Scottish Sanitary Survey Project

Sanitary Survey Report

Loch Creran

AB 129, 130, 131, 312 and 313

December 2007

Cefas

FOOD STANDARDS AGENCY SCOTLAND

Buidheann Inbhe-Bìdhe an Alba

Report Distribution – Loch Creran

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

** Distribution of draft and final reports to harvesters in undertaken by the relevant local authority.

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Acknowledgements

We are thankful to the following persons and agencies who provided assistance and information used in the following report.

Argyll & Bute Council
Christine McLachlan
SEPA Registry Office Dingwall
Scottish Water
Dr. Alan Lilly, Macaulay Land Research Institute

1. General description

Loch Creran is a fjordic sea loch that runs east to west for a length of about 12km and opens to the Lynn of Lorn. The loch is divided by sills into four basins. The maximum water depth in the loch is 49 metres.

There is relatively high input of freshwater into the loch from the River Creran, which flows forms Loch Baile Mhic Chailein approximately 4km upstream from the head of the Loch Creran.

Loch Creran is a Designated Special Area of Conservation (SAC) for biogenic reefs of the tube worm (*Serpula vermicularis*) and horse mussels (*Modiolus modiolus*), both of which occur in shallow, sublittoral zones around the margins of the loch.

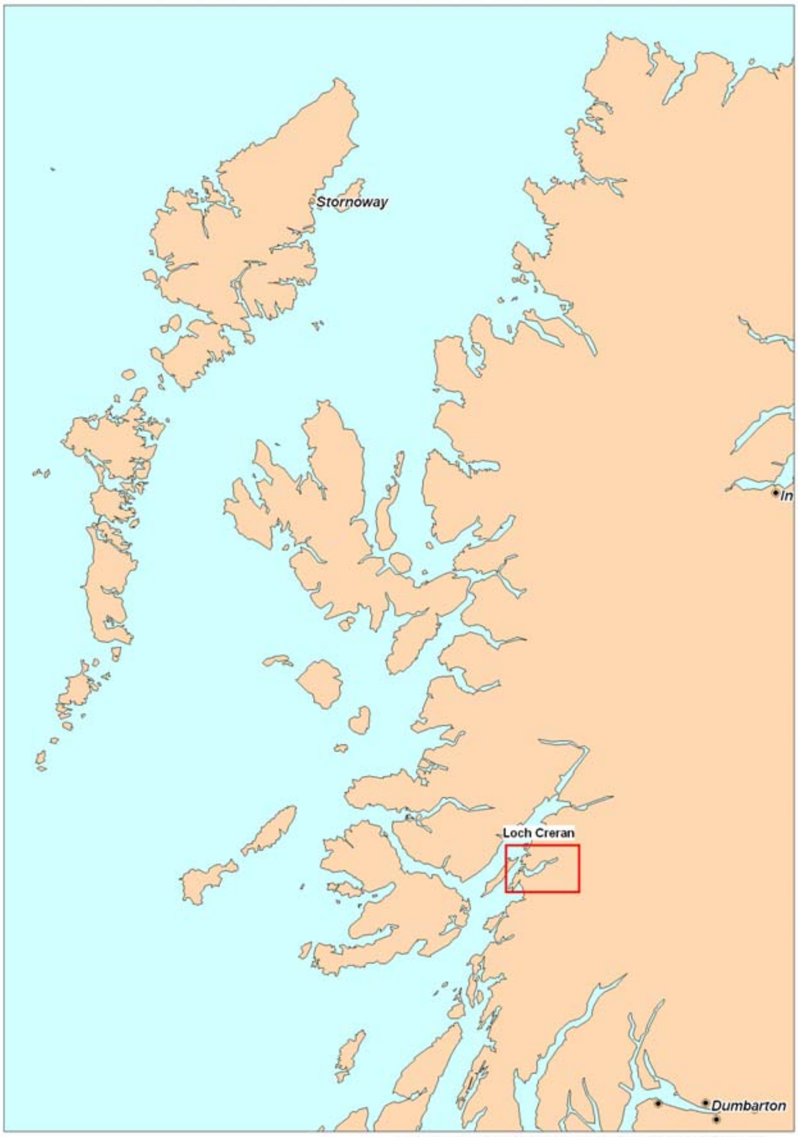

Figure 1.1 Location of Loch Creran on west coast of Scotland

2. Fishery

The fishery at Loch Creran is comprised of two mussel (*Mytilus edulis*) farms and three pacific oyster (*Crassostrea gigas*) farms as listed below:

Table 2.1 Mussel and oyster farms at Loch Creran

Production Area	Site	SIN	Species
Inner Loch Creran	Inner Creran	AB 313 709 08	Common mussels
Loch Creran East	East - Barrington	AB 129 021 13	Pacific oysters
Loch Creran West	Loch Creran	AB 312 020 08	Common mussels
Loch Creran West: Rubha Mor	Rubha Mor Loch Creran Ferlochan	AB 130 022 13 AB 130 742 13	Pacific oysters
Loch Creran West: Shian	Shian Fisheries	AB 131 023 13	Pacific oysters

Inner Loch Creran AB 313

The current production area boundary for Inner Loch Creran is given as the area bounded by lines drawn between NM 9086 4117 to NM 9192 4233 and between NM 9900 4398 to NM 9900 4477. The entire production area lies within the designated Shellfish Growing Water.

The RMP for the production area is currently located within the Inner Creran site. The reported RMP grid reference is NM 953 436.

This site actually consists of 2 distinct areas of mussel floats, either side of the East-Barrington oyster production site. The area of floats to the southwest consists of 4 lines, and had no harvestable mussels at the time of sampling. The lines are to be moved about 200m to the south and west in the near future to prevent damage to underwater reefs. The area to the north and east consists of 3 lines, and had mussels of a harvestable size.

Loch Creran East AB 129

The current production area boundary for Loch Creran East is given as the area bounded by lines drawn between NM 9437 4300 to NM 9564 4223 then from NM 9900 4477 to NM 9900 4398. The entire production area lies within the designated Shellfish Growing Water.

The RMP for the production area is currently located within the East Barrington site. The reported RMP grid reference is NM 949 430.

The site is an area of trestle grown oysters. Stock of a range of sizes was observed including some of market size. The grower reports that they take 2-

3 years to reach harvestable size. Harvesting generally takes place during the winter months.

Loch Creran West AB 312

The current production area boundary for Loch Creran West is given as the area bounded by lines drawn between NM 9002 4379 to NM 9002 4332 and NM 9089 4114 to NM 9193 4233, and NM 8984 4248 to NM 8980 4240. The entire production area lies within the designated Shellfish Growing Water.

The RMP for the production area is currently located within the Loch Creran site. The reported RMP grid reference as of 21/12/2007 is NM 912 425.

The site consists of a floating raft that currently has no stock on aside from 2 bags of mussels held at the RMP. There is also a larger area of long lines on floats to the south of the raft (4 lines). There is currently no stock on these lines.

Loch Creran West: Rubha Mor AB 130

The current production area boundary for Loch Creran West: Rubha Mor is given as the area bounded by lines drawn between NM 9089 4114 to NM 9193 4233 and NM 9437 4300 to NM 9564 4223. The entire production area lies within the designated Shellfish Growing Water.

The RMP for the production area is currently located within the Rubha Mor site. The reported RMP grid reference is NM 916 406.

Rubha Mor is an oyster trestle site that was untended at the time the site visit was undertaken. Loch Creran Ferlochan is an active oyster trestle site. Stock of a range of sizes was observed including some of market size. The grower from Ferlochan advised that the Rubha Mor site is privately owned rather than a Crown Estates lease. The site is currently for sale.

Loch Creran West: Shian AB 131

The current production area boundary for Loch Creran West: Shian is given as the area bounded by lines drawn between NM 9002 4379 to NM 9002 4332 and NM 9089 4114 to NM 9193 4233 and NM 8984 4248 to NM 8980 4240. The entire production area lies within the designated Shellfish Growing Water.

The RMP for the production area is currently located within the Shian Fisheries site. The reported grid reference is NM 909 422.

Stock of a range of sizes was observed including some of market size, and harvesting was taking place at the time of survey.

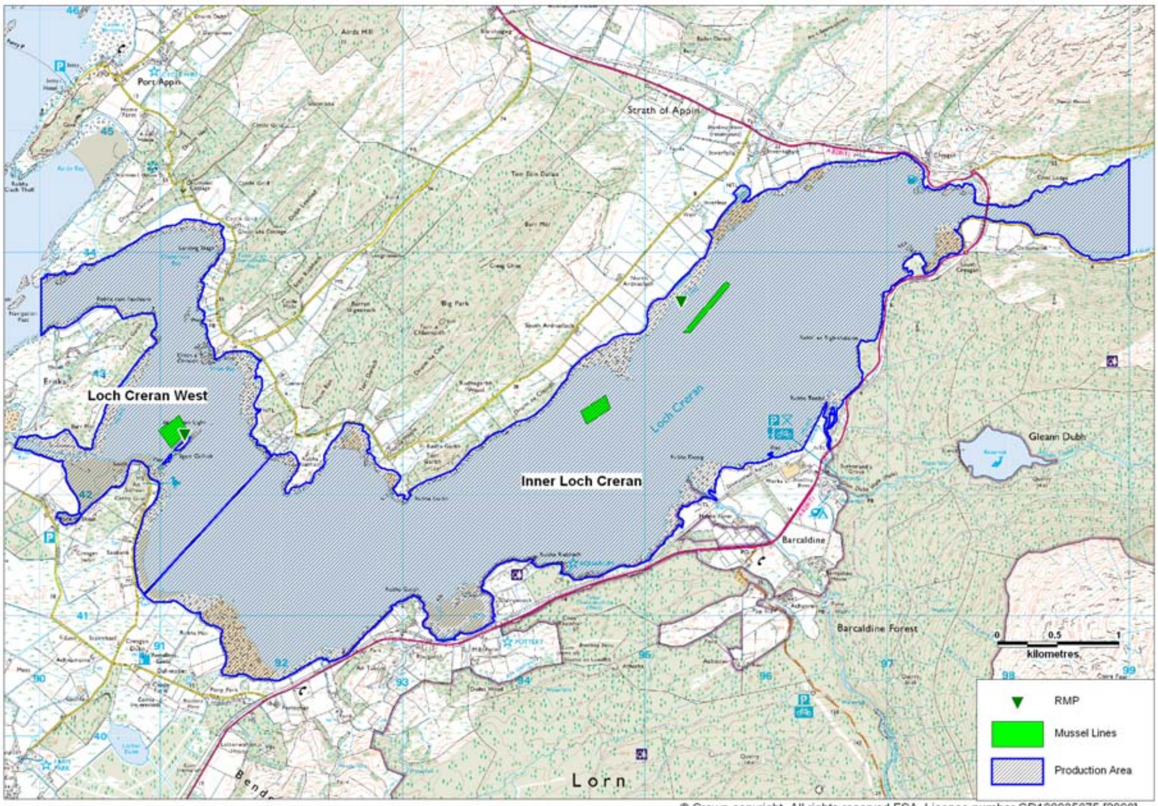

Figure 2.1 Map of Loch Creran Mussel Fisheries

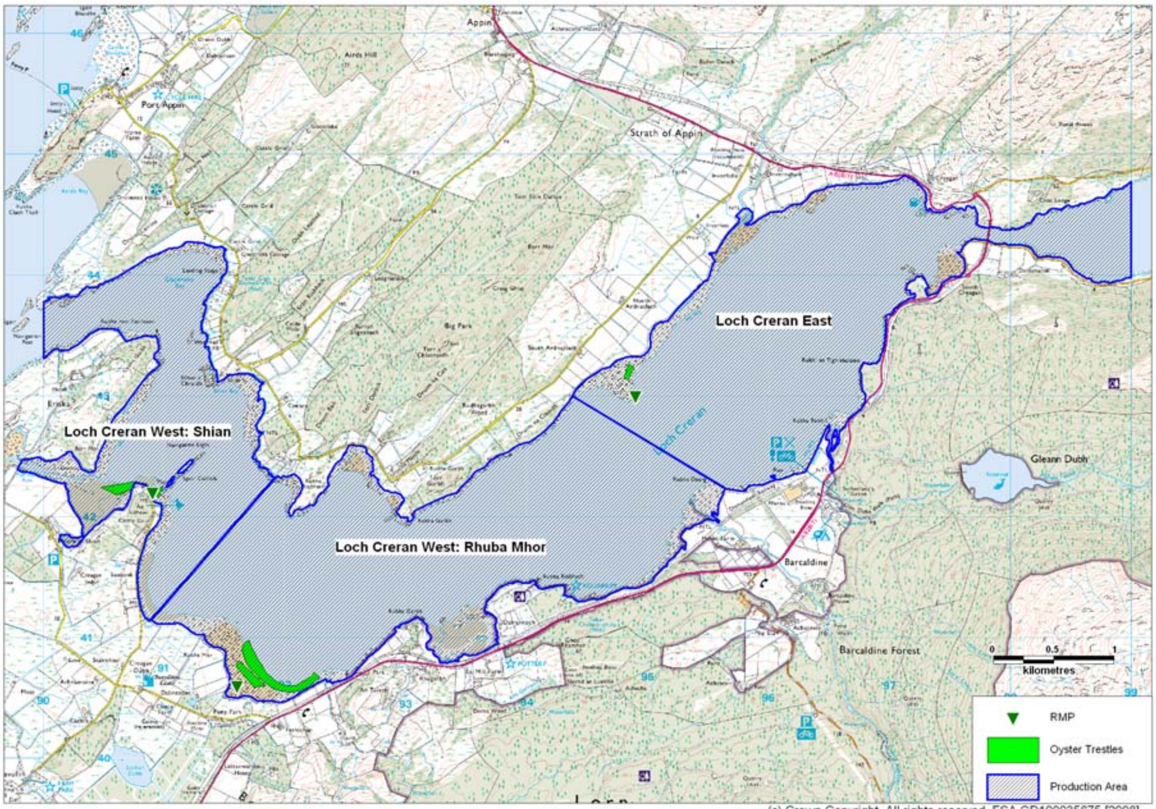

Figure 2.2 Map of Loch Creran Oyster Fisheries

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 Loch Creran.

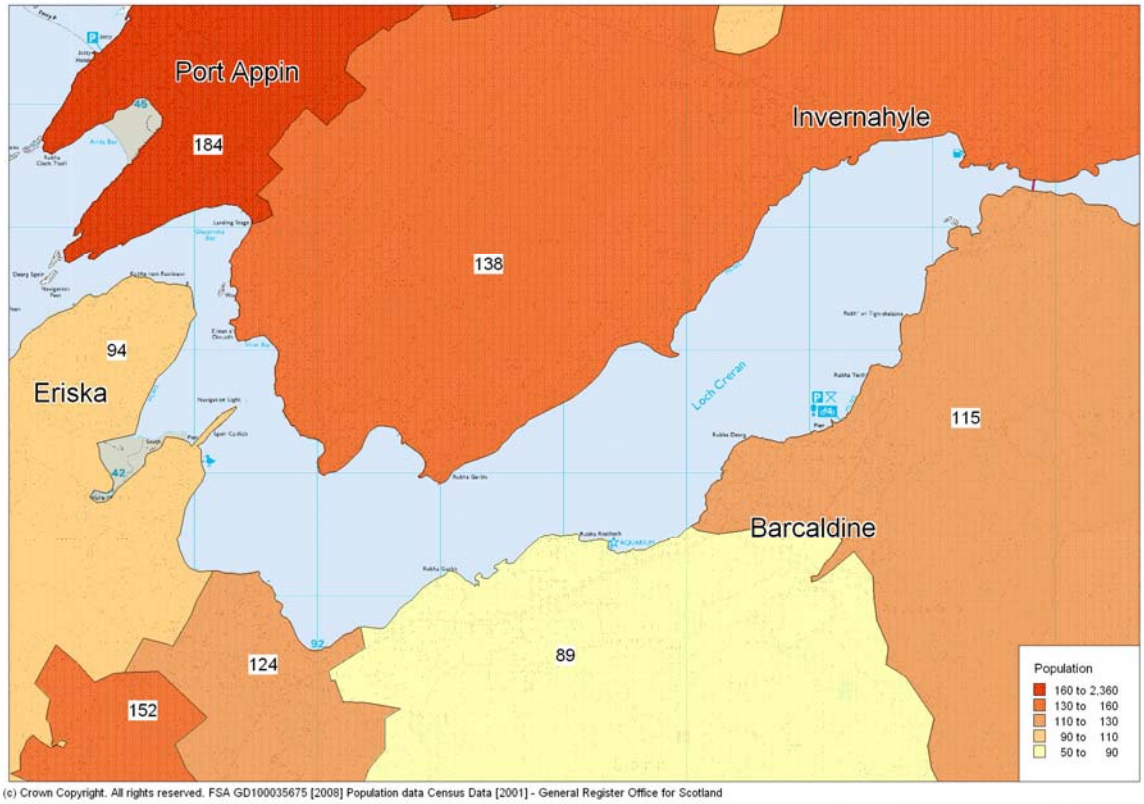

Figure 3.1 Population map for Loch Creran

The population for the seven census output areas bordering immediately on Loch Creran are:

60QD000708	115
60QD000709	89
60QD000576	124
60QD000706	152
60QD000707	94
60QD000710	184
60QD000100	138

On the northwestern side of the loch is the settlement of Port Appin, near Airds Bay and on the north eastern side is the settlement of Invernahyle. On the southeastern side of the loch is the larger settlement of Barcaldine and on southwestern shore is the settlement of Eriska. However, most of the population is concentrated towards this eastern side of the loch and any associated faecal pollution from human sources will be concentrated in these areas.

4. Sewage Discharges

Scottish Water identified two community septic tanks for the area surrounding Loch Creran. They are detailed in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

NGR	Discharge Name	Discharge Type	Level of Treatment	Consented flow (DWF) m3/d	Consented/ design pop	Q&S III Planned improvement?
NM 9640 4120	Barcaldine Old Sawmill	Continuous	Septic Tank		9	N
NM 9070 4560	Port Appin	Continuous	Septic Tank		30	N

Data on sanitary content was available for the Port Appin discharge only. It had an average biological oxygen demand (BOD) of 5.1 mg/l and suspended solids (SS) of 6.1 mg/l. No information was available on the bacteriological content of the discharges.

A number of discharge licences were held by SEPA for the area of Loch Creran. These are listed in Table 4.2 and mapped in figure 4.1 and figure 4.2.

Table 4.2 SEPA discharge points

Ref No.	NGR of discharge	Discharge Name	Discharge Type	Consented flow (DWF) m3/d	Consented/ design PE	Notes
CAR/L/1000365	NM 9410245990	Appin STW	Treated/Combined Sewage Overflow	44	200	-
CAR/L/1000365	NM 9410245990	Appin STW	Sewage (Public) Secondary	-	-	-
CAR/L/1000420	NM 9070045600	-	Sewage (Public) Primary	-	-	-
CAR/S/1009904	NM 9079045410	-	Sewage (Private) Secondary	3.4	17	Domestic
CAR/R/1010729	NM 9060043300	-	Sewage (Private) Secondary	-	5	Domestic
CAR/R/1015596	NM 9111045710	Benderloch	Sewage (Private) Primary	-	5	Domestic
CAR/R/1013701	NM 8987639797	Ledaig	Sewage (Private) Primary	-	5	Domestic
CAR/R/1013171	NM 8990039600	Benderloch	Sewage (Private) Secondary	-	6	Domestic
CAR/R/1012001	NM 9169940331	Seafield, Pony Park	Sewage (Private) Primary	-	6	Domestic
CAR/R/1016477	NM 9292040730	Timberscome	Sewage (Private) Primary	-	6	Domestic
CAR/R/1013803	NM 9575941391	Oban	Sewage (Private) Primary	-	5	Domestic
CAR/R/1019378	NM 9106045910	Ardtur Croft	Sewage (Private) Primary	-	5	Domestic
CAR/R/1018247	NM 9107645844	Bothan Darroch, Rowanlee & Sycheida	Sewage (Private) Primary	-	16	Domestic
CAR/R/1019134	NM 9074045480	Straithard	Sewage (Private) Primary	-	5	Domestic
CAR/R/1018319	NM 8967039464	Monadh	Sewage (Private) Primary	-	5	Domestic
CAR/R/1019519	NM 8979039370	Kiel Crofts	Sewage (Private) Primary	-	6	Domestic
CAR/R/1017596*	NM 8921040720	-	Sewage (Private) Primary	-	5	Domestic
CAR/R/1020567*	NM 8997039900	-	Sewage (Private) Primary	-	5	Domestic

*These discharges licences have been requested from SEPA but not yet received, as a result have been given an estimate of 5 consented design/PE with the knowledge that they are 'sewage (private) primary.'

Additional discharges, including septic tanks and outfall pipes were also observed during the shoreline survey and are listed in table 4.3. These were not confirmed as active or discharging during the survey, however their locations have been included in the mapped discharges in Figure 4.1. Further details can be found in the shoreline survey report in the appendix.

Table 4.3 Observations of potential sewage discharges

No.	Date	NGR	Description of potential sewage discharge
1	29-JUL-07	NM 97273 44611	110m orange plastic sewer pipe from large house under construction (not yet connected)
2	29-JUL-07	NM 96739 44765	Concrete slab on lawn - might be septic tank cover (no vent observed)
3	30-JUL-07	NM 90902 42243	Presumed septic tank outlet pipe 4" orange plastic running out at least 20m past this point into area of trestles.
4	31-JUL-07	NM 90268 45357	4" ceramic pipe to shoreline, 2 inspection covers and vent further up (i.e. septic discharge) smelly and flowing.
5	31-JUL-07	NM 90295 45387	4" metal pipe from septic tank – foul smell but not sure if flowing.
6	31-JUL-07	NM 90345 45498	4" metal pipe to shore, not flowing, no smell.
7	31-JUL-07	NM 90427 45511	4" metal pipe not flowing.
8	31-JUL-07	NM 90449 45552	4" metal pipe not flowing.
9	31-JUL-07	NM 90468 45587	5" metal pipe, trickle, surrounded by faecal material including sweetcorn.
10	31-JUL-07	NM 90592 45613	4" plastic sewer pipe broken.
11	31-JUL-07	NM 90682 45578	4" plastic sewer pipe discharging foul smelling water.
12	31-JUL-07	NM 90700 45596	5" plastic sewer pipe flowing.
13	31-JUL-07	NM 90771 45660	7" metals sewer pipe, flowing fairly rapidly, water grey with foul smell, toilet paper at end and sewage related debris all around.
14	31-JUL-07	NM 90196 45312	Probably a septic tank but no overflow (pump-out variety?).
15	31-JUL-07	NM 94314 41323	Outflow from Sealife Centre into stream (2 x 12" ribbed plastic pipes). Foul smell.
16	21-NOV-07	NM 91498 43722	Septic tank in garden?
17	21-NOV-07	NM 91777 43132	Septic outflow from one house. Not flowing at time, but had been discharging grey water recently.

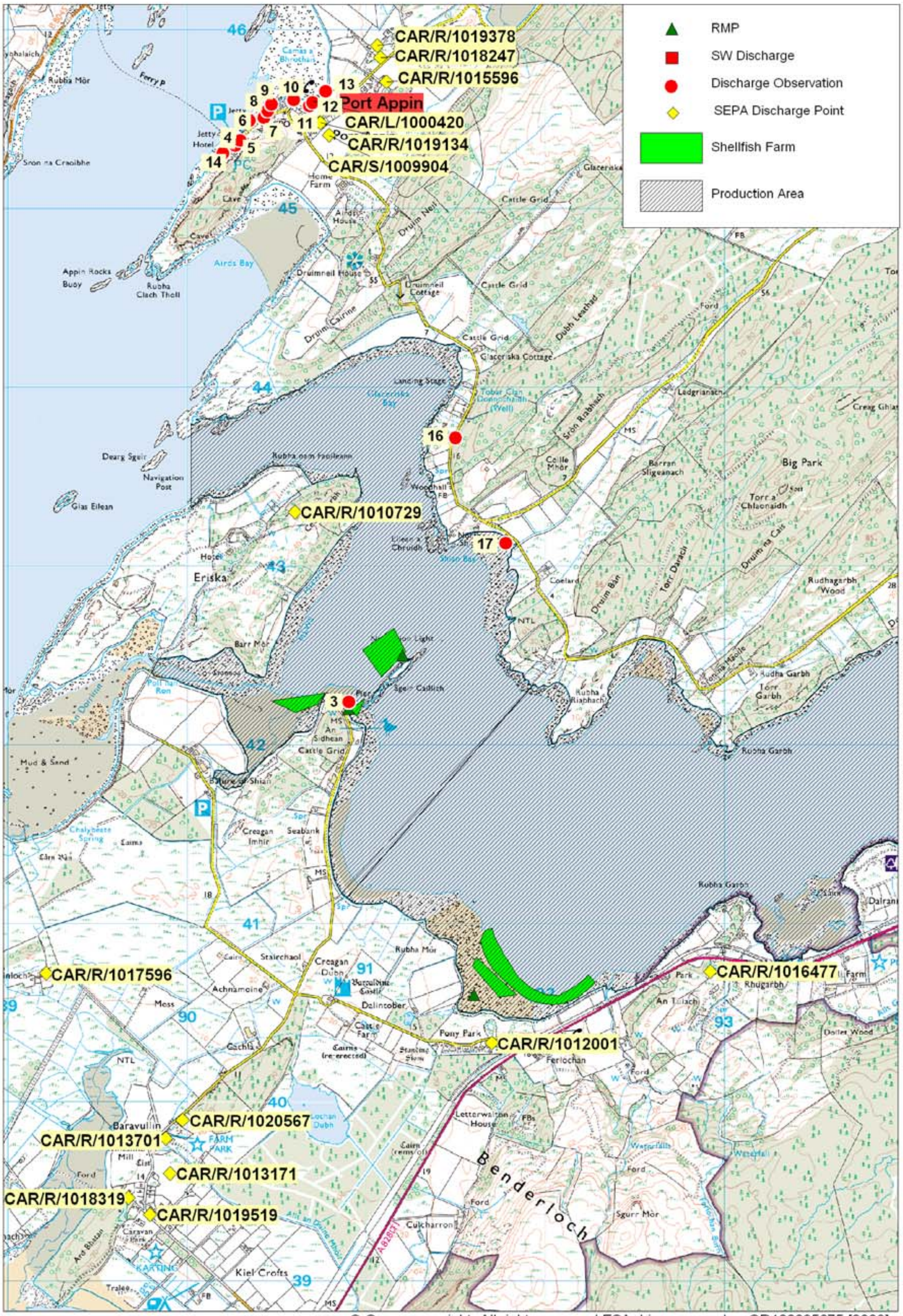

Figure 4.1 Map of discharges at Loch Creran - West

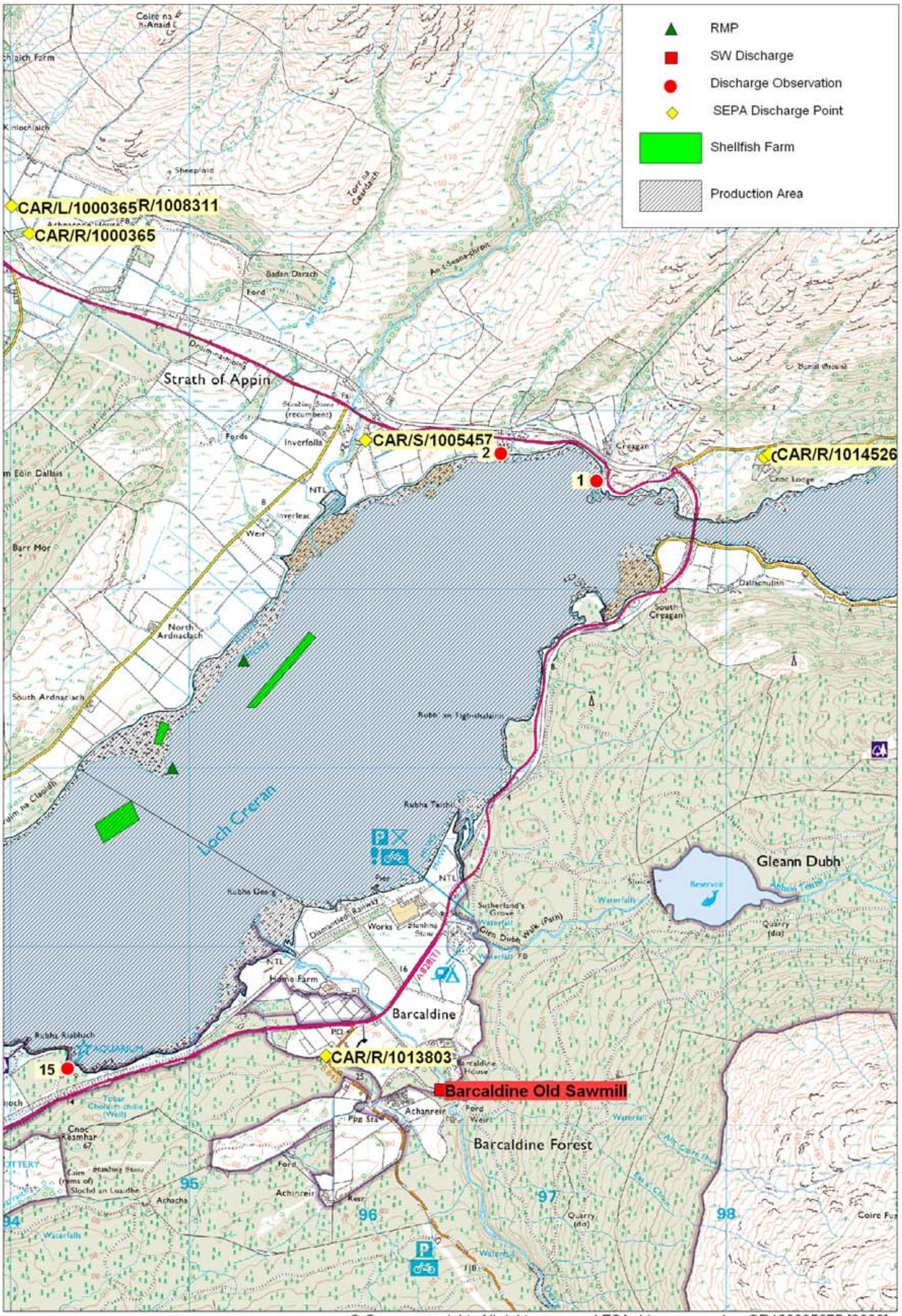

Figure 4.2 Map of discharges at Loch Creran – East

The majority of the sewage inputs to the fishery are at the far eastern and western ends of the loch. Sources closest to the fisheries would likely have the greatest impact locally. Observed discharges 6 and 7 will most acutely impact the oyster farm at Loch Creran East - Barrington and also the mussel farms sited just offshore. At the western end of the loch, the private discharges are generally located further from the oyster farms with the exception of the observed discharge 9, the septic tank discharge at Loch Creran Shian Fisheries. This discharge pipe was removed subsequent to the shoreline survey and replaced with a soakaway system.

There are a large number of sewage inputs in the area of Port Appin to the west, however these are roughly 5km along the coastline from the nearest shellfish farm and less likely to affect the fisheries within Loch Creran itself.

5. Geology and soils

Component soils and their associations were identified using uncoloured soil maps (scale 1:50,000) obtained from the Macaulay Institute. The relevant soil associations and component soils were then researched 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 (see the glossary at the end of this section).

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.

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% and can be classified as freely draining soils.

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. In addition, they also have a very high surface % runoff of between 48.4 – 60%, confirming that they are poorly draining.

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 the regions mapped have an average surface % runoff of 44.3%, so it is likely that in this case they would be poorly draining.

Maps were produced using these seven soil type groups and whether they are characteristically freely or poorly draining. The map of component soils and their associated drainage classes for the area around Loch Creran can be found in Figure 5.1.

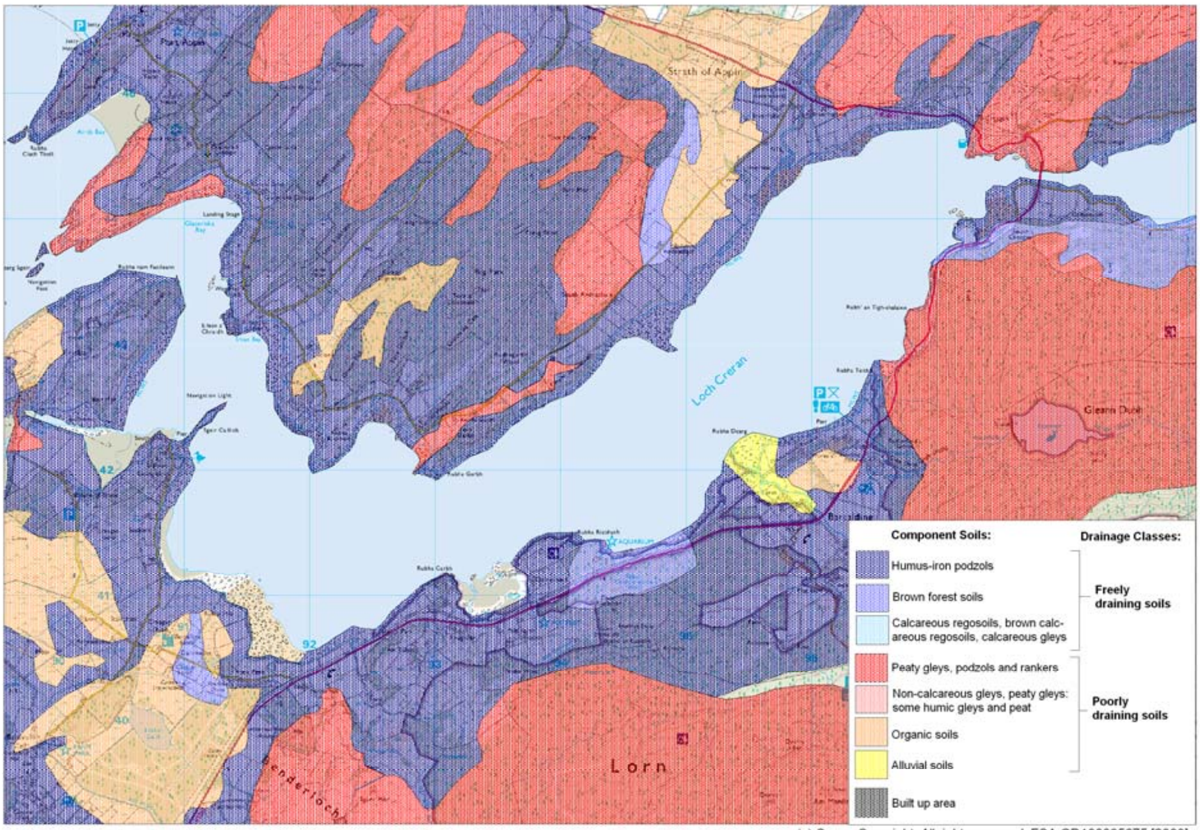

Figure 5.1 Map of component soils and drainage classes for Loch Creran

There are five main types of component soils visible in this area. The predominant soil type is humus-iron podzols. This component soil covers a vast area of coastline and inland surrounding the loch, especially towards the western end. The second most dominant soil is composed of peaty gleys, podzols and rankers. This component soil covers a small stretch of coastline on the eastern side of the loch but is mostly found further inland, north and south of the loch. Organic soils cover small of patches of land on the north and south of the loch. Brown forest soils only cover four small areas, three of which are close to the southern coastline of the loch. Finally, alluvial soils cover the tributaries of the Rubha Dearg river on the southern coastline.

In summary, the soils found further inland from Loch Creran are poorly draining and therefore will have higher surface runoff, whereas for the more freely draining soils found along most of the coastline of Loch Creran, surface runoff is reduced as the permeability of the soil has increased. As a consequence, the potential for runoff contaminated with *E. coli* from animal waste will be fairly low in most areas apart from the eastern end of the loch.

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.

6. Land cover

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

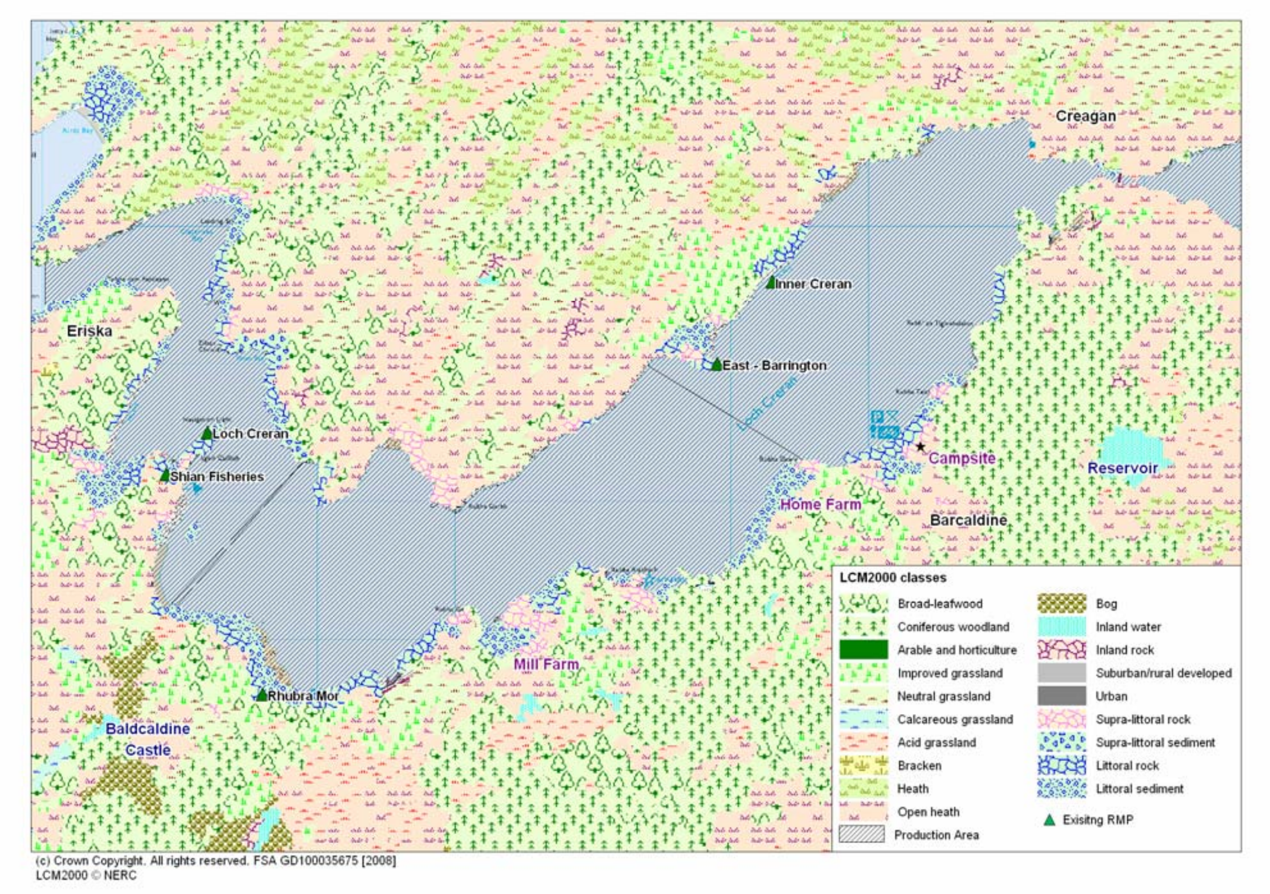

Figure 6.1 LCM2000 class data map for Loch Creran

The land cover for Loch Creran is very varied on both sides of the loch. On the southeast side of the loch, coniferous woodland is shown to dominate, however there are also patches of acid grassland, broad-leaf woodland and open heath. On the southwest side of the loch, the land cover is patchier with areas of acid grassland, open heath, improved grassland, broad-leaf woodland, coniferous woodland and bog. The north side of the loch is also diverse in land cover, with open heath and improved grassland dominating the coast with areas of broad-leaf woodland, neutral grassland and coniferous woodland further inland. Along both the northern and southern coastline of the loch there are areas of littoral rock, littoral sediment and supra-littoral rock.

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

There are no large developed areas on the shore of Loch Creran. Adjacent to the Loch Creran East oyster site, and the Inner Loch Creran mussel site is a large area of improved grassland, which might be expected to contribute to contamination at these sites, particularly following periods of heavy rainfall. Adjacent to Loch Creran West:Rubha Mor is a combination of improved, land and deciduous forest, which would be expected to contribute less in terms of contamination than improved pasture alone. The land adjacent to Loch Creran West: Shian is a mixure of mainly unimproved grassland and deciduous forest, which would be expected to contribute relatively little contamination from surface runoff.

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, waste-water treatment, etc.

With regard to potential sources of pollution of animal origin, agricultural census data to parish level was requested from the Scottish Government. The request was declined on the grounds of confidentiality because the parishes in most cases contained only a small number of farms making it possible to determine specific data for individual farms. The only significant source of information was therefore the shoreline survey (see Appendix 1), which only relates to the time of the site visit on 29th – 31st July 2007 and the 21st November 2007.

The shoreline survey identified that concentrations of livestock appeared to be relatively low overall, however some cattle and sheep were observed. Generally, fences prevented livestock from gaining access to the shoreline, however livestock were observed on the shoreline at two points (one with cattle on the north shore and a second with sheep on the south shore). In both these places, a considerable amount of dung was observed below the high water mark. The geographical spread of contamination at the shores of the loch would therefore be concentrated within these areas. The cattle observed on the north shore, adjacent to the Loch Creran East oyster fishery and the Inner Loch Creran mussel fishery are likely to impact on both of these fisheries, particularly the oyster fishery which is closer to the shore. This should be taken into account when identifying the location of a routine monitoring point (RMP).

There is no local information concerning seasonal livestock numbers available for the surrounding area of Loch Creran. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

Cattle were observed in several areas near or on the fisheries. 73 cattle and 28 sheep were observed along the shoreline above the Loch Creran East and Inner Loch Creran shellfish farms. Cattle droppings are much larger and generally less consolidated than sheep droppings and would contribute larger amounts of bacteria to streams and runoff in the vicinity. This would be likely to have a significant impact on bacterial concentrations observed in the loch near where this runoff discharges.

Seven cattle were observed just behind the shoreline near the Loch Creran West Rubha Mhor oyster fishery. Water samples collected from two fresh water streams in the vicinity contained 410 and 5900 cfu *E. coli*/100 ml, indicating high levels of faecal contamination.

There appeared to be less impact from farm animals at the Loch Creran West Shian sites as the only livestock observed in the area were 25 sheep located across the loch on the northern shore. Sheep droppings washed off the land on this side of the loch may impact the fisheries on the opposite shore but their effect is likely to be diluted.

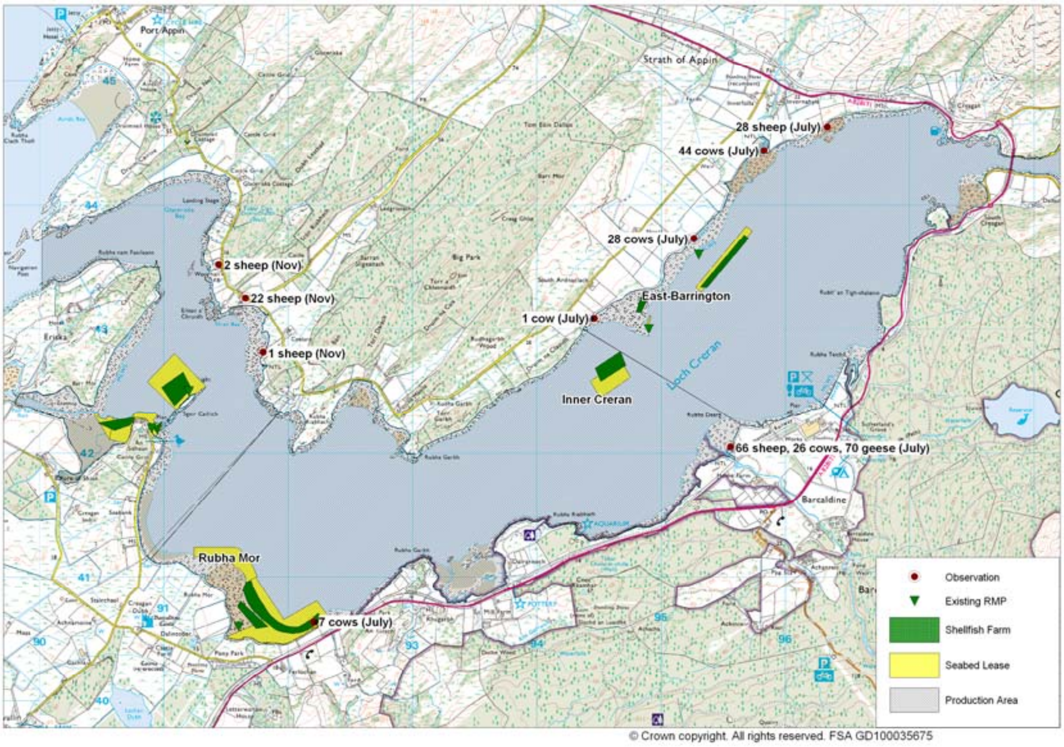

Figure 7.1 Map of livestock observations at Loch Creran

8. Wildlife

8.1 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. Survey results from 2000 showed minimum numbers in Loch Creran to be 67. There were a minimum of 527 common seals reported in the wider Firth of Lorn to the south of Loch Creran.

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. There are no breeding colonies reported in or near Loch Creran, however it could be expected that grey seals might be found foraging in the loch from time to time.

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).

Seals will forage widely for food and it is likely that seals will feed near the mussel farms at some point in time. 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.

8.2 Cetaceans

A variety of cetacean species are routinely observed around the west coast of Scotland.

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.

As Loch Creran has a restricted depth at its entrance due to the presence of a sill at 7m, it is unlikely that the loch would be visited by larger cetaceans, though dophins could enter and feed in the loch. Their presence, however, is likely to be sporadic and unpredictable and so will not be taken into account with regard to establishing sampling plans for Loch Creran production areas.

8.3 Birds

A number of seabird species are known to breed in Argyll & Bute and the most significant of these are described in table 8.2.

Of these, only the cormorants and gulls are likely to be breeding in the area of Loch Creran in appreciable numbers. Distribution of nesting sites near the harvesting areas is not known. Though nesting occurs in early summer, these birds are likely to be present in the area throughout the year. Impact to the fisheries is likely to be very localised where birds rest on floats or oyster trestles.

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. There are no RSPB reserves at Loch Creran.

Waterfowl (ducks and geese) and wading birds are present in Loch Creran at various times from autumn through winter. Few of these birds would be expected to be present during the summer months. As Loch Creran does not host large overwintering populations, the presence of these birds is likely to be variable. Wading birds would be concentrated on intertidal mud flats and would have the highest impact at the Shian fisheries site, where there is suitable substrate to host a population of wading birds. However, this are of mud flats is relatively small and the impact of wading bird faeces on the fishery is unpredictable.

Table 8.2 Breeding seabirds of Argyll & Bute

Common name	Species	Population	Common name	Species	Population
European Shag	*Phalacrocorax aristotelis*	3341	Great Cormorant	*Phalacrocorax carbo*	231*
Black-headed Gull	*Larus ridibundus*	586	Common Gull	*Larus canus*	2683
Lesser Black-backed Gull	*Larus fuscus*	3235	Herring Gull	*Larus argentatus*	15370
Great Black-backed Gull	*Larus marinus*	1736	Black-legged Kittiwake	*Rissa tridactyla*	8976
Common Tern	*Sterna hirundo*	1362	Arctic Tern	*Sterna paradisaea*	1823
Common Guillemot	*Uria aalge*	42697	Black Guillemot	*Cepphus grille*	3046
Razorbill	*Alca torda*	9056	Atlantic Puffin	*Fratercula arctica*	2597*

*Population number based on Apparently Occupied Sites, Territories, Nests or Burrows. These may equate to more than one adult.

Overwintering geese would tend to be found on farm fields and open grassland. This habitat is most abundant along the north shoreline near North Ardnaclach and along the southwest shore above Shian. 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 though no estimates of numbers were available at the writing of this report so it is not possible to properly evaluate their contribution.

8.4 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. Much of the southern shoreline of Loch Creran is part of the Barcaldine Forest and there is substantial forested area on the northern shore of the loch to the south of Port Appin. While no population data were available for these areas, it can be presumed that they host populations of deer. The DCS did not have information on deer in these specific areas.

Deer, like cattle and other ruminants, shed *E. coli*, *Salmonella* and other potentially pathogenic bacteria via their faeces and it is likely that some of the indicator organisms detected in the streams feeding into Loch Creran will be of deer origin, and it may be expected that their contribution is year round, but minor.

8.5 Other

The European Otters (Lutra lutra) is present around Scotland with some areas hosting populations of international significance. Coastal otters, such as those likely to be found in Loch Creran, 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 10m 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. While otters are known to occur around the Loch Creran area, it is not considered to be home to a substantial population.

8.6 Summary

Wildlife impacts to the fisheries in Loch Creran are likely to be very localised and unpredictable. While some wildlife species can harbour bacteria and viruses that can cause illness in humans, their faeces are considered to pose a lower risk to human health than either human or livestock faecal contamination.

9. Meteorological data

The nearest weather station is located at Strath of Appin, approximately 0.5 km to the north of Loch Creran. Daily rainfall values were purchased from the Meteorological Office for the period 1/1/2003 to 31/10/2006 inclusive, although there were no records for 131 days during this period. Due to the very close proximity of the weather station to Loch Creran, rainfall recorded here is likely to be very similar to that experienced on the loch and surrounding land.

The nearest major weather stations are located at Tiree (90 km to the west) and at Bishopton, Glasgow (90 km to the south east). Of the two, Tiree is probably the most appropriate to use because of its location on the west coast. Rainfall data was recorded on all but 11 days from 1/1/2003 to 31/12/2006. Wind direction was recorded at 3 hourly intervals for the majority of the period 1/1/2003 to 31/12/2006. It is likely that the rainfall and wind patterns at Tiree are broadly similar to those at Loch Creran, but are liable to differ on any given day due to the distance between the two. Differences in local topography may also affect wind patterns.

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

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).

The influence of rainfall on microbiological quality will depend on factors such as local geology, topography, land use and sewerage infrastructure.

9.1.1 Rainfall at Strath of Appin

Due to the missing data it is not appropriate to present total rainfall at Strath of Appin by year or month. Instead, Figures 9.1 and 9.2 summarise the pattern of rainfall recorded at Strath of Appin. The box and whisker plots present the distribution of individual daily rainfall values (observations) by year (Figure 9.1) or by month (Figure 9.2). The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

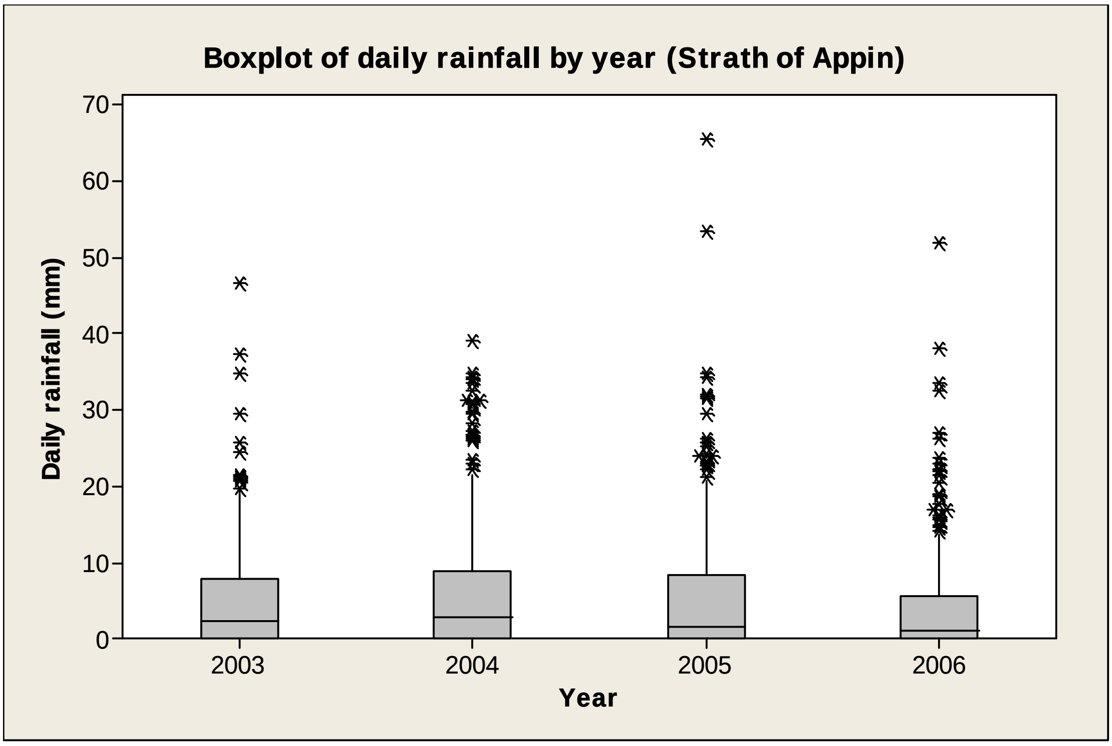

Figure 9.1 Boxplot of daily rainfall at Strath of Appin by year

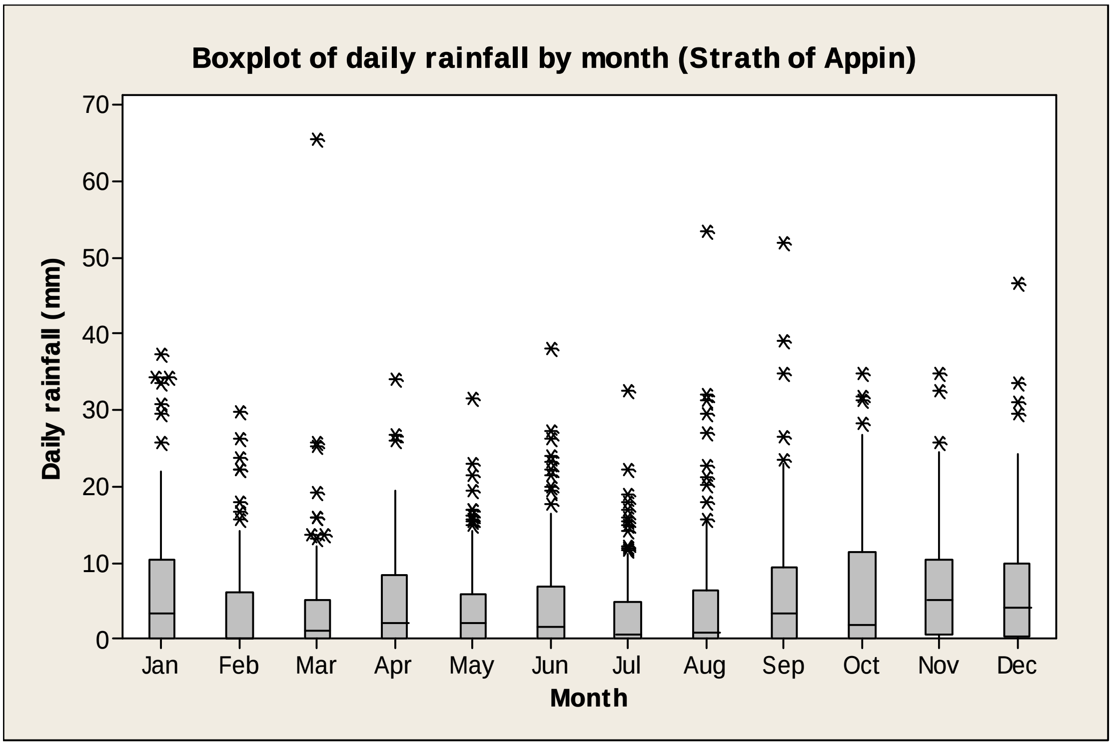

Figure 9.2 Boxplot of daily rainfall values at Strath of Appin by month

The wettest months were September to January inclusive. For the period considered here, only 30.7% of days for which records were available experienced no rainfall. 45.2% of days experienced rainfall of 1mm or less.

9.1.2 Rainfall at Tiree

As the rainfall records from Tiree are more complete, total annual rainfall and mean monthly rainfall can be calculated, and are presented in Figures 9.3 and 9.4. Boxplots of daily rainfall values by year and by month are presented in Figures 9.5 and 9.6 to allow their comparison with the pattern of rainfall at Strath of Appin.

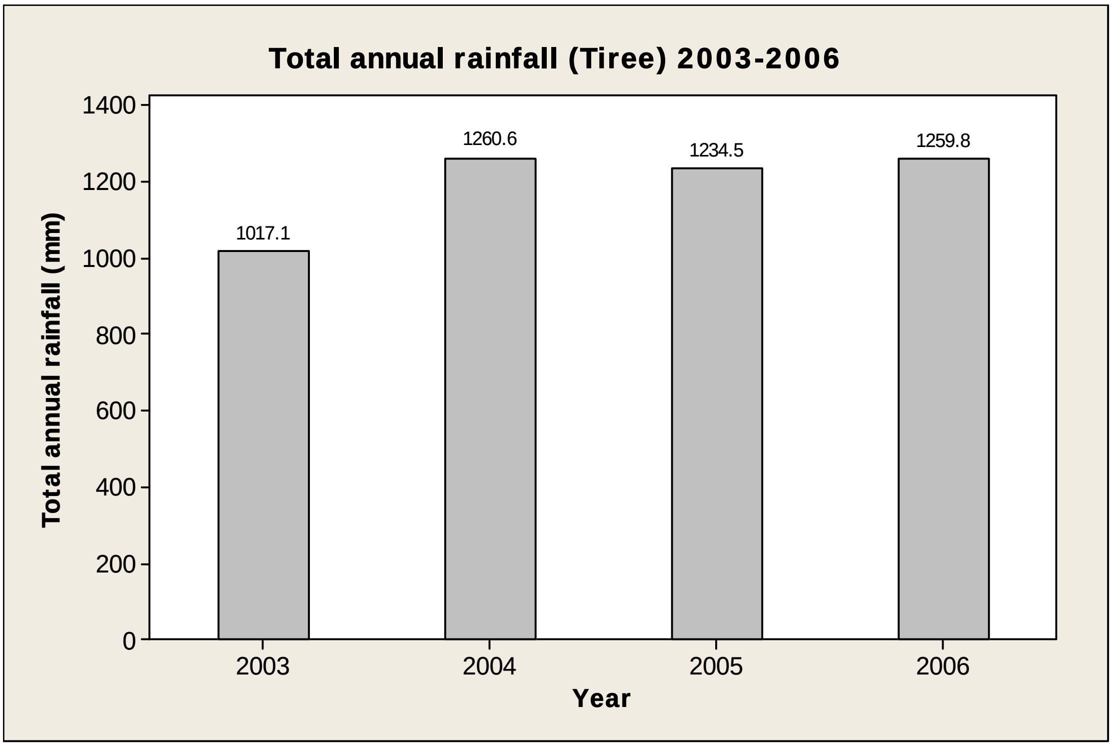

Figure 9.3 Total annual rainfall at Tiree 2003-2006 (no records for 11 days in 2006).

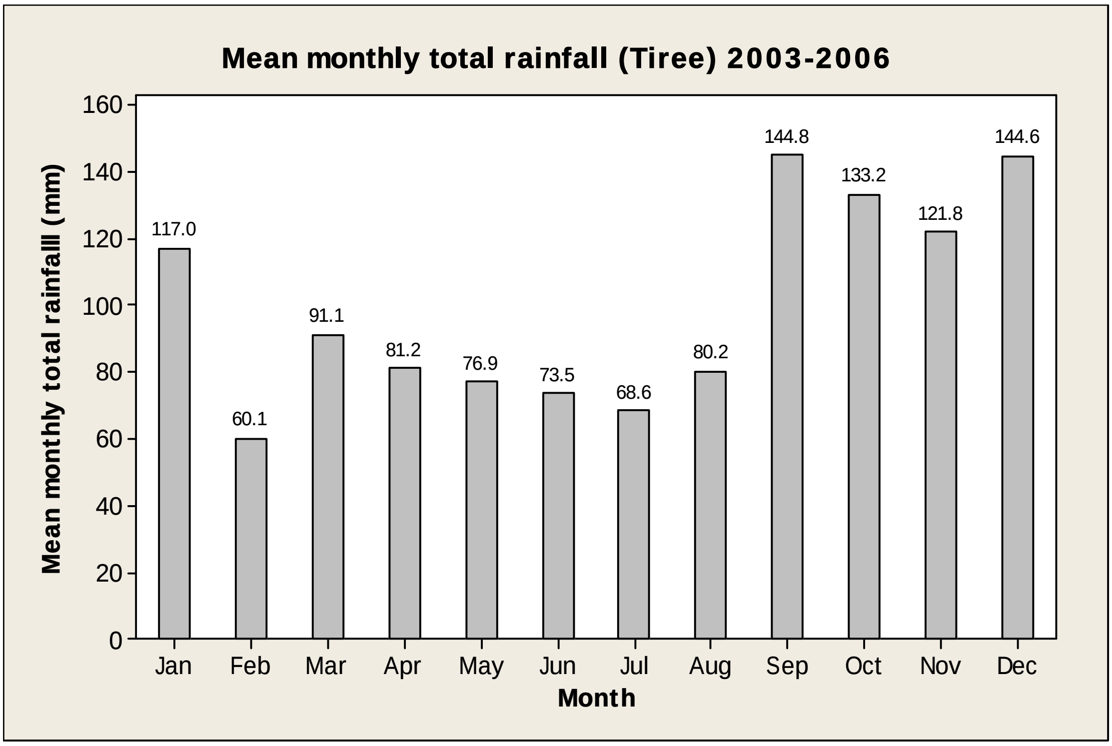

Figure 9.4 Mean total monthly rainfall at Tiree 2003-2006 (no records for 6 days in August 2006 and 5 days in October 2006).

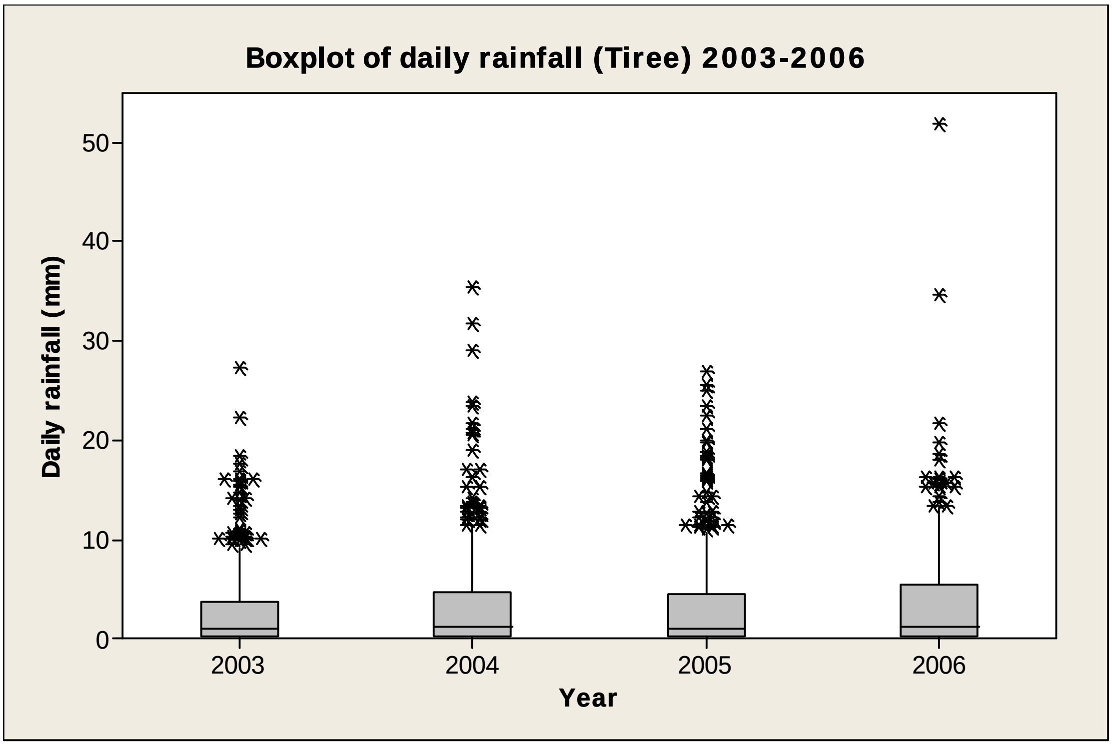

Figure 9.5 Boxplot of daily rainfall at Tiree by year

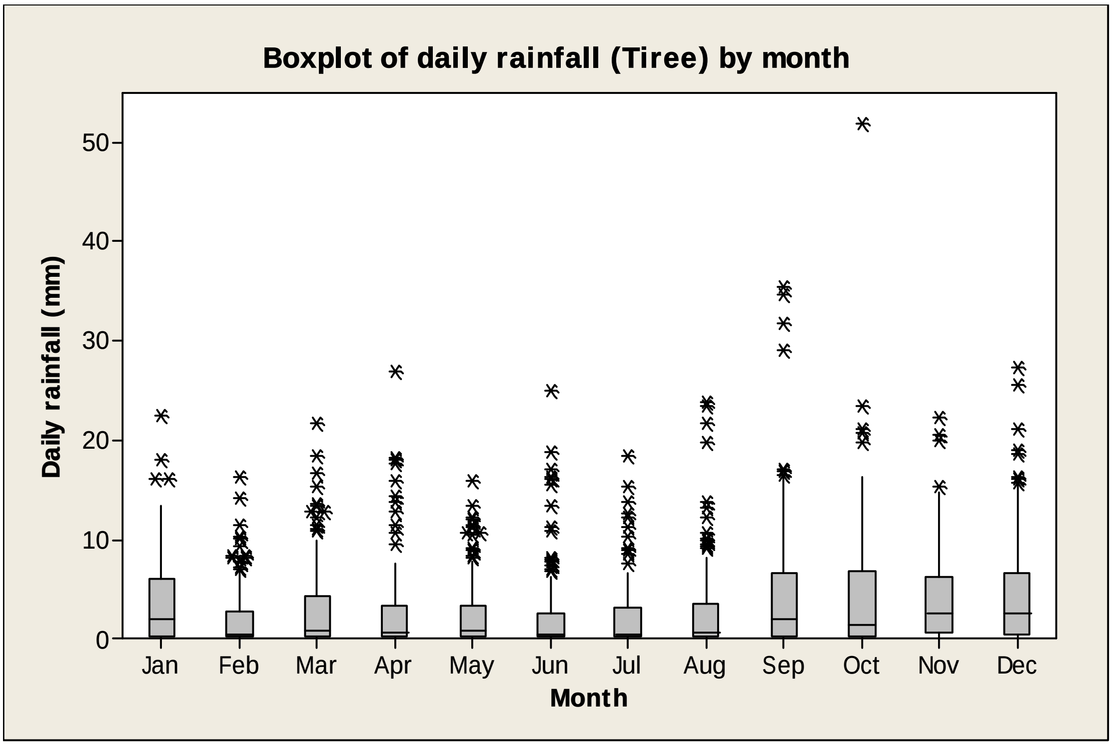

Figure 9.6 Boxplot of daily rainfall at Tiree by month

As with Strath of Appin, the wettest months were September, October, November, December and January. For the period considered here (2003-2006), only 13.3% of days experienced no rainfall. 50.7% of days experienced rainfall of 1mm or less.

A comparison of Tiree rainfall data with Scotland average rainfall data for the period of 1970-2000 is presented in Table 9.1 (Data from Met office website © Crown copyright). This indicates that rainfall in Tiree was lower than the average for the whole of Scotland for every month of the year, but there were fewer dry days in Tiree during the autumn and winter.

Table 9.1 - Comparison of Tiree mean monthly rainfall with Scottish average 1970-2000.

Month	Scotland rainfall (mm)	Tiree rainfall (mm)	Scotland - days of rainfall >= 1mm	Tiree - days of rainfall >= 1mm
Jan	170.5	142.5	18.6	20.1
Feb	123.4	98.2	14.8	15.8
Mar	138.5	104.5	17.3	18.1
Apr	86.2	67.1	13	11.6
May	79	54.1	12.2	10.8
Jun	85.1	61.5	12.7	11.2
Jul	92.1	77.5	13.3	13.6
Aug	107.4	98.7	14.1	14.0
Sep	139.7	118.6	15.9	16.5
Oct	162.6	142.7	17.7	18.8
Nov	165.9	136.6	17.9	19.7
Dec	169.6	134.5	18.2	20.4
Whole year	1520.1	1236.4	185.8	190.6

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

9.2 Wind

Strong winds may affect circulation of water and tide heights. 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. These currents create return currents, the path of which depends on local bathymetry. A strong wind combined with a spring tide may result in higher than usual tides which will carry accumulated faecal matter from livestock, in and above the normal high water mark, into the loch.

Wind data collected at the Tiree weather station is summarised by season and presented in figures 9.7 to 9.11.

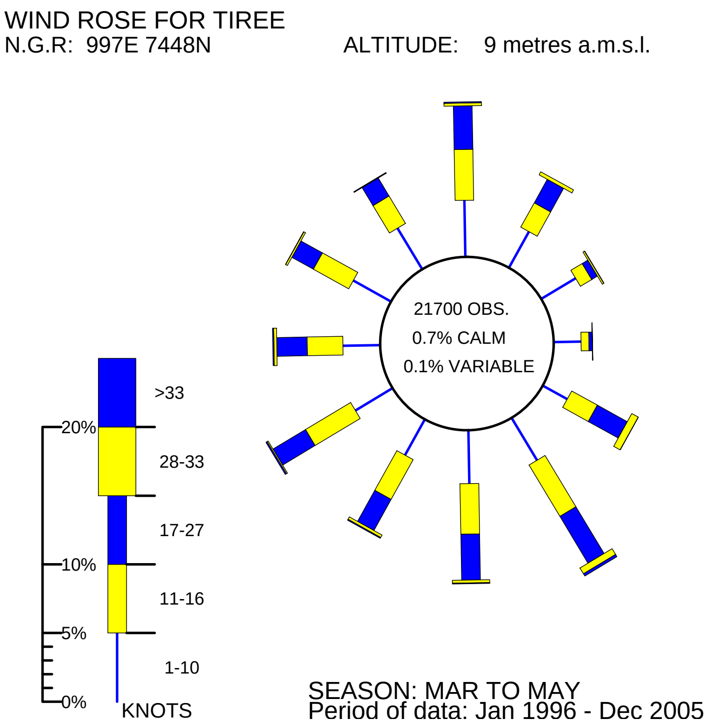

Figure 9.7 Wind rose for Tiree (March to May)

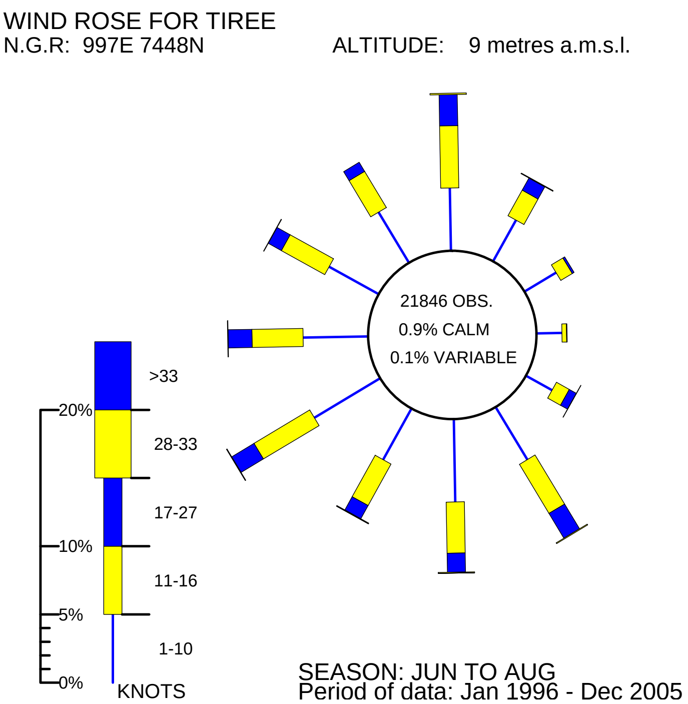

Figure 9.8 Wind rose for Tiree (June to August)

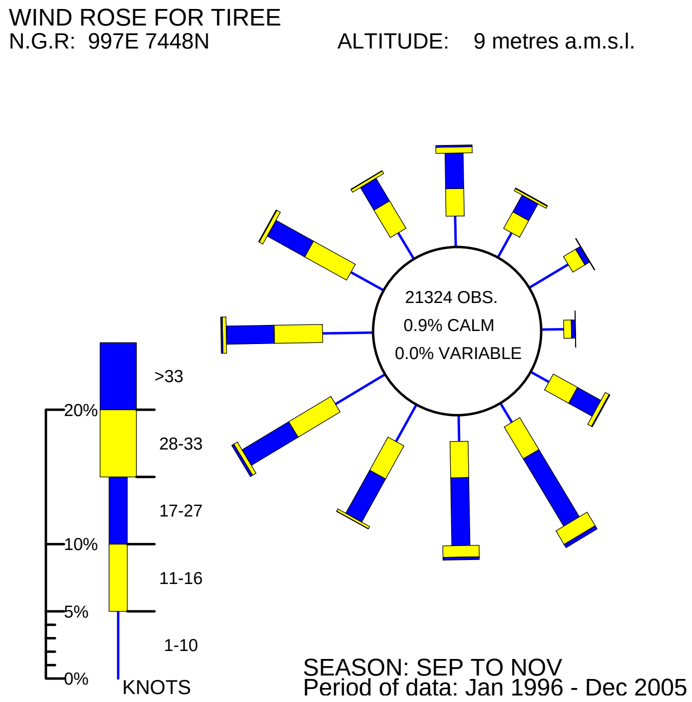

Figure 9.9 Wind rose for Tiree (September to November)

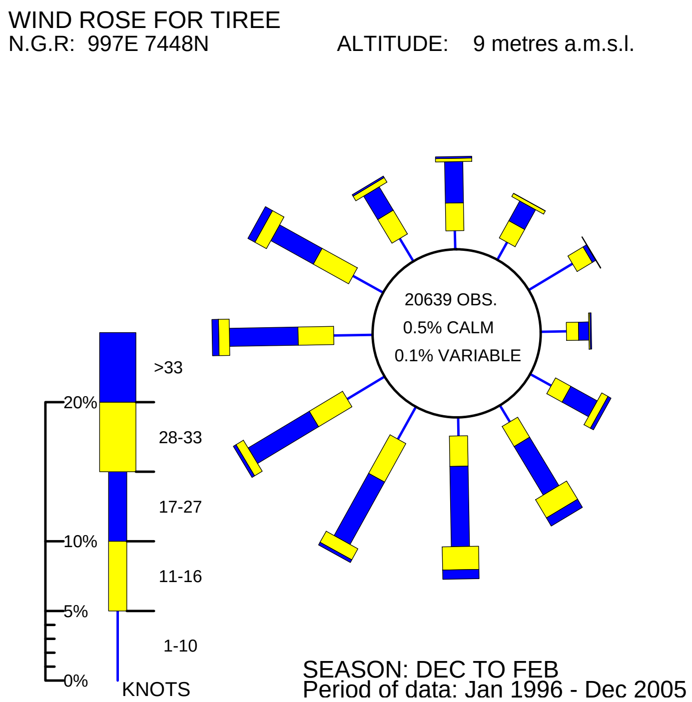

Figure 9.10 Wind rose for Tiree (December to February)

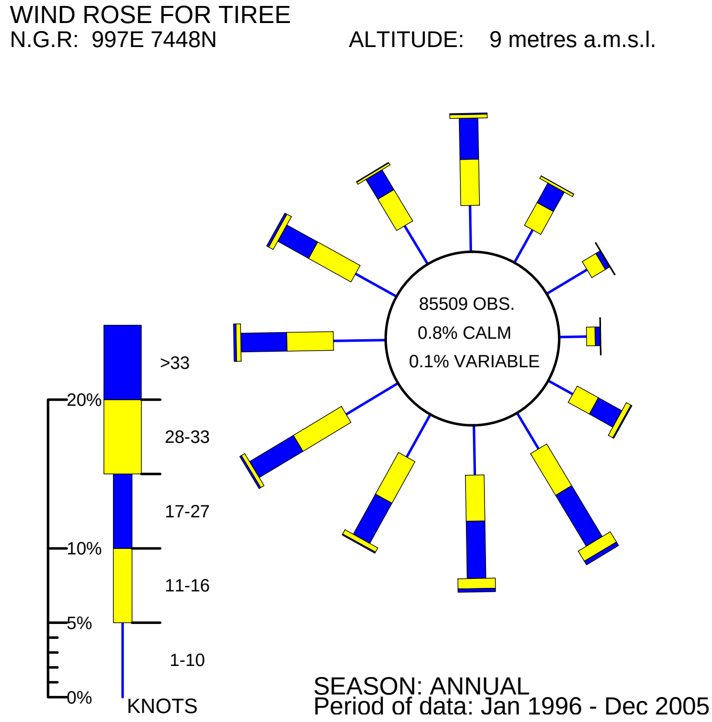

Figure 9.11 Wind rose for Tiree (All year)

The prevailing wind direction at Tiree is from the south and west, but wind direction often changes markedly from day to day with the passage of weather systems. Winds are generally lightest in the summer and strongest in the winter.

Loch Creran has an east-west aspect, is about 12 km long in total, and has constrictions at its entrance in the west, and another constriction towards its eastern end. It is surrounded by hills and so winds will be funnelled up or down the loch to some extent. Winds blowing in an easterly or westerly direction along the length of the loch will have the greatest effect on circulation overall, but winds from other directions may be more effective in carrying contamination from point sources straight to growing areas depending on their relative positions. Loch Creran, however, has strong tidal currents, and these are likely to be more important overall to the circulation of water within the loch than wind driven currents.

10. Current and Historical Classification Status

The survey area consists of 2 separate areas currently classified for mussel production, and three separate areas currently classified for oyster production.

10.1 Areas classified for mussel production

Figure 10.1 presents a map of the two areas currently classified for mussel production.

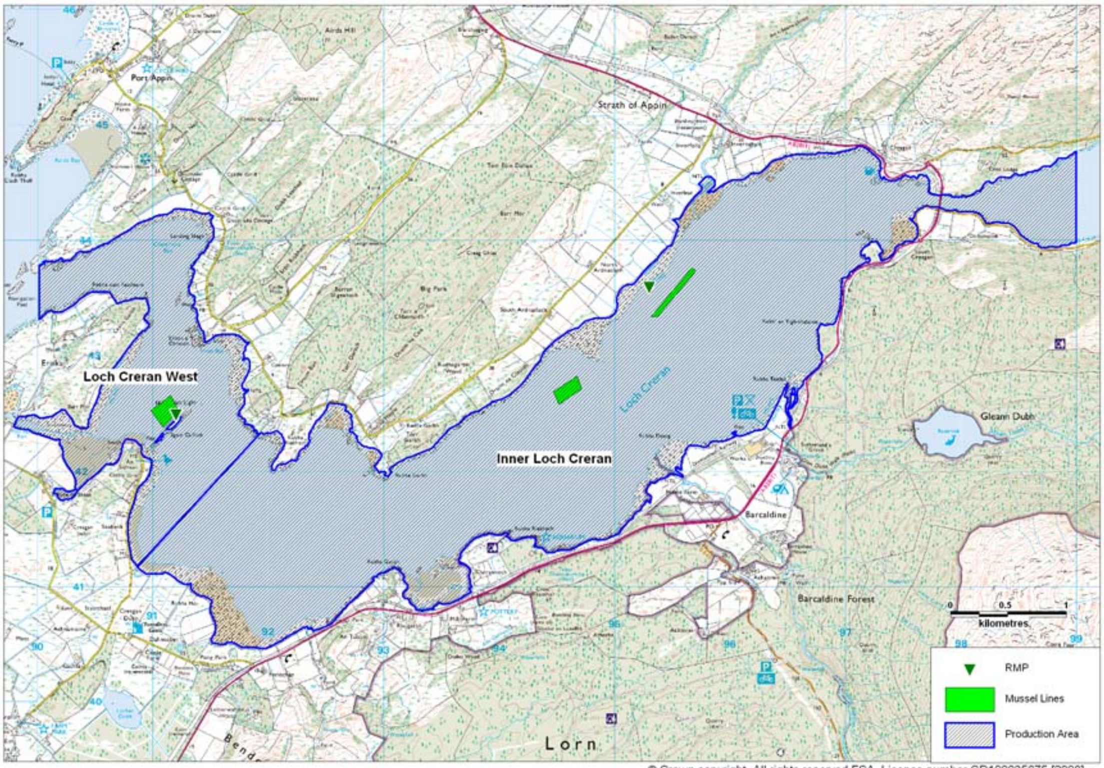

Figure 10.1 - Map of current mussel production areas within Loch Creran

10.1.1 Loch Creran West (AB 312) classification history

Table 10.1 Loch Creran West Classification history

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

Prior to 2005, the classification covered all mussel production within the Loch. In 2005 the Loch was split into the two existing mussel production areas which are classified separately.

10.1.2 Inner Loch Creran (AB 313) classification history

Table 10.2 Inner Loch Creran classification history

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

Prior to 2005, the classification covered all mussel production within the Loch. In 2005 the Loch was split into the two existing mussel production areas which are classified separately.

10.1.3 Comparison of classifications (mussel production areas)

Since the production area was split, Inner Loch Creran has received a slightly less favourable classification to Loch Creran West with 5 months of B classification (May to September) compared to 4 months for Loch Creran West (June to September)

10.2 Areas classified for oyster production

Figure 10.2 presents a map of the three areas currently classified for pacific oyster production.

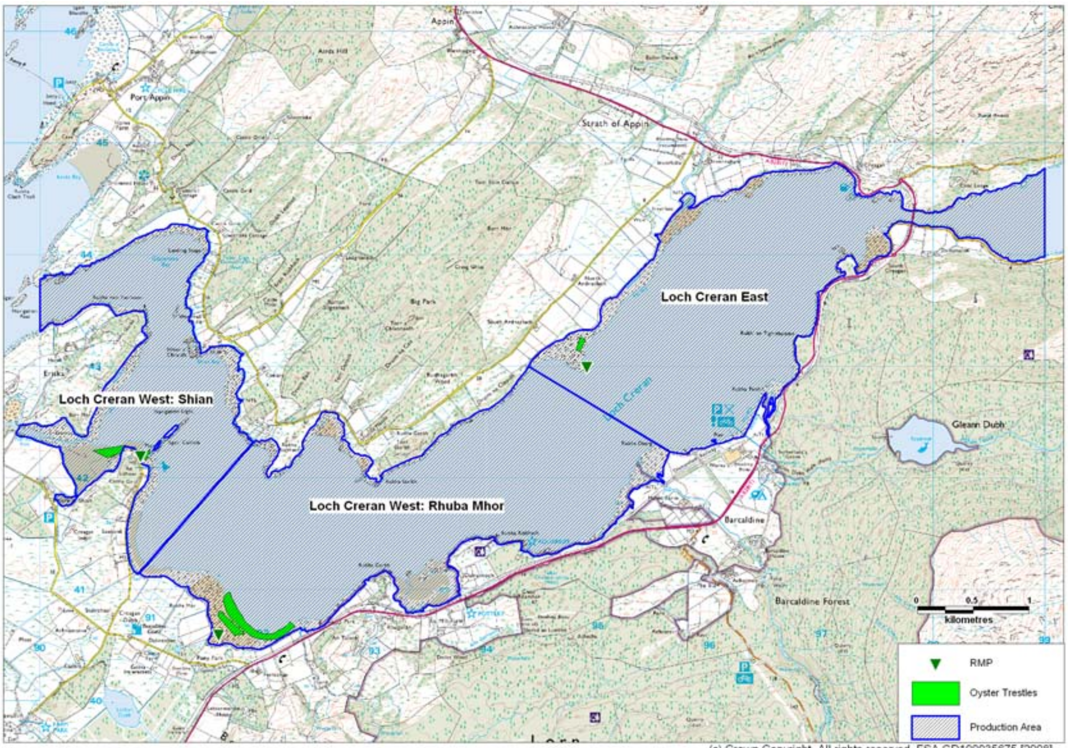

Figure 10.2 - Map of current oyster production areas within Loch Creran

10.2.1 Loch Creran West: Shian (AB 131) classification history

Table 10.3 Loch Creran West: Shian classification history

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

In 2001 and 2002, the classification covered all oyster production within Loch Creran. In 2003, the production area was split and the classification covered both the Loch Creran West: Shian and Loch Creran West Rubha Mor production areas. In 2004 the production area was split again and the current boundaries were established.

10.2.2 Loch Creran West: Rubha Mor (AB 130) classification history

Table 10.4 Loch Creran West: Rubha Mor classification history

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

In 2001 and 2002, the classification covered all oyster production within Loch Creran. In 2003, the production area was split and the classification covered both the Loch Creran West: Shian and Loch Creran West Rubha Mor production areas. In 2004 the production area was split again and the current boundaries were established.

10.2.3 Loch Creran East (AB 129) classification history

Table 10.5 Loch Creran East classification history

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

In 2001 and 2002, the classification covered all oyster production within Loch Creran. In 2003, the production area was split and the current boundaries for Loch Creran East were established.

10.2.4 Comparison of classifications (Oyster production areas)

Loch Creran West: Shian currently holds a seasonal A/B classification, with 4 months of B classification (September to December). The classification has changed every year since 2003.

Loch Creran West: Rubha Mor currently holds an A classification all year round. For the 3 years prior to this, it held a seasonal A/B classification, with 5 months of B classification (June to October).

Loch Creran East currently holds a seasonal B/C classification, with 3 months of C classification (July to September). Prior to this it held a year round B classification for 4 years, and before this a seasonal A/B classification.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken from the Loch Creran production areas up to the end of 2006 were extracted from the database and validated according to the criteria described in the standard operating procedure for validation of historical *E. coli* data for sanitary survey reports. All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intervalvular fluid. All samples with a reported result of <20 were assigned a nominal value of 10, and all samples with a reported result of >18000 were assigned a nominal value of 36000 for the purposes of graphical presentation and analysis. It must be noted that six figure grid references, as estimated from an ordnance survey map, are only accurate to the nearest 100m.

For Loch Creran West (AB 312), no samples were rejected on the basis of major geographical or date discrepancies. A total of 5 horse mussel samples were taken from this production area in addition to the common (rope) mussel samples.

For Inner Creran (AB 313), no mussel samples were rejected on the basis of major geographical or date discrepancies. A total of 4 carpet clam samples were also taken from this production area in addition to the mussel samples.

For Loch Creran West: Shian (AB 131), one pacific oyster sample reported as originating from the Loch Creran West: Shian production area was rejected as its reported sampling location fell 2.5 km outside the production area boundaries. A total of 2 native oyster samples were also taken from this production area in addition to the pacific oyster samples.

For Loch Creran West: Rubha Mor (AB 130), one sample was rejected as although the reported sampling location was within the production area, its origin was reported to be from another production area. Another sample with a reported sampling location was rejected as its origin was reported to be from 'Loch Creran Depuration'. One sample had a reported collection date 304 days after analysis and arrival date, and as it could not be determined which of these dates was correct the sample was rejected.

For Loch Creran East (AB 129), no samples were rejected on the basis of major geographical or date discrepancies.

11.2 Summary of results by site

11.2.1 Summary of sampling and results - Loch Creran West

Common mussels were sampled from two reported locations within the production area as shown on Figure 11.1 (section 11.3) and in Table 11.1. The reported sampling location changed at the end of 2003 from a location just on the southern shore adjacent to the production area, to a location within the appropriate Crown Estates lease boundaries, at the current RMP.

The horse mussel samples were taken from 3 locations near the northern shoreline of the production area. Sampling locations for the rope mussels are shown in Figure 11.1, and results are summarised in Table 11.1.

The 53 mussel samples reported as originating from a location on the south shore just outside the production area and approximately 250m from the mussel lines (NM 909422, 1999-2003) are unlikely to have been collected here as no mussel aquaculture is possible at this location. It may be assumed that they were collected from the same area of mussel floats from which the later samples were collected from.

Table 11.1 - Summary of results from Loch Creran West

Sampling summary				
Production area	Loch Creran West	Loch Creran West	Loch Creran West	Loch Creran West
Site	Loch Creran	Loch Creran	Loch Creran	Loch Creran
Species	Common mussels	Common mussels	Common mussels	Horse mussels
SIN	AB 312	AB 312	AB 312	AB 312
Location sampled	NM 909422	NM 912425	NM909422 & NM912425 combined	NM913435, NM914431, NM914435
Location of RMP	NM 912425	NM 912425	NM 912425	NM 912425
Total no of samples	53	31	84	5
No. 1999	9	0	9	0
No. 2000	10	0	10	0
No. 2001	10	0	10	0
No. 2002	12	0	12	5
No. 2003	12	0	12	0
No. 2004	0	10	10	0
No. 2005	0	10	10	0
No. 2006	0	11	11	0
Results Summary (*E. coli* mpn/100g)				
Minimum	<20	<20	<20	<20
Maximum	1300	9100	9100	310
Median	40	160	50	20
Geometric mean	52.8	163	80.0	33.7
90 percentile	292	1300	735	214
95 percentile	580	6300	1300	262
No. exceeding 230/100g	6 (11%)	11 (25%)	17 (20%)	1 (20%)
No. exceeding 1000/100g	1 (2%)	6 (19%)	7 (8%)	0 (0%)
No. exceeding 4600/100g	0 (0%)	2 (6%)	2 (2%)	1 (0%)
No. exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)	2 (0%)

Samples taken from NM 912425 (2004 onwards) returned higher mean results than those taken from NM 909422 (pre 2004) (T-test, T-value=-2.95, p=0.005, Appendix 4) indicating either a general increase in contamination, a geographical effect, or a combination of both.

The horse mussel samples are not considered further in this report due to the small number of samples taken.

11.2.2 Summary of sampling and results - Inner Loch Creran

Common mussels were sampled from two locations within the production area as shown on Figure 11.1 and in Table 11.2. The reported sampling location changed at the end of 2003 from a location within the south western set of mussel lines to the current RMP, which is close to the north eastern set of mussel lines, but does not fall within the crown estates lease or the actual location of the mussel lines. Carpet clam samples were taken from two locations near the Creagan bridge.

Table 11.2 - Summary of results from Inner Loch Creran

Sampling summary				
Production area	Inner Loch Creran	Inner Loch Creran	Inner Loch Creran	Inner Loch Creran
Site	Inner Creran	Inner Creran	Inner Creran	Inner Creran
Species	Common mussels	Common mussels	Common mussels	Carpet clams
SIN	AB 313	AB 313	AB 313	AB 313
Location sampled	NM945426	NM953436	NM 945426 & NM 953436 combined	NM 979422, NM 981443
Location of RMP	NM 953436	NM 953436	NM 953436	None
Total no of samples	32	31	63	3
No. 2001	8	0	8	0
No. 2002	12	0	12	3
No. 2003	12	0	12	0
No. 2004	0	11	11	0
No. 2005	0	10	10	0
No. 2006	0	10	10	0
Results Summary (*E. coli* mpn/100g)				
Minimum	<20	<20	<20	<20
Maximum	750	5400	5400	1100
Median	40	160	90	70
Geometric mean	56.6	196	104	91.7
90 percentile	472	3500	1190	894
95 percentile	590	5400	3390	997
No. exceeding 230/100g	4 (12.5%)	12 (39%)	16 (25%)	1 (33%)
No. exceeding 1000/100g	0 (0%)	7 (23%)	7 (11%)	1 (33%)
No. exceeding 4600/100g	0 (0%)	3 (10%)	3 (5%)	0 (0%)
No. exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Samples taken from NM 953436 (2004 onwards) returned higher mean results than those taken from NM 945426 (pre 2004) (T-test, T-value=-3.17, p=0.003, Appendix 4) indicating either a general increase in contamination, a geographical effect, or a combination of both.

The carpet clam samples are not considered further in this report due to the small number of samples of this species taken, which are not directly comparable with the mussel results.

11.2.3 Summary of sampling and results - Loch Creran West: Shian

Pacific oysters were sampled from one location, which falls just outside the production area, and about 20m from the nearest trestles. This is within the 100m level of accuracy attained when estimating a grid reference from and Ordnance Survey map. This location is also the RMP. Two native oyster samples were also taken from this location but were not included in calculating the geometric mean presented in Figure 11.2. Results are summarised in Table 11.3.

Table 11.3 - Summary of results from Loch Creran West: Shian

Sampling summary		
Production area	Loch Creran West: Shian	Loch Creran West: Shian
Site	Shian Fisheries	Shian Fisheries
Species	Pacific oysters	Native oysters
SIN	AB 131	AB 131
Location	NM 909422	NM 909422
Location of RMP	NM 909422	None
Total no of samples	95	2
No. 1999	12	0
No. 2000	12	0
No. 2001	11	0
No. 2002	11	0
No. 2003	14	2
No. 2004	12	0
No. 2005	12	0
No. 2006	11	0
Results Summary (*E. coli* mpn/100g)		
Minimum	<20	<20
Maximum	9100	1100
Median	110	555
Geometric mean	96.5	105
90 percentile	730	991
95 percentile	1300	1050
No. exceeding 230/100g	17 (18%)	1 (50%)
No. exceeding 1000/100g	6 (6%)	1 (50%)
No. exceeding 4600/100g	2 (2%)	0 (0%)
No. exceeding 18000/100g	0 (0%)	0 (0%)

The native oyster samples are not considered further in this report due to the small number of samples taken. It is possible that these were pacific oyster samples assigned to the wrong species.

11.2.4 Summary of sampling and results - Loch Creran West: Rubha Mor

Pacific oysters were sampled from 5 locations within this production area. All samples from the Loch Creran West: Rubha Mor: Rubha Mor were taken within approximately 250m of each other, close to or within the actual farm boundaries. On many occasions prior to 2004, two samples were taken from Loch Creran West: Rubha Mor: Rubha Mor on the same day. Samples taken from the Loch Creran West: Rubha Mor: Loch Creran Ferlochan site were reported as taken from a point approximately 300m north of the Crown Estates lease boundary, beyond the intertidal zone but within the production area boundaries. Figure 11.2 shows the geometric mean result by sampling location. Results are summarised in Table 11.4.

Table 11.4 Summary of results from Loch Creran West: Rubha Mor

Sampling summary						
Production area	Loch Creran West: Rubha Mor	Loch Creran West: Rubha Mor	Loch Creran West: Rubha Mor	Loch Creran West: Rubha Mor	Loch Creran West: Rubha Mor	Loch Creran West: Rubha Mor
Site	Rubha Mor	Rubha Mor	Rubha Mor	Loch Creran Ferlochan	Rubha Mor	All sites (2)
Species	Pacific oysters	Pacific oysters	Pacific oysters	Pacific oysters	Pacific oysters	Pacific oysters
SIN	AB13002213	AB13002213	AB13002213	AB13074213	AB13002213	AB130
Location sampled	NM918405	NM916406	NM916407	NM918415	NM918407	All combined
Location of RMP	NM 916406	NM 916406	NM 916406	NM 916406	NM 916406	NM 916406
Total no of samples	90	42	16	9	1	158
No. 1999	20	0	0	0	0	20
No. 2000	22	0	0	0	0	22
No. 2001	24	0	0	0	0	24
No. 2002	22	0	0	0	0	22
No. 2003	2	11	11	0	0	24
No. 2004	0	8	5	0	1	14
No. 2005	0	12	0	0	0	12
No. 2006	0	11	0	9	0	20
Results Summary (*E. coli* mpn/100g)						
Minimum	<20	<20	20	<20	70	<20
Maximum	1700	>18000	500	310	70	>18000
Median	110	45	160	10	70	70
Geometric mean	96.3	64.4	124	33.5	70	83.4
90 percentile	500	310	465	238	70	500
95 percentile	750	2300	500	274	70	750
No. exceeding 230/100g	22 (24%)	6 (14%)	5 (30%)	1 (11%)	0 (0%)	34 (22%)
No. exceeding 1000/100g	4 (4%)	3 (7%)	0 (0%)	0 (0%)	0 (0%)	7 (4%)
No. exceeding 4600/100g	0 (0%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
No. exceeding 18000/100g	0 (0%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)

A comparison of results by sampling location indicates no significant difference (One-way ANOVA, p=0.116, Appendix 4).

11.2.5 Summary of sampling and results - Loch Creran East

Pacific oysters were sampled from one location within this production area, at the RMP. Figure 11.2 shows the sampling location and geometric mean result. Results are summarised in Table 11.5.

Table 11.5 Summary of results from Loch Creran East

Sampling summary	
Production area	Loch Creran East
Site	East: Barrington
Species	Pacific oysters
SIN	AB 129
Location sampled	NM 949430
Location of RMP	NM 949430
Total no of samples	56
No. 2002	8
No. 2003	12
No. 2004	12
No. 2005	12
No. 2006	12
Results Summary (*E. coli* mpn/100g)	
Minimum	<20
Maximum	>18000
Median	500
Geometric mean	492
90 percentile	5400
95 percentile	9100
No. exceeding 230/100g	38 (68%)
No. exceeding 1000/100g	20 (36%)
No. exceeding 4600/100g	9 (15%)
No. exceeding 18000/100g	1 (2%)

11.3 Overall geographic patterns in results

Table 11.6 presents a summary of results for commercially cultures shellfish by production area. Table 11.7 presents a summary of results by reported grid reference for all samples, where more than one sample has been taken from that grid reference. Figure 11.1 presents the geometric mean sampling result (mpn/100g), the number of samples taken, the period sampled and the site sampled for all rope mussel samples. Figure 11.2 presents the same as Figure 11.1 but for pacific oyster samples.

Table 11.6 Summary comparison of results by production area

Sampling summary					
Production area	Loch Creran West	Inner Loch Creran	Loch Creran West: Shian	Loch Creran West: Rubha Mor	Loch Creran East
Species	Common mussels	Common mussels	Pacific oysters	Pacific oysters	Pacific oysters
SIN	AB 312	AB 313	AB 131	AB 130	AB 129
Total no of samples	84	63	95	158	56
No. 1999	9	0	12	20	0
No. 2000	10	0	12	22	0
No. 2001	10	8	11	24	0
No. 2002	12	12	11	22	8
No. 2003	12	12	14	24	12
No. 2004	10	11	12	14	12
No. 2005	10	10	12	12	12
No. 2006	11	10	11	20	12
Results Summary (*E. coli* mpn/100g)					
Minimum	<20	<20	<20	20	<20
Maximum	9100	5400	9100	>18000	>18000
Median	50	90	110	70	500
Geometric mean	80.0	104	96.5	83.4	492
90 percentile	735	1190	730	500	5400
95 percentile	1300	3390	1300	750	9100
No. exceeding 230/100g	17 (20%)	16 (25%)	17 (18%)	34 (22%)	38 (68%)
No. exceeding 1000/100g	7 (8%)	7 (11%)	6 (6%)	7 (4%)	20 (36%)
No. exceeding 4600/100g	2 (2%)	3 (5%)	2 (2%)	1 (1%)	9 (15%)
No. exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)	1 (1%)	1 (2%)

Table 11.7 Summary of results by reported sampling location

Production Area	**Site**	**Grid reference**	**Species**	**No. samples**	**Geometric mean result (mpn/100g)**	**Sampling period**
Loch Creran West	Loch Creran	NM909422	Common mussels	53	52.8	1999 to 2003
Loch Creran West	Loch Creran	NM912425	Common mussels	31	163	2004 to 2006
Inner Loch Creran	Inner Creran	NM945426	Common mussels	32	56.6	2001 to 2003
Inner Loch Creran	Inner Creran	NM953436	Common mussels	31	196	2004 to 2006
Loch Creran West: Shian	Shian Fisheries	NM909422	Pacific oysters	95	96.5	1999 to 2006
Loch Creran West: Rubha Mor	Rubha Mor	NM918405	Pacific oysters	90	96.3	1999 to 2003
Loch Creran West: Rubha Mor	Rubha Mor	NM916406	Pacific oysters	42	64.4	2003 to 2006
Loch Creran West: Rubha Mor	Rubha Mor	NM916407	Pacific oysters	16	124	2003 to 2004
Loch Creran West: Rubha Mor	Loch Creran Ferlochan	NM918415	Pacific oysters	9	33.5	2006 to 2006
Loch Creran East	East - Barrington	NM949430	Pacific oysters	56	492	2002 to 2006

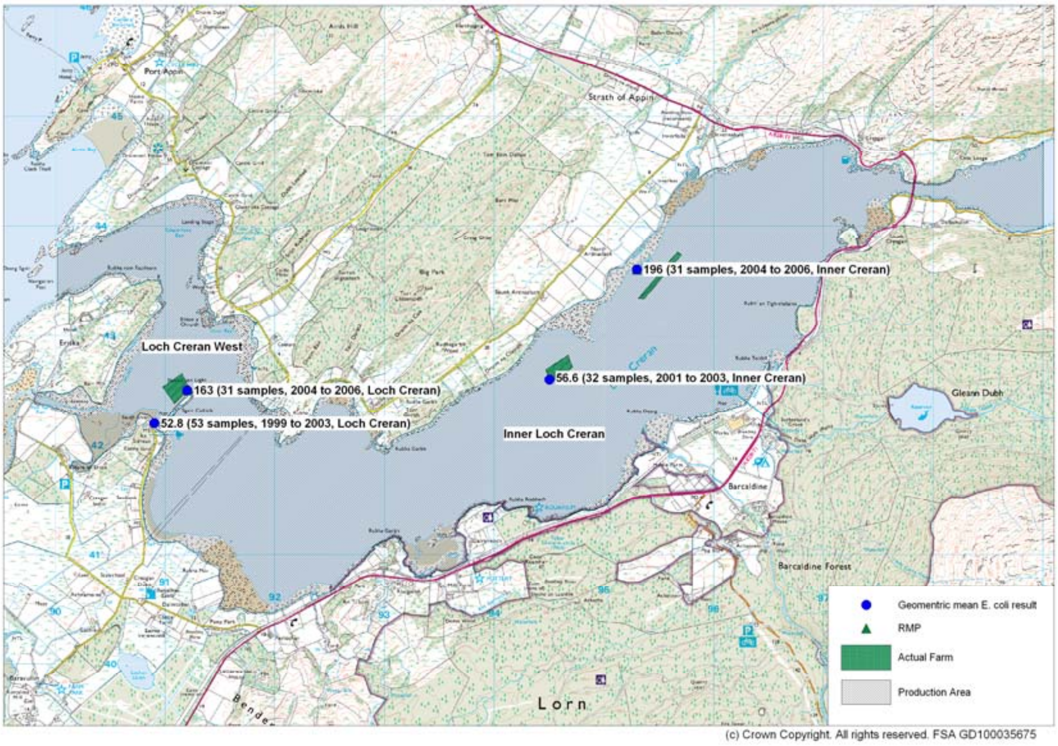

Figure 11.1 Geometric mean result by sampling location (rope mussel samples).

The results from the two mussel production areas are similar (T-test, T-value=0.97, p=0.332, Appendix 4). For both mussel production sites, the sampling point changed in January 2004. In both cases this led to a significant deterioration in results (see sections 11.2.1 and 11.2.2).

A comparison of all results obtained for the two sites pre January 2004 indicates that there is no statistically significant difference between sites (T-test, T-value=0.25, p=0.803, Appendix 4). A comparison of the results obtained for the two mussel sites from January 2004 on also indicates that there is no significant difference between sites (T-test, T-value=0.40, p=0.693, Appendix 4). This suggests that microbiological quality is similar at the two mussel sites, and the deterioration in results noted in sections 11.2.2 and 11.2.3 reflects a decrease in water quality affecting the whole loch.

It should be noted that the reported sampling location for samples collected from Loch Creran West before January 2004 is incorrect and it is not known where exactly these samples were taken from (see Section 11.2.1).

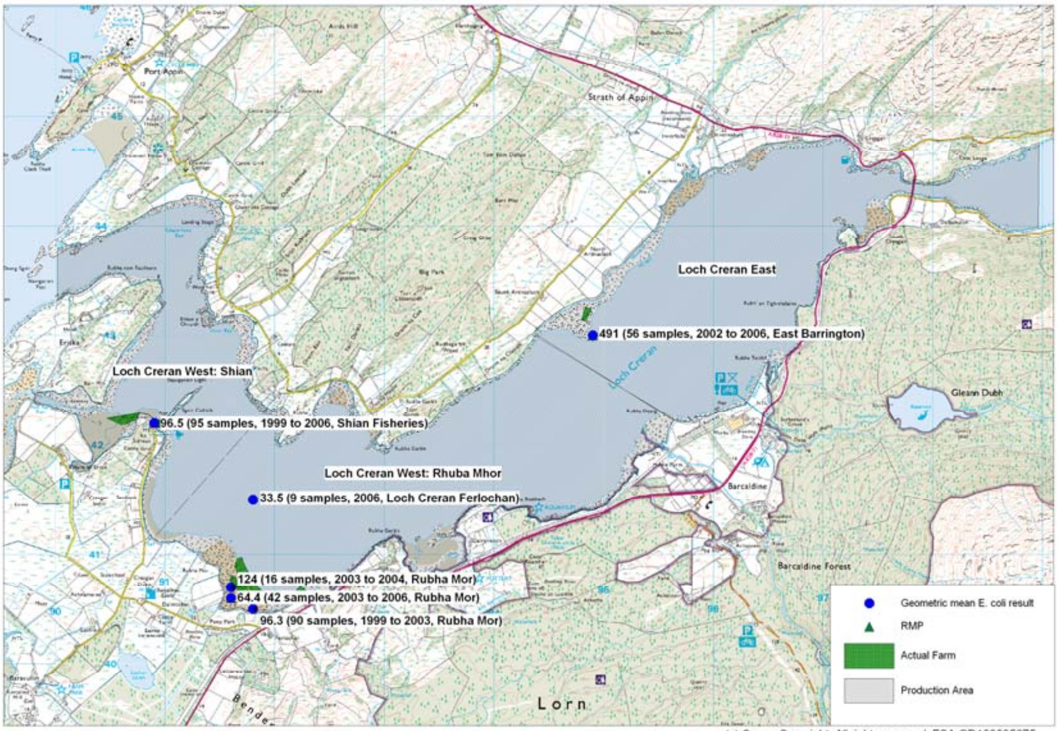

Figure 11.2 Geometric mean result by sampling location (pacific oyster samples).

A significant difference in results between oyster production areas was found (One-way ANOVA, p=0.000, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) indicates that the results from Loch Creran East are significantly higher than those obtained for Loch Creran West: Rubha Mor and Loch Creran West: Shian, which are not significantly different from each other. Therefore, it is concluded that a localised source of contamination is affecting Loch Creran East, but neither of the other oyster production areas. No significant differences in results between the locations sampled within Loch Creran West: Rubha Mor were found (see Section 11.2.4).

Because of differences in physiology and culture methods between oysters and mussels, it is not appropriate to compare the results for the two different species directly.

11.4 Overall temporal pattern of results

Figures 11.3 to 11.12 present plots of individual results against time for all commercial shellfish samples. Figures 11.3, 11.5, 11.7, 11.9 and 11.11 present scatterplots of results by date, and are fitted with a loess smoother, a regression based smoother line calculated by the Minitab statistical software. These smoother lines help highlight any apparent underlying trends or cycles. Figures 11.4, 11.6, 11.8, 11.10 and 11,12 present boxplots of *E. coli* results by year. Figure 11.13 presents the geometric mean by year for individual production areas together.

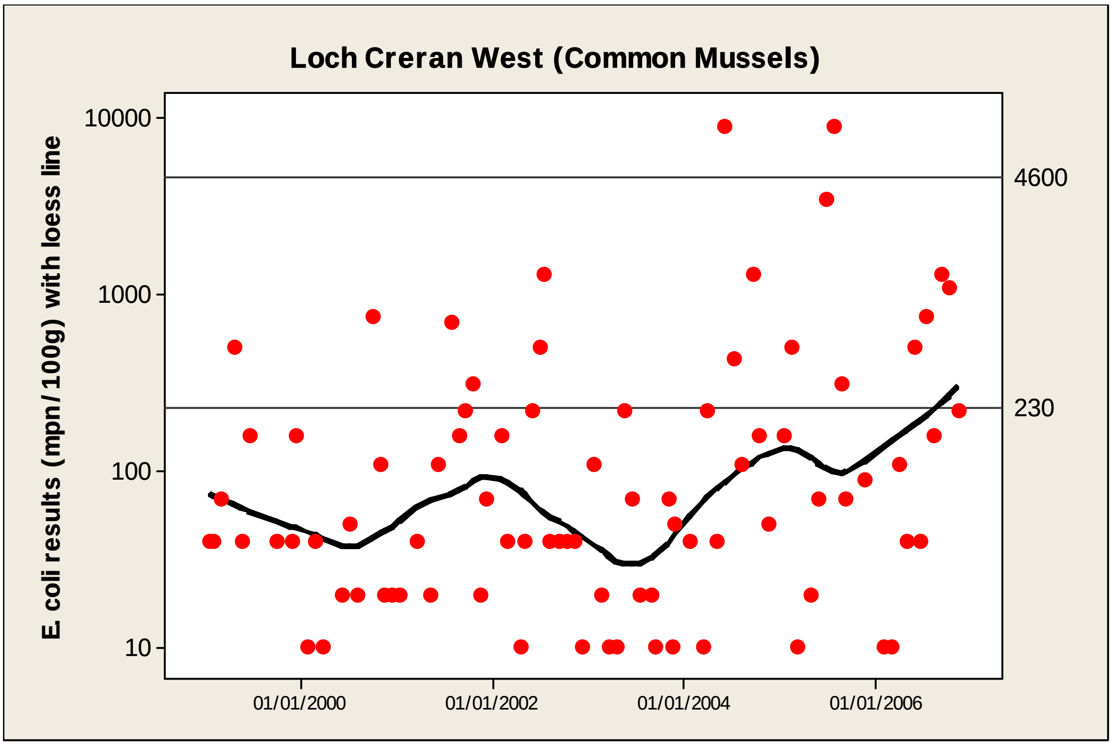

Figure 11.3 Scatterplot of results by date with loess smoother (Loch Creran West mussels)

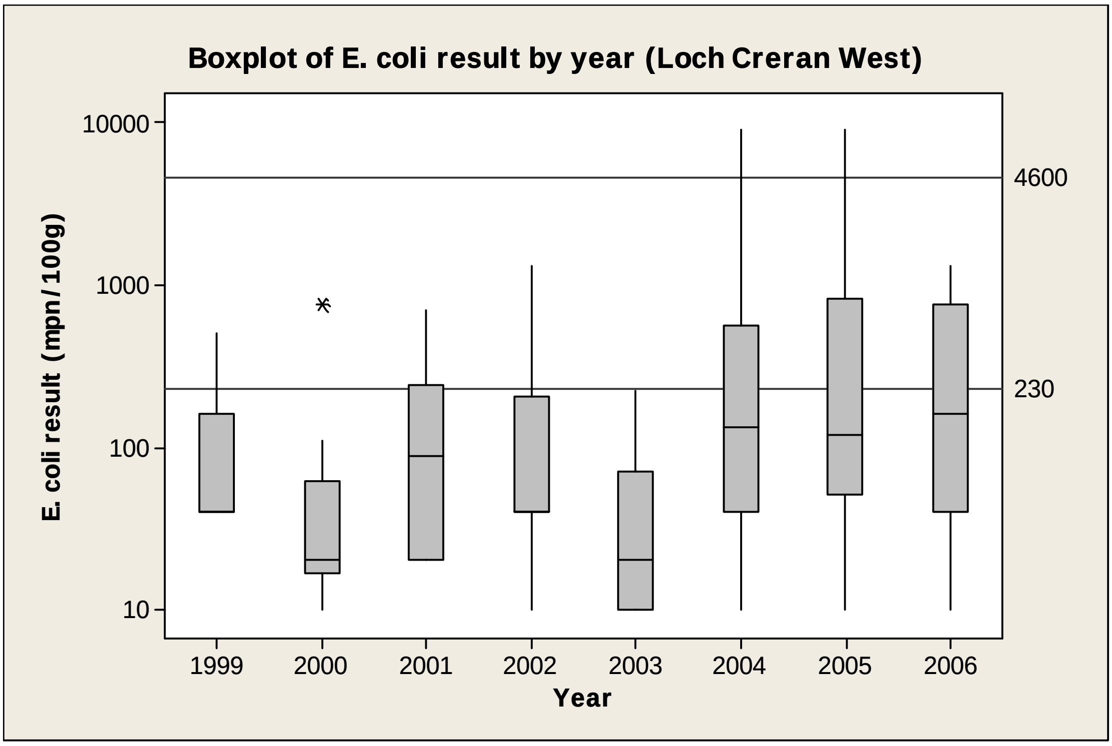

Figure 11.4 Boxplot of results by year (Loch Creran West)

Figures 11.3 and 11.4 suggest an overall deterioration in microbiological quality in recent years occurring mainly in 2004 just after the reported sampling location changed. The impression of a cycle is given on Figure 11.3, with peaks at the beginning of 2002 and the beginning of 2005, and a trough in early-mid 2003. The reason for this is unclear, as it does not appear to coincide with any obvious triggers such as season or rainfall.

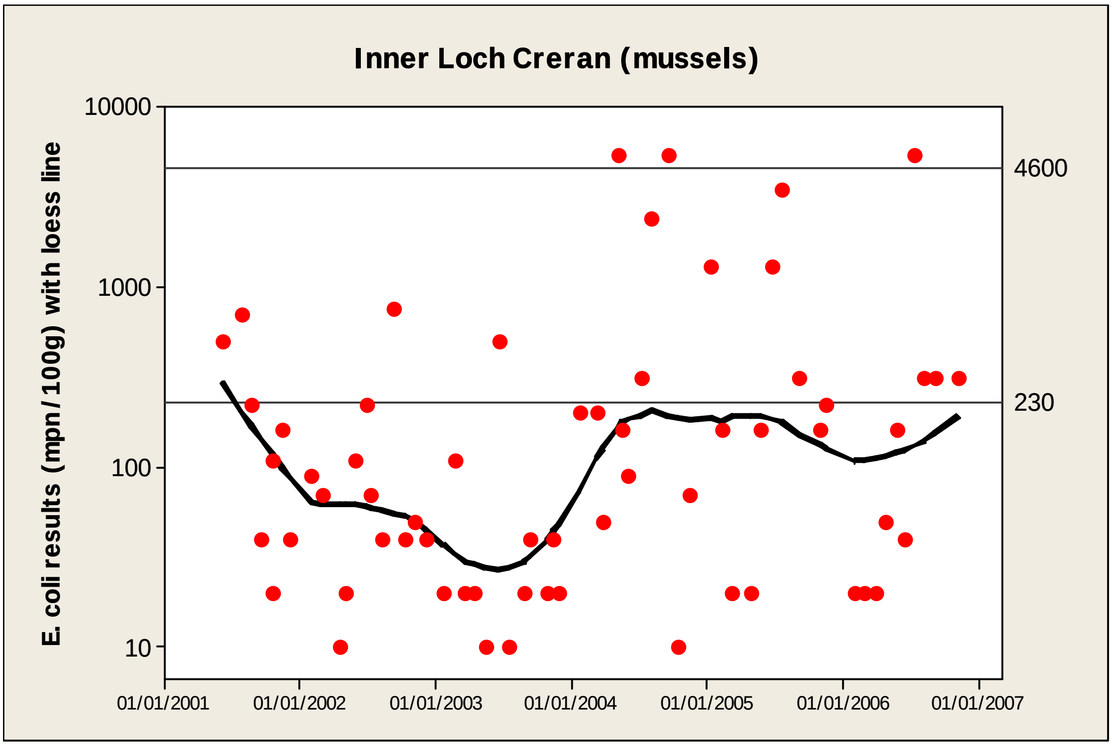

Figure 11.5 Scatterplot of results by date with loess smoother (Inner Loch Creran mussels)

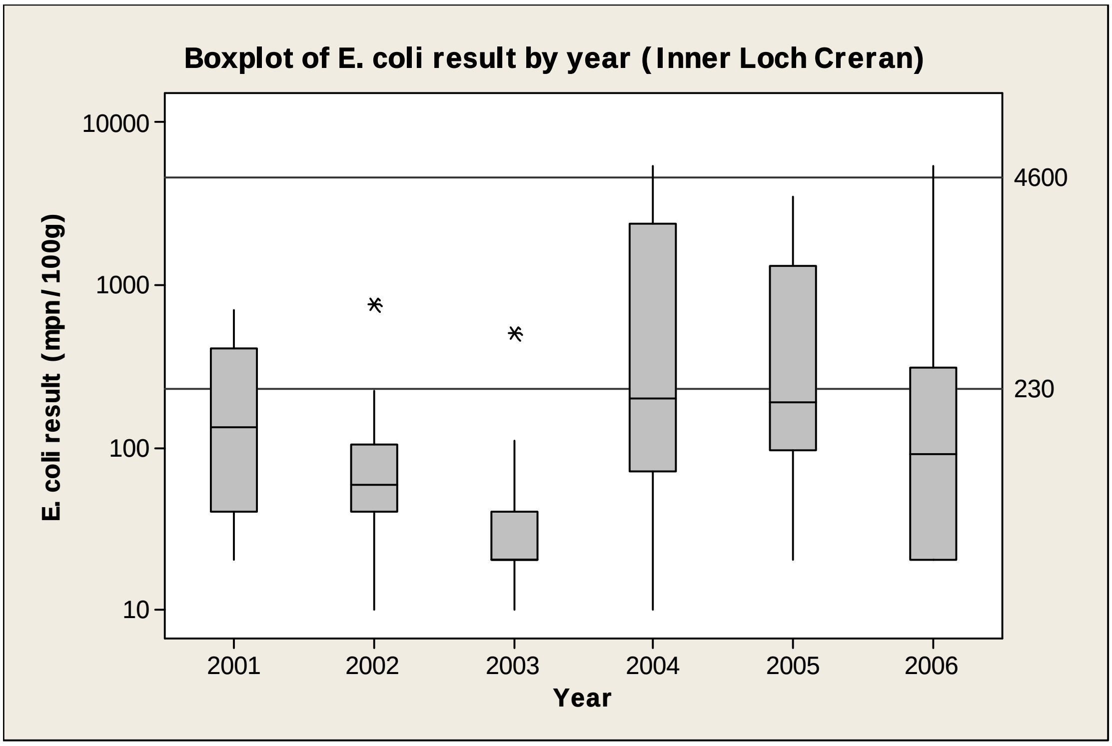

Figure 11.6 Boxplot of results by year (Inner Loch Creran)

Figures 11.5 and 11.6 show deterioration in microbiological quality in early 2004, around the time when the sampling point moved. Results appear to have been improving up to this point.

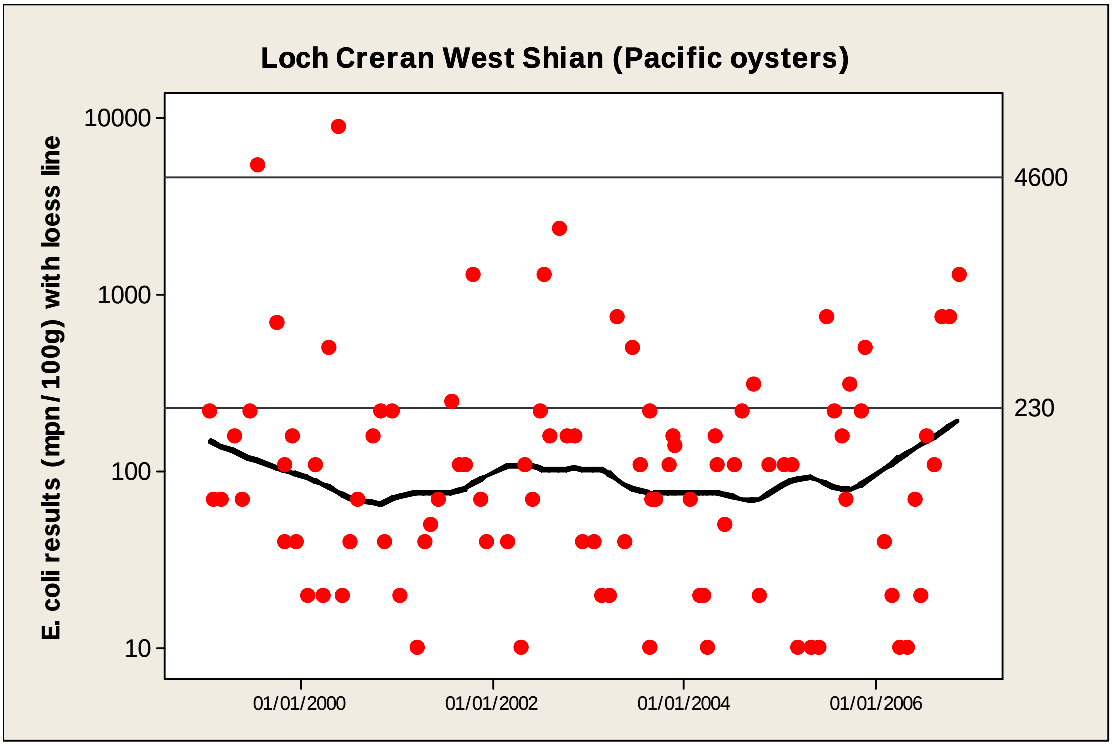

Figure 11.7 Scatterplot of results by date with loess smoother (Loch Creran West: Shian oysters)

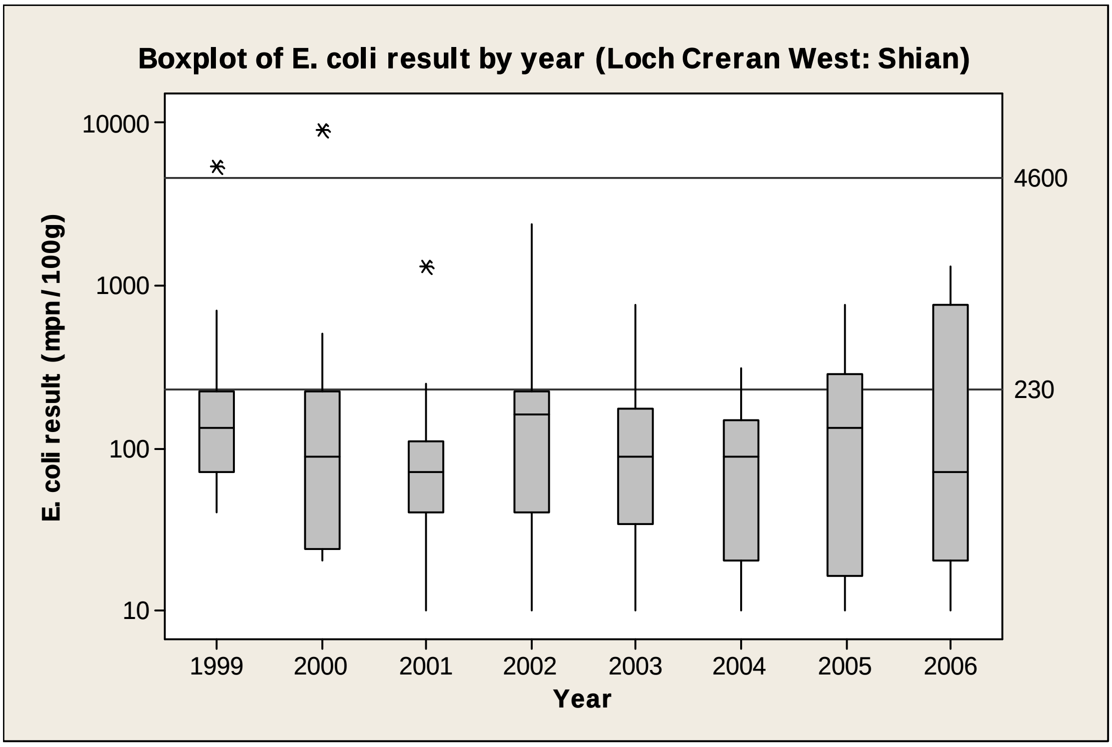

Figure 11.8 Boxplot of results by year (Loch Creran West: Shian)

No trends or cycles are apparent in Figures 11.7 or 11.8.

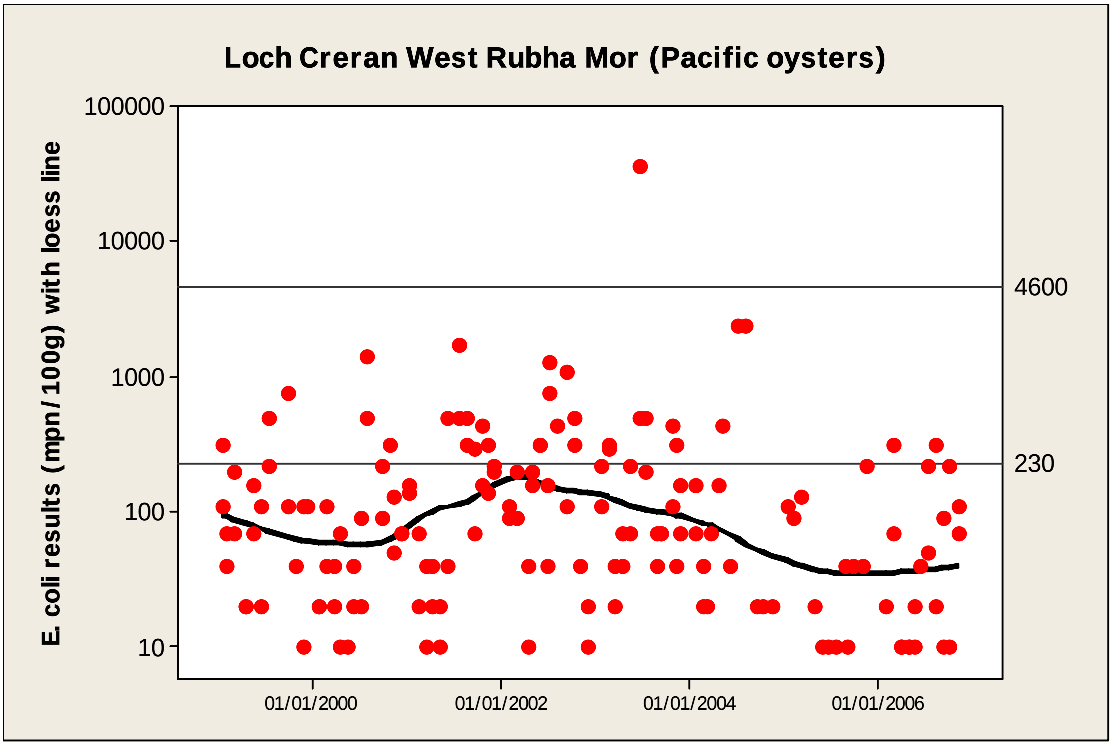

Figure 11.9 Scatterplot of results by date with loess smoother (Loch Creran West: Rubha Mor oysters)

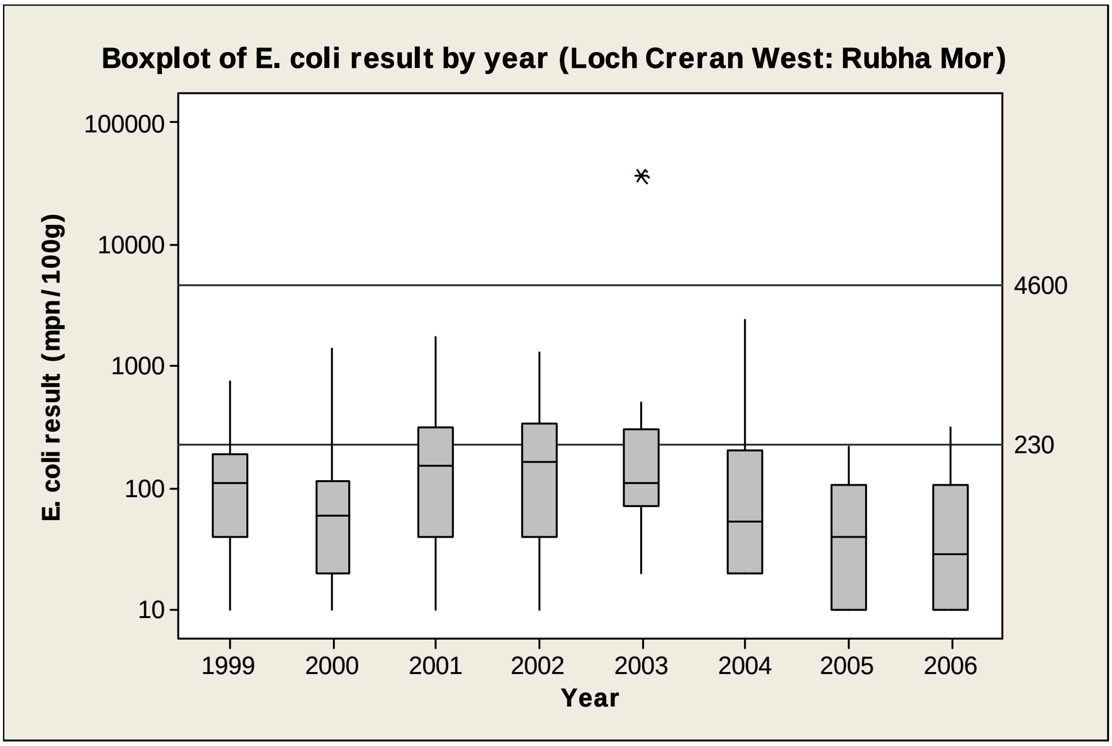

Figure 11.10 Boxplot of results by year (Loch Creran West: Rubha Mor)

A slight improvement in microbiological quality since 2002 can be seen in Figures 11.9 and 11.10.

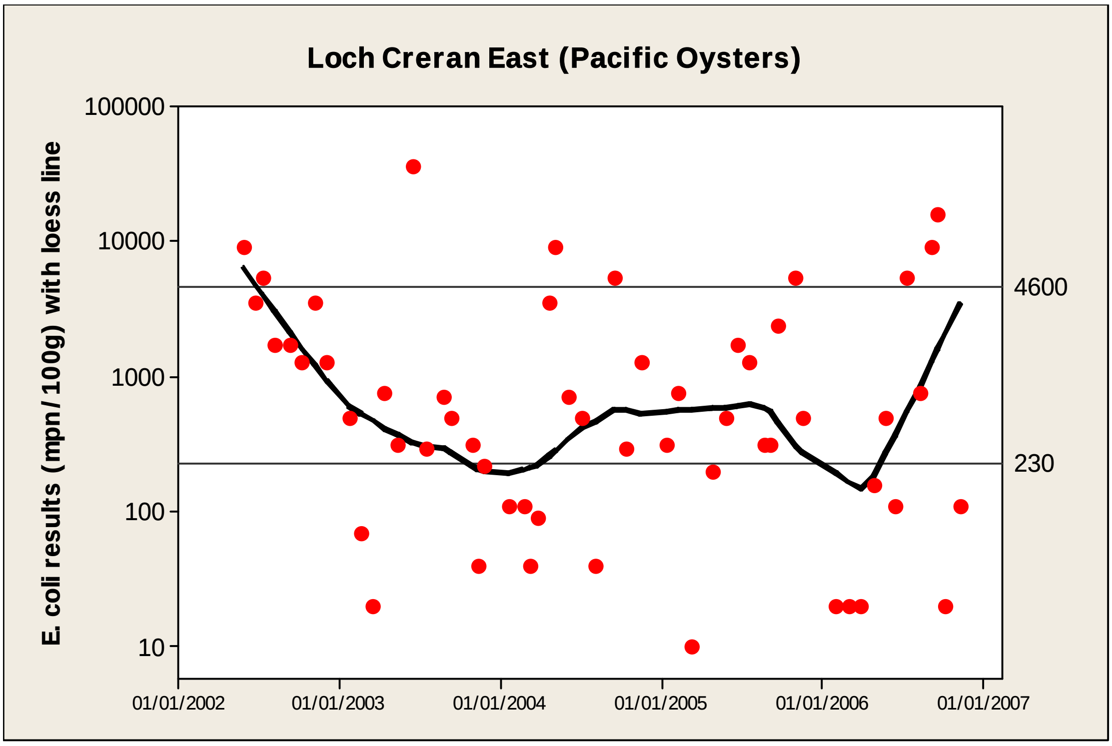

Figure 11.12 Scatterplot of results by date with loess smoother (Loch Creran East osyters)

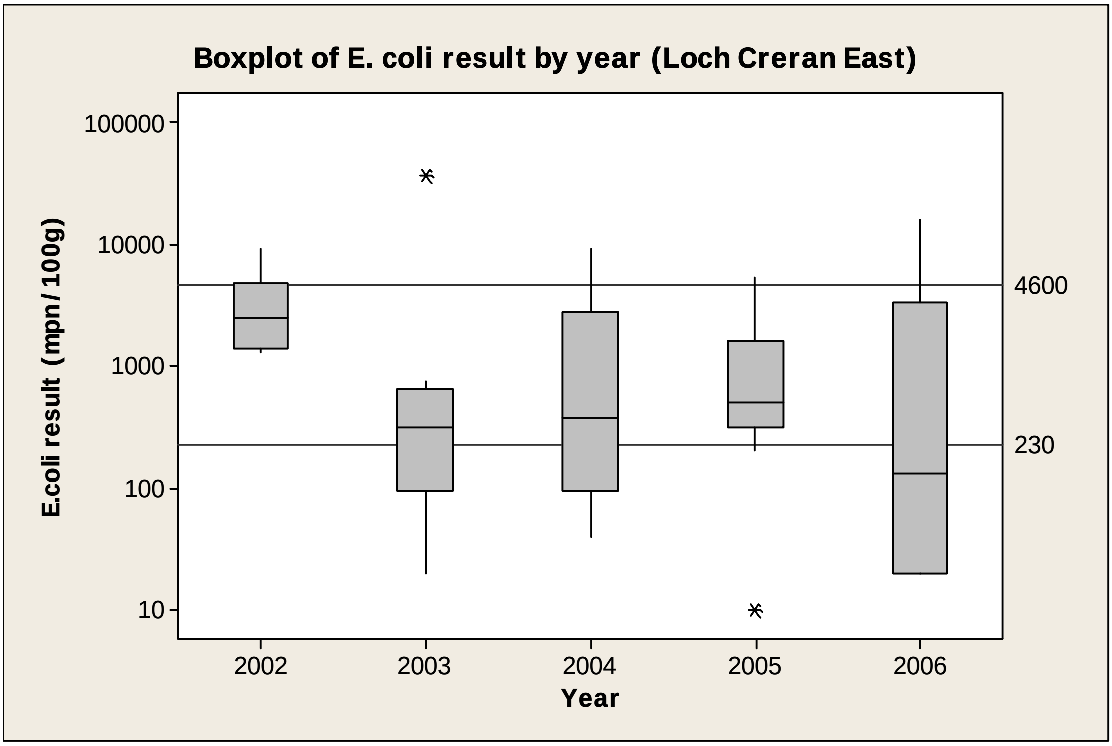

Figure 11.13 Boxplot of results by year (Loch Creran East)

There is an apparent overall improvement in microbiological quality from 2002-2003, followed by a period of relative stability, with a deterioration towards the end of 2006 indicated in Figures 11.11 and 11.12.

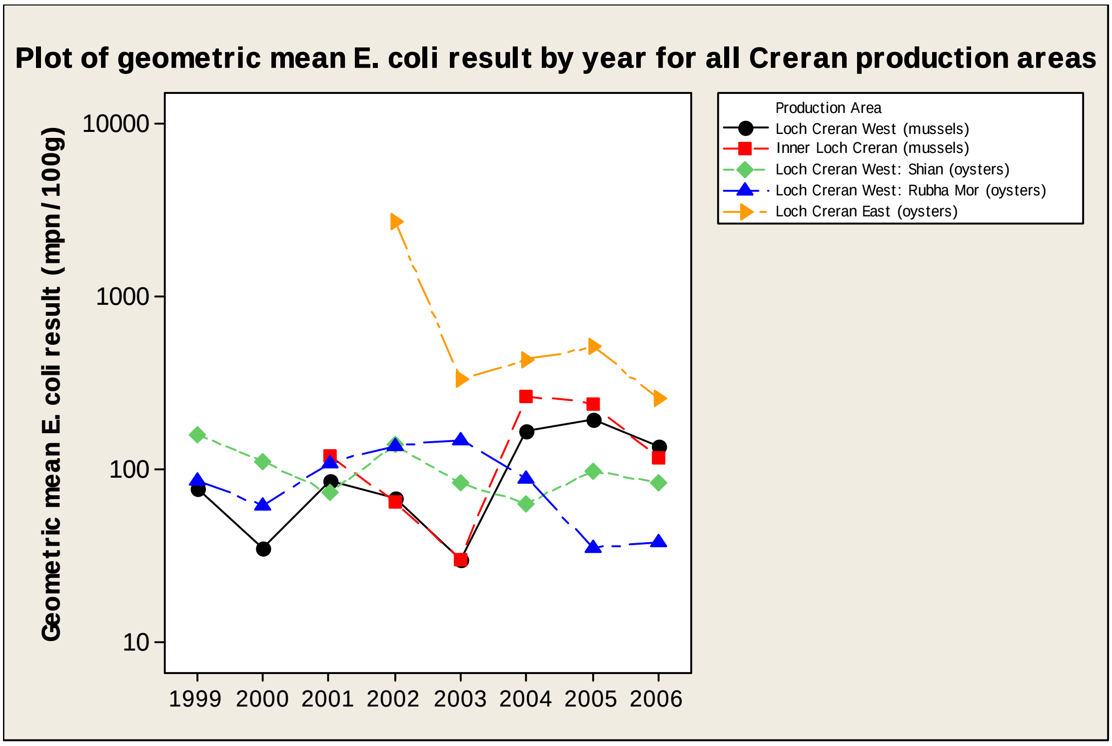

Figure 11.13 Geometric mean *E. coli* result by year for each production area

In summary, the temporal pattern of results for the two mussel production areas were very similar, with a distinct increase in levels of contamination in 2004. For the oyster production areas, trends appeared weaker and more site specific. This may be expected as mussels are cultivated in the better mixed open water but oysters are cultivated in the shallow intertidal zone and are more likely to be affected by localised sources such as freshwater inputs to the adjacent shoreline.

11.5 Seasonal pattern of results

Season dictates not only weather patterns, but livestock numbers and movements, presence of wild animals and patterns of human occupation.

Figures 11.14 to 11.18 present the geometric mean of results by month (+ 2 times the standard error) by production area. Figure 11.19 presents this data in one line plot (error bars omitted for clarity).

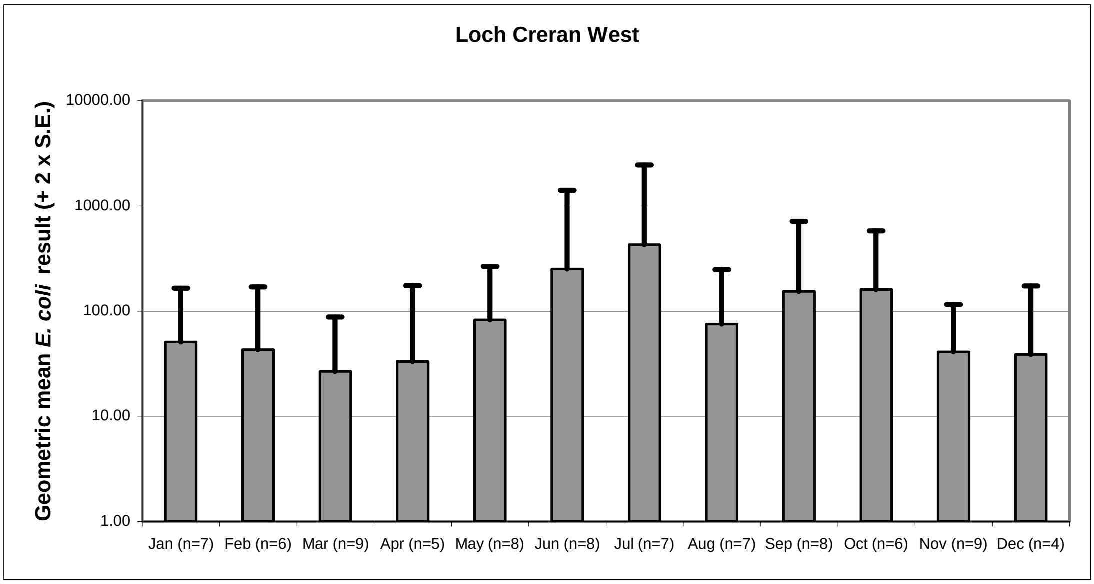

Figure 11.14 Geometric mean result by month (Loch Creran West mussels)

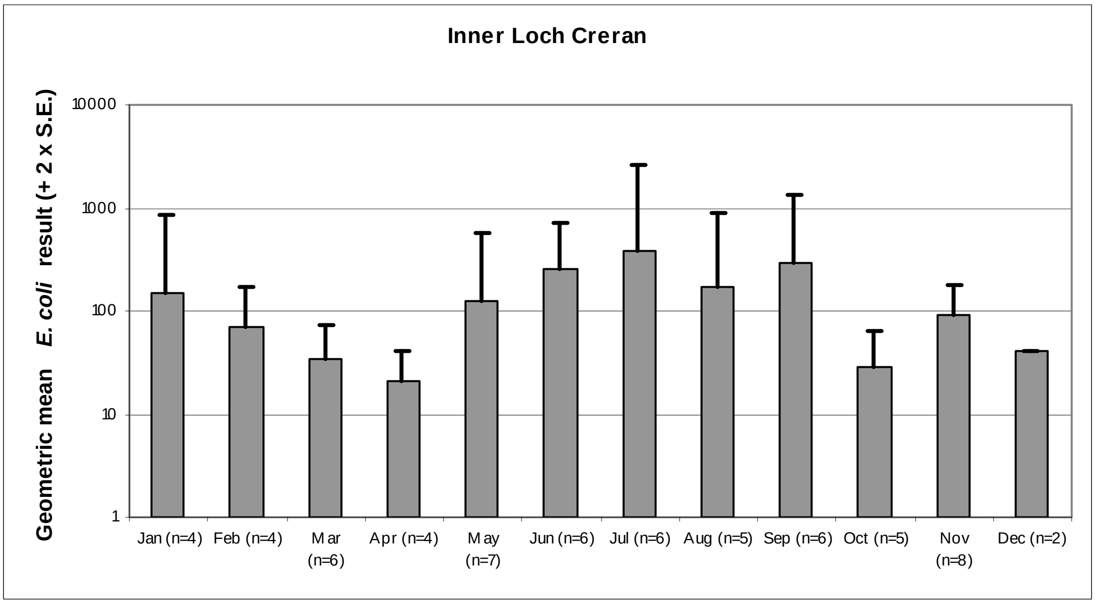

Figure 11.15 Geometric mean result by month (Inner Loch Creran mussels)

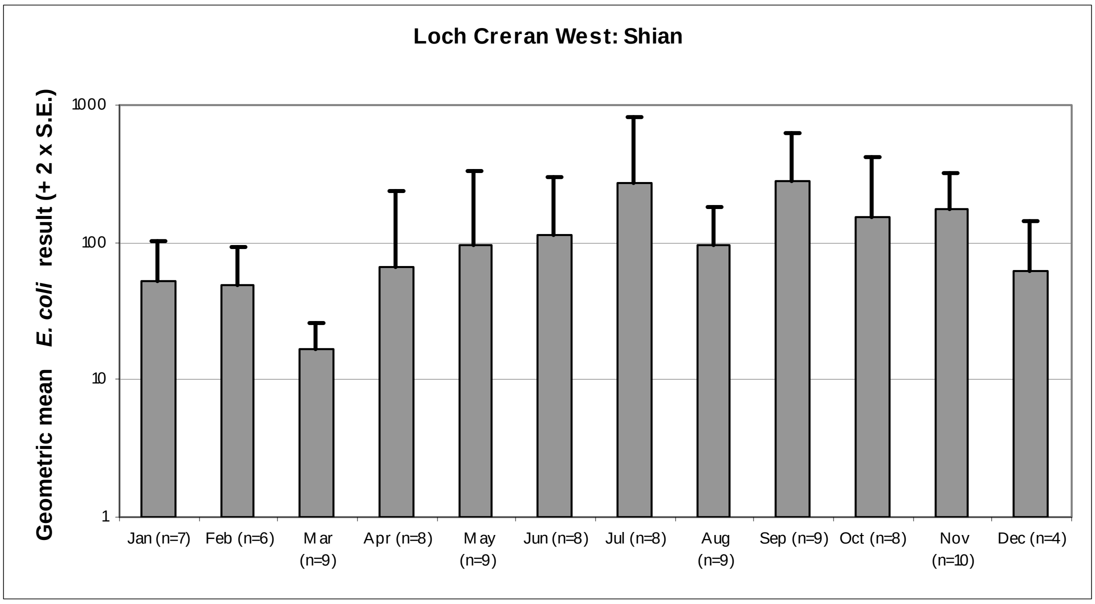

Figure 11.16 Geometric mean result by month (Loch Creran West: Shian oysters)

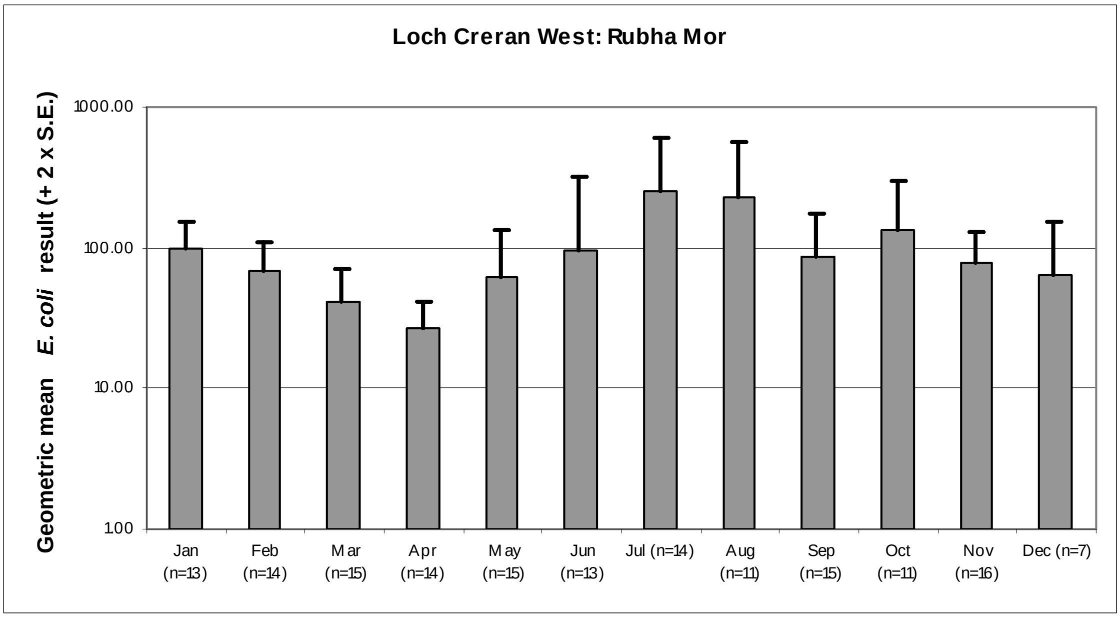

Figure 11.17 Geometric mean result by month (Loch Creran West: Rubha Mor oysters)

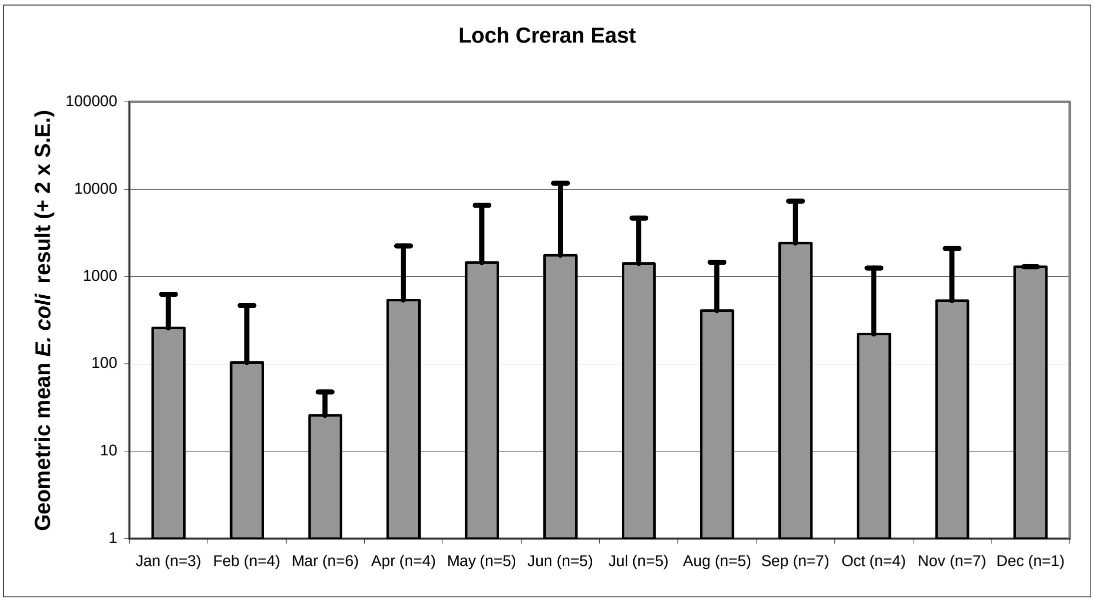

Figure 11.18 Geometric mean result by month (Loch Creran East oysters)

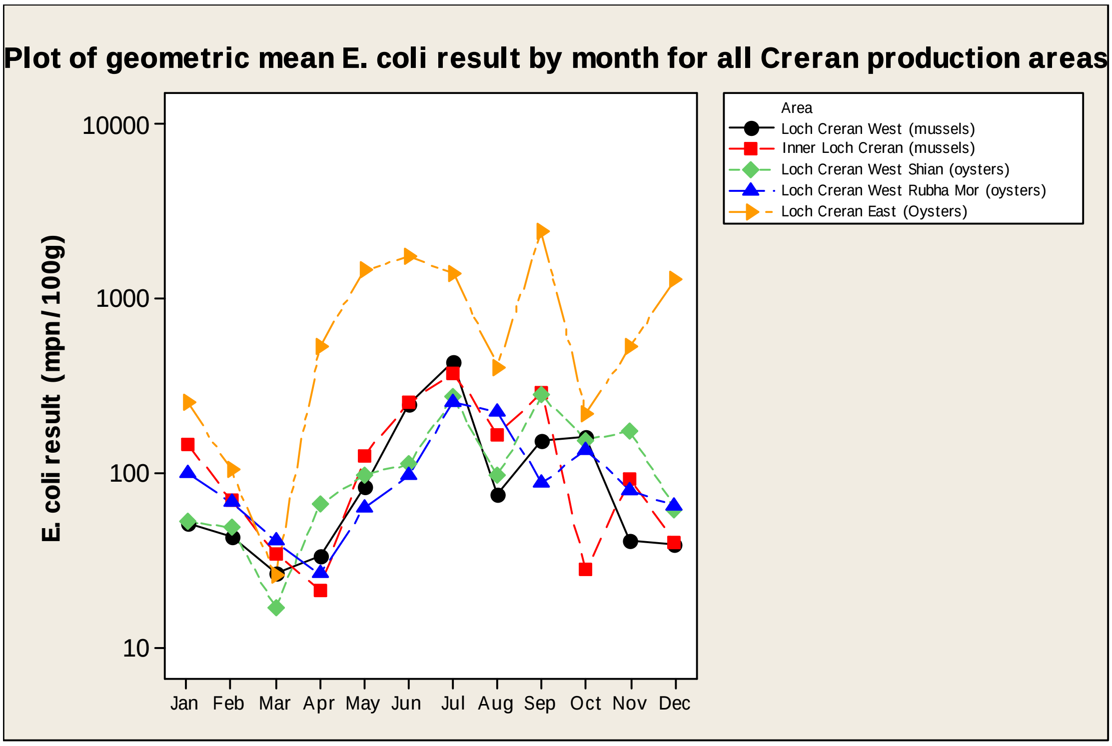

Figure 11.19 Geometric mean *E. coli* result by month (all Creran production areas).

The overall trend for both mussels and oysters is for lowest mean results in the March/April, steadily increasing to highest mean results in July. The late summer autumn period experiences high but more variable results, possibly reflecting the more changeable weather patterns experienced at this time of year. Results during the winter are generally lower, decreasing through the season towards spring. Oysters and mussels from Inner Loch Creran and Loch Creran East follow a similar pattern of peaks and troughs during the autumn suggesting they are affected by the same inputs.

Seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February). Figures 11.20 to 11.24 present boxplots of *E. coli* results by season for each production area.

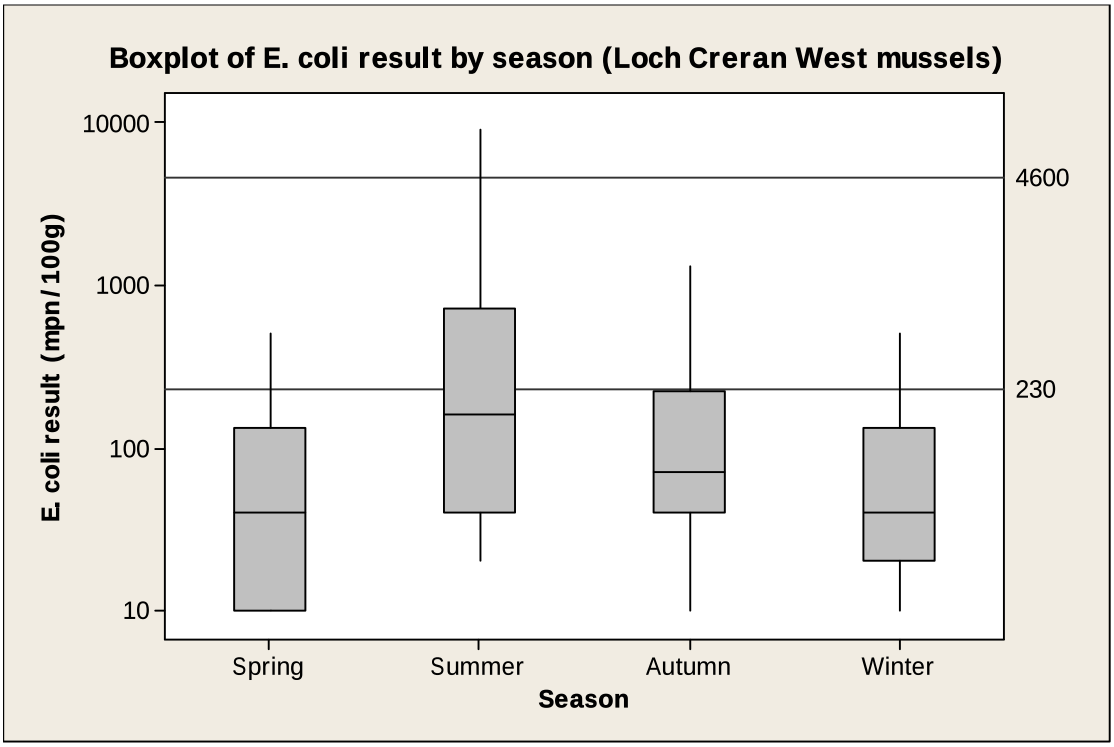

Figure 11.20 Boxplot of result by season (Loch Creran West)

A statistically significant seasonal effect was observed for Loch Creran West (One-way ANOVA, p=0.003, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) identified that results in the summer higher than those in the spring and winter, and that all other seasonal differences were not statistically significant.

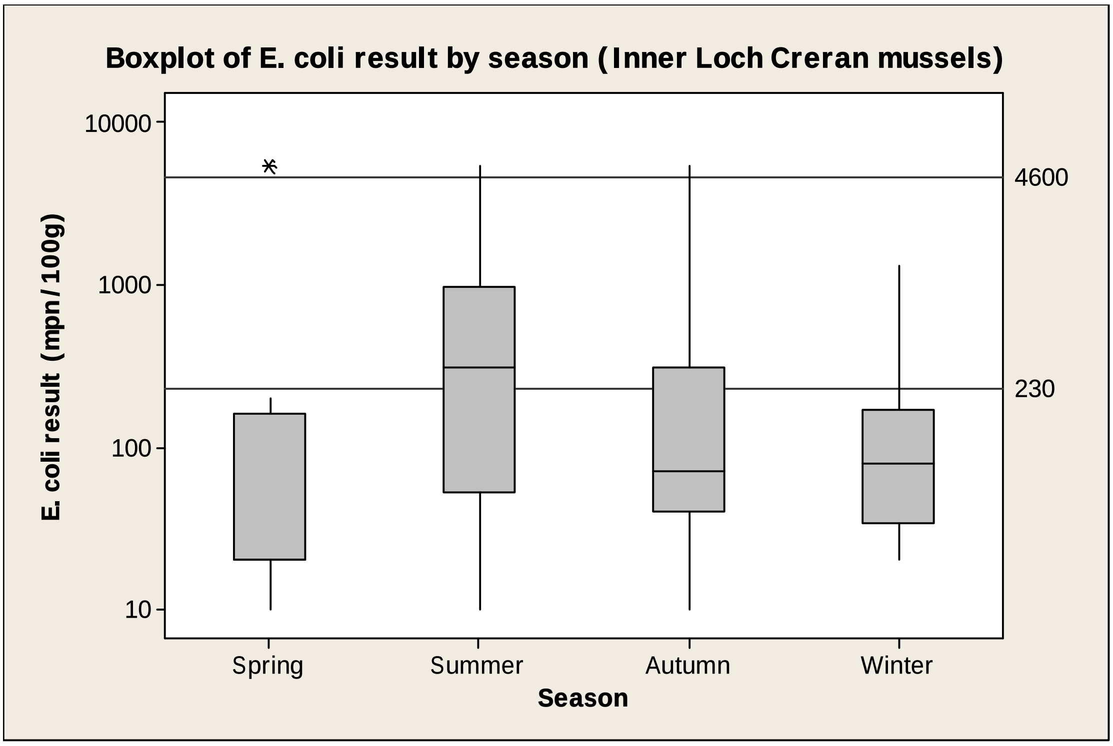

Figure 11.21 Boxplot of result by season (Inner Loch Creran)

A statistically significant seasonal effect was observed for Inner Loch Creran (One-way ANOVA, p=0.037, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) identified that results in the summer higher than those in the spring, and that all other seasonal differences were not statistically significant.

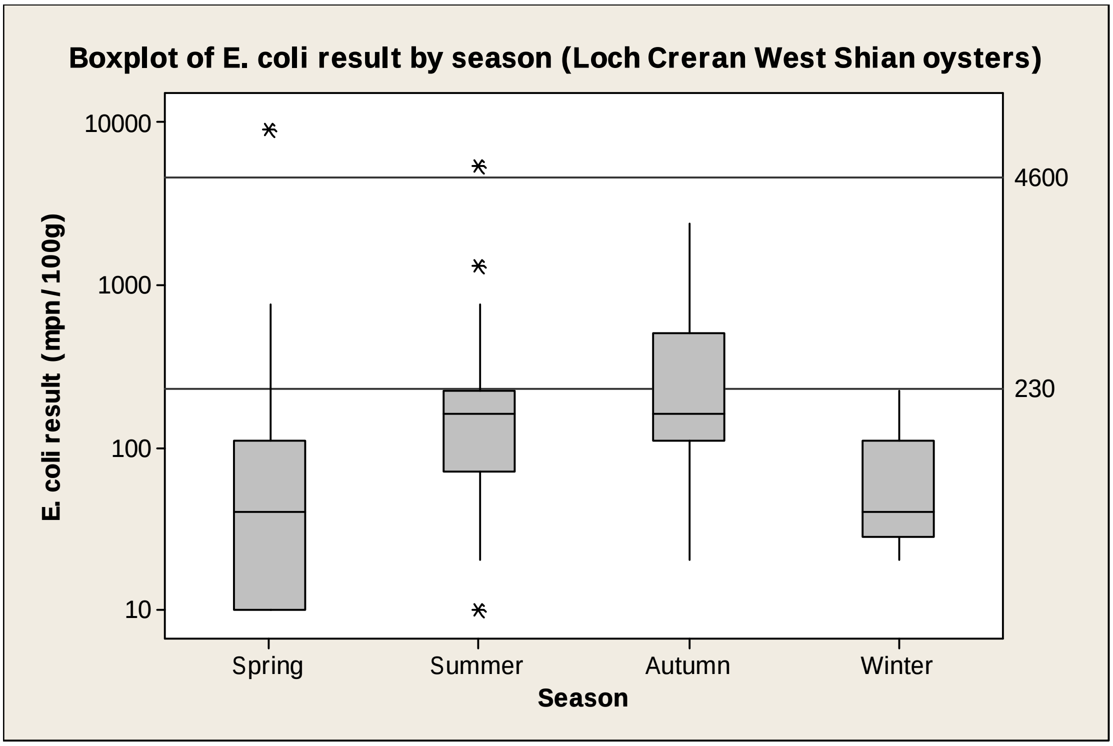

Figure 11.22 Boxplot of result by season (Loch Creran West: Shian)

A statistically significant seasonal effect was observed for Loch Creran West: Shian (One-way ANOVA, p=0.000, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) identified that results in the spring were lower than those in the summer and autumn, and results in the were winter lower than in the autumn, and that all other seasonal differences were not statistically significant.

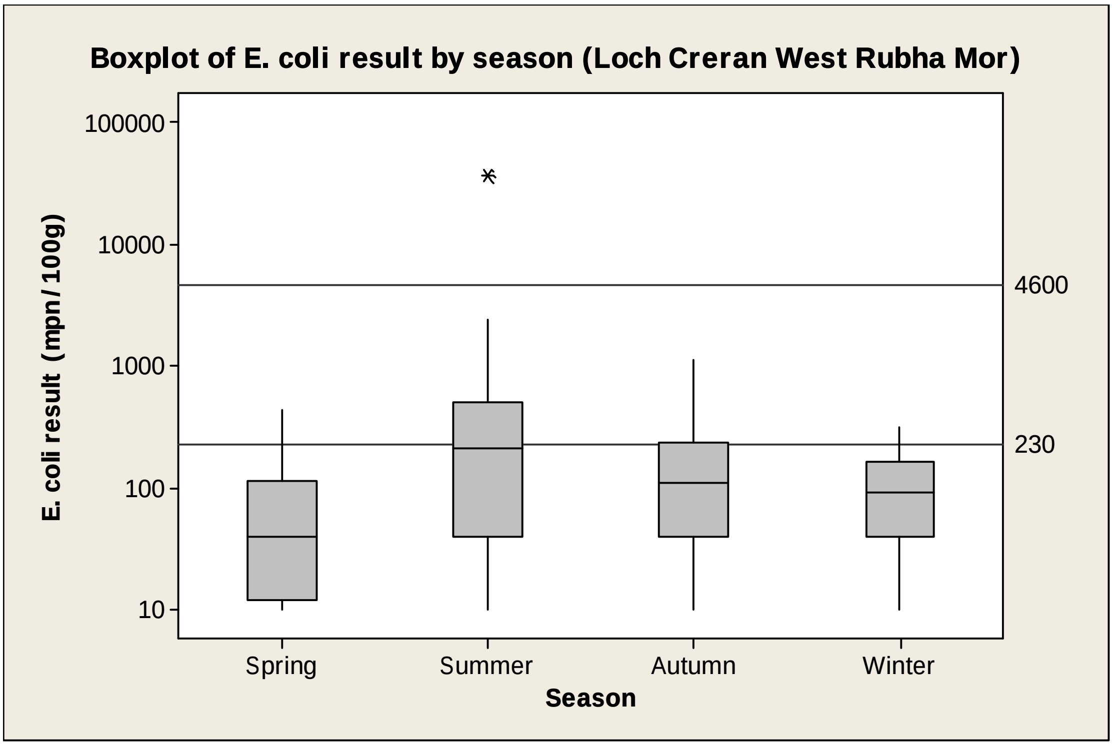

Figure 11.23 Boxplot of result by season (Loch Creran West: Rubha Mor)

A statistically significant seasonal effect was observed for Loch Creran West: Rubha Mor (One-way ANOVA, p=0.000, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) identified that results in the summer and autumn were higher than those in the spring, and that all other seasonal differences were not statistically significant.

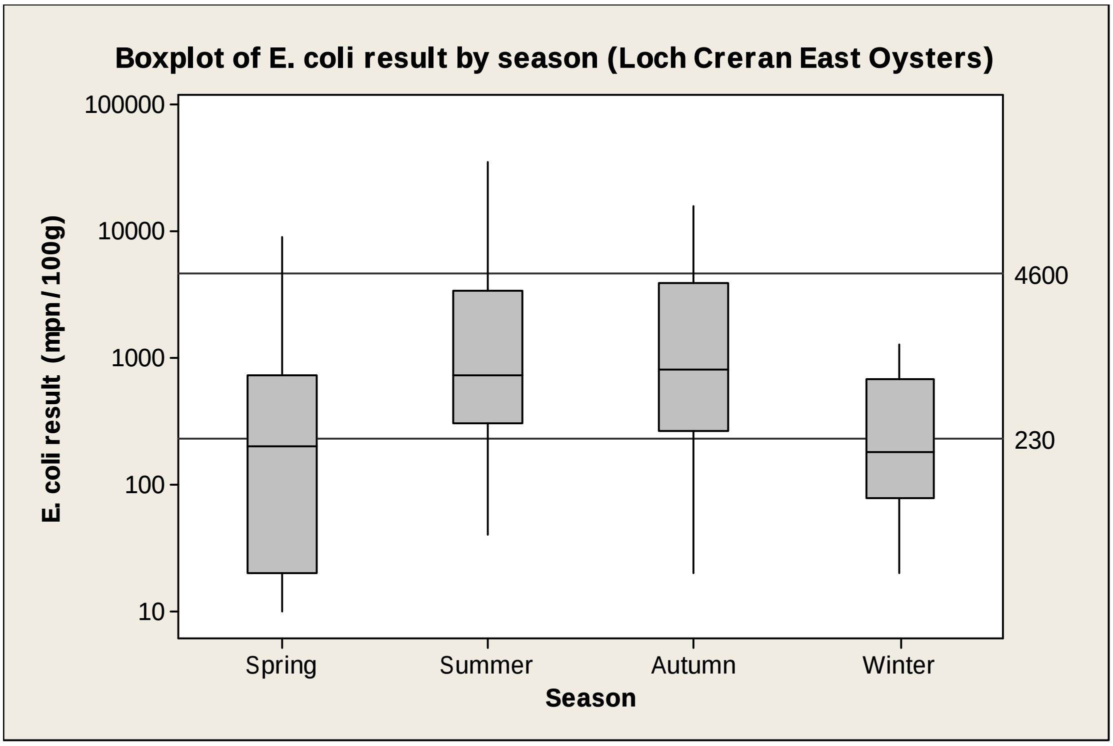

Figure 11.24 Boxplot of result by season (Loch Creran East)

Although the results obtained in the summer and autumn were generally higher than those obtained in the spring and winter, no statistically significant seasonal effect was observed for Loch Creran East (One-way ANOVA, p=0.058, Appendix 4).

In summary, the overall trend is for highest results in the summer and autumn, lower results in the winter, and lowest results in the spring. Water temperature is highest during the summer and autumn. Summer and Autumn is the period when stock levels are highest. Highest levels of human occupation occur in the summer due to toursim. The wettest weather occurs in autumn and winter. It is likely that a combination of these factors and possibly others is responsible for the seasonal trends in results observed in Loch Creran.

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 for each production area within the loch.

11.6.1 Analysis of results by recent rainfall

The nearest weather station is Strath of Appin, approximately 0.5 km to the north of Loch Creran. Rainfall data is available for 1/1/2003 to 31/10/2006 inclusive, although records are unavailable for 131 days during this period.

The coefficient of determination was calculated for *E. coli* results by production area and rainfall in the previous two days at Strath of Appin. Figures 11.25, 11.27, 11.29, 11.31 and 11.33 present scatterplots of *E. coli* result and rainfall for each production area. Figures 11.26, 11.28, 11.30, 11.32 and 11.34 present boxplots of results by rainfall quartile (quartile 1 = 0 to 0. 50 mm, quartile 2 = 0.50 to 5.80 mm, quartile 3 = 5.8 to 16.4 mm, quartile 4 = more than 16.4 mm).

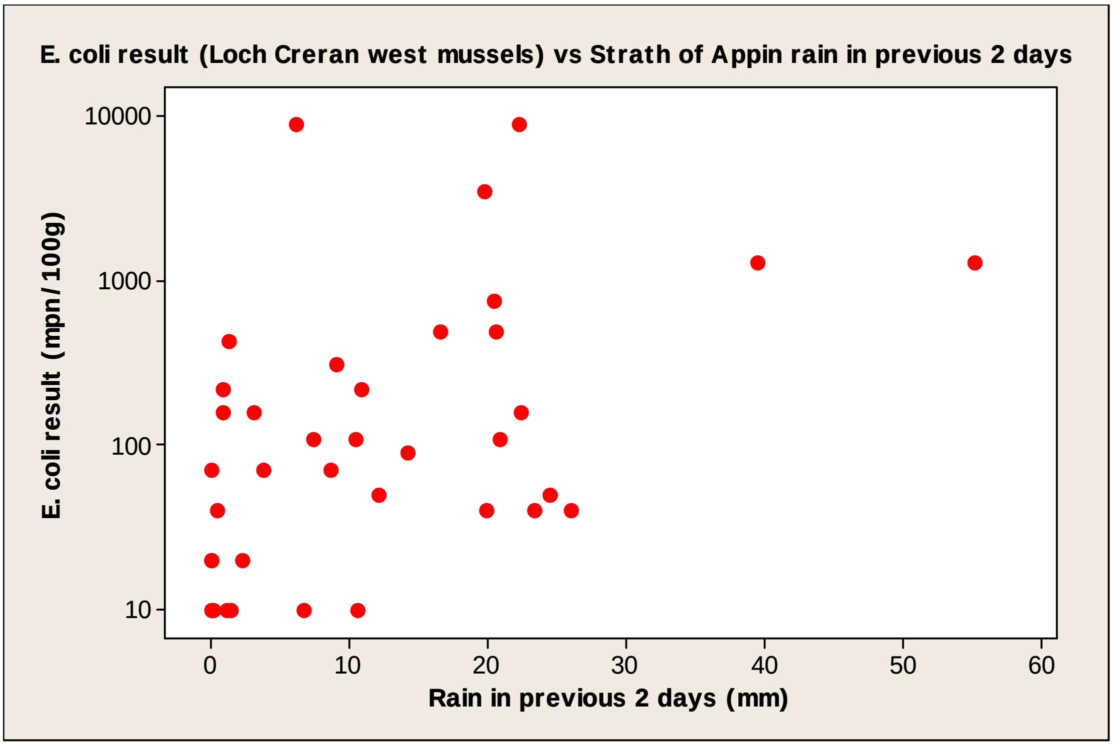

Figure 11.25 Scatterplot of result against rainfall in previous 2 days (Loch Creran West)

The coefficient of determination indicates that there is a weak but significant positive relationship between the *E. coli* result and the rainfall in the previous two days (Adjusted R-sq=21.0%, p=0.002, Appendix 4).

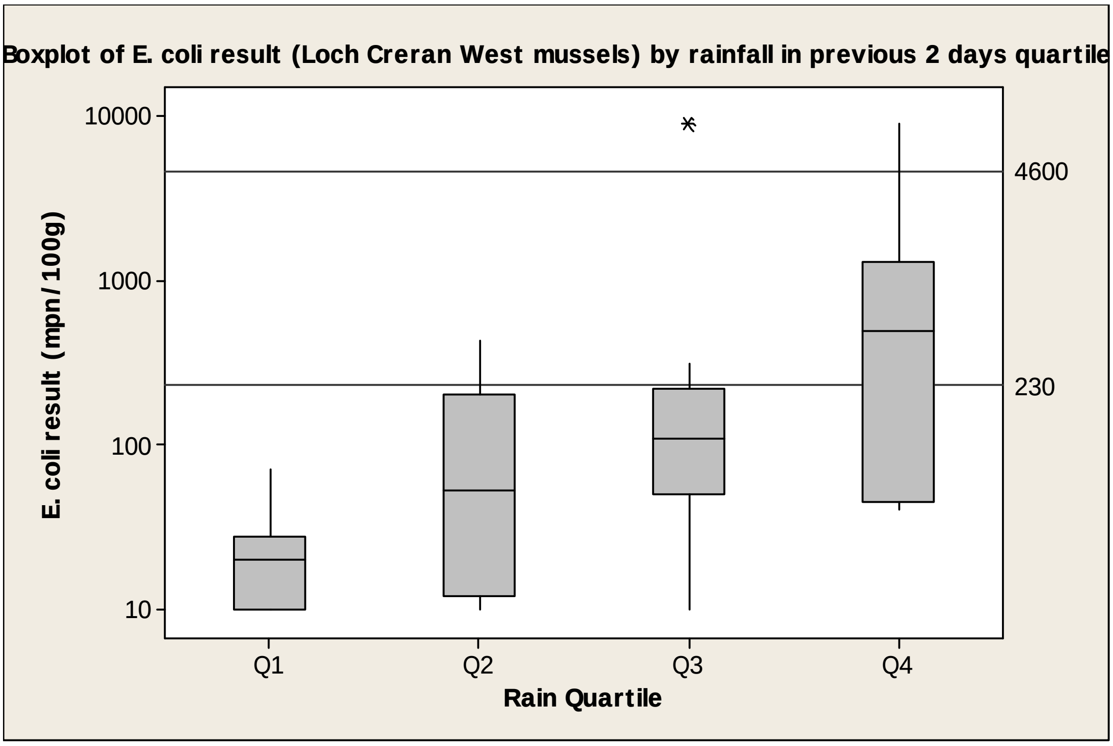

Figure 11.26 Boxplot of result by rainfall in previous 2 days quartile (Loch Creran West)

A statistically significant effect was observed (One-way ANOVA, p=0.008, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) identified that results for quartile 4 were significantly higher than those for quartile 1, and that all other differences were not statistically significant.

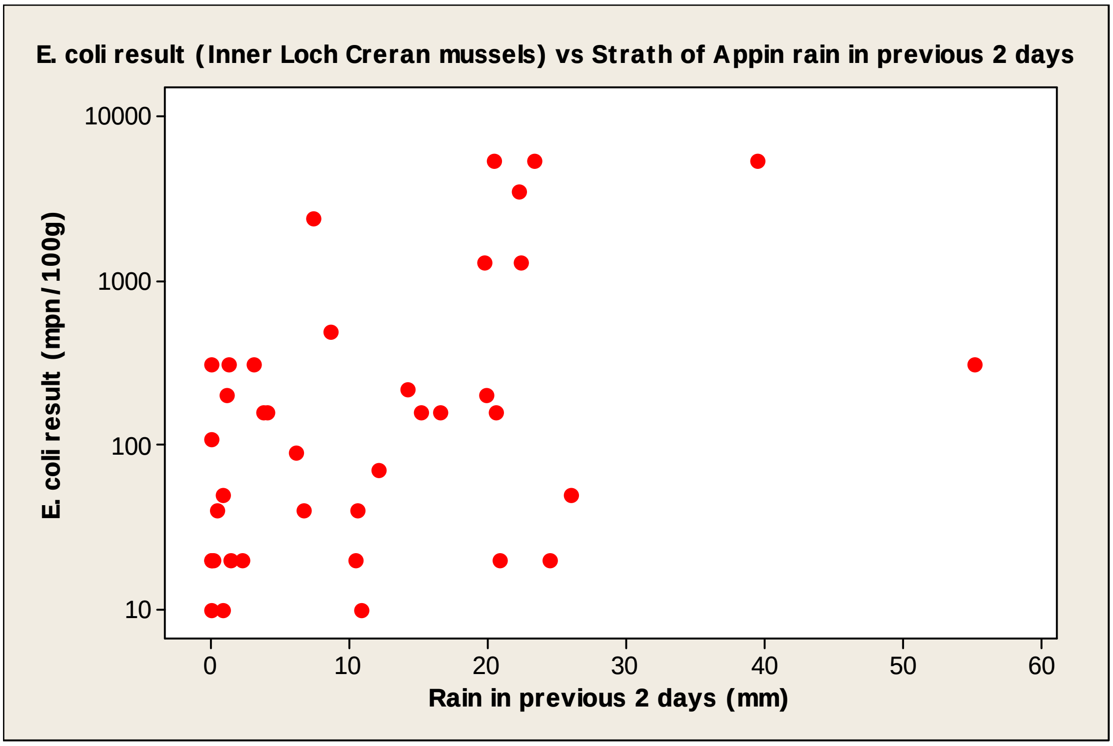

Figure 11.27 Scatterplot of result against rainfall in previous 2 days (Inner Loch Creran)

The coefficient of determination indicates that there is a weak but significant positive relationship between the *E. coli* result and the rainfall in the previous two days (Adjusted R-sq=18.9%, p=0.003, Appendix 4).

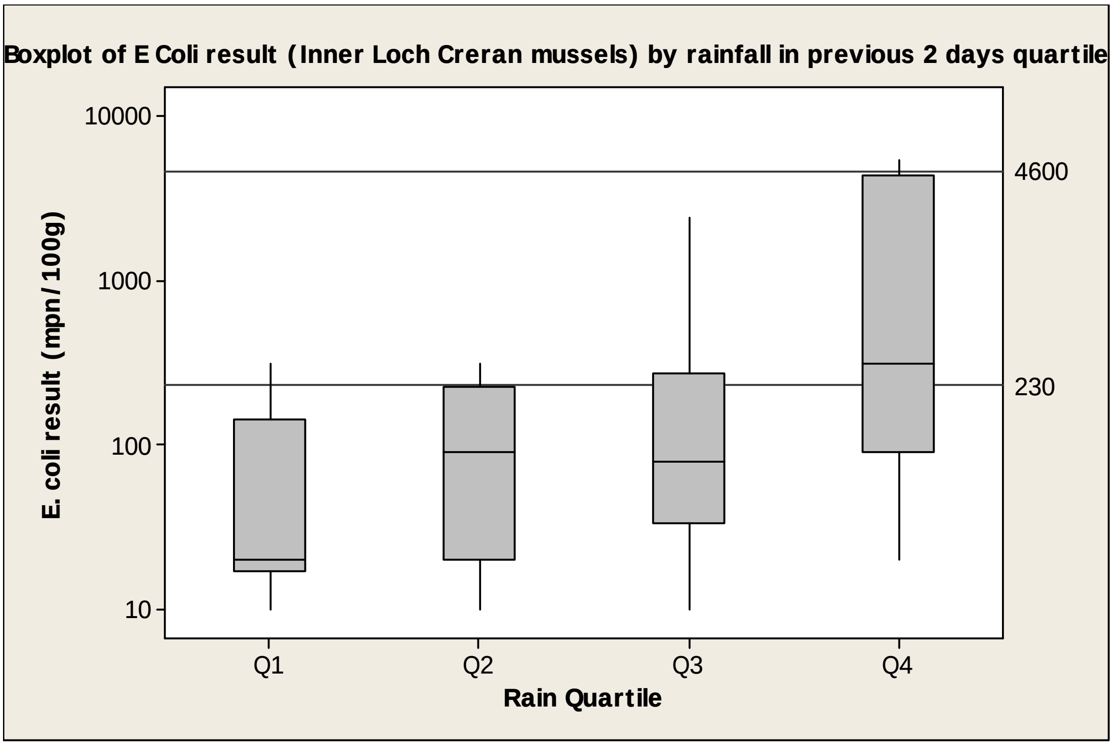

Figure 11.28 Boxplot of result by rainfall in previous 2 days quartile (Inner Loch Creran)

A statistically significant effect was observed (One-way ANOVA, p=0.015, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) identified that results for quartile 4 were significantly higher than those for quartile 1, and that all other differences were not statistically significant.

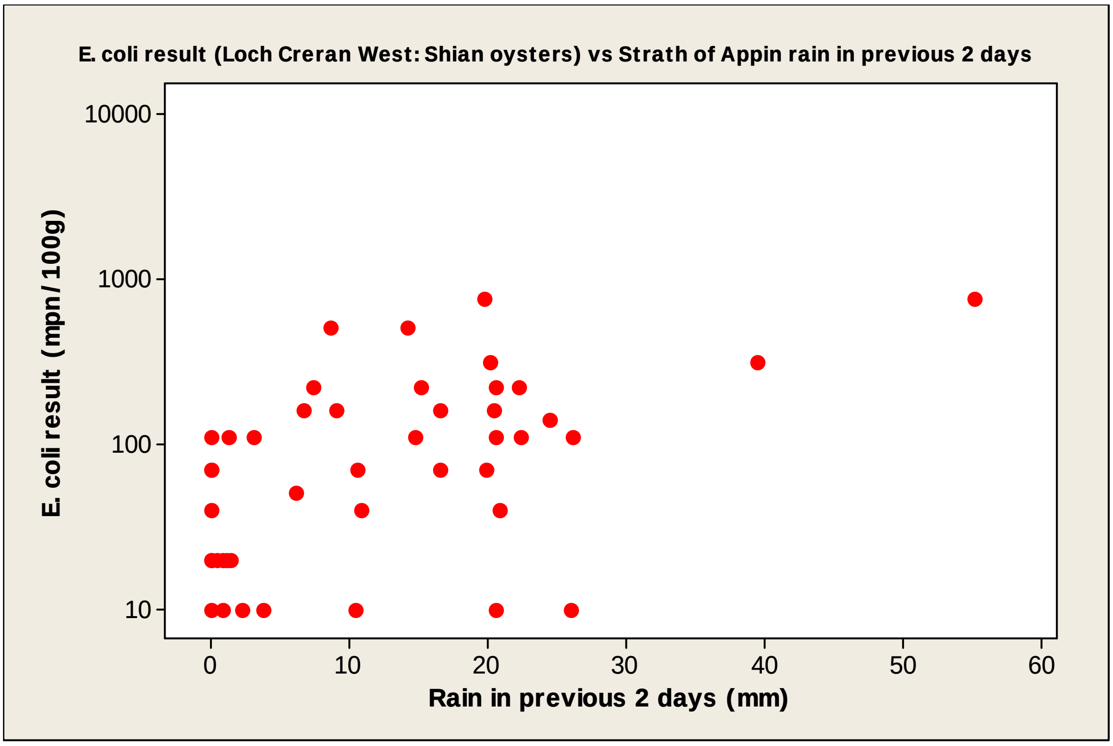

Figure 11.29 Scatterplot of result against rainfall in previous 2 days (Loch Creran West:Shian)

The coefficient of determination indicates that there is a weak but significant positive relationship between the *E. coli* result and the rainfall in the previous two days (Adjusted R-sq=24.2%, p=0.000, Appendix 4).

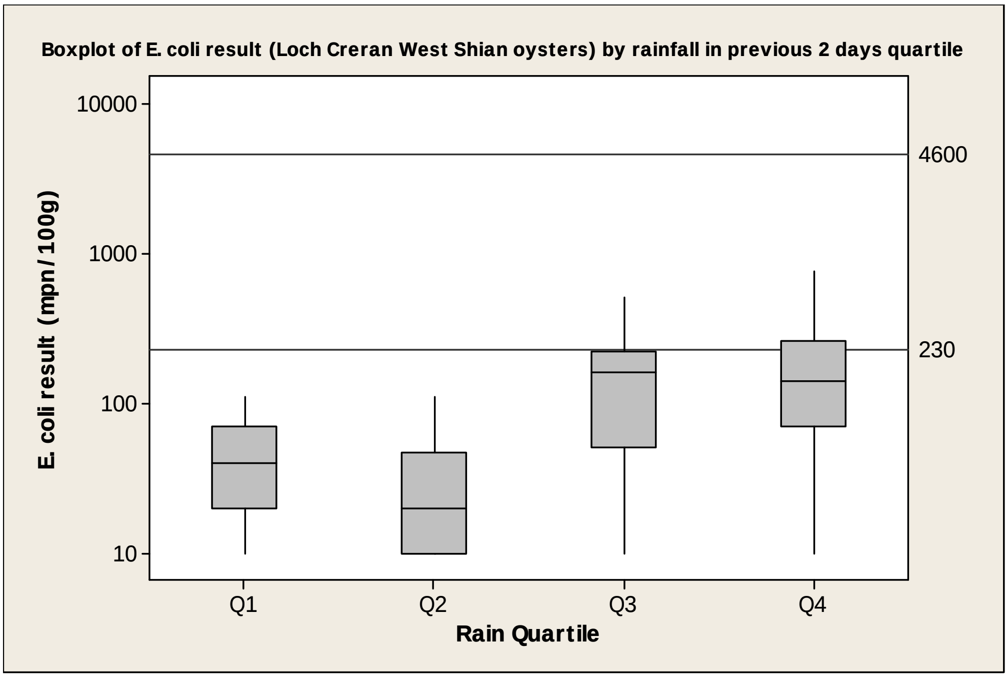

Figure 11.30 Boxplot of result by rainfall in previous 2 days quartile (Loch Creran West: Shian)

A statistically significant effect was observed (One-way ANOVA, p=0.002, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) identified that results for quartiles 3 and 4 were significantly higher than those for quartile 2, and that all other differences were not statistically significant.

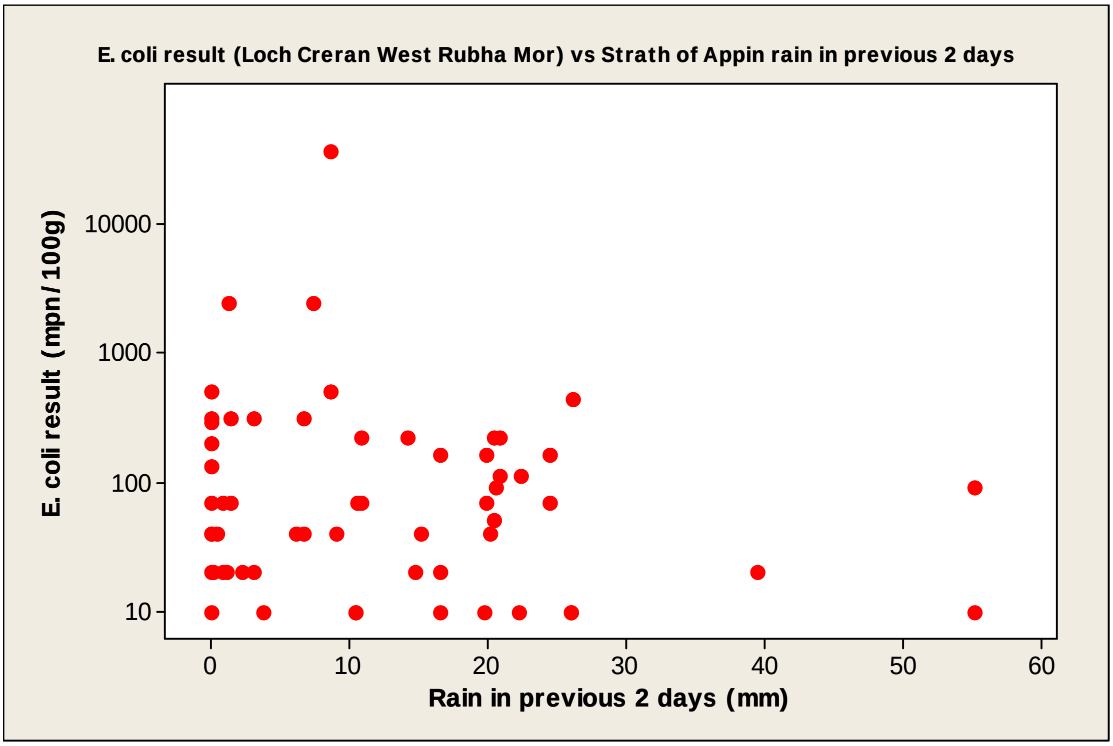

Figure 11.31 Scatterplot of result against rainfall in previous 2 days (Loch Creran West: Rubha Mor)

The coefficient of determination indicates that there is no significant relationship between the *E. coli* result and the rainfall in the previous two days (Adjusted R-sq=0.9%, p=0.220, Appendix 4).

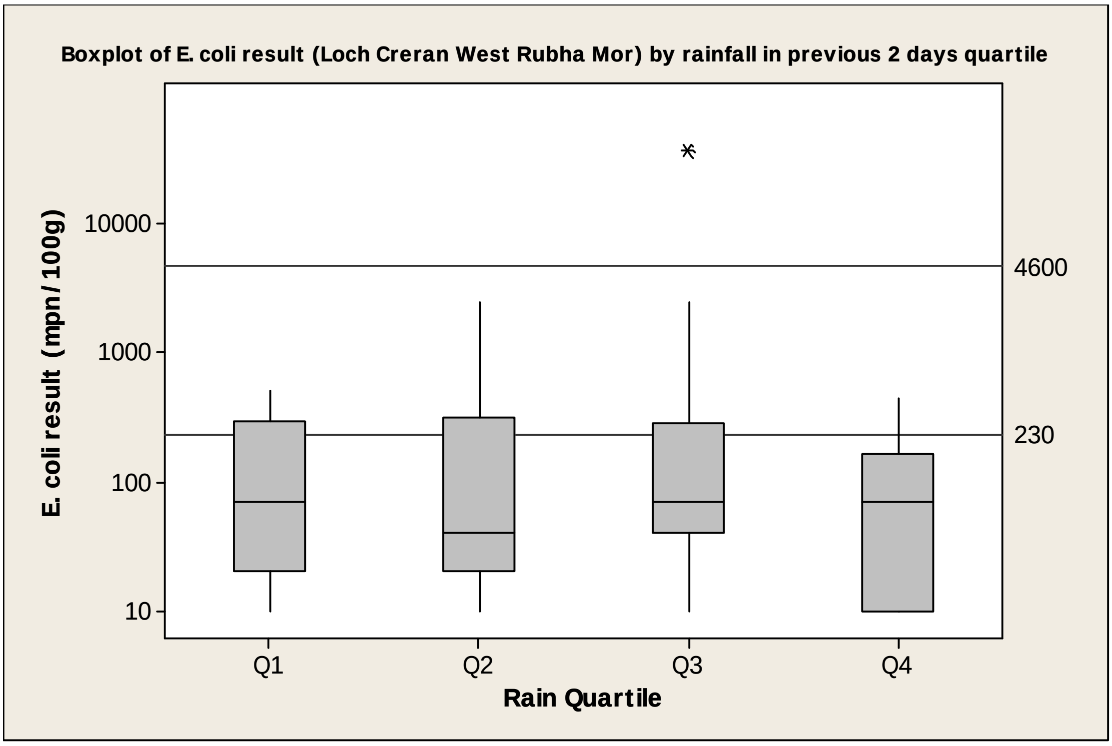

Figure 11.32 Boxplot of result by rainfall in previous 2 days quartile (Loch Creran West: Rubha Mor)

There was no difference in results obtained for each rain quartile (One way ANOVA, p=0.468, Appendix 4).

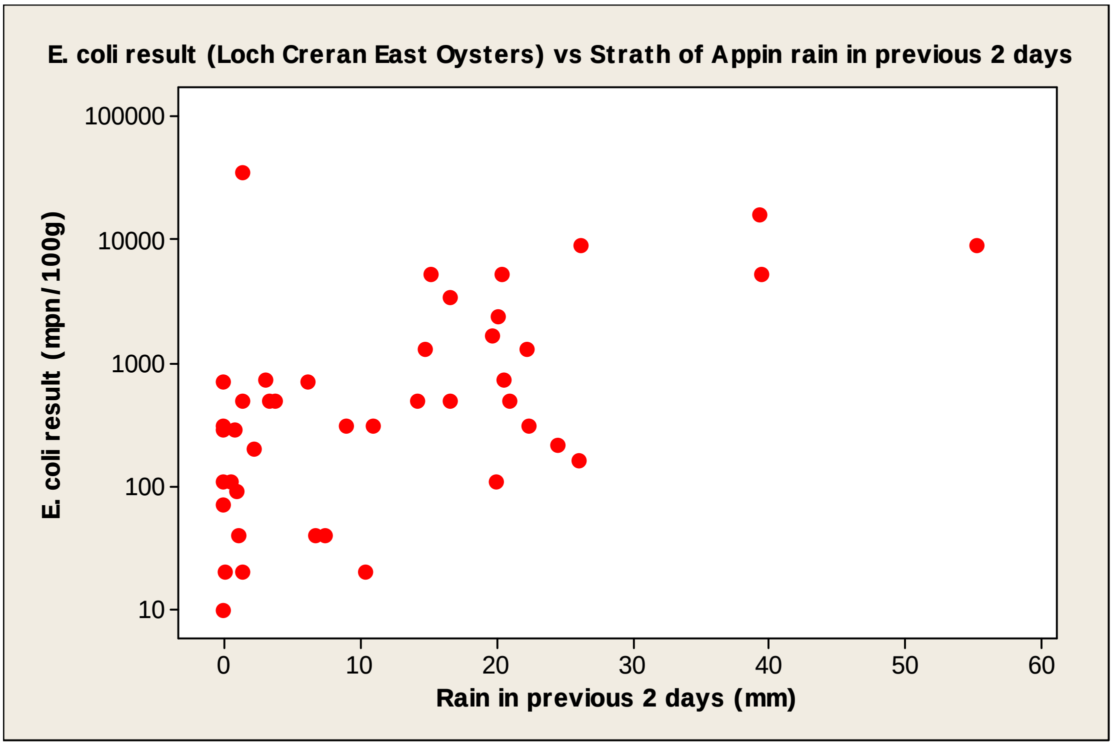

Figure 11.33 Scatterplot of result against rainfall in previous 2 days (Loch Creran East)

The coefficient of determination indicates that there is a significant positive relationship between the *E. coli* result and the rainfall in the previous two days (Adjusted R-sq=30.5%, p=0.000, Appendix 4).

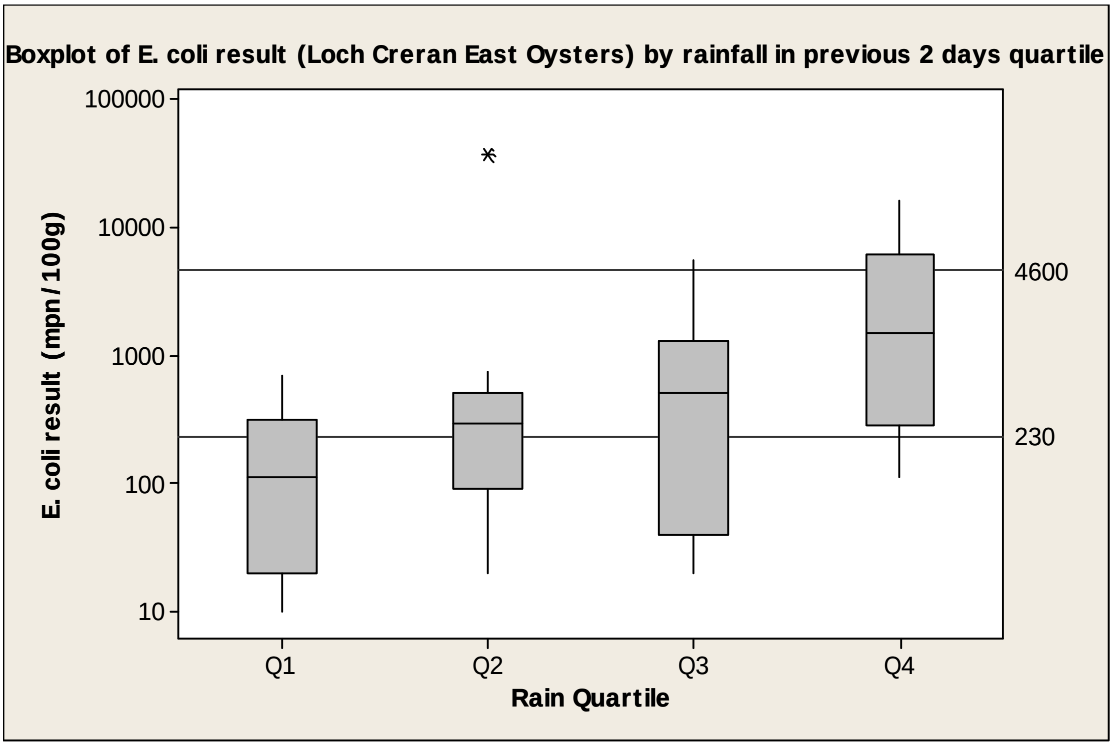

Figure 11.34 Boxplot of result by rainfall in previous 2 days quartile (Loch Creran East)

A statistically significant effect was observed (One-way ANOVA, p=0.016, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) identified that results for quartile 4 were significantly higher than those for quartile 1, and that all other differences between quartiles were not statistically significant.

Overall, weak positive relationships between rainfall in the previous two days and *E. coli* result were observed at four of the five production areas. The strongest relationship between rainfall and *E. coli* result was observed at Loch Creran East (Adjusted R-sq=30.5%). A similar but slightly weaker relationship was found at Loch Creran West: Shian (Adjusted R-sq=24.9%). The two mussel sites had similar adjusted R-sq values (21.0% for Loch Creran West, 18.9% for Inner Loch Creran). For all of these four sites, significant differences in results between rainfall quartiles were found, with higher results associated with the higher rainfall quartiles and median result increasing steadily across the quartiles. No relationship between rainfall and *E. coli* result was found at Loch Creran West: Rubha Mor suggesting it is not close to any rainfall related source of contamination.

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 Loch Creran East was investigated in an identical manner to that carried out for rain in the previous two days. The associated scatterplots and boxplots are presented in Figures 11.35 to 11.44. Interquartile ranges for 7 days rainfall were as follows; quartile 1 = 0 to 13.0 mm; quartile 2 = 13.0 to 31.8 mm; quartile 3 = 31.8 to 54 mm; quartile 4 = more than 54 mm.

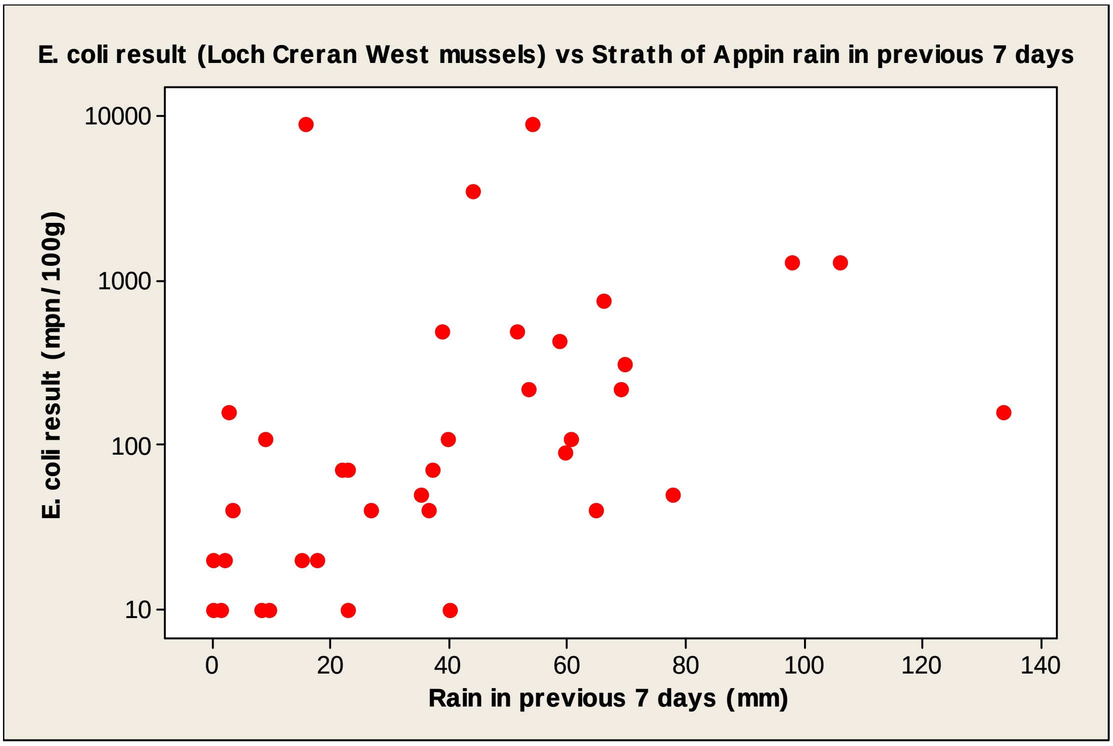

Figure 11.35 Scatterplot of result against rainfall in previous 7 days (Loch Creran West)

The coefficient of determination indicates that there is a weak but significant positive relationship between the *E. coli* result and the rainfall in the previous seven days (Adjusted R-sq=21.2%, p=0.002, Appendix 4).

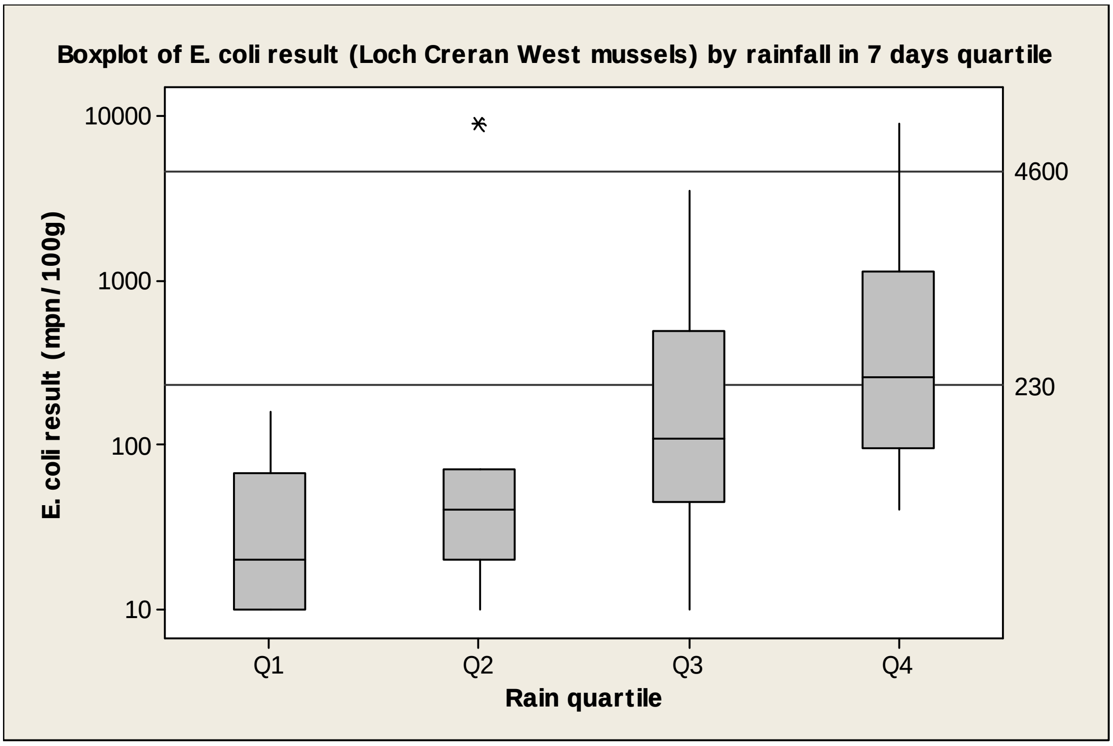

Figure 11.36 Boxplot of result by rainfall in previous 7 days quartile (Loch Creran West)

A statistically significant effect was observed (One-way ANOVA, p=0.011, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) identified that results for quartile 4 were significantly higher than those for quartile 1, and that all other differences between quartiles were not statistically significant.

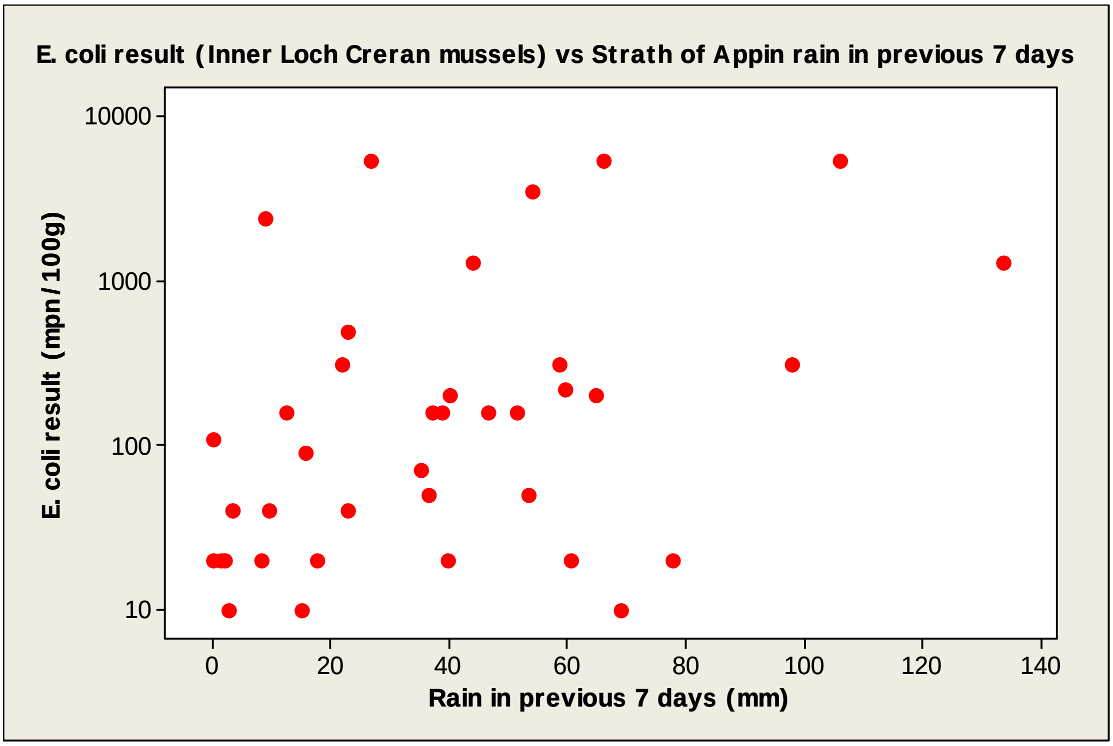

Figure 11.37 Scatterplot of result against rainfall in previous 7 days (Inner Loch Creran)

The coefficient of determination indicates that there is a weak but significant positive relationship between the *E. coli* result and the rainfall in the previous seven days (Adjusted R-sq=15.3%, p=0.009, Appendix 4).

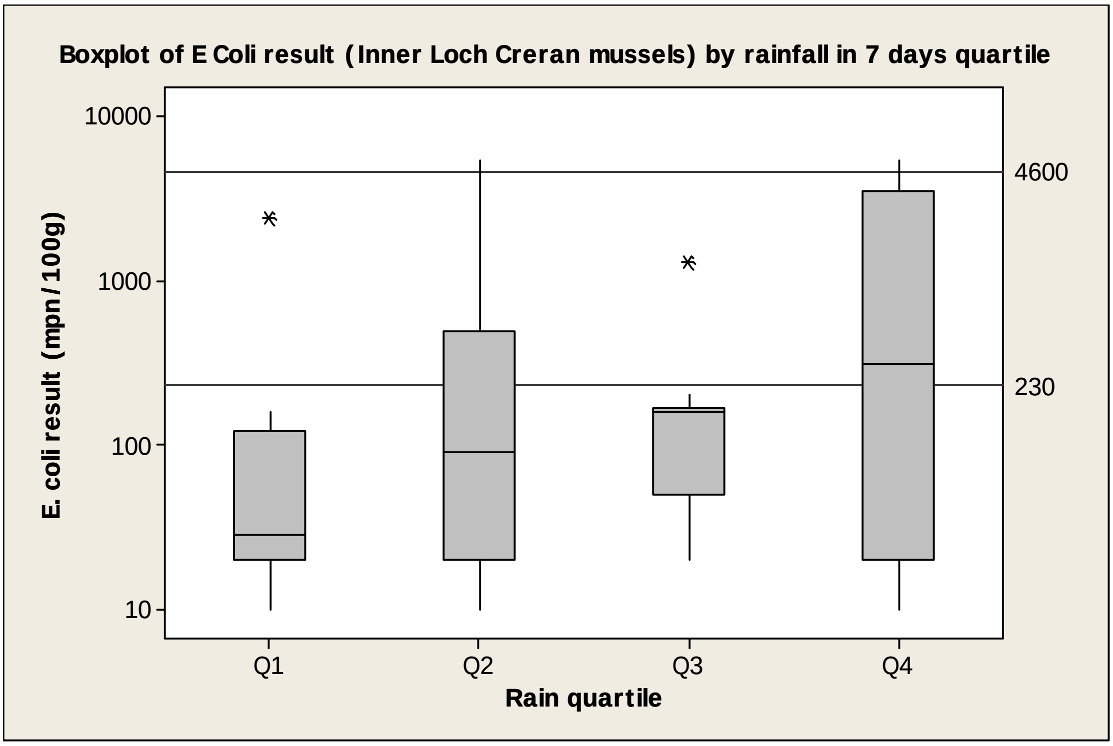

Figure 11.38 Boxplot of result by rainfall in previous 7 days quartile (Inner Loch Creran)

No relationship between rainfall quartile and result was detected (One way ANOVA, p=0.185, Appendix 4).

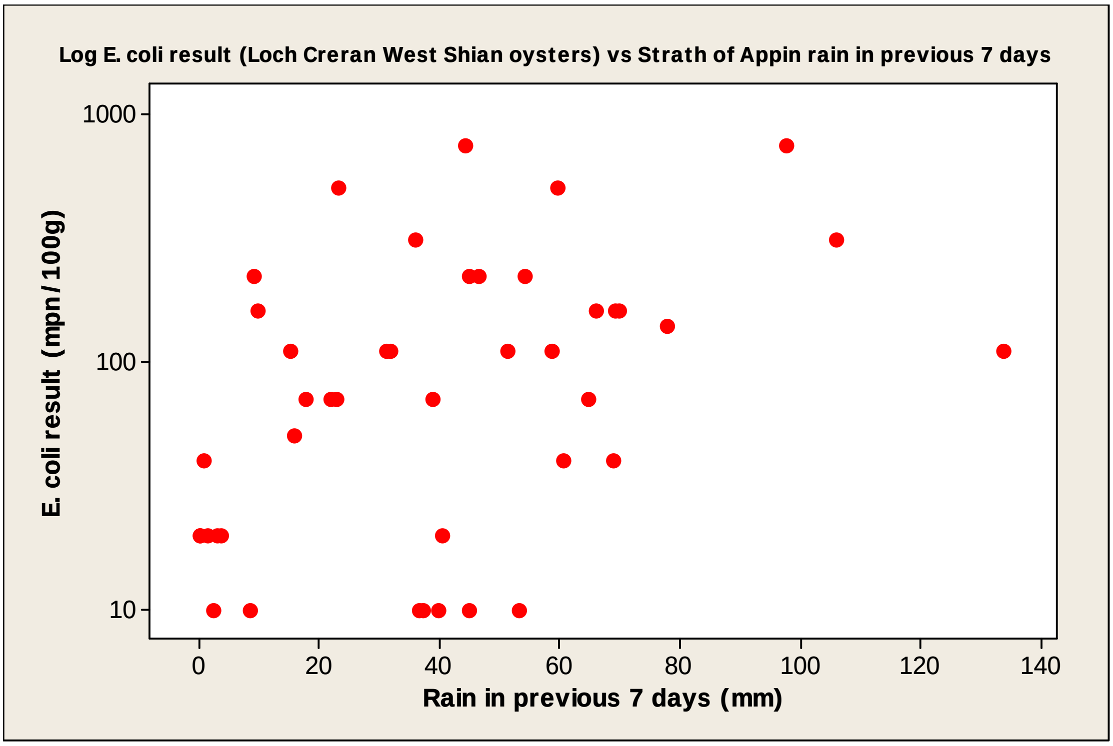

Figure 11.39 Scatterplot of result against rainfall in previous 7 days (Loch Creran West: Shian)

The coefficient of determination indicates that there is a weak but significant positive relationship between the *E. coli* result and the rainfall in the previous seven days (Adjusted R-sq=15.7%, p=0.005, Appendix 4).

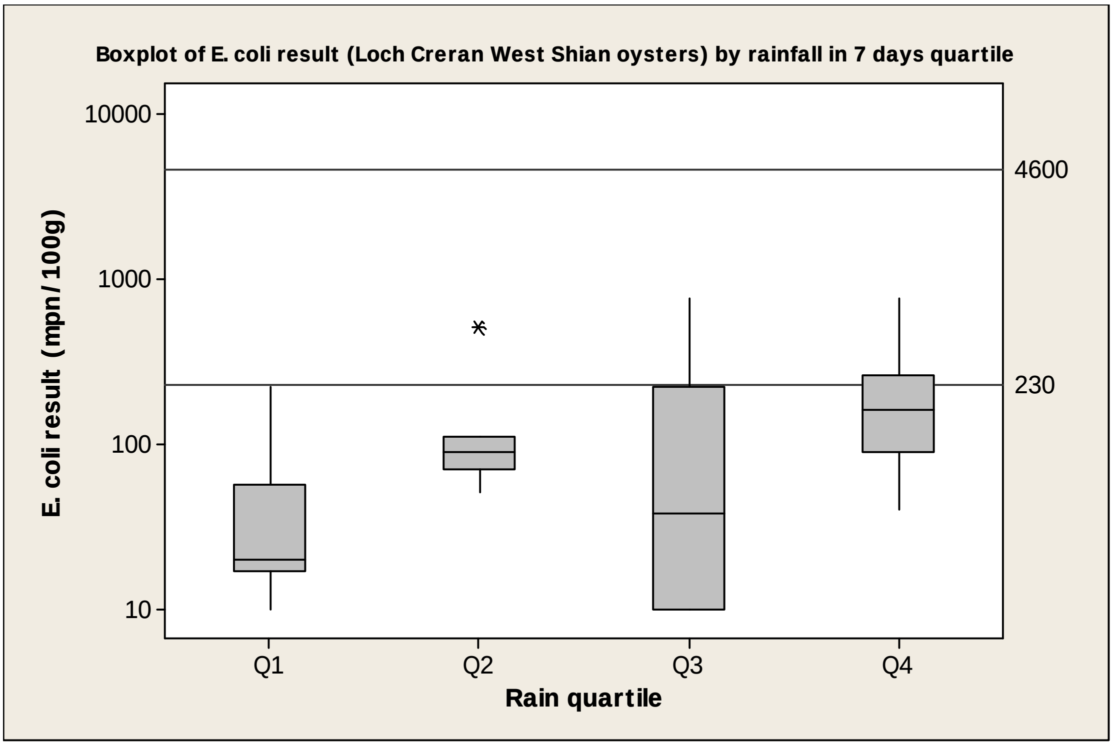

Figure 11.40 Boxplot of result by rainfall in previous 7 days quartile (Loch Creran West: Shian)

A statistically significant effect was observed (One-way ANOVA, p=0.009, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) identified that results for quartile 4 were significantly higher than those for quartile 1, and that all other differences between quartiles were not statistically significant.

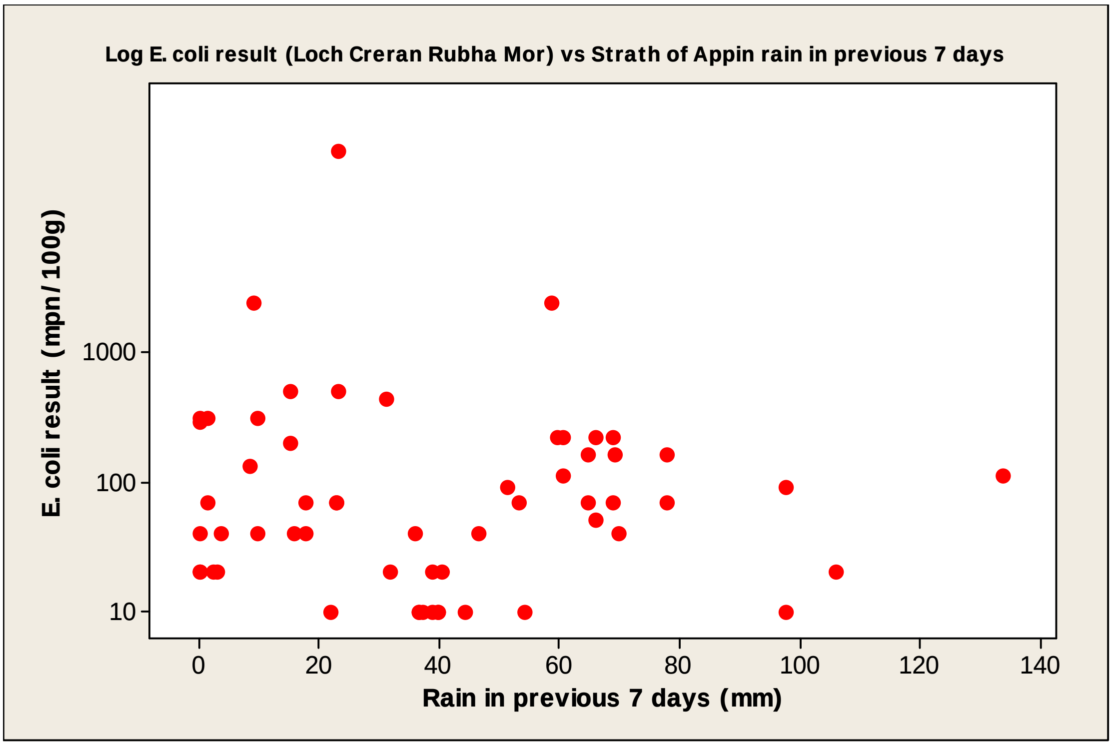

Figure 11.41 Scatterplot of result against rainfall in previous 7 days (Loch Creran West: Rubha Mor)

The coefficient of determination indicates that there is no relationship between the *E. coli* result and the rainfall in the previous seven days (Adjusted R-sq=0.0%, p=0.655, Appendix 4).

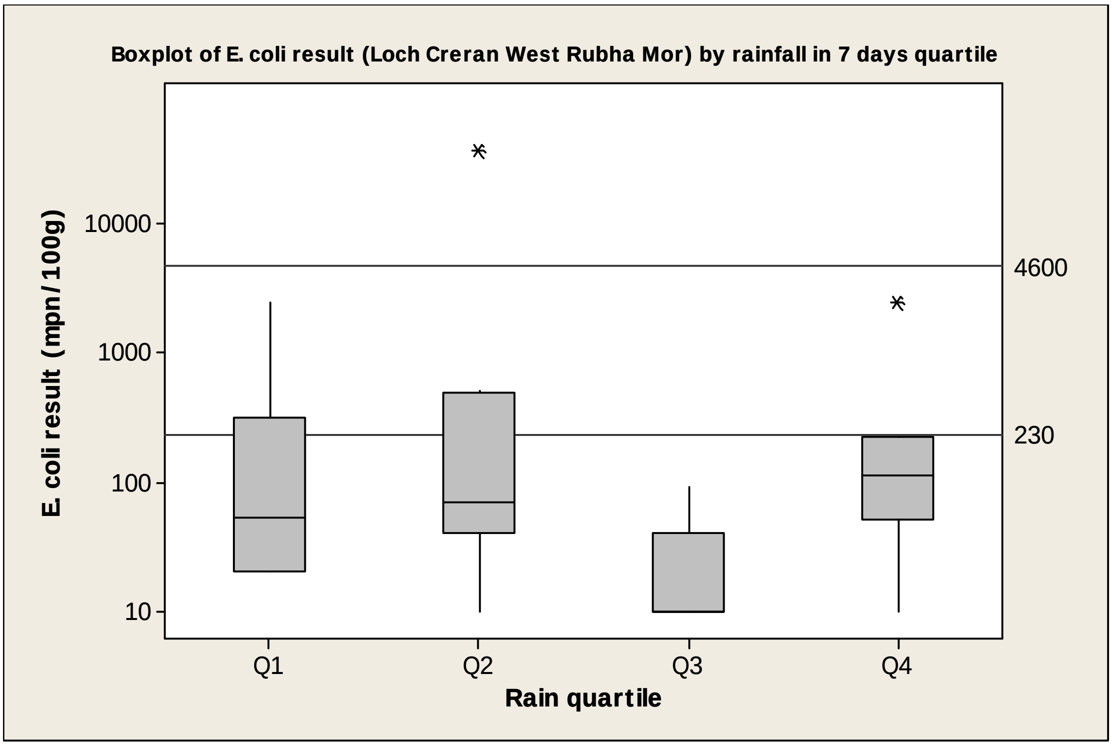

Figure 11.42 Boxplot of result by rainfall in previous 7 days quartile (Loch Creran West: Rubha Mor)

A statistically significant effect was observed (One-way ANOVA, p=0.005, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) identified that results for quartile 3 were significantly lower than those for all other quartiles, and that all other differences between quartiles were not statistically significant.

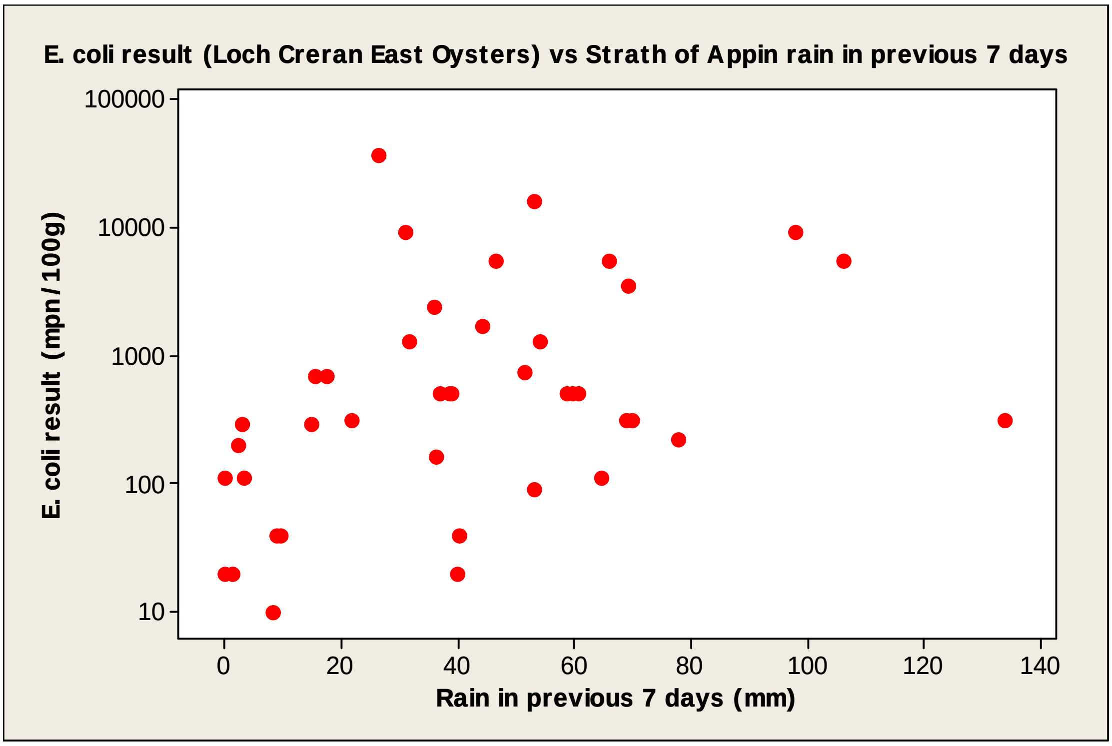

Figure 11.43 Scatterplot of result against rainfall in previous 7 days (Loch Creran East)

The coefficient of determination indicates that there is a weak but significant positive relationship between the *E. coli* result and the rainfall in the previous seven days (Adjusted R-sq=14.6%, p=0.008, Appendix 4).

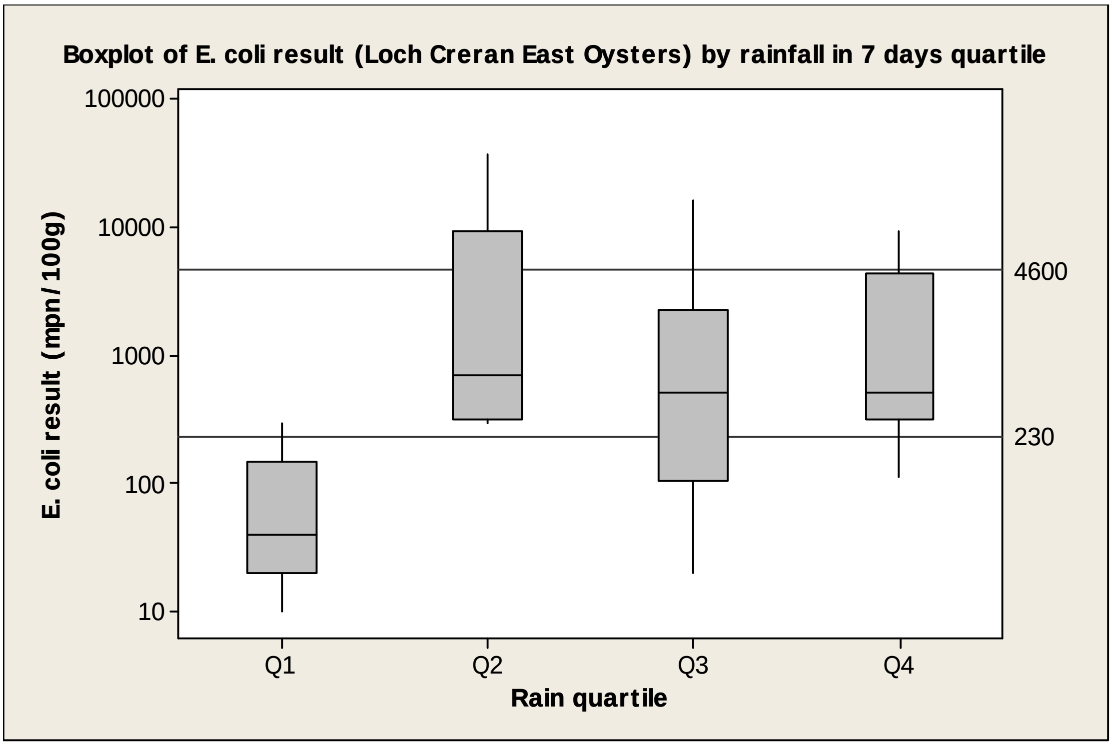

Figure 11.44 Boxplot of result by rainfall in previous 7 days quartile (Loch Creran East)

A statistically significant effect was observed (One-way ANOVA, p=0.001, Appendix 4). A post ANOVA test (Tukeys comparison, Appendix 4) identified that results for quartile 1 were significantly lower than those for all other quartiles, and that all other differences between quartiles were not statistically significant. This suggests a saturation effect, where only a relatively small amount of rain spread over 7 days is sufficient to fully mobilise rainfall dependant sources of contamination.

Overall, weak positive relationships between rainfall in the previous 7 days and *E. coli* result were observed at 4 of the 5 production areas.

The two mussel sites had similar adjusted R-sq values to each other (21.2% for Loch Creran West, 15.3% for Inner Loch Creran) and to the ones derived for previous two days rainfall. Although a steady increase in median results across the rain quartiles was found for both sites, a significant difference in results by quartile was found for Loch Creran West only.

Loch Creran East and Loch Creran West: Shian were found to have weaker relationships between result and rainfall in the previous seven days (R-sq values of 15.7% and 14.6% respectively) compared to rainfall in the previous two days (R-sq values of 30.5% and 24.9% respectively). Although results differed significantly between rainfall quartiles for both these sites with higher quartiles giving higher results, there was less of a steady increase in median result across the quartiles than was observed when rainfall in the previous 2 days was considered, with a possible saturation effect observed for Loch Creran East. The reason for this weaker relationship compared to that observed with rainfall in the previous two days for these two sites may be in part a consequence of their location in the intertidal zone. Here, they are likely to be exposed to more localised and shortlived runoff events compared to the mussels, which are cultured in the deeper better mixed water towards the middle of the loch.

Although no relationship between rainfall and *E. coli* result was found by regression analysis for Loch Creran West: Rubha Mor, results obtained for rainfall quartile 3 were significantly lower than for all other quartiles. It is uncertain why this effect is seen.

11.6.2 Analysis of results by lunar state

Lunar state dictates tide size, with the largest tides occurring 2 days after either a full or new moon. With the larger tides, circulation of water in the loch will increase, and more of the shoreline will be covered, potentially washing more faecal contamination from livestock into the loch.

Virtually all samples gathered from Loch Creran were collected on the larger tides, presumably due to the requirement for spring tides when sampling the oyster operations. As a consequence, no analysis of the effects of tide size was carried out.

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 and rainfall patterns.

Water temperature at the time of sample collection was recorded for too few of the samples (3) from Loch Creran West, so no analysis was possible. For all other production areas, the coefficient of determination was calculated for *E. coli* results by production area and water temperature at the time of sample collection.

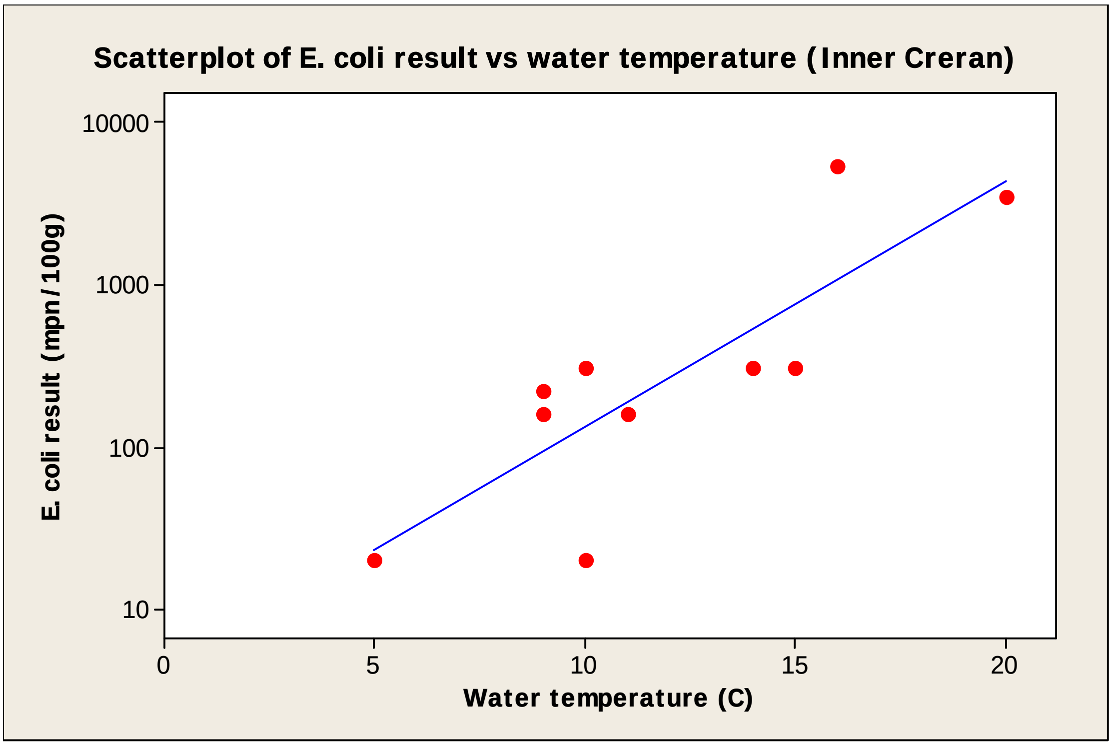

Figure 11.45 Scatterplot of result against water temperature at time of sampling (Inner Loch Creran) with best fit line

The coefficient of determination indicates that there is a significant positive relationship between the *E. coli* result and the water temperature (Adjusted R-sq=65.5%, p=0.003, Appendix 4).

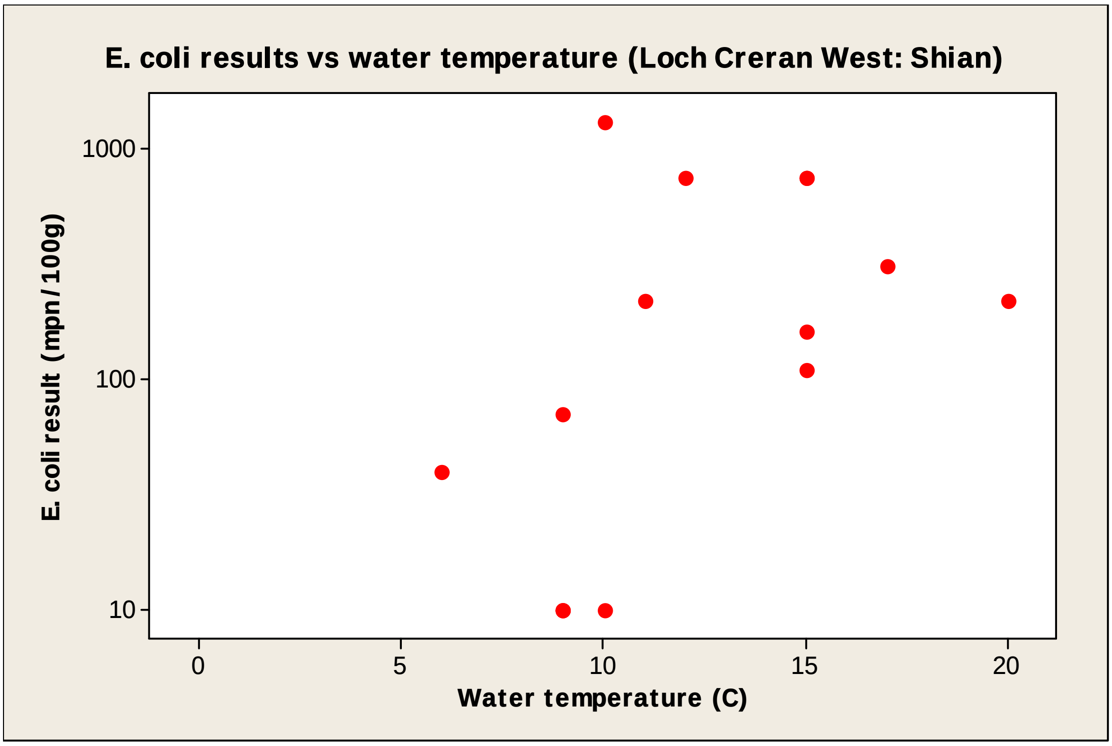

Figure 11.46 Scatterplot of result against water temperature at time of sampling (Loch Creran West: Shian)

The coefficient of determination indicates that there is a weak but significant positive relationship between the *E. coli* result and the water temperature at time of sampling (Adjusted R-sq=24.2%, p=0.036, Appendix 4).

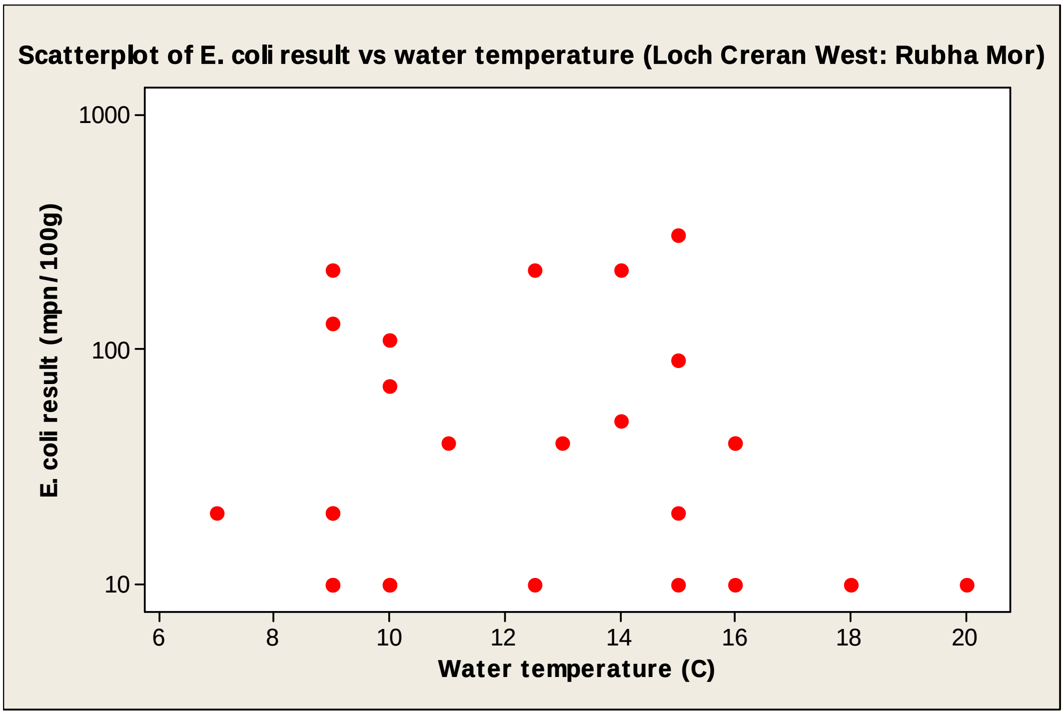

Figure 11.47 Scatterplot of result against water temperature at time of sampling (Loch Creran West: Rubha Mor)

The coefficient of determination indicates that there is no relationship between the *E. coli* result and the water temperature at time of sampling (Adjusted R-sq=0.0%, p=0.892, Appendix 4).

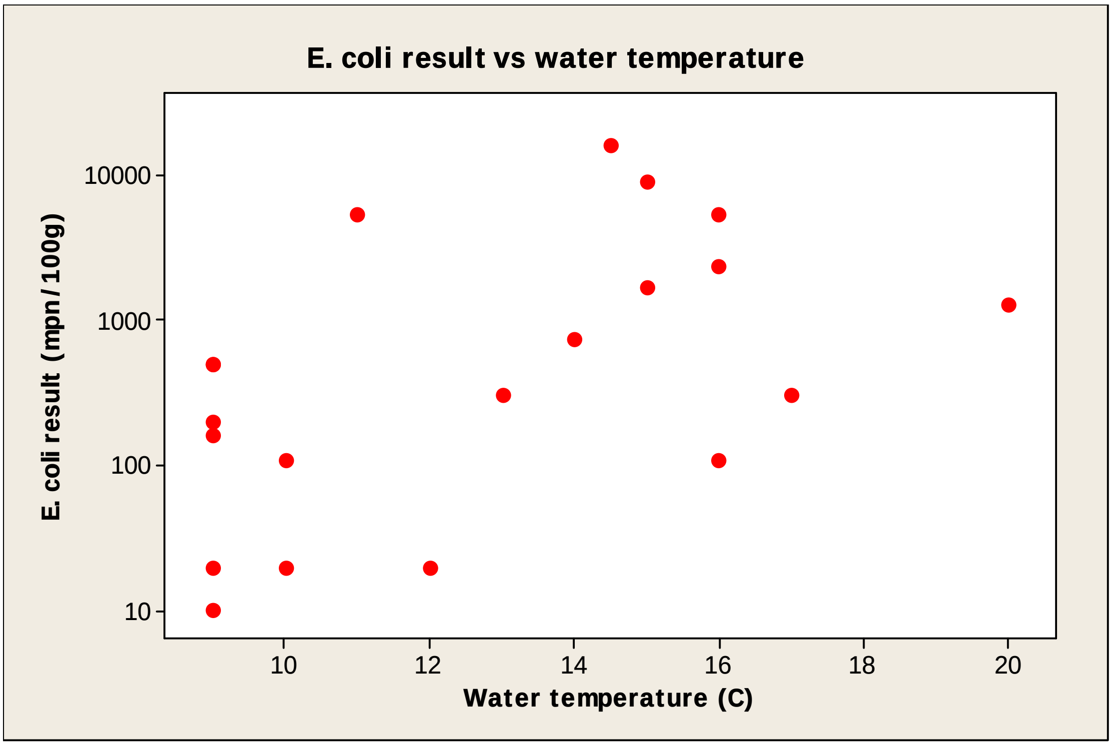

Figure 11.48 Scatterplot of result against water temperature at time of sampling (Loch Creran East)

The coefficient of determination indicates that there is a significant positive relationship between the *E. coli* result and the water temperature at time of sampling (Adjusted R-sq=23.8%, p=0.017, Appendix 4).

Positive relationships between water temperature and *E. coli* result was found for three of the four production areas evaluated. Sample numbers were relatively low for all of these analyses. The strongest relationship was found with Inner Loch Creran (Adjusted R-sq=65.5%). Weaker relationships were found at Loch Creran West: Shian and Loch Creran East (Adjusted R-sq of 24.2% and 23.8% respectively). This pattern is in overall agreement with the seasonal pattern of results. No relationship between water temperature and *E. coli* result was found at Loch Creran West: Rubha Mor, possibly as a consequence of all results from this area where temperature records were available yielding relatively low results.

11.6.4 Analysis of results by wind direction

Winds are likely to change water circulation patterns in Loch Creran and therefore affect the distribution of contamination. Mean wind direction for the 7 days prior to each sample being collected was calculated from wind data recorded at the Tiree weather station (where data was available), and mean result by mean wind direction in the previous 7 days is plotted in Figures 11.49 to 11.53 for each individual production area.

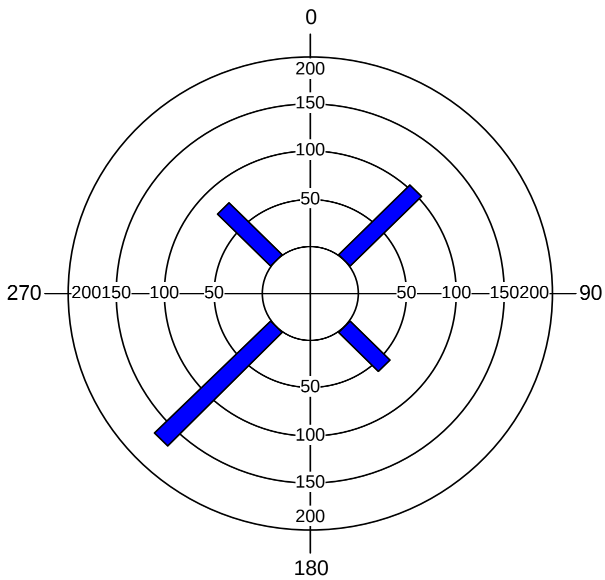

Figure 11.49 Circular histogram of geometric mean *E. coli* result by wind direction (Loch Creran West)

No significant correlation between wind direction and *E. coli* result was found for Loch Creran West (circular-linear correlation, r=0.248, p=0.122, Appendix).

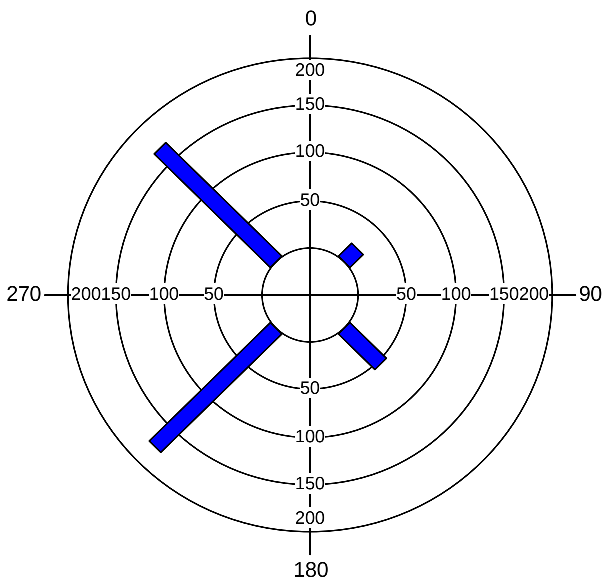

Figure 11.50 Circular histogram of geometric mean *E. coli* result by wind direction (Inner Loch Creran)

A significant correlation between wind direction and *E. coli* result was found for Inner Loch Creran (circular-linear correlation, r=0.343, p=0.018, Appendix). Results were higher when the wind was blowing from the west.

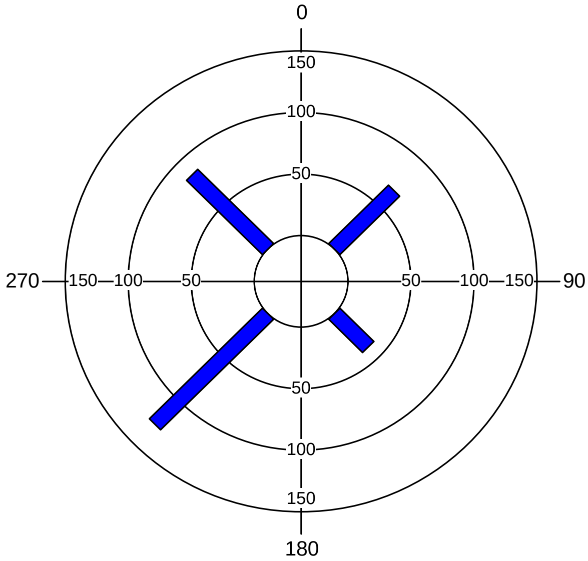

Figure 11.51 Circular histogram of geometric mean *E. coli* result by wind direction (Loch Creran West: Shian)

A significant correlation between wind direction and *E. coli* result was found for Loch Creran West: Shian (circular-linear correlation, r=0.309, p=0.024, Appendix). Results were higher when the wind was blowing from the west.

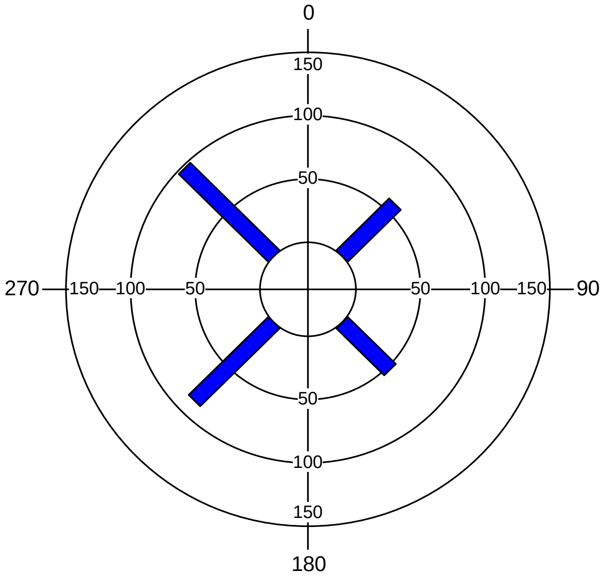

Figure 11.52 Circular histogram of geometric mean *E. coli* result by wind direction (Loch Creran West: Rubha Mor)

No significant correlation between wind direction and *E. coli* result was found for Loch Creran West: Rubha Mor (circular-linear correlation, r=0.141, p=0.312, Appendix).

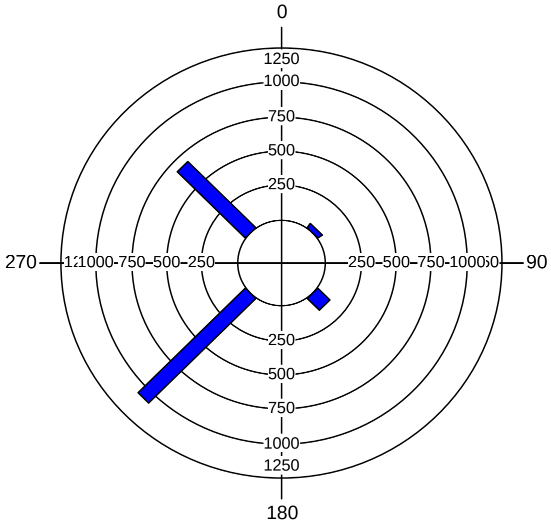

Figure 11.53 Circular histogram of geometric mean *E. coli* result by wind direction (Loch Creran East)

A significant correlation between wind direction and *E. coli* result was found for Loch Creran East (circular-linear correlation, r=0.403, p=0.002, Appendix), with higher results occurring when the wind is blowing from the west.

Overall, a correlation between wind direction and results was found at three of the 5 production areas (Inner Loch Creran (p=0.018), Loch Creran West: Shian (p=0.024) and Loch Creran East (p=0.002)). For all of these three areas, results were highest when the wind had been blowing from the west. This would generate an onshore wind blowing over a large expanse of water for the sites near the eastern side of the loch (Inner Loch Creran and Loch Creran East) where the strongest correlations were found. At the relatively exposed oyster site at Loch Creran East, wave action may resuspend sediment bound contamination during periods of strong southerly or south westerly winds.

It must be noted the prevailing wind direction is from the south west, and a high proportion of the samples were taken when the wind had been blowing from this direction. Also, when the wind is blowing from this direction it is likely to be stronger.

11.7 Results stability and recommended sampling frequency

When a production area has had 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 may be decreased from monthly to bimonthly.

This is not appropriate for any of the production areas within Loch Creran, as they have all held seasonal classifications at some point in the last three years.

12. Designated Shellfish Growing Waters Data

The production areas considered in this report are part of a SEPA shellfish growing water. The extent of the area and the location of the SEPA designated monitoring points are shown on figure 12.1.

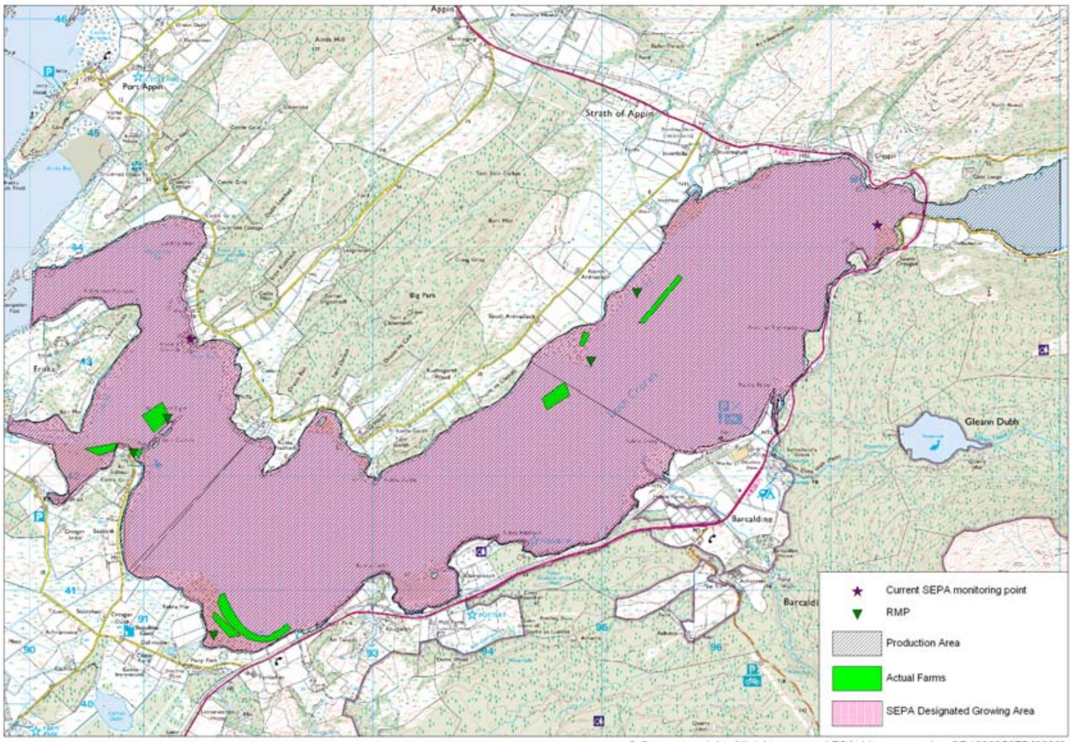

Figure 12.1 Map showing SEPA designated growing water and monitoring points

The monitoring regime requires the following testing:

- Quarterly for Salinity, dissolved oxygen, pH, temperature, visible oil
- Quarterly sampling for faecal coliforms in mussels
- Annual sampling for metals and organohalogens in mussels
- Twice yearly for metals in water

Monitoring started in 2000, and results to the end of 2006 have been provided by SEPA. Monitoring results for faecal coliforms in mussels are presented in Table 12.1.

Table 12.1. SEPA faecal coliform results (F. coli / 100g) for shore mussels gathered from Loch Creran.

	Site	South Shian	North Shian
	NGR	NM 907 422	NM 91446 43117
2000	Q1		
	Q2	<20*	
	Q3	20	
	Q4	750	
2001	Q1	40	
	Q2	40	
	Q3	110	
	Q4	110	
2002	Q1	110	
	Q2	160	
	Q3	20	
	Q4	40	
2003	Q1	310	
	Q2		
	Q3		>18000**
	Q4		1300
2004	Q1		90
	Q2		110
	Q3		750
	Q4		70
2005	Q1		200
	Q2		310
	Q3		700
	Q4		90
2006	Q1		
	Q2		<10***
	Q3		610
	Q4		>1500****

* Assigned a nominal value of 10 for the calculation of the geometric mean
** Assigned a nominal value of 36000 for the calculation of the geometric mean
*** Assigned a nominal value of 5 for the calculation of the geometric mean
**** Assigned a nominal value of 3000 for the calculation of the geometric mean

Prior to Q2 of 2003, the mussel samples were taken from a point on the south shore at South Shian. The geometric mean result for these samples was 69.5 faecal coliforms / 100g. From Q3 of 2003 onwards, the samples were taken from the current designated monitoring point on the north shore at North Shian. The geometric mean result for these samples was 342 faecal coliforms / 100g. Although the samples are separated temporally, this suggests a higher level of contamination on the north shore than on the south shore.

Levels of faecal coliforms are usually closely correlated to levels of *E. coli* often at a ratio of approximately 1:1. The ratio depends on a number of factors, such as environmental conditions and the source of contamination and as a consequence the results presented in Table 12.1 are not directly comparable with other shellfish testing results presented in this report. Nevertheless, the geometric mean faecal coliform result for shore mussels gathered from South Shian are lower than the geometric mean *E. coli* results found at the two mussel aquaculture sites (80 and 104 mpn/100g) which are in turn lower than the geometric mean faecal coliform result from shore mussels gathered from North Shian.

Monitoring results for physical and chemical parameters are not presented or discussed in this report.

13. Bathymetry and Hydrodynamics

It is recommended that the Hydrography Methods Document be consulted for background information on the methods applied. This site was chosen for an extended hydrographic assessment but without application of a computer model.

Physical Characteristics

Loch Creran (OS reference NM900430) is a tidal fjordic sea loch on the west coast of Scotland. Primary data comes from the Sea Loch Catalogue (SLC) produced by the SMBA. The Loch connects to the larger Loch Linnhe through a sill. It can be divided in to two areas the Upper and Lower Lochs, with the lower loch having three basins and associated sills (figure 13.1). The loch is 12.8 km long; the deepest basin has a maximum depth of 49 m. Average depth at low water is 13.4 m. The primary sill is 7 m deep with two more sills in the lower loch of 11m and 15 m depth. The upper loch has a very shallow sill of 3 m. We have no information on turbidity at the present time, although observations during the shoreline survey suggest relatively clear water.

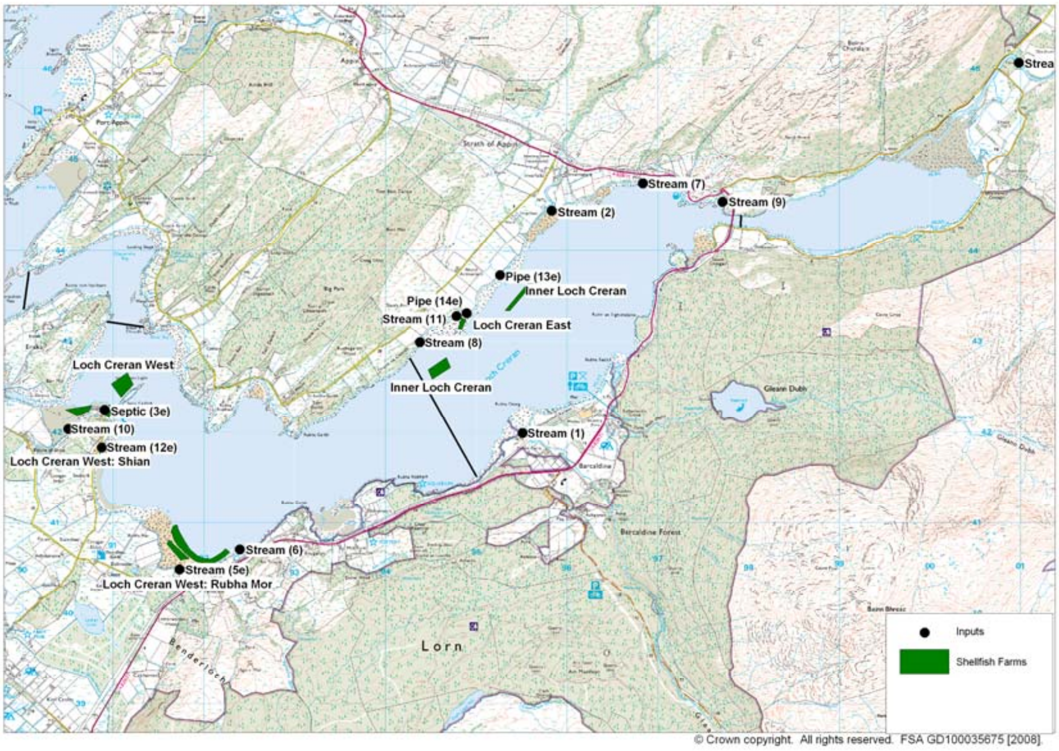

Figure 13.1 Leased sites together with potential sources identified by shoreline survey and ranked by magnitude (*E. coli* per day) with 'e' denoting estimated values. Also marked are approximate locations of sills (black lines).

Tides

The spring tidal range is stated in the SLC as 3.3 m, with the high water area being 15.1 km^2 and the low water being 13.3 km^2. The low water volume of the loch is 177.6 M m^3. The volume of water that passes by tidal action across the sills can thus be estimated to give mean velocities at the four sills of 82, 61, 5, 54 cm s^{-1}. The velocity associated with the third sill for example gives an effective transport distance of 1km over a tidal cycle. It is suggested that 5 cm s^{-1} is a rough upper value for tidal velocities in the main basin of the loch. Typical advection distances over a 6 hour tidal period away from the sills will therefore be around 0.7 km. The relatively high velocities near the mouth associated with sills 1 and 2 equate to large transports (greater than 15km) but as speeds are high only in the vicinity of the sills, the actual distance travelled over a tidal cycle will be much less (say around 3km). In the main basin, tidal currents will be considerably weaker, with tidal movement of particles perhaps less than 1km.

Flushing time is defined in the SLC as the time for 60% of the original water of the loch to be exchanged by tidal action. This time scale is an important one in relation to the retention of *E. coli*. For Loch Creran, flushing time is stated to be reasonably short at around 3 days. However this assumes complete replacement of the tidally exchanged water on each tide. Studies at loch Etive (Edwards and Edelsten, 1976) indicated a 50% exchange efficiency and applying this to Loch Creran gives 6.5 days for the tidal flushing time, which may be a more realistic value. Salt balance calculations suggest 12 days. Some water in the deeper basins will remain isolated for longer than this but the surface waters will generally be exchanged much more rapidly. Wind effects modify the flushing time in a manner difficult to quantify without modelling.

Wind driven flows

Figure 13.2 gives the wind rose at Tiree. While being a more exposed location than Loch Creran, this station will be broadly representative of the wind directions experienced at the loch.

Table 13.1 Wind speed and surface currents

Wind Speed (knots)	Surface current (cm s^{-1}) average	% time	Distance transported in hour (km)
>33	72	1.2%	2.6
28 –33	62	3.8%	2.2
17 - 27	45	28.1%	1.6
11 - 16	31	30.3%	1.1
0 -10	10	36.6%	0.37

Wind speeds are greater than 10 knots occur 63% of the time with effective transport surface transport distance of > 0.4 km h^{-1}. Over a 12-hour period this could in theory move material about a third of the length of the loch. Approx 54% of the time the wind direction is in a quadrant from 180 – 270°, this direction broadly aligns with the major axis of the loch and the likelihood of the formation of wind rows. These would act to transport material from near shore to offshore and increase the potential for dilution of contaminants.

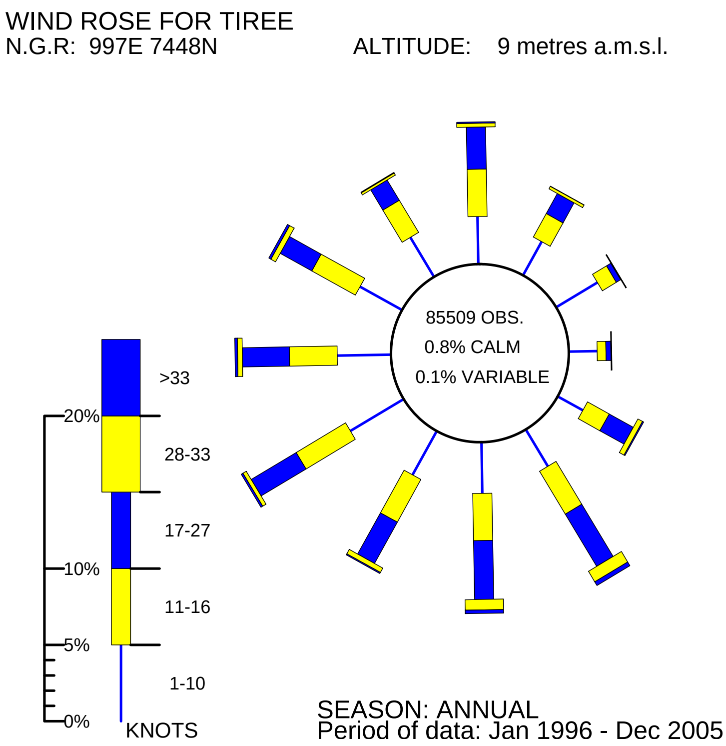

Figure 13.2 Wind rose at Tiree.

Density driven flows

Annual rainfall is given as 2000 mm per year with a runoff of 286.3 m^3 from a watershed of 164 km^2. Loch Creran has a relatively low freshwater input compared to the exchange of water due to the tide. The ratio of freshwater runoff volume to tidal prism is estimated as 1:80. Salinity and temperature sections measured in the loch (Tyler 1983) show a classic two layer structure with fresh water at the surface moving toward the mouth and more saline water moving up the loch at depth. Temperature was found to be less important than salinity in determining vertical density structure (Tyler 1983). Upper layer depth was measured to be between 4 and 8 m. No information concerning the lateral (cross-loch) distribution of salinity was found. However, sills will have the effect of enhancing lateral mixing. Density driven flows by freshwater are not likely to be strong except after periods of heavy rain. However, freshwater inputs will create a persistent seaward movement of water at the surface. Since freshwater inputs are likely to be associated with sources of *E.coli,* this surface water is likely to be important with regard to shellfish contamination.

Related studies

The loch has been relatively well studied, partly due to its proximity to the marine laboratory at Dunstaffnage. However no data records for any measurements carried out at Loch Creran reside at the British Oceanographic Data Centre. Much of the work in Loch Creran has focused on biology/ecology, rather than physical oceanography/hydrography. Relevant studies include:

- A series of hydrographic studies were undertaken in the loch during the 1970s by researchers from the Dunstaffnage laboratory (e.g. Landless and Edwards, 1976).
- PhD thesis University of Strathclyde, Glasgow (Tyler 1983, Jones 1979)
- Staff and students at Napier College have carried out fieldwork mainly focusing on phytoplankton and nutrient dynamics (e.g. Laurent *et al*., 2006).
- Scottish Natural Heritage Commissioned Report No. 151 (ROAME No. F02AA409), “The establishment of site condition monitoring of the subtidal reefs of Loch Creran Special Area of Conservation”. This study was carried out by a team from Herriott Watt University, St Andrews University and Scottish natural Heritage and concentrated on biological status.

Transport and dilution with respect to known sources

For sources identified by the shoreline survey, the measured *E. coli* concentrations and flow rates were converted to loadings (Figure 13.3). Sources were ordered according to size of loading (*E. coli* per second). Stream 1 and 2 within the main body of the loch appear to provide the largest inputs followed by the septic tank over flow near the mouth (this value is a nominal as a sample was unable to be obtained) and the River Creran at the estuary head. Other sources were much smaller. Note, some of the flow rates and hence loadings are estimated. The following assessment is based on the values measured on the day of the shoreline survey and so may be unrepresentative.

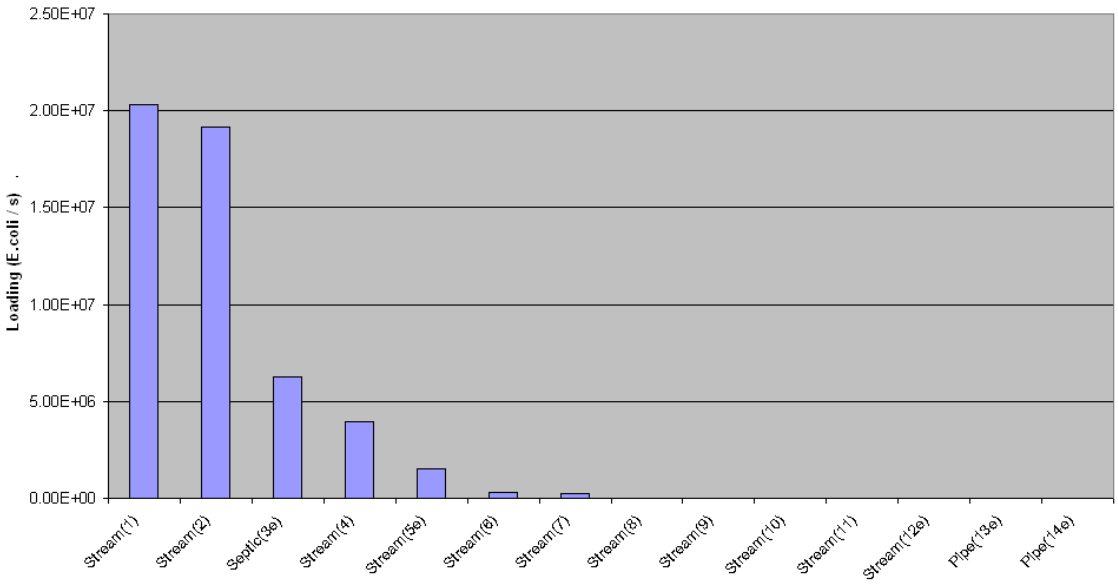

Figure 13.3 Loch Creran loadings by source. Refer to figure 13.1 for source locations.

A crude *E. coli* concentration averaged over the loch can be derived by summing all inputs, multiplying by the estimated flushing time and dividing by the loch volume. This gives a value of 8 x10^4 *E. coli* m^{-3} using the shortest flushing time (3 days) and is thus an underestimate. Nevertheless, the concentration lies between those equivalent to class A (1 x10^4 *E. coli* m^{-3}) and class B (1 x10^6 *E. coli* m^{-3}) status. Even at this broad level it seems that shellfisheries in the loch are likely to reach class B classification at best. As noted before however, this calculation assumes that the loadings measured during the shoreline survey are representative of average conditions and estimates, when used, are not excessive.

The River Creran ('stream 4') at the head of the loch provides a potential source of contamination that will effect surface waters of the loch for its entire length.

Consideration is now given to individual production areas in relation to the sources identified by the shoreline survey. Without extensive observations or numerical modelling the discussion that follows is necessarily reliant on expert judgement and is a subjective assessment.

The two sites Loch Creran West and Loch Creran West: Shian (Figure 13.1) are very likely to be impacted by discharges from the septic tank – 'septic (3e)'. On an ebb tide, Loch Creran West is likely to lie on a direct pathway from the source, whilst on a flood tide any material released on the previous ebb is likely to be brought in to impact Loch Creran West: Shian. Mitigating effects are the relatively vigorous tidal flows at the mouth that should cause material to be diluted and flushed out relatively quickly. Note that *E. coli* concentrations and loadings were unable to be measured for Septic (3) so the loading value assigned is a nominal one. Nevertheless, unless inputs from this source are very intermittent or very small, we would expect the Western Creran leased areas to be significantly impacted.

Two inputs (streams 5 and 6) flow directly into the tow sites at Loch Creran West: Rubha Mor (Figure 13.1). Note that *E. coli* concentrations and loadings were not measured for stream 5 so the loading value assigned is a nominal one. During the shoreline survey measurements from stream 6 showed relatively low concentrations of *E. coli*. Nevertheless because of its proximity, a dilution calculation suggests that the area would fail Class A classifications due to stream 6. Estimates of tidal excursion also indicate that Loch Creran West: Rubha Mor would be impacted by discharges from septic (3).

Inner Loch Creran and Loch Creran East would both be expected to lie within the influence of the relatively highly contaminated source, stream (2). Dilution in this part of the loch would expected to be weak. The tidal excursion at this location would be sufficient for material to reach the eastern area of mussel lines (adjacent to pipe 13) and probably the more western area of mussel lines as well. The seaward moving surface density flow would tend to increase the likelihood of material impacting the sites. However, prevailing westerly winds would be expected to have the opposite effect, pushing material eastward along the side of the loch then returning it along the centre, potentially missing the production areas. Set against this is the possibility of material being brought across the loch from the relatively highly contaminated source, stream (1), by the setting up of wind rows as described in the Hydrography Methods document.

Any future shellfish operations in the upper basin beyond the 4th sill (figure 13.1) are likely to be impacted by water from the river Creran, which had comparatively high loadings of *E. coli.*

Summary and conclusions

Tidal transport velocities near the sills at the loch mouth are high (greater than 50 cm s^{-1}). In the main basins tides are much weaker and wind driven flows are probably more important for transporting material. Currents driven by fresh water are not likely to be significant except after heavy rain. Contaminant input rates seem rather high relative to the rate at which water is flushed out and crude estimates suggest that even average levels of *E. coli* would be above that required for class A status. Detailed discussions relating known sources with production areas on the basis of the hydrography and dilution concluded that all sites are potentially impacted by *E. coli* concentrations sufficient to fail class A classification.

The location of inputs and physical characteristics described in this section suggest that:

- The RMP for Loch Creran West and Loch Creran West: Shian should be located as close to septic discharge 3e as possible.
- The RMP for Loch Creran West: Rubha Mor should be located as clost to stream 5 as possible.

- The RMP for Inner Loch Creran and Loch Creran East should be located as close to stream 2 as possible.
- Any future shellfish operations in the north basin, beyond the 4th sill should be classified separately from the current production areas.

14. River Flow

A river gauging station was present on the River Creran at Taraphocain (grid reference NN 019 468), however monitoring was discontinued after 1981.

Mean flows measured between 1977 and 1981 at this location were 4.77 m3/s. A flow duration curve for that location is shown below in Figure 14.1. High flows in all seasons are over two orders of magnitude higher than low flows, indicating that the river flow rates may vary markedly in response to rainfall events. At low to base flow conditions, flow volumes during the June to September time period were roughly half those observed during December to March. In section 9, figure 9.4 shows that mean monthly rainfall (2003-2006) was markedly higher from September to January than from February to August. Unfortunately, more recent data on flows were not available and so care should be taken in making direct comparisons with current data.

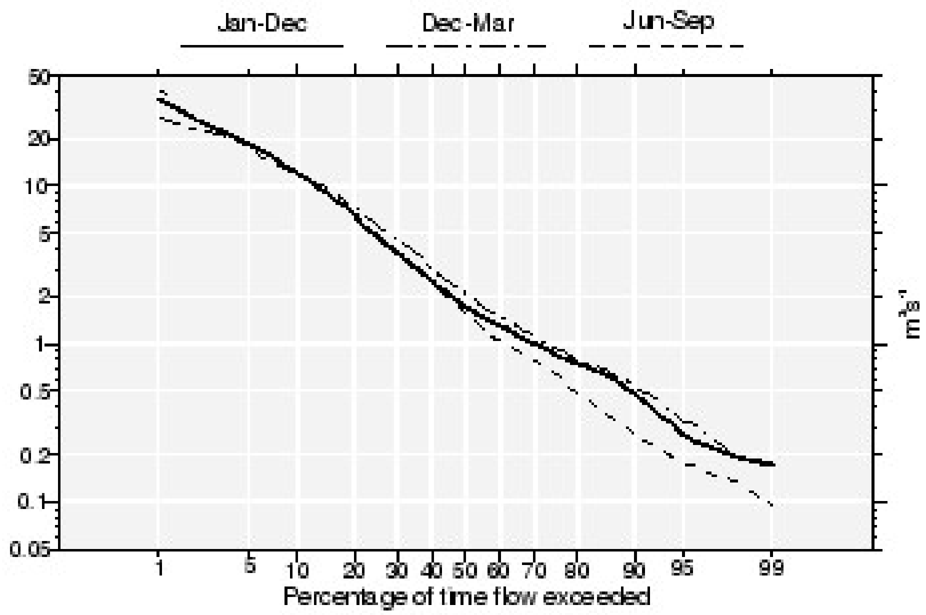

Figure 14.1 Flow duration curve for gauged daily flows on River Creran at Taraphocain. Source: National River Flow Archive, Centre for Ecology & Hydrology.

Significant rivers and streams were recorded and measured during the shoreline survey conducted on 29-31 July 2007 and a revisit on 21 November 2007. Flow was estimated during the July survey and a flow meter was used for measurement in November. Water samples were collected from the larger streams and analysed for *E.coli* content. Loadings were then calculated for each stream and are listed in Table 14.1. Streams and loadings were plotted on a map as illustrated in Figure 14.1. Streams are labelled with the number assigned in the first column of Table 14.1. It must be noted that these numbers do not correspond to those listed in Figure 13.1 or Table 13.3. Loadings on Figure 14.2 are displayed in digital scientific format, where 1E+10 is equal to 1 x 10^{10}.

As shown on the map, the highest observed loadings were associated with two streams discharging into the upper end of the loch. The An Iola enters the loch less than 1 km northeast of the eastern segment of the Inner Loch Creran mussel farm and less than 2 km northeast of the Loch Creran East oyster farm. This stream was measured and sampled during both shoreline visits, and both results are presented in Table 14.1 and Figure 14.2. Both flow rate and bacterial concentrations were higher in July than in November, though it is not possible to draw broader conclusions from this.

Table 14.1 River flows and bacterial loadings – Loch Creran

No	Grid Ref	Description	Date	Width (m)	Depth (m)	Meas. Flow (m s^{-1})	Flow (m^3 /day)	*E.coli* (cfu/ 100 ml)	Loading (*E.coli* /day)
1	NM 97710 44536	Stream	July 07	0.77	0.08	0.3	2000	70	1.1×10^9
2	NM 96832 44736	Stream	July 07	0.78	0.02	0.3	400	4900	2.0×10^{10}
3	NM 95828 44437	An Iola	July 07	19	0.09	0.4	60000	2800	1.7×10^{12}
4	NM 94781 43278	Stream	July 07	0.30	0.02	0.2	100	600	6.2×10^8
5	NM 94375 42987	Stream	July 07	0.25	0.03	0.3	2000	800	1.6×10^9
6	NN 00975 46070	River Creran	July 07	7.36	0.22	1.43	200000	170	3.4×10^{11}
7	NM 95509 41986	Dearg Abhainn	July 07	2.20	0.17	0.875	28000	6200	1.8×10^{12}
8	NM 92394 40699	Ferlochan Burn	July 07	1.60	0.10	0.45	6000	410	2.6×10^{10}
9	NM 91728 40481	Stream	July 07	1.30	0.10	0.1	1000	5900	6.6×10^{10}
10	NM 90502 42030	Stream	July 07	2.08	0.05	0.08	1000	90	7.1×10^8
11	NM 94314 41323	Stream	July 07	1.60	0.03	0.3	1000	6600	8.2×10^{10}
12	NM 91806 43095	Stream	Nov 07	2.95	0.07	0.235	4000	100	2.1×10^9
13	NM 91769 42650	Stream	Nov 07	2.25	0.05	0.419	4000	100	2.0×10^9
14	NM 95856 44461	An Iola	Nov 07	9.70	0.13	0.2305	25000	100	2.5×10^9
15	NM 96497 42551	Stream	Nov 07	6.40	0.09	0.172	9000	N/A	8.3×10^8

Dearg Abhainn discharges into the loch along the southern shore opposite the Inner Creran and Loch Creran East, though still within 2 km. These provide significant amounts of bacteria to the loch and would affect water quality in the area. Of potentially higher significance to the Loch Creran East oyster farm however, are two smaller streams, numbers 4 and 5 on the table. Stream number 4 discharges amongst the oyster trestles and is an important source of bacterial contamination in these oysters. Stream number 5 discharges 0.4 km to the southwest of the oyster farm and would impact the oyster fishery as the incoming tide swept the discharge up the loch and across the oyster farm. This discharge would also impact the lower half of the mussel operation, which lies 0.3 km offshore from it.

Overall, bacterial loads delivered to the upper half of the loch via streams and rivers would be expected to lead to poorer water quality in this half of the loch when compared to the lower half.

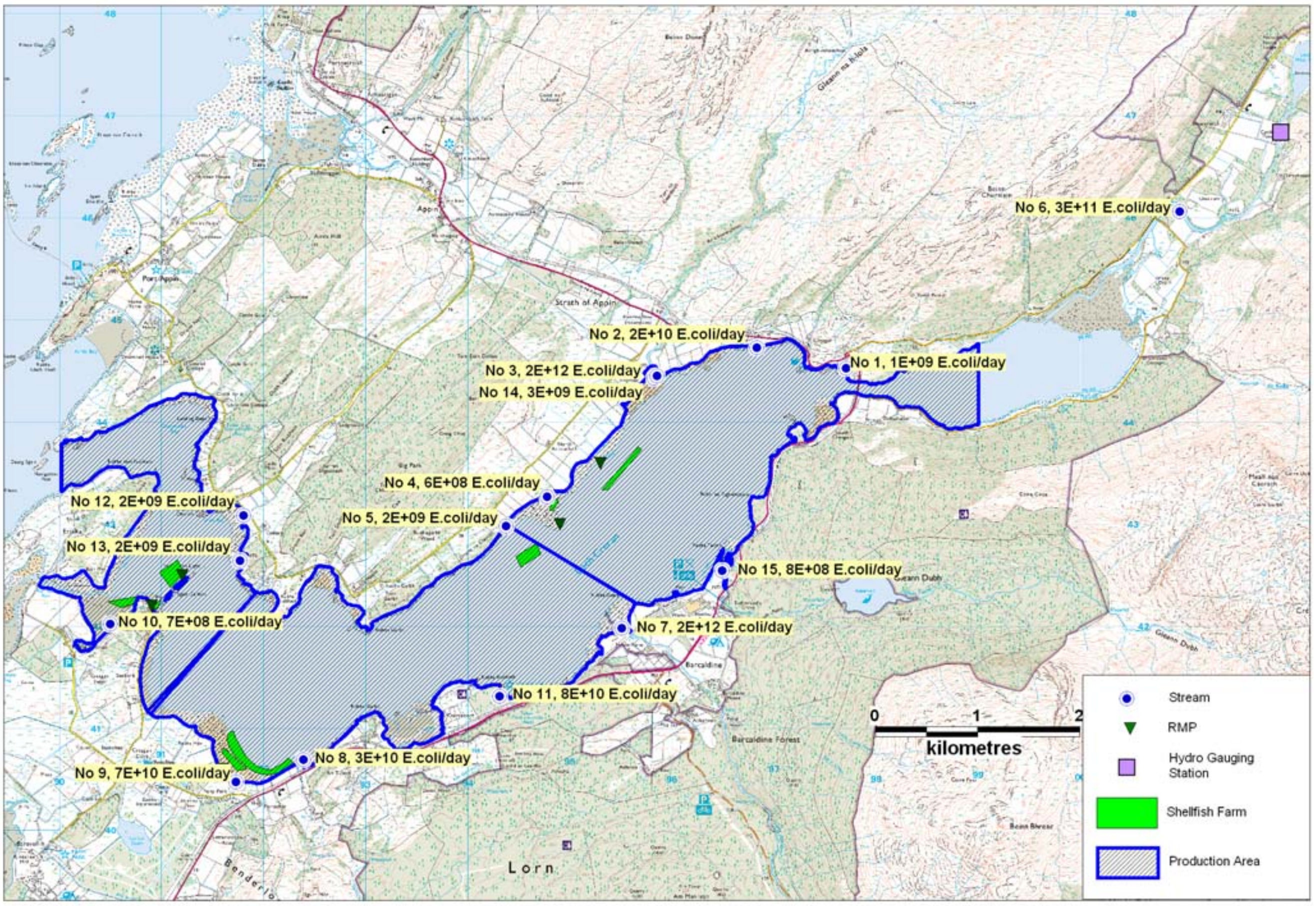

Figure 14.2 Map of river loadings at Loch Creran

15. Shoreline Survey Overview

All seawater samples taken from the boat around the areas of mussel cultivation had relatively low levels of contamination (10 or <10 *E. coli* / 100 ml). A seawater sample taken from the shore near the mouth of the loch on a flooding tide gave a result of <10 *E. coli* / 100 ml indicating that incoming seawater from the Lynn of Lorn also had relatively low levels of contamination at the time of sampling. Generally, seawater samples taken from the shore had low levels of contamination. Higher levels of contamination (220 and 620 *E. coli* / 100 ml) were found in the two seawater samples taken from the shore with the lowest salinity (28.5 and 27.8 g NaCl / L), the former on the north east shore at Creagan, the latter on the south shore close to the Rubha Mor / Loch Creran: Ferlochan sites.

There are areas where yacht moorings were observed. Significant concentrations were found at Barcaldine (2 jettys, 45 small yachts on moorings), between the Rubha Mor and Shian Fisheries sites (jetty and 5 small boats on moorings) and just offshore from the Shian Fisheries site (12 large yachts on moorings).

There is a sea life centre and seal sanctuary on the south shore of the loch. Outflow from exhibit tanks and ponds discharges into a small stream which then flows into the loch. A water sample collected from the stream below the discharge contained high concentrations of *E. coli* (6600 cfu/100 ml) and salinity consistent with sea water.

Loch Creran covers a large area, with active production sites for both oysters and mussels spread throughout it. As a consequence microbial contamination due to point or localised sources may vary considerably between production sites. The following were the potentially most significant sources identified in the vicinity of production sites.

- The river 'An Iola' discharging within 1.5 km of, and on the same shore as, the Loch Creran East and Inner Creran sites. Cattle were also observed on the shoreline and by the river here.
- Land run-off from improved pasture in the immediate vicinity of the Loch Creran East and Loch Creran West Rubha Mor oyster sites.
- A septic tank outflow discharging beyond the trestles at the eastern end of the Loch Creran West: Shian site. This may contribute to the *E. coli* contamination and, even if the *E. coli* output is too low to affect the classification status, is a potential source of pathogens.
- The large yachts moored within a few hundred metres of the Loch Creran West: Loch Creran site and the Loch Creran West: Shian sites were certainly large enough to provide overnight accomodation and discharges from these may impact these two sites.

16. Overall Assessment

Human Sewage Impacts

With a local human population at the last census of 896, Loch Creran has relatively low inputs of human sewage. The largest discharge in the area is at Point Appin, located outside the loch and to the North. Discharges from this area are direct to the Firth of Lorn and are unlikely to significantly impact the fisheries within the loch. A sample of seawater collected from near the second sill of the loch on a flooding tide showed low levels of contamination, indicating that pollution from Point Appin was either not transported into Loch Creran or was so dilute as to have minimal effect.

Of greater significance to the fisheries are smaller, private discharges located closer to the fisheries. Locations of consented discharges were obtained for a number of small septic tanks serving single households. In addition, further septic tank outfalls were observed during the shoreline survey. Most significant of these was a septic tank outfall at the Loch Creran West: Shian oyster site.

Sewage discharges closest to the fisheries are most likely to have a deleterious impact on the microbiological quality of shellfish harvested there.

Agricultural Impacts

There was little reported in the way of arable agriculture in the vicinity of the loch. However there was some grazing of livestock, particularly of cattle, that would provide a significant source of faecal contaminants to the loch.

Cattle observed during the shoreline survey in fields along the northern shore of the loch near the Inner Creran and East Barrington sites would be a significant source of *E. coli* to these fisheries. Livestock kept at Barcaldine could impact these fisheries, as well, though are likely to be a less significant impact that those kept closer to the shellfish farms. Seawater collected from the shoreline here contained 220 cfu *E.coli* / 100 ml indicating significant faecal contamination.

Livestock kept on grassland at Ferlochan near the Rubha Mor and Ferlochan fisheries would contribute bacterial contamination at those fisheries. A seawater sample collected from the shoreline at this site contained 620 cfu *E. coli*/100 ml, indicating relatively high levels of faecal contamination entering the water. This sample also had the lowest salinity of those collected, indicating high input of fresh water.

There is a small area of improved grassland behind the Loch Creran West: Shian fishery and while livestock was not specifically observed on the site during the shoreline survey this area is suitable for grazing. Should it be utilised for grazing at any point, the impact to the fishery of land runoff contaminated with livestock faeces could be significant due to close proximity to the shoreline.

Wildlife Impacts

Wildlife impacts to the loch are less easily determined. While there are some seals and otters present, there are no records of large numbers of these animals utilising Loch Creran. While some larger marine mammals can easily pass into and out of the loch, the presence of sills would serve to deter very large animals, such as the larger whales, from entering the loch. Of those species that are likely to use the loch for foraging and feeding, their presence is likely to be limited in duration and the impact to the fisheries unpredictable and fleeting.

A discharge from the seal sanctuary and sea life centre southwest of Barcaldine was found to contain significant concentrations of faecal bacteria. The nearest farm to this is the southern part of Inner Creran mussel farm. Though the mussel farm lies nearer the opposite shore of the loch to the discharge and is not likely to be significantly affected directly, the discharge does add to overall contaminant levels within the upper section of the loch.

Seasonal Variation

Loch Creran has a number of tourist attractions, including Barcaldine Forest and a Sea Life Centre on its southern shore where there are also campgrounds and caravan sites. Caravans were observed on the south shore and north shores, with the higher number along the south shore.

Yacht moorings and marinas provide accomodation for 100+ boats in the area and would be expected to be more heavily utilised in summer than in winter. The most significant impact of these would be on the Shian fisheries site as there is an area of moorings for large boats very near the mussel lines. As long term liveaboards are not permitted, any impact from pumping of septic waste overboard would be dependent upon seasonal use and occupation of the boats.

Seasonal variations in livestock population are to be expected with an increase in numbers after the birth of lambs and calves in late spring.

Rainfall for the nearest major rainfall station (Tiree) shows that rainfall amounts are higher than the Scottish average in the winter months and slightly lower than the Scottish average in the summer months. Recorded average rainfall was significantly higher from September through January when compared to rainfall recorded from February to August.

Rivers and Streams

River and stream inputs to Loch Creran are numerous, with most contributing loadings of between $2x10^9$ and $2x10^{12}$ *E. coli* per day. Highest loadings were associated with rivers discharging into the upper end of the loch. These would contribute to high overall levels of bacteria within upper Loch Creran and the bacterial concentrations would tend to be higher in the fresher surface water of the loch. The oyster farm at Loch Creran East: Barrington is significantly impacted by a small stream that carried a loading of 6.2×10^8 *E. coli* per day on the day of survey directly to the area of oyster trestles. In addition, the river An Iola contributed 1.7×10^{12} *E. coli*/day to the loch near to the mussel and oyster farms located in the upper portion of the loch.

Meteorology and Movement of Contaminants

Rainfall appeared to be weakly positively correlated with *E. coli* results obtained during classification monitoring aside from samples taken from the Rubha Mor oyster site, at which there was no correlation at all with those environmental parameters examined.

Winds on the west coast of Scotland are predominantly from the southwest or west and this aligns with the general orientation of the loch, allowing for the possibility of wind row formation leading to the movement of contaminants away from the shore toward the centre of the loch and to dilution of the contaminants. However, loadings to the loch were found in the hydrographic analysis to be sufficient to cause all shellfisheries within the loch to fail class A requirements. It must be noted that these calculations are based on measurements taken during the shoreline survey in the summer, when contamination is at its highest.

Analysis of Results

A geographic comparison of historic monitoring results indicated that there was no significant difference between the two mussel production sites. The reported sampling location for both these sites changed at the beginning of 2004, after which the results were significantly higher for both sites. This effect may have both a temporal and spatial basis. A geographic analysis of the oyster production sites revealed that results were significantly higher at the Loch Creran East site compared to the other two sites.

The overall temporal pattern of historic monitoring results for the two mussel production areas were very similar, with a significant increase in levels of contamination in 2004. For the oyster production areas, trends appeared weaker and more site specific.

The overall seasonal pattern observed in the historic monitoring results for both mussels and oysters is for lowest mean results in the March/April, steadily increasing to highest mean results in July. The late summer/autumn period experiences high but more variable results, possibly reflecting the more changeable weather patterns experienced at this time of year. Results during the winter are generally lower, decreasing through the season towards spring.

Weak positive relationships between rainfall in the previous two and seven days and historic monitoring results were observed at four of the five production areas. No relationship between recent rainfall and result was found at Loch Creran West: Rubha Mor.

No analysis of the effects of tide size on historic monitoring results was undertaken as the vast majority of samples for all sites were gathered on larger spring tides.

Positive relationships between water temperature and historic monitoring results were found for three of the four production areas evaluated. The strongest relationship was found with Inner Loch Creran, with weaker relationships found at Loch Creran West: Shian and Loch Creran East. No relationship between water temperature and *E. coli* result was found at Loch Creran West: Rubha Mor. Insufficient data was available to evaluate the effects of temperature at Loch Creran West.

A correlation between wind direction and historic monitoring results was found at three of the 5 production areas (Inner Loch Creran, Loch Creran West: Shian and Loch Creran East). For all of these three areas, results were highest when the wind had been blowing from the west.

Sampling conducted during the shoreline survey indicated high levels of contamination in some areas of the loch. Higher *E.coli* concentrations were observed in seawater samples with lower salinities, which may indicate that the source of contamination was a freshwater input.

Shellfish samples collected during the shoreline survey showed varying levels of contamination across the loch. Concentrations of *E. coli* exceeding the threshold for B classification were found in samples taken from nearest the bridge at the head of the loch (5400 mpn *E. coli*/100 g). No other shellfish samples collected approached this level of contamination. Samples taken from the mussels and oysters in the eastern half of the loch generally showed higher levels of contamination than those taken from the western end of the loch. Of eight samples collected here, five contained greater than 230 mpn *E. coli*/100 g. Of the two mussel samples collected at the same location at different depths, the deeper sample showed markedly lower bacterial contamination (20 mpn *E. coli*/100 g at 8 metres depth vs. 500 mpn *E. coli*/100 g near the surface). Of the samples taken from the western half of the loch, only one contained concentrations of *E. coli* greater than 230/100 grams. This was an oyster sample taken from near a septic tank outfall at the Shian fisheries site.

Results of sampling done for the shoreline survey are very specific to the date and conditions present at the time and therefore care should be exercised in drawing broader conclusions from this data.

17. Recommendations

Currently, five separate production areas exist for Loch Creran. It is recommended that these be combined and reduced to three distinct and non-overlapping geographic areas.

Given that there is currently no production on the Crown Estates lease north east of the Creagan bridge at the head of the main basin, it is recommended that this be excluded from the production area. Given the levels of contamination observed and the predicted movement of contaminants, should this lease come back into production it should be considered as a separate area.

The three recommended area boundaries and RMPs are as follows:

1) Upper Loch Creran
Production area is that bounded by lines drawn between NM 9550 4400 and NM 9678 4328 and between NM 9407 4265 and NM 9500 4144 extending to MHWS.

This area encompasses both the Inner Creran mussel farms and the Barrington oyster farm. It is impacted by faecal pollution from both sides of the loch and the boundaries have been drawn to exclude the area nearest where the river An Iola discharges to the loch and the innermost sections of the old production boundary as these are likely to be more highly contaminated.

The RMP for mussels is recommended to be at NM 9566 4371. This places it at the northern end of the fishery, which is likely to be more polluted than the southern end due to its proximity to the river An Iola which was shown to be a significant source of *E. coli* to the loch. Sampling depth is recommended to be 1 metre due to concentration of contaminants in the fresh water layer near the surface.

The RMP for oysters is recommended to be at NM 9485 4322. This places it on the actual farm and near the stream that runs through the trestles.

Sampling frequency for both RMPs is recommended to be monthly due to the seasonal effects seen in historical results.

2) Loch Creran Rubha Mor
Production area is bounded by lines drawn between NM 9300 4200 and NM 9300 4112 and between NM 9110 4112 and NM 9203 4201extending to MHWS.

This area encompasses the extent of the Rubha Mor seabed lease and extends to both sides of the loch. Levels of contamination within this area are expected to be broadly similar. Boundaries were set at reasonable landmarks.

It is recommended that the RMP be relocated to NM 9222 4065. This lies at the northern extent of the oyster farm near where Ferlochan Burn discharges to the loch. This end of the farm is likely to have the highest levels of contamination and so sampling from here would be most protective of public health.

Sampling frequency is recommended to remain monthly due to variability observed in historical monitoring results.

3) Loch Creran Shian

The recommended production area is bounded by lines drawn between NM 9100 4210 and NM 9175 4251 and between NM 9097 4327 and NM 9142 4323 and between NM 9030 4200 and NM 9053 4200 and between NM 9033 4240 and NM 9020 4228 extending to MHWS.

Boundaries were drawn to roughly encompass an area extending from the second sill located to the north of the Shian mussel farm and extending southward to encompass the full oyster farm.

It is recommended that the RMP for mussels be set at NM 9107 4244. This lies on the southern end of the existing mussel farm and would detect any contamination from sources along the shoreline at Shian. Sampling depth is recommended to be 1 metre as there is the potential for higher levels of contamination to occur in fresher water cap over the denser seawater.

For oysters, it is recommended that the RMP be retained at NM 9094 4220. This location allows for the greatest protection of public health as it is likely to more highly impacted by nearby sources of faecal contamination than other locations on the fishery. As the discharge nearest this location has been removed, it is further recommended that an extended bacteriological survey be undertaken at the existing RMP and at a second monitoring point on the western oyster site at NM 9057 4221 with 6 samples to be taken at monthly intervals.

Once the bacteriological survey has been completed, the data will be reviewed to determine which point reflected the higher levels of contamination from potential sources of pollution. This will then be identified as the RMP for ongoing monitoring.

Monitoring frequency at both the mussel and oyster RMPs is recommended to continue at monthly intervals due to variability of historical monitoring results.

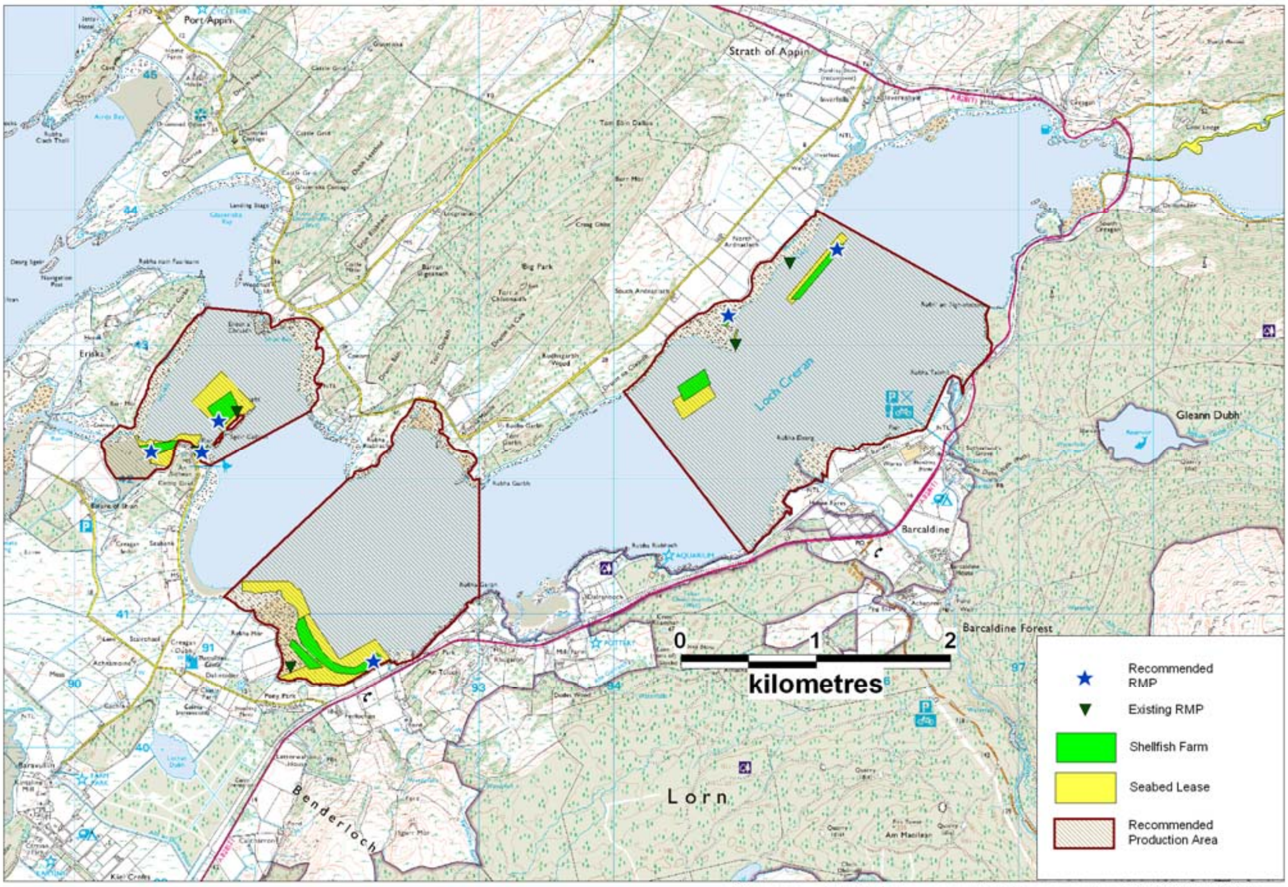

Figure 17.1 Map of recommendations for Loch Creran

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19. List of Tables and Figures

Tables

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1. Shoreline Survey Report
2. Sampling Plan
3. Tables of Typical Faecal Bacteria Concentrations
4. Statistical Data
5. Hydrographic Methods
6. Norovirus Testing Summary

Shoreline Survey Report

Survey Area: Loch Creran
AB313, AB129, AB312, AB130 & AB131

Scottish Sanitary Survey Project

Shoreline Survey Report

Production Areas:

Area Name	SIN	Site Name	Species
Inner Loch Creran	AB 313 709 08	Inner Creran	Common mussel
Loch Creran East	AB 129 021 13	East-Barrington	Pacific Oyster
Loch Creran West	AB 312 020 08	Loch Creran	Common mussel
Loch Creran West: Rubha Mor	AB 130 742 13	Loch Creran Ferlochan	Pacific Oyster
	AB 130 022 13	Rubha Mor	Pacific Oyster
Loch Creran West: Shian	AB 131 023 13	Shian Fisheries	Pacific Oyster

Harvesters:
Isle of Shuna Shellfish (Inner Creran and Loch Creran)
Creran Oysters (East - Barrington)
Caledonian Oysters (Loch Creran Ferlochan)
Operation currently for sale (Rubha Mor)
Shian Fisheries (Shian Fisheries)

Local Authority: Argyll and Bute Council
Status: All sites and areas are currently classified for production.
Date Surveyed: 29-31/7/07 and 21/11/07
Surveyed by: Ron Lee, Christine McLachlan, Alastair Cook
Existing RMPs: NM953436, NM949430, NM912425, NM916406, NM909422
Area Surveyed: See Figures 1-5.

Weather observations

29-31/7/07 - Light westerly winds, sunny spells, occasional showers (sometimes heavy).
21/11/07 - Fresh northerly winds, overcast.

Site Observations

Maps showing the specific observations made on site are shown in Figures 1-5 and listed in Table 1. Water and shellfish samples were collected at sites marked on Figures 6 and 7. Bacteriology results are given in Tables 2 and 3. Photographs are presented in Figures 8 - 27.

Fishery

Inner Creran (AB31370908). This site actually consists of 2 distinct areas of mussel floats, either side of the East-Barrington oyster production site. The area of floats to the south west consists of 4 lines, and had no harvestable mussels at the time of sampling. The lines are to be moved about 200m to the south and west in the near future to prevent damage to underwater reefs. The area to the North and east consists of 3 lines, and had mussels of a harvestable size.

East - Barrington (AB12902113). The site is an area of trestle grown oysters. Stock of a range of sizes was observed including some of market size. The grower reports that they take 2-3 years to reach harvestable size, and are all supplied to Loch Fyne Oysters. Harvesting generally takes place during the winter months.

Loch Creran (AB31202008). The site consists of a floating raft, which currently has no stock on aside from 2 bags of mussels held at the RMP. There is also a larger area of ropes on floats to the south of the raft (4 lines). There is currently no stock on these ropes.

Loch Creran Ferlochan (AB13074213). This consists of a large area of oyster trestles. Stock of a range of sizes was observed including some of market size. Oysters were also seen in bags on the substrate as well as on trestles. This site borders on the Rubha Mor site.

Rubha Mor (AB13002213). This is an oyster trestle site. Stock of a range of sizes was observed including some of market size. The grower from the adjacent site (Ferlochan) advised that the site is privately owned rather than a crown estates lease. The site is currently for sale.

Shian Fisheries (AB13102313). This is an oyster trestle site. Stock of a range of sizes was observed including some of market size, and harvesting was taking place at the time of survey.

Additionally there were many areas of large wild mussels spread around the entire shoreline of the loch. Several other shore mussel samples were taken where the opportunity arose.

Sewage/Faecal Sources

Human - There are no major population centres on the shores of the loch, and human population in this area is relatively sparse. There are a number of houses and small settlements dotted around the loch, with the south shore more densely populated than the north shore. It is probable that many of these are not connected to mains sewerage although few obvious septic tank outflows were found discharging directly into the production area. Of note, a pipe presumed to be a septic overflow was found discharging beyond the oyster trestles at the Shian Fisheries site. The location of the Scottish Water discharge at Barcaldine Sawmill was confirmed but appeared somewhat derelict and did not seem to be discharging at the time of survey. A new sewer pipe was observed running from a house under construction near Creagan – this was not yet connected. Further a field at Port Appin at least 9 private septic overflows to the beach were found, as well as the Scottish Water discharge. Some of these discharges did not appear to be functioning correctly, and raw sewage and sanitary related debris was found on the shore here.

Livestock - concentrations of livestock appeared to be relatively low overall. Cattle and sheep were observed. Generally, fences prevent livestock gaining access on the shoreline, but livestock were observed on the shoreline at two places (cattle at one location on the north shore, and sheep at one location on the south shore). In both these places, a considerable amount of dung was observed below the high water mark.

A number of small rivers and streams discharge into the loch. These drain a mixture of forest and pasture. Water samples were taken, and discharge estimated for the larger watercourses and some of the numerous smaller streams.

There is a Sea Life Centre on the south shore of the loch, and exhibits include seals. The outflow from this discharges into a small stream, which discharges into the Loch.

All seawater samples taken from the boat around the areas of mussel cultivation had relatively low levels of contamination (10 or <10 *E. coli* / 100 ml). A seawater sample taken from the shore near the mouth of the loch on a flooding tide gave a result of <10 *E. coli* / 100 ml indicating that incoming seawater from the Lynn of Lorn also had relatively low levels of contamination at the time of sampling. Generally, seawater samples taken from the shore had low levels of contamination. Higher levels of contamination (220 and 620 *E. coli* / 100 ml) were found in the two seawater samples taken from the shore with the lowest salinity (28.5 and 27.8 g NaCl / L), the former on the north east shore at Creagan, the latter on the south shore close to the Rubha Mor / Loch Creran: Ferlochan sites.

Seasonal Population

The area is popular with tourists and as a consequence there is an increase in population in the summer months. One caravan/campsite was noted on the south shore, at Barcaldine where 13 mobile caravans were present. A holiday park was observed on the north shore where there were 8 trailers/caravans and 11 chalets. 3 large caravans were observed on the shoreline between the Rubha Mor and Shian Fisheries sites.

Boats/Shipping

No major ports are located within the loch. There are areas where yacht moorings were observed. Significant concentrations were found at Barcaldine (2 jettys, 45 small yachts on moorings), between the Rubha Mor and Shian Fisheries sites (jetty and 5 small boats on moorings) and just offshore from the Shian Fisheries site (12 large yachts on moorings). A few moorings and small boats were observed at other locations around the loch.

Land Use

The surrounding land is a mixture of mainly coniferous forest and pasture. Both cattle and sheep are reared on the pastureland. Human population in the area is relatively sparse, but there are houses dotted around the loch. The south shore is more densely populated than the north shore.

Wildlife/Birds

A flock of approximately 70 geese were seen grazing on the south shore (in the same area as the sheep noted above). Aside from this, no significant concentrations of wildlife were noted during the course of the survey. It was reported that the mussel ropes at Loch Creran West: Loch Creran had been stripped by eider ducks although none were seen at the time of survey.

Summary

Loch Creran covers a large area, with active production sites for both oysters and mussels spread throughout it. As a consequence microbial contamination due to point or localised sources may vary considerably between production sites. The following were the potentially most significant sources identified in the vicinity of production sites.

- The river 'An Iola' discharging within 1.5 km of and on the same shore as the East Barrington and Inner Creran sites. Cattle were observed on the shoreline and by the river here.
- Land run-off in the immediate vicinity of the East – Barrington and Loch Creran – Ferlochan oyster sites.
- A septic tank outflow discharging beyond the trestles at the eastern end of the Shian fisheries site.
- The large yachts moored within a few hundred metres of the Loch Creran West:Loch Creran site and the Shian fisheries site were certainly large enough to provide overnight accommodation, and discharges from these may impact these two sites.

Figure 1. Map of Shoreline Observations (Port Appin area)

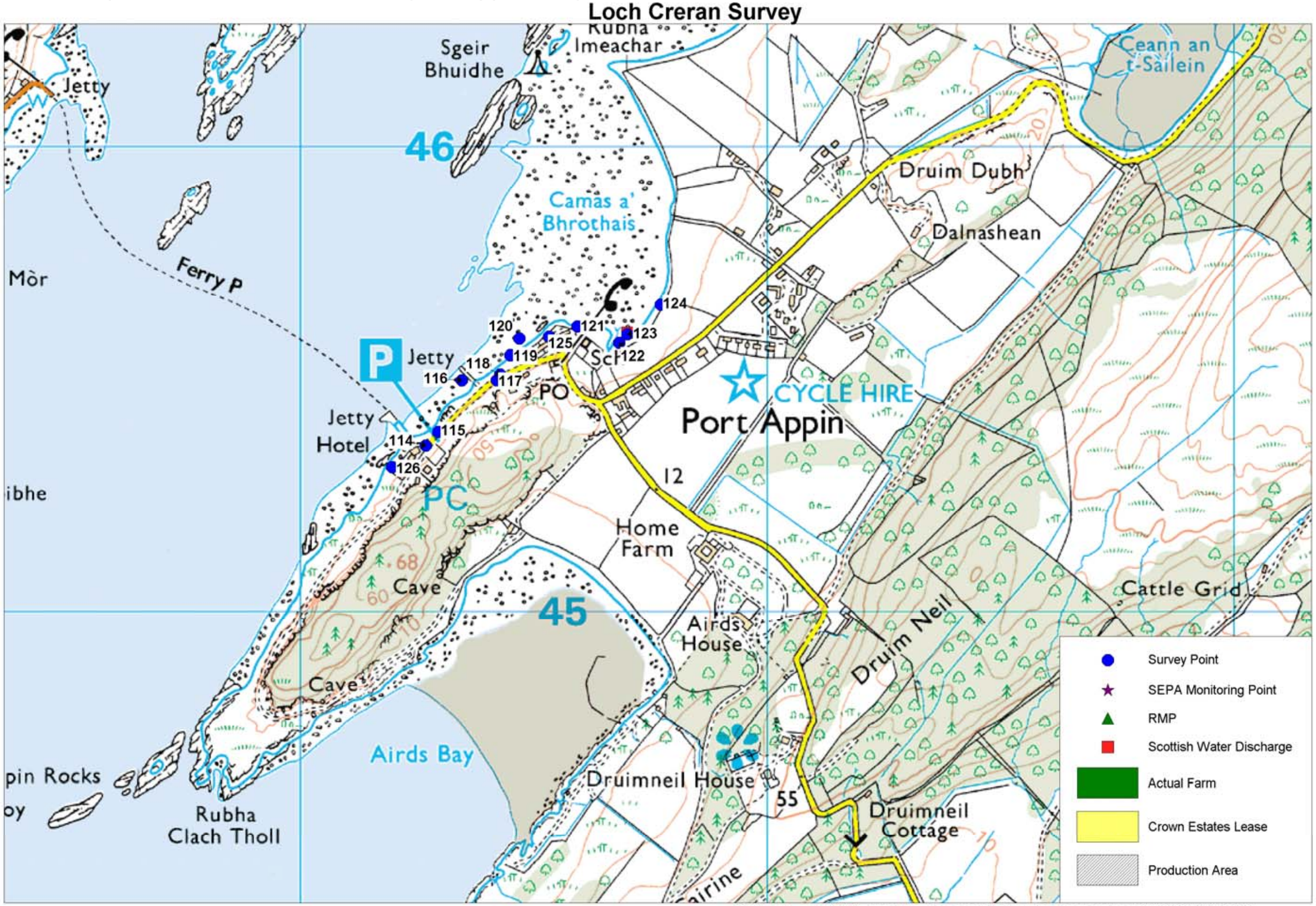


Figure 2. Map of shoreline observations (North West)

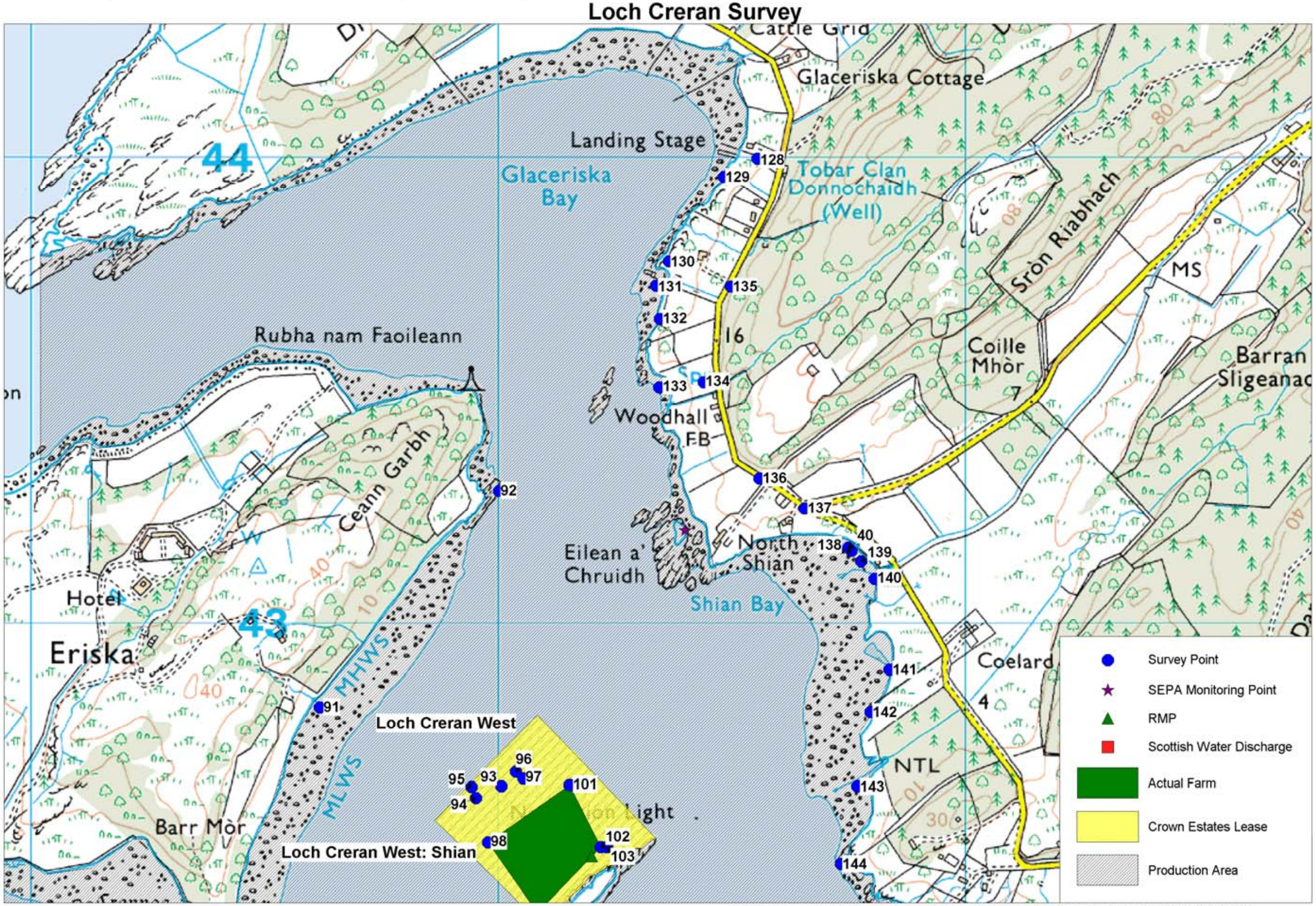


Figure 3. Map of Shoreline Observations (South West)

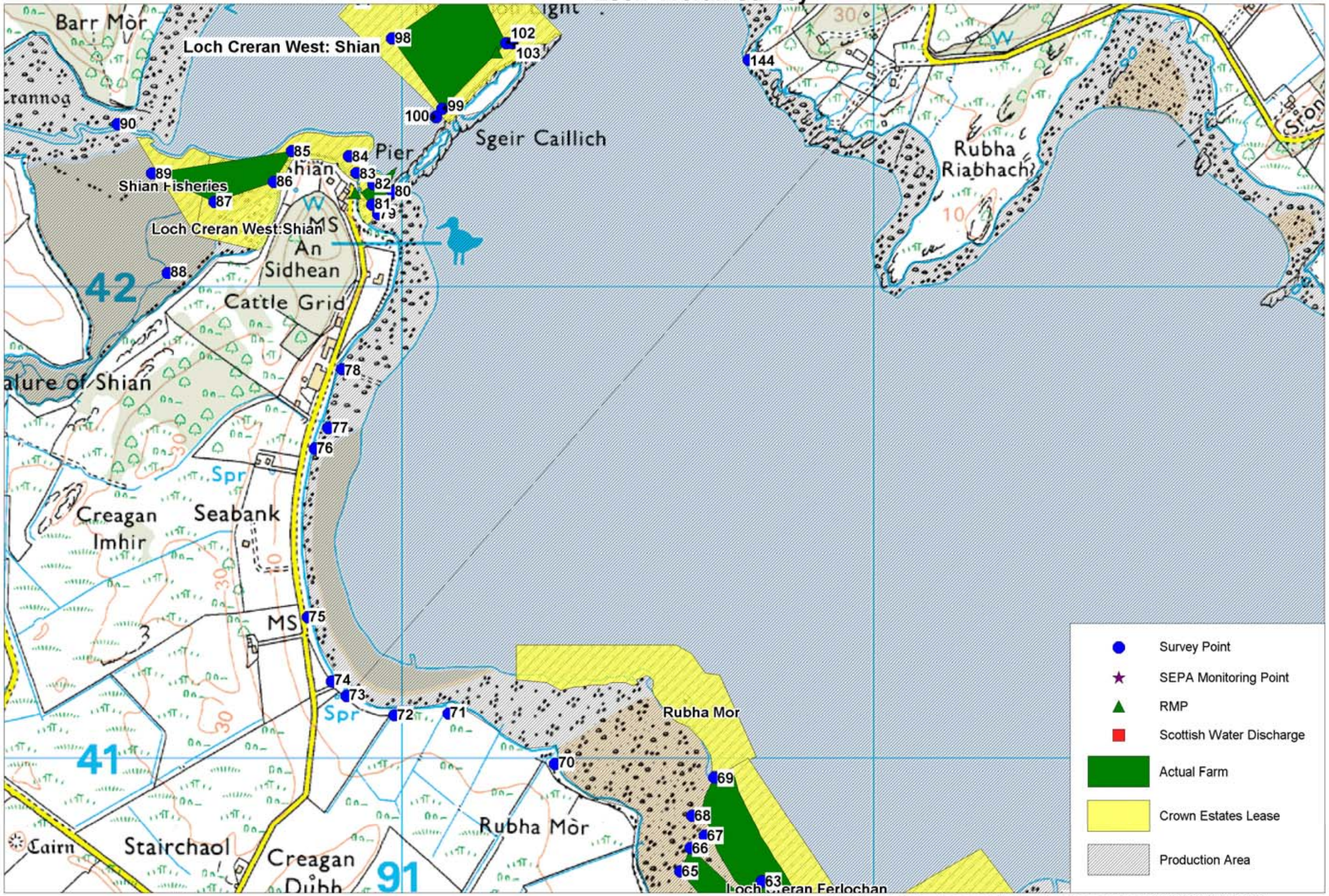


Figure 4. Map of shoreline observations (Rubha Mor)

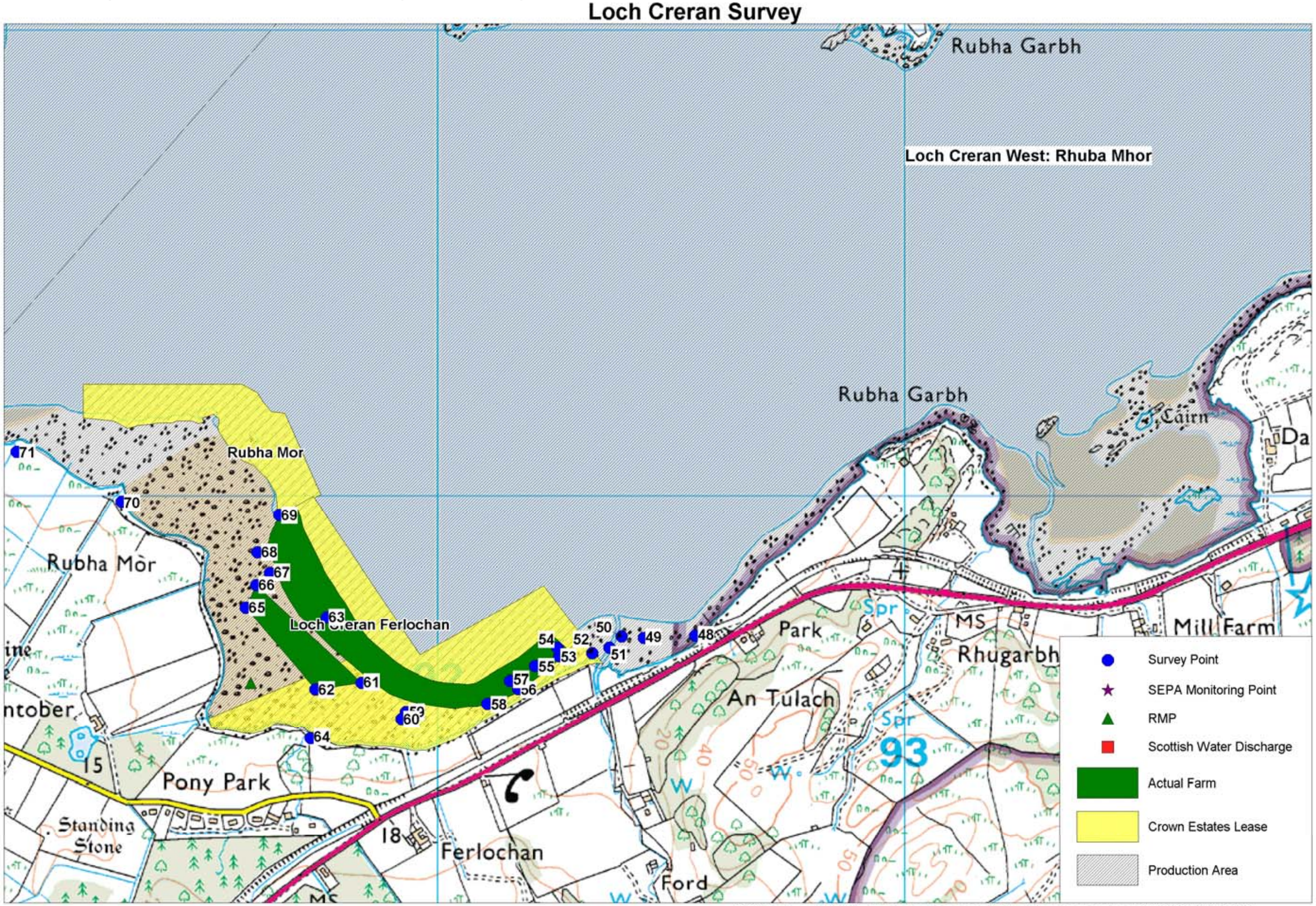


Figure 5. Map of shoreline observations (Central Loch Creran)

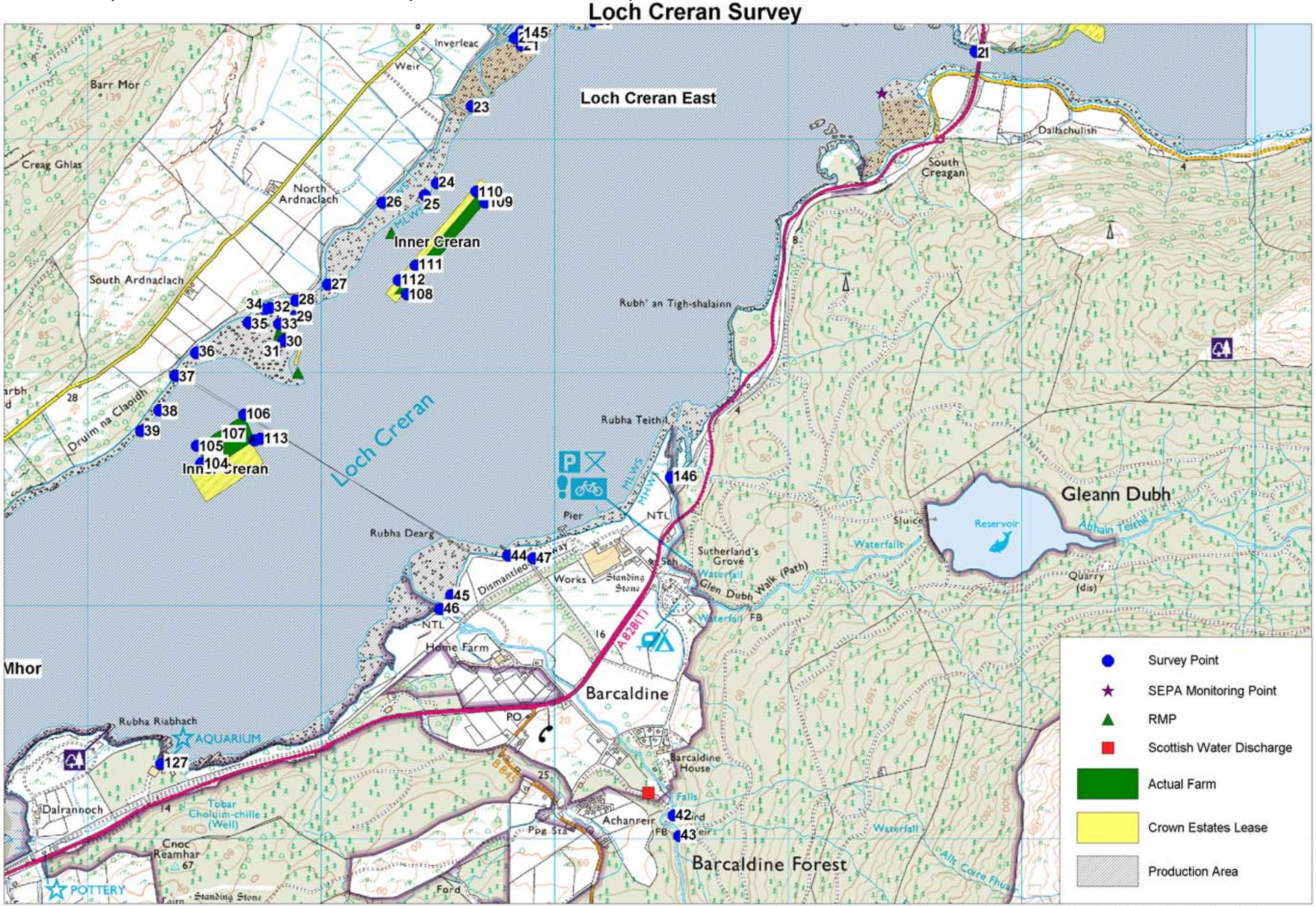


Figure 6. Map of shoreline observations (East Loch Creran)

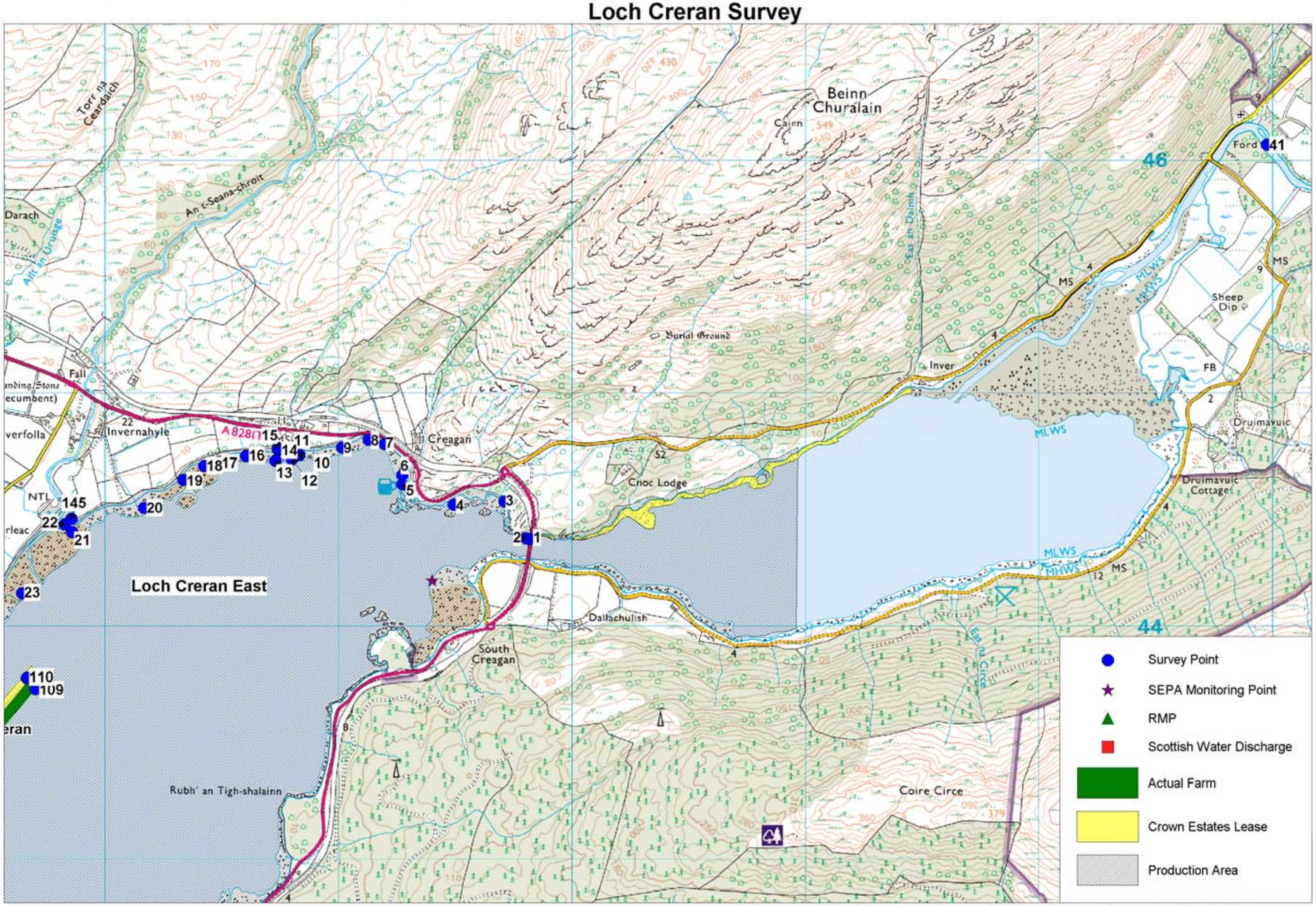


Table 1. Shoreline Observations

No.	Date and time	NGR	East	North	Photograph	Description
1	29-JUL-07 10:51:07AM	NM 97819 44374	197819	744374		Water sample 1, tide ebbing at time of sampling
2	29-JUL-07 10:54:55AM	NM 97803 44377	197803	744377	Figure 6	Shellfish Sample 1 (wild mussel).
3	29-JUL-07 11:21:18AM	NM 97710 44536	197710	744536		Stream 77x8xestimated0.3m/s. Water sample 2 (Fresh)
4	29-JUL-07 11:33:33AM	NM 97492 44523	197492	744523		Broken trestles, empty oyster bags and shells
5	29-JUL-07 11:47:18AM	NM 97273 44611	197273	744611	Figure 7	110m orange plastic sewer pipe from large house under construction (not yet connected)
6	29-JUL-07 11:49:48AM	NM 97272 44651	197272	744651		Small stream seeping through beach, mooring buoy in middle of bay
7	29-JUL-07 11:54:08AM	NM 97197 44781	197197	744781		Small surface drain under road (30cm concrete pipe), flowing slowly into pebbles on beach.
8	29-JUL-07 11:56:42AM	NM 97129 44800	197129	744800		Small surface drain under road (30cm concrete pipe), flowing slowly into pebbles on beach.
9	29-JUL-07 11:59:53AM	NM 97015 44767	197015	744767		4 houses 50-100m back from shoreline (no associated pipes)
10	29-JUL-07 12:05:01PM	NM 96832 44736	196832	744736		Stream 78x2xestimated0.3m/s. Water sample 3 (Fresh)
11	29-JUL-07 12:09:07PM	NM 96815 44738	196815	744738	Figure 8	Holiday park, 8 trailers, 11 chalets further back over road. Also mooring occupied by small boat circa 20m out.
12	29-JUL-07 12:17:59PM	NM 96800 44718	196800	744718		Water sample 4. Taken at end of line of stones possibly concealing pipe.
13	29-JUL-07 12:22:22PM	NM 96730 44711	196730	744711	Figure 9	15cm black ribbed pipe mainly buried. Water oozing from rocks covering it estimated > 1L per min.
14	29-JUL-07 12:24:50PM	NM 96739 44758	196739	744758		Inspection cover
15	29-JUL-07 12:26:01PM	NM 96739 44765	196739	744765		Concrete slab on lawn - might be septic tank cover (no vent observed)
16	29-JUL-07 12:29:55PM	NM 96604 44731	196604	744731		Stream 40x2xestimated0.2m/s. Not sampled.
17	29-JUL-07 12:34:48PM	NM 96488 44705	196488	744705		Very small stream (trickle)
18	29-JUL-07 12:36:17PM	NM 96424 44689	196424	744689		Unidentified droppings
19	29-JUL-07 12:39:49PM	NM 96335 44628	196335	744628		28 sheep in field next to shoreline (fenced)
20	29-JUL-07 12:44:32PM	NM 96166 44508	196166	744508		Stream 35x3xestimated0.1m/s. Not sampled.
21	29-JUL-07 12:53:26PM	NM 95858 44404	195858	744404		Cow droppings on grass around high water mark
22	29-JUL-07 12:55:58PM	NM 95828 44437	195828	744437	Figure 10	River 19mx9cmxestimated0.4m/s. Water sample 5 (Fresh) 12:57. 40 cows in adjacent field (fenced) but 4 had escaped onto shoreline

23	29-JUL-07 1:10:57PM	NM 95644 44143	195644	744143		Braided stream 2.5mx5cmxestimated0.3m/s. Not sampled.
24	29-JUL-07 1:22:58PM	NM 95495 43813	195495	743813		Shellfish Sample 2 (wild mussel). Water sample 6.
25	29-JUL-07 1:34:44PM	NM 95443 43761	195443	743761		Stream 85cmx4cmxestimated 0.1m/s. Not sampled.
26	29-JUL-07 1:39:07PM	NM 95262 43728	195262	743728	Figure 11	Ribbed black plastic pipe 5" flowing from field into HW mark. Orange growth in water. Water sample 7 (Fresh 13:40). 28 cattle in field behind. 3 houses circa 300m back from shoreline.
27	29-JUL-07 1:53:28PM	NM 95028 43378	195028	743378		Stream 1mx3cmxestimated 0.2m/s. Not sampled.
28	29-JUL-07 2:02:34PM	NM 94890 43310	194890	743310		4" black ribbed pipe - land drain - flowing. Water sample 8 (fresh).
29	29-JUL-07 2:08:34PM	NM 94883 43239	194883	743239	Figure 12	Corner of trestles (East Barrington)
30	29-JUL-07 2:13:06PM	NM 94838 43134	194838	743134		Corner of trestles (East Barrington)
31	29-JUL-07 2:18:51PM	NM 94841 43140	194841	743140		Water sample 9.
32	29-JUL-07 2:54:31PM	NM 94781 43278	194781	743278		Stream 30x2xestimated 0.2m/s Water sample 10 (Fresh).
33	29-JUL-07 3:01:29PM	NM 94820 43208	194820	743208		Shellfish sample 3 (wild mussel).
34	29-JUL-07 3:06:18PM	NM 94758 43271	194758	743271		Cow droppings on grass around high water mark.
35	29-JUL-07 3:08:03PM	NM 94688 43213	194688	743213		Stream 30x2.5xestimated 0.2m/s. Not sampled.
36	29-JUL-07 3:14:07PM	NM 94463 43085	194463	743085	Figure 13	Stable bedding dumped at HW mark. 1 cow in field behind
37	29-JUL-07 3:17:20PM	NM 94375 42987	194375	742987		Stream 25x3xestimated 0.3m/s. Water sample 11 (Fresh).
38	29-JUL-07 3:28:54PM	NM 94306 42838	194306	742838		Water sample 12. Shellfish sample 4 (wild mussel).
39	29-JUL-07 3:38:49PM	NM 94229 42749	194229	742749		3 little buoys just off the shore.
40	29-JUL-07 5:59:28PM	NM 91750 43161	191750	743161		Water sample 13.
41	30-JUL-07 11:00:40AM	NN 00975 46070	200975	746070		River Creran 736x22x1.43m/s. Water sample 14 (fresh).
42	30-JUL-07 11:30:36AM	NM 96509 41102	196509	741102		No record - marked in error
43	30-JUL-07 11:37:10AM	NM 96533 41014	196533	741014	Figure 14	Barcaldine sawmill outflow. Not flowing much if at all. Might not be in use.
44	30-JUL-07 11:56:35AM	NM 95801 42215	195801	742215	Figure 15	Jetty. 45 boats moored just off (small yachts).
45	30-JUL-07 12:06:17PM	NM 95557 42046	195557	742046	Figure 16	36 sheep, 70 geese grazing on short grass on shoreline below tideline. Much excrement on grass. Had escaped from field behind through broken gate. A further 30 sheep and 26 cattle in the field behind.
46	30-JUL-07 12:11:34PM	NM 95509 41986	195509	741986		Stream 220x17x0.875m/s. Water sample Creran 15 (fresh).
47	30-JUL-07 12:27:24PM	NM 95907 42202	195907	742202		Caravan park 13 caravans

48	30-JUL-07 12:44:21PM	NM 92551 40701	192551	740701		Water sample 16.
49	30-JUL-07 12:48:20PM	NM 92441 40696	192441	740696		Pile of oyster bags. Boat on mooring circa 50m out. Oyster processing shed on shoreline.
50	30-JUL-07 12:50:19PM	NM 92394 40699	192394	740699		Stream 160x10x0.45m/s. Water 17 (fresh).
51	30-JUL-07 1:00:39PM	NM 92368 40675	192368	740675		End of row of oyster bags on ground.
52	30-JUL-07 1:02:57PM	NM 92331 40663	192331	740663		Other end of row of bags on ground.
53	30-JUL-07 1:05:30PM	NM 92260 40656	192260	740656		Corner of trestles (Rubha Mor / Loch Creran Ferlochan).
54	30-JUL-07 1:06:57PM	NM 92256 40675	192256	740675		5m out to corner of trestles (too deep to access by foot).
55	30-JUL-07 1:12:20PM	NM 92208 40635	192208	740635		Water sample 18. 7 cows in field behind shoreline.
56	30-JUL-07 1:15:33PM	NM 92172 40587	192172	740587		Corner of trestles.
57	30-JUL-07 1:16:26PM	NM 92155 40604	192155	740604		Corner of trestles 5m out from here (too deep to access by foot).
58	30-JUL-07 1:18:06PM	NM 92106 40555	192106	740555		Corner of rrestles.
59	30-JUL-07 1:27:05PM	NM 91932 40537	191932	740537		4 houses circa 100m back from shoreline.
60	30-JUL-07 1:31:13PM	NM 91922 40522	191922	740522		Shellfish sample 5 (wild mussels).
61	30-JUL-07 1:36:39PM	NM 91837 40600	191837	740600	Figure 17	Corner of trestles.
62	30-JUL-07 1:40:51PM	NM 91738 40586	191738	740586		Corner of trestles.
63	30-JUL-07 1:46:37PM	NM 91762 40740	191762	740740		Water sample 19.
64	30-JUL-07 2:02:12PM	NM 91728 40481	191728	740481		Stream 130x10cm, flow not estimated. Water sample 20 (fresh).
65	30-JUL-07 2:10:49PM	NM 91589 40761	191589	740761		Corner of trestles.
66	30-JUL-07 2:12:01PM	NM 91611 40810	191611	740810		Corner of trestles.
67	30-JUL-07 2:12:54PM	NM 91641 40836	191641	740836		Corner of trestles.
68	30-JUL-07 2:13:46PM	NM 91614 40879	191614	740879		Corner of trestles.
69	30-JUL-07 2:15:52PM	NM 91661 40960	191661	740960		Corner of trestles.
70	30-JUL-07 2:26:57PM	NM 91323 40988	191323	740988		Very small stream (trickle).
71	30-JUL-07 2:34:25PM	NM 91098 41095	191098	741095		Very small stream (trickle).
72	30-JUL-07 2:37:49PM	NM 90983 41092	190983	741092		Very small stream. 2 cows in field behind.
73	30-JUL-07 2:40:29PM	NM 90881 41133	190881	741133		Very small stream.
74	30-JUL-07 2:41:16PM	NM 90850 41164	190850	741164		3 large caravans just behind shoreline. Very small stream. 5 small boats moored in bay and 4 empty moorings

75	30-JUL-07 2:44:53PM	NM 90799 41300	190799	741300		Small stream from 18" pipe (land drain under road). 4 houses over road.
76	30-JUL-07 2:54:39PM	NM 90814 41658	190814	741658		Small stream.
77	30-JUL-07 2:59:05PM	NM 90843 41701	190843	741701		12" surface water pipe from under road. Salmon processing plant behind.
78	30-JUL-07 3:02:35PM	NM 90872 41826	190872	741826		Salmon jetty. Small stream Water sample Creran 21 (fresh).
79	30-JUL-07 3:13:38PM	NM 90948 42155	190948	742155	Figure 18	Corner of trestles (Shian Fisheries).
80	30-JUL-07 3:15:17PM	NM 90979 42202	190979	742202		Corner of trestles 10m further out (too deep to access by foor).
81	30-JUL-07 3:16:54PM	NM 90936 42175	190936	742175		Corner of trestles.
82	30-JUL-07 3:18:13PM	NM 90938 42219	190938	742219		Water sample 22.
83	30-JUL-07 3:21:16PM	NM 90902 42243	190902	742243	Figure 19	Presumed septic tank outlet pipe 4" orange plastic running out at least 20m past this point into area of trestles. 2 houses on shoreline.
84	30-JUL-07 3:31:00PM	NM 90886 42279	190886	742279		Water sample 24. Shellfish sample 6 (wild mussels). 12 large yachts moored in bay.
85	30-JUL-07 3:33:15PM	NM 90766 42290	190766	742290		Corner of trestles.
86	30-JUL-07 3:35:25PM	NM 90727 42224	190727	742224		Corner of trestles.
87	30-JUL-07 3:38:40PM	NM 90601 42181	190601	742181		Corner of trestles.
88	30-JUL-07 3:41:49PM	NM 90502 42030	190502	742030		Stream 208x5.5x0.08m/s. Water sample 25.
89	30-JUL-07 3:55:23PM	NM 90469 42242	190469	742242		Corner of trestles.
90	30-JUL-07 4:08:21PM	NM 90396 42347	190396	742347		Shellfish sample 7 (wild mussel).
91	30-JUL-07 4:28:48PM	NM 90618 42819	190618	742819		Small stream
92	30-JUL-07 4:41:39PM	NM 91002 43284	191002	743284		Water sample 23.
93	31-JUL-07 10:11:58AM	NM 91007 42650	191007	742650	Figure 20	RMP. Shellfish sample 8 (bagged mussel). Water sample 26.
94	31-JUL-07 10:25:37AM	NM 90952 42625	190952	742625		Corner of raft (Loch Creran).
95	31-JUL-07 10:25:47AM	NM 90943 42648	190943	742648		Corner of raft.
96	31-JUL-07 10:26:21AM	NM 91038 42681	191038	742681		Corner of raft.
97	31-JUL-07 10:26:30AM	NM 91054 42667	191054	742667		Corner of raft.
98	31-JUL-07 10:27:16AM	NM 90978 42529	190978	742529	Figure 21	Corner of floats (Loch Creran).
99	31-JUL-07 10:28:05AM	NM 91084 42379	191084	742379		Corner of floats.
100	31-JUL-07 10:28:21AM	NM 91071 42362	191071	742362		Water sample 27. No mussels on ropes at present due to duck damage.

101	31-JUL-07 10:32:21AM	NM 91153 42652	191153	742652		Corner of floats.
102	31-JUL-07 10:33:04AM	NM 91220 42519	191220	742519		Corner of floats.
103	31-JUL-07 10:33:14AM	NM 91233 42519	191233	742519		Water sample 28.
104	31-JUL-07 10:42:05AM	NM 94486 42610	194486	742610	Figure 22	Corner of floats (Inner Creran). This site to be moved a few 100ms SW in the near future because of reefs underneath.
105	31-JUL-07 10:42:28AM	NM 94467 42685	194467	742685		Corner of floats (4 lines).
106	31-JUL-07 10:43:13AM	NM 94670 42819	194670	742819		Corner of floats.
107	31-JUL-07 10:43:46AM	NM 94713 42709	194713	742709		Corner of floats.
108	31-JUL-07 10:45:48AM	NM 95368 43337	195368	743337		Corner of floats.
109	31-JUL-07 10:46:56AM	NM 95701 43731	195701	743731	Figure 23	Corner of floats.
110	31-JUL-07 10:50:14AM	NM 95664 43778	195664	743778		Water sample 29.
111	31-JUL-07 10:53:53AM	NM 95405 43460	195405	743460		Water sample. Shellfish sample 9 (mussel, top of ropes) shellfish sample 10 (mussel, bottom of 8m long ropes).
112	31-JUL-07 11:01:51AM	NM 95333 43397	195333	743397		Corner of floats.
113	31-JUL-07 11:04:17AM	NM 94738 42716	194738	742716		Water sample 31.
114	31-JUL-07 1:43:42PM	NM 90268 45357	190268	745357		4" ceramic pipe to shoreline, 2 inspection covers and vent further up (i.e. septic discharge) smelly and flowing.
115	31-JUL-07 1:48:35PM	NM 90295 45387	190295	745387		4" metal pipe from septic tank – foul smell but not sure if flowing.
116	31-JUL-07 1:54:42PM	NM 90345 45498	190345	745498		4" metal pipe to shore, not flowing, no smell.
117	31-JUL-07 1:58:05PM	NM 90420 45498	190420	745498		2" plastic pipe running parallel to shore mainly buried
118	31-JUL-07 1:59:08PM	NM 90427 45511	190427	745511		4" metal pipe not flowing.
119	31-JUL-07 2:01:15PM	NM 90449 45552	190449	745552		4" metal pipe not flowing.
120	31-JUL-07 2:02:35PM	NM 90468 45587	190468	745587	Figure 24	5" metal pipe, trickle, surrounded by faecal material including sweetcorn.
121	31-JUL-07 2:05:48PM	NM 90592 45613	190592	745613		4" plastic sewer pipe broken.
122	31-JUL-07 2:08:55PM	NM 90682 45578	190682	745578		4" plastic sewer pipe discharging foul smelling water.
123	31-JUL-07 2:10:22PM	NM 90700 45596	190700	745596		5" plastic sewer pipe flowing.
124	31-JUL-07 2:15:46PM	NM 90771 45660	190771	745660	Figure 25	7" metal sewer pipe, flowing fairly rapidly, water grey with foul smell, toilet paper at end and sewage related debris all around.
125	31-JUL-07 2:23:58PM	NM 90532 45591	190532	745591		Horse droppings.
126	31-JUL-07 2:36:52PM	NM 90196 45312	190196	745312		Probably a septic tank but no overflow (pump-out variety?).

127	31-JUL-07 3:10:34PM	NM 94314 41323	194314	741323		Outflow from Sealife Centre into stream (2 x 12" ribbed plastic pipes). Foul smell. Stream size 160x3x0.3m/s. Water sample 32 (fresh). Shellfish sample 11 (wild mussel) from rocks on shoreline below.
128	21-NOV-07 9:47:23AM	NM 91555 43997	191555	743997		3 caravans & boatshed. 5 unoccupied moorings.
129	21-NOV-07 9:50:49AM	NM 91483 43958	191483	743958		Sewage related debris (purple cotton bud)
130	21-NOV-07 9:55:36AM	NM 91366 43777	191366	743777		3 houses on shoreline.
131	21-NOV-07 9:57:20AM	NM 91338 43724	191338	743724		Boatshed and small jetty.
132	21-NOV-07 9:58:36AM	NM 91346 43652	191346	743652		Caravan.
133	21-NOV-07 10:03:30AM	NM 91345 43506	191345	743506		Seawater sample Creran November 1.
134	21-NOV-07 10:07:08AM	NM 91440 43517	191440	743517		Large house, 2 sheep.
135	21-NOV-07 10:13:48AM	NM 91498 43722	191498	743722		Septic tank in garden?
136	21-NOV-07 10:22:46AM	NM 91559 43311	191559	743311		House
137	21-NOV-07 10:23:50AM	NM 91656 43246	191656	743246		Field of 22 sheep.
138	21-NOV-07 10:26:25AM	NM 91756 43155	191756	743155		2 houses, trailer home, yacht on mooring.
139	21-NOV-07 10:27:25AM	NM 91777 43132	191777	743132		Septic outflow from one house. Not flowing at time, but had been discharging grey water recently.
140	21-NOV-07 10:29:42AM	NM 91806 43095	191806	743095		Stream 295cmx7cmx0.235m/s. Water sample Creran November 2 (fresh).
141	21-NOV-07 10:35:19AM	NM 91838 42900	191838	742900		Sewage related plastic in tideline.
142	21-NOV-07 10:37:28AM	NM 91797 42809	191797	742809		One sheep on shore.
143	21-NOV-07 10:40:27AM	NM 91769 42650	191769	742650		Stream 225cmx5cmx0.419m/s. Water sample Creran November 3 (fresh).
144	21-NOV-07 10:49:36AM	NM 91734 42483	191734	742483		Seawater sample Creran November 4.
145	21-NOV-07 11:43:12AM	NM 95856 44461	195856	744461		Stream (An Iola). 970cm wide. Depth and flow measured at 4 points on transect. 10cm (0.245m/s), 14cm (0.266m/s), 17cm (0.189m/s), 11cm (0.222m/s). Water sample Creran November 5 (fresh).
146	21-NOV-07 12:12:05PM	NM 96497 42551	196497	742551		Stream. 640cm wide. Depth and flow measured at 4 points on transect. 11cm (0.286 m/s), 9cm (0.240m/s), 7cm (0.051m/s), 8cm (0.111m/s). Water sample Creran November 6 (fresh).

Table 2. Water Sample Results

Sample	Date	Sample ID	Type	NGR	E. coli (cfu/100 ml)	Salinity (g/L)
1	29/07/2007	Creran1	Sea	NM 97819 44374	40	31.6
2	29/07/2007	Creran2	Fresh	NM 97710 44536	70	0.0
3	29/07/2007	Creran3	Fresh	NM 96832 44736	4900	0.0
4	29/07/2007	Creran4	Sea	NM 96800 44718	220	28.5
5	29/07/2007	Creran5	Fresh	NM 95828 44437	2800	0.0
6	29/07/2007	Creran6	Sea	NM 95495 43813	10	31.6
7	29/07/2007	Creran7	Fresh	NM 95262 43728	60	0.0
8	29/07/2007	Creran8	Fresh	NM 94890 43310	50	0.0
9	29/07/2007	Creran9	Sea	NM 94841 43140	<10	32.0
10	29/07/2007	Creran10	Fresh	NM 94781 43278	600	0.0
11	29/07/2007	Creran11	Fresh	NM 94375 42987	800	0.0
12	29/07/2007	Creran12	Sea	NM 94306 42838	70	31.1
13	29/07/2007	Creran13	Sea	NM 91750 43161	90	31.6
14	30/07/2007	Creran14	Fresh	NN 00975 46070	170	0.0
15	30/07/2007	Creran15	Fresh	NM 95509 41986	6200	0.0
16	30/07/2007	Creran16	Sea	NM 92551 40701	620	27.8
17	30/07/2007	Creran17	Fresh	NM 92394 40699	410	0.0
18	30/07/2007	Creran18	Sea	NM 92208 40635	<10	30.9
19	30/07/2007	Creran19	Sea	NM 91762 40740	10	32.2
20	30/07/2007	Creran20	Fresh	NM 91728 40481	5900	0.0
21	30/07/2007	Creran21	Fresh	NM 90872 41826	460	0.9
22	30/07/2007	Creran22	Sea	NM 90938 42219	<10	32.9
23	30/07/2007	Creran23	Sea	NM 91002 43284	<10	33.6
24	30/07/2007	Creran24	Sea	NM 90886 42279	<10	33.4
25	30/07/2007	Creran25	Fresh	NM 90502 42030	90	3.7
26	31/07/2007	Creran26	Sea	NM 91007 42650	10	33.8
27	31/07/2007	Creran27	Sea	NM 91071 42362	10	32.9
28	31/07/2007	Creran28	Sea	NM 91233 42519	<10	33.6
29	31/07/2007	Creran29	Sea	NM 95664 43778	<10	31.6
30	31/07/2007	Creran30	Sea	NM 95405 43460	<10	31.8
31	31/07/2007	Creran31	Sea	NM 94738 42716	<10	31.8
32	31/07/2007	Creran32	Sea	NM 94314 41323	6600	32.2
33	21/11/2007	CreranNov1	Sea	NM 91345 43506	0	30.9
34	21/11/2007	CreranNov2	Fresh	NM 91806 43095	<100	-
35	21/11/2007	CreranNov3	Fresh	NM 91769 42650	<100	-
36	21/11/2007	CreranNov4	Sea	NM 91734 42483	2	31.4
37	21/11/2007	CreranNov5	Fresh	NM 95856 44461	100	-
38	21/11/2007	CreranNov6	Fresh	NM 96497 42551	100	-

Table 3. Shellfish Sample Results

Sample ID	Type	NGR	E. coli (mpn/ 100g)	Depth (m)	FRNA bacteriophage (pfu/100g)	Norovirus genogroup I	Norovirus geongroup II
Creran1	Shore mussels	NM 97803 44377	5400	0	-	-	-
Creran2	Shore mussels	NM 95495 43813	750	0	-	-	-
Creran3	Shore mussels	NM 94820 43208	500	0	-	-	-
Creran4	Shore mussels	NM 94306 42838	110	0	-	-	-
Creran5	Shore mussels	NM 91922 40522	20	0	-	-	-
Creran6	Shore mussels	NM 90886 42279	40	0	-	-	-
Creran7	Shore mussels	NM 90396 42347	20	0	-	-	-
Creran8	Bagged mussels	NM 91007 42650	160	<1	-	-	-
Creran9	Rope mussels	NM 95405 43460	500	<1	-	-	-
Creran10	Rope mussels	NM 95405 43460	20	8	-	-	-
Creran11	Shore mussels	NM 94314 41323	70	0	-	-	-
Creran12	Oysters	NM 91600 40600	70	0	30	Not detected	Not detected
Creran13	Oysters	NM 90900 42200	430	0	960	Not detected	Not detected
Creran14	Oysters	NM 94900 43000	310	0	<30	Not detected	Not detected

Figure 7. Freshwater sample results map

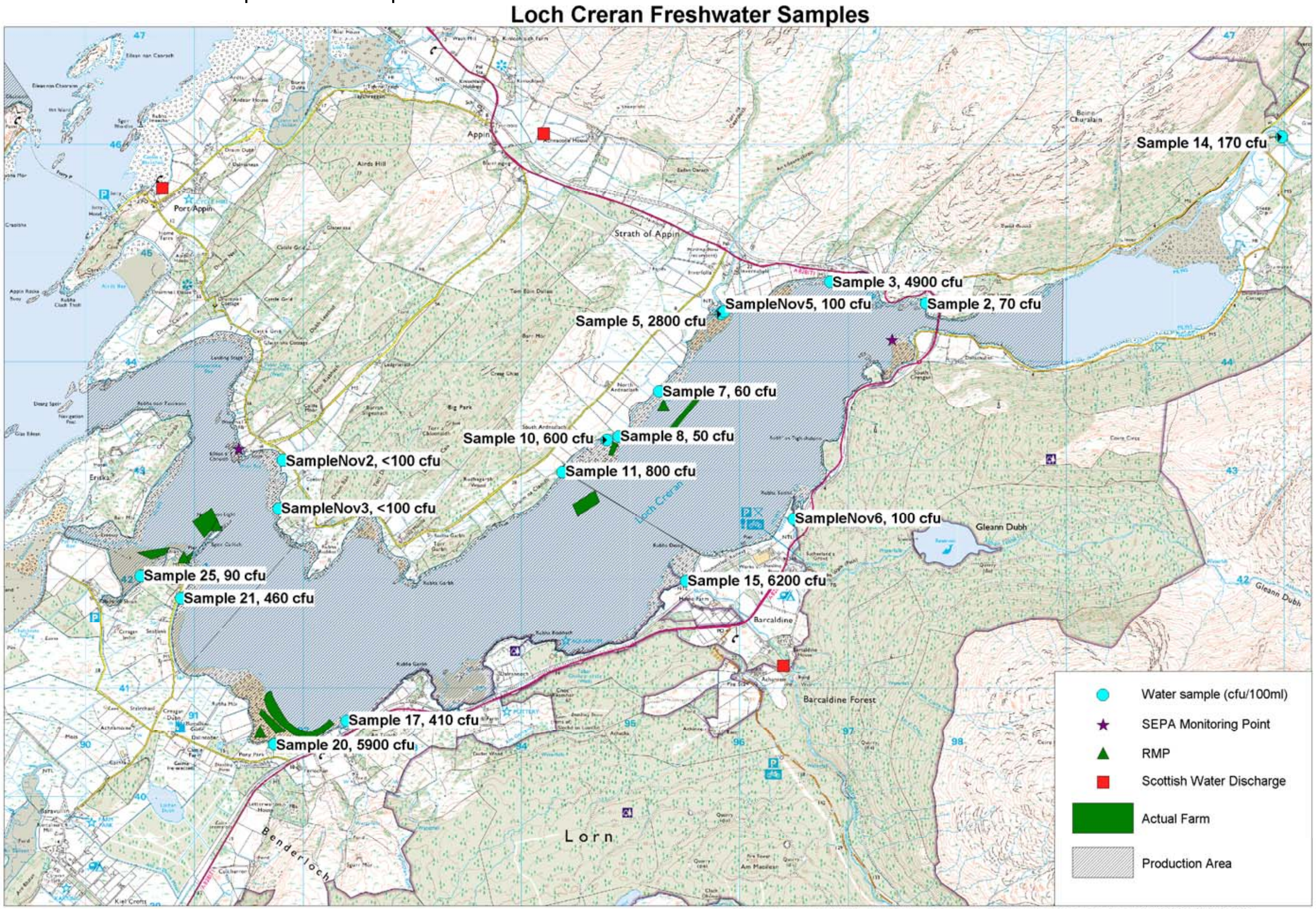


Figure 8. Seawater sample results map

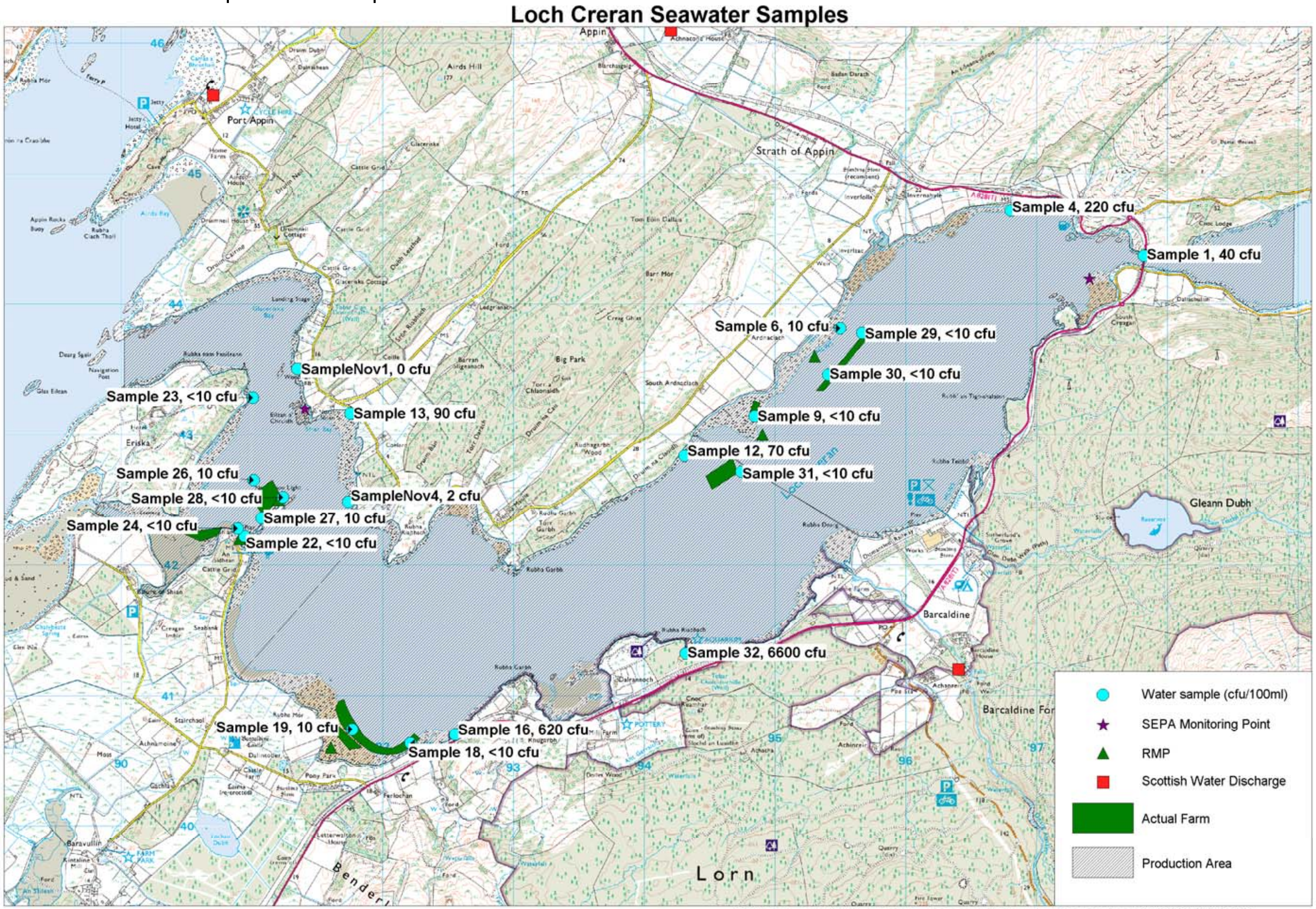


Figure 9. Shellfish sample results map

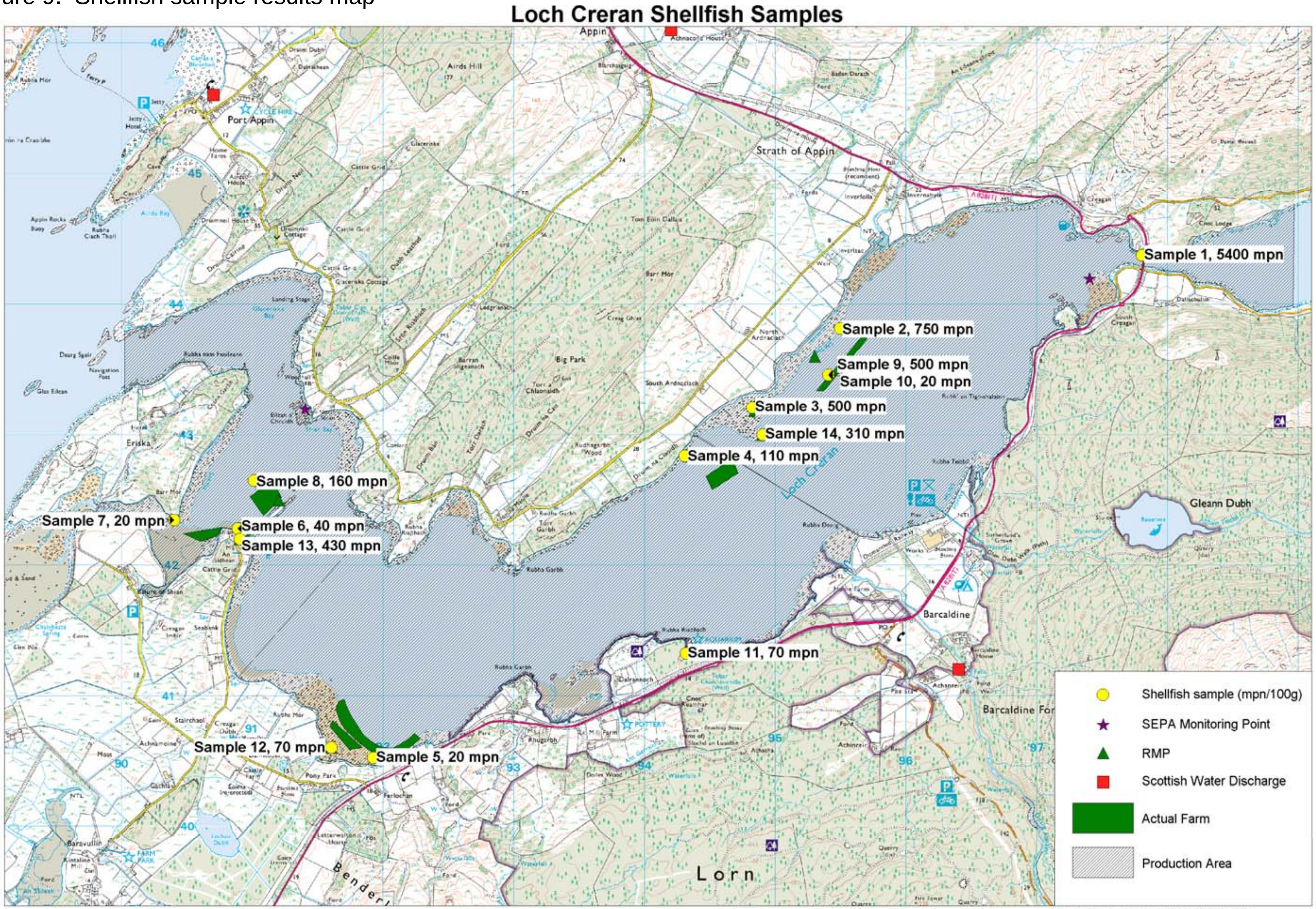


Figure 10. Wild mussels under the A828 road bridge

Figure 11. Sewer pipe from house under construction (not yet connected)

Figure 12. Holiday park

Figure 13. Possible septic discharge pipe

Figure 14. Mouth of the river 'An Iola'

Figure 15. Land drain adjacent to East: Barrington

Figure 16. Trestles at East: Barrington

Figure 17. Stable sweepings on shoreline

Figure 18. Barcaldine sawmill discharge

Figure 19. Yachts moored at Barcaldine

Figure 20. Livestock on shoreline

Figure 21. Trestles at Rubha Mor / Loch Creran Ferlochan

Figure 22. Trestles at Shian Fisheries

Figure 23. Presumed sewer pipe at Shian Fisheries

Figure 24. Mussel raft at Loch Creran West: Loch Creran

Figure 25. Floats at Loch Creran West: Loch Creran

Figure 26. Floats at Inner Creran

Figure 27. Floats at Inner Creran

Figure 28. Discharge at Port Appin

Figure 29. Discharge at Port Appin

Sampling Plan for Loch Creran

PRODUCTION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISHERY	NGR OF RMP	EAST	NORTH	TOLERANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Upper Loch Creran	Inner Creran	AB 313 709 08	Common mussel	Longline	NM 9566 4371	19566	74371	20	1	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan
Upper Loch Creran	Barrington	AB 129 021 13	Pacific oyster	Trestles	NM 9485 4322	19485	74322	10	NA	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan
Loch Creran Rubha Mor	Rubha Mor	AB 130 022 13	Pacific oyster	Trestles	NM 9222 4065	19222	74065	10	NA	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan
Loch Creran Shian	Shian Mussels	AB 312 020 08	Common mussel	Longline	NM 9107 4244	19107	74244	20	1	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan
Loch Creran Shian	Shian Oysters	AB 131 023 13	Pacific oyster	Trestles	NM 9094 4220	19094	74220	10	NA	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan
					NM 9057 4221	19057	74221	10	NA	Hand	Monthly for 6 month bacteriology survey only			

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

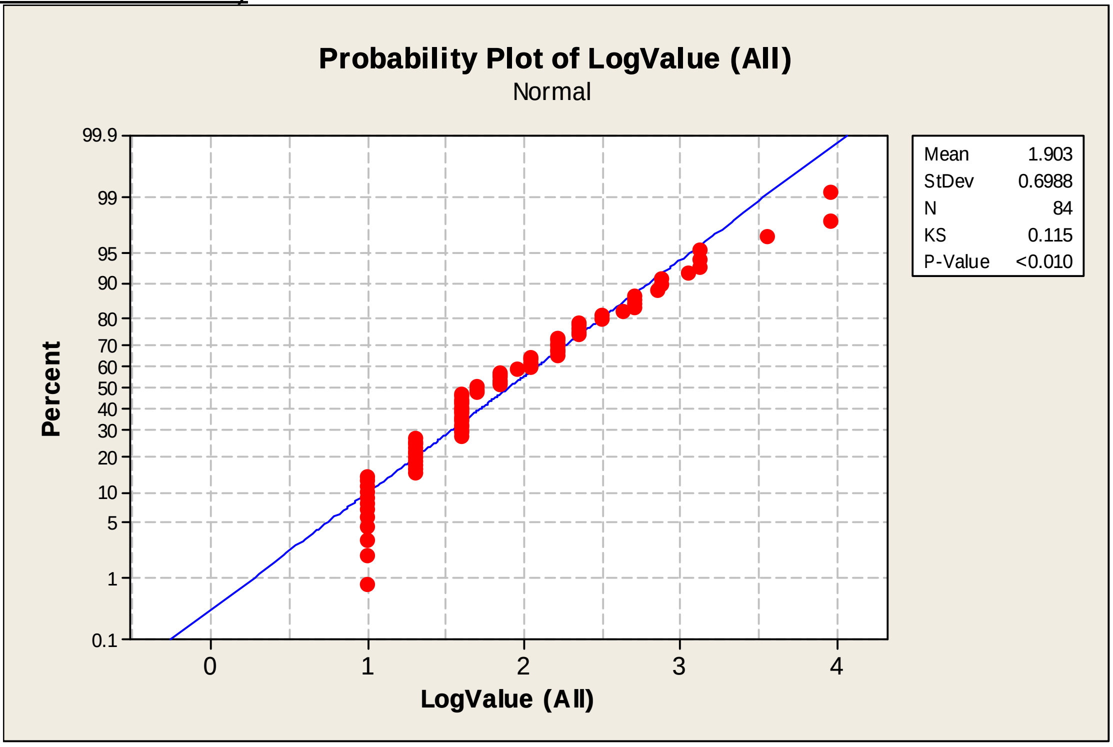
Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^8
Cow	230,000	23,600	5.4×10^9
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^8
Pig	3,300,000	2,700	8.9×10^8
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^8
Human	13,000,000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

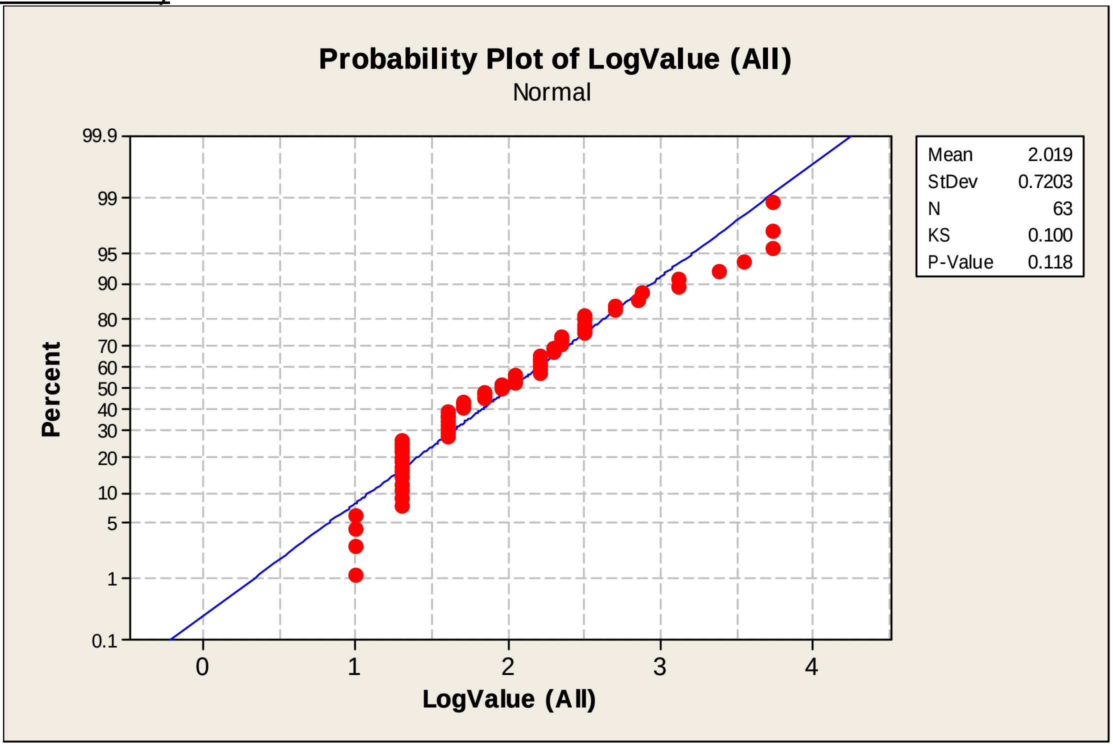
Statistical Data

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

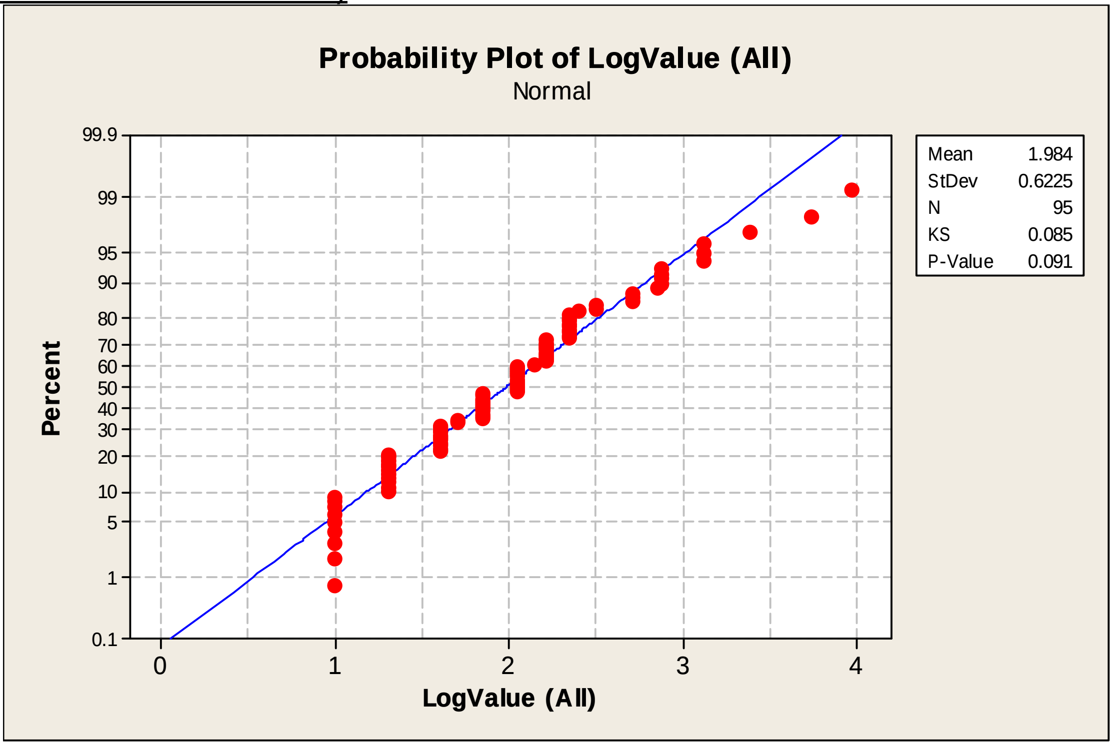
Distribution of results on log scale (with Kolmogorov-Smirnov normality test results) (Loch Creran West)



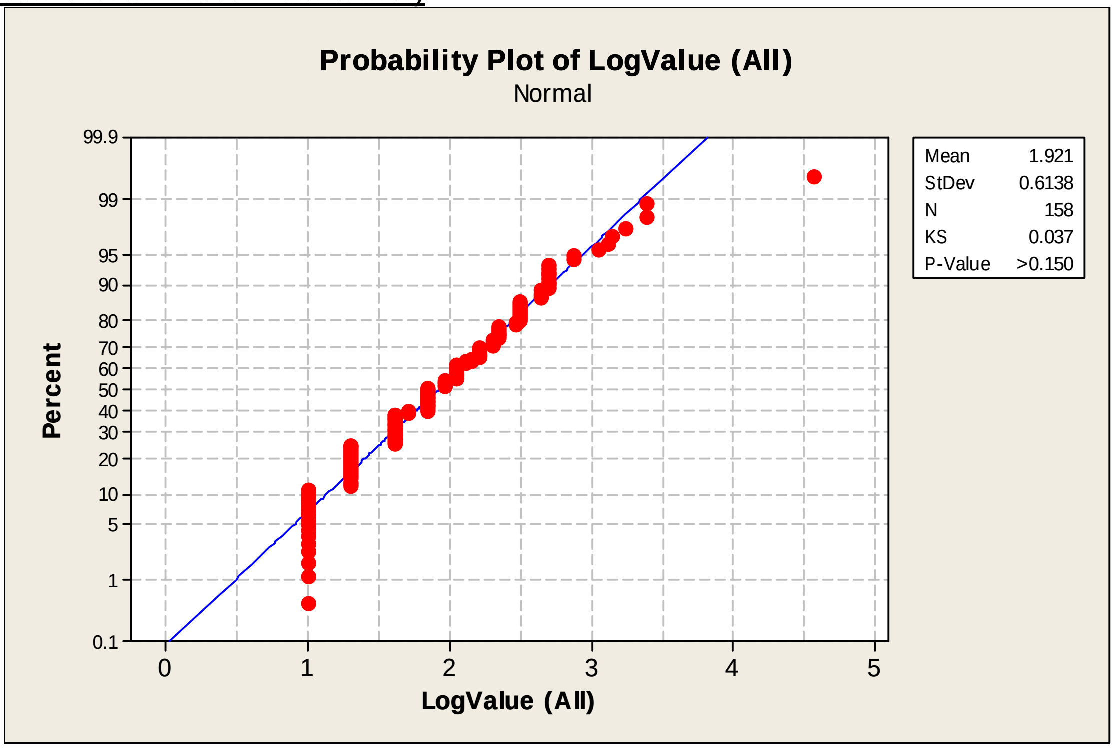
Distribution of results on log scale (with Kolmogorov-Smirnov normality test results) (Inner Creran)



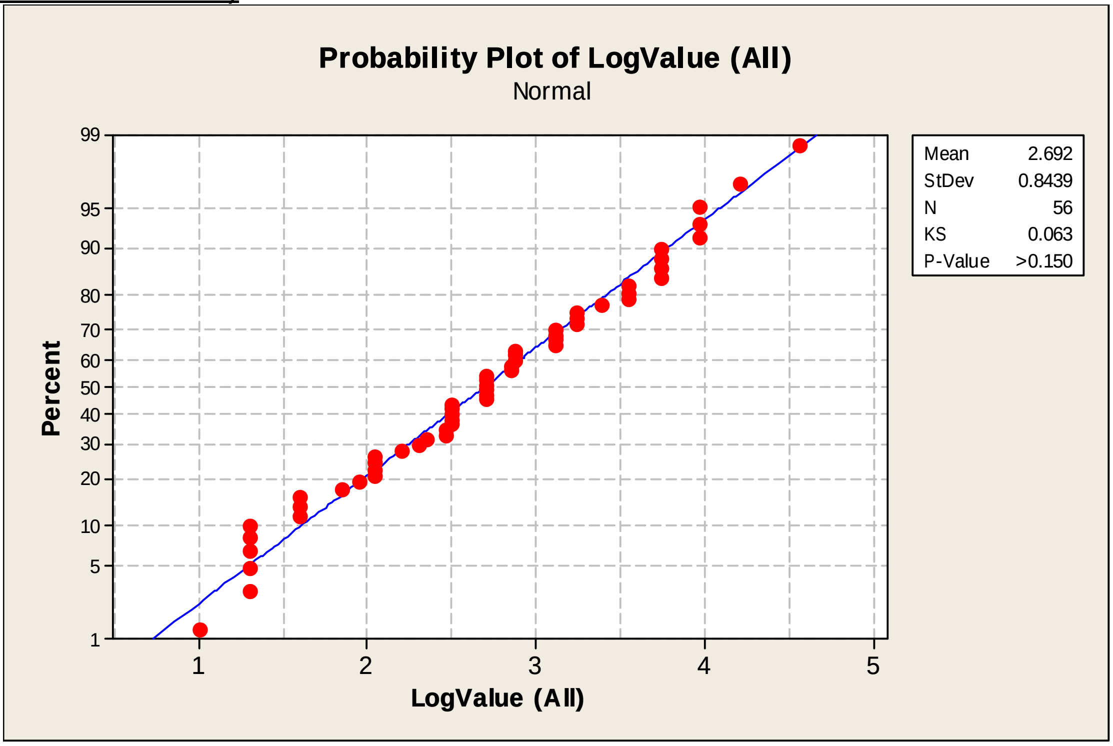
Distribution of results on log scale (with Kolmogorov-Smirnov normality test results) (Loch Creran West: Shian)



Distribution of results on log scale (with Kolmogorov-Smirnov normality test results) (Loch Creran West: Rubha Mor)



Distribution of results on log scale (with Kolmogorov-Smirnov normality test results) (Loch Creran East)



T-Test comparison of log result by reported sampling location (Loch Creran West)

```
Two-sample T for LogValue (All)

MapRef      N   Mean  StDev  SE Mean
NM909422   53  1.723  0.548    0.075
NM912425   31  2.212  0.822     0.15


Difference = mu (NM909422) - mu (NM912425)
Estimate for difference:  -0.489
95% CI for difference:  (-0.823, -0.155)
T-Test of difference = 0 (vs not =): T-Value = -2.95  P-Value = 0.005  DF = 45
```

T-Test comparison of log result by reported sampling location (Inner Loch Creran)

```
Two-sample T for NM945426 vs NM953436

            N   Mean  StDev  SE Mean
NM945426   32  1.753  0.537    0.095
NM953436   31  2.293  0.788     0.14


Difference = mu (Pre 2004) - mu (2004 On)
Estimate for difference:  -0.540
95% CI for difference:  (-0.882, -0.198)
T-Test of difference = 0 (vs not =): T-Value = -3.17  P-Value = 0.003  DF = 52
```

ANOVA comparison of log result by sampling location (Loch Creran West: Rubha Mor)

```
Source   DF      SS     MS     F      P
MapRef    4   2.773  0.693  1.88  0.116
Error   153  56.385  0.369
Total   157  59.158

S = 0.6071   R-Sq = 4.69%   R-Sq(adj) = 2.20%


                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level      N    Mean   StDev  ---------+---------+---------+---------+
NM916406  42  1.8089  0.7235                 (--*--)
NM916407  16  2.0926  0.4668                    (----*----)
NM918405  90  1.9837  0.5639                     (-*-)
NM918407   1  1.8451       *  (-------------------*-------------------)
NM918415   9  1.5245  0.6470          (-----*------)
                              ---------+---------+---------+---------+
                                     1.20      1.80      2.40      3.00

Pooled StDev = 0.6071
```

T-Test comparison of log result (Loch Creran West and Inner Loch Creran all results)

```
Two-sample T for mussel log result

mussel site         N   Mean  StDev  SE Mean
Inner Loch Creran  63  2.019  0.720    0.091
Loch Creran West   84  1.903  0.699    0.076


Difference = mu (Inner Loch Creran) - mu (Loch Creran West)
Estimate for difference:  0.115
95% CI for difference:  (-0.119, 0.350)
T-Test of difference = 0 (vs not =): T-Value = 0.97  P-Value = 0.332  DF = 131
```

T-Test comparison of log result (Loch Creran West and Inner Loch Creran pre 2004 results only)

```
Two-sample T for NM945426 vs NM909422

           N   Mean  StDev  SE Mean
NM945426  32  1.753  0.537    0.095
NM909422  53  1.723  0.548    0.075


Difference = mu (NM945426) - mu (NM909422)
Estimate for difference:  0.030
95% CI for difference:  (-0.212, 0.272)
T-Test of difference = 0 (vs not =): T-Value = 0.25  P-Value = 0.803  DF = 66
```

T-Test comparison of log result (Loch Creran West and Inner Loch Creran January 2004 and later results only)

```
Two-sample T for NM953436 vs NM912425

           N   Mean  StDev  SE Mean
NM953436  31  2.293  0.788     0.14
NM912425  31  2.212  0.822     0.15


Difference = mu (NM953436) - mu (NM912425)
Estimate for difference:  0.081
```

```
95% CI for difference:  (-0.328, 0.490)
T-Test of difference = 0 (vs not =): T-Value = 0.40  P-Value = 0.693  DF = 59
```

ANOVA comparison of log result by production area (oyster production areas) with Tukeys comparison

```
Source        DF       SS      MS      F      P
oyster site    2   25.814  12.907  29.31  0.000
Error        306  134.751   0.440
Total        308  160.565

S = 0.6636   R-Sq = 16.08%   R-Sq(adj) = 15.53%



Level                        N    Mean   StDev
Loch Creran East            56  2.6918  0.8439
Loch Creran West: Rubha    158  1.9212  0.6138
Loch Creran West: Shian     95  1.9844  0.6225

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level                     ---------+---------+---------+---------+
Loch Creran East                                 (-----*-----)
Loch Creran West: Rubha   (--*---)
Loch Creran West: Shian    (---*----)
                          ---------+---------+---------+---------+
                                2.10      2.40      2.70      3.00

Pooled StDev = 0.6636


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

Individual confidence level = 98.01%


oyster site = Loch Creran East subtracted from:

oyster site                 Lower   Center    Upper
Loch Creran West: Rubha   -1.0122  -0.7706  -0.5291
Loch Creran West: Shian   -0.9691  -0.7074  -0.4458

oyster site               ---------+---------+---------+---------+
Loch Creran West: Rubha   (------*------)
Loch Creran West: Shian    (-------*------)
                          ---------+---------+---------+---------+
                               -0.70     -0.35      0.00      0.35


oyster site = Loch Creran West: Rubha Mor subtracted from:

oyster site                Lower  Center   Upper
Loch Creran West: Shian  -0.1385  0.0632  0.2648

oyster site              ---------+---------+---------+---------+
Loch Creran West: Shian                          (-----*-----)
                         ---------+---------+---------+---------+
                              -0.70     -0.35      0.00      0.35
```

ANOVA Comparison of log result by season (Loch Creran West) with Tukeys comparison

```
Source                 DF      SS     MS     F      P
Season (all results)    3   6.440  2.147  5.04  0.003
Error                  80  34.094  0.426
Total                  83  40.534

S = 0.6528   R-Sq = 15.89%   R-Sq(adj) = 12.73%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --+---------+---------+---------+-------
1      22  1.6259  0.5802   (------*-------)
2      22  2.3076  0.8265                     (-------*-------)
3      23  1.9661  0.6334           (-------*-------)
4      17  1.6536  0.4910  (--------*--------)
                           --+---------+---------+---------+-------
                           1.40      1.75      2.10      2.45

Pooled StDev = 0.6528


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season (all results)

Individual confidence level = 98.96%

Season (all results) = 1 subtracted from:

Season
(all
results)    Lower  Center   Upper  -------+---------+---------+---------+--
2          0.1654  0.6817  1.1981                    (-------*------)
3         -0.1705  0.3403  0.8510                (------*------)
4         -0.5253  0.0277  0.5808          (-------*-------)
                                   -------+---------+---------+---------+--
                                       -0.70      0.00      0.70      1.40


Season (all results) = 2 subtracted from:

Season
(all
results)    Lower   Center    Upper  -------+---------+---------+---------+--
3         -0.8522  -0.3415   0.1692       (------*------)
4         -1.2070  -0.6540  -0.1010  (-------*-------)
                                     -------+---------+---------+---------+--
                                         -0.70      0.00      0.70      1.40


Season (all results) = 3 subtracted from:

Season
(all
results)    Lower   Center   Upper  -------+---------+---------+---------+--
4         -0.8603  -0.3125  0.2352       (-------*------)
                                    -------+---------+---------+---------+--
                                        -0.70      0.00      0.70      1.40
```

ANOVA Comparison of log result by season (Inner Loch Creran) with Tukeys comparison

```
Source                 DF      SS     MS     F      P
Season (all results)    3   4.266  1.422  3.01  0.037
Error                  59  27.905  0.473
Total                  62  32.171
```

```
S = 0.6877   R-Sq = 13.26%   R-Sq(adj) = 8.85%


                           Individual 95% CIs For Mean Based on Pooled StDev
Level   N    Mean   StDev    +---------+---------+---------+---------
1      17  1.7172  0.6828    (--------*---------)
2      17  2.4109  0.7866                       (---------*--------)
3      19  1.9857  0.6626            (--------*--------)
4      10  1.9266  0.5417       (-----------*-----------)
                             +---------+---------+---------+---------
                           1.40      1.75      2.10      2.45

Pooled StDev = 0.6877


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season (all results)

Individual confidence level = 98.95%


Season (all results) = 1 subtracted from:

Season
(all
results)    Lower  Center   Upper  -------+---------+---------+---------+--
2          0.0699  0.6937  1.3176                   (--------*--------)
3         -0.3386  0.2685  0.8757             (--------*--------)
4         -0.5154  0.2094  0.9342           (---------*---------)
                                   -------+---------+---------+---------+--
                                       -0.70      0.00      0.70      1.40


Season (all results) = 2 subtracted from:

Season
(all
results)    Lower   Center   Upper  -------+---------+---------+---------+--
3         -1.0324  -0.4252  0.1820    (--------*--------)
4         -1.2091  -0.4843  0.2405  (---------*---------)
                                    -------+---------+---------+---------+--
                                        -0.70      0.00      0.70      1.40


Season (all results) = 3 subtracted from:

Season
(all
results)    Lower   Center   Upper  -------+---------+---------+---------+--
4         -0.7697  -0.0591  0.6514        (---------*---------)
                                    -------+---------+---------+---------+--
                                        -0.70      0.00      0.70      1.40
```

ANOVA Comparison of results by season (Loch Creran West: Shian) with Tukeys comparison

```
Source                DF      SS     MS     F      P
Season (all results)   3   6.937  2.312  7.13  0.000
Error                 91  29.492  0.324
Total                 94  36.428

S = 0.5693   R-Sq = 19.04%   R-Sq(adj) = 16.37%


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

```
1      26  1.6735  0.7174  (-------*------)
2      25  2.1499  0.5813                  (-------*------)
3      27  2.2942  0.5044                       (------*-------)
4      17  1.7245  0.3447  (--------*---------)
                           --+---------+---------+---------+-------
                           1.50      1.80      2.10      2.40

Pooled StDev = 0.5693


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season (all results)

Individual confidence level = 98.96%


Season (all results) = 1 subtracted from:

Season
(all
results)    Lower  Center   Upper  -------+---------+---------+---------+--
2          0.0591  0.4763  0.8935                 (------*------)
3          0.2114  0.6206  1.0299                    (-----*------)
4         -0.4136  0.0509  0.5155          (-------*-------)
                                   -------+---------+---------+---------+--
                                       -0.60      0.00      0.60      1.20


Season (all results) = 2 subtracted from:

Season
(all
results)    Lower   Center   Upper  -------+---------+---------+---------+--
3         -0.2691   0.1443  0.5577              (-----*------)
4         -0.8936  -0.4254  0.0428    (-------*-------)
                                    -------+---------+---------+---------+--
                                        -0.60      0.00      0.60      1.20


Season (all results) = 3 subtracted from:

Season
(all
results)    Lower   Center    Upper  -------+---------+---------+---------+--
4         -1.0309  -0.5697  -0.1086  (-------*------)
                                     -------+---------+---------+---------+--
                                         -0.60      0.00      0.60      1.20
```

ANOVA Comparison of results by season (Loch Creran West: Rubha Mor) with Tukeys comparison

```
Source                 DF      SS     MS     F      P
Season (all results)    3   8.313  2.771  8.39  0.000
Error                 154  50.845  0.330
Total                 157  59.158

S = 0.5746   R-Sq = 14.05%   R-Sq(adj) = 12.38%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --+---------+---------+---------+-------
1      44  1.6140  0.5176  (------*-----)
2      38  2.2458  0.7839                         (-------*------)
3      42  1.9752  0.5237              (------*------)
4      34  1.8893  0.4024          (-------*------)
```

```
                           --+---------+---------+---------+-------
                           1.50      1.75      2.00      2.25

Pooled StDev = 0.5746


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season (all results)

Individual confidence level = 98.96%


Season (all results) = 1 subtracted from:

Season
(all
results)    Lower  Center   Upper  ----+---------+---------+---------+-----
2          0.3016  0.6318  0.9620                    (------*-----)
3          0.0396  0.3612  0.6829               (-----*------)
4         -0.0652  0.2753  0.6158             (------*-----)
                                   ----+---------+---------+---------+-----
                                    -0.50      0.00      0.50      1.00


Season (all results) = 2 subtracted from:

Season
(all
results)    Lower   Center    Upper  ----+---------+---------+---------+-----
3         -0.6044  -0.2706   0.0633    (------*-----)
4         -0.7085  -0.3565  -0.0045  (------*------)
                                     ----+---------+---------+---------+-----
                                      -0.50      0.00      0.50      1.00


Season (all results) = 3 subtracted from:

Season
(all
results)    Lower   Center   Upper  ----+---------+---------+---------+-----
4         -0.4299  -0.0859  0.2581       (------*------)
                                    ----+---------+---------+---------+-----
                                     -0.50      0.00      0.50      1.00
```

ANOVA Comparison of log result by season (Loch Creran East)

```
Source                DF      SS     MS     F      P
Season (all results)   3   5.196  1.732  2.65  0.058
Error                 52  33.969  0.653
Total                 55  39.165

S = 0.8082   R-Sq = 13.27%   R-Sq(adj) = 8.26%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -----+---------+---------+---------+----
1      15  2.3461  0.9638      (-------*-------)
2      15  3.0001  0.7312                   (-------*-------)
3      18  2.8967  0.8026                 (-------*-------)
4       8  2.3010  0.6009  (----------*----------)
                           -----+---------+---------+---------+----
                              2.00      2.50      3.00      3.50

Pooled StDev = 0.8082
```

Regression analysis (log Result versus rain in previous 2 days).

(Loch Creran West)

```
The regression equation is
Result (prev 2 days rain = 1.66 + 0.0315 Rain in prev 2 days


Predictor                Coef   SE Coef      T      P
Constant               1.6603    0.1611  10.30  0.000
Rain in prev 2 days  0.031491  0.009579   3.29  0.002


S = 0.717668   R-Sq = 23.1%   R-Sq(adj) = 21.0%


Analysis of Variance

Source          DF       SS      MS      F      P
Regression       1   5.5663  5.5663  10.81  0.002
Residual Error  36  18.5417  0.5150
Total           37  24.1080


Unusual Observations

     Rain in     Result
      prev 2    (prev 2
Obs     days  days rain    Fit  SE Fit  Residual  St Resid
 14      6.1      3.959  1.852   0.128     2.107     2.98R
 17     39.4      3.114  2.901   0.290     0.213     0.32 X
 26     22.2      3.959  2.359   0.154     1.600     2.28R
 38     55.2      3.114  3.399   0.433    -0.285    -0.50 X

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

ANOVA comparison of log Result versus rainfall quartile (previous 2 days) (Loch Creran West) with Tukeys comparison

```
Source              DF      SS     MS     F      P
Q prev 2 days rain   3   7.063  2.354  4.70  0.008
Error               34  17.045  0.501
Total               37  24.108

S = 0.7080   R-Sq = 29.30%   R-Sq(adj) = 23.06%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --------+---------+---------+---------+-
Q1      6  1.2914  0.3088  (---------*--------)
Q2      8  1.7410  0.6204           (-------*-------)
Q3     11  2.0525  0.7955                 (------*------)
Q4     13  2.5196  0.7930                         (------*------)
                           --------+---------+---------+---------+-
                                1.20      1.80      2.40      3.00

Pooled StDev = 0.7080


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Q prev 2 days rain

Individual confidence level = 98.93%


Q prev 2 days rain = Q1 subtracted from:
```

```
Q prev
2 days
rain      Lower  Center   Upper  ------+---------+---------+---------+---
Q2      -0.5832  0.4497  1.4825          (---------*----------)
Q3      -0.2095  0.7612  1.7318              (---------*--------)
Q4       0.2843  1.2282  2.1722                   (--------*---------)
                                 ------+---------+---------+---------+---
                                    -1.0       0.0       1.0       2.0


Q prev 2 days rain = Q2 subtracted from:

Q prev
2 days
rain      Lower  Center   Upper  ------+---------+---------+---------+---
Q3      -0.5772  0.3115  1.2002          (--------*--------)
Q4      -0.0809  0.7786  1.6380               (--------*-------)
                                 ------+---------+---------+---------+---
                                    -1.0       0.0       1.0       2.0


Q prev 2 days rain = Q3 subtracted from:

Q prev
2 days
rain      Lower  Center   Upper  ------+---------+---------+---------+---
Q4      -0.3165  0.4670  1.2506             (-------*-------)
                                 ------+---------+---------+---------+---
                                    -1.0       0.0       1.0       2.0
```

Regression analysis (log Result versus rain in previous 2 days). (Inner Loch Creran)

```
The regression equation is
Result (prev 2 days rain = 1.76 + 0.0303 Rain in prev 2 days


Predictor                 Coef   SE Coef      T      P
Constant                1.7622    0.1616  10.90  0.000
Rain in prev 2 days   0.030323  0.009662   3.14  0.003


S = 0.727924   R-Sq = 21.0%   R-Sq(adj) = 18.9%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   5.2192  5.2192  9.85  0.003
Residual Error  37  19.6053  0.5299
Total           38  24.8245


Unusual Observations

     Rain in     Result
      prev 2    (prev 2
Obs     days  days rain    Fit  SE Fit  Residual  St Resid
 18     39.4      3.732  2.957   0.293     0.775      1.16 X
 39     55.2      2.491  3.436   0.437    -0.945     -1.62 X

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

ANOVA comparison of log Result versus rainfall quartile (previous 2 days) (Inner Loch Creran) with Tukeys comparison

```
Source              DF      SS     MS     F      P
Q prev 2 days rain   3   6.310  2.103  3.98  0.015
Error               35  18.515  0.529
Total               38  24.824

S = 0.7273   R-Sq = 25.42%   R-Sq(adj) = 19.02%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ----+---------+---------+---------+-----
Q1      6  1.5726  0.5680  (---------*---------)
Q2     10  1.8595  0.5463         (-------*-------)
Q3     10  1.9930  0.6979           (-------*-------)
Q4     13  2.6516  0.9052                       (------*------)
                           ----+---------+---------+---------+-----
                             1.20      1.80      2.40      3.00

Pooled StDev = 0.7273


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Q prev 2 days rain

Individual confidence level = 98.92%


Q prev 2 days rain = Q1 subtracted from:

Q prev
2 days
rain      Lower  Center   Upper  ------+---------+---------+---------+---
Q2      -0.7250  0.2869  1.2987          (---------*---------)
Q3      -0.5915  0.4204  1.4322           (---------*---------)
Q4       0.1119  1.0790  2.0460                  (---------*--------)
                                 ------+---------+---------+---------+---
                                    -1.0       0.0       1.0       2.0


Q prev 2 days rain = Q2 subtracted from:

Q prev
2 days
rain      Lower  Center   Upper  ------+---------+---------+---------+---
Q3      -0.7428  0.1335  1.0098          (-------*--------)
Q4      -0.0321  0.7921  1.6163                 (-------*-------)
                                 ------+---------+---------+---------+---
                                    -1.0       0.0       1.0       2.0


Q prev 2 days rain = Q3 subtracted from:

Q prev
2 days
rain      Lower  Center   Upper  ------+---------+---------+---------+---
Q4      -0.1656  0.6586  1.4828               (--------*-------)
                                 ------+---------+---------+---------+---
                                    -1.0       0.0       1.0       2.0
```

Regression analysis (log Result versus rain in previous 2 days). (Loch Creran West: Shian)

```
The regression equation is
Rain in prev 2 days = - 7.96 + 11.0 Result (prev 2 days rain
```

```
Predictor                     Coef  SE Coef      T      P
Constant                    -7.962    5.475  -1.45  0.153
Result (prev 2 days rain  10.955    2.841   3.86  0.000


S = 10.3431   R-Sq = 26.1%   R-Sq(adj) = 24.4%


Analysis of Variance

Source          DF      SS      MS      F      P
Regression       1  1590.7  1590.7  14.87  0.000
Residual Error  42  4493.1   107.0
Total           43  6083.8


Unusual Observations

     Result
      (prev  Rain in
     2 days   prev 2
Obs    rain     days    Fit  SE Fit  Residual  St Resid
 39    1.00    26.00   2.99    2.87     23.01      2.32R
 44    2.88    55.20  23.53    3.31     31.67      3.23R

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

ANOVA comparison of log Result versus rainfall quartile (previous 2 days) (Loch Creran West: Shian) with Tukeys comparison

```
Source              DF      SS     MS     F      P
Q prev 2 days rain   3   4.100  1.367  5.97  0.002
Error               40   9.154  0.229
Total               43  13.254

S = 0.4784   R-Sq = 30.93%   R-Sq(adj) = 25.75%


                           Individual 95% CIs For Mean Based on Pooled StDev
Level   N    Mean   StDev    +---------+---------+---------+---------
Q1      7  1.5622  0.3750        (----------*---------)
Q2      9  1.3652  0.4079    (--------*--------)
Q3     11  2.0617  0.5028                         (-------*-------)
Q4     17  2.0817  0.5275                           (-----*------)
                             +---------+---------+---------+---------
                           1.05      1.40      1.75      2.10

Pooled StDev = 0.4784


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Q prev 2 days rain

Individual confidence level = 98.94%


Q prev 2 days rain = Q1 subtracted from:

Q prev
2 days
rain      Lower   Center   Upper  --------+---------+---------+---------+-
Q2      -0.8431  -0.1970  0.4491        (--------*--------)
Q3      -0.1204   0.4994  1.1193                  (--------*--------)
Q4      -0.0563   0.5194  1.0952                   (-------*--------)
                                  --------+---------+---------+---------+-
```

```
                                           -0.70      0.00      0.70      1.40


Q prev 2 days rain = Q2 subtracted from:

Q prev
2 days
rain     Lower  Center   Upper  --------+---------+---------+---------+-
Q3      0.1202  0.6965  1.2727                      (-------*-------)
Q4      0.1880  0.7165  1.2450                       (------*-------)
                                --------+---------+---------+---------+-
                                     -0.70      0.00      0.70      1.40


Q prev 2 days rain = Q3 subtracted from:

Q prev
2 days
rain      Lower  Center   Upper  --------+---------+---------+---------+-
Q4      -0.4761  0.0200  0.5161             (------*------)
                                 --------+---------+---------+---------+-
                                      -0.70      0.00      0.70      1.40
```

Regression analysis (log Result versus rain in previous 2 days) (Loch Creran West: Rubha Mor)

```
The regression equation is
Result (prev 2 days rain = 1.96 - 0.00891 Rain in prev 2 days


Predictor                 Coef   SE Coef      T      P
Constant                1.9615    0.1250  15.69  0.000
Rain in prev 2 days  -0.008912  0.007183  -1.24  0.220


S = 0.688809   R-Sq = 2.6%   R-Sq(adj) = 0.9%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.7303  0.7303  1.54  0.220
Residual Error  58  27.5186  0.4745
Total           59  28.2488


Unusual Observations

     Rain in     Result
      prev 2    (prev 2
Obs     days  days rain     Fit  SE Fit  Residual  St Resid
  7      8.6     4.5563  1.8849  0.0927    2.6714      3.91R
 28      1.3     3.3802  1.9499  0.1186    1.4303      2.11R
 29      7.4     3.3802  1.8956  0.0955    1.4846      2.18R
 59     55.2     1.9542  1.4696  0.3212    0.4846      0.80 X
 60     55.2     1.0000  1.4696  0.3212   -0.4696     -0.77 X

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

ANOVA comparison of log Result versus rainfall quartile (previous 2 days) (Loch Creran West: Rubha Mor)

```
Source              DF      SS     MS     F      P
Q prev 2 days rain   3   1.242  0.414  0.86  0.468
```

```
Error               56  27.007  0.482
Total               59  28.249

S = 0.6945   R-Sq = 4.39%   R-Sq(adj) = 0.00%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ----+---------+---------+---------+-----
Q1     11  1.8835  0.5671     (-------------*-------------)
Q2     11  1.8054  0.7164  (-------------*-------------)
Q3     16  2.0660  0.9139          (-----------*----------)
Q4     22  1.7052  0.5403   (---------*---------)
                           ----+---------+---------+---------+-----
                             1.50      1.80      2.10      2.40

Pooled StDev = 0.6945
```

Regression analysis (log Result versus rain in previous 2 days) (Loch Creran East)

```
The regression equation is
Result (prev 2 days rain = 2.18 + 0.0373 Rain in prev 2 days


Predictor                Coef   SE Coef      T      P
Constant               2.1802    0.1482  14.71  0.000
Rain in prev 2 days  0.037252  0.008449   4.41  0.000


S = 0.699558   R-Sq = 32.2%   R-Sq(adj) = 30.5%


Analysis of Variance

Source          DF       SS      MS      F      P
Regression       1   9.5130  9.5130  19.44  0.000
Residual Error  41  20.0646  0.4894
Total           42  29.5776


Unusual Observations

     Rain in     Result
      prev 2    (prev 2
Obs     days  days rain    Fit  SE Fit  Residual  St Resid
  4      1.4      4.556  2.232   0.140     2.324      3.39R
 42     55.2      3.959  4.236   0.379    -0.277     -0.47 X

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

ANOVA comparison of log Result versus rainfall quartile (previous 2 days) (Loch Creran East) with Tukeys comparison

```
Source              DF      SS     MS     F      P
Q prev 2 days rain   3   6.776  2.259  3.86  0.016
Error               39  22.802  0.585
Total               42  29.578

S = 0.7646   R-Sq = 22.91%   R-Sq(adj) = 16.98%


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

```
Q1      7  1.9981  0.6688  (--------*---------)
Q2     11  2.4719  0.8528           (-------*-------)
Q3     11  2.5565  0.7874             (-------*------)
Q4     14  3.1404  0.7150                       (------*------)
                           ------+---------+---------+---------+---
                               1.80      2.40      3.00      3.60

Pooled StDev = 0.7646


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Q prev 2 days rain

Individual confidence level = 98.93%


Q prev 2 days rain = Q1 subtracted from:

Q prev
2 days
rain      Lower  Center   Upper  -----+---------+---------+---------+----
Q2      -0.5170  0.4738  1.4646           (---------*---------)
Q3      -0.4323  0.5584  1.5492            (---------*--------)
Q4       0.1937  1.1423  2.0909                  (--------*---------)
                                 -----+---------+---------+---------+----
                                   -1.0       0.0       1.0       2.0


Q prev 2 days rain = Q2 subtracted from:

Q prev
2 days
rain      Lower  Center   Upper  -----+---------+---------+---------+----
Q3      -0.7891  0.0846  0.9584        (--------*--------)
Q4      -0.1571  0.6685  1.4941              (--------*-------)
                                 -----+---------+---------+---------+----
                                   -1.0       0.0       1.0       2.0


Q prev 2 days rain = Q3 subtracted from:

Q prev
2 days
rain      Lower  Center   Upper  -----+---------+---------+---------+----
Q4      -0.2418  0.5839  1.4095              (-------*-------)
                                 -----+---------+---------+---------+----
                                   -1.0       0.0       1.0       2.0
```

Regression analysis (log Result versus rain in previous 7 days). (Loch Creran West)

```
The regression equation is
Result prev 7 days rain = 1.53 + 0.0123 Rain in prev 7 days


Predictor                Coef   SE Coef     T      P
Constant               1.5322    0.1915  8.00  0.000
Rain in prev 7 days  0.012306  0.003766  3.27  0.002


S = 0.725985   R-Sq = 23.4%   R-Sq(adj) = 21.2%


Analysis of Variance

Source          DF        SS       MS      F      P
Regression       1    5.6287   5.6287  10.68  0.002
```

```
Residual Error  35  18.4469  0.5271
Total           36  24.0756


Unusual Observations

     Rain in
      prev 7  Result prev
Obs     days  7 days rain    Fit  SE Fit  Residual  St Resid
 14       16        3.959  1.724   0.150     2.235     3.15R
 20      134        2.204  3.178   0.373    -0.973    -1.56 X
 25       44        3.544  2.074   0.120     1.470     2.05R
 26       54        3.959  2.198   0.131     1.761     2.47R

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

ANOVA comparison of log Result versus rainfall quartile (previous 7 days) (Loch Creran West) with Tukeys comparison

```
Source              DF      SS     MS     F      P
Q prev 7 days rain   3   6.864  2.288  4.39  0.011
Error               33  17.211  0.522
Total               36  24.076

S = 0.7222   R-Sq = 28.51%   R-Sq(adj) = 22.01%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -----+---------+---------+---------+----
Q1      9  1.3833  0.4685  (-------*-------)
Q2      7  1.8362  0.9860        (---------*--------)
Q3      9  2.1636  0.7510               (-------*-------)
Q4     12  2.5025  0.6816                      (------*------)
                           -----+---------+---------+---------+----
                              1.20      1.80      2.40      3.00

Pooled StDev = 0.7222


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Q prev 7 days rain

Individual confidence level = 98.94%


Q prev 7 days rain = Q1 subtracted from:

Q prev
7 days
rain      Lower  Center   Upper  ------+---------+---------+---------+---
Q2      -0.5328  0.4529  1.4386            (---------*--------)
Q3      -0.1417  0.7803  1.7023                (--------*--------)
Q4       0.2568  1.1192  1.9817                    (-------*--------)
                                 ------+---------+---------+---------+---
                                    -1.0       0.0       1.0       2.0


Q prev 7 days rain = Q2 subtracted from:

Q prev
7 days
rain      Lower  Center   Upper  ------+---------+---------+---------+---
Q3      -0.6583  0.3274  1.3130          (---------*---------)
Q4      -0.2639  0.6663  1.5965              (---------*--------)
                                 ------+---------+---------+---------+---
```

```
                                   -1.0       0.0       1.0       2.0


Q prev 7 days rain = Q3 subtracted from:

Q prev
7 days
rain      Lower  Center   Upper  ------+---------+---------+---------+---
Q4      -0.5235  0.3390  1.2014             (-------*--------)
                                 ------+---------+---------+---------+---
                                   -1.0       0.0       1.0       2.0
```

Regression analysis (log Result versus rain in previous 7 days). (Inner Loch Creran)

```
The regression equation is
Result prev 7 days rain = 1.69 + 0.0108 Rain in prev 7 days


Predictor                Coef   SE Coef     T      P
Constant               1.6875    0.1935  8.72  0.000
Rain in prev 7 days  0.010827  0.003908  2.77  0.009


S = 0.751677   R-Sq = 17.6%   R-Sq(adj) = 15.3%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   4.3374  4.3374  7.68  0.009
Residual Error  36  20.3407  0.5650
Total           37  24.6781


Unusual Observations

     Rain in
      prev 7  Result prev
Obs     days  7 days rain    Fit  SE Fit  Residual  St Resid
 13       27        3.732  1.978   0.130     1.755      2.37R
 17        9        3.380  1.783   0.168     1.597      2.18R
 21      134        3.114  3.135   0.392    -0.021     -0.03 X

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

ANOVA comparison of log Result versus rainfall quartile (previous 7 days). (Inner Loch Creran)

```
Source              DF      SS     MS     F      P
Q prev 7 days rain   3   3.221  1.074  1.70  0.185
Error               34  21.457  0.631
Total               37  24.678

S = 0.7944   R-Sq = 13.05%   R-Sq(adj) = 5.38%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ------+---------+---------+---------+---
Q1     10  1.7034  0.6944  (---------*---------)
Q2      7  2.1114  0.9393        (-----------*-----------)
Q3     10  2.0776  0.4867         (----------*---------)
Q4     11  2.4865  0.9845                  (---------*--------)
                           ------+---------+---------+---------+---
```

```
                               1.50      2.00      2.50      3.00

Pooled StDev = 0.7944
```

Regression analysis (log Result versus rain in previous 7 days). (Loch Creran West: Shian)

```
The regression equation is
Result prev 7 days rain = 1.54 + 0.00768 Rain in prev 7 days


Predictor                Coef   SE Coef      T      P
Constant               1.5368    0.1296  11.85  0.000
Rain in prev 7 days  0.007681  0.002587   2.97  0.005


S = 0.515070   R-Sq = 17.7%   R-Sq(adj) = 15.7%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   2.3385  2.3385  8.81  0.005
Residual Error  41  10.8772  0.2653
Total           42  13.2156


Unusual Observations

     Rain in
      prev 7  Result prev
Obs     days  7 days rain     Fit  SE Fit  Residual  St Resid
 24      134       2.0414  2.5638  0.2552   -0.5224     -1.17 X

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

ANOVA comparison of log Result versus rainfall quartile (previous 7 days). (Loch Creran West: Shian) with Tukeys comparison

```
Source              DF      SS     MS     F      P
Q prev 7 days rain   3   3.384  1.128  4.47  0.009
Error               39   9.832  0.252
Total               42  13.216

S = 0.5021   R-Sq = 25.60%   R-Sq(adj) = 19.88%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
Q1     10  1.4654  0.4597  (--------*--------)
Q2      8  2.0072  0.3061               (---------*----------)
Q3     12  1.6866  0.7120         (-------*--------)
Q4     13  2.1768  0.3761                       (-------*-------)
                           -------+---------+---------+---------+--
                                1.40      1.75      2.10      2.45

Pooled StDev = 0.5021


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Q prev 7 days rain

Individual confidence level = 98.93%
```

```
Q prev 7 days rain = Q1 subtracted from:

Q prev
7 days
rain      Lower  Center   Upper  -------+---------+---------+---------+--
Q2      -0.0965  0.5418  1.1801               (----------*----------)
Q3      -0.3550  0.2212  0.7973           (---------*--------)
Q4       0.1454  0.7114  1.2774                   (---------*--------)
                                 -------+---------+---------+---------+--
                                     -0.60      0.00      0.60      1.20


Q prev 7 days rain = Q2 subtracted from:

Q prev
7 days
rain      Lower   Center   Upper  -------+---------+---------+---------+--
Q3      -0.9348  -0.3206  0.2936   (----------*---------)
Q4      -0.4350   0.1696  0.7743            (---------*---------)
                                  -------+---------+---------+---------+--
                                      -0.60      0.00      0.60      1.20


Q prev 7 days rain = Q3 subtracted from:

Q prev
7 days
rain      Lower  Center   Upper  -------+---------+---------+---------+--
Q4      -0.0484  0.4902  1.0289                (--------*--------)
                                 -------+---------+---------+---------+--
                                     -0.60      0.00      0.60      1.20
```

Regression analysis (log Result versus rain in previous 7 days). (Loch Creran West: Rubha Mor)

```
The regression equation is
Result prev 7 days rain = 1.90 - 0.00135 Rain in prev 7 days


Predictor                 Coef   SE Coef      T      P
Constant                1.9037    0.1491  12.77  0.000
Rain in prev 7 days  -0.001350  0.003007  -0.45  0.655


S = 0.699970   R-Sq = 0.4%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.0988  0.0988  0.20  0.655
Residual Error  56  27.4377  0.4900
Total           57  27.5365


Unusual Observations

     Rain in
      prev 7  Result prev
Obs     days  7 days rain     Fit  SE Fit  Residual  St Resid
  7       23       4.5563  1.8728  0.1039    2.6835      3.88R
 28       59       3.3802  1.8247  0.1090    1.5555      2.25R
 29        9       3.3802  1.8918  0.1293    1.4884      2.16R
 33      134       2.0414  1.7232  0.2991    0.3182      0.50 X

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

ANOVA comparison of log Result versus rainfall quartile (previous 7 days) (Loch Creran West: Rubha Mor) with Tukeys comparison

```
Source              DF      SS     MS     F      P
Q prev 7 days rain   3   5.859  1.953  4.87  0.005
Error               54  21.677  0.401
Total               57  27.536

S = 0.6336   R-Sq = 21.28%   R-Sq(adj) = 16.90%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev   -+---------+---------+---------+--------
Q1     14  1.9490  0.6369                (------*------)
Q2     12  2.1608  0.9328                    (------*-------)
Q3     13  1.2773  0.3572   (------*------)
Q4     19  1.9756  0.5428                  (-----*----)
                            -+---------+---------+---------+--------
                           1.00      1.50      2.00      2.50

Pooled StDev = 0.6336


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Q prev 7 days rain

Individual confidence level = 98.95%


Q prev 7 days rain = Q1 subtracted from:

Q prev
7 days
rain      Lower   Center    Upper  ---------+---------+---------+---------+
Q2      -0.4492   0.2118   0.8727              (--------*-------)
Q3      -1.3188  -0.6717  -0.0246     (-------*-------)
Q4      -0.5651   0.0266   0.6184             (------*-------)
                                   ---------+---------+---------+---------+
                                        -0.80      0.00      0.80      1.60


Q prev 7 days rain = Q2 subtracted from:

Q prev
7 days
rain      Lower   Center    Upper  ---------+---------+---------+---------+
Q3      -1.5560  -0.8834  -0.2109  (-------*-------)
Q4      -0.8046  -0.1852   0.4343           (-------*------)
                                   ---------+---------+---------+---------+
                                        -0.80      0.00      0.80      1.60


Q prev 7 days rain = Q3 subtracted from:

Q prev
7 days
rain     Lower  Center   Upper  ---------+---------+---------+---------+
Q4      0.0936  0.6983  1.3030                      (-------*------)
                                ---------+---------+---------+---------+
                                     -0.80      0.00      0.80      1.60
```

Regression analysis (log Result versus rain in previous 7 days). (Loch Creran East)

```
The regression equation is
Result prev 7 days rain = 2.18 + 0.0113 Rain in prev 7 days


Predictor                Coef   SE Coef      T      P
Constant               2.1790    0.2075  10.50  0.000
Rain in prev 7 days  0.011323  0.004044   2.80  0.008


S = 0.785369   R-Sq = 16.7%   R-Sq(adj) = 14.6%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   4.8344  4.8344  7.84  0.008
Residual Error  39  24.0554  0.6168
Total           40  28.8898


Unusual Observations

     Rain in
      prev 7  Result prev
Obs     days  7 days rain    Fit  SE Fit  Residual  St Resid
  3       26        4.556  2.477   0.137     2.080      2.69R
 21      134        2.491  3.693   0.393    -1.201     -1.77 X

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

ANOVA comparison of log Result versus rainfall quartile (previous 7 days) (Loch Creran East) with Tukeys comparison

```
Source              DF      SS     MS     F      P
Q prev 7 days rain   3  10.487  3.496  7.03  0.001
Error               37  18.403  0.497
Total               40  28.890

S = 0.7052   R-Sq = 36.30%   R-Sq(adj) = 31.14%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --+---------+---------+---------+-------
Q1      9  1.7392  0.4987  (------*------)
Q2      7  3.1819  0.7873                    (------*-------)
Q3     12  2.7150  0.8563               (-----*-----)
Q4     13  2.9259  0.6211                  (-----*----)
                           --+---------+---------+---------+-------
                           1.40      2.10      2.80      3.50

Pooled StDev = 0.7052


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Q prev 7 days rain

Individual confidence level = 98.93%


Q prev 7 days rain = Q1 subtracted from:

Q prev
7 days
rain     Lower  Center   Upper  ----+---------+---------+---------+-----
```

```
Q2      0.4878  1.4427  2.3977                    (--------*---------)
Q3      0.1403  0.9759  1.8115                (--------*-------)
Q4      0.3650  1.1867  2.0085                   (-------*-------)
                                ----+---------+---------+---------+-----
                                 -1.0       0.0       1.0       2.0
```

```
Q prev 7 days rain = Q2 subtracted from:

Q prev
7 days
rain      Lower   Center   Upper  ----+---------+---------+---------+-----
Q3      -1.3681  -0.4668  0.4344  (--------*--------)
Q4      -1.1444  -0.2560  0.6324     (-------*--------)
                                  ----+---------+---------+---------+-----
                                   -1.0       0.0       1.0       2.0
```

```
Q prev 7 days rain = Q3 subtracted from:

Q prev
7 days
rain      Lower  Center   Upper  ----+---------+---------+---------+-----
Q4      -0.5478  0.2108  0.9695           (------*-------)
                                 ----+---------+---------+---------+-----
                                  -1.0       0.0       1.0       2.0
```

Regression analysis (log Result vs water temperature). (Inner Loch Creran)

```
The regression equation is
logres (water temp) = 0.606 + 0.152 water temp


Predictor       Coef  SE Coef     T      P
Constant      0.6057   0.4491  1.35  0.214
water temp   0.15165  0.03567  4.25  0.003


S = 0.463600   R-Sq = 69.3%   R-Sq(adj) = 65.5%


Analysis of Variance

Source          DF      SS      MS      F      P
Regression       1  3.8843  3.8843  18.07  0.003
Residual Error   8  1.7194  0.2149
Total            9  5.6037
```

Regression analysis (log Result vs water temperature) (Loch Creran West: Shian)

```
The regression equation is
temp logres = 0.720 + 0.109 temp


Predictor     Coef  SE Coef     T      P
Constant    0.7204   0.5897  1.22  0.244
temp       0.10880  0.04649  2.34  0.036


S = 0.666776   R-Sq = 29.6%   R-Sq(adj) = 24.2%


Analysis of Variance
```

```
Source          DF      SS      MS     F      P
Regression       1  2.4354  2.4354  5.48  0.036
Residual Error  13  5.7797  0.4446
Total           14  8.2151


Unusual Observations

             temp
Obs  temp  logres    Fit  SE Fit  Residual  St Resid
 15  10.0   3.114  1.808   0.199     1.306     2.05R

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

Regression analysis (log Result vs water temperature) (Loch Creran West: Rubha Mor)

```
The regression equation is
result for temp = 1.56 - 0.0042 temp


Predictor      Coef  SE Coef      T      P
Constant     1.5622   0.3885   4.02  0.000
temp       -0.00419  0.03043  -0.14  0.892


S = 0.523019   R-Sq = 0.1%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  0.0052  0.0052  0.02  0.892
Residual Error  25  6.8387  0.2735
Total           26  6.8439


Unusual Observations

             result
Obs  temp  for temp    Fit  SE Fit  Residual  St Resid
 27  20.0     1.000  1.478   0.254    -0.478     -1.05 X

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

Regression analysis (log Result vs water temperature) (Loch Creran East)

```
The regression equation is
logres temp = 0.756 + 0.146 temp


Predictor     Coef  SE Coef     T      P
Constant    0.7563   0.7265  1.04  0.312
temp       0.14585  0.05545  2.63  0.017


S = 0.822685   R-Sq = 27.8%   R-Sq(adj) = 23.8%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   4.6831  4.6831  6.92  0.017
Residual Error  18  12.1826  0.6768
Total           19  16.8657
```

Circular-linear correlation of wind direction and log result (Loch Creran West)

CIRCULAR-LINEAR CORRELATION
creran west mussels

Variables (& observations)	r	p
wind direction & logresult (37)	0.248	0.122

Circular-linear correlation of wind direction and log result (Inner Loch Creran)

CIRCULAR-LINEAR CORRELATION
Inner creran
Analysis begun: 07 January 2008 14:13:24

Variables (& observations)	r	p
Angles & Linear (37)	0.343	0.018

Circular-linear correlation of wind direction and log result (Loch Creran West: Shian)

CIRCULAR-LINEAR CORRELATION
creran west shian
Analysis begun: 07 January 2008 16:55:15

Variables (& observations)	r	p
Angles & Linear (42)	0.309	0.024

Circular-linear correlation of wind direction and log result (Loch Creran West: Rubha Mor)

CIRCULAR-LINEAR CORRELATION
creran west rubha mor
Analysis begun: 08 January 2008 15:36:29

Variables (& observations)	r	p
Angles & Linear (62)	0.141	0.312

Circular-linear correlation of wind direction and log result (Loch Creran East)

CIRCULAR-LINEAR CORRELATION
creran east
Analysis begun: 09 January 2008 10:09:35

Variables (& observations)	r	p
Angles & Linear (41)	0.403	0.002

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.

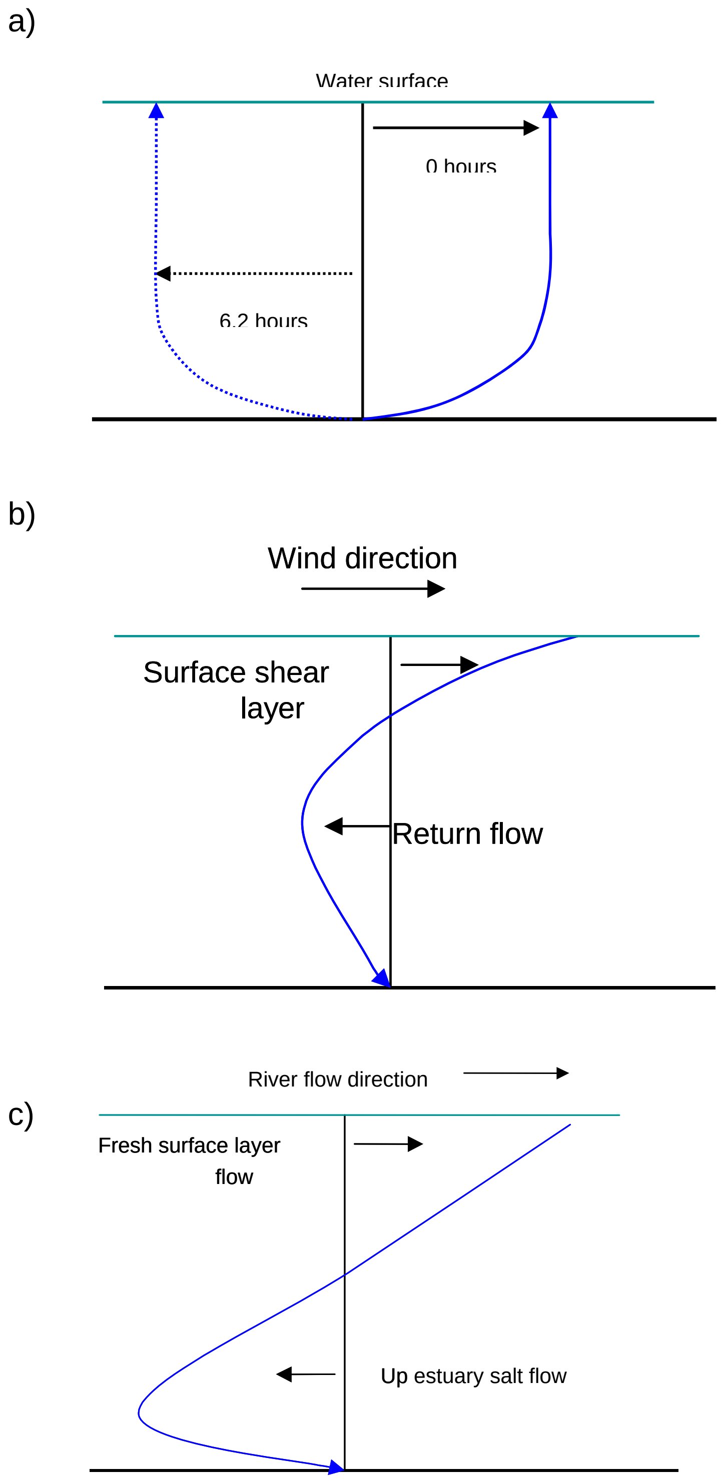


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

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

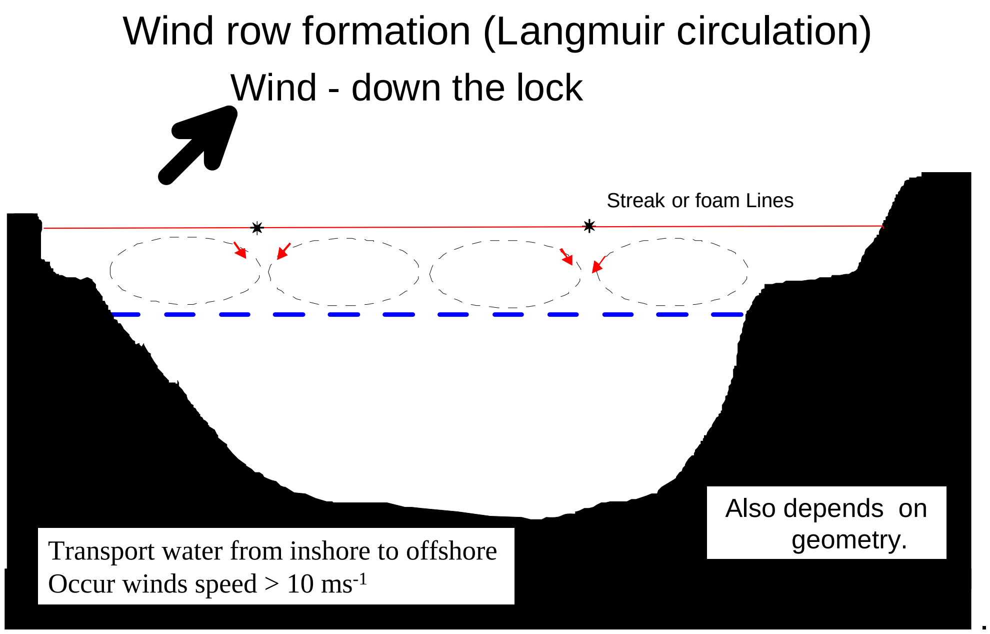


Figure 2: Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

2.0 Basic Assessment

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

3.0 More Detailed Assessment

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

3.1 Modelling approach

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

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

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

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

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

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

3.2 Non-modelling approach

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

1. Near-shore flows will generally align parallel to the shore.
2. Tidal flows are bi-directional, thus sources on either side of a production area are potentially polluting.
3. For tidal flows, the tidal excursion gives an idea of the likely main ‘region of influence’ around an identified pollutant source.

4. Wind driven flows can drive material from any direction depending on the wind direction. Wind driven current speeds are usually at a maximum when the wind direction is aligned with the principle axis of the loch.
5. Density driven flows generally have a preferred direction.
6. Material will be drawn out in the direction of current, often forming long thin ‘plumes’.
7. Estimates of flow speed combined with T_{90} will give a ‘region of influence’.
8. The ratio of river run-off to tidal prism gives an indication of the importance of density effects.

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

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

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

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

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

Class A: 1 bacterium per 100 ml = 10^4 m^{-3}
Class B: 100 bacterium per 100 ml = 10^6 m^{-3}

3.2.1 Integrated inputs

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

$$C = S T_f / V$$

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

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

3.2.2 Individual inputs

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

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

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

References

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

Glossary of terms

The following technical terms appear in the hydrographic assessment.

Bathymetry. The underwater topography given as depths relative to some fixed reference level e.g. mean sea level.
Hydrography. Study of the movement of water in navigable waters e.g. along coasts, rivers, lochs, estuaries.
Tidal period. The dominant tide around the UK is the twice daily one generated by the moon. It has a period of 12.42 hours. For nearshore so-called rectilinear tidal currents then roughly speaking water will flow one way for 6.2 hours then back the other way for 6.2 hours.
Tidal range. The difference in height between low and high water. Will change over a month.
Tidal excursion. The distance travelled by a particle over one half of a tidal cycle (roughly~6.2 hours). Over the other half of the tidal cycle the particle will move in the opposite direction leading to a small net movement related to the tidal residual. The excursion will be largest at Spring tides.
Tidal residual. For the purposes of these documents it is taken to be the tidal current averaged over a complete tidal cycle. Very roughly it gives an idea of the general speed and direction of travel due to tides for a particle over a period of several days.
Tidal prism. The volume of water brought into an estuary or sea loch during half a tidal cycle. Equal to the difference in estuary/sea loch volume at high and low water.
Spring/Neap Tides. The strongest tides in a month are called spring tides and the weakest are called neap tides. Spring tides occur every 14 days with neaps tides occurring 7 days after springs. Both tidal range and tidal currents are strongest at Spring tides.
Tidal diamonds. The tidal velocities measured and printed on admiralty charts at specific locations are called tidal diamonds.
Wind driven shear/surface layer. The top metre or so of the surface that generally moves in the rough direction of the wind typically at a speed that is a few percent (~3%)of the wind speed.
Return flow. Often a surface flow at the surface is accompanied by a compensating flow in the opposite direction at the bed (see figure 1).
Stratification. The splitting of the water into two layers of different density with the less dense layer on top of the denser one. Due to either temperature or salinity differences or a combination of both.

Norovirus Testing Summary
Loch Creran

Oyster samples taken from oyster farms at Rubha Mor, Shian Fisheries and East Barrington were submitted for Norovirus analysis quarterly between August 2007 and May 2008. An additional sample was collected in April at the East Barrington site as agreed between the harvester and FSAS.

Results are tabulated below by site.

Rubha Mor

Ref No.	Date rec'd	NGR	GI	GII
07/395	02/08/07	NM 91600 40600	Not detected	Not detected
07/763	23/11/07	NM 91754 40656	Not detected	Positive
08/26	19/02/08	NM 91754 40654	Positive	Positive
08/115	20/05/08	NM 91734 40656	Positive	Not detected

Shian Fisheries

Ref No.	Date rec'd	NGR	GI	GII
07/396	02/08/07	NM 90900 42200	Not detected	Not detected
07/762	23/11/07	NM 90939 42217	Not detected	Positive at Limit of Detection
08/27	19/02/08	NM 90938 42218	Not detected	Not detected
08/114	20/05/08	NM 90937 42218	Not detected	Not detected

East Barrington

Ref No.	Date rec'd	NGR	GI	GII
07/397	02/08/07	NM 94900 43000	Not detected	Not detected
07/764	23/11/07	NM 94664 43193	Not detected	Not detected
08/25	19/02/08	NM 94862 43194	Positive	Positive
08/80	22/04/08	NM 94881 43227	Positive at Limit of Detection	Not detected
08/116	20/05/08	NM 94862 43248	Not detected	Not detected