Scottish Sanitary Survey Project

Sanitary Survey Report
Loch Fyne: Stonefield
AB 435 840 13
August 2009

Cefas

FOOD STANDARDS AGENCY SCOTLAND
Buidheann Inbhe-Bìdhe an Alba

Report Distribution – Loch Fyne Stonefield

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1. General Description

Loch Fyne is fiordic loch over 70km in length with a northeast to south west orientation. There are two sills, one at Minard and one at Otter Ferry. The maximum depth of the loch is more than 180m.

The Stonefield production area is one of five in the loch and is situated approximately 12 km from the mouth of the loch and 13 and 26 km respectively to the south of the two sills. The town of Tarbert lies at the head of East Loch Tarbert, an inlet of Loch Fyne to the south of the production area. This sanitary survey was undertaken due to the application to classify the area for the production of Pacific oysters, which were not previously farmed here.

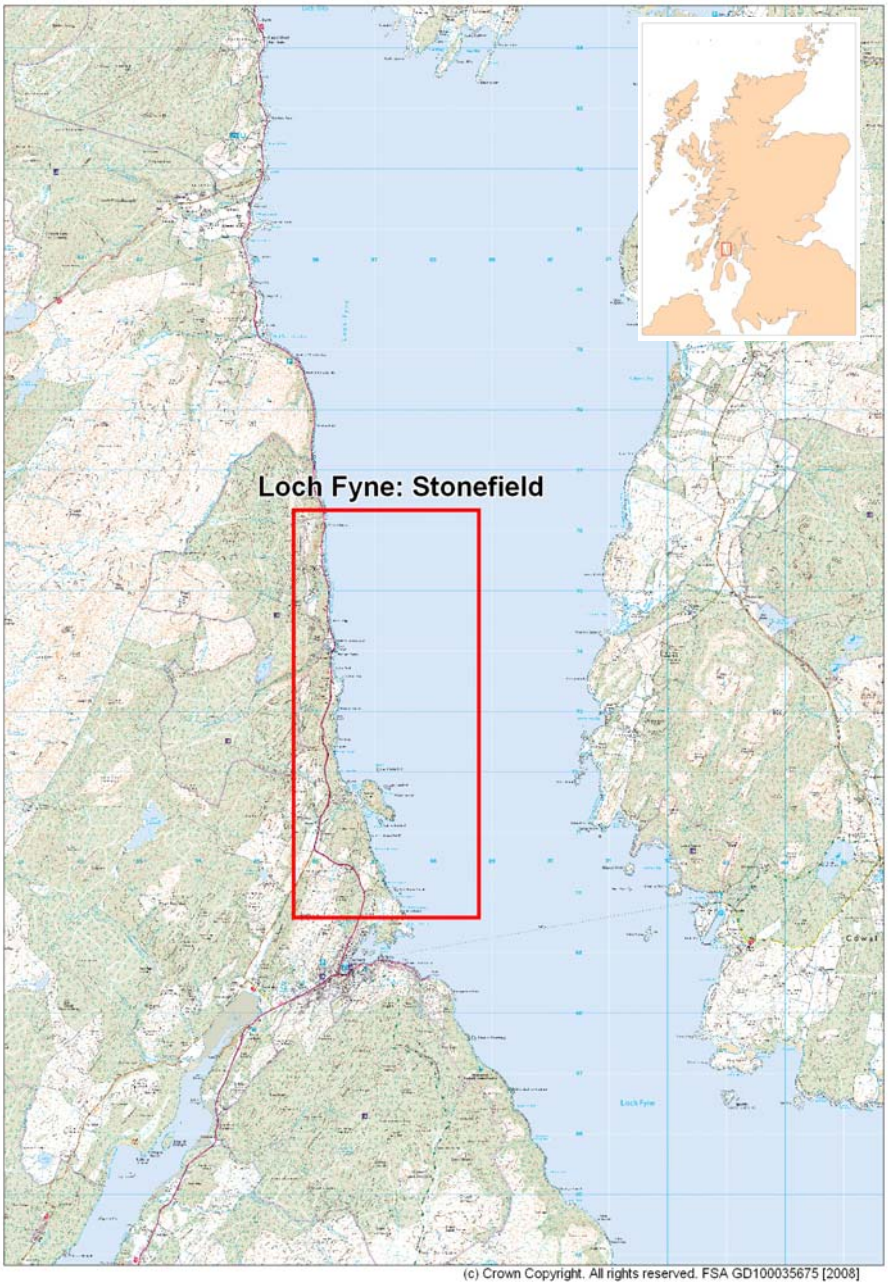

Figure 1.1 Location of Loch Fyne: Stonefield

2. Fishery

The fishery at Loch Fyne Stonefield consists of two distinct areas, north and south of Barmore Island, named North Bay and South Bay. Within the North Bay area, there are two separate shellfish sites. Queen scallops are cultured in both the North Bay and South Bay sites, while Pacific oysters are cultured at the North Bay sites only.

Table 2.1 Loch Fyne: Stonefield shellfish sites

Production Area	Site	SIN	Species
Loch Fyne: Stonefield	North Bay Oysters	AB 435 840 13	Pacific oyster
Loch Fyne: Stonefield	North Bay	AB 154 043 15	Queen scallops
Loch Fyne: Stonefield	South Bay	AB 154 044 15	Queen scallops

The boundaries for the Loch Fyne: Stonefield production area are currently listed as the area bounded by lines drawn between NR 8617 7600 and NR 8800 7600 and between NR 8800 7600 and NR 8800 7000 and between NR 8800 7000 and NR 8727 7000 extending to MHWS.

The reported RMP grid reference for Loch Fyne: Stonefield (queen scallops) is NR 864720. The area is currently classified for the production of queen scallops. There is currently no RMP for Pacific oysters, as the area has not been previously classified for them.

Both species are grown in lantern nets suspended approximately 10 m from the surface from float lines running parallel to the shore. The lantern nets themselves are approximately 2 m deep and about 50 cm in diameter. There are two culture sites, North Bay and South Bay. The South Bay consists of one block of lantern nets. Within the North Bay site there are two blocks, one larger block to the south, and a smaller block to the north.

Queen scallops are grown from natural seed settled onto the gear *in situ*. When the larvae are ready to settle (as determined using a plankton trawl) nets are deployed in the South Bay site onto which they settle. These are then transferred to the North Bay site, where they are grown to a harvestable size. From settlement of larvae to harvest takes around 3 years. They are either processed and frozen at the processing facility in Tarbert, or exported live to Spain. Harvesting can occur at any time of the year, dependent on demand, and only occurs at the North Bay site, with the South Bay site dedicated entirely to the collection of seed. Up until the beginning of 2007, shellfish samples were taken from the South Bay site for classification monitoring, implying that harvesting may have occurred from this site in the past.

Pacific oysters are grown from 20g seed stock, and from this they reach a harvestable size in around 24 months. They are only grown in and harvested from the two blocks at the North Bay.

Figure 2.1 shows the relative positions of the shellfisheries, Food Standard Agency Scotland designated production area, seabed lease areas and the RMP.

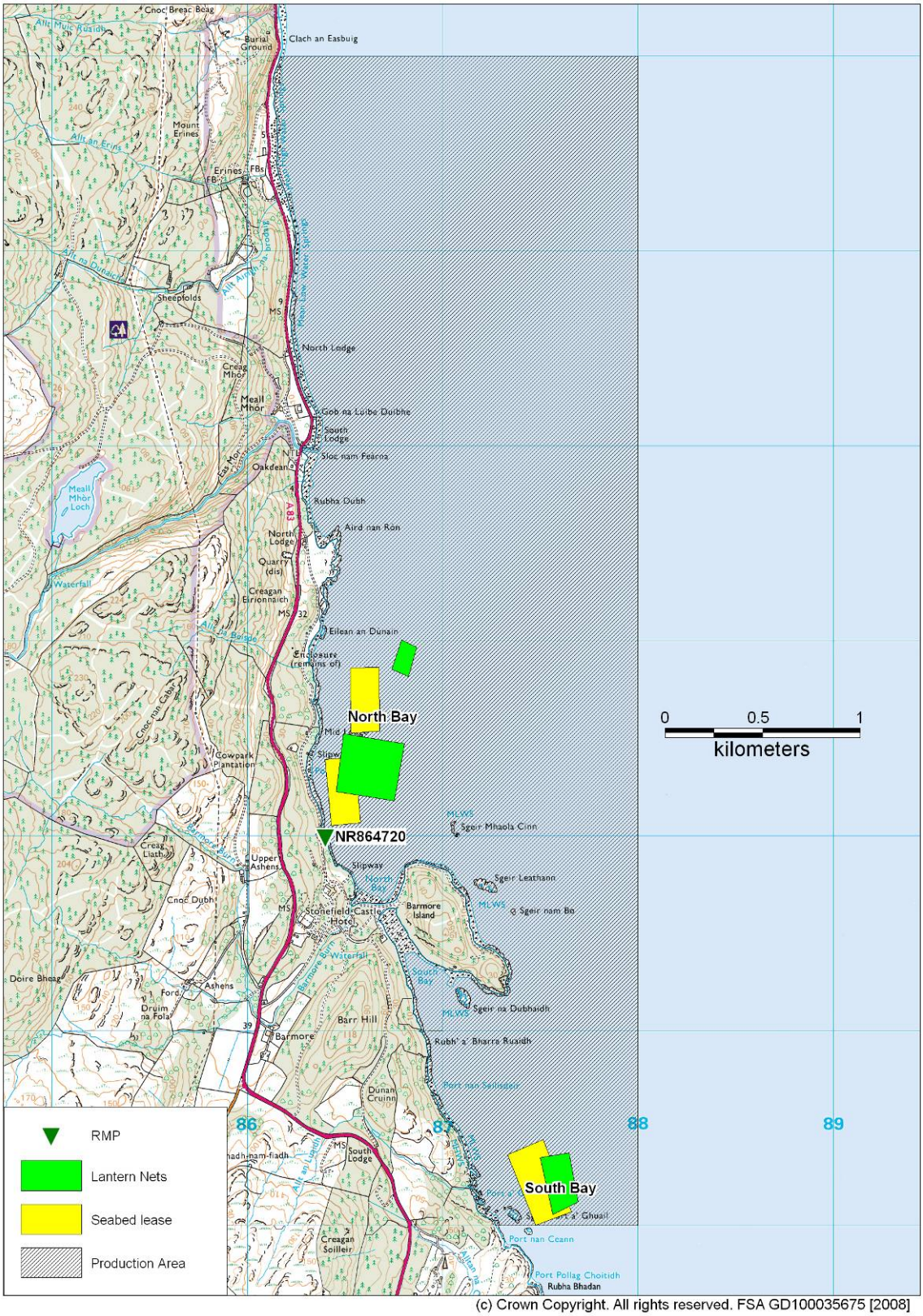

Figure 2.1 Loch Fyne: Stonefield Fishery

3. Human Population

Figure 3.1 below shows information obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of the Loch Fyne: Stonefield production area.

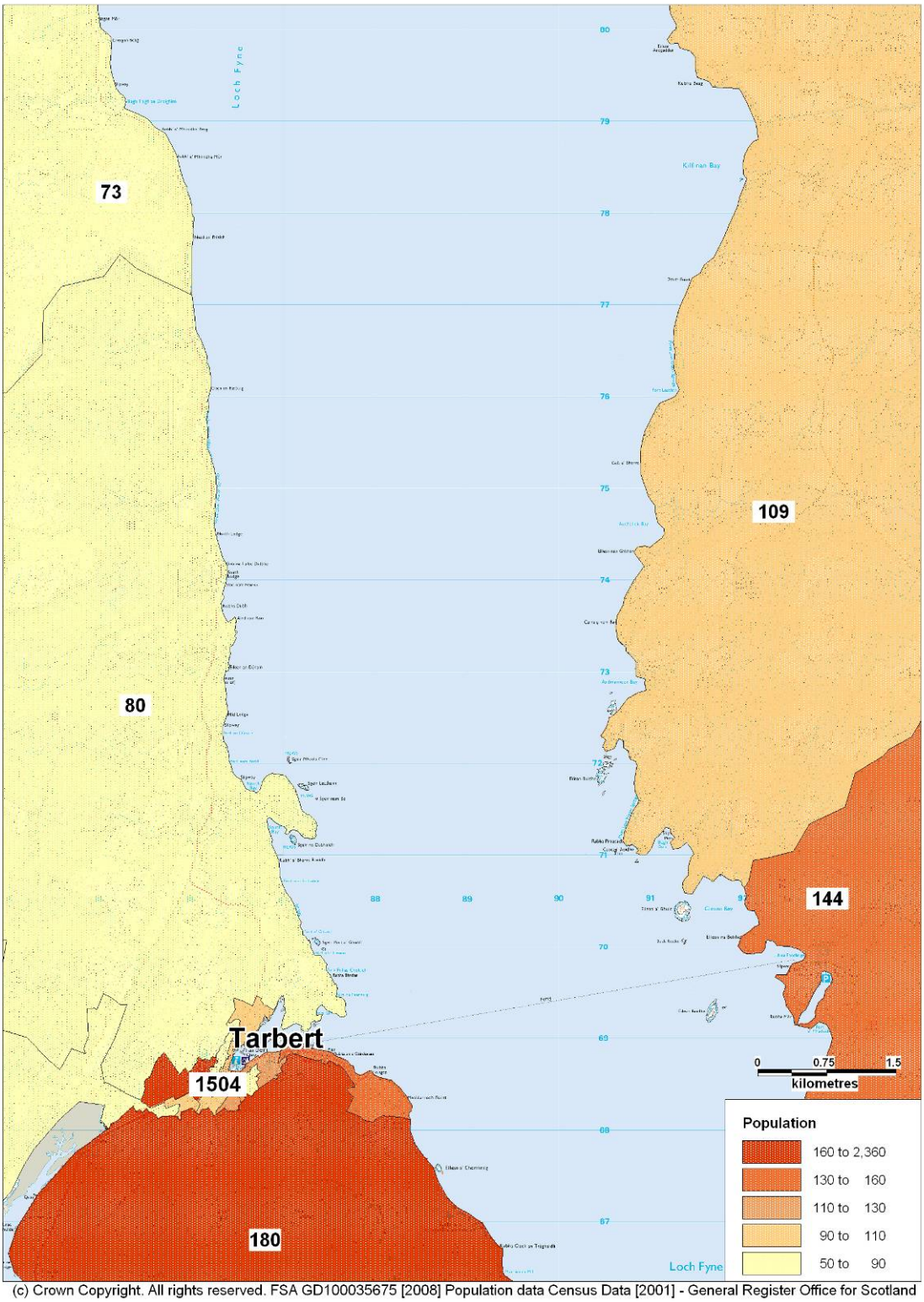

Figure 3.1 Population near Loch Fyne: Stonefield

Less than 2 km to the south of the production area is the town of Tarbert, which is composed of twelve census output areas and has a combined human population of 1504 (according to the 2001 UK census). The population for the other five census output areas bordering immediately on Loch Fyne near the Stonefield production area are:

60QD000688	73
60QD000057	80
60QD000054	180
60QD000015	109
60QD000014	144
Total	586

Along the western shore of the loch adjacent to the production area, the population is very low and widely dispersed. As the majority of the population is concentrated in the town of Tarbert, any associated faecal pollution from human sources is likely to arise from this area and would have a more acute impact at the southern end of the shellfishery.

There will be an increase in population in the area during the summer months. Large numbers of yachts visit Tarbert during the summer, generally on their way to or from the islands. There are at least four hotels in Tarbert. Stonefield Castle, located on the mainland by Barmore Island, operates as a hotel, and moorings in North Bay are used by the hotel's customers. There are a few holiday cottages at Barfad Farm, just north of Tarbert. No campsites were seen during the shoreline survey.

4. Sewage Discharges

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

Table 4.1 Discharges identified by Scottish Water

NGR	Discharge Name	Consent No.	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented /design PE
NR 8787 7084	Tarbert Barfad	CAR/L/1017648	continuous	Septic Tank	417	1658
NR 8683 6918	Tarbert Gravel Road PS2	WPC-W-71228	intermittent	6mm screen on overflow	25.4	106
NR 8658 6872	Tarbert Harbour Street PS1	WPC-W-71225	intermittent	6mm screen on overflow	417	1658
NR 8758 6878	Tarbert Pier Rd PS1	WPC-W-71226	intermittent	6mm screen on overflow	44.9	188

A number of discharge consents have been issued within this area and provided by SEPA. These are listed in Table 4.2. The first four consents correspond to the four discharges listed in Table 4.1. At the time of writing this report, detailed copies of the consents had not been received.

Table 4.2 Discharge consents issued by SEPA

Ref no	Grid ref	Discharge type	Discharge vol m^3/day	PE	Discharges to	Name
CAR/L/1017648	NR 8787 7084	Sewage (Public) Primary			Loch Fyne, South Bay	Tarbert Barfad
WPC-W-71228	NR 8683 6918	Treated sewage	25.4	106	East Loch Tarbert	Satellite Pumping Station 2
WPC-W-71225	NR 8658 6872	Treated sewage	417	1658	East Loch Tarbert	Transfer Pumping Station 1
WPC-W-71226	NR 8758 6878	Treated sewage	44.9	188	East Loch Tarbert	Satellite Pumping Station 1
CAR/L/1018435*	NR 8681 6925	Sewage (Public) EO & CSO	25.4	106	East Loch Tarbert	Satellite Pumping Station 2
CAR/R/1018377	NR 8689 6862	Domestic	5			

*This the updated license number for WPC-W-71228.

A number of sewage outfalls and septic tanks were recorded during the shoreline survey. Their locations have been included in the mapped discharges in Figure 4.1, and details are listed in Table 4.3.

Table 4.3 Discharges observed during shoreline survey

No.	Date and time	Position	Description
1	30-SEP-08 9:00:55AM	NR 87572 68761	Tarbert Sewage pumping station 1 (Scottish Water). Storm overflow next to it.
2	30-SEP-08 9:52:34AM	NR 86571 68914	20cm cast iron pipe to underwater
3	30-SEP-08 10:00:22AM	NR 86806 69247	Tarbert Sewage pumping station 2 (Scottish water).
4	30-SEP-08 10:04:27AM	NR 86879 69262	10 cm cast iron pipe to underwater
5	30-SEP-08 11:17:09AM	NR 86337 72546	Inspection cover in garden, no pipe to shore found, believed to be a soakaway system.
6	30-SEP-08 11:38:40AM	NR 86311 73535	Septic tank in lawn, no pipe to shore seen.
7	01-OCT-08 8:47:39AM	NR 86784 69151	12 cm cast iron pipe to underwater.
8	01-OCT-08 9:46:03AM	NR 86585 68700	Scottish Water storm holding tank.
9	01-OCT-08 11:33:22AM	NR 86783 70105	Tarbert waste water treatment plant. No tertiary treatment. Waste water is pumped over Barr Hill and out to sea off South Bay in about 40m of water.
10	01-OCT-08 12:28:09PM	NR 86270 73863	12cm faded orange plastic sewer pipe to underwater.
11	01-OCT-08 12:33:40PM	NR 86284 73981	Septic outfall from one house to stream.

The only population centre in the area is Tarbert, which is served by a Scottish Water sewerage system. Wastewater is collected in Tarbert, and pumped up to the treatment works to the north of the town. Here it is treated by screening and septic tank. It is then pumped out to sea, where it is discharged approximately 900m offshore in about 40m of water, approximately 500m north east of the South Bay site. This system also incorporates three intermittent storm discharges within East Loch Tarbert. Scottish Water report that the modelled predicted spill frequency is no more than 10 significant spills (> $50m^3$) each per year from each of these three CSOs. The Pier Rd PS1 appeared to be spilling following very heavy rain at the time of the shoreline survey. The system was commissioned in late 2005, and before this the sewage system in Tarbert consisted of multiple septic tanks discharging mainly to East Loch Tarbert.

In addition, three private cast iron sewer pipes to the shore were observed during the shoreline survey within Tarbert, but it is believed that these are no longer in use. SEPA list a consent for a private sewage discharge (CAR/R/1018377) away from the shoreline in south Tarbert, presumably to soakaway as no details regarding the permit were provided by SEPA.

Outside of Tarbert, a further four discharges were noted during the shoreline survey, all located to the north of Barmore Island. Two were septic tanks discharging to soakaway, one was a septic tank discharge to a stream, and one was a septic tank discharge to the shore. No discharge from Stonefield Castle Hotel was seen discharging direct to Loch Fyne during the shoreline survey, and SEPA do not list a consent for a sewage discharge from here. A hotel representative confirmed the existence of a septic tank, and it was subsequently identified by the hotel that the tank is pumped out rather than discharging to the environment.

The marina at Tarbert is large and is busy with visiting yachts, particularly during the summer months. Potentially, over 150 yachts could moor here. Additionally, in East Loch Tarbert, there are a few more moorings, a ferry terminal which serves a small car ferry, and a few fishing boats. There are no pumpout facilities anywhere in Loch Fyne. There are several moorings in North Bay, near the Stonefield Castle hotel. Two fish farms with associated barges reside to the north of North Bay.

Sanitary debris was noted during the shoreline survey on the shore at Tarbert, and to the north of the production area boundaries just south of Inverneil, though this was located 5.5 km north of the northern production area boundary.

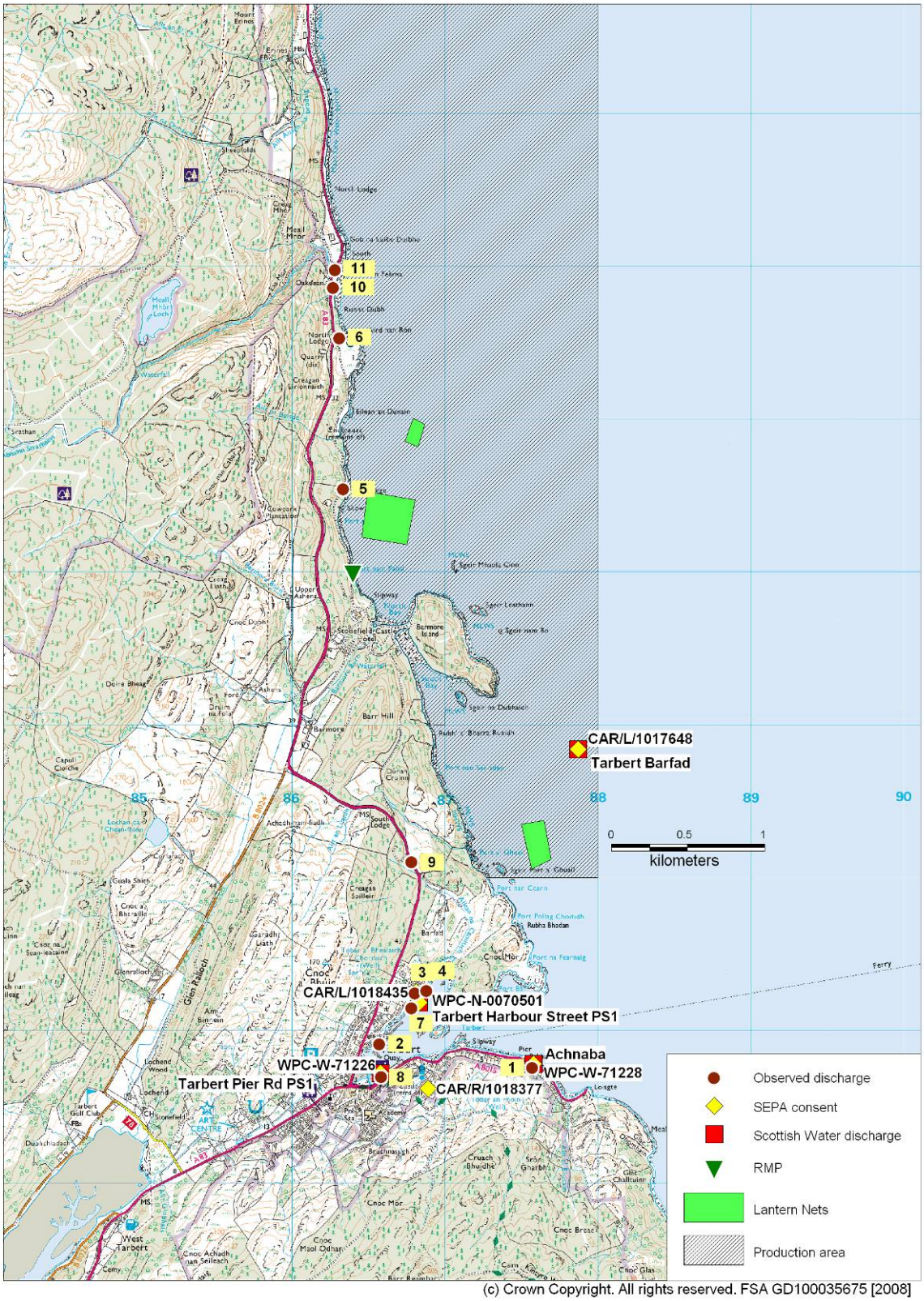

Figure 4.1 Sewage discharges at Loch Fyne: Stonefield

5. Geology and soils

Geology and soil types were assessed following the method described in Appendix 3. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded blue indicate freely draining soils, whereas areas shaded red indicate more poorly draining soils.

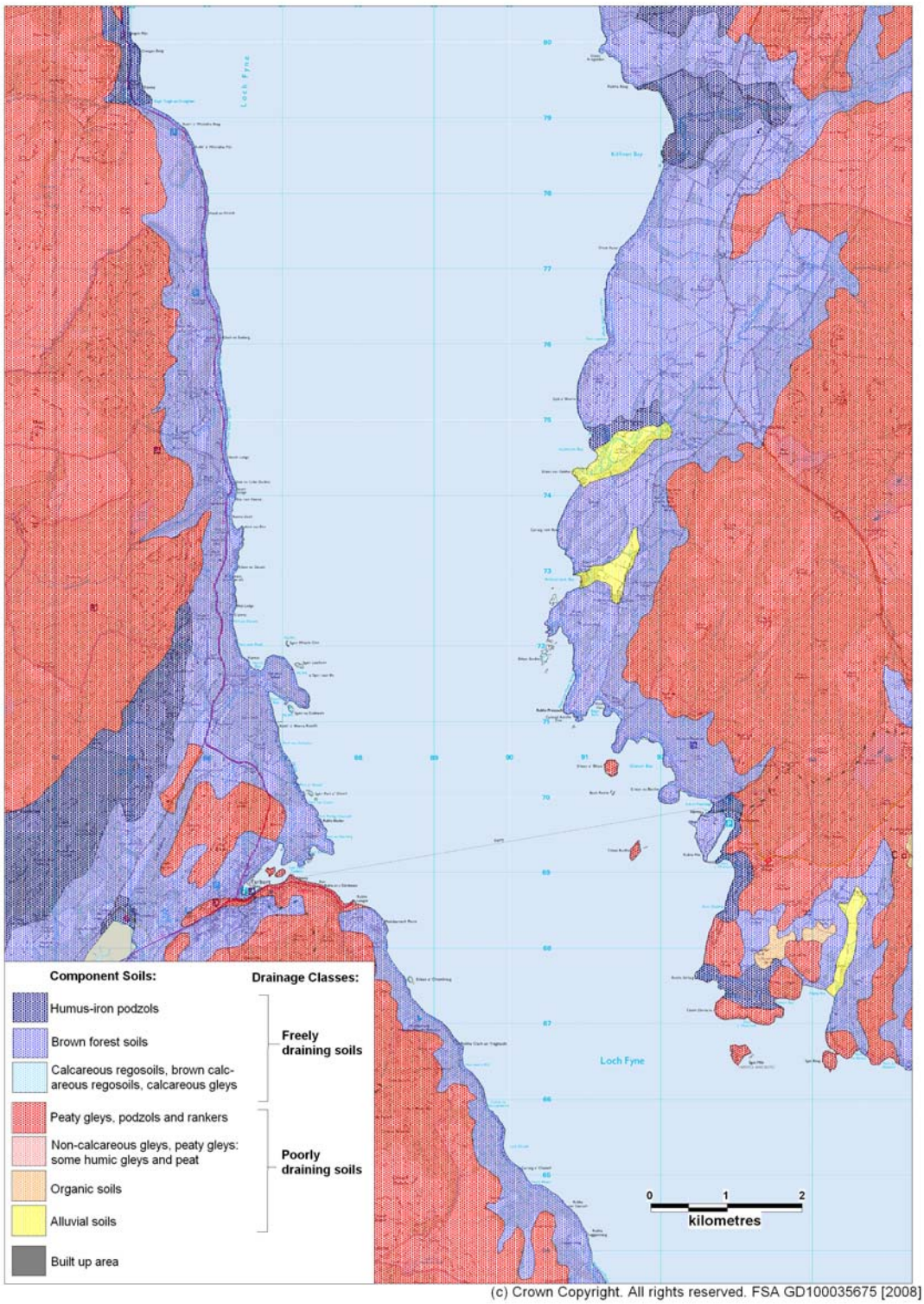

Figure 5.1 Component soils and drainage classes for Loch Fyne Stonefield

The soils immediately bordering the shoreline are predominantly freely draining, being mostly brown forest soils with some areas of humus-iron podzols. Three small areas of alluvial soil are present on the western shoreline of the loch, and on both sides the soils inland are predominantly poorly draining gleys, podzols and peat.

On either side of the loch, surface run off from inland areas is likely to be high, potentially resulting in higher levels of faecal contamination entering streams draining these areas.

In contrast, along the coastline of the loch, the contribution from surface runoff would be lower. However, as this band is narrower on the western side of the loch the amount of runoff carried via streams here would be dominated by the larger area of poorly drained soils located inland.

Therefore, the potential for runoff contaminated with *E. coli* from human and/or animal waste is likely to be higher along the western shore of the loch compared to the eastern side. This effect would be most pronounced at the northern end of the shoreline shown in Figure 5.1.

6. Land Cover

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

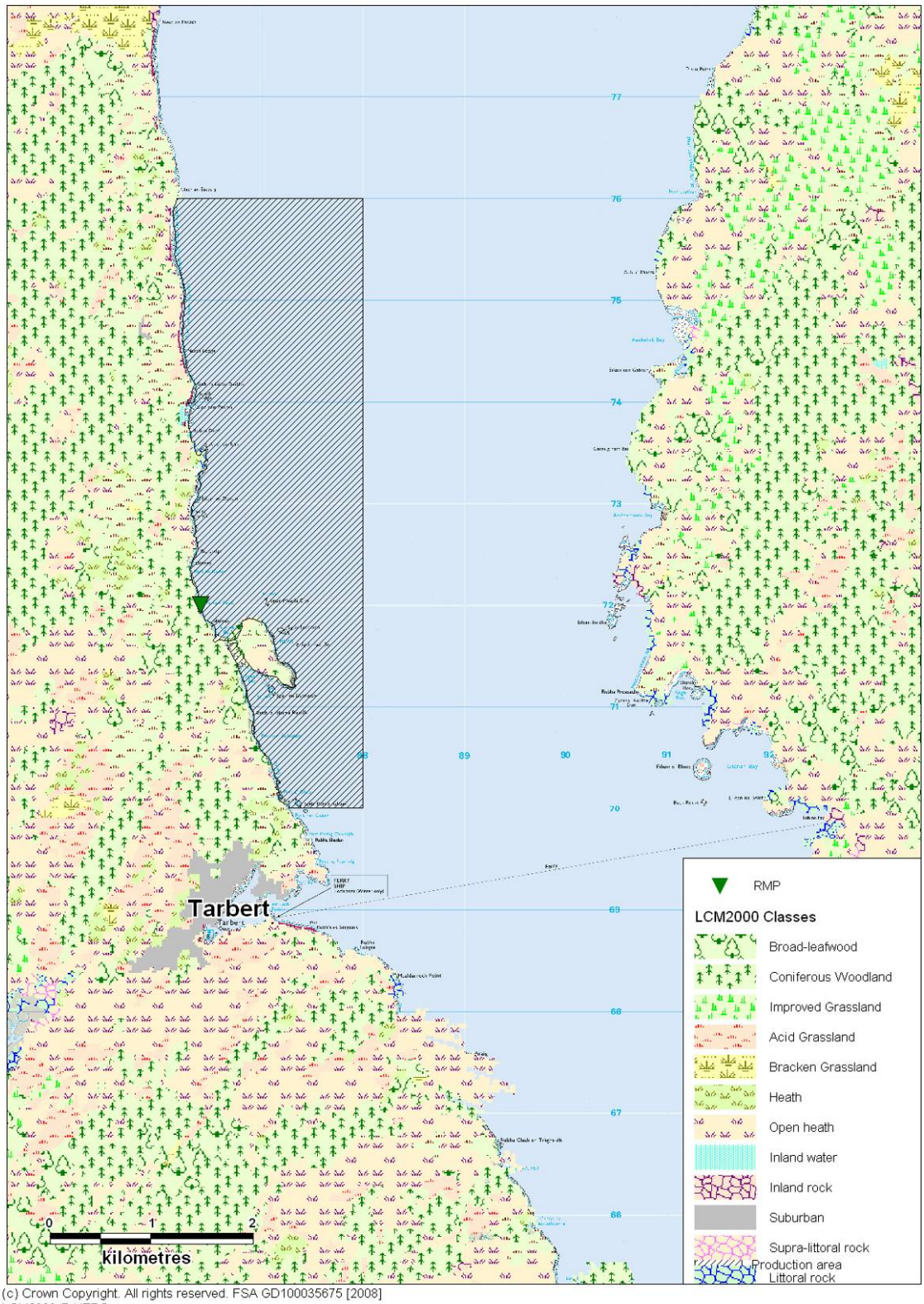

Figure 6.1 LCM2000 class land cover data for Loch Fyne Stonefield

Coniferous and broadleaf woodland dominates most of the land either side of the loch with patches of heath and grassland interspersed. The suburban settlement of Tarbert is located on the western shore, south of the Loch Fyne: Stonefield production area. Scattered areas of improved grassland are located on the eastern side of the loch.

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

Therefore, the most significant expected loadings attributable to land cover type are likely to occur south of the production area at Tarbert. Temporary localised increases in contribution may be expected from areas of coniferous woodland when logging activities are underway. Loadings attributed to the improved pasture on the eastern shore are less likely to affect the production area.

7. Farm Animals

With regard to potential sources of pollution of animal origin, agricultural census data was requested from the Scottish Government. Agricultural census data was provided by the Scottish Government Rural and Environment Research and Analysis Directorate (RERAD) for the parishes of South Knapdale and Kilfinan. These parishes cover a total land area of 299 km^2 and 129 km^2 respectively. The parish of South Knapdale covers the western side of the loch in the vicinity of the production area. The parish of Kilfinan borders on the eastern side of Loch Fyne and so will be less significant in terms of livestock contributions to pollution in the vicinity of the shellfish farm here. Reported livestock populations for these parishes in 2008 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data.

Table 7.1 Livestock census data for South Knapdale & Kilfinan Parishes, 2008

	South Knapdale		Kilfinan	
	Holdings	Numbers	Holdings	Numbers
Total Pigs	*	*	*	*
Total Poultry	7	69	*	*
Total Cattle	8	1230	9	1236
Total Sheep	14	11710	10	11186
Total Deer	*	*	0	-
Horses and Ponies	8	63	*	*

* Data withheld on confidentiality basis.

Both pigs and deer are farmed somewhere within the South Knapdale parish, however specific data on numbers could not be provided. Due to the large area of the parishes, this data does not provide detailed information on the livestock numbers likely to be present in the area immediately surrounding Loch Fyne: Stonefield.

The only information specific to the area near the shellfishery was therefore the shoreline survey (see Appendix 8), which only relates to the time of the site visit on 30th September – 1st October 2008. The spatial distribution of animals observed during the shoreline survey is illustrated in Figure 7.1.

The land adjacent to the production area is hilly and forested, with almost nothing in the way of pasture. A total of only 11 sheep and 2 peacocks were seen during the shoreline survey. Although there are significant numbers of sheep and cattle in the agricultural parish, the limited amount of grassland and pasture available along the western shore near the production area indicates it is unlikely that livestock will kept here in large numbers. Given the very low numbers and densities of livestock observed in the local area, their contribution to the levels of contamination in the production area will be minor, with no specific areas of impact. Over the wider catchment area, it is likely that livestock will contribute to the overall background levels of *E. coli* in Loch Fyne. The spatial distribution of livestock observed and noted during the shoreline survey is illustrated in Figure 7.1.

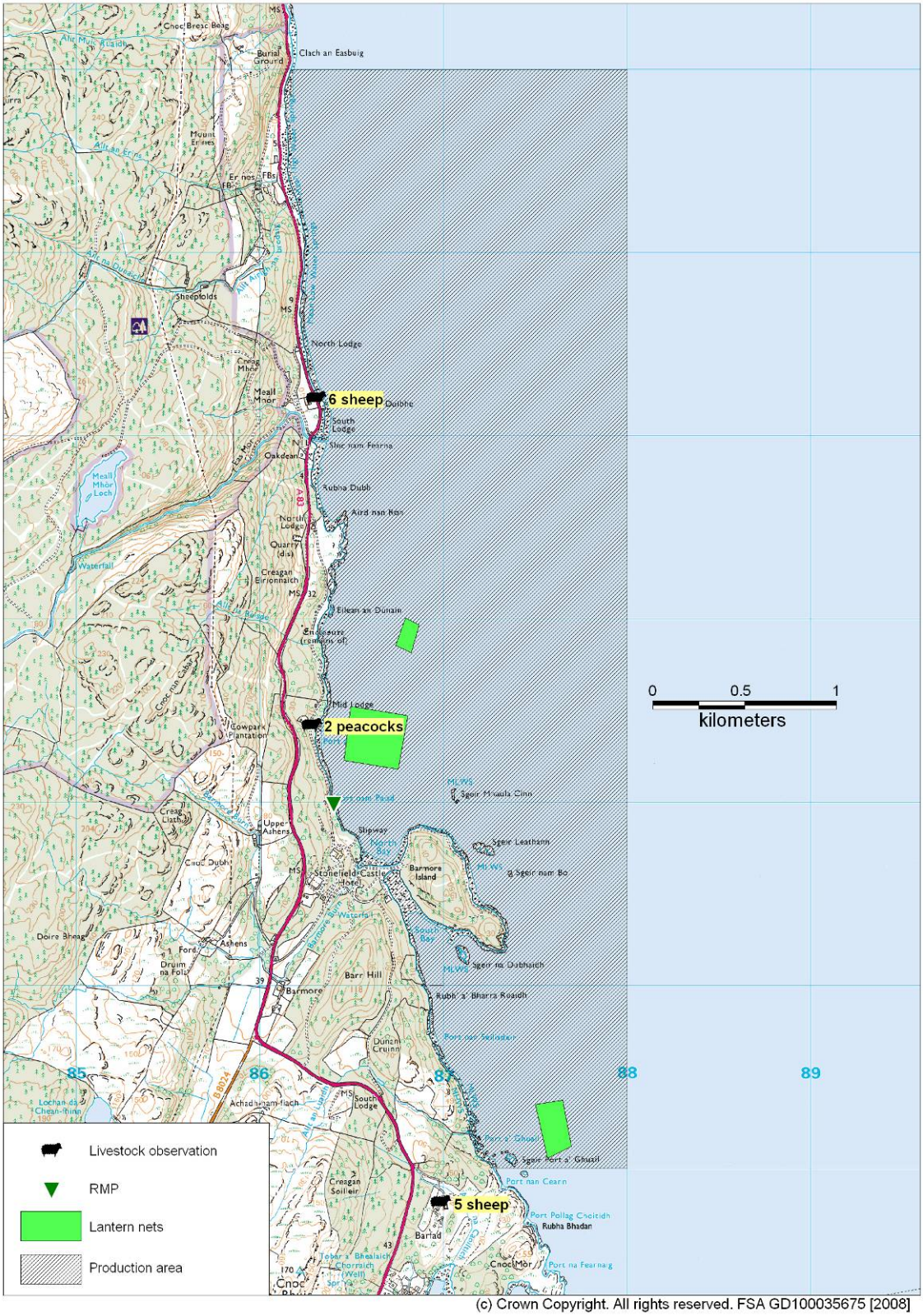

Figure 7.1 Livestock observations at Loch Fyne: Stonefield

8. Wildlife

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

Seals
Two species of pinniped (seals, sea lions, walruses) are commonly found around the coasts of Scotland: These are the European harbour, or common, seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). 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. For the survey area named 'Clyde Estuary', covering the area from Southend to Loch Ryan (and presumably including Loch Fyne), a total count of 991 was recorded when the area was last surveyed (1996).

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. No breeding colonies were reported in or near Loch Fyne, however it is possible that grey seals might be found in the loch from time to time.

Seals will range widely hunting for food and it is likely that they will feed near the shellfish farm 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. No seals were observed during the shoreline survey.

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

There are no sills or other obstruction preventing even the larger cetaceans from potentially visiting the area, which is about 11km from the mouth of the loch, 3.3 km wide, and over 50m deep in the middle, but it is an enclosed sea loch so the smaller species such as dolphins and porpoises are more likely visitors. Their presence is likely to be sporadic and unpredictable. None were seen during the course of the shoreline survey, but the grower did report that dolphins have been seen in the area from time to time.

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

Seabird populations were investigated all over Britain as part of the SeaBird 2000 census (Mitchell *et al*, 2004). The area was surveyed in early June of 1999. Total counts of all species recorded within 5 km of the trestles are presented in Table

8.1. Counts were of occupied nests or territories, so actual numbers of seabirds breeding in the area will be higher as each count represents a breeding pair.

Table 8.1 Seabird counts within 5 km of the production area

Common name	Species	Count	Method
Herring Gull	*Larus argentatus*	194	Occupied nests
Great cormorant	*Phalacrocorax carbo*	65	Occupied nests
European Shag	*Phalacrocorax aristotelis*	33	Occupied nests
Great Black-backed Gull	*Larus marinus*	27	Occupied nests
Lesser Black-backed Gull	*Larus fuscus*	1	Occupied territory
Black-headed Gull	*Larus ridibundus*	1	Occupied nests

The vast majority of these birds were seen on small rocky islands on the east shore of the loch. One breeding pair of herring gulls was recorded on Barmore island, and one breeding pair of black-headed gulls was recorded on a small rocky island just south of the South Bay site, and these were the only records in close proximity to the production area. Nevertheless, it is likely that these birds will forage within the production area, and may rest on the floats supporting the lantern nets. An aggregation of about 20 gulls was seen on Barmore Island during the shoreline survey. Nesting occurs in early summer, after which some species disperse. Gulls are likely to be present in the area throughout the year.

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 Fyne.

Waterfowl (ducks and geese) are present in Loch Fyne at various times from autumn through winter. Few of these birds would be expected to be present during the summer months. Overwintering geese would tend to be found on farm fields and open grassland. 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. No estimates of numbers were available at the writing of this report and so it is not possible to properly evaluate their contribution, although this would be expected to be low as there is little in the way of open grassland on the adjacent shores. As Loch Fyne does not host large overwintering populations, the presence of these birds is likely to be variable.

Aside from a group of around 20 seagulls on a rock near Barmore Island, no significant aggregations of birds were seen on the shoreline survey.

Deer

Deer will be present particularly in wooded areas where the habitat is best suited for them. Most of the land adjacent to the Loch Fyne: Stonefield production area is wooded. While no population data was available for this area, it can be presumed that it hosts a significant population of deer.

It is likely that some of the faecal indicator organisms detected in the streams feeding into Loch Fyne in the vicinity of the Stonefield production area will be of deer origin and it may be expected that their contribution would be year round.

Otters

No otters were observed during the shoreline survey, however otters are known to occur around the Loch Fyne area. The area is large, and not considered to host a substantial population so it is unlikely that otters constitute a significant source of faecal contamination to the fishery.

Summary

Wildlife impacts to the fisheries in Loch Fyne are likely to be localised and unpredictable. However, the effect of such contamination should be detected intermittently during regular monitoring based on the plan.

9. Meteorological data

The nearest weather station is located at Skipness House, approximately 13 km to the south of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily rainfall in mm). Data were unavailable for January and December 2006. It is likely that the rainfall experienced at Skipness House is similar to that experienced at the production area due to their proximity.

The nearest major weather station where wind is measured is located at Glasgow: Bishopton, approximately 50 km to the east of the production area. Wind direction was recorded at 3 hourly intervals for the majority of the period 1/1/1996 to 31/12/2007. It is likely that the overall wind patterns are broadly similar in terms of seasonality and strength, but the patterns of wind direction are liable to be affected by local topography. Winds may differ significantly between Glasgow and Loch Fyne Stonefield at any given time due to the distance between the two.

9.1 Rainfall at Skipness House

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and wastewater treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003). Total annual rainfall and mean monthly rainfall were calculated, and are presented in Figures 9.1 and 9.2.

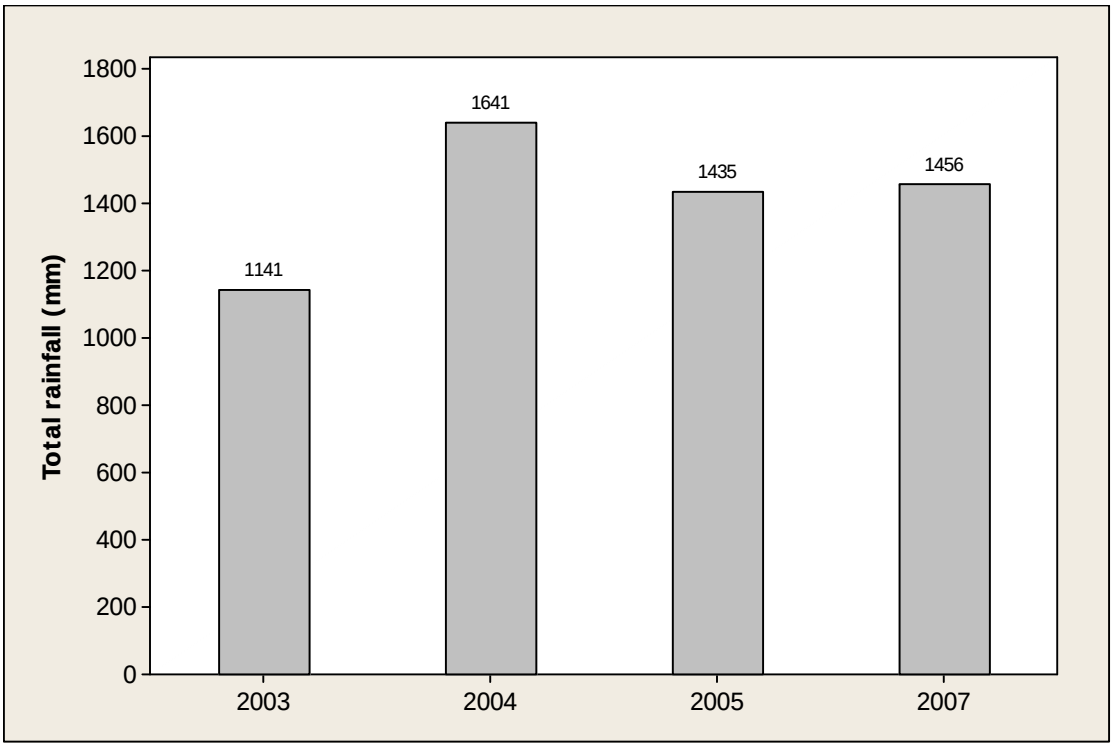

Figure 9.1 Total annual rainfall at Skipness House, 2003 – 2007
(2006 data omitted due to missing values)

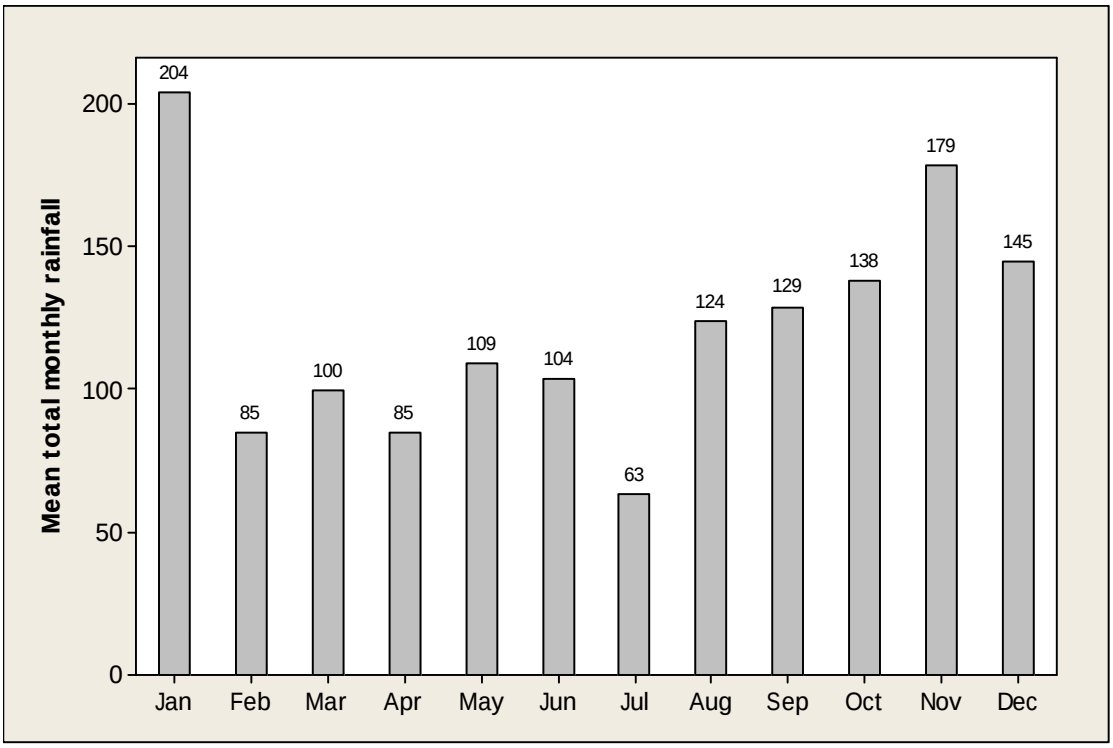

Figure 9.2 Mean total monthly rainfall at Skipness House, 2003 - 2007

Interannual variation is much less than monthly variation. The wettest months were January and November, and the driest month was July. For the period considered here, 50% of days experienced rainfall of 1 mm or less and 13% of days experienced 10 mm or more.

It can therefore be expected that levels of rainfall-dependant faecal contamination entering the loch will be generally higher during the autumn and early winter, but episodes of contamination following heavy rain may occur at any time of year. It is also probable that faecal matter will build up on pastures during the drier summer months when stock levels are at their highest, leading to more significant faecal contamination of runoff at the onset of wetter weather. From the mean monthly total rainfall values presented in Figure 9.2, these effects would be expected to occur principally in August and perhaps November.

9.2 Wind at Glasgow

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

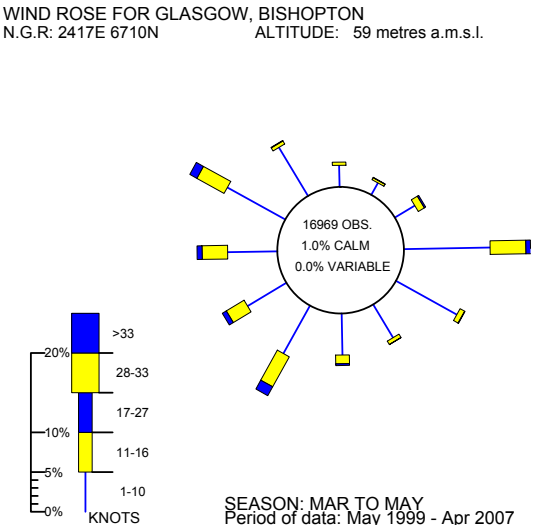

Figure 9.3 Wind rose for Glasgow: Bishopton (March-May)

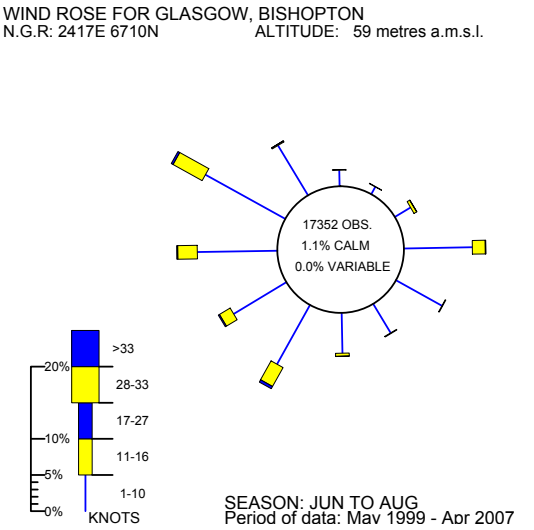

Figure 9.4 Wind rose for Glasgow: Bishopton (June-August)

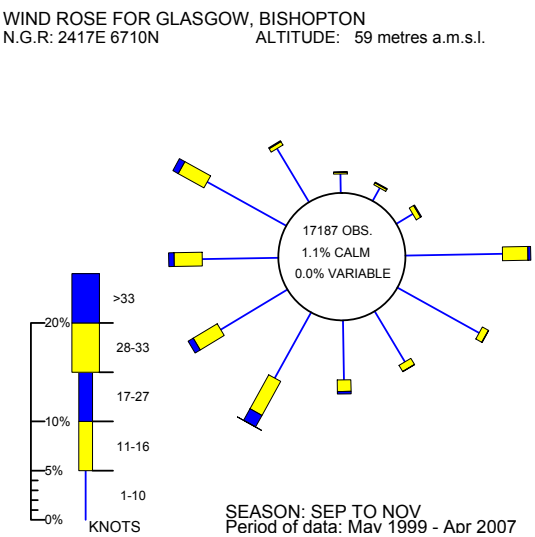

Figure 9.5 Wind rose for Glasgow: Bishopton (September-November)

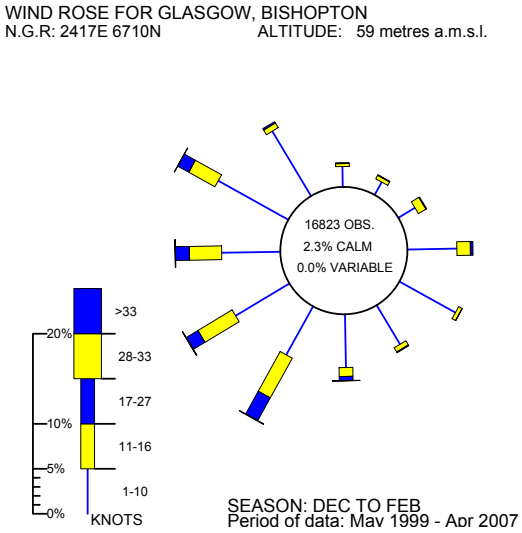

Figure 9.6 Wind rose for Glasgow: Bishopton (December-February)

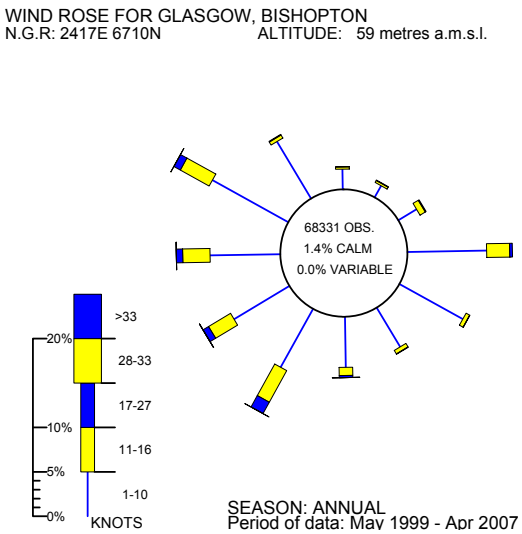

Figure 9.7 Wind rose for Glasgow: Bishopton (All year)

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

Loch Fyne has a south to north aspect at Stonefield, facing the Sound of Bute to the south. It is about 60 km long and about 3 km wide, and is surrounded by hills rising to over 500 m in places. The loch will receive shelter from winds from most directions, but is more open to southerly or northerly winds, which would be funnelled up or down the Loch by the surrounding hills so it is likely that at loch Fyne Stonefield wind patterns may along more along the north-south axis compared to those recorded at Glasgow: Bishopton.

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

Although tidally driven circulation of water in the Loch is important due to its tidal range, wind effects are likely to cause significant changes in water circulation. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s in the direction of the wind. These surface water currents create return currents which may travel along the bottom or sides of the loch depending on bathymetry. Either way, strong winds will increase the circulation of water and hence dilution of contamination from point sources within the loch. There may be some instances where contamination from settlements may be carried to production sites by wind driven currents. An example may be a southerly wind carrying contamination from the settlement of Tarbert along the shore towards the production sites.

10. Current and historical classification status

Loch Fyne: Stonefield has been classified for the production of queen scallops since prior to 2001. It was also classified for the production of king scallops in 2001, but not since. The area has not yet been classified for Pacific oysters. The classification history for queen scallops from 2001 on is presented in Table 10.1, and for king scallops in Table 10.2. The area has usually been classified as an A, but in 2006 and 2008-2009 was classified as a seasonal A/B. The currently designated RMP lies 230 m away from the nearest lantern net. A map of the current production area can be found in Section 2, Figure 2.1.

Table 10.1 Classification history, Loch Fyne Stonefield, queen scallops

	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	A	A	A	A	A	A
2003	A	A	A	A	A	A	A	A	A	A	A	A
2004	A	A	A	A	A	A	A	A	A	A	A	A
2005	A	A	A	A	A	A	A	A	A	A	A	A
2006	A	A	A	A	A	A	A	A	B	B	B	B
2007	A	A	A	A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	B	B	A	A
2009	A	A	A	A	A	A	A	A	B	B	B	B
2010	A	A	A									

Table 10.2 Classification history, Loch Fyne Stonefield, king scallops

	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

11. Historic *E. coli* data

11.1 Validation of historical data

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

No samples were rejected on the basis of major geographical discrepancies. For the 8 samples collected post February 2007 sampling locations were recorded using a GPS to a nominal 1 m accuracy. These details were not recorded in the FSAS database, where a nominal 100 m accuracy grid reference was recorded instead. Original paper copies of the sample submission forms were obtained, and sampling locations were corrected as required, and rounded to 10 m accuracy.

Two samples had an analysis date of 19 days post the collection date, so these were excluded from the analysis.

A total of 22 samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation.

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

11.2 Summary of microbiological results

A summary of all sampling and results by is presented in Table 11.1.

Table 11.1 Summary of results from Loch Fyne Stonefield

Sampling Summary										
Production area	Loch Fyne: Stonefield	Loch Fyne: Stonefield	Loch Fyne: Stonefield	Loch Fyne: Stonefield	Loch Fyne: Stonefield	Loch Fyne: Stonefield	Loch Fyne: Stonefield	Loch Fyne: Stonefield	Loch Fyne: Stonefield	Loch Fyne: Stonefield
Site	North Bay	South Bay	North Bay	North Bay	North Bay	North Bay	North Bay	North Bay	North Bay	North Bay
Species	Queen scallops	Queen scallops	Queen scallops	Queen scallops	Queen scallops	Queen scallops	Queen scallops	Queen scallops	Queen scallops	Queen scallops
SIN	AB-154-43-15	AB-154-44-15	AB-154-43-15	AB-154-43-15	AB-154-43-15	AB-154-43-15	AB-154-43-15	AB-154-43-15	AB-154-43-15	AB-154-43-15
Location	NR864720	NR870712	NR86797231	NR86757230	NR86767229	NR86767223	NR86707224	NR86697237	NR86727246	NR86717244
Total no of samples	57	54	0	0	0	0	0	0	0	0
No. 2002	11	10	0	0	0	0	0	0	0	0
No. 2003	10	10	0	0	0	0	0	0	0	0
No. 2004	11	10	0	0	0	0	0	0	0	0
No. 2005	12	11	0	0	0	0	0	0	0	0
No. 2006	12	12	0	0	0	0	0	0	0	0
No. 2007	1	1	1	1	1	1	1	1	1	1
Results Summary										
Minimum	<20	<20								
Maximum	3500	3500								
Median	40	70	90	<20	110	<20	90	160	<20	160
Geometric mean	48.5	72.0								
90 percentile	310	292								
95 percentile	444	500								
No. exceeding 230/100g	8 (14%)	7 (13%)								
No. exceeding 1000/100g	2 (4%)	1 (2%)								
No. exceeding 4600/100g	0 (0%)	0 (0%)								
No. exceeding 18000/100g	0 (0%)	0 (0%)								

11.3 Overall geographical pattern of results

Sampling location for samples taken post February 2007 was recorded using a GPS at the time of sampling, and so, although recorded to a nominal 1 m accuracy, are actually accurate to ≤10 m. All were taken from the larger south block of lantern nets at North Bay site, on different dates and at different locations. The results of these samples, where the recorded sampling location is considered reliable, are shown in Figure 11.1. Samples taken prior to this were assigned to one of two nominal locations depending on which site they originated from, neither of which coincide with the location of the lantern nets. For the samples taken prior to February 2007 therefore, a comparison was undertaken of results by site (North and South Bay), for those occasions when both sites were sampled.

Both South Bay and North Bay were sampled on the same day (and hence under broadly the same environmental conditions) on a total of 52 occasions. These results are presented as a boxplot in Figure 11.2. The majority (33) of these occasions were before the Tarbert STW was commissioned in April 2005 and therefore will not necessarily reflect the current pattern of contamination in the area. Geometric mean results were 71 MPN/100g for South Bay and 49 MPN/100g for North Bay, with results statistically significantly higher for South Bay (paired T-Test, T=-2.16, p=0.035, Appendix 6).

A total of 14 results of over 230 *E. coli* MPN/100g were reported from the two sites on the days when both sites were sampled. The proportions occurring at the two sites are presented in Table 11.2.

Table 11.2 Proportion of historic *E. coli* sampling result over 230 MPN/100g by site when both sites were sampled on the same day

	North Bay	South Bay
No. results > 230 MPN/100g	7 (13%)	7 (13%)
No. results < 230 MPN/100g	45	45

For the subset of data where both sites had been sampled on the same day, they showed an identical proportion of results over 230 *E. coli* MPN/100g. However, as they are geographically separate and potentially impacted by different sources of contamination, they have been considered separately in further analyses.

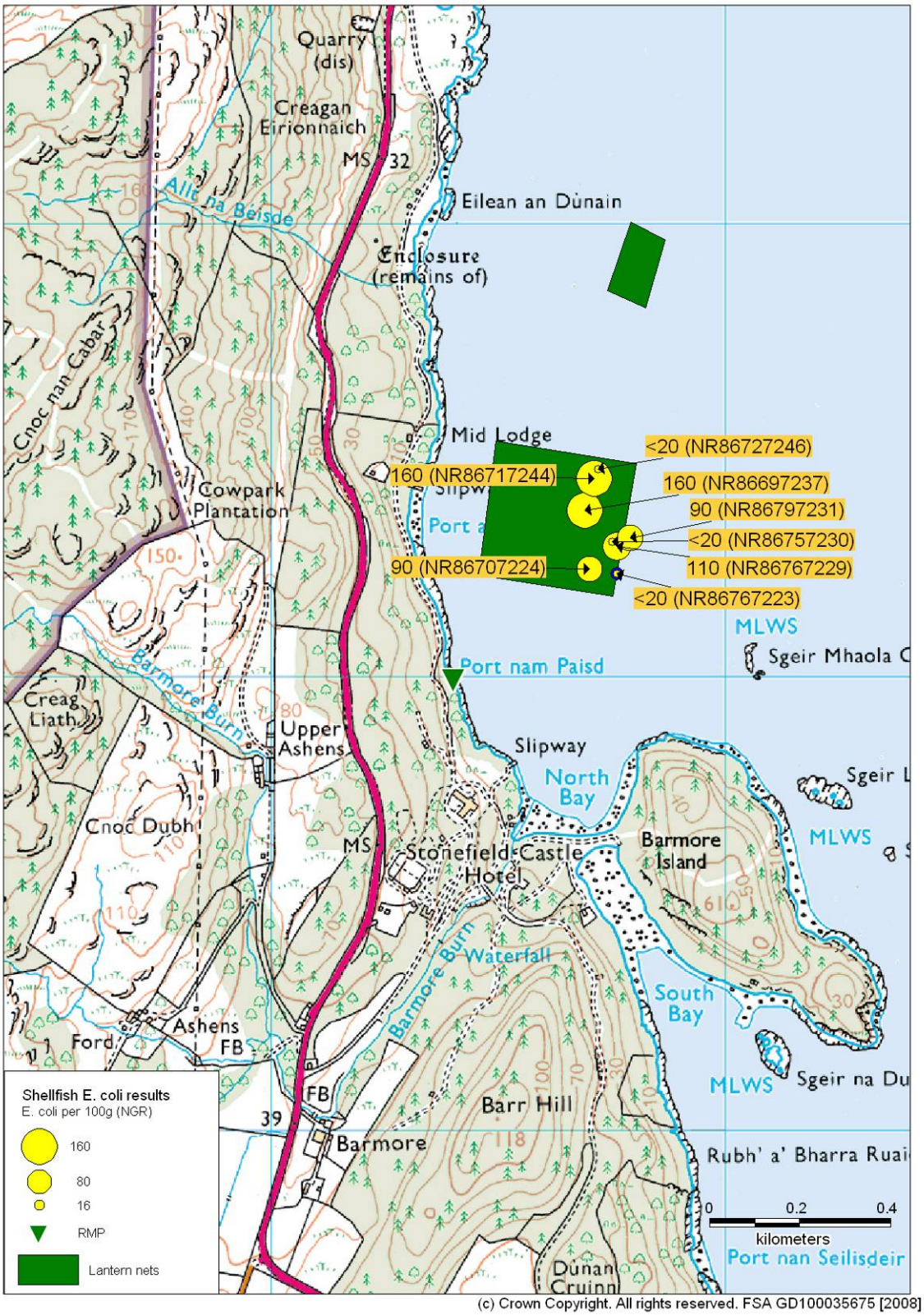

Figure 11.1 Sampling points and *E. coli* results for samples Feb - Dec 2007

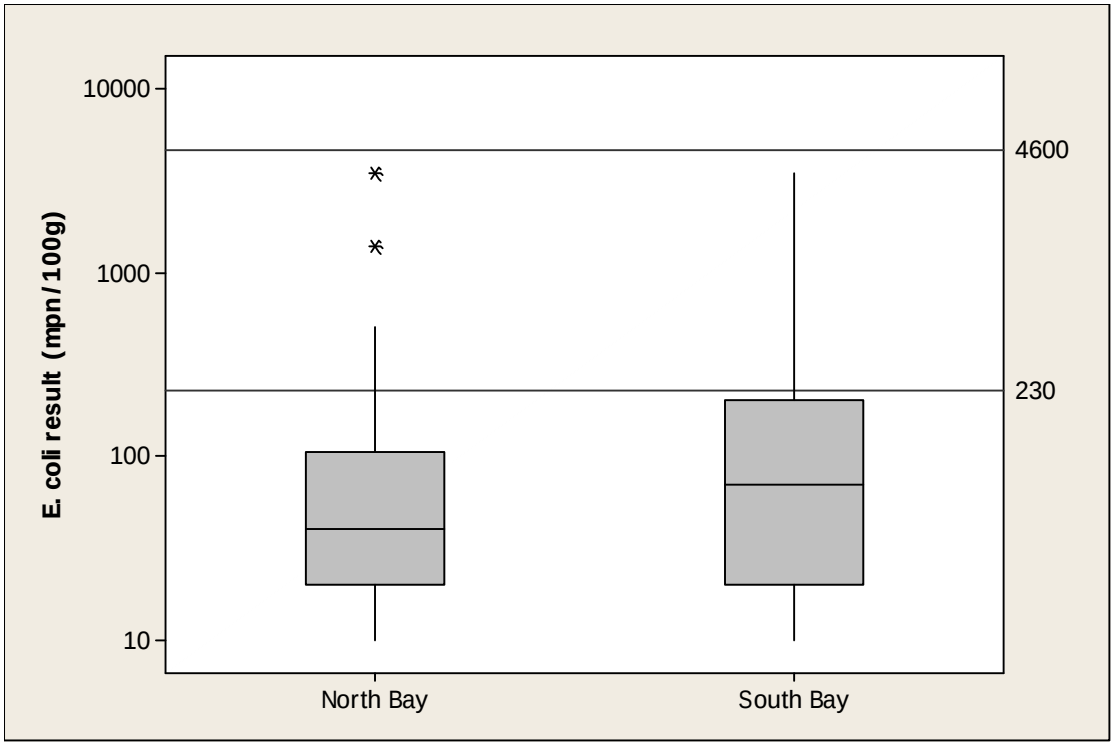

Figure 11.2 Boxplot of *E. coli* result by site for days when both sites are sampled

11.4 Overall temporal pattern of results

Figure 11.3 presents a scatter plot of individual results against date for all samples taken from Loch Fyne: Stonefield. They are also fitted with loess lines, which stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away.

No obvious overall improvement or deterioration, or trends or cycles can be seen for either area in Figure 11.3, aside from possibly a period of improved water quality around 2003 and early 2004. This may have some association with the fact that 2003 was a relatively dry year (see Section 9.1).

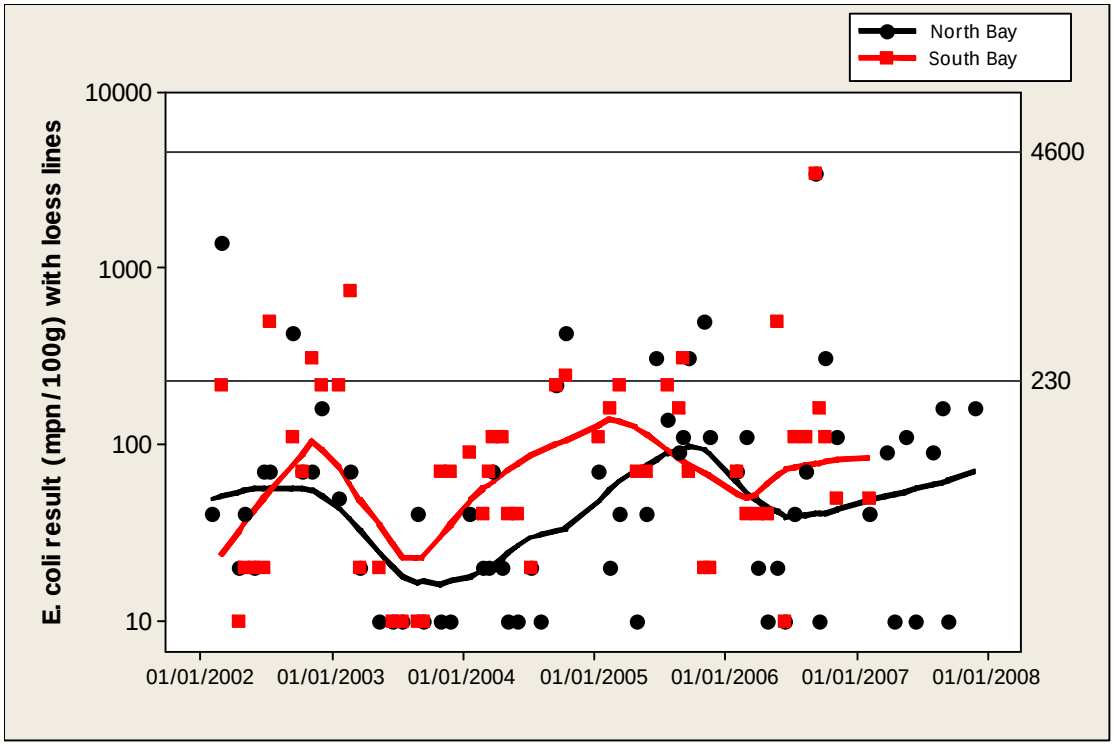

Figure 11.3 Scatterplot of *E. coli* results by site and date with loess smoother

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figure 11.4 present the geometric mean *E. coli* result by month (+ 2 times the standard error).

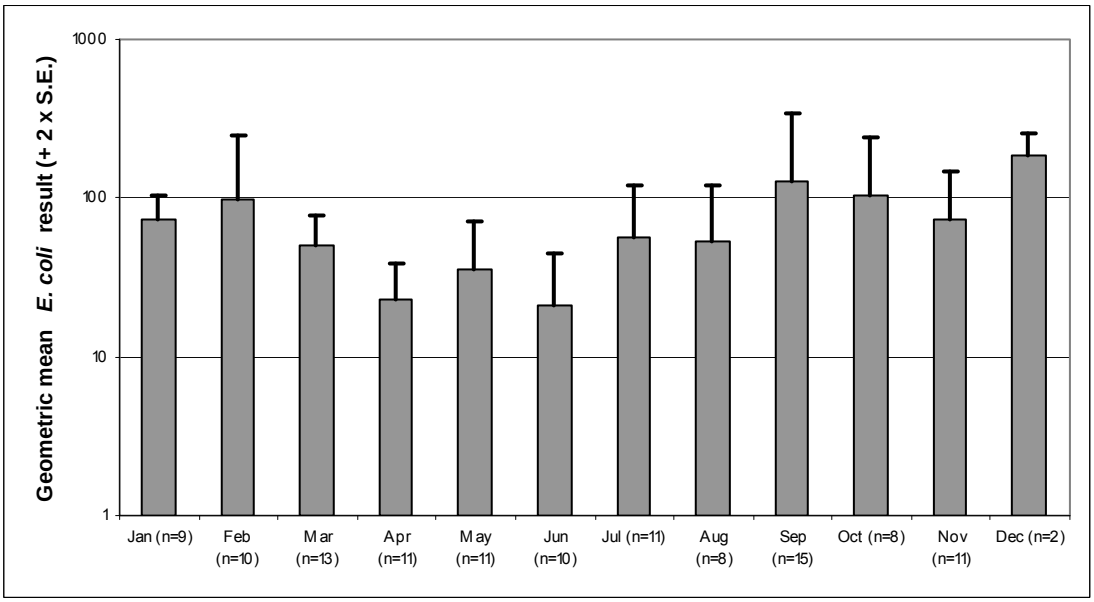

Figure 11.4 Geometric mean *E. coli* result by month (both sites combined)

Highest mean results occurred in September and December. Lowest results occurred in April and June. A tendency for higher results in the autumn and winter months is apparent. It must be noted that only two samples were submitted in December, compared to between 8 and 15 for the other months.

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

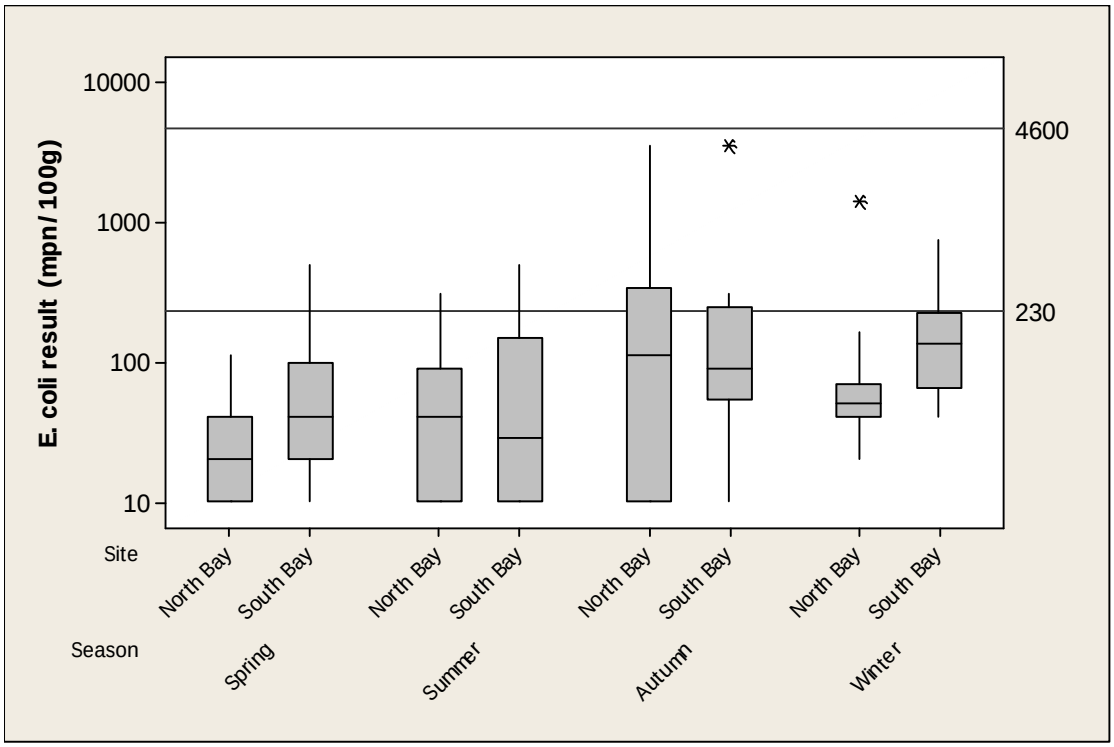

Figure 11.5 Boxplot of *E. coli* result by site and by season

Figure 11.5 shows boxplots of *E. coli* shellfish results by season for the two sites. A significant difference was found between results by season (One-way ANOVA, p=0.013, Appendix 6) for North Bay. A post ANOVA test (Tukeys comparison, Appendix 4) indicates that results for the autumn were significantly higher than those in the spring. No significant difference was found between results by season (One-way ANOVA, p=0.063, Appendix 6) for South Bay. The highest results at both sites were found during the autumn.

11.6 Comparison of results before and after construction of Tarbert STW

The Tarbert STW was commissioned in late 2005. This resulted in a change from multiple small discharges to East Loch Tarbert to one single discharge to South Bay. Figure 11.6 presents a boxplot comparing results from each site before and after this change.

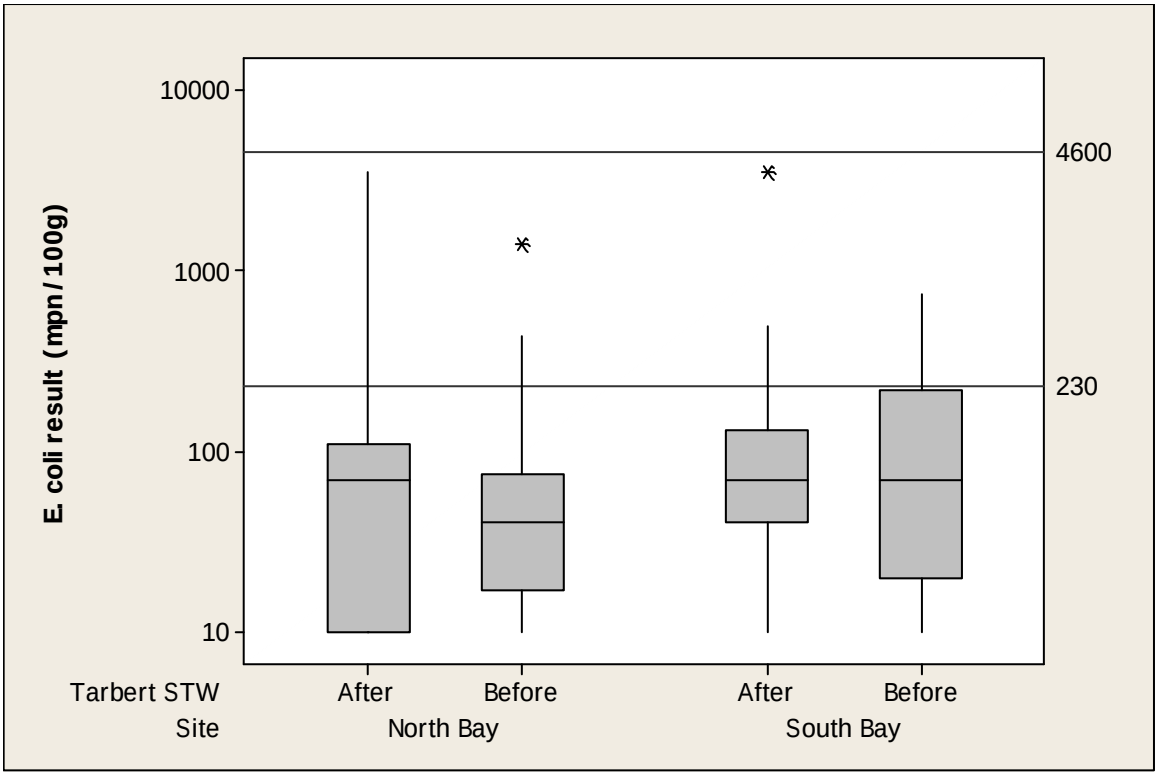

Figure 11.6 Boxplot of *E. coli* results before and after the commissioning of Tarbert STW

No significant difference was found between results before and after for either North Bay (T-test, T=0.64, p=0.527, Appendix 6) or South Bay (T-test, T=0.47, p=0.643, Appendix 6) suggesting that the discharge is not responsible for a significant increase in contamination at either site. A very slight increase in mean result following the construction was seen at both sites.

11.7 Analysis of results against environmental factors

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

11.7.1 Analysis of results by recent rainfall

The nearest weather station is Skipness House, approximately 13 km to the south of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily rainfall in mm). Figure 11.7 presents a scatterplot of *E. coli* results against rainfall for both production areas. A Spearman's rank correlation was carried out between 2 day rainfall and *E. coli* results.

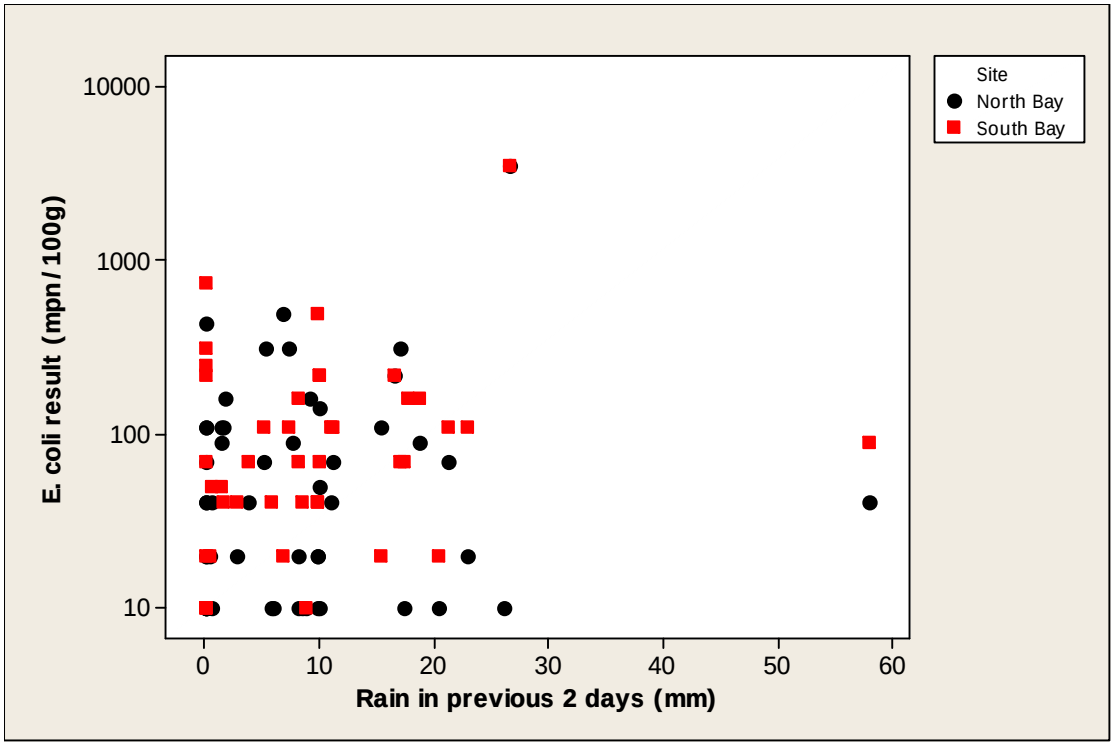

Figure 11.7 Scatterplot of *E. coli* result against rainfall in previous 2 days

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous two days for either North Bay (Spearman's rank correlation=0.096, p=0.493, Appendix 6) or South Bay (Spearman's rank correlation=0.286, p=0.063, Appendix 6).

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

A weak positive correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous seven days for both North Bay (Spearman's rank correlation=0.383, p=0.005, Appendix 6) and South Bay (Spearman's rank correlation=0.307, p=0.045, Appendix 6).

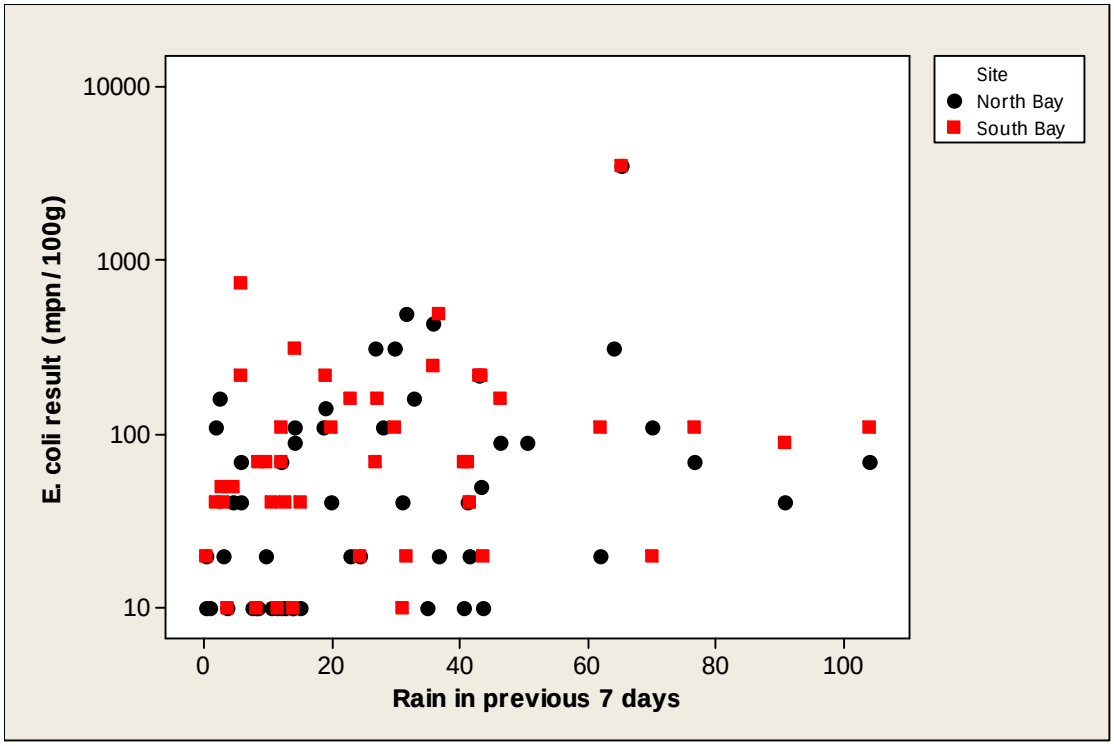

Figure 11.8 Scatterplot of *E. coli* result against rainfall in previous 7 days

11.7.2 Analysis of results by tide height and state

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the loch. Figure 11.11 presents a scatterplot of *E. coli* results by predicted height of the previous high water at East Loch Tarbert (predictions from Totaltide tidal prediction software). It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

The coefficient of determination indicates that there was no relationship between the *E. coli* result and predicted height of the previous tide for North Bay (Adjusted R-sq=0.4%, p=0.263, Appendix 4) or for South Bay (Adjusted R-sq=0.0%, p=0.472, Appendix 4).

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in shellfish can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results.

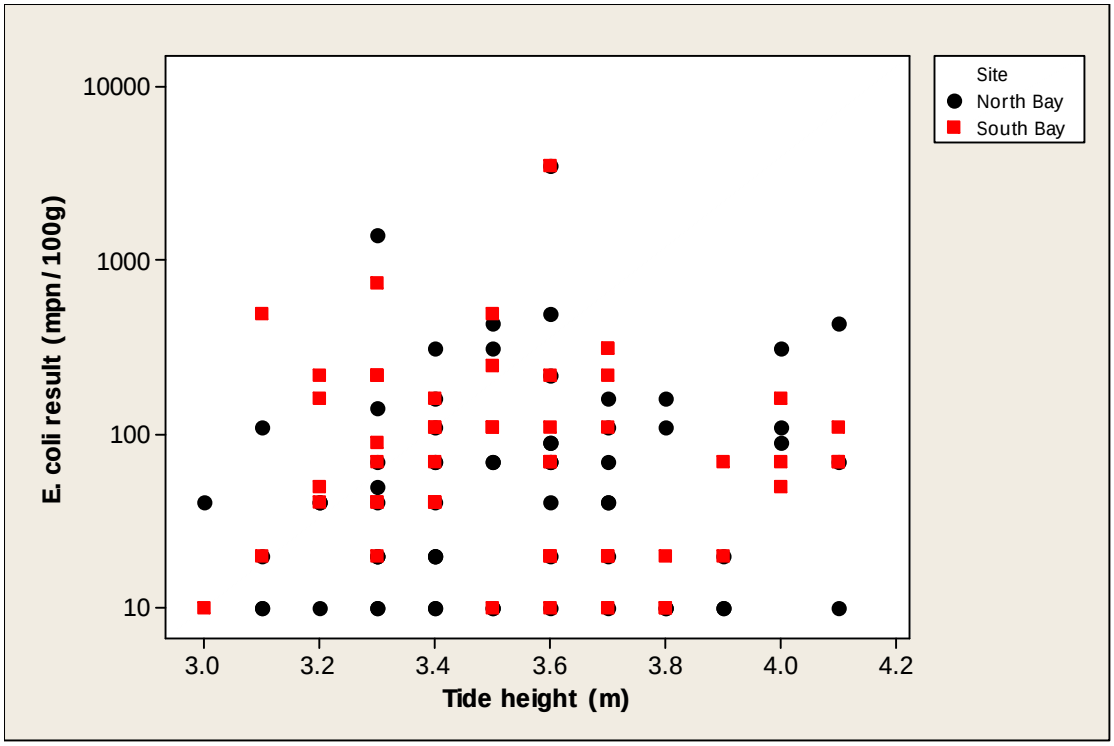

Figure 11.9 Scatterplot of *E. coli* result by tide size

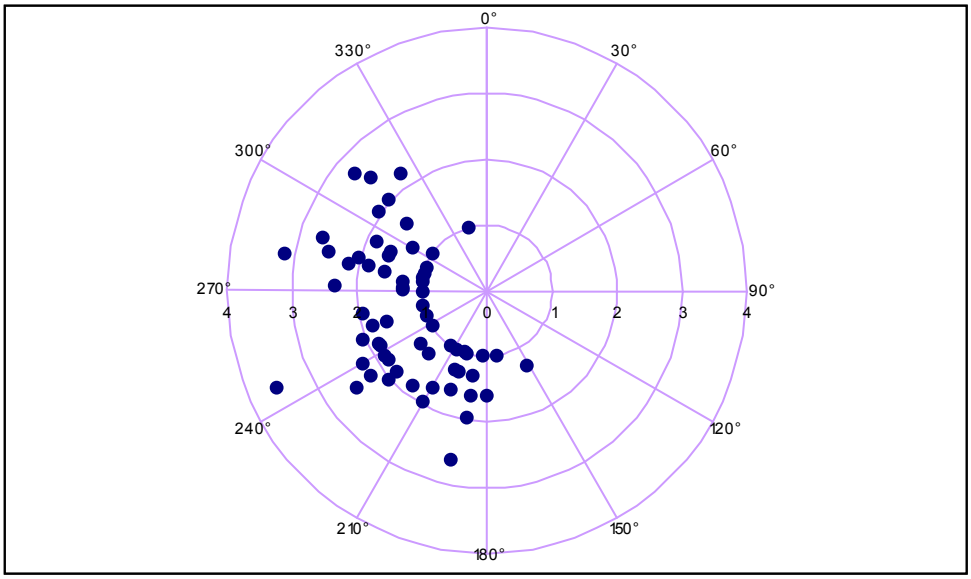

Figure 11.10 Polar plot of log10 *E. coli* result tidal state (North Bay). High water is at 0 degrees, low water is at 180 degrees

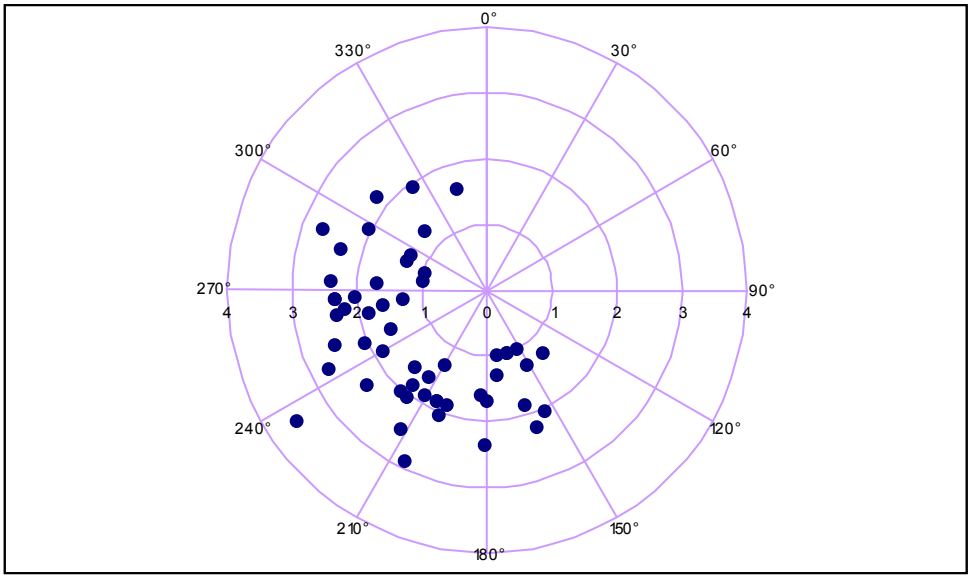

Figure 11.11 Polar plot of Log10 *E. coli* result by tidal state (South Bay)
High water is at 0 degrees, low water is at 180 degrees

A significant correlation was found between tidal state and *E. coli* result at both North Bay (circular-linear correlation, r=0.227, p=0.04, Appendix 6) and South Bay (circular-linear correlation, r=0.061, p<0.001, Appendix 6). For North Bay mean results were higher on average during the second half of the flood tide, and for South Bay results were higher on average during the first half of the flood tide. During the flood tide the water flows in a northerly direction. No samples were collected during the majority of the ebb tide until around low water at either site. The reasons for this are unclear.

11.7.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns.

Figure 11.12 shows the shellfish *E. coli* results for both North Bay and South Bay plotted against the seawater temperature at time of sampling. The coefficient of determination indicates that there was no relationship between the *E. coli* result and water temperature for North Bay (Adjusted R-sq=0.0%, p=0.340, Appendix 6) or for South Bay (Adjusted R-sq=0.0%, p=0.911, Appendix 6).

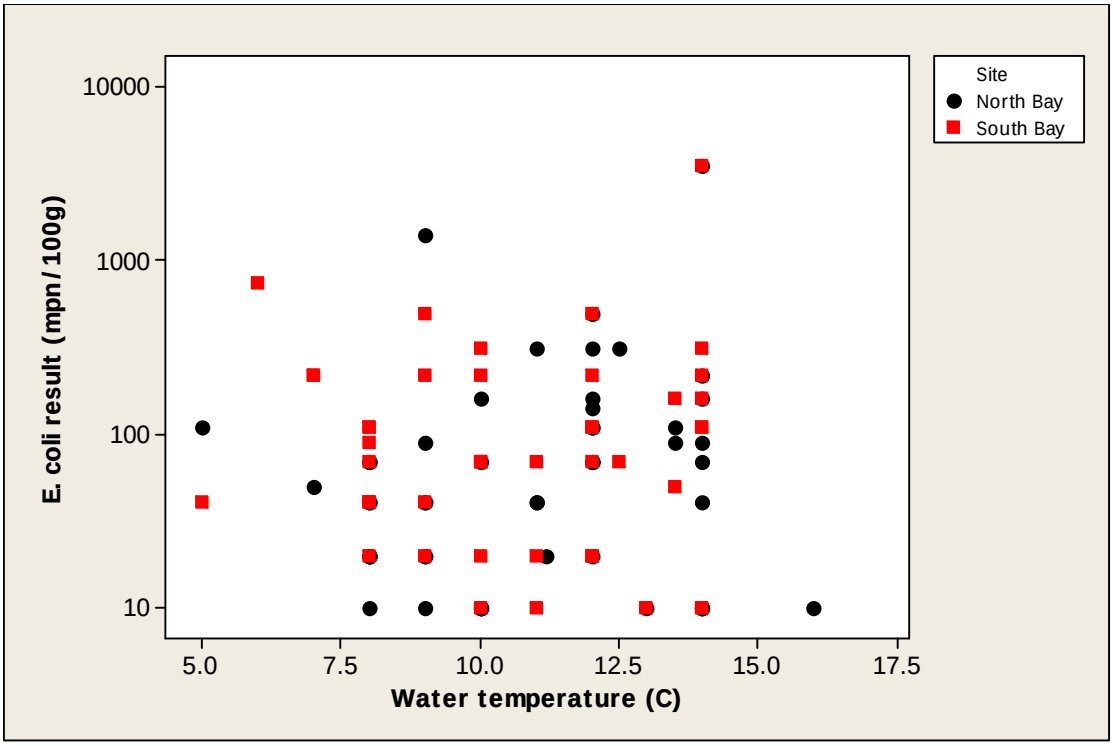

Figure 11.12 Scatterplot of *E. coli* result by water temperature

11.7.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns in the production area. However, due to the distance between the production area and the nearest weather station for which wind records were available, and differences in local topography between the two, it was not appropriate to compare wind data and results from the two.

11.8 Evaluation of peak results

No results over 4600 *E. coli* MPN/100g were reported. Three results over 1000 *E. coli* MPN/100g were reported. The first was collected in February 2002 from the North Bay site. The second and third were both collected on the same day in September 2006, one from each site, following a period of heavy rainfall.

Table 11.3 Historical *E. coli* sampling results over 1000 MPN/100g

Collection date	*E. coli* result (MPN/100g)	Location sampled	Site	2 day rainfall (mm)	7 day rainfall (mm)	Previous tide height	Time since high water
27/02/2002	1400	NR864720	North Bay	*	*	3.3 m	09:44
07/09/2006	3500	NR864720	North Bay	26.6	65.2	3.6 m	08:31
07/09/2006	3500	NR870712	South Bay	26.6	65.2	3.6 m	08:11

* Data not available

11.9 Summary and conclusions

A statistically significant difference in mean *E. coli* result was detected between the two sites. The highest geometric mean result came from South Bay. No significant difference was found between the two sites in the proportion of results over 230 *E. coli* MPN/100g.

Although a slight increase in geometric mean result was seen at North Bay following the construction of Tarbert STW, no significant difference was found between results before and after its construction for either site suggesting that the discharge does not have a major impact on the microbiological quality of the shellfish at the two sites.

A seasonal effect was found for North Bay only, with mean results significantly higher in the autumn compared to the spring. No relationship between water temperature and *E. coli* result was found for either site.

No relationship was found between rainfall in the previous 2 days and *E. coli* result at either site. A weak positive correlation was found between rainfall in the previous 7 days at both sites. This effect was stronger at the North Bay site.

No significant influence of tide size (i.e. spring or neap) was found at either site. Significant correlations between results and tidal state at time of sampling (i.e. high/low and ebb/flood) were found at both sites. Highest results were experienced on the second half of the flood tide at North Bay, and the first half of the flood tide at South Bay. This suggests that sources of contamination on the west shore of the Loch, to the south of the fisheries may be of importance. It must be noted however, that few samples were taken on an ebbing tide from either site, so whether levels of contamination may be higher at this state of the tide is uncertain.

The two highest individual results occurred in the early autumn following a wet week with westerly winds. Both these samples were taken on the same date, one from each site.

The relatively small amount of data available precluded the assessment of the effect of interactions between environmental factors on the *E. coli* concentrations in shellfish.

11.10 Sampling frequency

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

12. Designated Shellfish Growing Waters Data

The area considered in this report is also a shellfish growing water which was designated in 1998 and has been monitored by SEPA. The growing water encompasses the entire shoreline of Loch Fyne aside from a few stretches around large settlements, and the full extent of this is not shown on Figure 12.1. There are 3 designated monitoring points, one at Loch Fyne Head (48 km north east of the Loch Fyne: Stonefield production area), one at Loch Gair (15 km north of the production area), and one at Whitehouse Bay, 5 km to the north of the production area.

The monitoring requires the following testing:

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

Monitoring results for faecal coliforms in shore mussels from 1999 to the end of 2007 have been provided by SEPA. These results are presented in Table 12.1.

Figure 12.1 Designated shellfish growing water and the Whitehouse Bay monitoring point

Table 12.1 SEPA faecal coliform results (faecal coliforms/100ml[1]) for non-commercial shellfish gathered from Whitehouse Bay.

	Site	Loch Fyne outer/Whitehouse Bay
	OS Grid Ref.	NR 864 720/NR 85111 81114
	Q3	1600
1999	Q4	
	Q1	40
	Q2	
	Q3	20
2000	Q4	310
	Q1	110
	Q2	<20[2]
	Q3	20
2001	Q4	
	Q1	250
	Q2	40
	Q3	410
2002	Q4	70
	Q1	750
	Q2	
	Q3	250
2003	Q4	110
	Q1	110
	Q2	40
	Q3	2200
2004	Q4	220
	Q1	70
	Q2	2200
	Q3	220
2005	Q4	265
	Q1	<20[2]
	Q2	20
	Q3	5400
2006	Q4	24000
	Q1	700
	Q2	190
	Q3	180000
2007	Q4	265

[1] The faecal coliform determinand in the Shellfish Waters Directive is expressed per 100 ml, rather than the more usual per 100 g used in shellfish hygiene – in practice, the difference is not important

[2] Assigned a nominal value of 10 for the purpose of calculating the geometric mean

The geometric mean result of all shore mussel samples was 236 faecal coliforms / 100 ml. Results ranged from <20 to 180000 faecal coliforms/100 ml. Results were highest for quarter 3, and lowest for quarter 2, but differences between results by quarter were not significant (One-way ANOVA, p=0.193, Appendix 4). This is a similar seasonal pattern to that observed for the classification samples.

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. The geometric mean level of contamination in shore mussels taken as part of the SEPA monitoring point is considerably higher than the overall geometric mean of all queen scallop samples tested for *E. coli* (57.9 MPN/100 g) as part of the classification monitoring. This is likely due to geographical differences in levels of contamination (samples were taken 5 km to the north of the production area boundary), and differences in accumulation of faecal bacteria by the two different bivalve species. The very high results obtained in the shellfish waters monitoring at Whitehouse Bay in Q4 of 2006 (24000 /100 ml) and Q3 of 2007 (180000 per 100 ml) indicates that the monitoring point at that location is subject to extreme levels of faecal contamination on occasions.

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

13. River Flow

The following rivers and streams were measured and sampled during the shoreline survey. These represent the largest freshwater inputs into the production area. Heavy rain had fallen prior to the survey, and logging was underway in the hills above North Bay. The measurements and calculated loadings are given in Table 13.1 and the locations and loadings shown in Figure 13.1 (Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1 x 10^3, in this case it would be written as 1E+3).

Table 13.1 River loadings for Loch Fyne Stonefield

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow (m^3/day)	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	NR 86316 72185	Stream	0.50	0.08	0.351	1210	100	$1.2x10^5$
2	NR 86320 72426	Stream*	1.10	0.15	0.229	3270	300	$9.8x10^5$
3	NR 86304 72827	Stream*	0.75	0.10	0.291	1890	200	$3.8x10^5$
4	NR 86298 72864	Allt na Beisde	0.90	0.28	0.908	19800	<100****	$9.9x10^5$
5	NR 87322 69864	Stream	0.15	0.02	0.333	86	<100****	$4.3x10^3$
6	NR 86991 70235	Allt an Luaidh	1.60	0.08	1.001	11100	<100****	$5.5x10^5$
7	NR 86534 71617	Barmore Burn	3.30	**	**	18000	200	$3.6x10^6$
8	NR 86233 73799	Stream	0.98	0.08	0.194	1310	<100****	$6.6x10^4$
9	NR 86284 73981	Abhainn Strachainn	7.00	0.12	0.543	39400	100	$3.9x10^6$
10	NR 86142 75236	Allt Airigh-na-brodaig	***	***	***	10200	<100****	$5.1x10^5$
11	NR 85931 77180	Artilligan Burn	0.70	0.25	1.750	26500	<100****	$1.3x10^6$
12	NR 84974 79305	Stronchullin Burn	9.20	**	**	66600	100	$6.7x10^6$

* turbid due to logging activity
**depth and flow measured at several points across the transect, individual measurements not shown
***measured in two separate sections, individual measurements not shown
**** Assigned a nominal value of 50 for calculation of loading

Stream inputs had levels of *E. coli* up to 300 cfu/100 ml. The two streams discoloured by logging activities had levels of *E. coli* of 200 and 300 cfu/100 ml, and those unaffected (10 streams) had levels of <100 to 200 cfu/100 ml. The levels of *E. coli* in the streams sampled was relatively low in comparison with that of streams sampled during surveys of other areas. This is likely to be primarily due to the areas drained being almost entirely forested, and hence devoid of livestock.

Of the streams listed here, six streams with a total loading of $6.1x10^6$ *E. coli*/day discharge within 1 km of the North Bay site, whereas only two (with a total loading of $5.6x10^5$ *E. coli*/day) discharge within 1 km of the South Bay site. Therefore it is possible that the North Bay site will be more affected by contamination carried into the loch from land runoff of local origin. However, these inputs are only very small fraction of all freshwater inputs to Loch Fyne. Salinity measurements taken during the shoreline survey were very similar at

North Bay and South Bay suggesting that overall freshwater influence is similar at the two sites although this does not mean that the impact of local freshwater sources will be the same.

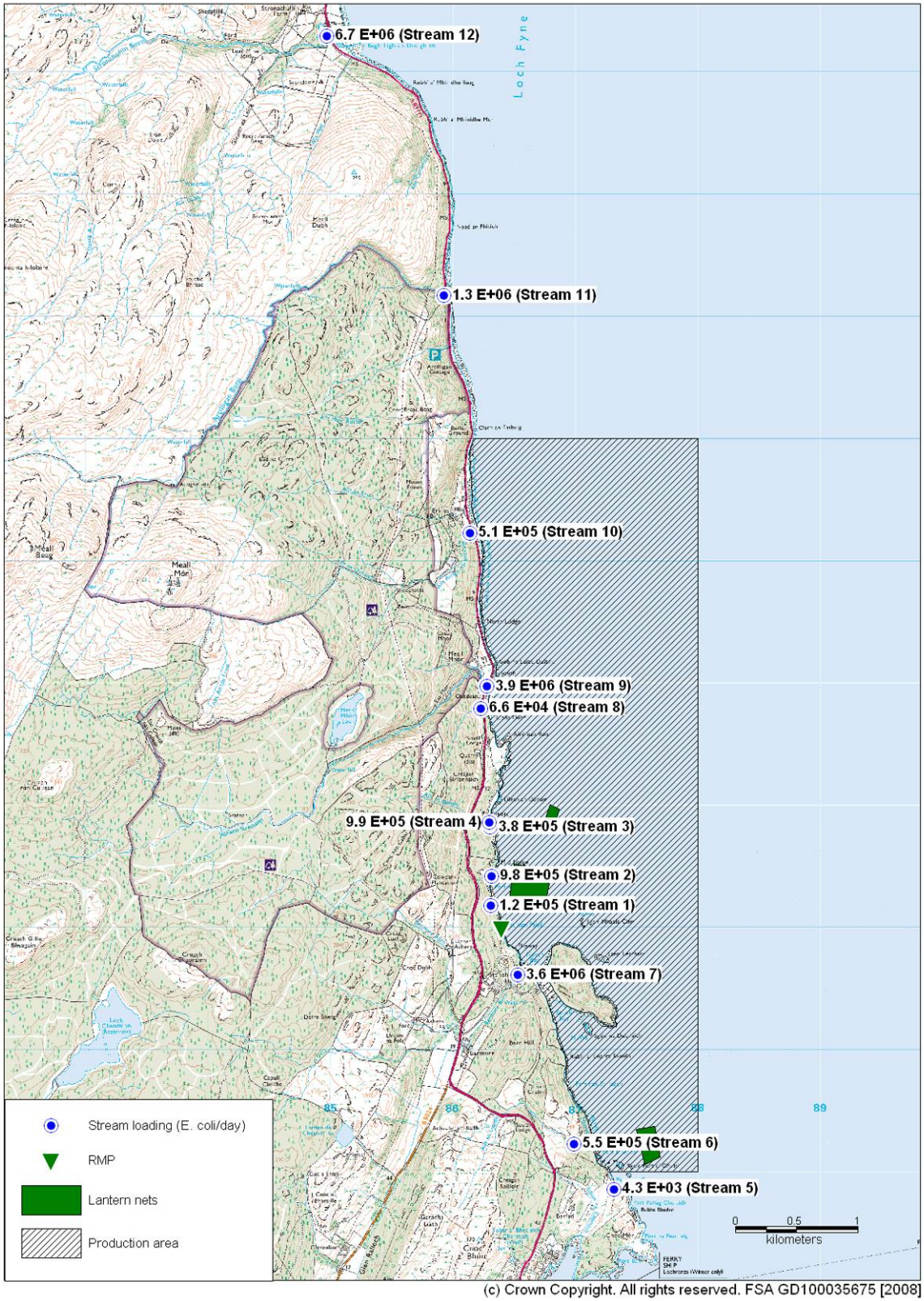

Figure 13.1 Location of significant streams and loadings

14. Bathymetry and Hydrodynamics

Loch Fyne is a 65 km long sea loch, with an area of 183.7 km^2 at high water. Its catchment area is 894 km^2. The Loch Fyne: Stonefield production area is located on the west shore, approximately 12 km from the mouth of the loch. Here, the loch is approximately 3.5 km wide and has a north south aspect.

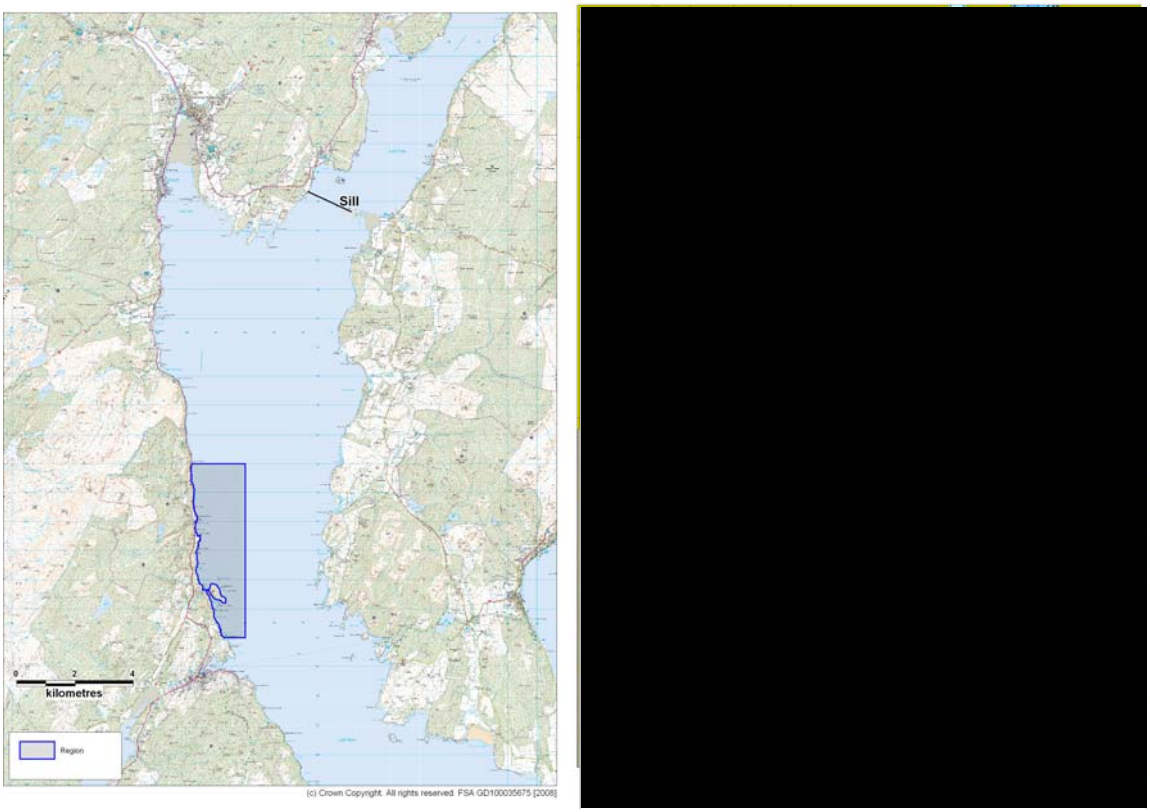

Figure 14.1 Loch Fyne Stonefield - OS
Figure 14.2 Bathymetry of Loch Fyne Stonefield (small scale)

The charts show that this part of the loch is steep sided and deep (over 100m in places). There are no sills between the fishery and the mouth of the loch. The nearest sill lies approximately 9.5 km northeast of the production area boundary and is marked in Figure 14.1. The Scottish Sea Loch Catalogue (Edwards and Sharples, 1986) indicates that the loch as a whole takes 13 days to fully flush, although this is likely to be an underestimate since it assumes the complete replacement of water on each incoming tide. In addition, each of the three basins will have its own local flushing characteristics, with the relatively open waters of the outer basin where the fishery is located being more dynamic than the inner areas. Fresh/tidal flow ratio, is low (0.2) due to the large size and volume of the loch, resulting in salinities generally close to that of open sea water. The shellfish are cultured between 100 and 500 m from the shore, suspended 10 m below the surface in depths of 20-50 m. Barmore Island protrudes into the loch between the North Bay and South Bay sites. The Tarbert sewage works discharge is in between 30 and 50 m of water about 900 m offshore and 500 m from the South Bay site.

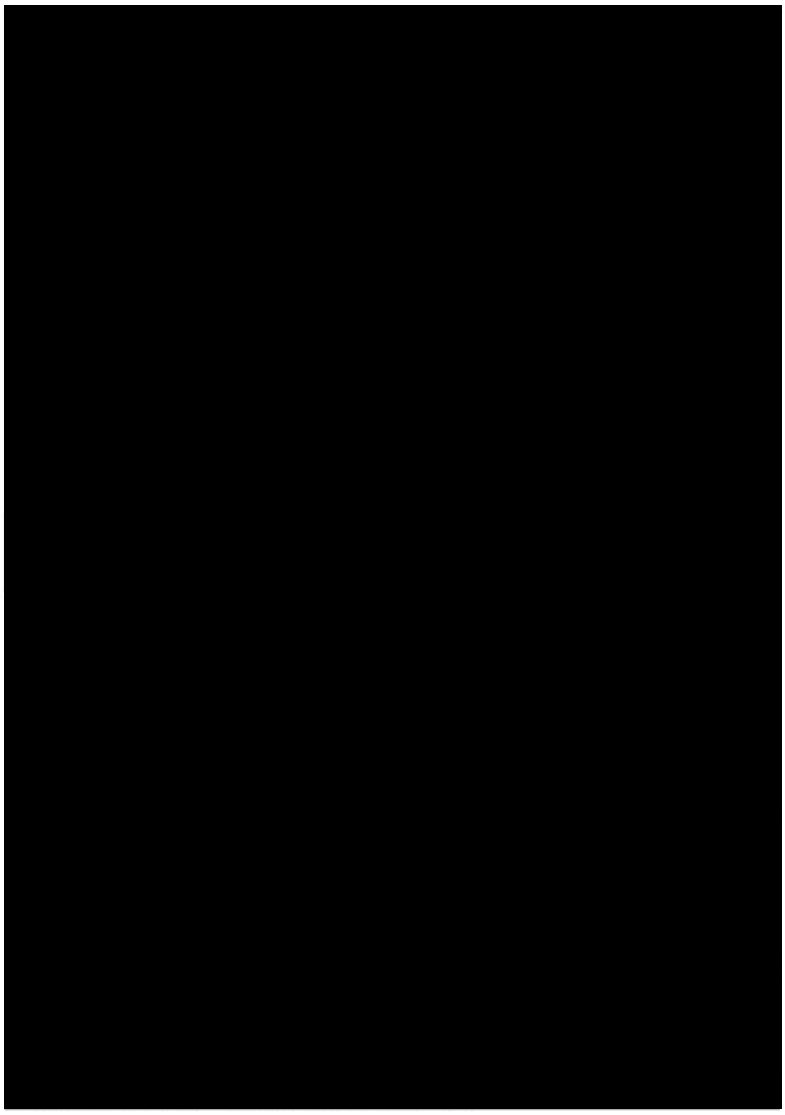

Figure 14.3 Bathymetry of Loch Fyne Stonefield (large scale).

The Tarbert sewage discharge is represented by the red square.

14.1 Tidal Curve and Description

The two tidal curves below are for East Loch Tarbert, just to the south of the production area. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 24/10/08 and the second is for seven days beginning 00.00 GMT on 1/11/08. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

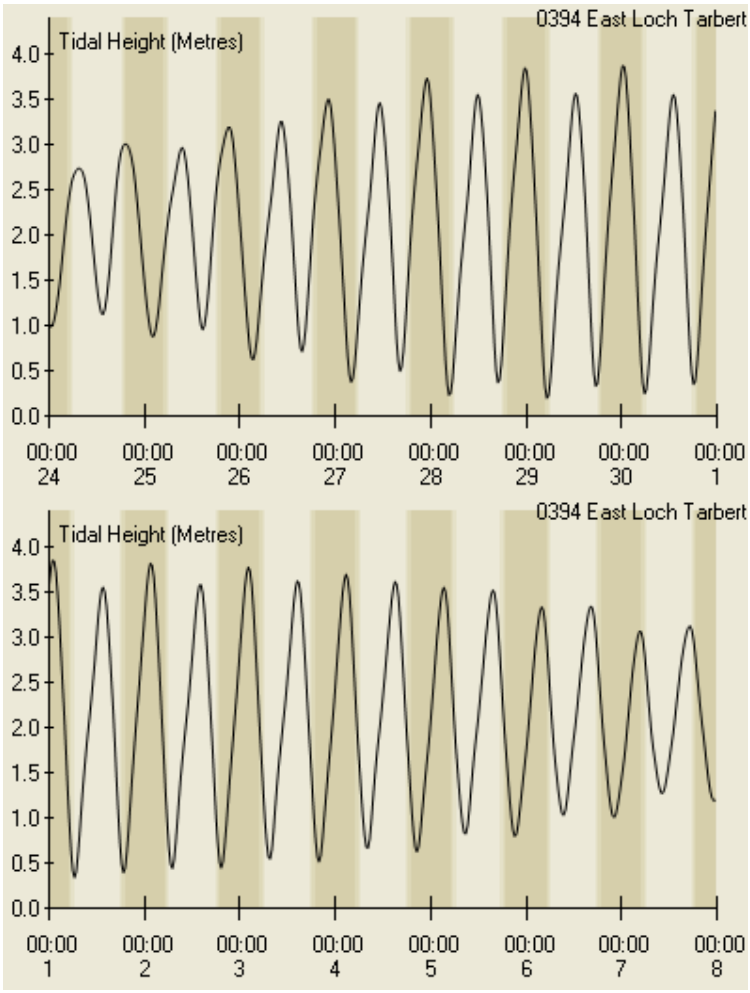

Figure 14.4 Tidal curves for East Loch Tarbert

The following is the summary description for East Loch Tarbert from TotalTide:

East Loch Tarbert is a Secondary Non-Harmonic port. The tide type is Semi-Diurnal.

HAT	4.2 m
MHWS	3.6 m
MHWN	2.9 m
MSL	2.03 m
MLWN	1.0 m
MLWS	0.3 m

Predicted heights are in metres above Chart Datum. The tidal range at spring tide is approximately 3.3 m and at neap tide 1.9 m.

14.2 Currents

Currents in the loch will be driven by a combination of tide, wind and freshwater inputs. This section aims to make a simple assessment of water movements around the area. Barmore Island, which protrudes from the shore of the loch

between the two production sites is likely to complicate long-shore flow patterns here.

The nearest tidal stream information available on the 'Total tide' tide prediction software is located about 13 km to the north of the production area, approximately at the location of the sill next to Lochgilphead. This indicates that water flows in a northerly direction on the flood tide, and a southerly direction on an ebb tide. Tidally driven current speeds here can reach 1.1 knots, but this is likely to be faster than that experienced by Loch Fyne Stonefield due to the effect of the sill at the location.

Tidally driven currents at Loch Fyne Stonefield will move along the shore in a northerly direction on the flood tide, and in a southerly direction on the ebb tide. Near to the shore, this north-south flow will be disrupted by Barmore Island, creating eddies on the downcurrent side of the island and speeding up flow around the upcurrent side of the island. Tidal currents may carry contamination from the Tarbert STW discharge towards the South Bay site on the ebb tide, and towards the North Bay site on the flood tide. However, the discharge location is further offshore than the fishery and in relatively deep water, and so it is unclear as to how much the microbiological status of the fishery will be affected by this source. Contamination from East Loch Tarbert will be carried towards the fishery on the flood tide and would be expected to primarily affect the South Bay site..

Wind driven flows are likely to be important, and may alter flow patterns around the loch considerably. They tend to create a surface flow in the direction of the wind, and a return flow along the bottom of the loch sometimes in the opposite direction but strongly influenced by bathymetry. Within the basins wind driven flows will often set up a system of circular current patterns (gyres) at the basin scale (a basin is an area between two sills). As the loch is steep sided, and has a north south aspect at this point, northerly and southerly winds will be funnelled along the loch and will have the greatest effect on circulation.

The loch has a large catchment area (894 km^2) and so freshwater inputs to the loch as a whole are high, although still smaller than tidal exchange under average conditions. The size and depth of the Loch will result in a relatively small overall salinity reduction, but during periods of high freshwater input a surface layer of fresher water may form within basins which is likely to carry higher levels of contamination from land runoff. Salinity profiles taken around the culture sites during the shoreline survey, following heavy rain and strong northerly winds indicated that salinity ranged from about 31 ppt at the surface to about 32 ppt at 10m depth confirming a lack of stratification here.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 30th October to 1st November 2008 following a period of wet weather.

The fishery consists of two sites (North Bay and South Bay) where lantern nets are deployed suspended from float lines at a depth of 10m. The South Bay site is dedicated entirely to the collection of queen scallop seed. Once settled, these are transferred to the North Bay site for ongrowing and harvesting. Pacific oysters are also grown in lantern nets from seed stock at the North Bay site only.

The main human settlement in the area is the town of Tarbert, just to the south of the production area. Waste water from here is pumped up to a sewage works to the north of the town. Here it is treated by septic tank and pumped to an outfall 900m offshore near the South Bay site at a depth of about 40m. Additionally, this system includes three CSOs which discharge intermittently to East Loch Tarbert. One of these appeared to be flowing at the time of survey. Additionally, four private septic tanks/discharges were seen spread along the shore to the north of Barmore Island.

There will be an increase in population in the area during the summer months. Large numbers of yachts visit Tarbert during the summer months, generally on their way to or from the islands. There are at least four hotels in Tarbert. Stonefield Castle operates as a hotel, and moorings in North Bay are used by the hotels customers. There are a few holiday cottages at Barfad Farm, just north of Tarbert. No campsites were seen during the course of the survey.

The land adjacent to the production area is primarily coniferous forest, with areas of deciduous forest and boggy heath. Logging activities were underway in the hills above North Bay at the time of survey. Only two very small areas of pasture were seen, supporting a total of 11 sheep. A total of 9 ducks were seen at the South Bay site, and 20 seagulls were seen on a rock by Barmore Island. Aside from these, no significant aggregations of wildlife were seen during the course of the survey.

There is a large marina in Tarbert, which is a popular stop-off point for yachts heading to and from the islands during the summer months. A total of 78 yachts were counted in Tarbert Bay, mainly in the marina. The marina appeared to have the capacity for about 3 times this number of yachts, and new pontoons were being deployed at the time of survey. Additionally, 1 small car ferry, 5 fishing vessels and 10 smaller boats were counted in Tarbert Bay. A few unoccupied moorings were seen in North Bay, by the Stonefield Castle hotel. Two fish farms with associate barges were seen to the north of North Bay.

E. coli levels in seawater samples ranged from <1 to >10000 cfu/100 ml. Highest results occurred in East Loch Tarbert, including a result of >10000 cfu/100 ml from next to the Scottish Water pumping station on the south shore (where a storm overflow was running at the time of sampling) and a result of 2000 cfu/100 ml from the pontoons within the marina. Outside of East Loch Tarbert, all

samples, with one exception, had *E. coli* levels of less than 10 cfu/100ml. The one exception was a sample taken from the shore just north of the North Bay site which gave a result of 110 *E. coli* cfu/100 ml.

Salinity profiles showed surface salinities of around 31 ppt, rising to around 32 ppt at 10 m depth. Heavy rain and strong northerly winds were experienced the day prior to the survey, so conditions on the day would not necessarily be representative of typical conditions on site.

Shellfish samples gave results of 70 to 500 *E. coli* MPN/100 g. An oyster sample tested positive (at very low levels) for norovirus genogroup I and negative for norovirus genogroup II. No samples were taken from the South Bay site, as this site is only used for the collection of seed, and never holds mature stock of a harvestable size.

A number of streams discharge into the production area, draining areas of forest. Two streams discoloured by logging activities had levels of *E. coli* of 200 and 300 cfu/100 ml, and those unaffected (10 streams) had levels of <100 to 200 cfu/100 ml, so levels of contamination were relatively low in all cases.

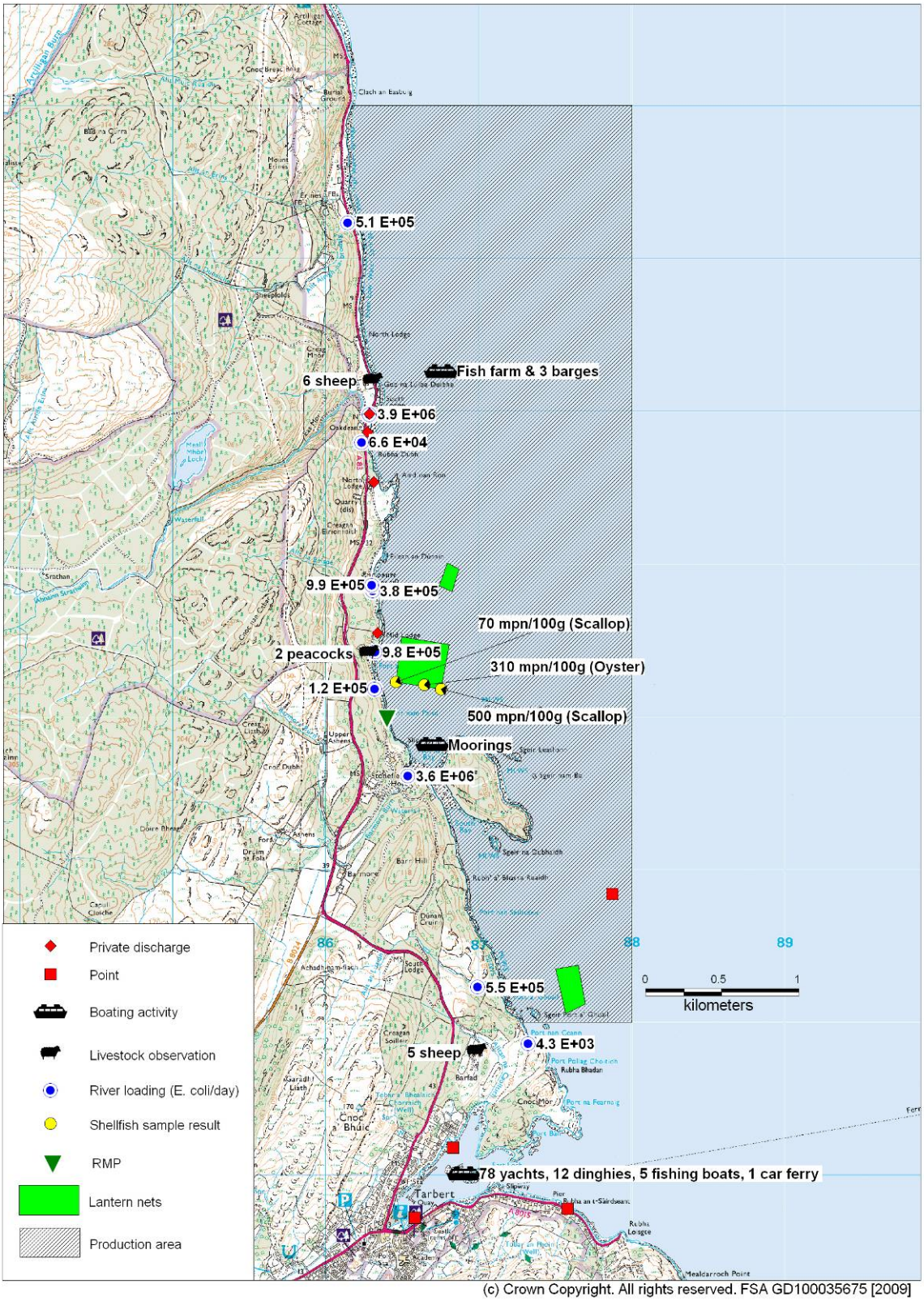

Figure 15.1 Summary of shoreline observations

16. Overall Assessment

Human sewage impacts

The only population centre in the immediate area is Tarbert, which is served by a Scottish Water sewerage system with capacity for a population equivalent of 1658. Wastewater is collected pumped from Tarbert to the treatment works to the north of the town where it is treated via septic tank then discharged approximately 900m offshore in about 40 m of water, approximately 500m north east of the South Bay site. A comparison of historic monitoring results found no significant difference between results from before and after the construction of Tarbert STW at either site. Although the results covered two separate periods and hence are not directly comparable, they do indicate that the new discharge arrangements have not resulted in significantly different levels of *E. coli* in the shellfish.

There are also three CSOs in Tarbert associated with this system, so spills to East Loch Tarbert might be expected during very wet weather. These CSOs are closest to the South Bay site, so their impacts, if any, would be more likely to have a greater impact there than at the North Bay site.

Outside of Tarbert, a further four discharges were noted during the shoreline survey, all located to the north of Barmore Island. The two closest to the fishery were septic tanks discharging to soakaway. Of the other two, one was a septic tank discharging to a stream, and one was a septic tank discharging to the shore, both to the north of the northern of the two sets of nets in North Bay. As both the former discharge to soakaway, and the latter two were a considerable distance from the fishery, none of these are expected to significantly impact on the fishery.

The marina at Tarbert is large and is busy during the summer months in particular with visiting yachts. Potentially, over 150 yachts could moor here. Additionally, there are a few more moorings in East Loch Tarbert, a ferry terminal which serves a small car ferry, and a few fishing boats operating from here. There are no pumpout facilities anywhere in Loch Fyne. There are several moorings in North Bay, by the Stonefield Castle hotel. Two fish farms with associate barges reside to the north of North Bay. Therefore there are likely to be inputs associated with boat traffic, which is heaviest in East Loch Tarbert, so these may on the whole affect the South Bay site more. On the other hand, a small number of yachts may actually be resident at the Stonefield Castle moorings in North Bay at certain times. Givne that there are no explicit controls on discharges from fishing and pleasure boats, these could give rise to faecal contamination, mainly to the south of South Bay and also to the south of the North Bay site.

Agricultural impacts

The land adjacent to the production area is hilly and forested, with almost nothing in the way of pasture. A total of only 11 sheep were seen during the shoreline

survey. Given the very low numbers and densities of livestock in the area, their contribution to the levels of contamination in the production area will be minor.

Wildlife impacts

Potential wildlife impacting on the shellfishery include deer, seals, waterbirds, dolphins and possibly otters, but impacts from these animals are likely to be minor and difficult to predict temporally and geographically. Deer inputs may be carried into the loch via streams in areas where logging is occurring.

Seasonal variation

There are at least four hotels in Tarbert. Stonefield Castle, on the shore of North Bay operates as a hotel. There are a few holiday cottages at Barfad Farm, just north of Tarbert.

The weather is colder, wetter and windier in the autumn and winter months. A significant seasonal pattern was found in historic monitoring results for North Bay, with higher *E. coli* levels in queen scallops in the autumn compared to the spring. No significant seasonal pattern was seen for South Bay. No relationship between water temperature and *E. coli* results was found at either site.

Higher numbers of visiting yachts are to be expected during the summer months. These will mainly be visiting Tarbert, but there are also a few moorings in North Bay used by guests at the Stonefield Castle Hotel.

Rivers and streams

A number of streams discharge into the production area, draining areas of mainly forest, with almost nothing in terms of pasture. Levels of contamination in these streams was relatively low in all cases, even where they were discoloured from logging activity at the time of sampling. Total stream inputs (*E. coli* / day as measured during the shoreline survey) within 1 km of the North Bay site were an order of magnitude higher than within 1 km of the South Bay site. These inputs are only very small fraction of all freshwater inputs to Loch Fyne, and salinity measurements taken during the shoreline survey were very similar at North Bay and South Bay suggesting that overall freshwater influence is similar at the two sites. Nevertheless, impacts from local stream discharges might be expected to be higher at the North Bay site.

Meteorology, hydrology, and movement of contaminants

Currents in the loch will be driven by a combination of tide, wind and freshwater inputs. Tidally driven currents at Loch Fyne Stonefield will move along the shore in a northerly direction on the flood tide, and in a southerly direction on the ebb tide. It is probable that the currents speed up and/or are diverted offshore as they pass around Barmore Island and the shallower water adjacent to it. It is possible that tidal currents will carry contamination from the Tarbert STW discharge towards the South Bay site on the ebb tide, and towards the North Bay site on the flood tide. However, given that the discharge is further offshore than

the shellfish, and in relatively deep water, it is not clear as to the extent that the discharge will impact on the fishery. Contamination from East Loch Tarbert will be carried towards the fishery on the flood tide but will principally impact on the South Bay site. Significant correlations between tidal state at time of sampling (i.e. high/low and ebb/flood) and historic *E. coli* monitoring results were found at both sites. Highest results were experienced on the second half of the flood tide at North Bay, and the first half of the flood tide at South Bay. However, very few samples were taken on the ebb tide, so levels of contamination during this part of the tidal cycle could not be assessed and so definitive conclusions with regard to tidal effects, and possible location of the main impacting sources, could not be determined.

Wind driven flows are likely to be important, and may alter flow patterns around the loch considerably. As the loch is steep sided, and has a north south aspect at this point, northerly and southerly winds will be funnelled along the loch and will have the greatest effect on circulation. No correlation was found between wind direction and historic *E. coli* monitoring results for either site.

No relationship was found between rainfall in the previous 2 days and historic *E. coli* monitoring results for either site. A significant correlation was found between rainfall in the previous 7 days and historic *E. coli* monitoring results at North Bay and South Bay, with a stronger correlation at the North Bay site. This is consistent with the shoreline survey finding that levels of contamination associated with freshwater inputs are higher at North Bay.

It must be stressed that the *E. coli* results will be a combination of many factors, including the loadings of contaminants for various sources entering the loch, the way that these are transported within the loch due to tide and wind, and the rates of uptake and depuration by the shellfish themselves. The amount of historical data was too limited to undertake an analysis of the interaction of factors.

Temporal and geographical patterns of sampling results

No overall improvement or deterioration of results was apparent over the course of the *E. coli* classification sampling history. When the results from 52 occasions when both sites were sampled were compared, *E. coli* results were significantly higher at South Bay compared to North Bay. This implies that the RMP should be set at South Bay – however, this site is used for the capture of scallop spat only and not for production. The proportion of results over 230 *E. coli* MPN/100 g and the highest *E. coli* level recorded was the same for both sites. At the North Bay site, for the small number of sampling occasions for which specific location information was available, the two highest results (both 160 *E. coli* MPN/100 g) were recorded towards the northern end of the more southerly of the two blocks of lines – the more northerly block had not been sampled on any occasion.

The Shellfish Waters Directive monitoring of faecal coliforms in mussels approximately 5 km north of the production area showed very high results on single occasions during 2006 and 2007 (24000 MPN/100 ml and 180000 MPN/100 ml respectively). This implies at least intermittent extreme faecal contamination to the north of the production area.

E. coli levels in seawater samples taken during the shoreline survey ranged from <1 to >10000 cfu/100 ml, with highest results arising in East Loch Tarbert. Outside of Tarbert Bay, all samples, with one exception, had *E. coli* levels of less than 10 cfu/100ml. The one exception was a sample taken from the shore just north of the North Bay site which gave a result of 110 *E. coli* cfu/100 ml, although no obvious sources of this contamination were found. Shellfish samples were only taken from the North Bay site and gave results of 70 to 500 *E. coli* MPN/100 g, and low levels of norovirus were detected in an oyster sample. Results of sampling undertaken as part of the shoreline survey are specific to the conditions on the date of sampling, and care should be exercised in drawing broader conclusions from this data.

Norovirus results

Of the four samples of Pacific oysters taken from the North Bay site between September 2009 and June 2009, three were positive for norovirus genogroup I (two at the limit of detection) and two were positive for norovirus genogroup II (one at the limit of detection). The sample taken in June 2009 was negative for both genogroups. The detailed results are presented in Appendix 9. These results indicate that oysters at the North Bay site are subject to human faecal contamination.

Conclusions

Contamination from the Tarbert sewage treatment works does not appear to impact significantly on the shellfishery in either North or South Bay. The greatest overall contribution of faecal contamination to the existing production area is likely to arise from the vicinity of Tarbert and East Loch Tarbert, to the South of South Bay. As the South Bay site is only used for the collection of spat and growing on of seed, and not for the production of marketable stock, there is no need for it to be classified. There are localised significant inputs to North Bay itself. Some of these are south of, or adjacent to the southern block of nets and some adjacent to, or north of the northern block. Limited geographical assessment of monitoring results across the southern block indicates that contamination may be highest at the northern end. The highest result obtained from seawater during the shoreline survey was also found on the shore to the north of the northern block. Finally, the intermittent extreme levels of contamination have been found in the Shellfish Waters Directive monitoring five kilometres to the north of the production area which indicates a source of faecal contamination impacting on that area.

17. Recommendations

The current production area boundaries for are lines drawn between NR 8617 7600 and NR 8800 7600 and between NR 8800 7600 and NR 8800 7000 and between NR 8800 7000 and NR 8727 7000 extending to MHWS. The current RMP for queen scallops is located at NR 864 720, and samples are taken from the North Bay site. The current boundaries include the South Bay site. However, this site is only used currently for the collection of queen scallop seed, which are then transferred to the North Bay site where they are grown on for a period of more than two years. Therefore, the South Bay area does not need to be classified and will be excluded from the production area as it lies nearer the most significant sources of contamination identified. It is therefore recommended that the production area should be redefined as follows: The area bounded by lines drawn between NR 8646 7352 and NR 8700 7352 and between NR 8700 7352 and NR 8700 7183 extending to MHWS.

Within the North Bay site, there are two blocks of lantern nets. There are potential sources of contamination impacting on both areas and it is presently difficult to determine on which the RMP should be located. It is therefore recommended that a bacteriological survey be undertaken at the following two points for both species:

NR 8648 7225
NR 8680 7298

and the results reviewed after 3 samples of each species have been taken from each set of lines, with at least two weeks between sampling occasions. Given the lack of mature stock on the northern block, a bag or net of adult shellfish will need to be placed at the specified location at least two weeks before being sampled.

Sampling depth is to be 10 m, the depth at which the shellfish are suspended.

Due to the seasonal changes in levels of contamination it is recommended that monthly sampling be maintained for this production area.

Note: After circulation of the draft of this report, Argyll & Bute Council advised that the northern set of lines within the North Bay site had been destroyed by a storm and subsequently removed, leaving the single remaining block of lines at the North Bay site. The RMP should therefore be set at NR 8648 7225, which is on the remaining block. If lines are replaced north of the existing block, a bacteriological survey should be undertaken to determine whether the RMP should be relocated.

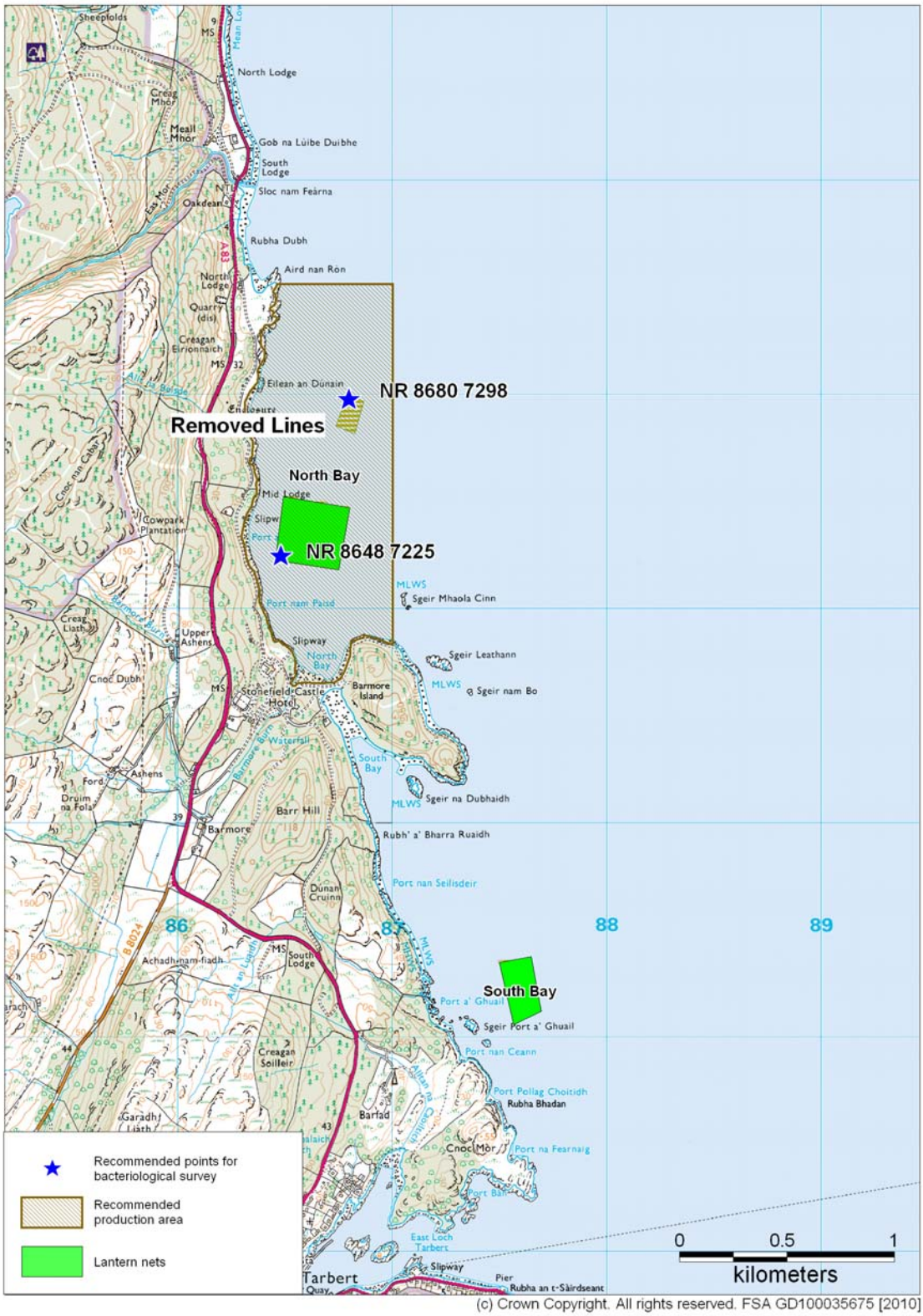

Figure 17.1 Recommended production area boundaries and points for a bacteriological survey

18. References

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Sampling Plan for Loch Fyne Stonefield

PRODUCTION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISHERY	NGR OF RMP	EAST	NORTH	TOLERANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQUENCY OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Loch Fyne Stonefield	North Bay South	AB 435	Pacific Oysters	Lantern nets	NR 8648 7225	186480	672250	10 m	10 m	Hand	Monthly	Argyll & Bute	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan
Loch Fyne Stonefield	North Bay South	AB 154	Queen Scallops	Lantern nets	NR 8648 7225	186480	672250	10 m	10 m	Hand	Monthly	Argyll & Bute	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan

Table of Proposed Boundaries and RMPs – Loch Fyne: Stonefield

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Loch Fyne Stonefield	Queens Scallops	AB 154 043 15 and AB 154 044 15	Area bounded by lines drawn between NR 8617 7600 and NR 8800 7600 and between NR 8800 7600 and NR 8800 7000 and between NR 8800 7000 and NR 8727 7000 extending to MHWS	NR 864720	Area bounded by lines drawn between NR 8646 7352 and NR 8700 7352 and between NR 8700 7352 and NR 8700 7183 extending to MHWS	NR 8648 7225	Boundaries restricted to exclude South Bay site which is only used for spat collection
Loch Fyne Stonefield	Pacific oysters	AB 435 840 13	None	None	Area bounded by lines drawn between NR 8646 7352 and NR 8700 7352 and between NR 8700 7352 and NR 8700 7183 extending to MHWS	NR 8648 7225	

Geology and Soils Information

Component soils and their associations were identified using uncoloured soil maps (scale 1:50,000) obtained from the Macaulay Institute. The relevant soils associations and component soils were then investigated to establish basic characteristics. From the maps seven main soil types were identified: 1) humus-iron podzols, 2) brown forest soils, 3) calcareous regosols, brown calcareous regosols, calcareous gleys, 4) peaty gleys, podzols, rankers, 5) non-calcareous gleys, peaty gleys: some humic gleys, peat, 6) organic soils and 7) alluvial soils.

Humus-iron podzols are generally infertile and physically limiting soils for productive use. In terms of drainage, depending on the related soil association they generally have a low surface % runoff, of between 14.5 – 48.4%, indicating that they are generally freely draining.

Brown forest soils are characteristically well drained with their occurrence being restricted to warmer drier climates, and under natural conditions they often form beneath broadleaf woodland. With a very low surface % runoff of between 2 – 29.2%, brown forest soils can be categorised as freely draining (Macaulay Institute, 2007).

Calcareous regosols, brown regosols and calcareous gleys are all characteristically freely draining soils containing free calcium carbonate within their profiles. These soil types have a very low surface % runoff at 14.5%.

Peaty gleys, peaty podzols and peaty rankers contribute to a large percentage of the soil composition of Scotland. They are all characteristically acidic, nutrient deficient and poorly draining. They have a very high surface % runoff of between 48.4 – 60%.

Non-calcareous gleys, peaty gleys and humic gleys are generally developed under conditions of intermittent or permanent water logging. In Scotland, non-calcareous gleys within the Arkaig association are most common and have an average surface % runoff of 48.4%, indicating that they are generally poorly draining.

Organic soils often referred to as peat deposits and are composed of greater than 60% organic matter. Organic soils have a surface % runoff of 25.3% and although low, due to their water logged nature, results in them being poorly draining.

Alluvial soils are confined to principal river valleys and stream channels, with a wide soil textural range and variable drainage. However, the alluvial soils encountered within this region have an average surface % runoff of 44.3%, so it is likely that in this case they would be poorly draining.

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website

and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and it's potential impact on runoff.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

Gley: A sticky, bluish-grey subsurface layer of clay developed under intermittent or permanent water logging.

Podzol: Infertile, non-productive soils. Formed in cool, humid climates, generally freely draining.

Rankers: Soils developed over noncalcareous material, usually rock, also called 'topsoil'.

Regosol: coarse-textured, unconsolidated soil lacking distinct horizons. In Scotland, it is formed from either quartzose or shelly sands.

References

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

General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

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

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

Table 1 Cetacean sightings in 2007 – Western Scotland.

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

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

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

Birds

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

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

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

delawarensis) approximately 1.77 x 10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). An earlier study found that geese averaged from 5.23 to 18.79 defecations per hour while feeding, though it did not specify how many hours per day they typically feed (Bedard and Gauthier, 1986).

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

Deer

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

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

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

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

Otters

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

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

References:

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

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

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

Poppe, C., Smart, N., Khakhria, R., Johnson, W., Spika, J., and Prescott, J. (1998). Salmonella typhimurium DT104: A virulent drug-resistant pathogen. Canadian Veterinary Journal, 39:559-565.

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

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

Tables of Typical Faecal Bacteria Concentrations

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

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	282	2.8×10^{6} * (-)	2.3×10^{6}	3.2×10^{6}
Crude sewage discharges	252	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	79	3.5×10^{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	1.0×10^{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	3.3×10^{5} * (-)	2.9×10^{5}	3.7×10^{5}	184	5.0×10^{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	2.8×10^{5} * (-)	2.2×10^{5}	3.5×10^{5}	93	5.1×10^{5} * (+)	3.1×10^{5}	8.5×10^{5}
Oxidation ditch	35	2.0×10^{5}	1.1×10^{5}	3.7×10^{5}	5	5.6×10^{5}		
Trickling/sand filter	11	2.1×10^{5}	9.0×10^{4}	6.0×10^{5}	8	1.3×10^{5}		
Rotating biological contactor	80	1.6×10^{5}	1.1×10^{5}	2.3×10^{5}	2	6.7×10^{5}		
Tertiary	179	1.3×10^{3}	7.5×10^{2}	2.2×10^{3}	8	9.1×10^{2}		
Reedbed/grass plot	71	1.3×10^{4}	5.4×10^{3}	3.4×10^{4}	2	1.5×10^{4}		
Ultraviolet disinfection	108	2.8×10^{2}	1.7×10^{2}	4.4×10^{2}	6	3.6×10^{2}		

Source: Kay, D. et al (2008) Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42, 442-454.

Comparison of faecal indicator concentrations (average numbers/g wet weight) excreted in the faeces of warm-blooded animals

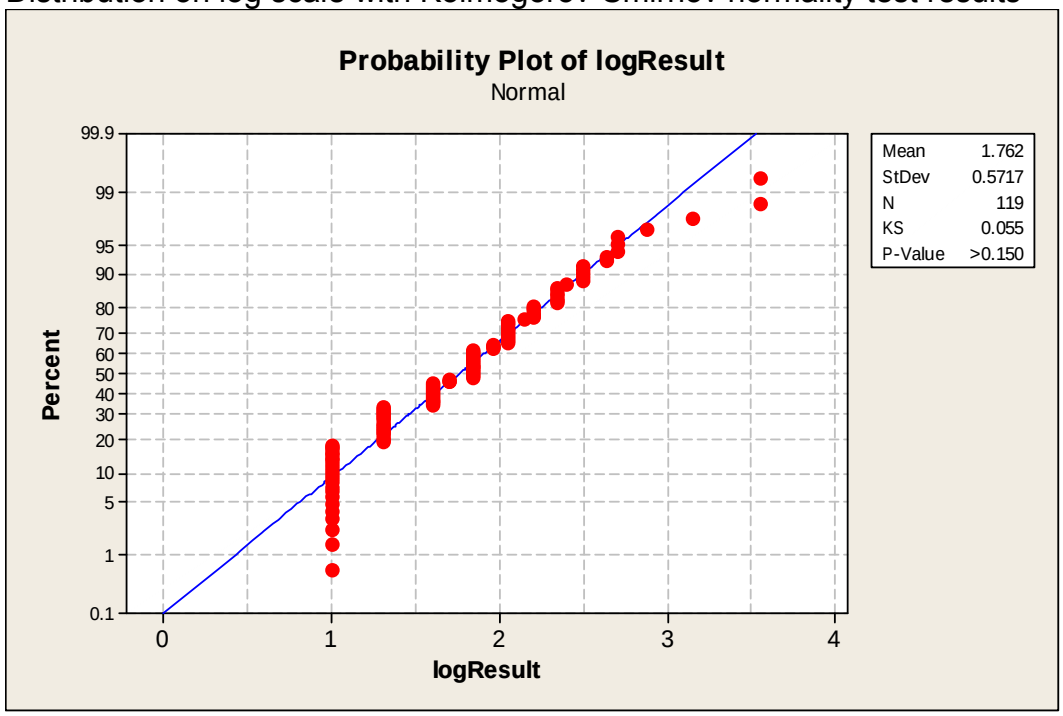
Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^{8}
Cow	230,000	23,600	5.4×10^{9}
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^{8}
Pig	3,300,000	2,700	8.9×10^{8}
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^{8}
Human	13,000,000	150	1.9×10^{9}

Source: Adapted from Geldreich 1978 by Ashbolt et al in World Health Organisation (WHO) Guidelines, Standards and Health. 2001. Ed. by Fewtrell and Bartram. IWA Publishing, London.

Statistical data

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

Distribution on log scale with Kolmogorov-Smirnov normality test results



Section 11.3. T-test comparison of results by site

```
Paired T for log result North Bay - log result South Bay

                        N     Mean   StDev  SE Mean
log result North Bay   52   1.6911  0.5941   0.0824
log result South Bay   52   1.8536  0.5530   0.0767
Difference             52  -0.1624  0.5413   0.0751


95% CI for mean difference: (-0.3131, -0.0117)
T-Test of mean difference = 0 (vs not = 0): T-Value = -2.16  P-Value = 0.035
```

Section 11.5 ANOVA comparison of results by season (North Bay)

```
Source        DF      SS     MS     F      P
season north   3   3.524  1.175  3.89  0.013
Error         61  18.418  0.302
Total         64  21.943

S = 0.5495   R-Sq = 16.06%   R-Sq(adj) = 11.93%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev   -+---------+---------+---------+--------
1      19  1.4103  0.3588   (-------*-------)
2      17  1.5759  0.5080        (--------*-------)
3      18  1.9919  0.7424                  (-------*--------)
4      11  1.8175  0.5103             (----------*----------)
                          -+---------+---------+---------+--------
                          1.20      1.50      1.80      2.10

Pooled StDev = 0.5495


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

Individual confidence level = 98.96%


season north = 1 subtracted from:

season
north     Lower  Center   Upper  --------+---------+---------+---------+-
2       -0.3195  0.1656  0.6508             (--------*---------)
3        0.1036  0.5816  1.0596                     (---------*--------)
4       -0.1433  0.4072  0.9578                (----------*----------)
                                --------+---------+---------+---------+-
                                     -0.50      0.00      0.50      1.00


season north = 2 subtracted from:

season
north     Lower  Center   Upper  --------+---------+---------+---------+-
3       -0.0755  0.4160  0.9074                (---------*---------)
4       -0.3207  0.2416  0.8039             (----------*----------)
                                --------+---------+---------+---------+-
                                     -0.50      0.00      0.50      1.00


season north = 3 subtracted from:

season
north     Lower   Center   Upper  --------+---------+---------+---------+-
4       -0.7305  -0.1743  0.3818     (-----------*----------)
                                --------+---------+---------+---------+-
                                     -0.50      0.00      0.50      1.00
```

Section 11.5 ANOVA comparison of results by season (South Bay)

```
Source        DF      SS     MS     F      P
season south   3   2.118  0.706  2.59  0.063
Error         50  13.623  0.272
Total         53  15.741

S = 0.5220   R-Sq = 13.46%   R-Sq(adj) = 8.26%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  ------+---------+---------+---------+---
1      16  1.7045  0.4375     (--------*--------)
2      12  1.6277  0.6122  (---------*---------)
3      16  2.0147  0.5971               (--------*--------)
4      10  2.1248  0.3771                 (----------*----------)
                          ------+---------+---------+---------+---
                              1.50      1.80      2.10      2.40

Pooled StDev = 0.5220
```

Section 11.6 T-test comparison of results before and after the construction of Tarbert STW (North Bay)

```
Two-sample T for North bay logres

North
bay
status   N   Mean  StDev  SE Mean
Post    21  1.713  0.645     0.14
Pre     42  1.636  0.549    0.085


Difference = mu (Post) - mu (Pre)
Estimate for difference:  0.077
95% CI for difference:  (-0.257, 0.411)
T-Test of difference = 0 (vs not =): T-Value = 0.47  P-Value = 0.643  DF =
34
```

Section 11.6 T-test comparison of results before and after the construction of Tarbert STW (South Bay)

```
Two-sample T for South Bay logres

South
Bay
Status   N   Mean  StDev  SE Mean
Post    13  1.971  0.618     0.17
Pre     39  1.848  0.522    0.084


Difference = mu (Post) - mu (Pre)
Estimate for difference:  0.123
95% CI for difference:  (-0.278, 0.524)
T-Test of difference = 0 (vs not =): T-Value = 0.64  P-Value = 0.527  DF =
18
```

Section 11.7.1 Spearmans Rank correlation of results and rain in previous 2 days (North Bay)

```
Pearson correlation of 2dayrainrankednorth and resultrankednorth = 0.096
P-Value = 0.493
```

Section 11.7.1 Spearmans Rank correlation of results and rain in previous 2 days (South Bay)

```
Pearson correlation of 2drainranksouth and resultrankedsouth = 0.286
P-Value = 0.063
```

Section 11.7.1 Spearmans Rank correlation of results and rain in previous 7 days (North Bay)

```
Pearson correlation of 7dayrainrankednorth and resultrankednorth = 0.383
P-Value = 0.005
```

Section 11.7.1 Spearmans Rank correlation of results and rain in previous 7 days (South Bay)

```
Pearson correlation of 7drainranksouth and resultrankedsouth = 0.307
P-Value = 0.045
```

Section 11.7.2 Regression analysis - Result versus height of previous tide (North Bay)

```
The regression equation is
logres north = 0.604 + 0.306 Tide size north


Predictor          Coef  SE Coef     T      P
Constant         0.6038   0.9585  0.63  0.531
Tide size north  0.3058   0.2707  1.13  0.263


S = 0.584276   R-Sq = 2.0%   R-Sq(adj) = 0.4%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.4357  0.4357  1.28  0.263
Residual Error  63  21.5069  0.3414
Total           64  21.9426


Unusual Observations

      Tide
      size  logres
Obs  north   north     Fit  SE Fit  Residual  St Resid
  2   3.30  3.1461  1.6130  0.0957    1.5331      2.66R
 53   3.60  3.5441  1.7047  0.0749    1.8393      3.17R

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

Section 11.7.2 Regression analysis - log Result versus versus height of previous tide (South Bay)

```
The regression equation is
logres south = 2.55 - 0.197 tide size south


Predictor           Coef  SE Coef      T      P
Constant          2.5545   0.9660   2.64  0.011
tide size south  -0.1969   0.2720  -0.72  0.472


S = 0.547444   R-Sq = 1.0%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.1571  0.1571  0.52  0.472
Residual Error  52  15.5841  0.2997
Total           53  15.7412


Unusual Observations

      tide
      size  logres
Obs  south   south     Fit  SE Fit  Residual  St Resid
 50   3.60  3.5441  1.8455  0.0762    1.6986      3.13R

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

Section 11.7.2 Circular-linear correlation of tide state and log result (North Bay)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 01 September 2008 11:04:39

Variables (& observations)	r	p
Angles & Linear (65)	0.227	0.04

Section 11.7.2 Circular-linear correlation of tide state and log result (South Bay)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 01 September 2008 11:11:18

Variables (& observations)	r	p
Angles & Linear (54)	0.417	1.27E-04

Section 11.7.3 Regression analysis - log Result versus water temperature (North Bay)

```
The regression equation is
Logresult North = 1.34 + 0.0321 Temp North


Predictor      Coef  SE Coef     T      P
Constant     1.3393   0.3721  3.60  0.001
Temp North  0.03206  0.03328  0.96  0.340


S = 0.587279   R-Sq = 1.8%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.3201  0.3201  0.93  0.340
Residual Error  52  17.9346  0.3449
Total           53  18.2548


Unusual Observations

      Temp  Logresult
Obs  North      North     Fit  SE Fit  Residual  St Resid
  1    9.0     3.1461  1.6279  0.1023    1.5183      2.63R
 35    5.0     2.0414  1.4996  0.2126    0.5418      0.99 X
 42   14.0     3.5441  1.7882  0.1300    1.7559      3.07R

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

Section 11.7.3 Regression analysis - log Result versus water temperature (South Bay)

```
The regression equation is
Logresult South = 1.91 - 0.0038 Temp South

Predictor       Coef  SE Coef      T      P
Constant      1.9144   0.3693   5.18  0.000
Temp South  -0.00382  0.03388  -0.11  0.911


S = 0.566956   R-Sq = 0.0%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.0041  0.0041  0.01  0.911
Residual Error  44  14.1433  0.3214
Total           45  14.1474


Unusual Observations

      Temp  Logresult
Obs  South      South     Fit  SE Fit  Residual  St Resid
 36    5.0     1.6021  1.8953  0.2079   -0.2933     -0.56 X
 43   14.0     3.5441  1.8609  0.1418    1.6831      3.07R

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

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

Section 12 ANOVA comparison of SEPA results by quarter

```
Source   DF      SS     MS     F      P
Quarter   3   4.448  1.483  1.69  0.193
Error    26  22.758  0.875
Total    29  27.206

S = 0.9356   R-Sq = 16.35%   R-Sq(adj) = 6.70%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  -----+---------+---------+---------+----
Q1     8  2.0810  0.6292       (---------*--------)
Q2     6  1.8544  0.8435  (----------*-----------)
Q3     9  2.8322  1.2372                 (--------*---------)
Q4     7  2.5639  0.8349            (----------*---------)
                          -----+---------+---------+---------+----
                             1.40      2.10      2.80      3.50

Pooled StDev = 0.9356
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Hydrographic Methods

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

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only 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.

Background processes

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

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

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

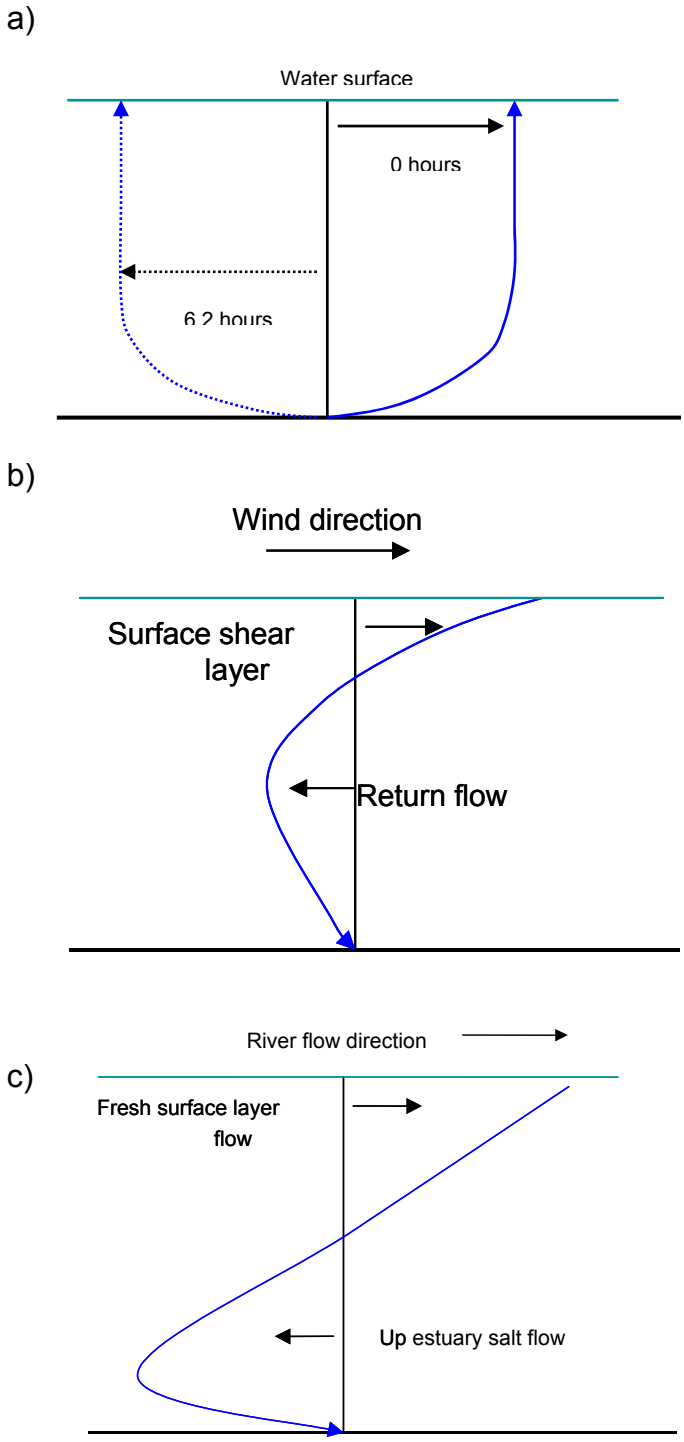

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

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

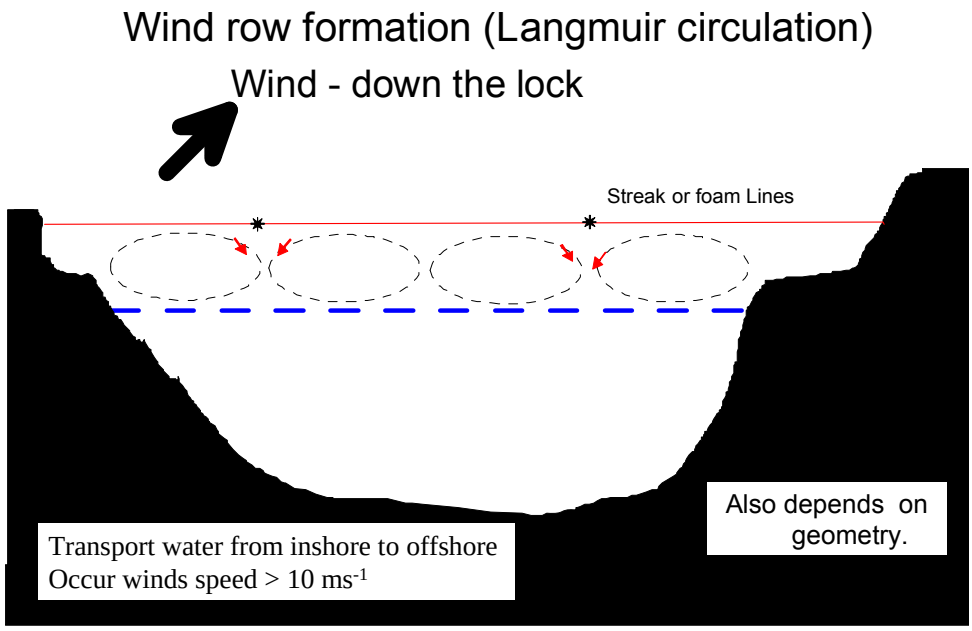

Figure 2. Schematic of wind driven ‘wind row’ currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Shoreline Survey Report

Survey Area: Loch Fyne: Stonefield (AB 435)

Scottish Sanitary Survey Project

Shoreline Survey Report

Study sites:

Production Area	Site	SIN	Species
Loch Fyne: Stonefield	Stonefield	AB 435 840 13	Pacific.oyster
Loch Fyne: Stonefield	North Bay	AB 154 043	Queen scallops
Loch Fyne: Stonefield	South Bay	AB 154 044	Queen scallops

Harvester: Mr Gordon Goldsworthy
Status: Currently classified for harvest of queen scallops only, new application for classification for oysters.
Date Surveyed: 30/9/08 to 1/10/08.
Surveyed by: Christine McLachlan, Alastair Cook
Existing RMPs: NR 864720
Area Surveyed: See Figure 1.

Weather observations

30/9/08 – 2 Km/h NW wind, rain, 12 ºC.
01/10/08 – 11 Km/h NW wind, rain, 11 ºC.
Very heavy rain had fallen on the day preceding the survey.

Site Observations

Specific observations made on site are mapped in Figure 1 and listed in Table 1. Water and shellfish samples and salinity profiles were taken at sites marked on Figures 2 and 3 and 4. Bacteriology results are given in Tables 2 and 3. Virus testing results are presented in Table 4. Salinity profiles are presented in Table 5. Photographs are presented in Figures 5-23.

Fishery

Both queen scallops and Pacific oysters are cultured at this site. Both species are grown in lantern nets suspended approximately 10 m from the surface from float lines running parallel to the shore. The lantern nets themselves are approximately 2m deep and about 50cm in diameter.

Pacific oysters are grown from 20g seed stock, and reach a harvestable size within 24 months.

Queen scallops are grown from natural seed settled onto the gear *in situ*. When the larvae are ready to settle (as determined using a plankton trawl) nets are deployed in the South Bay site onto which they settle. These are then transferred to the North Bay site, where they are grown to a harvestable size. From settlement of larvae to harvest takes around 3 years. They are either processed and frozen at the processing facility in

Tarbert, or exported live to Spain. Harvesting can occur at any time of the year and is dependent on demand.

Shellfish are only harvested from the North Bay site, with the South Bay site dedicated entirely to the collection of queen scallop seed. Within the North Bay site there are two blocks, one larger block to the south, and a smaller block to the north. At the time of survey, there were no mature shellfish on the smaller of these two blocks, so no shellfish samples were taken here. The two species are mixed together within these two blocks, with no specific area dedicated to any one species.

The fishery has been in operation for about 20 years, and 15 staff are employed as a result of the farm.

Sewage/Faecal Sources

Human – The settlement of Tarbert, approximately 1.5 km south of the South Bay site, and 3.5 km South of the North Bay site is the main population centre in the area. Waste water from Tarbert is pumped to the sewage works at the side of the A83 just north of the town. Here it is treated by screening and settlement only, pumped over Barr Hill and out to sea. The outfall is several hundred metres offshore and lies offshore from South Bay in water which is about 40 m deep. Within the town of Tarbert, two Scottish Water pumping stations and a storm holding tank were seen. Sanitary related debris was seen in the tideline in two places in Tarbert. An overflow next to the pumping station on the south shore was flowing at the time of survey, although it is uncertain whether this contained sewage. A seawater sample taken next to the discharge gave a result of >10000 *E. coli* cfu/100 ml, suggesting that it possibly did at the time. In addition to this three cast iron sewer pipes were seen on the north shore, although it is believed that these are no longer in use.

There is little in terms of human habitation on the shores adjacent to the fishery. No septic tank overflow to the shore was seen at either Stonefield Castle or the large house just to the north of here. Further north, two private discharges from individual houses were found. At the northerly extent of the survey area some sanitary related debris was found in the tideline.

There is significant boat traffic in the area including yachts, fishing vessels, fish farms and ferries.

Livestock – The land adjacent to the production area is hilly and forested, with almost nothing in the way of pasture. A total of only 11 sheep and 2 peacocks were seen during the survey.

A number of streams discharge into the production area, draining areas of forest. Water samples were taken, and discharge estimated for the larger streams. Heavy rain had fallen prior to the survey, and logging was underway in the hills above North Bay. Stream inputs had levels of *E. coli*

up to 300 cfu/100ml. The two streams discoloured by logging activities had levels of *E. coli* of 200 and 300 cfu/100ml, and those unaffected (10 streams) had levels of <100 to 200 cfu/100ml.

E. coli levels in seawater samples ranged from <1 to >10000 cfu/100ml. Highest results occurred in Tarbert Bay, including a result of >10000 cfu/100ml from next to the Scottish Water pumping station on the south shore (where a storm overflow was running at the time of sampling) and a result of 2000 cfu/100ml from the pontoons within the marina area. Outside of Tarbert Bay, all samples, with one exception, had *E. coli* levels of less than 10 cfu/100ml. The one exception was a sample taken from the shore just north of the North Bay site which gave a result of 110 *E. coli* cfu/100ml.

Salinity profiles showed surface salinities of around 31 ppt, rising to around 32 ppt at 10 m depth. Heavy rain and strong northerly winds were experienced the day prior to the survey. A few wind rows were seen.

Shellfish samples gave results of 70 to 500 *E. coli* mpn/100g. An oyster sample tested positive (at very low levels) for norovirus genogroup I and negative for norovirus genogroup II. All samples were.taken from the larger (south) block in North Bay, as this was the only place were mature stock was present. No samples were taken from the South Bay site, as this site is only used for the collection of seed, and never holds mature stock of a harvestable size.

Seasonal Population

A local sampling office (and resident of Tarbert) advised that large numbers of yachts visit Tarbert during the summer months, generally on their way to or from the islands. There are at least four hotels in Tarbert. Stonefield Castle operates as a hotel, and moorings in North Bay are used by the hotels customers. There are a few holiday cottages at Barfad Farm, just north of Tarbert. No campsites were seen during the course of the survey.

Boats/Shipping

There is a large marina in Tarbert, which is a popular stop-off point for yachts heading to and from the islands during the summer months. A total of 78 yachts were counted in Tarbert Bay, mainly in the marina. The marina appeared to have the capacity for about 3 times this number of yachts, and new pontoons were being deployed at the time of survey. Additionally, 1 small car ferry, 5 fishing vessels and 10 smaller boats were counted in Tarbert Bay. A few unoccupied moorings were seen in North Bay, by the Stonefield Castle hotel. Two fish farms with associate barges were seen to the north of North Bay.

Land Use

The surrounding land is primarily forest, with a mixture of deciduous woodlands and coniferous plantations. In the hills adjacent to North Bay, logging was taking place at the time of survey, and two streams draining this area appeared turbid as a consequence, but did not carry particularly high levels of *E. coli*. Some areas of bog and heath were also seen. Only two very small areas of pasture were seen, supporting a total of 11 sheep.

Wildlife/Birds

A total of 9 ducks were seen at the South Bay site. Also, 20 seagulls were seen on a rock by Barmore Island. Aside from these, no significant aggregations of wildlife were seen during the course of the survey. Seals and dolphins are reported to be in the area from time to time.

General observations

Recorded observations apply to the date of survey only. Animal numbers were recorded on the day from the observer's point of view. This does not necessarily equate to total numbers present as natural features may obscure individuals and small groups of animals from view.

Dimensions and flows of watercourses were estimated at the most convenient point of access and not necessarily at the point at which the watercourses enter the production area.

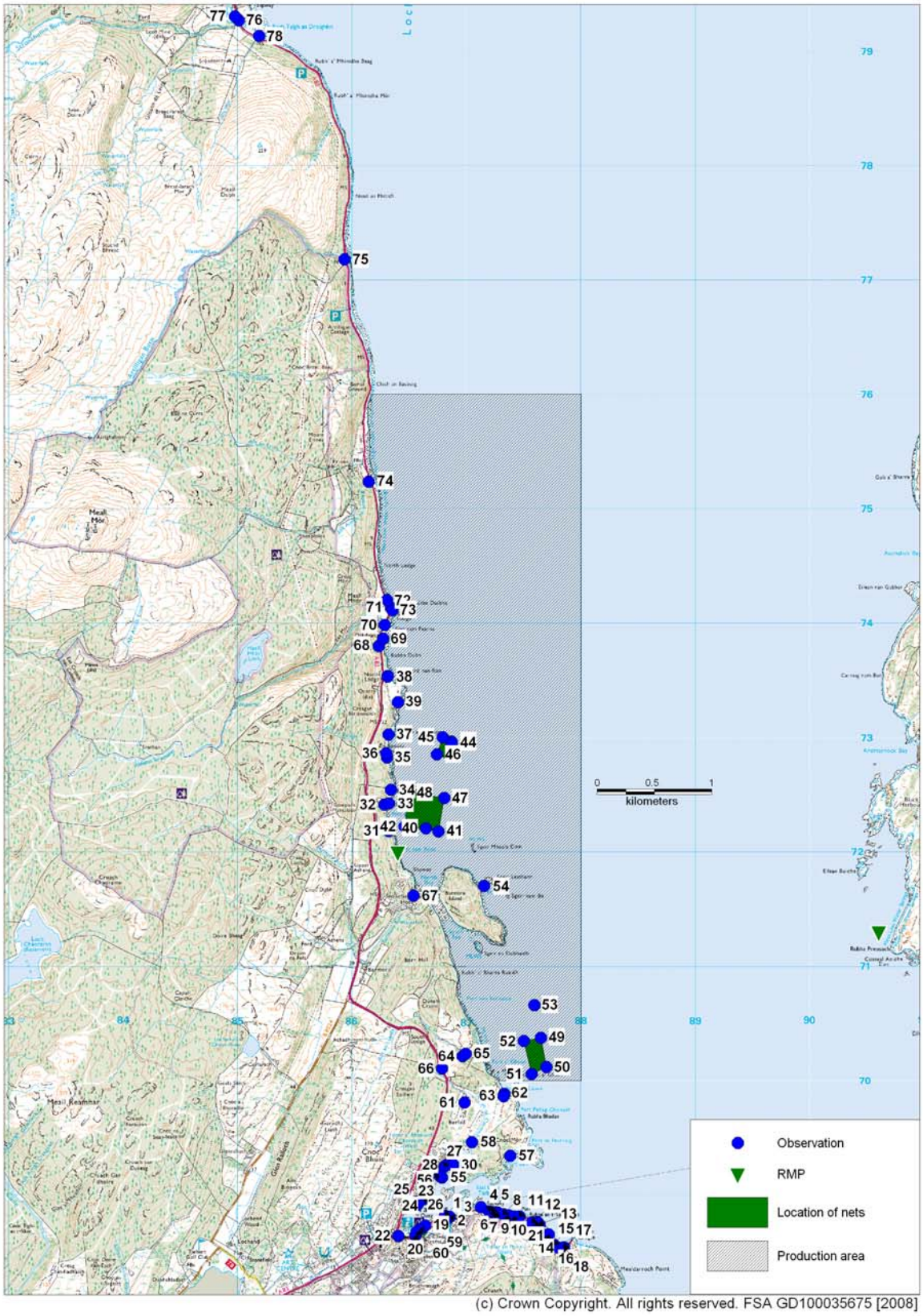

Figure 1. Map of Shoreline Observations

Table 1. Shoreline observations

No.	Date and time	Position	Photograph	Description
1	30-SEP-08 8:46:24AM	NR 86811 68818	Figure 5	30 cm ceramic pipe not flowing probably surface drain
2	30-SEP-08 8:46:56AM	NR 86852 68809		Inspection cover in layby. 1 yacht moored just off.
3	30-SEP-08 8:52:08AM	NR 87124 68894	Figure 6	Ferry terminal
4	30-SEP-08 8:54:33AM	NR 87196 68857		Inspection cover
5	30-SEP-08 8:54:57AM	NR 87228 68851		Inspection cover
6	30-SEP-08 8:55:10AM	NR 87246 68848		Stream
7	30-SEP-08 8:55:35AM	NR 87272 68846		Inspection cover
8	30-SEP-08 8:56:09AM	NR 87317 68833		Inspection cover. 2 dinghies on moorings
9	30-SEP-08 8:56:48AM	NR 87365 68823		Inspection cover
10	30-SEP-08 8:57:20AM	NR 87411 68812		Inspection cover. 30cm pipe running parallel to shore.
11	30-SEP-08 8:58:00AM	NR 87462 68811	Figure 7	30cm pipe parallel to shore broken here. Presumably no longer in use.
12	30-SEP-08 9:00:55AM	NR 87572 68761	Figures 8 and 9	Tarbert Sewage pumping station 1 (Scottish Water). Storm overflow next to it (or just surface drain) running. Pipeline continues along the shore.
13	30-SEP-08 9:03:50AM	NR 87635 68744		Inspection cover
14	30-SEP-08 9:05:15AM	NR 87718 68655		Inspection cover
15	30-SEP-08 9:06:32AM	NR 87764 68565		Stream
16	30-SEP-08 9:07:15AM	NR 87803 68538		Small culverted stream
17	30-SEP-08 9:07:48AM	NR 87848 68541		Inspection cover
18	30-SEP-08 9:10:56AM	NR 87850 68544		Inspection cover
19	30-SEP-08 9:26:56AM	NR 86636 68733		3 fishing boats tied up.
20	30-SEP-08 9:28:22AM	NR 86552 68646		Jetty, 1 fishing boat and 4 dinghies
21	30-SEP-08 9:36:08AM	NR 87617 68763		Seawater sample 1.
22	30-SEP-08 9:44:53AM	NR 86404 68642		Stream
23	30-SEP-08 9:49:25AM	NR 86564 68940	Figure 10	Presumed sewage pumping station.
24	30-SEP-08 9:52:21AM	NR 86569 68914	Figure 11	Marina, about 65 large yachts moored here. Room for about 3 times this number, and expansion of pontoons ongoing. Oil on water surface.
25	30-SEP-08 9:52:34AM	NR 86571 68914	Figure 12	20cm cast iron pipe to underwater
26	30-SEP-08 9:55:32AM	NR 86621 68961		Seawater sample 2
27	30-SEP-08 10:00:22AM	NR 86806 69247	Figure 13	Tarbert Sewage pumping station 2 (Scottish Water).
No.	**Date and time**	**Position**	**Photograph**	**Description**
28	30-SEP-08 10:01:27AM	NR 86820 69260		Stream
29	30-SEP-08 10:03:48AM	NR 86880 69267		12 yachts, 1 fishing vessel and 6 dinghies in bay on moorings.

No.	Date and time	Position	Photograph	Description
30	30-SEP-08 10:04:27AM	NR 86879 69262	Figure 14	10 cm cast iron pipe to underwater.
31	30-SEP-08 10:56:01AM	NR 86316 72185		Stream 50cmx8cmx0.351m/s. Freshwater sample 3.
32	30-SEP-08 11:01:45AM	NR 86280 72414		Wooden chalet, boathouse, 2 peacocks.
33	30-SEP-08 11:06:02AM	NR 86320 72426		Stream (turbid from logging runoff) 110cmx15cmx0.229m/s. Freshwater sample 4.
34	30-SEP-08 11:17:09AM	NR 86337 72546		Large house, inspection cover in garden, no pipe to shore found. (Grower later advised that it has a soakaway type system).
35	30-SEP-08 11:24:06AM	NR 86304 72827		Stream (turbid from logging runoff) 75cmx10cmx0.291m/s. Freshwater sample 5.
36	30-SEP-08 11:28:09AM	NR 86298 72864		Stream 90cmx28cmx0.908m/s. Freshwater sample 6.
37	30-SEP-08 11:32:06AM	NR 86318 73028		Shed.
38	30-SEP-08 11:38:40AM	NR 86311 73535		House with septic tank in lawn, no pipe to shore seen.
39	30-SEP-08 11:44:52AM	NR 86398 73311		Seawater sample 7.
40	30-SEP-08 12:55:43PM	NR 86643 72208	Figure 15	Oyster sample 1. Oyster sample norovirus1. Seawater sample 8. Salinity profile 1.
41	30-SEP-08 1:09:24PM	NR 86752 72180	Figure 16	Corner. Seawater sample 9. Scallop sample 2. Salinity profile 2.
42	30-SEP-08 1:19:57PM	NR 86456 72226		Corner. Seawater sample 10. Scallop sample 3. Salinity profile 3.
43	30-SEP-08 1:33:32PM	NR 86867 72966		Corner.
44	30-SEP-08 1:33:39PM	NR 86870 72959		Seawater sample 11. Salinity profile 4. No stock on this block so no shellfish samples.
45	30-SEP-08 1:41:51PM	NR 86791 73005		Corner.
46	30-SEP-08 1:43:17PM	NR 86739 72854		Corner.
47	30-SEP-08 1:46:10PM	NR 86804 72472		Corner.
48	30-SEP-08 1:57:35PM	NR 86493 72523		Corner.
49	30-SEP-08 2:18:12PM	NR 87649 70374		Corner. 9 ducks disturbed.
50	30-SEP-08 2:19:51PM	NR 87695 70120		Corner.
51	30-SEP-08 2:21:05PM	NR 87566 70057		Corner. Seawater sample 12. Salinity profile 5.
52	30-SEP-08 2:28:18PM	NR 87500 70348		Corner.
53	30-SEP-08 2:30:39PM	NR 87590 70662		Seawater sample 13.
54	30-SEP-08 2:37:45PM	NR 87153 71703		Seals are reported to haul out on this rock, maximum 8, none seen today but about 20 seagulls here.
55	01-OCT-08 8:47:39AM	NR 86784 69151	Figure 17	Seawater sample 14. 12 cm cast iron pipe to underwater.
56	01-OCT-08 8:50:37AM	NR 86765 69165	Figure 18	Sanitary debris in tideline.
57	01-OCT-08 9:26:07AM	NR 87380 69344		Seawater sample 15.
58	01-OCT-08 9:34:09AM	NR 87045 69463		Sanitary debris in tideline.
59	01-OCT-08 9:46:03AM	NR 86585 68700	Figure 19	Scottish Water storm holding tank, reported to overflow sometimes.
60	01-OCT-08 9:48:33AM	NR 86563 68680		Water sample 16.

61	01-OCT-08 10:29:32AM	NR 86983 69809		Field of 5 sheep.
62	01-OCT-08 10:48:42AM	NR 87329 69886		Seawater sample 17.
63	01-OCT-08 10:50:45AM	NR 87322 69864		Stream 15cmx2cmx0.333m/s. Freshwater sample 18.
64	01-OCT-08 11:15:29AM	NR 86964 70215		Nothing
65	01-OCT-08 11:18:42AM	NR 86991 70235		Stream 160cmx8cmx1.001m/s. Freshwater sample 19.
66	01-OCT-08 11:33:22AM	NR 86783 70105	Figure 20	Tarbert waste water treatment plant. No tertiary treatment. Waste water is pumped over Barr Hill and out to sea off South Bay in about 40m of water.
67	01-OCT-08 11:52:59AM	NR 86534 71617		Stream, 330cm wide, at 50cm across transect 10cm deep and 0.147m/s, at 150cm across transect 25cm deep and 0.207m/s, at 250 cm across transect 20cm deep and 1.001m/s. Freshwater sample 20.
68	01-OCT-08 12:24:06PM	NR 86233 73799		Stream 98cmx8cmx0.194m/s. Freshwater sample 21.
69	01-OCT-08 12:28:09PM	NR 86270 73863	Figure 21	12cm faded orange plastic sewer pipe to underwater (1 house)
70	01-OCT-08 12:33:40PM	NR 86284 73981	Figure 22	Stream, possible septic outfall from one house just u/s of where sampled. 7mx12cmx0.543m/s (sampled under bridge on flat concrete). Freshwater sample 22.
71	01-OCT-08 12:42:33PM	NR 86338 74133		Fish farm with 3 barges just offshore.
72	01-OCT-08 12:44:04PM	NR 86304 74198		6 sheep.
73	01-OCT-08 12:46:37PM	NR 86352 74112		Seawater sample 23.
74	01-OCT-08 1:01:08PM	NR 86142 75236		Stream (measured in two halves). 45cmx15cmx0.581m/s and 80cmx10cmx0.916m/s. Freshwater sample 24.
75	01-OCT-08 1:21:50PM	NR 85931 77180		Stream 70cmx25cmx1.750m/s. Freshwater sample 25.
76	01-OCT-08 1:35:46PM	NR 85010 79272		2 x 30cm orange plastic pipes on riverbed and bank, purpose uncertain.
77	01-OCT-08 1:42:30PM	NR 84974 79305		Stream 920cm wide. At 2.5m across transect depth was 15cm flow was 0.368m/s. At 5m across transect depth was 25cm, flow was 0.656m/s. At 7.5m across transect depth was 20cm and flow was 0.808m/s. Freshwater sample 26.
78	01-OCT-08 1:54:40PM	NR 85186 79134		Seawater sample 27. Sanitary related debris in tideline.

Table 2. Water sample *E. coli* results

Sample ID	Date and time	Position	Type	*E. coli* cfu/100ml	Salinity (g/L)
LFS1	30-SEP-08 9:36:08AM	NR 87617 68763	Seawater	>10000	32.9
LFS2	30-SEP-08 9:55:32AM	NR 86621 68961	Seawater	2000	28.7
LFS3	30-SEP-08 10:56:01AM	NR 86316 72185	Freshwater	100	
LFS4	30-SEP-08 11:06:02AM	NR 86320 72426	Freshwater	300	
LFS5	30-SEP-08 11:24:06AM	NR 86304 72827	Freshwater	200	
LFS6	30-SEP-08 11:28:09AM	NR 86298 72864	Freshwater	<100	
LFS7	30-SEP-08 11:44:52AM	NR 86398 73311	Seawater	110	30.2
LFS8	30-SEP-08 12:55:43PM	NR 86643 72208	Seawater	3	34.5
LFS9	30-SEP-08 1:09:24PM	NR 86752 72180	Seawater	3	34.7
LFS10	30-SEP-08 1:19:57PM	NR 86456 72226	Seawater	7	34.2
LFS11	30-SEP-08 1:33:39PM	NR 86870 72959	Seawater	9	33.8
LFS12	30-SEP-08 2:21:05PM	NR 87566 70057	Seawater	7	34.0
LFS13	30-SEP-08 2:30:39PM	NR 87590 70662	Seawater	6	34.5
LFS14	01-OCT-08 8:47:39AM	NR 86784 69151	Seawater	350	19.3
LFS15	01-OCT-08 9:26:07AM	NR 87380 69344	Seawater	2	33.1
LFS16	01-OCT-08 9:48:33AM	NR 86563 68680	Seawater	80	32.5
LFS17	01-OCT-08 10:48:42AM	NR 87329 69886	Seawater	4	33.4
LFS18	01-OCT-08 10:50:45AM	NR 87322 69864	Freshwater	<100	
LFS19	01-OCT-08 11:18:42AM	NR 86991 70235	Freshwater	<100	
LFS20	01-OCT-08 11:52:59AM	NR 86534 71617	Freshwater	200	
LFS21	01-OCT-08 12:24:06PM	NR 86233 73799	Freshwater	<100	
LFS22	01-OCT-08 12:33:40PM	NR 86284 73981	Freshwater	100	
LFS23	01-OCT-08 12:46:37PM	NR 86352 74112	Seawater	<1	34.2
LFS24	01-OCT-08 1:01:08PM	NR 86142 75236	Freshwater	<100	
LFS25	01-OCT-08 1:21:50PM	NR 85931 77180	Freshwater	<100	
LFS26	01-OCT-08 1:42:30PM	NR 84974 79305	Freshwater	100	
LFS27	01-OCT-08 1:54:40PM	NR 85186 79134	Seawater	19	32.0

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

No.	Date and time	Position	Species	*E. coli* mpn/100g
1	30-SEP-08 12:55:43PM	NR 86643 72208	Pacific oyster	310
2	30-SEP-08 1:09:24PM	NR 86752 72180	Queen scallop	500
3	30-SEP-08 1:19:57PM	NR 86456 72226	Queen scallop	70

Table 4. Oyster norovirus testing results

No.	Date and time	Position	Species	Norovirus Genogroup I	Norovirus Genogroup II
08/190	30-SEP-08 12:55:43PM	NR 86643 72208	Pacific oyster	<12.7 copies/g	Not detected

Table 5. Salinity profiling results

Profile No.	Date and time	Position	Depth (m)	Salinity (ppt)	Temperature (ºC)
1	30-SEP-08 12:55:43PM	NR 86643 72208	0	31	12.8
1	30-SEP-08 12:55:43PM	NR 86643 72208	2.5	31.3	12.8
1	30-SEP-08 12:55:43PM	NR 86643 72208	5	31.4	12.9
1	30-SEP-08 12:55:43PM	NR 86643 72208	7.5	31.5	12.8
1	30-SEP-08 12:55:43PM	NR 86643 72208	10	31.8	12.9
2	30-SEP-08 1:09:24PM	NR 86752 72180	0	31.3	12.8
2	30-SEP-08 1:09:24PM	NR 86752 72180	2.5	31.3	12.8
2	30-SEP-08 1:09:24PM	NR 86752 72180	5	31.5	12.8
2	30-SEP-08 1:09:24PM	NR 86752 72180	7.5	31.7	12.9
2	30-SEP-08 1:09:24PM	NR 86752 72180	10	32	12.8
3	30-SEP-08 1:19:57PM	NR 86456 72226	0	30.9	12.9
3	30-SEP-08 1:19:57PM	NR 86456 72226	2.5	31.4	12.8
3	30-SEP-08 1:19:57PM	NR 86456 72226	5	31.5	12.8
3	30-SEP-08 1:19:57PM	NR 86456 72226	7.5	31.7	12.8
3	30-SEP-08 1:19:57PM	NR 86456 72226	10	31.9	12.9
4	30-SEP-08 1:33:39PM	NR 86870 72959	0	30.9	12.9
4	30-SEP-08 1:33:39PM	NR 86870 72959	2.5	31.4	12.9
4	30-SEP-08 1:33:39PM	NR 86870 72959	5	31.7	12.9
4	30-SEP-08 1:33:39PM	NR 86870 72959	7.5	31.9	12.9
4	30-SEP-08 1:33:39PM	NR 86870 72959	10	32.1	12.9
5	30-SEP-08 2:21:05PM	NR 87566 70057	0	31.4	12.9
5	30-SEP-08 2:21:05PM	NR 87566 70057	2.5	31.4	12.9
5	30-SEP-08 2:21:05PM	NR 87566 70057	5	31.6	12.9
5	30-SEP-08 2:21:05PM	NR 87566 70057	7.5	31.7	12.9
5	30-SEP-08 2:21:05PM	NR 87566 70057	10	31.8	12.8

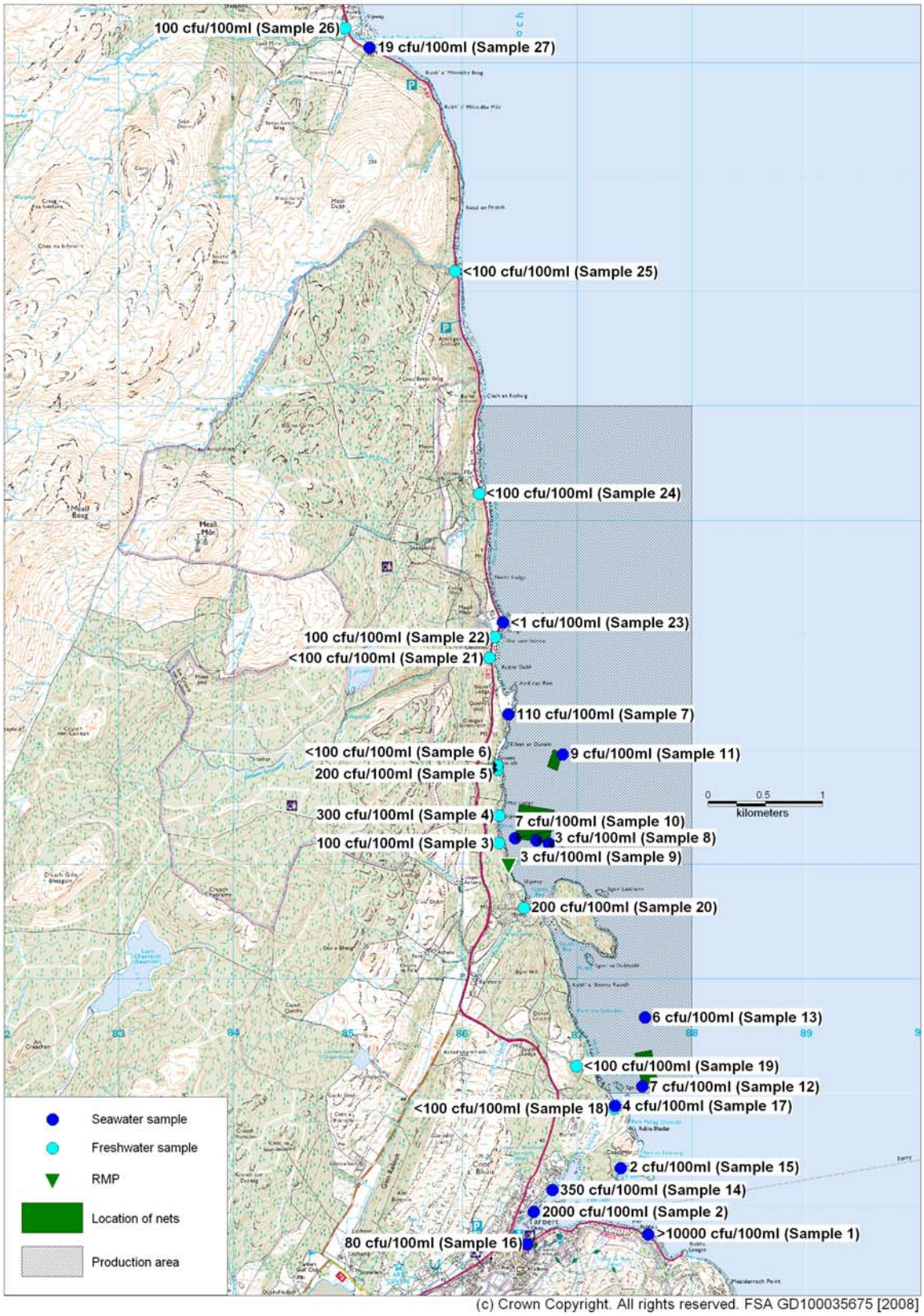

Figure 2. Water sample results map

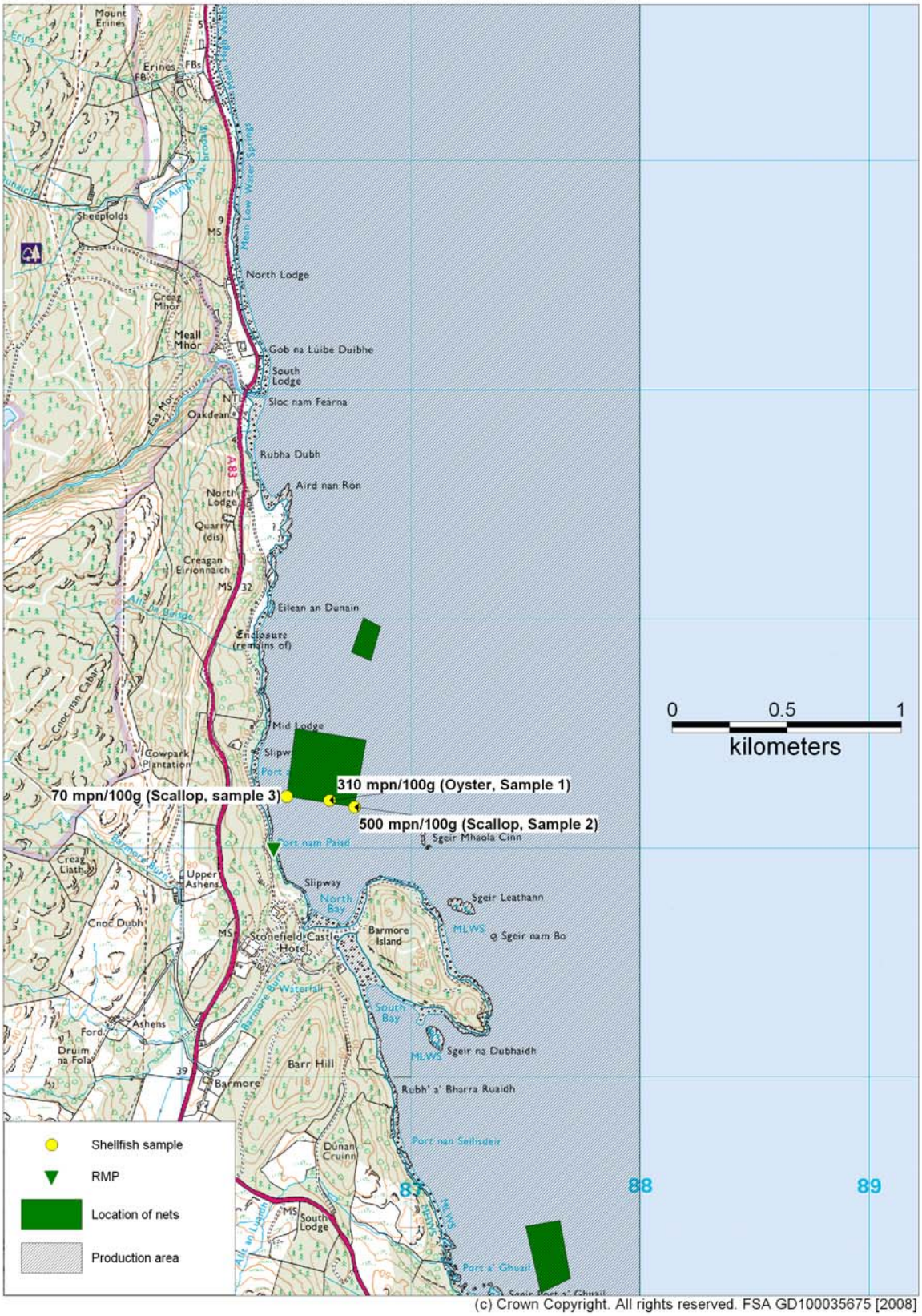

Figure 3. Shellfish sample results map

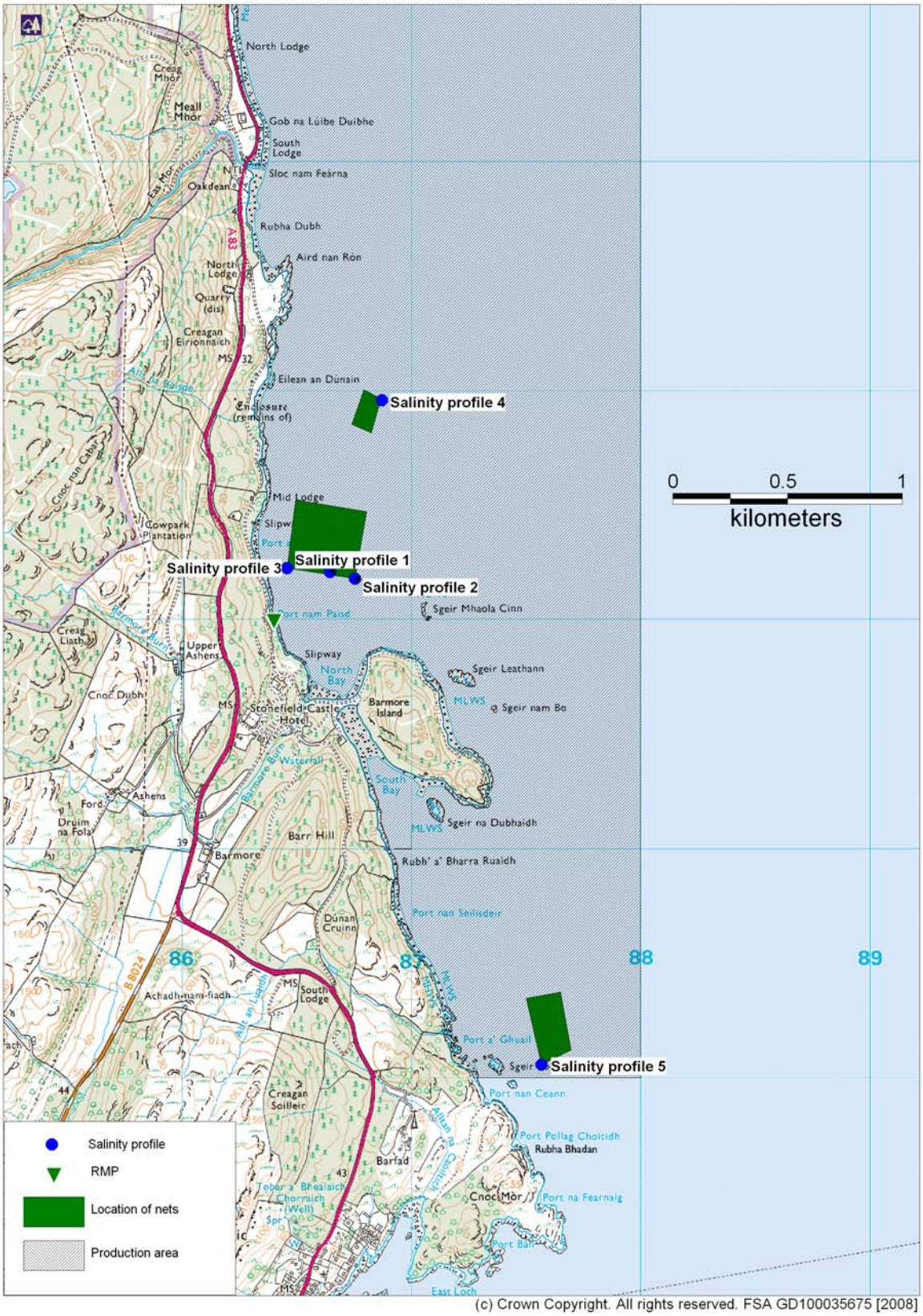

Figure 4 Salinity profile map

Figure 5 Surface water drain in Tarbert

Figure 6 Tarbert Ferry Terminal

Figure 7 Broken ceramic pipe, Tarbert

Figure 8 Scottish Water pumping station, Tarbert

Figure 9. Storm overflow next to Scottish Water pumping station, Tarbert

Figure 10 Presumed sewage pumping station, Tarbert

Figure 11 Part of Tarbert Marina

Figure 12 Cast iron sewer pipe, Tarbert

Figure 13 Scottish Water pumping station, Tarbert

Figure 14 Cast iron sewer pipe, Tarbert

Figure 15. Lantern net

Figure 16. Newly settled queen scallops.

Figure 17. Cast iron sewer pipe, Tarbert

Figure 18. Sanitary related debris, Tarbert

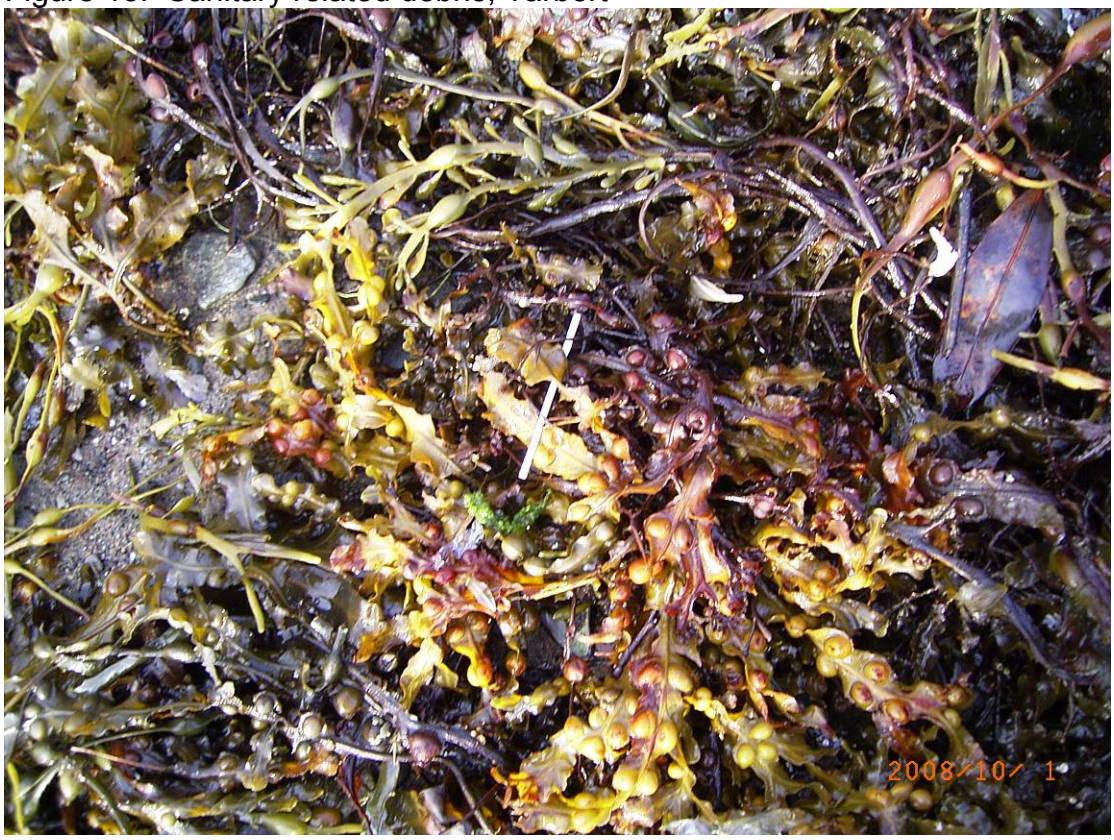

Figure 19. Scottish Water storm holding tank, Tarbert

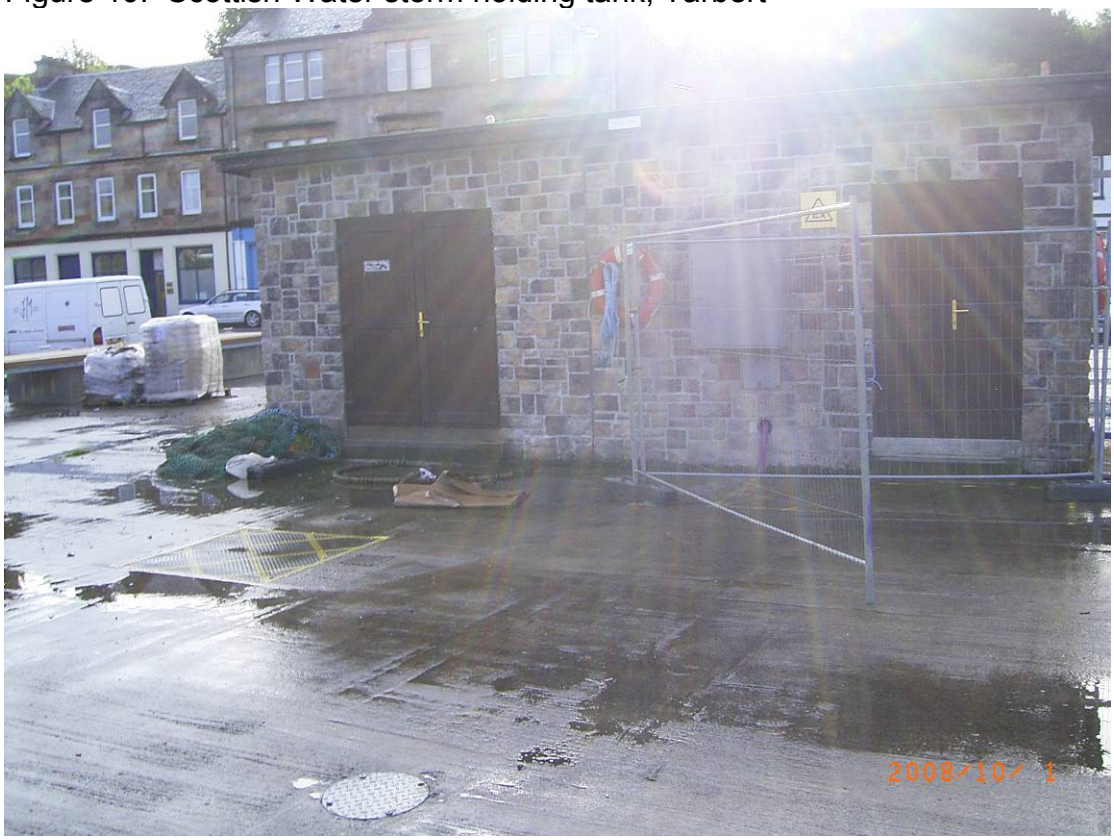

Figure 20. Tarbert Sewage treatment works

Figure 21. Private discharge, north of Tarbert

Figure 22. Private septic discharge to stream, north of Tarbert

Figure 23. Forestry operations on hills adjacent to North Bay

Norovirus Testing Summary

Loch Fyne Stonefield (AB 435 840 13)

Pacific oyster samples were taken from Loch Fyne Stonefield on a quarterly basis and submitted for Norovirus analysis beginning with the date of the shoreline survey. One further sampling event is due before the completion of this testing.

Results are tabulated below.

Ref No.	Date	NGR	Site	GI	GII
08/190	30/9/08	NR 86643 72208	North Bay	Positive at limit of detection	Not detected
08/302	8/12/08	NR 86649 72202	North Bay	Positive at limit of detection	Positive at limit of detection
09/019	2/3/09	NR 86638 72208	North Bay	Positive	Positive
09/152	22/06/09	NR 86645 72215	North Bay	Not detected	Not detected