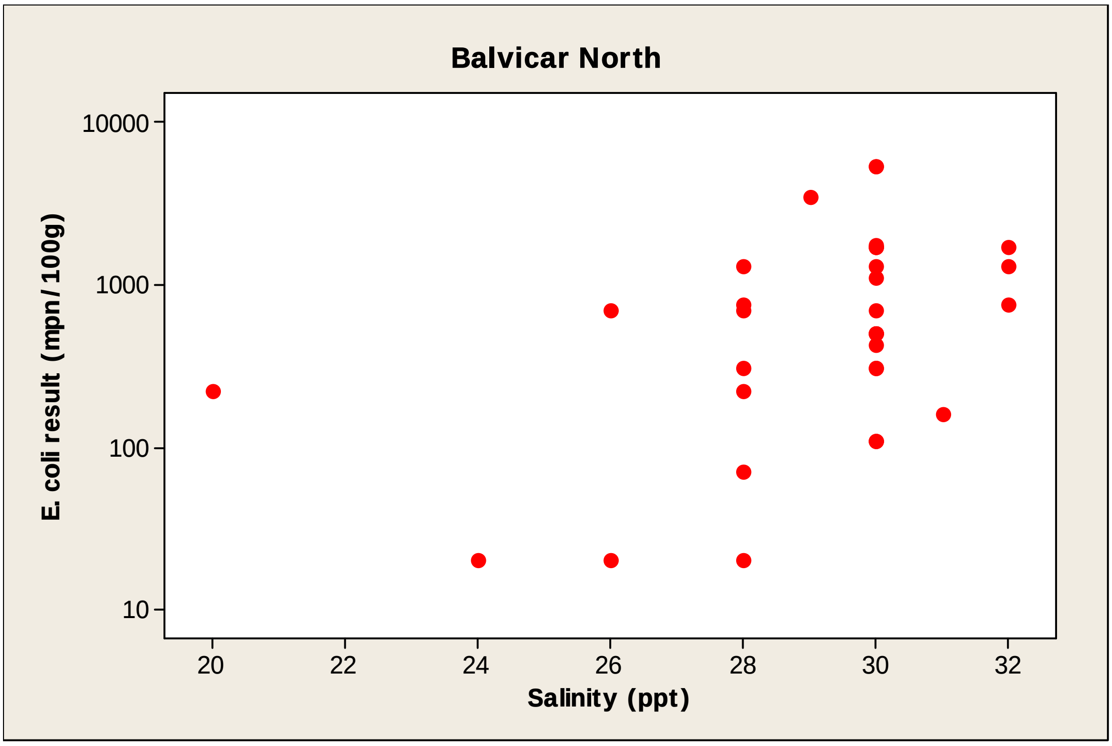


Figure 11.39 Scatterplot of E. coli result by salinity (Balvicar North oysters)

The coefficient of determination indicates that there was a very weak positive relationship between the *E. coli* result and salinity for Balvicar North (Adjusted R-sq=15.8%, p=0.010, Appendix 6). This is unusual as higher levels of contamination are generally associated with increased freshwater input.

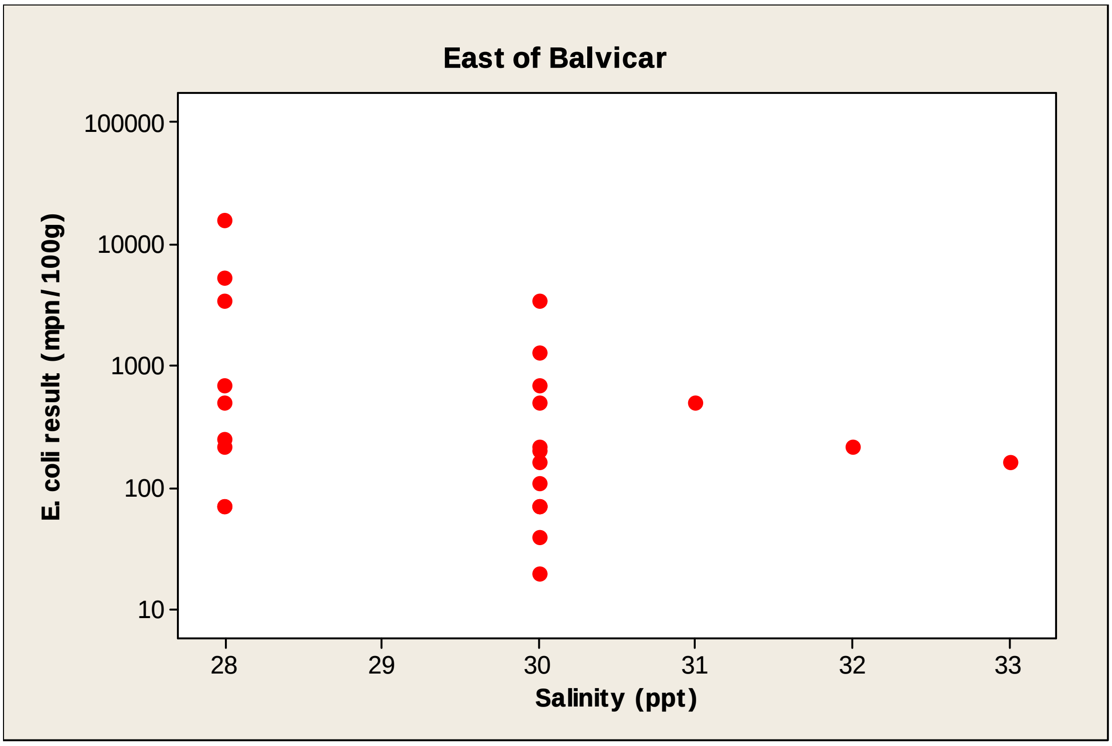


Figure 11.40 Scatterplot of E. coli result by salinity (East of Balvicar mussels)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity for East of Balvicar (Adjusted R-sq=5.2%, p=0.141, Appendix 6).

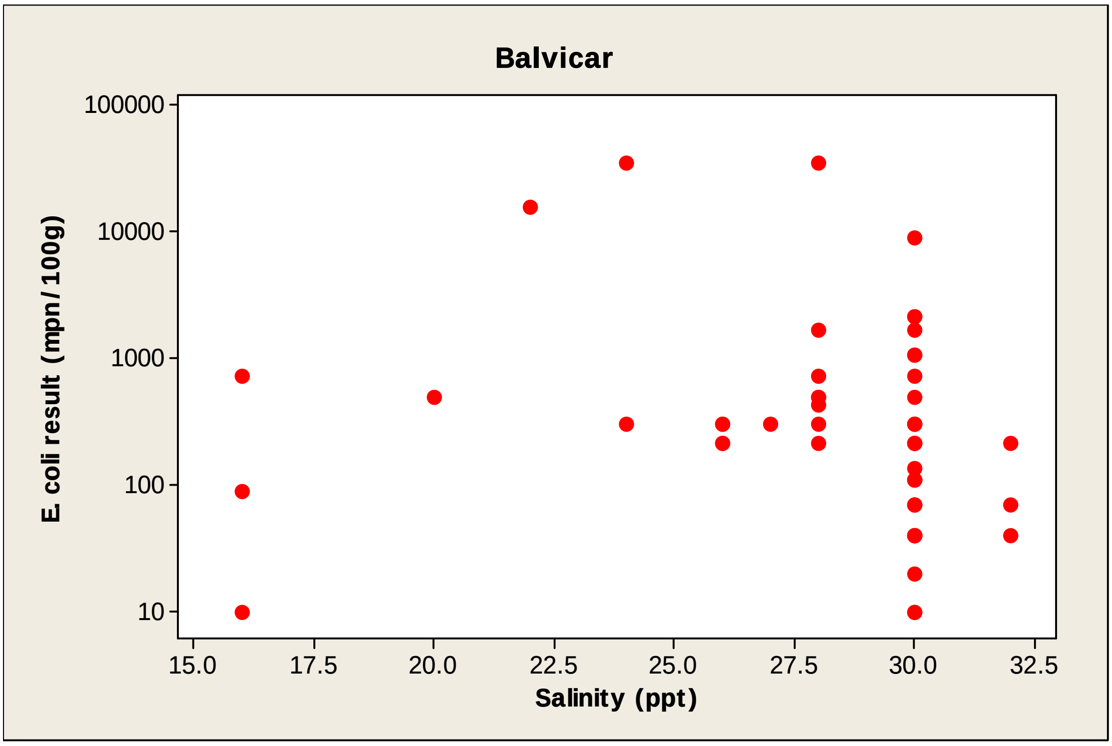


Figure 11.41 Scatterplot of E. coli result by salinity (Balvicar oysters)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity for Balvicar (Adjusted R-sq=0.4%, p=0.270, Appendix 6).

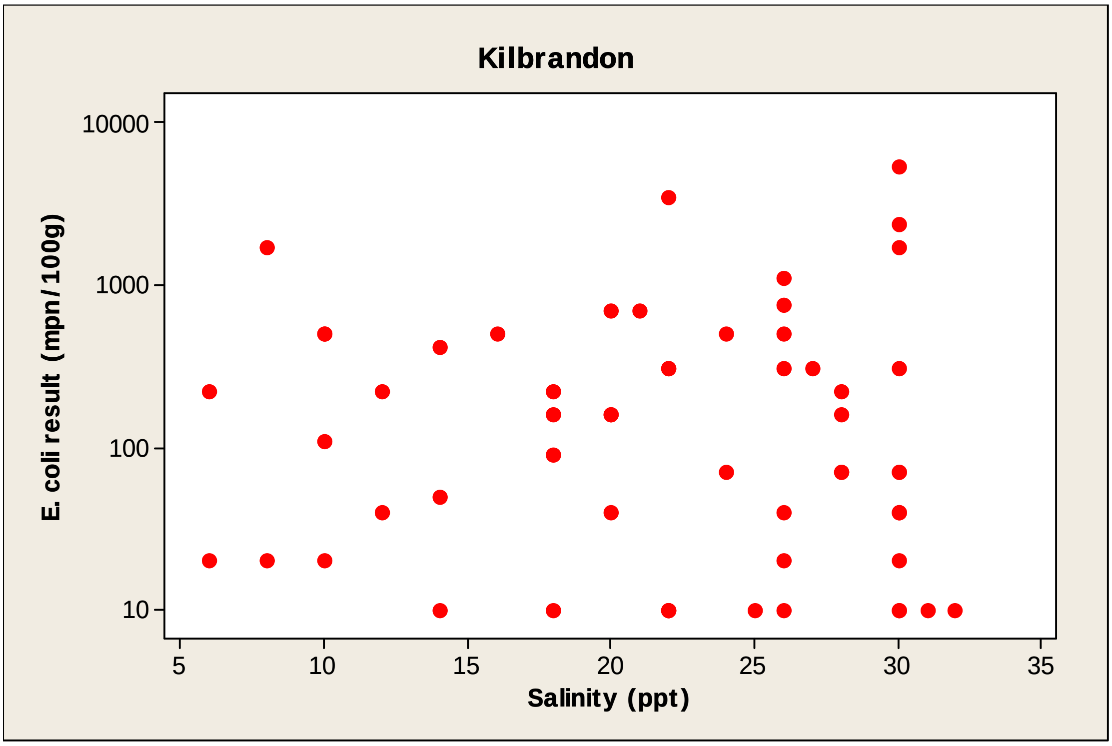


Figure 11.42 Scatterplot of E. coli result by salinity (Kilbrandon)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity for Kilbrandon (Adjusted R-sq=0.0%, p=0.754, Appendix 6). A greater range of salinities were recorded at this site compared to the other sites.

11.7 Evaluation of peak results

The circumstances under which the 14 results of over 4600 *E. coli* MPN/100g occurred are presented in Table 11.4.

Table 11.4 Historic *E. coli* sampling peak results

Collection Date	*E. coli* result (MPN/100g)	Site	Species	2 day rain (mm)	7 day rain (mm)	Water temperature	7 day wind direction	Salinity (ppt)
26/06/2002	16000	Kilbrandon	Oysters	*	*	14ºC	*	*
18/06/2003	>18000	Balvicar	Oysters	7.6	25	10ºC	217º	28
05/05/2004	5400	Ardshellach	Oysters	25	29.6	10ºC	*	30
02/06/2004	9100	Balvicar	Oysters	5.3	10.4	13ºC	114º	30
04/08/2004	5400	Kilbrandon	Oysters	2.8	5.3	16ºC	37º	30
22/06/2005	16000	Balvicar	Oysters	34.2	69.6	16ºC	*	22
22/06/2005	16000	East of Balvicar	Mussels	34.2	69.6	16ºC	*	28
20/07/2005	5400	Balvicar North	Oysters	6.8	58.1	14ºC	257º	30
20/07/2005	5400	East of Balvicar	Mussels	6.8	58.1	14ºC	257º	28
21/09/2005	5400	Balvicar North	Oysters	19.7	46.3	14ºC	250º	30
06/09/2006	>18000	Balvicar	Oysters	71.5	124.7	14ºC	211º	24
20/09/2006	9100	Balvicar	Oysters	42.1	56.6	*	200º	*
13/06/2007	16000	Balvicar	Oysters	13.8	14.1	15ºC	94º	*
13/06/2007	5400	East of Balvicar	Mussels	13.8	14.1	13ºC	94º	*

* Data not available

All samples were collected during either May (1), June (7), July (2), August (1) or September (3). Mean water temperature was 13.8 ºC and ranged from 10 to 16 ºC.

Six of the samples were from Balvicar (9% of all samples from this site), three were from East of Balvicar (10% of samples from this site), two were from Balvicar North (5% of samples from this site), two were from Kilbrandon (3% of samples from this site), one was from Ardshellach (3% of samples from this site) and none were from Rubha nan Ron South. The highest two individual results (>18000 *E. coli* MPN/100g) both came from Balvicar. On the first date which this occurred, the Kilbrandon site was also sampled and the result was 2400 *E. coli* MPN/100g. On the second date when this occurred, Ardshellach, Balvicar North, and East of Balvicar were also sampled, and the respective results were 40, 1300 and 3500 *E. coli* MPN/100g.

Mean 2 day rainfall for these samples was 21.8 mm, which falls in the upper quartile of 2 day rainfall recorded at Kimelford between 2003 and 2007. Mean 7 day rainfall for these samples was 44.7 mm, which falls within the second highest quartile of 7 day rainfall recorded at Kimelford between 2003 and 2007. Mean salinity for these samples was 28 ppt and ranged from 22 to 30 ppt.

Samples were collected under a range of wind directions, most commonly south westerly, which is the prevailing wind direction.

11.8 Summary and conclusions

Geographic patterns in mussel results could not be investigated as there is only one mussel site, and samples taken from this site were taken from a small area.

Comparisons of mean results when the oyster sites were sampled on the same day revealed that results for Ardshellach and Balvicar North were significantly higher than those for Balvicar, and results for Ardshellach were significantly higher for those at Kilbrandon. No differences were detected beteen Ardshellach and Balvicar North, or between Balvicar and Kilbrandon. No differences were detected between Rubha nan Ron South and any of the other oyster sites, but this site was sampled on fewer occasions. On this basis, Ardshellach and Balvicar appear to group together, as do Balvicar and Kilbrandon.

Although comparisons of mean results can be useful in highlighting differences in overall levels of contamination between the sites, it is how the results fall in relation to threshold levels which ultimately determine the classification a production area receives. Their overall rank in terms of proportion of results exceeding 230 *E. coli* MPN/100g was Balvicar North (71%) > Ardshellach (68%) > Rubha nan Ron South (50%) > Balvicar (49%) > Kilbrandon (34%). Samples were often taken on different occasions, so the overall results may not be directly comparable. It was possible to carry out a similar analysis using results from when four of these sites were sampled on the same day. This ranked the sites in terms of proportion of all results exceeding 230 *E. coli* MPN/100g in exactly the same order (Balvicar North (85%) > Ardshellach (77%) > Balvicar (54%) > Kilbrandon (35%)). The proportions of results exceeding 230 *E. coli* MPN/100g generally support the groupings suggested by the analysis of mean results, except that they suggest Kilbrandon and Balvicar are distinct from each other and may receive quite different classifications if monitored separately.

Balvicar had the highest proportion of results over 4600 *E. coli* MPN/100g, and the only two results over 18000 *E. coli* MPN/100g, and when these results arose samples taken on the same day from other sites never exceeded 4600 *E. coli* MPN/100g. This lends further support to the separate monitoring of Balvicar to Kilbrandon, and to Ardshellach and Balvicar North.

Table 11.5 summarises the findings of sections 11.4 to 11.6.

Table 11.5 Summary of environmental influences on *E. coli* result by site

Site	Ardshellach	Balvicar North	East of Balvicar	Rubha nan Ron South	Balvicar	Kilbrandon
Species	Pacific oysters	Pacific oysters	Mussels	Pacific oysters	Pacific oysters	Pacific oysters
Number of samples	34	41	29	12	65	64
Mean result (MPN/100g)	356	448	334	246	271	120
% of results over 230 MPN/100g	68%	71%	48%	50%	49%	34%
Overall temporal trends	Deteriorated 2004 to 2005, improved from 2005	Improved from 2005	Slight improvement from 2005, peaks in summer	Too few samples to assess	Deteriorated in 2002 and 2003	Improved 2002 to 2004, deteriorated from 2005 to 2007
Seasonality	No significant difference between seasons	No significant difference between seasons	No significant difference between seasons	Too few samples to assess	Summer results higher than Winter and Spring, Autumn result higher than Winter	No significant difference between seasons
Rainfall	No relationship between rainfall and results	No relationship between rainfall and results	No relationship between rainfall and results	Too few samples to assess	Positive correlation between results and 2 day but not 7 day rainfall	No relationship between rainfall and results
Temperature	No relationship between temperature and results	No relationship between temperature and results	Very weak positive relationship	Too few samples to assess	Weak positive relationship between temperature and results	Extremely weak positive relationship
Wind	No relationship between wind and results	No relationship between wind and results	No relationship between wind and results	Too few samples to assess	North and west winds at Glasgow correlated with lower results	No relationship between wind and results
Salinity	No relationship between salinity and results	Very weak positive relationship	No relationship between salinity and results	Too few samples to assess	No relationship between salinity and results	No relationship between salinity and results

Significant seasonal, rainfall and wind effects were only found at the Balvicar site, suggesting that sources and pathways of contamination at this site may be different to the others, further supporting the previous conclusion that Balvicar should be monitored separately to Kilbrandon, and to Ardshellach and Balvicar North. The strongest relationship between temperature and results was found at the Balvicar site, but weaker relationships between result and temperature were also found at the East of Balvicar and Kilbrandon sites. A very weak positive relationship between salinity and results was found at Balvicar North. This was not expected as often increasing freshwater inputs are associated with increasing levels of contamination, and as this site located on a small island in the middle of the Sound it is the least likely to be influenced by freshwater inputs.

Of the results over 4600 *E. coli* MPN/100g, all were collected between May and September at water temperatures over 10 ºC, usually following a two day period of higher rainfall.

It should be noted that the relatively small amount of data for each site 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 these production areas as they have held seasonal classifications in the last three years.

11.10 Norovirus testing results

Norovirus testing was carried out at five of the oyster sites on a quarterly basis starting from the date of the shoreline survey. Results of this testing is presented in Table 11.6. A negative test result does not necessarily mean that the sample contained no norovirus, although no negative testing samples have been associated with outbreaks of norovirus amongst consumers. If a sample tests positive or positive at or below the theoretical limit of detection, this means that viral genetic material was detected, not that viable viruses were present, so positive testing samples are not necessarily capable of causing illness. Higher levels of virus are likely to be associated with a higher risk to consumers.

Table 11.6 Summary of norovirus testing results

	Noro Group	Aug-08	Nov-08	Feb-09	May-09
Ardshellach	GI	ND	ND	ND	ND
	GII	ND	**POS**	ND	**LOD**
Balvicar North	GI	ND	ND	ND	ND
	GII	ND	**POS**	ND	ND
Rubha nan Ron South	GI	ND	**POS**	ND	ND
	GII	ND	**LOD**	ND	**LOD**
Balvicar	GI	ND	**POS**	ND	ND
	GII	ND	ND	ND	**LOD**
Kilbrandon	GI	ND	**LOD**	**LOD**	ND
	GII	ND	ND	ND	ND

ND = Not detected
LOD = Positive at or below the theoretical limit of detection
POS = Positive.

Norovirus was not detected at any of the sites in August 2008, but on all other occasions norovirus was detected in at least one sample. Norovirus was detected at all sites in November 2008, at Kilbrandon only in February 2009, and at Ardshellach, Rubha nan Ron South and Balvicar in May 2009. At all sites sampled except Balvicar North, norovirus was detected on 2 separate occasions, whereas at Balvicar North it was detected once. This indicates that all sites are impacted by contamination of human origin to some extent. Highest levels and prevalence were recorded in November 2008. There appeared to be spatial separation in the results, with the two genogroup II positive samples occurring at northern sites and the two genogroup I positive samples occurring at southern sites. A number of samples were positive at or near the limit of detection for both genogroups. During the winter sampling date in February 2009, only one site was positive at the limit of detection for genogroup I and genogroup II was not detected at any of the sites.

12. Designated Shellfish Growing Waters Data

The area considered in this report is also a shellfish growing water which was designated in 2000. The growing water encompasses an almost identical area to the two production areas covered by this report. The extent of the growing water is shown on Figure 12.1.

The monitoring requires the following testing:

- Quarterly for salinity, dissolved oxygen, pH, temperature, visible oil
- Twice yearly for metals in water
- Quarterly for faecal coliforms in mussels

Monitoring results for faecal coliforms in shore mussels from 2000 to the end of 2007 have been provided by SEPA, and are presented in Table 12.1. Throughout 2000 and 2001, samples were taken from NM 764 153 which is the current RMP for the Seil Sound: Kilbrandon production area. During 2002 and the fist quarter of 2003, samples were taken from NM 778 182, by Oban Seil. For the remainder of the sampling history, samples were taken from NM 78282 15618, at the pier in Ardmaddy Bay.

The geometric mean result of all mussel samples from NM 764 153 was 317 faecal coliforms / 100g. Results ranged from 40 to 1300 faecal coliforms/100g. The geometric mean result of all mussel samples from NM 778 182 was 298 faecal coliforms / 100g. Results ranged from 90 to 1700 faecal coliforms/100g. The geometric mean result of all mussel samples from NM 78282 15618 was 1330 faecal coliforms / 100g. Results ranged from 160 to 91000 faecal coliforms/100g. There was no significant difference in mean result between sampling locations (One way ANOVA, p=0.080, 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 and as a consequence the results presented in Table 12.1 are not directly comparable with other shellfish testing results presented in this report. As different species of shellfish accumulate and purge contamination at different rates, it is not appropriate to compare mussel results with oyster results. The geometric mean levels of faecal coliforms in shore mussels taken from NM 764 153 and NM 778 182 were slightly lower than the overall geometric mean of all rope mussel samples tested for *E. coli* from the East of Balvicar site as part of the classification monitoring (334 MPN/100g), while the geometric mean result was higher at Seil Sound: Ardmaddy Pier (NM 78282 15618). These results indicate markedly higher levels of contamination impacting at Ardmaddy Bay.

At Ardmaddy Pier, no significant difference was found in results between quarters (One-way ANOVA, p=0.498, Appendix 6), although all results over 4600 *E. coli* / 100g occurred during Q3 and Q4, indicating the worst contamination effects occurred during the latter half of the year. Too few samples were taken from the other sites to test for seasonal effects.

Results for the physical and chemical parameters monitored by SEPA are not presented in this report.

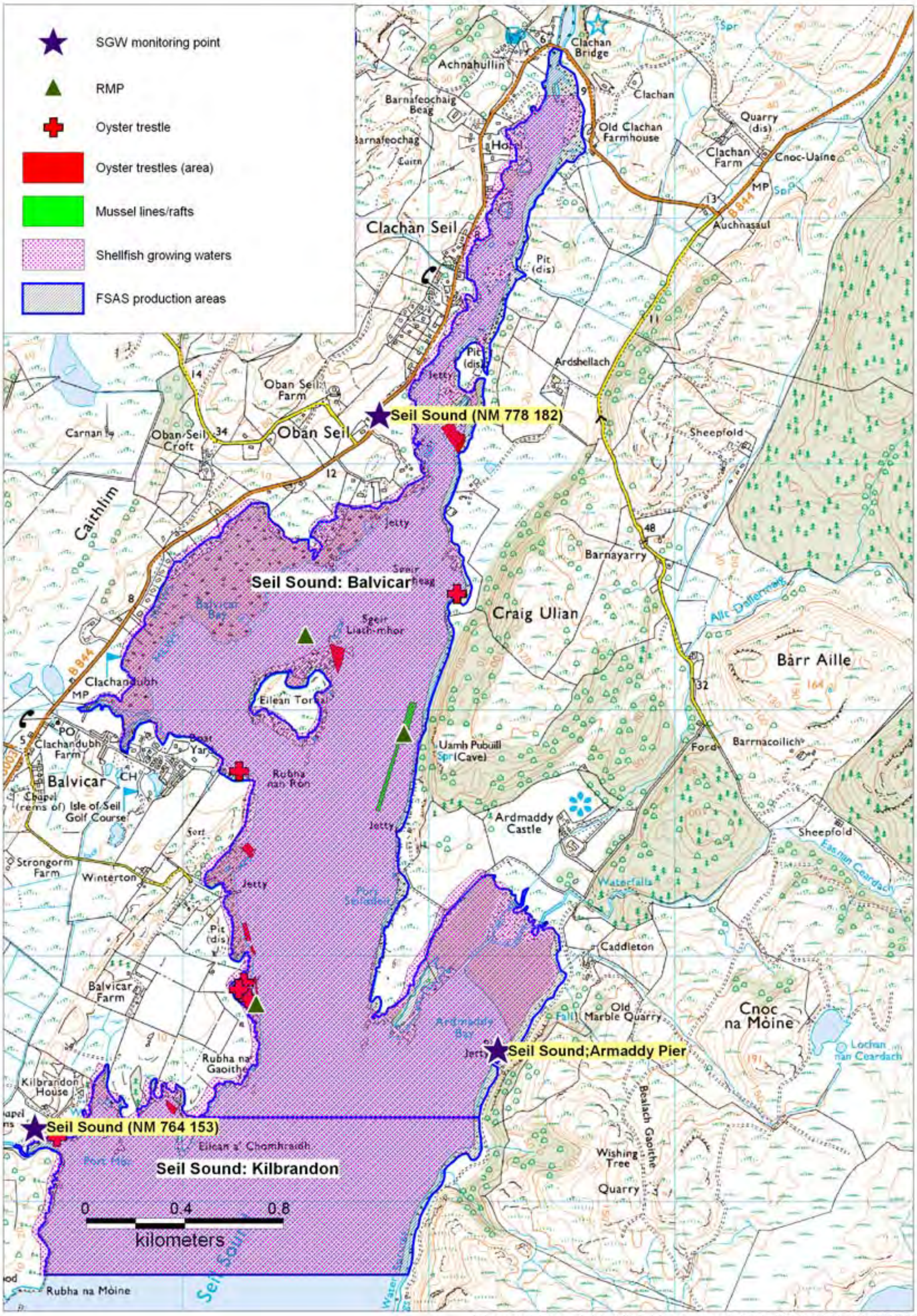


Figure 12.1 Shellfish growing waters and mussel sampling locations

The present SEPA scheme for classifying the quality of non-estuarine coastal waters has recently down-graded 5.7km of coastline in the area from a class A to a class B due to the microbiological inputs. However, it is expected that much of this downgrading will be removed following the completion of improvements to water quality in the area (S Walker pers com. 2009)

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

	Site	Seil Sound;Armaddy Pier	Seil Sound	Seil Sound
	OS Grid Ref.	NM 78282 15618	NM 778 182	NM 764 153
2000	Q1			
	Q2			500
	Q3			500
	Q4			1300
2001	Q1			70
	Q2			700
	Q3			40
	Q4			500
2002	Q1		1700	
	Q2		90	
	Q3		310	
	Q4		310	
2003	Q1		160	
	Q2			
	Q3	5400		
	Q4	160		
2004	Q1	750		
	Q2	220		
	Q3	500		
	Q4	220		
2005	Q1	750		
	Q2	750		
	Q3	310		
	Q4	500		
2006	Q1	1025		
	Q2	1750		
	Q3	12550		
	Q4	12550		
2007	Q1	300		
	Q2	465		
	Q3	35000		
	Q4	91000		

13. River Flow

There are no gauging stations on streams draining to Seil Sound. The following streams were measured and sampled during the shoreline survey. These represent the largest freshwater inputs into Seil Sound. During the week preceeding the survey, 22.6 mm of rain fell at Kimelford, while 5.4 mm of rain fell during the survey itself, mostly on the second of the three days.

Table 13.1 Stream flows and loadings

No	Grid Ref	0Width (m)	Depth (m)	Measured Flow (m/s)	Flow in m^3/day	*E. coli* (cfu/ 100ml)	Loading (*E. coli* per day)
1	NM 78491 19674	0.11	0.01	0.908	86	600	$5.2x10^8$
2	NM 78459 19545	0.20	0.03	0.016	8	200	$1.7x10^7$
3	NM 78339 19345	0.78	0.05	0.062	209	49000	$1.0x10^{11}$
4	NM 78163 18772	0.39	0.02	0.421	284	5000	$1.4x10^{10}$
5	NM 77920 18188	0.21	0.05	0.160	145	3100	$4.5x10^9$
6	NM 77321 17827	0.50	0.02	0.010	9	300	$2.6x10^7$
7	NM 77304 17825	0.24	0.02	0.295	122	200	$2.4x10^8$
8	NM 76616 16983	1.15	0.45	0.450	20120	5200	$1.0x10^{12}$
9	NM 76367 15177	1.23	0.20	0.409	8693	200	$1.7x10^{10}$
10	NM 78571 18677	1.90	0.23	0.566	21370	100	$2.1x10^{10}$
11	NM 78327 16386	0.15	0.02	1.019	264	1900	$5.0x10^9$
12	NM 78445 16312	3.10	0.25	0.322	21561	1400	$3.0x10^{11}$
13	NM 78592 16239	2.20	0.20	0.080	3041	100	$3.0x10^9$
14	NM 78585 15968	0.96	0.10	0.657	5449	24000	$1.3x10^{12}$
15	NM 78620 19286	0.48	0.02	0.271	225	200	$4.5x10^8$

The streams drain areas of grassland, woodland and some developed areas, and had widely varying levels of *E. coli* (100 - 49000 cfu/100ml) at the time of survey. The total loading contributed by all these streams at the time of survey was 2.8×10^{12} *E. coli* per day, roughly equivalent to a discharge of septic tank treated wastewater from a population of 350. Stream inputs are concentrated around Ardmaddy Bay (58% of the measured stream loadings) and Clachan Sound (36% of the measured stream loadings), with some inputs to Balvicar Bay (5% of measured loadings) and at Kilbrandon (1% of measured loadings).

The highest overall *E. coli* loading was for stream 14 which discharges in Ardmaddy Bay, over 1 km away from the nearest shellfish site. It is uncertain why the stream contained such high levels of *E. coli*, as it drains an area of rough grassland, although it may receive inputs from a house at Caddleton. The second highest *E. coli* loading was for stream 8. This received inputs from two sewage pipes, and the water sample was taken downstream of these inputs. The third highest loading was for stream 3, which had the highest concentration of *E. coli* of any stream sampled. An aggregation of ducks was seen around the mouth of this stream, and it may receive inputs from houses adjacent to it but back from the shoreline. None of these streams discharge in close proximity to any of the shellfish sites. Also of interest is stream 9, which discharges to a small partially enclosed bay within which the Kilbrandon site is located, so any contamination carried by this stream would be expected to impact on this site.

Following heavy rain, the loadings contributed by these streams would be expected to increase significantly. Streams may be the principal pathways by which diffuse contamination from livestock will be carried into the production areas, and some may have additional inputs from private septic tanks not seen during the survey or listed by SEPA.

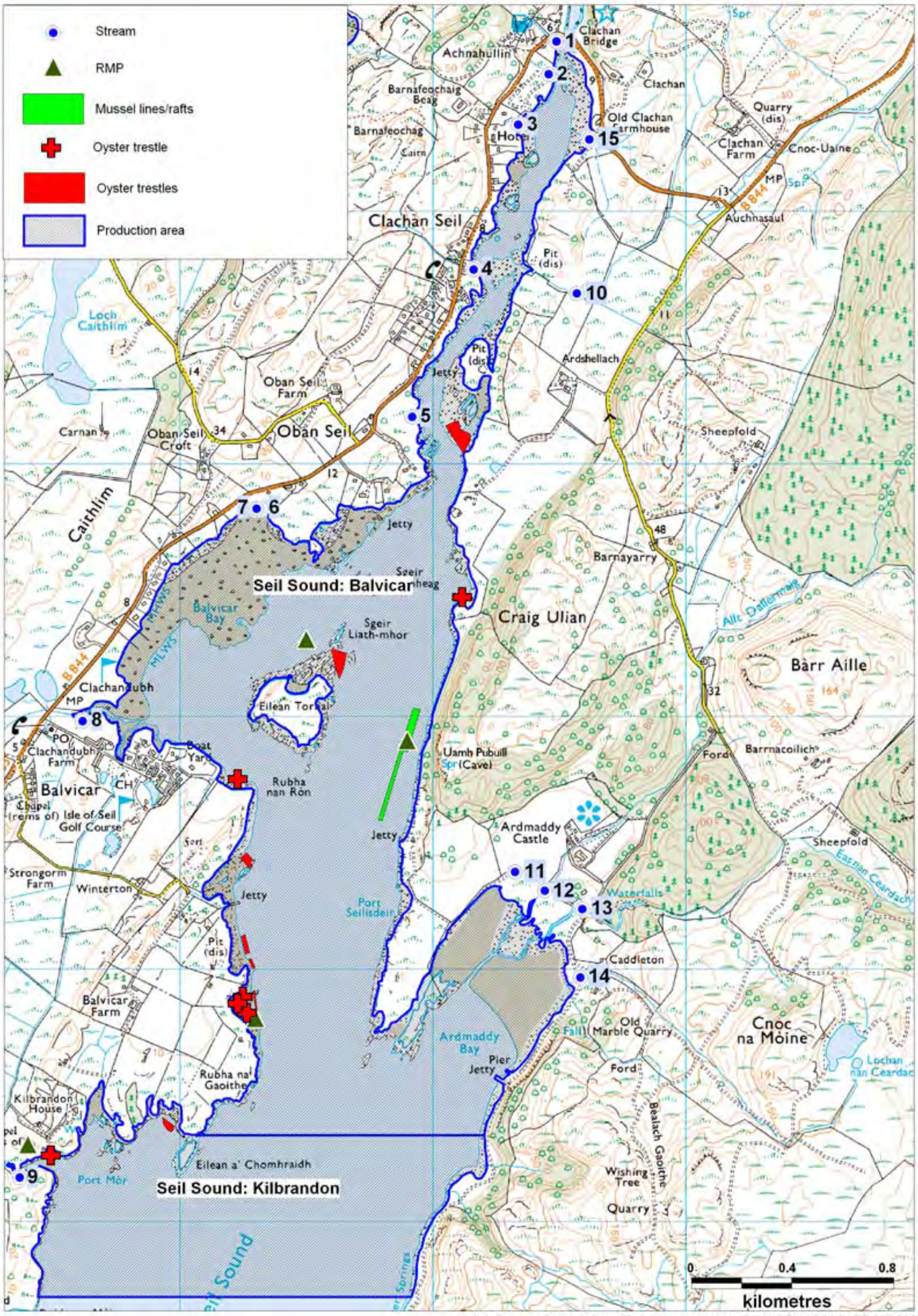


Figure 13.1 Stream locations

14. Bathymetry and Hydrodynamics

This site was chosen for a hydrodynamic modelling assessment using the Hydrotrack model described in Appendix 6. This document can be consulted for background information on the model and the methods applied.

Physical Characteristics

Seil Sound is located between the mainland and the island of Seil in Argyll. The sound is an extension of the Sound of Jura, but also contains separate connections to the West Scottish shelf in the west (Cuan Sound) and north (Clachan Sound). The average depth is 20-25 m with some extremes to 60 m near the southern end (Admiralty Chart Firth of Lorne).

Tides

Spring tidal range is given as 2.3 m at Seil Sound, with neap tidal range of 0.9 m (Admiralty Chart). Kayakers have reported a south-flowing tide under the Clachan Bridge at ebb, indicating that the tide at this point is roughly in phase with the tide at the southern entrance to Seil Sound (see http://www.gla.ac.uk/medicalgenetics/seakayaking_seil.htm). The shoreline survey indicated strong flows through Clachan Sound on a spring tide, but measurements were not made.

Wind driven flows

Wind statistics measured at Glasgow: Bishopton (Figure 14.1) were judged to be roughly representative of the wind speed and directions experienced at Seil Sound. The annual average shows the overall prevailing direction of the wind is from the west, and the strongest winds come from this direction. Stronger winds are also experienced from the east, presumably due in part to local topography - Bishopton is in the Clyde Valley, which has a west to east aspect. The axis of Seil Sound is approximately aligned in a southwest-northeast direction, so that winds from the southwest are expected to have a large influence on the hydrodynamics in the sound.

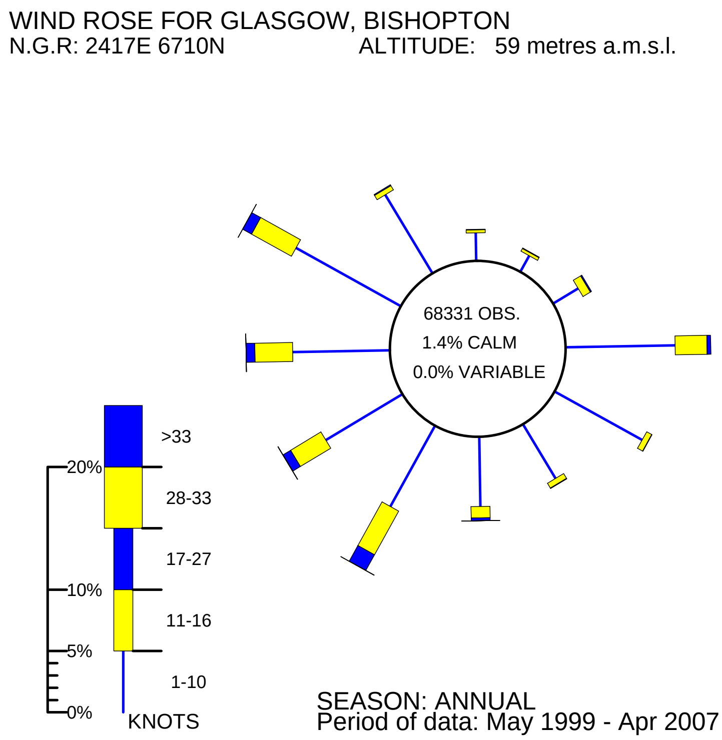


Figure 14.1 Annual wind rose for Glasgow: Bishopton.

Density driven flows

Over the entire sound freshwater inputs are estimated to be small compared to tidal inputs. The shoreline survey revealed 15 significant streams entering the sound (see Table 14.1) within the modelled area (depicted in Figure 14.2). The discharge of these streams ranged from 8 m^3/day to 21560 m^3/day.

Related studies

The only related study found was the SEPA shellfish growing water report for Seil Sound which provided no detailed information on the hydrography of the sound (see http://www.sepa.org.uk/water/shellfish_waters/site_reports.aspx).

Model study

Set-up

The area covered by the model is shown in Figure 14.2 and represents Seil Sound north up to Clachan Bridge and south down to Rubha na Moine. The resolution of the model (the grid spacing) was 40 m x 40 m and variations in currents down to this length scale can be represented. A single semi-diurnal (12.4 hour period) tidal flow was applied to the open boundary in the south (connection to the West Scottish Shelf via the Sound of Jura and Cuan Sound, maximum velocities of 1.2 m/s). This resulted in a tidal range of 1.61 metres within the Sound representing an average value between the spring and neap tidal ranges. The same boundary condition was applied to the northern boundary at Clachan Bridge. Due to the uncertainty of the north model boundary, 2 extra experiments were performed: one with a stronger tidal current and one with a weaker tidal current imposed at this location. The strong current corresponds to maximum velocities of 2.0 m/s, while the weaker current corresponds to maximum velocities of 0.6 m/s. Results are shown for the standard set-up only (boundary conditions of equal strength). The results for the 3 different experiments (using the 3 different tidal velocities at Clachan Bridge) were similar unless stated otherwise. River forcing was not included in the model as the flows reported by the shoreline survey are minor compared to the tidal flow. All identified river sources were included in the contaminants particle tracking study.

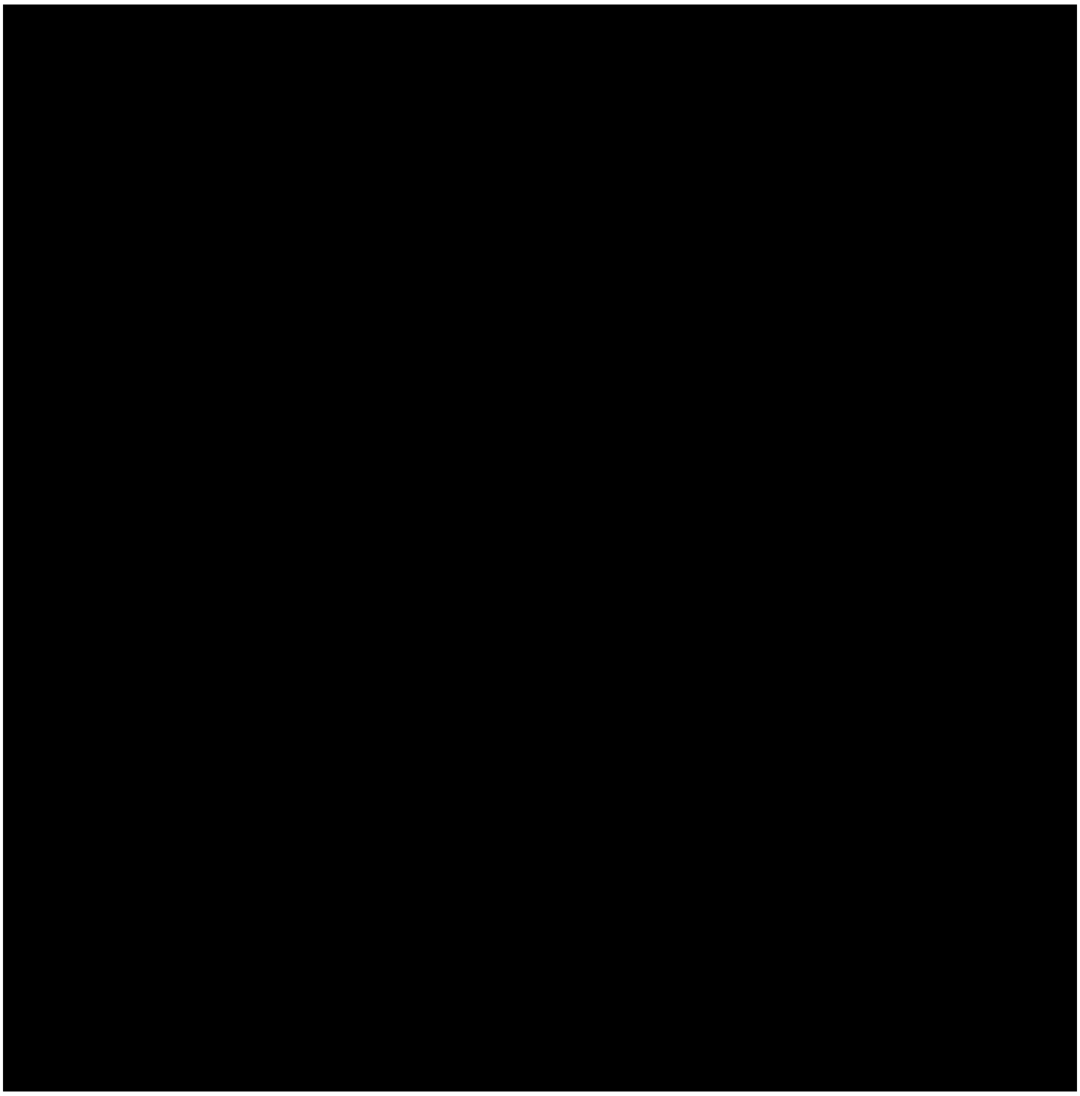


Figure 14.2 Model domain with depths (m). With permission SeaZone Ltd.

In addition to the tidal forcing, the model response to constant winds blowing from the north, south, east and west directions at a speed of 5 m/s (gentle to moderate breeze) was calculated. The effect of the surrounding topography is likely to cause alignment of winds along the axis of the sound and so south-westerly and north-easterly winds were also simulated. In all scenarios, the forcing was applied for 4 tidal cycles (49 hours and 36 minutes) so that a constant (equilibrium) wind driven current pattern was attained. Particles were released into the combined tidal and wind generated currents from locations identified as potential sources during the shoreline survey. Particles were released at hourly intervals during a complete tidal cycle and were then followed for 2 days. Please note that the wind statistics from Glasgow are only used to interpret the model results, as the wind forcing applied to the model is quite idealised.

It should be emphasised that the wind driven flows are set up as a consequence of persistent winds from a given direction. At any particular time winds will vary dynamically in strength and direction and so the results shown correspond to an idealised situation. They are nevertheless indicative of the response that might be expected. Riverine input into the model was excluded based on flow rates observed during the shoreline survey, which may not be representative of conditions more generally. Freshwater inputs in reality are confined to a surface layer.

Limitations of using a depth-integrated model are discussed in the hydrography methods document. These concern the inability of the model to describe the vertical structure within the water column and will affect the modelling of wind and density driven flows in particular. Surface flows are likely to carry the majority of a bacterial load, so that the present model results may not give a good indication of the movement of contaminants on intertidal areas with river inflow.

Contaminant sources

All sources identified during the shoreline survey have been included in the model study. Table 14.1 gives an overview of these sources.

Table 14.1 River flows measured during shoreline survey, Seil Sound

No.	Grid Ref	Description	Flow in m^3/day	*E. coli* (cfu/100ml)	Loading (*E. coli* per day)
R1	NM 78491 19674	Stream	86	600	$5.2x10^8$
R2	NM 78459 19545	Stream	8	200	$1.7x10^7$
R3	NM 78339 19345	Stream	209	49000	$1.0x10^{11}$
R4	NM 78163 18772	Stream	284	5000	$1.4x10^{10}$
R5	NM 77920 18188	Stream	145	3100	$4.5x10^9$
R6	NM 77321 17827	Stream	9	300	$2.6x10^7$
R7	NM 77304 17825	Stream	122	200	$2.4x10^8$
R8	NM 76616 16983	Stream	20120	5200	$1.0x10^{12}$
R9	NM 76367 15177	Stream	8693	200	$1.7x10^{10}$
R10	NM 78571 18677	Stream	21370	100	$2.1x10^{10}$
R11	NM 78327 16386	Stream	264	1900	$5.0x10^9$
R12	NM 78445 16312	Stream	21561	1400	$3.0x10^{11}$
R13	NM 78592 16239	Stream	3041	100	$3.0x10^9$
R14	NM 78585 15968	Stream	5449	24000	$1.3x10^{12}$
R15	NM 78620 19286	Stream	225	200	$4.5x10^8$

Table 14.2 Scottish water sewage discharges, Seil Sound

No.	Discharge Name	NGR of discharge	Discharge Type	Level of Treatment	Consented flow m^3/day	Consented/ design PE
ST1	Clachan Seil	NM 7830 1900	continuous	septic tank	24.12	
ST2	Clachan Seil CSO/EO	NM 7820 1880	intermittent	6mm screen		
ST3	Balvicar	NM 7645 1692	continuous	Septic tank		
ST4	Clachan Seil Upper	NM 78051874	continuous	Septic Tank		51
ST5	Balvicar ST	NM 768168	continuous	Septic Tank		

Table 14.3 SEPA discharge consents to water, Seil Sound

	Ref No.	NGR of discharge	Discharge Type	Population Equivalent	Discharges to
ST6	CAR/R/1015858	NM 7842 1940	Domestic	12	Clachan Sound
ST7	CAR/R/1013702	NM 7826 1896	Domestic	7	Seil Sound

Results

Particle paths

Figures 14.3a-o show the particle paths calculated by the model for the different forcings (tides only, tides + winds) for each release point of contaminants. Some sources are close together and are therefore represented by one common release point. In some cases the release point was moved somewhat offshore to represent a worst case scenario where particles are transported by the main currents. The results indicate a strong wind dependence (in the absence of strong tidal flows) that determines for example the flow direction around the island of Eilean Tor in the main part of the Sound. Residual flow patterns (flow averaged over a tidal cycle, so net transport) shown in Figure 14.4 (for Balvicar Bay) and 14.5 (for Ardmaddy Bay), indicate a clockwise gyre around Eilean Tor under south, west and south-westerly winds. An anti-clockwise gyre is found under north, east and north-eastern winds, while the tide only residual flow pattern (no wind imposed) indicates a complex pattern of small gyres around Eilean Tor. These gyre patterns lead to contaminant transport southwards from sources in Balvicar Bay and the southern end of Clachan Sound to lease sites south and east of Eilean Tor, while also giving rise to northward transport of contaminants from sources in Ardmaddy Bay. It is therefore concluded that all lease sites within Seil Sound can be impacted by contaminants under certain conditions. The particle tracking results are discussed below for each affected area of Seil Sound.

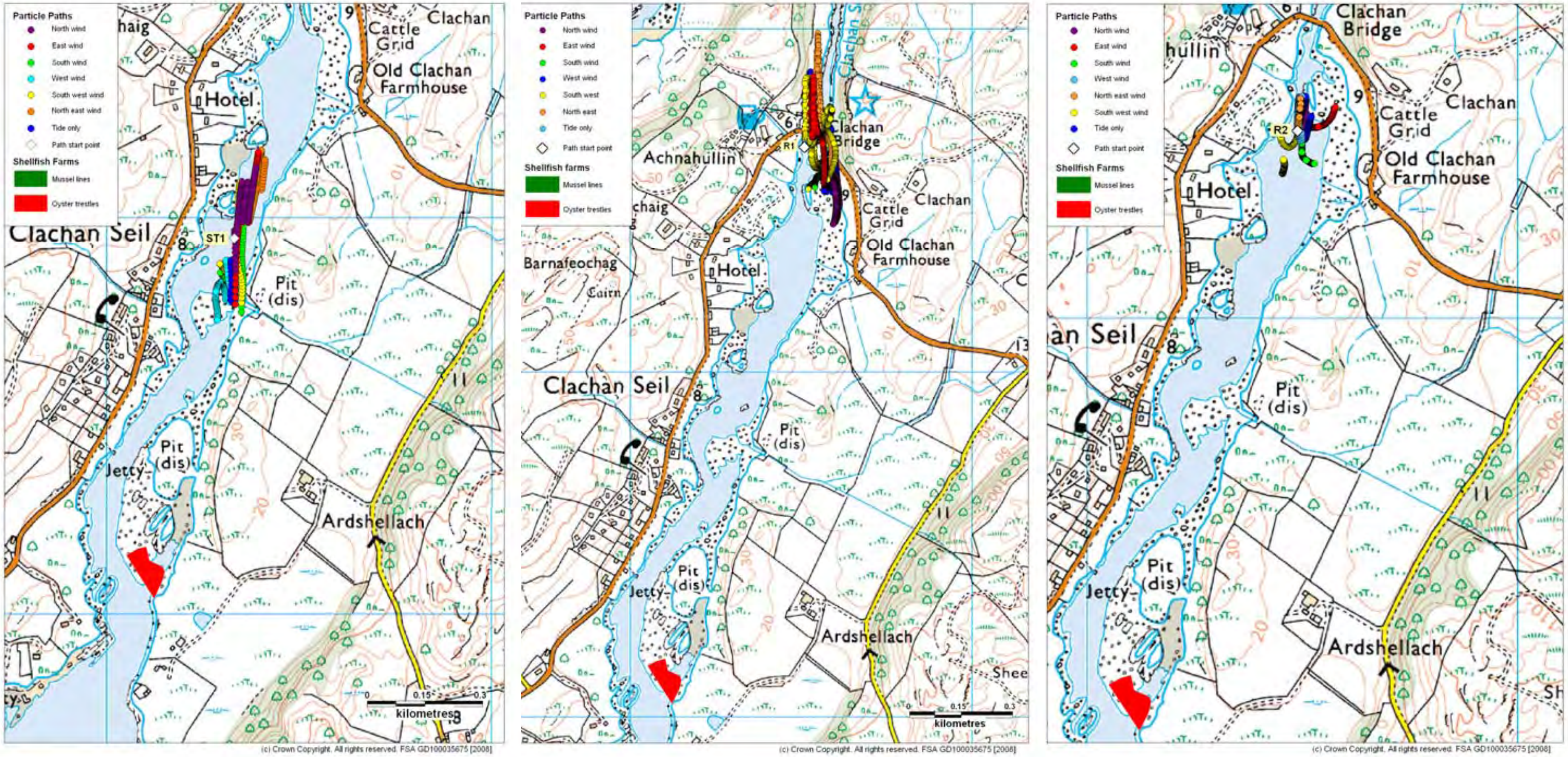
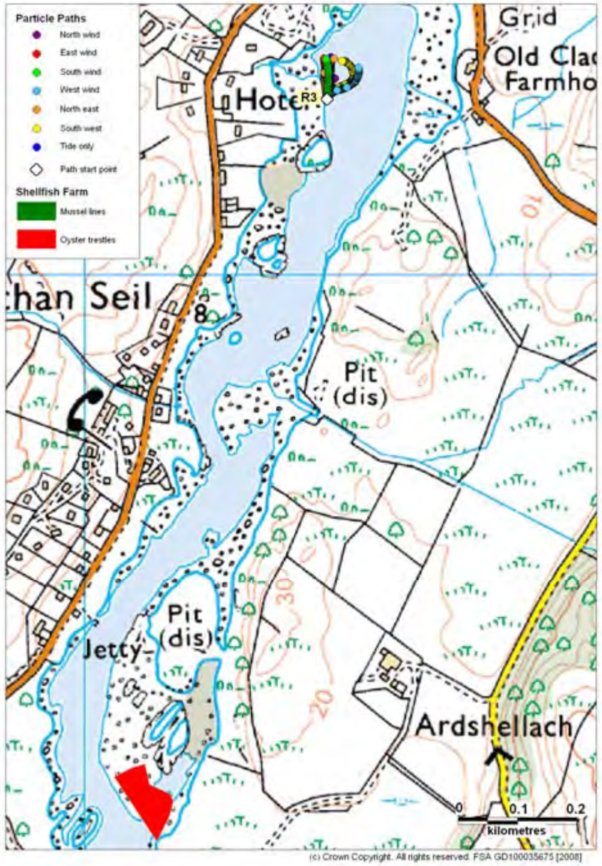
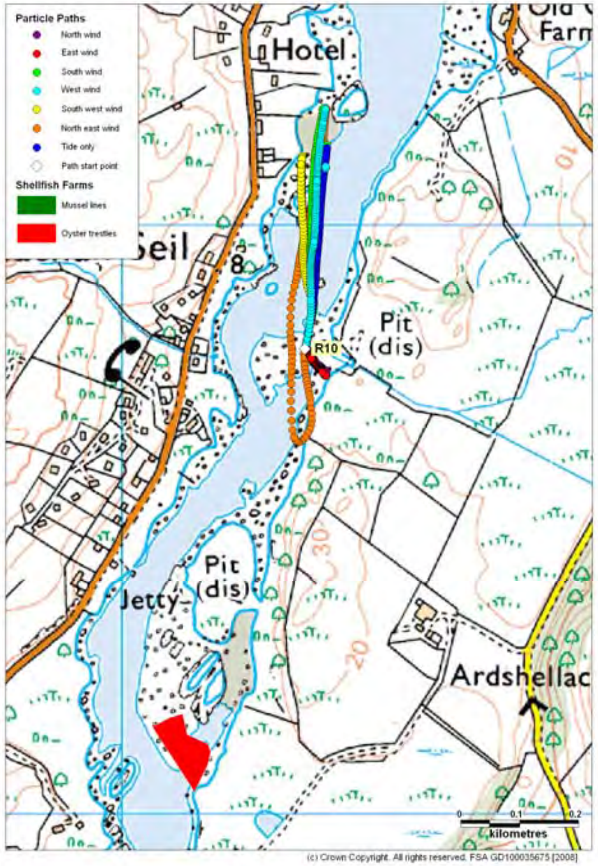


Figure 14.3 a Particle paths of particles released at sources ST1 and ST7. Particles released at every hour and under different wind directions.
Figure 14.3 b Particle paths of particles released at sources R1. Particles released at every hour and under different wind directions.
Figure 14.3 c Particle paths of particles released at sources R2. Particles released at every hour and under different wind directions.





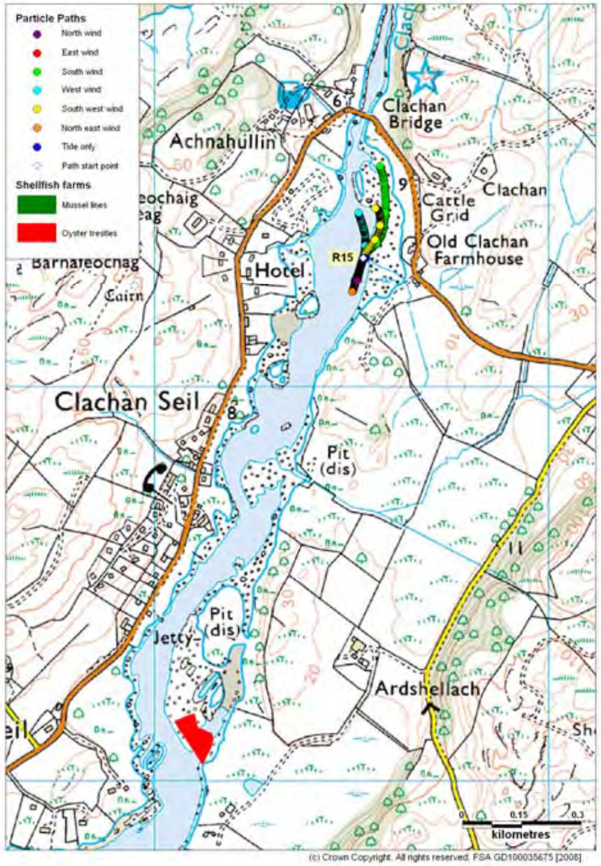
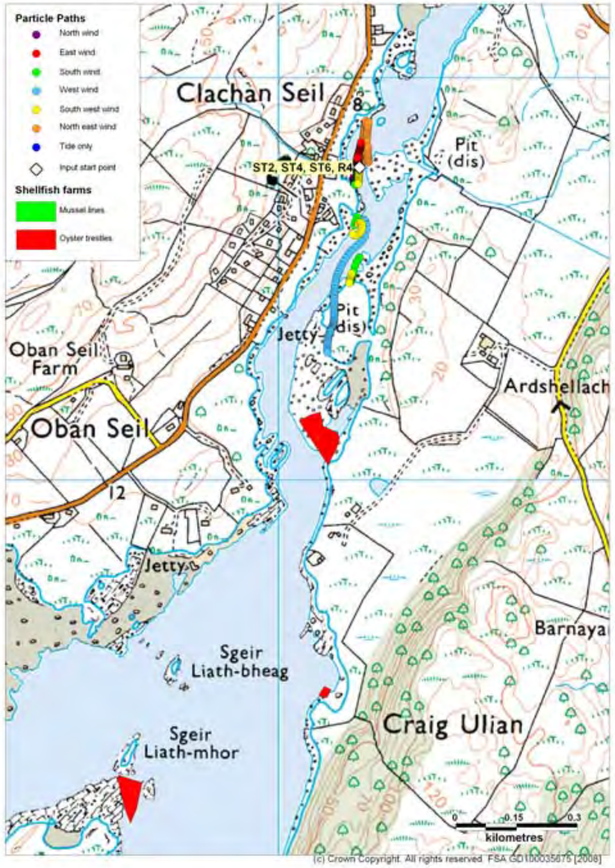
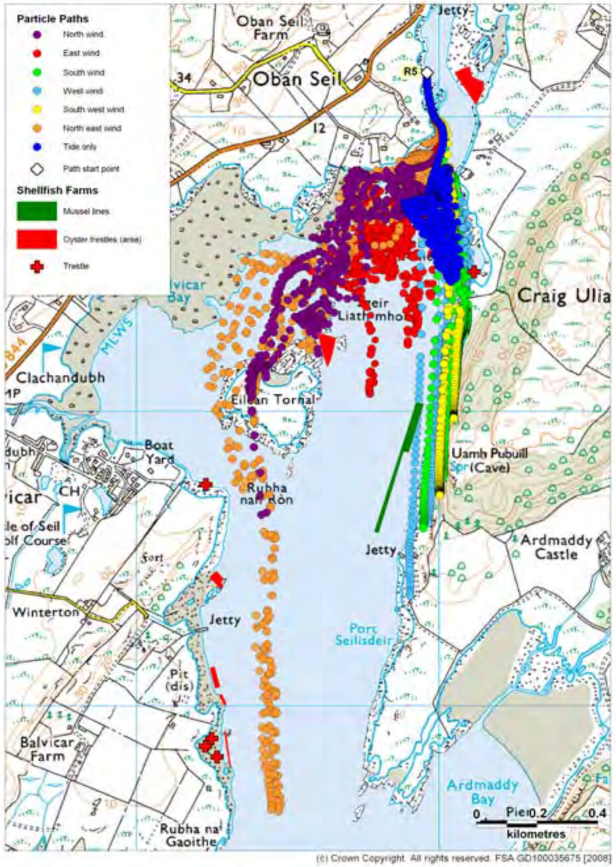


Figure 14.3 d Particle paths of particles released at source R3. Particles released at every hour and under different wind directions.
Figure 14.3 e Particle paths of particles released at source R10. Particles released at every hour and under different wind directions.
Figure 14.3 f Particle paths of particles released at source R15. Particles released at every hour and under different wind directions.





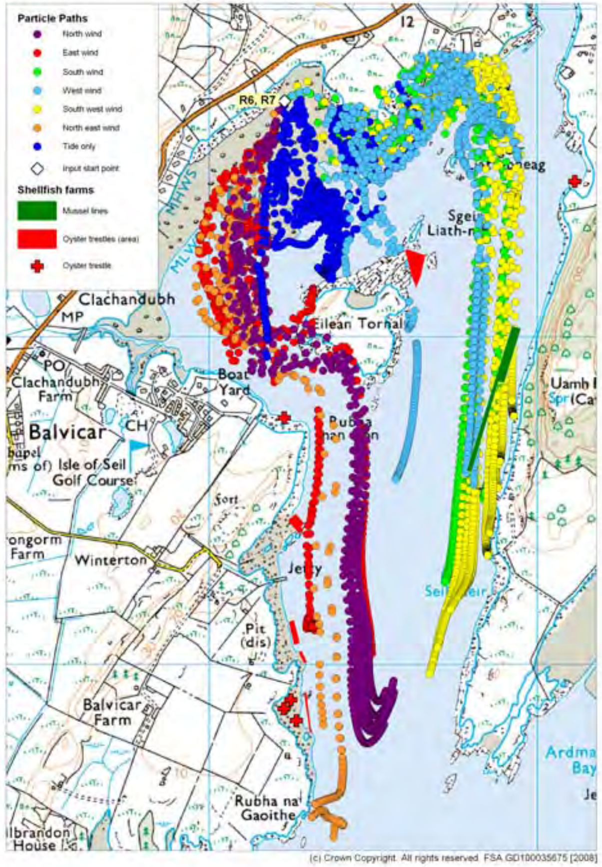


Figure 14.3 g Particle paths of particles released at sources ST2, ST4, ST6 and R4. Particles released at every hour and under different wind directions.

Figure 14.3 h Particle paths of particles released at source R5. Particles released at every hour and under different wind directions.

Figure 14.3 i Particle paths of particles released at sources R6 and R7. Particles released at every hour and under different wind directions.

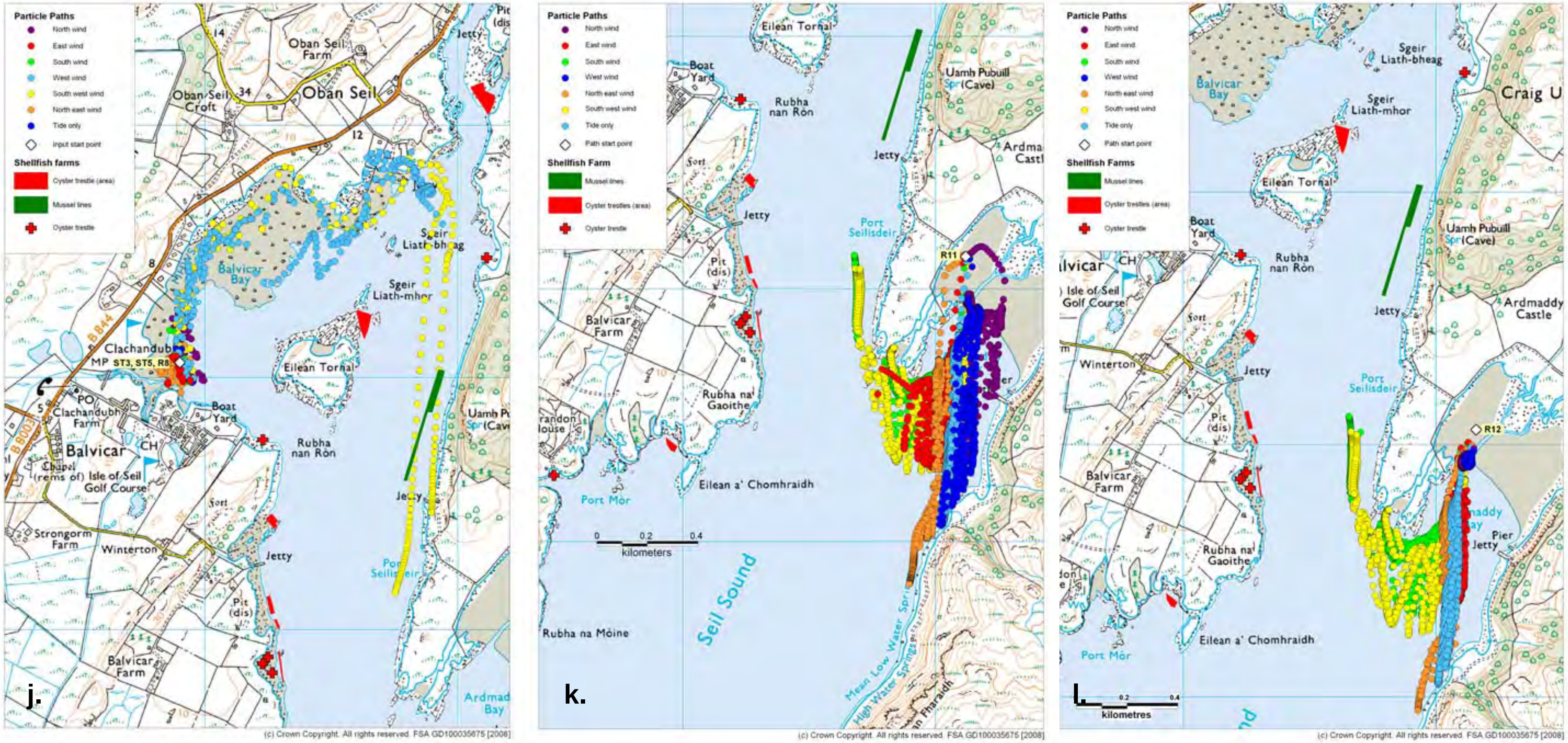
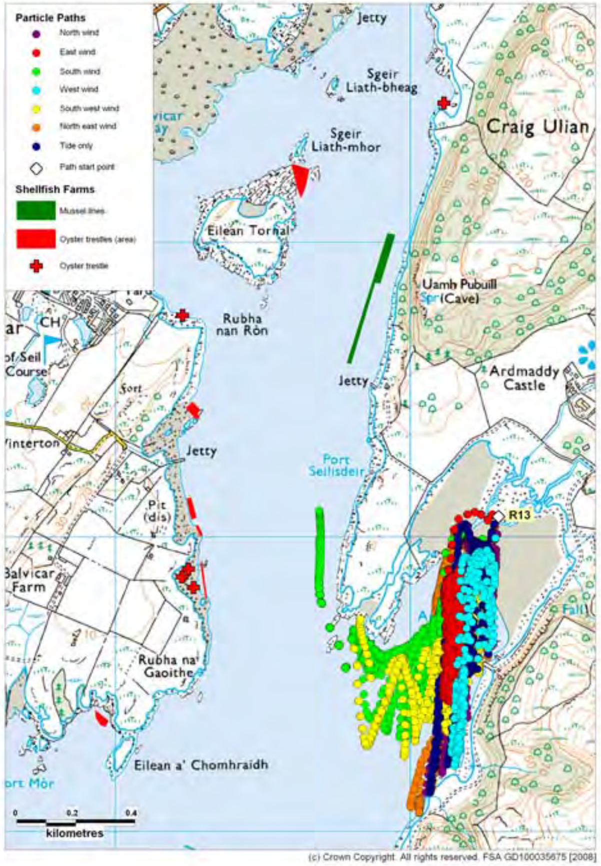
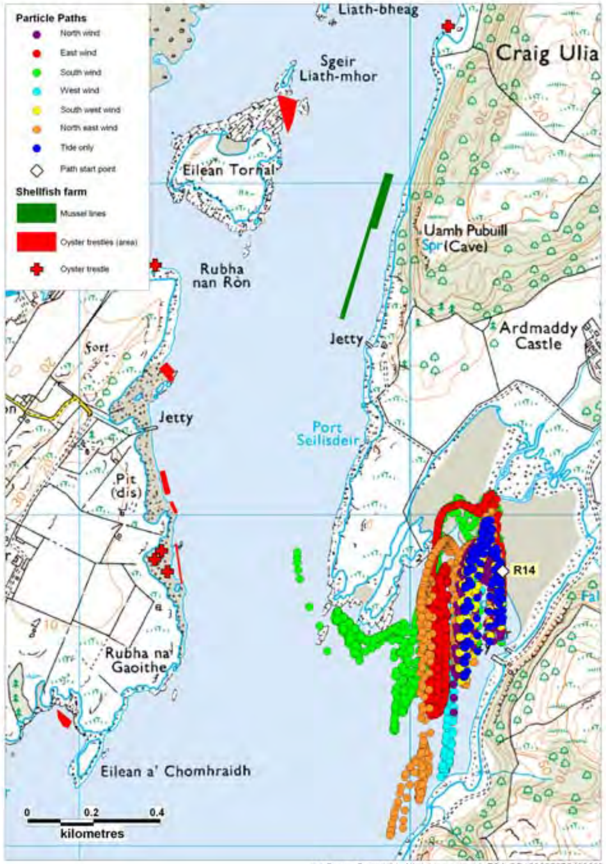


Figure 14.3 j Particle paths of particles released at sources R8 and ST3 and ST5, (Balvicar). Particles released at every hour and under different wind directions. The particles for these sources were placed slightly offshore, in order to account for offshore transport through the tidal channels found in this location: these channels are too narrow to be resolved by the model.

Figure 14.3 k Particle paths of particles released at source R11. Particles released at every hour and under different wind directions.

Figure 14.3 l Particle paths of particles released at source R12. Particles released at every hour and under different wind directions.





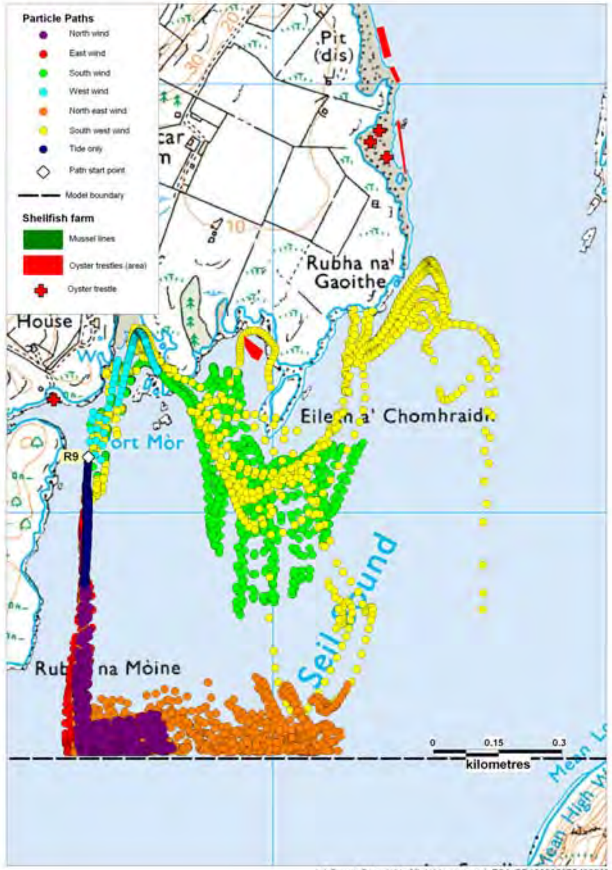


Figure 14.3 m Particle paths of particles released at source R13. Particles released at every hour and under different wind directions.
Figure 14.3 n Particle paths of particles released at source R14. Particles released at every hour and under different wind directions.
Figure 14.3 o Particle paths of particles released at source R9. Particles released at every hour and under different wind directions. The southern model boundary at Rubha na Moine causes the particles to appear to bounce there.

Model results for source R9 in Kilbrandon (Figure 14.3 o) are not deemed representative as the particle paths are clearly influenced by the imposed southern model boundary. Nevertheless, the Kilbrandon site (see Figures 14.3o) is located very close to contaminant source R9, and is therefore predicted to be impacted under all circumstances. The Kilbrandon and Island sites are predicted to likely be impacted during south, west and south-westerly winds.

Particles released from the riverine sources R11, R12, R13 and R14 in Ardmaddy Bay (Figures 14.3 k,l,m,n) generally stay within the bay, mainly impacting on the south-eastern shore. However, the model results show that particles from these sources can travel northwards under south and south-westerly winds. Due to the clockwise gyre these particles do not reach East of Balvicar mussel site (see Figure 14.5 for the residual current pattern in this area). The release points for these sources are located on an intertidal area, which is not taken into account in the particle tracking. The paths shown here therefore represent a worst case scenario, where there is always a residual flow present on the flat to transport the particles. In reality this may be limited to parts of the tidal cycle.

The sources at Balvicar (R8, ST3, ST5) have been allocated a common release point for the particles, which is slightly offshore of Balvicar within Balvicar Bay (see Figure 14.3 j). The particles tend to stay within the direct vicinity of the release point, due to the shallow nature of the bay and local gyres. However, under west and south-westerly winds the particles from these sources can travel extensively and reach the East of Balvicar mussel site (under south-westerly winds), while coming close to the Balvicar North site at Craig Ulian (west winds). This is due to the wind-driven gyre around Eilean Tor and the ability of western winds to push particles released in Balvicar Bay into the main gyre. Results for both a weaker and a stronger current at the northern boundary at Clachan Bridge showed that particles could also reach the east side of Eilean Tor under southern winds.

Particles released in the northern part of Balvicar Bay, south of Oban Seil, are from the riverine sources R6 and R7 (depicted in Figure 14.3 i). This area is intertidal, and the same restrictions as mentioned for the sources in Ardmaddy Bay apply here. Under purely tidal conditions (no wind), calculated particle paths show movement of the particles only within Balvicar Bay. North, east and north-easterly winds show particle transport southwards out of Balvicar Bay following the west coast of Seil Sound and impacting on the Balvicar and Rubha Nan Ron South sites. By contrast (due to the gyre around Eilean Tor) south, west and south-westerly winds show particles travelling along the east coast of Seil Sound and impacting on the East of Balvicar mussel site. During conditions with western winds an impact on the Balvicar North site at Sgeir Liath-mhor was found.

The river located at the southward end of Clachan Sound (R5) shows the potential to transport contaminants far into Seil Sound (see Figure 14.3 h). Particles released here can travel up to the Balvicar North site at Sgeir Liath-mhor (under north, east and north-easterly wind conditions), travel westward round Eilean Tor and impact on the Balvicar and Rubha nan Ron South sites (north and north-easterly winds) and travel eastward round Eilean Tor and southward along the east coast of Seil Sound to impact upon the East of Balvicar mussel site (south, west and south-westerly winds). These latter conditions also impact on the Balvicar North site at Craig Ulian, which can also see contamination under purely tidal conditions. Model results for both the stronger and weaker boundary conditions imposed at Clachan Bridge also showed particles travelling down to the East of Balvicar mussel site under no-wind conditions (tidal forcing only). Due to the strong flows in the narrow strait of Clachan Sound, an impact from this source on the Ardshellach site was not found. However, an impact upon the Balvicar and Rubha nan Ron South sites under north and north-east winds cannot be excluded, as particles have the potential to travel down the west coast of Seil Sound under these conditions.

The sources located well within Clachan Sound all show very local contamination paths (figures 14.3 a-g). Although a direct impact upon the Ardshellach site was not found, an impact cannot be excluded due to the close proximity of the sources R4, R5, R10, ST2 and ST4. Particles from source R4, ST2 and ST4 are predicted to travel southwards towards the small peninsula located north of the Ardshellach site. Transport of particles northwards through Clachan Sound into the Firth of Lorn is also very likely.

Summary

The model study of Seil Sound showed a strong dependence of transport paths on wind direction, due to the relatively weak tidal currents experienced in some areas, and the open geometry of the sound (no narrow channels or sills). Without winds, tidal flows were found to lead to mainly localised transport (impact of source R5 on the Balvicar North site at Craig Ulian). During north, east or north-easterly winds an anti-clockwise gyre was predicted around Eilean Tor, causing particles released at the northern end of Balvicar Bay (sources R5, R6, R7) to impact on the Balvicar and Rubha nan Ron South sites. For these wind directions, source R5 also impacted on the Balvicar North site at Sgeir Liath-mhor. In contrast, winds blowing from the south, west or south-west were predicted to cause a clockwise circulation around Eilean Tor, leading to transport of particles from sources in Balvicar Bay (R6, R7, R8 and all sewage sources in Balvicar) northwards around Eilean Tor (possible impacts on the Balvicar North site at Craig Ulian) and then southwards to the East of Balvicar mussel site. Under these conditions, sources at the southward end of Clachan Sound (R5) also showed an impact on Balvicar North site at Craig Ulian and the East of Balvicar mussel site. The sources at Ardmaddy Bay showed potential northward travel under these conditions, but did not reach the East of Balvicar mussel site due to the clockwise gyre. The Kilbrandon and Island sites are likely to be impacted by the sources R9 and R15 due to their close proximity to the sites. South, west and south-westerly winds will favour an impact here.

The particle tracking study showed that all lease sites can be impacted by potential contaminant sources under certain conditions. The only exception was the Ardshellach site, but as this site is extremely close to source R5 a possible impact cannot be excluded.

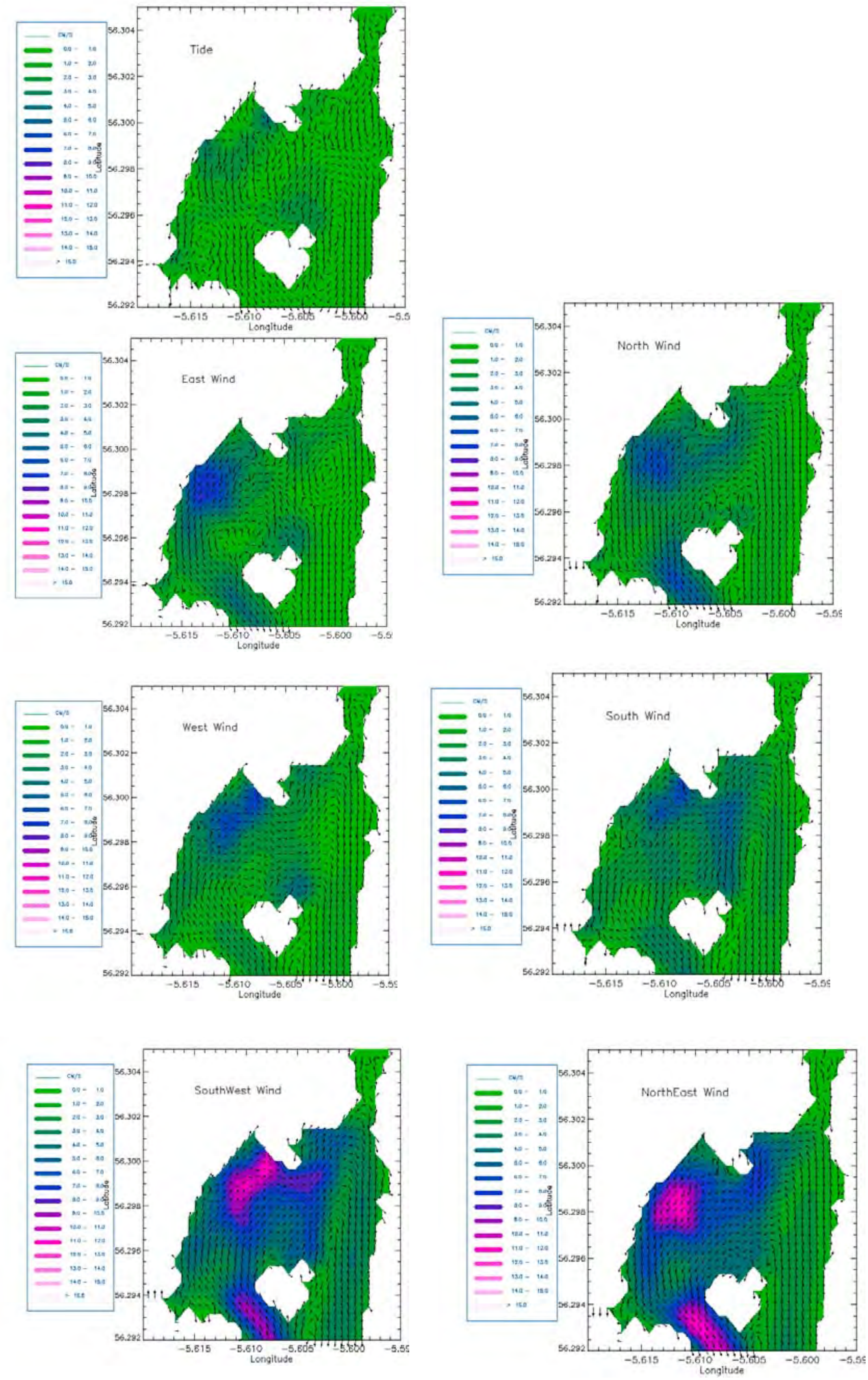


Figure 14.4 Residual currents in Balvicar Bay for tidal forcing only and with imposed wind directions.
Colour distribution indicates residual current speed and arrows give the direction.
Arrows plotted at every model grid point.

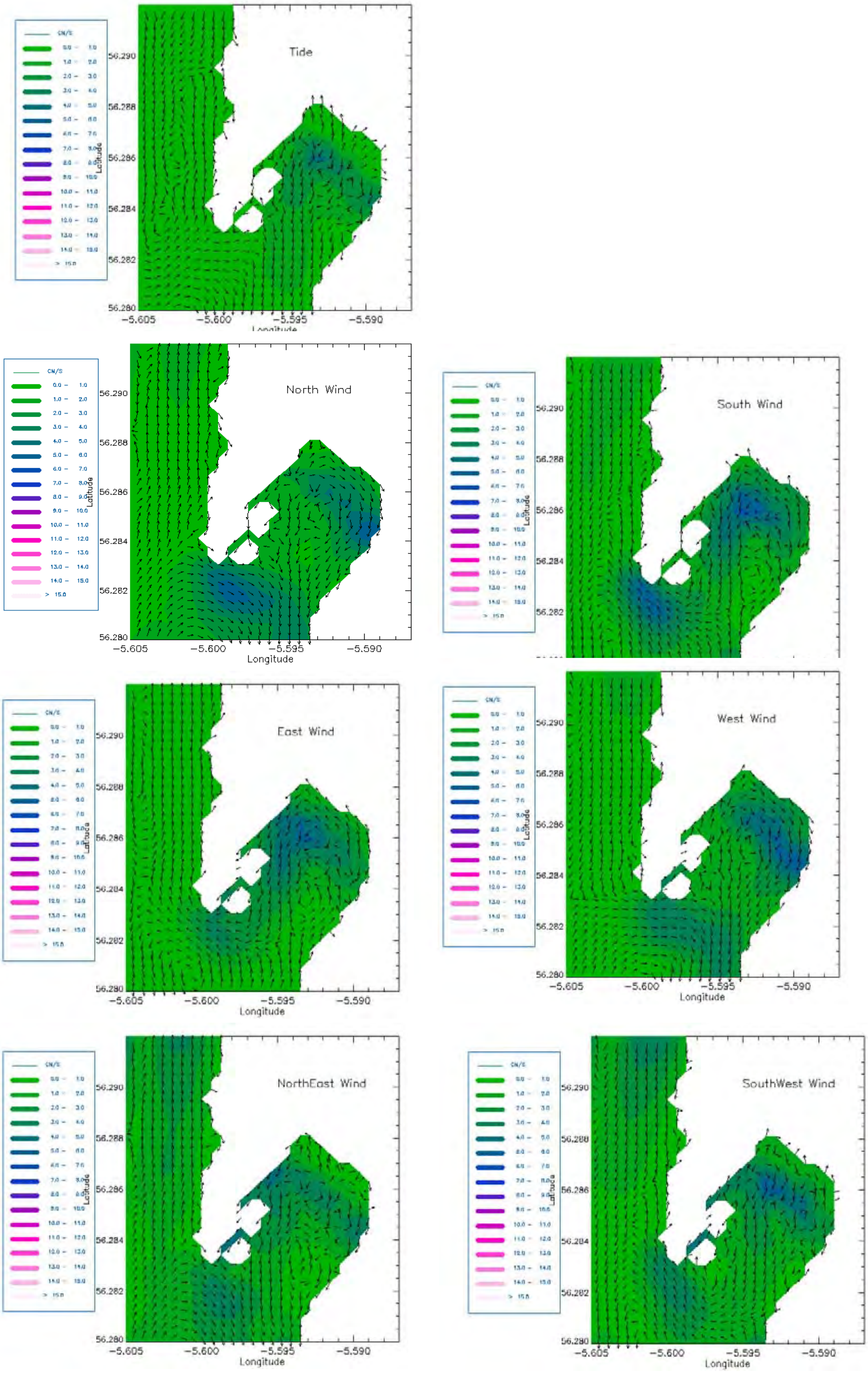


Figure 14.5 Residual currents in Ardmaddy Bay. Colour distribution indicates residual current speed and arrows give the direction. Arrows plotted at every model grid point.

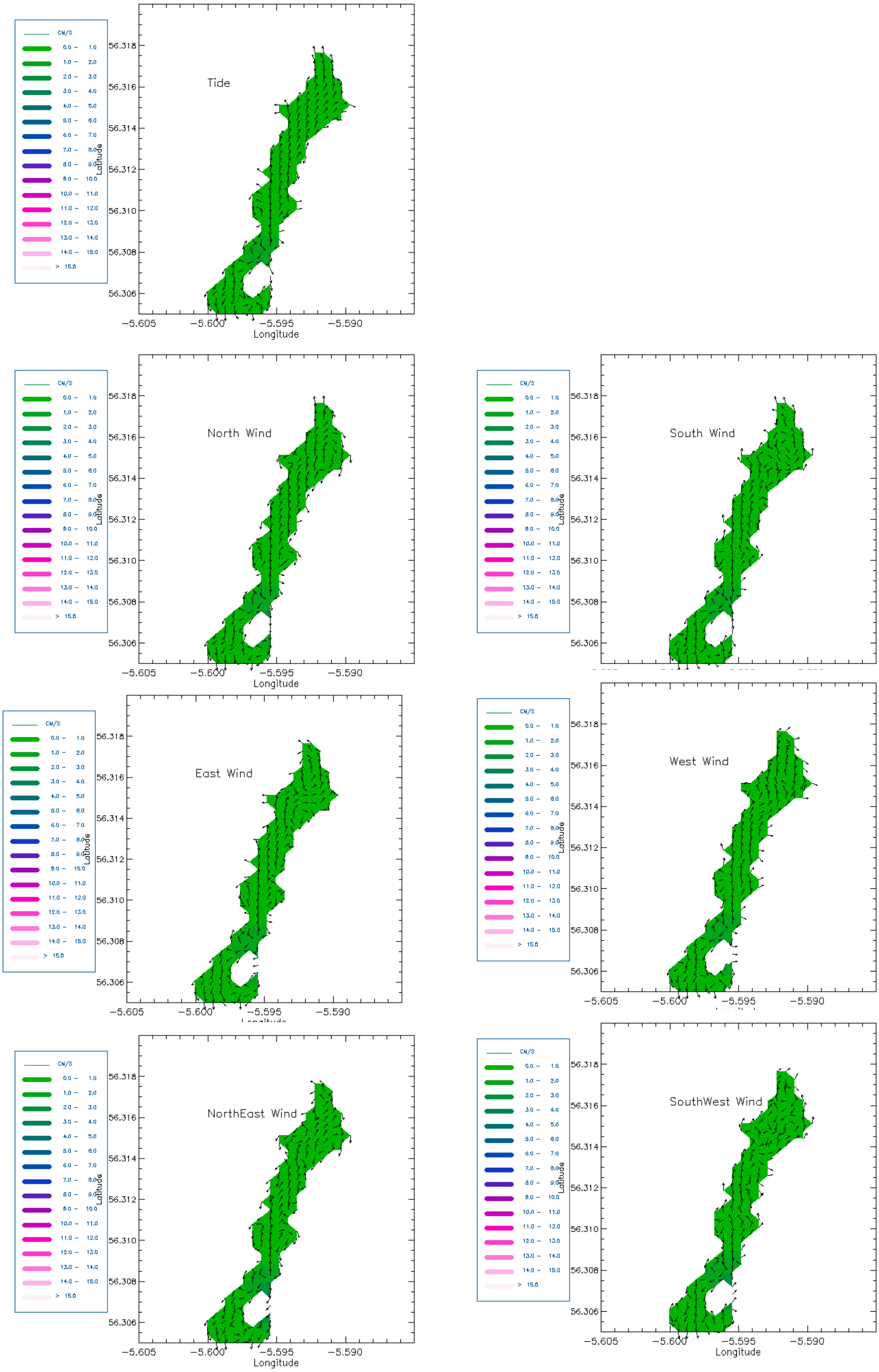


Figure 14.6 Residual currents in Clachan Sound. Colour distribution indicates residual current speed and arrows give the direction. Arrows plotted at every model grid point.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 19th to the 21st August 2008. The full shoreline survey report is presented in Appendix 8.

Within the Seil Sound: Balvicar production area there were four Pacific oyster trestle sites and one rope mussel site, and within Seil Sound: Kilbrandon production area there were two Pacific oyster sites. Details of these fisheries, together with their locations were recorded. These details are presented in Section 2 of this report.

Most of the human population is on the west shore in the settlements of Clachan Seil and Balvicar. These are served by a mixture of private and small Scottish Water owned septic tanks spread all along the settled areas, some of which discharge to Seil Sound. A total of 26 of these were observed on the west shore. During the survey, construction of a new sewerage system was underway, and the catchment area of this will include most of Clachan Seil and Balvicar, so the majority of discharges observed will be replaced by this system in 2009. A further two private discharges were observed on the east shore, one of which was located about 130 m southeast of the East of Balvicar mussel lines. A total of 43 yachts and small boats were seen on moorings in Seil Sound, mainly around Clachan Seil and Balvicar. Therefore, the greatest inputs of human sewage were in the area of Clachan Seil and Balvicar, and although the situation will change on completion of the new sewerage system, greatest inputs are anticipated to remain in these areas.

A number of dwellings seen on the shoreline survey were likely to be holiday homes. Coach tours regularly visit the ‘Atlantic Bridge’ which is a recognised tourist destination. Also, more visiting yachts are expected during the summer months, so the human population in the area is likely to be higher during the summer.

The land surrounding the production areas are a mixture of grassland and heathland with some wooded areas mainly on the east shore. Highest concentrations of livestock were observed at Balvicar Farm (82 sheep with access to the shore) and Ardmaddy Castle (52 cattle and 36 sheep fenced from the shore). An aggregation of 33 ducks was seen on the shoreline at Clachan Seil, and about 100 seagulls were seen on the intertidal zone at Ardmaddy Bay. The local sampling officer also advised that large numbers of geese (over 100 birds at times) are often seen on the golf course at Balvicar, at Balvicar farm and at Ardshellach, and that a small colony of seals (6-8 animals) are usually resident during the summer months on two small rocky islets just north of the Balvicar North site. Neither seals nor geese were seen during the shoreline survey, however.

A total of 15 streams were sampled and measured, representing the major freshwater inputs to Seil Sound. Three of these streams had *E. coli* levels of over 5000 cfu/100ml. One of these discharges at Balvicar, and received inputs from 3 small sewer pipes, and contained 5200 *E. coli* cfu/100ml. Another discharges at Clachan Seil, and had an aggregation of ducks around it at the time of survey, and contained 49000 *E. coli* cfu/100ml. The third discharged at Ardmaddy Bay, and contained 24000 *E. coli* cfu/100ml, but there was no obvious reason for this high level of contamination.

Oyster samples were taken from Balvicar, both Balvicar North sites, Ardshellach, both Rubha nan Ron sites and Kilbrandon. They gave results of 20 to 750 *E. coli* MPN/100g. The two highest results occurred in oysters taken from the Kilbrandon site and the main Rubha nan Ron site. Four mussel samples were taken from East of Balvicar, near the surface and the bottom of the ropes at each end. Although differences were small, the results at the southern end, near a private discharge pipe were the highest, and the surface samples were more contaminated than those at depth at both ends. Full shellfish sampling results are presented in Table 3 and Figure 3 of the shoreline survey report (Appendix 8).

E. coli levels in seawater samples ranged from 1 to 480 cfu/100ml. Salinities ranged from 25.1 ppt in Ardmaddy Bay to 34.3 ppt around the mussel lines, All samples had a salinity of over 30 ppt apart from the sample taken in Ardmaddy Bay, which has four significant streams discharging to it. Full seawater sampling results are presented in Table 2 and Figure 2 of the shoreline survey report (Appendix 8).

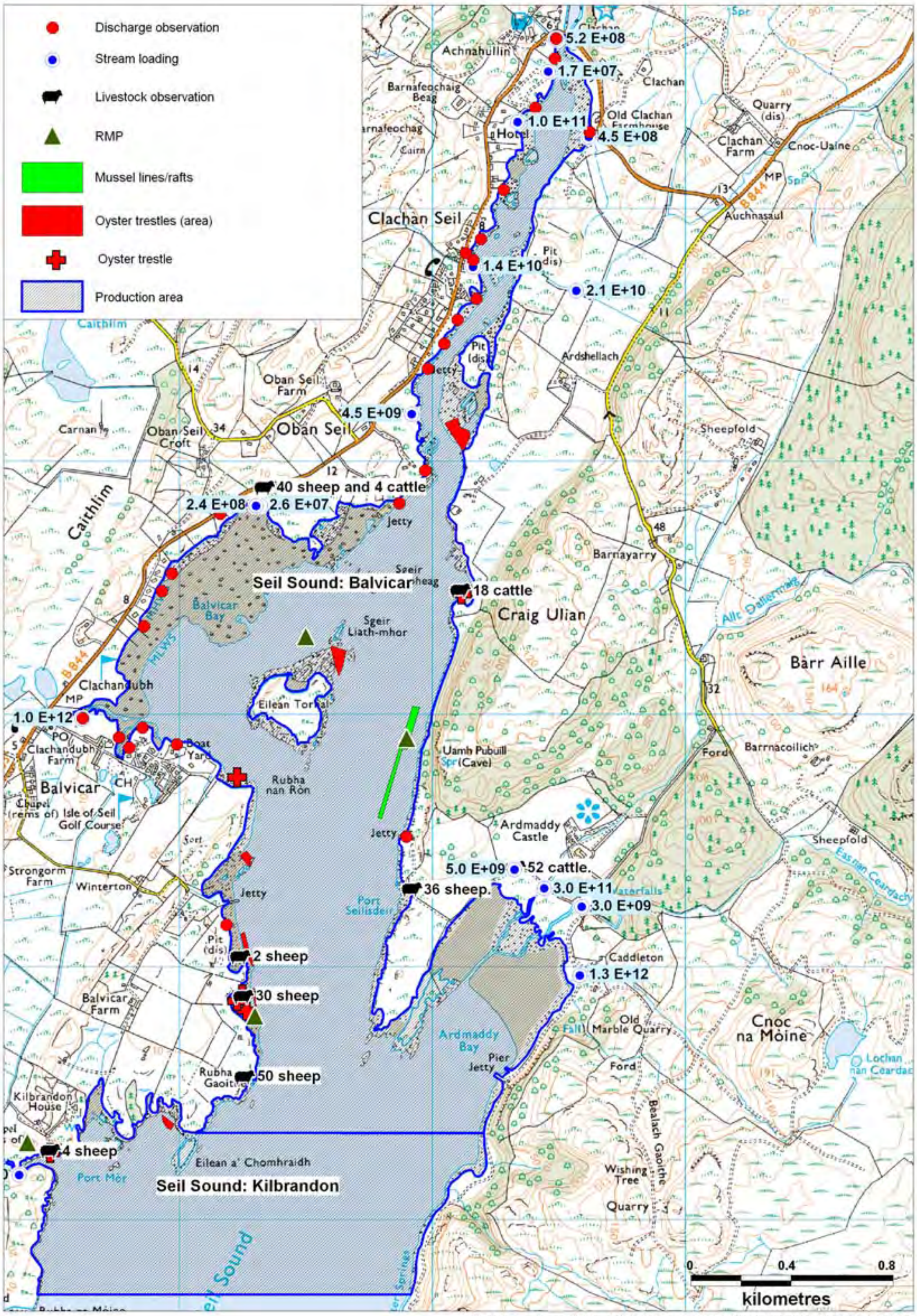


Figure 15.1 Summary of shoreline observations

16. Overall Assessment

Human sewage impacts

Most of the discharges in the area were small private septic tanks, although there were small Scottish Water septic tanks at both Clachan Seil and Balvicar. The majority were spread along the west shore with high concentrations around Clachan Seil and Balvicar. Only two private septic tank discharges were seen on the east shore, but one of these was located about 130 m to the south east of the East of Balvicar mussel site, so may be expected to impact on this site, with greater impacts at the southern end of the site. On the west shore south of Balvicar, where a large proportion of the oyster sites were located, only one small private discharge pipe was seen between the Balvicar and Rubha Nan Ron South sites which was not flowing at the time, but is likely to impact on these two sites when in operation.

At the time of survey, Scottish Water were undertaking a major overhaul of sewage treatment in the area. This scheme was essentially completed by June 2009. The catchment area includes the majority of houses in Clachan Seil and Balvicar, and all but three of the observed discharges fall within this. Although it is not compulsory for households to be connected, a high level of connection is reported and observed during a subsequent visit, although it is probable that a handful of private septic discharges will remain within the catchment area. The new treatment works is a membrane bioreactor (MBR) plant, and so is expected to produce effluent of a high quality (equivalent to tertiary treatment) reducing the overall loading discharged from Clachan Seil and Balvicar to much less than one population equivalent of septic tank discharge.

The treated water will eventually be discharged to just below MLWS towards the north end of Balvicar Bay. This is just under 300 m from the Balvicar North (Island) site. In addition to the treatment works, there will be 6 pumping stations along the pipelines that will have emergency overflows. Four of these are at Clachan Seil, two are at Balvicar, and there is a combined sewer overflow at the treatment works. Modelling works undertaken by Scottish Water predict a very low frequency and volume of spills, and that spills will only occur at the treatment works overflow. Spills will contain a mixture of raw sewage as well as some surface water from domestic sewers such as roof runoff, so are likely to have a significant localised impact on water quality.

Overall, the new scheme should result in a considerable decrease in the amount of indicator bacteria being discharged to the Sound from human sources. Broadly speaking improvements may be expected at most sites, particularly those closest to Clachan Seil (Ardshellach) and Balvicar (Rubha nan Ron South), whereas a minor deterioration may be possible at the site closest to the discharge (Balvicar North), and very occasionally this site may be significantly impacted by spills from the treatment works. Also, a significant increase in viral contamination may occur at this site.

The timing of these improvements poses significant problems in making the monitoring recommendations for this area. The system is due to be completed near or just prior to the time when the recommendations will be implemented, so it is desirable to make recommendations which will reflect the status of Seil Sound post improvement. It is however not appropriate to make firm recommendations in the context of public health protection based on a system which had not yet been fully installed at the time of shoreline survey, and the performance of which cannot be predicted for certain. Shoreline survey and historical *E. coli* monitoring data, which are important considerations when making recommendations, all relate to pre improvement conditions. Therefore, it is desirable that this sanitary survey be reviewed within three years, with particular consideration given to the treatment works performance, spill frequency, and classification monitoring results.

Seil Sound also receives significant boat traffic. Several areas of moorings were seen during the shoreline survey, mainly around Clachan Seil and Balvicar. Some of these were of sufficient size for people to live on board, and most appeared to be pleasure craft. A tour boat based in the sound has a marine toilet that discharges directly to the sea, making it a possible source of contamination when the head is used within the sound. Therefore, higher inputs around Clachan Seil and Balvicar may be anticipated during the summer months, although it is difficult to be precise about potential impacts from these sources.

Agricultural impacts

Agricultural census data for 2008 indicated that agriculture in the neighbouring parishes was dominated by sheep production, with significant numbers of cattle as well. This was confirmed by shoreline survey observations, which were the only source of detailed information relating to the immediate vicinity of Seil Sound. Several areas of pasture on the shores of Seil Sound upon which livestock were observed. At Balvicar Farm, a total of 82 sheep were seen, some of which were on the shore. Therefore, diffuse inputs may be expected all along the shore where the Balvicar site is located. 18 cattle were seen on the shore at Craig Ulian, next the Balvicar North (Craig Ulian) site so some inputs may be expected in this area. At Ardmaddy Castle, 52 cattle and 36 sheep were seen, and these were fenced from the shore so it is likely that streams draining this area will be the most important pathway by which contamination from these is carried into the sound. 40 sheep and 4 cattle were seen just south of Oban Seil, and 4 sheep were seen near the Kilbrandon site. These observations must treated with caution however, as they only apply to the time of survey.

Wildlife impacts

Potential wildlife impacts to the fisheries at Seil Sound include seals, waterfowl, seabirds, deer and otters.

It is reported that a small number of seals (6-7) often haul out on the small rocky islets by the main Balvicar North site during the summer, so although it is likely they forage around all sites on occasion, their impact would likely be greatest at Balvicar North.

Large concentrations of geese (over 100 birds at times) are reported year round but more often during the winter on the golf course just north of Balvicar, around Balvicar farm, and on the mainland around Ardshellach. Therefore, diffuse impacts from geese may be expected at the Ardshellach, Balvicar North (Craig Ulian), Balvicar, and both Rubha Nan Ron sites, although as these animals are highly mobile their presence in any given area will be unpredictable.

An aggregation of 33 ducks and one swan was seen on the shore at Clachan Seil during the shoreline survey, but this is not particularly close to any of the sites, and applied to the day of survey only. Although there are no significant breeding colonies in the area, seabirds are likely to be present, for example about 100 gulls were seen in Ardmaddy Bay during the shoreline survey. These birds are likely to forage in all intertidal areas, and so their impacts are unpredictable.

Deer and otters are likely to be present in the area in small numbers, but again their impacts will be minor and unpredictable in nature.

Seasonal variation

A number of dwellings seen on the shoreline survey were likely to be holiday homes. Coach tours regularly visit the 'Atlantic Bridge' which is a recognised tourist destination. Also, more visiting yachts may be expected during the summer months, so the human population in the area and associated inputs are likely to be higher during the summer.

Livestock populations in the area will increase during the spring as lambs and calves are born, then decrease from the autumn as animals are sent to market. Therefore inputs from livestock are likely to be higher during the summer months.

A small number of seals reside on small islands by the Bavicar North (island) site primarily during the summer months. Geese are present on some areas of grassland by Seil Sound all year round, but are reported to be present more often during the winter.

Significant seasonal differences in historical *E. coli* monitoring results were found at the Balvicar site. Results in the summer were significantly higher than those in the winter and spring, and results in the autumn were significantly higher than in the winter. No seasonal effects on historical *E. coli* monitoring results were seen at the other sites investigated (Balvicar North (Island), Rubha Nan Ron South, Ardshellach, Kilbrandon and East of Balvicar). Quarterly sampling for norovirus found the highest levels and prevalence of norovirus were in quarter 4, when it was detected at all five sites sampled. It was not detected at any of the sites in quarter 3, and was deteced at one site in quarter and at 3 sites in quarter 2. This suggests that there is variation in levels of norovirus contamination throughout the year.

The weather is wetter and windier in the winter months, so more rainfall dependent contamination such as runoff from pastures and discharges from sewer overflows may be expected at these times.

Rivers and streams

The shoreline survey was the only source of information on the bacterial loadings of streams discharging to Seil Sound. These streams drained areas of grassland, woodland and some developed areas, and had widely varying levels of *E. coli* at the time of survey. The total loading contributed by all these streams at the time of survey was 2.8×10^{12} *E. coli* per day, roughly equivalent to a discharge of septic tank treated wastewater from a population of 350. Stream inputs are concentrated around Ardmaddy Bay (58% of the measured stream loadings) and Clachan Sound (36% of the measured stream loadings), with some inputs to Balvicar Bay (5% of measured loadings) and at Kilbrandon (1% of measured loadings).

Ardmaddy Bay, where steams are most concentrated is not particularly close to any of the shellfish sites, but given the amount of freshwater inputs here they are likely to have some effect on water quality in Seil Sound. Shellfish growing waters monitoring results show high levels of contamination in Ardmaddy Bay. Ardmaddy Bay is closest to the Balvicar site, but this is on the opposite shore. Contamination from Ardmaddy Bay may be expected to impact on the East of Balvicar site, which although it is over 1 km away, is also on the east shore.

Streams discharging to Clachan Sound may be expected to have the greatest impact on the Ardshellach site, which is closest. Those discharging to Balvicar Bay may be expected to have the greatest impacts on the Rubha nan Ron South (boatyard) site and possibly Balvicar North (Island).

Also of interest is the stream which discharges to a small partially enclosed bay within which the Kilbrandon site is located, so any contamination carried by this stream would be expected to impact on the Kilbrandon site, and on the Island site to a lesser extent. A much greater range of salinities were recorded at the Kilbrandon site than for any other site when historical *E. coli* samples were collected, indicating that this site has the greatest freshwater influence. The Island site was never sampled.

Following heavy rain, the loadings contributed by these streams would be expected to increase significantly. Streams may be the principal pathways by which diffuse contamination from livestock will be carried into the production areas, and some may have additional inputs from private septic tanks not seen during the survey or listed be SEPA.

Contrary to these predictions, a relationship between recent rainfall and *E. coli* results was only found at the Balvicar site, and not at East of Balvicar, Ardshellach, Rubha Nan Ron South, Balvicar North (Island), and most surprisingly Kilbrandon. A relationship between salinity and historical *E. coli* monitoring results was found at the Balvicar North (Island) site, but this relationship was weak, and unexpectedly results were higher when salinity was higher. This suggests that increasing levels of freshwater inputs do not directly result in measurable increases in *E. coli* in shellfish at most sites.

Meteorology, hydrology, and movement of contaminants

Currents in coastal waters are driven by a combination of tide, wind and freshwater inputs. Freshwater inputs were deemed to be fairly insignificant in relation to tidal exchange for Seil Sound as a whole, so not believed to significantly influence flows around Seil Sound. The effects of winds and tides on the paths of particles emerging from selected existing sewage discharges and streams were modelled. This study showed a strong dependence of transport paths on wind direction, due to the relatively weak tidal currents experienced in some areas, and the open geometry of the sound. Without winds, tidal flows were found to lead to mainly localised transport. Sources north of the Ardshellach site remained entrained within Clachan Sound and did not impact on any sites regardless of wind direction. During north, east or north-easterly winds an anti-clockwise gyre was predicted around Eilean Tor, causing particles released at the northern end of Balvicar Bay to impact on the Balvicar and Rubha nan Ron South sites. For these wind directions, a stream at Oban Seil also impacted on the Balvicar North (Island) site. In contrast, winds blowing from the south, west or south-west were predicted to cause a clockwise circulation around Eilean Tor, leading to transport of particles from sources in Balvicar Bay northwards around Eilean Tor (possibly impacting on the Balvicar North site at Craig Ulian) and then southwards to the East of Balvicar mussel site. Under these conditions, sources at the southward end of Clachan Sound such as the stream at Oban Seil also showed an impact on Balvicar North site at Craig Ulian and the East of Balvicar mussel site. The sources at Ardmaddy Bay showed potential northward travel under these conditions, but did not reach the East of Balvicar mussel site due to the clockwise gyre. The Kilbrandon and Island sites are likely to be impacted by the stream discharging near the Kilbrandon site due to their close proximity. South, west and south-westerly winds will favour an impact here.

The particle tracking study showed that all lease sites can be impacted by potential contaminant sources under certain conditions. The only exception was the Ardshellach site, but as this site is very close to a stream a possible impact cannot be excluded. Some potentially significant inputs were not used in the particle tracking study. These include a private sewer pipe discharging on the east shore just south of the East of Balvicar mussel site, and a private sewer pipe discharging on the west shore between the Rubha nan Ron South and Balvicar sites. These may be expected to impact on the sites adjacent to them under most conditions. The new Scottish Water treatment plant outfall was also not investigated. Given the pattern of residual currents in the area, this may be expected to impact on the Balvicar North (island) site under tide only or west wind conditions, and to be carried towards the south under north and east wind conditions possibly towards the Rubha Nan Ron South sites, and to be carried north and east, then south under south and southwest wind conditions, possibly towards the East of Balvicar site.

Significant rainfall and wind effects on historical *E. coli* monitoring results were only found at the Balvicar site, suggesting that sources and pathways of contamination at this site may be different to the others. The strongest relationship between water temperature and results was found at the Balvicar site, but weaker relationships between result and temperature were also found at the East of Balvicar and Kilbrandon sites. A very weak positive relationship between salinity and results was found at Balvicar North (island). This was not expected as usually increasing freshwater inputs are associated with increasing levels of contamination, and as this site located on a small island in the middle of the Sound it is the least likely to be influenced by freshwater inputs. The effect of the high/low and spring neap tidal cycles on historic *E. coli* monitoring results was not investigated as sampling was targeted towards low water on spring tides.

Temporal and geographical patterns of sampling results

Varying temporal trends were noted in the historic *E. coli* monitoring results at different sites. At Balvicar, there was an apparent deterioration in 2002 and 2003. At Balvicar North (island) there was and apparent improvement since 2005. At Ardshellach, results deteriorated in 2004 and 2005, then improved from 2005. At East of Balvicar, a slight improvement was apparent from 2005, and results appeared to peak during the summer months. At Kilbrandon, results appeared to improve from 2002 to 2004, then deteriorated from 2005 to 2007. Insufficient samples were taken from other sites to investigate overall temporal trends. Overall temporal trends had similarities at the Balvicar North (island), Ardshellach, and East of Balvicar sites (i.e. an improvement from 2005), but the other two sites showed different apparent trends. Reasons for these apparent trends are not known, but they do suggest that sites on the west shore are affected by different sources of contamination, whereas there are some similarities between sites near the east shore, or on the island in the middle of the sound.

Geographic patterns in historic mussel *E. coli* monitoring results could not be investigated as there is only one mussel site, and samples taken from this site were taken from a small area.

Of the eight discrete areas of oyster trestles, three had no *E. coli* monitoring history (Island site, Balvicar North (Craig Ulian), and Rubha Nan Ron (boatyard)). Also, no samples were taken from the Balvicar (Caledonian) trestles, but these are located in close proximity to the Balvicar site, so could be considered an extension of the same site.

Comparisons of historic *E. coli* monitoring results when the oyster sites were sampled on the same day revealed that mean results for Ardshellach and Balvicar North (island) were significantly higher than those for Balvicar, and that results for Ardshellach were significantly higher than for Kilbrandon. No differences were detected between Ardshellach and Balvicar North, or between Balvicar and Kilbrandon. No differences were detected between Rubha nan Ron South and any of the other oyster sites, but this site was sampled on fewer occasions. On this basis, Ardshellach and Balvicar appear to group together, as do Balvicar and Kilbrandon.

How the results fall in relation to threshold levels determines the classification a production area receives. The proportion of results over 230 MPN/100g when four sites were all sampled on the same day were Balvicar North (85%) > Ardshellach (77%) > Balvicar (54%) > Kilbrandon (35%). Balvicar had the highest proportion of results over 4600 MPN/100g (9% overall), and the only two results over 18000 MPN/100g. This analysis generally supports the groupings suggested by the analysis of mean results, except they suggest Kilbrandon and Balvicar are distinct from each other and may receive quite different classifications if monitored separately.

Therefore, of the four oyster sites with sufficient monitoring history to assess whether the results differ sufficiently to potentially justify separate monitoring, Balvicar North (Island) and Ardshellach appear to group together, whereas Balvicar and Kilbrandon appear to group separately from the other two sites and each other.

Norovirus was detected at all sites sampled (Ardshellach, Balvicar North, Rubha nan Ron South, Balvicar and Kilbrandon) on at least one of the four sampling occasions. There appeared to be spatial separation in the November 2008 samples, with genogroup II positive samples coming from the northern sampling locations and genogroup I positive samples coming from the southern sampling locations. However, as this pattern appeared to break down on other sampling dates it is not possible to draw firm conclusions regarding spatial variation in contamination from this data. It is significant to note that human faecal contamination appeared to affect all the sampled sites at some point in the year.

During the course of the shoreline survey, shellfish samples were taken from all sites with stock present. These have been mapped in the shoreline survey report (Appendix 7, Figure 3). Four mussel samples were taken from East of Balvicar, near the surface and the bottom of the ropes at each end. Although differences were small, the samples taken at the southern end, near a private discharge pipe gave the two highest results, and the surface samples gave higher results than those taken from the bottom of the lines at both ends of the site. Oyster samples were taken from Balvicar, both Balvicar North sites, Ardshellach, both Rubha nan Ron sites and Kilbrandon. They gave results of 20 to 750 *E. coli* MPN/100g. The two highest results occurred in oysters taken from the Kilbrandon site and the main Rubha nan Ron site. The sample taken from the Rubha nan Ron South (boatyard) site gave a lower result (310 MPN/100g) than that from the main Rubha nan Ron South site. Intermediate results arose from the Balvicar North (Island) site and the Balvicar site (220 and 200 MPN/100g respectively). The two lowest results occurred in samples taken from the two sites on the east shore (Ardshellach and Balvicar North (Craig Ulian)). The geographical patterns of oyster results generally disagree with those found in the historical *E. coli* monitoring data. Although the reported sampling locations may generally be more accurate for shoreline surveys compared to historic monitoring samples taken prior to 2007 when new protocols were implemented, historic monitoring data can generally be considered to be more representative of between site differences, as samples were collected on multiple occasions under a range of conditions. Therefore, historic monitoring results will be given more weight than shoreline survey results when considering the sampling plan.

E. coli levels in seawater samples taken during the shoreline survey ranged from 1 to 480 cfu/100ml. The highest two results arose from a sample taken at Ardmaddy Bay and in a sample taken alongside a septic tank outflow adjacent to the southern end of the East of Balvicar mussel lines (480 and 230 *E. coli* cfu/100 ml respectively). Salinities ranged from 25.1 ppt in Ardmaddy Bay to 34.3 ppt around the mussel lines, All samples had a salinity of over 30 ppt apart from the sample taken in Ardmaddy Bay, which has more freshwater input than the rest of Seil Sound. Overall, these water sampling results sugest that contamination is highest in Ardmaddy bay, probably as a consequence of the higher level of freshwater inputs here, and that the septic tank outfall by the East of Balvicar site may have significant localised effects on levels of contamination here.

17. Recommendations

It is recommended that Seil Sound be divided into three production areas for oysters, and one production area for mussels. Recommendations are summarised in Figure 17.1.

<u>Seil Sound North (TBA, Pacific oysters)</u>. This production area should include the Ardshellach site, and both Balvicar North sites. Historic *E. coli* monitoring results suggest the Balvicar North (Island) sites and the Ardshellach site could be monitored together. The third site (Balvicar North (Craig Ulian)) has not been sampled, but lies between the two other sites, on the less contaminated eastern shore, so a separate production area for this site cannot be justified. Therefore, the recommended production area boundaries for Seil Sound North (oysters) are an area bounded by lines drawn between NM 7793 1831 and NM 7812 1831 and between NM 7753 1761 and NM 7754 1716 and between NM 7760 1711 and NM 7804 1711 extending to MHWS.

It is recommended that the RMP be placed at the north western extremity of the Balvicar North (Island) site, as this site has historically been slightly more contaminated than the Ardshellach site, and this location would place the RMP closest to the small seal colony and the new Scottish Water discharge. Therefore it is recommended that the RMP be set at NM 7760 1726. Only stock of a harvestable size should be sampled. No sampling depth is applicable, and a sampling tolerance should be set at 10 m. Although no significant seasonal or water temperature effect was found in historic *E. coli* monitoring results for either Balvicar North (Island) or Ardshellach, an element of seasonality in some potential sources is anticipated so it is recommended that monthly monitoring be continued.

<u>Seil Sound: Balvicar (AB 247, Pacific oysters).</u> This production area should include the Balvicar, Balvicar (Caledonian), Rubha nan Ron South and Rubha nan Ron South (Boatyard sites), which essentially form a broken line of trestles spread along about a kilometre of fairly homogeneous shoreline. Therefore, the recommended production area boundaries are lines drawn between NM 7716 1680 and NM 7745 1680 and between NM 7745 1680 and NM 7745 1554 and between NM 7745 1554 and NM 7727 1554 extending to MHWS.

The location of a private sewer pipe and the distribution of livestock suggests the RMP should be set towards the northern end of the Balvicar site, close to the sewer pipe but also capturing the more diffuse inputs from the livestock in this area. Historically some very contaminated samples have been reported from the Balvicar site. It could be argued that the Rubha nan Ron South (Boatyard) site is closer to Balvicar and the boat moorings here, which may cause higher or differing levels of contamination from that experienced at the other sites within this area. Currently this site is only at an experimental stage, so harvesting is unlikely to occur until 2012 at the earliest. Although only one sample was taken from the Rubha nan Ron South (Boatyard) site during the shoreline survey, this did not suggest markedly different levels of contamination here than from anywhere else sampled. On balance, it is therefore recommended that the RMP be set towards the northern end of the Balvicar site, at NM 7725 1612. Only stock of a harvestable size should be sampled. No sampling depth is applicable, and sampling tolerance should be set at 10 m. A significant seasonal effect was found in historic *E. coli* monitoring results for Balvicar, and an element of seasonality in some potential sources within Seil Sound is anticipated so it is recommended that monthly monitoring be continued.

<u>Seil Sound: Kilbrandon (AB 248, Pacific oysters).</u> This production area should include the Kilbrandon and Island sites, which are two adjacent sites within 500 m of each other. It is predicted that both will be affected by the same local source of contamination, namely the stream which discharges just to the west of the Kilbrandon site. There is no reason for the production area to extend outside of Port Mor Bay. Therefore, the recommended production area boundaries are an area inshore of a line drawn between NM 7651 1516 and NM 7705 1534 extending to MHWS.

Of these two sites, the Kilbrandon site is closest and most likely to be affected by the main source in the area, the river which discharges at the western end of the bay, so the RMP should be set at this site. Therefore it is recommended that the RMP be established at NM 7649 1526. Only stock of a harvestable size should be sampled. No sampling depth is applicable, and a sampling tolerance should be set at 10 m. Although no significant seasonal effect was found in historic *E. coli* monitoring results for Kilbrandon, an element of seasonality in some potential sources is anticipated so it is recommended that monthly monitoring be continued.

Neither of the sites within this production area are currently harvesting commercially. Although restocking is planned at both sites, the earliest that harvesting is likely to occur is in 2012. Therefore, it is recommended that the area be declassified until the sites are nearer production.

<u>Seil Sound: East (TBA, common mussels).</u> There is only one mussel farm in Seil Sound, and it is recommended that boundaries are set to allow for movement of the site in winds and tides, and some expansion, but to exclude other potentially more contaminated areas. Although the Rubha nan Ron site is listed as a mussel site in the classification document, mussels have never been cultured at this site, so the boundaries need not include this site. Therefore, the recommended production area boundaries are lines drawn between NM 7804 1711 and NM 7769 1710 and between NM 7769 1710 and NM 7770 1652 and between NM 7770 1652 and NM 7790 1653 extending to MHWS.

Shellfish samples taken during the shoreline survey at the southern end of the site gave the highest results, and the surface samples gave higher results than those taken from the bottom of the lines at both ends of the site. The southern end of the site is closer to a small septic tank discharge, which may be expected to impact on the fishery, as well as possibly the freshwater inputs at Ardmaddy Bay. Therefore it is recommended that the RMP be set at NM

7780 1659. Sampling depth should be 1 m to capture any contamination in the fresher water at the surface. Sampling tolerance should be set at 20 m to allow for some movement of the lines with tide and wind.

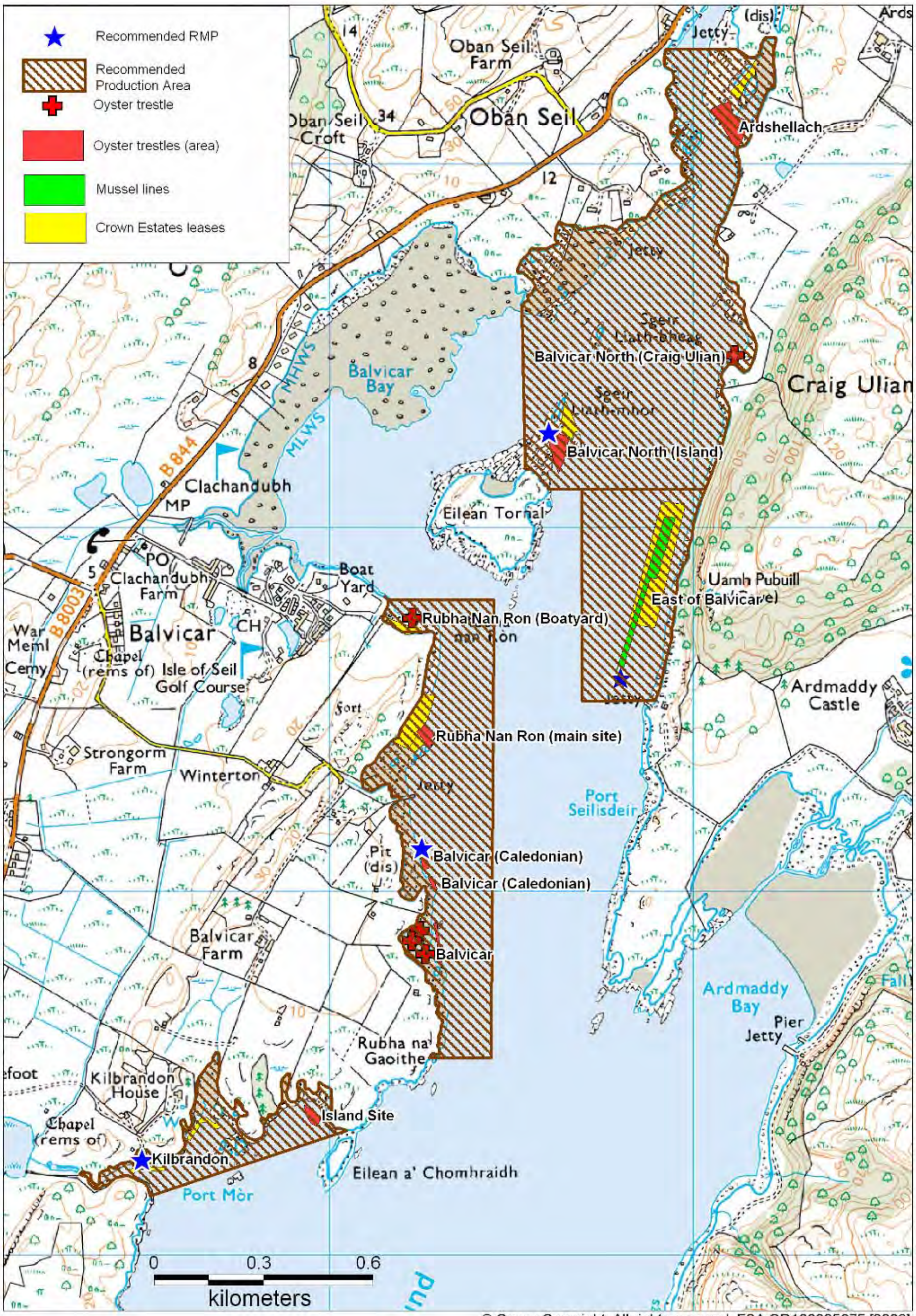


Figure 17.1 Recommendations for Seil Sound

Due to the large changes to sewage infrastructure in the area, it is recommended that the sanitary survey recommendations be reviewed in three years time, with particular consideration given to the new treatment works performance, its spill frequency, any changes in the status of the fisheries, and classification monitoring results.

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Sampling Plan for Seil Sound

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
Seil Sound North	Ardshellach, Balvicar North (Craig Ulian), Balvicar North (Island)	TBA	Pacific oyster	Trestle	NM 7760 1726	177600	717260	10	NA	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan
Seil Sound Balvicar	Balvicar, Balvicar (Caldonian), Rubha nan Ron South, Rubha nan Ron South (Boatyard)	AB 247	Pacific oyster	Trestle	NM 7725 1612	177250	716120	10	NA	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan
* Seil Sound Kilbrandon	Kilbrandon, Island site	AB 248	Pacific oyster	Trestle	NM 7649 1526	176490	715260	10	NA	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan
Seil Sound East	East fo Balvicar	TBA	Mussel	Rope	NM 7780 1659	177800	716590	20	1	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan

* Recommend declassification of Seil Sound Kilbrandon until site is nearer commercial production (anticipated 2012).

Table of Proposed Boundaries and RMPs – Seil Sound

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Seil Sound North	Pacific oysters	Previously AB 247 071 and AB 247 735 New Prod Area TBA	Area bounded by lines drawn between NM 7851 1969 and NM 7854 1968 and NM 7707 1534 and NM 7821 1534.	NM 775 173 NM 773 158	Area bounded by lines drawn between NM 7793 1831 and NM 7812 1831 and between NM 7753 1761 and NM 7754 1716 and between NM 7760 1711 and NM 7804 1711 extending to MHWS.	NM 7760 1726	Part of former Seil Sound Balvicar production area, includes Ardshellach, Balvicar North (Island) and Balvicar North (Craig Ulian) sites
Seil Sound Balvicar	Pacific oyster	AB 247 728 AB 247 072	Area bounded by lines drawn between NM 7851 1969 and NM 7854 1968 and NM 7707 1534 and NM 7821 1534.	NM 775 173 NM 773 158	Area bounded by lines drawn between NM 7716 1680 and NM 7745 1680 and between NM 7745 1680 and NM 7745 1554 and between NM 7745 1554 and NM 7727 1554 extending to MHWS.	NM 7725 1612	Area reduced, now only includes the Balvicar and two Rubha nan Ron South sites
Seil Sound Kilbrandon	Pacific oysters	AB 248 073	Area bounded by lines drawn between NM 7707 1534 and NM 7821 1534 between NM 7644 1470 (Rubha na Moine) and NM 7791 1470	NM 764 153	Area inshore of a line drawn between NM 7651 1516 and NM 7705 1534 extending to MHWS.	NM 7649 1526	Boundaries reduced to include Port Mor Bay only, still includes Kilbrandon and Island site sites. Recommend declassification until nearer production (Ant 2012).
Seil Sound East	Common mussels	Previously AB 247 703 New Prod Area TBA	Area bounded by lines drawn between NM 7851 1969 and NM 7854 1968 and NM 7707 1534 and NM 7821 1534.	NM 779 169	Area bounded by lines drawn between NM 7804 1711 and NM 7769 1710 and between NM 7769 1710 and NM 7770 1652 and between NM 7770 1652 and NM 7790 1653 extending to MHWS.	NM 7780 1659	Part of former Seil Sound Balvicar production area. Area reduced. Still contains East of Balvicar site.

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 1.21×10^4 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:

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Tables of Typical Faecal Bacteria Concentrations

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

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 2 way ANOVA comparison of results when five oyster sites were sampled on the same day

```
Factor       Type   Levels  Values
Site         fixed       5  Ardshellach, Balvicar, Balvicar North, Kilbrandon,
                            Rubha nan Ron South
CollectDate  fixed       8  21/09/2005, 02/11/2005, 16/11/2005, 01/02/2006,
                            01/03/2006, 29/03/2006, 14/06/2006, 09/08/2006

Analysis of Variance for logresult, using Adjusted SS for Tests

Source       DF   Seq SS  Adj SS  Adj MS     F      P
Site          4   3.8855  3.8855  0.9714  5.15  0.003
CollectDate   7   6.1684  6.1684  0.8812  4.67  0.001
Error        28   5.2782  5.2782  0.1885
Total        39  15.3321

S = 0.434172   R-Sq = 65.57%   R-Sq(adj) = 52.05%

Unusual Observations for logresult

Obs  logresult      Fit   SE Fit  Residual  St Resid
 15    1.00000  2.10846  0.23781  -1.10846     -3.05 R
 17    1.00000  1.78270  0.23781  -0.78270     -2.15 R

R denotes an observation with a large standardized residual.

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable logresult
All Pairwise Comparisons among Levels of Site

Site = Ardshellach  subtracted from:

Site                  Lower   Center      Upper
Balvicar             -1.265  -0.6327  -0.000291
Balvicar North       -0.354   0.2783   0.910733
Kilbrandon           -0.973  -0.3410   0.291437
Rubha nan Ron South  -0.931  -0.2989   0.333496

Site                 ------+---------+---------+---------+
Balvicar             (-------*-------)
Balvicar North                   (------*-------)
Kilbrandon               (-------*-------)
Rubha nan Ron South      (-------*-------)
                     ------+---------+---------+---------+
                        -0.80      0.00      0.80      1.60

Site = Balvicar  subtracted from:

Site                   Lower  Center   Upper
Balvicar North        0.2786  0.9110  1.5435
Kilbrandon           -0.3407  0.2917  0.9242
Rubha nan Ron South  -0.2986  0.3338  0.9662

Site                 ------+---------+---------+---------+
Balvicar North                          (-------*-------)
Kilbrandon                       (-------*-------)
Rubha nan Ron South              (-------*-------)
                     ------+---------+---------+---------+
                        -0.80      0.00      0.80      1.60

Site = Balvicar North  subtracted from:
```

Site	Lower	Center	Upper
Kilbrandon	-1.252	-0.6193	0.01314
Rubha nan Ron South	-1.210	-0.5772	0.05520

```
Site                 ------+---------+---------+---------+
Kilbrandon           (-------*-------)
Rubha nan Ron South   (-------*-------)
                     ------+---------+---------+---------+
                        -0.80      0.00      0.80      1.60
```

Site = Kilbrandon subtracted from:

Site	Lower	Center	Upper
Rubha nan Ron South	-0.5904	0.04206	0.6745

```
Site                 ------+---------+---------+---------+
Rubha nan Ron South           (-------*------)
                     ------+---------+---------+---------+
                        -0.80      0.00      0.80      1.60
```

Tukey Simultaneous Tests
Response Variable logresult
All Pairwise Comparisons among Levels of Site

Site = Ardshellach subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Balvicar	-0.6327	0.2171	-2.915	0.0499
Balvicar North	0.2783	0.2171	1.282	0.7041
Kilbrandon	-0.3410	0.2171	-1.571	0.5275
Rubha nan Ron South	-0.2989	0.2171	-1.377	0.6468

Site = Balvicar subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Balvicar North	0.9110	0.2171	4.197	0.0021
Kilbrandon	0.2917	0.2171	1.344	0.6670
Rubha nan Ron South	0.3338	0.2171	1.538	0.5478

Site = Balvicar North subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Kilbrandon	-0.6193	0.2171	-2.853	0.0572
Rubha nan Ron South	-0.5772	0.2171	-2.659	0.0865

Site = Kilbrandon subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Rubha nan Ron South	0.04206	0.2171	0.1937	0.9997

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable logresult
All Pairwise Comparisons among Levels of CollectDate

```
CollectDate = 21/09/2005  subtracted from:

CollectDate   Lower  Center    Upper  -------+---------+---------+---------
02/11/2005   -1.416  -0.517   0.3817       (-------*------)
16/11/2005   -1.924  -1.025  -0.1261   (------*-------)
01/02/2006   -1.958  -1.059  -0.1601   (------*-------)
01/03/2006   -1.893  -0.994  -0.0950   (-------*------)
29/03/2006   -2.068  -1.169  -0.2701  (------*-------)
14/06/2006   -1.770  -0.871   0.0276    (-------*------)
09/08/2006   -1.206  -0.307   0.5920         (------*-------)
                                      -------+---------+---------+---------
                                          -1.2       0.0       1.2
```

```
CollectDate = 02/11/2005  subtracted from:

CollectDate   Lower   Center   Upper  -------+---------+---------+---------
16/11/2005   -1.407  -0.5078  0.3912       (-------*------)
01/02/2006   -1.441  -0.5419  0.3571       (------*-------)
01/03/2006   -1.376  -0.4767  0.4223        (------*-------)
29/03/2006   -1.551  -0.6519  0.2471      (-------*------)
14/06/2006   -1.253  -0.3542  0.5448         (------*-------)
09/08/2006   -0.689   0.2102  1.1092             (-------*------)
                                      -------+---------+---------+---------
                                          -1.2       0.0       1.2
```

```
CollectDate = 16/11/2005  subtracted from:

CollectDate   Lower   Center   Upper  -------+---------+---------+---------
01/02/2006   -0.933  -0.0340  0.8650           (-------*------)
01/03/2006   -0.868   0.0311  0.9301            (------*-------)
29/03/2006   -1.043  -0.1440  0.7550          (-------*------)
14/06/2006   -0.745   0.1537  1.0527             (------*-------)
09/08/2006   -0.181   0.7181  1.6171                 (-------*------)
                                      -------+---------+---------+---------
                                          -1.2       0.0       1.2
```

```
CollectDate = 01/02/2006  subtracted from:

CollectDate   Lower   Center   Upper  -------+---------+---------+---------
01/03/2006   -0.834   0.0652  0.9642            (-------*------)
29/03/2006   -1.009  -0.1100  0.7890           (------*-------)
14/06/2006   -0.711   0.1877  1.0867             (-------*------)
09/08/2006   -0.147   0.7521  1.6511                  (------*-------)
                                      -------+---------+---------+---------
                                          -1.2       0.0       1.2
```

```
CollectDate = 01/03/2006  subtracted from:

CollectDate   Lower   Center   Upper  -------+---------+---------+---------
29/03/2006   -1.074  -0.1752  0.7238          (-------*------)
14/06/2006   -0.776   0.1225  1.0215             (------*-------)
09/08/2006   -0.212   0.6869  1.5859                 (-------*------)
                                      -------+---------+---------+---------
                                          -1.2       0.0       1.2
```

```
CollectDate = 29/03/2006  subtracted from:

CollectDate    Lower  Center  Upper  -------+---------+---------+---------
14/06/2006   -0.6013  0.2977  1.197              (------*-------)
09/08/2006   -0.0369  0.8621  1.761                   (------*-------)
                                     -------+---------+---------+---------
                                         -1.2       0.0       1.2
```

```
CollectDate = 14/06/2006  subtracted from:

CollectDate    Lower  Center  Upper  -------+---------+---------+---------
09/08/2006   -0.3346  0.5644  1.463                (-------*------)
                                     -------+---------+---------+---------
                                         -1.2       0.0       1.2
```

Tukey Simultaneous Tests
Response Variable logresult
All Pairwise Comparisons among Levels of CollectDate
CollectDate = 21/09/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
02/11/2005	-0.517	0.2746	-1.884	0.5723
16/11/2005	-1.025	0.2746	-3.733	0.0169
01/02/2006	-1.059	0.2746	-3.857	0.0124
01/03/2006	-0.994	0.2746	-3.620	0.0222
29/03/2006	-1.169	0.2746	-4.258	0.0045
14/06/2006	-0.871	0.2746	-3.174	0.0620
09/08/2006	-0.307	0.2746	-1.118	0.9473

CollectDate = 02/11/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
16/11/2005	-0.5078	0.2746	-1.849	0.5940
01/02/2006	-0.5419	0.2746	-1.973	0.5161
01/03/2006	-0.4767	0.2746	-1.736	0.6651
29/03/2006	-0.6519	0.2746	-2.374	0.2921
14/06/2006	-0.3542	0.2746	-1.290	0.8951
09/08/2006	0.2102	0.2746	0.766	0.9936

CollectDate = 16/11/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
01/02/2006	-0.0340	0.2746	-0.1239	1.0000
01/03/2006	0.0311	0.2746	0.1134	1.0000
29/03/2006	-0.1440	0.2746	-0.5245	0.9994
14/06/2006	0.1537	0.2746	0.5597	0.9991
09/08/2006	0.7181	0.2746	2.6151	0.1925

CollectDate = 01/02/2006 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
01/03/2006	0.0652	0.2746	0.2373	1.0000
29/03/2006	-0.1100	0.2746	-0.4006	0.9999
14/06/2006	0.1877	0.2746	0.6836	0.9968
09/08/2006	0.7521	0.2746	2.7390	0.1525

CollectDate = 01/03/2006 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
29/03/2006	-0.1752	0.2746	-0.6379	0.9979
14/06/2006	0.1225	0.2746	0.4463	0.9998
09/08/2006	0.6869	0.2746	2.5017	0.2357

CollectDate = 29/03/2006 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
14/06/2006	0.2977	0.2746	1.084	0.9550
09/08/2006	0.8621	0.2746	3.140	0.0668

CollectDate = 14/06/2006 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
09/08/2006	0.5644	0.2746	2.055	0.4657

Section 11.3 2 way ANOVA comparison of results when four oyster sites were sampled on the same day

```
Factor       Type   Levels  Values
Site         fixed       4  Ardshellach, Balvicar, Balvicar North, Kilbrandon
CollectDate  fixed      26  21/01/2004, 24/03/2004, 21/04/2004, 05/05/2004,
                            02/06/2004, 05/07/2004, 04/08/2004, 15/09/2004,
                            13/10/2004, 15/11/2004, 09/02/2005, 09/03/2005,
                            27/04/2005, 25/05/2005, 22/06/2005, 20/07/2005,
                            22/08/2005, 05/09/2005, 21/09/2005, 02/11/2005,
                            16/11/2005, 01/02/2006, 01/03/2006, 29/03/2006,
                            14/06/2006, 09/08/2006

Analysis of Variance for logresult, using Adjusted SS for Tests

Source        DF   Seq SS   Adj SS  Adj MS      F      P
Site           3  11.2591  11.2591  3.7530  10.08  0.000
CollectDate   25  20.4132  20.4132  0.8165   2.19  0.005
Error         75  27.9119  27.9119  0.3722
Total        103  59.5842

S = 0.610048   R-Sq = 53.16%   R-Sq(adj) = 35.67%

Unusual Observations for logresult

Obs  logresult      Fit   SE Fit  Residual  St Resid
 18    3.95904  2.28148  0.32214   1.67756      3.24 R
 22    2.87506  1.81880  0.32214   1.05626      2.04 R
 71    1.30103  2.41522  0.32214  -1.11419     -2.15 R
 86    1.00000  2.06350  0.32214  -1.06350     -2.05 R

R denotes an observation with a large standardized residual.

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable logresult
All Pairwise Comparisons among Levels of Site

Site = Ardshellach  subtracted from:

Site             Lower   Center    Upper  ---------+---------+---------+------
-
Balvicar        -0.780  -0.3354   0.1097          (-----*------)
Balvicar North  -0.276   0.1692   0.6142                 (-----*------)
Kilbrandon      -1.134  -0.6891  -0.2440     (-----*------)
                                          ---------+---------+---------+------
-
                                               -0.70      0.00      0.70
Site = Balvicar  subtracted from:

Site             Lower   Center    Upper
Balvicar North  0.0595   0.5046  0.94965
Kilbrandon     -0.7987  -0.3536  0.09141

Site            ---------+---------+---------+-------
Balvicar North                      (-----*------)
Kilbrandon              (-----*-----)
                ---------+---------+---------+-------
                      -0.70      0.00      0.70

Site = Balvicar North  subtracted from:

Site         Lower   Center    Upper  ---------+---------+---------+-------
Kilbrandon  -1.303  -0.8582  -0.4132  (------*-----)
                                      ---------+---------+---------+-------
                                           -0.70      0.00      0.70
```

Tukey Simultaneous Tests
Response Variable logresult
All Pairwise Comparisons among Levels of Site

Site = Ardshellach subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Balvicar	-0.3354	0.1692	-1.982	0.2038
Balvicar North	0.1692	0.1692	1.000	0.7499
Kilbrandon	-0.6891	0.1692	-4.073	0.0007

Site = Balvicar subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Balvicar North	0.5046	0.1692	2.982	0.0198
Kilbrandon	-0.3536	0.1692	-2.090	0.1657

Site = Balvicar North subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Kilbrandon	-0.8582	0.1692	-5.072	0.0000

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable logresult
All Pairwise Comparisons among Levels of CollectDate

CollectDate = 21/01/2004 subtracted from:

```
CollectDate   Lower    Center  Upper  ------+---------+---------+---------+
24/03/2004   -1.396   0.25078  1.898           (-------*-------)
21/04/2004   -0.684   0.96351  2.611               (-------*-------)
05/05/2004   -0.670   0.97692  2.624               (-------*-------)
02/06/2004   -1.141   0.50608  2.153            (--------*-------)
05/07/2004   -1.604   0.04340  1.691          (-------*-------)
04/08/2004   -0.218   1.42869  3.076                 (-------*-------)
15/09/2004   -0.817   0.83035  2.477              (-------*-------)
13/10/2004   -1.723  -0.07605  1.571         (--------*-------)
15/11/2004   -1.308   0.33963  1.987           (--------*-------)
09/02/2005   -1.308   0.33963  1.987           (--------*-------)
09/03/2005   -1.439   0.20780  1.855           (-------*-------)
27/04/2005   -0.912   0.73550  2.383             (--------*-------)
25/05/2005   -0.950   0.69748  2.345             (-------*--------)
22/06/2005   -0.131   1.51603  3.163                 (--------*-------)
20/07/2005   -0.682   0.96528  2.612               (-------*-------)
22/08/2005   -1.264   0.38352  2.031            (-------*-------)
05/09/2005   -1.512   0.13523  1.782          (--------*-------)
21/09/2005   -0.257   1.39002  3.037                 (-------*-------)
02/11/2005   -0.719   0.92821  2.575              (--------*-------)
16/11/2005   -1.354   0.29340  1.941           (-------*--------)
01/02/2006   -1.359   0.28811  1.935           (-------*--------)
01/03/2006   -1.315   0.33232  1.979           (--------*-------)
29/03/2006   -1.336   0.31146  1.959           (--------*-------)
14/06/2006   -0.939   0.70783  2.355             (--------*-------)
09/08/2006   -0.612   1.03536  2.682               (-------*-------)
                                      ------+---------+---------+---------+
                                         -2.0       0.0       2.0       4.0
```

```
CollectDate = 24/03/2004  subtracted from:

CollectDate   Lower   Center  Upper  ------+---------+---------+---------+
21/04/2004   -0.934   0.7127  2.360             (--------*-------)
05/05/2004   -0.921   0.7261  2.373             (--------*-------)
02/06/2004   -1.392   0.2553  1.902           (-------*--------)
05/07/2004   -1.855  -0.2074  1.440         (-------*-------)
04/08/2004   -0.469   1.1779  2.825                (-------*-------)
15/09/2004   -1.068   0.5796  2.227             (-------*-------)
13/10/2004   -1.974  -0.3268  1.320        (-------*--------)
15/11/2004   -1.558   0.0888  1.736          (-------*--------)
09/02/2005   -1.558   0.0888  1.736          (-------*--------)
09/03/2005   -1.690  -0.0430  1.604          (-------*-------)
27/04/2005   -1.162   0.4847  2.132            (-------*--------)
25/05/2005   -1.200   0.4467  2.094            (-------*-------)
22/06/2005   -0.382   1.2652  2.912                (-------*--------)
20/07/2005   -0.933   0.7145  2.362             (--------*-------)
22/08/2005   -1.514   0.1327  1.780          (--------*-------)
05/09/2005   -1.763  -0.1156  1.532         (-------*--------)
21/09/2005   -0.508   1.1392  2.786               (--------*-------)
02/11/2005   -0.970   0.6774  2.325             (-------*--------)
16/11/2005   -1.605   0.0426  1.690          (-------*-------)
01/02/2006   -1.610   0.0373  1.684          (-------*-------)
01/03/2006   -1.566   0.0815  1.729          (-------*--------)
29/03/2006   -1.586   0.0607  1.708          (-------*--------)
14/06/2006   -1.190   0.4570  2.104            (-------*--------)
09/08/2006   -0.863   0.7846  2.432              (-------*-------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0


CollectDate = 21/04/2004  subtracted from:

CollectDate   Lower  Center   Upper  ------+---------+---------+---------+
05/05/2004   -1.634   0.013  1.6605          (-------*-------)
02/06/2004   -2.105  -0.457  1.1897       (--------*-------)
05/07/2004   -2.567  -0.920  0.7270     (-------*--------)
04/08/2004   -1.182   0.465  2.1123            (-------*--------)
15/09/2004   -1.780  -0.133  1.5140         (-------*--------)
13/10/2004   -2.687  -1.040  0.6076     (-------*-------)
15/11/2004   -2.271  -0.624  1.0233       (-------*-------)
09/02/2005   -2.271  -0.624  1.0233       (-------*-------)
09/03/2005   -2.403  -0.756  0.8914      (-------*-------)
27/04/2005   -1.875  -0.228  1.4191         (-------*-------)
25/05/2005   -1.913  -0.266  1.3811        (--------*-------)
22/06/2005   -1.095   0.553  2.1997             (-------*-------)
20/07/2005   -1.645   0.002  1.6489          (-------*-------)
22/08/2005   -2.227  -0.580  1.0671       (-------*-------)
05/09/2005   -2.475  -0.828  0.8189      (-------*-------)
21/09/2005   -1.221   0.427  2.0736            (-------*-------)
02/11/2005   -1.682  -0.035  1.6118          (-------*-------)
16/11/2005   -2.317  -0.670  0.9770      (--------*-------)
01/02/2006   -2.323  -0.675  0.9717      (--------*-------)
01/03/2006   -2.278  -0.631  1.0159       (-------*-------)
29/03/2006   -2.299  -0.652  0.9951       (-------*-------)
14/06/2006   -1.903  -0.256  1.3914        (--------*-------)
09/08/2006   -1.575   0.072  1.7190          (-------*--------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0
```

```
CollectDate = 05/05/2004  subtracted from:

CollectDate   Lower  Center   Upper  ------+---------+---------+---------+
02/06/2004   -2.118  -0.471  1.1763       (--------*-------)
05/07/2004   -2.581  -0.934  0.7136     (-------*--------)
04/08/2004   -1.195   0.452  2.0989            (-------*-------)
15/09/2004   -1.794  -0.147  1.5006         (-------*--------)
13/10/2004   -2.700  -1.053  0.5942    (--------*-------)
15/11/2004   -2.284  -0.637  1.0098       (-------*-------)
09/02/2005   -2.284  -0.637  1.0098       (-------*-------)
09/03/2005   -2.416  -0.769  0.8780      (-------*-------)
27/04/2005   -1.889  -0.241  1.4057         (-------*-------)
25/05/2005   -1.927  -0.279  1.3677        (--------*-------)
22/06/2005   -1.108   0.539  2.1862            (--------*-------)
20/07/2005   -1.659  -0.012  1.6355          (-------*-------)
22/08/2005   -2.241  -0.593  1.0537       (-------*-------)
05/09/2005   -2.489  -0.842  0.8054      (-------*-------)
21/09/2005   -1.234   0.413  2.0602            (-------*-------)
02/11/2005   -1.696  -0.049  1.5984          (-------*-------)
16/11/2005   -2.331  -0.684  0.9636      (--------*-------)
01/02/2006   -2.336  -0.689  0.9583      (--------*-------)
01/03/2006   -2.292  -0.645  1.0025       (-------*-------)
29/03/2006   -2.313  -0.665  0.9817      (--------*-------)
14/06/2006   -1.916  -0.269  1.3780        (--------*-------)
09/08/2006   -1.589   0.058  1.7056          (-------*--------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0
```

```
CollectDate = 02/06/2004  subtracted from:

CollectDate   Lower   Center  Upper  ------+---------+---------+---------+
05/07/2004   -2.110  -0.4627  1.184       (--------*-------)
04/08/2004   -0.725   0.9226  2.570              (--------*-------)
15/09/2004   -1.323   0.3243  1.971           (--------*-------)
13/10/2004   -2.229  -0.5821  1.065       (-------*-------)
15/11/2004   -1.814  -0.1665  1.481         (-------*-------)
09/02/2005   -1.814  -0.1665  1.481         (-------*-------)
09/03/2005   -1.945  -0.2983  1.349        (--------*-------)
27/04/2005   -1.418   0.2294  1.877           (-------*-------)
25/05/2005   -1.456   0.1914  1.839           (-------*-------)
22/06/2005   -0.637   1.0099  2.657               (-------*-------)
20/07/2005   -1.188   0.4592  2.106            (-------*--------)
22/08/2005   -1.770  -0.1226  1.525         (-------*--------)
05/09/2005   -2.018  -0.3709  1.276        (-------*-------)
21/09/2005   -0.763   0.8839  2.531              (-------*--------)
02/11/2005   -1.225   0.4221  2.069            (-------*-------)
16/11/2005   -1.860  -0.2127  1.434         (-------*-------)
01/02/2006   -1.865  -0.2180  1.429         (-------*-------)
01/03/2006   -1.821  -0.1738  1.473         (-------*-------)
29/03/2006   -1.842  -0.1946  1.453         (-------*-------)
14/06/2006   -1.445   0.2017  1.849           (-------*-------)
09/08/2006   -1.118   0.5293  2.176            (--------*-------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0
```

```
CollectDate = 05/07/2004  subtracted from:

CollectDate   Lower   Center  Upper  ------+---------+---------+---------+
04/08/2004   -0.262   1.3853  3.032               (-------*-------)
15/09/2004   -0.860   0.7869  2.434            (-------*-------)
13/10/2004   -1.767  -0.1194  1.528       (-------*--------)
15/11/2004   -1.351   0.2962  1.943         (-------*--------)
09/02/2005   -1.351   0.2962  1.943         (-------*--------)
09/03/2005   -1.483   0.1644  1.812         (-------*-------)
27/04/2005   -0.955   0.6921  2.339           (-------*--------)
25/05/2005   -0.993   0.6541  2.301           (-------*--------)
22/06/2005   -0.175   1.4726  3.120               (-------*--------)
20/07/2005   -0.725   0.9219  2.569            (--------*-------)
22/08/2005   -1.307   0.3401  1.987         (--------*-------)
05/09/2005   -1.555   0.0918  1.739        (-------*--------)
21/09/2005   -0.301   1.3466  2.994              (--------*-------)
02/11/2005   -0.762   0.8848  2.532            (-------*--------)
16/11/2005   -1.397   0.2500  1.897         (-------*-------)
01/02/2006   -1.402   0.2447  1.892         (-------*-------)
01/03/2006   -1.358   0.2889  1.936         (-------*--------)
29/03/2006   -1.379   0.2681  1.915         (-------*--------)
14/06/2006   -0.983   0.6644  2.312           (-------*--------)
09/08/2006   -0.655   0.9920  2.639             (-------*-------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0


CollectDate = 04/08/2004  subtracted from:

CollectDate   Lower  Center   Upper  ------+---------+---------+---------+
15/09/2004   -2.245  -0.598  1.0488      (-------*-------)
13/10/2004   -3.152  -1.505  0.1424  (-------*--------)
15/11/2004   -2.736  -1.089  0.5581    (--------*-------)
09/02/2005   -2.736  -1.089  0.5581    (--------*-------)
09/03/2005   -2.868  -1.221  0.4262    (-------*-------)
27/04/2005   -2.340  -0.693  0.9539      (--------*-------)
25/05/2005   -2.378  -0.731  0.9159      (-------*--------)
22/06/2005   -1.560   0.087  1.7345          (-------*--------)
20/07/2005   -2.111  -0.463  1.1837       (--------*-------)
22/08/2005   -2.692  -1.045  0.6020     (-------*-------)
05/09/2005   -2.941  -1.293  0.3537   (--------*-------)
21/09/2005   -1.686  -0.039  1.6085          (-------*-------)
02/11/2005   -2.148  -0.500  1.1466       (-------*--------)
16/11/2005   -2.782  -1.135  0.5118    (-------*--------)
01/02/2006   -2.788  -1.141  0.5065    (-------*--------)
01/03/2006   -2.744  -1.096  0.5508    (--------*-------)
29/03/2006   -2.764  -1.117  0.5299    (-------*--------)
14/06/2006   -2.368  -0.721  0.9263      (-------*--------)
09/08/2006   -2.040  -0.393  1.2538        (-------*-------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0
```

```
CollectDate = 15/09/2004  subtracted from:

CollectDate   Lower   Center   Upper  ------+---------+---------+---------+
13/10/2004   -2.554  -0.9064  0.7407     (-------*--------)
15/11/2004   -2.138  -0.4907  1.1564       (--------*-------)
09/02/2005   -2.138  -0.4907  1.1564       (--------*-------)
09/03/2005   -2.270  -0.6226  1.0246       (-------*-------)
27/04/2005   -1.742  -0.0948  1.5523         (--------*-------)
25/05/2005   -1.780  -0.1329  1.5143         (-------*--------)
22/06/2005   -0.961   0.6857  2.3328             (-------*--------)
20/07/2005   -1.512   0.1349  1.7821          (--------*-------)
22/08/2005   -2.094  -0.4468  1.2003        (-------*-------)
05/09/2005   -2.342  -0.6951  0.9520      (--------*-------)
21/09/2005   -1.087   0.5597  2.2068             (-------*-------)
02/11/2005   -1.549   0.0979  1.7450          (-------*--------)
16/11/2005   -2.184  -0.5369  1.1102       (-------*--------)
01/02/2006   -2.189  -0.5422  1.1049       (-------*--------)
01/03/2006   -2.145  -0.4980  1.1491       (--------*-------)
29/03/2006   -2.166  -0.5189  1.1282       (-------*--------)
14/06/2006   -1.770  -0.1225  1.5246         (-------*--------)
09/08/2006   -1.442   0.2050  1.8521           (-------*-------)
                                      ------+---------+---------+---------+
                                         -2.0       0.0       2.0       4.0

CollectDate = 13/10/2004  subtracted from:

CollectDate   Lower  Center  Upper  ------+---------+---------+---------+
15/11/2004   -1.231  0.4157  2.063            (-------*-------)
09/02/2005   -1.231  0.4157  2.063            (-------*-------)
09/03/2005   -1.363  0.2838  1.931           (-------*--------)
27/04/2005   -0.836  0.8115  2.459              (-------*-------)
25/05/2005   -0.874  0.7735  2.421              (-------*-------)
22/06/2005   -0.055  1.5921  3.239                  (-------*-------)
20/07/2005   -0.606  1.0413  2.688               (-------*-------)
22/08/2005   -1.188  0.4596  2.107            (-------*--------)
05/09/2005   -1.436  0.2113  1.858           (-------*-------)
21/09/2005   -0.181  1.4661  3.113                 (-------*--------)
02/11/2005   -0.643  1.0043  2.651               (-------*-------)
16/11/2005   -1.278  0.3694  2.017            (-------*-------)
01/02/2006   -1.283  0.3642  2.011            (-------*-------)
01/03/2006   -1.239  0.4084  2.055            (-------*-------)
29/03/2006   -1.260  0.3875  2.035            (-------*-------)
14/06/2006   -0.863  0.7839  2.431              (-------*-------)
09/08/2006   -0.536  1.1114  2.759               (--------*-------)
                                    ------+---------+---------+---------+
                                       -2.0       0.0       2.0       4.0

CollectDate = 15/11/2004  subtracted from:

CollectDate   Lower   Center  Upper  ------+---------+---------+---------+
09/02/2005   -1.647   0.0000  1.647          (-------*-------)
09/03/2005   -1.779  -0.1318  1.515         (-------*--------)
27/04/2005   -1.251   0.3959  2.043            (-------*-------)
25/05/2005   -1.289   0.3579  2.005            (-------*-------)
22/06/2005   -0.471   1.1764  2.824                (-------*-------)
20/07/2005   -1.021   0.6257  2.273             (-------*-------)
22/08/2005   -1.603   0.0439  1.691          (-------*-------)
05/09/2005   -1.852  -0.2044  1.443         (-------*-------)
21/09/2005   -0.597   1.0504  2.698               (-------*-------)
02/11/2005   -1.059   0.5886  2.236             (-------*-------)
16/11/2005   -1.693  -0.0462  1.601          (-------*-------)
01/02/2006   -1.699  -0.0515  1.596          (-------*-------)
01/03/2006   -1.654  -0.0073  1.640          (-------*-------)
29/03/2006   -1.675  -0.0282  1.619          (-------*-------)
14/06/2006   -1.279   0.3682  2.015            (-------*-------)
09/08/2006   -0.951   0.6957  2.343             (-------*--------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0
```

```
CollectDate = 09/02/2005  subtracted from:

CollectDate   Lower   Center  Upper  ------+---------+---------+---------+
09/03/2005   -1.779  -0.1318  1.515         (-------*--------)
27/04/2005   -1.251   0.3959  2.043            (-------*-------)
25/05/2005   -1.289   0.3579  2.005            (-------*-------)
22/06/2005   -0.471   1.1764  2.824                (-------*-------)
20/07/2005   -1.021   0.6257  2.273             (-------*-------)
22/08/2005   -1.603   0.0439  1.691          (-------*-------)
05/09/2005   -1.852  -0.2044  1.443         (-------*-------)
21/09/2005   -0.597   1.0504  2.698               (-------*-------)
02/11/2005   -1.059   0.5886  2.236             (-------*-------)
16/11/2005   -1.693  -0.0462  1.601          (-------*-------)
01/02/2006   -1.699  -0.0515  1.596          (-------*-------)
01/03/2006   -1.654  -0.0073  1.640          (-------*-------)
29/03/2006   -1.675  -0.0282  1.619          (-------*-------)
14/06/2006   -1.279   0.3682  2.015            (-------*-------)
09/08/2006   -0.951   0.6957  2.343             (-------*--------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0
```

```
CollectDate = 09/03/2005  subtracted from:

CollectDate   Lower    Center  Upper  ------+---------+---------+---------+
27/04/2005   -1.119   0.52770  2.175            (--------*-------)
25/05/2005   -1.157   0.48968  2.137            (-------*--------)
22/06/2005   -0.339   1.30823  2.955                (--------*-------)
20/07/2005   -0.890   0.75748  2.405              (-------*-------)
22/08/2005   -1.471   0.17572  1.823           (-------*-------)
05/09/2005   -1.720  -0.07257  1.575         (--------*-------)
21/09/2005   -0.465   1.18223  2.829                (-------*-------)
02/11/2005   -0.927   0.72041  2.368             (--------*-------)
16/11/2005   -1.562   0.08561  1.733          (-------*--------)
01/02/2006   -1.567   0.08031  1.727          (-------*--------)
01/03/2006   -1.523   0.12452  1.772          (--------*-------)
29/03/2006   -1.543   0.10366  1.751          (--------*-------)
14/06/2006   -1.147   0.50003  2.147            (--------*-------)
09/08/2006   -0.820   0.82756  2.475              (-------*-------)
                                      ------+---------+---------+---------+
                                         -2.0       0.0       2.0       4.0
```

```
CollectDate = 27/04/2005  subtracted from:

CollectDate   Lower   Center  Upper  ------+---------+---------+---------+
25/05/2005   -1.685  -0.0380  1.609          (-------*-------)
22/06/2005   -0.867   0.7805  2.428              (-------*-------)
20/07/2005   -1.417   0.2298  1.877           (-------*-------)
22/08/2005   -1.999  -0.3520  1.295        (-------*-------)
05/09/2005   -2.247  -0.6003  1.047       (-------*-------)
21/09/2005   -0.993   0.6545  2.302             (-------*--------)
02/11/2005   -1.454   0.1927  1.840           (-------*-------)
16/11/2005   -2.089  -0.4421  1.205        (-------*-------)
01/02/2006   -2.095  -0.4474  1.200        (-------*-------)
01/03/2006   -2.050  -0.4032  1.244        (-------*-------)
29/03/2006   -2.071  -0.4240  1.223        (-------*-------)
14/06/2006   -1.675  -0.0277  1.619          (-------*-------)
09/08/2006   -1.347   0.2999  1.947           (-------*--------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0
```

```
CollectDate = 25/05/2005  subtracted from:

CollectDate   Lower   Center  Upper  ------+---------+---------+---------+
22/06/2005   -0.829   0.8186  2.466             (-------*-------)
20/07/2005   -1.379   0.2678  1.915          (-------*--------)
22/08/2005   -1.961  -0.3140  1.333       (-------*--------)
05/09/2005   -2.209  -0.5623  1.085      (-------*-------)
21/09/2005   -0.955   0.6925  2.340            (-------*--------)
02/11/2005   -1.416   0.2307  1.878          (-------*-------)
16/11/2005   -2.051  -0.4041  1.243       (-------*-------)
01/02/2006   -2.057  -0.4094  1.238       (-------*-------)
01/03/2006   -2.012  -0.3652  1.282       (-------*-------)
29/03/2006   -2.033  -0.3860  1.261       (-------*-------)
14/06/2006   -1.637   0.0103  1.657         (-------*-------)
09/08/2006   -1.309   0.3379  1.985          (--------*-------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0
```

```
CollectDate = 22/06/2005  subtracted from:

CollectDate   Lower  Center   Upper  ------+---------+---------+---------+
20/07/2005   -2.198  -0.551  1.0964      (-------*-------)
22/08/2005   -2.780  -1.133  0.5146   (-------*--------)
05/09/2005   -3.028  -1.381  0.2663  (-------*-------)
21/09/2005   -1.773  -0.126  1.5211        (-------*--------)
02/11/2005   -2.235  -0.588  1.0593      (-------*-------)
16/11/2005   -2.870  -1.223  0.4245   (-------*-------)
01/02/2006   -2.875  -1.228  0.4192   (-------*-------)
01/03/2006   -2.831  -1.184  0.4634   (-------*-------)
29/03/2006   -2.852  -1.205  0.4426   (-------*-------)
14/06/2006   -2.455  -0.808  0.8389     (-------*-------)
09/08/2006   -2.128  -0.481  1.1665      (--------*-------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0
```

```
CollectDate = 20/07/2005  subtracted from:

CollectDate   Lower   Center   Upper  ------+---------+---------+---------+
22/08/2005   -2.229  -0.5818  1.0654      (-------*-------)
05/09/2005   -2.477  -0.8301  0.8171     (-------*-------)
21/09/2005   -1.222   0.4247  2.0719           (-------*-------)
02/11/2005   -1.684  -0.0371  1.6101         (-------*-------)
16/11/2005   -2.319  -0.6719  0.9753     (--------*-------)
01/02/2006   -2.324  -0.6772  0.9700     (--------*-------)
01/03/2006   -2.280  -0.6330  1.0142      (-------*-------)
29/03/2006   -2.301  -0.6538  0.9933     (--------*-------)
14/06/2006   -1.905  -0.2575  1.3897       (--------*-------)
09/08/2006   -1.577   0.0701  1.7172         (-------*--------)
                                      ------+---------+---------+---------+
                                         -2.0       0.0       2.0       4.0
```

```
CollectDate = 22/08/2005  subtracted from:

CollectDate   Lower   Center  Upper  ------+---------+---------+---------+
05/09/2005   -1.895  -0.2483  1.399        (-------*-------)
21/09/2005   -0.641   1.0065  2.654              (-------*-------)
02/11/2005   -1.102   0.5447  2.192           (--------*-------)
16/11/2005   -1.737  -0.0901  1.557        (--------*-------)
01/02/2006   -1.743  -0.0954  1.552        (--------*-------)
01/03/2006   -1.698  -0.0512  1.596         (-------*-------)
29/03/2006   -1.719  -0.0721  1.575        (--------*-------)
14/06/2006   -1.323   0.3243  1.971          (--------*-------)
09/08/2006   -0.995   0.6518  2.299            (-------*-------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0
```

```
CollectDate = 05/09/2005  subtracted from:

CollectDate   Lower  Center  Upper  ------+---------+---------+---------+
21/09/2005   -0.392  1.2548  2.902               (-------*--------)
02/11/2005   -0.854  0.7930  2.440             (-------*-------)
16/11/2005   -1.489  0.1582  1.805          (-------*-------)
01/02/2006   -1.494  0.1529  1.800          (-------*-------)
01/03/2006   -1.450  0.1971  1.844          (-------*-------)
29/03/2006   -1.471  0.1762  1.823          (-------*-------)
14/06/2006   -1.075  0.5726  2.220            (-------*-------)
09/08/2006   -0.747  0.9001  2.547             (--------*-------)
                                    ------+---------+---------+---------+
                                       -2.0       0.0       2.0       4.0

CollectDate = 21/09/2005  subtracted from:

CollectDate   Lower  Center   Upper  ------+---------+---------+---------+
02/11/2005   -2.109  -0.462  1.1853       (--------*-------)
16/11/2005   -2.744  -1.097  0.5505    (--------*-------)
01/02/2006   -2.749  -1.102  0.5452    (-------*--------)
01/03/2006   -2.705  -1.058  0.5894    (--------*-------)
29/03/2006   -2.726  -1.079  0.5686    (--------*-------)
14/06/2006   -2.329  -0.682  0.9649      (--------*-------)
09/08/2006   -2.002  -0.355  1.2925        (-------*-------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0

CollectDate = 02/11/2005  subtracted from:

CollectDate   Lower   Center  Upper  ------+---------+---------+---------+
16/11/2005   -2.282  -0.6348  1.012       (-------*-------)
01/02/2006   -2.287  -0.6401  1.007       (-------*-------)
01/03/2006   -2.243  -0.5959  1.051       (-------*-------)
29/03/2006   -2.264  -0.6167  1.030       (-------*-------)
14/06/2006   -1.868  -0.2204  1.427         (-------*-------)
09/08/2006   -1.540   0.1072  1.754          (--------*-------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0

CollectDate = 16/11/2005  subtracted from:

CollectDate   Lower     Center  Upper  ------+---------+---------+---------+
01/02/2006   -1.652  -0.005297  1.642         (-------*-------)
01/03/2006   -1.608   0.038917  1.686         (-------*-------)
29/03/2006   -1.629   0.018058  1.665         (-------*-------)
14/06/2006   -1.233   0.414423  2.062           (-------*-------)
09/08/2006   -0.905   0.741954  2.389            (--------*-------)
                                       ------+---------+---------+---------+
                                          -2.0       0.0       2.0       4.0

CollectDate = 01/02/2006  subtracted from:

CollectDate   Lower   Center  Upper  ------+---------+---------+---------+
01/03/2006   -1.603  0.04421  1.691         (-------*-------)
29/03/2006   -1.624  0.02336  1.670         (-------*-------)
14/06/2006   -1.227  0.41972  2.067           (-------*-------)
09/08/2006   -0.900  0.74725  2.394             (-------*-------)
                                     ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0

CollectDate = 01/03/2006  subtracted from:

CollectDate   Lower    Center  Upper  ------+---------+---------+---------+
29/03/2006   -1.668  -0.02086  1.626         (-------*-------)
14/06/2006   -1.272   0.37551  2.023           (-------*-------)
09/08/2006   -0.944   0.70304  2.350            (--------*-------)
                                      ------+---------+---------+---------+
                                         -2.0       0.0       2.0       4.0
```

```
CollectDate = 29/03/2006  subtracted from:

CollectDate   Lower  Center  Upper  ------+---------+---------+---------+
14/06/2006   -1.251  0.3964  2.043            (-------*-------)
09/08/2006   -0.923  0.7239  2.371             (--------*-------)
                                    ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0


CollectDate = 14/06/2006  subtracted from:

CollectDate   Lower  Center  Upper  ------+---------+---------+---------+
09/08/2006   -1.320  0.3275  1.975           (--------*-------)
                                    ------+---------+---------+---------+
                                        -2.0       0.0       2.0       4.0
```

Tukey Simultaneous Tests
Response Variable logresult
All Pairwise Comparisons among Levels of CollectDate
CollectDate = 21/01/2004 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
24/03/2004	0.25078	0.4314	0.5814	1.0000
21/04/2004	0.96351	0.4314	2.2336	0.8665
05/05/2004	0.97692	0.4314	2.2647	0.8512
02/06/2004	0.50608	0.4314	1.1732	1.0000
05/07/2004	0.04340	0.4314	0.1006	1.0000
04/08/2004	1.42869	0.4314	3.3120	0.1856
15/09/2004	0.83035	0.4314	1.9249	0.9668
13/10/2004	-0.07605	0.4314	-0.1763	1.0000
15/11/2004	0.33963	0.4314	0.7873	1.0000
09/02/2005	0.33963	0.4314	0.7873	1.0000
09/03/2005	0.20780	0.4314	0.4817	1.0000
27/04/2005	0.73550	0.4314	1.7050	0.9921
25/05/2005	0.69748	0.4314	1.6169	0.9961
22/06/2005	1.51603	0.4314	3.5145	0.1142
20/07/2005	0.96528	0.4314	2.2377	0.8646
22/08/2005	0.38352	0.4314	0.8891	1.0000
05/09/2005	0.13523	0.4314	0.3135	1.0000
21/09/2005	1.39002	0.4314	3.2224	0.2261
02/11/2005	0.92821	0.4314	2.1518	0.9022
16/11/2005	0.29340	0.4314	0.6802	1.0000
01/02/2006	0.28811	0.4314	0.6679	1.0000
01/03/2006	0.33232	0.4314	0.7704	1.0000
29/03/2006	0.31146	0.4314	0.7220	1.0000
14/06/2006	0.70783	0.4314	1.6409	0.9952
09/08/2006	1.03536	0.4314	2.4002	0.7740

CollectDate = 24/03/2004 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
21/04/2004	0.7127	0.4314	1.6522	0.9947
05/05/2004	0.7261	0.4314	1.6833	0.9933
02/06/2004	0.2553	0.4314	0.5918	1.0000
05/07/2004	-0.2074	0.4314	-0.4807	1.0000
04/08/2004	1.1779	0.4314	2.7306	0.5400
15/09/2004	0.5796	0.4314	1.3436	0.9998
13/10/2004	-0.3268	0.4314	-0.7577	1.0000
15/11/2004	0.0888	0.4314	0.2060	1.0000
09/02/2005	0.0888	0.4314	0.2060	1.0000
09/03/2005	-0.0430	0.4314	-0.0996	1.0000
27/04/2005	0.4847	0.4314	1.1237	1.0000
25/05/2005	0.4467	0.4314	1.0355	1.0000
22/06/2005	1.2652	0.4314	2.9331	0.3953

20/07/2005	0.7145	0.4314	1.6564	0.9946
22/08/2005	0.1327	0.4314	0.3077	1.0000
05/09/2005	-0.1156	0.4314	-0.2679	1.0000
21/09/2005	1.1392	0.4314	2.6410	0.6065
02/11/2005	0.6774	0.4314	1.5704	0.9974
16/11/2005	0.0426	0.4314	0.0988	1.0000
01/02/2006	0.0373	0.4314	0.0865	1.0000
01/03/2006	0.0815	0.4314	0.1890	1.0000
29/03/2006	0.0607	0.4314	0.1407	1.0000
14/06/2006	0.4570	0.4314	1.0595	1.0000
09/08/2006	0.7846	0.4314	1.8188	0.9825

CollectDate = 21/04/2004 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
05/05/2004	0.013	0.4314	0.031	1.0000
02/06/2004	-0.457	0.4314	-1.060	1.0000
05/07/2004	-0.920	0.4314	-2.133	0.9094
04/08/2004	0.465	0.4314	1.078	1.0000
15/09/2004	-0.133	0.4314	-0.309	1.0000
13/10/2004	-1.040	0.4314	-2.410	0.7679
15/11/2004	-0.624	0.4314	-1.446	0.9992
09/02/2005	-0.624	0.4314	-1.446	0.9992
09/03/2005	-0.756	0.4314	-1.752	0.9888
27/04/2005	-0.228	0.4314	-0.529	1.0000
25/05/2005	-0.266	0.4314	-0.617	1.0000
22/06/2005	0.553	0.4314	1.281	0.9999
20/07/2005	0.002	0.4314	0.004	1.0000
22/08/2005	-0.580	0.4314	-1.345	0.9998
05/09/2005	-0.828	0.4314	-1.920	0.9677
21/09/2005	0.427	0.4314	0.989	1.0000
02/11/2005	-0.035	0.4314	-0.082	1.0000
16/11/2005	-0.670	0.4314	-1.553	0.9978
01/02/2006	-0.675	0.4314	-1.566	0.9975
01/03/2006	-0.631	0.4314	-1.463	0.9991
29/03/2006	-0.652	0.4314	-1.512	0.9985
14/06/2006	-0.256	0.4314	-0.593	1.0000
09/08/2006	0.072	0.4314	0.167	1.0000

CollectDate = 05/05/2004 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
02/06/2004	-0.471	0.4314	-1.091	1.0000
05/07/2004	-0.934	0.4314	-2.164	0.8973
04/08/2004	0.452	0.4314	1.047	1.0000
15/09/2004	-0.147	0.4314	-0.340	1.0000
13/10/2004	-1.053	0.4314	-2.441	0.7478
15/11/2004	-0.637	0.4314	-1.477	0.9989
09/02/2005	-0.637	0.4314	-1.477	0.9989
09/03/2005	-0.769	0.4314	-1.783	0.9862
27/04/2005	-0.241	0.4314	-0.560	1.0000
25/05/2005	-0.279	0.4314	-0.648	1.0000
22/06/2005	0.539	0.4314	1.250	0.9999
20/07/2005	-0.012	0.4314	-0.027	1.0000
22/08/2005	-0.593	0.4314	-1.376	0.9997
05/09/2005	-0.842	0.4314	-1.951	0.9617
21/09/2005	0.413	0.4314	0.958	1.0000
02/11/2005	-0.049	0.4314	-0.113	1.0000
16/11/2005	-0.684	0.4314	-1.585	0.9970
01/02/2006	-0.689	0.4314	-1.597	0.9967
01/03/2006	-0.645	0.4314	-1.494	0.9987
29/03/2006	-0.665	0.4314	-1.543	0.9980
14/06/2006	-0.269	0.4314	-0.624	1.0000
09/08/2006	0.058	0.4314	0.135	1.0000

CollectDate = 02/06/2004 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
05/07/2004	-0.4627	0.4314	-1.073	1.0000
04/08/2004	0.9226	0.4314	2.139	0.9072
15/09/2004	0.3243	0.4314	0.752	1.0000
13/10/2004	-0.5821	0.4314	-1.349	0.9997
15/11/2004	-0.1665	0.4314	-0.386	1.0000
09/02/2005	-0.1665	0.4314	-0.386	1.0000
09/03/2005	-0.2983	0.4314	-0.691	1.0000
27/04/2005	0.2294	0.4314	0.532	1.0000
25/05/2005	0.1914	0.4314	0.444	1.0000
22/06/2005	1.0099	0.4314	2.341	0.8095
20/07/2005	0.4592	0.4314	1.065	1.0000
22/08/2005	-0.1226	0.4314	-0.284	1.0000
05/09/2005	-0.3709	0.4314	-0.860	1.0000
21/09/2005	0.8839	0.4314	2.049	0.9374
02/11/2005	0.4221	0.4314	0.979	1.0000
16/11/2005	-0.2127	0.4314	-0.493	1.0000
01/02/2006	-0.2180	0.4314	-0.505	1.0000
01/03/2006	-0.1738	0.4314	-0.403	1.0000
29/03/2006	-0.1946	0.4314	-0.451	1.0000
14/06/2006	0.2017	0.4314	0.468	1.0000
09/08/2006	0.5293	0.4314	1.227	1.0000

CollectDate = 05/07/2004 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
04/08/2004	1.3853	0.4314	3.2114	0.2315
15/09/2004	0.7869	0.4314	1.8243	0.9818
13/10/2004	-0.1194	0.4314	-0.2769	1.0000
15/11/2004	0.2962	0.4314	0.6867	1.0000
09/02/2005	0.2962	0.4314	0.6867	1.0000
09/03/2005	0.1644	0.4314	0.3811	1.0000
27/04/2005	0.6921	0.4314	1.6044	0.9965
25/05/2005	0.6541	0.4314	1.5163	0.9984
22/06/2005	1.4726	0.4314	3.4138	0.1463
20/07/2005	0.9219	0.4314	2.1371	0.9079
22/08/2005	0.3401	0.4314	0.7885	1.0000
05/09/2005	0.0918	0.4314	0.2129	1.0000
21/09/2005	1.3466	0.4314	3.1217	0.2786
02/11/2005	0.8848	0.4314	2.0511	0.9368
16/11/2005	0.2500	0.4314	0.5795	1.0000
01/02/2006	0.2447	0.4314	0.5673	1.0000
01/03/2006	0.2889	0.4314	0.6698	1.0000
29/03/2006	0.2681	0.4314	0.6214	1.0000
14/06/2006	0.6644	0.4314	1.5403	0.9980
09/08/2006	0.9920	0.4314	2.2995	0.8329

CollectDate = 04/08/2004 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
15/09/2004	-0.598	0.4314	-1.387	0.9996
13/10/2004	-1.505	0.4314	-3.488	0.1220
15/11/2004	-1.089	0.4314	-2.525	0.6908
09/02/2005	-1.089	0.4314	-2.525	0.6908
09/03/2005	-1.221	0.4314	-2.830	0.4671
27/04/2005	-0.693	0.4314	-1.607	0.9964
25/05/2005	-0.731	0.4314	-1.695	0.9926
22/06/2005	0.087	0.4314	0.202	1.0000
20/07/2005	-0.463	0.4314	-1.074	1.0000
22/08/2005	-1.045	0.4314	-2.423	0.7595
05/09/2005	-1.293	0.4314	-2.999	0.3523
21/09/2005	-0.039	0.4314	-0.090	1.0000
02/11/2005	-0.500	0.4314	-1.160	1.0000

16/11/2005	-1.135	0.4314	-2.632	0.6133
01/02/2006	-1.141	0.4314	-2.644	0.6042
01/03/2006	-1.096	0.4314	-2.542	0.6788
29/03/2006	-1.117	0.4314	-2.590	0.6439
14/06/2006	-0.721	0.4314	-1.671	0.9939
09/08/2006	-0.393	0.4314	-0.912	1.0000

CollectDate = 15/09/2004 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
13/10/2004	-0.9064	0.4314	-2.101	0.9209
15/11/2004	-0.4907	0.4314	-1.138	1.0000
09/02/2005	-0.4907	0.4314	-1.138	1.0000
09/03/2005	-0.6226	0.4314	-1.443	0.9993
27/04/2005	-0.0948	0.4314	-0.220	1.0000
25/05/2005	-0.1329	0.4314	-0.308	1.0000
22/06/2005	0.6857	0.4314	1.590	0.9969
20/07/2005	0.1349	0.4314	0.313	1.0000
22/08/2005	-0.4468	0.4314	-1.036	1.0000
05/09/2005	-0.6951	0.4314	-1.611	0.9963
21/09/2005	0.5597	0.4314	1.297	0.9999
02/11/2005	0.0979	0.4314	0.227	1.0000
16/11/2005	-0.5369	0.4314	-1.245	0.9999
01/02/2006	-0.5422	0.4314	-1.257	0.9999
01/03/2006	-0.4980	0.4314	-1.155	1.0000
29/03/2006	-0.5189	0.4314	-1.203	1.0000
14/06/2006	-0.1225	0.4314	-0.284	1.0000
09/08/2006	0.2050	0.4314	0.475	1.0000

CollectDate = 13/10/2004 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
15/11/2004	0.4157	0.4314	0.9636	1.0000
09/02/2005	0.4157	0.4314	0.9636	1.0000
09/03/2005	0.2838	0.4314	0.6580	1.0000
27/04/2005	0.8115	0.4314	1.8813	0.9742
25/05/2005	0.7735	0.4314	1.7932	0.9852
22/06/2005	1.5921	0.4314	3.6907	0.0719
20/07/2005	1.0413	0.4314	2.4140	0.7653
22/08/2005	0.4596	0.4314	1.0654	1.0000
05/09/2005	0.2113	0.4314	0.4898	1.0000
21/09/2005	1.4661	0.4314	3.3986	0.1517
02/11/2005	1.0043	0.4314	2.3281	0.8171
16/11/2005	0.3694	0.4314	0.8565	1.0000
01/02/2006	0.3642	0.4314	0.8442	1.0000
01/03/2006	0.4084	0.4314	0.9467	1.0000
29/03/2006	0.3875	0.4314	0.8983	1.0000
14/06/2006	0.7839	0.4314	1.8172	0.9826
09/08/2006	1.1114	0.4314	2.5765	0.6538

CollectDate = 15/11/2004 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
09/02/2005	0.0000	0.4314	0.0000	1.0000
09/03/2005	-0.1318	0.4314	-0.3056	1.0000
27/04/2005	0.3959	0.4314	0.9177	1.0000
25/05/2005	0.3579	0.4314	0.8296	1.0000
22/06/2005	1.1764	0.4314	2.7271	0.5426
20/07/2005	0.6257	0.4314	1.4504	0.9992
22/08/2005	0.0439	0.4314	0.1017	1.0000
05/09/2005	-0.2044	0.4314	-0.4738	1.0000
21/09/2005	1.0504	0.4314	2.4350	0.7517
02/11/2005	0.5886	0.4314	1.3644	0.9997
16/11/2005	-0.0462	0.4314	-0.1072	1.0000
01/02/2006	-0.0515	0.4314	-0.1194	1.0000

01/03/2006	-0.0073	0.4314	-0.0169	1.0000
29/03/2006	-0.0282	0.4314	-0.0653	1.0000
14/06/2006	0.3682	0.4314	0.8536	1.0000
09/08/2006	0.6957	0.4314	1.6128	0.9962

CollectDate = 09/02/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
09/03/2005	-0.1318	0.4314	-0.3056	1.0000
27/04/2005	0.3959	0.4314	0.9177	1.0000
25/05/2005	0.3579	0.4314	0.8296	1.0000
22/06/2005	1.1764	0.4314	2.7271	0.5426
20/07/2005	0.6257	0.4314	1.4504	0.9992
22/08/2005	0.0439	0.4314	0.1017	1.0000
05/09/2005	-0.2044	0.4314	-0.4738	1.0000
21/09/2005	1.0504	0.4314	2.4350	0.7517
02/11/2005	0.5886	0.4314	1.3644	0.9997
16/11/2005	-0.0462	0.4314	-0.1072	1.0000
01/02/2006	-0.0515	0.4314	-0.1194	1.0000
01/03/2006	-0.0073	0.4314	-0.0169	1.0000
29/03/2006	-0.0282	0.4314	-0.0653	1.0000
14/06/2006	0.3682	0.4314	0.8536	1.0000
09/08/2006	0.6957	0.4314	1.6128	0.9962

CollectDate = 09/03/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
27/04/2005	0.52770	0.4314	1.2233	1.0000
25/05/2005	0.48968	0.4314	1.1352	1.0000
22/06/2005	1.30823	0.4314	3.0327	0.3309
20/07/2005	0.75748	0.4314	1.7560	0.9885
22/08/2005	0.17572	0.4314	0.4074	1.0000
05/09/2005	-0.07257	0.4314	-0.1682	1.0000
21/09/2005	1.18223	0.4314	2.7406	0.5326
02/11/2005	0.72041	0.4314	1.6700	0.9939
16/11/2005	0.08561	0.4314	0.1985	1.0000
01/02/2006	0.08031	0.4314	0.1862	1.0000
01/03/2006	0.12452	0.4314	0.2887	1.0000
29/03/2006	0.10366	0.4314	0.2403	1.0000
14/06/2006	0.50003	0.4314	1.1592	1.0000
09/08/2006	0.82756	0.4314	1.9184	0.9680

CollectDate = 27/04/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
25/05/2005	-0.0380	0.4314	-0.088	1.0000
22/06/2005	0.7805	0.4314	1.809	0.9835
20/07/2005	0.2298	0.4314	0.533	1.0000
22/08/2005	-0.3520	0.4314	-0.816	1.0000
05/09/2005	-0.6003	0.4314	-1.392	0.9996
21/09/2005	0.6545	0.4314	1.517	0.9984
02/11/2005	0.1927	0.4314	0.447	1.0000
16/11/2005	-0.4421	0.4314	-1.025	1.0000
01/02/2006	-0.4474	0.4314	-1.037	1.0000
01/03/2006	-0.4032	0.4314	-0.935	1.0000
29/03/2006	-0.4240	0.4314	-0.983	1.0000
14/06/2006	-0.0277	0.4314	-0.064	1.0000
09/08/2006	0.2999	0.4314	0.695	1.0000

CollectDate = 25/05/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
22/06/2005	0.8186	0.4314	1.898	0.9716
20/07/2005	0.2678	0.4314	0.621	1.0000

22/08/2005	-0.3140	0.4314	-0.728	1.0000
05/09/2005	-0.5623	0.4314	-1.303	0.9999
21/09/2005	0.6925	0.4314	1.605	0.9964
02/11/2005	0.2307	0.4314	0.535	1.0000
16/11/2005	-0.4041	0.4314	-0.937	1.0000
01/02/2006	-0.4094	0.4314	-0.949	1.0000
01/03/2006	-0.3652	0.4314	-0.847	1.0000
29/03/2006	-0.3860	0.4314	-0.895	1.0000
14/06/2006	0.0103	0.4314	0.024	1.0000
09/08/2006	0.3379	0.4314	0.783	1.0000

CollectDate = 22/06/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
20/07/2005	-0.551	0.4314	-1.277	0.9999
22/08/2005	-1.133	0.4314	-2.625	0.6180
05/09/2005	-1.381	0.4314	-3.201	0.2367
21/09/2005	-0.126	0.4314	-0.292	1.0000
02/11/2005	-0.588	0.4314	-1.363	0.9997
16/11/2005	-1.223	0.4314	-2.834	0.4642
01/02/2006	-1.228	0.4314	-2.847	0.4554
01/03/2006	-1.184	0.4314	-2.744	0.5301
29/03/2006	-1.205	0.4314	-2.792	0.4945
14/06/2006	-0.808	0.4314	-1.874	0.9754
09/08/2006	-0.481	0.4314	-1.114	1.0000

CollectDate = 20/07/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
22/08/2005	-0.5818	0.4314	-1.349	0.9997
05/09/2005	-0.8301	0.4314	-1.924	0.9670
21/09/2005	0.4247	0.4314	0.985	1.0000
02/11/2005	-0.0371	0.4314	-0.086	1.0000
16/11/2005	-0.6719	0.4314	-1.558	0.9977
01/02/2006	-0.6772	0.4314	-1.570	0.9974
01/03/2006	-0.6330	0.4314	-1.467	0.9990
29/03/2006	-0.6538	0.4314	-1.516	0.9984
14/06/2006	-0.2575	0.4314	-0.597	1.0000
09/08/2006	0.0701	0.4314	0.162	1.0000

CollectDate = 22/08/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
05/09/2005	-0.2483	0.4314	-0.5756	1.0000
21/09/2005	1.0065	0.4314	2.3333	0.8142
02/11/2005	0.5447	0.4314	1.2627	0.9999
16/11/2005	-0.0901	0.4314	-0.2089	1.0000
01/02/2006	-0.0954	0.4314	-0.2212	1.0000
01/03/2006	-0.0512	0.4314	-0.1187	1.0000
29/03/2006	-0.0721	0.4314	-0.1670	1.0000
14/06/2006	0.3243	0.4314	0.7518	1.0000
09/08/2006	0.6518	0.4314	1.5111	0.9985

CollectDate = 05/09/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
21/09/2005	1.2548	0.4314	2.9089	0.4118
02/11/2005	0.7930	0.4314	1.8383	0.9801
16/11/2005	0.1582	0.4314	0.3667	1.0000
01/02/2006	0.1529	0.4314	0.3544	1.0000
01/03/2006	0.1971	0.4314	0.4569	1.0000
29/03/2006	0.1762	0.4314	0.4085	1.0000
14/06/2006	0.5726	0.4314	1.3274	0.9998
09/08/2006	0.9001	0.4314	2.0867	0.9258

CollectDate = 21/09/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
02/11/2005	-0.462	0.4314	-1.071	1.0000
16/11/2005	-1.097	0.4314	-2.542	0.6784
01/02/2006	-1.102	0.4314	-2.554	0.6696
01/03/2006	-1.058	0.4314	-2.452	0.7405
29/03/2006	-1.079	0.4314	-2.500	0.7077
14/06/2006	-0.682	0.4314	-1.581	0.9971
09/08/2006	-0.355	0.4314	-0.822	1.0000

CollectDate = 02/11/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
16/11/2005	-0.6348	0.4314	-1.472	0.9990
01/02/2006	-0.6401	0.4314	-1.484	0.9989
01/03/2006	-0.5959	0.4314	-1.381	0.9996
29/03/2006	-0.6167	0.4314	-1.430	0.9994
14/06/2006	-0.2204	0.4314	-0.511	1.0000
09/08/2006	0.1072	0.4314	0.248	1.0000

CollectDate = 16/11/2005 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
01/02/2006	-0.005297	0.4314	-0.01228	1.0000
01/03/2006	0.038917	0.4314	0.09022	1.0000
29/03/2006	0.018058	0.4314	0.04186	1.0000
14/06/2006	0.414423	0.4314	0.96072	1.0000
09/08/2006	0.741954	0.4314	1.72000	0.9911

CollectDate = 01/02/2006 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
01/03/2006	0.04421	0.4314	0.10250	1.0000
29/03/2006	0.02336	0.4314	0.05414	1.0000
14/06/2006	0.41972	0.4314	0.97300	1.0000
09/08/2006	0.74725	0.4314	1.73228	0.9903

CollectDate = 01/03/2006 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
29/03/2006	-0.02086	0.4314	-0.04836	1.0000
14/06/2006	0.37551	0.4314	0.87050	1.0000
09/08/2006	0.70304	0.4314	1.62978	0.9956

CollectDate = 29/03/2006 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
14/06/2006	0.3964	0.4314	0.9189	1.0000
09/08/2006	0.7239	0.4314	1.6781	0.9935

CollectDate = 14/06/2006 subtracted from:

CollectDate	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
09/08/2006	0.3275	0.4314	0.7593	1.000

Section 11.3 Chi square test on proportion of all results exceeding 230mpn/100g by site

```
Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

              Balvicar                    Rubha nan
   Balvicar      North  Ardshellach  Ron South  Kilbrandon  Total
1        32         29           23          6          22    112
      33.70      21.26        17.63       6.22       33.19
      0.086      2.818        1.636      0.008       3.770

2        33         12           11          6          42    104
      31.30      19.74        16.37       5.78       30.81
      0.093      3.035        1.762      0.009       4.060

Total    65         41           34         12          64    216

Chi-Sq = 17.277, DF = 4, P-Value = 0.002
```

Section 11.3 Chi square test on proportion of results exceeding 230mpn/100g by site when four sites were sampled on the same day

```
Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

              Balvicar
   Balvicar      North  Ardshellach  Kilbrandon  Total
1        14         22           20           9     65
      16.25      16.25        16.25       16.25
      0.312      2.035        0.865       3.235

2        12          4            6          17     39
       9.75       9.75         9.75        9.75
      0.519      3.391        1.442       5.391

Total    26         26           26          26    104

Chi-Sq = 17.190, DF = 3, P-Value = 0.001
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (Ardshellach oysters)

```
Source  DF      SS     MS     F      P
Season   3   1.016  0.339  0.78  0.516
Error   30  13.083  0.436
Total   33  14.099

S = 0.6604   R-Sq = 7.21%   R-Sq(adj) = 0.00%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
1      10  2.7489  0.4154               (----------*---------)
2       8  2.6443  0.6126           (-----------*-----------)
3      10  2.4422  0.8359       (----------*----------)
4       6  2.2813  0.7232  (-------------*-------------)
                           -------+---------+---------+---------+--
                                2.00      2.40      2.80      3.20

Pooled StDev = 0.6604
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (Balvicar North oysters)

```
Source  DF      SS     MS     F      P
Season   3   0.223  0.074  0.16  0.922
Error   37  17.052  0.461
Total   40  17.275

S = 0.6789   R-Sq = 1.29%   R-Sq(adj) = 0.00%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
1      13  2.7281  0.5136              (----------*----------)
2      11  2.6585  0.7561           (-----------*-----------)
3      12  2.6304  0.7396           (----------*-----------)
4       5  2.4836  0.7337  (-----------------*-----------------)
                           -------+---------+---------+---------+--
                                2.10      2.45      2.80      3.15

Pooled StDev = 0.6789
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (East of Balvicar mussels)

```
Source  DF      SS     MS     F      P
Season   3   3.224  1.075  2.30  0.102
Error   25  11.698  0.468
Total   28  14.922

S = 0.6840   R-Sq = 21.61%   R-Sq(adj) = 12.20%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  --+---------+---------+---------+-------
1      9  2.3084  0.4056               (------*-------)
2      8  2.9845  0.8723                         (--------*-------)
3      9  2.5300  0.6815                  (-------*-------)
4      3  1.9161  0.8185  (-------------*------------)
                          --+---------+---------+---------+-------
                          1.20      1.80      2.40      3.00

Pooled StDev = 0.6840
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (Balvicar oysters)

```
Source  DF      SS     MS     F      P
Season   3  12.889  4.296  8.34  0.000
Error   61  31.412  0.515
Total   64  44.301

S = 0.7176   R-Sq = 29.09%   R-Sq(adj) = 25.61%

                           Individual 95% CIs For Mean Based on Pooled StDev
Level   N    Mean   StDev    +---------+---------+---------+---------
1      18  2.1288  0.7150              (----*-----)
2      18  2.9211  0.8176                           (-----*----)
3      19  2.6646  0.7262                       (----*-----)
4      10  1.6638  0.4551    (-------*------)
                             +---------+---------+---------+---------
                           1.20      1.80      2.40      3.00

Pooled StDev = 0.7176
```

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

Individual confidence level = 98.96%

Season = 1 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
2        0.1597   0.7923  1.4249                  (-----*----)
3       -0.0885   0.5357  1.1599                (----*-----)
4       -1.2135  -0.4650  0.2835        (-----*-----)
                                  -------+---------+---------+---------+--
                                      -1.2       0.0       1.2       2.4

Season = 2 subtracted from:

Season    Lower   Center    Upper  -------+---------+---------+---------+--
3       -0.8808  -0.2566   0.3676          (----*----)
4       -2.0058  -1.2573  -0.5088  (------*-----)
                                   -------+---------+---------+---------+--
                                       -1.2       0.0       1.2       2.4

Season = 3 subtracted from:

Season    Lower   Center    Upper  -------+---------+---------+---------+--
4       -1.7422  -1.0007  -0.2593    (------*-----)
                                   -------+---------+---------+---------+--
                                       -1.2       0.0       1.2       2.4
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (Kilbrandon oysters)

```
Source  DF      SS     MS     F      P
Season   3   3.310  1.103  1.93  0.135
Error   60  34.348  0.572
Total   63  37.657

S = 0.7566   R-Sq = 8.79%   R-Sq(adj) = 4.23%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
1      20  1.9327  0.7057         (-------*--------)
2      17  2.4292  0.8912                     (--------*--------)
3      17  2.0661  0.7178           (---------*--------)
4      10  1.7972  0.6611  (-----------*-----------)
                           -------+---------+---------+---------+--
                                1.60      2.00      2.40      2.80

Pooled StDev = 0.7566
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 2 day rainfall (Ardshellach oysters)

```
Pearson correlation of result ranked and 2day rain ranked = 0.284
P-Value = 0.116
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 2 day rainfall (Balvicar North oysters)

```
Pearson correlation of result ranked and 2 day rain ranked = 0.289
P-Value = 0.074
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 2 day rainfall (East of Balvicar mussels)

```
Pearson correlation of result ranked and 2 day rain ranked = 0.171
P-Value = 0.383
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 2 day rainfall (Balvicar oysters)

```
Pearson correlation of result ranked and 2 day rain ranked = 0.384
P-Value = 0.005
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 2 day rainfall (Kilbrandon oysters)

```
Pearson correlation of result ranked and 2 day rain ranked = 0.060
P-Value = 0.677
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 7 day rainfall (Ardshellach oysters)

```
Pearson correlation of result ranked and 7 day rain ranked = 0.142
P-Value = 0.437
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 7 day rainfall (Balvicar North oysters)

```
Pearson correlation of result ranked and 7 day rain ranked = 0.073
P-Value = 0.660
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 7 day rainfall (East of Balvicar mussels)

```
Pearson correlation of result ranked and 7 day rain ranked = 0.148
P-Value = 0.451
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 7 day rainfall (Balvicar oysters)

```
Pearson correlation of result ranked and 7 day rain ranked = 0.234
P-Value = 0.094
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 7 day rainfall (Kilbrandon oysters)

```
Pearson correlation of result ranked and 7 day rain ranked = -0.056
P-Value = 0.698
```

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (Ardshellach oysters)

```
The regression equation is
logresultWT = 2.21 + 0.0363 WaterTemp

Predictor      Coef  SE Coef     T      P
Constant     2.2122   0.4009  5.52  0.000
WaterTemp   0.03626  0.03400  1.07  0.295

S = 0.627126   R-Sq = 3.9%   R-Sq(adj) = 0.5%
```

```
Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.4475  0.4475  1.14  0.295
Residual Error  28  11.0120  0.3933
Total           29  11.4595

Unusual Observations

Obs  WaterTemp  logresultWT    Fit  SE Fit  Residual  St Resid
  2        8.0        1.000  2.502   0.160    -1.502     -2.48R
 10       10.0        1.000  2.575   0.123    -1.575     -2.56R

R denotes an observation with a large standardized residual.
```

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (Balvicar North oysters)

```
The regression equation is
logresultWT = 2.96 - 0.0295 WaterTemp

Predictor      Coef  SE Coef      T      P
Constant     2.9623   0.4182   7.08  0.000
WaterTemp  -0.02952  0.03483  -0.85  0.402

S = 0.681740   R-Sq = 2.0%   R-Sq(adj) = 0.0%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.3339  0.3339  0.72  0.402
Residual Error  35  16.2669  0.4648
Total           36  16.6008

Unusual Observations

Obs  WaterTemp  logresultWT    Fit  SE Fit  Residual  St Resid
 19       19.0        1.301  2.401   0.282    -1.100     -1.77 X
 30        6.0        1.301  2.785   0.224    -1.484     -2.30R
 34       14.0        1.000  2.549   0.140    -1.549     -2.32R

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

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (East of Balvicar mussels)

```
The regression equation is
logresultWT = 1.41 + 0.0944 WaterTemp

Predictor     Coef  SE Coef     T      P
Constant    1.4126   0.5475  2.58  0.016
WaterTemp  0.09437  0.04346  2.17  0.040

S = 0.690794   R-Sq = 15.9%   R-Sq(adj) = 12.5%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   2.2502  2.2502  4.72  0.040
Residual Error  25  11.9299  0.4772
Total           26  14.1801
```

```
Unusual Observations

Obs  WaterTemp  logresultWT    Fit  SE Fit  Residual  St Resid
 20        5.0        1.301  1.884   0.341    -0.583     -0.97 X

X denotes an observation whose X value gives it large leverage.
```

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (Balvicar oysters)

```
The regression equation is
logresultWT = 0.986 + 0.126 WaterTemp


Predictor     Coef  SE Coef     T      P
Constant    0.9862   0.3606  2.73  0.008
WaterTemp  0.12589  0.03036  4.15  0.000


S = 0.746345   R-Sq = 23.5%   R-Sq(adj) = 22.1%

Analysis of Variance

Source          DF       SS      MS      F      P
Regression       1   9.5757  9.5757  17.19  0.000
Residual Error  56  31.1937  0.5570
Total           57  40.7693

Unusual Observations

Obs  WaterTemp  logresultWT     Fit  SE Fit  Residual  St Resid
  3       12.0       1.0000  2.4968  0.0995   -1.4968     -2.02R
 17       10.0       4.5563  2.2451  0.1072    2.3112      3.13R
 49       14.0       4.5563  2.7486  0.1253    1.8077      2.46R

R denotes an observation with a large standardized residual.
```

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (Kilbrandon oysters)

```
The regression equation is
logresultWT = 1.37 + 0.0611 WaterTemp

Predictor     Coef  SE Coef     T      P
Constant    1.3705   0.3618  3.79  0.000
WaterTemp  0.06108  0.02987  2.04  0.046

S = 0.742958   R-Sq = 6.9%   R-Sq(adj) = 5.3%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   2.3079  2.3079  4.18  0.046
Residual Error  56  30.9113  0.5520
Total           57  33.2192

Unusual Observations

Obs  WaterTemp  logresultWT     Fit  SE Fit  Residual  St Resid
  6       14.0       4.2041  2.2256  0.1199    1.9785      2.70R

R denotes an observation with a large standardized residual.
```

Section 11.6.4 Circular linear correlation for 7 day wind direction and *E. coli* result (Ardshellach oysters)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 05 November 2008 10:46:31

Variables (& observations)	r	p
Angles & Linear (29)	0.225	0.268

Section 11.6.4 Circular linear correlation for 7 day wind direction and *E. coli* result (Balvicar North oysters)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 05 November 2008 11:05:46

Variables (& observations)	r	p
Angles & Linear (36)	0.137	0.537

Section 11.6.4 Circular linear correlation for 7 day wind direction and *E. coli* result (East of Balvicar mussels)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 05 November 2008 11:07:47

Variables (& observations)	r	p
Angles & Linear (26)	0.133	0.664

Section 11.6.4 Circular linear correlation for 7 day wind direction and *E. coli* result (Balvicar oysters)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 05 November 2008 11:02:52

Variables (& observations)	r	p
Angles & Linear (45)	0.395	0.001

Section 11.6.4 Circular linear correlation for 7 day wind direction and *E. coli* result (Kilbrandon oysters)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 05 November 2008 11:09:30

Variables (& observations)	r	p
Angles & Linear (43)	0.111	0.612

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (Ardshellach oysters)

```
The regression equation is
logresultSal = 0.53 + 0.0702 Salinity

Predictor      Coef  SE Coef     T      P
Constant      0.525    1.270  0.41  0.682
Salinity    0.07023  0.04384  1.60  0.119
```

```
S = 0.638657   R-Sq = 7.4%   R-Sq(adj) = 4.5%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   1.0468  1.0468  2.57  0.119
Residual Error  32  13.0523  0.4079
Total           33  14.0991

Unusual Observations

Obs  Salinity  logresultSal    Fit  SE Fit  Residual  St Resid
  1      20.0         2.342  1.930   0.403     0.413      0.83 X
  2      30.0         1.000  2.632   0.121    -1.632     -2.60R
 10      30.0         1.000  2.632   0.121    -1.632     -2.60R
 32      22.0         1.301  2.070   0.320    -0.769     -1.39 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 (Balvicar North oysters)

```
The regression equation is
logresultSal = - 0.73 + 0.117 Salinity


Predictor     Coef  SE Coef      T      P
Constant    -0.732    1.256  -0.58  0.564
Salinity   0.11701  0.04306   2.72  0.010

S = 0.578845   R-Sq = 18.3%   R-Sq(adj) = 15.8%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   2.4745  2.4745  7.39  0.010
Residual Error  33  11.0570  0.3351
Total           34  13.5315

Unusual Observations

Obs  Salinity  logresultSal     Fit  SE Fit  Residual  St Resid
  1      20.0        2.3424  1.6085  0.4032    0.7339      1.77 X
 18      28.0        1.3010  2.5446  0.1084   -1.2436     -2.19R
 28      24.0        1.3010  2.0766  0.2398   -0.7755     -1.47 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 (East of Balvicar mussels)

```
The regression equation is
logresultSal = 7.19 - 0.159 Salinity

Predictor     Coef  SE Coef      T      P
Constant     7.189    3.088   2.33  0.029
Salinity   -0.1592   0.1045  -1.52  0.141

S = 0.695034   R-Sq = 9.2%   R-Sq(adj) = 5.2%
```

```
Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   1.1215  1.1215  2.32  0.141
Residual Error  23  11.1107  0.4831
Total           24  12.2322

Unusual Observations

Obs  Salinity  logresultSal    Fit  SE Fit  Residual  St Resid
  4      28.0         4.204  2.731   0.211     1.473      2.22R
 24      33.0         2.204  1.935   0.389     0.269      0.47 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 (Balvicar oysters)

```
The regression equation is
logresultSal = 3.30 - 0.0323 Salinity

Predictor      Coef  SE Coef      T      P
Constant     3.3024   0.8222   4.02  0.000
Salinity   -0.03227  0.02894  -1.11  0.270

S = 0.795552   R-Sq = 2.3%   R-Sq(adj) = 0.4%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.7867  0.7867  1.24  0.270
Residual Error  53  33.5439  0.6329
Total           54  34.3306

Unusual Observations

Obs  Salinity  logresultSal    Fit  SE Fit  Residual  St Resid
 11      16.0         1.954  2.786   0.368    -0.832     -1.18 X
 15      28.0         4.556  2.399   0.107     2.157      2.74R
 25      30.0         3.959  2.334   0.120     1.625      2.07R
 35      22.0         4.204  2.593   0.208     1.612      2.10R
 40      16.0         2.875  2.786   0.368     0.089      0.13 X
 42      16.0         1.000  2.786   0.368    -1.786     -2.53RX
 48      24.0         4.556  2.528   0.161     2.028      2.60R

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 (Kilbrandon oysters)

```
The regression equation is
logresultSal = 2.13 - 0.0043 Salinity

Predictor      Coef  SE Coef      T      P
Constant     2.1275   0.3149   6.76  0.000
Salinity   -0.00431  0.01367  -0.32  0.754

S = 0.769700   R-Sq = 0.2%   R-Sq(adj) = 0.0%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.0589  0.0589  0.10  0.754
Residual Error  55  32.5841  0.5924
Total           56  32.6430
```

```
Unusual Observations

Obs  Salinity  logresultSal    Fit  SE Fit  Residual  St Resid
 29      30.0         3.732  1.998   0.152     1.734      2.30R

R denotes an observation with a large standardized residual.
```

Section 12 One way ANOVA comparison of SEPA monitoring results by sampling location

```
Source             DF      SS     MS     F      P
Sampling location   2   2.901  1.451  2.78  0.080
Error              27  14.089  0.522
Total              29  16.990

S = 0.7224   R-Sq = 17.08%   R-Sq(adj) = 10.93%


                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level            N    Mean   StDev  ----+---------+---------+---------+-----
NM 764 153       7  2.5004  0.5553     (----------*----------)
NM 778 182       5  2.4743  0.4785  (------------*-------------)
NM 78282 15618  18  3.1241  0.8161                     (------*------)
                                    ----+---------+---------+---------+-----
                                      2.00      2.50      3.00      3.50

Pooled StDev = 0.7224
```

Section 12 One way ANOVA comparison of SEPA sampling results by quarter at Ardmaddy Bay

```
Source      DF      SS     MS     F      P
Ardmaddy Q   3   1.714  0.571  0.83  0.498
Error       14   9.609  0.686
Total       17  11.323

S = 0.8285   R-Sq = 15.14%   R-Sq(adj) = 0.00%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  ---+---------+---------+---------+------
Q1     4  2.8095  0.2306  (------------*------------)
Q2     4  2.7820  0.3775  (------------*-----------)
Q3     5  3.5131  0.8889              (----------*-----------)
Q4     5  3.2606  1.2105          (-----------*----------)
                          ---+---------+---------+---------+------
                           2.10      2.80      3.50      4.20

Pooled StDev = 0.8285
```

Hydrographic Methods

1.0 Introduction

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. This document collects together information common to all hydrographic assessments avoiding the repetition of information in each individual report.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only and is not discussed in any detail in this document. 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 focus on this more detailed hydrographic assessment and describes the common methodology applied to all sites.

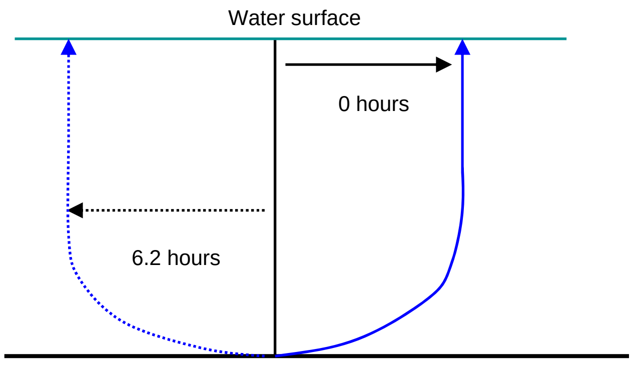
The regulations require an appreciation of the hydrography and currents within a region classified for shellfish production.

1.1 Background processes

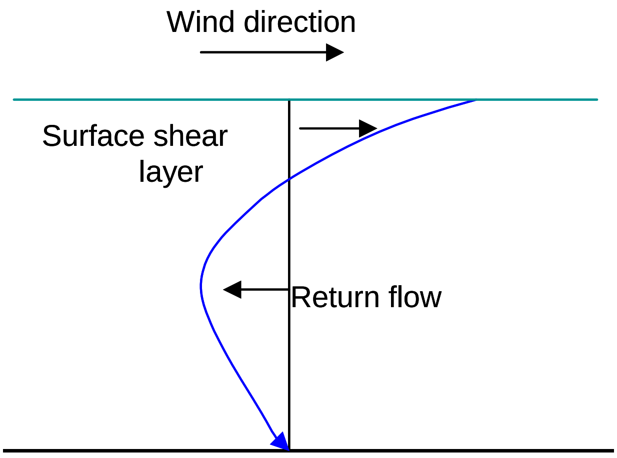
This section gives an overview of the hydrographic processes relevant to sanitary surveys.

Movement in the estuarine and coastal waters is generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences. Unless tidal flows are weak they usually dominate over the short term (~12 hours) and move material over the length of the tidal excursion. The tidal residual flow acts over longer time scales to give a net direction of transport. 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.

a)



b)



c)

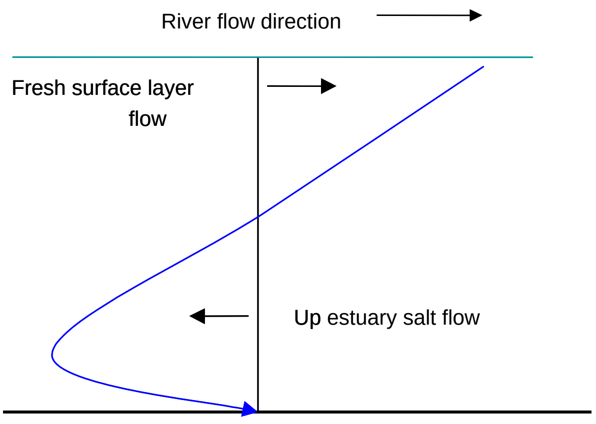


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

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.

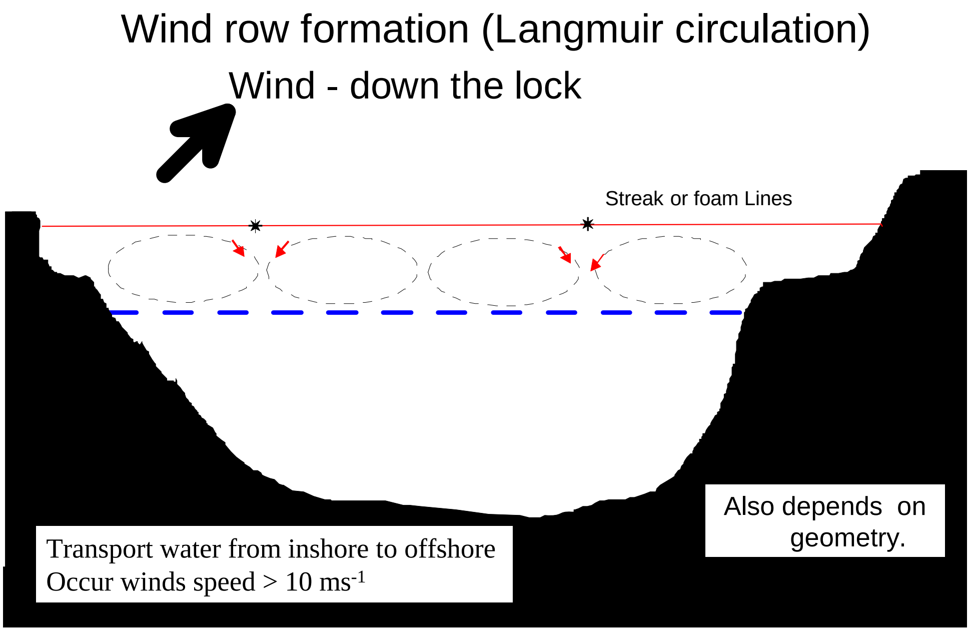


Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

2.0 Basic Assessment

This will be applied to most sites and consists of a description of bathymetry and the tidal regime obtained from admiralty charts and tidal diamonds and is not described in detail here.

3.0 More Detailed Assessment

This is applied at the request of the regulator (FSAS) when particular circumstances apply. Typically this will be at sites where production areas regular fail or where unusual results have been reported.

3.1 Modelling approach

The Hydrotrack computer model is used. This is able to simulate depth averaged tidal currents and give some indication of wind driven currents. Model output from the model is analysed to provide information on:

- Particle paths due to tides and winds.
- Residual current patterns due to tide and winds.

Tidal forcing is a simple sinusoidal current applied at the model boundary. Where possible the assumption is made that the change in tidal phase across the boundary is negligible. Basic checking of the model is limited to the available data. In most cases this is limited to reproducing the observed tidal range. If tidal diamond or current meter observations are available, model results are checked against these.

Model calculations are carried out for five cases: tides only and tides plus winds from north, south east and west directions. The resulting winds patterns are for winds blowing constantly for 48 hours so that a steady current pattern is produced. In reality of course winds are highly variable. For each of these cases the results over the last two tidal periods are analysed to provide tidal phase and amplitude and the residual current. The paths of particles moving with the water and starting from known sources of contamination are calculated using the analysed currents. For point sources very near the shore, model release points may be moved slightly offshore out to ensure particles are caught by the prevailing current and not trapped at the release point.

For a given water body, the strength of the applied wind is chosen to ensure wind driven currents are large relative to the tidal currents so that particle paths clearly show the wind driven movement.

Although Hydrotrack calculates currents over the spatial area of a water body, it cannot calculate the vertical profile of currents. Although adequate for tidal flows this has limitations for wind and density driven systems characteristic of many sea lochs. Therefore the modelling approach is more usefully applied to tidally dominated systems or shallow regions where vertical structure may be less significant.

3.2 Non-modelling approach

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’.
7. Estimates of flow speed combined with T_{90} will give a ‘region of influence’.
8. The ratio of river run-off to tidal prism gives an indication of the importance of density effects.

Many Scottish shell fish 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.

For the more detailed assessment of sea loch regions, the “Sea Loch catalogue” 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.

Dilution calculations in regions with steep and variable bathymetry typical of sea lochs are extremely difficult. The following methods are applied.

For class A and B classifications, correlation data (European Commission 1996) suggest the following water concentration need to be achieved:

Class A: 1 *E. coli* per 100 ml = 10^4 m^{-3}
Class B: 100 *E. coli* per 100 ml = 10^6 m^{-3}

3.2.1 Integrated Inputs

Given *E. coli* loadings and estimates of water body volume and flushing time, the *E. coli* concentration averaged over the entire water body can be estimated from:

$$C = S T_f / V$$

C = number *E. coli* m^{-3}
S = Sum of all loadings (number of *E. coli* per day)
T_f = Flushing time (days)
V = Water body volume (m^3)

This can then be compared with the Class A and B requirements.

<u>3.2.2 Individual inputs</u>

For a source with a loading M *E. coli* per second, discharging into water flowing at speed u (ms^{-1}), the number of *E. coli* per meter in the flow direction is given by M/u (*E. coli* m^{-1}). To achieve a target concentration of T, the cross sectional area that the material needs to be mixed over is given by

$$A = M/(u\ T)$$

Assuming an average depth for the water body this can be converted to a distance offshore. A subjective judgement can then made as to whether this is likely to occur over the relevant time scales (< 3 days). That is, will the required dilution occur quickly enough that only localised impacts would be expected? For sea lochs the assumption is made that away from the sills, mixing is likely to be quite weak.

4.0 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.

5.0 Glossary

The following technical terms 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

Seil Sound: Balvicar
AB 247
&
Seil Sound: Kilbrandon
AB 248

Scottish Sanitary Survey Project Cefas

Shoreline Survey Report

Production Area:

Production Area	Site	SIN	Species
Seil Sound: Balvicar	Balvicar North	AB 247 735 13	Pacific Oysters
Seil Sound: Balvicar	Rubha nan Ron South	AB 247 728 13	Pacific Oysters
Seil Sound: Balvicar	Balvicar	AB 247 072 13	Pacific Oysters
Seil Sound: Balvicar	Ardshellach	AB 247 071 13	Pacific Oysters
Seil Sound: Balvicar	East of Balvicar	AB 247 703 08	Common Mussels
Seil Sound: Kilbrandon	Island Site	AB 248 784 13	Pacific Oysters
Seil Sound Kilbrandon	Kilbrandon	AB 248 073 13	Pacific Oysters

Harvesters: Balvicar North and Ardshellach, Patrick Cadzow
Balvicar and Island site, Ewan McAskill
Rubha nan Ron South, James Robertson
East of Balvicar, Jack MacGregor
Kilbrandon, Phillip Guy
Status: Currently all are classified for harvest.
Date Surveyed: 19/8/08 to 21/8/08.
Surveyed by: Christine McLachlan, Donald Campbell, Ewan McDougall, Alastair Cook
Existing RMPs: NM775173, NM773158, NM779169, NM764153
Area Surveyed: See Figure 1.

Weather observations

19/8/08 – 8 Km/h SE wind, overcast, 14 C.
20/8/08 – 5 Km/h N wind, rain, 15 C.
21/8/08 – 6 Km/h NW wind, overcast, 14 C.

Site Observations

Specific observations made on site are mapped in Figure 1 and listed in Table 1. Water and shellfish samples were collected at sites marked on Figures 2 and 3. Bacteriology results are given in Tables 2 and 3. Photographs are presented in Figures 4-7.

Fishery

Balvicar North. This consists of two areas of trestles, one on an island in the middle of Seil Sound where trestles are spread out at low density over a large area, and one on the eastern shore at Craig Ulian. Stock of a range of sizes was present, including those of a harvestable size.

Rubha nan Ron South. This consists of an area of trestles on the west shore of Seil Sound, just south of Balvicar. A processing shed is located on the shoreline above this site, where depuration facilities may be installed at some point in the future. Stock of a range of sizes was present including those of a harvestable size. In addition to the main block of trestles, the grower also has 2 trestles just to the east of the boatyard at Balvicar. Planning permission has been granted for a further 300 trestles to be deployed here.

Balvicar. This site consists of a few areas of trestles, some of which have old stock on, but most of which were empty. The site has been inactive for a year or so, but harvesting would normally be undertaken during the autumn.

Also at the Balvicar site are some additional rows of trestles extending towards the Rubha nan Ron site. These are the property of Mr Vijk of Caledonian Oysters. Stock of a range of sizes was present including of a harvestable size.

Ardshellach. This consists of an area of trestles on the east shore at Ardshellach. Stock of a range of sizes was present on site including of a harvestable size.

East of Balvicar. This mussel site consists of two lines with 10 m droppers, and 5 rafts with 10m droppers. Stock of a range of sizes was present on site, including of a harvestable size. Harvesting usually occurs during the summer months, but is dependent on demand.

Kilbrandon. This consists of a small area of trestles that are relatively high on the shoreline. It is not in commercial production at present, and a few bags of mature oysters are held here to allow sampling to maintain classification.

Island Site. This consists of an area of 114 trestles. This site was not visited during the shoreline survey. The extent of the site was subsequently measured by the local sampling officer during October 2008. There was no stock on this site at the time.

Oysters in this production area take about 3 years to reach a harvestable size. Additionally, a few king scallops, queen scallops and small native oysters were found in some areas near the low tide mark, and empty shells of a range of species such as clams, cockles and razors were present.

<u>Sewage/Faecal Sources</u>

Human – The settlements of Clachan Seil and Balvicar lie on the western shore of Seil Sound. Clachan Seil is served by a mixture of private septic tanks and a larger Scottish Water septic tank. Balvicar is served by private septic tanks. Locations of all observed discharges to the production area are listed in Table 1. On the east side of the loch, one sewer pipe from a private residence discharges to the shore approximately 130 m southeast of the East of Balvicar mussel lines. A total of 43 yachts and small boats were seen on moorings in Seil Sound, mainly around Clachan Seil and Balvicar. At the time of survey, Scottish Water were undertaking construction of a new sewerage system, which is intended to serve Balvicar and Clachan Seil. Houses currently with private discharges will be able to connect to this system, although they will not be compelled to if they do not want to.

Livestock – There are several areas of pasture on the shores of Seil Sound. The largest concentrations of these were around Balvicar Farm (82 sheep with some on the shore) and Ardmaddy Castle (52 cattle and 36 sheep in fields).

A number of small streams drain into the production area, draining areas of pasture, bog and forest. Water samples were taken, and discharge estimated where the streams were of sufficient size for flow to be measured. Stream inputs had levels of *E. coli* of up to just over 5000 cfu/100ml, but two streams with considerably higher levels of *E. coli* were found. One of these discharges was in Clachan Seil, where the water contained 49000 *E. coli* cfu/100ml and 33 ducks and duck droppings were found nearby. The other discharges to the east shore at Caddleton, where 24000 *E. coli* cfu/100ml was found.

E. coli levels in seawater samples ranged from 1 to 480 cfu/100ml. Salinities ranged from 25.1 parts per thousand in Ardmaddy Bay to 34.2 parts per thousand in the open water around the mussel lines. Aside from the sample taken in Ardmaddy Bay, which has 4 streams discharging into it, all samples were over 30 ppt.

Shellfish samples gave results of 20 to 750 *E. coli* mpn/100g. The two highest results occurred in oysters taken from the Rubha nan Ron and Kilbrandon sites.

Oyster samples were taken from five locations for norovirus testing. All samples tested negative for genogroups I and II.

The laboratory was unable to receive samples on the day they arrived, so samples were not processed within the recommended 24 hour time limit. Samples were received and processed by the laboratory within 48 hours of collection. However, the sample temperatures on arrival at the laboratory were 14.2ºC, which is outwith the recommended temperature range of 1-8ºC. As a consequence, these results should be considered indicative only.

<u>Seasonal Population</u>

A number of the dwellings seen on the shoreline survey are likely to be holiday homes. Coach tours regularly visit the ‘Atlantic Bridge’, which crosses Seil sound at the north extremity of the production area with at least 2 seen during the course of the survey. The area is also frequented by yachts, which are likely to be more numerous during the summer months.

Boats/Shipping

Several areas of moorings were seen in the production area, mainly around Clachan Seil and Balvicar. A total of 43 yachts and small boats were seen, with one larger vessel at Balvicar boat yard. Some of these were of sufficient size for people to live on board, and most were pleasure craft so it is likely that impacts from these are higher during the summer months.

Land Use

The surrounding land is a mixture of pasture, bog, forest, houses and gardens. The majority of the population lives on the west side of Seil Sound on Seil Island, which is lower lying and is mainly covered by bog and pasture. The land to the east of Seil Sound is more forested, although there are large areas of pasture here also.

Wildlife/Birds

An aggregation of 33 ducks and one swan was seen on the shore at Clachan Seil. Rabbit droppings were also seen here. 100 seagulls were seen feeding in the intertidal zone at Ardmaddy bay. Aside from these, no significant aggregations of wildlife were seen during the course of the survey. The local sampling officer, a resident of Clachan Seil, advises that a small colony of seals (6-8 animals) haul out on the small rocky islets of Sgeir Liath Mhor and Beag, near the Balvicar north site during the summer months. Also, large concentrations of geese (over 100 birds at times) are seen year round but more often during the winter on the golf course just north of Balvicar, around Balvicar farm, and on the mainland around Ardshellach.

General observations

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 production area.

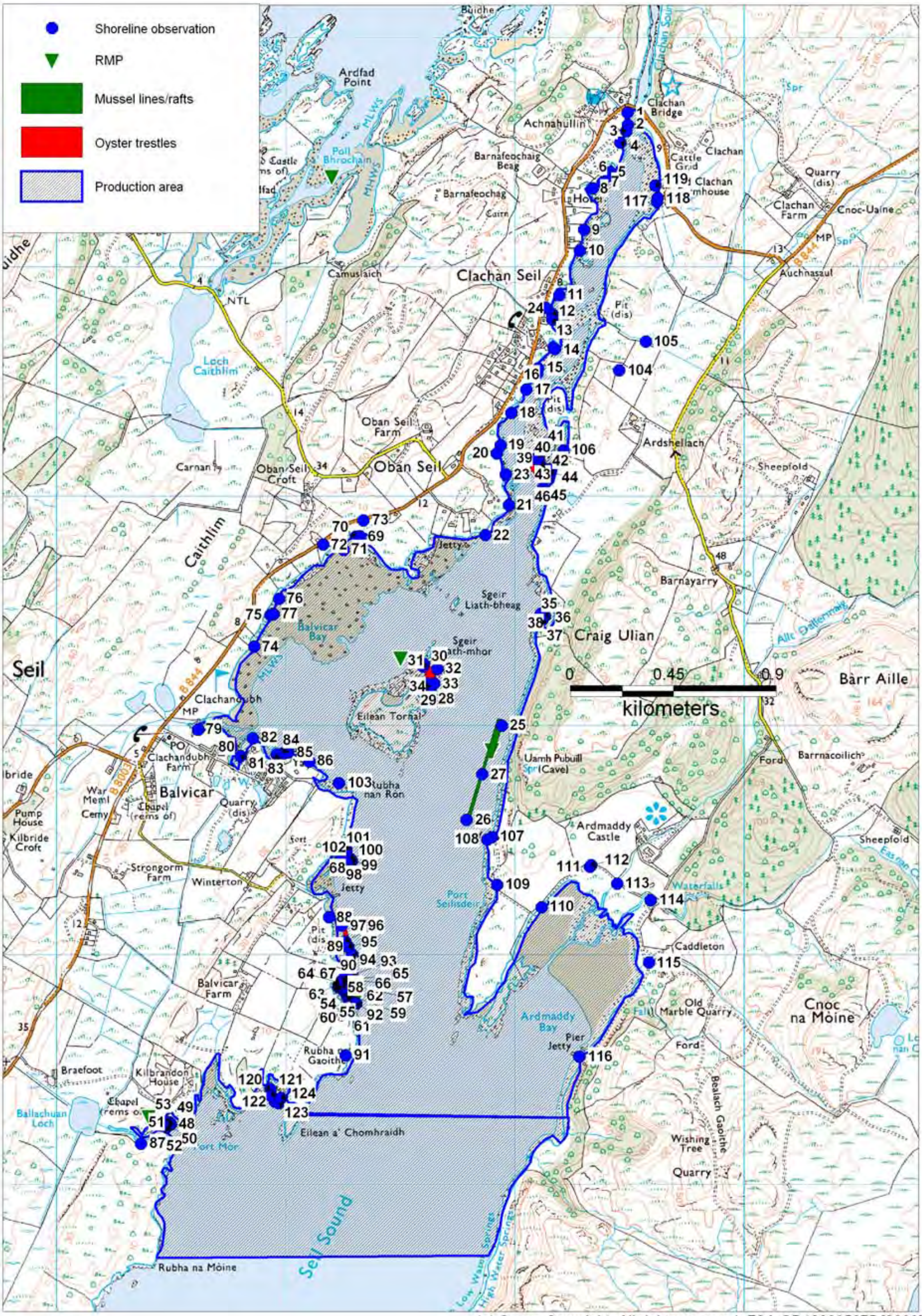


Figure 1. Map of Shoreline Observations

Table 1. Shoreline observations

No.	Date and time	Position	Photograph	Description
1	19-AUG-08 10:17:08AM	NM 78491 19674	Figure 4	Culverted stream 1cmx11cmx0.908m/s. Seil Freshwater 1. Also vent in concrete and 110mm orange sewer pipe to underwater on shore below.
2	19-AUG-08 10:22:40AM	NM 78492 19622		Seil Seawater 2.
3	19-AUG-08 10:24:48AM	NM 78486 19594		110mm black plastic sewer pipe to shore, sweetcorn and toilet paper around end.
4	19-AUG-08 10:28:13AM	NM 78459 19545		Stream 20cmx3cmx0.016m/s. Seil Freshwater 3.
5	19-AUG-08 10:37:21AM	NM 78415 19415		Rabbit droppings
6	19-AUG-08 10:38:05AM	NM 78409 19400		150mm metal sewer pipe, trickle coming from end.
7	19-AUG-08 10:39:34AM	NM 78382 19371		5 boats on moorings
8	19-AUG-08 10:41:10AM	NM 78339 19345		Stream 78cmx5cmx0.062m/s. Seil freshwater 4. 9 ducks, swan or goose droppings also.
9	19-AUG-08 10:49:12AM	NM 78302 19165		24 ducks, 1 swan, 5 boats on moorings.
10	19-AUG-08 10:52:32AM	NM 78283 19074		150mm metal sewer pipe to underwater.
11	19-AUG-08 10:58:50AM	NM 78193 18880	Figure 5	110mm orange sewer pipe, trickling, excrement and tiolet paper around end.
12	19-AUG-08 11:02:08AM	NM 78162 18797		150mm metal sewer pipe to underwater.
13	19-AUG-08 11:03:25AM	NM 78163 18772		Stream 39cmx2cmx0.421m/s. Seil Freshwater 5.
14	19-AUG-08 11:09:50AM	NM 78175 18643		110mm orange sewer pipe, not flowing but odour detected.
15	19-AUG-08 11:12:46AM	NM 78101 18560		120mm broken ceramic sewer pipe not flowing
16	19-AUG-08 11:13:41AM	NM 78097 18538		Yacht and 3 small boats moored.
17	19-AUG-08 11:15:43AM	NM 78048 18466		120mm metal sewer pipe to underwater and 110mm orange plastic pipe alongside it
18	19-AUG-08 11:19:22AM	NM 77983 18366		110mm orange plastic sewer pipe to underwater. Also Yacht and jetty
19	19-AUG-08 11:23:06AM	NM 77937 18225		Jetty and 3 Yachts
20	19-AUG-08 11:24:28AM	NM 77920 18188		Stream 21cmx5cmx0.16m/s. Seil Freshwater 6
21	19-AUG-08 11:33:09AM	NM 77973 17963		Broken 120mm ceramic sewer pipe.
22	19-AUG-08 11:39:40AM	NM 77870 17833		100mm metal sewer pipe
23	19-AUG-08 11:47:47AM	NM 77960 18097		Seil seawater 7.
24	19-AUG-08 12:00:07PM	NM 78133 18824	Figure 6	Scottish water communal septic tank (outflow not visible, serves about 20 houses).
25	19-AUG-08 12:46:46PM	NM 77942 17001		Seil seawater 8. Seil mussel 1 (bottom) and Seil mussel 9 (top).
26	19-AUG-08 1:01:39PM	NM 77788 16590		Seil seawater 9. Seil mussel 2 (top) and 3 (bottom).
27	19-AUG-08 1:12:35PM	NM 77857 16789	Figure 7	End of far line
28	19-AUG-08 1:16:12PM	NM 77631 17149		Corner of trestles (Balvicar North)
29	19-AUG-08 1:17:01PM	NM 77618 17184		Corner of trestles (Balvicar North)
30	19-AUG-08 1:17:56PM	NM 77599 17259		Corner of trestles (Balvicar North)
31	19-AUG-08 1:18:03PM	NM 77602 17268		Corner of trestles (Balvicar North)
32	19-AUG-08 1:19:12PM	NM 77660 17249		Corner of trestles (Balvicar North)
33	19-AUG-08 1:21:01PM	NM 77646 17185		Corner of trestles (Balvicar North)
34	19-AUG-08 1:22:21PM	NM 77626 17168		Seil seawater 10. Oyster norovirus sample (Balvicar North). Seil oyster 10
35	19-AUG-08 1:30:33PM	NM 78113 17489	Figure 8	Corner of trestles (Balvicar North). 18 cows on shore.

No.	Date and time	Position	Photograph	Description
36	19-AUG-08 1:32:40PM	NM 78129 17481		Corner of trestles (Balvicar North). Seil seawater 11. Seil oyster 4.
37	19-AUG-08 1:36:00PM	NM 78120 17462		Corner of trestles (Balvicar North)
38	19-AUG-08 1:36:18PM	NM 78115 17461		Corner of trestles 20m out (Balvicar North)
39	19-AUG-08 1:45:36PM	NM 78050 18149		Corner of trestles (Ardshellach). Oyster norovirus sample (Ardshellach) and Seil oyster 5.
40	19-AUG-08 1:48:30PM	NM 78078 18164	Figure 9	Corner of trestles (Ardshellach).
41	19-AUG-08 1:48:48PM	NM 78102 18171		Corner of trestles (Ardshellach).
42	19-AUG-08 1:49:16PM	NM 78110 18136		Corner of trestles (Ardshellach).
43	19-AUG-08 1:49:48PM	NM 78145 18120		Corner of trestles (Ardshellach).
44	19-AUG-08 1:50:04PM	NM 78150 18107		Corner of trestles (Ardshellach).
45	19-AUG-08 1:50:21PM	NM 78144 18083		Corner of trestles (Ardshellach).
46	19-AUG-08 1:51:07PM	NM 78122 18039		Corner of trestles (Ardshellach). Seil seawater 12
47	19-AUG-08 2:23:41PM	NM 76493 15263	Figure 10	Corner of trestles (Kilbrandon)
48	19-AUG-08 2:23:59PM	NM 76497 15262		Corner of trestles (Kilbrandon)
49	19-AUG-08 2:24:08PM	NM 76490 15261		Corner of trestles (Kilbrandon)
50	19-AUG-08 2:24:28PM	NM 76482 15262		Corner of trestles (Kilbrandon)
51	19-AUG-08 2:24:38PM	NM 76484 15268		Corner of trestles (Kilbrandon)
52	19-AUG-08 2:25:20PM	NM 76478 15250		Seil seawater 13.
53	19-AUG-08 2:26:54PM	NM 76491 15271		Seil oyster 11 (sample 11 rejected due to dead shellfish, resampled from NM76491 15271 on 21/8/08). Oyster norovirus sample (Kilbrandon). 4 sheep on shore, 1 small boat moored in the bay.
54	19-AUG-08 2:52:04PM	NM 77227 15862		Corner of trestles (Balvicar)
55	19-AUG-08 2:52:11PM	NM 77231 15871		Corner of trestles (Balvicar)
56	19-AUG-08 2:52:18PM	NM 77234 15872		Corner of trestles (Balvicar)
57	19-AUG-08 2:52:31PM	NM 77245 15876		Corner of trestles (Balvicar)
58	19-AUG-08 2:52:47PM	NM 77235 15860		Corner of trestles (Balvicar)
59	19-AUG-08 2:53:32PM	NM 77265 15832	Figure 11	Corner of trestles (Balvicar)
60	19-AUG-08 2:53:38PM	NM 77268 15832		Corner of trestles (Balvicar)
61	19-AUG-08 2:53:56PM	NM 77270 15823		Corner of trestles (Balvicar)
62	19-AUG-08 2:54:36PM	NM 77267 15823		Corner of trestles (Balvicar)
63	19-AUG-08 2:58:10PM	NM 77231 15879		Seil seawater 14
64	19-AUG-08 3:05:29PM	NM 77233 15880		Seil oyster 6. Oyster norovirus sample (Balvicar)
65	19-AUG-08 3:05:47PM	NM 77244 15889		Row of bags of smaller oysters on substrate (Balvicar).
66	19-AUG-08 3:06:01PM	NM 77249 15896		Row of bags of smaller oysters on substrate (Balvicar).
67	19-AUG-08 3:06:38PM	NM 77235 15880		Row of bags of smaller oysters on substrate (Balvicar).
68	19-AUG-08 3:23:46PM	NM 77239 16432		Seil oyster 7. Oyster norovirus sample (Rubha Nan Ron).
69	20-AUG-08 10:07:29AM	NM 77321 17827		Stream 50cmx2cmx0.01m/s. Seil freshwater 15.
70	20-AUG-08 10:12:23AM	NM 77304 17825		Stream 24cmx2cmx0.295m/s. Seil freshwater 16.
71	20-AUG-08 10:17:06AM	NM 77252 17768		Seil seawater 17.
72	20-AUG-08 10:23:26AM	NM 77162 17791		Septic pipe, presumably to soakaway as not visible on shore
73	20-AUG-08 10:30:17AM	NM 77338 17896		40 sheep and 4 cattle on landward side of road.

No.	Date and time	Position	Photograph	Description
74	20-AUG-08 10:38:33AM	NM 76861 17346		110mm orange plastic sewer pipe to underwater.
75	20-AUG-08 10:43:15AM	NM 76932 17484		110mm orange plastic sewer pipe not flowing.
76	20-AUG-08 10:46:17AM	NM 76970 17554		110mm orange plastic sewer pipe trickling.
77	20-AUG-08 10:48:50AM	NM 76946 17487		Seil seawater 18
78	20-AUG-08 11:02:48AM	NM 76617 16983		2 sewer pipes to burn (serving about 10 houses).
79	20-AUG-08 11:07:36AM	NM 76616 16983	Figure 12	Stream 115cmx45cmx0.45m/s. Seil freshwater 19 (taken downstream of sewer pipes).
80	20-AUG-08 11:14:17AM	NM 76762 16908		120mm ceramic broken sewer pipe and 120mm cast iron sewer pipe.
81	20-AUG-08 11:18:58AM	NM 76801 16868		110mm orange plastic sewer pipe not flowing.
82	20-AUG-08 11:20:51AM	NM 76855 16946		110mm orange plastic sewer pipe, excrement around the end.
83	20-AUG-08 11:33:44AM	NM 76960 16875		Jetty, 18 boats/yachts, 5 fishing boats and some empty moorings.
84	20-AUG-08 11:34:59AM	NM 76991 16880		110mm orange plastic sewer pipe.
85	20-AUG-08 11:36:26AM	NM 77008 16884		Seil seawater 20
86	20-AUG-08 11:40:43AM	NM 77102 16845		Boatyard. Some large boats in storage, one in water, yachts overwinter here.
87	20-AUG-08 12:09:08PM	NM 76367 15177		Stream 123cmx20cmx0.409m/s. Seil freshwater 21
88	20-AUG-08 12:59:22PM	NM 77187 16165		110mm orange plastic sewer pipe not flowing.
89	20-AUG-08 1:02:42PM	NM 77243 16040		2 sheep on shore
90	20-AUG-08 1:08:34PM	NM 77255 15882		30 sheep on shore
91	20-AUG-08 1:15:29PM	NM 77260 15563		50 sheep on pasture
92	20-AUG-08 1:21:18PM	NM 77307 15790		End of empty row of trestles (Balvicar) extending out 10m from here. A few oyster bags but abandoned.
93	20-AUG-08 1:28:14PM	NM 77289 15912		Other end of row of trestles (Balvicar)
94	20-AUG-08 1:30:40PM	NM 77289 16002		Start of row of trestles (Balvicar), extends about 20m out from here. Bags of smaller oysters.
95	20-AUG-08 1:32:43PM	NM 77272 16037		Other end of row of trestles (Balvicar).
96	20-AUG-08 1:35:04PM	NM 77259 16059		Start of row of trestles (Balvicar), extends about 30m out from here. Larger oysters in bags.
97	20-AUG-08 1:37:36PM	NM 77242 16130		Other end of row of trestles (Balvicar).
98	20-AUG-08 1:44:53PM	NM 77275 16398		Corner of trestles (Balvicar).
99	20-AUG-08 1:45:29PM	NM 77288 16409		Corner of trestles (Balvicar).
100	20-AUG-08 1:46:00PM	NM 77280 16420		Corner of trestles (Balvicar).
101	20-AUG-08 1:48:22PM	NM 77264 16460		Corner of trestles (Balvicar). Seil seawater 22
102	20-AUG-08 1:50:36PM	NM 77240 16439		Corner of trestles (Balvicar).
103	20-AUG-08 1:57:44PM	NM 77231 16750	Figure 13	2 trestles (permission for 300 granted here). Seil seawater 23. Seil oyster 8.
104	21-AUG-08 10:13:17AM	NM 78455 18551		11 cattle
105	21-AUG-08 10:17:03AM	NM 78571 18677		Stream 190cmx23cmx0.566m/s. Seil freshwater 24.
106	21-AUG-08 10:38:36AM	NM 78212 18201		Seil seawater 25.
107	21-AUG-08 10:58:26AM	NM 77899 16515	Figure 14	110mm cast iron sewer pipe, dripping and paper around end.
108	21-AUG-08 11:02:11AM	NM 77879 16504		Seil seawater 26.
109	21-AUG-08 11:07:30AM	NM 77921 16307		36 sheep.
110	21-AUG-08 11:09:29AM	NM 78116 16209		About 100 seagulls on shore in bay.
111	21-AUG-08 11:13:20AM	NM 78327 16386		Stream 15cmx2cmx1.019m/s. Seil freshwater 27.

No.	Date and time	Position	Photograph	Description
112	21-AUG-08 11:17:12AM	NM 78332 16392		52 cattle.
113	21-AUG-08 11:19:27AM	NM 78445 16312		Stream 310cmx25cmx0.322m/s. Seil freshwater 28.
114	21-AUG-08 11:26:21AM	NM 78592 16239		Stream 220cmx20cmx0.08m/s. Seil freshwater 29.
115	21-AUG-08 11:35:17AM	NM 78585 15968		Stream 96cmx10cmx0.657m/s. Seil freshwater 30.
116	21-AUG-08 11:42:40AM	NM 78280 15557		Fish farm shed, jetty, 3 small boats. Seil seawater 31.
117	21-AUG-08 12:09:54PM	NM 78620 19286		Stream 48cmx2cmx0.271m/s. Seil freshwater 32.
118	21-AUG-08 12:13:42PM	NM 78623 19303		110mm plastic sewer pipe not flowing but grey around end.
119	21-AUG-08 12:15:07PM	NM 78612 19357		Seil seawater 33.
120	October 2008	NM 76932 15414	Figure 15	Corner of trestles (Island site)
121	October 2008	NM 76935 15386		Corner of trestles (Island site)
122	October 2008	NM 76951 15361		Corner of trestles (Island site)
123	October 2008	NM 76967 15354		Corner of trestles (Island site)
124	October 2008	NM 76979 15377		Corner of trestles (Island site)

Table 2. Water sample *E. coli* results

Name	Date and time	Position	Type	E. coli (cfu/100ml)	Salinity (ppt)
Seil 1	19-AUG-08 10:17:08AM	NM 78491 19674	Freshwater	600	
Seil 2	19-AUG-08 10:22:40AM	NM 78492 19622	Seawater	17	34.2
Seil 3	19-AUG-08 10:28:13AM	NM 78459 19545	Freshwater	200	
Seil 4	19-AUG-08 10:41:10AM	NM 78339 19345	Freshwater	49000	
Seil 5	19-AUG-08 11:03:25AM	NM 78163 18772	Freshwater	5000	
Seil 6	19-AUG-08 11:24:28AM	NM 77920 18188	Freshwater	3100	
Seil 7	19-AUG-08 11:47:47AM	NM 77960 18097	Seawater	170	30.3
Seil 8	19-AUG-08 12:46:46PM	NM 77942 17001	Seawater	6	34.2
Seil 9	19-AUG-08 1:01:39PM	NM 77788 16590	Seawater	4	34.0
Seil 10	19-AUG-08 1:22:21PM	NM 77626 17168	Seawater	1	34.0
Seil 11	19-AUG-08 1:32:40PM	NM 78129 17481	Seawater	26	33.2
Seil 12	19-AUG-08 1:51:07PM	NM 78122 18039	Seawater	11	32.3
Seil 13	19-AUG-08 2:25:20PM	NM 76478 15250	Seawater	16	32.0
Seil 14	19-AUG-08 2:58:10PM	NM 77231 15879	Seawater	7	33.8
Seil 15	20-AUG-08 10:07:29AM	NM 77321 17827	Freshwater	300	
Seil 16	20-AUG-08 10:12:23AM	NM 77304 17825	Freshwater	200	
Seil 17	20-AUG-08 10:17:06AM	NM 77252 17768	Seawater	100	33.8
Seil 18	20-AUG-08 10:48:50AM	NM 76946 17487	Seawater	37	34.0
Seil 19	20-AUG-08 11:07:36AM	NM 76616 16983	Freshwater	5200	
Seil 20	20-AUG-08 11:36:26AM	NM 77008 16884	Seawater	5	34.0
Seil 21	20-AUG-08 12:09:08PM	NM 76367 15177	Freshwater	200	
Seil 22	20-AUG-08 1:48:22PM	NM 77264 16460	Seawater	48	33.8
Seil 23	20-AUG-08 1:57:44PM	NM 77231 16750	Seawater	9	33.8
Seil 24	21-AUG-08 10:17:03AM	NM 78571 18677	Freshwater	100	
Seil 25	21-AUG-08 10:38:36AM	NM 78212 18201	Seawater	51	33.8
Seil 26	21-AUG-08 11:02:11AM	NM 77879 16504	Seawater	230	33.8
Seil 27	21-AUG-08 11:13:20AM	NM 78327 16386	Freshwater	1900	
Seil 28	21-AUG-08 11:19:27AM	NM 78445 16312	Freshwater	1400	
Seil 29	21-AUG-08 11:26:21AM	NM 78592 16239	Freshwater	100	
Seil 30	21-AUG-08 11:35:17AM	NM 78585 15968	Freshwater	24000	
Seil 31	21-AUG-08 11:42:40AM	NM 78280 15557	Seawater	480	25.1
Seil 32	21-AUG-08 12:09:54PM	NM 78620 19286	Freshwater	200	
Seil 33	21-AUG-08 12:15:07PM	NM 78612 19357	Seawater	70	32.0

Table 3. Shellfish *E. coli* sample testing results

Name	Date & time	Position	Site	Species	Depth	*E. coli* mpn/100g
Seil 1	19-AUG-08 12:46:46PM	NM 77942 17001	East of Balvicar	Mussel	10 m	20
Seil 2	19-AUG-08 1:01:39PM	NM 77788 16590	East of Balvicar	Mussel	1 m	220
Seil 3	19-AUG-08 1:01:39PM	NM 77788 16590	East of Balvicar	Mussel	10 m	290
Seil 4	19-AUG-08 1:32:40PM	NM 78129 17481	Balvicar North	Pacific oyster		110
Seil 5	19-AUG-08 1:45:36PM	NM 78050 18149	Ardshellach	Pacific oyster		20
Seil 6	19-AUG-08 3:05:29PM	NM 77233 15880	Balvicar	Pacific oyster		200
Seil 7	19-AUG-08 3:23:46PM	NM 77239 16432	Rubha nan Ron	Pacific oyster		750
Seil 8	20-AUG-08 1:57:44PM	NM 77231 16750	Rubha nan Ron	Pacific oyster		310
Seil 9	19-AUG-08 12:46:46PM	NM 77942 17001	East of Balvicar	Mussel	1 m	200
Seil 10	19-AUG-08 1:22:21PM	NM 77626 17168	Balvicar North	Pacific oyster		220
Seil 11	21-AUG-08 12:50:00PM	NM 76491 15271	Kilbrandon	Pacific oyster		750

Table 4. Oyster norovirus testing results

Lab reference	**Site**	**Date and time**	**Position**	**Norovirus genogroup I**	**Norovirus genogroup II**
08/170	Balvicar North	19-AUG-08 1:22:21PM	NM 77626 17168	ND*	ND*
08/168	Ardshellach	19-AUG-08 1:45:36PM	NM 78050 18149	ND*	ND*
08/169	Kilbrandon	19-AUG-08 2:26:54PM	NM 76491 15271	ND*	ND*
08/166	Balvicar	19-AUG-08 3:05:29PM	NM 77233 15880	ND*	ND*
08/165	Rubha Nan Ron	19-AUG-08 3:23:46PM	NM 77239 16432	ND*	ND*

*ND = not detected

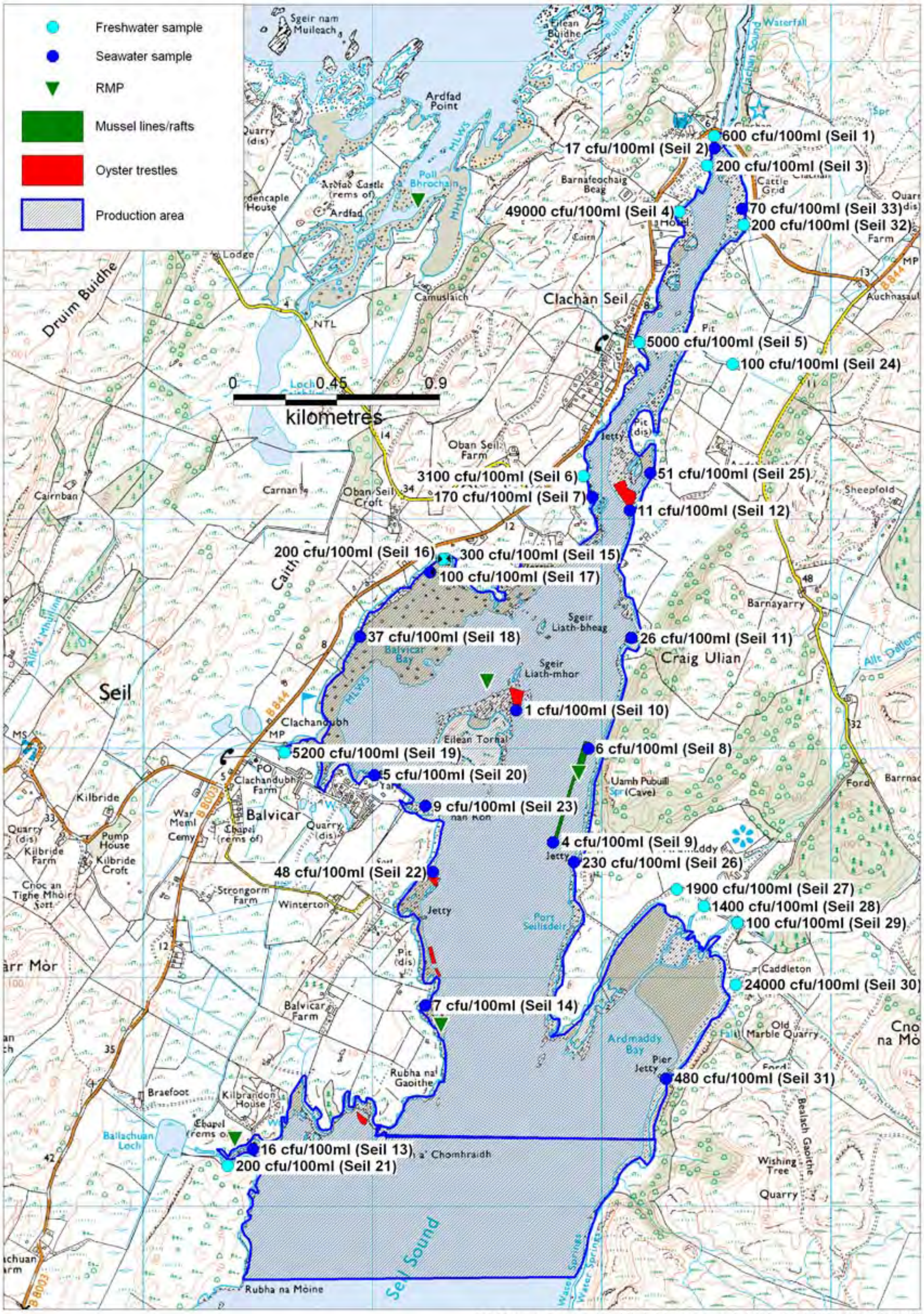


Figure 2. Water sample results map

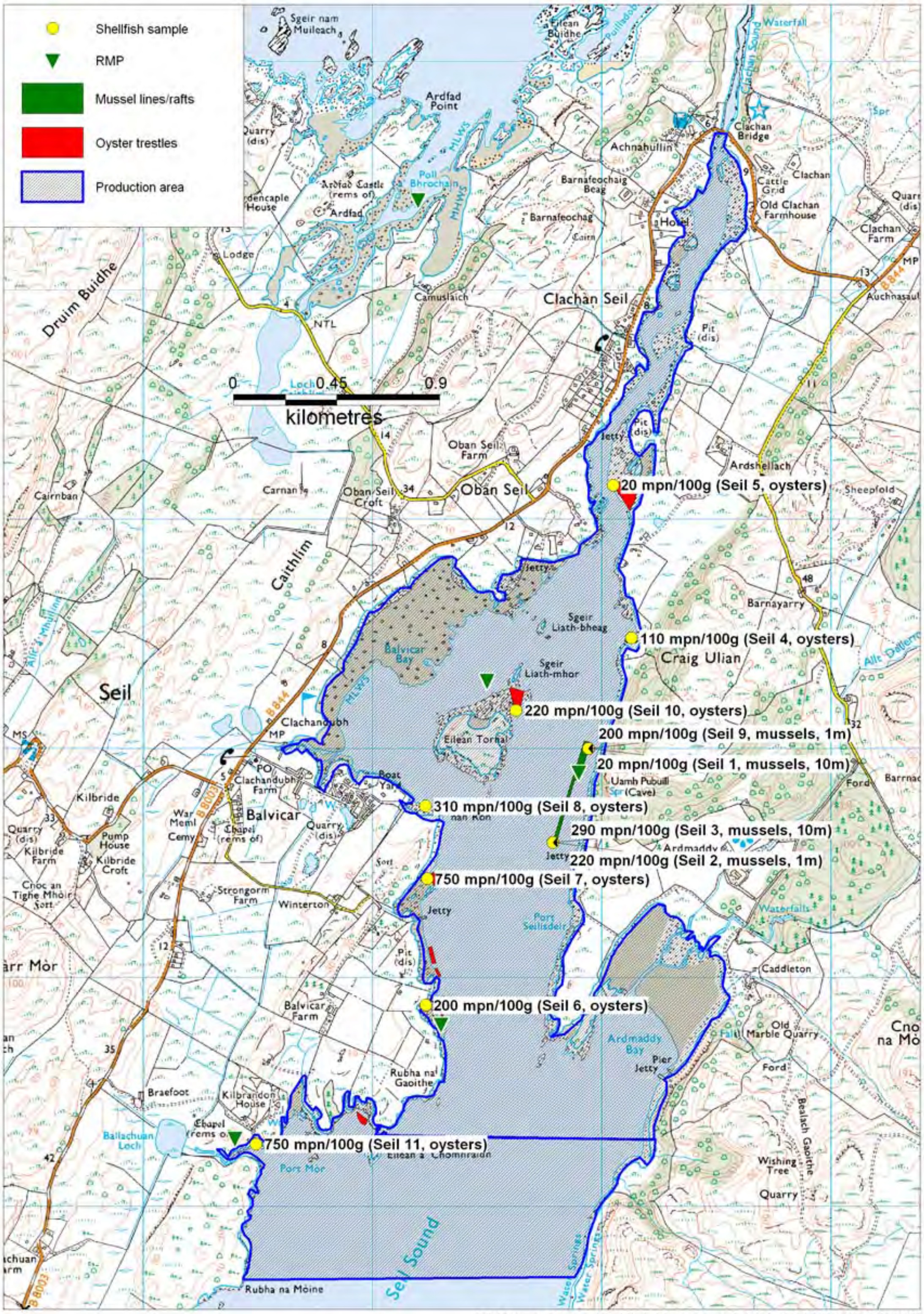


Figure 3. Shellfish sample results map

Figure 4 Stream at Clachan Seil with sewer vent

Figure 5 Private sewer pipe at Clachan Seil

Figure 6 Communal septic tank at Clachan Seil

Figure 7 Mussel lines and rafts, East of Balvicar

Figure 8 Trestles at Balvicar North with cattle in background

Figure 9. Trestles at Ardshellach

Figure 10 Trestles at Kilbrandon site

Figure 11 Trestles at Balvicar

Figure 12 Sewer outflow to stream at Balvicar

Figure 13 Trestles near boatyard, Rubha Nan Ron

Figure 14 Mussel lines and rafts with private sewer pipe in foreground

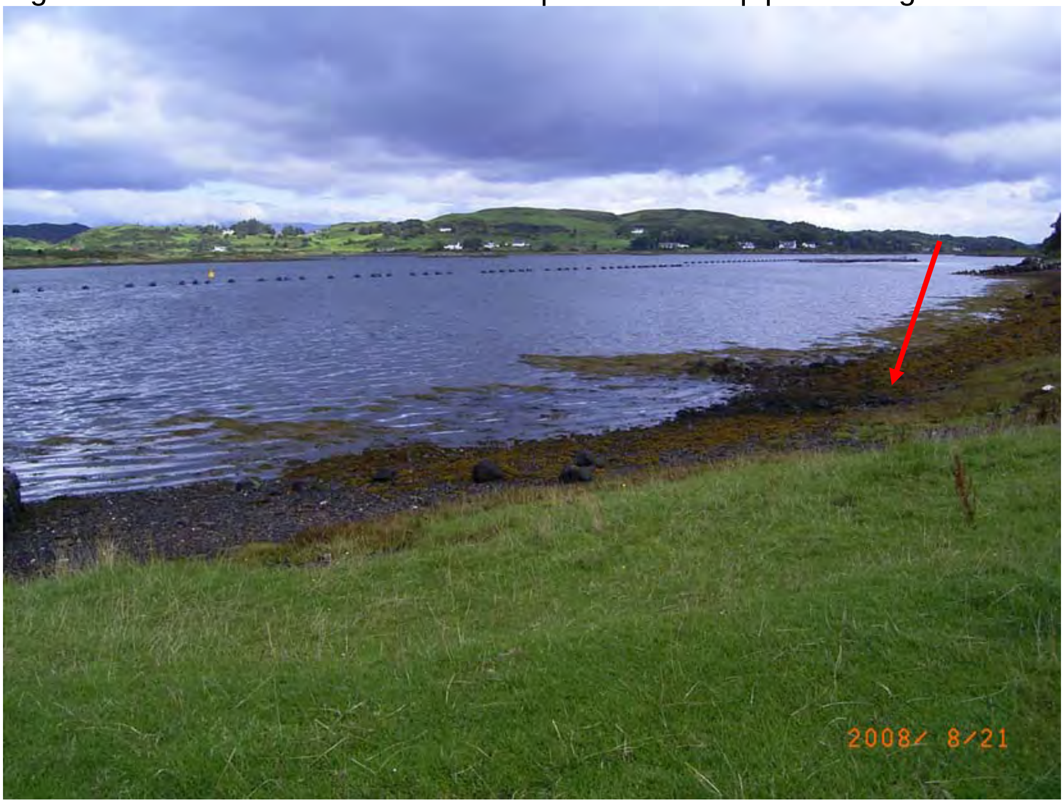


Figure 15. Trestles at Island site

Norovirus Testing Summary

Seil Sound Balvicar (AB247) and Seil Sound Kilbrandon (AB248)

Pacific oyster samples were taken quarterly from five sites within Seil Sound and submitted for Norovirus analysis beginning 19/8/2008. Results are tabulated below. Locations of sample points used for norovirus testing are shown on the map overleaf.

Ref No.	Date	NGR	Site	GI*	GII*
08/168	19/08/2008	NM 78050 18149	Ardshellach	Not detected	Not detected
08/170	19/08/2008	NM 77626 17168	Balvicar North	Not detected	Not detected
08/165	19/08/2008	NM 77239 16432	Rubha nan Ron South	Not detected	Not detected
08/166	19/08/2008	NM 77233 15880	Balvicar	Not detected	Not detected
08/169	19/08/2008	NM 76491 15271	Kilbrandon	Not detected	Not detected
08/255	12/11/2008	NM 78053 18147	Ardshellach	Not detected	Positive
08/254	12/11/2008	NM 77623 17168	Balvicar North	Not detected	Positive
08/260	13/11/2008	NM 77239 16434	Rubha nan Ron South	Positive	Positive at LOD
08/258	13/11/2008	NM 77231 15875	Balvicar	Positive	Not detected
08/259	13/11/2008	NM 76490 15266	Kilbrandon	Positive at LOD	Not detected
09/014	11/02/2009	NM 78051 18150	Ardshellach	Not detected	Not detected
09/012	11/02/2009	NM 77624 17165	Balvicar North	Not detected	Not detected
09/013	09/02/2009	NM 77240 16434	Rubha nan Ron South	Not detected	Not detected
09/011	09/02/2009	NM 77231 15874	Balvicar	Not detected	Not detected
09/010	09/02/2009	NM 76493 15268	Kilbrandon	Positive at LOD	Not detected
09/081	06/05/09	NM 78052 18150	Ardshellach	Not detected	Positive at LOD
09/082	06/05/09	NM 77621 17164	Balvicar North	Not detected	Not detected
09/079	06/05/09	NM 77239 16433	Rubha nan Ron South	Not detected	Positive at LOD
09/078	06/05/09	NM 77232 15874	Balvicar	Not detected	Positive at LOD
09/080	06/05/09	NM 76492 15271	Kilbrandon	Not detected	Not detected

* LOD - Limit of detection

Norovirus sample points: