Scottish Sanitary Survey Project

Sanitary Survey Report

Arran: Lamlash Bay (NA007) & Arran: Whiting Bay (NA009)

July 2010

Report Distribution – Arran: Lamlash Bay and Arran: Whiting Bay

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1. General Description

Lamlash Bay and Whiting Bay are located on the east side of the Isle of Arran, which is situated in the outer reaches of the Firth of Clyde. The 8 km coastline of Lamlash Bay extends from Clauchlands Point in the north to Kingcross Point in the south. Holy Island lies across most of the mouth of Lamlash Bay. Whiting Bay stretches from Largymore in the south to Kingcross Point in the north and is fully exposed to the Firth of Clyde. This sanitary survey was triggered by the high risk matrix scores achieved for both Lamlash Bay and Whiting Bay, which were mainly driven by monitoring results outwith the classification.

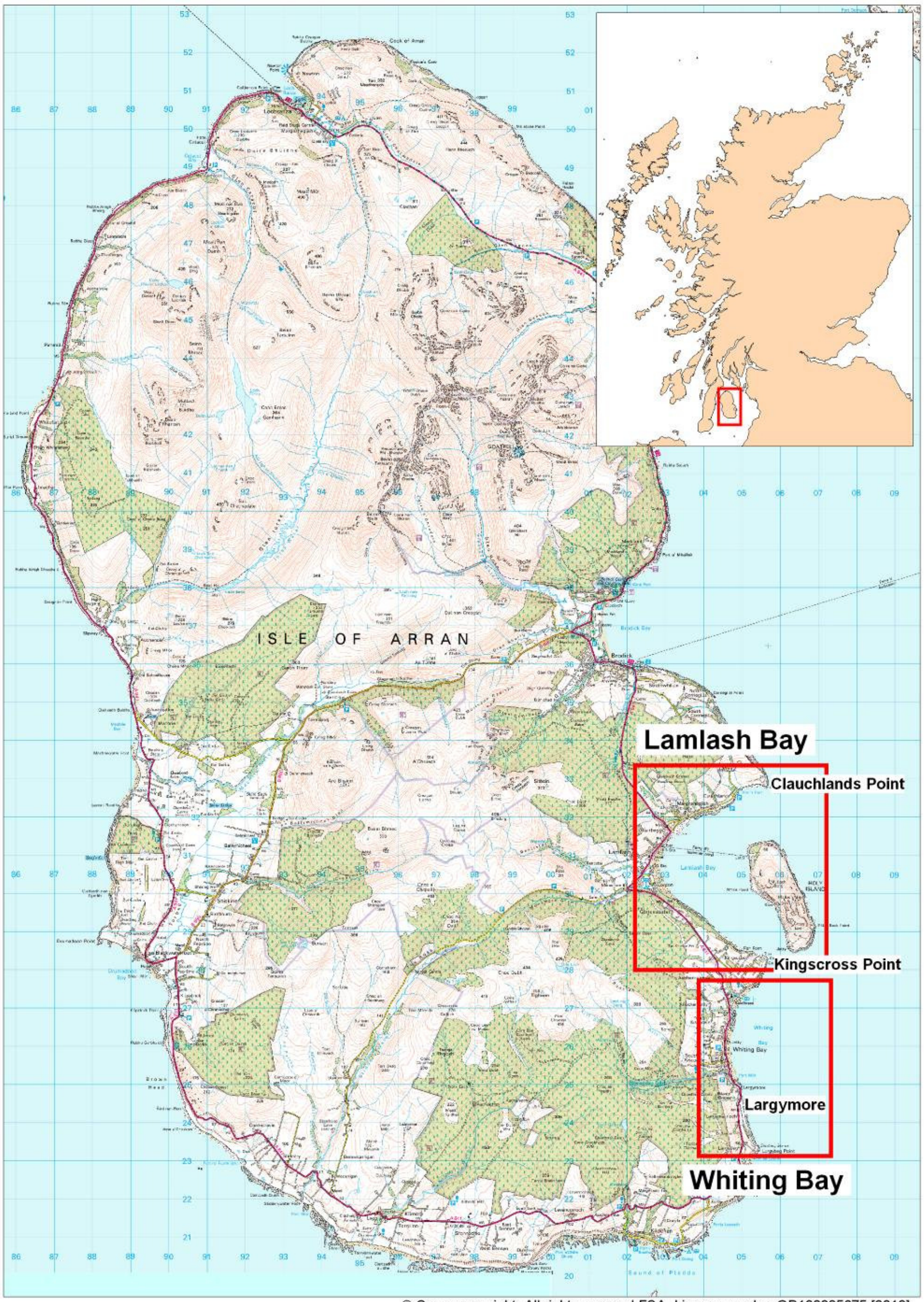


Figure 1.1 Location of Lamlash Bay and Whiting Bay

2. Fishery

The survey area encompasses two existing production areas as listed in Table 2.1.

Table 2.1 Arran production areas

Production Area	Site	SIN	Species
Arran Lamlash Bay	Lamlash Bay	NA 007 329 08	Common mussel
Arran Whiting Bay	Whiting Bay	NA 009 331 16	Razor clams

The Lamlash Bay production area is bounded by lines drawn between NS 0268 3100 to NS 0517 3100 and from NS 0433 2900 to NS 0613 2900. The nominal Representative Monitoring Point (RMP) is situated at NS 035 297 in the south west corner of the Crown Estate (CE) lease area. The mussel farm at Lamlash Bay consists of three mussel lines with a ladder system and one raft.

The Whiting Bay production area is bounded by lines drawn between NS 0558 2800 to NS 0600 2800 and NS 0600 2500 to NS 0489 2500 and NS 0600 2800 to NS 060 250. The nominal RMP is located at NS 050 260. The razor beds at Whiting Bay lie below mean low water springs and extend along the whole length of the bay. The harvester intends to fish the entire area, diving to harvest them by hand. This method of harvest will constrain to some extent the exploitable area as it is likely to become impractical at depths of over 30 m, although it must be noted that no harvester has exclusive rights to the shellfish here, so other operators using other techniques such as dredging may also exploit this area.

Figure 2.1 shows the relative positions of the RMP, production areas and seabed lease areas at Arran: Lamlash and Whiting Bays.

Figure 2.1 Lamlash Bay and Whiting Bay Fishery

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Lamlash and Whiting Bay at the time of last census (2001).

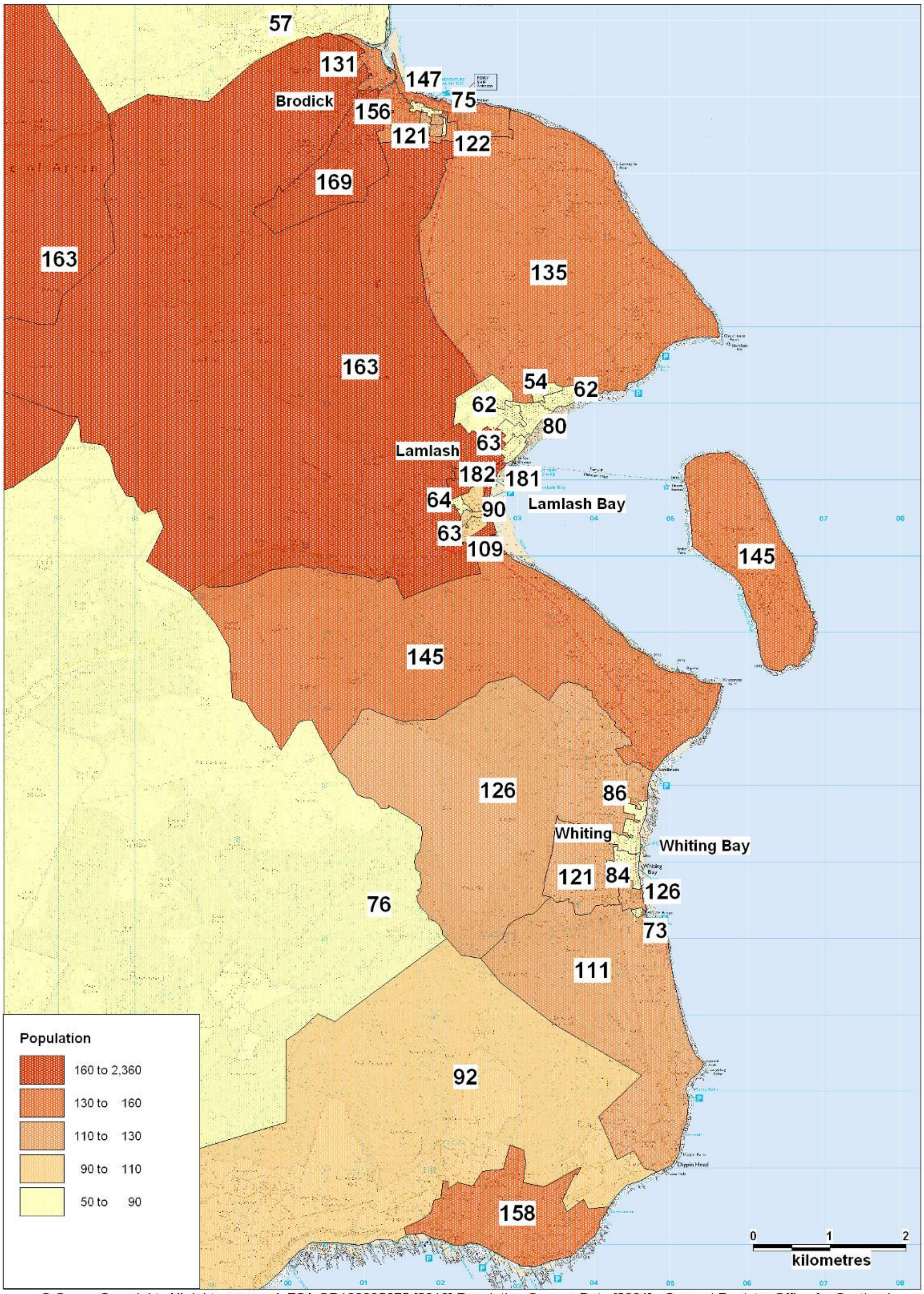


Figure 3.1 Human population surrounding Lamlash Bay and Whiting Bay

There are three main centres of human population along this stretch of coastline. Of most importance to the fisheries are the villages of Lamlash (population 1010) which lies immediately to the north of the mussel fishery at Lamlash Bay, and Whiting (population 490) which runs along most of the shore of Whiting Bay in which the razor fishery is located. The third population centre is at Brodick (population 1411), which lies about 7 km to the north of the mussel fishery at Lamlash Bay. Sewage discharges are likely to be concentrated around these settlements and these will impact on nearby fisheries. Whether discharges from Brodick impact on the fisheries will depend on their location and size as well as local hydrography.

Outside of these settlements population densities are lower, but there are numerous individual dwellings lining the roads running along the coast. Therefore, a significant propoportion of the populations in the larger coastal census output areas may be concentrated at or near the shoreline. These homes are more likely to be on private septic systems, which may discharge to the sea (see Section 4).

There are a number of places offering tourist accommodation in both Lamlash and Whiting, including a large caravan park at Cordon, on Lamlash Bay. There is also a private retreat on Holy Island with accommodation for up to 135 guests that is accessible by daily ferry sailings during the summer months. Therefore population in the area is expected to be signficantly higher during the summer months.

4. Sewage Discharges

There are numerous sewages discharges along the east coast of Arran. The locations of Scottish water community septic tanks, their associated overflow discharges, small private discharges for which SEPA have issued consents, and any suspected sewage discharge pipes recorded during the shoreline survey are presented in the summary map (Figure 4.1).

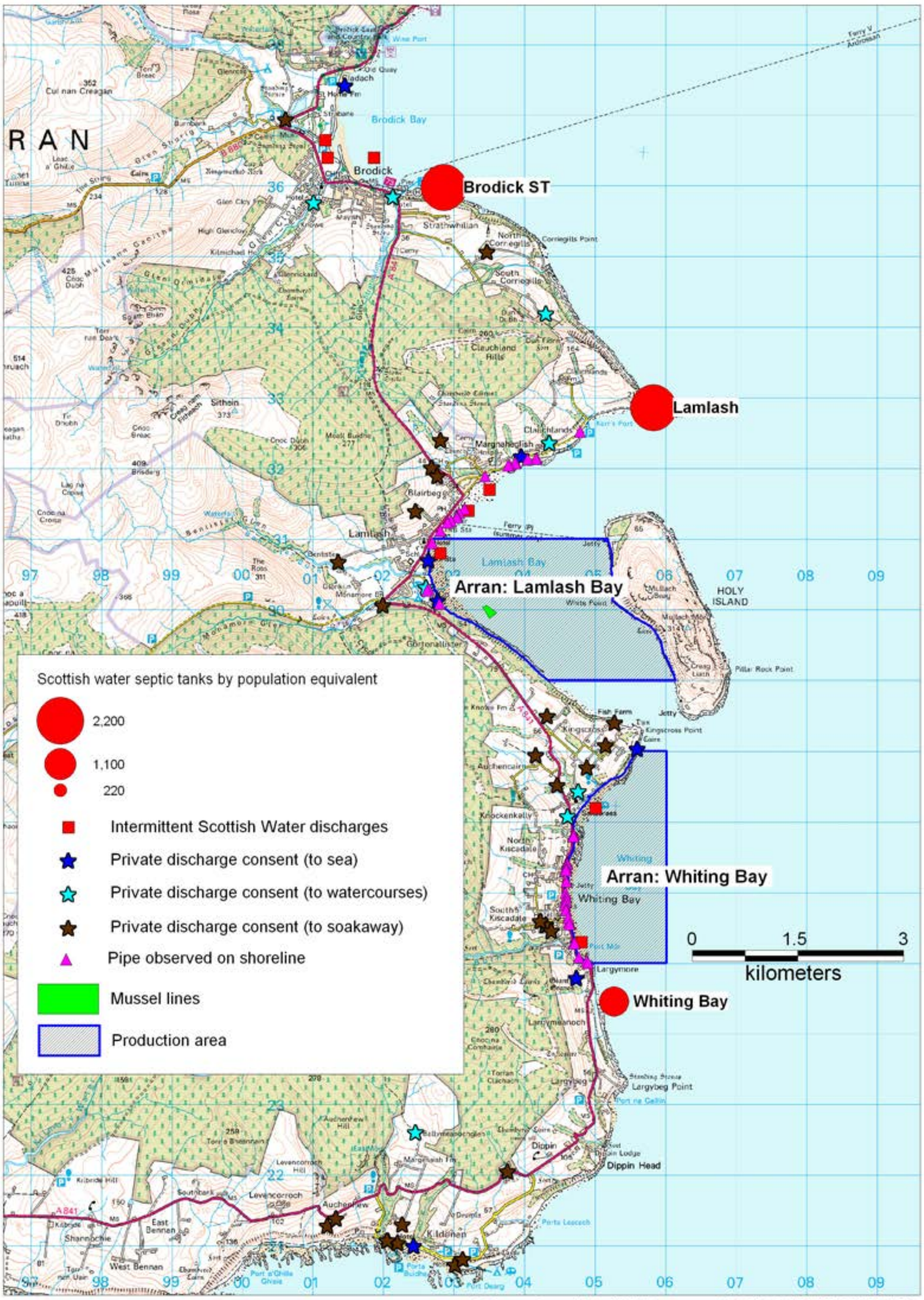


Figure 4.1 Overview map of discharges to the survey area

There are three Scottish Water community septic tank discharges with associated overflow discharges to this stretch of coastline, one at Whiting Bay, one at Lamlash, and one at Brodick. Details of these are presented in Table 4.1. No information on spill volumes and frequencies was available for the intermittent discharges. All Scottish Water discharges are to coastal waters.

Table 4.1Scottish Water discharges

Grid reference	Discharge Name	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consent/ design pop
NS 0285 3598	Brodick	continuous	septic tank	972.1	2108
NS 0117 3665	Douglas Place (Brodick) CSO	intermittent	6mm screening	38.6	none stated
NS 012 364	Golf Course (Brodick) PS EO	intermittent	none	none stated	none stated
NS 0186 3640	Brodick PS1 CSO & EO	intermittent	6mm screening, $243m^3$ storage	972.1	2108
NS 0582 3286	Lamlash	continuous	septic tank	973	2160
NS 035 317	Lamlash PS3 CSO & EO	intermittent	6mm screening	972.6	2160
NS 032 314	Lamlash PS2 CSO & EO	intermittent	6mm screening	715.6	none stated
NS 028 308	Lamlash PS1 CSO & EO	intermittent	6mm screening	626.9	none stated
NS 0526 2446	Whiting Bay	continuous	septic tank	315.6	994
NS 050 272	Whiting Bay PS1 CSO & EO	intermittent	6mm screening	110.1	none stated
NS 048 253	Whiting Bay PS2 CSO & EO	intermittent	6mm screening	315.6	994

SEPA provided details of all consented sewage discharges to the area shown in Figure 4.1. These are presented in Table 4.2, and each record is highlighted according to whether they discharge to sea, watercourse or land (soakaway). Discharge consent details for the Scottish Water discharges were provided but are not presented in Table 4.2 as all relevant information on these has already been shown in Table 4.1. The sewerage system at Whiting Bay, as shown in Table 4.1 was in the very final stages of construction at the time of writing. Previous to this system, there were two untreated sewage outfalls serving Whiting Bay where the pumping stations are located.

As there has not historically been a requirement to register septic systems in Scotland, this list is unlikely to cover all discharges in the area. A physical survey of the shoreline of Lamlash Bay and Whiting Bay was undertaken and all observations relating to potential discharge pipes along the shoreline is presented in Table 4.3. A number of these were sampled and/or measured for flow and these details are also presented in Table 4.3, although it must be noted that discharge volume and possibly sanitary content will vary considerably with time, and an estimation of loading (in *E. coli*/day) from instantaneous readings may therefore be quite misleading. Although some showed obvious signs of carrying foul water such as odour, sewage fungus, and high levels of *E. coli*, it is quite likely that many only carry surface runoff.

Table 4.2 Discharges identified by SEPA (excluding Scottish Water discharges)

Ref No.	Grid reference	Discharge Type	Level of Treatment	Consented/ design PE	Discharges to
CAR/R/1032950	NS 01450 37430	Domestic	Septic tank	15	Sea
CAR/R/1032948	NS 00610 36950	Domestic	Septic tank	15	Land
CAR/R/1027944	NS 02134 35852	Domestic	Package treatment plant	6	Watercourse
CAR/R/1057021	NS 01011 35768	Domestic	Septic tank	11	Watercourse
CAR/R/1015653	NS 03464 35073	Domestic	Septic tank	15	Land
CAR/R/1036138	NS 04300 34200	Domestic	Septic tank and Puraflo Modules	5	Watercourse
CAR/R/1016803	NS 02804 32406	Domestic	Septic tank	15	Land
CAR/R/1012502	NS 04350 32370	Domestic	Septic tank	14	Watercourse
CAR/R/1015782	NS 03953 32177	Domestic	Septic tank	10	Sea
CAR/R/1049550	NS 02677 32018	Domestic	Septic tank	10	Land
CAR/R/1045205	NS 02760 31900	Domestic	Septic tank	10	Land
CAR/R/1020734	NS 02450 31400	Domestic	Septic tank	8	Land
CAR/R/1021063	NS 02635 30702	Domestic	Septic tank	5	Sea
CAR/R/1016012	NS 01360 30680	Domestic	Septic tank	10	Land
CAR/R/1017449	NS 02600 30320	Domestic	Septic tank	5	Watercourse
CAR/R/1020914	NS 02766 30135	Domestic	Septic tank	5	Sea
CAR/R/1025686	NS 01985 30068	Domestic	Septic tank	6	Land
CAR/R/1050162	NS 04316 28508	Domestic	Septic tank	16	Land
CAR/R/1014273	NS 05271 28414	Domestic	Septic tank	9	Land
CAR/R/1025068	NS 05144 28092	Domestic	Septic tank	5	Land
CAR/R/1030954	NS 05594 28046	Domestic	Septic tank	15	Sea
CAR/R/1038341	NS 04156 27953	Domestic	Septic tank	5	Land
CAR/R/1016904	NS 04880 27780	Domestic	Septic tank	6	Land
CAR/R/1031243	NS 04460 27530	Domestic	Septic tank	5	Land
CAR/R/1012027	NS 04760 27440	Domestic	Septic tank	6	Watercourse
CAR/R/1015533	NS 04610 27090	Domestic	Septic tank	6	Watercourse
CAR/R/1021889	NS 04221 25605	Domestic	Septic tank	5	Land
CAR/R/1021952	NS 04298 25557	Domestic	Septic tank	5	Land
CAR/R/1057524	NS 04294 25546	Domestic	Septic tank	16	Watercourse
CAR/R/1055556	NS 04379 25466	Domestic	Septic tank	10	Land
CAR/R/1010341	NS 04729 24800	Domestic	Septic tank	9	Sea
CAR/R/1016028	NS 02450 22612	Domestic	Septic tank	5	Watercourse
CAR/R/1045315	NS 03760 22060	Domestic	Septic tank	10	Land
CAR/R/1031364	NS 01323 21389	Domestic	Septic tank	15	Land
CAR/R/1031304	NS 02263 21308	Domestic	Septic tank	5	Land
CAR/R/1031363	NS 01200 21290	Domestic	Septic tank	5	Land
CAR/S/1015991	NS 02060 21080	Treated sewage effluent	STW/Infiltration system	50	Land
CAR/R/1025996	NS 02050 21080	Domestic	Package plant	6	Land
CAR/R/1018123	NS 02200 21050	Domestic	Septic tank	28	Land
CAR/R/1020762	NS 02424 21006	Domestic	Septic tank	12	Sea
CAR/R/1046158	NS 03121 20815	Domestic	Septic tank	5	Land
CAR/R/1031413	NS 03010 20740	Domestic	Septic tank	32	Land

Table 4.3 Potential sewage discharge pipes observed during the shoreline survey.

No	Date	Grid Reference	Observation	SEPA consent
1	15/09/2009	NS 04779 32526	Small pipe running under road, very small flow.	
2	15/09/2009	NS 04166 32149	Pipe with sewage fungus inside, 15 cm diameter.	
3	15/09/2009	NS 04154 32134	Iron pipe, very small flow.	
4	15/09/2009	NS 04042 32131	Pipe with sewage fungus, 15 cm diameter, measured and sampled, >100000 *E. coli* cfu/100ml, loading of >7.4×10^{8} *E. coli*/day	
5	15/09/2009	NS 03870 32088	Grey plastic pipe inside clay pipe. Signs of flow but none at time of survey.	
6	15/09/2009	NS 03857 32077	Large blue plastic pipe, 38 cm diameter, flow > 0.5l/s	
7	15/09/2009	NS 03781 32049	Clay pipe, diameter 30cm, very little flow	
8	15/09/2009	NS 03764 32040	Surface water pipe x2, very little flow	
9	15/09/2009	NS 03437 31893	Lamlash PS3. Grey pipe, flowing, covered in rocks. Sample of discharge contained 100 *E. coli* cfu/100ml	
10	15/09/2009	NS 03146 31427	Large pipe discharging into the sea.	
11	15/09/2009	NS 03067 31374	Pipe encased in concrete, discharge contained 54000 *E. coli* cfu/100ml, loading of 1.1×10^{10} *E. coli* cfu/day.	
12	15/09/2009	NS 03031 31330	Two pipes encased in concrete. Seawater sample taken alongside contained 10 *E. coli* cfu/100ml.	
13	15/09/2009	NS 03031 31312	Inspection cover and pipe encased in concrete, not enough flow to sample	
14	15/09/2009	NS 02949 31264	Pipe encased in concrete, discharging under water, seawater sample taken by end contained 6700 *E. coli* cfu/100ml.	
15	15/09/2009	NS 02901 31233	Two pipes flowing under RNLI building, broken in parts.	
16	16/09/2009	NS 02798 31121	Pipe running into the sea, seawater sample taken alongside contained 10 *E. coli* cfu/100ml	
17	16/09/2009	NS 02684 30950	Concrete pipe leading out to sea	
18	16/09/2009	NS 02612 30270	Outfall pipe discharging into the stream under water, bad odour	CAR/R/1017449?
19	16/09/2009	NS 02649 30294	Outfall pipe discharging to stream, bad odour and sewage fungus	CAR/R/1017449?
20	16/09/2009	NS 02787 30087	Two plastic pipes, one with slits cut into it. No flow.	CAR/R/1020914
21	17/09/2009	NS 04690 26829	Pipe blocked with stones, no flow.	
22	17/09/2009	NS 04686 26800	3 pipes, no flow.	
23	17/09/2009	NS 04597 26428	Two drainage pipes	
24	17/09/2009	NS 04597 26414	Three drainage pipes	
25	17/09/2009	NS 04592 26362	Concrete pipe, very little flow, green algae, sample of discharge contained 400 *E. coli* cfu/100ml	
26	17/09/2009	NS 04584 26347	Two pipes coming out of sea wall, flow from one. Seawater sample here contained 50 *E. coli* cfu/100ml	
27	17/09/2009	NS 04581 26319	25cm inner diameter concrete pipe coming out of the wall, small flow, sewage fungus. Sample of discharge contained >100000 *E. coli* cfu/100ml	
28	17/09/2009	NS 04586 26159	Outfall pipe, possible gutter	
29	17/09/2009	NS 04575 25996	Outfall pipe, blocked with stones, no flow	
30	17/09/2009	NS 04580 25931	Whiting Bay PS2. Two pipes measured and sampled. Left pipe contained 28000 *E. coli* cfu/100ml, right pipe contained >100000 *E. coli* cfu/100ml. Combined loading > 5.9×10^{10} *E. coli* cfu/day. Lots of sewage fungus present.	
31	17/09/2009	NS 04573 25876	Large blue pipe, very small flow. Seawater sample next to end contained 1700 *E. coli* cfu/100ml	
32	17/09/2009	NS 04569 25827	Large pipe shore, possibly not in use anymore	
33	17/09/2009	NS 04579 25760	Large plastic pipe (flowing), sample of discharge contained 300 *E. coli* cfu/100ml, loading of 3.7×10^{7} *E. coli* cfu/day	
34	17/09/2009	NS 04580 25757	Concrete pipe flowing into the sea, strong smell of sewage. Sample of discharge contained >100000 *E. coli* cfu/100ml, loading of >2.9×10^{10} *E. coli* cfu/day	
35	17/09/2009	NS 04617 25648	Pipe into sea, very little flow	
36	17/09/2009	NS 04624 25590	Iron pipe, very slow drip	
37	17/09/2009	NS 04630 25553	Whiting Bay PS2.	
38	17/09/2009	NS 04693 25289	Pipe with some flow into the river, freshwater sample from river contained 200 *E. coli* cfu/100ml	
39	17/09/2009	NS 04703 25282	Plastic pipe, no flow	
40	17/09/2009	NS 04765 25083	Pipe flowing out of sea wall into the sea, sample of discharge contained < 100 *E. coli* cfu/100ml, loading of < 1.1×10^{7} *E. coli* cfu/day	
41	17/09/2009	NS 04873 25035	Concrete pipe, broken, small flow, sewage fungus present, seawater sample taken next to pipe contained 16 *E. coli* cfu/100ml	
42	17/09/2009	NS 04895 25008	Broken concrete pipe, diverted to plastic pipe, flowing onto shore. Strong odour, sewage fungus. Sample of discharge contained >100000 *E. coli* cfu/100ml	

Lamlash Bay

Figure 4.2 presents a map showing the location of all individual discharges presented in Tables 4.1 to 4.3 for Lamlash Bay.

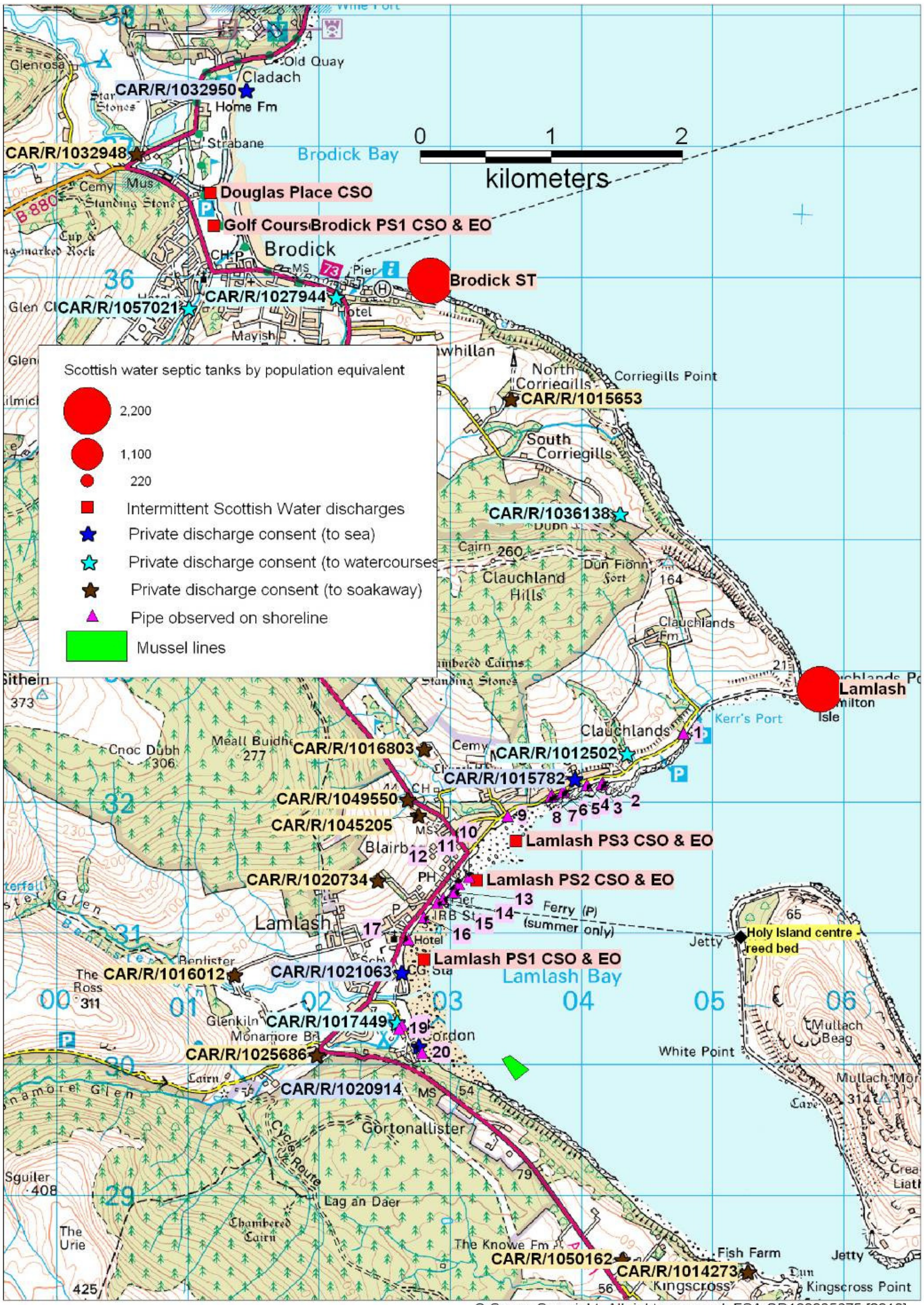


Figure 4.2 Sewage discharges at Lamlash Bay (Brodick to Kingscross Point)

Within Lamlash Bay, all known discharges to seawater or watercourse lie to the north of the mussel site, and to the south there is a stretch of coast of over 2 km in length to which there are no known discharges. The largest discharge is from the Lamlash septic tank, which is consented to serve a population of 2160 and is located off Cluachlands Point at the very northern extremity of the bay. Also associated with this system are three combined CSO & EO discharges. No information was available on spill frequency from the CSOs,, but spills are most likely to be associated with heavy rainfall. Also within Lamlash Bay there are three private discharge consents to seawater and two private discharge consents to watercourse. A total of 19 pipes were recorded within Lamlash Bay during the shoreline survey spread along the shore of Lamlash, at least 6 of which showed strong signs of being active sanitary discharges.

Further to the north lies the settlement of Brodick, where there is a Scottish Water septic tank consented to serve a population of 2108 and three associated intermittent discharges two of which are CSOs and hence are likely to operate following high rainfall events. There are also two SEPA consents for private discharges to watercourses and one to sea. It is probable that there are further unregistered private discharges here, but the shoreline here was not surveyed, given the distance from the fisheries.

On Holy Island there is a hotel and visitor centre that can accommodate up to 135 guests and is served by a reed bed treatment system discharging to the sea. The location of this system could not be confirmed on the shoreline survey, but it is presumably located on the north western tip of the island by the centre.

Whiting Bay

Figure 4.2 presents a map showing the location of all individual discharges presented in Tables 4.1 to 4.3 for Lamlash Bay.

The main discharge at Whiting Bay is the Scottish Water septic tank that is consented to serve a population of 994, and has two associated intermittent discharges, both of which incorporate CSOs so are likely to be rainfall dependent. There are also four SEPA consents for private discharges to watercourse (2) or sea (2) at Whiting Bay. During the shoreline survey a further 21 pipes were seen on the shoreline of Whiting Bay, at least 5 of which showed strong sings of being an active sanitary discharge. On the south east coast of Arran around Kildonan there are a further two SEPA consents for private discharges to water (one to sea, one to watercourse). It is quite likely that there are further unregistered private discharges here, but the shoreline here was not surveyed.

Car ferries run daily from Brodick to the mainland, and there is a daily passenger ferry from Lamlash to Holy Island during the summer, though the Holy Island ferry is very small and unlikely to have a discharge. During the shoreline survey, five yachts were seen moored off Lamlash and 30 small boats were recorded in a boat yard next to the jetty at Lamlash. The Clyde Cruising Club Sailing Directions for the Firth of Clyde indicates that there are moorings for visiting yachts off the pier at Lamlash and a range of onshore facilities. There is less boat traffic in Whiting Bay, with only two pleasure boats recorded on moorings here during the shoreline survey.

Figure 4.3 Sewage discharges at Whiting Bay (south of Kingscross Point)

In conclusion, there are multiple private discharges as well as Scottish Water communal septic tank discharges and associated overflows to both Lamlash Bay and Whiting Bay. At Lamlash Bay all of these sources lie to the north of the fishery, so it is possible that the northern end of the mussel site may be subject to higher levels of contamination. The main Scottish Water discharge is located at the headland at the northern end of the bay, about 3 km from the fishery so it may not have a major impact on the fishery. At Whiting Bay, the main Scottish Water discharge (post improvements) lies over 500 m to the south of the production area boundary.

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, pink and orange indicate poorly draining soils and the areas shaded light blue and dark blue indicate freely draining soils.

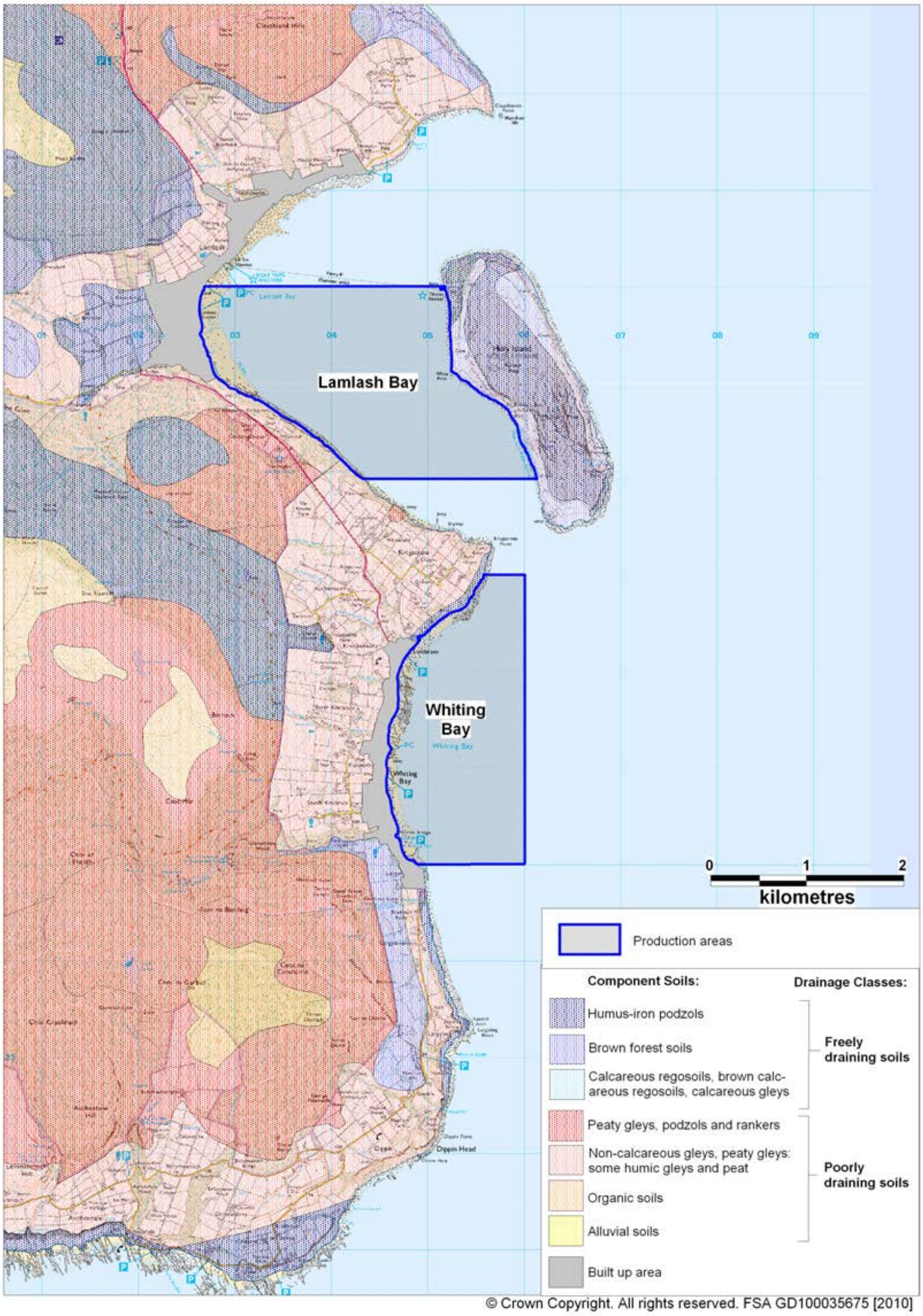


Figure 5.1 Lamlash Bay and Whiting Bay soil drainage

Five types of component soils are present in the area: peaty gleys, podzols and rankers, organic soils, non-calcareous gleys, peaty gleys, some humic gleys and peat and humus iron podzols and brown forest soils. The humus iron podzols and brown forest soils are freely draining; therefore the potential for runoff in these areas is reduced. The peaty gleys, podzols and rankers, organic soils, non-calcareous gleys, peaty gleys, some humic gleys and peat are poorly draining. The built up areas covering most of the central shoreline of Lamlash and Whiting Bay are also poorly draining. Overall, the potential for runoff contaminated with *E. coli* from human and/or animal waste is intermediate to high for this area, as the majority of the component soils surrounding both bays are composed of poorly draining soils and have large built up areas. There are unlikely to be spatial differences in contamination levels across the fisheries as a result of soil drainage effects.

6. Land Cover

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

Figure 6.1 LCM2000 class land cover data for Lamlash Bay and Whiting Bay

There are four dominant types of land cover shown in Figure 6.1: coniferous woodland, dwarf shrub heath, open dwarf shrub heath and improved grassland. There are also small patches of broadleaf woodland, inland rock and arable land. There are two built up areas; the settlements of Lamlash and Whiting.

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.

Logging is likely to occur in the coniferous forests from time to time, and runoff from recently logged areas may be subject to increased levels of contamination, but as levels of contamination within woodland soils would generally be very low, this effect is unlikely to be of significance to the fisheries.

Therefore, the overall predicted contribution of contaminated runoff from these land cover types would be low to intermediate and would be expected to increase significantly following rainfall events. It is likely that the shoreline next to the built up areas of Lamlash and Whiting would be subject to higher levels of contamination.

7. Farm Animals

Agricultural census data to parish level was requested from the Scottish Government. Agricultural census data was provided by the Rural Environment, Research and Analysis Directorate (RERAD) for the Kilbride parish, encompassing a land area of 158.7 km^2 covering the eastern half of Arran and including Holy Island. Reported livestock populations for the parishes in 2007 and 2008 are listed in Table 7.1.

Table 7.1 Livestock numbers in Kilbride in 2007 and 2008

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Pigs	0	0	0	0
Poultry	7	487	7	485
Cattle	11	1029	10	975
Sheep	13	2990	14	3279
Horses and ponies	10	57	9	52

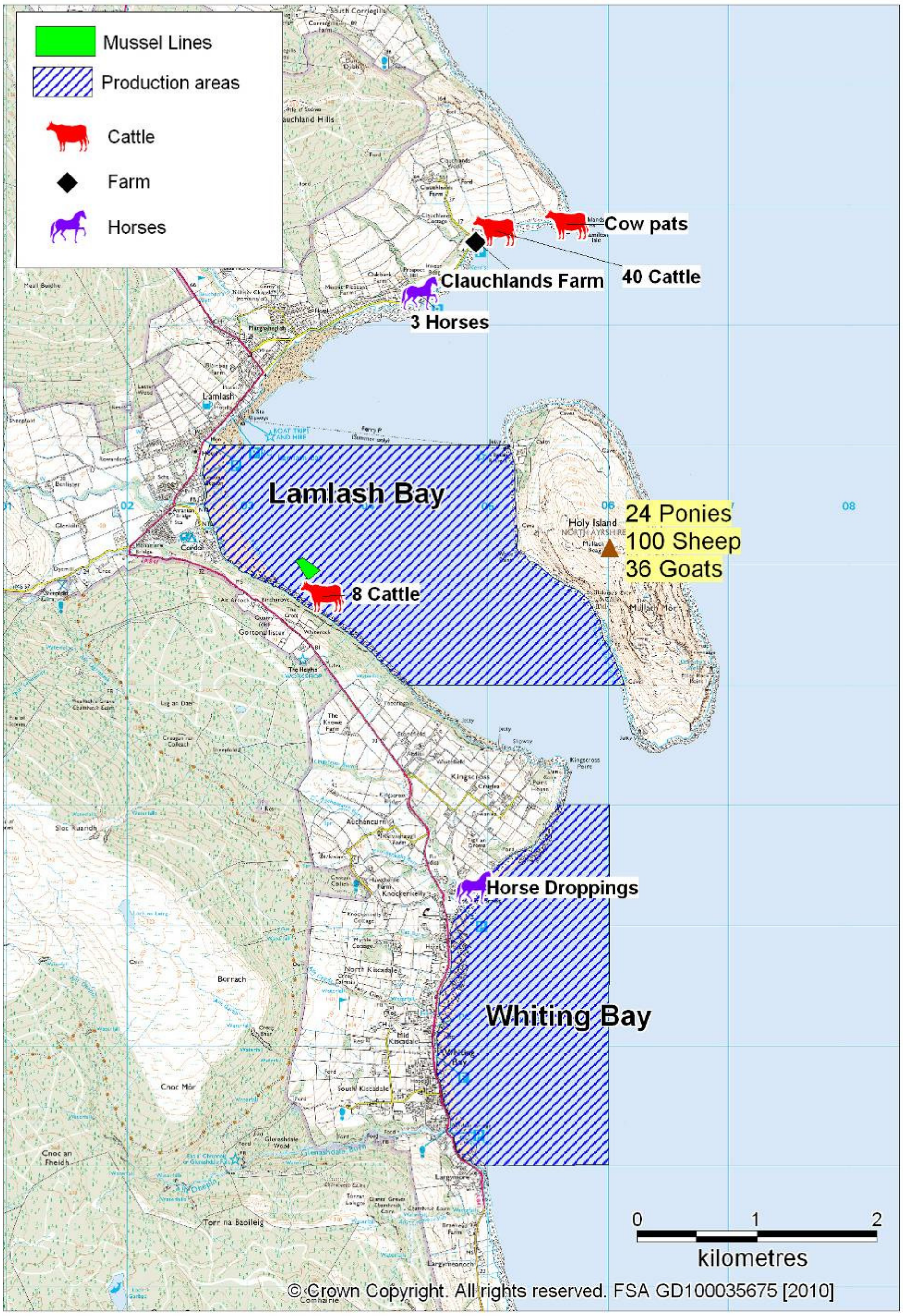
This information indicates that sheep and cattle are the main species of livestock within the Kilbride parish. However, this data does not provide information on their numbers immediately surrounding Whiting Bay and Lamlash Bay. A resident of Holy Island indicated that 24 ponies, 100 sheep and 36 goats are present on the island. These animals are mainly feral, and roam freely around the island without husbandry. Locations and numbers of livestock observed were recorded during the shoreline survey (see Appendix). This only relates to the time of the site visit on 15-16 September 2009 (Lamlash Bay) and 17 September 2009 (Whiting Bay). The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. This information should be treated with caution, as it applies only to the survey dates and is dependent upon the point of view of the observer (some animals may have been obscured from view by the terrain).

The two largest known concentrations of animals are at Clauchlands Farm at the northern end of Lamlash Bay and on Holy Island. Clauchland's Farm has a dairy operation and above ground slurry storage according to North Ayrshire Council planning records. No information was available regarding the capacity of the storage tank. It can be expected that this slurry would normally be spread on land around the farm. If a heavy rain should follow soon after slurry is spread, contamination of could be carried via runoff to watercourses and into the bay. A further 8 cattle were observed on a hill behind the mussel site at Lamlash Bay. As this location is much closer to the mussel farm, animal faecal contamination originating there would be likely to impact water quality at the mussel farm, particularly if the animals had access to nearby watercourses or the shoreline itself.

Horse droppings were observed at Whiting Bay, indicating that horses are excercised on the beach there. Depending on the frequency of use and numbers of animals, this could be a significant source of faecal contamination to the razor fishery, particularly near the shore.

Some seasonality to livestock populations is expected. Information on the production cycle used at the dairy farm was not available so it is not known when animal numbers are likely to be higher due to the presence of calves. Sheep are generally bred seasonally, with 1-3 lambs born in the spring to each ewe, leading to a seasonal increase in the sheep population until lambs are sent to market in the autumn.

Overall, based on the information obtained and observations made during the shoreline survey, the potential for contamination of water from livestock droppings is higher at Lamlash Bay than at Whiting Bay, and that risk is highest at the north end of the bay in the vicinity of Clauchlands Farm. Figure



7.1 Livestock observations at Lamlash and Whiting Bay

8. Wildlife

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

Seals

Two species of seal are commonly found around the coasts of Scotland: These are the European harbour, or common, seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). Scotland hosts significant populations of both species.

A survey conducted by the Sea Mammal Research Unit in 2007 estimated a population of 811 common seals within the Firth of Clyde (from Loch Ryan to Mull of Kintyre) with some haul out sites on the east coast of Arran. They also report a minor breeding colony of grey seals within the Firth of Clyde between Arran and the Ayrshire coast, so it is possible this species is also present at least occasionally in the Lamlash Bay/ Whiting Bay area.

Five seals (species uncertain) were seen during the shoreline survey towards the northern end of Lamlash Bay confirming their presence in the area.

Whales/Dolphins

A variety of whales and dolphins are routinely observed off the west coast of Scotland. It is possible that some of the smaller species of cetaceans enter the area from time to time, although any impact of their presence is likely to be fleeting and unpredictable.

Birds

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

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

The vast majority of seabird breeding sites were on Holy Island. Greatest impacts would be expected in the vicinity of their nest sites, although it is likely that they forage widely throughout the area. Gulls, which for the majority of the seabirds recorded are likely to be present all year round. Around 250 seabirds (mainly gulls) were recorded during the shoreline survey on Hamilton Isle, just off Cluachlands Point, and about 300 were recorded on a rocky spit in the center of Whiting Bay, with smaller numbers of these birds also recorded at various other points.

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

Common name	Species	Count	Method	Individual /pair
Northern Fulmar	*Fulmarus glacialis*	104	Occupied sites	Pairs
Great black-backed gull	*Larus marinus*	1	Occupied territory	Pairs
Herring gull	*Larus argentatus*	292	Occupied nests Occupied territory	Pairs
European shag	*Phalacrocorax aristotelis*	16	Occupied nests	Pairs
Black Guillemot	*Cepphus grylle*	6	Individuals on land	Individuals
Common gull	*Larus canus*	96	Occupied nests Occupied territory	Pairs
Lesser black-backed gull	*Larus fuscus*	494	Occupied nests Occupied territory	Pairs

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 Ayrshire. Two geese and 16 ducks were observed by the shore of Whiting Bay.

Wading birds would be concentrated on intertidal areas. A few waders (18 oystercatchers) were seen at Lamlash Bay during the shoreline survey.

Deer

Deer will be present particularly in wooded areas where the habitat is best suited for them. There are large wooded areas near the east coast of Arran. While no population data was available for this area, it is known that there are both red and roe deer on the island, although none was seen during the shoreline survey. It is therefore possible that some of the faecal indicator organisms detected in the streams draining the east side of Arran will be of deer origin and it may be expected that their contribution would be year round.

Otters

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

Summary

In summary, the main wildlife species potentially impacting on the production areas are seabirds, seals and deer. The main seabird breeding area is Holy Island, and shoreline observations suggest favoured resting sites at Hamilton Isle at the northern end of Lamlash Bay, and a rocky outcrop in the centre of Whiting Bay so impacts from seabirds may be higher in these areas. Seals are likely to forage throughout the area in small numbers. Small amounts of contamination of deer origin will be carried into coastal waters via land runoff. However, as these animals are highly mobile, their impacts on the fishery will generally be unpredictable, and deposition of faeces by wildlife is likely to be widely distributed around the area.

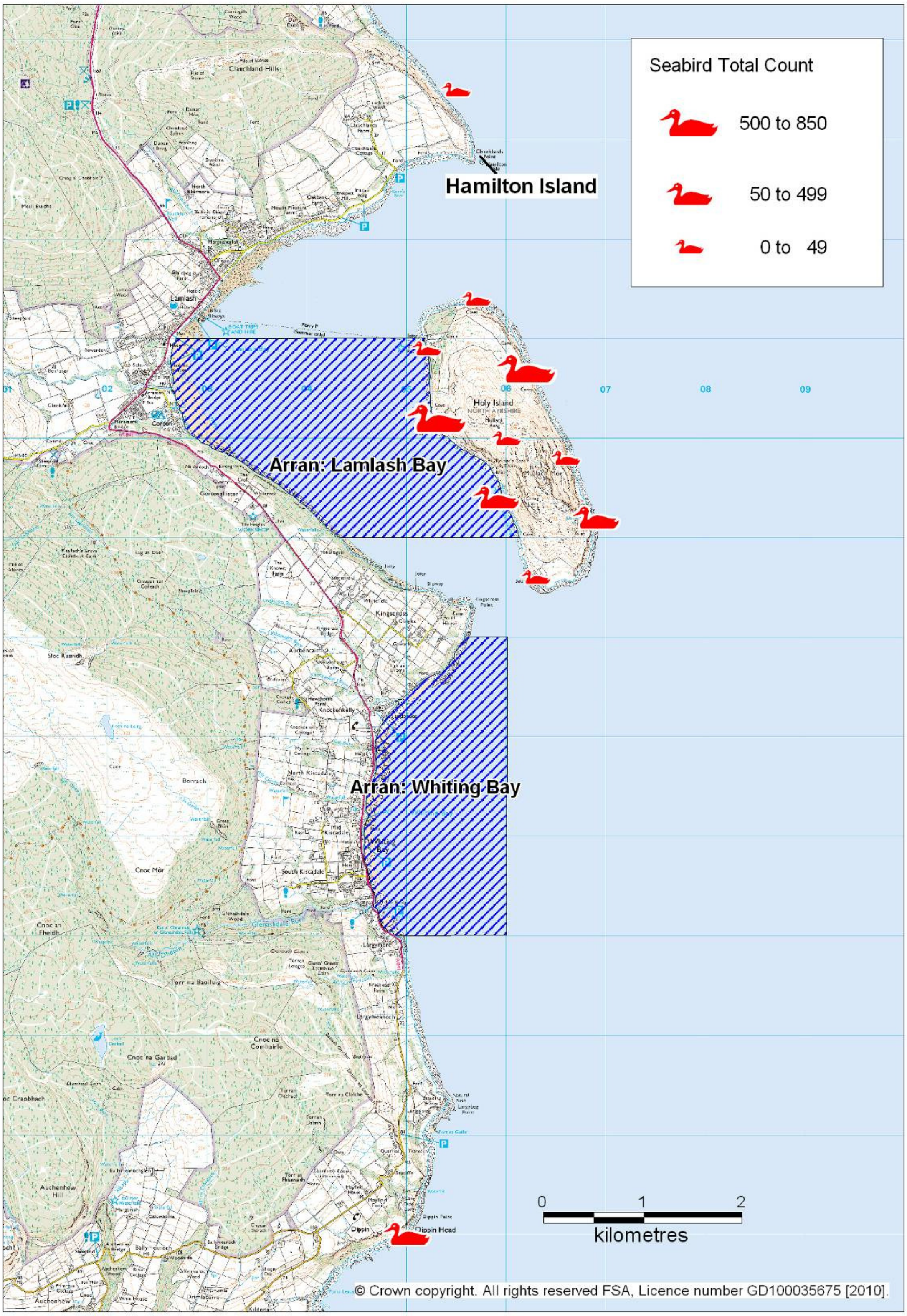


Figure 8.1 Breeding seabird counts within 5 km of the two production areas

9. Meteorological data

The nearest weather station is located at Arran: Brodick, approximately 7 km to the north of the Lamlash Bay and 11 km to the north of Whiting Bay. Uninterrupted rainfall data was available for 2003-2008 inclusive. The nearest weather station for which wind data is available is at Prestwick Airport, approximately 31 km to the west of the fisheries. Local topography may skew wind patterns at the fisheries and at Prestwick in different ways, and conditions at any given time may differ due to the distance between them. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish at Lamlash Bay and Whiting Bay.

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

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003). Figures 9.1 and 9.2 present box and whisker plots summarising the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median represented by a line within the box. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

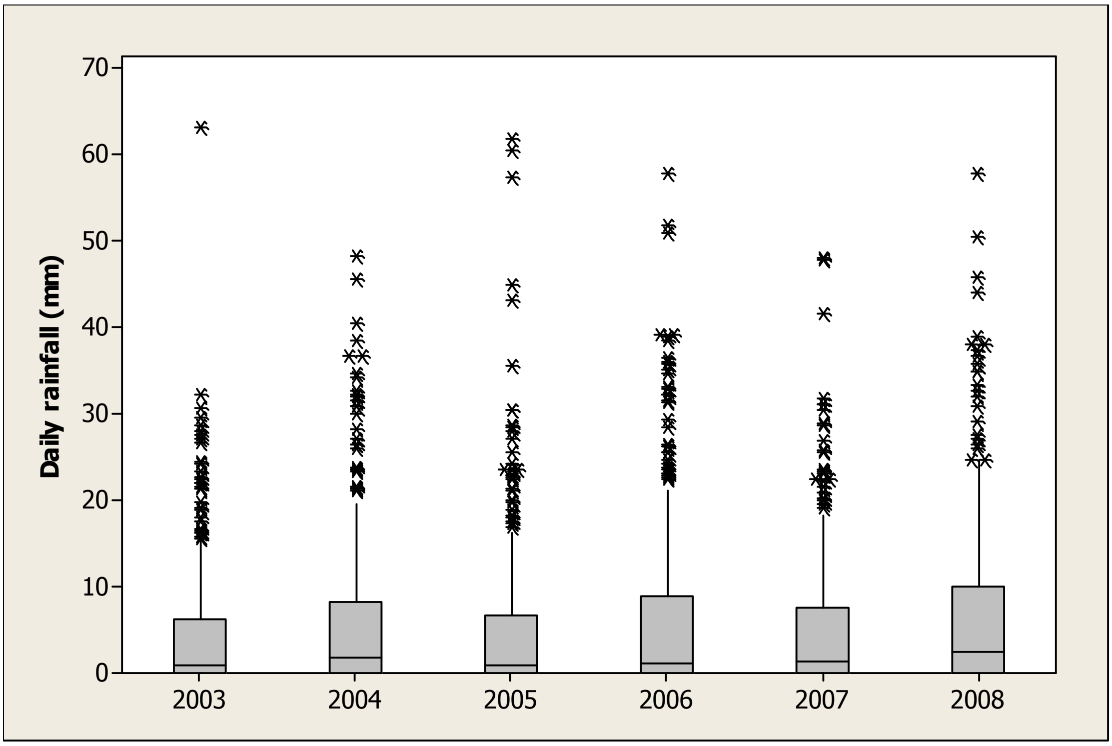


Figure 9.1 Box plot of daily rainfall values by year at Arran: Brodick, 2003-2008

Figure 9.1 shows that rainfall patterns were similar between the years presented here, with 2003 being the driest year and 2008 the wettest.

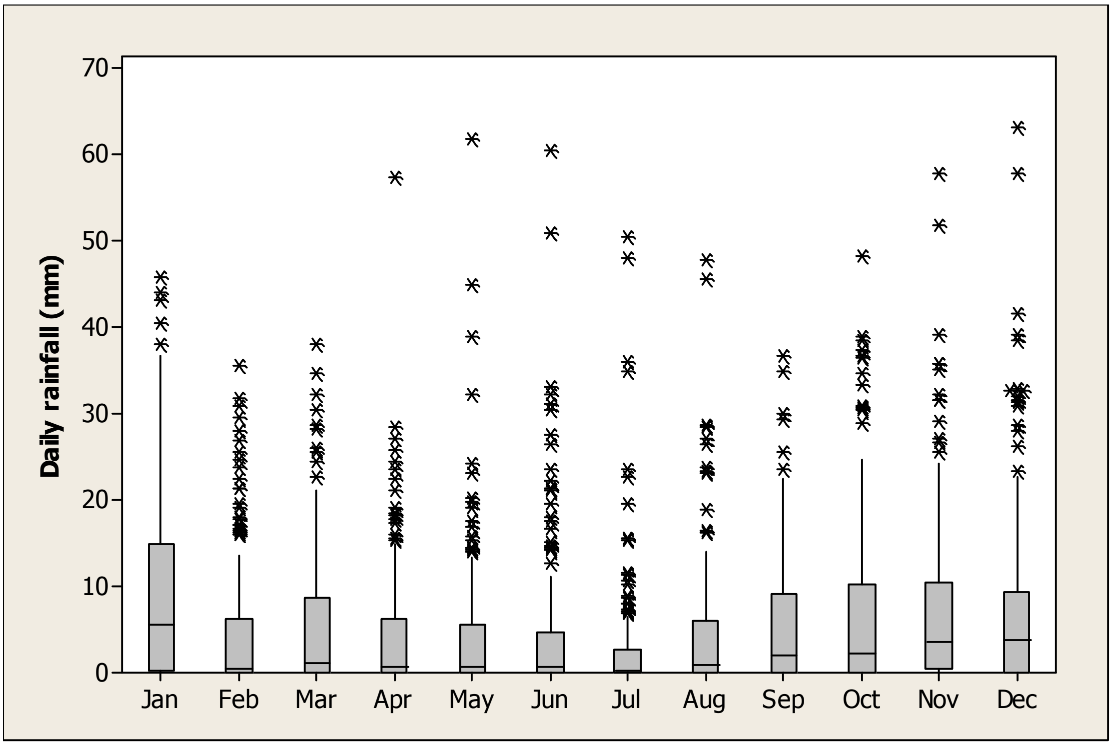


Figure 9.2 Box plot of daily rainfall values by month at Arran: Brodick, 2003-2008

The wettest month was January, and September to December were also relatively wet months. The driest month was July. Days with high rainfall can occur at any time of the year. For the period considered here (2003-2008), 42% of days experienced rainfall less than 1 mm, and 12% of days experienced rainfall of 10 mm or more.

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

9.2 Wind

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

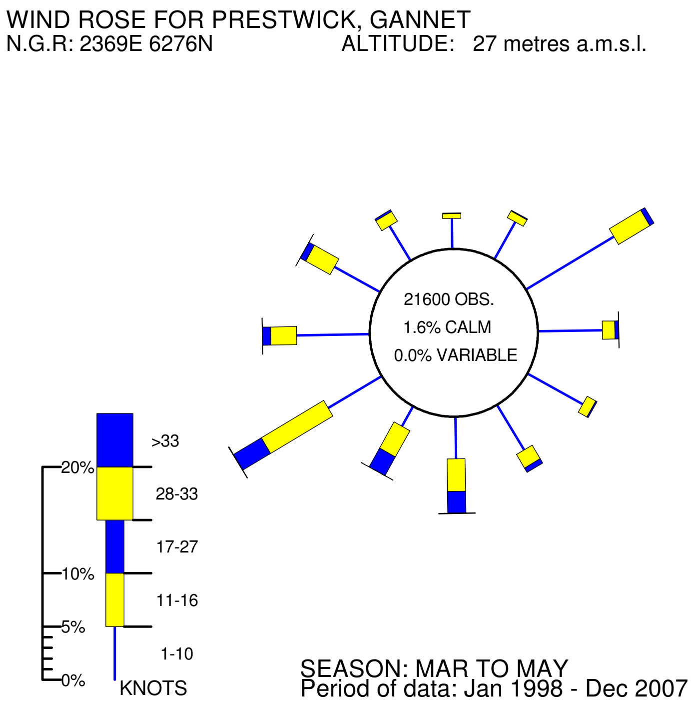


Figure supplied by the Meteorological Office under licence. Crown copyright 2010

Figure 9.3 Wind rose for Prestwick (March to May)

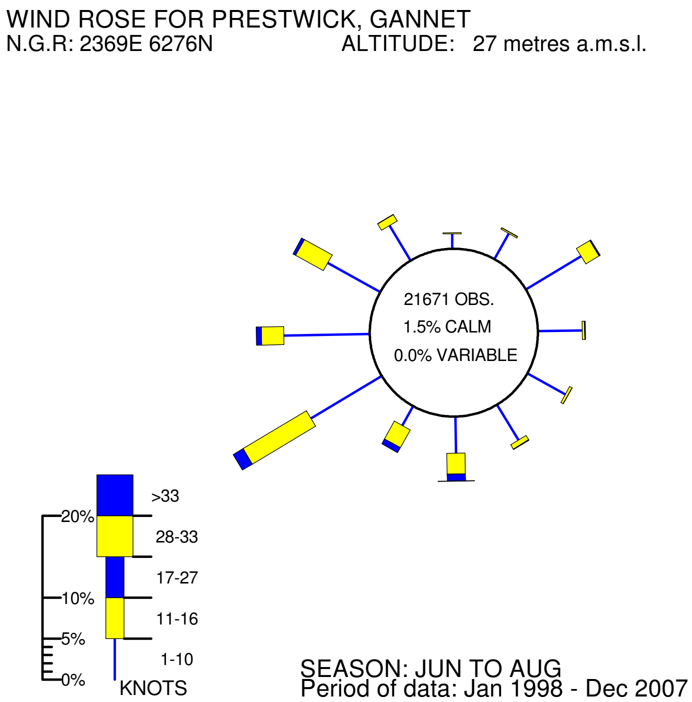


Figure supplied by the Meteorological Office under licence. Crown copyright 2010

Figure 9.4 Wind rose for Prestwick (June to August)

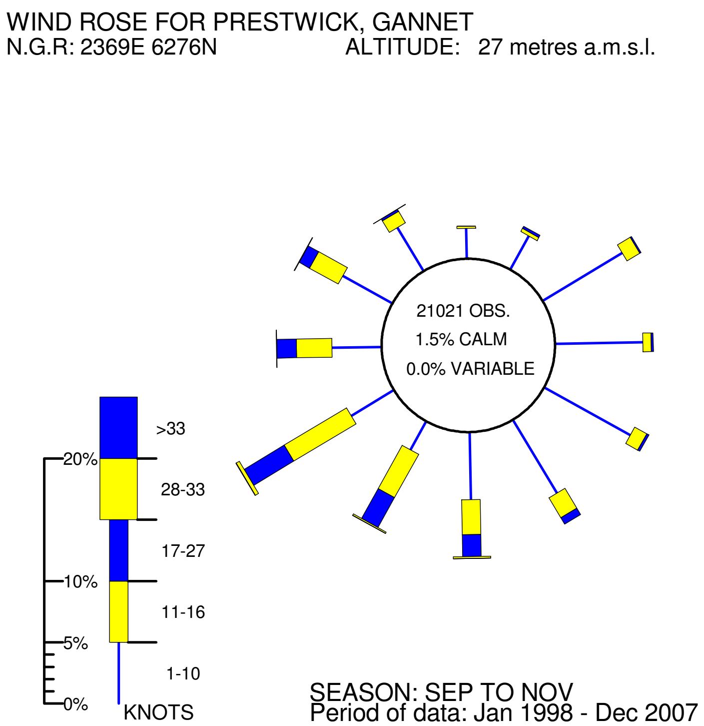


Figure supplied by the Meteorological Office under licence. Crown copyright 2010

Figure 9.5 Wind rose for Prestwick (September to November)

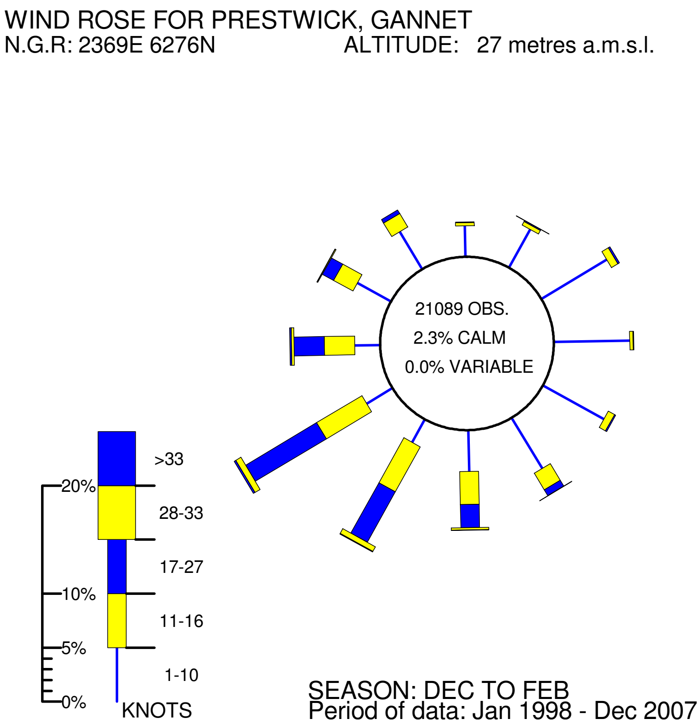


Figure 9.6 Wind rose for Prestwick (December to February)

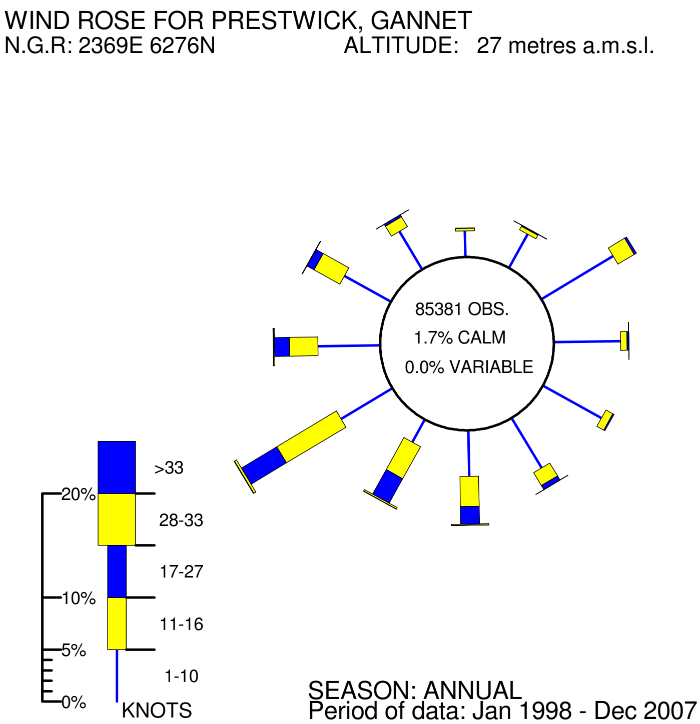


Figure 9.7 Wind rose for Prestwick (All year)

The prevailing wind direction at Prestwick is from the southwest, but wind direction often changes markedly from day to day with the passage of weather systems. Winds are lightest in the summer and strongest in the winter. North easterly winds are more frequent during the spring. Prestwick is located on the west coast of the mainland, whereas the fisheries are located on the east coast of Arran. Therefore, it may be expected that the overall wind patterns at the fisheries may differ somewhat from than observed at Prestwick. Whiting Bay is more exposed to the east, while Lamlash Bay receives considerable shelter from easterly winds from Holy Island which lies across most of its mouth.

Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore strong winds may significantly alter the pattern of surface currents at the fisheries, subsequently affecting the movement of freshwater-associated contamination. Strong winds may affect tide height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter from livestock, in and above the normal high water mark, into the production area. An onshore wind will result in increased wave action, which may resuspend any organic matter settled in the substrate.

10. Current and historical classification status

Arran: Lamlash Bay is currently classified for the harvest of mussels, and Arran: Whiting Bay is currently classified for the harvest of razors. Classification histories for these two species/areas are presented in Tables 10.1 and 10.2. A map of the current production areas can be found in Section 2, Figure 2.1.

Table 10.1 Classification history, Arran: Lamlash Bay, mussels

	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	B	B	B	B	B	B	B	B	B	B	B	B
2004	B	B	A	A	A	A	B	B	B	B	B	B
2005	B	B	A	A	A	A	B	B	B	B	B	B
2006	B	B	A	A	A	A	A	A	A	B	B	B
2007	B	B	A	A	A	A	A	A	A	B	B	B
2008	B	B	A	A	A	A	A	A	B	B	B	B
2009	B	B	B	B	B	B	B	B	B	B	B	B
2010	B	B	B	B	B	B	B	B	B	B	B	B
2011	B	B	B									

Lower case denotes a provisional classification

Arran: Lamlash Bay received a year round B classification for mussels in 2002 (provisional) and 2003. From 2004 to 2008/9, it received seasonal A/B classifications, with the timing and number of A months varying slightly from year to year, although they generally fell in the spring and summer. For 2009/10, the classification reverted to a year round B.

Table 10.2 Classification history, Arran: Whiting Bay, razors

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*	*a*
2002	*	*	*	*	*	*	*	*	*	*	*	*
2003	A	A	A	A	A	A	A	A	A	A	A	A
2004	*	*	*	*	*	*	*	*	*	*	*	*
2005	*a*	*a*	*a*	*b*	*b*	*a*	*a*	*a*	*a*	*a*	*a*	*a*
2006	A	A	A	B	B	B	A	A	A	A	A	A
2007	A	A	A	B	B	B	B	A	A	A	A	A
2008	A	A	A	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	B	B	B	B	B	B	B	B	B
2011	B	B	B									

Lower case denotes a provisional classification
* Declassified

Arran: Whiting Bay received a provisional year round A classification for razors in 2001. It was declassified in 2002, then received an A classification for 2003. It was declassified again in 2004. It then received a provisional seasonal A/B classification in 2005. From 2006 to 2008/9 it received seasonal A/B classifications, with the timing and number of A months varying from year to year. For 2009/10 it received a year round B classification. The period of A classification (when it applied) for mussels occurred during the spring/summer, when a generally worse classification was seen in razors.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken at Arran: Lamlash Bay and Arran: Whiting Bay from the beginning of 2002 up to September 28, 2009 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

Two razor samples reported from Arran: Whiting Bay had reported sampling locations that fell within Arran: Lamlash Bay (NS 038 297) and so were not used in the analysis. Seventeen consecutive razor samples from Arran: Whiting Bay were reported from NS 057 027, which is about 23 km south of production area. Although this cannot be verified, it is likely that this was a small typographical error on the pre printed sample submission forms, and the reported sampling location should have actually been NS 057 270, which does fall within the production area, and was sampled on another occasion. Therefore, to avoid discarding a significant part of the sampling history for this area, the grid references for these 17 samples were adjusted to NS 057 270. Another two razor samples from Arran: Whiting Bay had a reported sampling location that fell 3 m outside of the production area. These samples were included in the analysis as the error was within the 100 m accuracy applied during that period.

Five mussel samples reported from Arran: Lamlash Bay had reported sampling locations 19 km north of the production area (NS 036 500), and so were not used in the analysis. Two mussel samples reported from Arran: Lamlash Bay had reported sampling locations 17 km north of the production area (NS 034 390), and were also excluded from the analysis. Another mussel sample from Arran: Lamlash Bay had reported sampling location that fell 16 m outside of the production area. This sample was included in the analysis as the error was within the 100 m accuracy applied during that period.

6 razor samples from the Arran: Whiting Bay and 4 mussel samples from the Arran: Lamlash Bay had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. One mussel sample from Arran: Lamlash Bay had the result reported as >18000, and this was assigned a nominal value of 36000 for these purposes.

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

Results for sand gapers from Arran: Whiting Bay will not be considered in any further analyses as only two samples were submitted.

11.2 Summary of microbiological results

A summary of all sampling and results by production area and species sampled is presented in Table 11.1 overleaf.

Table 11.1 Summary of historical sampling and results

Sampling Summary		
Production area	Arran: Lamlash Bay	Arran: Whiting Bay
Site	Lamlash Bay	Whiting Bay
Species	Common mussels	Razors
SIN	NA-007-329-08	NA-009-331-16
Location	8 locations	13 locations
Total no of samples	56	46
No. 2002	7	6
No. 2003	9	5
No. 2004	6	6
No. 2005	7	6
No. 2006	6	6
No. 2007	10	7
No. 2008	6	6
No. 2009	5	4
Results Summary		
Minimum	<20	<20
Maximum	>18000	1300
Median	165	130
Geometric mean	196	126
90 percentile	1300	725
95 percentile	3980	1010
No. exceeding 230/100g	24 (43%)	15 (33%)
No. exceeding 1000/100g	9 (16%)	3 (7%)
No. exceeding 4600/100g	3 (5%)	0 (0%)
No. exceeding 18000/100g	1 (2%)	0 (0%)

Lamlash Bay

A total of three mussel samples from Arran: Lamlash Bay gave results of over 4600 *E. coli* MPN/100g. The details of these are presented in Table 11.2.

Table 11.2 Results greater than 4600 *E. coli* MPN/100g - Lamlash Bay mussels

Collection date	GridRef	*E. coli* (MPN/100g)	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tide (spring/neap)	Tide (high/ low)
19/02/2003	NS 035 297	5400	0	0.3	*	*	Spring	Low
10/10/2007	NS 038 297	9100	16.9	36.8	*	*	Increasing	Flood
10/06/2008	NS 035 298	>18000	0.1	18.6	*	*	Decreasing	Low

* Data not available

One sample was taken in February, one in June, and one in October. They were taken following a range of rainfalls, and under varying tidal conditions. Water temperature and salinity at the time of sampling was not recorded for these three samples.

Whiting Bay

No razor samples from Arran: Whiting Bay had results of over 4600 *E. coli* MPN/100g. A total of three samples from this area gave results of over 1000 *E. coli* MPN/100g. The details of these are presented in Table 11.3.

Table 11.3 Results greater than 1000 *E. coli* MPN/100g for Whiting Bay razors

Collection date	GridRef	*E. coli* (MPN/100g)	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tide (spring/neap)	Tide (high/ low)
07/02/2007	NS 057 270	1100	0	4.2	*	*	Decreasing	Low
17/09/2008	NS 05294 27460	1300	46.5	94.2	14	33	Spring	Flood
02/09/2009	NS 05323 27470	1100	*	*	*	33	Increasing	Flood

* Data not available

One sample was taken in February, and two in September. Rainfall records were available for two of these samples, one of which was taken during an almost dry period, the other during a very wet period. They were taken under a range of tidal conditions. Water temperature was recorded on only one occasion, and on both occasions where salinity was recorded it was 33 ppt, approaching that of full strength seawater.

11.3 Overall geographical pattern of results

Lamlash Bay

Figure 11.1 presents a map showing geometric mean result by reported sampling locations for Arran: Lamlash Bay.

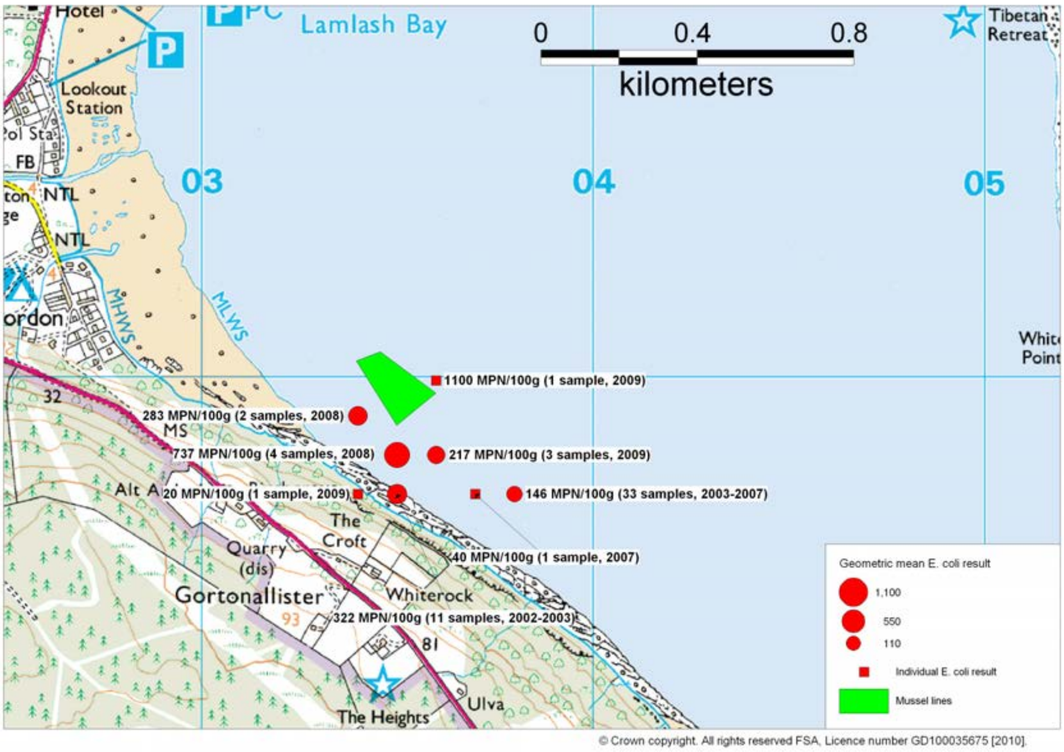


Figure 11.1 Map of sampling points and geometric mean result for Lamlash Bay mussels

No geographic patterns are apparent in Figure 11.1. No significant difference was found in mean result between the eight sampling locations presented in Figure 11.1 (One-way ANOVA, p=0.374, Appendix 6). Most of the sampling locations do not fall on the present location of the mussel lines as recorded during the shoreline survey, however this may be due in part to the 100 m accuracy used in recording the sampled location. The highest recorded result came from NS 035 298, immediately south of the southernmost corner of the lines.

Whiting Bay

Figure 11.2 presents a map showing geometric mean result by reported sampling locations for Arran: Whiting Bay (razors only). In Figure 11.2, results for a cluster of 9 samples taken in 2008-2009 within an approximately 50m x 50m area are presented together as a geometric mean for clarity.

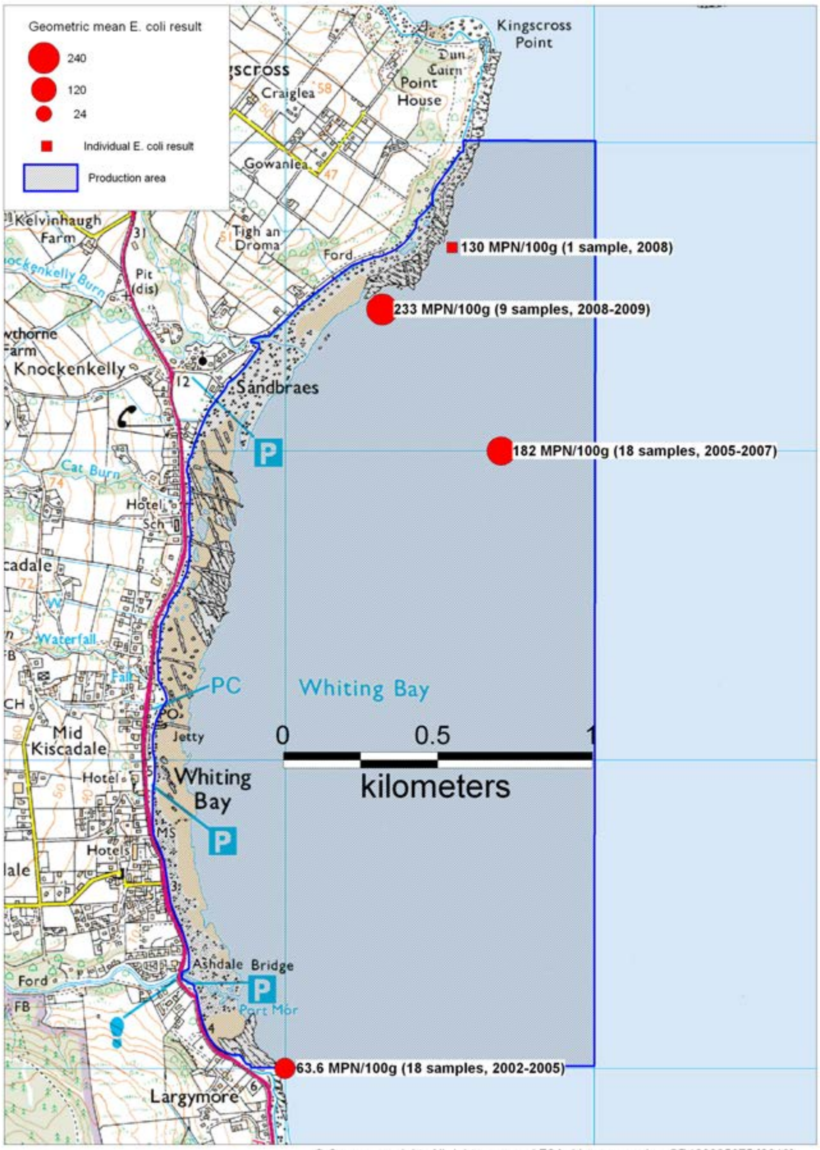


Figure 11.2 Map of sampling points and geometric mean result for Whiting Bay razors

Figure 11.2 gives the impression of higher results towards the north of the production area. The apparent trend may therefore represent a temporal rather than a spatial effect. No significant difference in mean result was found between the four sampling locations presented in Figure 11.2 (One-way ANOVA, p=0.070, Appendix 6). For this analysis the cluster of 9 samples taken from a small area were treated as being from the same sampling location, as they were on Figure 11.2. From 2008 onwards sampling locations were recorded by GPS by official control samplers but before this grid references were preprinted on the sample submission forms before sampling took place so it is uncertain if these accurately reflect the actual position sampled.

11.4 Overall temporal pattern of results

Figures 11.3 and 11.4 present scatter plots of individual results against date for each site, fitted with trend lines calculated using two different techniques.

The first is a geometric mean of the previous 5 samples, the current sample and the following 6 samples, referred to as a rolling geometric mean (black line). The second is a loess line (blue line), which stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The 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. Both lines help to highlight any underlying trends or cycles that might be obscured by shorter term variations in results.

Lamlash Bay

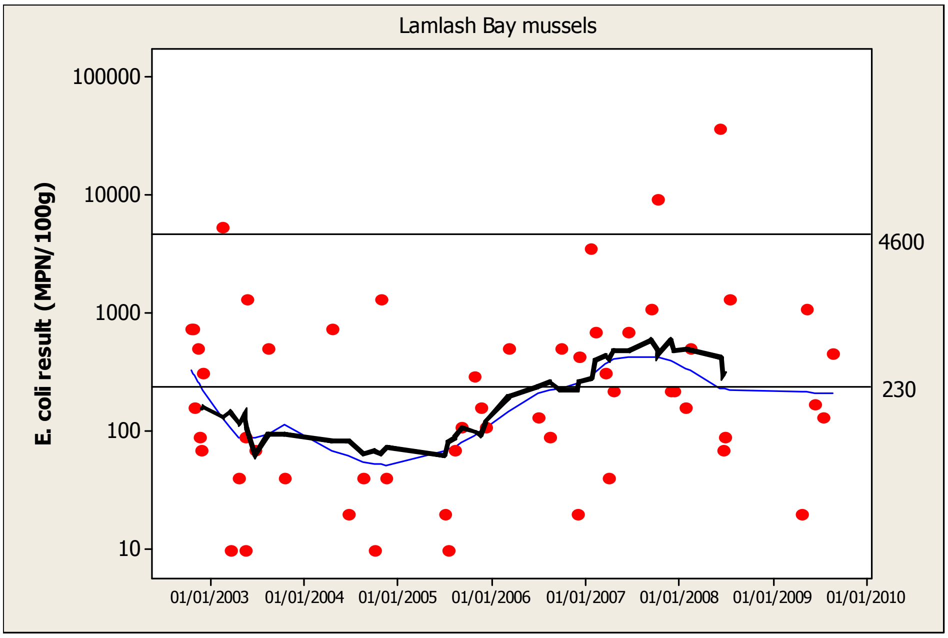


Figure 11.3 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line) (Lamlash Bay mussels)

Figure 11.3 suggests peaks in results occurred in 2003 and again in 2007-2008, and these were associated with results greater than 4600 *E. coli*/100 g. Results greater than 230 *E. coli* MPN/100g occurred throughout the period.

Whiting Bay

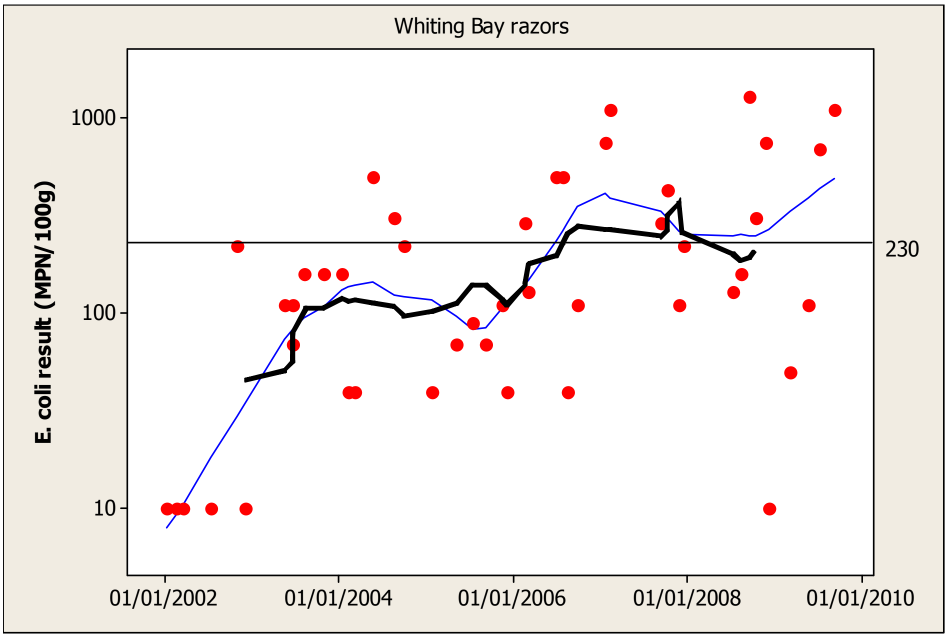


Figure 11.4 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line) (Whiting Bay razors)

Figure 11.4 shows an overall deterioration in results throughout the sampling history. An initial, large increase in results occurs in 2003, when there appears to be a change from a succession of very low results in 2002 to intermediate results in 2003. A second stepwise increase in results appears between late 2005 and 2007, which coincides approximately with a change in reported sampling locations from the south to the north end of the production area. This may be due to either a spatial or temporal effect.

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 11.5 and 11.6 present boxplots of *E. coli* result by month for Arran: Lamlash Bay and Arran: Whiting Bay respectively.

Lamlash Bay

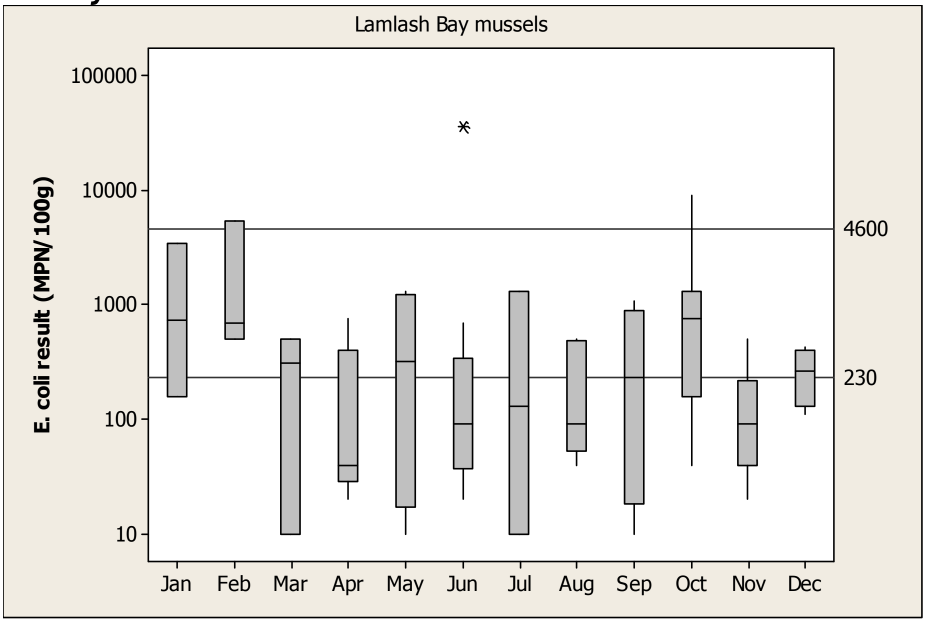


Figure 11.5 Boxplot of results by month (Lamlash Bay mussels)

January, February and October have had higher results on average. Results in other months were widely spread, with no obvious pattern. The highest individual result occurred in June.

Whiting Bay

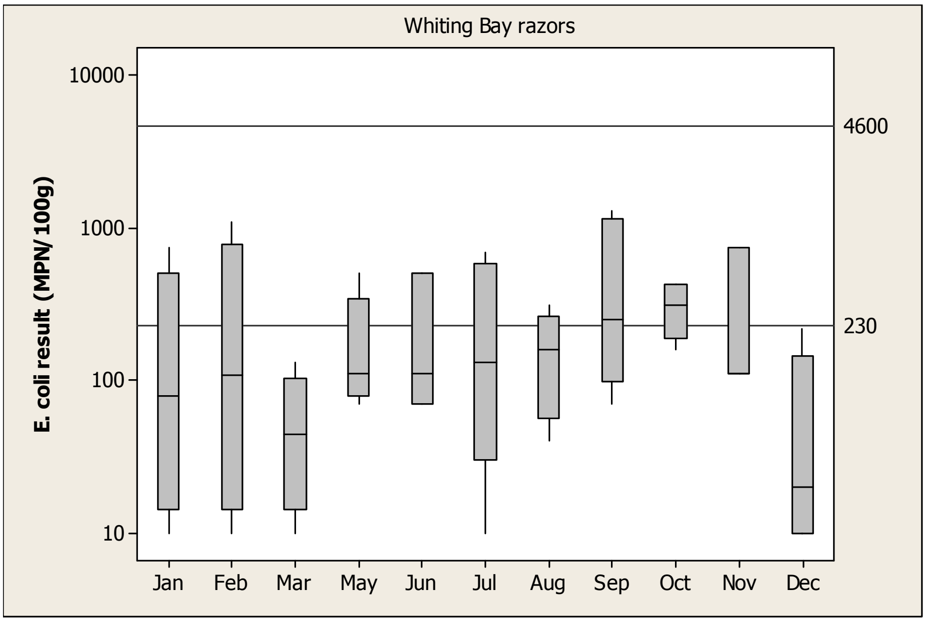


Figure 11.6 Boxplot of results by month (Whiting Bay razors)

More low results occurred from November to March at Whiting Bay, which was roughly opposite to what was observed at Lamlash Bay. The median for November co-locates with the first quartile, which is the bottom of the box. No samples were collected during the month of April.

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

Lamlash Bay

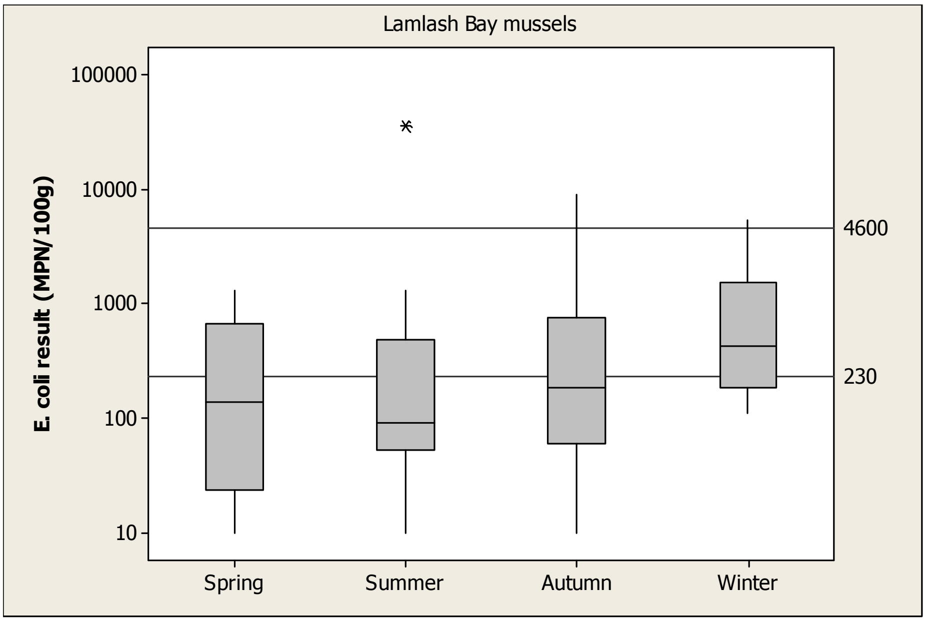


Figure 11.7 Boxplot of result by season (Lamlash Bay mussels)

Generally higher results were seen in winter than in the other seasons. No statistically significant difference was found between results by season for the Arran: Lamlash Bay (One-way ANOVA, p=0.241, Appendix 6).

Whiting Bay

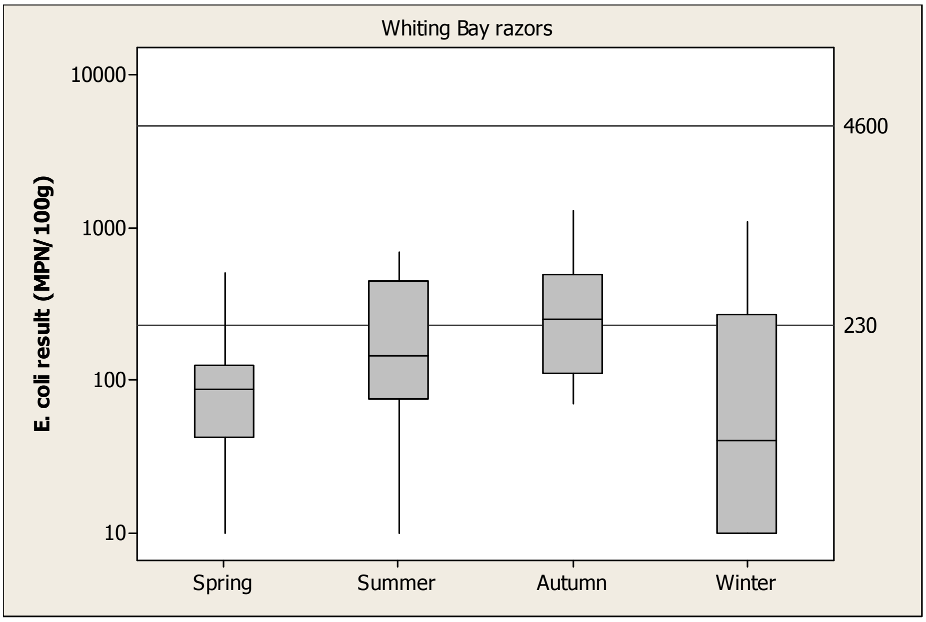


Figure 11.8 Boxplot of result by season (Whiting Bay razors)

For razors at Whiting Bay, higher results were generally seen in summer and autumn and low results were generally seen in winter. A statistically significant difference was found between results by (One-way ANOVA, p=0.031, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the autumn were significantly higher than those for winter.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station is at Arran: Brodick, approximately 7 km to the north of the Lamlash Bay and 11 km to the north of Whiting Bay. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2008 (total daily rainfall in mm).). 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 2 and 7 days and sample results were investigated and are presented below. In all cases, Spearman's Rank correlations were carried out between results and rainfall.

Two-day antecedent rainfall

Lamlash Bay

Figure 11.9 presents a scatterplot of *E. coli* results against rainfall for Lamlash Bay mussels.

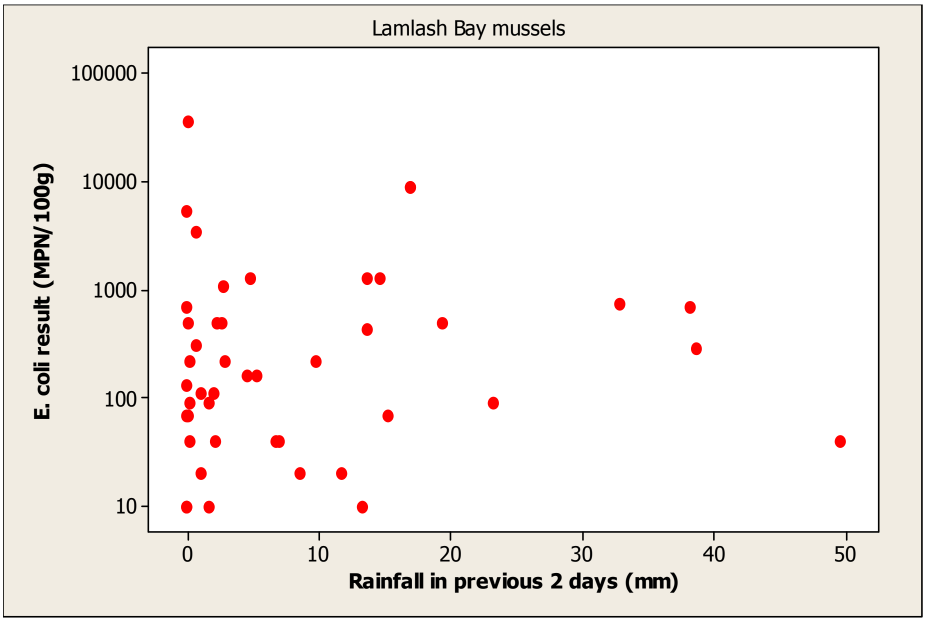


Figure 11.9 Scatterplot of result against 2-day rainfall (Lamlash Bay mussels)

No correlation was found between *E. coli* results for Lamlash Bay mussels and rainfall in the previous 2 days (Spearman's rank correlation=0.107, p=0.488, Appendix 6). Higher results were seen after no rainfall and low results were seen after the highest rainfall values.

Whiting Bay
Figure 11.10 presents a scatterplot of *E. coli* results against rainfall for: Whiting Bay razors.

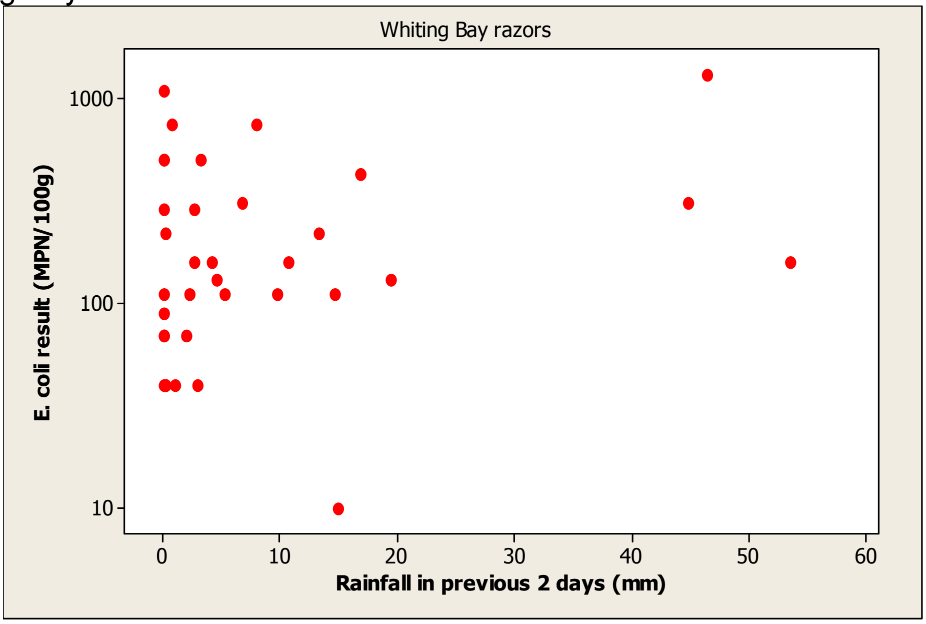


Figure 11.10 Scatterplot of result against 2- day rainfall (Whiting Bay razors)

No correlation was found between *E. coli* results for Whiting Bay razors and rainfall in the previous 2 days (Spearman's rank correlation=0.201, p=0.239, Appendix 6). High results were seen after no and high rainfall. However, results less than 100 *E. coli*/100 g were not seen after rainfall >15mm/2 days.

Seven-day antecedent rainfall

Lamlash Bay
Figure 11.11 presents a scatterplot of *E. coli* results against rainfall for the 7 days prior to sampling for Lamlash Bay.

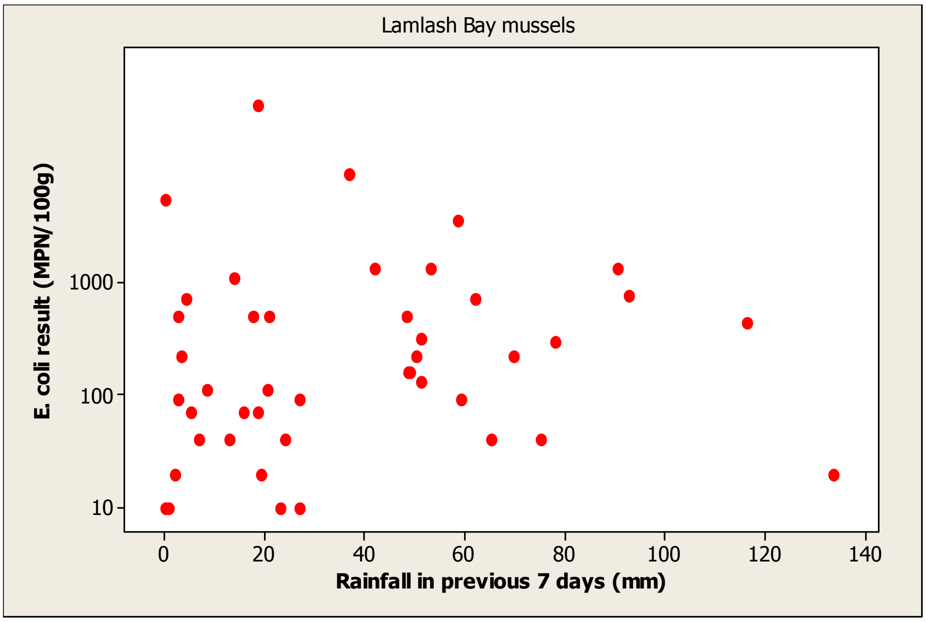


Figure 11.11 Scatterplot of result against 7-day rainfall (Lamlash Bay mussels)

No correlation was found between *E. coli* results for Lamlash Bay mussels and rainfall in the previous 7 days (Spearman's rank correlation= 0.215, p=0.161, Appendix 6). Again, high results were seen after nor or low rainfall and low results were seen at the highest rainfall values.

Whiting Bay

Figure 11.12 presents a scatterplot of *E. coli* results against rainfall for the 7 days prior to sampling for Whiting Bay.

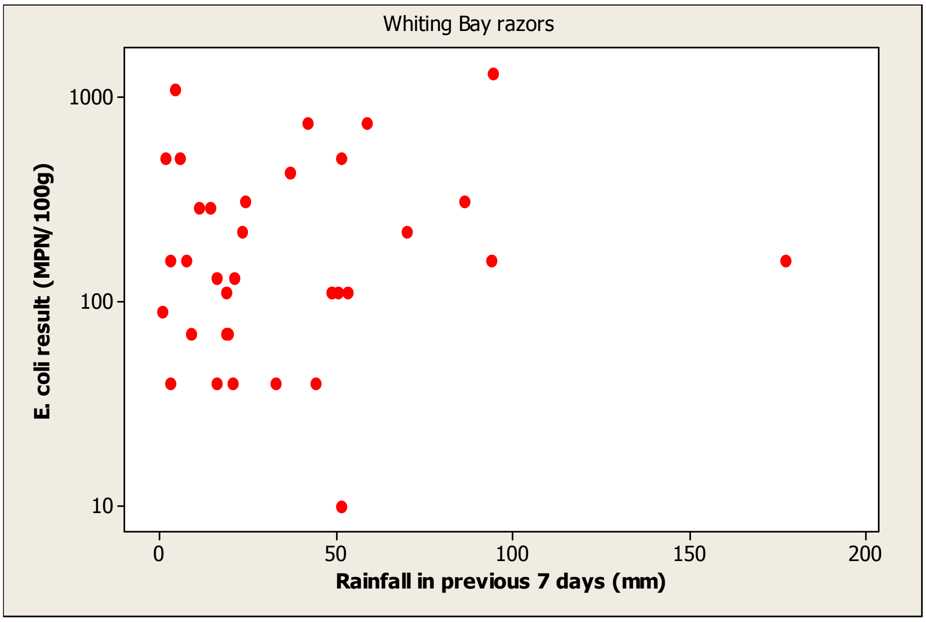


Figure 11.12 Scatterplot of results against 7-day rainfall (Whiting Bay razors)

No correlation was found between *E. coli* results for Whiting Bay razors and rainfall in the previous 7 days (Spearman's rank correlation= 0.125, p=0.469, Appendix 6). High results occurred after both no and high rainfall. Results >100 *E. coli*/100 g were not seen after preceding rainfall exceeding 60 mm/7 days.

11.6.2 Analysis of results by tidal height and state

Spring/Neap 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 the loch. Figures 11.13 and 11.14 present polar plots of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle for Lamlash Bay mussels and Whiting Bay razors respectively. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *E. coli* MPN/100g are plotted in red. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

Lamlash Bay

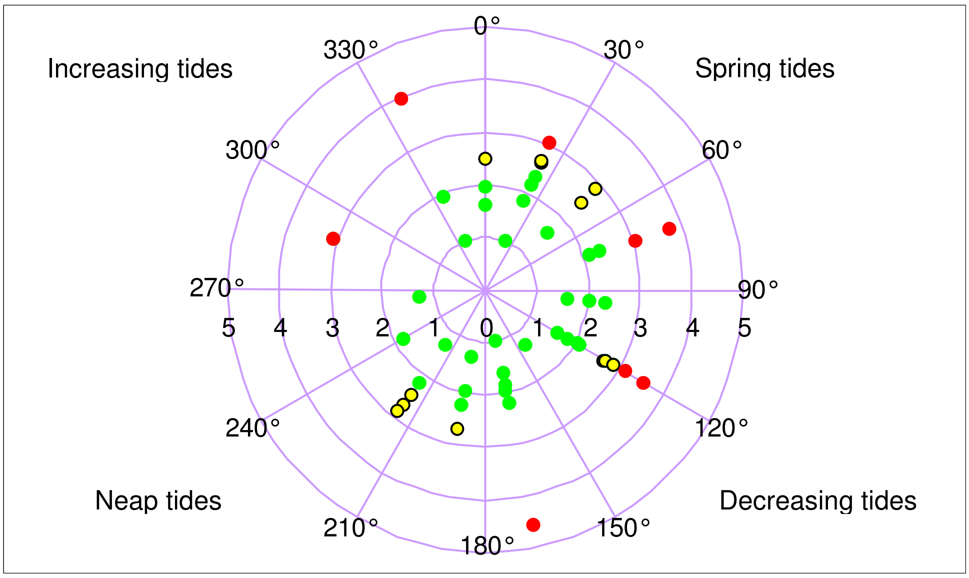


Figure 11.13 Polar plot of log_{10} *E. coli* results on the spring/neap tidal cycle (Lamlash Bay mussels)

No correlation was found between *E. coli* results and the spring/neap cycle for Lamlash Bay mussels (circular-linear correlation, r=0.102, p=0.574, Appendix 6).

Whiting Bay

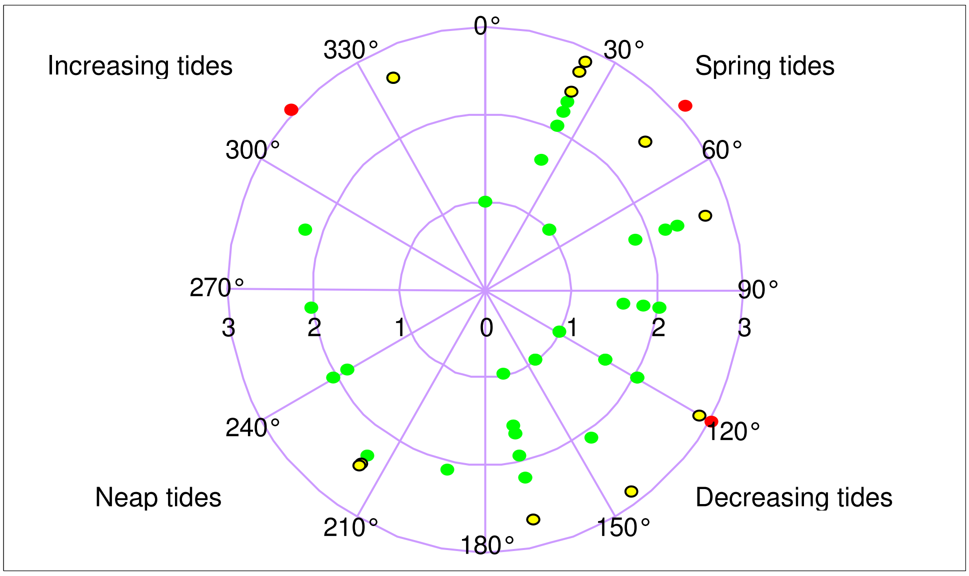


Figure 11.14 Polar plot of log_{10} *E. coli* results on the spring/neap tidal cycle (Whiting Bay razors)

A weak correlation was found between *E. coli* results and the spring/neap cycle for the Whiting Bay razors (circular-linear correlation, r=0.280, p=0.034, Appendix 6), suggesting levels of *E. coli* were not random in relation to the spring/neap tidal cycle, but this correlation was weak. High results did not occur in the first half of increasing tides from neaps.

High/Low cycles

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figures 11.15 and 11.16 present polar plots of $\log_{10}$ *E. coli* results on the lunar high/low tidal cycle for the Lamlash Bay mussels and Whiting Bay razors respectively. High water is at 0º, and low water is at 180º. Again, results under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *E. coli* MPN/100g are plotted in red.

Lamlash Bay

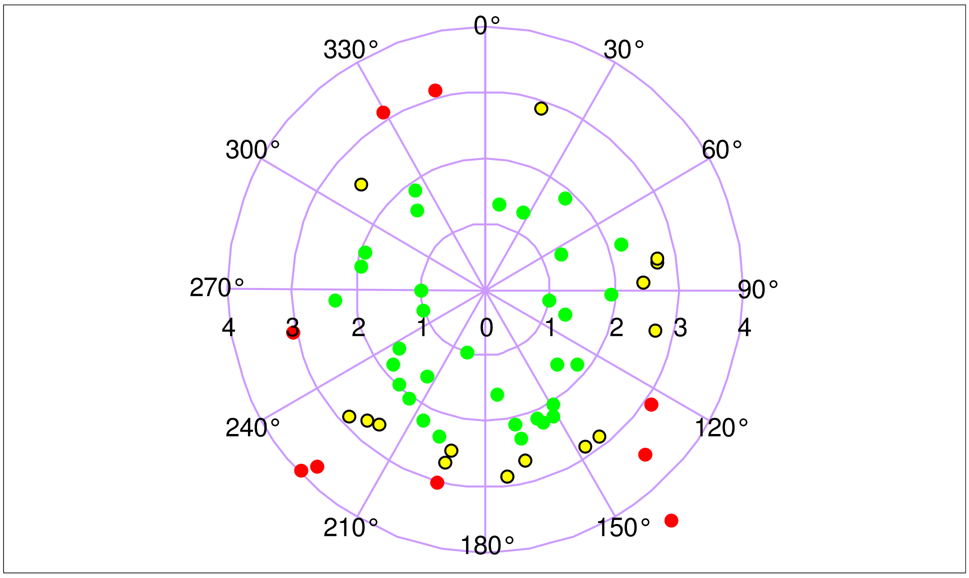


Figure 11.15 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (Lamlash Bay mussels).

No correlation was found between *E. coli* results and the high/low tidal cycle for Lamlash Bay mussels (circular-linear correlation, r=0.183, p=0.168, Appendix 6).

Whiting Bay

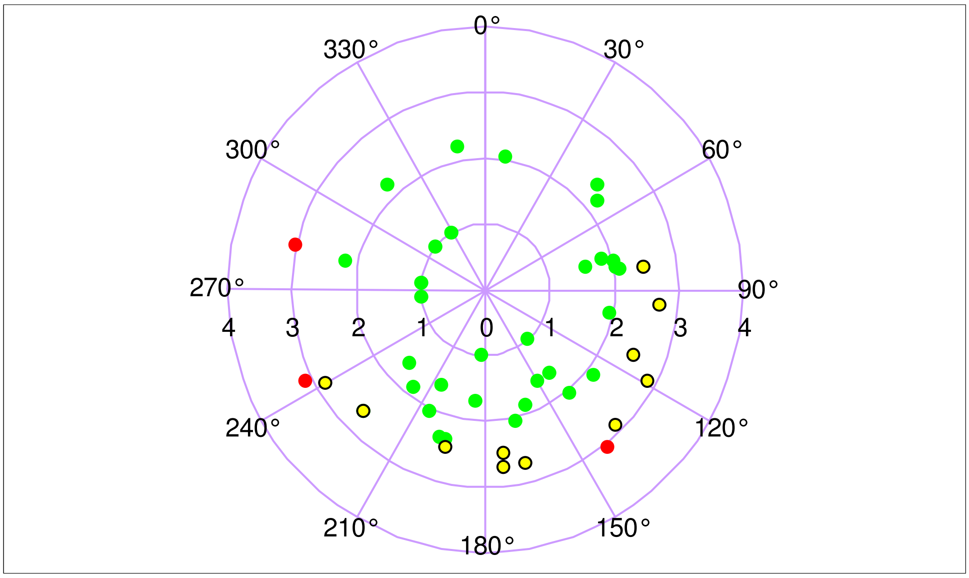


Figure 11.16 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (Whiting Bay razors).

No correlation was found between *E. coli* results and the high/low cycle for Whiting Bay razors (circular-linear correlation, r=0.185, p=0.229, Appendix 6). Results >230 E. coli/100 g tended to occur away from high water, although fewer samples were collected at high water.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Figure 11.17 presents a scatterplot of *E. coli* results against water temperature for the Arran: Whiting Bay razors. For Arran: Lamlash Bay mussels, water temperature was only recorded on six sampling occasions, so there was insufficient data available for a meaningful assessment of water temperature effects for this production area.

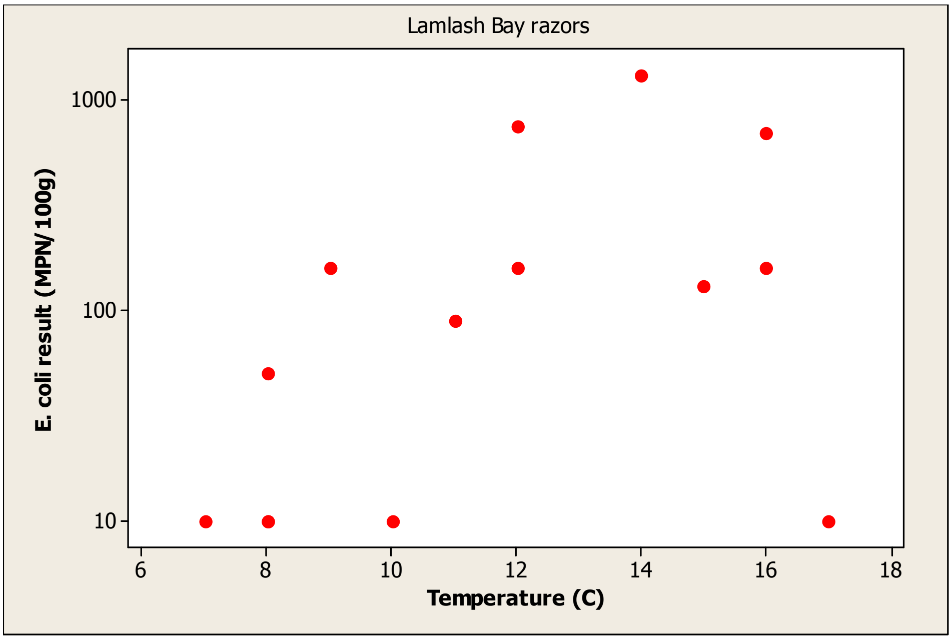


Figure 11.17 Scatterplot of result by water temperature (Lamlash Bay razors)

The coefficient of determination indicates that there was no relationship between the *E. coli* results and water temperature for Arran: Lamlash Bay razors (Adjusted R-sq=17.1%, p=0.079, Appendix 6). Higher results do generally appear to occur at higher water temperatures, but water temperature was only recorded on 14 sampling occasions.

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns within the production area. However, the nearest wind station for which records were available was Prestwick Airport, approximately 31 km to the west of the fisheries. Given the differences in local topography and distance between the two it is likely that the overall patterns of wind direction differ, and that the wind strength and direction may differ significantly at any given time. Therefore it was not considered appropriate to compare *E. coli* results at Arran with wind readings taken at Prestwick.

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 11.18 and 11.19 present scatter plots of *E. coli* result against salinity for Arran: Lamlash Bay mussels and Arran: Whiting Bay razors respectively, where salinity readings were available.

Lamlash Bay

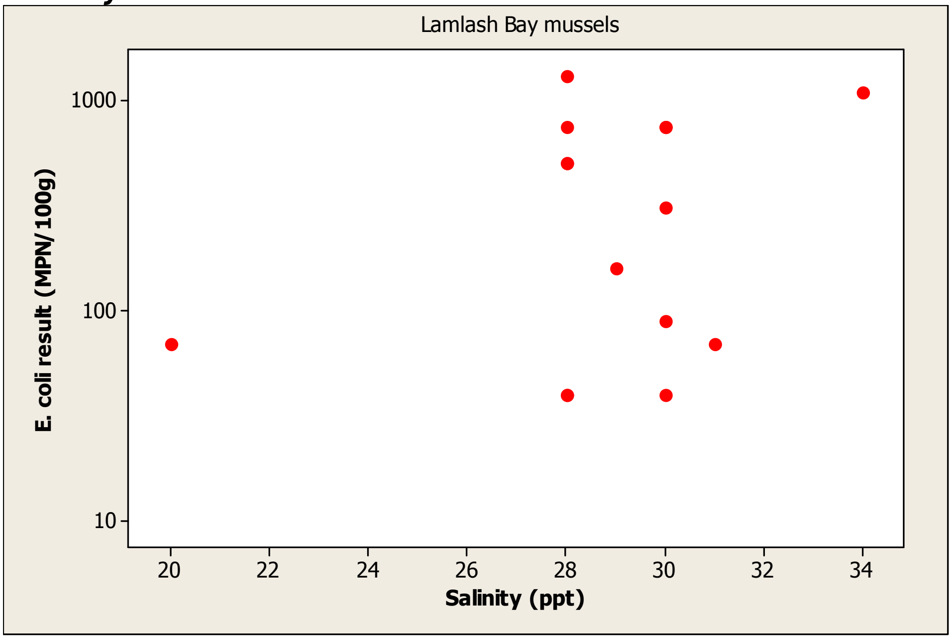


Figure 11.18 Scatterplot of result by salinity (Lamlash Bay mussels)

The coefficient of determination indicates that there was no relationship between *E. coli* results and salinity for Arran: Lamlash Bay mussels (Adjusted R-sq=0.8%, p=0.310, Appendix 6).

Whiting Bay

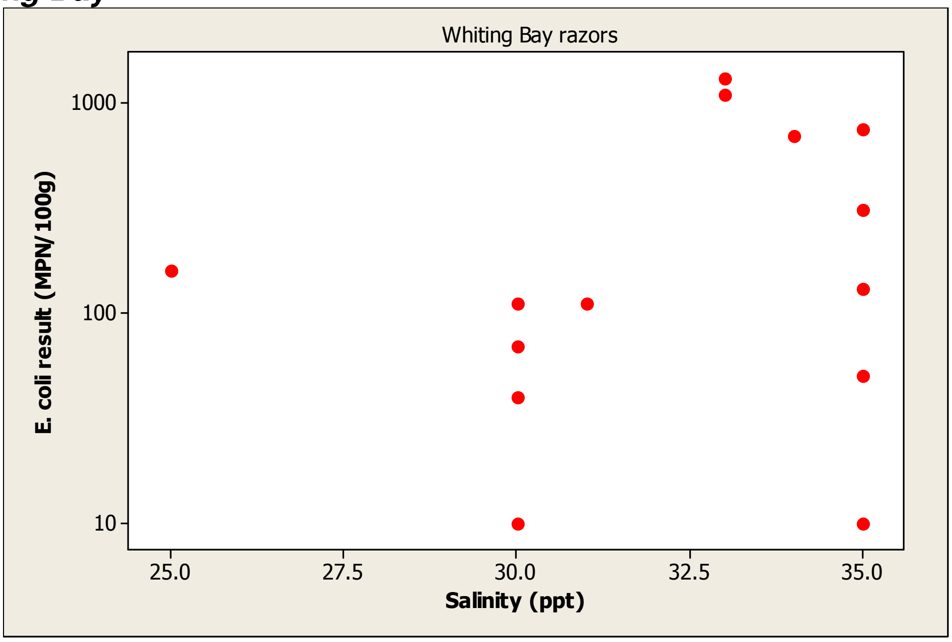


Figure 11.19 Scatterplot of result by salinity (Whiting Bay razors)

The coefficient of determination indicates that there was no relationship between *E. coli* results and salinity for Arran: Whiting Bay razors (Adjusted R-sq=0.0%, p=0.477, Appendix 6).

11.7 Summary and conclusions

Lamlash Bay

No obvious geographical pattern in levels of contamination was apparent within Lamlash Bay. A peak in results occurred in 2007 and 2008 at Lamlash Bay indicating that there had been some deterioration in water quality at that time. Although no statistically significant difference was found between results obtained by season, results tended to be higher generally during the winter. This corresponded roughly with the classification history, which showed that periods of A classification tended to occur during the spring and summer months.

Analysis of results against environmental factors showed that highest results occurred after low or moderate rainfall and low results after higher rainfall in both the 2-day and 7-day periods prior to sampling, though no statistically significant correlation was found in either case. No correlation was found between *E. coli* result and salinity, however salinity was only recorded for a small number of samples.

No correlation was found between either the spring/neap or high low tidal cycle and levels of *E. coli* in mussels at Lamlash Bay.

Whiting Bay

When sample results at Whiting Bay were mapped, there appeared to be higher levels of contamination in samples taken towards the northern end of the production area, but it is possible that this reflected a temporal effect rather than a spatial one. There did not appear to be any patterns in levels of contamination in relation to distance from the shore. It must be noted that the accuracy of sampling locations before 2008 cannot be assured.

For Whiting Bay razors an overall deterioration in sampling results throughout the sampling history was apparent, although it is possible that this was a consequence of the reported sampling location moving northwards over the years. The deterioration occurred in two main steps, one in 2003 and one in 2006/7. A significant seasonal pattern was found here, with results in the autumn significantly higher than those in the winter. Higher results generally occurred at higher water temperatures but this relationship was not statistically significant.

A weak correlation was found between *E. coli* results and the spring/neap cycle for the Whiting Bay razors, and high results did not occur during the first half of the increasing tide. However, only a small number of samples were collected during this phase of the spring/neap cycle. No statistically significant correlation was found between results at Whiting Bay and the high/low tidal cycle, though high results tended to occur on the lower half of the high/low cycle.

11.8 Sampling frequency

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

12. Designated Shellfish Growing Waters Data

The survey area does not coincide with a designated shellfish growing water.

13. Rivers and streams

The following rivers and streams were measured and sampled during the shoreline survey. These represent the most significant freshwater inputs into the production area. The survey was undertaken in dry conditions.

Table 13.1River loadings for Lamlash Bay and Whiting Bay

No.	Position	Width (m)	Depth (m)	Flow (m/s)	Discharge (m^3/d)	*E. coli* (cfu/100ml)	*E. coli* loading (cfu/day)
1	NS 05234 32846	1	0.115	0.131	1300	1000	$1.3x10^{10}$
2	NS 05001 32761	1	0.11	0.0825	784	<100	$<7.8x10^{8}$
3	NS 04900 32701	1.7	0.295	0.107	4640	18000	$8.3x10^{11}$
4	NS 04905 32692	0.4	0.1	1.794	6200	17000	$1.1x10^{12}$
5	NS 04680 32357	1.95	0.09	0.0395	599	<100	$<6.0x10^{8}$
6	NS 04449 32261	0.85	0.1	0.351	2580	5700	$1.5x10^{11}$
7	NS 04425 32263	0.6	0.09	0.048	224	400	$9.0x10^{8}$
8	NS 03581 31951	0.38	0.04	1.527	2000	2900	$5.8x10^{10}$
9	NS 03398 31870	4.4	0.145	0.1455	8020	900	$7.2x10^{10}$
10	NS 03117 31522	0.3	0.03	0.408	317	2200	$7.0x10^{9}$
11	NS 02798 31122	0.45	0.07	0.068	185	100	$1.9x10^{8}$
12	NS 02690 30970	0.22	0.02	0.71	270	3500	$9.4x10^{9}$
13	NS 02657 30518	8	0.275	0.115	21900	2300	$5.0x10^{11}$
14	NS 02649 30294	4.77	0.235	0.1555	15100	26700*	$4.0x10^{12}$
15	NS 05172 27562	0.25	0.03	0.12	78	<100	$<7.8x10^{7}$
16	NS 04925 27366	5.4	0.21	0.093	9110	6000	$5.5x10^{11}$
17	NS 04734 27088	0.7	0.06	0.12	435	9000	$3.9x10^{10}$
18	NS 04686 26832	1.2	0.04	0.338	1400	1500	$2.1x10^{10}$
19	NS 04675 26588	0.62	0.04	0.231	495	<100	$<4.9x10^{8}$
20	NS 04589 26218	1.7	0.1	0.355	5210	7000	$3.6x10^{11}$
21	NS 04596 26186	0.5	0.04	0.149	257	<100	$<2.6x10^{8}$
22	NS 04675 25309	16.5	0.37	0.0625	33000	2500	$8.2x10^{11}$

* Geometric mean result from two samples

Water samples from five streams contained <100 *E. coli* cfu/100ml, so their loadings could only be calculated as being less than a certain value. Two water samples were taken from one stream (14) and the geometric mean *E. coli* result was used for the calculation of its loading. The streams generally drain areas of forest or heath further back before flowing through the urban areas along the coastal strip. Therefore, some may receive sewage inputs as well as contamination from diffuse sources such as wildlife and livestock.

Within Lamlash Bay, a total of 14 streams were sampled and measured, all of which were to the north of the fishery. The Ordnance Survey map shows a few other very small streams adjacent to and south of the fishery that were not surveyed. Stream 14 is likely to be of greatest impact to the mussel fishery as it carried the highest loading and is closest to the site. Levels of *E. coli* and shoreline observations indicate that this stream is subject to significant faecal contamination. Stream 13 is also likely to be of significance. At the northern end of Lamlash Bay were another two streams carrying quite high *E. coli* levels and loadings (3 & 4). These high levels may have been due in part to inputs from a nearby dairy farm.

Within Whiting Bay, three streams had relatively high loadings (16, 20 & 22) and these were located at the northern end, the middle and the southern end of the bay respectively. Therefore their impacts will be quite evenly spread along the shore of Whiting Bay although it is probable that there are hotspots of contamination in the immediate vicinity of where these streams discharge.

The points where streams were measured and sampled are shown in Figure 14.1 together with the calculated loadings. Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1×10^3, in digital format it is written as 1E+3.

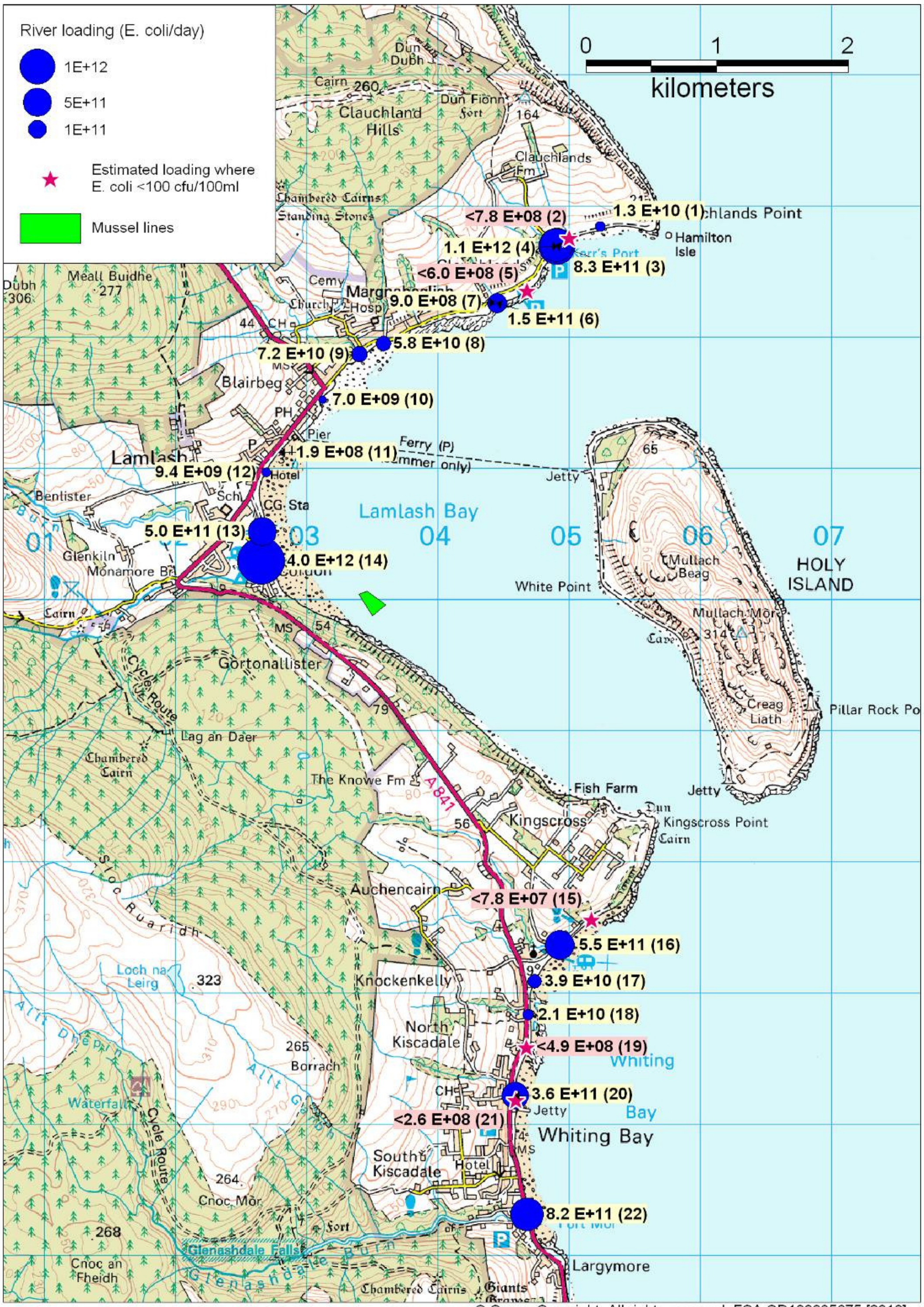


Figure 13.1Stream loadings

14. Bathymetry and Hydrodynamics

Currents in coastal waters are driven by a combination of tide, wind and freshwater inputs. This section aims to make a simple assessment of water movements around the area. Figure 14.1 shows the OS map of the east coast of Arran and Figure 14.2 shows the bathymetry of the same area.

The isle of Arran lies within the very outer reaches of the Firth of Clyde. Lamlash Bay is about 4.5 km in width, with the majority of its mouth obscured by the 3.1 km long Holy Island. Within the bay depths are up to between 30 and 50 m. To the north of Holy Island there is a shallower area across the mouth of the Bay where depths are between 10 and 15 m. The other entrance to the bay, at the south end of Holy Island, is only about 0.5 km in width. These features may impede the flow of water to some extent. Whiting Bay is a less distinct Bay, about 5 km in width. The depth gradually increases to about 30 m within 1 km of the shore, although there are a few small areas between 1 and 3 km from the shore where the depth rises to between 20 and 30 m.

The mussel lines at Lamlash Bay lie in 20-30 m of water. The exact extent of the razor beds at Whiting Bay is not known, although they are reported to be present throughout the entire bay below the low water mark. Harvesting razors from depths of more than 30 m is likely to be impractical. Therefore the fishery will mainly be confined to within about 1- 2 km of the shore, so the current production area boundaries are likely to cover the most of the exploitable beds.

Figure 14.1 OS map of Lamlash Bay and Whiting Bay

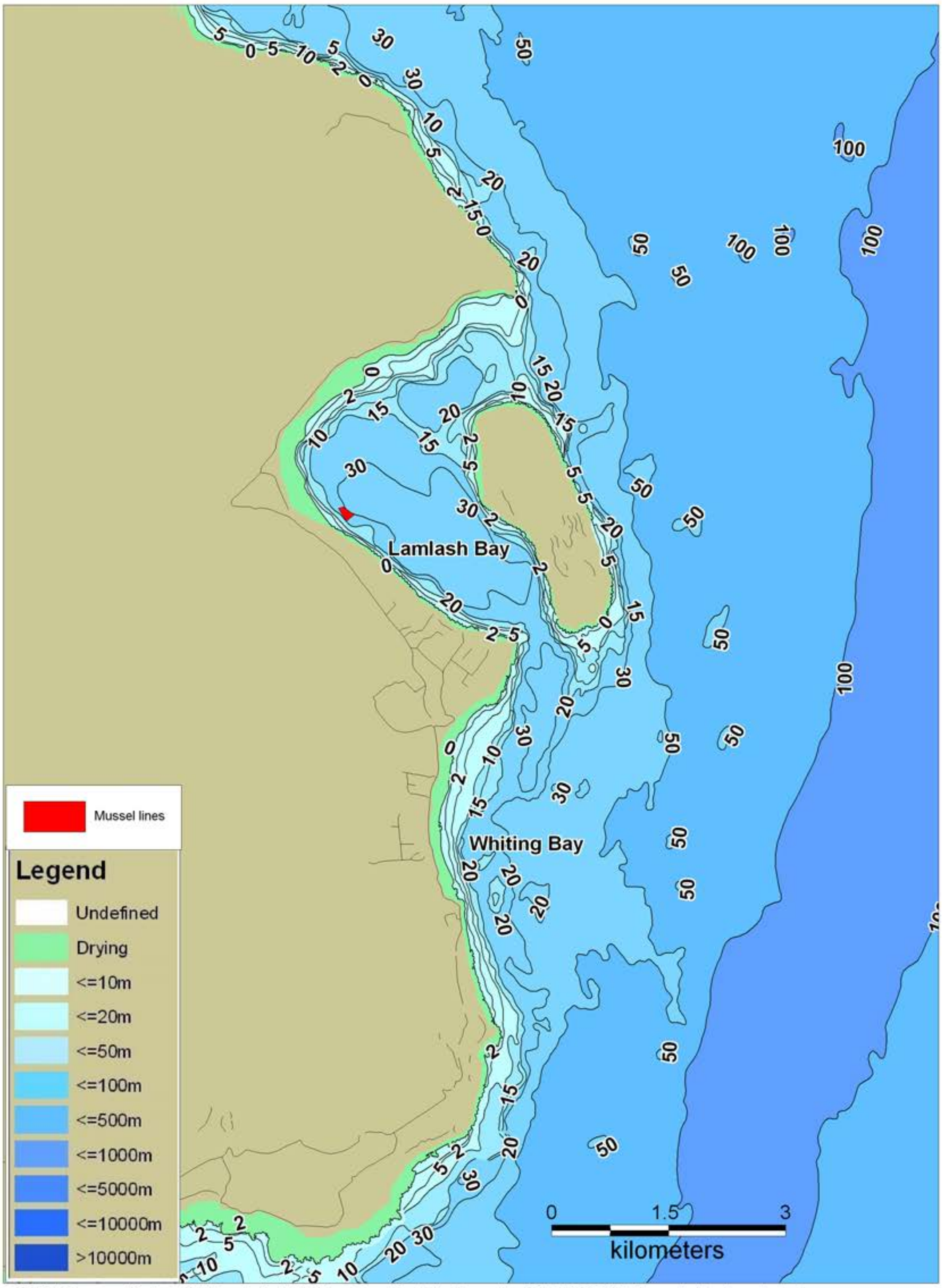


Figure 14.2 Bathymetry of Lamlash Bay and Whiting Bay

14.1 Tidal Curve and Description

The two tidal curves below are for Brodick which lies just to the north of Lamlash Bay. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 08/09/09 and the second is for seven days beginning 00.00 BST on 15/09/09. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

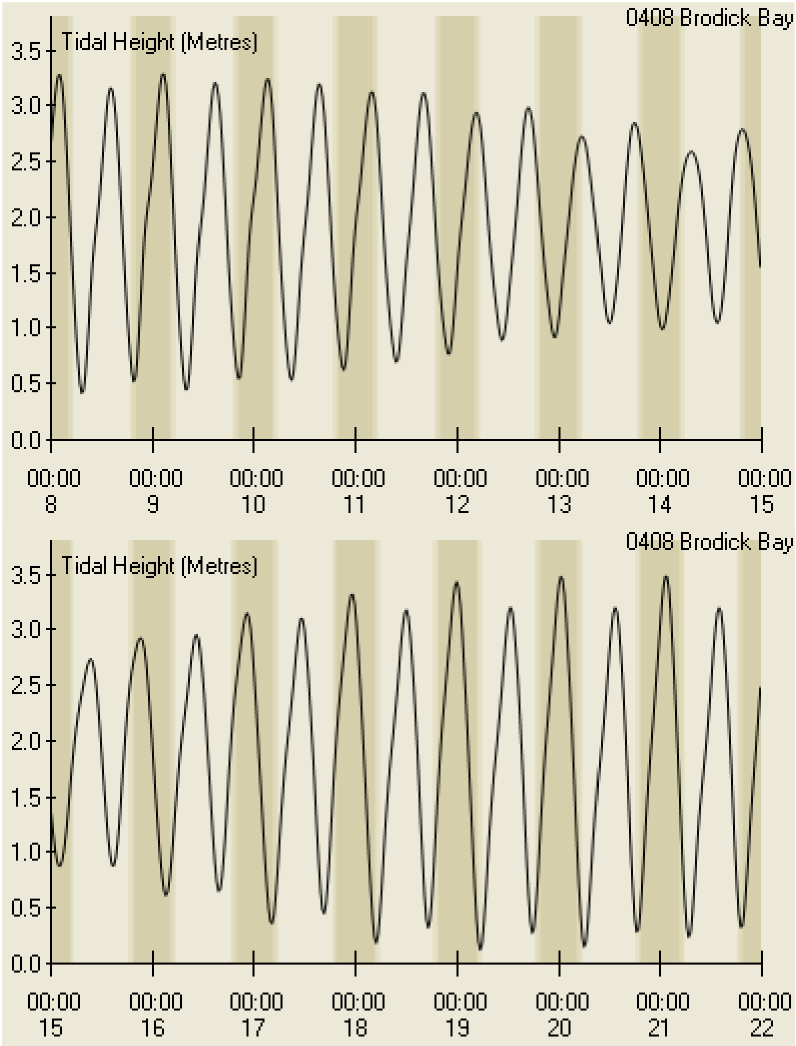


Figure 14.3 Tidal curves for Brodick

Brodick Bay is a Secondary Non-Harmonic port. The tide type is Semi-Diurnal.

HAT	3.6 m
MHWS	3.2 m
MHWN	2.7 m
MSL	1.9 m
MLWN	1.0 m
MLWS	0.4 m

The heights are in metres above chart datum. The tidal range at spring tide is therefore approximately 2.8 m and at neap tide 1.7 m, so tidal ranges here are moderate.

14.2 Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Tidal stream information was available for one station just to the south of Holy Island. The location of this station, together with the tidal streams for peak flood and ebb tide at springs, are presented in Figure 14.4 and the tidal diamond is presented in Table 14.1.

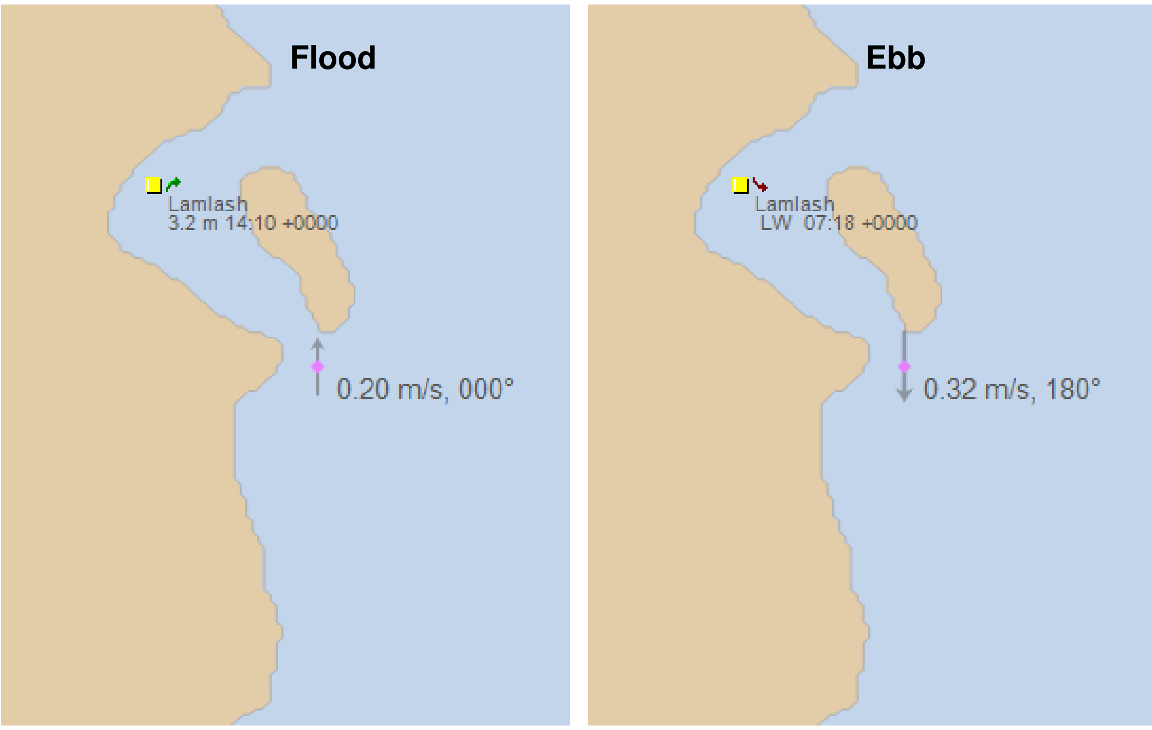


Figure 14.4 Spring tidal streams at SN040I.

Table 14.1 Tidal streams for station SN040I (taken from TotalTide)

Time	Direction	Spring rate	Neap Rate
-06h	000°	0.21 m/s	0.10 m/s
-05h	000°	0.21 m/s	0.10 m/s
-04h	000°	0.21 m/s	0.10 m/s
-03h	000°	0.21 m/s	0.10 m/s
-02h	000°	0.15 m/s	0.10 m/s
-01h	000°	0.05 m/s	0.05 m/s
HW	180°	0.05 m/s	0.05 m/s
+01h	180°	0.21 m/s	0.10 m/s
+02h	180°	0.31 m/s	0.21 m/s
+03h	180°	0.31 m/s	0.21 m/s
+04h	180°	0.21 m/s	0.10 m/s
+05h	000°	0.05 m/s	0.00 m/s
+06h	000°	0.21 m/s	0.10 m/s

There is a clear bi-directional tidal flow at this station. Highest current speeds arise on the south bound ebb tide, but the north bound (flood) tide runs for more of the tidal cycle. Therefore, sources of contamination discharging to the shore in this area are likely to be transported along the shoreline by these tidal flows, creating a region of impact either side. Based on the tidal diamond, the distance a particle would be transported during the course of a flood or ebb tide would be about 4.3 km on a spring tide and 2.4 km on a neap tide, although tidal flows are likely to be slightly slower close to the shore.

Very similar tidal flows to SN040I are expected in Whiting Bay, which has a fairly simple bathymetric profile. Levels of contamination are generally likely to be higher in razors closer to the shore at Whiting Bay as most of the identified sources discharge to the shoreline and the seabed shelves rapidly giving high dilution within a relatively short distance from shore. Given the likely particle transport distances, the impacts of discharges to Lamlash Bay are likely to be minor at most relative to those within Whiting Bay.

Tidal currents in Lamlash Bay are likely to be broadly similar with bi-directional north-south tidal flows, but possibly more complex given its bathymetry. The Clyde Cruising Club Sailing Directions for the Firth of Clyde states that south-flowing spring tidal streams at the north entrance to Lamlash Bay run up to approximately 0.5 m/s and up to 0.75 m/s at the south entrance. North-flowing streams are slightly weaker. As these entrances are constrictions to the flow of water, flows in the main body of Lamlash Bay where the mussel lines are located are likely to be slower, so the regions of impact around shoreline sources are likely to be smaller but more acute.

Given the tidal regime in the area, wind driven flows are expected to be less influential in determining movement of contaminants within the two bays. Strong winds will create a surface current in the same direction as the wind, but bed currents may well move in a different or even opposite direction. Onshore winds, however, will increase wave action and this may resuspend sediment and contaminants in the water. Winds are likely to have less of an effect in Lamlash Bay as it is more sheltered.

Density driven flows are likely to be of little or no importance in either bay given their open nature, the strength of tidal exchange and the relatively meagre freshwater inputs. Four salinity profiles were taken within Lamlash Bay during the shoreline survey showed very little vertical difference in salinity within Lamlash Bay with an average surface salinity of 31.1 ppt and an average of 32.5 ppt at a depth of 10 m. These readings are similar to those found in offshore stations within the Clyde Sea at that time of year (e.g. Midgeley *et al*, 2001). Boxplots of salinities recorded during the collection of *E. coli* classification monitoring samples are presented in Figure 14.5.

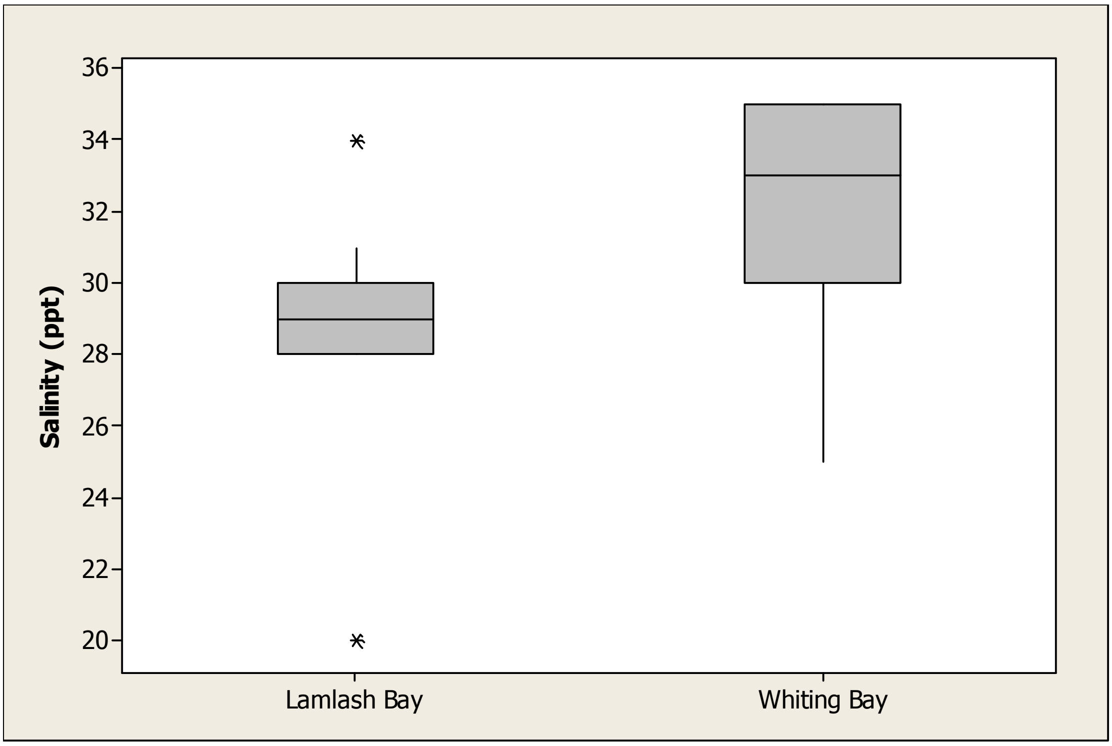


Figure 14.4 Salinities recorded during classification monitoring

There was generally little salinity reduction in either area relative to observed surface salinities at offshore stations in the Clyde Sea. Figure 14.5 suggests that there is a slightly greater freshwater influence within Lamlash Bay, which is not surprising as it is more enclosed and receives a higher volume of freshwater inputs according to shoreline survey measurements.

14.3 Conclusions

Tidally driven flows are bi-directional along the north south axis, with a particle transport distance over the course of a flood or ebb tide in the region of 4.3 km on springs and 2.4 km on neaps. This may be somewhat reduced in the main body of Lamlash Bay. Tidal flows will create a region of impact along the shoreline either side of any point sources, so sources closer to the fisheries will be of most importance. Levels of contamination in the razor beds at Whiting Bay are therefore likely to be higher nearer to the shore. Wind driven flows are likely to have a more minor and variable influence over surface currents, and density driven flows are unlikely to be of significance.

Contamination from the Lamlash Bay septic tank discharge at Clauchlands Point will be carried into the bay on an ebbing tide, but some may be carried past the east coast of Holy Island. Given the particle transport distances, sources at Brodick are unlikely to impact significantly at Lamlash Bay, and the impacts of discharges to Whiting Bay on the Lamlash Bay fishery are likely to be minor. Contamination from the discharge at Holy Island is likely to be carried south along the shore of the island on a southbound tide and so will probably not impact on the fishery at Lamlash Bay, but may have some impacts on the razor beds at Whiting Bay.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 15^{th}-17^{th} September 2009 under dry and calm conditions.

The mussel farm at Lamlash Bay consisted of 3 mussel lines with a ladder system and a mussel raft. The razor fishery at Whiting Bay is a wild fishery, with the beds extending out from the low water mark all along the Bay. The whole area is exploited, and the razors are collected by divers.

The towns of Lamlash and Whiting are both served by separate Scottish Water treatment works. Three associated pumping stations with overflow discharges were seen at Lamlash, and two at Whiting. In both bays there were numerous potential private sewage outfall pipes, some of which showed strong signs of being active sewage discharges, although many appeared inactive or were carrying levels of *E. coli* suggestive of surface water rather than sewage. Car ferries run daily between Brodick and the mainland. There is also a passenger ferry that runs daily to Holy Island from Lamlash during the summer months. At Lamlash five yachts were seen on moorings, and about 30 smaller boats were recorded at a boatyard by the pier. Two pleasure boats were recorded within Whiting Bay.

The shoreline of Lamlash Bay and Whiting Bay is predominantly urban. Behind this it is mainly woodland with some patches of heath and grassland. There are some logged areas behind Lamlash Bay. The only livestock seen during the survey were 40 cattle and 3 horses at the northern end of Lamlash Bay, and 8 cattle on a hill back from the shore by the mussel site at Lamlash. Large numbers of seabirds, mainly gulls, were seen. Small numbers of seals were seen in Lamlash Bay, and small numbers of ducks and geese were seen on the shore of Whiting Bay.

A total of 22 streams were sampled and measured during the shoreline survey, some of which were carrying quite high levels of *E. coli*. In general, they were quite evenly spread around the area. The largest calculated *E. coli* loading was for a stream receiving sewage inputs which discharges just to the north of the mussel site at Lamlash Bay.

Seawater samples taken during the course of the survey showed high levels of contamination in some localised areas along the shore of both Lamlash and Whiting Bay in the vicinity of some of the possible sewage discharge pipes, with the highest overall levels found within Lamlash Bay. Samples of surface water taken just offshore at the mussel site in Lamlash Bay contained fairly low levels of contamination.

Four salinity profiles were taken within Lamlash Bay during the shoreline survey showed very little vertical difference in salinity within Lamlash Bay with an average surface salinity of 31.1 ppt and an average of 32.5 ppt at a depth of 10 m.

Three mussel samples were taken from the mussel site at Lamlash Bay. The sample taken towards the top of the lines contained 160 *E. coli* MPN/100g and the two taken towards the bottom of the lines both contained 20 *E. coli* MPN/100g.

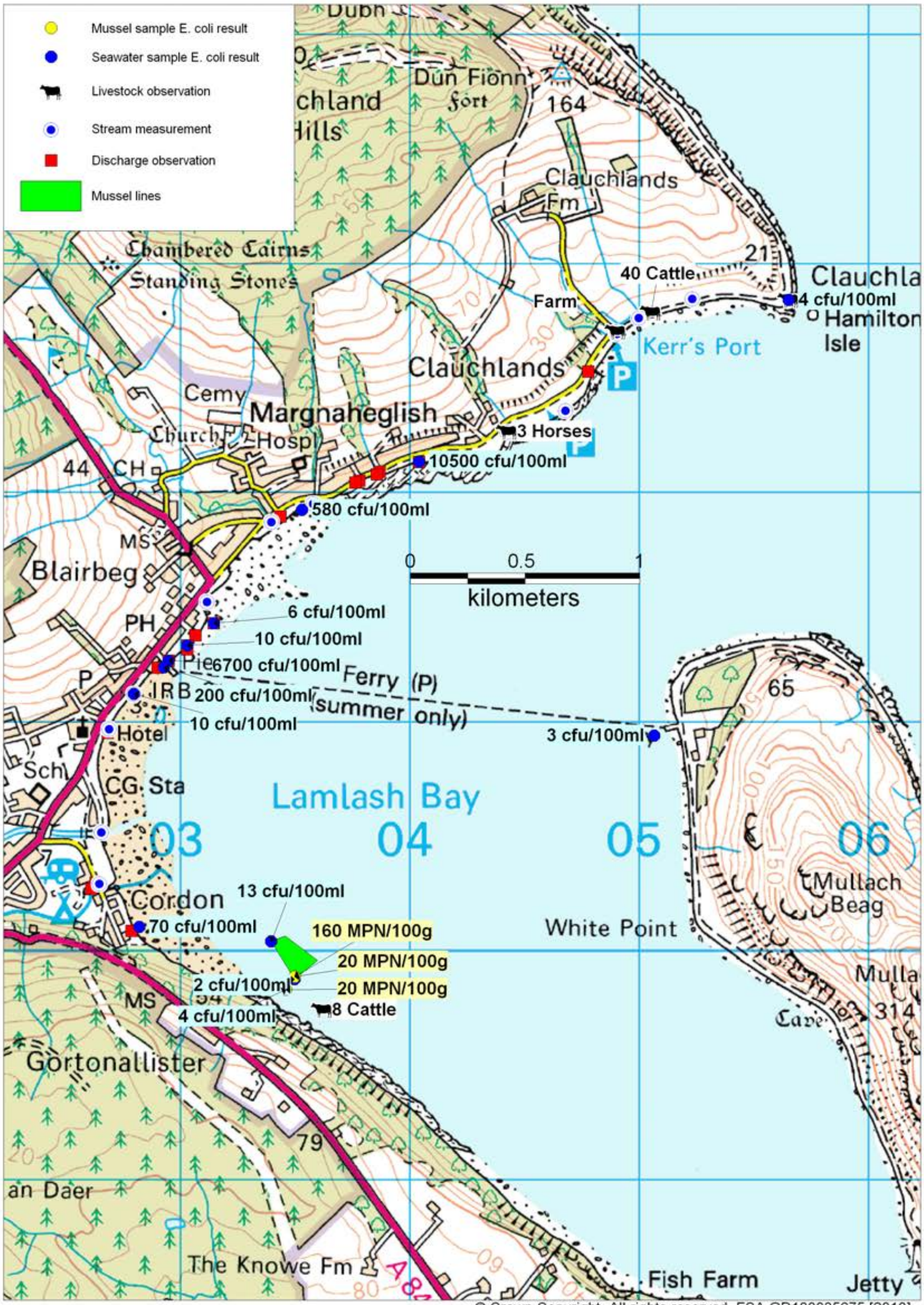


Figure 15.1Summary of shoreline observations (Lamlash Bay)

Figure 15.2 Summary of shoreline observations (Whiting Bay)

16. Overall Assessment

Human sewage impacts

There are numerous sewages discharges along the east coast of Arran. The main ones within the survey area are three Scottish Water community septic tank discharges with associated overflow discharges, one at Brodick, one at the northern end of Lamlash Bay, and one at the southern end of Whiting Bay. There are also a considerable number of small private discharges from these settlements, so human sewage inputs are likely to be a significant source of contamination at both fisheries.

Within Lamlash Bay, all known discharges to seawater or watercourses lie to the north of the mussel site, and to the south there is a stretch of coast of over 2 km in length to which there are no known discharges. Therefore, greater impacts may occur at the north end of the site, although the site is only about 200 m long so whether there is a consistent noticeable difference in levels of contamination in shellfish at the two ends is uncertain. The main Scottish Water discharge is located at the headland at the northern end of the bay, about 3 km from the fishery so it may not have a major impact on the fishery. Also associated with this system are three combined CSO & EO discharges that are closer to the fishery and the CSOs may operate following heavy rainfall events. There are also some private discharges to Lamlash Bay, with 19 pipes recorded during the shoreline survey spread along the shore of Lamlash, at least 6 of which showed strong signs of being active sewage discharge. There is also a moderate-sized discharge on the north west shore of Holy Island, the impacts of which will depend on water circulation patterns. Discharges from further afield (Brodick, Whiting) are likely to be of much less impact to Lamlash Bay. There is significant boat traffic in Lamlash Bay centred around the pier at Lamlash and the moorings just offshore from here, also to the north of the fishery. As any visiting yachts will probably be occupied and have onboard toilets these are believed to be most likely to discharge overboard.

At Whiting Bay, the main Scottish Water discharge lies over 500 m to the south of the current production area boundaries, and the associated overflows lie at the north and south ends of the bay. During the shoreline survey a further 21 pipes were seen along the shoreline of Whiting Bay, at least 5 of which showed strong signs of being an active sanitary discharge. Therefore greatest impacts would be expected at the south end of the razor beds, although the smaller discharges along the shore of the bay will probably create smaller hotspots of contamination in their vicinity. Additional and potentially quite major impacts will occur at the north and south end of the beds when the overflow discharges are in operation.

Agricultural impacts

Most of the coastal strip along the shores of Whiting Bay and Lamlash Bay is urban, and behind this the land is mainly forested, so livestock are absent from most parts. The main concentration of livestock within the study area was found to be a dairy farm at the northern end of Lamlash Bay. Contamination from these animals will be carried into the sea by streams draining the areas they graze, and two streams draining the dairy farm contained high levels of *E. coli* when sampled during the shoreline survey. Therefore greatest impacts from livestock will occur at the northern end of Lamlash Bay.

Cattle are likely to be housed indoors during the winter, with slurry collected and stored for a time, then subsequently spread on fields which form part of the dairy farm. Slurry could conceivably be spread at any time of year, depending on the farm's storage capacity, ground conditions and the growing cycle. However, as slurry production is likely to be higher during the winter it is anticipated that spreading will occur especially during the spring when storage tanks reach capacity after the winter housing period. Should heavy rain follow soon after slurry is spread, this can result in large amounts of contamination being carried into watercourses.

Sheep, goats and ponies present on Holy Island are not husbanded so faecal waste is likely to be widely spread around the island where the terrain is suitable for the animals. Therefore, impacts from this source will be assumed to be evenly distributed spatially.

Given the observed numbers, impacts from livestock are likely to be of less significance than those from human sources as human population in the area is considerably higher, and human waste is mainly discharged (post treatment) directly to the sea.

Wildlife impacts

The main wildlife species potentially impacting on the production areas are seabirds, seals and deer. Most seabird nesting sites were on Holy Island, and shoreline observations suggest favoured resting sites at Hamilton Isle at the northern end of Lamlash Bay, and a rocky outcrop in the centre of Whiting Bay so impacts from seabirds may be higher in these areas. It is possible that they also rest on the mussel floats potentially resulting in significant but patchy contamination of the shellfish below. Seals are likely to forage throughout the area in small numbers. Small amounts of contamination of deer origin will be carried into coastal waters via land runoff. However, as these animals are highly mobile, their impacts on the fishery will generally be unpredictable, and deposition of faeces by wildlife is likely to be widely distributed around the area. Therefore, impacts from wildlife will be minimal compared with those from other sources.

Seasonal variation

The isle of Arran is a popular tourist destination, and there are several places offering tourist accommodation at both Lamlash Bay and Whiting Bay. Numbers of visiting yachts are likely to be higher during the summer months. Therefore it is anticipated that inputs from human sources will peak in the summer.

Livestock numbers are likely to be higher in the summer, so inputs from livestock may be higher during the summer, particularly following high rainfall events. Livestock are likely to access watercourses to drink more frequently during warmer weather. Cattle at the dairy farm may be housed indoors in winter and their slurry collected for later application to fields, so inputs from the dairy farm may be greatly reduced at these times. There is likely to be some seasonality to the spreading of slurry on fields, but it is not known when slurry is typically spread at the dairy farm.

Weather is wetter and windier during the winter months, so in general more rainfall dependent contamination such as sewer overflows may be expected during these times, although high rainfall events can happen at any time.

No statistically significant seasonal pattern in historic *E. coli* monitoring results was found at Lamlash Bay. A significant seasonal pattern in historic *E. coli* monitoring results was found at Whiting Bay, with results in the autumn significantly higher than those in the winter.

In conclusion, human population is likely to increase at both Whiting Bay and Lamlash Bay during the summer months and more visiting yachts may be expected at Lamlash Bay. There is also likely to be an increase in contamination of livestock origin during the summer months, the effects of which would be more important to Lamlash Bay. Significant seasonal variation in *E. coli* levels within shellfish was found at Whiting Bay only, with highest results during the autumn.

Rivers and streams

The streams discharging to Lamlash Bay and Whiting Bay generally drain areas of forest or heath further back before flowing through the urban areas along the coastal strip. Some receive sewage inputs as well as contamination from diffuse sources such as wildlife and in some cases livestock. Significant freshwater inputs were sampled and measured during the shoreline survey, and their *E. coli* loading calculated.

At Lamlash Bay all sampled streams lay to the north of the fishery, although there are a few other very small streams adjacent to and south of the fishery. Two streams with high measured loadings ($4.0x10^{12}$ and $5.0x10^{11}$ *E. coli* / day) discharge about 800 and 900 m from the fishery respectively, and these are likely to be the most significant streams impacting on the fishery and may result in higher levels of contamination at the northern end of the mussel lines. At the northern end of Lamlash Bay two streams draining the dairy farm carried quite high *E. coli* levels and loadings at the time of survey and it is probable that these also make some contribution to contamination found at the mussel site.

Within Whiting Bay, three streams carried quite high loadings and these were located at the northern end, the middle and the southern end of the bay respectively. Therefore their impacts will be quite evenly spread along the shore of Whiting Bay although it is probable that there are hotspots of contamination in the immediate vicinity of where these streams discharge.

Meteorology, hydrology, and movement of contaminants

Water circulation in the area is dominated by tides. Tidally driven flows along this part of the Arran coast are bi-directional along the north south axis, with a particle transport distance over the course of a flood or ebb tide in the region of 4.3 km on springs and 2.4 km on neaps. This may be somewhat reduced in the main body of Lamlash Bay. Therefore, the vast majority of contamination found in shellfish at Lamlash Bay will originate from sources within Lamlash Bay, and the razor beds at Whiting Bay will also be mainly impacted by local sources. Tidal flows will create a region of impact along the shoreline either side of any point sources, the size and magnitude of this being determined by the loading carried by the source and tidal transport distances.

At Lamlash Bay, the most important sources will be the two streams discharging just to the north of the fishery both of which receive sewage inputs, although contamination from all sources along Lamlash may be carried across the fishery on a south flowing tide. The main Scottish Water discharge from Lamlash is at Clauchlands Point, about 3 km to the north of the fishery, so contamination from this source will be subject to some mixing and dilution as it crosses the sill at the north end of the bay, and will probably only be carried as far as the fishery towards the end of an ebbing spring tide.

Wind driven flows are likely to have a more minor and variable influence over surface currents, more so at Whiting Bay as it is more exposed. Density driven flows are unlikely to be of any significance.

Increased stream loadings, and spills containing untreated sewage from CSOs may be expected following heavy rainfall. However, for both production areas no correlation was found between *E. coli* results and recent rainfall, and no relationship was found between *E. coli* results and salinity. A small range of salinities were recorded and these were generally typical of those recorded in the open water of the Clyde Sea. Salinities were on average slightly lower at Lamlash Bay which is not surprising as it is more enclosed and receives a larger volume of freshwater inputs.

Temporal and geographical patterns of sampling results

No obvious geographical pattern in historic *E. coli* monitoring results was apparent within Lamlash Bay. When sample results at Whiting Bay were mapped, there appeared to be higher levels of contamination in samples taken towards the northern end of the production area, though it is not clear whether this effect was spatial or temporal. It must be noted that the sewerage scheme for Whiting Bay described in this report was not in place throughout the period covered by these samples, so present geographic patterns of contamination are likely to be different from those when the sampling took place. Also, before 2008 it is uncertain whether the reported sampling locations are accurate.

A peak in historic sampling *E. coli* monitoring results occurred in 2007 and 2008 at Lamlash Bay. For Whiting Bay razors an overall deterioration in sampling results throughout the sampling history was apparent, although it is possible that this was a consequence of the reported sampling location moving northwards over time.

Seawater samples taken during the course of the shoreline survey showed high levels of contamination in some localised areas along the shore of both Lamlash and Whiting Bay in the vicinity of some of the possible sewage discharge pipes, with the highest overall levels found within Lamlash Bay. Samples of surface water taken just offshore at the mussel site in Lamlash Bay contained moderate levels of contamination.

Three mussel samples were taken from the mussel site at Lamlash Bay. The sample taken towards the top of the lines contained 160 *E. coli* MPN/100g and the two taken towards the bottom of the lines both contained 20 *E. coli* MPN/100g.

Overall conclusions

Arran: Lamlash Bay

All identified (fixed) sources of contamination within Lamlash Bay lie to the north of the fishery, so boundaries should be limited to exclude this potentially more contaminated area adjacent to the town of Lamlash, and the RMP should be set at the northern inshore end of the site to best capture contamination from these sources. There is the possibility of higher levels of contamination at the surface at times, and although there is little evidence to suggest this occurs at this site it is a commonly observed pattern and the reverse would not be expected to occur. Therefore, monitoring samples should be taken from near the top of the water column.

Contamination from sources on Holy Island will generally not be expected to impact on the mussel site in Lamlash Bay.

Arran: Whiting Bay

As the fishery is depth limited it is unlikely to extend much more than 2 km offshore. The current production area boundaries encompass most of the exploitable area, but by moving them out by a further 1 km would ensure that the whole area can be fished.

Sources of contamination are spread all along the shore of Whiting Bay. It is expected that these will be transported along the shore by tidal currents, so in general, higher levels of contamination would be expected nearer the shore. It is possible that contamination from Holy Island may impact towards the northern end of the more offshore part of the bed, but this is likely to be minor compared to that experienced in the inshore parts of the bed. The location and size of impacting sources mean that it is likely that the south western corner of the bed will be subject to highest levels of contamination as this is the closest point to the most significant stream discharging to the bay, the main Scottish Water discharge and one of the associated CSOs. Historic *E. coli* monitoring results suggest higher levels of contamination towards the north of the area. However, all these samples were taken before the sewerage system at Whiting Bay was upgraded, and the accuracy of the reported sampling locations before 2008 cannot be assured.

As the area was not eligible for reduced monitoring under the stability assessment, it is advised that monthly monitoring be continued.

17. Recommendations

Recommendations for monitoring the fisheries at Lamlash and Whiting Bay are described below and illustrated in Figure 17.1.

Arran: Lamlash Bay

Production Area

Recommended production area boundaries are lines drawn between NS 0306 2990 and NS 0357 3024 and between NS 0357 3024 and NS 0421 2981 and between NS 0421 2981 and NS 0390 2939 extending to MHWS.

RMP

It is recommended that the RMP be set at NS 0341 3003, where it may be necessary to hang a dedicated sampling bag to ensure mature stock is always available for sampling.

Depth

Recommended sampling depth is1-3 metres

Sampling Tolerance

A standard tolerance of 20 m is recommended to allow for the movement of the lines in the tide.

Frequency

As the area was not eligible for reduced monitoring under the stability assessment, it is advised that monthly monitoring be continued.

Arran: Whiting Bay

Production Area

The main Scottish Water discharge lies about 500 m to the south of the production area boundaries, so the present southern boundary should be maintained in order to prevent any exploitation in its immediate vicinity. Recommended production area boundaries are lines drawn between NS 0558 2800 and NS 0700 2800 and between NS 0700 2800 and NS 0700 2500 and between NS 0700 2500 and NS 0490 2500 extending to MHWS.

RMP

The RMP should be set at the south western corner of the production area, to best capture contamination from the largest identified sources. Therefore, it is recommended that the RMP be set at NS 0508 2511.

Sampling Tolerance

A tolerance of 100 m is recommended to ensure sufficient stock is consistently available for sampling. All razors submitted for testing should exceed the statutory minimum landing size (100 mm), and preferably be of market size (about 150 mm or larger).

Frequency

As the area was not eligible for reduced monitoring under the stability assessment, it is advised that monthly monitoring be continued.

Figure 17.1 Recommendations for Arran: Lamlash Bay and Arran: Whiting Bay

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4. General Information on Wildlife Impacts
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Sampling Plan for Arran: Lamlash Bay and Arran: Whiting Bay

PRODUCTION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISHERY	NGR OF RMP	EAST	NORTH	TOLERANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICERS
Arran: Lamlash Bay	Lamlash Bay	NA 007 329 08	Common mussels	Longline/ raft	NS 0341 3003	203410	630030	20	1-3	Hand	Monthly	North Ayrshire Council	Andrew Miller William Murray	Andrew Miller William Murray
Arran: Whiting Bay	Whiting Bay	NA 009 331 16	Razors	Wild beds	NS 0508 2511	205080	625110	100	N/A	Hand	Monthly	North Ayrshire Council	Andrew Miller William Murray	Andrew Miller William Murray

Table of Proposed Boundaries and RMPs

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Arran: Lamlash Bay	Common mussels	NA 007 329 08	Area bounded by lines drawn between NS 0268 3100 to NS 0517 3100 and from NS 0433 2900 to NS 0613 2900.	NS 035 297	Area bounded by lines drawn between NS 0306 2990 and NS 0357 3024 and between NS 0357 3024 and NS 0421 2981 and between NS 0421 2981 and NS 0390 2939 extending to MHWS	NS 0341 3003	Production area restricted to exclude shoreline adjacent to the town of Lamlash, RMP relocated to the northwestern corner of the mussel site.
Arran: Whiting Bay	Razors	NA 009 331 16	Area bounded by lines drawn between NS 0558 2800 to NS 0600 2800 and NS 0600 2500 to NS 0489 2500 and NS 0600 2800 to NS 060 250	NS 050 260	Area bounded by lines drawn between NS 0558 2800 and NS 0700 2800 and between NS 0700 2800 and NS 0700 2500 and between NS 0700 2500 and NS 0490 2500 extending to MHWS	NS 0508 2511	Area extended further offshore, RMP relocated to south western corner of production area.

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.

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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:

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

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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.

<u>Section 11.3 One-way ANOVA comparison of results by sampling location (Lamlash Bay)</u>

```
Source    DF      SS     MS     F      P
GridRef    7   4.446  0.635  1.11  0.374
Error     48  27.539  0.574
Total     55  31.985

S = 0.7574   R-Sq = 13.90%   R-Sq(adj) = 1.35%

                                  Individual 95% CIs For Mean Based on
                                  Pooled StDev
Level          N    Mean   StDev  --+---------+---------+---------+-------
NS 034 297     1  1.3010       *  (------------*------------)
NS 034 299     2  2.4515  0.3499              (--------*--------)
NS 035 298     4  2.8674  1.2639                     (-----*-----)
NS 036 298     3  2.3357  0.2892               (------*-------)
NS 0360 2999   1  3.0414       *                (------------*------------)
NS035297      11  2.5081  0.6129                    (---*---)
NS037297       1  1.6021       *     (-----------*------------)
NS038297      33  2.1650  0.7644                   (-*-)
                                  --+---------+---------+---------+-------
                                  0.0       1.2       2.4       3.6
Pooled StDev = 0.7574
```

<u>Section 11.3 One-way ANOVA comparison of results by sampling location (Whiting Bay)</u>

```
Source                 DF      SS     MS     F      P
NGR rounded for geogs   4   2.963  0.741  2.35  0.070
Error                  41  12.926  0.315
Total                  45  15.889

S = 0.5615   R-Sq = 18.65%   R-Sq(adj) = 10.71%



Level                      N    Mean   StDev
NS 05315 27460 (cluster)   9  2.3679  0.7038
NS 05542 27660             1  2.1139       *
NS050250                   2  2.1505  0.7756
NS050260                  16  1.7602  0.5710
NS057270                  18  2.2607  0.4519

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level                     ----+---------+---------+---------+-----
NS 05315 27460 (cluster)                   (-----*------)
NS 05542 27660            (------------------*------------------)
NS050250                        (-------------*------------)
NS050260                           (---*----)
NS057270                                   (----*---)
                          ----+---------+---------+---------+-----
                            1.20      1.80      2.40      3.00

Pooled StDev = 0.5615
```

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

```
Source  DF      SS     MS     F      P
Season   3   2.456  0.819  1.44  0.241
Error   52  29.529  0.568
Total   55  31.985

S = 0.7536   R-Sq = 7.68%   R-Sq(adj) = 2.35%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ---------+---------+---------+---------+
1      12  2.0852  0.7780  (----------*----------)
2      17  2.1755  0.8361      (--------*---------)
3      18  2.3234  0.7291          (--------*--------)
4       9  2.7259  0.5754                 (-----------*------------)
                           ---------+---------+---------+---------+
                                 2.00      2.40      2.80      3.20
Pooled StDev = 0.7536
```

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

```
Source  DF      SS     MS     F      P
Season   3   2.994  0.998  3.25  0.031
Error   42  12.895  0.307
Total   45  15.889

S = 0.5541   R-Sq = 18.84%   R-Sq(adj) = 13.04%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --------+---------+---------+---------+-
1       8  1.8802  0.4874  (-----------*----------)
2      12  2.1416  0.5200            (--------*--------)
3      14  2.4364  0.3911                     (--------*-------)
4      12  1.8110  0.7549   (--------*--------)
                           --------+---------+---------+---------+-
                                1.75      2.10      2.45      2.80
Pooled StDev = 0.5541


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

Individual confidence level = 98.93%


Season = 1 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
2       -0.4146   0.2614  0.9374            (---------*--------)
3       -0.1002   0.5562  1.2126                 (--------*--------)
4       -0.7453  -0.0693  0.6067       (---------*---------)
                                  -------+---------+---------+---------+--
                                     -0.70      0.00      0.70      1.40

Season = 2 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
3       -0.2879   0.2948  0.8774              (-------*--------)
4       -0.9353  -0.3307  0.2740     (-------*--------)
                                  -------+---------+---------+---------+--
                                     -0.70      0.00      0.70      1.40
```

```
Season = 3 subtracted from:

Season    Lower   Center    Upper  ---------+---------+---------+---------+--
4       -1.2081  -0.6254  -0.0428  (-------*-------)
                                   ---------+---------+---------+---------+--
                                       -0.70      0.00      0.70      1.40
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (Lamlash Bay)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.107
P-Value = 0.488
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (Whiting Bay)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.201
P-Value = 0.239
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (Lamlash Bay)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.215
P-Value = 0.161
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (Whiting Bay)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.125
P-Value = 0.469
```

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 20 November 2009 11:22:11

Variables (& observations)	r	p
Angles & Linear (56)	0.102	0.574

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 20 November 2009 11:22:50

Variables (& observations)	r	p
Angles & Linear (46)	0.28	0.034

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 20 November 2009 11:21:21

Variables (& observations)	r	p
Angles & Linear (56)	0.183	0.168

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 20 November 2009 11:23:35

Variables (& observations)	r	p
Angles & Linear (46)	0.185	0.229

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (Lamlash Bay)

```
The regression equation is
log e coli for temperature = 0.615 + 0.108 temperature


Predictor       Coef  SE Coef     T      P
Constant      0.6147   0.6823  0.90  0.385
temperature  0.10802  0.05634  1.92  0.079

S = 0.701931   R-Sq = 23.4%   R-Sq(adj) = 17.1%

Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  1.8111  1.8111  3.68  0.079
Residual Error  12  5.9125  0.4927
Total           13  7.7235

Unusual Observations

                   log e coli
                          for
Obs  temperature  temperature    Fit  SE Fit  Residual  St Resid
  4         17.0        1.000  2.451   0.355    -1.451     -2.40R

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

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (Lamlash Bay)

```
The regression equation is
log e coli for salinity = 0.79 + 0.0545 salinity


Predictor     Coef  SE Coef     T      P
Constant     0.785    1.492  0.53  0.608
salinity   0.05451  0.05155  1.06  0.310


S = 0.565695   R-Sq = 7.9%   R-Sq(adj) = 0.8%
```

```
Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  0.3577  0.3577  1.12  0.310
Residual Error  13  4.1601  0.3200
Total           14  4.5179


Unusual Observations

                 log e coli
Obs  salinity  for salinity    Fit  SE Fit  Residual  St Resid
  6      20.0         1.845  1.875   0.477    -0.030     -0.10 X

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

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (Whiting Bay)

```
The regression equation is
log e coli for salinity = 0.61 + 0.0475 salinity


Predictor     Coef  SE Coef     T      P
Constant     0.607    2.094  0.29  0.777
salinity   0.04749  0.06475  0.73  0.477


S = 0.698433   R-Sq = 4.3%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  0.2624  0.2624  0.54  0.477
Residual Error  12  5.8537  0.4878
Total           13  6.1161


Unusual Observations

                 log e coli
Obs  salinity  for salinity    Fit  SE Fit  Residual  St Resid
  6      25.0         2.204  1.794   0.503     0.410      0.85 X

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

Hydrographic Methods

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

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

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

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

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

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

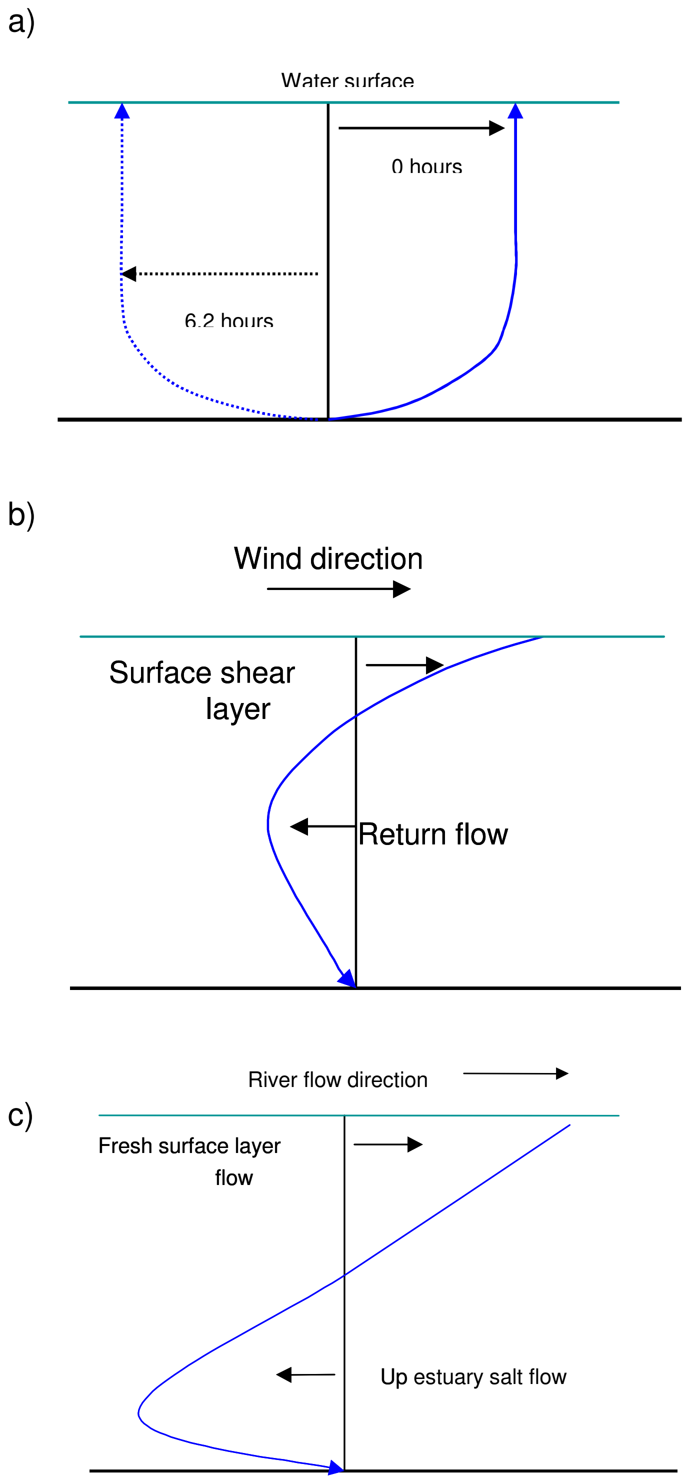

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

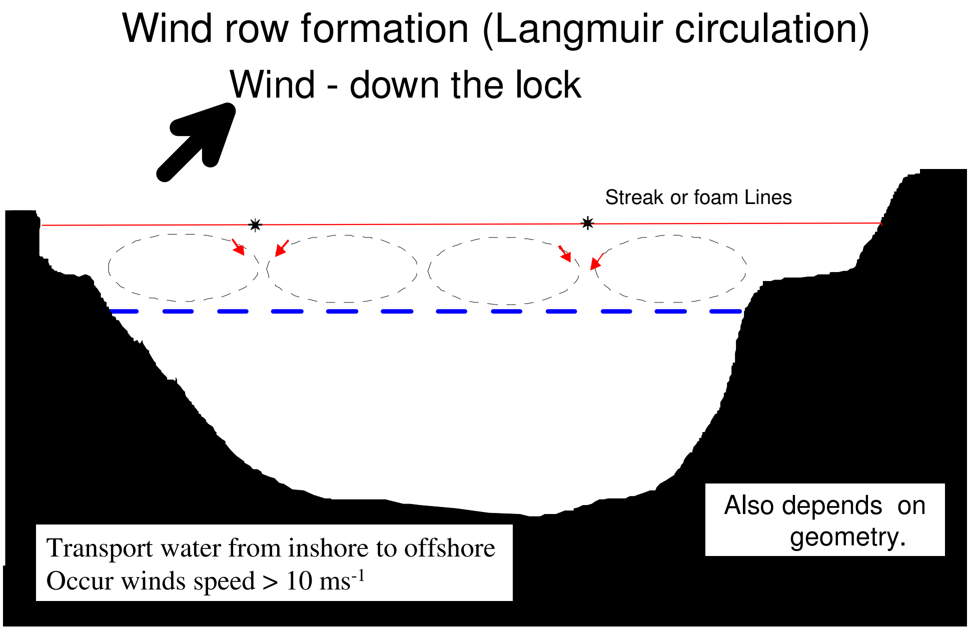

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

<u>Non-modelling Assessment</u>

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

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

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

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

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

Lamlash Bay & Whiting Bay
NA 007 & NA 009

Scottish Sanitary Survey Project Cefas

Shoreline Survey Report

Production area:	Arran: Lamlash Bay	Arran: Whiting Bay
Site name:	Lamlash Bay	Whiting Bay
SIN:	NA 007 329 08	NA 009 331 16
Species:	Common Mussels	Razors
Harvester:	Billy Currie	Hector Stewart
Local Authority:	North Ayrshire Council	North Ayrshire Council
Status:	Existing	Existing
Date Surveyed:	15th & 16th September	17th September 2009
Surveyed by:	Jessica Larkham, Michelle Price-Hayward, Andrew Miller	Jessica Larkham, Michelle Price-Hayward, William Murray
Existing RMP:	NS 035 297	NS 050 260
Area Surveyed:	See Figure 1	See Figure 2

Weather observations
Tuesday 15th September: Fine, dry, wind force 1, Air temp 19°C
Wednesday 16th September: Fine, dry, wind force 2, Air temp 18°C
Thursday 17th September: Fine, dry, wind force 1, Air temp 19°C

Site Observations

Fishery

Lamlash Bay: Currently the mussel farm at Lamlash Bay consists of 3 mussel lines with a ladder system and one raft system.

Whiting Bay: The wild razor bed at Whiting Bay begins past mean low water springs and extends the stretch of the bay. The harvester intends to fish the entire area.

Sewage/Faecal Sources

Population surrounding both Lamlash and Whiting Bay is fairly high. The towns Lamlash and Whiting are both connected to a series of sewage pumping stations. There are three pumping stations in Lamlash and two pumping stations in Whiting. Associated outfall pipes were not spotted for all five pumping stations. In both bays there were numerous sewage outfall pipes discharging into the sea, some of these may have been connected to individual private septic tanks. Several of the outfall pipes observed along the shoreline had a strong foul odour and sewage fungus present.

Adjacent to Lamlash Bay is Holy Island. Holy Island is a Buddhist retreat and also has a hotel and visitor centre serving up to 135 guests. The hotel is connected to a reed bed sewage system.

Livestock – The only livestock observed during the shoreline survey were 40 cattle on the dairy farm at the northern end of Lamlash Bay, 3 horses were also observed close to here.

Seasonal Population

A seasonal increase in population is expected in Lamlash and Whiting, as the Isle of Arran is popular with tourists especially during the summer months. The area is also popular with outdoor enthusiasts all year round. There are numerous B&Bs, hotels and restaurants in Lamlash and Whiting catering for these tourists. There is also a large caravan park at Cordon in Lamlash Bay. Holy Island is a Buddhist retreat with a visitors centre, yoga centre and a hotel (with a capacity for 135 people), there is a ferry service that runs to the island daily in the summer months.

Boats/Shipping

Car ferries run daily from Brodick (the next bay north of Lamlash Bay) to Ardrossan on mainland Scotland. A daily passenger ferry runs from Lamlash pier to the jetty on Holy Island, in the summer months.

At the time of the shoreline survey there were 5 sailing boats moored in Lamlash Bay and 30 small to medium boats in the boat yard next to Lamlash Pier, the RNLI lifeboat is also stationed here. At Whiting Bay there is one jetty and at the time of the shoreline survey only two pleasure boats were moored in the bay.

Land Use

The land directly surrounding Lamlash and Whiting Bay is predominantly urban due to the presence of the Lamlash and Whiting settlements. The land behind the settlement of Lamlash is predominantly dense woodland with some logged areas and some patches of improved and natural grassland. The land behind Whiting is also predominantly dense woodland with small patches of heath land and neutral grassland.

Wildlife/Birds

A total of 250 sea birds (predominantly gulls and cormorants) were observed on Hamilton Isle at the far northern end of Lamlash Bay. A further 65 gulls, 16 oyster catchers and 5 seals were counted along the northern shoreline of the bay, whilst 18 gulls were observed towards the centre of the shoreline.

At Whiting Bay a total of 300 gulls were observed on a rocky outcrop at the centre of the bay, slightly further north of this point a further 2 geese, 16 ducks and 20 gulls were observed on the shoreline. At the southern end of the bay near Largymore, 14 gulls were observed.

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 voe or loch.

Figure 1. Shoreline observations at Lamlash Bay

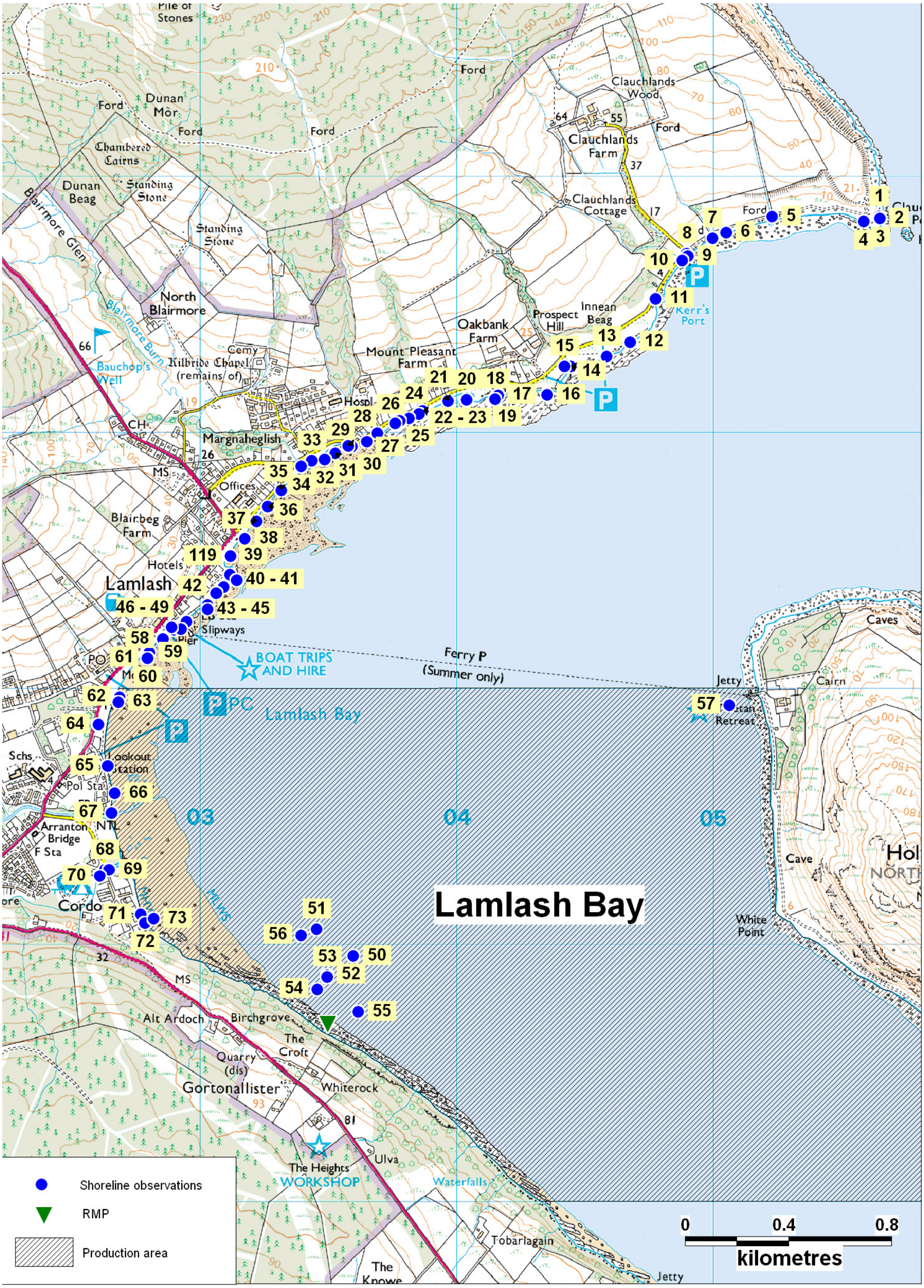

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Figure 2. Shoreline observations at Whiting Bay

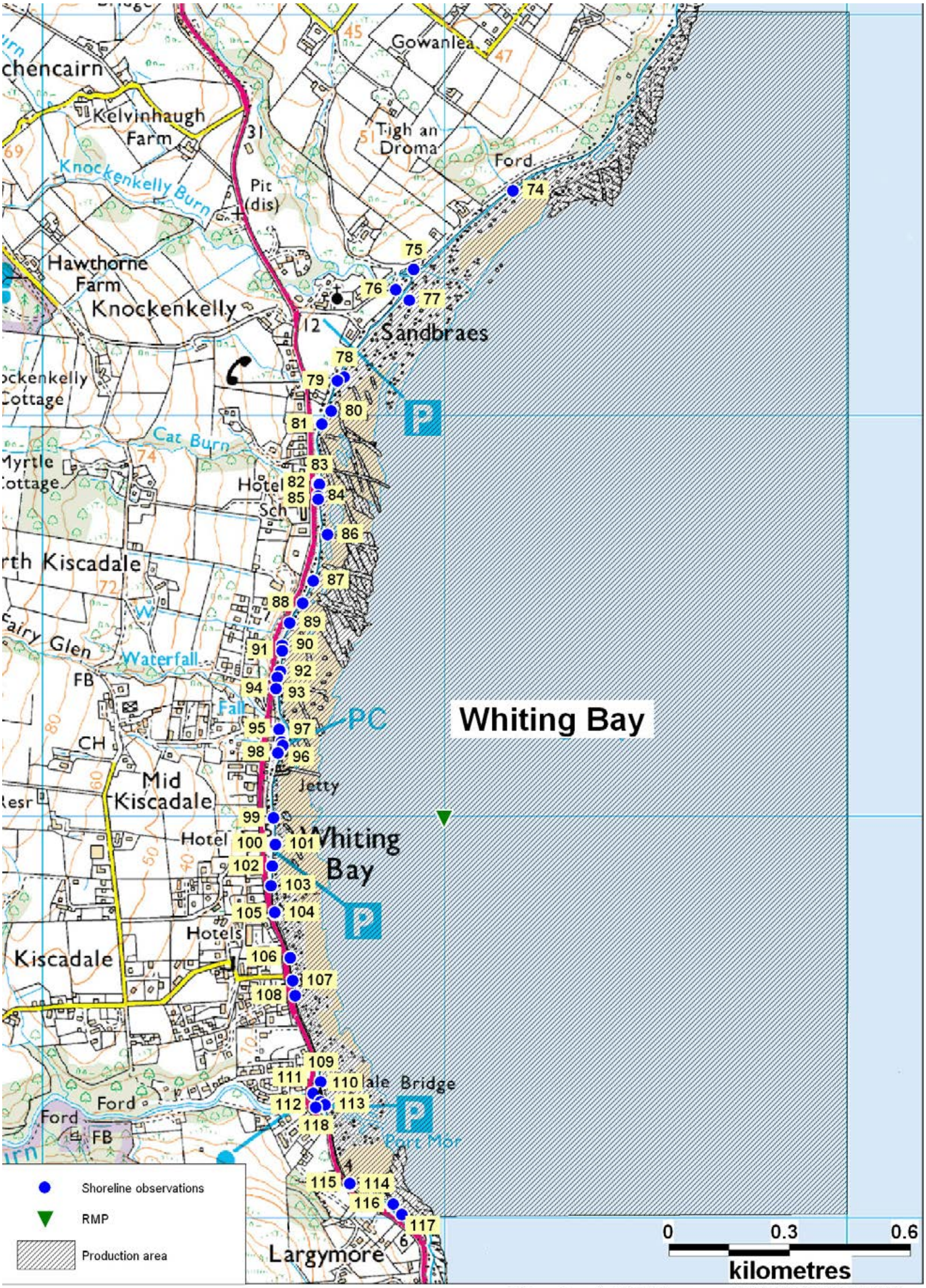

Table 1. Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Description
1	15/09/2009	09:50	NS 05649 32847	205649	632847	Figure 6.	Hamilton Isle - 250 sea birds (black headed gulls, herring gulls, cormorants) 1 seal
2	15/09/2009	10:03	NS 05654 32839	205654	632839	-	Lamlash Bay sea water sample 1 (LBSW1) smell of sewage/guana
3	15/09/2009	10:03	NS 05654 32839	205654	632839	-	Cow pats on shoreline
4	15/09/2009	10:09	NS 05590 32828	205590	632828	-	Water trickling down off road. Logged area to west.
5	15/09/2009	10:21	NS 05234 32846	205234	632846	-	Stream W 1.00, 1st D 0.15, 1st Flow 0.168, 2nd D 0.08, 2nd Flow 0.094. Lamlash Bay fresh water sample 1 (LBFW1)
6	15/09/2009	10:35	NS 05054 32784	205054	632784	-	Large plastic pipe - blocked with stones. 40 cattle. Lamlash SSP drinking water electrical plant.
7	15/09/2009	10:43	NS 05001 32761	205001	632761	-	Culvert W 1.00, 1st D 0.12, 1st Flow 0.037, 2nd D 0.10, 2nd Flow 0.128. Lamlash Bay fresh water 2 (LBFW2). Lots of mussel, clam and winkle shells on the shoreline.
8	15/09/2009	10:53	NS 04900 32701	204900	632701	Figure 7.	Clauchlands Dairy Farm, car park (1 caravan in). Stream W 1.7, 1st D 0.37, 1st Flow 0.156, 2nd D 0.22, 2nd Flow 0.058. Lamlash Bay fresh water sample 3 (LBFW3). Stream splits into two before reaching the sea.
9	15/09/2009	11:05	NS 04905 32692	204905	632692	-	Pipe with large water flow (located below above stream - unsure if from same source). Inner D 0.48, W 0.40, D 0.10, Flow 1.794. Lamlash Bay fresh water sample 4 (LBFW4)
10	15/09/2009	11:14	NS 04883 32674	204883	632674	-	Culvert, inner D 0.45, W 0.30, D 0.12, Flow 1.512. No sample
11	15/09/2009	11:21	NS 04779 32526	204779	632526	-	12 oyster catchers, 20 gulls. Small pipe running under road, very small flow.
12	15/09/2009	11:28	NS 04680 32357	204680	632357	-	Stream W 1.95, 1st D 0.09, 1st Flow 0.053, 2nd D 0.09, 2nd Flow 0.026. Lamlash Bay fresh water sample 5 (LBFW5). 2 sailing boats, 3 moored boats.
13	15/09/2009	11:39	NS 04589 32301	204589	632301	-	Arran Outdoor Education Centre jetty
14	15/09/2009	11:45	NS 04449 32261	204449	632261	-	Stream W 0.85, D 0.10, Flow 0.351. Lamlash Bay fresh water sample 6 (LBFW6)
15	15/09/2009	11:52	NS 04425 32263	204425	632263	Figures 8 & 9.	Stream (foul odour, sewage fungus, orange bacteria) W 0.60, D 0.09, Flow 0.048. Lamlash Bay fresh water sample 7 (LBFW7). 3 horses in field.

No.	Date	Time	NGR	East	North	Associated photograph	Description
16	15/09/2009	12:03	NS 04356 32150	204356	632150	-	More sewage fungus on shoreline. 4 houses behind. 45 gulls, 4 oyster catches, 5 seals.
17	15/09/2009	12:16	NS 04166 32149	204166	632149	-	Pipe with sewage fungus inside, not enough flow to sample. Inner D 0.15.
18	15/09/2009	12:19	NS 04154 32134	204154	632134	Figure 10.	Iron pipe, very small flow.
19	15/09/2009	12:33	NS 04042 32132	204042	632132	-	Lamlash Bay sea water sample 2 (LBSW2). Stream flowing into sea. 20 m fresh water influence on area. Salinity readings: 3ppt, 17 ppt, 23 ppt, 27 ppt, 30 ppt.
20	15/09/2009	12:33	NS 04042 32131	204042	632131	-	Pipe with sewage fungus D 0.15, Flow 3.5secs/30ml. Lamlash Bay fresh water sample 8 (LBFW8). 1 heron.
21	15/09/2009	12:39	NS 03969 32126	203969	632126	Figure 11.	Inspection cover, can hear water flow below
22	15/09/2009	12:46	NS 03870 32088	203870	632088	-	Grey plastic pipe inside clay pipe. Signs of flow but none at time of survey.
23	15/09/2009	12:47	NS 03857 32077	203857	632077	-	Large blue plastic pipe, large flow, inner diameter 0.38, flow D 0.03, flow W 0.16, flow (jug) over 1 litre less than 2/sec
24	15/09/2009	12:51	NS 03818 32058	203818	632058	-	Inspection cover
25	15/09/2009	12:52	NS 03781 32049	203781	632049	-	Clay pipe inner D 0.30, very small flow
26	15/09/2009	12:53	NS 03764 32040	203764	632040	-	Surface water pipe x2, very small flow
27	15/09/2009	12:56	NS 03695 32001	203695	632001	-	Inspection cover
28	15/09/2009	12:57	NS 03653 31968	203653	631968	-	1 large inspection cover, 2 small ones
29	15/09/2009	12:59	NS 03594 31947	203594	631947	Figure 12.	Inspection cover, covered in algae. 5 other inspection covers
30	15/09/2009	13:03	NS 03581 31951	203581	631951	Figure 13.	Stream through culvert W 1.15, D 0.04, W of flow 0.38, flow 1.527. Lots of green algae on shoreline. Lamlash Bay fresh water sample 9 (LBFW9)
31	15/09/2009	13:12	NS 03531 31921	203531	631921	-	Lamlash Bay sea water sample 3 (LBSW3), salinity 26 ppt.
32	15/09/2009	13:21	NS 03489 31898	203489	631898	-	2 inspection covers
33	15/09/2009	13:22	NS 03437 31893	203437	631893	Figure 14.	Lamlash PS3 - Electrical unit, 4 inspection covers in ground. Grey pipe flow, covered in rocks. Lamlash Bay fresh water 10 (LBFW10)
34	15/09/2009	13:29	NS 03398 31870	203398	631870	Figure 15.	Large stream W 4.4, 1st D 0.20, 1st flow 0.087, 2nd D 0.09, 2nd flow 0.204. Lamlash Bay fresh water sample 11 (LBFW11)
35	15/09/2009	13:40	NS 03319 31776	203319	631776	-	Inspection cover (can hear running water)
36	15/09/2009	13:42	NS 03267 31713	203267	631713	-	Stream, appears to have high nutrient content, no sample taken

No.	Date	Time	NGR	East	North	Associated photograph	Description
37	15/09/2009	13:43	NS 03223 31655	203223	631655	-	Inspection cover
38	15/09/2009	13:45	NS 03177 31587	203177	631587	-	Stagnant water, sewage fungus
39	15/09/2009	13:47	NS 03117 31522	203117	631522	-	Lamlash PS2. Grey pipe W 0.30, D 0.03, flow 0.408, Lamlash Bay fresh water sample 12 (LBFW12)
40	15/09/2009	13:54	NS 03119 31447	203119	631447	-	2 inspection covers
41	15/09/2009	13:55	NS 03146 31427	203146	631427	-	Lamlash Bay sea water sample 4 (LBSW4). Taken at end of large pipe discharging into the sea. 27 moored boats visible
42	15/09/2009	14:03	NS 03094 31400	203094	631400	-	Inspection cover
43	15/09/2009	14:07	NS 03067 31374	203067	631374	Figure 15.	Pipe encased in concrete, W 0.20, flow 3 secs/700ml. Lamlash Bay fresh water sample 13 (LBFW13)
44	15/09/2009	14:14	NS 03031 31330	203031	631330	-	Two pipes encased in concrete. Lamlash Bay sea water sample 5 (LBSW5), salinity ppt 28. Boat yard behind with 30 small/med boats in
45	15/09/2009	14:15	NS 03031 31312	203031	631312	-	Inspection cover and pipe encased in concrete, not enough flow to sample
46	15/09/2009	14:25	NS 02949 31264	202949	631264	Figure 16.	Pipe encased in concrete, flowing under water, Lamlash Bay sea water sample 6 (LBSW6)
47	15/09/2009	14:27	NS 02901 31233	202901	631233	-	Pier and RNLI base. Two pipes flowing under RNLI building, pipe broken in parts
48	15/09/2009	14:32	NS 02929 31234	202929	631234	-	Lamlash Bay sea water sample 7 (LBSW7). Lamlash Bay periwinkle sample
49	15/09/2009	14:37	NS 02891 31242	202891	631242	-	Public toilets
50	16/09/2009	09:37	NS 03599 29958	203599	629958	Figure 17.	South east end of mussel lines
51	16/09/2009	09:39	NS 03457 30064	203457	630064	-	North east end of mussel lines
52	16/09/2009	09:48	NS 03499 29885	203499	629885	-	Lamlash Bay mussel sample 1 (top of line, sea temp 15.1℃), Lamlash Bay mussel sample 2 (8m down, bottom of loop). Salinity profile: 1m 31.20 ppt, 15.3℃, 5m 31.8 ppt, 15.1℃, 10m 32.54 ppt 14.5℃
53	16/09/2009	10:06	NS 03499 29876	203499	629876	-	Lamlash Bay sea water sample 8 (LBSW8) taken from 1 m depth at mussel lines. South west end of mussel lines
54	16/09/2009	10:09	NS 03461 29829	203461	629829	Figure 18.	Mussel raft, Lamlash Bay mussel sample 3 (9 m down). Salinity profile: 1m 30.93 ppt, 15.3℃, 5m 31.88 ppt, 15℃, 10m 32.88 ppt, 14.7℃. Lamlash Bay sea water sample 9 (LBSW9) taken from 1m under raft
55	16/09/2009	10:24	NS 03620 29741	203620	629741	-	Lamlash Bay sea water sample 10 (LBSW10). Salinity profile: 1m 30.79,

No.	Date	Time	NGR	East	North	Associated photograph	Description
							15.2℃, 5m 31.73, 15.2℃, 10m 32.25, 14.8℃. No houses on adjacent shoreline, 6 further up the hill. 8 cows on hill. Hotel/Buddhist Centre on Holy Island (135 person capacity) reed bed sewage system
56	16/09/2009	10:34	NS 03396 30040	203396	630040	-	North west end of mussel lines. Lamlash Bay sea water sample 11 (LBSW11)
57	16/09/2009	10:42	NS 05067 30938	205067	630938	-	Lamlash Bay sea water sample 12 (LBSW12), taken off shore from Holy Isle hotel. Salinity profile: 1m 31.58 ppt, 15℃, 5m 32.2 ppt, 14.9℃, 10m 32.3 ppt, 14.7℃
58	16/09/2009	12:18	NS 02858 31196	202858	631196	-	Ground seepage
59	16/09/2009	12:20	NS 02804 31142	202804	631142	-	18 gulls
60	16/09/2009	12:22	NS 02798 31121	202798	631121	-	Pipe running into the sea, Lamlash Bay sea water sample 13 (LBSW13), salinity 28 ppt
61	16/09/2009	12:25	NS 02798 31122	202798	631122	-	Large concrete pipe, W 0.45, D of flow 0.07, flow 0.068, Lamlash Bay fresh water sample 14 (LBFW14)
62	16/09/2009	12:41	NS 02690 30970	202690	630970	-	Stream W 0.22, D 0.02, flow 0.710, Lamlash Bay fresh water sample 15 (LBFW15)
63	16/09/2009	12:44	NS 02684 30950	202684	630950	-	Concrete pipe leading out to sea, couldn't find end of pipe
64	16/09/2009	12:47	NS 02607 30862	202607	630862	-	Lamlash WWPS 2006, NS 026 309 Scottish Water
65	16/09/2009	12:50	NS 02643 30700	202643	630700	-	Inspection cover
66	16/09/2009	12:53	NS 02669 30594	202669	630594	-	Inspection cover
67	16/09/2009	13:03	NS 02657 30518	202657	630518	Figure 19.	Burn passing under Arranton Bridge, W 8m, 1st D 0.26, 1st flow 0.135, 2nd D 0.29, 2nd flow 0.095. Pooh stick method: 11 secs/2m Lamlash Bay fresh water sample 16 (LBFW16).
68	16/09/2009	13:22	NS 02632 30296	202632	630296	-	Cordon Caravan Park
69	16/09/2009	13:27	NS 02649 30294	202649	630294	-	Stream W 4.77, 1st D 0.19, 1st flow 0.132, 2nd D 0.28, 2nd flow 0.179. Lamlash Bay fresh water sample 17 (LBFW17) from left side of river. Lamlash Bay fresh water sample 18 (LBFW18) from right side of river. Outfall pipe discharging into the stream, bad odour and sewage fungus present.
70	16/09/2009	13:44	NS 02612 30270	202612	630270	-	Outfall pipe discharging into the stream under water, bad odour
71	16/09/2009	13:54	NS 02772 30121	202772	630121	-	Small burn
72	16/09/2009	13:55	NS 02787 30087	202787	630087	-	New plastic pipe running to the shore, no flow or sign of flow at time of

No.	Date	Time	NGR	East	North	Associated photograph	Description
							shoreline survey. Next to it is another plastic pipe with a blue bracket on and slits cut into it to allow drainage, possible soakaway.
73	16/09/2009	13:59	NS 02822 30103	202822	630103	-	Lamlash Bay sea water sample 14 (LBSW14)
74	17/09/2009	10:02	NS 05172 27562	205172	627562	-	Burn running into sea W 0.25, D 0.03, flow 0.242. Whiting Bay fresh water sample 1 (WBFW1)
75	17/09/2009	10:20	NS 04925 27366	204925	627366	-	Burn running into sea W 5.40, 1st D 0.17, 1st flow 0.098, 2nd D 0.25, 2nd flow 0.088. Whiting Bay fresh water sample 2 (WBFW2)
76	17/09/2009	10:35	NS 04880 27315	204880	627315	Figure 20.	Whiting Bay PS1, 2 inspection covers. Horse droppings.
77	17/09/2009	10:37	NS 04913 27289	204913	627289	-	Whiting Bay sea water sample 1 (WBSW1). Salinity 30 ppt.
78	17/09/2009	10:44	NS 04751 27097	204751	627097	-	Inspection cover
79	17/09/2009	10:45	NS 04734 27088	204734	627088	-	Small stream W 0.70, D 0.06, flow 0.120. Whiting Bay fresh water sample 3 (WBFW3)
80	17/09/2009	10:56	NS 04719 27012	204719	627012	-	Ground seepage
81	17/09/2009	10:57	NS 04696 26980	204696	626980	-	Inspection cover
82	17/09/2009	11:03	NS 04686 26832	204686	626832	-	Burn W 1.2, D 0.04, flow 0.338. Whiting Bay fresh water sample 4 (WBFW4). 2 geese, 16 ducks, 20 gulls.
83	17/09/2009	11:14	NS 04690 26829	204690	626829	-	Pipe blocked with stones, no flow
84	17/09/2009	11:15	NS 04686 26800	204686	626800	-	3 pipes, no flow
85	17/09/2009	11:15	NS 04686 26792	204686	626792	-	2 herons, 18 gulls, 6 other seabirds on rock in front of shoreline
86	17/09/2009	11:17	NS 04710 26703	204710	626703	Figure 21.	Large group of approximately 300 birds (gulls)
87	17/09/2009	11:23	NS 04675 26588	204675	626588	-	Burn W 0.62, D 0.04 flow 0.231. Whiting Bay fresh water sample 5 (WBFW5)
88	17/09/2009	11:30	NS 04648 26533	204648	626533	-	Ground seepage
89	17/09/2009	11:31	NS 04616 26483	204616	626483	-	Small burn, no where suitable to measure flow, algae growing. Whiting Bay fresh water sample 6 (WBFW6)
90	17/09/2009	11:37	NS 04597 26428	204597	626428	-	Two drainage pipes
91	17/09/2009	11:38	NS 04597 26414	204597	626414	-	Three drainage pipes
92	17/09/2009	11:42	NS 04592 26362	204592	626362	-	Concrete pipe, very little flow, green algae, no where to measure flow, possible sewage outfall. Whiting Bay fresh water sample 7 (WBFW7)
93	17/09/2009	11:43	NS 04584 26347	204584	626347	-	Two pipes coming out of sea wall flow from one. Whiting Bay sea water sample 2 (WBSW2)

No.	Date	Time	NGR	East	North	Associated photograph	Description
94	17/09/2009	11:47	NS 04581 26319	204581	626319	Figure 22.	25cm inner diameter concrete pipe coming out of the wall, small flow, lots of sewage fungus. Whiting Bay fresh water sample 8 (WBFW8)
95	17/09/2009	11:52	NS 04589 26218	204589	626218	-	Burn W 1.7, D 0.10, flow 0.355. Whiting Bay fresh water sample 9 (WBFW9)
96	17/09/2009	11:59	NS 04596 26186	204596	626186	-	Small burn W 0.50, D 0.04, flow 0.149. Whiting Bay fresh water sample 10 (WBFW10)
97	17/09/2009	12:05	NS 04598 26178	204598	626178	-	Public toilets, outfall pipe, no flow
98	17/09/2009	12:05	NS 04586 26159	204586	626159	-	Outfall pipe, possible gutter
99	17/09/2009	12:09	NS 04575 25996	204575	625996	-	Outfall pipe, blocked with stones, no flow
100	17/09/2009	12:12	NS 04582 25933	204582	625933	-	Iron pipe leading down to the shoreline, corroded and broken, not in use.
101	17/09/2009	12:14	NS 04580 25931	204580	625931	Figure 23.	Whiting Bay PS2. Two pipes. Left pipe - Whiting Bay fresh water sample 11, flow (jug) 1 sec/litre, Right pipe - Whiting Bay fresh water sample 12, flow (jug) 2.5 secs/litre. Lots of sewage fungus present
102	17/09/2009	12:23	NS 04573 25876	204573	625876	-	Large blue pipe, very small flow. Whiting Bay sea water sample 3 (WBSW3)
103	17/09/2009	12:29	NS 04569 25827	204569	625827	-	Large pipe flowing down to shore, possibly not in use anymore
104	17/09/2009	12:31	NS 04579 25760	204579	625760	-	Large plastic pipe (flowing), Whiting Bay fresh water sample 13 (WBFW13), flow (jug) 7 secs/litre, 0.30 inner diameter
105	17/09/2009	12:34	NS 04580 25757	204580	625757	Figure 24.	Concrete pipe flowing into the sea, strong smell of sewage. Whiting Bay fresh water sample 14 (WBFW14) flow (jug) 3 secs/litre
106	17/09/2009	12:43	NS 04617 25648	204617	625648	-	Pipe into sea, very little flow
107	17/09/2009	12:44	NS 04624 25590	204624	625590	-	Iron pipe, very slow drip
108	17/09/2009	12:45	NS 04630 25553	204630	625553	Figure 25.	Sign for Whiting Bay PS2. Sign: Montrose Terr SEP NS 046 253. 8 inspection covers
109	17/09/2009	12:52	NS 04693 25339	204693	625339	-	Sanitary debris (face wipe)
110	17/09/2009	12:53	NS 04683 25311	204683	625311	-	Inspection cover, two pleasure boats moored in bay
111	17/09/2009	12:54	NS 04675 25309	204675	625309	Figure 26.	River under Ashdale Bridge W 16.5, 1st D 0.44 1st flow 0.021, 2nd D 0.30, 2nd flow 0.104. Whiting Bay fresh water sample 15 (WBFW15)
112	17/09/2009	13:07	NS 04693 25289	204693	625289	-	Pipe with some flow into the river, Whiting Bay fresh water sample 16 (WBFW16)
113	17/09/2009	13:11	NS 04703 25282	204703	625282	-	Plastic pipe, no flow

No.	Date	Time	NGR	East	North	Associated photograph	Description
114	17/09/2009	13:18	NS 04765 25083	204765	625083	-	Pipe flowing out of sea wall into the sea, flow (jug) 8 secs/litre. Whiting Bay fresh water sample 17 (WBFW17)
115	17/09/2009	13:22	NS 04766 25086	204766	625086	-	14 gulls
116	17/09/2009	13:27	NS 04873 25035	204873	625035	-	Concrete pipe, broken, small flow, sewage fungus present. Whiting Bay sea water sample 4 (Whiting Bay sea water sample 4)
117	17/09/2009	13:35	NS 04895 25008	204895	625008	-	Broken concrete pipe, diverted to plastic pipe, flowing onto shore. Strong odour, sewage fungus. Whiting Bay fresh water sample 18 (WBFW18)
118	17/09/2009	14:02	NS 04680 25275	204680	625275	-	Bridge with sign and 3 inspection covers
119	17/09/2009	14:31	NS 03122 31520	203122	631520	-	Lamlash Bay fresh water sample 12 (LBFW12)

Photos referenced in the table can be found attached as Figures 6 - 26.

Sampling

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

Seawater samples were tested for salinity using a hand held refractometer. These readings are recorded in Table 1 as salinity in parts per thousand (ppt).

Samples of seawater were also tested for salinity by the laboratory using a salinity meter under more controlled conditions. These results are shown in Table 2, given in units of grams salt per litre of water. This is the same as ppt.

Table 2. Water sample results

No.	Date	Sample	Grid Ref	Type	*E. coli* (cfu/100 ml)	Salinity (g/L)
1	15/09/2009	LBFW1	NS 05234 32846	Fresh Water	1000	-
2	15/09/2009	LBFW2	NS 05001 32761	Fresh Water	>100	-
3	15/09/2009	LBFW3	NS 04900 32701	Fresh Water	18000	-
4	15/09/2009	LBFW4	NS 04905 32692	Fresh Water	17000	-
5	15/09/2009	LBFW5	NS 04680 32357	Fresh Water	<100	-
6	15/09/2009	LBFW6	NS 04449 32261	Fresh Water	5700	-
7	15/09/2009	LBFW7	NS 04425 32263	Fresh Water	400	-
8	15/09/2009	LBFW8	NS 04042 32131	Fresh Water	>100000	-
9	15/09/2009	LBFW9	NS 03581 31951	Fresh Water	2900	-
10	15/09/2009	LBFW10	NS 03437 31893	Fresh Water	<100	-
11	15/09/2009	LBFW11	NS 03398 31870	Fresh Water	900	-
12	17/09/2009	LBFW12	NS 03122 31520	Fresh Water	2200	-
13	15/09/2009	LBFW13	NS 03067 31374	Fresh Water	54000	-
14	16/09/2009	LBFW14	NS 02798 31122	Fresh Water	100	-
15	16/09/2009	LBFW15	NS 02690 30970	Fresh Water	3500	-
16	16/09/2009	LBFW16	NS 02657 30518	Fresh Water	2300	-
17	16/09/2009	LBFW17	NS 02649 30294	Fresh Water	7600	-
18	16/09/2009	LBFW18	NS 02649 30294	Fresh Water	94000	-
19	15/09/2009	LBSW1	NS 05654 32839	Sea Water	4	32.5
20	15/09/2009	LBSW2	NS 04042 32132	Sea Water	10500	12.0
21	15/09/2009	LBSW3	NS 03531 31921	Sea Water	580	24.3
22	15/09/2009	LBSW4	NS 03146 31427	Sea Water	6	24.7
23	15/09/2009	LBSW5	NS 03031 31330	Sea Water	10	29.8
24	15/09/2009	LBSW6	NS 02949 31264	Sea Water	6700	26.5
25	15/09/2009	LBSW7	NS 02929 31234	Sea Water	200	26.5
26	16/09/2009	LBSW8	NS 03499 29876	Sea Water	2	32.9
27	16/09/2009	LBSW9	NS 03461 29829	Sea Water	4	32.2
28	16/09/2009	LBSW11	NS 03396 30040	Sea Water	13	32.7
29	16/09/2009	LBSW12	NS 05067 30938	Sea Water	3	33.2
30	16/09/2009	LBSW13	NS 02798 31121	Sea Water	10	22.2
31	16/09/2009	LBSW14	NS 02822 30103	Sea Water	70	26.9
32	17/09/2009	WBFW1	NS 05172 27562	Fresh Water	<100	-
33	17/09/2009	WBFW2	NS 04925 27366	Fresh Water	6000	-

34	17/09/2009	WBFW3	NS 04734 27088	Fresh Water	9000	-
35	17/09/2009	WBFW4	NS 04686 26832	Fresh Water	1500	-
36	17/09/2009	WBFW5	NS 04675 26588	Fresh Water	<100	-
37	17/09/2009	WBFW6	NS 04616 26483	Fresh Water	3700	-
38	17/09/2009	WBFW7	NS 04592 26362	Fresh Water	<100	-
39	17/09/2009	WBFW8	NS 04581 26319	Fresh Water	>100000	-
40	17/09/2009	WBFW9	NS 04589 26218	Fresh Water	7000	-
41	17/09/2009	WBFW10	NS 04596 26186	Fresh Water	<100	-
42	17/09/2009	WBFW11	NS 04580 25931	Fresh Water	28000	-
43	17/09/2009	WBFW12	NS 04580 25931	Fresh Water	>100000	-
44	17/09/2009	WBFW13	NS 04579 25760	Fresh Water	300	-
45	17/09/2009	WBFW14	NS 04580 25757	Fresh Water	>100000	-
46	17/09/2009	WBFW15	NS 04675 25309	Fresh Water	2500	-
47	17/09/2009	WBFW16	NS 04693 25289	Fresh Water	200	-
48	17/09/2009	WBFW17	NS 04765 25083	Fresh Water	<100	-
49	17/09/2009	WBFW18	NS 04895 25008	Fresh Water	>100000	-
50	17/09/2009	WBSW1	NS 04913 27289	Sea Water	130	32.3
51	17/09/2009	WBSW2	NS 04584 26347	Sea Water	50	28.5
52	17/09/2009	WBSW3	NS 04573 25876	Sea Water	1700	31.3
53	17/09/2009	WBSW4	NS 04873 25035	Sea Water	16	32.7

Table 3. Shellfish sample results

No.	Date	Sample	Grid Ref	Type	*E. coli* (MPN/100 g)
1	16/09/09	LMBS1	NS 03499 29885	Common mussel	160
2	16/09/09	LMBS2	NS 03499 29885	Common mussel	20
3	16/09/09	LMBS3	NS 03461 29829	Common mussel	20

Figure 3. Lamlash Bay water sample results

Figure 4. Whiting Bay water sample results

Figure 5. Shellfish sample results

Photographs

Figure 6. 250 sea birds on Hamilton Isle

Figure 7. Stream running down from farm, water sample no.3

Figure 8. Sewage fungus present in stream, water sample 7

Figure 9. Orange bacteria present in the same stream as above

Figure 10. Pipe with sewage fungus inside, flow too small to sample

Figure 11. Pipe with sewage fungus on shoreline below, water sample 8

Figure 12. Inspection cover covered in algae

Figure 13. Stream through culvert, inspection covers, water sample 9


Figure 14. Lamlash PS3, electrical unit and 4 inspection covers in the ground


Figure 15. Large stream, water sample 11


Figure 15. Pipe encased in concrete, large flow, water sample 13


Figure 16. Pipe encased in concrete, flowing under water, water sample 24

Figure 17. South east end of mussel farm

Figure 18. Mussel raft

Figure 19. Burn passing under Arranton Bridge, water sample 16

Figure 20. Whiting Bay PS1

Figure 21. Large group (approximately 300) sea birds

Figure 22. Pipe coming out of wall, sewage fungus, water sample 39


Figure 23. Two pipe below Whiting Bay PS2, water samples 42 & 43


Figure 24. Concrete pipe flowing into sea, very strong smell of sewage, water sample 45

Figure 25. Montrose Terr SEP

Figure 26. River under Ashdale Bridge, water sample 46