Scottish Sanitary Survey Project

Sanitary Survey Report
Campbeltown Loch
AB 371, AB 029 and AB 407
August 2008

Cefas

FOOD STANDARDS AGENCY
SCOTLAND
Buidheann Inbhe-Bìdhe an Alba

Report Distribution – Campbeltown Loch

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1. General Description

Campbeltown Loch is a short, east-facing loch 2.4 km long by approximately 1.3km wide with an entrance facing northeast. The loch is 10-20 metres deep over much of its area, though there is an area of shoaling around an island to the south side of the loch entrance and it is in this area that there are wild fisheries for cockles and shore mussels, and a small-scale oyster fishery. A mussel raft is also planned near the south shore of the loch. A sanitary survey is being undertaken in response to the application for classification of Pacific oyster (*Crassostrea gigas*) and common mussels (*Mytilus* sp.) farms in Campbeltown Loch and Kildalloig Bay, near the mouth of the Loch.

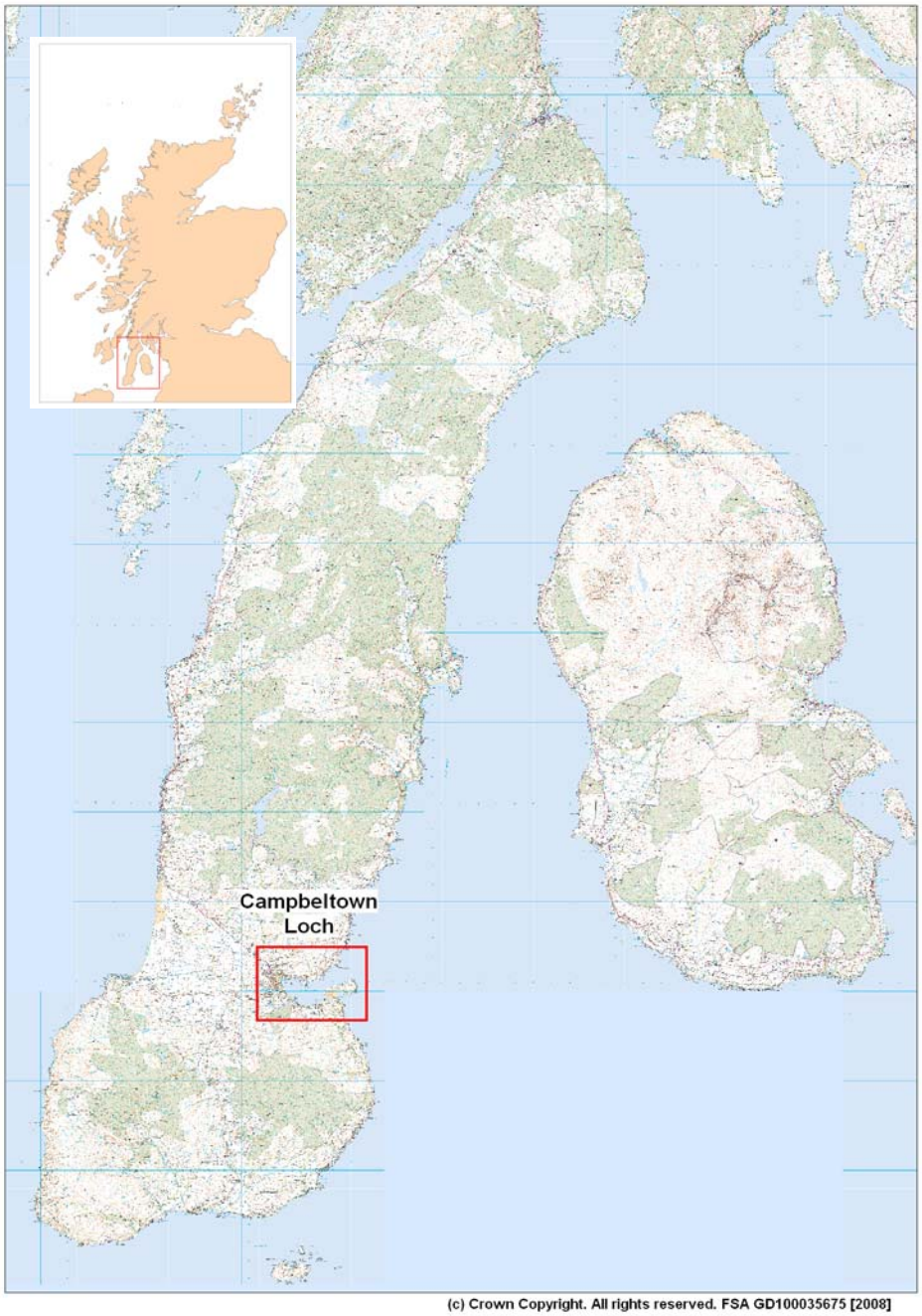

Figure 1.1 Location of Campbeltown Loch

2. Fishery

There are four sites falling into three production areas within the survey area, as listed in Table 2.1 below and illustrated in Figures 2.1 and 2.2. Two of these sites, Kildalloig Bay Oysters and Pointhouse Bay, relate to new applications for production and are not currently classified.

Table 2.1. Campbeltown Loch production areas

Production Area	Site	SIN	Species
Campbeltown Loch: Kildalloig Bay	Kildalloig Bay Oysters (new)	AB 371 778 13	Pacific oyster
Campbeltown Loch: Kildalloig Bay	Kildalloig Bay Mussels	AB 371 760 08	Common mussels (wild)
Campbeltown Loch	Kildalloig Bay	AB 029 008 04	Common cockles (wild)
Campbeltown Loch: Pointhouse Bay (proposed)	Pointhouse Bay	AB 407 808 08	Common mussels

The production areas and fisheries are shown in Figures 2.1 (AB371) and 2.2 (AB029). The proposed new production area at Campbeltown Loch: Pointhouse Bay is not illustrated as it falls wholly within the same boundaries as AB029, and is to be assigned boundaries based on the results of this sanitary survey.

Campbeltown Loch: Kildalloig Bay Oysters (AB 371 778 13). This fishery consisted of a single trestle of Pacific oysters at the time of the shoreline survey. The trestle had been laid to assess the viability of production at this site. The grower reports good growth at this location, and a further trestle was to have been installed shortly after the shoreline survey. Although this site shares the same boundaries as Kildalloig Bay Mussels, it will be assigned a separate RMP as it is a different species.

Campbeltown Loch: Kildalloig Bay mussels (AB 371 760 08). This is a wild fishery, covering much of the Doirlinn, an intertidal sand spit between Davaar Island and the mainland along the southern shore of the loch. Exploitation is light and is only carried out privately by locals for personal consumption, mainly during the summer. The RMP for this production area is assigned at NR 748 202, and it is currently classified for harvest. The area identified as mussel beds in Figure 2.1 is the area where the main concentrations of mussel 'shoals' were located. Mussels were also present on rocks around much of Campbeltown Loch and Kildalloig Bay. Shore mussels are the property of the Crown Estate in Scotland, and it is an offence to collect them without permission. No distinction is made between personal or commercial gathering. No Crown Estates permits to collect mussels have been issued here, but in practice the Crown Estates are unlikely to object to mussels being gathered for personal consumption. There is no legal commercial fishery here and thus no necessity to maintain a classification.

Campbeltown Loch cockles (AB 029 008 04). This is a wild fishery, covering much of the Doirlinn. Exploitation is mainly limited to locals gathering for personal consumption, but from time to time commercial gangs harvest the area when stocks are in sufficient abundance. Harvesting mainly occurs during the summer. This production area has an RMP assigned at NR 752 198. Stock levels seemed to be fairly low at the time of the shoreline survey, with higher densities towards the north east of the beds. The extent of the cockle beds was estimated by the type of substrate and the presence of live cockles on the surface, with no detailed stock survey carried out.

Campbeltown Loch mussels (AB 407 808 08). No apparatus or stock was in place at the time of the shoreline survey. According to the harvester, a raft is to be positioned just to the east of the NATO pier in Pointhouse Bay at some point in the future, from which ropes will be suspended to assess the viability of the fishery. From deployment of the raft to first harvest is likely to be around three years. There is no current RMP for this production area as it has not yet been classified for harvest. As there are currently no raft or mussels on this site, it was agreed with FSAS that the assessment and recommendations in this report will not consider the planned mussel aquaculture operation. This will be reviewed later if the situation changes.

There are currently no Crown Estates seabed leases for shellfish farms within the area.

There were no depuration facilities at Campbeltown Loch at the time this report was written.

In addition to these fisheries, locals also gather periwinkles for personal consumption from the Doirlinn. No application has been made to classify this fishery, and there is not believed to be any commercial exploitation of this species. Therefore, this fishery will not be considered further in this report.

Figure 2.1 presents a detailed map showing the position of the production areas, RMPs, oyster trestles, the approximate positions of the cockle and mussel beds and the planned location of the mussel raft.

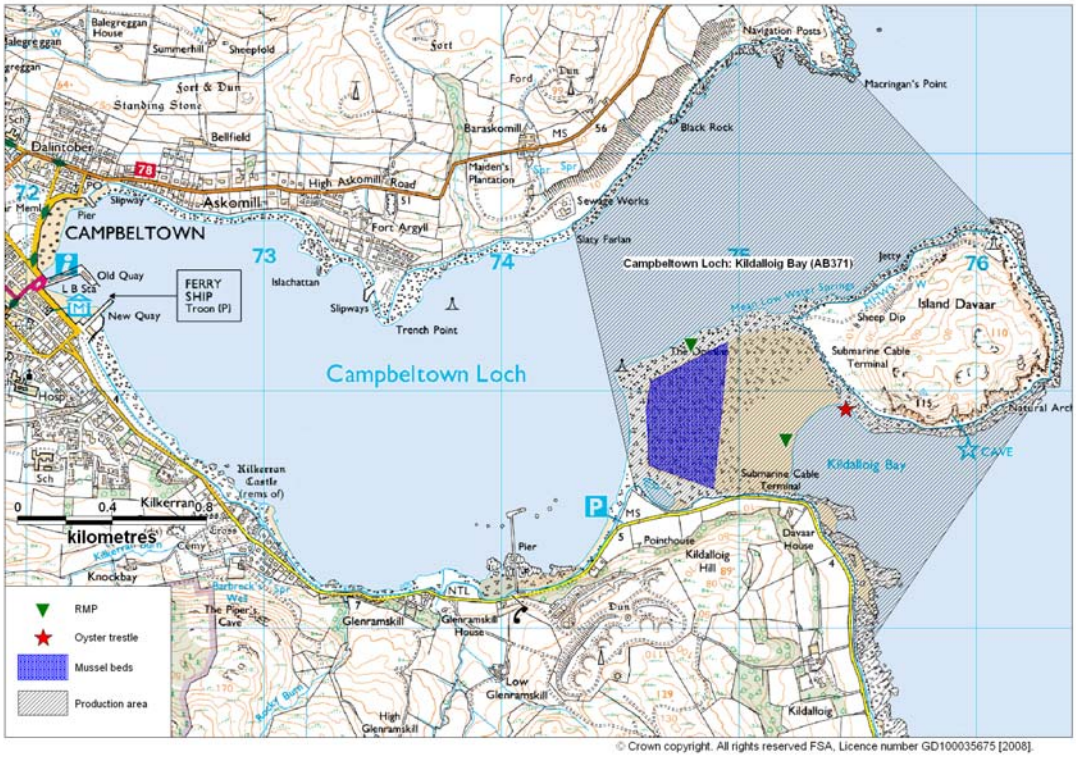

Figure 2.1 Campbeltown Loch: Kildalloig Bay fishery (AB371)

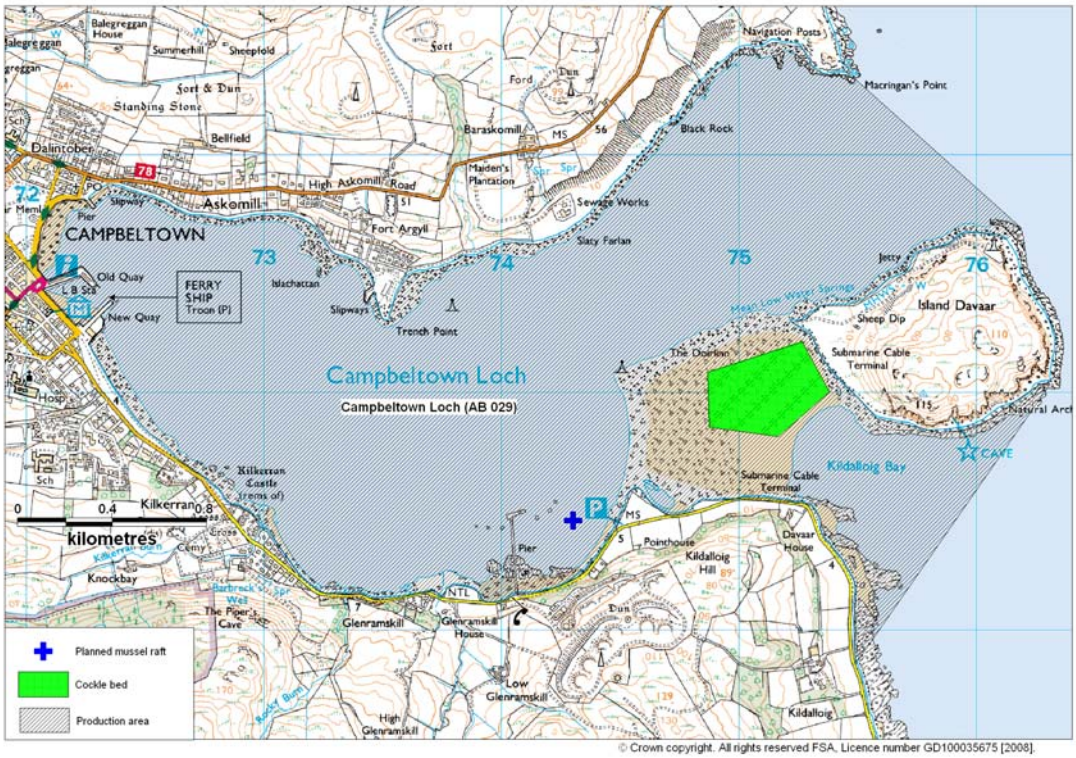

Figure 2.2 Campbeltown Loch cockle fishery (AB029)

3. Human Population

The figure below shows information obtained from the General Register Office for Scotland on the population within the census output in the vicinity of Campbeltown Loch.

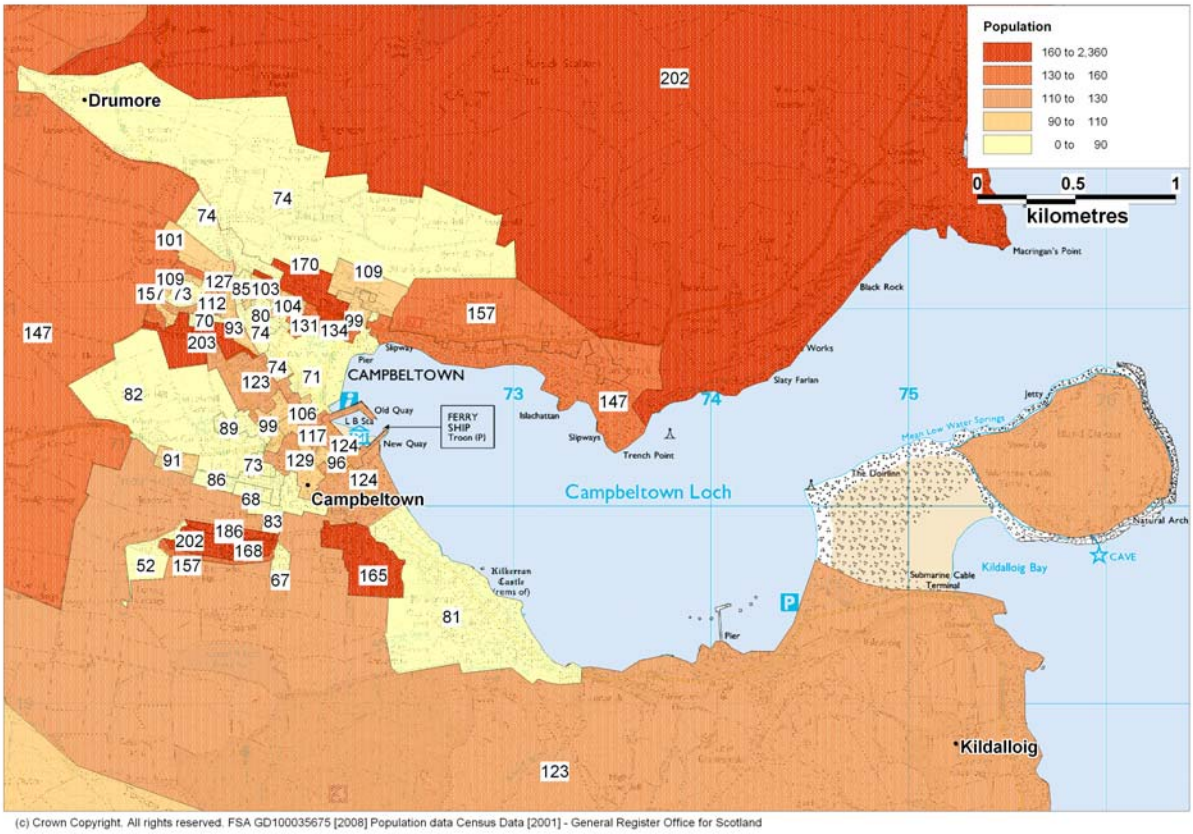

Figure 3.1 Human population surrounding Campbeltown Loch

There are a total of 50 census output areas in the area of Campbeltown Loch. The 2001 census recorded the population of this area (see map above) to be 5771. The majority of the population is resident in Campbeltown itself, with a recorded population of 5144.

The area is remote, with little industry. The largest employer is Vesta, a manufacturer of wind turbines. Two distilleries and a fishing fleet of up to 30 boats provide further employment. There is some tourism. Accommodation is available in Campbeltown in the way of B&Bs and several small hotels, with caravan sites available approximately 5 miles north along the coast in Peninver. Scottish Water estimated 300 overnight visitors in determining wastewater capacity requirements.

There is a marina with capacity for 60 boats and plans to redevelop the marina to double the capacity to attract visiting yachts.

Therefore, it is likely that there will be significant inputs of human sewage to the loch, the majority of which will originate from Campbeltown at the head of the loch.

4. Sewage Discharges

Community sewage discharges were identified by Scottish Water for the area around Campbeltown Loch. These are listed in Table 4.1. No sanitary or microbiological data were available for these discharges.

Table 4.1 Discharges identified by Scottish Water

NGR	Discharge Name	Discharge Type	Level of Treatment	Consented flow (DWF)	Consented/ design pop	SEPA Consent No.	Planned improve-ment?
NR74334 20621	Campbeltown WWTW	Continuous	MBR (equivalent to tertiary)	2082 m^3/d	26520	WPC-W-22734	No
NR 7218 2062	Kinloch Park WWPS, CSO & EO	Intermittent	6mm screening	35.64 l/s	8388	CAR/L/1000560	Yes
NR 7315 2064	Low Askomill Satellite PS1 EO, CSO	Intermittent	15mm bar screen	21.6 m^3/d	90	CAR/L/1000561	No
NR 7249 2075	Low Askomill Satellite PS2 EO, CSO	Intermittent	15mm bar screen	57.6 m^3/d	240	CAR/L/1000563	No
NR 7397 1942	Kilkerran PS EO	Intermittent	15mm bar screen	36 m^3/d	150	CAR/L/1000562	No

SEPA have issued the discharge consents listed in Table 4.2. As there was historically no requirement to register private sewage and septic tank discharges in Scotland, this list will not include all the discharges that may be present in the area. The first five consents listed apply to the Scottish Water discharges listed in Table 4.1.

Table 4.2 Discharge consents provided by SEPA

Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Notes
WPC-W-22734	NR 74334 20621	Treated Sewage Effluent	Tertiary	2082 (max)	26520 (max)	Campbeltown WWTW
CAR/L/1000560	NR 7227 2062	Sewage (Public) CSO & EO	6mm screening	-	-	Kinloch Park WWPS
CAR/L/1000561	NR 7315 2064	Sewage (Public) CSO & EO	10mm screen on CSO, 15mm screen on EO	21.6	90	Low Askomill PS1
CAR/L/1000563	NR 7249 2075	Sewage (Public) CSO & EO	10mm screen on CSO, 15mm screen on EO	57.6	240	Low Askomill PS2
CAR/L/1000562	NR 7397 1942	Sewage (Public) EO	15mm screen	36	150	Kilkerran PS
WPC-W-30105	NR 7525 2113	Other effluent food processing	-	635 (max). Flows HW to +3.5 hours only	na	Creamery, consent indicates whey waste and washings only
CAR/R/1020927	NR 7362 1912	Sewage (Public) Primary	Package treatment plant	-	10	To soakaway
CAR/R/1020931	NR 7109 2173	Sewage (Public) Primary	Septic tank	-	6	To soakaway
CAR/R/1019349	NR 7019 2033	Sewage (Public) Primary	Septic tank	-	12	To soakaway
CAR/R/1021045	NR 7100 1960	Sewage (Public) Primary	Septic tank	-	50	To soakaway
CAR/R/1019680	NR 7353 2097	Sewage (Public) Primary	Septic tank	-	5	To soakaway
CAR/R/1025653	NR 7056 2038	Sewage (Public) Primary	Septic tank	-	5	To soakaway
CAR/R/1025788	NR 7520 1951	Sewage (Public) Primary	Septic tank	-	14	To soakaway
CAR/R/1026991	NR 7012 2085	Sewage (Public) Primary	Septic tank	-	5	To soakaway
CAR/R/1020938	NR 7019 2032	Sewage (Public) Primary	Septic tank	-	12	To soakaway

A number of sewage outfalls were recorded during the shoreline survey. Their locations have been included in the mapped discharges in Figure 4.1, and details are listed in Table 4.3. Other sewage related infrastructure noted during the shoreline survey such as inspection covers and vents on the sewage pipeline along the north shore are not listed in Table 4.3.

Table 4.3 Potential discharges observed during shoreline survey

No.	Date	Grid Reference	Observation
1	06-MAY-08	NR 72498 20827	Sewage inspection covers and enclosure in lay by. Marker post about 20m off. Inspection cover with vent on either side of lay by. Pumping station.
2	06-MAY-08	NR 73196 20721	Sewage inspection covers and enclosure in lay by. Inspection cover with vent on shore below. Pumping station.
3	06-MAY-08	NR 72827 20743	Faded orange plastic sewer pipe to sea
4	07-MAY-08	NR 72021 20620	Kinloch sewage pumping station. Marker post indicating outfall just off shore.
5	07-MAY-08	NR 74287 20692	Campbeltown STW discharge circa 60m off from here. Boil visible on surface. STW behind.
6	07-MAY-08	NR 72837 19560	100mm cast iron pipe to underwater
7	07-MAY-08	NR 72896 19522	Inspection cover, concrete pipe casing heading to sea. 110mm orange plastic pipe alongside.
8	07-MAY-08	NR 72999 19429	110mm orange plastic sewer pipe to sea mainly buried.
9	07-MAY-08	NR 73092 19315	300mm ceramic pipe to HW mark (not flowing)
10	07-MAY-08	NR 73178 19210	150mm metal pipe to underwater.
11	07-MAY-08	NR 73212 19177	120mm metal pipe to high water mark (not flowing)
12	07-MAY-08	NR 73239 19161	110mm metal pipe to underwater
13	07-MAY-08	NR 73571 19128	150mm cast iron pipe to underwater
14	07-MAY-08	NR 73685 19153	150mm metal pipe and 150mm plastic pipe alongside each other to underwater
15	07-MAY-08	NR 74334 19211	250mm ceramic pipe to HW mark, not flowing.
16	08-MAY-08	NR 75974 20624	Septic tank with pipe over cliff.
17	08-MAY-08	NR 76043 20617	Pipe to sea at bottom of cliff
18	08-MAY-08	NR 75247 19542	Septic tank with overflow to beach, ooze at end.
19	08-MAY-08	NR 75554 18698	Septic pipe to beach, trickle coming from end.

The majority of Campbeltown, aside from its southeastern extremities, is on a public mains sewerage system. This system also serves Macrihanish, Stewarton and Drumlemble. The total estimated population the system actually serves is 7388 (including 300 overnight visitors) with an additional estimated 1000 day visitors. There are four Scottish Water pumping stations along the shore at Campbeltown, three of which have a combined sewer overflow and all of which have an emergency overflow. The pumping station at Kinloch Park also has a storm water holding tank. Wastewater entering the system is pumped to the Scottish Water treatment plant at Slaty Farlan. This is a membrane bioreactor (MBR) plant, which uses membrane cartridges manufactured by Zenon. MBRs combine activated sludge with a low-pressure ultrafiltration step, and due to the small pore size in the membrane they are very effective at removing bacteria (nominal pore size 0.4 µm, absolute pore size 0.1 µm).

The membrane manufacturers report average concentrations of total coliforms in the effluent of < 2.2/100 ml. Removal of viruses is likely to be less effective due to their smaller size. A study using membranes produced by the same company found that the overall somatic and F-specific coliphage removal by

the system varied from 3.1 to 5.8 logs and 3.3 to 5.7 logs, respectively. Of these, up to 2.3 logs of somatic coliphages and up to 2.5 logs of F-specific coliphages were removed in the aeration or the MBR tanks prior to the ultrafiltration step (Zhanga & Farahbakhsh, 2007). No faecal coliforms were found in the permeate, but most permeate samples contained total coliforms at levels up to 250 cfu/100 ml. The treated water at Campbeltown is discharged just offshore from the treatment plant, and it is likely that tidal flows will mainly transport it along the north shore rather than across the loch towards the Doirlinn.

The Campbeltown sewerage system was designed to handle levels of infiltration that are significantly lower than those it actually experiences. As a consequence, the sewer system becomes overloaded and spills from the Kinloch Park pumping station to the inner loch occur on a frequent basis during wet weather. Sanitary related debris was seen along the north shore of Inner Campbeltown Loch during the shoreline survey, where this discharge is likely to have a considerable effect on water quality in the loch when in operation. It is approximately 2.5 km from the shellfish beds on the Doirlinn. Improvements to the system are planned, and although the exact form these will take has not yet been decided, it is probable that they would involve increasing the capacity of the system thereby reducing the spill frequency at Kinloch Park and relocating its overflow discharge to the outer loch. It is not known if and how often spills occur from Low Askomill Pumping Stations 1 and 2 and Kilkerran Pumping Station.

A total of 10 private discharges (septic tank overflows) to the south shore of Campbeltown Loch east of Kilkerran were observed during the shoreline survey. A further two were observed on Davaar Island discharging to outer Campbeltown Loch. Additionally, an overflow from Davaar house discharges to Kildalloig Bay, and an overflow from Kildalloig Farm discharges to the south of Kildalloig Bay. As these are small private discharges, it is likely their impact would be fairly localised so the discharge from Davaar House would be the most significant of these to the existing fishery. One possible private sewage discharge was seen on the north shore, although it is uncertain whether this was still in use as its path crossed the Scottish water sewage pipeline to the treatment works.

SEPA lists consents for an additional seven discharges inland from the shore and not identified by Scottish Water or during the shoreline survey. All of these are small private septic tanks (or in one case, a package treatment plant) which discharge to soakaway. Two other similar consents for septic tank discharge to soakaway are recorded on the south shore. At least one of these (CAR/R/1025788) was recorded on the shoreline survey, and actually had a running overflow to the shore (observation 18). The other (CAR/R/1020927) may have been associated with either observation 13 or 14, which appeared to be septic discharge pipes to underwater, so it could not be confirmed whether they were flowing. Also, SEPA lists the creamery discharge (WPC-W-30105) to the outer loch near Macringan's Point in about 20m of water. This comprises of milk processing waste only (whey and washwater). This discharge only operates on the first half of the ebb tide, so

contamination from this source will initially be carried out of the loch. The microbiological content of this discharge is not known.

Yachts, fishing boats and larger ships frequent the loch, so there are likely to be some sewage inputs from boat traffic. The harbour master reported that there are typically 10-12 commercial ship movements per week from the New Quay, as well as 15-20 movements per year at the NATO pier. There are 12 fishing boats berthed at Old Quay and a further 20-25 landings per week mainly by Irish fishing boats. There are two septic tanks associated with the office building and fish market toilets on Old Quay, however, these are emptied by truck and do not discharge to the loch. Toilets in the disused ferry terminal are connected to town mains sewerage.

The yacht marina at Campbeltown currently has 50 boats, and funding has been made available to increase the number of berths by a further 50-60 over the next few years. There are currently no pumpout facilities for yachts or ships at Campbeltown.

Therefore, depending on patterns of circulation within the loch, potentially important sewage sources include the private discharges to the south shore of the loch, the Kinloch Park CSO/EO, which is reported to spill frequently, the Campbeltown WWTW outflow, which is large but the effluent is of high quality, and the other three Scottish Water emergency discharges, although it is not known how frequently these spill. Sewage inputs from boats discharging heads as they enter or leave the loch, though sporadic, could be locally significant.

Subsequent to completion of the draft of this report, Scottish Water provided plans for a new CSO to discharge adjacent the main WWTW outfall at Slaty Farlan, though with a discharge point further offshore. This will augment the current system, providing additional capacity and moving the primary location of spills to the outer loch. Though spills will primarily discharge via Slaty the Farlan outfall, under some conditions spills will still occur at Kinloch Park and Low Askomill PS 1.

The proposed new outfall will be located much closer to the cockle and oyster fisheries located on or near the Doirlinn and Davaar Island. While modelling studies undertaken on behalf of Scottish Water predict that the impact to waters over the shellfisheries will be within 100 FC/ 100 ml, an impact at this level is still sufficient to increase contamination levels found within the shellfish. The most likely area to be impacted by this discharge is the northern edge of the Diorlinn, where cockles are commercially harvested.

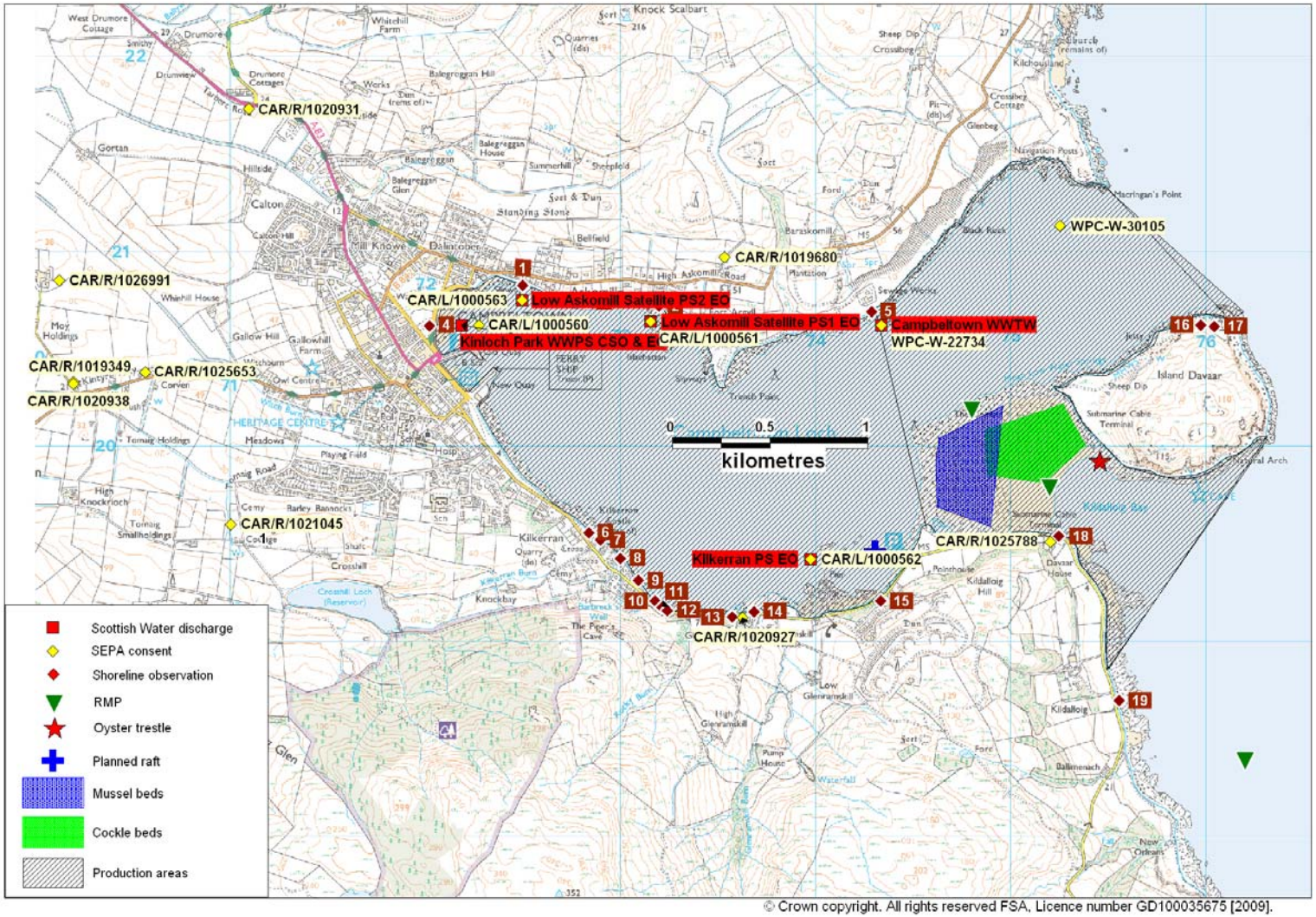

Figure 4.1 Sewage discharges at Campbeltown Loch

5. Geology and soils

Geology and soils types were assessed following the method described in Appendix 3. A map of the resulting soil drainage classes is shown in Figure 5.1, with red areas indicating poorly draining soils and blue indicating well drained soils.

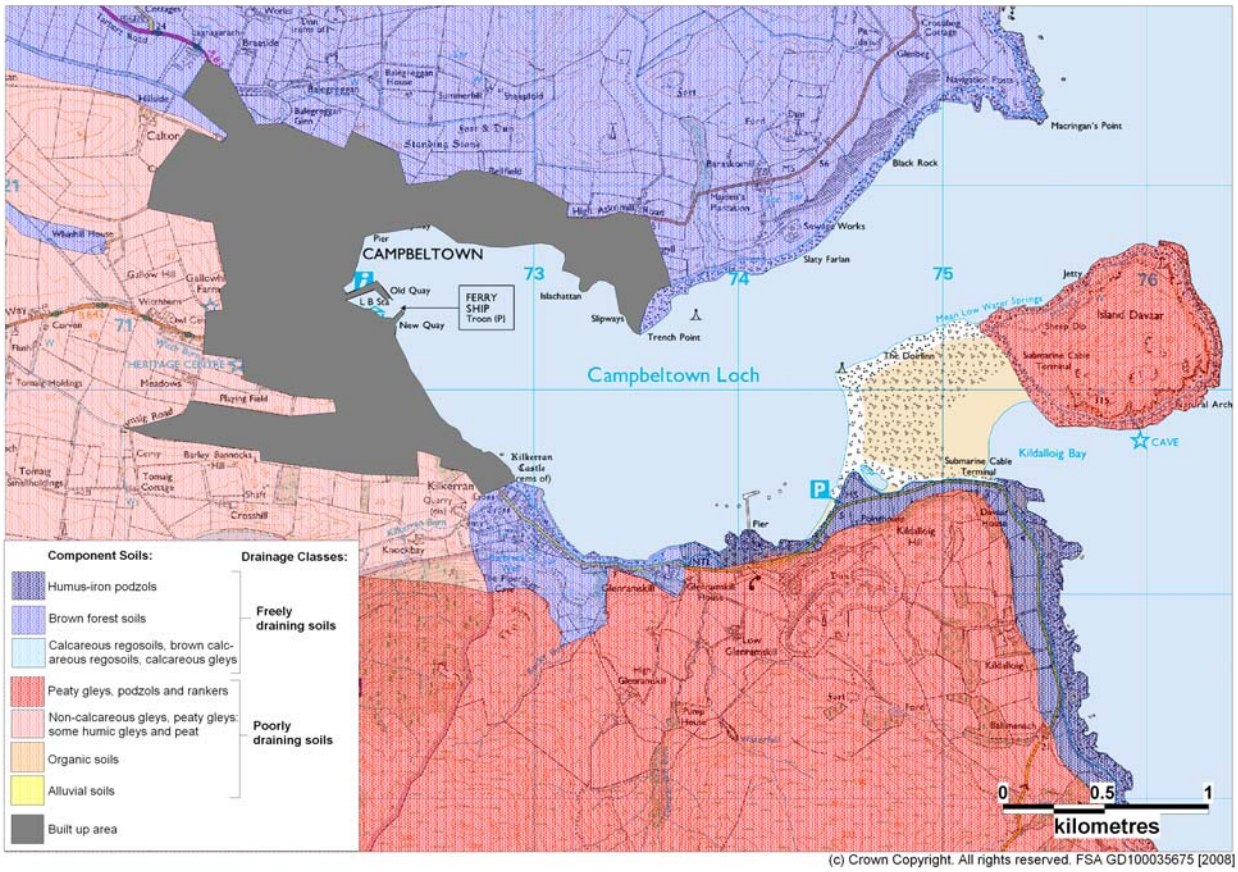

Figure 5.1 Component soils and drainage classes for Campbeltown Loch.

There are four main types of component soils visible in this area. The most dominant soil type is composed of brown forest soils and occupies the land north of Campbeltown Loch and also a small area on the southern shore. The second dominant soil type is composed of non-calcareous gleys, peaty gleys, some humic gleys and peat. This soil type covers the western coastline behind the built up area of Campbeltown. The third component soil type is peaty gleys, podzols and rankers and these occupy an area further inland on the southern coastline. The fourth component soil type is humus-iron podzols and these are present on a small area of land on the southern coastline near the NATO pier.

The brown forest soils and humus-iron podzols are classed as freely draining soils and the peaty gleys, podzols and rankers and noncalcareous gleys, peaty gleys, some humic gleys and peat are classed as poorly draining soils.

In the poorly draining soils found along the western and southern coastline of Campbeltown Loch, surface run off is likely to be high. In the more freely draining soils found along the southern coastline and stretch of land behind Campbeltown, surface runoff is likely to be lower due to increased soil permeability. The highest

potential for runoff is from the built up area of Campbeltown itself, as this will have large areas of impermeable surfaces.

The potential for runoff contaminated with *E. coli* from human and/or animal waste is therefore likely to be highest from Campbeltown at the head of the loch, relatively high along the southern shore where the majority of soil including the catchment areas of the Kilkerran, Rocky and Ramskill Burns is poorly draining, and relatively low on the northern shore outside the built up area, where the soil is freely draining.

6. Land Cover

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

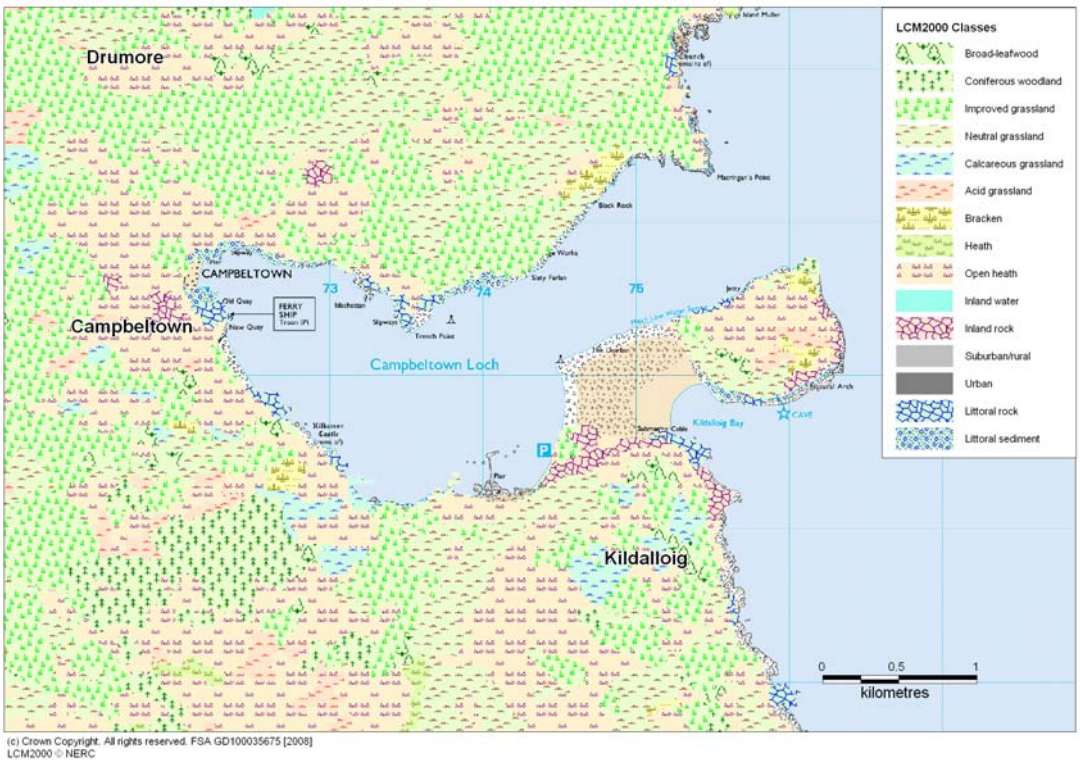

Figure 6.1 LCM2000 class land cover data for Campbeltown Loch

Figure 6.2 OS map showing the urban developed area of Campbeltown Loch.

There are many different land cover types surrounding Campbeltown Loch. On Island Davaar, to the east of Campbeltown Loch there is a large amount of open heath land and neutral grassland with some small areas of bracken, improved grassland and inland rock. The land on the southeastern coastline around Kildalloig is a mixture of open heath land, neutral grassland, improved grassland and calcareous grassland with bands of littoral and supra-littoral rocks around the headland. To the south of Campbeltown, further inland is a large area of coniferous woodland and several smaller patches of broad-leaf wood.

Agricultural census data was received from the Scottish Government Rural and Environment Research and Analysis Directorate (RERAD) for Campbeltown Parish. Of a total agricultural parish area of 17800 hectares, 5245 hectares were under crops or grass, a further 5414 hectares were used for rough grazing, and 561 hectares of farmed land were listed as woodland. This parish covers a large area of the south Kintyre peninsula as well as the smaller area around Campbeltown Loch. No further detail was available regarding the spatial distribution of these categories of farmed land.

The LCM2000 data suggests that there are no urban or rural developed areas where the town of Campbeltown should be. Observations during the shoreline survey confirm that this data is incorrect and there is a large urban developed area as shown by the OS map in Figure 6.2. The area of land behind the town of Campbeltown is mainly improved grassland. The majority of the land cover on the northern coastline of Campbeltown Loch is improved or neutral grassland with some areas of acid grassland and a small patch of bog.

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 would be expected to increase significantly after marked rainfall events to approximately 4.6×10^{10} – 1.3×10^{11} cfu km^{-2} hr^{-1} for developed areas, 1.2×10^{11} cfu km^{-2} hr^{-1} for improved grassland (the two most prevalent cover types in the area) and 2.5×10^{10} cfu km^{-2} hr^{-1} for other land cover types.

7. Farm Animals

Regulation (EC) No. 854/2004 requires the competent authority to:

(a) make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area;
(b) examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, wastewater treatment, etc.

Agricultural census data was received from the Scottish Government Rural and Environment Research and Analysis Directorate (RERAD) for Campbeltown Parish. This parish covers a large area of the south Kintyre peninsula as well as the smaller area around Campbeltown Loch. Recorded livestock populations for the parish in 2007 and 2008 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data.

Table 7.1 Livestock census data for Campbeltown parish (Source: RERAD)

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Total pigs	*	*	3	574
Total poultry	10	269	12	337
Total cattle	54	9567	54	9577
Total sheep	43	25185	40	25420
Horses used in Agriculture	*	*	0	0
Horses and Ponies	7	32	6	27

* Data withheld on confidentiality basis.

No further detail regarding spatial variation in populations was available, however the overall numbers for the parish are relatively large for a coastal parish with an average 177 cattle per holding and 636 sheep per holding. Livestock observations were recorded during the shoreline survey (see Appendix 8). These only relate to the time of the site visit on 30th April – 1st May 2008 and are minimum numbers as it is quite likely that some animals were not visible at the time due to vegetation, topography, or presence on fields further from the shore. Livestock observations are presented in Figure 7.1. The ratio of sheep to cattle observed during the shoreline survey was higher than that reported in the Parish as a whole. The numbers of animals observed were significantly lower than the averages per holding for the parish, indicating that more livestock may be present in the area than were observed on the day.

The shoreline survey identified that the highest concentrations of livestock were present around Kildalloig Farm, on the south shore of Kildalloig Bay so it is likely that diffuse inputs from livestock will be greatest adjacent to this area. Livestock are removed from the fields adjacent to the shore here during the summer months

to allow the production of silage. Slurry is spread on these fields during the summer months when the weather conditions are appropriate. Lower densities of livestock were seen on Davaar Island, on the northeast shore, and on the south shore by the NATO pier. There was no local information available for the area surrounding Campbeltown Loch concerning the seasonal numbers of livestock, but livestock numbers are likely to be highest during the summer months following the birth of lambs and calves in the spring.

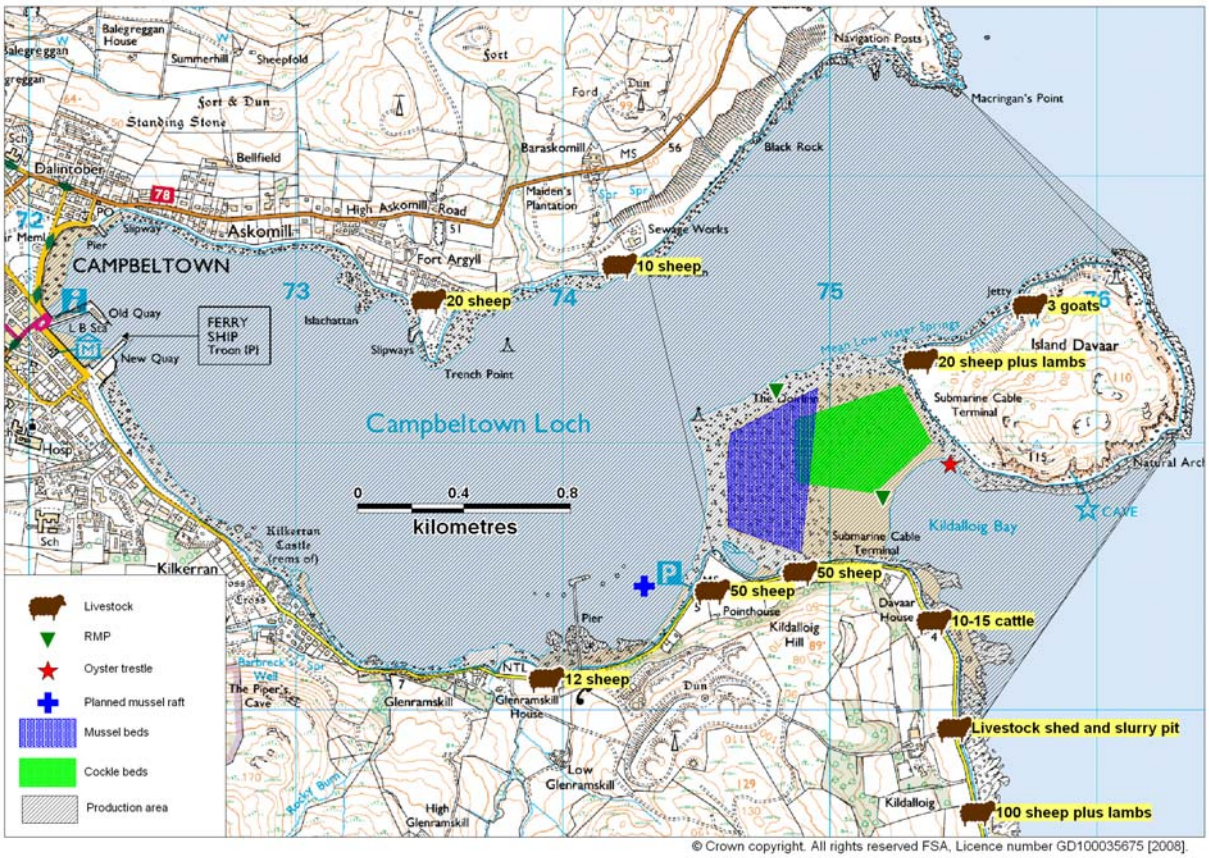

Figure 7.1 Livestock observations at Campbeltown Loch

8. Wildlife

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

Seals

Two seals (species uncertain) were observed in Campbeltown Loch during the course of the shoreline survey, and the grower reported that there is a seal haulout area to the south of Kildalloig Bay.

According to figures held by Scottish Natural Heritage, there were 991 common seals recorded in 1996 for the survey area 'Strathclyde, Firth of Clyde' covering the area from the Mull of Kintyre to Loch Ryan.

There are no grey seal breeding colonies reported in or near Campbeltown Loch, however it could is possible that grey seals might be found foraging in the loch from time to time. Seals will forage widely for food and it is likely that seals will feed near the shellfisheries on occasion. However, the population is relatively small in relation to the size of the area concerned and is highly mobile therefore it is likely that any impact will be unpredictable.

Whales/Dolphins

Whales and dolphins are relatively common off the west coast of Scotland and a following in Table 8.1 is a list of sightings recorded by the Hebridean Whale and Dolphin trust. These are reported to the trust by ferry skippers, whale watch boats and other observers.

Table 8.1 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.

No whales or dolphins (cetaceans) were observed during the course of the shoreline survey though dolphins or porpoises may occasionally be present in Campbeltown Loch. However, their presence is likely to be sporadic and unpredictable and so will not be taken into account with regard to establishing sampling plans for Campbeltown Loch production areas.

Birds

The Royal Society for Protection of Birds (RSPB) has no reserves at or near Campbeltown Loch.

Wading birds are present on the intertidal areas of the loch, though information on numbers and specific locations was not available at the time this report was written. It is possible that waterfowl (ducks and geese) overwinter in the area, but again no specific information on this was available. Overwintering geese would tend to be found on farm fields and open grassland such as that found at Kildalloig farm and on Davaar Island. These birds are most likely to be present during the autumn and winter months, so tentatively they may have a greater impact during the winter.

SeaBird 2000 census counts of all seabird species recorded within 5 km of the trestles during a survey of the area are presented in Table 8.2. Where counts were of occupied nesting sites, actual numbers of seabirds breeding in the area will be higher.

Table 8.2 Seabird counts within 5km of the area

Common name	Species	Count	Date	Method
Black Guillemot	*Cepphus grylle*	41	08/04/2001	Individuals on land
Common Tern	*Sterna hirundo*	10	10/06/2000	Occupied nests

The guillemots were recorded at various locations between Kildalloig Bay and the head of the loch, and the terns were recorded at the NATO pier. Nesting occurs in early summer and after this the birds generally disperse.

Gulls were observed during the shoreline survey and at least some species are likely to be year round inhabitants. Seabirds, including gulls, may have a highly localised impact near their nesting areas as well where they rest on floats, buoys or other floating objects.

Deer

Deer will be present particularly in wooded areas where the habitat is best suited for them. There are some small areas of woodland near the south shore of Campbeltown Loch, but the majority of land is open grassland. While no population data was available for this area, it is probable that the area hosts small populations of deer.

It is possible that some of the indicator organisms detected in the streams feeding into Campbeltown Loch will be of deer origin, and it may be expected that their contribution would be year round but minor.

No other wildlife species were either observed or known to reside in the vicinity of Campbeltown Loch.

Summary

Potential wildlife impacts to the fisheries include seals, water birds, dolphins, deer and otters. Impacts are likely to be relatively minor, localised and unpredictable and will therefore not be explicitly taken into account in determining the sampling plan.

9. Meteorological data

The nearest weather station with relatively complete rainfall records is located at Macrihanish, 8 km to the west of the production area. Rainfall data was supplied for the period 1/1/2003 to 31/10/2007 (total daily rainfall in mm). For this period, total daily rainfall was not recorded on only 6 days. Wind data was not recorded at either of these stations. It is likely that rainfall experienced at Macrihanish is similar to that experienced at the production area due to their close proximity.

The nearest major weather station is located at Prestwick, approximately 62 km to the east of the production area. Wind direction was provided at 3 hourly intervals for the majority of the period 1/1/2003 to 31/12/2007. It is likely that the wind patterns at Prestwick are broadly similar to those at Campbeltown Loch, but are liable to differ on any given day. Local topography will also affect wind strength and direction.

This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within the Campbeltown Loch production area.

9.1 Rainfall

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

9.1.1 Rainfall at Macrihanish

Total annual rainfall and mean monthly rainfall at Macrihanish are presented in Figures 9.1 and 9.2.

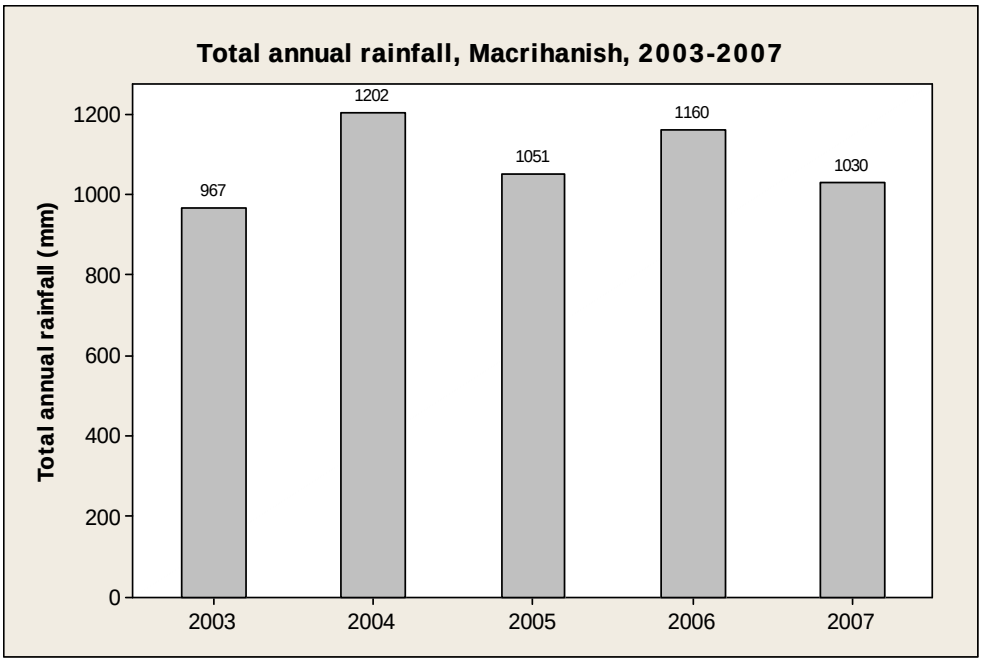

Figure 9.1 Total annual rainfall at Macrihanish 2003-2007.

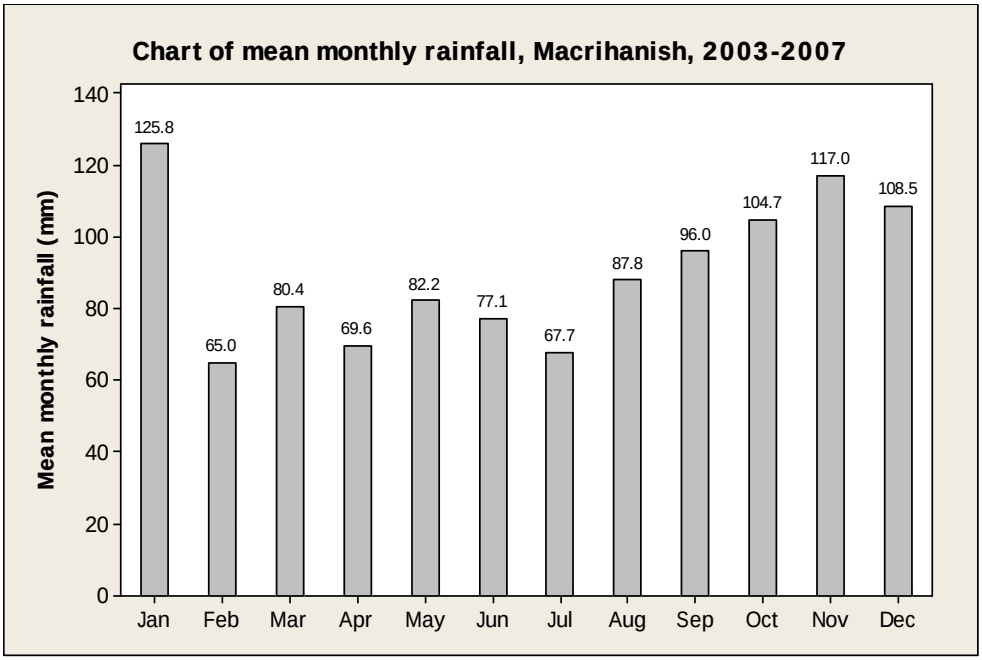

Figure 9.2 Mean total monthly rainfall at Macrihanish 2003-2007.

The wettest months were from October to January. For the period considered here (2003-2007), 52% of days experienced rainfall of 1mm or less, and 9% of days received rainfall of 10mm or over. 2003 was the driest year, and 2004 was the wettest year, but differences between the years were minor.

An important source of contamination in Campbeltown Loch is the Scottish Water overflow at the head of the loch, which frequently discharges following rainfall. It can therefore be expected that levels of rainfall dependant faecal contamination entering the loch will be generally higher during the autumn and early winter, but episodes of contamination following heavy rain may occur at any time of year. It is also probable that faecal matter will build up on pastures during the drier summer months when stock levels are at their highest, leading to more significant faecal contamination of runoff at the onset of the wetter weather in the autumn.

9.2 Wind

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

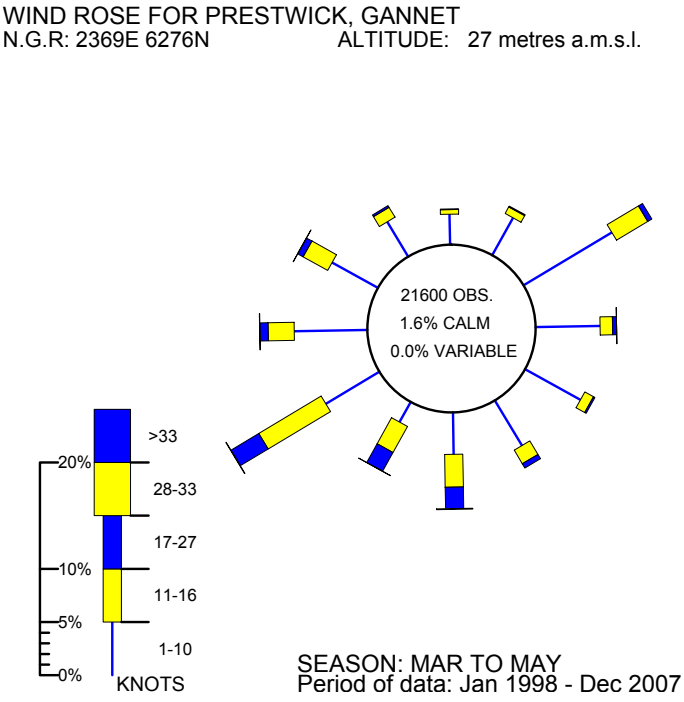

Figure 9.3 Wind rose for Prestwick (March to May)

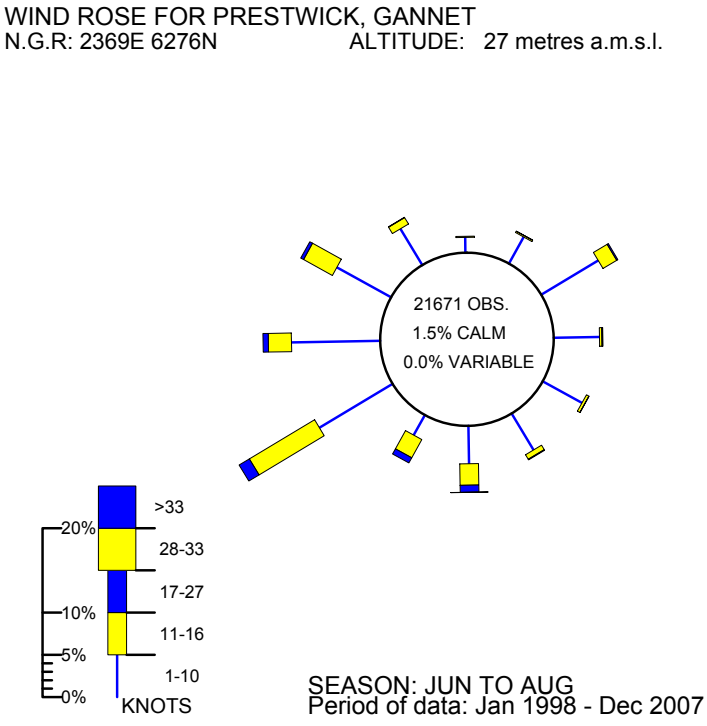

Figure 9.4 Wind rose for Prestwick (June to August)

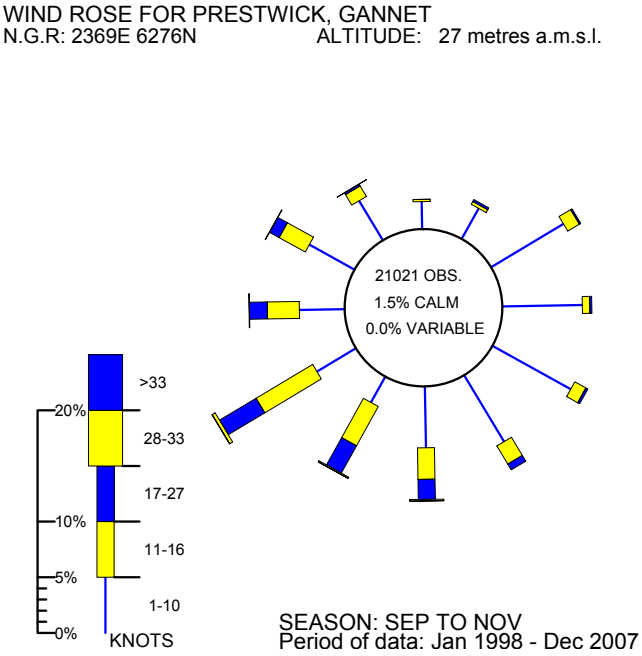

Figure 9.5 Wind rose for Prestwick (September to November)

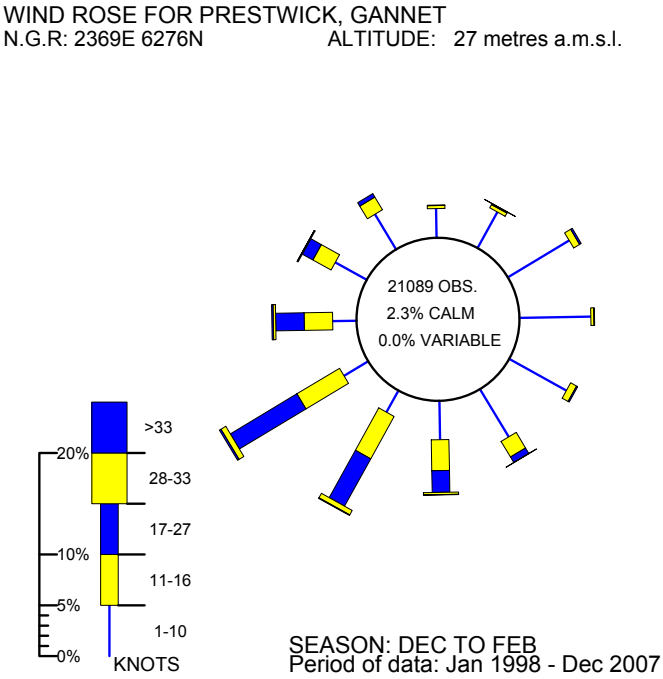

Figure 9.6 Wind rose for Prestwick (December to February)

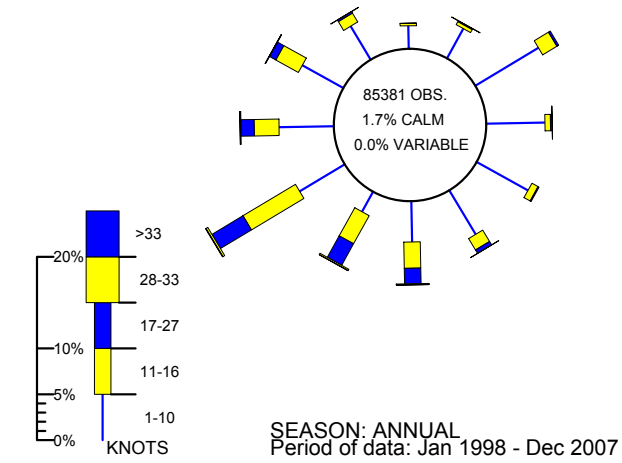

Figure 9.7 Wind rose for Prestwick (All year)

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.

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. As well as creating currents, strong winds may affect tide height depending on wind direction and local hydrodynamics.

Campbeltown Loch is located on the east coast of the Kintyre peninsula. Strong winds are likely to significantly change the circulation of water within Campbeltown Loch. The loch as a whole is most exposed to easterly winds, although Davaar Island gives some shelter. Westerly winds will be funnelled down the loch by the surrounding land. Depending on the wind direction, wind driven currents may assist the transport of contamination from point sources to the shellfisheries.

10. Current and historical classification status

Campbeltown Loch (AB029) has been classified for the harvest of cockles since 2005. The classification history for cockles is presented in Table 10.1. In 2005, the area received a provisional B classification, and since 2006 the area has received a seasonal B/C classification. The RMP lies within the production area in the intertidal zone. A map of the current production area is presented in Figure 10.1.

Table 10.1. Classification history, Campbeltown Loch cockles

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005*	B	B	B	B	B	B	B	B	B	B	B	B
2006	B	B	B	B	B	C	C	C	C	B	B	B
2007	B	B	B	B	B	C	C	C	C	C	B	B
2008	B	B	B	B	C	C	C	C	C	B	B	B
2009	B	B	B									

*Provisional classification

The same geographical area has also been classified for the harvest of wild mussels since 2006 (Campbeltown Loch: Kildalloig Bay, AB371). In 2006 and 2007, the area was classified as a B, and in 2008/9 it was classified as a seasonal A/B. The assigned RMP lies within the production area in the intertidal zone.

Table 10.2. Classification history, Campbeltown Loch: Kildalloig Bay mussels

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

Campbeltown Loch: Kildalloig Bay (AB371) has not yet been classified for the harvest of Pacific oysters, and Campbeltown Loch (AB407) has not yet been classified for mussels, but interim boundaries for these two production areas were proposed by the FSAS, and these are indicated in Figure 10.1.

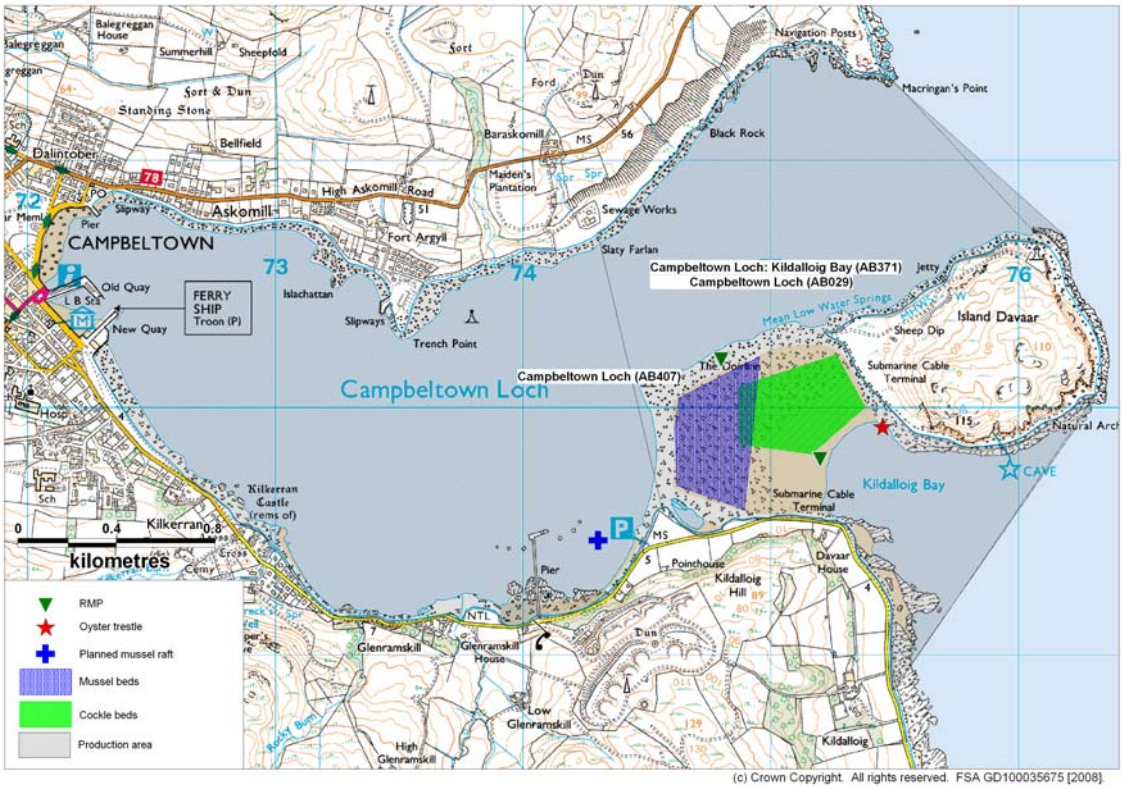

Figure 10.1 Campbeltown Loch production areas

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken from Campbeltown Loch up to the end of 2007 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

Three cockle samples (from two points which fell over 100m outside the production area boundaries) were excluded from the analysis on the basis of geographical discrepancies. Two other cockle sampling points fell outside the production area, but within 100 m of its boundaries. As 100 m is the level of accuracy to which the RMPs were historically specified, these samples fell within that tolerance and so were included in the analysis. One mussel sampling location from which one sample was taken was reported as NM748202, which is 100km north of the production area. It is assumed that the actual sampling location was NR748202, which falls within the production area, and this was adjusted accordingly. Some of the cockle sampling locations did not fall within the area of the cockle bed as estimated during the shoreline survey. The accuracy of the sampling location can only be assured for samples taken after the start of the official control sampling programme in April 2007, when 10 figure grid references recorded by GPS were reported.

Two mussel samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. One mussel and two cockle samples had the result reported as >18000, and were assigned a nominal value of 36000 for statistical assessment and graphical presentation.

All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intravalvular fluid. All statistical analyses in this section were carried out using log transformed *E. coli* results.

11.2 Summary of microbiological results by area/species

A summary of all cockle and mussel sampling and results is presented in Table 11.1. Summary results for all samples are presented by species together summary results for each sampling point where more than one sample was taken. Results for locations sampled only once are not presented in this table.

In addition to the mussel and cockle samples, one Pacific oyster sample was taken from NR 753201 in April 2007, and yielded a result of 70 *E. coli* mpn/100g.

Table 11.1 Summary of sampling and results from Campbeltown Loch

Sampling Summary						
Production area	Campbeltown Loch	Campbeltown Loch	Campbeltown Loch	Campbeltown Loch: Kildalloig Bay	Campbeltown Loch: Kildalloig Bay	Campbeltown Loch: Kildalloig Bay
Site	Kildalloig Bay	Kildalloig Bay	Kildalloig Bay	Kildalloig Bay	Kildalloig Bay	Kildalloig Bay
Species	Common cockles	Common cockles	Common cockles	Common mussels	Common mussels	Common mussels
SIN	AB-29-8-4	AB-29-8-4	AB-29-8-4	AB-371-760-8	AB-371-760-8	AB-371-760-8
Location	All 14 locations	NR752198	NR752199	All 14 locations	NR748202	NR752198
Total no of samples	37	23	2	31	17	2
No. 2004	9	1	2	0	0	0
No. 2005	11	11	0	11	5	1
No. 2006	10	10	0	12	11	1
No. 2007	7	1	0	8	1	0
Results Summary						
Minimum	40	50	500	<20	20	<20
Maximum	>18000	>18000	1700	>18000	>18000	310
Median	750	1100	1100	160	110	160
Geometric mean	898	1140	922	169	197	55.7
90 percentile	6880	14600		700	1010	
95 percentile	20000	34000		1075	8320	
No. exceeding 230/100g	30 (81%)	19 (83%)		14 (45%)	7 (41%)	
No. exceeding 1000/100g	17 (46%)	12 (52%)		2 (6%)	2 (12%)	
No. exceeding 4600/100g	6 (16%)	5 (22%)		1 (3%)	1 (6%)	
No. exceeding 18000/100g	2 (5%)	2 (9%)		1 (3%)	1 (6%)	

11.3 Overall geographical pattern of results

Figure 11.1 presents a map of individual results by reported sampling locations for cockles. Figure 11.2 presents the same for mussels. Each sampling point was randomly offset by a small distance using the disperse points function in Mapinfo to allow the presentation of individual results at locations sampled on multiple occasions. Table 11.2 presents geometric mean *E. coli* results from the RMPs and all other locations combined, and from before and after the start of the Official Control sampling programme in early 2007 as further supporting information to the following assessment.

Table 11.2 Geometric mean *E. coli* results from the RMPs and all other locations combined, and from before and after the start of the OC sampling programme

	Geometric mean *E. coli* result	
	Cockles	Mussels
From the RMP	1140 (n=23)	197 (n=17)
From all other locations	608 (n=14)	140 (n=14)
Pre OC sampling	975 (n=31)	176 (n=24)
Post OC sampling	584 (n=6)	147 (n=7)

11.3.1 Cockles

In December 2004, nine cockle samples were taken from eight separate locations during the course of one week. These samples are labelled on Figure 11.1, and two fell on land. Results ranged from 310 to 2400 *E. coli* mpn/100g with no apparent spatial pattern, and the RMP was set at the sampling point that returned the highest result. Following this, all samples were reportedly taken from the RMP until the start of the Official Control sampling programme in 2007. After the start of the OC sampling programme, all sampling locations were recorded by GPS at the time of sampling.

Therefore, the main cluster of 23 samples is located at the RMP. As these samples were all taken before the start of the OC sampling programme the accuracy of the sampling location cannot be confirmed. The highest result reported for cockles came from this location. The overall geometric mean result of samples taken from this location was 1140 *E. coli* mpn/100g, which is higher than the geometric mean result for all cockle samples taken from all other locations (608 *E. coli* mpn/100g). A T-test comparison of results of samples taken from the RMP and those taken from elsewhere show that this difference is not statistically significant (T-test, T=-1.21, p=0.233, Appendix 6).

Since the start of the OC sampling programme, samples were taken around the northeastern extremity of the bed, where Sampling Officers believe stock densities to be highest. The geometric mean of these six sample results was 584 *E. coli* mpn/100g, lower than the geometric mean for all samples taken before the start of the OC sampling programme (975 *E. coli* mpn/100g), but when samples taken from before the start of the programme were compared with those taken after, the difference was not found to be significant (T-test, T=0.6, p=0.567, Appendix 6).

Although the cluster of samples around the RMP gives the visual impression on Figure 11.1 that higher levels of contamination are present here, this is may just be a consequence of the higher number of samples taken in this cluster producing a greater range of results. It must also be noted that samples reported from here may have actually been taken from anywhere on the Doirlinn.

In conclusion, there is a tentative and possibly misleading impression of higher levels of contamination in cockles towards the south of the cockle bed based on all historical *E. coli* monitoring results, and no spatial pattern was apparent when multiple locations were sampled during December 2004.

11.3.2 Mussels

On 27/4/2005 six mussel samples were taken from separate locations widely spread across the area. These samples are labelled on Figure 11.2. Results ranged from 70 to 500 *E. coli* mpn/100g. The highest result came from the northern extremity of the bed, and the next two highest results (both 310 mpn/100g) came from the south shore of Kildalloig Bay, possibly suggesting slightly higher levels of contamination here at the time of sampling. The lowest result came from the southern end of the Doirlinn by Pointhouse. The RMP was set at the sampling point that returned the highest result. Following this, all but two samples were reportedly taken from the RMP until the start of the Official Control sampling programme in 2007. After the start of the OC sampling programme, all sampling locations were recorded by GPS at the time of sampling.

Therefore, the main cluster of 17 samples is located at the RMP. These samples were all taken before the start of the Official Control sampling programme, so the accuracy of the sampling location cannot be confirmed. The highest result reported for mussels came from this location. The overall geometric mean result of samples taken from this location was 197 *E. coli* mpn/100g, which is higher than the geometric mean result for all other mussel samples (139 *E. coli* mpn/100g). A T-test comparison of results of samples taken from the RMP and those taken from elsewhere show that this difference in not statistically significant (T-test, T=-0.6, p=0.552, Appendix 6).

Since the start of the Official Control sampling programme, samples were taken towards the southern extremity of the bed. The geometric mean of these six sample results was 147 *E. coli* mpn/100g, lower than the geometric mean for all other sample results (176 *E. coli* mpn/100g) but when compared with samples from before the start of the programme the difference was not significant (T-test, T=-0.27, p=0.796, Appendix 6). Therefore, although the cluster of samples around the RMP gives the visual impression on Figure 11.2 of higher levels of contamination here, this is may just be a consequence of the higher number of samples taken in this cluster producing a greater range of results. It must also be noted that samples reported from the RMP may possibly have actually been taken from anywhere on the Doirlinn.

In conclusion, there is a tentative and possibly misleading impression of higher levels of contamination towards the north of the mussel bed based on all historical *E. coli* monitoring results, and based on samples taken on one day in April 2005,

there may have been slightly higher levels of contamination on the south shore of Kildalloig Bay than elsewhere.

11.3.3 Conclusions

Overall, the two species tentatively show the opposite pattern in levels of contamination across the north south axis, along which the sampling locations were mainly aligned. These tentative, but opposite spatial patterns do however align temporally, i.e. sampling results have showed lower levels of contamination since the start of the OC sampling programme, so this possible effect may be a temporal rather than a geographical one. Possible explanations to support a temporal rather than a spatial effect include improved sample handling practices following the start of the OC sampling programme, or a slight improvement in water quality in the area, but there is no evidence available to substantiate either of these hypotheses.

When multiple locations were sampled over a short time period at the start of sampling, no spatial pattern was apparent in cockles, and there was the tentative suggestion of higher levels of contamination on the south shore of Kildalloig Bay in mussels.

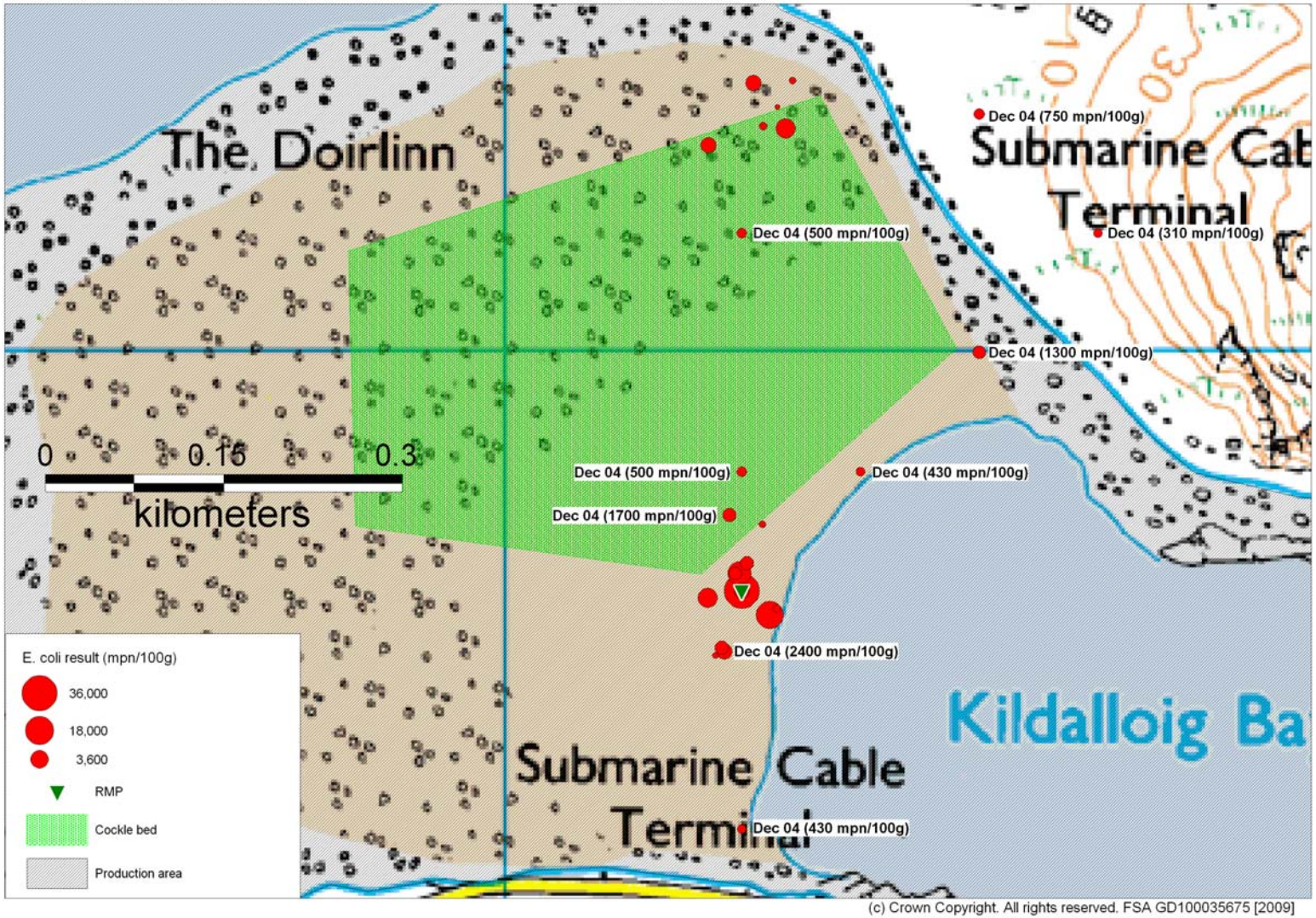

Figure 11.1 Cockle sampling *E. coli* results

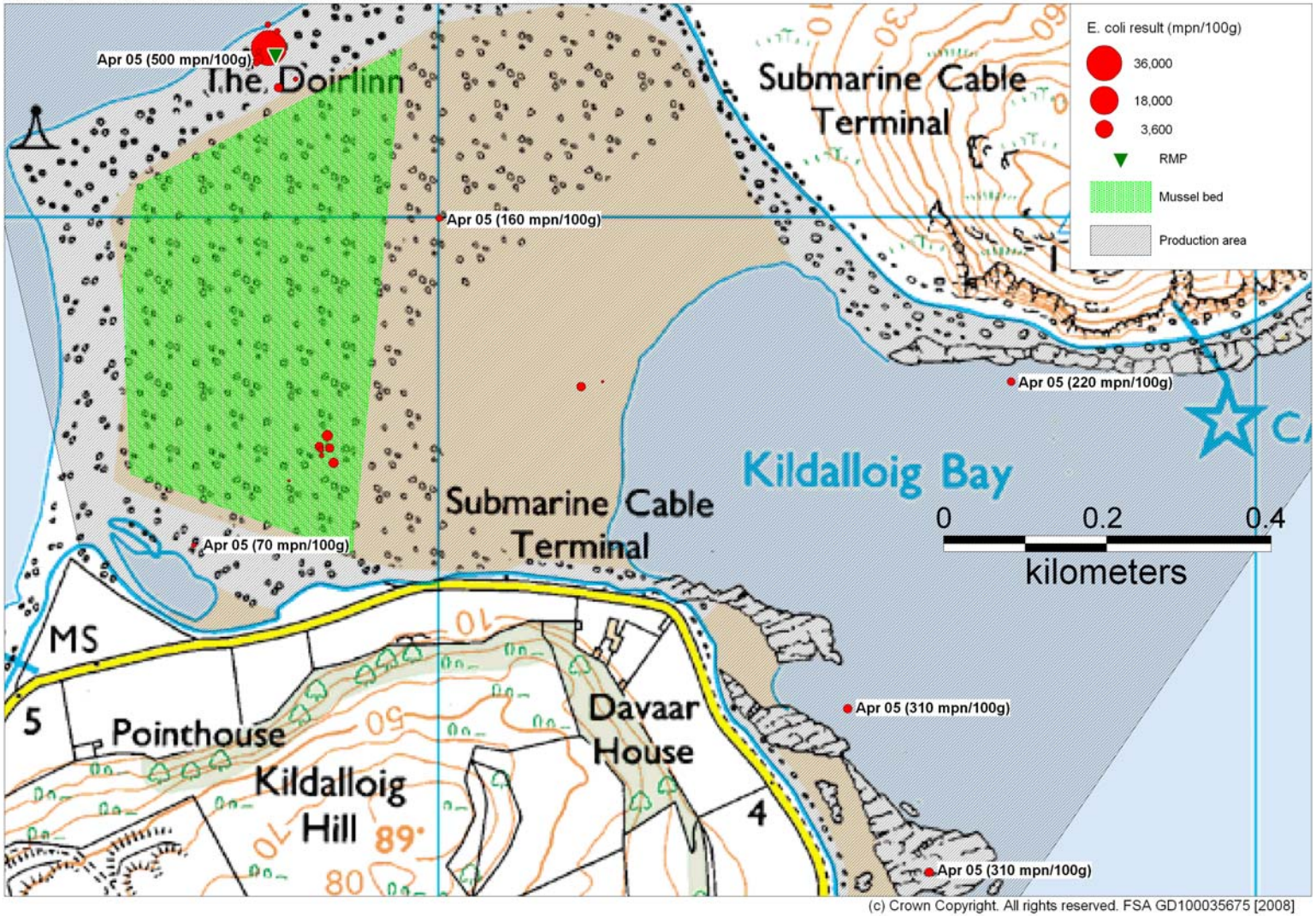

Figure 11.2 Mussel sampling *E. coli* results

11.4 Overall temporal pattern of results

Figure 11.3 and 11.4 present scatter plots of individual results against date for cockle and mussel samples taken from Campbeltown Loch. Both are fitted with a loess smoother, a regression based smoother line calculated by the Minitab statistical software to help highlight any apparent underlying trends or cycles.

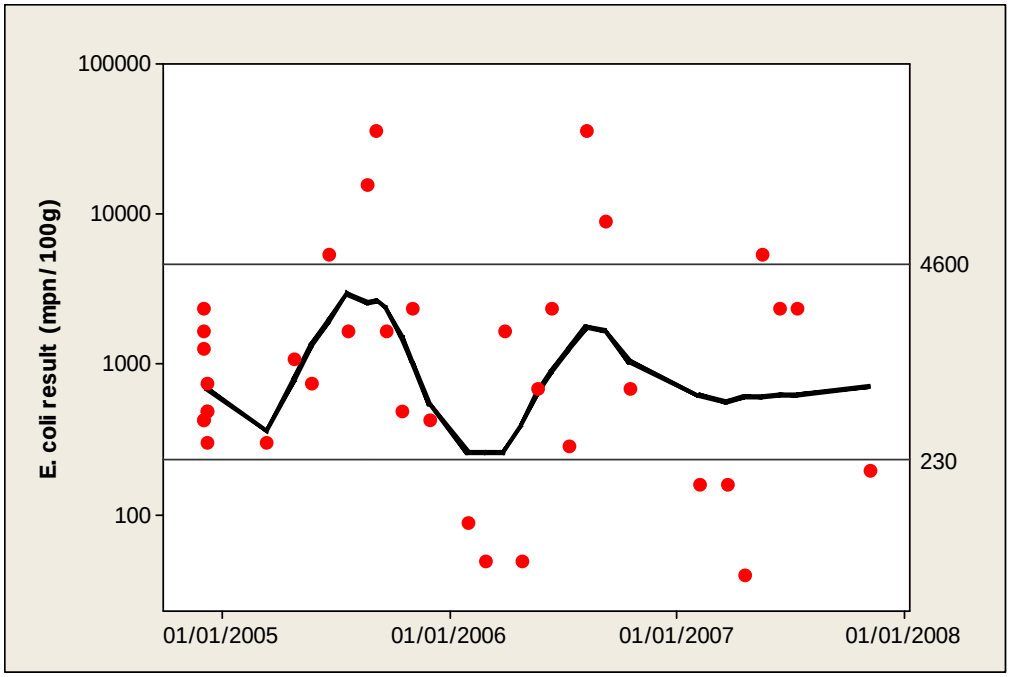

Figure 11.3 Scatter plot of *E. coli* results by date with loess smoother (cockles)

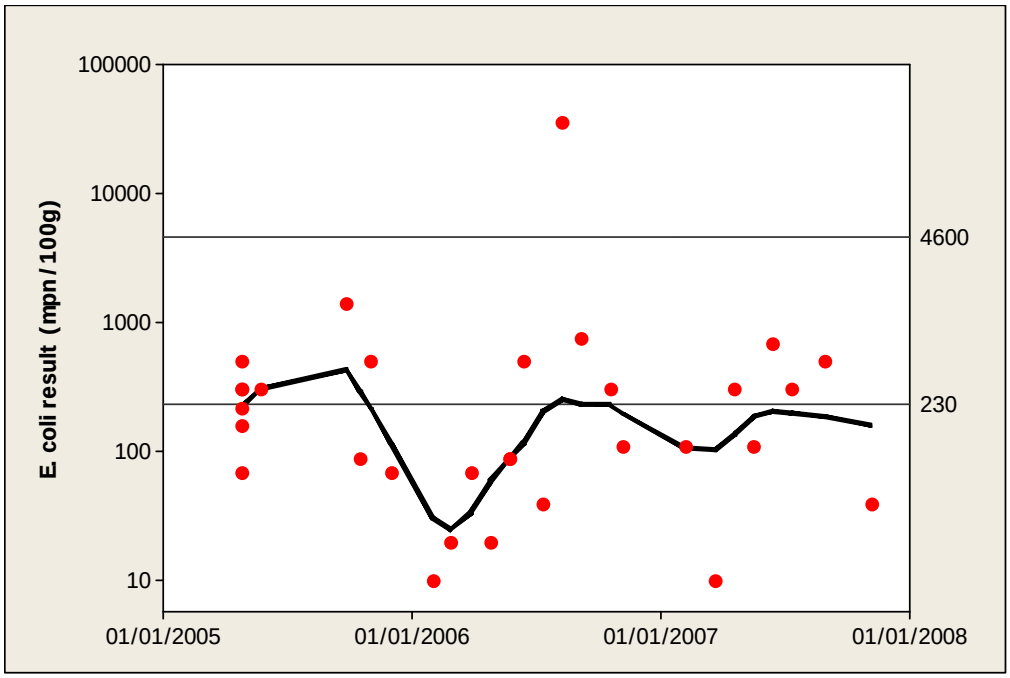

Figure 11.4 Scatter plot of *E. coli* results by date with loess smoother (mussels)

Figure 11.3 suggests seasonal cycles in levels of contamination with peaks in the 3rd quarter. Figure 11.4 suggests the same, but the trend is less clear than that seen in Figure 11.3.

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 the geometric mean *E. coli* result by month (+ 2 times the standard error) for cockles and mussels respectively.

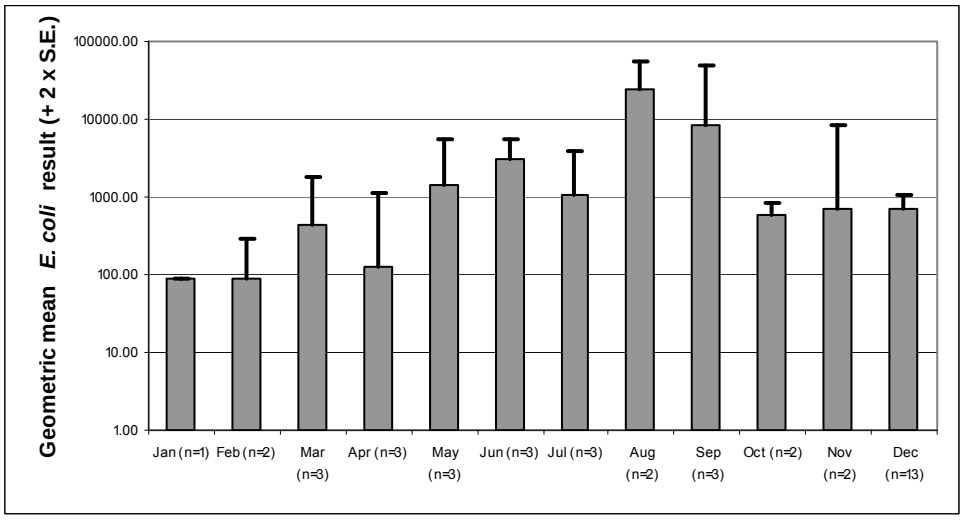

Figure 11.5 Geometric mean *E. coli* result by month (cockles)

Highest mean results for cockles occurred in August and September, and lowest mean results occurred from January and February, but it must be noted that numbers of samples taken in some months were low, and a large number of samples (9) were taken during December 2004.

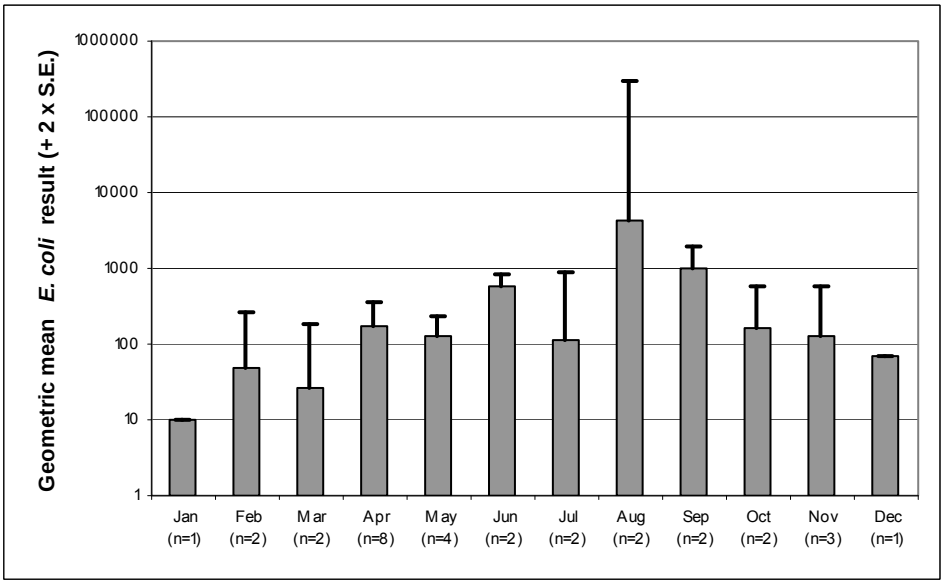

Figure 11.6 Geometric mean *E. coli* result by month (mussels)

Highest mean results for mussels occurred in August and September. It must be noted that numbers of samples taken in some months were low, and a large number of samples (6) were taken in April 2005. The pattern was very similar for the two species.

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

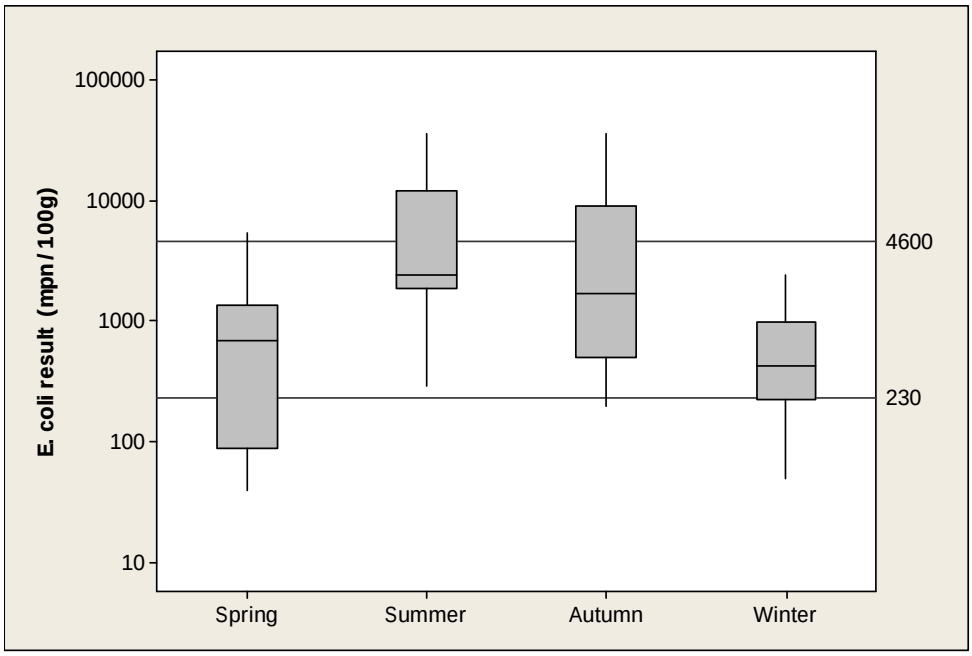

Figure 11.7 Box plot of *E. coli* result by season (cockles)

For cockles, a significant difference was found between results by season (One-way ANOVA, p=0.007, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicated that results for the summer were significantly higher than those in the winter and spring. As noted in previously, highest mean results occurred in August and September, one of which falls in summer, the other in autumn.

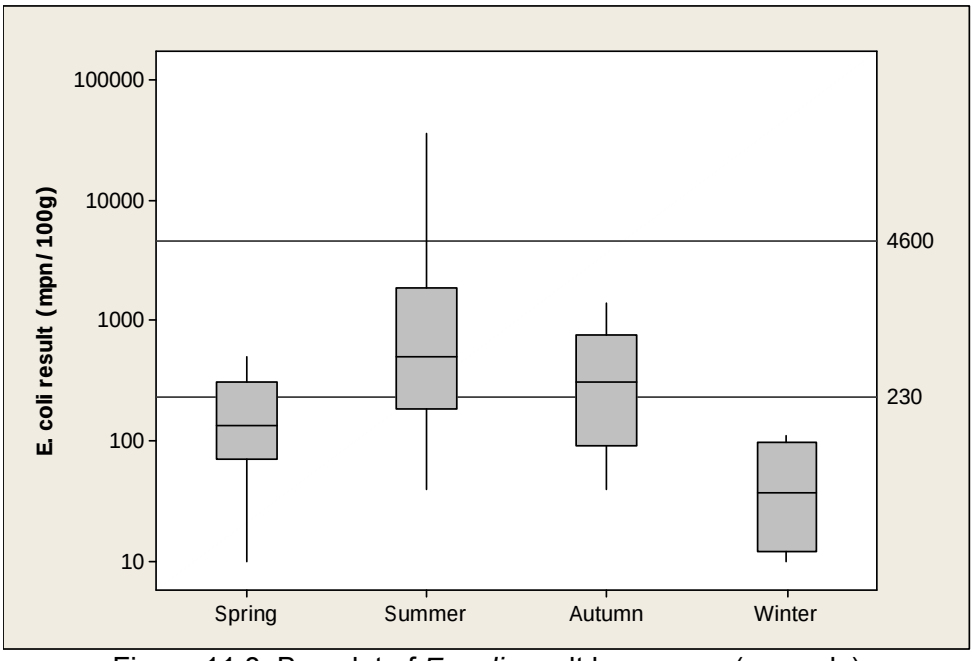

Figure 11.8 Box plot of *E. coli* result by season (mussels)

For mussels, a significant difference was also found between results by season (One-way ANOVA, p=0.020, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicated that results for the summer were significantly higher than those in the winter. The overall seasonal pattern of results was very similar to that observed in cockles, with highest results occurring in August and September, one of which falls in summer, the other in autumn.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station to Campbeltown Loch for which the majority of rainfall records were available was Macrihanish, approximately 8 km to the west of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily rainfall in mm). For this period only 6 days records were missing. The coefficient of determination was calculated for *E. coli* results and rainfall in the previous 2 days at Macrihanish. Figures 11.9 and 11.10 present a scatter plot of *E. coli* results against rainfall for cockles and mussels respectively. Figures 11.11 and 11.12 present box plots of results by previous 2 days rainfall quartile for mussels and oysters respectively (quartile 1 = 0 to 0.4 mm, quartile 2 = 0.4 to 3.0 mm, quartile 3 = 3.0 to 9.25 mm, quartile 4 = more than 9.25 mm).

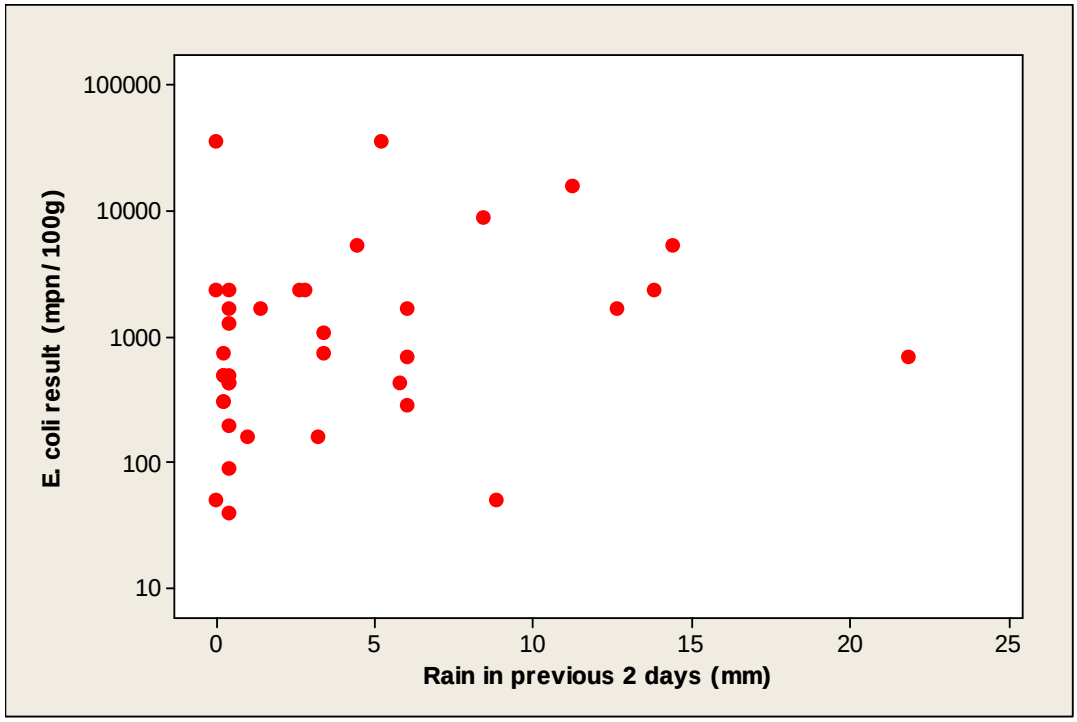

Figure 11.9 Scatter plot of *E. coli* result against rainfall in previous 2 days (cockles)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and the rainfall recorded in the previous two days for cockles (Adjusted R-sq=4.4%, p=0.113, Appendix 6).

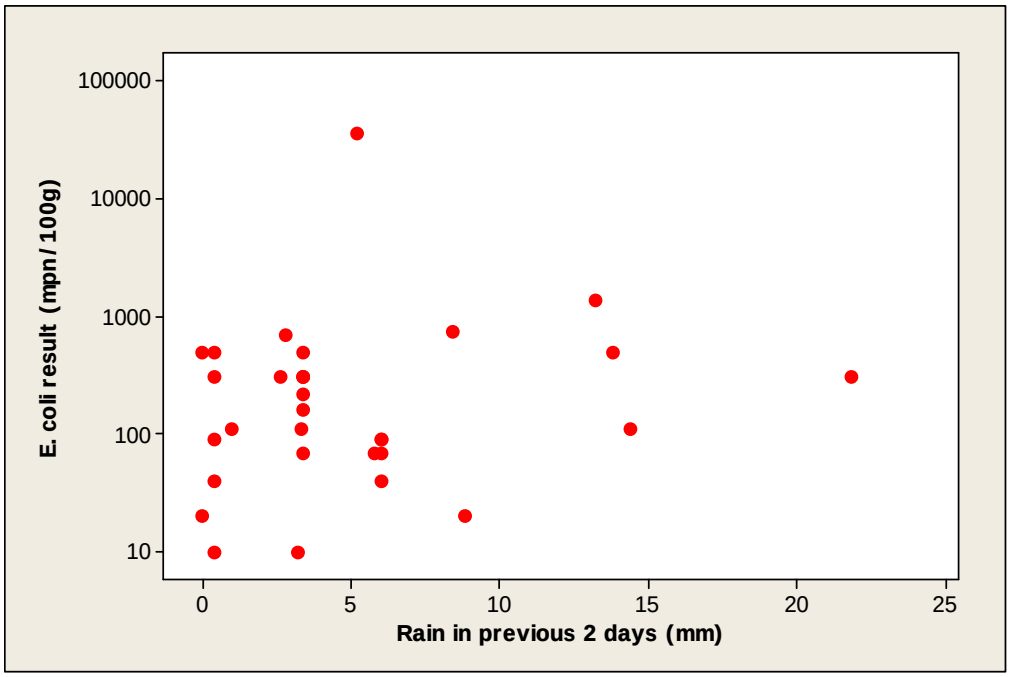

Figure 11.10 Scatter plot of *E. coli* result against rainfall in previous 2 days (mussels)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and the rainfall in the previous two days for mussels (Adjusted R-sq=0.3%, p=0.304, Appendix 6).

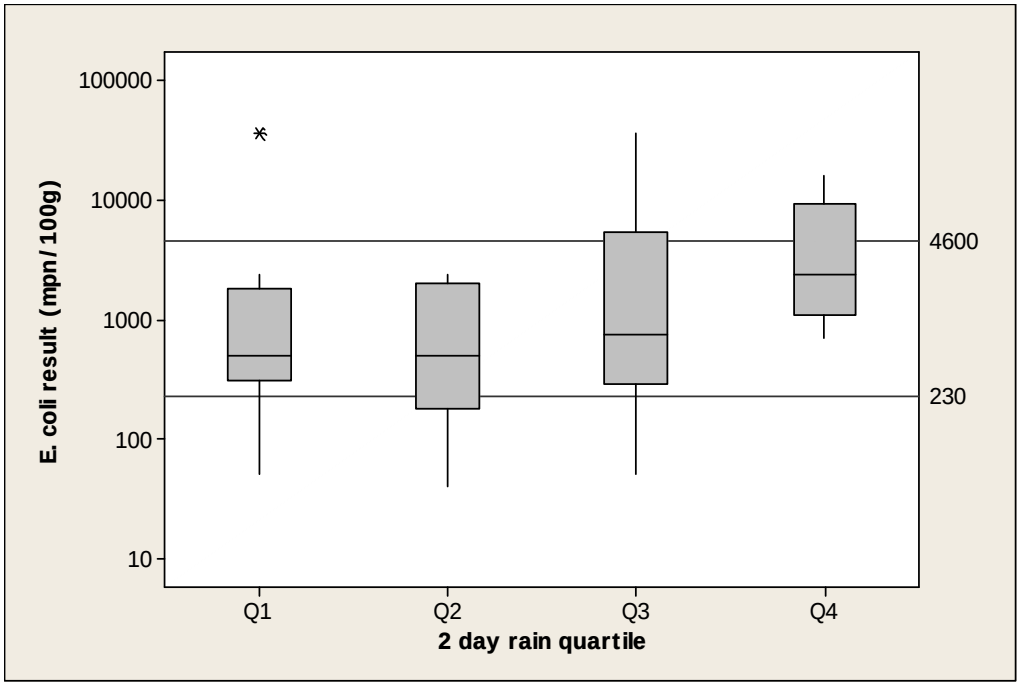

Figure 11.11 Box plot of *E. coli* result by rainfall in previous 2 days quartile (cockles)

Although the median result increased with increasing rainfall, no significant difference was found between the results for each 2-day rain quartile for cockles (One way ANOVA, p=0.282, Appendix 6).

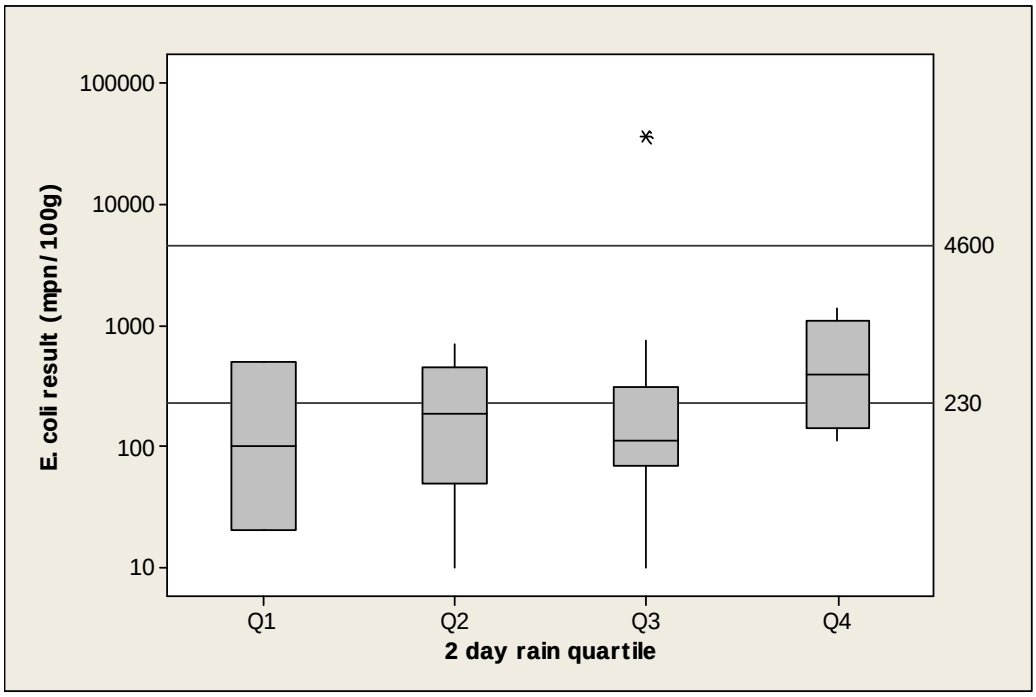

Figure 11.12 Box plot of *E. coli* result by rainfall in previous 2 days quartile (mussels)

Although the median result increased slightly with increasing rainfall, no significant difference was found between the results for each 2-day rain quartile for mussels (One way ANOVA, p=0.714, Appendix 6).

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results for Campbeltown Loch was investigated in an identical manner to the above. Interquartile ranges for 7 days rainfall were as follows; quartile 1 = 0 to 6.4 mm; quartile 2 = 6.4 to 18.7 mm; quartile 3 = 18.7 to 31.4 mm; quartile 4 = more than 31.4 mm.

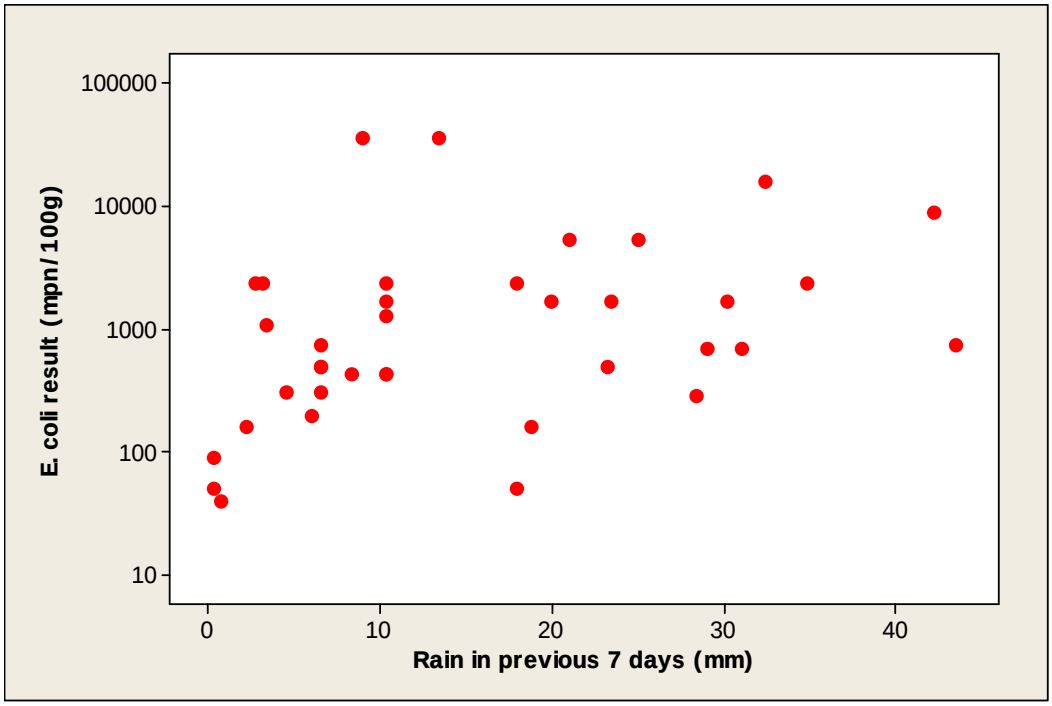

Figure 11.13 Scatter plot of *E. coli* result against rainfall in previous 7 days (cockles)

The coefficient of determination indicates that there was a very weak positive relationship between the *E. coli* result and the rainfall in the previous 7 days for cockles (Adjusted R-sq=11.3%, p=0.024, Appendix 6).

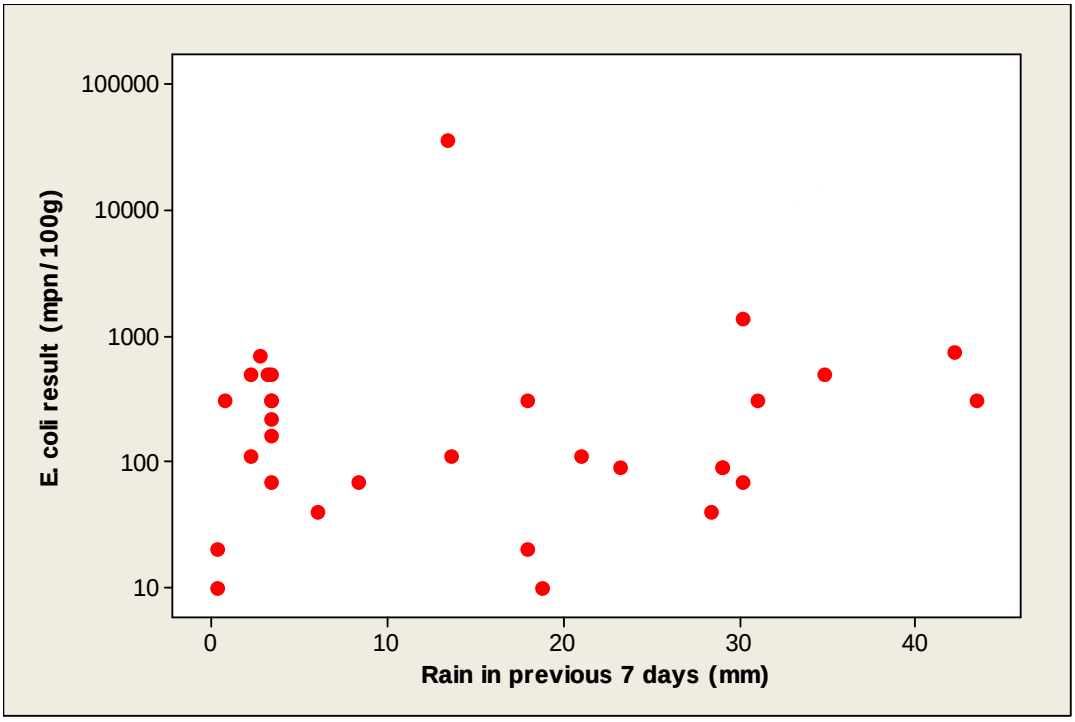

Figure 11.14 Scatter plot of *E. coli* result against rainfall in previous 7 days (mussels)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and the rainfall in the previous 7 days for mussels (Adjusted R-sq=0.0%, p=0.597, Appendix 6).

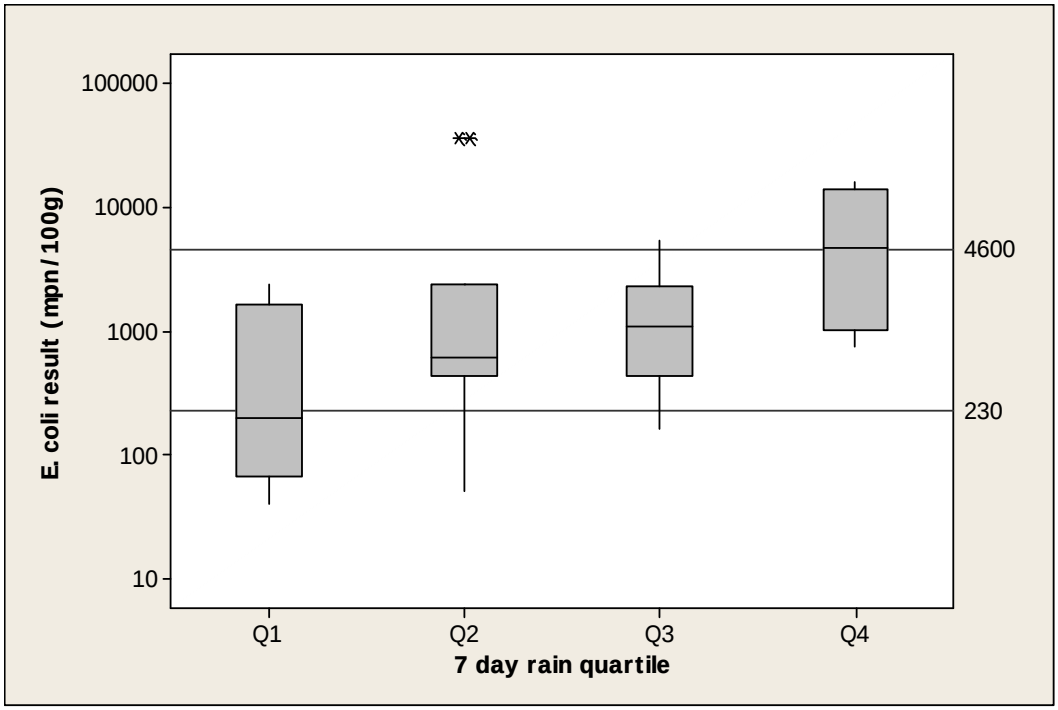

Figure 11.15 Box plot of *E. coli* result by rainfall in previous 7 days quartile (cockles)

A significant difference was found between the results for each 7-day rain quartile for cockles (One way ANOVA, p=0.041, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicated that results for quartile 1 were significantly lower than those for quartile 4. This confirms the finding from the regression analysis.

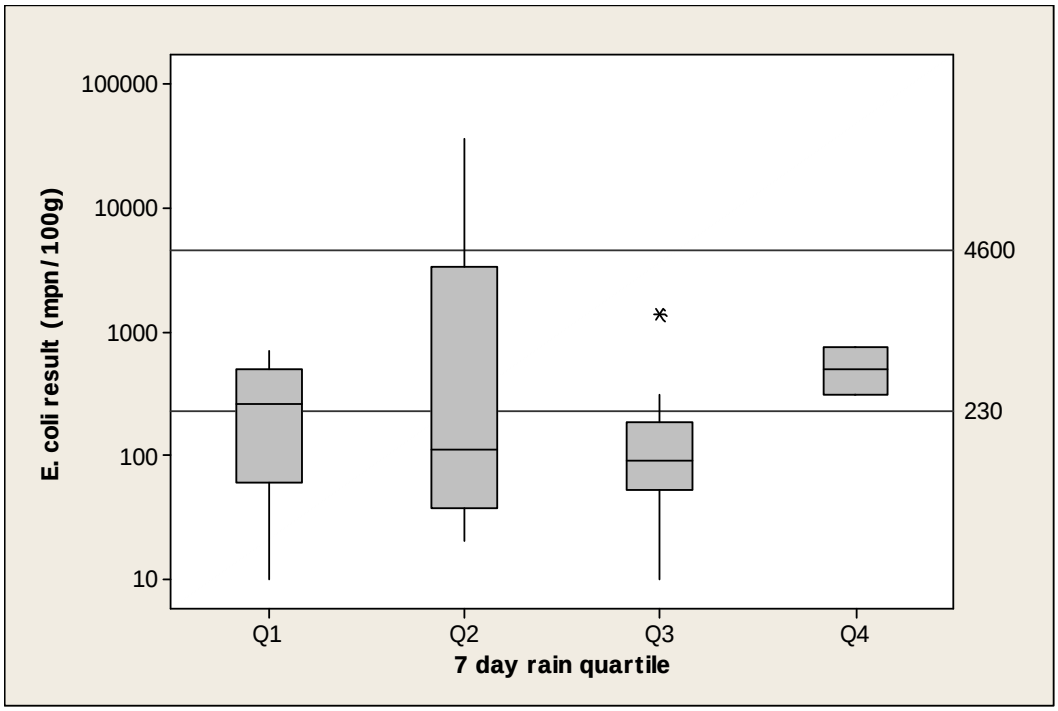

Figure 11.16 Box plot of *E. coli* result by rainfall in previous 7 days quartile (mussels)

No significant difference was found between the results for each 7-day rain quartile for oysters (One way ANOVA, p=0.444, Appendix 6).

Overall, no relationship between *E. coli* result and recent rainfall was found for mussels, but a weak relationship between results and rainfall in the last 7 days was found for cockles.

11.6.2 Analysis of results by tidal amplitude

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 11.17 and 11.18 present scatter plots of *E. coli* results by predicted height of the previous high water. It should be noted that local meteorological conditions such as wind strength and direction can also influence the height of tides and this is not taken into account.

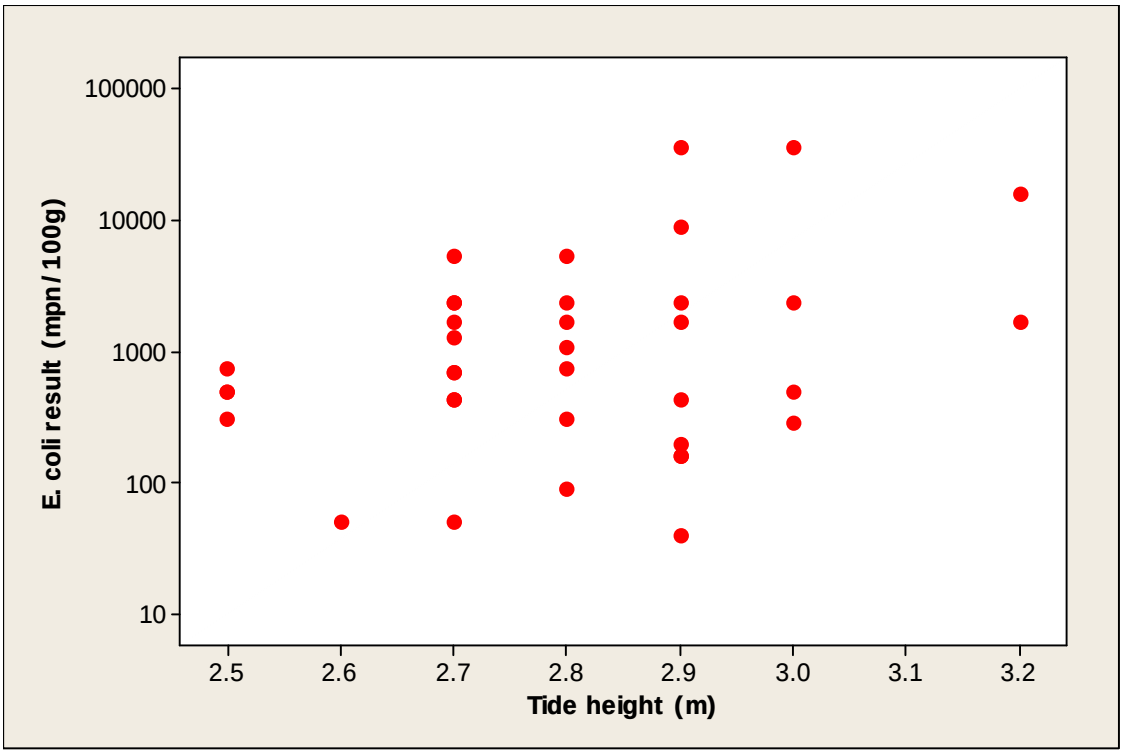

Figure 11.17. Scatter plot of *E. coli* result vs tide height (cockles)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and the height of the previous high water for cockles (Adjusted R-sq=6.9%, p=0.063, Appendix 6).

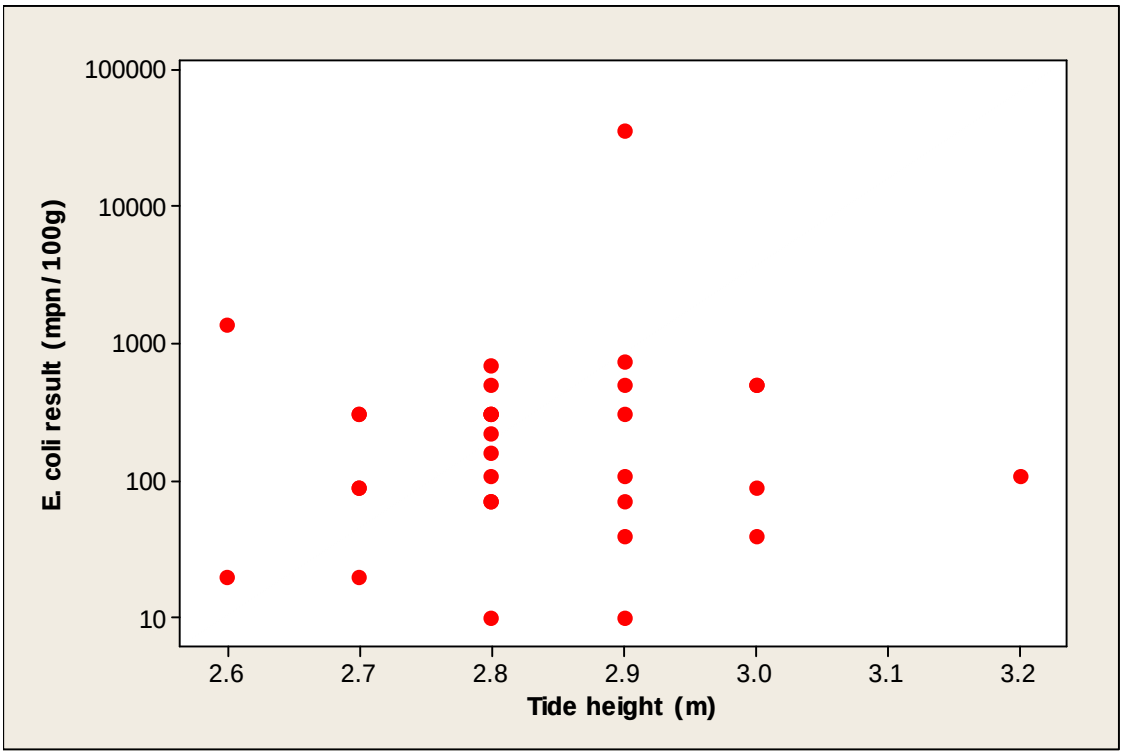

Figure 11.18. Scatter plot of *E. coli* result vs tide height (mussels)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and the height of the previous high water for mussels (Adjusted R-sq=0.0%, p=0.750, Appendix 6).

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. *E. coli* levels in shellfish can respond within a few hours or less to changes in *E. coli* levels in water, so tidal state at time of sampling (hours post high water) may affect *E. coli* results in some situations. The cockle and mussel fisheries here are only accessible at or near low water, and sampling has historically occurred during this time, so an investigation of *E. coli* results in relation to tidal state was not appropriate in this case.

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.

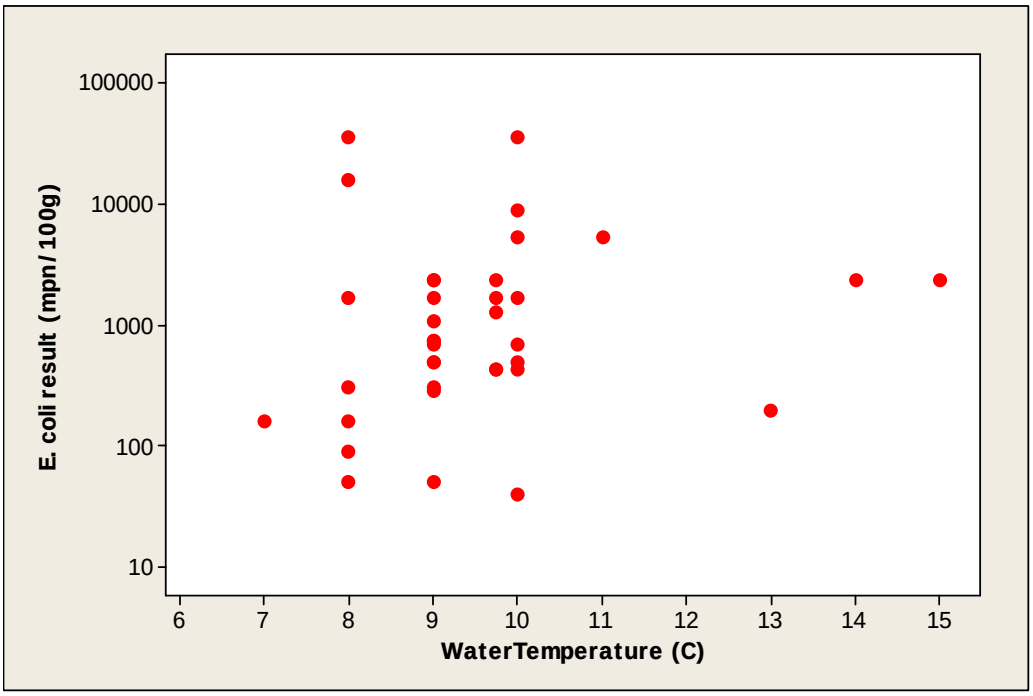

Figure 11.19 Scatter plot of *E. coli* result against water temperature at time of sampling (cockles)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and the water temperature at time of sampling (Adjusted R-sq=0.3%, p=0.302, Appendix 6). It must be noted that some surprisingly low water temperatures were recorded during the summer months (e.g. 8 ºC in August)

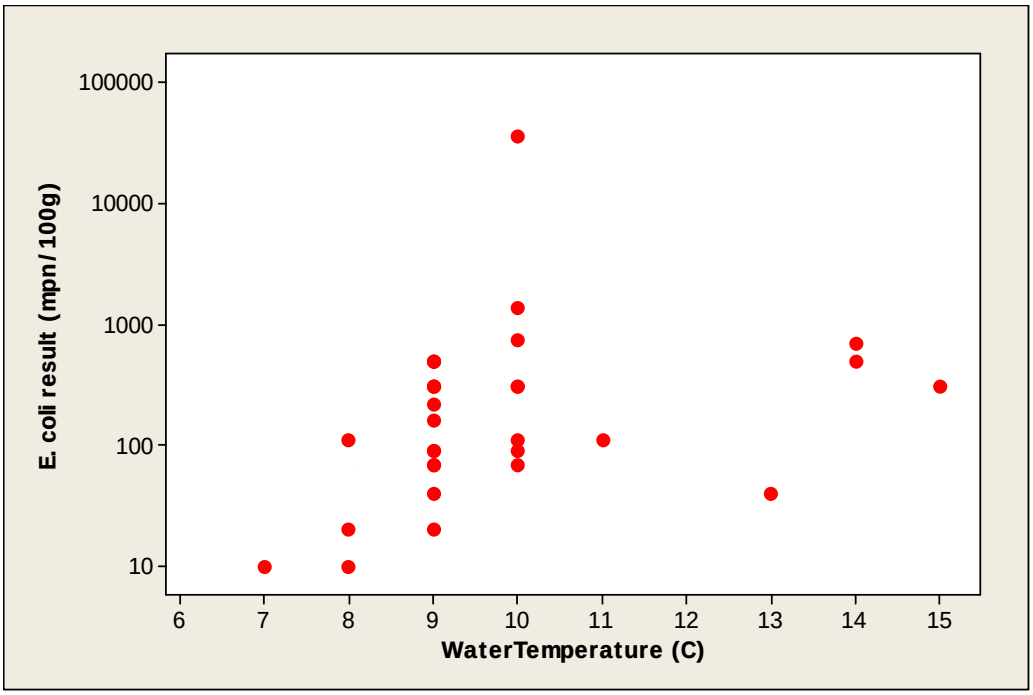

Figure 11.20 Scatter plot of *E. coli* result against water temperature at time of sampling (mussels)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and the water temperature at time of sampling for mussels (Adjusted R-sq=7.5%, p=0.073, Appendix 6).

11.6.4 Analysis of results by wind direction

Wind speed and direction may change water circulation patterns in the production area. Mean wind direction for the 7 days prior to each sample being collected was calculated from wind data recorded at the Prestwick: Gannet weather station, and mean *E. coli* result by mean wind direction in the previous 7 days is plotted in Figure 11.21 for cockles, and 11.22 for mussels.

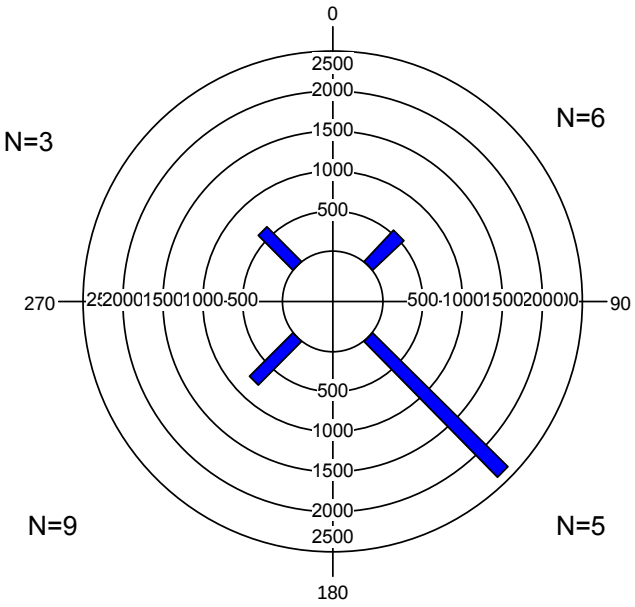

Figure 11.21 Circular histogram of geometric mean *E. coli* result by wind direction (cockles)

Figure 11.21 shows that the geometric mean *E. coli* result was highest in cockles when the wind was blowing from the southeast. However, this effect was not statistically significant, as no correlation was found between wind direction and *E. coli* result (circular-linear correlation, r=0.193, p=0.476, Appendix 6).

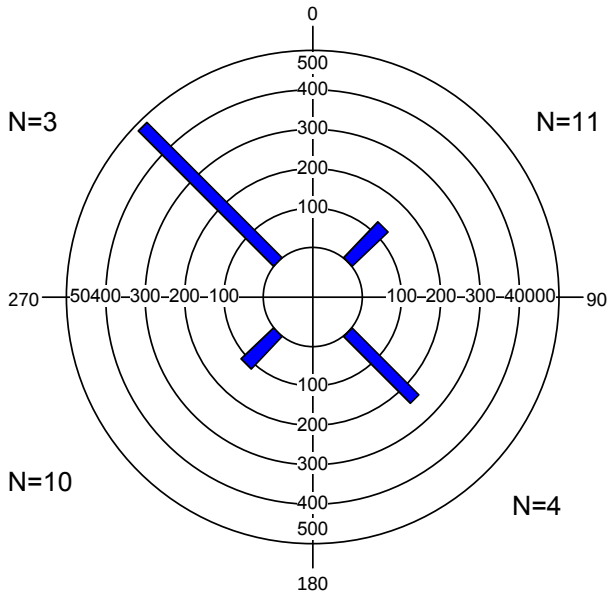

Figure 11.22 Circular histogram of geometric mean *E. coli* result by wind direction (mussels)

Figure 11.22 shows that the geometric mean *E. coli* result was higher in mussels when the wind was blowing from the northwest. However, this effect was not statistically significant, as no correlation was found between wind direction and *E. coli* result (circular-linear correlation, r=0.291, p=0.11, Appendix 6).

No correlation between mean wind direction in the previous 7 days and *E. coli* result was found for either species, but this does not necessarily mean that wind is unimportant. The wind data used is from a station located 62 km away, and the analysis considered only mean wind direction over 7 days. Sample numbers considered in the analysis were small. The analyses also did not include consideration of wind strength.

11.6.5 Evaluation of peak results

A total of 7 results of over 4600 *E. coli* mpn/100g were reported. Details of these are presented in Table 11.3.

Table 11.3. *E. coli* results over 4600 mpn/100g

Species	Date	*E. coli* result (mpn/100g)	Location	Tide height (m)	7 day wind direction	2 day rain quartile	7 day rain quartile	Water temperature (ºC)
Cockles	21/06/2005	5400	NR752198	2.7	212º	Q3	Q3	10
Cockles	23/08/2005	16000	NR752198	3.2	*	Q4	Q4	8
Cockles	06/09/2005	>18000	NR752198	3.0	138º	Q1	Q2	8
Cockles	09/08/2006	>18000	NR752198	2.9	294º	Q3	Q2	10
Mussels	09/08/2006	>18000	NR748202	2.9	294º	Q3	Q2	10
Cockles	07/09/2006	9100	NR752198	2.9	222º	Q3	Q4	10
Cockles	17/05/2007	5400	NR752201	2.8	55º	Q4	Q3	11

* Data not available

Of these 7 results, 6 were for cockles. All occurred between May and September on tides of 2.7m and above, at water temperatures between 8 and 11 ºC. They occurred under a variety of meteorological conditions.

11.6.6 Summary of environmental effects

Overall, the number of samples taken of each species was relatively low (37 cockles and 31 mussels) with environmental data not always available.

An analysis of geographic patterns in levels of contamination in the samples tentatively suggested that contamination was higher in cockles towards the southern end of the production area, and higher in mussels towards the northern end of the production area. When multiple locations were sampled over a short time period at when sampling commenced in 2004/2005, no spatial pattern was apparent in cockles, and there was the tentative suggestion of higher levels of contamination on the south shore of Kildalloig Bay in mussels. These conclusions must however be treated with caution as the overall patterns may be due to temporal effects, and reported sampling locations prior to the start of the OC sampling programme in 2007 may be inaccurate.

A seasonal effect was found, with results for both species highest in the summer, suggesting that either inputs are higher in summer and/or the uptake of bacteria by the shellfish is higher in warmer water. No relationship was found between water

temperature and results for either species, but it must be noted that some very low water temperatures were recorded during the summer (e.g. 8 ºC in August).

No relationship was found between *E. coli* result and recent rainfall for mussels. A weak positive relationship between results and rainfall in the last 7 days was found for cockles, but there was no relationship between results and rainfall in the previous 2 days.

No significant relationship was found between tide size and results for either species, but for cockles the median result increased as tide size increased, and the highest results occurred on spring tides.

No correlation was found between wind direction and magnitude of *E. coli* results.

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

11.7 Analysis of results against Kinloch Park CSO spill data

Frequent spills of raw sewage occurred from the Kinloch Park CSO to the head of Campbeltown Loch, resulting in significant decreases in water quality here. It is uncertain how much these spills affect the fishery on the Doirlinn. Scottish Water provided telemetry records from the Kinloch Park pumping station from July 2006, permitting comparison of spill occurrence with samples collected from this date onwards. As sample numbers were low, and spill data was provided by Scottish Water up until the end of October 2008, the FSAS results database was interrogated again in late 2008, and results for all samples collected during 2008 up to this point were included to make this important analysis as robust as possible.

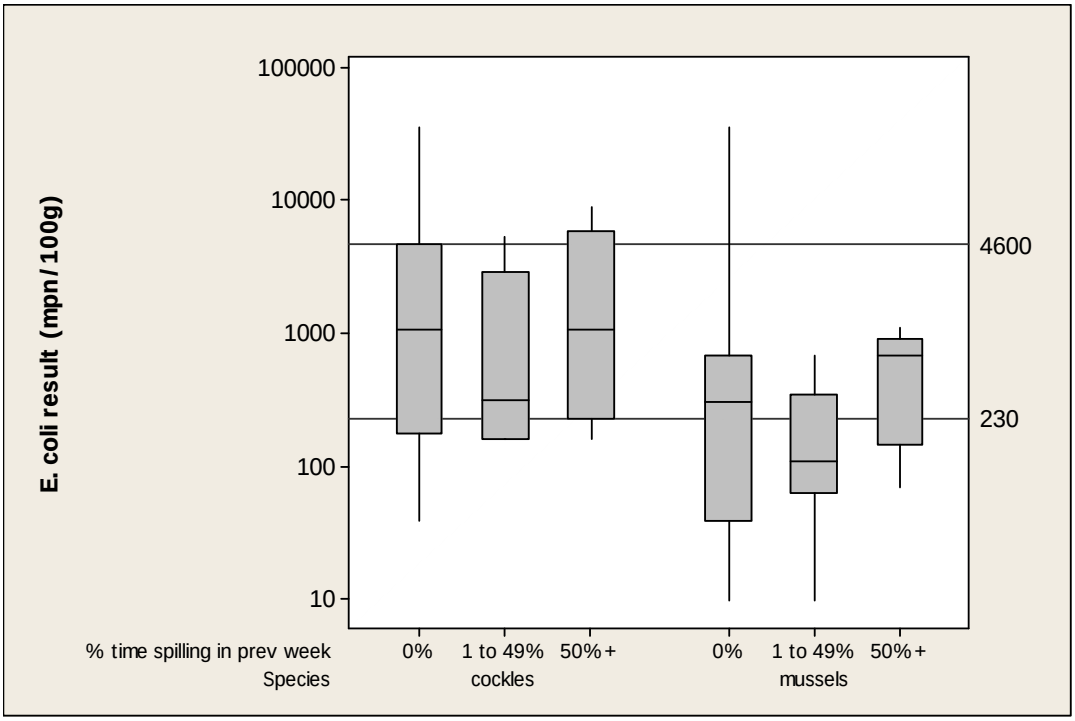

Figure 11.23 Box plot of *E. coli* results by percentage of time the Kinloch Park pumping station had spilled in the week before the sample was collected

No significant difference was found between the percentage of time spilling categories for either cockles (one-way ANOVA, p=0.807, Appendix 6) or mussels (one-way ANOVA, p=0.402, Appendix 6). It is therefore concluded from this fairly limited dataset (16 cockle samples and 22 mussel samples) that spills from Kinloch Park do not result in major increases in contamination at the shellfisheries on the Doirlinn. However, interacting factors such as wind direction or tidal state could potentially affect any such contamination and none of these were considered here.

In addition to the FSAS historical monitoring results, Argyll and Bute Council took water samples from four locations at Campbeltown Loch on 5/8/08 and again on 16/9/2008. These were taken during spill events at Kinloch Park. Approximate sampling locations (estimated from the site name) are plotted in Figure 11.24, and *E. coli* results are listed in Table 11.4.

Table 11.4 Argyll & Bute Council water sampling results, August-September 2008

Location	***E. coli* result (cfu/100ml)**	
	05/08/2008	**16/09/2008**
Doirlinn	<10	2000
Marina pontoon	300	6700
Harbour slipway	250	8200
Dalintober Beach	>10000	4600

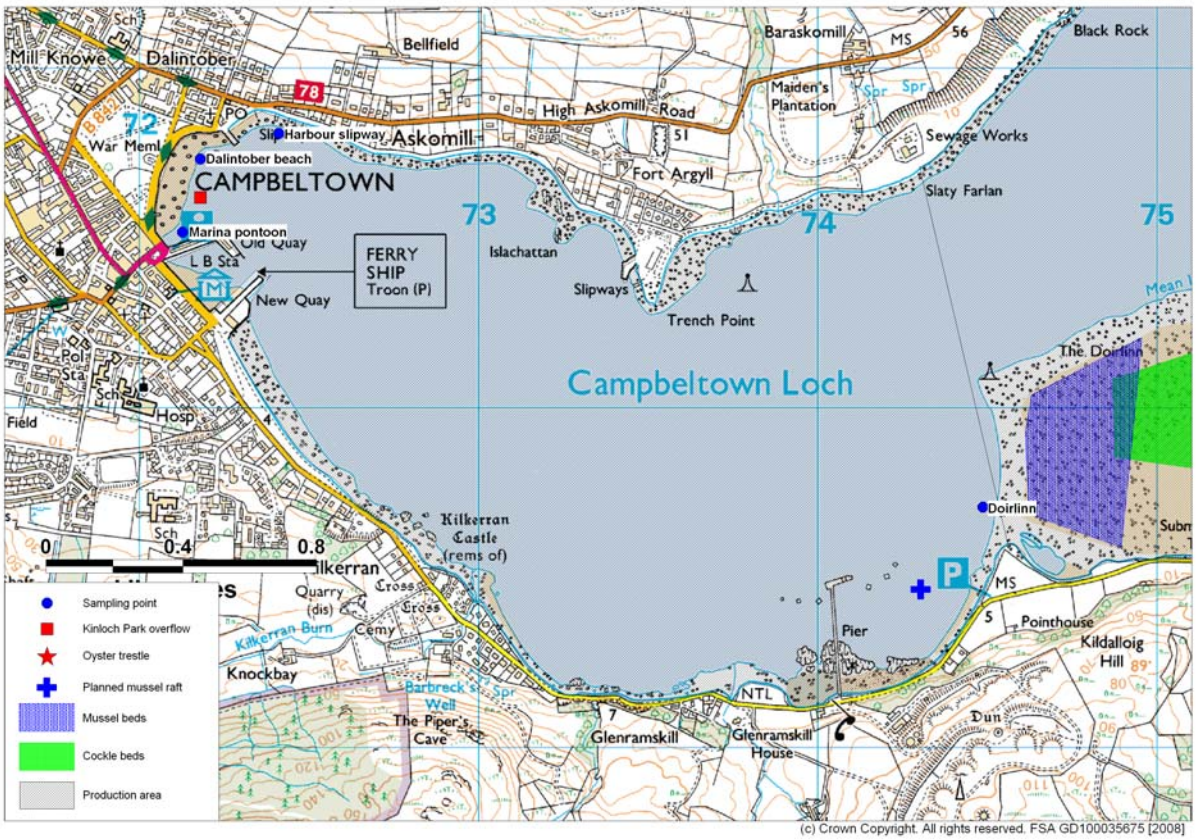

Figure 11.24. Argyll & Bute Council water sampling locations, August-September 2008.

On 5/8/2008 the system had been spilling almost continuously for over 4 days prior to the sampling. A very high result was obtained from Dalintober Beach, high results were obtained at the other two sites near the discharge, but levels were very low on the Doirlinn where the shellfish beds are located.

On 16/9/2008, the system had been spilling continuously from 08:00 on the 15/9/2008. Very high results were obtained at all three sampling points adjacent to the discharge. In contrast to the sampling of 5/8/2008, the water sample taken at the Doirlinn yielded a high result (2000 cfu/100ml).

These results imply that contamination was much more widely dispersed around the loch on the second sampling occasion. A total of 12.8 mm of rain fell at the Dippen rain gauge (data provided by Scottish Water) on the 3-4/8/2008, and 79.0 mm of rain fell on the 14-15/9/08, which could be described as exceptionally high. As considerably more rain had fallen immediately prior to the second sampling occasion it is quite possible that other rainfall dependent sources of contamination may have been the cause of the high result on the Doirlinn. It is uncertain at what state of the tide (high/low/ebb/flood) the samples were taken, and this would have been useful in assessing whether these differing spatial patterns were consistent with the Kinloch Park discharge being responsible for the high levels of contamination observed on the Doirlinn on the second occasion. Both samplings were undertaken during spring tides. No wind data was available for these dates at the time of writing of this report.

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 of the currently classified fisheries as they have both held seasonal classifications in the last three years.

12. Designated Shellfish Growing Waters Data

Campbeltown Loch is not a designated shellfish growing water.

13. Bathymetry and Hydrodynamics

Figure 13.1 Campbeltown Loch

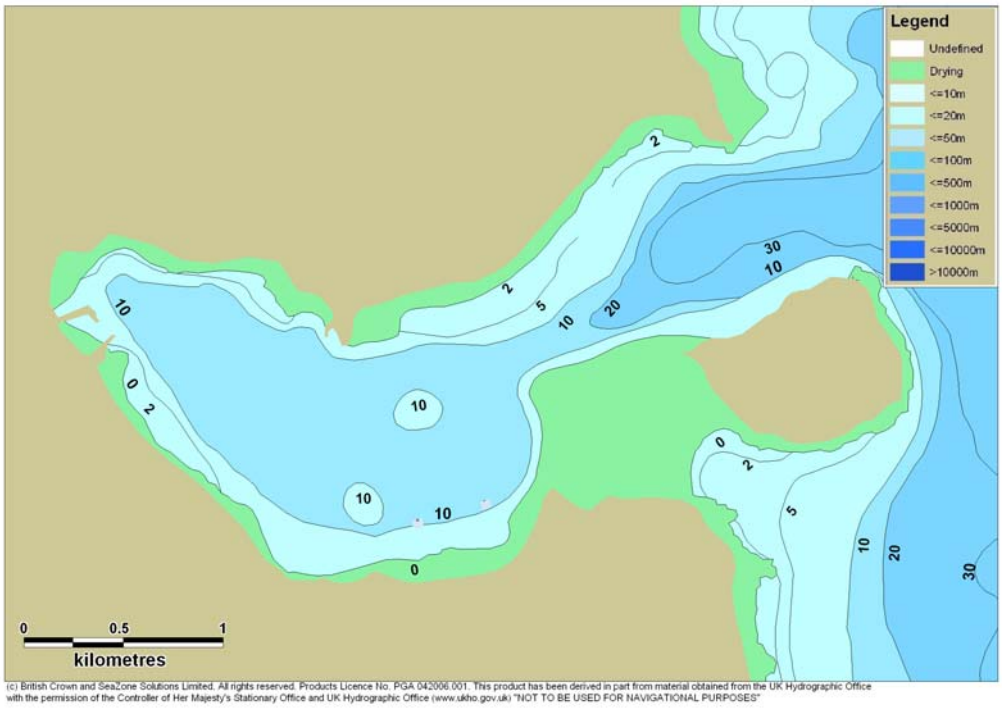

Figure 13.2 Bathymetry of Campbeltown

The chart above shows that the main body of the loch is fairly shallow (over 10m in most places, and up to 30m at its entrance). The wild shellfish beds and the oyster trestle are located on an intertidal area called the Doirlinn between Campbeltown Loch and Kildalloig Bay. Kildalloig Bay is relatively shallow. The highest elevation on the Doirlinn is a causeway used for vehicular access to Davaar Island. This causeway runs close to the western and northern edge of the Doirlinn. It is

underwater for approximately 3 hours either side of high water, therefore limiting the ingress of water from the main body of the loch to the wild shellfish beds and oyster trestles to these times.

13.1 Tidal Curve and Description

The two tidal curves below are for Campbeltown, which is located on the southwestern coastline of Scotland. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 06/05/08 and the second is for seven days beginning 00.00 GMT on 13/5/08. 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.

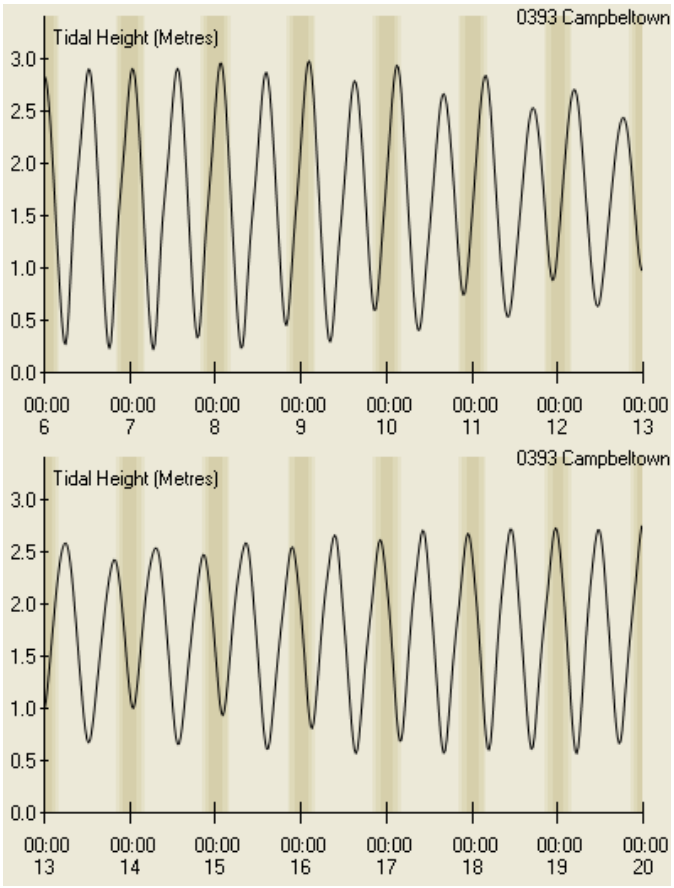

Figure 13.3 Tidal curves for Campbeltown

The following is the summary description for Campbeltown from TotalTide:

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

HAT	3.2 m	MSL	1.82 m
MHWS	2.9 m	MLWN	1.1 m
MHWN	2.5 m	MLWS	0.5 m

Predicted heights are in metres above chart datum. The tidal range at spring tide is approximately 2.4 m and at neap tide 1.4 m.

13.2 Currents

Currents in the loch will be driven by a combination of tide, wind and freshwater inputs. This section aims to make a simple assessment of water movements around the area. The complex bathymetry around the Doirlinn, which creates a barrier between Campbeltown Loch and Kildalloig Bay for around half of the tidal cycle, makes firm predictions difficult.

The nearest tidal stream information available is located outside Campbeltown Loch in Kilbrannan Sound. This indicates that water flows past the mouth of Campbeltown Loch in a northerly direction on the flood tide, and a southerly direction on an ebb tide. No tidal flow information was available for any location within Campbeltown Loch or Kildalloig Bay.

Along the north shore, tidally driven currents are likely to flow in a westerly direction on the flood tide, and in an easterly direction on the ebb tide. Therefore, the treated discharge from Slaty Farlan is likely to affect water quality on the north shore primarily. This is in agreement with the modelling outputs from a study commissioned by Scottish Water. It is not certain exactly where currents may take contamination from the Kinloch Park CSO, but the highest concentrations of sanitary debris were found on the north shore near the head of the loch.

Contamination from sources on the south shore are also likely to move along this shore in a westerly direction on the flood tide, and in an easterly direction on the ebb tide. Under ebb tide conditions, when the Doirlinn is fully covered for the top half of the tidal cycle, contamination from these sources may be carried over the shellfish beds here and into Kildalloig Bay. The movement of water from Campbeltown Loch, across the Doirlinn and into Kildalloig Bay is likely to mainly occur on the ebb tide, when the net flow of water in Kilbrannan Sound is in a southerly direction.

On the basis of this simplistic assessment of tidally driven currents, it could be concluded that the south west part of the shellfish beds on the Doirlinn would be most exposed to contamination moving out along the south shore of Campbeltown Loch on an ebb tide. Also, discharges to the north shore may be of much less significance to shellfish near the south shore or on the Doirlinn.

Wind driven flows are likely to be important, and may alter flow patterns around the loch considerably. They create a surface flow in the direction of the wind, and a return flow along the bottom of the loch in the opposite direction. The area is most exposed to easterly winds, and the local topography will result in westerly winds being funnelled down the loch to some extent. Westerly winds will drive surface currents from the inner loch towards the Doirlinn, and northerly winds will drive surface currents from the north shore and main body of the loch towards the Doirlinn. Easterly winds may curtail the tidal flow of water from the Loch, across the Doirlinn to Kildalloig Bay during the ebb tide.

Density driven flows are not usually likely to be of importance as the loch has a small catchment area (13 km^2) and so freshwater inputs are relatively low. During periods of heavy rainfall, a surface layer of fresh water, which is likely to carry

higher levels of contamination, will flow out of the loch, creating a return current of more dense seawater at depth. These currents would result in a net seaward flow of surface water, carrying contamination from sources in the inner loch out of its mouth as well as over the Doirlinn when this area is underwater.

14. River Flow

The following streams were measured and sampled during the shoreline survey. These represent the largest freshwater inputs into Campbeltown Loch.

Table 14.1 Stream loadings for Campbeltown Loch

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	NR 72366 20873	Stream	0.97	0.03	0.38	955.4	5800	5.5E+10
2	NR 73024 20752	Stream	0.48	0.03	0.03	37.3	7300	2.7E+09
3	NR 74844 21306	Stream	0.73	0.05	0.405	1277.2	<100*	6.4E+08
4	NR 74272 20678	Stream	0.03	0.11	0.433	123.5	<100*	6.2E+07
5	NR 73892 20590	Stream	0.83	0.02	0.275	394.4	<100*	2.0E+08
6	NR 72982 19396	Stream	1.74	0.06	0.166	1497.3	3300	4.9E+10
7	NR 73350 19130	Stream	0.35	0.04	0.452	546.7	100	5.5E+08
8**	NR 73746 19122	Stream (S1)	1.00	0.01	0.178	553.7	100	5.5E+08
		Stream (S2)	0.18	0.08	0.259			
		Stream (S3)	0.35	0.01	0.257			
9	NR 74169 19159	Stream	0.90	0.01	0.125	97.2	<100*	4.9E+07
10	NR 75559 18645	Stream	0.50	0.04	0.118	203.9	<100*	1.0E+08

* *E. coli* results with a value of <100 have been assigned a nominal value of 50 when calculating loadings.
** Stream 8 had to be measured in three separate sections

No major rivers discharge to Campbeltown Loch, and as the catchment area is only 13 km^2, freshwater inputs to the loch are relatively small. The cumulative effect of these streams will increase the *E. coli* levels in Campbeltown Loch, although no attempt to quantify the magnitude of this effect has been made. It must be noted that the calculated loadings are based on one observation only, and so may not represent prevailing conditions. Streams 1, 2 and 6 contributed the highest loadings and were considerably more contaminated than the other streams sampled. These flow through both rural areas and then urban areas nearer the shore. No streams discharge directly into Kildalloig Bay, but several discharge to the south shore east of Kilkerran and thus may impact on the fishery.

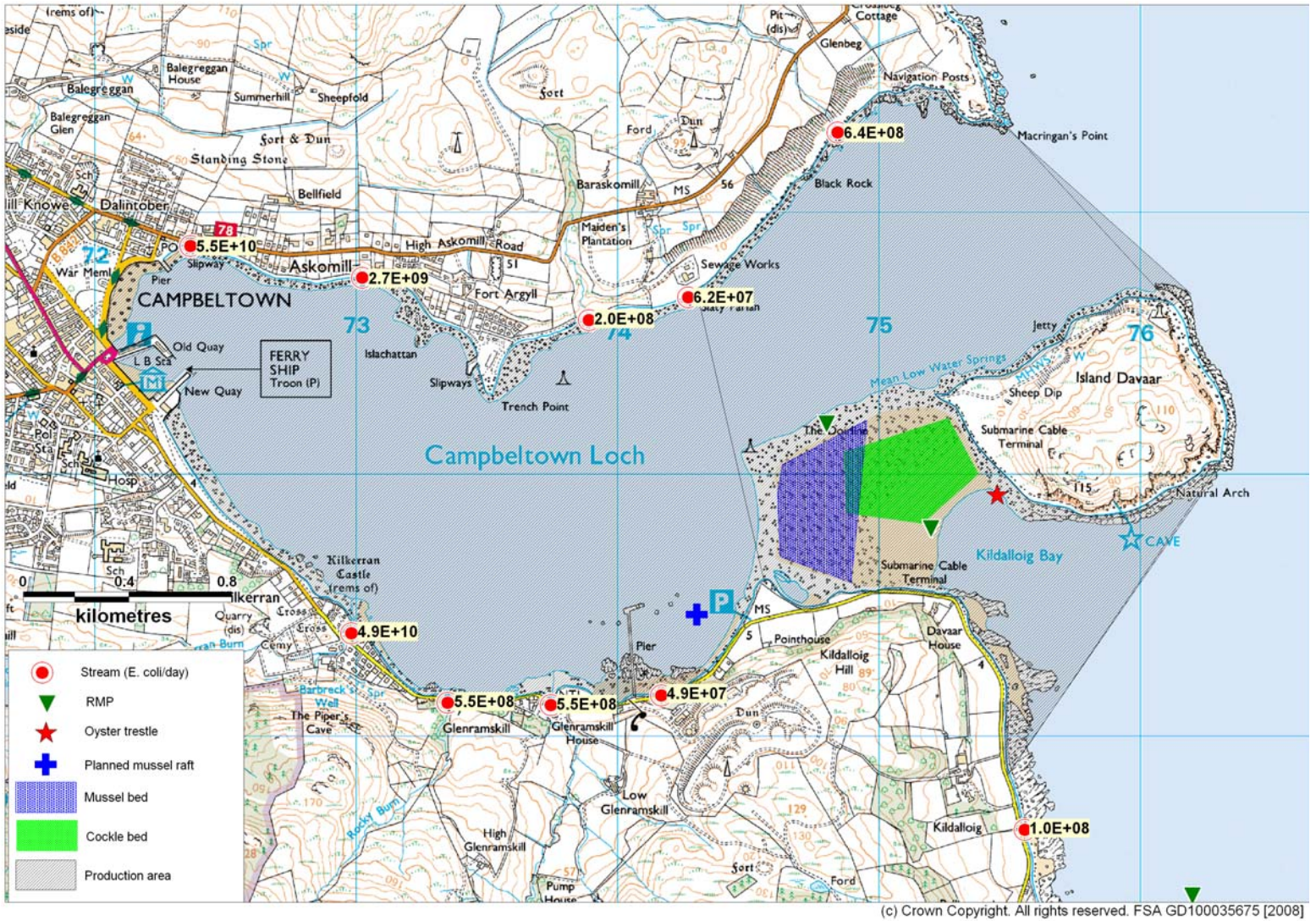

Figure 14.1 Significant streams and loadings at Campbeltown Loch

15. Shoreline Survey Overview

The sanitary survey at Campbeltown Loch was carried out in response to an application to harvest oysters from Kildalloig Bay.

The shoreline survey was conducted on the 6th to 8th May 2008 following a period of dry weather.

The fishery consisted of a single oyster trestle, and lightly exploited wild cockle and mussel beds on an intertidal shoal called the Doirlinn. Additionally, the harvester planned to deploy a mussel raft in Pointhouse Bay.

The majority of wastewater from Campbeltown is pumped from the Kinloch Park pumping station to the Scottish Water treatment works at Slaty Farlan, which is a membrane bioreactor system. This system is reported to overflow frequently during wet weather, resulting in spills from Kinloch Park which discharge into the loch just north of the main piers at the harbour. Sewage related debris was seen along much of the northeast shore. On the south shore, from Kilkerran east all houses are on private sewage systems, and 10 pipes discharging to the loch were seen in this area. Two private discharges to Kildalloig Bay and two private discharges from Davaar Island to outer Campbeltown were seen.

Campbeltown has three distilleries and several hotels and does experience an increase in population during the summer months. Due to its relatively remote location on the end of the Kintyre peninsula, it may not receive the same level of tourism as other more accessible but similar areas.

The land surrounding the loch is predominantly urban at its head. Along the north shore it is a mixture of gorse and pasture supporting some sheep. The south shore is similar, but with areas of improved pasture at its eastern end at Kildalloig Farm, where the highest numbers of livestock (sheep and cattle) were found. Slurry is spread on this pasture during the summer months. Davaar Island is pasture supporting a few sheep and goats. Two seals were seen in the main body of Campbeltown Loch.

Campbeltown Loch is a deepwater harbour, which is used by large freighters collecting timber and wind turbine parts from Macrihanish (two were seen during the course of the survey). The NATO pier on the south shore is used by naval vessels. Yachts use the moorings and pontoons near the head of the loch (21 were seen on the survey). A few fishing vessels operate from Campeltown (five were seen on the survey).

Shore mussel samples taken at various points around the loch generally had low levels of contamination (<230 *E. coli* mpn/100g). The one exception to this was a mussel sample taken from amongst the private discharges to the east of Kilkerran (2200 *E. coli* mpn/100g). The cockle and oyster sample taken from the Doirlinn both gave results of 500 *E. coli* mpn/100g, and the oyster sample tested positive for norovirus.

Generally, seawater samples taken from the loch gave *E. coli* results of <10 cfu/100ml. The highest result came from a sample collected in front of Kildalloig Farm (210 cfu/100ml) and another relatively high result (78 cfu/100ml) came from the harbour area at the head of the loch.

A few streams, but no major rivers discharge into the loch. These generally had relatively low levels of *E. coli* (100 cfu/100ml or less), but three had much higher levels of contamination (up to 7300 *E. coli* cfu/100ml).

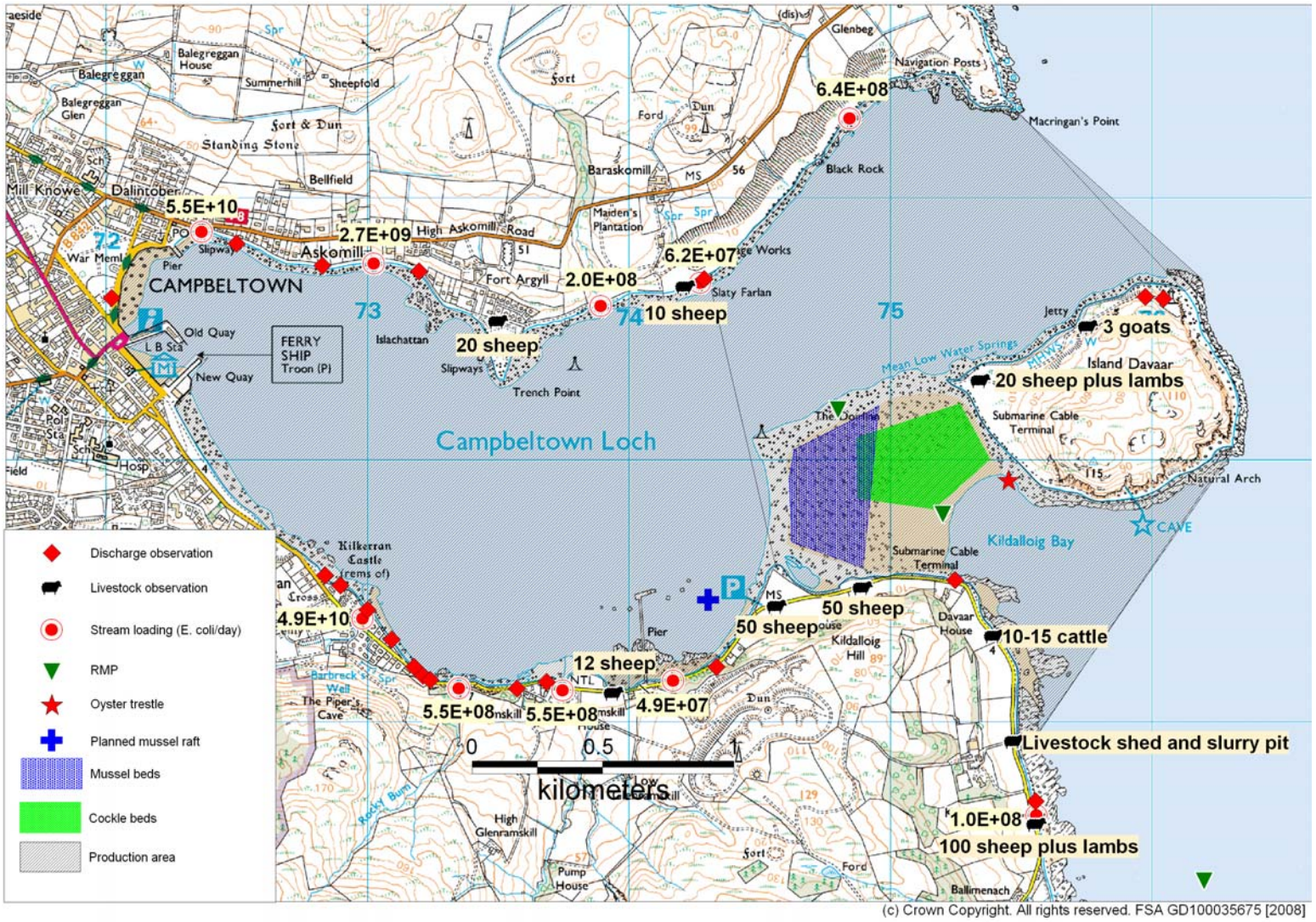

Figure 15.1 Summary of shoreline observations at Campbeltown Loch

16. Overall Assessment

Human sewage impacts

Campbeltown, together with Macrihanish and Drumlemble are served by the Scottish Water sewage works at Slaty Farlan on the north shore of the loch. This is an MBR plant, so effluent from here is likely to be very clean in bacteriological terms. The effluent is discharged just off from the sewage works, and so is likely mainly to impact along the north shore either side of the discharge. The system also incorporates a storm holding tank at Kinloch Park at the head of the loch. Spills containing raw sewage occur from here on a frequent basis following heavy rainfall. Sanitary debris was recorded in this area during the shoreline survey. While these spills will cause major impacts in the locality of the discharge, and decrease water quality in the loch as a whole, the level of impact on the existing and planned shellfisheries, the nearest of which is about 2.3 km away is uncertain. On one occasion when water samples were taken but Argyll & Bute Council following a spill contamination was found to be high in the immediate vicinity but not on the Doirlinn. On a second occasion when the same points were sampled following a spill, and exceptionally heavy rainfall, high levels of contamination were found at all sites including the site on the Doirlinn, but it is uncertain whether the high results here were a consequence of the Kinloch Park overflow, or other rainfall dependent sources of contamination. No relationship between historical *E. coli* classification results and spills was found despite reasonable sample numbers, so it is concluded that under normal conditions overflows from Kinloch Park do not result in major increases in levels of contamination of shellfish on the Doirlinn. However, interacting factors such as wind direction or tidal state could potentially affect any such contamination.

In addition to these major discharges there are 10 private discharges to the south shore of Campbeltown Loch east of Kilkerran, a further two on Davaar Island discharging to outer Campbeltown Loch, an overflow from Davaar house discharging to Kildalloig Bay, and an overflow from Kildalloig Farm discharging to the south of Kildalloig Bay. As these are small private discharges, it is likely their impact would be fairly localised so the discharge from Davaar House would be the most significant of these to the existing fishery due to its proximity.

It is likely that there are also relatively minor inputs from boat traffic.

Agricultural impacts

The highest concentrations of livestock were present around Kildalloig Farm, on the south shore of Kildalloig Bay so it is likely that diffuse inputs from livestock will be greatest adjacent to this area. Livestock are removed from the fields adjacent to the shore here during the summer months to allow the production of silage. Slurry is spread on these fields during the summer months when the weather conditions are appropriate. Lower densities of livestock were seen on Davaar Island, on the northeast shore, and on the south shore by the NATO pier. Livestock numbers are likely to be highest during the summer months.

Wildlife impacts

Potential wildlife impacting on the shellfishery includes seals, water birds, deer, dolphins and otters, but impacts from these animals are likely to be minor and difficult to predict temporally and geographically.

Seasonal variation

Campbeltown has three distilleries and several hotels and does experience an increase in population during the summer months. It has a busy marina with plans to expand capacity, indicating anticipated growth in tourism for the area.Higher numbers of visiting yachts are expected during the summer months.

Seasonal variations in livestock population are expected with an increase in numbers with the birth of lambs and calves in the spring. The weather is colder, wetter and windier in the autumn and winter months. A significant seasonal pattern was found in historic monitoring results, with higher *E. coli* levels in both species of shellfish (wild cockles and mussels) in the summer months.

Rivers and streams

No major rivers discharge to Campbeltown Loch, and as the catchment area is only 13 km^2, freshwater inputs to the loch are relatively small. Three of the 10 streams sampled during the shoreline survey contributed the highest loadings and were considerably more contaminated than the other streams sampled. Four streams discharge to the south shore within 1.5 km of the planned mussel raft location, including one of the more contaminated ones. No streams discharge directly into Kildalloig Bay.

Meteorology, hydrology, and movement of contaminants

Currents in the loch are likely to be driven primarily by tides and winds, with freshwater (density) driven currents of less importance due to the low freshwater inputs to the loch. Tidally driven currents will carry contamination originating from sources on the north shore along this shore rather than across the loch, so these sources will not have a great effect on shellfish on the south shore and the Doirlinn. Similar tidal currents will run along the south shore, and on the ebb tide these currents will carry contamination from sources here towards the shellfish beds on the Doirlinn. On the first half of the ebb tide, when the Doirlinn is covered, this contamination will be carried across the Doirlinn and into Kildalloig Bay. No significant relationship was found between historic *E. coli* monitoring results and tide size (spring/neap) for either cockles or mussels, but an increase in median result with increasing tide size was observed in cockles, tentatively suggesting that some contamination sources may be close enough to have an impact on spring tides, but far away enough to have less of an impact on neap tides.

The prevailing wind direction at Prestwick, the nearest Meteorological Office wind station, is from the southwest. The loch and Kildalloig Bay are most exposed to winds from the east, and winds from the west will be funnelled down the loch by the surrounding land. Westerly winds will drive surface currents from the inner

loch towards the Doirlinn, and northerly winds may drive surface currents from the north shore and main body of the loch towards the Doirlinn. Analysis of historic *E. coli* monitoring results found no correlation between mean wind direction in the previous 7 days and *E. coli* result.

A weak positive relationship was found between historic *E. coli* monitoring results and rainfall in the previous 7 days for cockles only. This suggests that some sources of microbial contamination affecting this production area are rainfall dependent, such as runoff from pasture and intermittent discharges, but this effect is minor and for one species only.

It must be stressed that the levels of contamination found in shellfish here will be due a combination of many factors, including the loadings of contaminants from various sources entering the loch, the way that these are transported within the loch due to tide and wind, and the rates of uptake and depuration by the shellfish themselves. The data available from historical monitoring were too limited to undertake a full analysis of the interaction of these factors.

Temporal and geographical patterns of sampling results

No overall improvement or deterioration of results was apparent over the course of the *E. coli* classification sampling history. A seasonal effect was found, with results for both species highest in the summer, suggesting that either inputs are higher in summer and/or the uptake of bacteria by the shellfish is higher in warmer water.

When all historic *E. coli* monitoring results were considered, cockles appeared to have higher levels of contamination towards the south of the bed, and mussels towards the north of the bed. These impressions must be treated with caution as they appear to be contradictory and may be attributed to temporal effects as the sampling locations changed with time. Also, the accuracy of reported sampling locations prior to the start of the OC sampling programme cannot be verified.

When multiple locations were sampled over a short time period at the start of historic *E. coli* monitoring, no spatial pattern was apparent in cockles, and there was the tentative suggestion of higher levels of contamination on the south shore of Kildalloig Bay in mussels.

Shore mussel samples taken at various points around the loch during the shoreline survey had low levels of contamination (<230 *E. coli* mpn/100g), including those taken by the Slaty Farlan sewage works (40 *E. coli* mpn/100g), by the Kinloch Park pumping station (70 *E. coli* mpn/100g) and from the Doirlinn adjacent to Kildalloig Farm (<20 *E. coli* mpn/100g). The one exception to this was a mussel sample taken from amongst the private discharges to the east of Kilkerran (2200 *E. coli* mpn/100g). A cockle and an oyster sample taken from the Doirlinn both gave results of 500 *E. coli* mpn/100g, and the oyster sample tested positive for both norovirus genogroups. The presence of norovirus within the oyster sample implies that contamination of human origin is impacting on the fishery. Generally, seawater samples taken during the shoreline survey gave *E. coli* results of <10 cfu/100ml. The highest result came from a sample collected in front of Kildalloig Farm (210 cfu/100ml) and another relatively high result (78 cfu/100ml) came from

the harbour area at the head of the loch. Results of sampling undertaken as part of the shoreline survey are specific to the conditions on the date of sampling, and care should be exercised in drawing broader conclusions from this data.

Footnote:

Subsequent to distribution of the draft of this report, Scottish Water provided further modelling information regarding the planned improvement scheme with CSO outfall moved offshore of the current WWTW outfall near Slaty Farlan. Once this outfall is in place and operational, which currently looks to be sometime in 2011, the new CSO discharge could potentially impact the cockle bed on the Doirlinn, with the greatest potential for impact along the northern edge of the bed. It is not clear whether any potential impact from spills would extend to the oyster trestles on Davaar Island, however this is considered less likely.

17. Recommendations

Campbeltown Loch: Kildalloig Bay oysters (AB 371 778 13)
The current boundaries for the AB 371 production area are lines drawn between NR 7550 1886 and NR 7631 2005 and between NR 7611 2066 and NR 7548 2134 and between NR 7430 2069 and NR 7456 1960. These boundaries include the outer area of Campbeltown Loch itself across to the north shore, but the actual fishery only consists of a very small area on the north shore of Kildalloig Bay. Given the possibility of contamination from sources in the main body of the loch, it is recommended that the boundaries for this site be restricted sufficiently to prevent expansion to potentially more contaminated areas, but not so restricted as to prevent expansion of the fishery in its present area. Therefore, the recommended boundaries for this production area are lines drawn between NR 7546 2002 and NR 7537 1993 and between NR 7537 1993 and NR 7548 1983 and between NR 7548 1983 and NR 7556 1991 extending to MHWS.

As the fishery is currently limited in area to a few square meters, no geographical considerations aside from its actual location can realistically be taken into account when setting the RMP. Therefore, it is recommended that the RMP for this oyster production area be set at NR 7545 1993 where the trestle is located. Only stock of a harvestable size should be sampled. No sampling depth is applicable. Due to the seasonal changes in levels of contamination observed in other shellfish species here, it is recommended that sampling should be carried out monthly.

Campbeltown Loch: Kildalloig Bay mussels (AB 371 760 08)
As there is no commercial fishery here, it is not necessary for the area to be classified. An RMP has therefore not been recommended.

Campbeltown Loch cockles (AB 029 008 04)
The current boundaries for this production area are lines drawn between NR 7550 1886 and NR 7631 2005 and between NR 7611 2066 and NR 7548 2134 and between NR 7430 2069 and NR 7456 1960. Although the boundaries include the outer area of Campbeltown Loch itself including the north shore, this fishery is limited to the intertidal area called the Doirlinn. It is recommended that the boundaries for this production area be restricted to include only the intertidal area of the Doirlinn. The recommended production area boundaries are therefore the area bounded by lines drawn between NR 7522 2031 and NR 7451 2009 and between NR 7451 2009 and NR 7455 1959 and between NR 7530 1953 and NR 7558 1990 extending to MHWS.

To inform the location of the RMP for the cockle fishery, a number of factors should be taken into account including the actual location of the shellfish, any sampling results, and the likely most important sources of contamination. Historic *E. coli* monitoring results tentatively suggest that higher levels of contamination occur in cockles towards the south of the bed, but the opposite tendency was seen for mussels. Neither the water nor the shellfish sampling results from the shoreline survey provide robust evidence for the location of the RMP in any particular place. The most relevant sources of contamination include discharges and streams on the south shore of Campbeltown Loch, agricultural runoff from the Kildalloig Farm area, and the private discharge from Davaar House. Overall, these suggest the

RMP should be set as far to the south and west as it is feasible to collect samples. It is therefore recommended that the RMP be set at NR 7490 1987, which lies in the far southwestern extent of the identified cockle bed. However, it is noted that cockle densities are believed to be greatest towards the north east of the beds so should there be insufficient stock within 100 meters of the suggested RMP, it may require review in consultation with the local sampling officer. Due to the seasonal changes in levels of contamination it is recommended that monthly sampling be maintained for this production area.

Campbeltown Loch mussels (AB 407 808 08)
The planned mussel raft was still not in position at the time of writing, so no RMP or sampling plan will be recommended for this site at present. If and when gear is deployed at this site, a sampling plan can be recommended on the basis of this sanitary survey.

Finally, it is recommended that the sampling plan be reviewed should significant changes occur to the location and nature of discharges from the Campbeltown public sewer system (for example, upon completion of any discharges to the centre of the loch.)

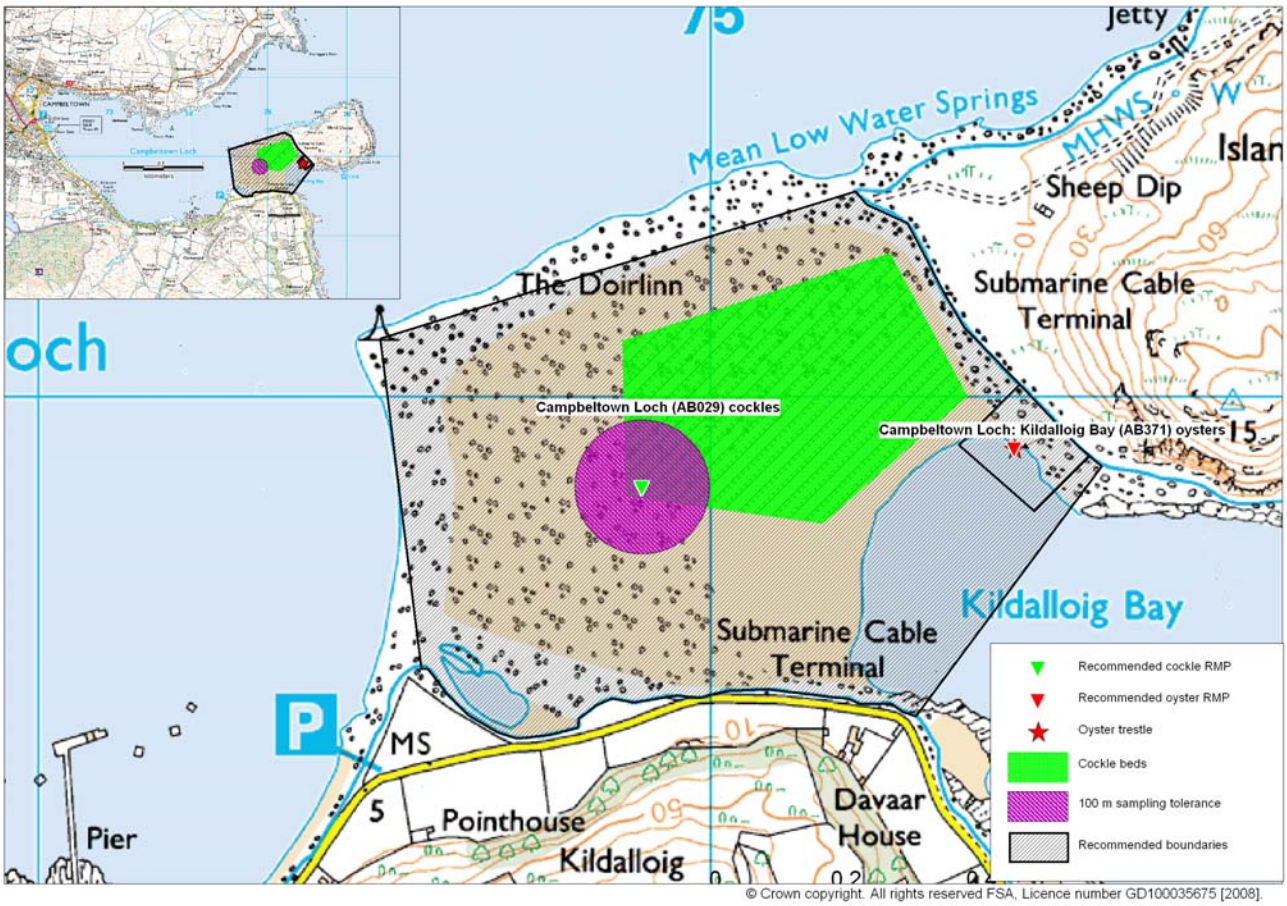

Figure 17.1 Recommended production area boundaries and RMPs for Campbeltown Loch

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Appendix 1

Sampling Plan for Campbeltown Loch

PRODUC-TION AREA	SITE NAME	SIN	SP.	TYPE OF FISH-ERY	NGR OF RMP	EAST	NORTH	TOLER-ANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Campbeltown Loch	Kildalloig Bay	AB 371	Pacific Oysters	Trestles	NR 7545 1993	17545	61993	10 m	N/A	Hand	Monthly	Argyll & Bute	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan
Campbeltown Loch	Kildalloig Bay	AB 029	Common Cockles	Wild harvest	NR 7490 1987	17490	61987	100 m	N/A	Hand	Monthly	Argyll & Bute	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan
Campbeltown Loch	Kildalloig Bay	AB 371	Common Mussels	Wild harvest	It is recommended that classification sampling be discontinued for this species.									
Campbeltown Loch	Pointhouse Bay	AB 407	Common Mussels	Rope	It is recommended that a sampling plan should be developed and instigated after the raft has been deployed.									

Comparative Table of Boundaries and RMPs – Campbeltown Loch

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Campbeltown Loch Cockle Bed	Common cockle	AB 029 008 04	The area bounded by lines drawn between NR 7550 1886 and NR 7631 2005 and between NR 7611 2066 and NR 7548 2134 and between NR 7430 2069 and NR 7456 1960	NR 752 198	**The area bounded by lines drawn between NR 7522 2031 and NR 7451 2009 and between NR 7451 2009 and NR 7455 1959 and between NR 7530 1953 and NR 7558 1990 extending to MHWS**	**NR 7490 1987**	Boundary and RMP amended
Campbeltown Loch: Kildalloig Bay Mussels	Common mussel - wild	AB 371 760 08	The area bounded by lines drawn between NR 7550 1886 and NR 7631 2005 and between NR 7611 2066 and NR 7548 2134 and between NR 7430 2069 and NR 7456 1960	NR 748 202	**Remove classification for mussels from production area**	**None recommended**	Area not harvested commercially, no CE permit in place for harvest of mussels
Campbeltown Loch: Kildalloig Bay	Pacific oysters	AB 371 778 13	New site lies within existing AB 371 production area as described above.	New area, no existing RMP	**The area bounded by lines drawn between NR 7546 2002 and NR 7537 1993 and between NR 7537 1993 and NR 7548 1983 and between NR 7548 1983 and NR 7556 1991 extending to MHWS**	**NR 7545 1993**	New boundary applies to oyster site only. New RMP
Campbeltown Loch Mussels	Common mussel - cultivated	AB 407 808 08	None	New area, no existing RMP	**FSAS have indicated no production area to be set at this time**	**None recommended**	No mussel raft in place, no seabed lease. Await installation of equipment and re-evaluate

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.

General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

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

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

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

Birds

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

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

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28×10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77×10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). An earlier study found that geese averaged from 5.23 to 18.79 defecations per hour while feeding, though it did not specify how many hours per day they typically feed (Bedard and Gauthier, 1986).

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

Deer

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

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

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

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

Other

The European Otter (*Lutra lutra*) is present around Scotland with some areas hosting populations of international significance. Coastal otters tend to be more active during the day, feeding on bottom-dwelling fish and crustaceans among the seaweed found on rocky inshore areas. An otter will occupy a home range extending along 4-5km of coastline, though these ranges may sometimes overlap (Scottish Natural Heritage website). Otters primarily forage within the 10 m depth contour and feed on a variety of fish, crustaceans and shellfish (Paul Harvey, Shetland Sea Mammal Group, personal communication).

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

References:

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

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

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

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

Tables of Typical Faecal Bacteria Concentrations

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

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	$1.7 \times 10^{7*}$ (+)	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

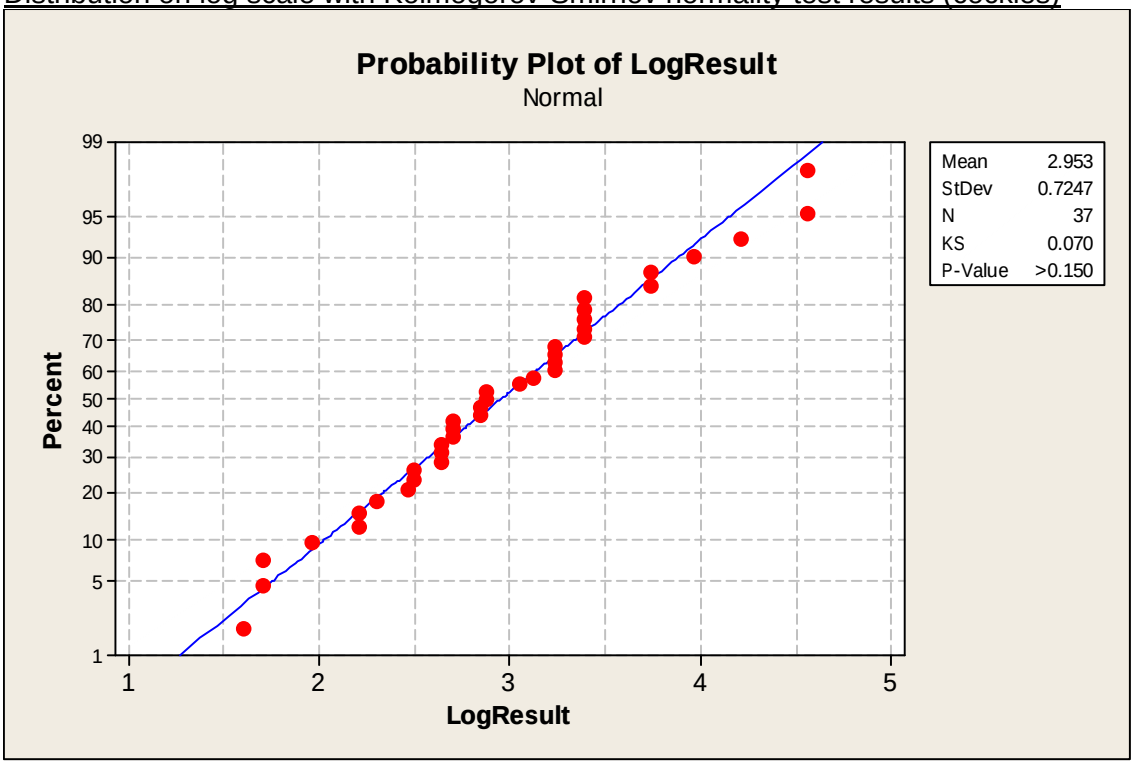
Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^{8}
Cow	230,000	23,600	5.4×10^{9}
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^{8}
Pig	3,300,000	2,700	8.9×10^{8}
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^{8}
Human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

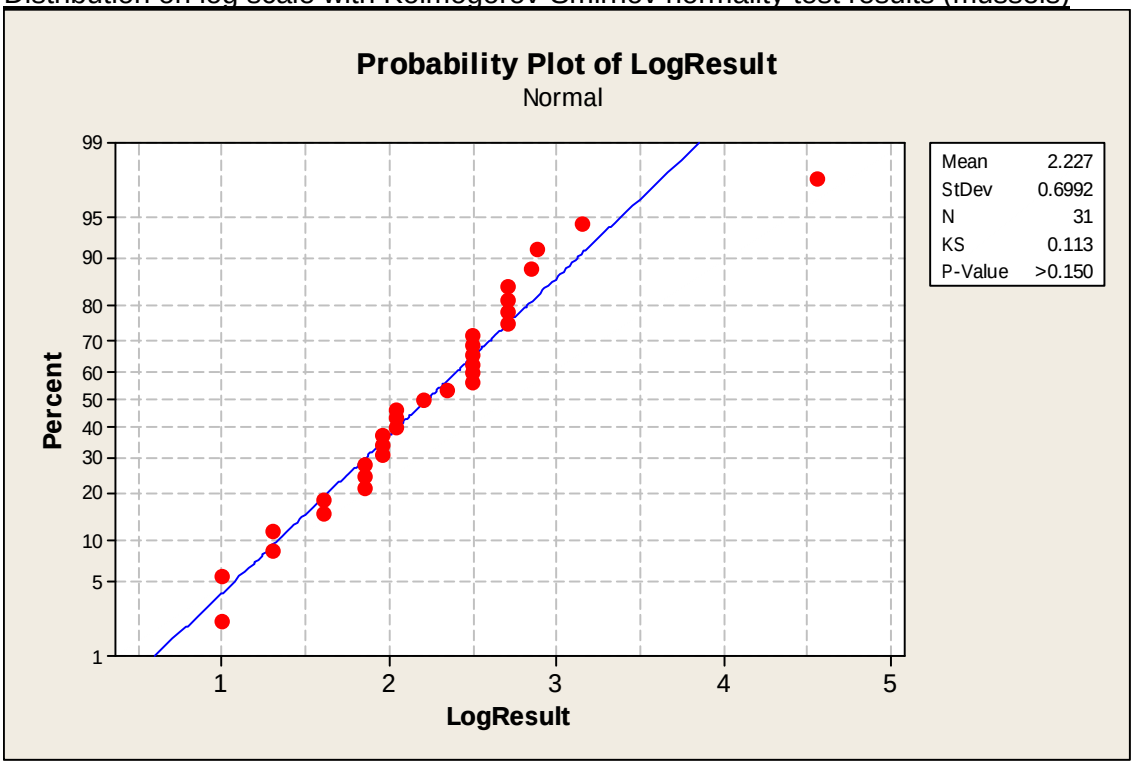
Statistical Data

All analyses were undertaken using log transformed results as this gives a more normal distribution.

Distribution on log scale with Kolmogorov-Smirnov normality test results (cockles)



Distribution on log scale with Kolmogorov-Smirnov normality test results (mussels)



Section 11.3.1 T-test comparison of cockle results taken from the RMP and elsewhere

```
Two-sample T for LogResult

rmp?   N   Mean  StDev  SE Mean
NOT   14  2.784  0.557     0.15
RMP   23  3.056  0.804     0.17


Difference = mu (NOT) - mu (RMP)
Estimate for difference:  -0.272
95% CI for difference:  (-0.728, 0.184)
T-Test of difference = 0 (vs not =): T-Value = -1.21  P-Value = 0.233  DF =
34
```

Section 11.3.1 T-test comparison of cockle results taken before and after the start of the OC sampling programme

```
Two-sample T for LogResult

OC?   N   Mean  StDev  SE Mean
n    31  2.989  0.709     0.13
y     6  2.767  0.846     0.35


Difference = mu (n) - mu (y)
Estimate for difference:  0.223
95% CI for difference:  (-0.678, 1.123)
T-Test of difference = 0 (vs not =): T-Value = 0.60  P-Value = 0.567  DF = 6
```

Section 11.3.1 T-test comparison of mussel results taken from the RMP and elsewhere

```
Two-sample T for logresult

RMP?    N   Mean  StDev  SE Mean
OTHER  14  2.145  0.586     0.16
RMP    17  2.294  0.792     0.19


Difference = mu (OTHER) - mu (RMP)
Estimate for difference:  -0.149
95% CI for difference:  (-0.657, 0.359)
T-Test of difference = 0 (vs not =): T-Value = -0.60  P-Value = 0.552  DF =
28
```

Section 11.3.1 T-test comparison of mussel results taken before and after the start of the OC sampling programme

```
Two-sample T for logresult

OC?    N   Mean  StDev  SE Mean
POST   7  2.167  0.665     0.25
PRE   24  2.245  0.722     0.15


Difference = mu (POST) - mu (PRE)
Estimate for difference:  -0.077
95% CI for difference:  (-0.726, 0.571)
T-Test of difference = 0 (vs not =): T-Value = -0.27  P-Value = 0.796  DF =
10
```

Section 11.5 ANOVA comparison of results by season (cockles)

```
Source  DF      SS     MS     F      P
Season   3   5.746  1.915  4.80  0.007
Error   33  13.158  0.399
Total   36  18.904

S = 0.6315   R-Sq = 30.40%   R-Sq(adj) = 24.07%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  ------+---------+---------+---------+---
1       9  2.6357  0.7049  (--------*-------)
2       8  3.5408  0.6375                   (--------*--------)
3       7  3.2816  0.7733             (---------*--------)
4      13  2.6344  0.4788    (------*------)
                          ------+---------+---------+---------+---
                              2.50      3.00      3.50      4.00

Pooled StDev = 0.6315


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

Individual confidence level = 98.94%


Season = 1 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
2        0.0742   0.9051  1.7361                   (-------*-------)
3       -0.2159   0.6459  1.5078                (-------*--------)
4       -0.7429  -0.0013  0.7403            (------*------)
                                  -------+---------+---------+---------+--
                                      -1.0       0.0       1.0       2.0


Season = 2 subtracted from:

Season    Lower   Center    Upper  -------+---------+---------+---------+--
3       -1.1443  -0.2592   0.6259        (-------*--------)
4       -1.6749  -0.9064  -0.1380  (-------*-------)
                                   -------+---------+---------+---------+--
                                       -1.0       0.0       1.0       2.0


Season = 3 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
4       -1.4489  -0.6472  0.1545     (-------*-------)
                                  -------+---------+---------+---------+--
                                      -1.0       0.0       1.0       2.0
```

Section 11.5 ANOVA comparison of results by season (mussels)

```
Source  DF      SS     MS     F      P
Season   3   4.434  1.478  3.90  0.020
Error   27  10.234  0.379
Total   30  14.668

S = 0.6157   R-Sq = 30.23%   R-Sq(adj) = 22.48%
```

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
1      14  2.0823  0.4852             (----*----)
2       6  2.8155  0.9629                       (------*-------)
3       7  2.4013  0.5544                  (------*------)
4       4  1.5469  0.4806  (--------*--------)
                          -------+---------+---------+---------+--
                               1.40      2.10      2.80      3.50

Pooled StDev = 0.6157


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

Individual confidence level = 98.92%


Season = 1 subtracted from:

Season    Lower   Center   Upper     +---------+---------+---------+--------
-
2       -0.0889   0.7332  1.5552                        (------*------)
3       -0.4609   0.3190  1.0989                     (------*-----)
4       -1.4906  -0.5354  0.4198              (-------*------)
                          +---------+---------+---------+--------
-
                                -2.4      -1.2       0.0       1.2


Season = 2 subtracted from:

Season    Lower   Center    Upper     +---------+---------+---------+-------
--
3       -1.3515  -0.4141   0.5232              (-------*------)
4       -2.3561  -1.2686  -0.1811     (--------*--------)
                                     +---------+---------+---------+-------
--
                                  -2.4      -1.2       0.0       1.2


Season = 3 subtracted from:

Season    Lower   Center   Upper     +---------+---------+---------+--------
-
4       -1.9104  -0.8544  0.2015          (--------*--------)
                          +---------+---------+---------+--------
-
                                -2.4      -1.2       0.0       1.2
```

Section 11.6.1 Regression analysis - log Result versus rain in previous 2 days (cockles)

```
The regression equation is
Rain 2 days = - 1.61 + 1.89 LogResult


Predictor    Coef  SE Coef      T      P
Constant   -1.614    3.535  -0.46  0.651
LogResult   1.890    1.164   1.62  0.113


S = 5.05924   R-Sq = 7.0%   R-Sq(adj) = 4.4%


Analysis of Variance
```

```
Source          DF      SS     MS     F      P
Regression       1   67.54  67.54  2.64  0.113
Residual Error  35  895.86  25.60
Total           36  963.40


Unusual Observations

                Rain 2
Obs  LogResult    days    Fit  SE Fit  Residual  St Resid
 16       4.56   0.000  6.998   2.042    -6.998     -1.51 X
 28       4.56   5.200  6.998   2.042    -1.798     -0.39 X
 30       2.85  21.800  3.763   0.841    18.037      3.62R

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

Section 11.6.1 Regression analysis - log Result versus rain in previous 2 days (mussels)

```
The regression equation is
LogResult = 2.09 + 0.0266 Rain 2 days


Predictor       Coef  SE Coef      T      P
Constant      2.0947   0.1781  11.76  0.000
Rain 2 days  0.02664  0.02545   1.05  0.304


S = 0.698116   R-Sq = 3.6%   R-Sq(adj) = 0.3%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.5342  0.5342  1.10  0.304
Residual Error  29  14.1336  0.4874
Total           30  14.6678


Unusual Observations

     Rain 2
Obs    days  LogResult    Fit  SE Fit  Residual  St Resid
 20     5.2      4.556  2.233   0.126     2.323      3.38R
 22    21.8      2.491  2.676   0.446    -0.184     -0.34 X

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

Section 11.6.1 ANOVA comparison of log Result versus rainfall quartile in previous 2 days (cockles)

```
Source     DF      SS     MS     F      P
2 day r q   3   2.038  0.679  1.33  0.282
Error      33  16.866  0.511
Total      36  18.904

S = 0.7149   R-Sq = 10.78%   R-Sq(adj) = 2.67%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ---+---------+---------+---------+------
```

```
Q1      8  2.8614  0.8298  (---------*----------)
Q2     13  2.7494  0.5962  (-------*-------)
Q3     11  3.0217  0.8196       (-------*--------)
Q4      5  3.4785  0.5156            (------------*------------)
                           ---+---------+---------+---------+------
                            2.50      3.00      3.50      4.00

Pooled StDev = 0.7149
```

Section 11.6.1 ANOVA comparison of log Result versus rainfall quartile in previous 2 days (mussels)

```
Source     DF      SS     MS     F      P
2 day r q   3   0.709  0.236  0.46  0.714
Error      27  13.959  0.517
Total      30  14.668

S = 0.7190   R-Sq = 4.83%   R-Sq(adj) = 0.00%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ----+---------+---------+---------+-----
Q1      2  2.0000  0.9885  (-----------------*-----------------)
Q2      8  2.1406  0.6199            (---------*-------)
Q3     17  2.2082  0.7770                (-----*-----)
Q4      4  2.5945  0.4589                (-----------*------------)
                           ----+---------+---------+---------+-----
                             1.20      1.80      2.40      3.00

Pooled StDev = 0.7190
```

Section 11.6.1 Regression analysis - log Result versus rain in previous 7 days (cockles)

```
The regression equation is
LogResult = 2.61 + 0.0221 Rain 7 days


Predictor        Coef   SE Coef      T      P
Constant       2.6112    0.1833  14.25  0.000
Rain 7 days  0.022126  0.009376   2.36  0.024


S = 0.682623   R-Sq = 13.7%   R-Sq(adj) = 11.3%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   2.5953  2.5953  5.57  0.024
Residual Error  35  16.3091  0.4660
Total           36  18.9043


Unusual Observations

     Rain 7
Obs    days  LogResult    Fit  SE Fit  Residual  St Resid
 12    43.4      2.875  3.571   0.285    -0.696     -1.12 X
 16     9.0      4.556  2.810   0.127     1.746      2.60R
 28    13.4      4.556  2.908   0.114     1.649      2.45R

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

Section 11.6.1 Regression analysis - log Result versus rain in previous 7 days (mussels)

```
The regression equation is
LogResult = 2.15 + 0.00509 Rain 7 days


Predictor        Coef   SE Coef      T      P
Constant       2.1499    0.1924  11.17  0.000
Rain 7 days  0.005087  0.009506   0.54  0.597


S = 0.707699   R-Sq = 1.0%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.1434  0.1434  0.29  0.597
Residual Error  29  14.5243  0.5008
Total           30  14.6678


Unusual Observations

     Rain 7
Obs    days  LogResult    Fit  SE Fit  Residual  St Resid
 20    13.4      4.556  2.218   0.128     2.338      3.36R

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

Section 11.6.1 ANOVA comparison of log Result versus rainfall quartile in previous 7 days (cockles)

```
Source     DF      SS     MS     F      P
7 day r q   3   4.128  1.376  3.07  0.041
Error      33  14.776  0.448
Total      36  18.904

S = 0.6692   R-Sq = 21.84%   R-Sq(adj) = 14.73%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
Q1      9  2.4504  0.6795  (-------*------)
Q2     14  3.0415  0.7709             (-----*-----)
Q3     10  3.0212  0.5043           (------*-------)
Q4      4  3.6046  0.5966                 (----------*----------)
                           -------+---------+---------+---------+--
                                2.40      3.00      3.60      4.20

Pooled StDev = 0.6692


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of 7 day r q

Individual confidence level = 98.94%


7 day r q = Q1 subtracted from:

7 day
```

```
r q      Lower  Center   Upper  -------+---------+---------+---------+--
Q2     -0.1832  0.5911  1.3654                (-------*-------)
Q3     -0.2619  0.5708  1.4034               (--------*-------)
Q4      0.0652  1.1542  2.2432                   (----------*---------)
                                -------+---------+---------+---------+--
                                    -1.0       0.0       1.0       2.0


7 day r q = Q2 subtracted from:

7 day
r q      Lower   Center   Upper  -------+---------+---------+---------+--
Q3     -0.7707  -0.0203  0.7300          (-------*------)
Q4     -0.4643   0.5631  1.5905             (----------*---------)
                             -------+---------+---------+---------+--
                                 -1.0       0.0       1.0       2.0


7 day r q = Q3 subtracted from:

7 day
r q      Lower  Center   Upper  -------+---------+---------+---------+--
Q4     -0.4887  0.5834  1.6555             (----------*----------)
                                -------+---------+---------+---------+--
                                    -1.0       0.0       1.0       2.0
```

Section 11.6.1 ANOVA comparison of log Result versus rainfall quartile in previous 7 days (mussels)

```
Source     DF      SS     MS     F      P
7 day r q   3   1.363  0.454  0.92  0.444
Error      27  13.305  0.493
Total      30  14.668

S = 0.7020   R-Sq = 9.29%   R-Sq(adj) = 0.00%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  -----+---------+---------+---------+----
Q1     14  2.1966  0.5680       (------*-----)
Q2      5  2.4470  1.2541       (-----------*----------)
Q3      9  1.9988  0.5858  (-------*-------)
Q4      3  2.6885  0.1921        (-------------*-------------)
                          -----+---------+---------+---------+----
                             1.80      2.40      3.00      3.60

Pooled StDev = 0.7020
```

Section 11.6.2 Regression analysis - log Result versus tide height (cockles)

```
The regression equation is
LogResult = - 0.68 + 1.30 Tide height


Predictor      Coef  SE Coef      T      P
Constant     -0.680    1.898  -0.36  0.722
Tide height  1.2963   0.6759   1.92  0.063


S = 0.699115   R-Sq = 9.5%   R-Sq(adj) = 6.9%


Analysis of Variance
```

```
Source          DF       SS      MS     F      P
Regression       1   1.7977  1.7977  3.68  0.063
Residual Error  35  17.1067  0.4888
Total           36  18.9043


Unusual Observations

       Tide
Obs  height  LogResult    Fit  SE Fit  Residual  St Resid
 15    3.20      4.204  3.468   0.292     0.736      1.16 X
 17    3.20      3.230  3.468   0.292    -0.238     -0.37 X
 28    2.90      4.556  3.079   0.132     1.477      2.15R
 33    2.90      1.602  3.079   0.132    -1.477     -2.15R

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

Section 11.6.2 Regression analysis - log Result versus tide height (mussels)

```
The regression equation is
LogResult = 1.30 + 0.33 Height of prev tide


Predictor             Coef  SE Coef     T      P
Constant             1.304    2.876  0.45  0.654
Height of prev tide  0.326    1.013  0.32  0.750


S = 0.709921   R-Sq = 0.4%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.0521  0.0521  0.10  0.750
Residual Error  29  14.6157  0.5040
Total           30  14.6678


Unusual Observations

     Height of
Obs  prev tide  LogResult    Fit  SE Fit  Residual  St Resid
 20       2.90      4.556  2.248   0.143     2.308      3.32R
 23       3.20      2.041  2.346   0.391    -0.304     -0.51 X

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

Section 11.6.3 Regression analysis - log Result versus water temperature (cockles)

```
The regression equation is
LogResult = 2.20 + 0.0789 WaterTemp


Predictor     Coef  SE Coef     T      P
Constant    2.2008   0.7280  3.02  0.005
WaterTemp  0.07891  0.07534  1.05  0.302


S = 0.723677   R-Sq = 3.0%   R-Sq(adj) = 0.3%
```

```
Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.5745  0.5745  1.10  0.302
Residual Error  35  18.3298  0.5237
Total           36  18.9043


Unusual Observations

Obs  WaterTemp  LogResult    Fit  SE Fit  Residual  St Resid
 16        8.0      4.556  2.832   0.166     1.724      2.45R
 28       10.0      4.556  2.990   0.124     1.566      2.20R
 35       14.0      3.380  3.306   0.357     0.075      0.12 X
 36       15.0      3.380  3.384   0.429    -0.004     -0.01 X

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

Section 11.6.3 Regression analysis - log Result versus water temperature (mussels)

```
The regression equation is
LogResult = 1.01 + 0.124 WaterTemp


Predictor     Coef  SE Coef     T      P
Constant    1.0077   0.6676  1.51  0.142
WaterTemp  0.12435  0.06695  1.86  0.073


S = 0.672321   R-Sq = 10.6%   R-Sq(adj) = 7.5%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   1.5593  1.5593  3.45  0.073
Residual Error  29  13.1085  0.4520
Total           30  14.6678


Unusual Observations

Obs  WaterTemp  LogResult    Fit  SE Fit  Residual  St Resid
 20       10.0      4.556  2.251   0.121     2.305      3.49R
 28       14.0      2.845  2.749   0.306     0.096      0.16 X
 29       15.0      2.491  2.873   0.368    -0.382     -0.68 X
 30       14.0      2.699  2.749   0.306    -0.050     -0.08 X

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

Section 11.6.4 Circular-linear correlation of wind direction and log result (cockles)

```
CIRCULAR-LINEAR CORRELATION
Analysis begun: 09 July 2008 10:24:44

Variables (& observations)     r       p
Angles & Linear (23)           0.193 0.476
```

Section 11.6.4 Circular-linear correlation of wind direction and log result (mussels)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 09 July 2008 10:30:46

Variables (& observations)	r	p
Angles & Linear (29)	0.291	0.11

Section 11.7 ANOVA comparison of results by Kinloch Park spill category (cockles)

```
Source              DF     SS     MS     F      P
% time spill cocks   2  0.296  0.148  0.22  0.807
Error               13  8.822  0.679
Total               15  9.118

S = 0.8238   R-Sq = 3.24%   R-Sq(adj) = 0.00%


                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level       N    Mean   StDev  ---------+---------+---------+---------+
A 0%        6  3.0134  1.0044       (-------------*--------------)
B 1 to 49%  6  2.7535  0.6576  (-------------*--------------)
C 50%+      4  3.0597  0.7339    (-----------------*-----------------)
                              ---------+---------+---------+---------+
                                     2.50      3.00      3.50      4.00

Pooled StDev = 0.8238
```

Section 11.7 ANOVA comparison of results by Kinloch Park spill category (mussels)

```
Source              DF      SS     MS     F      P
% time spill muss    2   1.109  0.555  0.96  0.402
Error               19  11.011  0.580
Total               21  12.121

S = 0.7613   R-Sq = 9.15%   R-Sq(adj) = 0.00%


                               Individual 95% CIs For Mean Based on
                               Pooled StDev
Level        N    Mean   StDev  --------+---------+---------+---------+-
A 0%         7  2.5265  1.1134       (------------*-----------)
B 1 to 49%  10  2.1195  0.5439  (---------*---------)
C 50%+       5  2.6196  0.4771       (-------------*--------------)
                               --------+---------+---------+---------+-
                                     2.00      2.50      3.00      3.50

Pooled StDev = 0.7613
```

Hydrographic Methods

1.0 Introduction

This document outlines the methodology used by Cefas to fulfil the requirements of the sanitary survey procedure with regard to hydrographic evaluation of shellfish production areas. It is written as far as possible to be understandable by someone who is not an expert in oceanography or computer modelling. This document collects together information common to all hydrographic assessments avoiding the repetition of information in each individual report.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only and is not discussed in any detail in this document. Selected sites will be assessed in more detail using either: 1) a hydrodynamic model, or 2) an extended consideration of sources, available field studies and expert assessment. This document will focus on this more detailed hydrographic assessment and describes the common methodology applied to all sites.

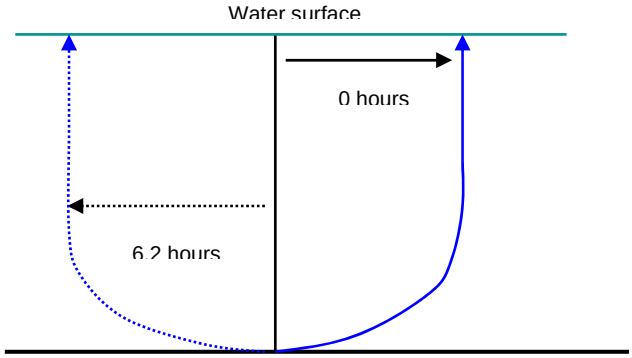
The regulations require an appreciation of the hydrography and currents within a region classified for shellfish production.

2.0 Background processes

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

Movement in the estuarine and coastal waters is generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences. Unless tidal flows are weak they usually dominate over the short term (~12 hours) and move material over the length of the tidal excursion. The tidal residual flow acts over longer time scales to give a net direction of transport. Whilst tidal flows generally move material in more or less the same direction at all depths, wind and density driven flows often move material in different directions at the surface and at the bed. Typical vertical profiles are depicted in figure 1. However, it should be understood that in a given water body, movement will often be the sum of all three processes.

a)



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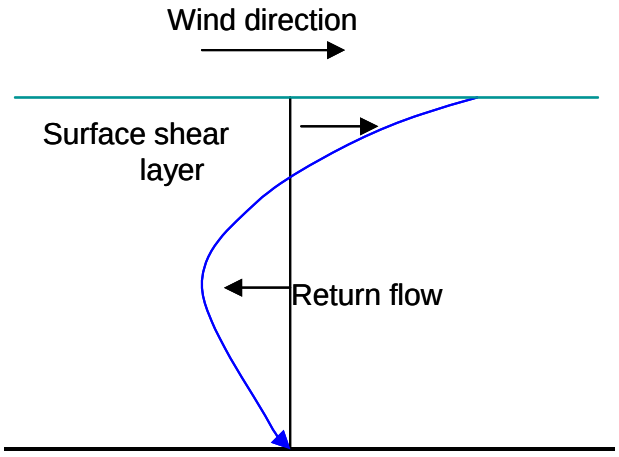

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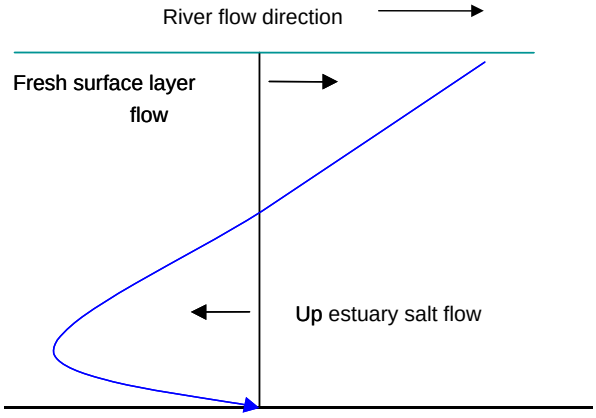

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

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

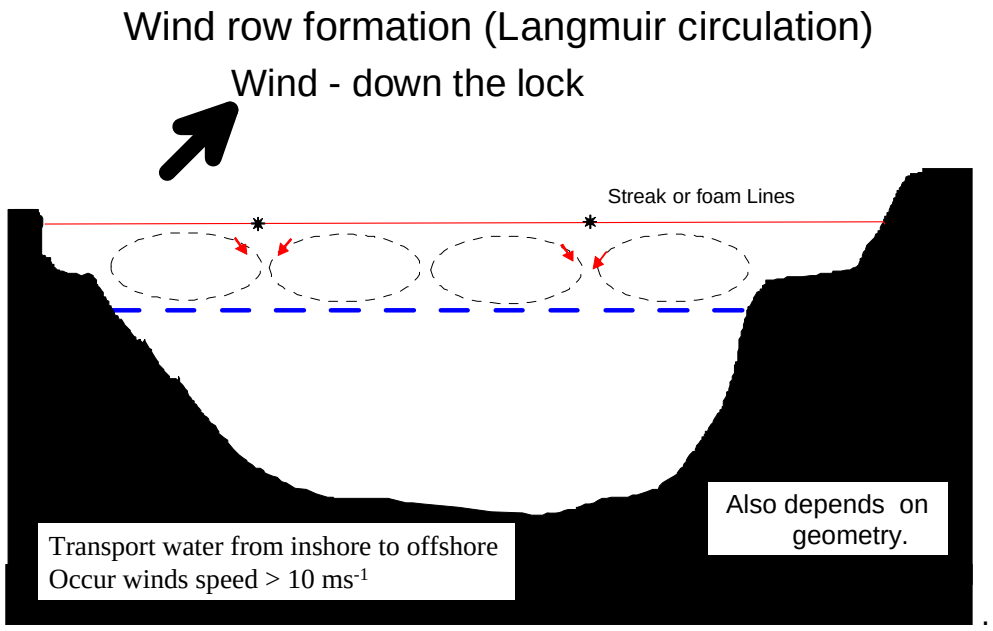

Figure 2: Schematic of wind driven ‘wind row’ currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Shoreline Survey Report

Campbeltown Loch: Kildalloig Bay (AB 371) and Campbeltown Loch (AB 029 and AB 407)

Scottish Sanitary Survey Project

Shoreline Survey Report

Production Areas:

Production Area	Site	SIN	Species
Campbeltown Loch: Kildalloig Bay	Kildalloig Bay Oysters	AB 371 778 13	Pacific oyster
Campbeltown Loch: Kildalloig Bay	Kildalloig Bay Mussels	AB 371 760 08	Common mussels
Campbeltown Loch	Kildalloig Bay	AB 029 008 04	Common cockles
Campbeltown Loch	Pointhouse Bay	AB 407 808 08	Common mussels

Harvesters: Mrs Mary Turner (Kildalloig Bay Oysters, Pointhouse Bay), General Public (Kildalloig Bay mussels and cockles)
Local Authority: Argyll and Bute Council
Status: Kildalloig Bay mussels and cockles are currently classified for harvest. Kildalloig Bay oysters and Pointhouse bay mussels are a new application.
Date Surveyed: 6/5/08 to 8/5/08
Surveyed by: Christine McLachlan, Alastair Cook
Existing RMPs: NR 748202, NR 752198
Area Surveyed: See Figure 1.

Weather observations

6/5/08 – Very light easterly winds, sunny, warm.
7/5/08 – Light easterly winds (6km/h), sunny, warm (19ºC).
8/5/08 – Light southeasterly (4km/h) winds, sunny, warm (17ºC).
No significant rain had fallen for several days prior to the survey.

Site Observations

Specific observations made on site are mapped in Figure 1 and listed in Table 1. The location of the shellfisheries is presented in Figure 2. Water and shellfish samples were collected at sites marked on Figures 3 and 4. Bacteriology results are given in Tables 2, 3 and 4. Photographs are presented in Figures 5-24.

Fishery
Kildalloig Bay Oysters (AB 371 778 13). This site currently consists of a single trestle of Pacific oysters (Figure 20), which has been laid to assess the viability of production at this site. The grower reports good growth at this location, and a further trestle was due to be laid shortly after the survey. Stock is supplied from another oyster farm in Argyll and Bute. The intended market is local hotels, restaurants and retailers. There are currently no depuration facilities available in the area.

Kildalloig Bay mussels (AB 371 760 08). This is a wild fishery, covering much of the Doirlinn, which is the intertidal area between Davaar Island and the mainland. Exploitation is light and is carried out privately by locals for personal consumption, mainly during the summer. Mussels were abundant in many areas all around Campbeltown Loch, but were particularly abundant on some areas of the Doirlinn, forming 'shoals' (Figure 22).

Kildalloig Bay cockles (AB 029 008 04). This is a wild fishery, covering much of the Doirlinn. Exploitation is mainly limited to locals gathering for personal consumption, but from time to time commercial gangs harvest the area when stocks are in sufficient abundance. Harvesting mainly occurs during the summer. Stocks appeared relatively sparse at the time of survey, but no detailed fishery survey was undertaken.

Pointhouse Bay mussels (AB 407 808 08). No apparatus or stock were in place at the time of survey. According to the harvester, a raft will be positioned here in the near future, from which ropes will be suspended to assess the viability of the fishery.

Additionally winkles are collected from the Doirlinn privately by locals for personal consumption. Empty shells of further exploitable species were seen in the area (e.g. razors, king and queen scallops, clams).

There are currently no Crown Estates seabed leases for shellfish farms within the area. A detailed map showing the position of the oyster trestles, the approximate positions of the cockle and mussel beds, and the approximate planned location of the Pointhouse bay mussel raft is shown in Figure 2.

Sewage/Faecal Sources

Human – Spread around the loch, centred at its head is the town of Campbeltown, with a population of around 6000. The majority of waste water from this settlement is pumped from the Kinloch pumping station, approximately at the head of the loch, to the Sewage works on the north shore opposite the Doirlinn, where it is treated by membrane bioreactor and discharged just offshore (Figures 12 and 13). The main sewage pipe runs along the north shore of the loch (Figure 9), and wastewater from the houses along this shore appears to feed into this pipe at regular intervals (Figure 8). The system is reported to struggle during wet periods, and this is reported to frequently result in untreated effluent being discharged from Kinloch pumping station to an overflow discharge just north of the main piers at the harbour. Evidence of these occurrences was seen in the form of cotton buds along much of the northeast shore of the loch (Figure 6). It should be noted that it was unlikely that the overflow discharge had been in operation in the days prior to the shoreline survey, as the weather had been dry for several days. Scottish Water are planning improvements to this system. These plans include moving the sewage works discharge further offshore, and rerouting the problematic overflow to the treatment works, where excess wastewater will either be stored and treated, or if necessary discharged here untreated.

On the south shore, from approximately the cemetery east, all houses are on private sewage systems, and numerous pipes discharging to the shore were seen along this stretch (e.g. Figures 16, 17 and 18). A few private sewage discharges to the shore were seen in the Kildalloig Bay and Pointhouse bay areas, and near the lighthouse on Davaar Island (Figure 21). The grower reported that there is also a septic tank system serving 7 houses at Fort Argyll on the north shore, but the exact location of this was not confirmed during the survey.

Livestock – Much of the area surveyed was urban. On the north shore, in the hills above the town and on the shoreline and hills to the east of town, 41 sheep were counted on pasture. Some cattle dung was observed in one place here. In most places outside of town on the north shore the animals had access to the shoreline. On the south shore, grassland was present on the hills above town. Around the Pointhouse and Kildalloig bay area were areas of improved grassland adjacent to the shore which supported relatively high densities of livestock (about 200 sheep and 10-15 cattle including those on higher ground further back) (Figure 24). The sheep are removed from the low-lying improved pasture during the summer months so silage can be produced. Slurry is spread on these fields in appropriate weather conditions during the summer months. A livestock shed and slurry pit were seen at Kildalloig Farm (Figure 23). On Davaar Island, relatively low numbers of sheep and a few goats were seen (20 and 3 respectively).

A few streams discharge into the loch. These drain a mixture of urban areas, pasture and some forest. Water samples were taken, and discharge estimated for these. It must be noted that water levels were low, as it had been dry for several days preceding the survey, and it is likely that their discharge will increase significantly following heavy rain.

Generally, seawater samples taken from the shore had fewer than 10 *E. coli* cfu/100ml. The highest result (210 *E. coli* cfu/100ml) came from a seawater sample collected from in front of Kildalloig farm. Another relatively high result (78 *E. coli* cfu/100ml) was found in the harbour area.

Shore mussel samples taken from around the loch generally contained fewer than 230 *E. coli* mpn/100g. The one mussel sample that exceeded this level (2200 *E. coli* mpn/100g) was taken from the south shore, in the area where a large number of private sewage discharges were seen. Both the cockle and oyster sample taken from the Doirlinn returned results of 500 *E. coli* mpn/100g, and the oyster sample tested positive for norovirus.

Seasonal Population

Campbeltown has 3 distilleries and a number of hotels, and does experience an increase in population in summer. The grower reported that Scottish Water had estimated that the population increases by 1000 during the summer months. Due to its relatively remote location on the southern end of the Kintyre peninsula, it may not receive the same level of tourism as other more accessible but similar areas.

Boats/Shipping

There is a deepwater harbour at Campbeltown, where a large freighter was seen loading with timber (Figure 14), and on the following day a different large freighter was seen loading with wind turbine parts. Five fishing boats operate from the harbour. 12 pleasure yachts were moored at a pontoon in the harbour area (Figure 5), 8 on moorings off the north shore, and one on moorings off the south shore.

In addition to the harbour and two mooring areas, the NATO pier (Figure 19) serves as a refuelling station for Naval vessels, although no activity was seen here during the course of the survey

Land Use

At the head of the loch, the shoreline is predominantly urban. Along the north shore the land is a mainly a mixture of gorse and pasture, behind the houses at its eastern end, and all the way down to the shoreline at the western end. The south shore is similar, but at its eastern end there are areas of improved pasture. Davaar Island is pasture.

Wildlife/Birds

No significant aggregations of wildlife were seen on the survey. Two seals were seen, one by the sewage works, and one in Campbeltown Loch just off the Doirlinn. The grower reports there is a seal haulout site on rocks to the south of Kildalloig Farm, but this was not observed during the survey. A few seagulls, oystercatchers and other waders were seen at various places around the loch. Three rabbits were seen between trench point and the sewage works.

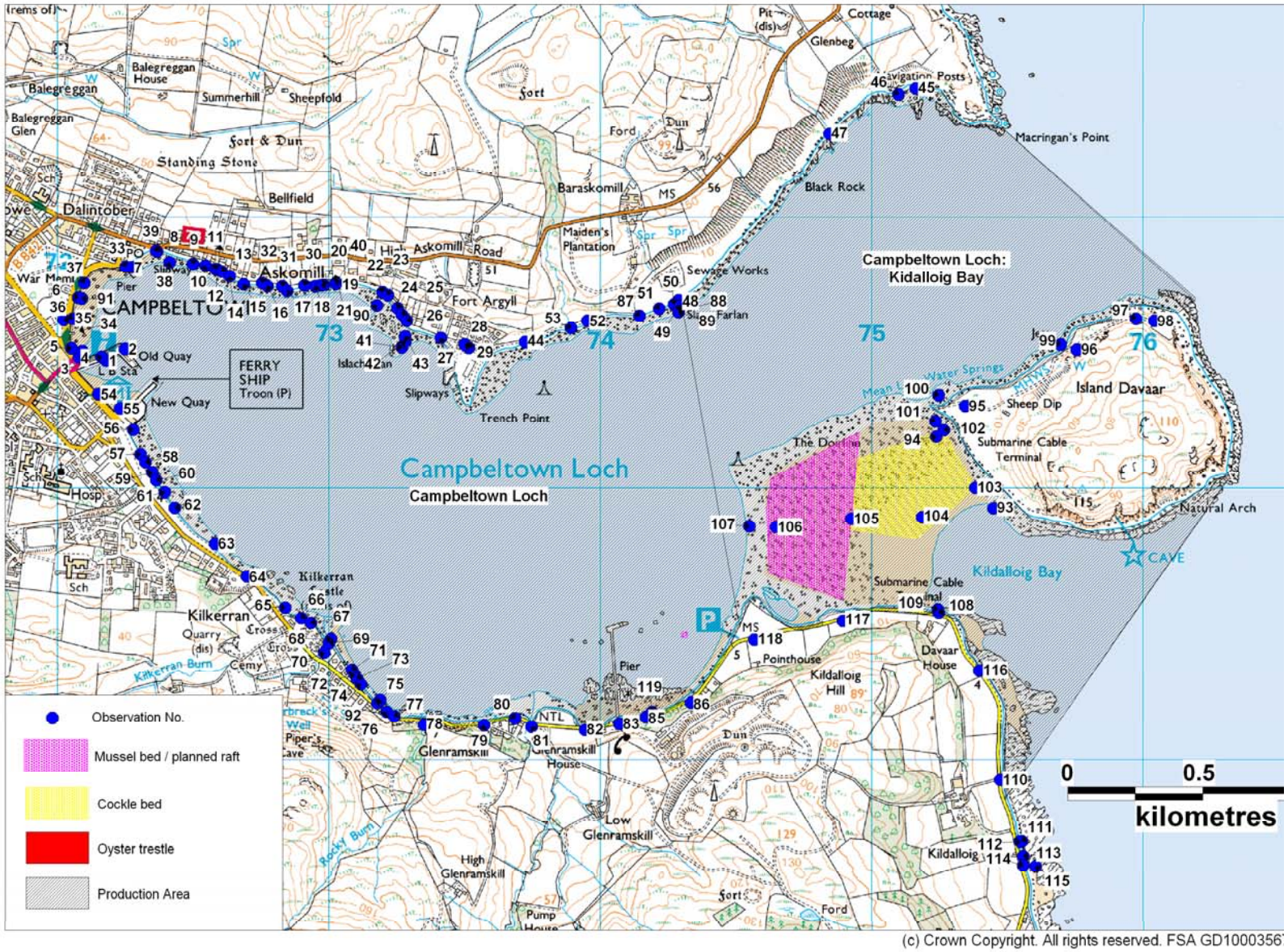

Figure 1. Map of Shoreline Observations

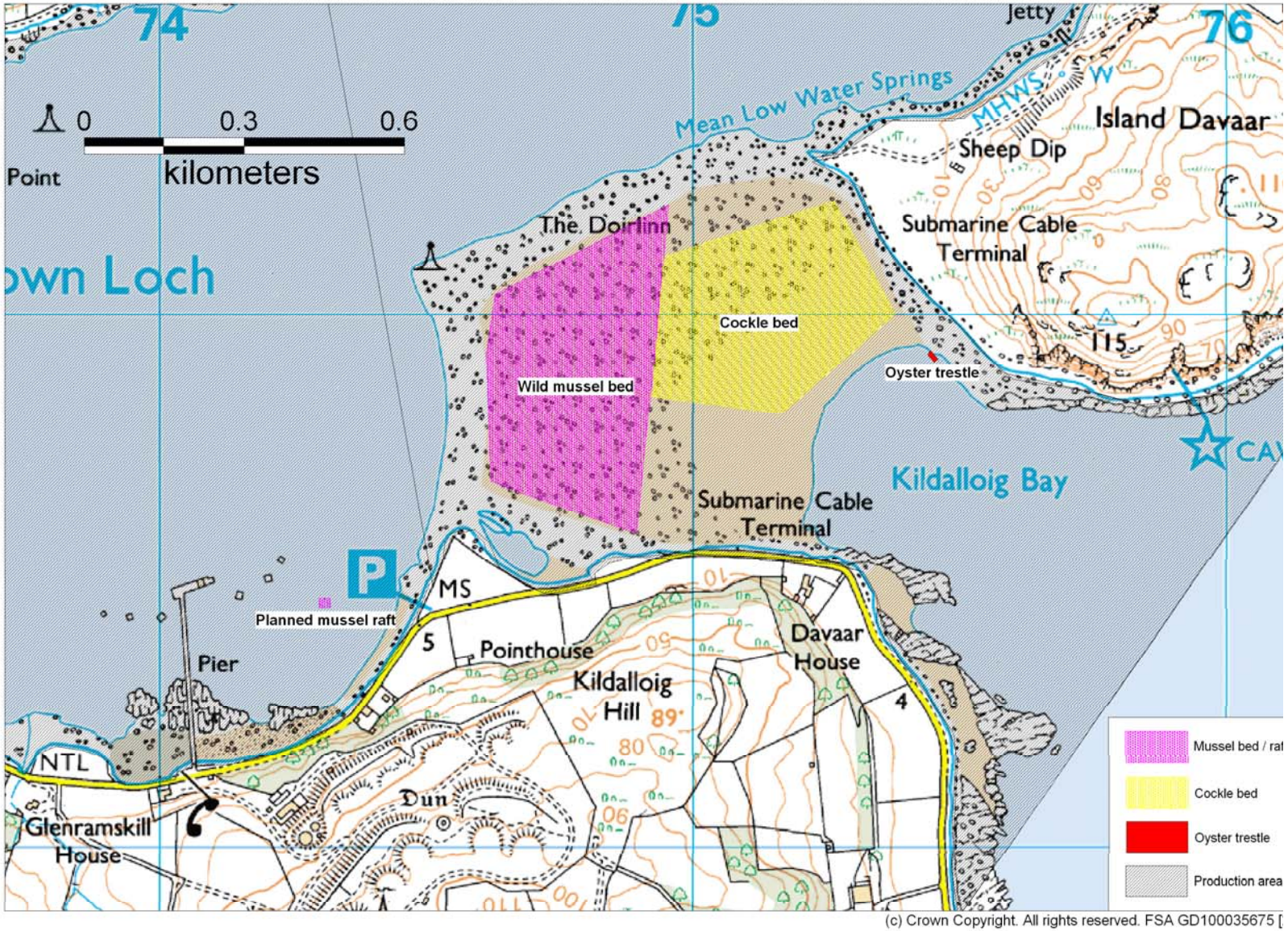

Figure 2. Detailed map of shellfisheries

Table 1. Shoreline Observations

No.	Date and Time	Grid Reference	Photograph	Description
1	06-MAY-08 2:48:25PM	NR 72177 20472		Fishing boat and Tug boat tied up
2	06-MAY-08 2:49:41PM	NR 72247 20513		Fish market
3	06-MAY-08 2:51:32PM	NR 72160 20485		Lifeboat and 4 fishing boats tied up
4	06-MAY-08 2:52:58PM	NR 72078 20483	Figure 5	Pontoon with 12 pleasure craft tied up
5	06-MAY-08 2:55:44PM	NR 72049 20517		White 13cm diameter pipe + metal 35cm pipe (surface drains?)
6	06-MAY-08 2:59:01PM	NR 72074 20702	Figure 6	Cotton buds in HW mark all along this stretch
7	06-MAY-08 3:07:17PM	NR 72273 20814		8 yachts on moorings just off here. SRD on shore.
8	06-MAY-08 3:09:07PM	NR 72362 20876		Stream (to be sampled next morning)
9	06-MAY-08 3:14:14PM	NR 72498 20827	Figure 7	Sewage inspection covers and enclosure in layby. Marker post about 20m off. Inspection cover with vent on either side of layby.
10	06-MAY-08 3:17:09PM	NR 72544 20821	Figure 8	2 x 150mm black plastic pipes
11	06-MAY-08 3:17:55PM	NR 72581 20808		Inspection cover with vent
12	06-MAY-08 3:19:10PM	NR 72588 20806		Black pipe and inspection cover
13	06-MAY-08 3:19:38PM	NR 72603 20799		150mm black pipe
14	06-MAY-08 3:20:11PM	NR 72632 20780		Inspection cover on shore with vent
15	06-MAY-08 3:20:55PM	NR 72684 20751		Inspection cover on shore with vent
16	06-MAY-08 3:22:13PM	NR 72772 20743		Inspection cover on shore with vent
17	06-MAY-08 3:24:29PM	NR 72845 20726		Inspection cover on shore with vent
18	06-MAY-08 3:28:01PM	NR 72949 20744		Black pipe
19	06-MAY-08 3:28:50PM	NR 72969 20746		Exposed concrete pipe casing running along shore
20	06-MAY-08 3:29:12PM	NR 72980 20748	Figure 9	Inspection cover on shore with vent
21	06-MAY-08 3:30:27PM	NR 73024 20755		Inspection cover on shore with vent, small stream
22	06-MAY-08 3:33:05PM	NR 73196 20721		Sewage inspection covers and enclosure in layby. Inspection cover with vent on shore below.
23	06-MAY-08 3:34:20PM	NR 73216 20711		Inspection cover on shore with vent
24	06-MAY-08 3:37:47PM	NR 73252 20664	Figure 10	Possible concrete pipe casing heading to sea.
25	06-MAY-08 3:38:10PM	NR 73268 20640		Black pipe
26	06-MAY-08 3:38:33PM	NR 73285 20617		Inspection cover on shore with vent, black pipe, marker post ~ 100m off
27	06-MAY-08 3:41:34PM	NR 73412 20554		2x Inspection cover with vent
28	06-MAY-08 3:43:52PM	NR 73514 20518		3 rabbits
29	06-MAY-08 3:52:36PM	NR 73500 20529		20 sheep on pasture on hill by radio mast
30	06-MAY-08 4:03:23PM	NR 72908 20746		Inspection cover on shore with vent, black pipe
31	06-MAY-08 4:05:30PM	NR 72827 20743		Faded orange plastic sewer pipe to sea
32	06-MAY-08 4:06:48PM	NR 72752 20756		Metal pipe and vent

No.	Date and Time	Grid Reference	Photograph	Description
33	06-MAY-08 4:14:53PM	NR 72250 20816		Inspection cover in alcove in sea wall
34	07-MAY-08 9:14:15AM	NR 72091 20505		Seawater sample 1
35	07-MAY-08 9:17:25AM	NR 72021 20620		Kinloch sewage pumping station
36	07-MAY-08 9:18:34AM	NR 72054 20625		Overflow from sewage pumping station at 95 degrees from here
37	07-MAY-08 9:24:39AM	NR 72097 20755		Overflow from sewage pumping station at 140 degrees from here
38	07-MAY-08 9:29:31AM	NR 72412 20833		Seawater sample 2
39	07-MAY-08 9:36:19AM	NR 72366 20873	Figure 11	Stream 97cmx3cmx0.38m/s. Freshwater sample 3
40	07-MAY-08 10:04:17AM	NR 73024 20752		Stream 48cmx3cmx0.03m/s. Freshwater sample 4
41	07-MAY-08 10:12:09AM	NR 73268 20519		Marker post previously noted here (when water higher) only marks rocks, no pipe.
42	07-MAY-08 10:13:31AM	NR 73280 20538		Seawater sample 5
43	07-MAY-08 10:24:59AM	NR 73279 20560		Shore mussel sample 1
44	07-MAY-08 10:37:47AM	NR 73722 20538		Pasture behind. Cattle dung. Dog droppings on path.
45	07-MAY-08 11:05:59AM	NR 75162 21473		Seawater sample 6. Land behind all along here is rough grazing with gorse. Wool on fences, sheep tracks, some dung. No fence to shore. 11 sheep seen higher on hill (fenced in up here).
46	07-MAY-08 11:20:10AM	NR 75098 21451		Shore mussel sample 2
47	07-MAY-08 11:31:58AM	NR 74844 21306		Stream 73cmx5cmx0.405m/s. Freshwater sample 7
48	07-MAY-08 11:46:09AM	NR 74287 20692	Figure 12	Campbeltown STW discharge circa 60m off from here. Boil visible on surface. STW behind.
49	07-MAY-08 11:47:12AM	NR 74293 20672		Seawater sample 8. 1 seal just off here
50	07-MAY-08 11:55:38AM	NR 74272 20678	Figure 13	Surface runoff (2 pipes) to beach. 3cmx11cmx0.433m/s. Freshwater sample 9
51	07-MAY-08 12:00:14PM	NR 74217 20662		10 sheep on top of hill behind.
52	07-MAY-08 12:03:58PM	NR 73952 20617		Livestock feeder behind.
53	07-MAY-08 12:05:28PM	NR 73892 20590		Stream 83cmx2cmx0.275m/s. Freshwater sample 10
54	07-MAY-08 12:50:35PM	NR 72148 20347	Figure 14	32 seagulls on water
55	07-MAY-08 12:52:36PM	NR 72229 20295	Figure 14	Seawater sample 11. Containership being loaded with wood alongside jetty. Another large ship waiting to be loaded in bay.
56	07-MAY-08 12:57:36PM	NR 72277 20216		SRD in tideline.
57	07-MAY-08 12:59:54PM	NR 72305 20127	Figure 15	250mm black metal pipe underwater (possible surface drain)
58	07-MAY-08 1:02:12PM	NR 72322 20097		250mm black metal pipe underwater (possible surface drain)
59	07-MAY-08 1:04:52PM	NR 72347 20060		Storm water overflow?
60	07-MAY-08 1:06:13PM	NR 72363 20031		Storm water overflow?
61	07-MAY-08 1:07:09PM	NR 72394 19987		250mm black metal pipe underwater (possible surface drain)
62	07-MAY-08 1:08:43PM	NR 72430 19930		150mm black metal pipe underwater (possible surface drain)
63	07-MAY-08 1:12:02PM	NR 72579 19796		Seawater sample 12
64	07-MAY-08 1:16:19PM	NR 72697 19675		Iron pipe containing telecoms cable heading out to sea
65	07-MAY-08 1:20:11PM	NR 72837 19560	Figure 16	100mm cast iron pipe to underwater
66	07-MAY-08 1:23:03PM	NR 72896 19522		Inspection cover, concrete pipe casing heading to sea. 110mm orange plastic pipe alongside.

No.	Date and Time	Grid Reference	Photograph	Description
67	07-MAY-08 1:25:05PM	NR 72933 19504		Inspection cover on beach
68	07-MAY-08 1:27:58PM	NR 73007 19444		Inspection cover on beach
69	07-MAY-08 1:28:41PM	NR 72999 19429		110mm orange platic sewer pipe to sea mainly buried.
70	07-MAY-08 1:30:51PM	NR 72982 19396		Stream 174cmx6cmx0.166m/s. Freshwater sample 13.
71	07-MAY-08 1:36:55PM	NR 73084 19331		2 x 7cm metal pipes partially buried.
72	07-MAY-08 1:37:59PM	NR 73092 19315		300mm ceramic pipe to HW mark (not flowing)
73	07-MAY-08 1:39:04PM	NR 73101 19301		Seawater sample 14
74	07-MAY-08 1:41:28PM	NR 73117 19279	Figure 17	110mm pastic pipe to underwater. I yacht moored ~100m off and 8 empty moorings. Houses then scrub/gorse/pasture behind.
75	07-MAY-08 1:44:34PM	NR 73178 19210		150mm metal pipe to underwater.
76	07-MAY-08 1:45:46PM	NR 73212 19177		120mm metal pipe to high water mark (not flowing)
77	07-MAY-08 1:46:55PM	NR 73239 19161		110mm metal pipe to underwater
78	07-MAY-08 1:50:34PM	NR 73350 19130		Stream 35cmx4cmx0.452m/s. Freshwater sample 15.
79	07-MAY-08 1:58:19PM	NR 73571 19128		150mm cast iron pipe to underwater
80	07-MAY-08 2:00:49PM	NR 73685 19153	Figure 18	150mm metal pipe and 150mm plastic pipe alongside each other to underwater
81	07-MAY-08 2:04:07PM	NR 73746 19122		Stream (measured in 3 sections). S1 100cmx1cmx0.178m/s. S2 18cmx8cmx.259m/s. S3 35cmx1cmx.257m/s. Freshwater sample 16.
82	07-MAY-08 2:20:47PM	NR 73943 19111		Field of 12 sheep
83	07-MAY-08 2:23:03PM	NR 74070 19133	Figure 19	NATO pier and depot (used for refuelling naval vessels)
84	07-MAY-08 2:25:40PM	NR 74169 19159		Stream 90cmx1cmx0.125m/s. Freshwater sample 17
85	07-MAY-08 2:29:35PM	NR 74168 19158		Seawater sample 18
86	07-MAY-08 2:34:16PM	NR 74334 19211		250mm ceramic pipe to HW mark, not flowing.
87	08-MAY-08 6:12:11AM	NR 74144 20635		Old cotton bud.
88	08-MAY-08 6:15:12AM	NR 74287 20653		Shore mussel sample 3
89	08-MAY-08 6:17:21AM	NR 74288 20649		No observation
90	08-MAY-08 6:42:42AM	NR 73176 20673		Shore mussel sample 4
91	08-MAY-08 6:47:56AM	NR 72087 20699		Shore mussel sample 5
92	08-MAY-08 7:00:05AM	NR 73188 19221		Shore mussel sample 6
93	08-MAY-08 7:47:51AM	NR 75448 19928	Figure 20	Oyster trestle (5 bags). Oyster sample 7. Also oyster sample taken for norovirus testing. Seawater sample 19.
94	08-MAY-08 8:18:06AM	NR 75237 20191		Cockle sample taken by Argyll & Bute council from this area.
95	08-MAY-08 8:25:23AM	NR 75345 20304		Field of 20 sheep plus lambs
96	08-MAY-08 8:31:57AM	NR 75756 20511		3 goats on hillside.
97	08-MAY-08 8:35:08AM	NR 75974 20624	Figure 21	Septic tank with pipe over cliff.
98	08-MAY-08 8:37:41AM	NR 76043 20617		Pipe to sea at bottom of cliff
99	08-MAY-08 8:45:03AM	NR 75696 20530		Seawater sample 20

No.	Date and Time	Grid Reference	Photograph	Description
100	08-MAY-08 8:59:46AM	NR 75246 20342		Seawater sample 21
101	08-MAY-08 9:10:05AM	NR 75235 20248		Shore mussel sample 8
102	08-MAY-08 9:12:59AM	NR 75266 20215		Estimated corner of cockle bed
103	08-MAY-08 9:16:45AM	NR 75381 20003		Estimated corner of cockle bed
104	08-MAY-08 9:36:47AM	NR 75185 19896		Estimated corner of cockle bed. Extends over to track
105	08-MAY-08 9:42:16AM	NR 74925 19890	Figure 22	Mussel shoals extend N from here to track and W to shore. Occasional cockle here, so bed if N from here, W to shore, down to LW mark to east (i.e. most of the Doirlinn)
106	08-MAY-08 9:51:04AM	NR 74647 19858		Shore mussel sample 9
107	08-MAY-08 9:59:35AM	NR 74549 19861		Seawater sample 22. 1 seal.
108	08-MAY-08 10:24:53AM	NR 75247 19542		Septic tank with overflow to beach, ooze at end.
109	08-MAY-08 10:26:31AM	NR 75243 19555		Seawater sample 23
110	08-MAY-08 10:32:09AM	NR 75474 18926	Figure 23	Farm with large slurry pit and livestock shed. Stream over beach (too small to sample/measure).
111	08-MAY-08 10:39:20AM	NR 75554 18698		Septic pipe to beach, trickle coming from end.
112	08-MAY-08 10:42:58AM	NR 75547 18698		Cotton bud
113	08-MAY-08 10:46:12AM	NR 75559 18645		Stream 50cmx4cmx0.118m/s. Freshwater sample 24
114	08-MAY-08 10:50:29AM	NR 75559 18610		Approximately 100 sheep in field behind plus lambs.
115	08-MAY-08 10:53:22AM	NR 75604 18608		Seawater sample 25 (no mussels along this bit)
116	08-MAY-08 10:59:15AM	NR 75396 19329		10-15 cattle 200m back
117	08-MAY-08 11:01:13AM	NR 74894 19512		50 sheep on improved pasture. Gorse/rough grassland further back.
118	08-MAY-08 11:08:04AM	NR 74566 19442	Figure 24	50 sheep on improved pasture
119	08-MAY-08 11:14:35AM	NR 74190 19177		Shore mussel sample 10. Seawater sample 26.

Table 2. Water Sample Results

Sample ID	Date	Grid reference	Type	*E. coli* (cfu/100g)	Salinity (g/L)
CT1	07-MAY-08 9:14:15AM	NR 72091 20505	Sea water	78	31.4
CT2	07-MAY-08 9:29:31AM	NR 72412 20833	Sea water	2	33.8
CT3	07-MAY-08 9:36:19AM	NR 72366 20873	Freshwater	5800	
CT4	07-MAY-08 10:04:17AM	NR 73024 20752	Freshwater	7300	
CT5	07-MAY-08 10:13:31AM	NR 73280 20538	Sea water	5	34.0
CT6	07-MAY-08 11:05:59AM	NR 75162 21473	Sea water	31	34.7
CT7	07-MAY-08 11:31:58AM	NR 74844 21306	Freshwater	<100	
CT8	07-MAY-08 11:47:12AM	NR 74293 20672	Sea water	0	34.9
CT9	07-MAY-08 11:55:38AM	NR 74272 20678	Freshwater	<100	
CT10	07-MAY-08 12:05:28PM	NR 73892 20590	Freshwater	<100	
CT11	07-MAY-08 12:52:36PM	NR 72229 20295	Sea water	1	34.3
CT12	07-MAY-08 1:12:02PM	NR 72579 19796	Sea water	8	35.0
CT13	07-MAY-08 1:30:51PM	NR 72982 19396	Freshwater	3300	
CT14	07-MAY-08 1:39:04PM	NR 73101 19301	Sea water	1	34.1
CT15	07-MAY-08 1:50:34PM	NR 73350 19130	Freshwater	100	
CT16	07-MAY-08 2:04:07PM	NR 73746 19122	Freshwater	100	
CT17	07-MAY-08 2:25:40PM	NR 74169 19159	Freshwater	<100	
CT18	07-MAY-08 2:29:35PM	NR 74168 19158	Sea water	8	34.5
CT19	08-MAY-08 7:47:51AM	NR 75448 19928	Sea water	3	33.4
CT20	08-MAY-08 8:45:03AM	NR 75696 20530	Sea water	2	31.3
CT21	08-MAY-08 8:59:46AM	NR 75246 20342	Sea water	1	32.7
CT22	08-MAY-08 9:59:35AM	NR 74549 19861	Sea water	0	34.0
CT23	08-MAY-08 10:26:31AM	NR 75243 19555	Sea water	8	33.8
CT24	08-MAY-08 10:46:12AM	NR 75559 18645	Freshwater	<100	
CT25	08-MAY-08 10:53:22AM	NR 75604 18608	Sea water	210	34.1
CT26	08-MAY-08 11:14:35AM	NR 74190 19177	Sea water	2	33.2

Table 3. Shellfish Sample *E. coli* Results

No	Species	Date and time collected	Grid reference	*E. coli* result (mpn/100g)
CT1	Shore mussels	07-MAY-08 10:24:59AM	NR 73279 20560	40
CT2	Shore mussels	07-MAY-08 11:20:10AM	NR 75098 21451	<20
CT3	Shore mussels	08-MAY-08 6:15:12AM	NR 74287 20653	40
CT4	Shore mussels	08-MAY-08 6:42:42AM	NR 73176 20673	40
CT5	Shore mussels	08-MAY-08 6:47:56AM	NR 72087 20699	70
CT6	Shore mussels	08-MAY-08 7:00:05AM	NR 73188 19221	2200
CT7	Oysters	08-MAY-08 7:47:51AM	NR 75448 19928	500
CT8	Shore mussels	08-MAY-08 9:10:05AM	NR 75235 20248	200
CT9	Shore mussels	08-MAY-08 9:51:04AM	NR 74647 19858	<20
CT10	Shore mussels	08-MAY-08 11:14:35AM	NR 74190 19177	<20
CT11	Cockles	08-MAY-08 08:00:00AM	NR 75237 20192	500
CT12	Shore mussels	08-MAY-08 08:45:00AM	NR 74891 19654	<20

Table 4. Oyster sample norovirus results

No	Species	Date and time collected	Grid reference	Norovirus Genogroup I	Norovirus Genogroup II
CTNoro	Oysters	08-MAY-08 7:47:51AM	NR 75448 19928	Positive	Positive

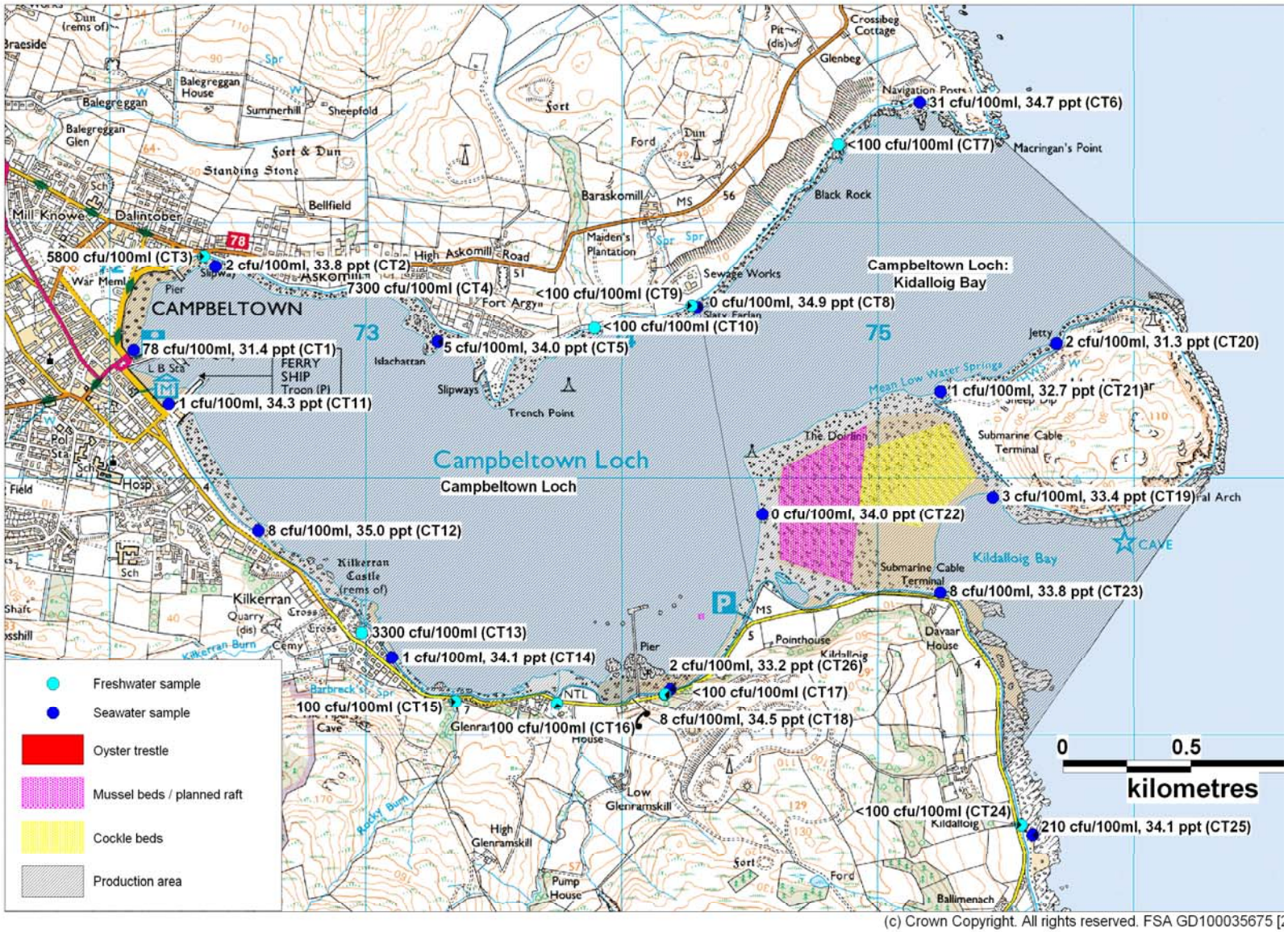

Figure 3. Water sample results map

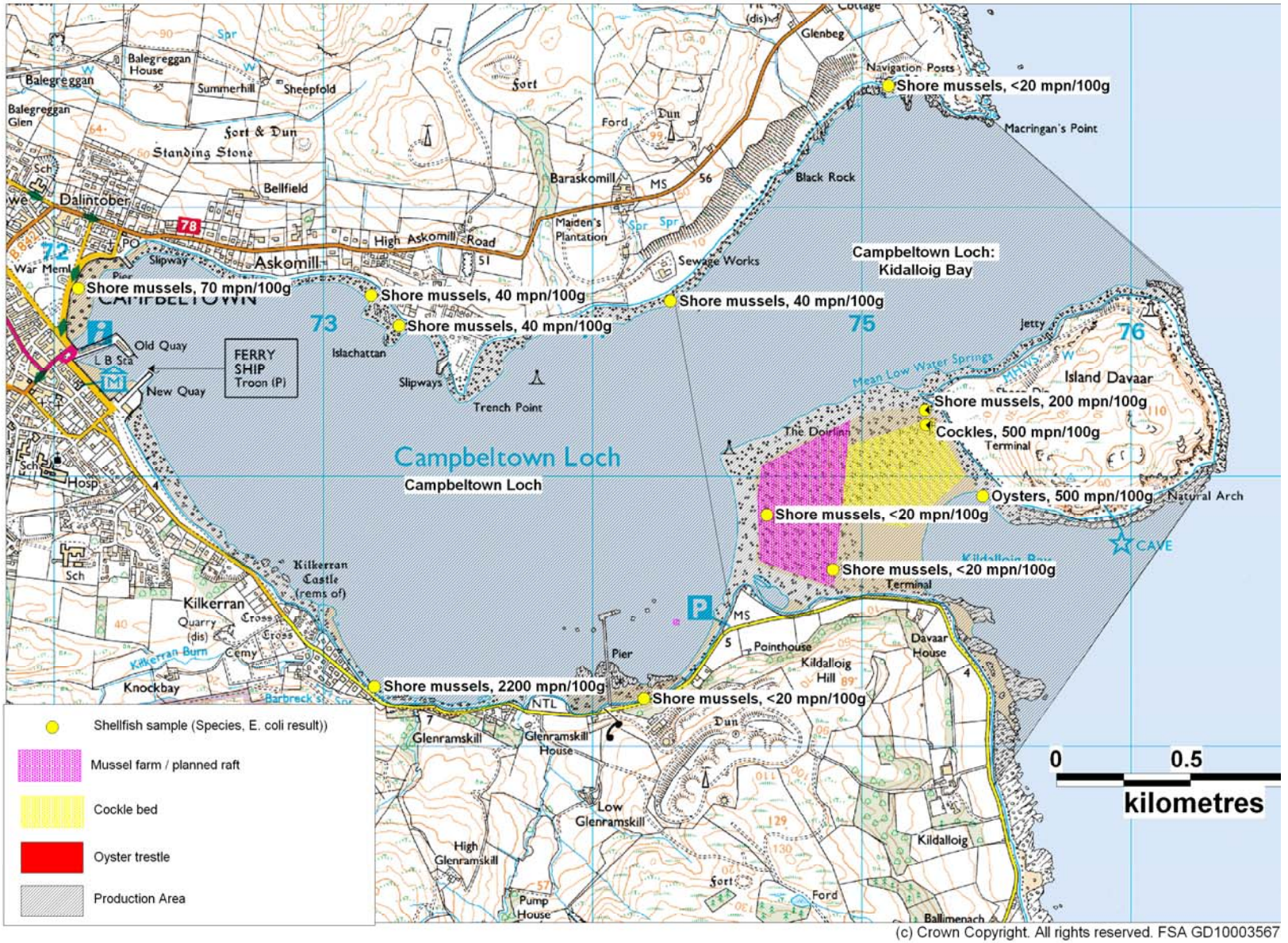

Figure 4. Shellfish sample results map

Photographs

Figure 5. Boats moored in Campbeltown harbour

Figure 6. Cotton buds in tideline

Figure 7. Inspection covers for sewage pipeline along northern shore

Figure 8. Black pipes to main sewage pipeline

Figure 9. Inspection cover with vent on north shore sewage pipeline

Figure 10. Inspection cover on north shore sewage pipeline with possible concrete pipe casing to sea behind.

Figure 11. Stream on north shore

Figure 12. Campbeltown sewage works outfall

Figure 13. Stream with Campbeltown STW in background

Figure 14. Gulls and ship in Campbeltown harbour

Figure 15. Presumed surface water pipe

Figure 16. Private sewage discharge

Figure 17. Private sewage discharge

Figure 18. Private sewage discharge

Figure 19. NATO Pier

Figure 20. Oyster trestle

Figure 21. Septic tank on Davaar Island

Figure 22. Mussel ‘shoal’ on the Doirlinn

Figure 23. Livestock shed and slurry pit

Figure 24. Sheep on improved pasture, with the Doirlinn in the background