Scottish Sanitary Survey Project

Sanitary Survey Report
West Loch Tarbert: Loup Bay (AB 299)
January 2010

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Report Distribution – West Loch Tarbert: Loup Bay

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

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

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1. General Description

West Loch Tarbert is located on the west coast of the Kintyre peninsula. The loch is 16.5 km in length, 0.65 km at its narrowest and 1.9 km at its widest point. Loup Bay is a bay on the southern shoreline of the outer reaches of the loch. It is a shallow bay with depths of up to 5 m. The majority of the loch is enclosed and therefore fairly sheltered. This sanitary survey coincides with the FSA funded norovirus study, which is being undertaken at this site throughout 2009.

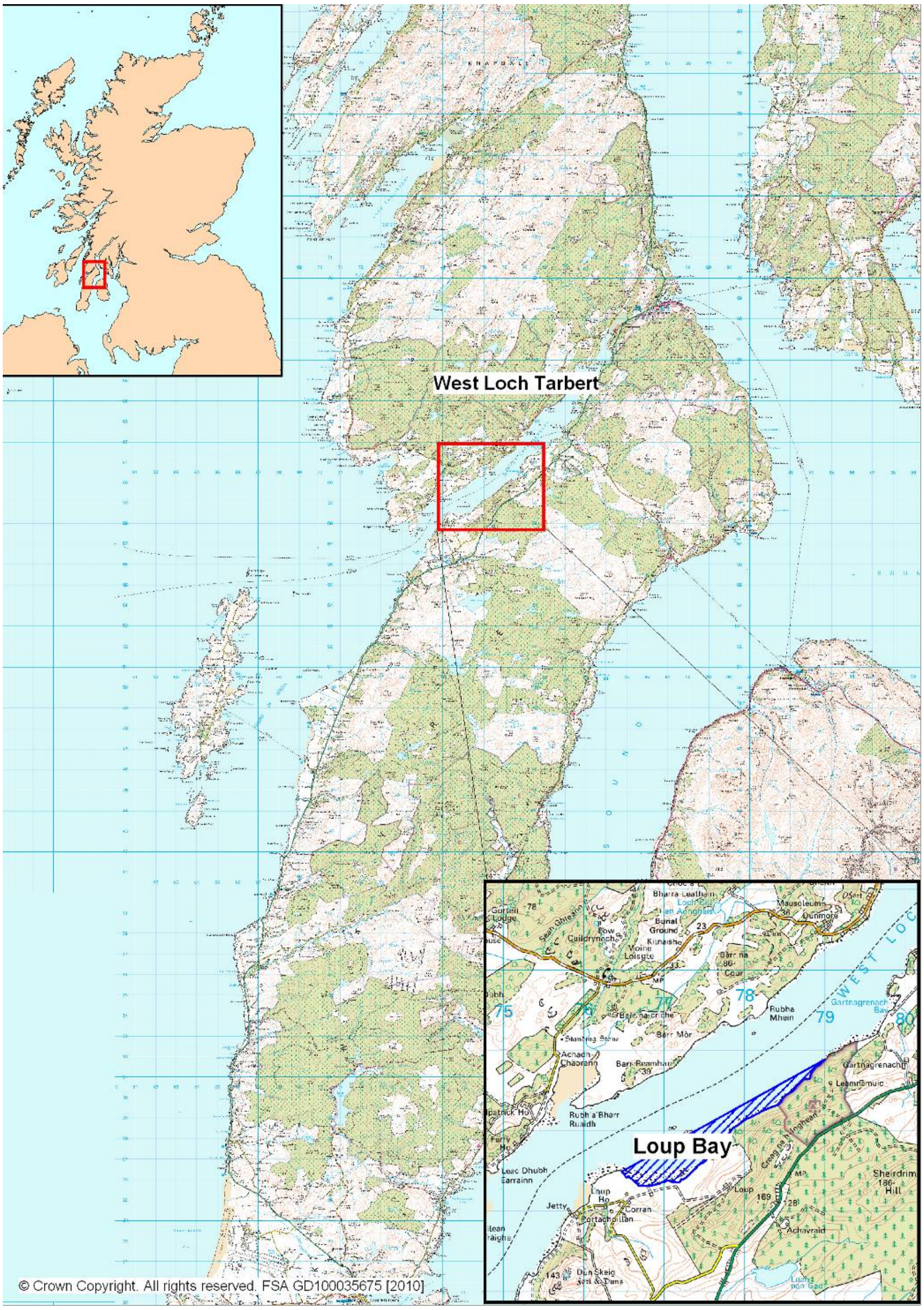


Figure 1.1 Location of West Loch Tarbert: Loup Bay

2. Fishery

The fishery at West Loch Tarbert: Loup Bay is composed of a single 10 hectare Pacific oyster farm.

Table 1. West Loch Tarbert: Loup Bay shellfish farms

Production Area	Site	SIN	Species
West Loch Tarbert: Loup Bay	Loup Bay	AB 299 084 13	Pacific oysters

The production area boundaries are currently defined as the area inshore of line drawn between NR 7647 5849 and NR 7900 5989 extending to MHWS. The nominal Representative Monitoring Point (RMP) grid reference is NR 768 585, which falls within the production area, crown estates lease and fishery area.

Pacific oysters are cultured in mesh bags suspended from ropes strung between stakes in the intertidal zone. Most ropes did not have any stock on them. On those ropes with stock, oysters of varying sizes were present including those of sufficient size for sampling purposes. Seed stock is sourced from a hatchery in Whitstable. It then takes 2-3 years to grow to maturity on the Loup Bay site. Timing of harvest is dictated by demand and toxin status, but can occur at any time of the year. The main markets are local ones, and the harvester reports demand is generally lowest between January and March. In 2008, there were particularly lengthy closures due to biotoxin levels. There is a processing shed with depuration facilities on the site. Pacific oysters from the Barvalla site (located nearer the head of West Loch Tarbert) are also depurated at this facility. Figure 2.1 shows the relative positions of the shellfisheries, Food Standard Agency Scotland designated production area, Crown Estates lease area and RMP.

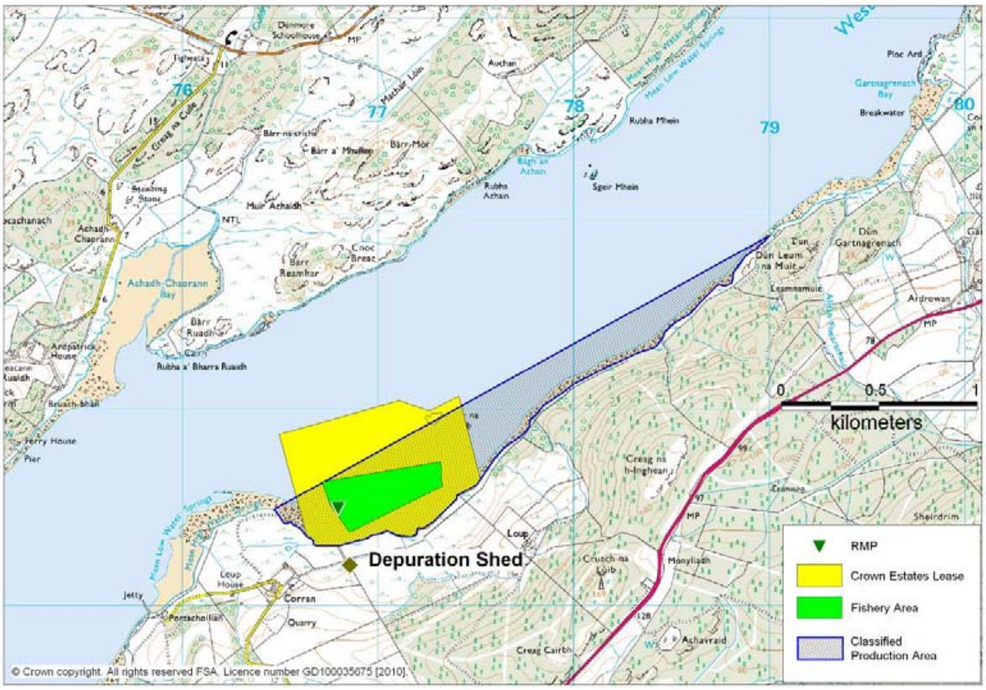


Figure 2.1 West Loch Tarbert: Loup Bay Fishery

3. Human Population

The figure below shows data obtained from the General Register Office for Scotland on the 2001 census population for areas adjacent to West Loch Tarbert.

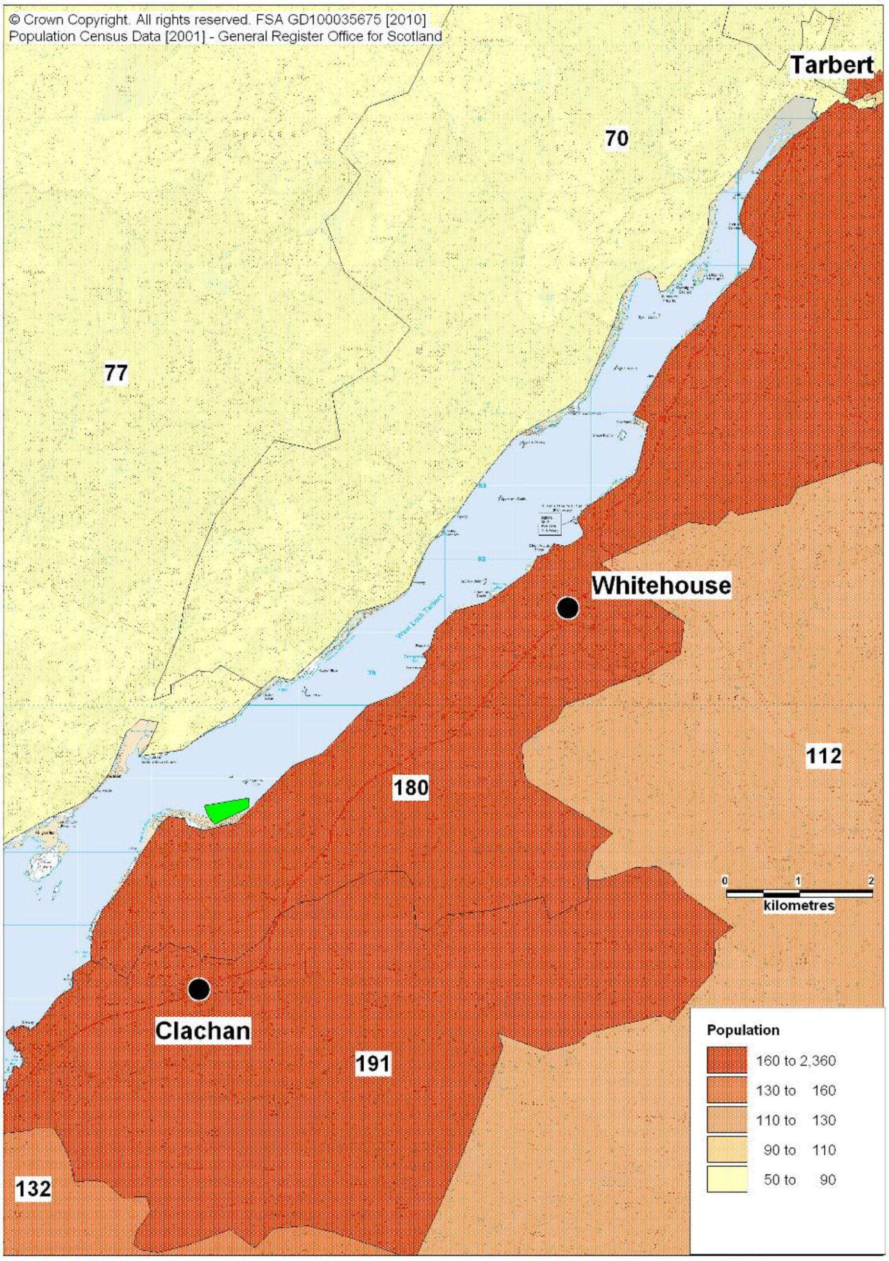


Figure 3.1 Human population surrounding West Loch Tarbert

Data were provided by census output area. The largest village in the area is Tarbert, with a population of1338. It is located approximately 13 km northeast of the fishery at Loup Bay. However, it falls outside of the West Loch Tarbert catchment area so any impacts from Tarbert would be to Loch Fyne.

Two small settlements, Clachan and Whitehouse, are located nearer to Loup Bay. Both settlements are very small and no specific population information was available for them. They fall within separate census output areas, both of which had fewer than 200 residents.

Tourism is likely to bring an increase in local population during the summer months as there is accomodation and other facilities for tourists in both Tarbert and Clachan.

Human population density is higher along the southern shore of the the loch, though the largest centre of population is a significant distance away from the fishery.

4. Sewage Discharges

There are no Scottish Water discharges to the survey area. Discharge consents were sought from the Scottish Environment Protection Agency, Dingwall registry office. Three discharge consents were identified within the area shown in Figure 4.1, the details of which are presented in Table 4.1. No consents were provided for discharges within the settlement of Clachan, which is located to the southwest of the fishery. Depending upon hydrodonamics within the area, sewage discharges associated with this community could conceivably affect microbiological water quality at the fishery.

Table 4.1 Discharges identified by SEPA

Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented/ design PE	Discharges to
CAR/R/1014393	NR 7566 5996	Domestic	Septic tank	5	Land
CAR/R/1014412	NR 7569 5998	Domestic	Septic tank	10	Land
CAR/R/1015770	NR 7918 6141	Domestic	Septic tank	5	Land
CAR/R/1021545	NR 7685 5690	Domestic	Septic tank	5	Land
CAR/R/1021847	NR 7594 5769	Domestic	Package plant	8	Land
CAR/R/1035131	NR 7617 6083	Domestic	Septic tank	5	Land
CAR/R/1040076	NR 7488 6136	Domestic	Septic tank	5	Land

All of these discharges are private septic tank discharges to soakaway and so should not impact on water quality within Loup Bay, assuming they are functioning correctly. As there has not historically been a requirement to register septic systems in Scotland, this list is unlikely to cover all septic tanks in the area. A physical survey of the shoreline adjacent to the fishery was undertaken and observations of septic tanks and/or outfalls present along the shoreline of Loup Bay are presented in Table 4.2.

Table 4.2 Discharges observed during shoreline survey

No.	Date	NGR	Observation
1	21-JUL-09	NR 75182 58789	Private sewer pipe to shore (dripping). 1 house
2	22-JUL-09	NR 76860 58204	Oyster shed, with toilet and septic tank to soakaway

Only two discharges were identified during the shoreline survey. One was a private discharge to the opposite shore of the loch from the fishery, over 1 km away from the oyster farm. The other was a small septic tank and soakaway associated with the oyster shed and depuration facility, which was just over 100 m from the shore of Loup Bay. This discharge is unlikely to impact on water quality within Loup Bay if it is functioning correctly. However, should it fail, it is likely to impact most acutely at the southwestern corner of the oyster farm.

Boating/Shipping

There is an active fishing pier at West Tarbert, near the head of the loch, from which several fishing boats operate and so have to pass Loup Bay on the way to and from fishing grounds. The Islay Ferry also passes Loup Bay as it travels between Islay and Kennacraig, but the grower reports that it never discharges waste within West Loch Tarbert. Yachts visit the loch and one was observed further toward the head of the loch during the shoreline survey. Clyde Cruising Club Sailing Directions for Kintyre to Ardnamurchan indicate suitable areas for yacht anchorages are located towards the head of the loch, with none in the area shown in Figure 4.1. Boating activity is likely to increase during the summer months.

In conclusion, there are no known sewage discharges in the vicinity of the fishery that are likely to significantly affect its bacteriological status. Not enough was known at the time of reporting about discharges from the community of Clachan to assess potential impact from any sewage discharges there. There are several discharges toward the head of the loch that may increase background levels of contamination within the loch but these are not expected to impact more heavily at one part of the Loup Bay fishery than another. Yachts and fishing boats may discharge overboard while passing Loup Bay, though it is not known how often this may occur. Any discharges from boats are more likely to occur during the summer months, when boating activity is anticipated to be higher.

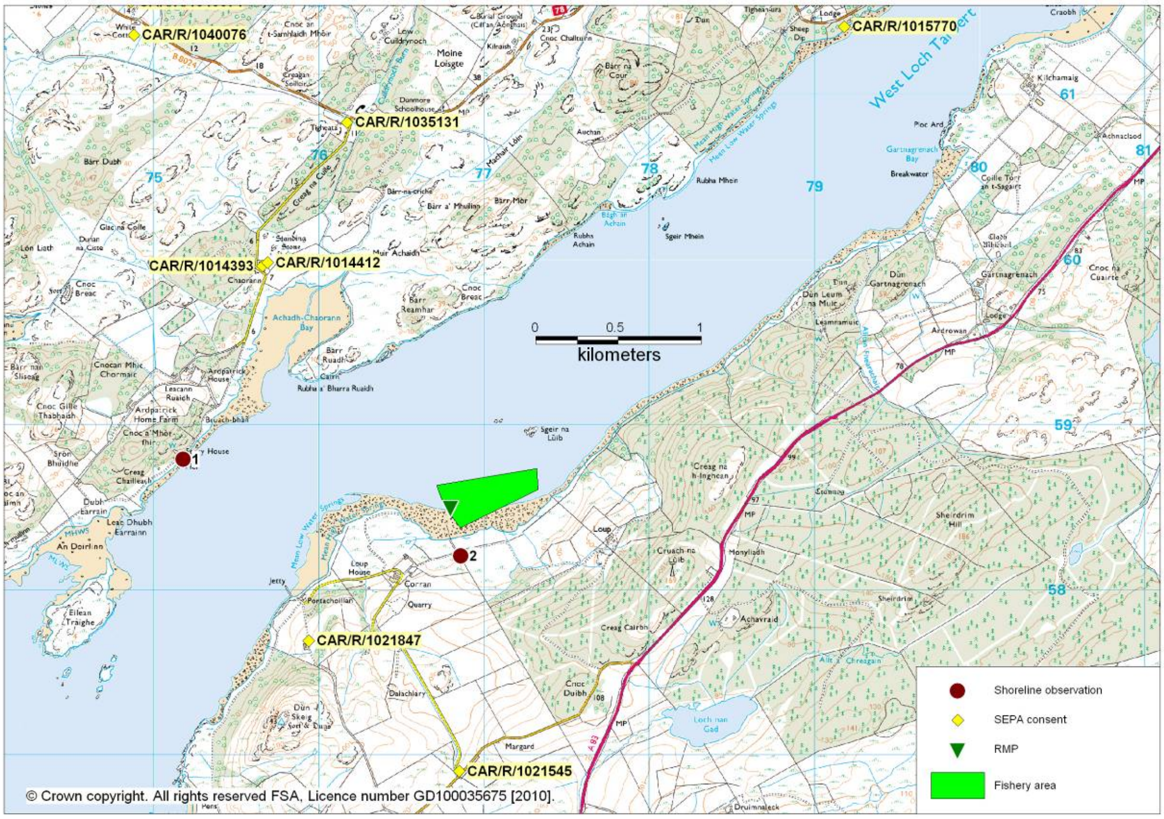


Figure 4.1 Sewage discharges at West Loch Tarbert: Loup Bay

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 2. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red and orange indicate poorly draining soils and the areas shaded dark blue and light blue indicate freely draining soils.

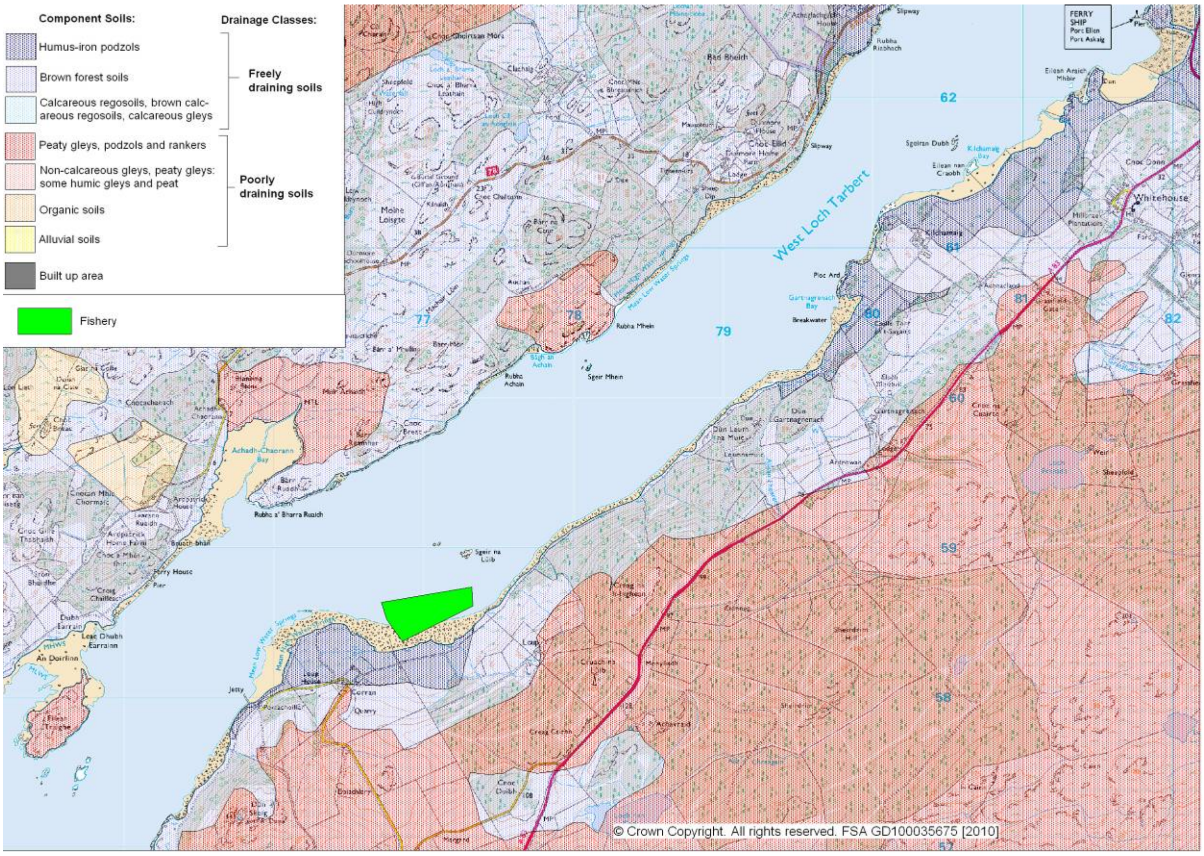


Figure 5.1 Component soils and drainage classes for Loup Bay

Figure 5.1 shows that there is a coastal strip of freely draining soils along the loch (humus-iron podzols and brown forest soils) of between 0.5 and 2 km in width. There are pockets of poorly-drained soils long the north shore, across from the fishery. This strip of freely-draining soils is narrowest adjacent to and south of the fishery. Streams entering the loch in this area are likely to pass through poorly drained areas, carrying higher volumes of runoff during periods of rain. While the septic tank associated with the oyster processing shed appears to be located on freely drained soil, the settlement of Clachan is located on an area of predominantly poorly draining soil. Therefore, any septic discharges from this community are more likely to impact water quality in streams or burns running from there to the loch itself and in turn could potentially impact on water quality at the fishery.

6. Land Cover

Land Cover Map 2000 data was obtained for the area, as shown in Figure 6.1 below:

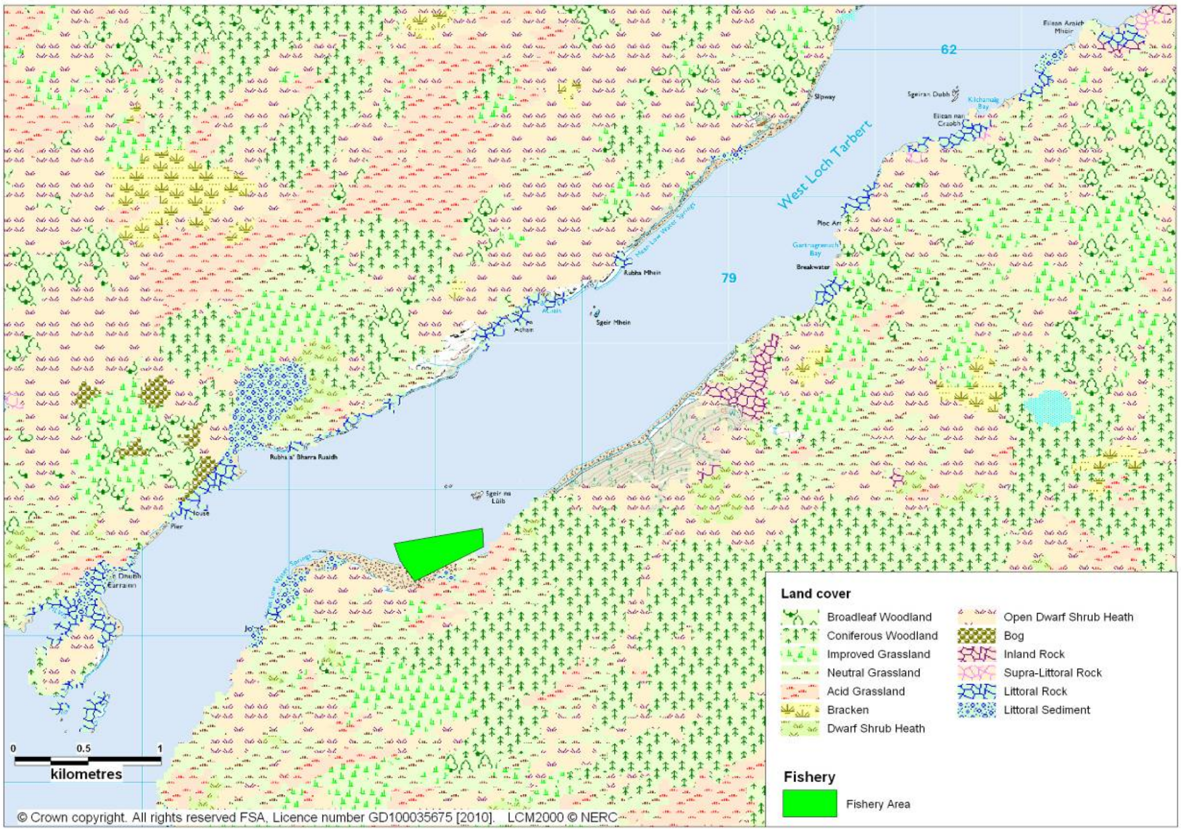


Figure 6.1 LCM2000 class land cover data for West Loch Tarbert: Loup Bay

On the shoreline directly adjacent Loup Bay the land cover is predominantly coniferous woodland, open heath and improved grassland. There is a gap in the LCM2000 data, with no recorded data for a stretch of approximately 1km of shoreline northeast of the fishery. On the shoreline opposite Loup Bay the land cover is a mixture of open heath, coniferous and broadleaf woodland, and improved grassland, with some areas of littoral sediment and rock along the shoreline.

The faecal coliform contribution in this area would be expected to be highest from from the improved grassland (approximately 8.3×10^{8} cfu km^{-2} hr^{-1}) and lower from the other land cover types (approximately 2.5×10^{8} cfu km^{-2} hr^{-1}) (Kay *et al.*, 2008). The contributions from all land cover types would be expected to increase significantly after marked rainfall events. This effect would be highest, at more than 100-fold, for areas of improved grassland.

Therefore, the overall predicted contribution of contaminated runoff from these land cover types would be low to intermediate, with a significant increase following rainfall events. Areas of improved grassland near the southwestern end of the fishery are expected to be a significant local source of diffuse faecal pollution to the fishery.

7. Farm Animals

Agricultural census data was requested from the Scottish Government Rural and Environment Research and Analysis Directorate (RERAD) for the South Knapdale and Kilcalmonel parishes, which border with West Loch Tarbert and cover areas of 299 and 117 km^2 respectively. Recorded livestock populations for the parishes for 2008 are presented in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reported would have made it possible to discern individual farm data.

Table 7.1 Livestock numbers in South Knapdale and Kilcalmonel, 2008

	South Kanpdale		Kilcalmonell	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	*	*
Poultry	5	44	10	349
Cattle	9	1270	10	1006
Sheep	15	13695	18	11052
Deer	*	*	0	0
Horses and Ponies	11	91	*	*

*Data withheld

Sheep outnumber cattle in these parishes by 10 to 1. Poultry are kept in small numbers as are pigs, though no data on the numbers of pigs kept were provided. Due to the large area of these parishes, this parish-level data does not provide sufficient information on the livestock numbers in the area immediately surrounding the oyster farm at Loup Bay. The only significant source of local information was therefore the shoreline survey (see Appendix), which only relates to the time of the site visit on 21-23 July 2009. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. This information should be treated with caution, as it applies only to the survey dates and is dependent upon the point of view of the observer (some animals may have been obscured from view by the terrain).

The shoreline survey identified significant numbers of sheep and cattle at the western end of Loup Bay. On pastures adjacent to Loup Bay, 97 sheep and 25 cattle were recorded. The majority of these were fenced in a field separated from the shore by a strip of marshland approximately 100 m wide, athough 22 of these sheep had free access to the shore just to the west of the fishery. Therefore, contamination from these animals is likely to be carried to the fishery via the many small watercourses draining to the shore of Loup Bay, or via direct deposition to the shore west of Loup Bay.

Further back from the shore, at Corran Farm, 6 chickens, 2 pigs and about 100 sheep were counted. Contamination from these animals would be carried into the loch via streams draining into the loch just to the west of Loup Bay. On the opposite shore, at Acach-Chaorann Bay, large amounts of sheep droppings and wool were recorded along the shoreline and in the water suggesting significant inputs from livestock in this area.

Numbers of sheep will approximately double during May following the birth of lambs, and decrease in the autumn as they are sent to market. All livestock are likely to access watercourses to drink more frequently during warmer weather. Therefore, a seasonal increase in faecal contamination from livestock is expected between May and October.

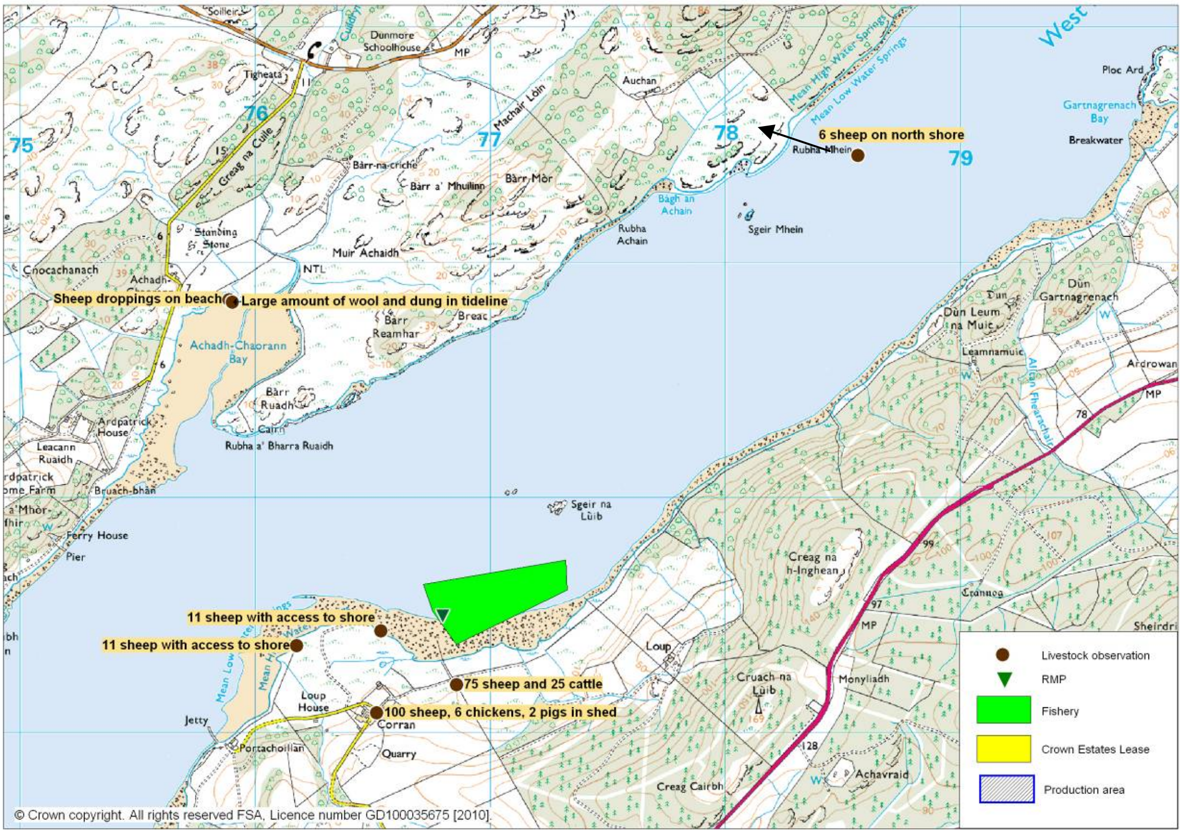


Figure 7.1 Shoreline survey livestock observations

8. Wildlife

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

Seals

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

A survey conducted by the Sea Mammal Research Unit in 2007 estimated a population of 4732 common seals from Appin to the Mull of Kintyre, so it is likely that this species is present in West Loch Tarbert. The exact locations of the haul out sites were not specified, so it is unclear whether they reside in the vicinity of West Loch Tarbert. No grey seal breeding colonies were recorded in the vicinity of West Loch Tarbert.

One seal (species uncertain) was seen during the shoreline survey, so it is likely that seals come into close proximity of the fishery at least some of the time.

Whales/Dolphins

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

Birds

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

Table 8.1 Counts of breeding seabirds within 5 km of Loup Bay

Common name	Species	Count	Count method	Individual/Pair
Common Gull	*Larus canus*	9	Occupied nests	pairs
Lesser Black-backed Gull	*Larus fuscus*	5	Occupied territory	pairs
Great Black-backed Gull	*Larus marinus*	6	Occupied territory	pairs
Black-headed Gull	*Larus ridibundus*	8	Occupied nests	pairs
Common Tern	*Sterna hirundo*	65	Occupied nests	pairs
Common/Arctic Tern	*Sterna paradisaea/hirundo*	4	Occupied territory	pairs

Numbers of breeding seabirds in the area are relatively low. The vast majority of seabird breeding sites were recorded on two small rocky islands about 4 km to the north-east of the production area. Greatest impacts would be expected in the vicinity of their nest sites, although it is likely that they hunt or feed throughout the loch. Gulls are likely to be present all year round.

Waterfowl (ducks and geese) are likely to be present in the area at various times, primarily to overwinter, or briefly during migration, although some species breed in Argyll and Bute. Although no geese were observed during the shoreline survey, the shellfish grower reports that geese roost on the shores of the loch on calm nights during the winter.

Wading birds would tend to be concentrated on intertidal areas, such as the area on which the fishery is located, although no aggregations were recorded during the shoreline survey.

Deer

Deer will be present particularly in wooded areas where the habitat is best suited for them. The shore adjacent to the production area to the north east of the fishery is wooded and deer are likely to be present in this area, although none were seen during the shoreline survey. No specific information on the deer population in this area was available from the Deer Commission for Scotland.

Otters

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

Summary

In summary, the wildlife species most likely to impact on water quality within the the production area are seabirds, deer, seals, and geese. In general, deposition of faeces by wildlife is likely to be widely distributed around the area. Any impact from deer faeces may be more likely to affect the northeastern end of the fishery, while impacts from geese on pasture areas adjacent to the fishery would occur predominantly during the winter months.

9. Meteorological data

The nearest weather station is located at Skipness House, approximately 12 km to the east of the fishery, for which rainfall data was available for 2003-2008 inclusive apart from the months of January and December 2006. The nearest weather station for which wind data is available is Glasgow: Bishpton, approximately 66 km to the east of the fishery. Overall wind patterns are likely to differ at the fishery and at Glasgow Bishopton, and local topography may skew these patterns in different ways so conditions at any given time are likely to differ between the two. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within Loup Bay.

9.1 Rainfall

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

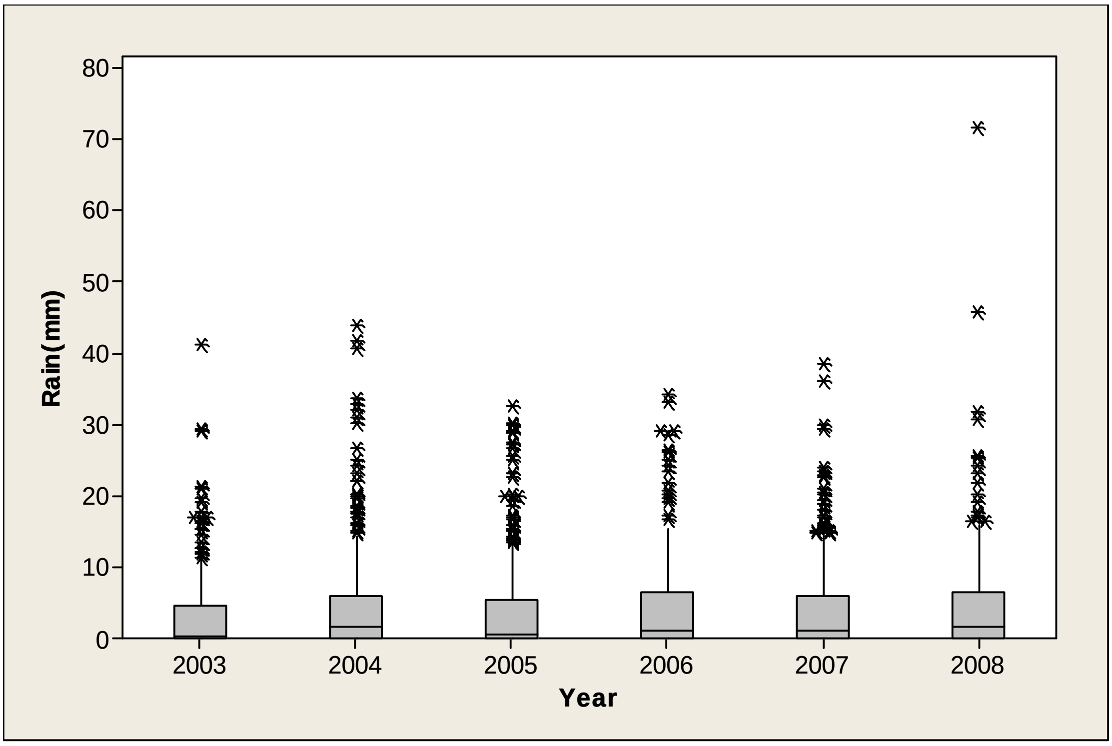


Figure 9.1 Box plot of daily rainfall values by year at Skipness House, 2003-2008

Figure 9.1 shows that over the years reviewed, median daily rainfall values were less than 5 mm per day, while maximum recorded rainfalls varied between just over 30 mm to over 70 mm, with 2008 being the wettest year and 2003 the driest.

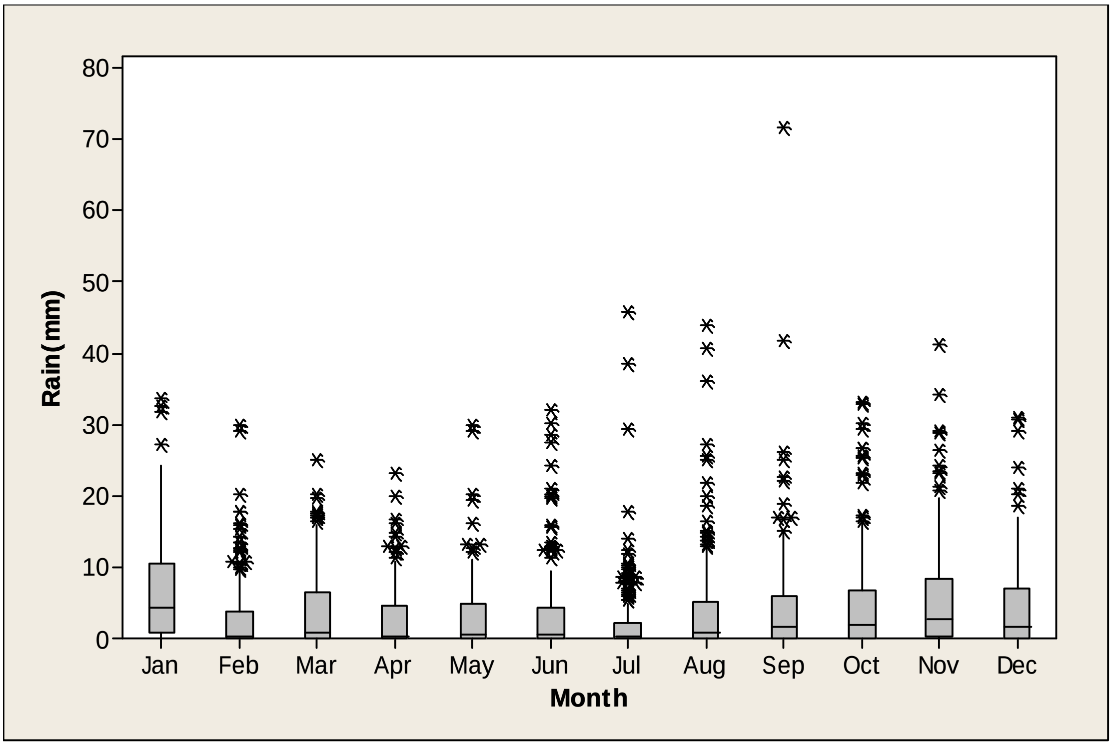


Figure 9.2 Box plot of daily rainfall values by month at Skipness House, 2003-2008

Rainfall begins to increase in August, remains elevated through to January, then drops off into February. Days with high rainfall can occur at any time of the year, although Figure 9.2 shows peak events increase in May, start to tail off in October and are lowest in April. Median rainfall shows a similar pattern, with a delay of around 2 months. For the period considered here (2003-2008), 49% of days experienced rainfall less than 1 mm, and 14% of days experienced rainfall of 10 mm or more.

It can therefore be expected that levels of rainfall dependent faecal contamination entering the production area from these sources will be higher during the autumn and winter months. It is possible that there is a build-up of faecal matter on pastures during the drier summer months when stock levels are at their highest which results in a 'first flush' of contaminated runoff following summer storms, or in the autumn at the onset of the wetter months although this could happen at any time of the year.

9.2 Wind

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

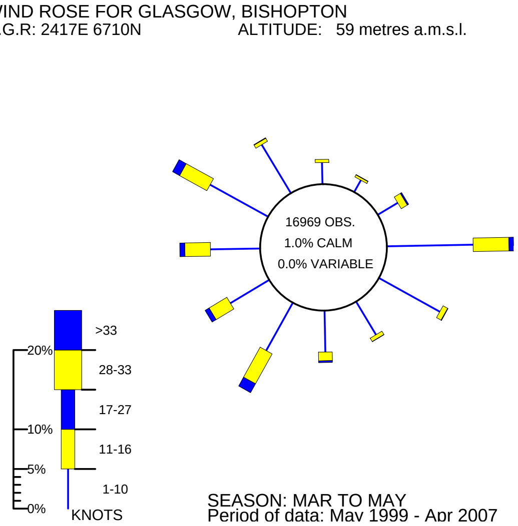


Figure 9.3 Wind rose for Glasgow: Bishopton (March to May)

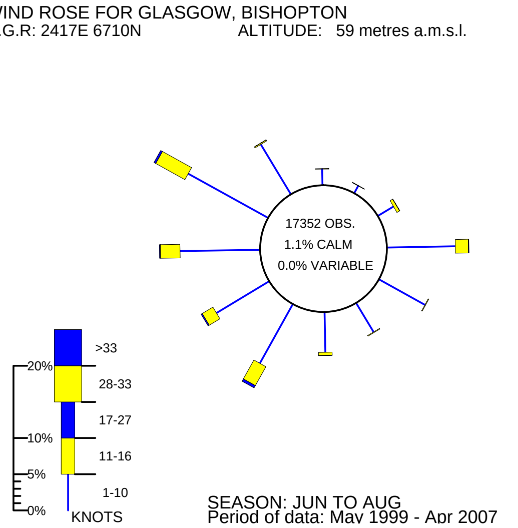


Figure 9.4 Wind rose for Glasgow: Bishopton (June to August)

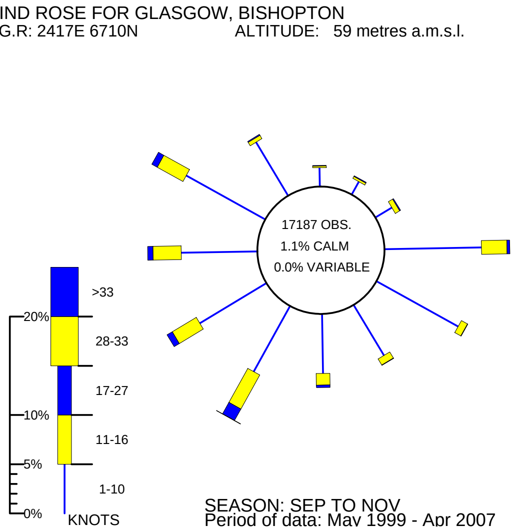


Figure 9.5 Wind rose for Glasgow: Bishopton (September to November)

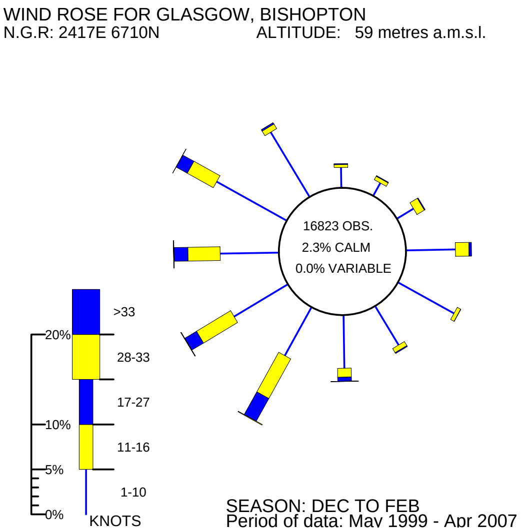


Figure 9.6 Wind rose for Glasgow: Bishopton (December to February)

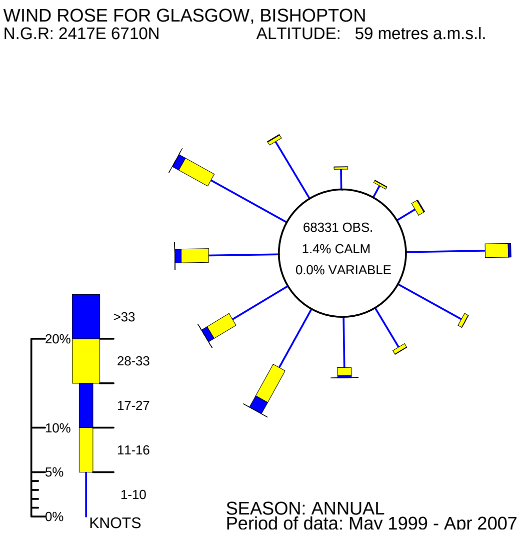


Figure 9.7 Wind rose for Glasgow: Bishopton (All year)

Glasgow is one of the less windy areas of Scotland, with a low frequency of gales compared to places such as the Western Isles and Shetland. 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 from June to August and stronger from December to February.

West Loch Tarbert has an south-west to north-east aspect, and so is most exposed to winds from these directions which would tend to be funnelled up or down the Loch by the surrounding hills so it is likely that at loch West Loch Tarbert wind patterns may align more along the south-west to north-east axis compared to those recorded at Glasgow: Bishopton.

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. Strong winds will increase the circulation of water and hence dilution of contamination from point sources within the loch. A strong northerly or north-westerly wind would create significant wave action at the fishery, which may result in the resuspension of any contamination within the sediment.

10. Current and historical classification status

West Loch Tarbert: Loup Bay is currently classified for the production of Pacific oysters. The classification history for the area is presented in Table 10.1. A map of the current production area can be found in Section 2, Figure 2.1.

Table 10.1 Classification history, West Loch Tarbert: Loup Bay, Pacific oysters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	B	B	B	B	B	B	B	B	B	B	B	B
2002	-	-	-	-	-	-	-	-	-	-	-	-
2003	A	A	A	A	B	B	B	B	B	B	B	B
2004	A	A	A	A	B	B	B	B	B	B	B	B
2005	B	B	B	B	B	B	B	B	B	B	B	B
2006	B	B	B	B	B	B	B	B	B	B	B	B
2007	B	B	B	A	B	B	B	B	B	B	B	B
2008	A	A	A	A	A	B	B	B	B	B	B	B
2009	B	A	A	A	A	A	B	B	B	B	B	B
2010	A	A	A									

The classification for this area has varied from a year round B (2001, 2005 and 2006) to a seasonal A/B (2003, 2004, and 2007/8 onwards). When it has been given a seasonal classification, the months from July to December have always been classified B.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken West Loch Tarbert: Loup Bay from the beginning of 2002 up to the 29th September 2009 were extracted from the Shellfish Hygiene System (SHS) database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

All samples plotted geographically within the production area. One sample had no *E. coli* result and so could not be used. One sample was received by the laboratory before its reported collection time and so was excluded from the anaylsis.

Seven samples had a reported result of <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. One sample had a reported result of >18000 and it was assigned a nominal value of 36000.

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

11.2 Summary of microbiological results

A summary of all sampling and results by location is presented in Table 11.1. From January 2008, sampling locations were reported to 1 m accuracy. These were rounded to 100 m accuracy for clarity of presentation.

Table 11.1 Summary of historical sampling and results

Sampling Summary				
Production area	West Loch Tarbert: Loup Bay	West Loch Tarbert: Loup Bay	West Loch Tarbert: Loup Bay	West Loch Tarbert: Loup Bay
Location No.	1	2	3	4
Site	Loup Bay	Loup Bay	Loup Bay	Loup Bay
Species	Pacific oysters	Pacific oysters	Pacific oysters	Pacific oysters
SIN	AB-299-084-13	AB-299-084-13	AB-299-084-13	AB-299-084-13
Location	NR768585 (RMP)	NR768584	NR769584	NR770585
Total no of samples	38	9	19	17
No. 2002	10	0	0	0
No. 2003	11	0	0	0
No. 2004	10	0	0	0
No. 2005	6	0	0	5
No. 2006	1	0	0	11
No. 2007	0	8	0	1
No. 2008	0	1	10	0
No. 2009	0	0	9	0
Results Summary				
Minimum	<20	<20	20	<20
Maximum	36000	500	3500	5400
Median	255	110	130	70
Geometric mean	287	89.6	147	107
90 percentile	2730	500	820	1010
95 percentile	5960	500	1340	2200
No. exceeding 230/100g	19 (50%)	2 (22%)	7 (37%)	6 (35%)
No. exceeding 1000/100g	11 (29%)	0 (0%)	2 (10%)	2 (11%)
No. exceeding 4600/100g	3 (8%)	0 (0%)	0 (0%)	1 (6%)
No. exceeding 18000/100g	1 (3%)	0 (0%)	0 (0%)	0 (0%)

11.3 Overall geographical pattern of results

Figure 11.1 presents a map showing geometric mean result by reported sampling locations, rounded to 100 m accuracy for samples reported to 1 m accuracy.

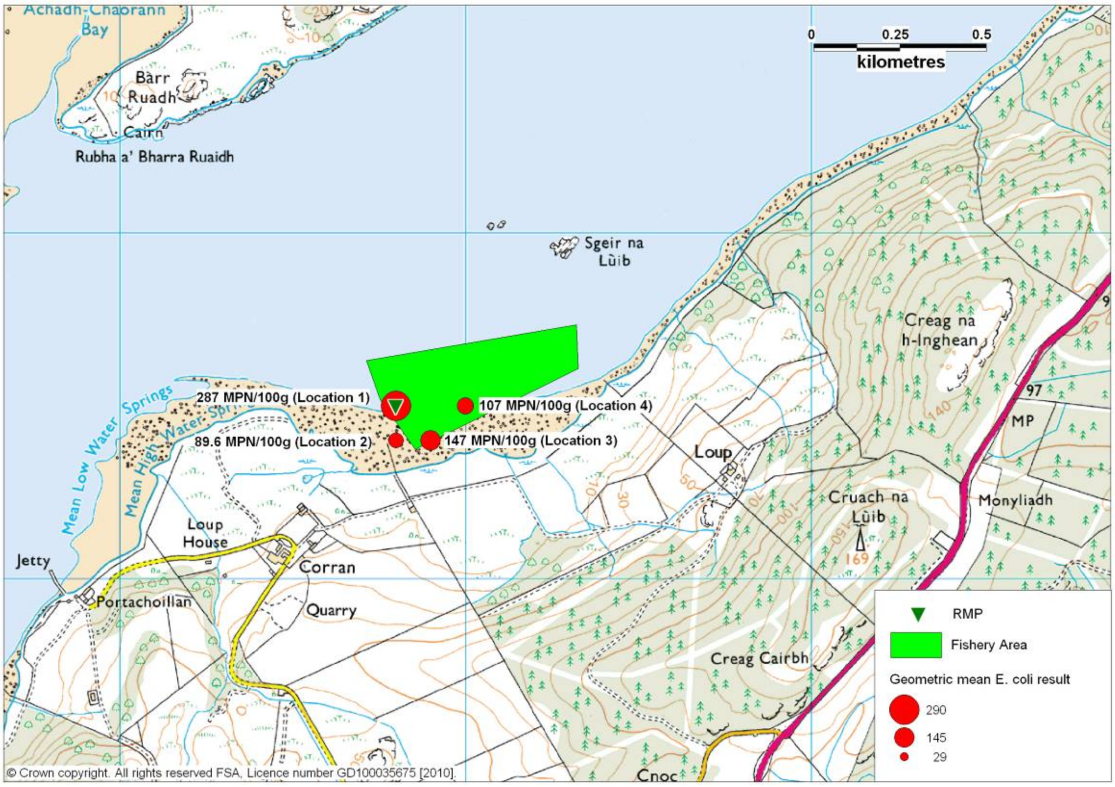


Figure 11.1 Map of sampling points and geometric mean result

Table 11.1 and Figures 11.1 and 11.2 show some variation in the geometric mean result and the proportion of results over 230 *E. coli* MPN/100g across the sampling locations. The highest mean result arose at the nominal RMP. The differences between the mean results by sampling location were not found to be statistically significant (One-way ANOVA, p=0.142, Appendix 6), nor were the differences in proportions of results over 230 *E. coli* MPN/100g (Chi-square=1.462, p=0.481) although samples from Location 2 could not be included in the latter analysis due to low sample numbers (n=9). It must be noted that these samples were collected on different occasions, so differences in results between the sampling locations may reflect temporal rather than spatial effects.

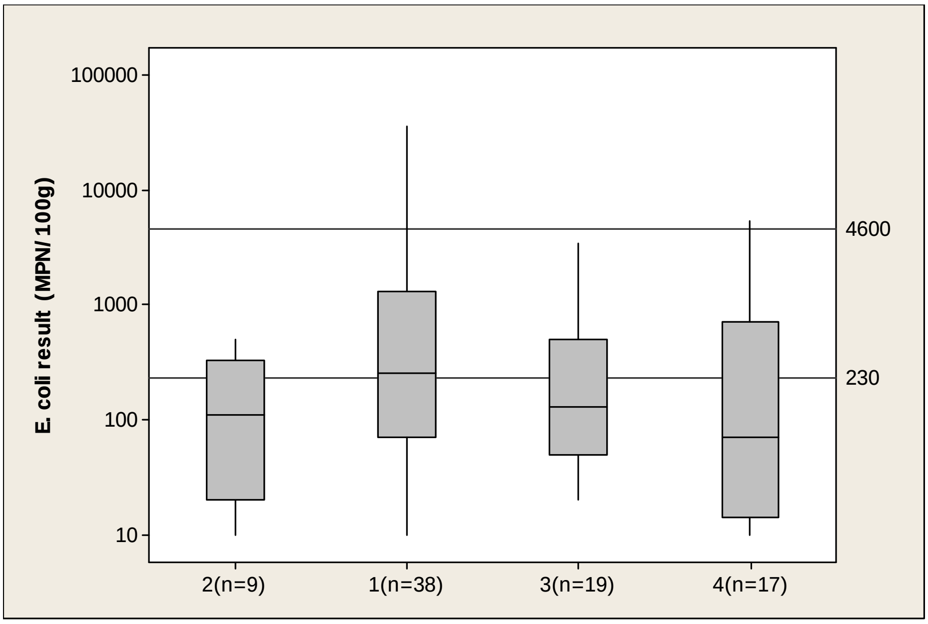


Figure 11.2 Boxplot of *E. coli* results by reported sampling location

11.4 Overall temporal pattern of results

Results were analysed for variation over time in order to determine whether results have changed markedly over the time during which monitoring has been undertaken.

Figure 11.3 presents a scatter plot of individual results against date, fitted with trend lines calculated using two different techniques. The first is a geometric mean of the previous 5 samples, the current sample and the following 6 samples, referred to as a rolling geometric mean (black line). The second is a loess line (blue 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. Both lines help to highlight any underlying trends or cycles that might be obscured by shorter term variations in results.

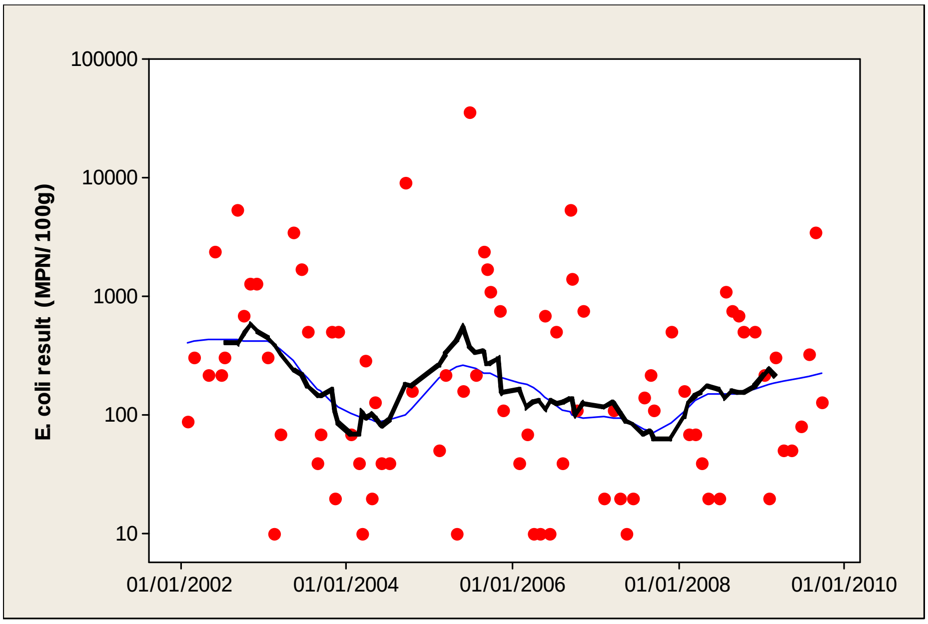


Figure 11.3 Scatterplot of *E. coli* results by date with rolling geometric mean (thick black line) and loess line (fine blue line)

Figure 11.3 suggests results have improved slightly overall, with a lower incidence of results over 1000 MPN/100 g from 2007. A peak in results appeared in 2005, when the highest recorded result (>18000 MPN/100 g) occurred.

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 presents a boxplot of *E. coli* result by month.

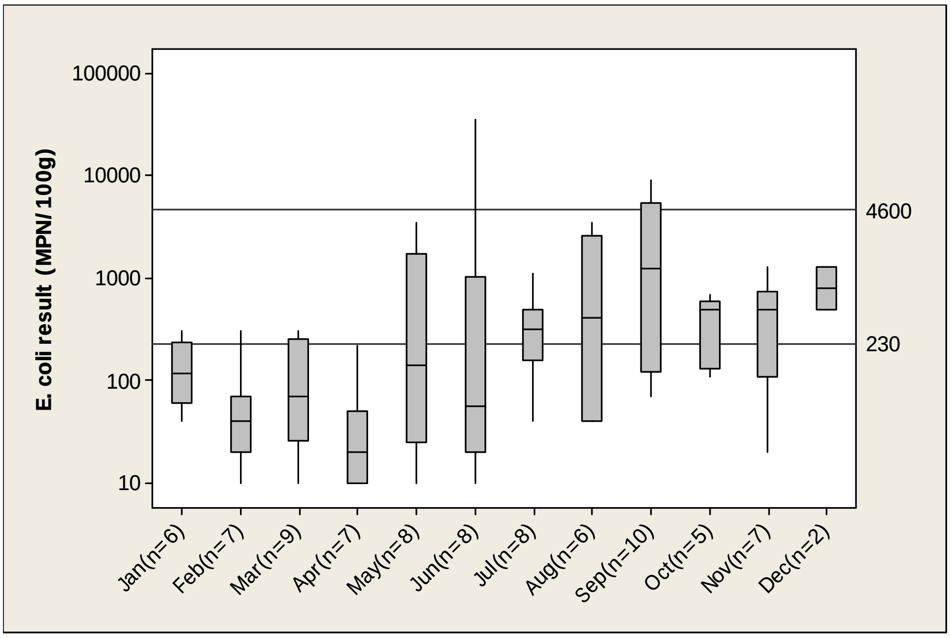


Figure 11.4 Boxplot of results by month

Lowest results occurred from January to April. Results in May and June were most variable. Results were generally higher during the second half of the year, with a higher likelihood of results exceeding 230 MPN/100 g from May - December. However, it should be noted that only 2 results were recorded in December.

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

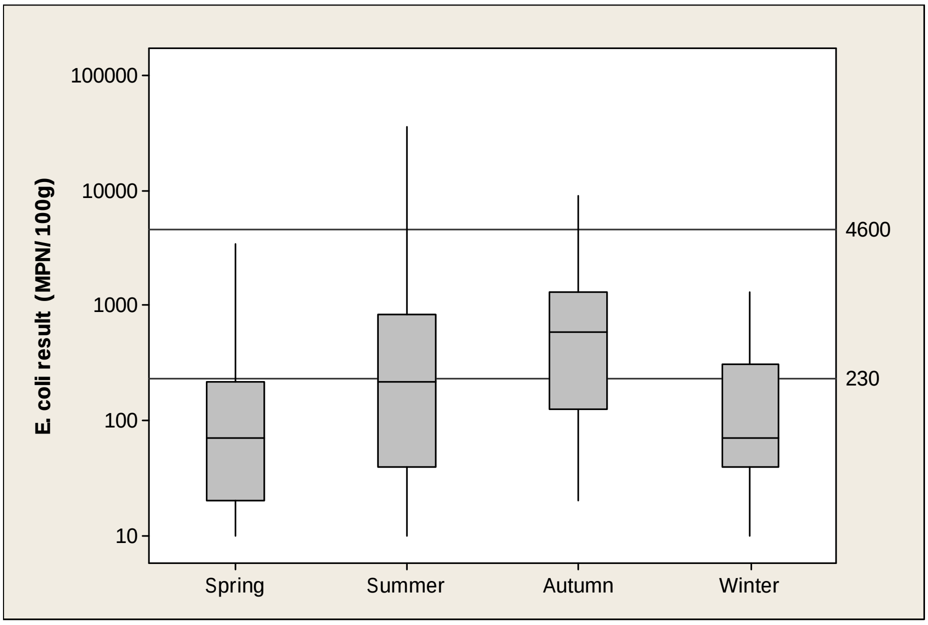


Figure 11.5 Boxplot of result by season

A significant difference was found between results by season (One-way ANOVA, p=0.001, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the autumn were significantly higher than those for the winter and spring. However, at least one result greater than 4600 MPN/100 g occurred during summer.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station is at Skipness House, approximately 12 km to the east of the fishery. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2008 (total daily rainfall in mm). As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationships between rainfall in the previous 2 and 7 days and sample results were investigated and are presented below.

Two-day antecedent rainfall

Figure 11.6 presents a scatterplot of *E. coli* results against rainfall that occurred in the two days prior to sampling.

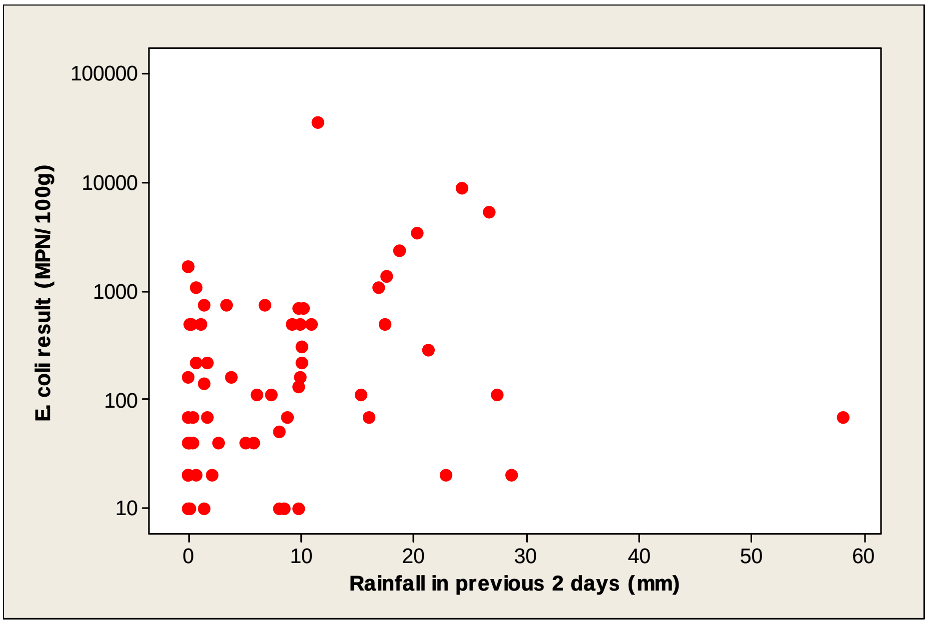


Figure 11.6 Scatterplot of result against rainfall in previous 2 days

A Spearman's Rank correlation was carried out between results and rainfall, which showed a positive correlation between *E. coli* result and rainfall in the previous two days (Spearman's rank correlation=0.321, p=0.010, Appendix 6). However, the highest recorded *E. coli* results occurred after relatively little rainfall (roughly 10 mm) while the *E. coli* result obtained after the highest rainfall (roughly 60 mm) was less than 100 MPN/100 g. This indicates that while generally higher two-day antecedent rainfall correlated with higher *E. coli* levels in shellfish, this was not necessarily always the case and that other factors may be complicating the picture.

Seven-day antecedent rainfall

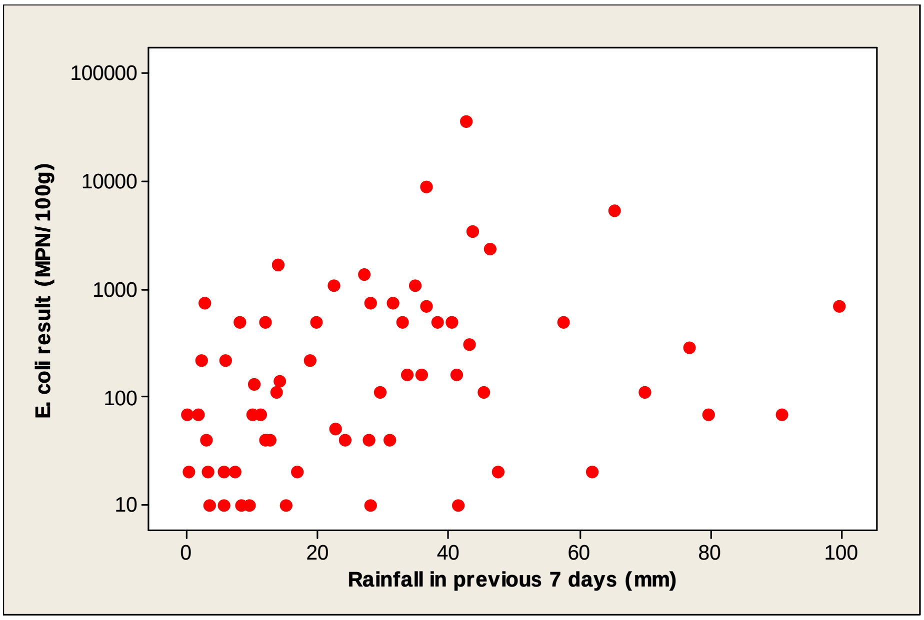


Figure 11.7 Scatterplot of result against rainfall in previous 7 days

A positive correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation= 0.354, p=0.004, Appendix 6). This affect appears to tail off for results collected after 7-day rainfall of greater than 60 mm, with higher rainfall no longer correlating clearly with higher *E. coli* levels in shellfish.

11.6.2 Analysis of results by tidal height and state

Larger (spring) tides occur every two weeks, and during these times water circulation 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 11.8 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle. Full and new moons occur at 0º, and half moons occur at 180º. Spring tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of under 230 *E. coli* MPN/100g (A results) are plotted in green, those between 230 and 1000 *E. coli* MPN/100g (B results) are plotted in yellow, and those over 4600 *E. coli* MPN/100g (C results) are plotted in red. Local meteorological conditions such as wind strength and direction can influence the height of tides at Loup Bay and these factors are not taken into account.

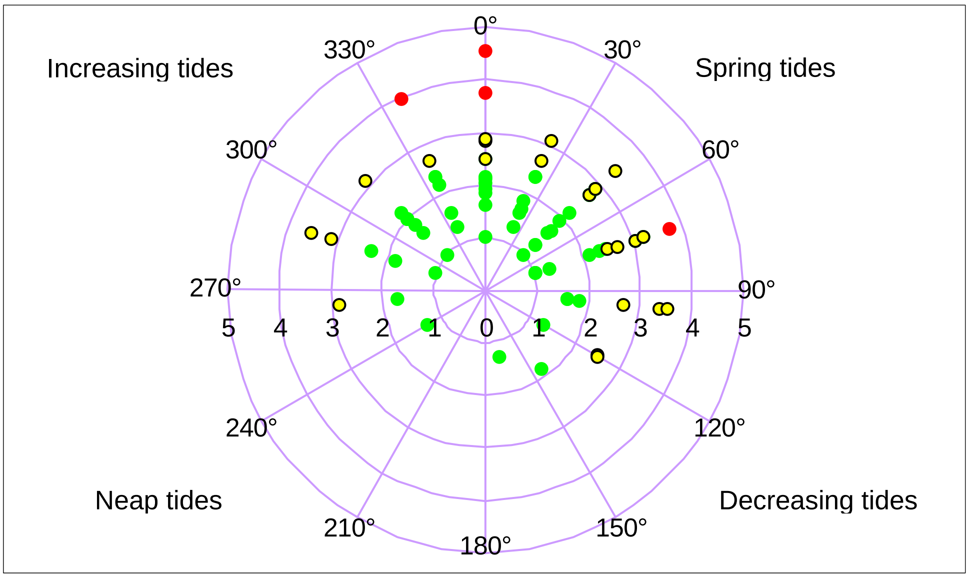


Figure 11.8 Polar plot of log_{10} *E. coli* results on the spring/neap tidal cycle

No correlation was found between *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.121, p=0.309, Appendix 6). Sampling at Loup Bay was targeted towards spring tides.

Direction and strength of flow around the production areas will change according to twice daily high/low tidal cycle. Depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (number of hours post high water) was compared with *E. coli* results. Figure 11.9 presents a polar plot of log_{10} *E. coli* results on the lunar high/low tidal cycle. High water is at 0º, and low water is at 180º. As in the previous figure, results are plotted in green, yellow or red according to their *E. coli* concentration.

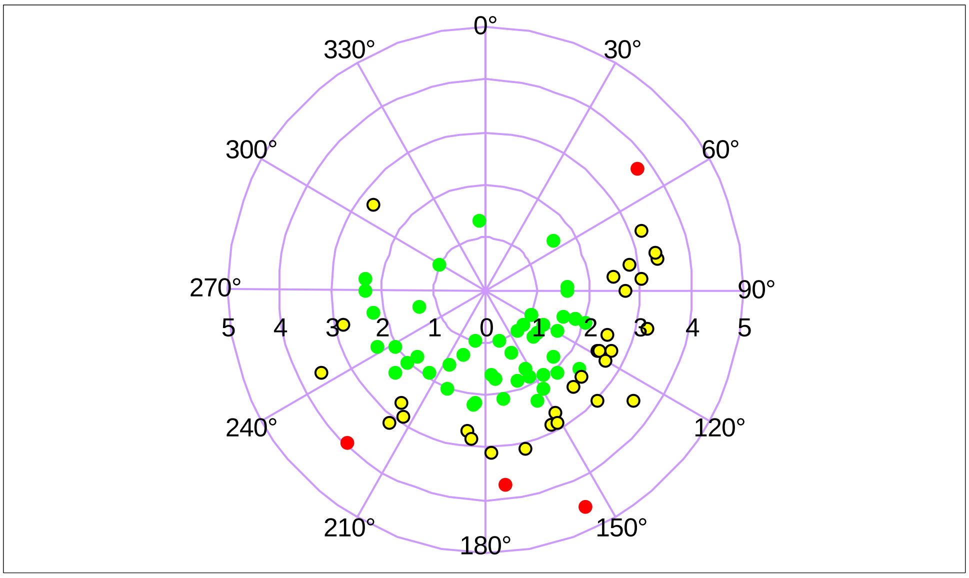


Figure 11.9 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle

No correlation was found between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.071, p=0.666, Appendix 6). Sampling was targeted around low water due to the nature of the fishery (only accessible at low tide) and so this analysis is more likely to reflect sources east of the oyster farm more than those to the west.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) as well as the feeding and elimination rates of shellfish. Therefore, water temperature may be an important predictor of *E. coli* levels in shellfish flesh. As water temperature is closely related to season, 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 11.10 presents a scatterplot of *E. coli* results against water temperature.

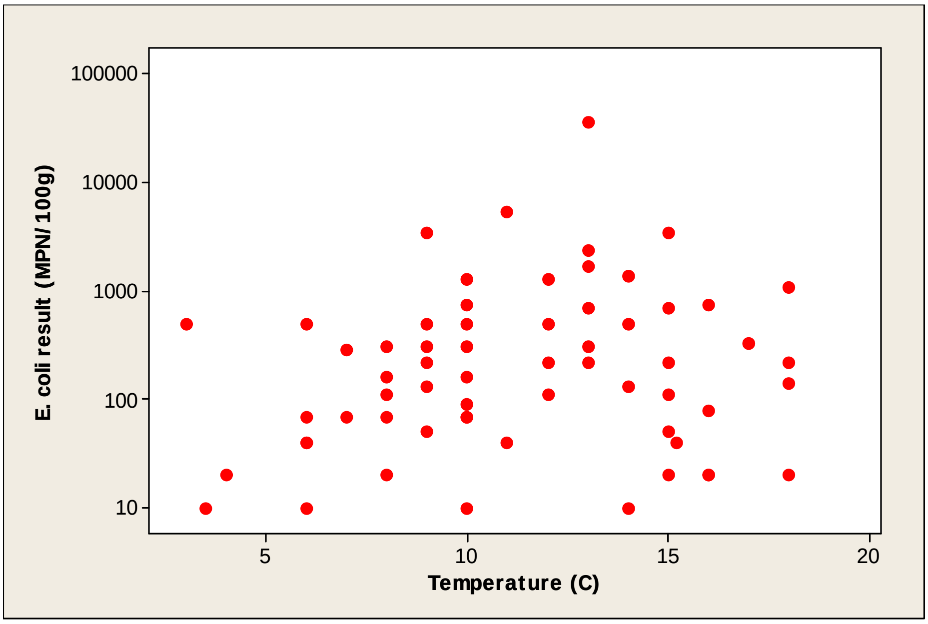


Figure 11.10 Scatterplot of result by water temperature

Linear regression analysis was undertaken on $\log_{10}$ *E. coli* against temperature. The coefficient of determination indicates that there was no relationship between the *E. coli* result and water temperature (Adjusted R-sq=1.2%, p=0.194, Appendix 6).

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns within the production area. However, the nearest wind station for which records were available was Glasgow: Bishpton, approximately 66 km to the east of the fishery. Given the differences in local topography and distance between the two it is likely that the overall patterns of wind direction differ, and that the wind strength and direction may differ significantly at any given time. Therefore it was not considered appropriate to compare *E. coli* results at Loup Bay with wind readings taken at Glasgow: Bishopton.

11.6.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.11 presents a scatter plot of *E. coli* result against salinity.

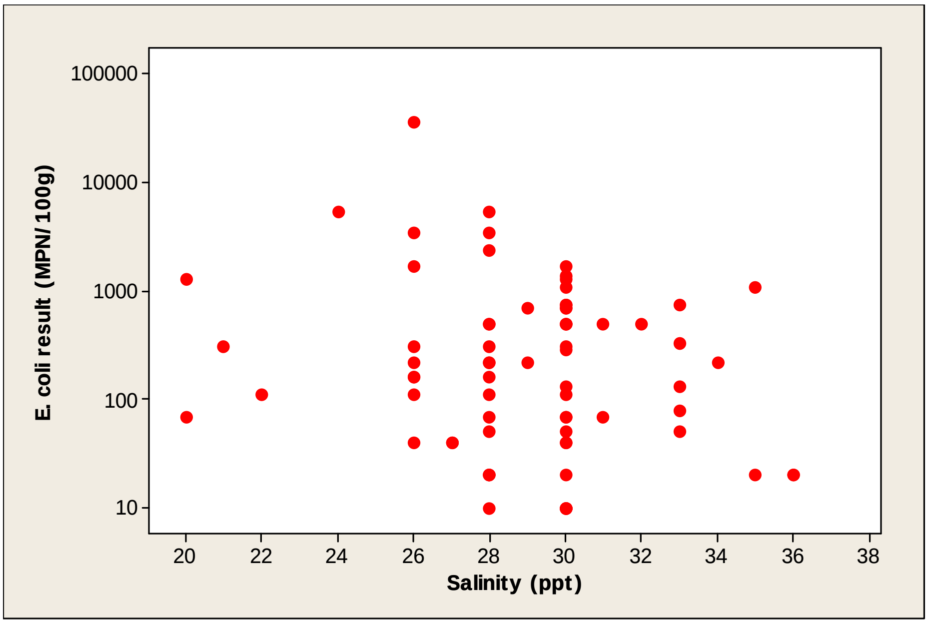


Figure 11.11 Scatterplot of result by salinity

Peak results (>1000 MPN/100 g) were more common at salinities below 30 ppt, however the coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity (Adjusted R-sq=3.0%, p=0.074, Appendix 6).

11.7 Evaluation of results over 4600 *E. coli* MPN/100g

A total of 4 samples gave a result of over 230 *E. coli* MPN/100g, and these are listed in Table 11.2.

Table 11.2 Historic *E. coli* mussel sampling results over 1000 *E. coli* MPN/100g

Collection date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
10-Sep-2002	5400	1 (RMP)	*	*	11	28	Ebb	Spring
13-Sep-2004	9100	1 (RMP)	24.2	36.5	*	*	Low	Increasing to Spring
22-Jun-2005	>18000	1 (RMP)	11.5	42.7	13	26	Low	Spring
07-Sep-2006	5400	4	26.6	65.2	*	24	Low	Spring

* Data unavailable

Of these results, 3 of 4 occurred at the nominal RMP(Location 1). One occurred in June, and three occurred in September. These results arose following moderate to high rainfall and at salinities towards the lower end of the reported range. Most were taken during spring tides around low water, however most samples from West Loch Tarbert: Loup Bay were taken during similar tidal conditions.

11.8 Summary and conclusions

No significant geographical pattern was found between *E. coli* results within the Loup Bay site, either in terms of mean result or the proportion of results exceeding 230 *E. coli* MPN/100g.

Overall, results appear to have improved slightly since 2002, with a lower incidence of high (>1000 MPN/100 g) results from 2007. A peak in results appears to have occurred in 2005, however the cause of this peak is not clear. According to the Met Office records, 2005 was not an especially rainy year so this peak would not appear to be directly related to rainfall levels. However, heavy rainfall after prolonged dry periods can result in greater land run-off. Significant differences in results by season was found, with results for the autumn significantly higher than those for the winter and spring. There appeared to be a relationship between *E. coli* results and water temperature, with E. coli concentrations increasing with water temperature up to 13°C, then decreasing with higher temperatures. However, no statistically significant correlation was found.

Positive correlations between both 2 and 7 day rainfall and *E. coli* result were found, with the correlation with 7 day rainfall very slightly stronger. While no statistically significant relationship was found between *E. coli* results and salinity, results greater than 1000 MPN/100 g appeared to be more common at salinities less than 30 ppt.

No correlations between *E. coli* results and either the spring/neap or high/low tidal cycles were found, although sampling effort was generally targeted towards low water on spring tides so there were few results at other states of tide on which to base comparison.

There was insufficient data with which to assess the effect of interactions between environmental factors on the *E. coli* concentrations in shellfish.

11.9 Sampling frequency

When a production area has held the same (non-seasonal) classification for 3 years, and the geometric mean of the results falls within a certain range it is recommended that the sampling frequency be decreased from monthly to bimonthly (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2007). This is not appropriate for Loup Bay as it has held seasonal classifications for the last three years.

12. Designated Shellfish Growing Waters Data

The Loup Bay production area coincides with the Loup (West Loch Tarbert) shellfish growing water designated in 2002. The extent of the growing water and the location of monitoring point is shown on Figure 12.1.

The monitoring requires the following testing:

- Quarterly for salinity, dissolved oxygen, pH, temperature, visible oil
- Every three years for metals and organohalogens in mussels
- Quarterly for faecal coliforms in mussels

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

Table 12.1 SEPA Faecal coliform results (faecal coliforms/100g) for shore mussels gathered from Loup Bay.

	Site	West Loch Tarbert 38 Corran
	OS Grid Ref.	NR 76792 58388
2002	Q1	
	Q2	
	Q3	
	Q4	310
2003	Q1	<20*
	Q2	
	Q3	1400
	Q4	750
2004	Q1	20
	Q2	70
	Q3	1700
	Q4	1300
2005	Q1	70
	Q2	1700
	Q3	750
	Q4	110
2006	Q1	220
	Q2	700
	Q3	110
	Q4	
2007	Q1	220
	Q2	
	Q3	
	Q4	

*Assigned a nominal value of 10 for calculation of geometric mean

The SGW sampling point is located approximately 100 m south of the RMP for the site. The geometric mean result of all shore mussel samples was 257 faecal coliforms/100 g. Results ranged from <20 to 1700 faecal coliforms/100g. Results were highest for quarter 3, and lowest for quarter 1, but differences between results by quarter were not quite significant (One-way ANOVA, p=0.068, Appendix 6). Levels of faecal coliforms are usually closely correlated to levels of *E. coli* often at a ratio of approximately 1:1. The ratio depends on a number of factors, such as environmental conditions and the source of contamination. As a consequence of this, and the fact that different bivalve species were monitored, the results presented in Table 12.1 are not directly comparable with other shellfish testing results presented in this report.

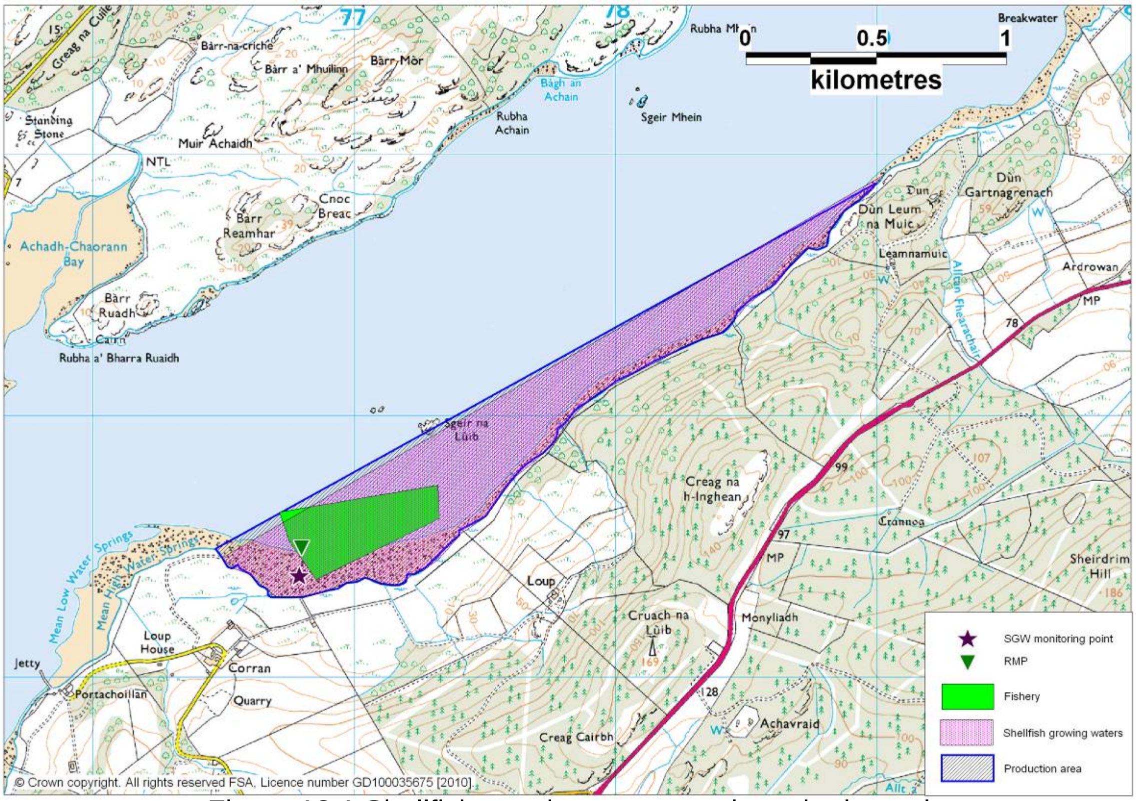


Figure 12.1 Shellfish growing waters and monitoring point

13. Rivers and streams

The following rivers and streams were measured and sampled during the shoreline survey. These represent the largest freshwater discharges into the production area. The survey was undertaken under relatively wet conditions.

Table 13.1 River loadings for Loup Bay

No.	Position	Width (m)	Depth (m)	Flow (m/s)	Discharge (m^3/d)	*E. coli* result (cfu/100ml)	*E. coli* loading (cfu/day)
1	NR 76243 60839	1.5	0.10	0.217	2812	800	$2.2x10^{10}$
2	NR 76821 58294	0.7	0.02	0.102	123	1100	$1.4x10^{9}$
3	NR 76982 58348	0.6	0.14	0.147	1067	700	$7.5x10^{9}$
4	NR 77096 58348	0.5	0.03	0.067	87	3100	$2.7x10^{9}$
5	NR 77125 58344	1.1	0.04	0.156	593	2800	$1.7x10^{10}$
6	NR 77159 58342	0.15	0.03	0.285	111	4900	$5.4x10^{9}$
7	NR 77227 58372	0.75	0.12	0.108	840	2900	$2.4x10^{10}$
8	NR 77618 58747	0.75	0.03	0.372	723	3000	$2.2x10^{10}$
9	NR 76790 58291	0.3	0.02	0.028	15	1000	$1.5x10^{8}$
10	NR 76627 58307	1.05	0.04	0.304	1103	500	$5.5x10^{9}$
11	NR 76128 58309	2.45	0.06	0.414	5258	4000	$2.1x10^{11}$

Of most significance to the fishery are streams 2 to 10 as they discharge to the shore adjacent to the fishery. These streams were small but they contained fairly high levels of *E. coli* in some cases, ranging from 700 to 4900. They drain a strip of marshy land, with a field holding livestock behind. These streams were not evenly distributed along the shore. A cluster of 4 streams along a 134 m stretch approximately in the middle of the shoreline adjacent to the fishery contributed over 50% of the total loading from these streams. Further west, along the shore of Loup Bay several more small streams draining wooded areas are apparent on the OS map, but these were not sampled or measured during the survey. It is likely that the loadings from these streams are similar or less than those sampled, as they drain wooded areas rather than pastures containing livestock.

In addition to these streams, a stream discharging approximately 660 m to the west of the fishery, just outside of Loup Bay around a small headland contributed a loading of $2.1x10^{11}$ *E. coli* cfu/day, and this is likely to contribute to levels of *E. coli* in Loup Bay.

There are many more freshwater inputs to West Loch Tarbert as a whole, and these will all contribute to levels of contamination found in this water body.

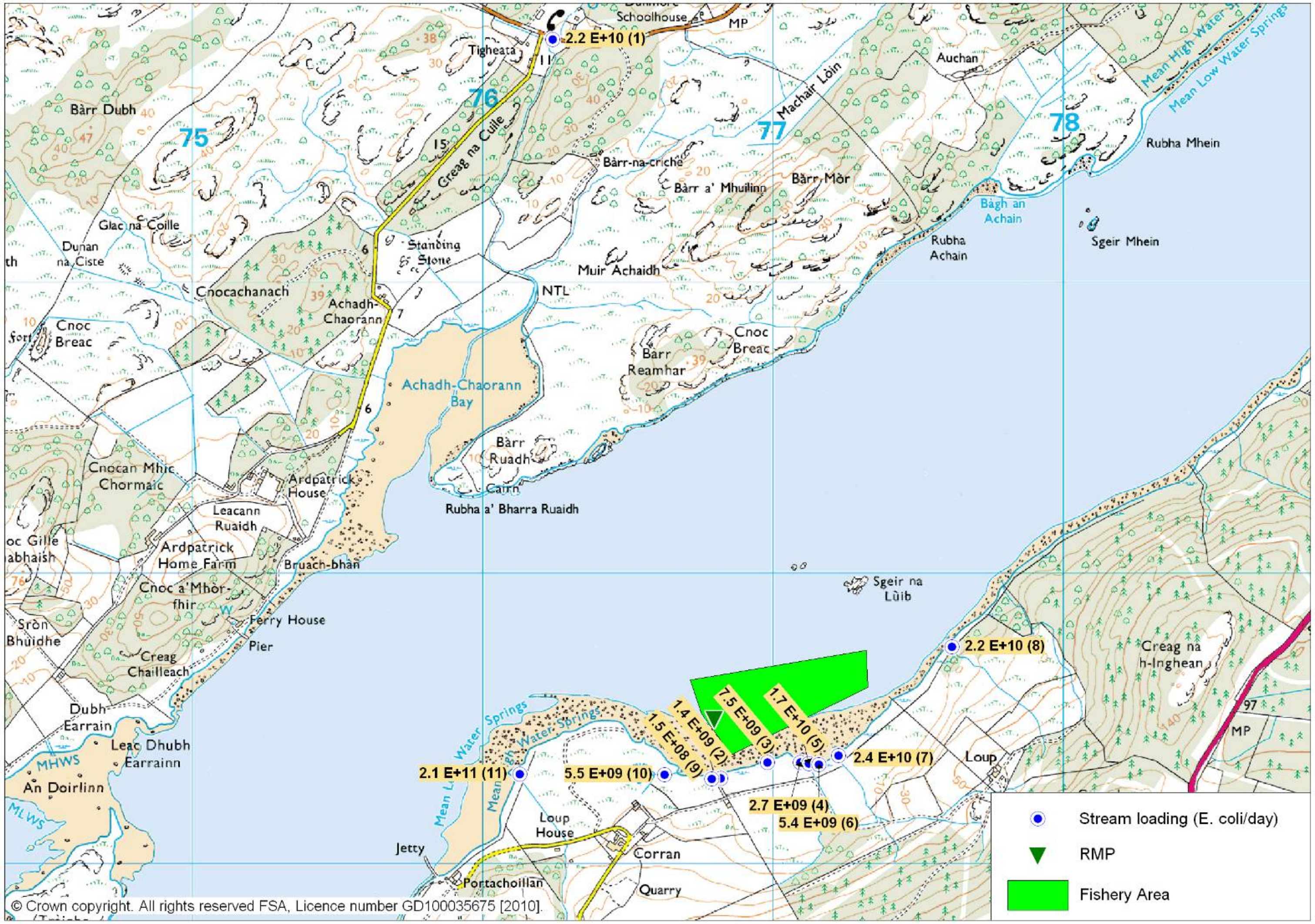


Figure 14.1 Loup Bay stream loadings

14. Bathymetry and Hydrodynamics

Currents in coastal waters and estuaries are driven by a combination of tide, wind and freshwater inputs. This section aims to make a simple assessment of water movements around the area. Figure 14.1 shows the OS map of the area of West Loch Tarbert that includes Loup Bay and Figure 14.2 shows the bathymetry of that part of the loch.

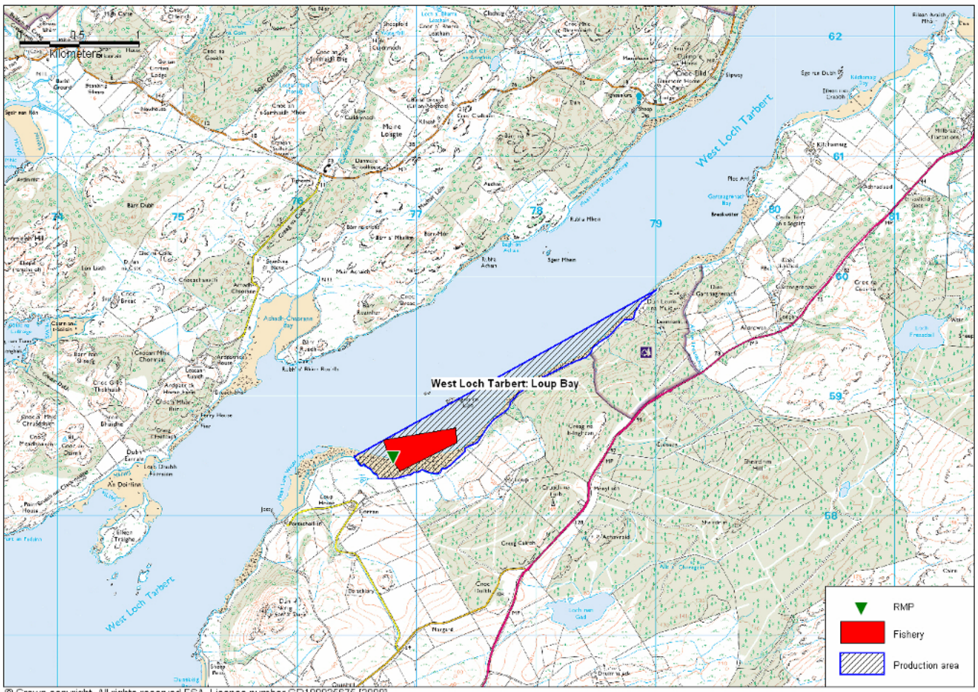


Figure 14.1 OS map of West Loch Tarbert – Loup Bay

Figure 14.2 Bathymetry of West Loch Tarbert- Loup Bay

14.1 Tidal Curve and Description

The two tidal curves presented in Figure 14.3 are for the Sound of Gigha. This secondary port is located on the east side of the Isle of Gigha, which lies south-west of the mouth of West Loch Tarbert. The first tidal curve is for seven days beginning 00.00 BST on 21/07/09 and the second is for seven days beginning 00.00 BST on 28/11/09. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

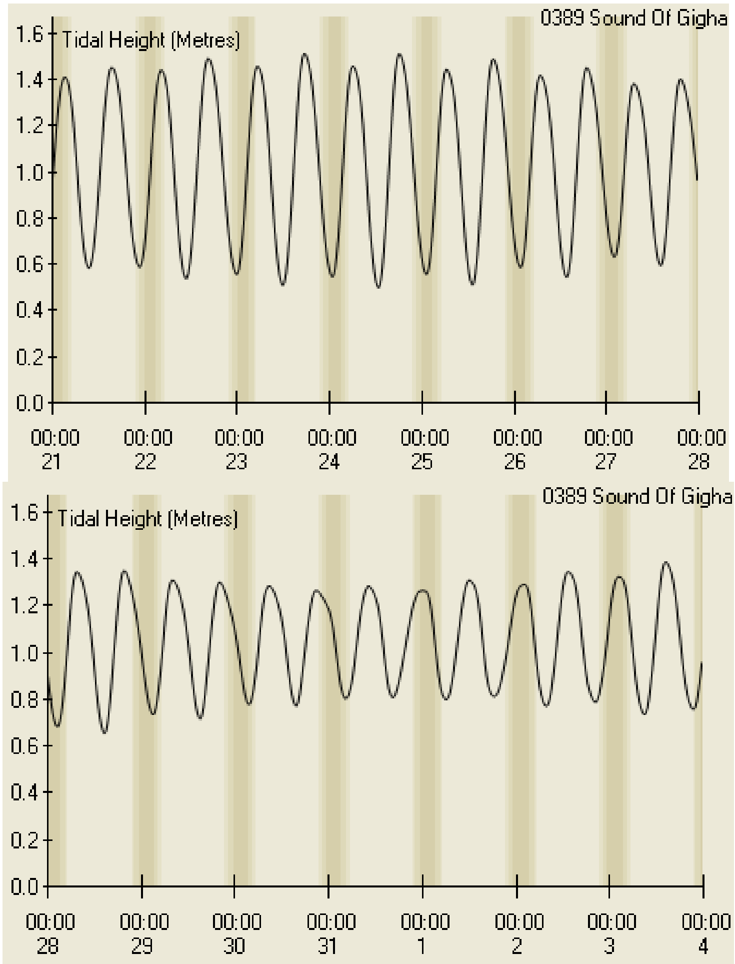


Figure 14.3 Tidal curves at the Sound of Gigha

The following is the summary description for Sound Of Gigha from TotalTide:
0389 Sound Of Gigha is a Secondary Non-Harmonic port. The tide type is Semi-Diurnal.

HAT	1.6 m
MHWS	1.5 m
MHWN	1.3 m
MSL	0.93 m
MLWN	0.8 m
MLWS	0.6 m

The tidal range at spring tide is therefore approximately 0.9 m and at neap tide 0.5 m.

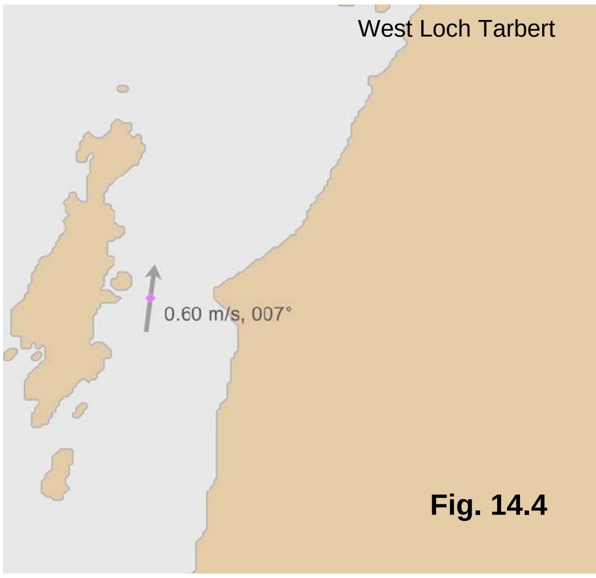
The loch itself is 16 km long. Through most of its length it is approximately 1 km wide. The Scottish Sea Lochs catalogue identifies 1 sill and 1 basin within the loch. The sill is 8 m deep and is located towards the mouth of the loch. The basin is located in the lower half of the loch. It is 32 m deep at its maximum with this deepest area close to the sill. In the upper loch the depth does not exceed 10 m. There are a number of intertidal areas along the shores of the loch with a large intertidal area at the head. The two maps show that the Loup Bay Pacific oyster fishery as observed at the time of the shoreline survey is located in a relatively large intertidal area in an open bay on the south side of the loch.

14.2 Currents

The only tidal stream information which was available from TotalTide was for a tidal diamond in the Sound of Gigha – none was available within West Loch Tarbert itself. The tidal diamond information is given below in Table 14.1. The associated spring tidal streams are shown in Figure 14.4 (flood tide) and Figure 14.5 (ebb tide).

Table 14.1 Tidal diamond for station SN039A – Sound of Gigha (55°40.80'N 5°42.60'W)

Time	Direction	Spring rate	Neap Rate
-06h	000°	0.51 m/s	0.15 m/s
-05h	009°	0.62 m/s	0.21 m/s
-04h	012°	0.57 m/s	0.21 m/s
-03h	015°	0.41 m/s	0.15 m/s
-02h	011°	0.26 m/s	0.10 m/s
-01h	150°	0.05 m/s	0.00 m/s
HW	185°	0.41 m/s	0.10 m/s
+01h	193°	0.62 m/s	0.21 m/s
+02h	183°	0.67 m/s	0.21 m/s
+03h	174°	0.51 m/s	0.15 m/s
+04h	193°	0.31 m/s	0.10 m/s
+05h	312°	0.10 m/s	0.05 m/s
+06h	353°	0.51 m/s	0.15 m/s



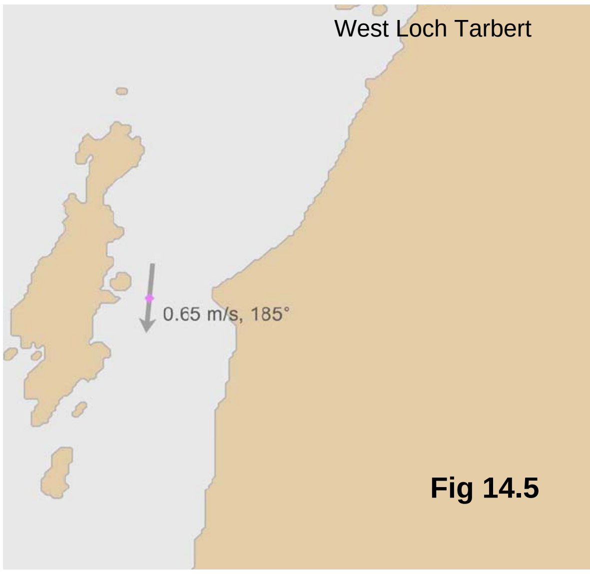


Figure 14.4 Spring flood tide at SN039A
Figure 14.5 Spring ebb tide at SN039A

Within West Loch Tarbert, the expected pattern of tidal flows is up the loch on a flooding tide, and back down the loch on an ebbing tide. Due to the small tidal range these currents are likely to be relatively slow. This is reflected in its moderately long calculated flushing time of 5 days (Edwards & Sharples, 1986), who also calculated that the current at the sill on spring tides was 0.13 m/s. Therefore, at the fishery site, tidal currents will move quite slowly in a north westerly direction along the shore on the flooding tide, and back in the opposite direction on the ebb, so sources along the west shore will be of much greater importance than those on the opposite shore. A small headland lies to the west of the site, so tidal flows may be slightly more restricted here than at the eastern end of the site.

There are two additional effects that could add to or otherwise modify these currents, one is density driven flows as a result of stratification, and the other is wind-driven flows. These effects will be superimposed on tidal flows. West Loch Tarbert has a southwest to northeast aspect, and so is most exposed to winds from these directions which would tend to be funnelled up or down the Loch by the surrounding hills. Southwesterly winds would tend to increase the surface currents associated with flood tides and reduce those associated with ebb tides. Northeasterly winds would have the opposite effect. There is also the potential for a return current at the sea bed.

The catchment area West Loch Tarbert as a whole is 110 km^2 and it has a calculated average salinity reduction of 0.7ppt indicating moderate freshwater influence (Edwards & Sharples, 1986). Mixing depth, which is the calculated extent of downward penetration of freshwater into the more dense seawater brought about by tidally induced turbulence is 0 m suggesting that there is little in the way of tidally induced mixing. Millar (1961) found that reduced salinity conditions in West Loch Tarbert were generally confined to the uppermost layers with minimal reduction in salinity near the sea bed. This all suggests that at times of high freshwater input stratification may occur, creating a seaward flowing surface current of fresher water, with a return current of more saline water at depth. This does not take wind driven mixing into account however. A single salinity profile was taken during the shoreline survey, about 1.2 km to the northeast of the fishery in a depth of 5.5 m. This indicated that there was not a marked difference in salinity through the water column, with salinities at all depths approaching that of full-strength seawater. Salinities in seawater samples taken from the shore were generally greater than 30 ppt. This limited data suggests density driven flows were unimportant in the shallow waters of the lower loch at the time, whereas the published information cited above indicates stratification is likely to occur at times within the loch as a whole.

Salinities recorded at the fishery during the collection of shellfish samples for *E. coli* classification monitoring averaged at 29 ppt and ranged from 20 to 36 ppt indicating occasional significant freshwater influence here.

The harvester at West Loch Tarbert identified that tidal exchange in the loch is limited due to the islands off the mouth and that low pressure off the west coast can suppress the already limited tidal range (N. Duncan, pers. comm.). The Clyde Cruising Club Sailing Directions for Kintyre to Ardnamurchan also notes that 'tides are much affected by meteorological conditions' (Clyde Cruising Club, 2007). Low pressure systems will therefore reduce tidal exchange, which will have two potential effects. The first is that only contamination from only local sources will tend to be of significance. The effects of these, however, may be greater due to reduced transport and dispersion. The second is that non-tidal influences on current, such as wind, will become relatively more significant.

14.3 Conclusions

It is presumed that tidal currents, although fairly weak, will predominate in the area of the fishery. The general transport of contamination will be along the loch, in the direction of tidal flows. The oyster trestles will be subject to contamination arising from sources on the southern side further up the loch on the falling tide and further down the loch on the rising tide. Impact from sources on the shore adjacent to the fishery is likely to be greatest between slack high tide to slack low tide, with any contamination being taken across the fishery as the tide falls. The extent of time over which the shellfish are exposed to contamination will be limited to the time that they are actually submerged and filtering. This means that those shellfish towards the main channel will be exposed to contamination longer – conversely, if the tidal current is bringing cleaner water, they will depurate contamination for a longer period.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 21st – 23rd July 2009 under wet conditions.

The fishery consists of just over 0.1 km^2 of stakes with ropes strung between them n the intertidal area of Loup Bay, from which bags of Pacific oysters are suspended. Stock of a range of sizes was present, including that of a harvestable size. Seed stock is sourced from a hatchery in Whitstable, and then takes 2-3 years to grow to a marketable size. Time of harvest is dictated by demand and toxin status, but can occur at any time of the year. On the adjacent shore there is a processing shed with depuration facilities, which also serves the Barvalla site further up West Loch Tarbert, which is under the same ownership.

Human population on the shores of West Loch Tarbert is low. There are no sewage discharges direct to the production area. One private sewer pipe was seen on the north shore opposite the fishery. A septic tank at the oyster processing shed discharges to soakaway. The pier at West Tarbert is an active fishing pier, so fishing boats will pass Loup Bay on their way to and from the fishing grounds. Also, ferries serving Islay sail from the Kennacraig Ferry terminal and pass Loup Bay on their way to and from the island but these do not discharge wastewater to West Loch Tarbert. Yachts visit the loch from time to time, with one seen further up the loch.

West Loch Tarbert is surrounded by forest, with some areas of pasture. On the shore adjacent to the fishery, a field of approximately 75 sheep and 25 cattle was recorded. Between this field and the shore was an area of marsh and reeds from which a number of small streams drain to the shore which will carry contamination from the livestock to the fishery, although the amount of contamination reaching the fishery may be reduced during its passage through the marsh. On fields just to the west of the fishery, 22 sheep with access to the shore were recorded. Slightly further back, around Corran Farm, On the opposite shore, at Acach-Chaorann Bay, large amounts of sheep droppings and wool were recorded along the shoreline and in the water. A seal was seen further up the loch, so it is likely that seals come into close proximity of the fishery from time to time. Also, seagulls were present around the loch but not in great numbers.

A total of 11 streams discharging to the survey area were sampled and measured. The majority of these were small streams discharging to the shore immediately adjacent to the fishery. The total loading contributed by these streams was 8.5×10^{10} *E. coli* cfu/day. The highest concentration of these streams was a cluster of 4 streams along a 134 m stretch approximately in the middle of the shoreline adjacent to the fishery, which contributed over 50% of the total loading from these streams.

Seawater samples contained levels of *E. coli* ranging from 3 to 580 cfu/100ml. The two highest results (580 and 300) were obtained within the fishery, indicating that contamination was highest here compared to other parts of the survey area at the time of survey. The highest of these was obtained at the eastern end of the fishery. Two oyster samples were taken, one from either end of the fishery, with the highest result arising at the western end of the fishery. A salinity profile taken in the middle of the loch indicated little freshwater influence and stratification, although the depth at this location was only 5 m.

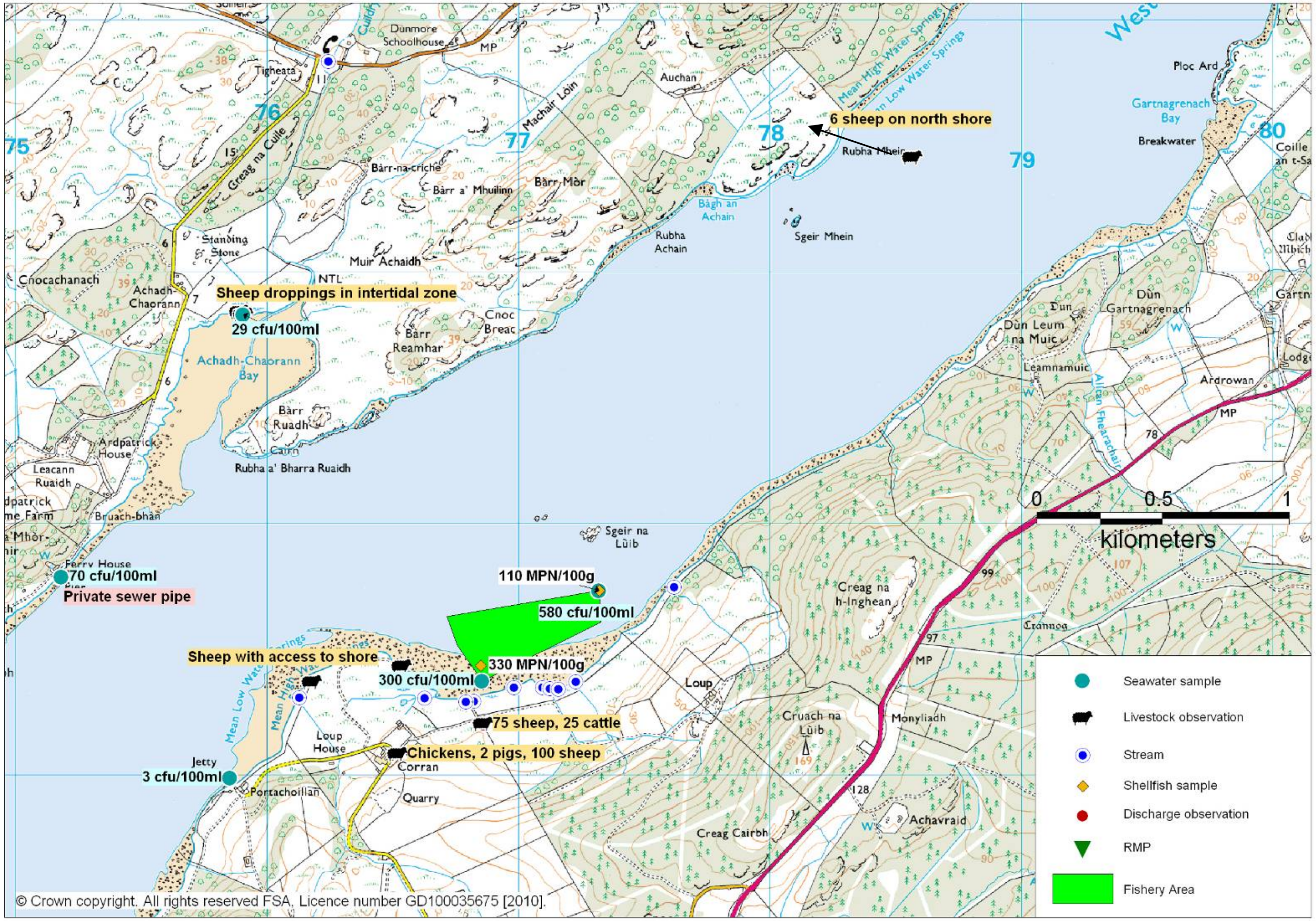


Figure 15.1 Summary of shoreline survey findings for West Loch Tarbert: Loup Bay

16. Overall Assessment

Human sewage impacts

The only discharge to the either the loch or to watercourses draining to the loch within the survey area was a small private discharge from an individual dwelling to the opposite shore and over 1 km away from the fishery. There are several discharges further northeast within the loch that are likely to increase background levels of contamination within the loch but these will not result in one particular area of the fishery being subject to higher levels of contamination than any other. Yachts and fishing boats may discharge overboard while passing Loup Bay, but it is not known how often this may occur.

Agricultural impacts

The shoreline survey identified the presence of significant numbers of livestock around the western end of Loup Bay around Corran Farm. Faecal contamination from livestock will mainly be carried into the loch by streams draining the pastures where animals graze. However, the potential for direct deposition to the intertidal zone just to the west of Loup Bay was also identified, as sheep observed here had access to the shoreline. On the opposite shore, at Acach-Chaorann Bay, large amounts of sheep droppings and wool were recorded along the shoreline and in the water suggesting significant inputs from livestock in this area.

In conclusion, livestock inputs are likely to be of significance to the fishery, and will be mainly carried into the production area via watercourses draining the pastures. Livestock were concentrated towards the western end of Loup Bay, suggesting that if a gradient of contamination of livestock origin exists across the fishery, contamination may be higher at the western end.

Wildlife impacts

Potential wildlife impacts to the fishery at Loup Bay include deer, seals, seabirds and geese. Faecal contamination from geese and deer are most likely to be carried to the fishery via local streams draining the land on which they are present. While deer represent a year-round source, geese are most likely to be present in winter. Seals and seabirds are more likely to directly deposit faecal material at or near the fishery. However, there are relatively few present in the area and so any impact is likely to be random and fleeting in nature.

The impact of faecal contamination from wildlife sources to the fishery is, therefore, presumed to be evenly distributed across the fishery except where it is likely to be carried in streams and direct runoff from land.

Seasonal variation

There is likely to be seasonal variation, with increases during the summer and early autumn months, from both human and agricultural activities. The area attracts tourism by both car and yacht and peak tourist season in many areas of Scotland tends to occur around the school holiday months of July and August.

Livestock numbers are likely to be higher in the summer, so the impact of faecal contamination from these sources are expected to be higher during the summer, particularly following moderate rainfall. Livestock are likely to access watercourses to drink more frequently during warmer weather.

The weather is wetter and windier in the winter months, so more rainfall dependent contamination such as runoff from pastures may generally be expected at these times, although high rainfall events can occur at any time of the year.

An analysis of historic *E. coli* monitoring data showed a significant seasonal effect, with results for the autumn significantly higher than those in the winter and spring. High results centred around the late summer/early autumn period, always with a water temperature of 9 ºC or more. Shellfish growing waters monitoring results showed a similar seasonal pattern, with highest levels of faecal coliforms in shore mussels in quarter 3, and lowest levels in quarter 1, but differences between results by quarter were not found to be statistically significant.

In conclusion, there is likely to be more contamination of human origin during the loch as a whole during the summer months, although the effects of this may not be so marked at Loup Bay as in other parts of the loch which receive sewage inputs from tourist accommodation. Numbers of sheep and cattle will be higher during the summer and early autumn, and they are more likely to access streams in the warmer months, so more contamination from livestock is likely to enter streams at these times. Analysis of historical *E. coli* monitoring data and shellfish growing waters monitoring data shows highest levels of contamination in the shellfish during the late summer/early autumn.

Rivers and streams

Freshwater inputs to the shore adjacent to the fishery consist of a series of small streams that drain a strip of boggy land along the shore. Behind the bog lies an area of pasture where significant numbers of sheep and cattle were present at the time of shoreline survey. At the time of survey, these streams contained fairly high levels of *E. coli* , ranging from 700 to 4900. These streams were not evenly distributed along the shore. A cluster of 4 streams along a 134 m stretch approximately in the middle of the shoreline adjacent to the fishery contributed over 50% of the total loading from these streams. In addition to these streams, a stream discharging approximately 660 m to the west of the fishery contributed significant levels of *E. coli* to Loup

Bay. Overall, given their locations, these stream inputs may impact slightly more towards the west end of the fishery.

Meteorology, hydrology, and movement of contaminants

The tidal range within West Loch Tarbert is small, and tidally driven currents within the loch are relatively weak, and can be suppressed by the presence of low pressure systems. Tidal influences will result in a bidirectional flow of water up and down along the shore of the loch as the tide floods and ebbs. Tidal flows at the fishery may be weaker at its western end which lies behind a small headland. Tidal flows will create a region of impact either side of sources discharging to the shore, with greater impacts closer to the source. Contamination sources close to the fishery will have the greatest impact on the microbiological quality of the shellfish. Sources on the opposite shore are less likely to reach the fishery.

There is some uncertainty about the importance of density driven currents, with the available literature suggesting stratification is likely to occur in West Loch Tarbert as a whole. However, no stratification was found in a salinity profile taken just offshore from the fishery site during the shoreline survey despite relatively high recent rainfall, suggesting stratification may not be a significant feature in this part of the loch, at least.

Positive correlations were found between historical *E. coli* monitoring results and rainfall in the previous 2 and 7 days suggesting that contaminated runoff is of some importance. Highest *E. coli* results tended to occur at salinities below 30 ppt, providing further indication that faecal contamination is reaching the fishery via rainfall runoff and local watercourses.

Temporal and geographical patterns of sampling results

After rounding to 100 m accuracy, historical *E. coli* monitoring samples were recorded from four locations. Highest mean result arose at the nominal RMP, at towards the north west corner of the fishery, and lowest mean result arose towards the south west corner of the fishery. The differences between the mean results by sampling location were not statistically significant, nor were the differences in proportions of results over 230 *E. coli* MPN/100g. As these samples were collected on different occasions, any differences in results between sampling locations may reflect temporal rather than spatial effects. Historical *E. coli* monitoring results suggest a slight overall improvement in results from 2002 to present, with a lower incidence of high results from 2007. A peak in results appears to have occurred in 2005, driven by a result of >18000 MPN/100 g that occurred in June of that year after moderate rainfall.

Seawater samples were taken at either end of the fishery during the shoreline survey, and showed fairly high levels of contamination within Loup Bay relative to samples taken from other areas of the loch at the time. The sample taken towards the eastern end of the fishery gave a slightly higher result than the one taken at the western end (580 and 300 *E. coli* cfu/100ml respectively). Oyster samples taken from these locations showed the opposite pattern, with

110 *E. coli* MPN/100g at the eastern end, and 330 *E. coli* MPN/100g at the western end.

Overall conclusions

The most significant source of faecal contamination to the Pacific oyster fishery at Loup Bay is diffuse pollution from grazed land drained by numerous watercourses discharging to the shoreline adjacent to the fishery. Positive correlations were found between historical *E. coli* monitoring results and recent rainfall suggesting that contaminated runoff is an important source of faecal indicator bacteria at Loup Bay. Given the location of these sources and the likely pattern of currents in the area, the southwestern corner of the fishery will be most affected by contamination from these sources.

Given the nature of the sources of contamination at Loup Bay, there is no evidence to suggest that the production area boundaries require adjustment to exclude any areas of particularly high contamination levels. However, the current production area boundaries do not fully encompass either the existing oyster farm or the entire Crown Estate seabed lease for this site.

The data suggest that there is seasonality in the identified sources of faecal contamination, which was confirmed by analysis of historical *E. coli* monitoring results. Therefore, the area does not meet the criteria identified in the good practice guide for reducing the sampling frequency from monthly to bimonthly.

17. Recommendations

Production Area

The existing production area boundaries should be expanded to include the full extent of the current oyster farm and the seabed lease area. Therefore, the boundaries have been amended to the area bounded by lines drawn between NR 7900 5989 to NR 7647 5890 to NR 7647 5849 and extending to MHWS. This area is illustrated, along with the extents of the oyster farm and the seabed lease, in Figure 17.1.

RMP

There is no compelling reason to relocate the RMP, which adequately reflects contamination from the nearest sources to the south and west of the oyster farm. Therefore, it is recommended that this be retained as NR 7680 5850.

Sampling Tolerance

Accessibility of the oyster farm can be affected by meteorological conditions, with low pressure weather systems leading to higher than normal sea levels and reducing the extent of the fishery that is exposed at low tide. Therefore, a sampling tolerance of 20 m is recommended to allow for variation in the low tide line.

Frequency

As the area does not meet the criteria identified in the good practice guide for reducing the sampling frequency, monthly sampling should be continued.

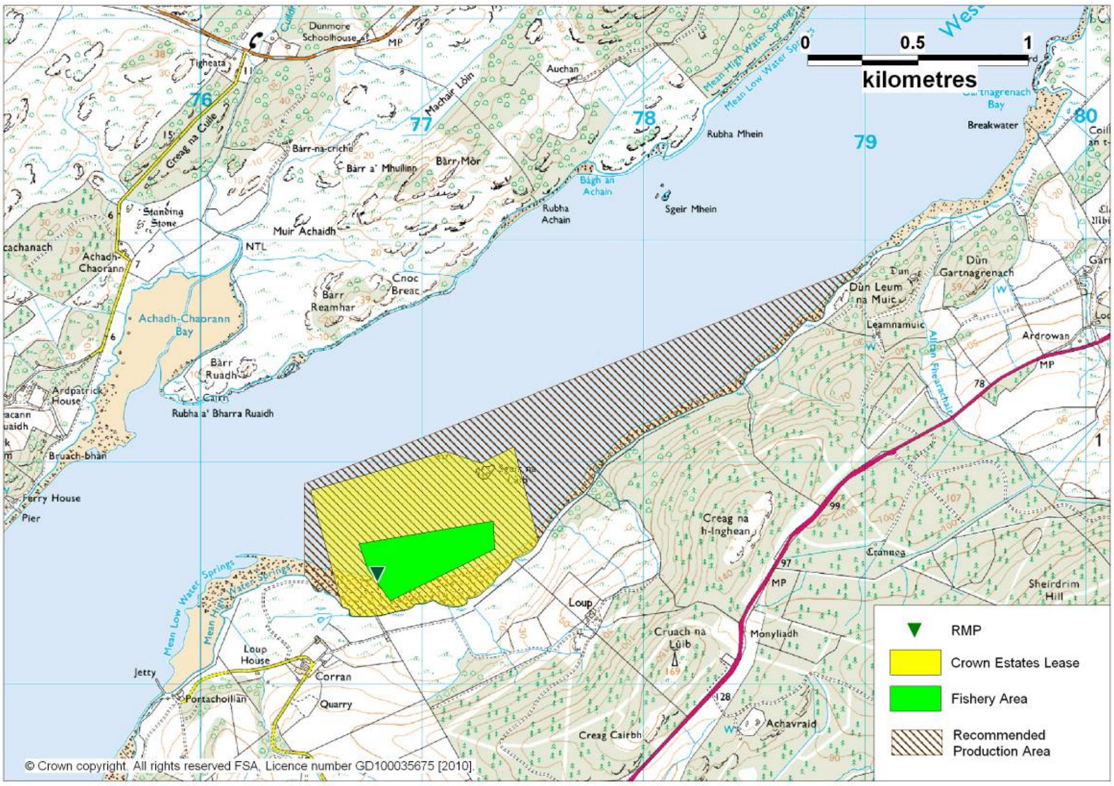


Figure 17.1 Recommendations for West Loch Tarbert: Loup Bay

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Sampling Plan for West Loch Tarbert: Loup Bay

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISH-ERY	NGR OF RMP	EAST	NORTH	TOLER-ANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
West Loch Tarbert: Loup Bay	Loup Bay	AB 299 084 13	Pacific oyster	Bags suspended from stakes and ropes	NR 7680 5850	176800	658500	20	N/A	Hand	Monthly	Argyll & Bute Council	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan

Table of Proposed Boundaries and RMPs

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
West Loch Tarbert: Loup Bay	Pacific oyster	AB 299 084 13	Area inshore of line drawn between NR 7647 5849 and NR 7900 5989 extending to MHWS	NR 768 585	Area bounded by lines drawn between NR 7900 5989 to NR 7647 5890 to NR 7647 5849 and extending to MHWS.	NR 7680 5850	Production area amended to include full extent of seabed lease. RPM retained and stated to 10m accuracy

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

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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.

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Tables of Typical Faecal Bacteria Concentrations

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

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	282	$2.8 \times 10^{6*}$ (-)	2.3×10^6	3.2×10^6
Crude sewage discharges	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	79	$3.5 \times 10^{6*}$ (-)	2.6×10^6	4.7×10^6
Storm sewage overflows					203	2.5×10^6	2.0×10^6	2.9×10^6
Primary	127	$1.0 \times 10^{7*}$ (+)	8.4×10^6	1.3×10^7	14	4.6×10^6 (-)	2.1×10^6	1.0×10^7
Primary settled sewage	60	1.8×10^7	1.4×10^7	2.1×10^7	8	5.7×10^6		
Stored settled sewage	25	5.6×10^6	3.2×10^6	9.7×10^6	1	8.0×10^5		
Settled septic tank	42	7.2×10^6	4.4×10^6	1.1×10^7	5	4.8×10^6		
Secondary	864	$3.3 \times 10^{5*}$ (-)	2.9×10^5	3.7×10^5	184	$5.0 \times 10^{5*}$ (+)	3.7×10^5	6.8×10^5
Trickling filter	477	4.3×10^5	3.6×10^5	5.0×10^5	76	5.5×10^5	3.8×10^5	8.0×10^5
Activated sludge	261	$2.8 \times 10^{5*}$ (-)	2.2×10^5	3.5×10^5	93	$5.1 \times 10^{5*}$ (+)	3.1×10^5	8.5×10^5
Oxidation ditch	35	2.0×10^5	1.1×10^5	3.7×10^5	5	5.6×10^5		
Trickling/sand filter	11	2.1×10^5	9.0×10^4	6.0×10^5	8	1.3×10^5		
Rotating biological contactor	80	1.6×10^5	1.1×10^5	2.3×10^5	2	6.7×10^5		
Tertiary	179	1.3×10^3	7.5×10^2	2.2×10^3	8	9.1×10^2		
Reedbed/grass plot	71	1.3×10^4	5.4×10^3	3.4×10^4	2	1.5×10^4		
Ultraviolet disinfection	108	2.8×10^2	1.7×10^2	4.4×10^2	6	3.6×10^2		

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

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

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

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

Statistical data

All *E. coli* data was log transformed prior to statistical tests.

<u>Section 11.3 One way ANOVA comparison of results by reported sampling location</u>

```
Source              DF      SS     MS     F      P
GridRef (rounded)    3   3.408  1.136  1.87  0.142
Error               79  48.060  0.608
Total               82  51.468

S = 0.7800   R-Sq = 6.62%   R-Sq(adj) = 3.08%


                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level      N    Mean   StDev  ---------+---------+---------+---------+
NR768584   9  1.9524  0.6201  (--------------*--------------)
NR768585  38  2.4576  0.8307                      (------*------)
NR769584  19  2.1669  0.6435             (---------*---------)
NR770585  17  2.0275  0.8660        (----------*----------)
                              ---------+---------+---------+---------+
                                     1.75      2.10      2.45      2.80

Pooled StDev = 0.7800
```

<u>Section 11.3 Chi squared comparison of proportion of results over 230 *E. coli* MPN/100g by reported sampling location</u>

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

       NR768585  NR769584  NR770585  Total
    1        19         7         6     32
          16.43      8.22      7.35
          0.401     0.180     0.248

    2        19        12        11     42
          21.57     10.78      9.65
          0.306     0.137     0.189

Total        38        19        17     74

Chi-Sq = 1.462, DF = 2, P-Value = 0.481
```

<u>Section 11.5 One way ANOVA comparison of *E. coli* results by season</u>

```
Source  DF      SS     MS     F      P
Season   3   9.547  3.182  6.00  0.001
Error   79  41.920  0.531
Total   82  51.468

S = 0.7284   R-Sq = 18.55%   R-Sq(adj) = 15.46%


                           Individual 95% CIs For Mean Based on Pooled StDev
Level   N    Mean   StDev    +---------+---------+---------+---------
1      24  1.8836  0.7313    (------*------)
2      22  2.3692  0.8638                (------*-------)
3      22  2.7173  0.6605                        (-------*-------)
4      15  1.9661  0.5848    (--------*---------)
                             +---------+---------+---------+---------
```

```
                           1.60      2.00      2.40      2.80

Pooled StDev = 0.7284


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

Individual confidence level = 98.96%


Season = 1 subtracted from:

Season    Lower  Center   Upper     +---------+---------+---------+---------
2       -0.0784  0.4856  1.0497                          (-------*-------)
3        0.2697  0.8337  1.3978                               (-------*-------)
4       -0.5464  0.0825  0.7115                 (--------*--------)
                                    +---------+---------+---------+---------
                                 -1.40     -0.70      0.00      0.70


Season = 2 subtracted from:

Season    Lower   Center   Upper     +---------+---------+---------+---------
3       -0.2281   0.3481  0.9243                          (-------*-------)
4       -1.0430  -0.4031  0.2368          (--------*--------)
                                     +---------+---------+---------+---------
                                  -1.40     -0.70      0.00      0.70


Season = 3 subtracted from:

Season    Lower   Center    Upper     +---------+---------+---------+---------
4       -1.3911  -0.7512  -0.1113     (--------*--------)
                                      +---------+---------+---------+---------
                                   -1.40     -0.70      0.00      0.70
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.321
P-Value = 0.010
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.354
P-Value = 0.004
```

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 18 November 2009 16:27:22

Variables (& observations)	r	p
Angles & Linear (83)	0.121	0.309

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 18 November 2009 16:26:33

Variables (& observations)	r	p
Angles & Linear (83)	0.071	0.666

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature

```
The regression equation is
log e coli for temperature = 1.90 + 0.0325 temperature


Predictor       Coef  SE Coef     T      P
Constant      1.8961   0.2950  6.43  0.000
temperature  0.03245  0.02472  1.31  0.194


S = 0.745004   R-Sq = 2.8%   R-Sq(adj) = 1.2%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.9564  0.9564  1.72  0.194
Residual Error  60  33.3019  0.5550
Total           61  34.2583


Unusual Observations

                   log e coli
                          for
Obs  temperature  temperature     Fit  SE Fit  Residual  St Resid
  7         11.0       3.7324  2.2531  0.0949    1.4793     2.00R
 29         13.0       4.5563  2.3180  0.1035    2.2383     3.03R

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

Section 11.6.5 Regression analysis – *E. coli* result vs salinity

```
The regression equation is
log e coli for salinity = 3.76 - 0.0522 salinity


Predictor      Coef  SE Coef      T      P
Constant     3.7644   0.8405   4.48  0.000
salinity   -0.05223  0.02882  -1.81  0.074


S = 0.775345   R-Sq = 4.4%   R-Sq(adj) = 3.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   1.9754  1.9754  3.29  0.074
Residual Error  72  43.2835  0.6012
Total           73  45.2589


Unusual Observations

                 log e coli
Obs  salinity  for salinity     Fit  SE Fit  Residual  St Resid
  1      21.0        2.4914  2.6674  0.2475   -0.1761     -0.24 X
  8      20.0        3.1139  2.7197  0.2746    0.3943      0.54 X
 18      20.0        1.8451  2.7197  0.2746   -0.8746     -1.21 X
```

29	26.0	4.5563	2.4063	0.1249	2.1500	2.81R
53	22.0	2.0414	2.6152	0.2209	-0.5738	-0.77 X
59	36.0	1.3010	1.8839	0.2209	-0.5829	-0.78 X
67	36.0	1.3010	1.8839	0.2209	-0.5829	-0.78 X

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

Section 12 One way ANOVA comparison of SGW sampling results by quarter

Source	DF	SS	MS	F	P
C2	3	3.109	1.036	3.08	0.068
Error	12	4.040	0.337		
Total	15	7.149			

S = 0.5803   R-Sq = 43.49%   R-Sq(adj) = 29.36%

```
                          Individual 95% CIs For Mean Based on Pooled StDev
Level  N    Mean   StDev    +---------+---------+---------+---------
Q1     5  1.7662  0.6070    (--------*---------)
Q2     3  2.6402  0.7150                (-----------*-----------)
Q3     4  2.8233  0.5428                     (---------*----------)
Q4     4  2.6304  0.4690                 (----------*---------)
                            +---------+---------+---------+---------
                          1.20      1.80      2.40      3.00
```

Pooled StDev = 0.5803

Hydrographic Methods

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

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

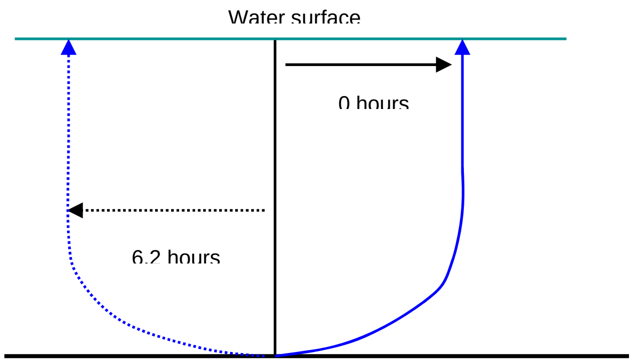
<u>Background processes</u>
Currents in estuarine and coastal waters are generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences.

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

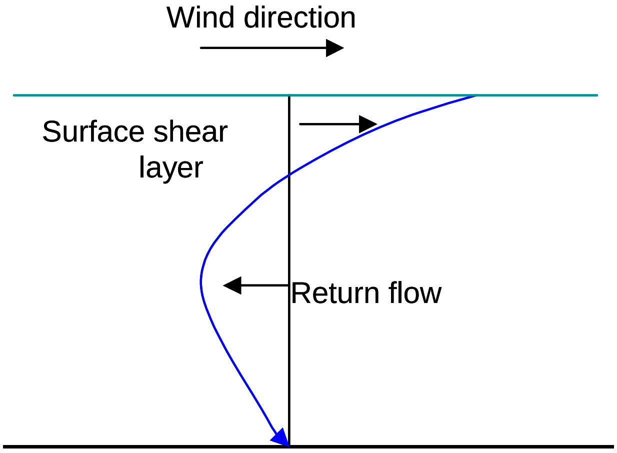
Wind and density driven current also lead to persistent movement of water and are particular important in regions of relatively low tidal velocities characteristic of many of the water bodies in Scottish waters. Whilst tidal flows generally move material in more or less the same direction at all depths,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

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

a)



b)



c)

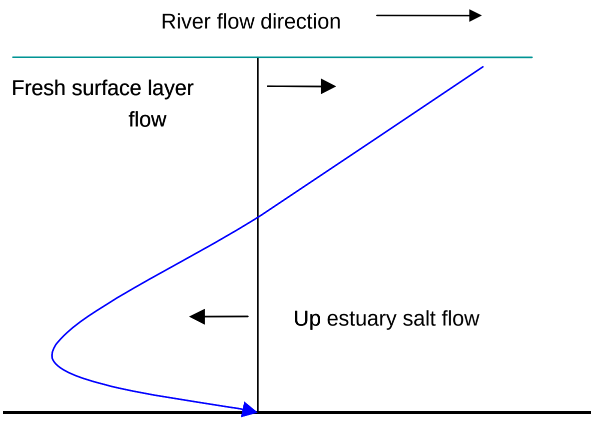


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

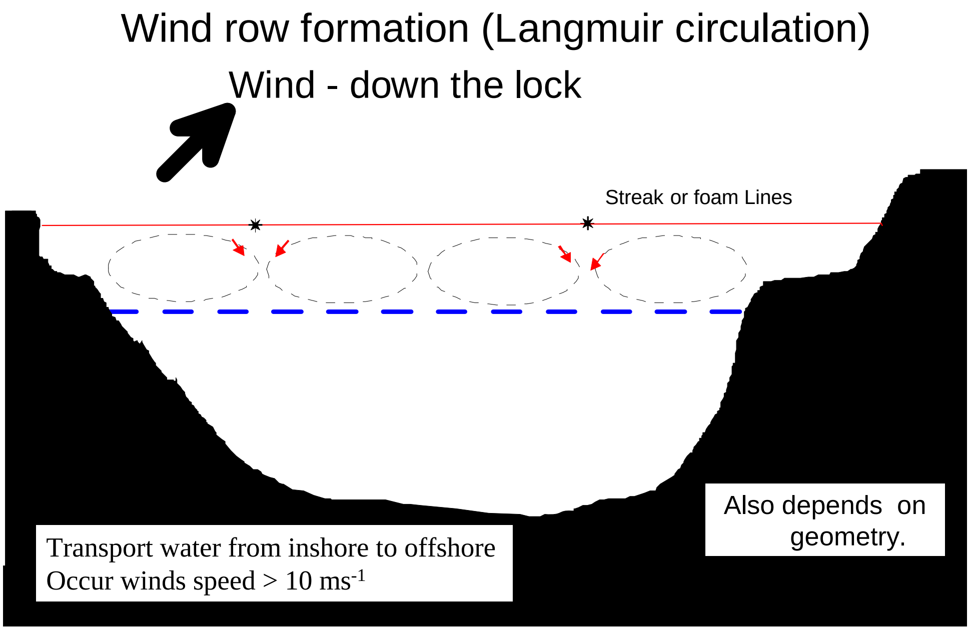


Figure 2. Schematic of wind driven ‘wind row’ currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

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

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

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

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

West Loch Tarbert: Loup Bay
AB 299

Scottish Sanitary Survey Project

Scottish Sanitary Survey Project

Shoreline Survey Report

Prod. area:	West Loch Tarbert: Loup Bay
Site name:	Loup Bay (AB 299 084 13)
Species:	Pacific oysters
Harvester:	N. Duncan
Local Authority:	Argyll & Bute Council
Status:	Existing site
Date Surveyed:	21-23 July 2009
Surveyed by:	William MacQuarrie, Alastair Cook
Existing RMP:	NR 768 585
Area Surveyed:	See Map in Figure 1

Weather observations

21 July: Overcast am, heavy rain pm Winds NE force 2-4. Air temp 14 °C.
22 July: Showers. Winds S force 2. Air temp 15 °C.
23 July: Showers. Winds W force 3. Air temp 14 °C.

Site Observations

Specific observations made on site are listed in Table 1 and mapped in Figure 1.

Fishery

Pacific oysters are cultured in mesh bags suspended from ropes strung between stakes in the intertidal zone. The tackle covers a large area (just over 0.1 km^2) but most ropes did not have any stock on them. Stock of a range of sizes was present, including that of a harvestable size. Seed stock is sourced from a hatchery in Whitstable, and then takes 2-3 years to grow to a marketable size. Time of harvest is dictated by demand and toxin status, but can occur at any time of the year. The main markets are local ones, and demand is generally lowest between January and March. In 2008, there were particularly lengthy closures due to biotoxins that heavily affected volume of sales. At the site there is a processing shed with depuration facilities. This also serves the Barvalla site further up West Loch Tarbert, which is under the same ownership.

Sewage/Faecal Sources

Human – population on the shores of West Loch Tarbert is low. There are no sewage discharges direct to the production area. One private sewer pipe was seen on the north shore opposite the fishery. A septic tank at the oyster processing shed discharges to soakaway.

Livestock – On the shore adjacent to the fishery, a field of approximately 75 sheep and 25 cattle was recorded. Between this field and the shore was an area of marsh and reeds from which a number of small streams drain to the shore which will carry contamination from the livestock to the fishery, although the amount of contamination reaching the fishery may be reduced during its passage through the marsh. On fields just to the west of the fishery, 22 sheep with access to the shore were recorded. Slightly further back, around Corran Farm, 6 chickens, 2 pigs and about 100 sheep were recorded. On the opposite shore, at Acach-Chaorann Bay, large amounts of sheep droppings and wool were recorded along the shoreline and in the water. No animals were seen, but it is possible that they were present in the area, sheltering somewhere from the poor weather at the time.

Seasonal Population

The area surrounding West Loch Tarbert is frequented by tourists, so an increase in population on its shores during the summer months is anticipated. However, the only holiday accommodation seen during the shoreline survey was further up the loch, where a static caravan park, and hotel and B&B accommodation was recorded. Camper vans were commonly encountered on the roads surrounding the Loch.

Boats/Shipping

The pier at West Tarbert is an active fishing pier, so fishing boats will pass Loup Bay on their way to and from the fishing grounds. Also, ferries serving Islay sail from the Kennacraig Ferry terminal and pass Loup Bay on their way to and from the island. The grower indicated that the ferry operators have stated that the septic waste from these ferries is pumped out rather than being discharged to sea. Yachts visit the loch from time to time, with one seen further up the loch.

Land Use

West Loch tarbert is surrounded by forest, with some areas of pasture. On the shore adjacent to the fishery, and around Corran Farm, there are areas of pasture. There is a strip of reedy marshland between this and the shore immediately adjacent to the fishery. To the east of the fishery, the shore is wooded. On the north shore opposite the fishery, there is a mixture of woodland and pasture. There is an area of rough pasture around Acach-Chaorann Bay where evidence of recent sheep grazing was recorded.

Wildlife/Birds

No major aggregations of wildlife were seen during the shoreline survey. A seal was seen further up the loch, so it is likely that seals come into close proximity of the fishery from time to time. Also, seagulls (species uncertain) were present around the loch but not in great numbers. The grower advised that geese roost on the shores of the loch on calm nights during winter.

Other information

Tidal amplitude at springs is about 1 m, but low pressure off the west coast can cancel out this modest tidal shift, so that when there is a run of depressions coming in off the North Atlantic there can be no tides at all for weeks at a time.

Sampling

Water and shellfish samples were collected during the survey. These were transferred to a coolbox and transported to Glasgow Scientific Services for analysis. Bacteriology results follow in Tables 2 and 3. Salinity profiles are presented in Table 4. Water and shellfish samples are not numbered consecutively in this report. The missing numbers refer to samples taken during the shoreline survey of West Loch Tarbert during the same week.

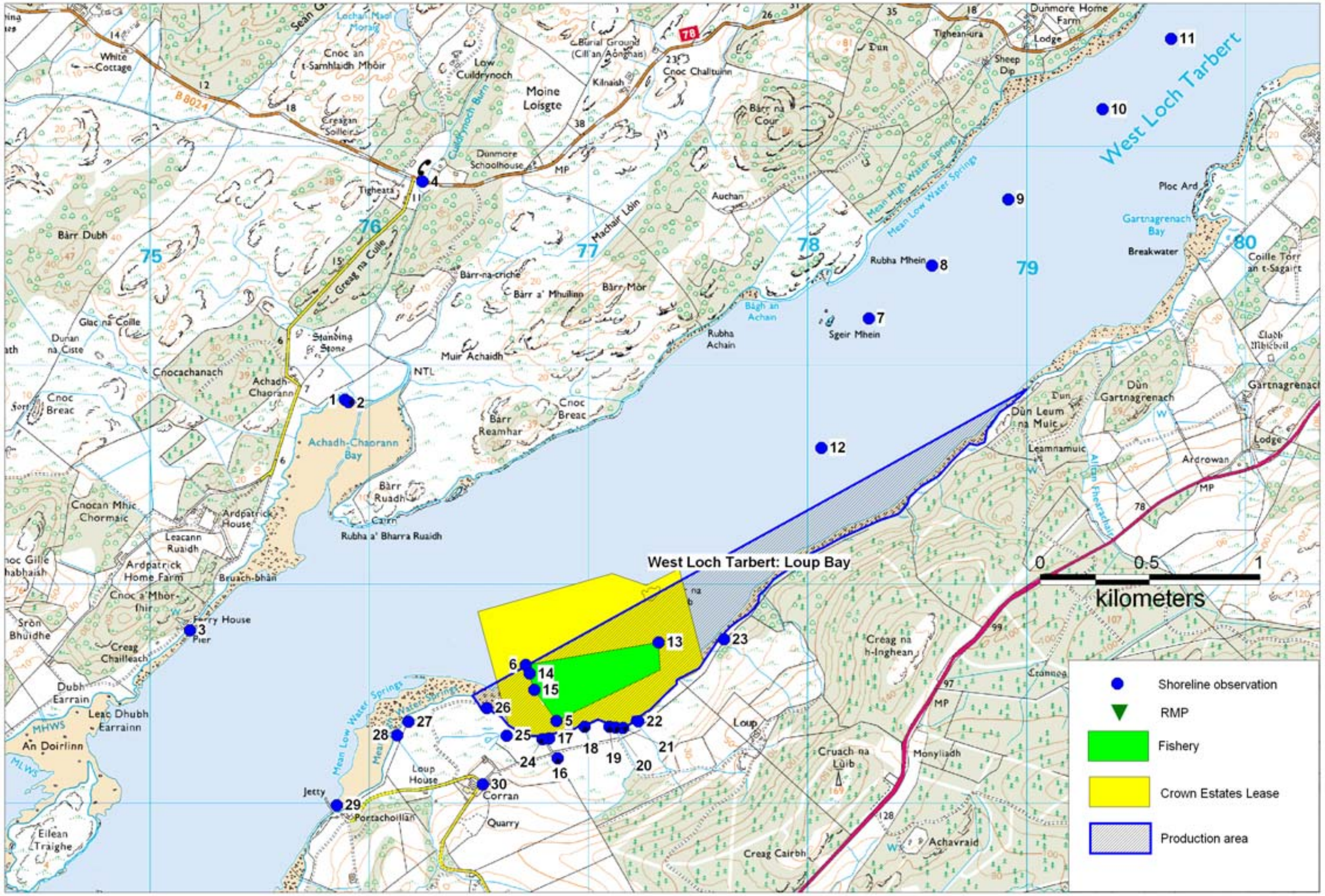


Figure 1. Map of Shoreline Observations

Table 1. Shoreline Observations

No.	Date and time	Position	Photograph	Description
1	21-JUL-09 1:17:46PM	NR 75890 59842	Figure 4	Sheep droppings in intertidal zone.
2	21-JUL-09 1:18:41PM	NR 75905 59832		Water sample 19 (seawater). Large amount of wool and dung in tideline. Sheep probably hiding from poor weather.
3	21-JUL-09 2:03:54PM	NR 75182 58789	Figure 5	Water sample 20 (seawater). Private sewer pipe (dripping). 1 house.
4	21-JUL-09 2:13:56PM	NR 76243 60839		Stream 150cmx10cmx0.217m/s. Water sample 21 (fresh).
5	22-JUL-09 9:46:20AM	NR 76755 58374		Corner of Loup Bay site. Water sample 22 (seawater).
6	22-JUL-09 10:14:53AM	NR 76715 58631		Corner of Loup Bay site.
7	22-JUL-09 10:26:54AM	NR 78279 60214		10 seagulls on marker post.
8	22-JUL-09 10:28:40AM	NR 78568 60456		6 sheep on north shore.
9	22-JUL-09 10:30:53AM	NR 78916 60758		1 seal in water.
10	22-JUL-09 10:33:52AM	NR 79346 61169		2 houses and 1 static caravan right on north shore. 15 cattle back from south shore.
11	22-JUL-09 10:36:07AM	NR 79658 61492		3 houses on north shore. 1 yacht on mooring.
12	22-JUL-09 12:20:39PM	NR 78063 59622		Salinity profile WLT2 (only 5.5m deep).
13	22-JUL-09 12:32:11PM	NR 77321 58734		Water sample 27 (seawater). Oyster sample 2 (*E. coli*). End of lines. Old large stock here.
14	22-JUL-09 12:47:01PM	NR 76732 58591		End of 3 lines
15	22-JUL-09 12:47:48PM	NR 76754 58516		End of 2 lines
16	22-JUL-09 12:59:12PM	NR 76860 58204	Figure 6	Oyster shed, with toilet and septic tank to soakaway. Field of about 75 sheep and 25 cattle.
17	22-JUL-09 1:14:37PM	NR 76821 58294		Stream 70cmx2cmx0.102m/s. Water sample 28 (freshwater).
18	22-JUL-09 1:20:59PM	NR 76982 58348		Stream 60cmx14cmx0.147m/s. Water sample 29 (freshwater).
19	22-JUL-09 1:26:17PM	NR 77096 58348		Stream 50cmx3cmx0.067m/s. Water sample 30 (freshwater).
20	22-JUL-09 1:28:47PM	NR 77125 58344		Stream 110cmx4cmx0.156m/s. Water sample 31 (freshwater).
21	22-JUL-09 1:30:41PM	NR 77159 58342		Stream 15cmx3cmx0.285m/s. Water sample 32 (freshwater).
22	22-JUL-09 1:34:32PM	NR 77227 58372		Stream 75cmx12cmx0.108m/s. Water sample 33 (freshwater).
23	22-JUL-09 1:47:49PM	NR 77618 58747		Stream 75cmx3cmx0.372m/s. Water sample 34 (freshwater).
24	23-JUL-09 12:23:59PM	NR 76790 58291		Stream 30cmx2cmc0.028m/s. Water sample 37 (freshwater).
25	23-JUL-09 12:28:24PM	NR 76627 58307		Stream 105cmx4cmx0.304m/s. Water sample 38 (freshwater).
26	23-JUL-09 12:32:38PM	NR 76536 58433		11 sheep with access to shore.
27	23-JUL-09 12:37:54PM	NR 76179 58370		11 more sheep with access to shore.

28	23-JUL-09 12:39:22PM	NR 76128 58309		Stream 245cmx6cmx0.414m/s. Water sample 39 (freshwater).
29	23-JUL-09 12:47:39PM	NR 75853 57989		House, jetty, 4 dinghys, no pipes seen. Water sample 40 (seawater).
30	23-JUL-09 1:19:53PM	NR 76518 58084		Corran Farm. 6 chickens, 2 pigs in shed, about 100 sheep in fields further up the hill.
31	27-JUL-09 10:50:00AM	NR 76850 58435		Oyster sample 4, taken for classification sampling. Original sample taken from this location for classification on the 22nd July was rejected due to the presence of 3 dead shells.

Photos referenced in the table can be found attached as Figures 4-6.

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

Dimensions and flows of watercourses are estimated at the most convenient point of access and not necessarily at the point at which the watercourses enter the loch.

Table 2. Water Sample Results

Sample No.	**Date and time**	**Position**	***E. Coli* (cfu/100ml)**	**Salinity / mg Cl/L**	**Salinity (ppt)**	**Type of Sample**
WLT19	21-JUL-09 1:18:41PM	NR 75905 59832	29	17600	32.0	Seawater
WLT20	21-JUL-09 2:03:54PM	NR 75182 58789	70	18500	33.6	Seawater
WLT21	21-JUL-09 2:13:56PM	NR 76243 60839	800			Freshwater
WLT22	22-JUL-09 9:46:20AM	NR 76755 58374	300	17700	32.2	Seawater
WLT27	22-JUL-09 12:32:11PM	NR 77321 58734	580	11100	20.2	Seawater
WLT28	22-JUL-09 1:14:37PM	NR 76821 58294	1100			Freshwater
WLT29	22-JUL-09 1:20:59PM	NR 76982 58348	700			Freshwater
WLT30	22-JUL-09 1:26:17PM	NR 77096 58348	3100			Freshwater
WLT31	22-JUL-09 1:28:47PM	NR 77125 58344	2800			Freshwater
WLT32	22-JUL-09 1:30:41PM	NR 77159 58342	4900			Freshwater
WLT33	22-JUL-09 1:34:32PM	NR 77227 58372	2900			Freshwater
WLT34	22-JUL-09 1:47:49PM	NR 77618 58747	3000			Freshwater
WLT37	23-JUL-09 12:23:59PM	NR 76790 58291	1000			Freshwater
WLT38	23-JUL-09 12:28:24PM	NR 76627 58307	500			Freshwater
WLT39	23-JUL-09 12:39:22PM	NR 76128 58309	4000			Freshwater
WLT40	23-JUL-09 12:47:39PM	NR 75853 57989	3	18300	33.2	Seawater

Table 3. Shellfish Sample Results

Sample	Date and time	Location	Eastings	Northings	*E. coli* (MPN/100g)
WLT2	22-JUL-09 12:32:11PM	NR 77321 58734	177321	658734	110
WLT4	27-JUL-09 10:50:00AM	NR 76850 58435	176850	658435	330

Table 4. Salinity profile

Salinity profile No.	Date and time	Location	Depth (m)	Salinity (ppt)	Temperature (ºC)
WLT2	22-JUL-09 12:20:39PM	NR 78063 59622	0	33.1	16.2
WLT2	22-JUL-09 12:20:39PM	NR 78063 59622	2.5	33.3	15.6
WLT2	22-JUL-09 12:20:39PM	NR 78063 59622	5	33.4	15.4

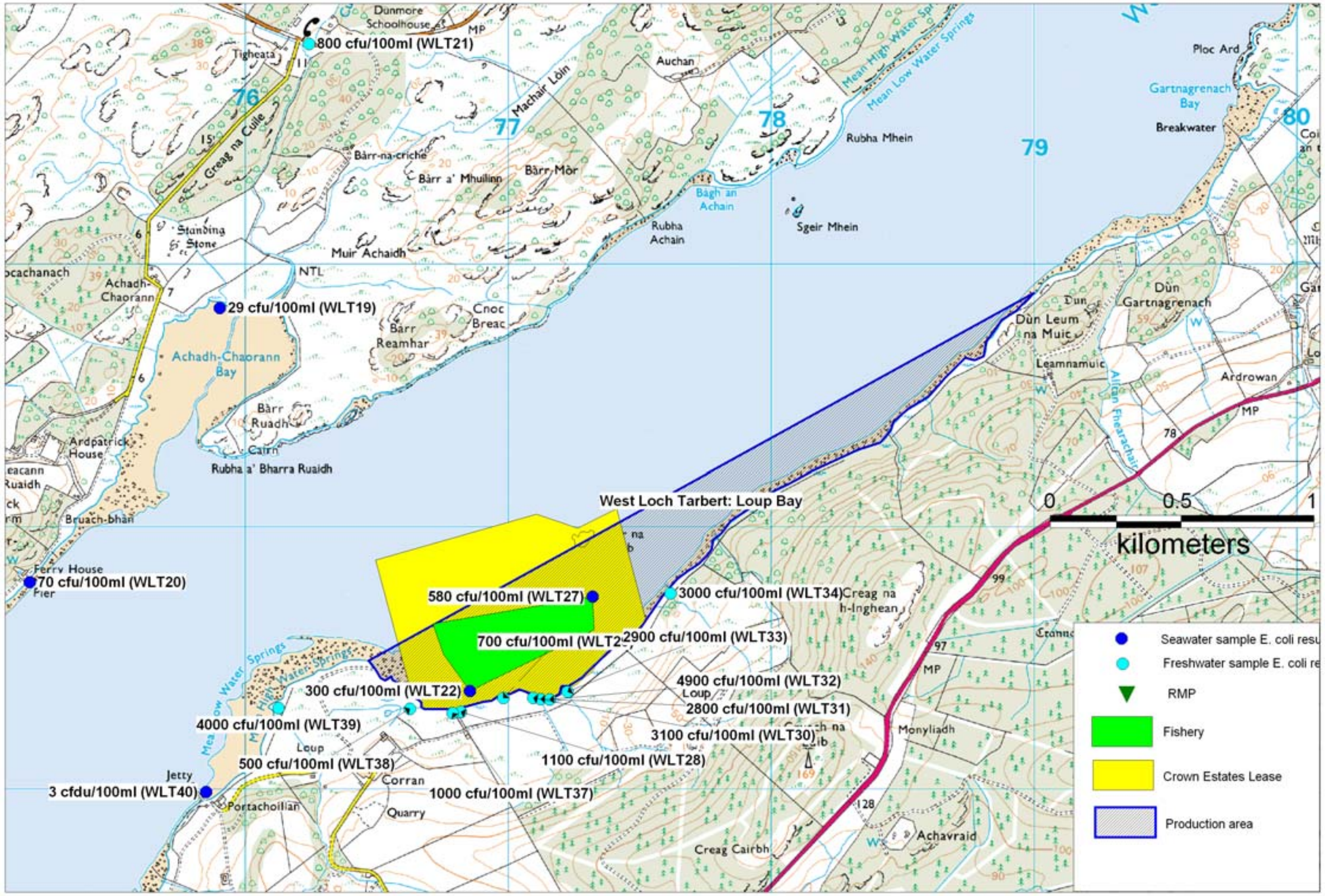


Figure 3. Water sample results map

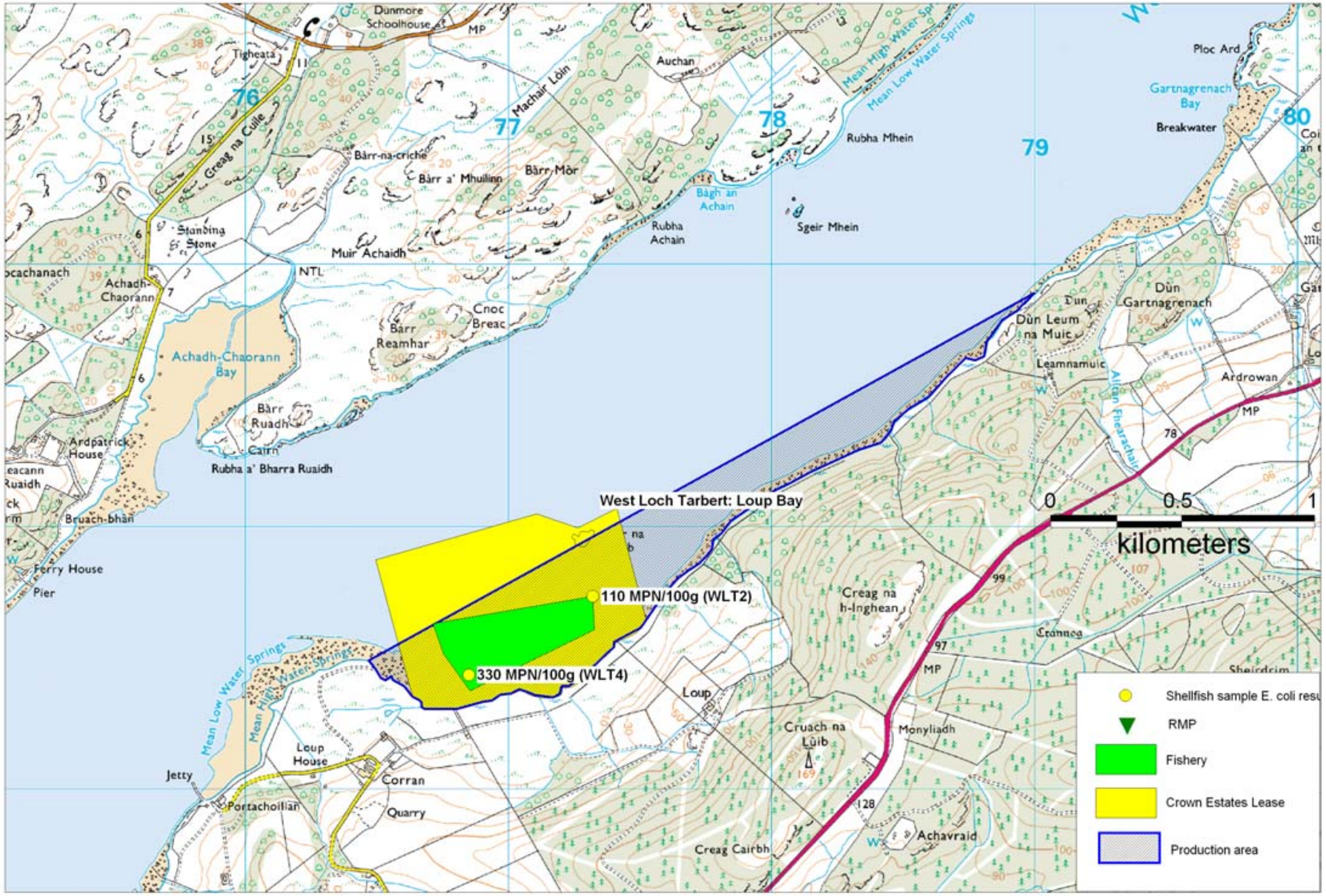


Figure 4. Shellfish sample results map

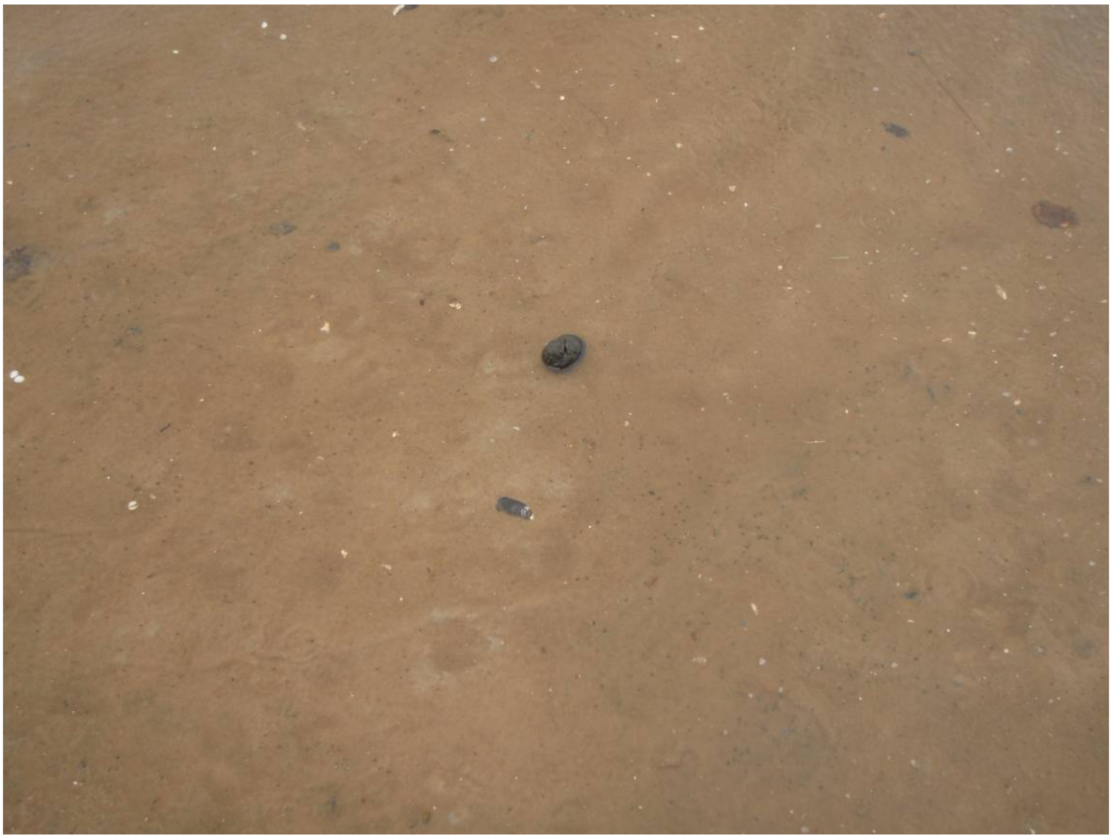


Figure 4

Figure 5


Figure 6