significantly different (p<0.01) to those recorded in 2012, but not 2010. However as explained in Section 4.4.4, counts at Areas 1, 8, 61, 21, 24 and 28 are significantly correlated with seven day antecedent rainfall. As spills are directly related to rainfall, it would be difficult to dissociate a relationship with PS spills from that with rainfall.

Table 5.7 identifies incidents of high (>4,600 *E. coli* MPN/100g) oyster and mussel flesh counts with antecedent rainfall and spill durations for PS identified as relevant to the investigation. It is notable that high counts at Areas 8 and 12 seem to occur after spills at West of Albert/Weighbridge, to which they are geographically closest compared to other areas. Area 25 showed a count of 3,500 on 6/12/10 which supports suggestion of a local influence.

Table 5.7 Incidences of high *E. coli* counts with antecedent rainfall and PS spills

Collection date	E. coli (MPN/100g) Oysters (O) Mussels (M)	Area	Antecedent rainfall (mm)			PS spills
			1 day	2 day	7 day	
05/11/2002	5,400 (O)	1	0.2	3.2	25.3	None recorded in previous seven days
21/07/2008	5,400 (M)	24	-	0.2	1.4	None recorded in previous seven days
21/07/2008	5,400 (M)	27	-	0.2	1.4	None recorded in previous seven days
28/10/2008	16,000 (M)	28	10.7	23.0	36.8	None recorded in previous seven days
12/11/2008	16,000 (O)	12	4.1	28.5	50.3	2 hour spill recorded at WA/W[1] on 6/11/08
15/12/2008	5,400 (O)	8	4.1	13.7	32.9	Total 4 hours of spill recorded at WA/W over 13 and 14/12/08
15/12/2008	5,400 (O)	12	4.1	13.7	32.9	Total 4 hours of spill recorded at WA/W over 13 and 14/12/08
10/02/2009	9,200 (O)	8	18.5	22.2	41.8	Intermittent spillage over 24 hours from 1000 on 9/2/09 at WA/W. 21 hour spill at La Retraite.
22/07/2009	24,000 (M)	27	4.5	6.6	19.8	None recorded in previous seven days
01/03/2010	5,400 (O)	24	1.4	53.5	87.6	Significant spills across the island on 28/2/10 including Archirondel (25 hours), Pontac (6), Le Hocq (12), Maupertuis (6), Bashfords (10), Le Dicq (7), WA/W (6)
06/12/2010	9200 (O)	12	1.6	39.8	60.0	Significant spills on 4/12/10 to 6/12/10 from WA/W (23 hours), Beaumont (16), St Martin (14), Becquet Vincent (46), Paul Mill (43), Archirondel (60)
26/09/2011	5,400 (M)	27	-	0.0	1.0	None recorded in previous seven days
07/02/2012	9,200 (O)	21	-	1.0	15.0	None recorded in previous seven days
07/02/2012	5,400 (O)	24	-	1.0	15.0	None recorded in previous seven days
08/05/2012	5,400 (O)	6	3.0	5.2	16.4	None recorded in previous seven days
08/05/2012	16,000 (O)	26	3.0	5.2	16.4	None recorded in previous seven days

1 West of Albert/Weighbridge

There is some uncertainty as to the exact discharge location for spills for some of the PS. Monitoring should be focused on those PS for which there is certainty of potential influence, be that via watercourse or via outfalls direct to the sea. In order to understand the relative FC loads which may be apportioned to the relevant PS spillages, it would be necessary to obtain more data on flows and concentrations to align with those on spill durations. As such no attempt to apportion loads to or between PS is made here or in the Sanitary Survey report.

DIRECT INPUTS FROM WILDLIFE

Current Understanding

The direct contribution from wildlife into waters surrounding the shellfisheries is potentially significant. The south eastern part of Jersey provides habitat for a variety of species and groups likely to provide faecal input include birds, seals and dolphins.

The Sanitary Survey report lists the significant bird populations present in the south-east Jersey Ramsar area. The report presents count data for 2010 for waders (2 days during January and February) and Brent goose (*Branta bernicla bernicla*) (winter migrants). The bird populations observed during the shoreline survey are also listed and their locations recorded. Bird data are considered further below.

Seals and dolphins are also mentioned in the Sanitary Survey report. The seal population may contribute to background levels of faecal contamination within the bays and may contribute to locally high levels of contamination where they have hauled out. However the report indicated that there is no evidence that one part of the shellfishery is more affected than another. The report stated that dolphins are unlikely to constitute a significant source of faecal contamination to the shellfishery as they tend to avoid water of less than 10m depth. The report concluded that the most significant potential wildlife source is shore birds present during winter or during spring/autumn migrations, and that they are most likely to affect those areas closest to shore in Grouville Bay. On the basis of this conclusion, inputs from dolphins and seals are not considered further.

Review of Bird Data

The inclusion of bird faecal matter into a water body can raise the measurable levels of bacteria beyond acceptable limits[1]. This is primarily because the bacteria content of bird faeces is high and it enters the water directly and untreated[2].

The South East Coast of Jersey Ramsar site includes the area of coast occupied by the shellfisheries. Many species of wintering shorebirds visit the area during annual migration passages, including Brent geese, an over-wintering migrant. Brent geese feed on sea grass and may roost on the water at high tide, which extends the period during which they may act as a source of faecal contamination. Black-headed gulls are present in thousands in the area from approximately October to March. Little gulls may also be present in significant numbers (up to 500) at a similar time. The 2011 shoreline survey recorded wildlife present throughout the area. In total 812

[1] Wright, M.E., Solo-Gabriele, H.M., Elmir, S. Fleming, L.E. (2009) 'Microbial load from animal faeces at a recreational beach', Marine Pollution Bulletin 58(11):1649-1656.

[2] Wither, A., Rehfisch, M., Austin, G. (2005) 'The impact of bird populations on the microbiological quality of bathing waters', *Water Science and Technology* 51(3):199-207

geese and 159 gulls were counted over the two day period.

La Société Jersiaise conducts regular counts of birds throughout Jersey. The most recent data available is that collected over the winter 2012-2013 on 2 December 2012, 30 December 2012 and 13 January 2013[3]. Sites adjacent to the shellfishery for which data are available are: Green Island, Le Hocq, Pontac and La Rocque.

A preliminary estimation has been undertaken of the contribution these birds make to faecal loadings in the waters around the shellfish areas (Table 5.8). This calculation is based on an estimate of gull *E.coli* daily loading of 2 x $10^{9 \text{ per bird}}$[4]. The calculated daily loading from birds at each site is within the same order of magnitude as the daily contribution from Bellozanne STW (Table 5.1). These figures will be significantly lower during other times of the year as the contribution is primarily from over-wintering shorebirds. However, the estimates suggest that further investigation should include monitoring of bird activity and populations local to the shellfish areas, potentially combined with species specific microbial source tracking analysis of *E. coli.*

Table 5.8 Estimated winter daily loading of *E.coli* from birds at four La Société Jersiaise bird sites located adjacent the shellfisheries

Average for the three winter surveys 2012-2013	Green Island	Le Hocq	Pontac	La Rocque
Total Number of Birds	430	125	771	384
E Coli loading per day	8.61E+11	2.51E+11	1.54E+12	7.68E+11

Clearly the gull daily loading figure can only be used as a guide and will not be accurate for all bird species. Further monitoring and analysis is necessary to determine:

Numbers and species of birds using the shoreline local to the shellfish areas, as well as those roosting on the shellfish areas

Accurate faecal daily loadings for each bird species

Modeling of the dispersion of faecal contribution to determine the geographic extent of the bird contribution.

INPUTS FROM BOATS

Jersey is a popular tourist destination and experiences a significant increase in population during the peak tourist season of May to September[5]. In 2011 a total of 689,700 visitors were recorded. A significant proportion of visitors arrive by boat; in 2011, 23,400 visitors were classed as yachtsmen. Multiple marinas and moorings are located around the island, with the largest located at St Helier. Smaller mooring are

[3] Jersey Birds (2013) http://www.jerseybirds.co.uk/news/downloads.php. Accessed 19 July 2013.
[4] Wither, A., Rehfisch, M., Austin, G. (2005) The impact of bird populations on the microbiological quality of bathing waters, *Water Science and Technology* 51(3):199-207
[5] Jersey Tourism (2011) *A Year in Review*

provided in the northern section of Grouville Bay and in La Rocque Harbour. Pollution from recreational boats should only be minimal, however the potential exists for improper disposal of waste. This sector therefore represents a potential source of faecal contamination. Additionally, the Port of Jersey at St Helier hosts a large fishing fleet and provides commercial port facilities. Ferry routes also cross through the area.

While boats may contribute to the background level of faecal contamination in in-shore waters, it is unlikely that boats would be a significant source of faecal contamination causing counts with the spatial distribution observed at the shellfish areas, i.e. significantly more elevated counts at the areas closer to shore.

PATHWAYS

INTRODUCTION

Each source may influence *E. coli* counts at the shellfish areas by means of a pathway. Pathways may be direct or characterised by very short distances. Contamination can also be conveyed over longer distances through movement of water by tides and currents, as influenced by wind, although the same forces will also enable dilution and dispersion. In this context, the effects of exposure to ultraviolet light (sunlight) on microbial survival must be taken into account, as must the countering effects of turbidity. T90 (the time taken for bacterial concentration in a sample to be reduced by 90% by irradiance) for waters in the English Channel has been estimated at around 50 hours, compared to 1-5 hours in the Mediterranean where waters are less turbid**Error! Bookmark not defined.**. The T90 for waters around the shellfish areas would depend on prevailing local conditions, but for the purposes of considering potential pathways for this investigation, a period of 50 hours is considered appropriate. Some of the potential sources are inland, including PS overflows and any other sources which could be conveyed to the marine environment via watercourses. However the time of travel in freshwater will be low due to the size and length of the watercourses and is unlikely to be significant.

General tidal circulation

Section 5 identified sources located locally, as well as to the north of the Grouville Bay areas, and to the west of the St Clement's Bay areas as far as St Aubin's Bay. Analysis of tidal stream data reported in the Sanitary Survey report supports drogue and ADCP survey work reported previously**Error! Bookmark not defined.** in the Data Review report, in suggesting that predominant tidal stream direction along the south coast is bi-directional on an east-west axis, with current speeds up to 1m/s (spring). On the east coast the tidal movement is again bi-directional; south on the flood, and north to westwards on the ebb tide, with speeds up to 1.2m/s. However, at the in-shore areas, tidal movements on the east coast are more complex in that there is a northerly current from half flood to half ebb, and a southerly movement from half ebb to half flood. This may mean that on the flood tide, material could be conveyed from the south coast, northwards up the east coast, at least in the in-shore areas.

Tidal streams off the south-east tip of the island (approximately 4km south-east of the Seymour Tower areas) were found to be faster (up to 2m/s) than on either the south or east coasts. Direction here was south to east on the flood, swinging from north to south-west on the ebb tide. The tidal currents indicate that both the Grouville Bay and St Clement's Bay areas may be influenced by sources from along the south coast, while only the those areas in Grouville Bay that are inundated at half tide are likely to be influenced by sources north of Grouville Bay on the east coast (as in-shore currents move in a southerly direction only from half ebb to half flood).

Tidal cycle

Section 13 of the Sanitary Survey report describes the characteristics of tides at St Helier, 4km to the west of the study area, using outputs from TotalTide:

Highest Astronomical Tide	12.2m
Mean High Water Springs	11.0m
Mean High Water Neap	8.1m
Mean Sea Level	6.02m
Mean Low Water Neap	4.0m
Mean Low Water Springs	1.4m
Lowest Astronomical Tide	0.1m

The tidal range at the shellfish areas is considered large, with an average of 9.6m at spring tide, and 4.1m neap. All of the shellfish growing areas are exposed at low tide.

Wind influences

As reported in the Sanitary Survey report, prevailing winds in Jersey are generally from the west. Winds tend to be stronger in winter than in summer. There are seasonal variations in prevailing wind patterns, with winds blowing from the east much of the time between December to May. Strong easterly winds may also occur in spring.

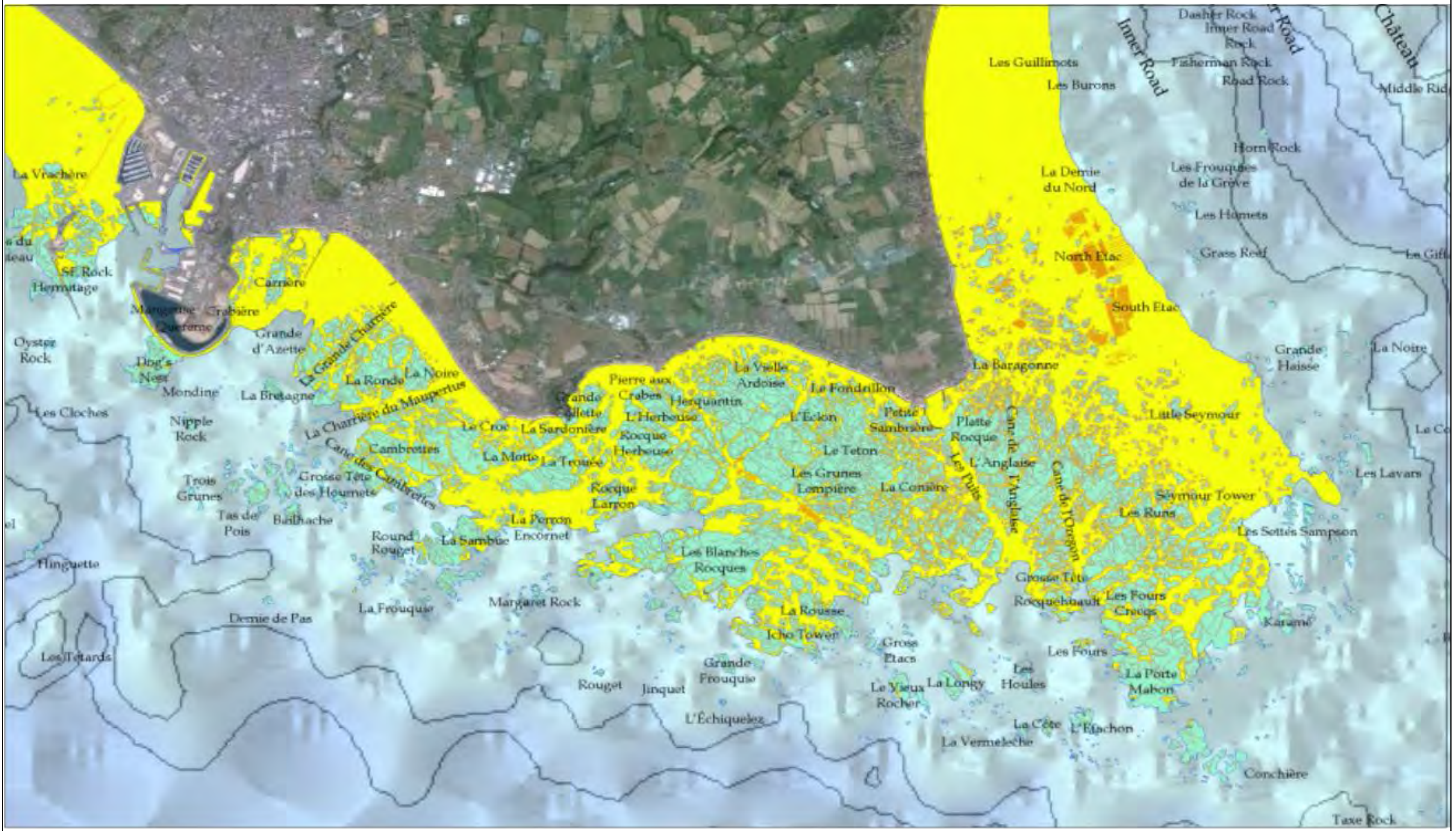
Easterly winds could affect contamination at the areas in two ways. Strong easterly winds could push the tide higher up the beach, thus enabling more mobilisation of faecal material. Easterly winds could also affect transfer of contaminants by tides and currents, potentially reducing rate of transfer from sources to the west of St Clement's Bay and increasing dispersion rates.

Local bathymetry

Grouville Bay is predominantly sandy, while St Clements Bay is predominantly rocky and characterised by gullies as shown in Figure 6.1.

Figure 6.1 Detail of inter-tidal zone around the shellfish areas[6]

[6] Map accessed at http://www.paulchambers.eu/jersey_marine/jersey-marinelife.html



Intertidal Rock
Intertidal Sands

South-east Jersey showing inter-tidal areas around shellfisheries

Jersey Shellfisheries Study

Kilometers 0 1.5 3

CASCADE

DIRECT

Faecal contamination can be introduced directly to the water or shore in proximity to the shellfish areas, for example from boats, dogs walked on the beach, or by birds and other wildlife. As discussed in Section 5.6, the most significant source of direct contamination is considered to be from wading and rafting birds. Sources, pathways and likely receptor areas are described in Table 6.1.

Table 6.1 Suspected direct source-pathway-receptor linkages

Source	Pathway	Receptor
Wading birds	Mobilisation (e.g. by the incoming tide, or rain on exposed areas on the ebbing tide) of faecal material from foreshore, channelled by gutters	Areas 8 and 25 in St Clement's Bay Areas 6 and 27 in Grouville Bay
Rafting birds	Direct release of faecal material into water column	Areas 6 and 27, also Areas 28, 24, 1 and 21 - all in Grouville Bay

From the 2012/13 count data, the highest Brent geese counts were observed at Pontac (mid Grouville Bay area), although on one of the three count occasions, significant geese numbers were also observed at Le Hocq. Other waders were distributed fairly consistently along the shoreline. Rafting birds were in highest numbers at La Rocque, although numbers during the three survey occasions did not suggest rafting birds would be a significant source.

There are two mechanisms by which these local sources could influence counts at the areas. The first mechanism is direct release of faeces into the water column which is subject to local circulation and tidal patterns, as well as wind. Sheltered areas where there is likely to be less dispersion will be most susceptible to transfer of contamination via this pathway. This may suggest that Areas 6 and 27, which are close to shore and in the lee of the island from westerly winds, could be affected. It is likely that all areas in Grouville Bay are likely to benefit less from dispersion effects than the St Clement’s Bay areas, due to Grouville Bay being more sheltered from prevailing westerly winds. Gutters such as the Le Hocq Gutter also provide a route by which contamination can be concentrated as the tide recedes. It is notable that irradiance will help to reduce the effects of this pathway, as shallow, still water will be less turbid.

The second mechanism is mobilisation and remobilisation of faeces that have been deposited in intertidal areas, at areas where wading birds have been grazing. Again distribution and concentration of contamination would be influenced by gutters and their interaction with tidal movements. On the flood tide, contamination would in general be mobilised away from the areas. If rain were to fall during low tide contamination would be washed off shore towards the areas via the channels and gutters in the inter-tidal area. Area 8 and 25 in St Clement’s Bay, and Areas 6 and 27 in Grouville Bay could be influenced in this way. Water column monitoring will help to identify the influences of bird sourced contamination, subject to improved understanding of the areas used by the birds.

INDIRECT

As indicated in Section 6.1.1 above, St Clement's Bay is only likely to be indicated by current borne sources from the west, while Grouville Bay areas could be influenced by sources on the south coast or by sources to the north. Sources, pathways and likely receptor areas are described in Table 6.2.

Table 6.2 Suspected indirect source-pathway-receptor linkages

Source	Pathway	Receptor
Bellozanne STW	Conveyance along south coast by flood tides, influenced by wind	Areas 12, 28 and 25 in St Clement's Bay Areas 1, 6, 21, 24, 27 and 28 in Grouville Bay
Agricultural/rural runoff in Baudrette Brook catchment (slurry spreading prohibited Oct - Dec inclusive)	Entry to marine environment via Dicq Slipway outfall, conveyance along south coast by flood tide, influenced by wind	Areas 12, 28 and 25 in St Clement's Bay Areas 1, 6, 21, 24, 27 and 28 in Grouville Bay
Urban runoff from St Helier and other south coast draining catchments	Entry to marine environment via outfalls (Weighbridge, Dicq Slipway, Le Dicq, La Greve d'Azette, Le Hocq, Pontac 1, Pontac 2, Le Bourg 1, Le Bourg 2), followed by conveyance along south coast by flood tide, influenced by wind	Areas 12, 28 and 25 in St Clement's Bay Areas 1, 6, 21, 24, 27 and 28 in Grouville Bay
Pumping Stations discharging to south coast outfalls: • Cavern - Weighbridge OF • Le Dicq - Le Dicq OF • Maupertuis - La Greve d'Azette OF • Le Hocq - Le Hocq OF • Pontac - Pontac OF (unclear as to 1 or 2)	Entry to marine environment via outfalls, followed by conveyance along south coast by flood tide, influenced by wind	Areas 12, 28 and 25 in St Clement's Bay Areas 1, 6, 21, 24, 27 and 28 in Grouville Bay
Agricultural/rural runoff in Queen's Valley Stream catchment (slurry spreading prohibited Oct - Dec inclusive)	Entry to marine environment via Longbeach outfall, conveyance southwards along east coast by tide, influenced by wind	Areas 1, 6, 21, 24, 27 and 28 in Grouville Bay
Urban runoff from east coast draining catchments	Entry to marine environment via outfalls (Beach Hotel Slip, Longbeach, Fort Henry, OF between Fort Henry and Fauvic, Fauvic, Le Hurel, OF between Le Hurel and Seymour, Seymour Slipway, conveyance southwards along east coast by tides, influenced by wind	Areas 1, 6, 21, 24, 27 and 28 in Grouville Bay
Pumping Stations discharging to east coast outfalls: • Le Rivage - Beach Hotel Slip OF • Fauvic - Fauvic OF	Entry to marine environment via outfalls, followed by conveyance southwards along east coast by tides, influenced by wind	Areas 1, 6, 21, 24, 27 and 28 in Grouville Bay

A number of potential sources including Bellozanne STW discharge to St Aubin's Bay.

It is therefore important to establish the characteristics of the pathway between the Bay and the nearest shellfish area, 7km to the south-east. Drogue and ADCP surveys were conducted in 2012 during a spring and neap tidal cycle to improve understanding of coastal hydrodynamics around St Aubin's Bay. This work is reviewed in the Data Review report. In summary, on the flood tide, water enters St Aubin's Bay flowing north to north-east, with a counter-clockwise eddy forming in the west side of the bay. On the ebb tide, water direction to the south of Jersey is to the west. Water exits St Aubin's Bay flowing south to southwest. The pattern of current direction is not significantly altered by the position in the spring neap cycle. All five drogues released on the neap tide high water survey exited the bay and became entrained in the offshore circulation indicating significant tidal circulation within the Bay, and exchange between inshore and offshore waters. The large tidal range in the area helps to enable this exchange.

The more recent drogue surveys support the conclusions of the Sanitary Survey report which reviewed a number of published and unpublished sources of information. The available information indicates that in St Clement's Bay, water will flow east on a flooding tide, and west on an ebb tide. In-shore in Grouville Bay, flows are northerly from half flood to half ebb, and southerly from half ebb to half flood. Further out the movement is bi-directional, southerly on the flood tide and northerly on the ebb tide. Due to the rocky topography of the inshore areas there will also be more complex local pathways through channels.

Assuming a current velocity of 0.5m/s, over a 6hr duration flood tide, it is feasible that a particle could be transferred the 7km distance between the First Tower outfall (containing effluent from Bellozanne STW) and the shellfish areas. Transfer times could be well within the estimated T90 of 50 hours for English Channel waters.

Assuming a similar velocity, it is feasible that contamination could be transferred from the same distance north of the areas, potentially bringing discharges from Beach Hotel Slip and the discharge of the Queen Valley Stream at Longbeach outfall into consideration. Further tracing studies would provide more information about the link between potential sources and receptors.

CONCLUSIONS

CLASSIFICATIONS AT THE SHELLFISH AREAS

The conceptual model proposed for the investigation was introduced in Section 3. This enabled consideration of the issue of faecal contamination at the shellfish areas in terms of the receptors, sources and pathways, and on this basis, Sections 4, 5 and 6 examined each in turn.

Section 4 reviewed the historic and current classifications attributed to the shellfish areas, and current understanding around patterns of contamination at the areas as gleaned primarily from two reports, the Sanitary Survey, reported in September 2012, and a report produced by the States of Jersey Environmental Protection team produced in October 2011 (Du Feu, 2011)**Error! Bookmark not defined.**. Classifications from the States of Jersey Department of the Environment notification reports show that since 2008, the frequency of A classifications has declined, such that since 2008, only the Seymour Tower areas (Areas 20 and 26) consistently attain Class A. However, since 2008 the classification system has changed and it has been demonstrated that several of the reductions may be due to a change in the classification process.

Provisional classifications for 2013 include a B classification for Area 26. There is a perception that reduced frequencies of A classifications are reflecting a reduction in water quality. However, there is no compelling evidence of a significant increase in shellfish contamination (as a result of water quality deterioration). The situation is complicated due to area de-classifications, merging of areas, and creation of new areas. Acknowledging this, in 2008, three of nine shellfish areas were at Class A, and six at Class B. In 2013, one of twelve is at Class A, one that had previously been Class A is provisionally at Class B, and the remaining ten are at Class B. Classifications of mussel areas have been consistent at Class B since 2008.

E. COLI COUNTS AT THE SHELLFISH AREAS

It has been suggested that a change in the sample analysing laboratory in May 2008 could be the cause of increased *E. coli* counts. To this end, analyses have been undertaken which show a significant difference between results pre and post this date. However, this is not conclusive and does not preclude a change in water quality, or other causative factors. It is fair to conclude that the change in laboratories is a potential source of variation over the time period, although as noted by the Sanitary Survey report, the data show no sustained change between the two sets of results. It is acknowledged that 2008 and 2009, years which saw high counts, were wet years compared to 2010 and 2011. Comparing oyster counts in 2008/9 to those from 2010/11 showed that incidences of high counts fell between the two periods (55% samples fell within the Class A threshold in 2008/9 compared to 80%

in 2010/11).

The Sanitary Survey report's analysis of count data was reviewed, and where appropriate supplemented by additional similar analysis using the extended dataset available. In terms of spatial variation in counts, analyses showed that location has a significant effect on counts in both oysters and mussels. The Sanitary Survey analysis found that oyster samples at Areas 20 and 26 showed significantly lower counts than elsewhere, and this was supported by subsequent analysis undertaken for this investigation, which also found that there was no significant difference between counts at Areas 20 and 26. These areas are furthest from shore, and the analysis suggests they are not affected by the influence or influences which affect areas further in-shore. Geomeans of counts were lowest at Areas 20 and 26. The highest geomean count occurred at Area 12, in the western area of St Clement's Bay. High counts also occurred in areas 28, 27 and 6 in Grouville Bay. Mussel counts were also significantly lower at areas further from shore. The highest mussel count geomean was at Area 27, close to shore at the southern end of Grouville Bay.

The Sanitary Survey report showed that counts at a number of the areas had increased over the winter of 2008/9, with little other appreciable change in counts over time. Analysis of the longer term dataset and use of the same analysis technique for this review suggested that there had been no change or a minor reduction in counts between 1996 and 2005 at Grouville Bay Areas 1, 21, 24, 6 and 27, followed by a gradual increase at the same areas between 2005 and 2013. The peak in counts in 2008/9 is still evident in the trendlines from the longer dataset at Areas 1, 21, 24, 6 and 27, all of which are in Grouville Bay. As the gradual increase since 2005 is only observed in the longer dataset it has been caused by increased counts since 2011. In St Clement's Bay, the dataset for Areas 12 and 25 is too short for meaningful temporal interpretation, while a similar pattern occurs at Area 8 as is seen in the Grouville Bay areas. Mussel count data showed no consistent patterns with time. The data show that there are influences on faecal contamination which vary over time and affect in-shore areas most. In St Clement's Bay, counts appear to be higher further west, and in Grouville Bay, counts appear to be higher towards the north (Area 28) and at the in-shore areas (Areas 21, 6, 27). Neither the Sanitary Survey nor this review found any consistent variation in counts with season. Areas 8 and 12 in St Clement's Bay have recorded five of the ten incidences of counts over 4,600 *E. coli* MPN/100g since 2005. In general, the baseline counts at the inner areas (all those except the Seymour Tower areas) suggest a consistent background level of faecal contamination. This suggests that it may not be realistic for all areas to attain Class A in the future.

Seven day antecedent rainfall was found to be correlated with oyster counts at Areas 1, 6, 21, 24 and 28 in Grouvillle Bay, and Area 8 in St Clement's Bay, and with mussel counts at Areas 28 and 24 in Grouville Bay, and Area 8 in St Clement's Bay. It is notable that results at Area 27, close to shore in Grouville Bay, showed no correlation for either mussel or oyster counts. However the analysis shows conclusive evidence that rainfall is a relevant factor towards increased counts, again most evident at the shoreward areas. A significant negative correlation with sunshine hours was found at approximately half of the areas. It is noted that most instances of high counts (>4,600 *E. coli* MPN/100g) occurred after significant rainfall. All of the high counts at Areas 8 and 12 occurred after PS spills of longer than two hours at West of Albert/Weighbridge, to which these areas are closest.

The long term dataset hints that there has been an increase in faecal contamination at the shellfish areas since the mid to late 1990s. However, it is not conclusive in this respect. The data do show that certain areas are influenced more than others, which suggests a common and consistent influence, as illustrated by the pan-area peak in 2008/9. In Grouville Bay the inshore and northern areas appear to be most susceptible, while in St Clement's Bay counts were higher towards the west (Area 12).

Future monitoring should be designed to pick up influences of intermittent rainfall runoff events and to establish the dry weather baseline count at the shellfish areas. Samples should be stored such that they can be subject to microbial source tracking (MST) analysis to determine likely source species. Water quality monitoring may be a useful proxy to flesh *E. coli* monitoring, especially if more continuous monitoring can be undertaken. However, it must be recognised that no clear relationship has been established between faecal coliform levels in shellfish tissue and the microbiological quality of the surrounding waters, excepting those waters which are polluted[7]. Recent research**Error! Bookmark not defined.** has found a significant correlation between *E. coli* or classification status and norovirus levels, providing support for the use of *E. coli* as an indicator organism on a site specific rather than sample specific basis.

SIGNIFICANT SOURCES

A conceptual model was developed to represent potential sources and provide a framework for the investigation. Identified sources comprised Bellozanne STW which discharges to St Aubin's Bay, PS overflows and direct inputs from birds, animals and boats. Surface water outfalls and watercourse discharge locations are not technically sources, but form the point at which inputs from the terrestrial environment, including runoff from agricultural and urban land, meet the marine environment. Surface water outfall and watercourse discharges are somewhat arbitrarily distinguished as both may receive foul (PS overflow) and surface water (rural and urban) run-off inputs.

Bellozanne STW

The STW, which treats sewage for approximately 85% of dwellings, includes UV

[7] Milne DP, Higgins JE, and Brodie IJ (1998) Investigation of the relationship between indicator bacteria in mussel flesh and intervalvular fluid and surrounding waters. Phase 3 SR97(07)F. SNIFFER.

disinfection, the efficacy of which is reduced at higher flows. The Sanitary Survey report estimated daily FC loads of 8.37E+12 cfu at mean flows. This report found that final effluent concentrations and loads during 2011 and 2012 had reduced compared to loads since 2008, with a mean daily load for 2012, calculated from measured daily flows and monthly geomean [FC] of 1.53E+12 cfu. This may be due to improved treatment processes at the STW. 2008 saw particularly high concentrations and loads, with a peak concentration of 30,000cfu/100ml in August. Were the STW to achieve final effluent concentrations of 280 to 260 cfu/100ml concentrations as is typical for effluent subject to UV treatment, daily loads would be around 8.5E+11 cfu. As described above, there was a peak in counts at the shellfish areas over the winter of 2008/9 - it is unlikely that these were driven by the high concentrations and loads at the STW in the middle of the year shown in Figure 5.1. The STW is a significant and constant source, the influence of which at the shellfish areas is dependent on the pathway as determined by tides, wind and time of transfer.

Sources via Surface Water Outfalls and Watercourses

Eighteen outfalls were identified from available records, which are considered relevant for further consideration as potential sources of faecal contamination at the shellfish areas. Fifteen of these are within 2km of the shellfish areas. Le Dicq, Dicq Slipway and Weighbridge outfalls are further away, but discharge along the southern coast, and receive potentially significant PS overflows and streamflow from Baudrette Brook in the case of Dicq Slipway. Eight of the identified outfalls discharge PS overflows. They may all receive and discharge septic material, including agricultural and urban runoff. Some outfalls may also discharge streamflows, including Longbeach outfall which discharges flows from the Queens Valley Stream, and as mentioned above Dicq Slipway outfall which discharges the Baudrette Brook.

Daily FC loads calculated from available concentration and flow data , and loads derived from a shoreline survey reported in the Sanitary Survey report suggested higher loads from outfalls to the centre and northern end of Grouville Bay (Beach Hotel Slip and Longbeach), and in the centre of St Clement's Bay (Pontac 1). However, for some outfalls no data were available, and none of the data consider intermittent influences. Future monitoring should seek to characterise the inputs from outfalls, taking into account PS spills and effects of rainfall on runoff and concentrations. Flow data and concentration data will need to be paired for accurate characterisation of loads. The available data indicate that loads are sufficiently high for the outfalls to constitute significant influences at a local scale, subject to dispersion effects of tides.

As for outfalls, data for streamflows and stream coliform concentrations are sparse. Available data were used to provide an indication of loads attributable to four of the eight watercourses discharging to the south and east of the island. Daily loads for the St Brelade's Stream, Sandy Brook, Vallée des Vaux and Grands Vaux varied between

7.52E+10 and 2.33E+11 cfu (presumptive FC). All four of the watercourses receive PS spills, suggesting that any monitoring should consider intermittent effects on contamination. Watercourses and surface water drainage systems will also transfer runoff from urban and rural land, the effects of which on faecal contamination will also be influenced by intermittent rainfall events. Concentrations in the Baudrette Brook (at the Dicq Slipway outfall) and Queens Valley Stream (at the Longbeach outfall) showed no seasonal variation as may be expected to reflect the prohibition of slurry spreading in October to December, although concentrations in the Queens Valley Stream did show a significant positive correlation with two day antecedent rainfall.

The estimated loads for outfalls and watercourses are one or two magnitudes lower than the lowest daily load estimated for the STW. However, they are significant dependent on the presence of a pathway between the outfall/watercourse discharge point and the shellfish areas. The estimates at this point take no account of the effects of intermittent influences such as rainfall/runoff events or PS spills. During monitoring, flow and concentration data will need to be paired to characterise loads. Samples would be stored such that high coliform concentration samples can be subject to MST analysis to further clarify potential sources as human, ruminant (i.e. slurry) or avian (i.e. poultry farms). Consideration at the point of which outfalls/watercourses discharge to the marine environment may provide further evidence for up-catchment investigation and management, for example of agricultural inputs.

Pumping Station Overflows

Data are currently recorded for spill time and duration at each PS. The data showed that spills in 2011 were minimal compared to the frequency of spills that occurred in 2010 and 2012. Further clarification is needed to determine the exact fate of each PS overflow before any are discounted as unable to influence faecal contamination at the shellfish areas. The data suggest a link between high counts at areas in St Clement's Bay, particularly at Areas 8 and 12, with spills at West of Albert/ Weighbridge to the west. However, it is difficult to dissociate a correlation between counts at the shellfish areas with spills, from that with rainfall, as spills are themselves influenced by rainfall. Estimation of loads will allow some estimate of source apportionment relative to other sources for a given rainfall event.

To estimate loads, spill rate monitoring and effluent concentration sampling will be required. Concentrations may vary according to PS location and varying influences of surface water and groundwater ingress to the sewerage system. Monitoring will be aided by any telemetered information available from TTS.

Direct Inputs from Wildlife and Boats

Initial high level estimations based on available data and information from the literature suggest that wading birds, including the migratory Brent geese, and rafting seabirds, comprise a potentially significant source of faecal contamination, in the same order of magnitude as that from the STW, noting that the STW is some 7km to the west. Further bird count and location data should be aligned with further information from the literature to more accurately characterise the inputs from this source, and to determine which areas are likely to be most susceptible, and when, taking into consideration effects of migratory birds. Water column count data allied to MST analysis will assist in confirming suspected avian source influence. It was concluded that inputs from seals, dolphins and boats are unlikely to be significant.

PATHWAYS

Pathways exist to enable direct transfer of local contamination from birds. Two mechanisms are likely to occur. The first is mobilisation and dispersion of faeces deposited by wading birds by the incoming tide, or rain on exposed areas on the ebbing tide. This could affect the near shore areas most in Grouville Bay, but may also affect Areas 8 and 25 in St Clement's Bay due to the concentrating effect of the Le Hocq Gutter. The second mechanism is direct release of faecal material by rafting birds in the vicinity of the beds. This could potentially affect all beds, although bird count data suggest La Rocque may be affected most. Further monitoring of birds (counts and species) will be needed to confirm this, probably allied to mitochondrial MST analysis.

Indirect pathways exist to transfer contamination from inland sources, including agricultural land, urban land and terrestrial PS, via watercourses and outfalls to the marine environment, and then via tidal currents to the shellfish areas.

In the marine environment, tidal direction on the south coast is bi-directional - from west to east on a flood tide, and reversing on the ebb tide. On the east coast, the tidal direction in waters further offshore is southerly on the flood tide, and northerly on the ebb tide. However, at the in-shore areas, tidal movements on the east coast are more complex in that there is a northerly current from half flood to half ebb, and a southerly movement from half ebb to half flood. This may mean that on the flood tide, material could be conveyed from the south coast, around La Rocque Point, northwards up the east coast, particularly if the material is close to shore and within the intertidal zone.

The tidal direction along the south coast would push effluent from Bellozanne STW, discharged via the Bellozanne stream at First Tower Outfall in St Aubin's Bay, towards the areas in St Clement's Bay. Material discharged from the Weighbridge outfall (which receives overflows from the Cavern PS), the Le Dicq outfall, Dicq Slipway, and La Greve d'Azette would also be conveyed towards the St Clement's Bay areas (Areas 5, 8 and 12). The northerly current up the east coast from half flood to half ebb may also enable transfer of material into Grouville Bay from this source.

On the east coast, the tidal currents may enable pathways between outfalls on the east coast and the Grouville Bay areas, noting that the southwards in-shore current on the east coast occurs from half ebb to half flood; these sources would therefore only be likely to affect the outer areas on this coast. Runoff conveyed by the Queen's Valley Stream via the Longbeach outfall, and any untreated effluent discharged by the Le Rivage and Fauvic PS via Beach hotel Slip and Fauvic outfalls, could therefore influence faecal contamination at the shellfish areas at Le Hurel Main Bed, but less likely at the in-shore Holding Beds.

The concentration data do not suggest that shellfish areas at Seymour Tower are significantly influenced by faecal contamination from any sources. These areas are therefore not the focus of further investigation. However, continued monitoring of counts at these sites provides a useful comparator.

SUMMARY

The following bullet points provide a succinct summary of the conclusions of the Strategic Review.

E. coli counts and classifications

Since 2008 the frequency of A classifications has declined although it has been demonstrated that this is largely due to a change in classification process. Only the Seymour Tower areas (Areas 20 and 26) have consistently attained Class A since this time.

Baseline counts suggest a consistent background level of contamination such that improvements to A classifications for areas other than Seymour Tower may be unrealistic.

This does not necessarily reflect a reduction in water quality, due to complications around area de-classifications, merging of areas, creation of new areas, and changes in analysis and sampling regime.

The change in laboratory in May 2008 is a potential source of variation in flesh *E. coli* counts noting that the count data show no sustained difference after the change in laboratories (perhaps as they are from different times when differences would be expected).

Oyster *E. coli* counts at Areas 20 and 26 (Seymour Tower) are significantly lower than elsewhere.

The highest mean oyster count was at Area 12 in St Clement's Bay, and the highest mean mussel count was at Area 27 in Grouville Bay. High counts also occurred at Areas 28, 27 and 6 in Grouville Bay.

There was a peak in counts over the winter of 2008/9 at Areas 1, 21, 24, 6 and 27 in Grouville Bay, suggesting a common influence.

There is a gradual slight increase in counts between 2005 and 2013 in Grouville Bay Areas 1, 21, 24, 6 and 27, and at Area 8 in St Clement's Bay.

In Grouville Bay higher counts are seen at the in-shore and northern areas, and in western part of St Clement's Bay.

Mussel and oyster counts are positively correlated with rainfall.

Highest counts at Areas 8 and 12 could be linked with PS spills at West of Albert/Weighbridge.

Sources

Coliform loads from Bellozanne STW were reduced in 2011 and 2012 compared to 2008 and 2009, potentially reflecting improved treatment. Loads could be redcued further if the STW achieved typical UV treated coliform concentrations.

Coliform loads discharged by outfalls at the centre and north of Grouville Bay and at the centre of St Clement's Bay may be significant, but more data especially when flows are high after rainfall is needed to clarify their influence.

Further data is required to say more about the influence of surface water outfalls and watercourses which may convey runoff from agricultural land.

The data suggest a link between high counts in St Clement's Bay and PS spills at West of Albert/Weighbridge, although a relationship is difficult to dissociate from rainfall.

Wading and rafting birds may constitute a significant influence as sources of untreated faecal material to the inter-tidal zone close to the areas, which can be mobilised by the incoming tide.

Inputs from seals, dolphins and boats are unlikely to be significant.

Pathways

Tidal currents could move material from St Aubin's Bay towards St Clement's Bay and potentially around the point to Grouville Bay. Material is unlikely to be conveyed from the east coast around the point towards St Clement's Bay.

This suggests a pathway between Bellozanne STW, Weighbridge/West of Albert outfall, Le Dicq outfall, Dicq Slipway and La Greve dAzette on the south coast and the shellfish areas at both Grouville Bay and St Clement's Bay.

There is a potential pathway between sources north of Grouville Bay, such as the Longbeach, Beach Hotel Slip, and Fauvic outfalls and the Grouville Bay shellfish areas.

There is a direct pathway between rafting birds which can input faecal material directly into the water around the shellfish areas.

There is a near direct pathway between wading birds which may use the intertidal zone around the areas, faecal material from which may be re-mobilised towards the shellfish areas by the incoming and outgoing tide.

APPENDICES

APPENDIX A

STATISTICAL ANALYSIS

SPATIAL ANALYSIS OF OYSTER FLESH *E. COLI* COUNTS

Oysters ANOVA - One way analysis of variance

Variables: Area_1 [no gaps], Area_21 [no gaps], Area_24 [no gaps], Area_28 [no gaps], Area_6 [no gaps], Area_27 [no gaps], Area_8 [no gaps], Area_25 [no gaps], Area_12 [no gaps], Area_20 [no gaps], Area_26 [no gaps]

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	121.719229	10	12.171923
Within Groups	516.301038	1538	0.335696
Corrected Total	638.020267	1548	

F (variance ratio) = 36.258725 $P < 0.0001$

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 4.558777, $|q^*| = 3.218654$
Pooled standard deviation = 0.579393

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Area_12 [no gaps] vs. Area_26 [no gaps]	1.092213 (0.847456 to 1.33697)	20.343258	P < 0.0001
Area_6 [no gaps] vs. Area_26 [no gaps]	0.797273 (0.595607 to 0.998939)	18.022845	P < 0.0001
Area_21 [no gaps] vs. Area_26 [no gaps]	0.77886 (0.571619 to 0.986102)	17.132922	P < 0.0001
Area_28 [no gaps] vs. Area_26 [no gaps]	0.909224 (0.657809 to 1.160638)	16.486503	P < 0.0001
Area_12 [no gaps] vs. Area_20 [no gaps]	1.014211 (0.724174 to 1.304248)	15.941297	P < 0.0001
Area_27 [no gaps] vs. Area_26 [no gaps]	0.762967 (0.544732 to 0.981203)	15.937808	P < 0.0001
Area_1 [no gaps] vs. Area_26 [no gaps]	0.691825 (0.488879 to 0.894771)	15.540437	P < 0.0001
Area_24 [no gaps] vs. Area_26 [no gaps]	0.720782 (0.509028 to 0.932536)	15.517471	P < 0.0001
Area_8 [no gaps] vs. Area_26 [no gaps]	0.640502 (0.438204 to 0.842799)	14.433718	P < 0.0001
Area_6 [no gaps] vs. Area_20 [no gaps]	0.719271 (0.464547 to 0.973995)	12.872738	P < 0.0001
Area_28 [no gaps] vs. Area_20 [no gaps]	0.831222 (0.535545 to 1.126898)	12.815878	P < 0.0001
Area_21 [no gaps] vs. Area_20 [no gaps]	0.700858 (0.441698 to 0.960019)	12.328476	P < 0.0001
Area_27 [no gaps] vs. Area_20 [no gaps]	0.684965 (0.416932 to 0.952999)	11.650041	P < 0.0001
Area_25 [no gaps] vs. Area_26 [no gaps]	0.739377 (0.438292 to 1.040462)	11.195024	P < 0.0001
Area_24 [no gaps] vs. Area_20 [no gaps]	0.64278 (0.379997 to 0.905563)	11.150982	P < 0.0001

Area_1 [no gaps] vs. Area_20 [no gaps]	0.613823 (0.358084 to 0.869562)	10.941936	P < 0.0001
Area_8 [no gaps] vs. Area_20 [no gaps]	0.5625 (0.307275 to 0.817724)	10.047276	P < 0.0001
Area_25 [no gaps] vs. Area_20 [no gaps]	0.661375 (0.322454 to 1.000296)	8.896056	P < 0.0001
Area_8 [no gaps] vs. Area_12 [no gaps]	-0.451711 (-0.683424 to -0.219998)	8.887053	P < 0.0001
Area_1 [no gaps] vs. Area_12 [no gaps]	-0.400388 (-0.632668 to -0.168108)	7.858094	P < 0.0001
Area_24 [no gaps] vs. Area_12 [no gaps]	-0.371431 (-0.611445 to -0.131418)	7.054899	P < 0.0001
Area_27 [no gaps] vs. Area_12 [no gaps]	-0.329246 (-0.574997 to -0.083494)	6.107631	P = 0.0008
Area_21 [no gaps] vs. Area_12 [no gaps]	-0.313353 (-0.549395 to -0.077311)	6.051906	P = 0.001
Area_6 [no gaps] vs. Area_12 [no gaps]	-0.29494 (-0.526102 to -0.063778)	5.816546	P = 0.002
Area_28 [no gaps] vs. Area_8 [no gaps]	0.268722 (0.029987 to 0.507457)	5.131389	P = 0.0131
Area_25 [no gaps] vs. Area_12 [no gaps]	-0.352836 (-0.674424 to -0.031248)	5.001739	P = 0.0181
Area_1 [no gaps] vs. Area_28 [no gaps]	-0.217399 (-0.456684 to 0.021886)	4.141804	P=0.115 stop
Area_6 [no gaps] vs. Area_8 [no gaps]	0.156771 (-0.028847 to 0.34239)	3.850291	P = 0.1906
Area_24 [no gaps] vs. Area_28 [no gaps]	-0.188442 (-0.435241 to 0.058357)	3.480823	P = 0.3284
Area_21 [no gaps] vs. Area_8 [no gaps]	0.138358 (-0.053303 to 0.33002)	3.290935	P = 0.4157
Area_28 [no gaps] vs. Area_12 [no gaps]	-0.182989 (-0.458627 to 0.092648)	3.026462	P = 0.5485
Area_27 [no gaps] vs. Area_8 [no gaps]	0.122465 (-0.081034 to 0.325965)	2.743463	P = 0.6907
Area_28 [no gaps] vs. Area_27 [no gaps]	0.146256 (-0.106126 to 0.398639)	2.641824	P = 0.7382
Area_1 [no gaps] vs. Area_6 [no gaps]	-0.105448 (-0.291774 to 0.080877)	2.579974	P = 0.7656
Area_21 [no gaps] vs. Area_28 [no gaps]	-0.130363 (-0.373302 to 0.112575)	2.446286	P = 0.8201
Area_28 [no gaps] vs. Area_25 [no gaps]	0.169847 (-0.156837 to 0.496531)	2.370161	P = 0.8478
Area_28 [no gaps] vs. Area_6 [no gaps]	0.111951 (-0.126249 to 0.350151)	2.14256	P = 0.915
Area_1 [no gaps] vs. Area_21 [no gaps]	-0.087035 (-0.279382 to 0.105311)	2.062817	P = 0.9329
Area_24 [no gaps] vs. Area_8 [no gaps]	0.08028 (-0.116252 to 0.276812)	1.862182	P = 0.966
Area_24 [no gaps] vs. Area_6 [no gaps]	-0.076491 (-0.272373 to 0.11939)	1.780191	P = 0.9753
Area_1 [no gaps] vs. Area_27 [no gaps]	-0.071142 (-0.275287 to 0.133002)	1.588691	P = 0.9894
Area_8 [no gaps] vs. Area_25 [no gaps]	-0.098875 (-0.389456 to 0.191706)	1.5512	P = 0.9912
Area_20 [no gaps] vs. Area_26 [no gaps]	0.078002 (-0.189121 to 0.345124)	1.331199	P = 0.9974
Area_21 [no gaps] vs. Area_24 [no gaps]	0.058079 (-0.143539 to 0.259696)	1.313217	P = 0.9977
Area_1 [no gaps] vs. Area_8 [no gaps]	0.051323 (-0.135686 to 0.238332)	1.251118	P = 0.9985
Area_6 [no gaps] vs. Area_25 [no gaps]	0.057896 (-0.232245 to 0.348038)	0.90968	P > 0.9999
Area_24 [no gaps] vs. Area_27 [no gaps]	-0.042185 (-0.255088 to 0.170717)	0.903298	P > 0.9999
Area_6 [no gaps] vs. Area_27 [no gaps]	0.034306 (-0.168565 to 0.237177)	0.770896	P > 0.9999
Area_1 [no gaps] vs. Area_25 [no gaps]	-0.047552 (-0.338585 to 0.243481)	0.74486	P > 0.9999
Area_1 [no gaps] vs. Area_24 [no gaps]	-0.028957 (-0.226157 to 0.168243)	0.669413	P > 0.9999
Area_21 [no gaps] vs. Area_25 [no gaps]	0.039483 (-0.254561 to 0.333528)	0.61214	P > 0.9999
Area_21 [no gaps] vs. Area_6 [no gaps]	-0.018413 (-0.209407 to 0.172582)	0.439486	P > 0.9999
Area_27 [no gaps] vs. Area_25 [no gaps]	0.02359 (-0.278303 to 0.325484)	0.356229	P > 0.9999
Area_21 [no gaps] vs. Area_27 [no gaps]	0.015893 (-0.192521 to 0.224308)	0.347639	P > 0.9999

Area_24 [no gaps] vs. Area_25 [no gaps]	-0.018595	(-0.315837 to 0.278647)	0.285191	P > 0.9999

Oysters ANOVA - Two way randomized block analysis of variance

Treatments: Area_1 [no gaps], Area_21 [no gaps], Area_24 [no gaps], Area_28 [no gaps], Area_6 [no gaps], Area_27 [no gaps], Area_8 [no gaps], Area_26 [no gaps]

Source of Variation	Sum Squares	DF	Mean Square
Between blocks (rows)	76.359971	69	1.106666
Between treatments (columns)	37.917036	7	5.416719
Residual (error)	135.460148	483	0.280456
Corrected total	249.737155	559	

F (VR between blocks) = 3.945956 P < 0.0001

F (VR between treatments) = 19.313987 P < 0.0001

Tukey multiple comparisons

Critical value (Studentized range) = 4.30287, $|q^*|$ = 3.030878
Pooled standard deviation = 0.529581

Comparison	Mean difference L	(95% CI)	|L/SE(L)|	P
Area_28 [no gaps] vs. Area_26 [no gaps]	0.845121	(0.572763 to 1.11748)	13.35168	P < 0.0001
Area_6 [no gaps] vs. Area_26 [no gaps]	0.83087	(0.558511 to 1.103229)	13.126525	P < 0.0001
Area_27 [no gaps] vs. Area_26 [no gaps]	0.790464	(0.518105 to 1.062822)	12.488166	P < 0.0001
Area_24 [no gaps] vs. Area_26 [no gaps]	0.76282	(0.490461 to 1.035179)	12.051434	P < 0.0001
Area_21 [no gaps] vs. Area_26 [no gaps]	0.731225	(0.458866 to 1.003584)	11.552282	P < 0.0001
Area_1 [no gaps] vs. Area_26 [no gaps]	0.685114	(0.412755 to 0.957473)	10.823795	P < 0.0001
Area_8 [no gaps] vs. Area_26 [no gaps]	0.559995	(0.287636 to 0.832354)	8.847103	P < 0.0001
Area_28 [no gaps] vs. Area_8 [no gaps]	0.285126	(0.012768 to 0.557485)	4.504578	P = 0.0327
Area_6 [no gaps] vs. Area_8 [no gaps]	0.270875	(-0.001484 to 0.543233)	4.279422	P = 0.0524 stop
Area_27 [no gaps] vs. Area_8 [no gaps]	0.230468	(-0.04189 to 0.502827)	3.641064	P = 0.1675
Area_24 [no gaps] vs. Area_8 [no gaps]	0.202825	(-0.069534 to 0.475183)	3.204331	P = 0.3146
Area_21 [no gaps] vs. Area_8 [no gaps]	0.17123	(-0.101129 to 0.443589)	2.705179	P = 0.5426
Area_1 [no gaps] vs. Area_28 [no gaps]	-0.160008	(-0.432366 to 0.112351)	2.527885	P = 0.6289
Area_1 [no gaps] vs. Area_6 [no gaps]	-0.145756	(-0.418115 to 0.126603)	2.30273	P = 0.733

Area_1 [no gaps] vs. Area_8 [no gaps]	0.125119 (-0.14724 to 0.397478)	1.976693	P = 0.8582
Area_21 [no gaps] vs. Area_28 [no gaps]	-0.113897 (-0.386255 to 0.158462)	1.799398	P = 0.9087
Area_1 [no gaps] vs. Area_27 [no gaps]	-0.10535 (-0.377708 to 0.167009)	1.664371	P = 0.9383
Area_21 [no gaps] vs. Area_6 [no gaps]	-0.099645 (-0.372004 to 0.172714)	1.574243	P = 0.9539
Area_24 [no gaps] vs. Area_28 [no gaps]	-0.082302 (-0.35466 to 0.190057)	1.300246	P = 0.9842
Area_1 [no gaps] vs. Area_24 [no gaps]	-0.077706 (-0.350065 to 0.194653)	1.227639	P = 0.9887
Area_24 [no gaps] vs. Area_6 [no gaps]	-0.06805 (-0.340409 to 0.204309)	1.075091	P = 0.995
Area_21 [no gaps] vs. Area_27 [no gaps]	-0.059239 (-0.331597 to 0.21312)	0.935884	P = 0.9979
Area_28 [no gaps] vs. Area_27 [no gaps]	0.054658 (-0.217701 to 0.327017)	0.863514	P = 0.9987
Area_1 [no gaps] vs. Area_21 [no gaps]	-0.046111 (-0.31847 to 0.226248)	0.728487	P = 0.9996
Area_6 [no gaps] vs. Area_27 [no gaps]	0.040406 (-0.231953 to 0.312765)	0.638359	P = 0.9998
Area_21 [no gaps] vs. Area_24 [no gaps]	-0.031595 (-0.303954 to 0.240764)	0.499152	P > 0.9999
Area_24 [no gaps] vs. Area_27 [no gaps]	-0.027644 (-0.300003 to 0.244715)	0.436732	P > 0.9999
Area_28 [no gaps] vs. Area_6 [no gaps]	0.014252 (-0.258107 to 0.28661)	0.225155	P > 0.9999

TEMPORAL ANALYSIS OF OYSTER FLESH *E. COLI* COUNTS

Season Effect - Area 21 One way analysis of variance

Variables: Summer, Winter, Autumn, Spring

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	2.697061	3	0.89902
Within Groups	71.666882	176	0.407198
Corrected Total	74.363943	179	

F (variance ratio) = 2.20782 P = 0.0889

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.66811, $|q^*|$ = 2.593815
Pooled standard deviation = 0.638121

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Summer vs. Winter	-0.342696 (-0.697615 to 0.012223)	3.541782	P = 0.0627 stop
Summer vs. Spring	-0.233846 (-0.579699 to 0.112007)	2.480163	P = 0.2993
Summer vs. Autumn	-0.224265 (-0.579184 to 0.130654)	2.31779	P = 0.3596
Winter vs. Autumn	0.118431 (-0.234442 to 0.471304)	1.231088	P = 0.8201
Winter vs. Spring	0.10885 (-0.234904 to 0.452604)	1.16151	P = 0.8443
Autumn vs. Spring	-0.009581 (-0.353335 to 0.334173)	0.102238	P = 0.9999

Season Effect - Area 1 One way analysis of variance

Variables: Summer, Winter, Autumn, Spring

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	5.047823	3	1.682608
Within Groups	63.611019	194	0.327892
Corrected Total	68.658841	197	

F (variance ratio) = 5.131593 P = 0.0019

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.664846, $|q^*|$ = 2.591508
Pooled standard deviation = 0.572618

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Summer vs. Winter	-0.430601 (-0.733567 to -0.127634)	5.208776	P = 0.0017
Summer vs. Spring	-0.343692 (-0.63913 to -0.048253)	4.263419	P = 0.0153
Summer vs. Autumn	-0.268111 (-0.566402 to 0.03018)	3.294047	P = 0.095 stop
Winter vs. Autumn	0.16249 (-0.13899 to 0.463969)	1.975256	P = 0.5029
Winter vs. Spring	0.086909 (-0.211749 to 0.385566)	1.066463	P = 0.8748
Autumn vs. Spring	-0.075581 (-0.369494 to 0.218333)	0.942429	P = 0.9096

Season Effect - Area 24 One way analysis of variance

Variables: Summer, Winter, Autumn, Spring

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	1.786653	3	0.595551
Within Groups	63.436608	160	0.396479
Corrected Total	65.223261	163	

F (variance ratio) = 1.5021 P = 0.2161

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.671632, $|q^*|$ = 2.596305
Pooled standard deviation = 0.629666

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Summer vs. Winter	-0.260753 (-0.626297 to 0.10479)	2.619086	P = 0.2531 stop
Winter vs. Autumn	0.245822 (-0.115344 to 0.606988)	2.499042	P = 0.293
Winter vs. Spring	0.213851 (-0.147315 to 0.575017)	2.174023	P = 0.4178
Summer vs. Spring	-0.046902 (-0.408068 to 0.314263)	0.47681	P = 0.9868

Autumn vs. Spring	-0.031971 (-0.388705 to 0.324763)	0.329056	P = 0.9955
Summer vs. Autumn	-0.014931 (-0.376097 to 0.346234)	0.151792	P = 0.9996

Season Effect - Area 28 One way analysis of variance

Variables: Summer, Winter, Autumn, Spring

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	1.231556	3	0.410519
Within Groups	29.065799	84	0.346021
Corrected Total	30.297354	87	

F (variance ratio) = 1.186396 P = 0.3199

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.706956, $|q^*|$ = 2.621282
Pooled standard deviation = 0.588236

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Autumn vs. Spring	0.33471 (-0.13569 to 0.80511)	2.637662	P = 0.2509 stop
Summer vs. Spring	0.210549 (-0.259851 to 0.680949)	1.65922	P = 0.6453
Winter vs. Spring	0.202368 (-0.263011 to 0.667747)	1.611955	P = 0.6661
Winter vs. Autumn	-0.132342 (-0.592159 to 0.327475)	1.066916	P = 0.8745
Summer vs. Autumn	-0.124161 (-0.589059 to 0.340737)	0.990022	P = 0.8968
Summer vs. Winter	0.008181 (-0.451636 to 0.467998)	0.065955	P > 0.9999

Season Effect - Area 6 One way analysis of variance

Variables: Summer, Winter, Autumn, Spring

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	0.347153	3	0.115718
Within Groups	62.720509	200	0.313603
Corrected Total	63.067662	203	

F (variance ratio) = 0.368995 P = 0.7755

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.66389, |q*| = 2.590831
Pooled standard deviation = 0.560002

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Autumn vs. Spring	0.1065 (-0.175787 to 0.388788)	1.3823	P = 0.7625 stop
Summer vs. Spring	0.086657 (-0.197147 to 0.370462)	1.118739	P = 0.8585
Winter vs. Spring	0.070865 (-0.21294 to 0.354669)	0.914855	P = 0.9165
Winter vs. Autumn	-0.035636 (-0.327279 to 0.256007)	0.447689	P = 0.989
Summer vs. Autumn	-0.019843 (-0.311486 to 0.2718)	0.249285	P = 0.998
Summer vs. Winter	0.015793 (-0.27732 to 0.308905)	0.19741	P = 0.999

Season Effect - Area 27 One way analysis of variance

Variables: Summer, Winter, Autumn, Spring

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	1.485634	3	0.495211
Within Groups	49.131905	141	0.348453
Corrected Total	50.617538	144	

F (variance ratio) = 1.42117 P = 0.2392

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.676862, $|q^*|$ = 2.600003
Pooled standard deviation = 0.590299

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Summer vs. Winter	0.257594 (-0.107011 to 0.6222)	2.597707	P = 0.2605 stop
Summer vs. Autumn	0.246127 (-0.116174 to 0.608428)	2.497849	P = 0.294
Summer vs. Spring	0.171632 (-0.19539 to 0.538655)	1.719425	P = 0.6179
Winter vs. Spring	-0.085962 (-0.445251 to 0.273327)	0.879712	P = 0.9249
Autumn vs. Spring	-0.074494 (-0.431444 to 0.282456)	0.76735	P = 0.9484
Winter vs. Autumn	-0.011468 (-0.365932 to 0.342997)	0.118955	P = 0.9998

Season Effect - Area 8 One way analysis of variance

Variables: Summer, Winter, Autumn, Spring

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	5.01029	3	1.670097
Within Groups	56.183194	197	0.285194
Corrected Total	61.193484	200	

F (variance ratio) = 5.856004 P = 0.0008

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.664361, $|q^*|$ = 2.591164
Pooled standard deviation = 0.534035

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Summer vs. Winter	-0.4517 (-0.731315 to -0.172084)	5.91953	P = 0.0002
Summer vs. Spring	-0.250238 (-0.527207 to 0.026731)	3.310703	P = 0.0924 stop
Summer vs. Autumn	-0.234586 (-0.512855 to 0.043683)	3.089122	P = 0.1312
Winter vs. Autumn	0.217114 (-0.058274 to 0.492501)	2.888959	P = 0.176
Winter vs. Spring	0.201462 (-0.072612 to 0.475535)	2.693545	P = 0.2294
Autumn vs. Spring	-0.015652 (-0.288352 to 0.257048)	0.210319	P = 0.9988

Season Effect - Area 25 One way analysis of variance

Variables: Summer, Winter, Autumn, Spring

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	4.506707	3	1.502236
Within Groups	16.550349	48	0.344799
Corrected Total	21.057056	51	

F (variance ratio) = 4.356846 P = 0.0086

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.763749, $|q^*|$ = 2.661438
Pooled standard deviation = 0.587196

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Summer vs. Winter	-0.867946 (-1.520273 to -0.215618)	5.007808	P = 0.0048
Summer vs. Autumn	-0.552627 (-1.182276 to 0.077022)	3.303349	P = 0.1041 stop
Winter vs. Spring	0.472481 (-0.132768 to 1.07773)	2.938129	P = 0.1751
Summer vs. Spring	-0.395465 (-1.01581 to 0.22488)	2.399357	P = 0.3367
Winter vs. Autumn	0.315319 (-0.299463 to 0.9301)	1.930411	P = 0.5271
Autumn vs. Spring	0.157162 (-0.423573 to 0.737897)	1.018571	P = 0.8886

Season Effect - Area 12 One way analysis of variance

Variables: Summer, Winter, Autumn, Spring

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	2.332377	3	0.777459
Within Groups	37.340375	92	0.405874
Corrected Total	39.672752	95	

F (variance ratio) = 1.91552 P = 0.1325

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.700452, |q*| = 2.616683
Pooled standard deviation = 0.637082

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Autumn vs. Spring	0.421797 (-0.053133 to 0.896728)	3.286463	P = 0.1001 stop
Winter vs. Spring	0.315969 (-0.162815 to 0.794754)	2.442078	P = 0.3158
Summer vs. Spring	0.307757 (-0.214325 to 0.829839)	2.181342	P = 0.4167
Winter vs. Autumn	-0.105828 (-0.555459 to 0.343802)	0.870964	P = 0.9268
Summer vs. Autumn	-0.11404 (-0.609523 to 0.381442)	0.851697	P = 0.9311
Summer vs. Winter	-0.008212 (-0.50739 to 0.490966)	0.060878	P > 0.9999

Season Effect - Area 20 One way analysis of variance

Variables: Summer, Winter, Autumn, Spring

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	0.924708	3	0.308236
Within Groups	11.666215	69	0.169076
Corrected Total	12.590923	72	

F (variance ratio) = 1.823066 P = 0.151

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.723289, |q*| = 2.63283
Pooled standard deviation = 0.411188

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Summer vs. Autumn	0.30578 (-0.065535 to 0.677095)	3.06615	P = 0.1425 stop
Summer vs. Spring	0.243682 (-0.102572 to 0.589935)	2.620328	P = 0.258
Winter vs. Autumn	0.152986 (-0.224086 to 0.530058)	1.510614	P = 0.7099
Summer vs. Winter	0.152794 (-0.224278 to 0.529867)	1.508722	P = 0.7107
Winter vs. Spring	0.090887 (-0.261533 to 0.443307)	0.960217	P = 0.9047
Autumn vs. Spring	-0.062099 (-0.408352 to 0.284155)	0.667752	P = 0.9649

Season Effect - Area 26 One way analysis of variance

Variables: Summer, Winter, Autumn, Spring

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	0.501111	3	0.167037
Within Groups	29.057113	144	0.201786
Corrected Total	29.558224	147	

F (variance ratio) = 0.827795 P = 0.4806

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.675943, $|q^*|$ = 2.599354
Pooled standard deviation = 0.449205

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Summer vs. Autumn	0.154266 (-0.126892 to 0.435424)	2.016921	P = 0.4852 stop
Autumn vs. Spring	-0.129889 (-0.40072 to 0.140942)	1.762963	P = 0.5983
Summer vs. Winter	0.084744 (-0.188804 to 0.358293)	1.138791	P = 0.8519
Winter vs. Autumn	0.069522 (-0.206113 to 0.345156)	0.927163	P = 0.9134
Winter vs. Spring	-0.060367 (-0.32329 to 0.202556)	0.843998	P = 0.9329
Summer vs. Spring	0.024377 (-0.24433 to 0.293084)	0.333479	P = 0.9954

ANALYSIS OF OYSTER FLESH *E. COLI* COUNTS - ENVIRONMENTAL INFLUENCES

Area 1 - Spearman's rank correlation - antecedent seven day cumulative rainfall

1-GM E.Coli vs. 1-7 Day Rain mm
Observations per sample = 198

Spearman's rank correlation coefficient (Rho) = 0.194279

95% CI for rho (Fisher's Z transformed) = 0.056365 to 0.324919

Upper side P = 0.0031 (H_1: positive correlation)
Lower side P = 0.9969 (H_1: negative correlation)
Two sided P = 0.0062 (H_1: any correlation)

Area 1 - Spearman's rank correlation - antecedent seven day sunshine hours

1-GM E.Coli vs. 1 - 7 Day Sun hrs
Observations per sample = 198

Spearman's rank correlation coefficient (Rho) = -0.274326

95% CI for rho (Fisher's Z transformed) = -0.398523 to -0.140249

Upper side P > 0.9999 (H_1: positive correlation)
Lower side P < 0.0001 (H_1: negative correlation)
Two sided P < 0.0001 (H_1: any correlation)

Area 21 - Spearman's rank correlation - antecedent seven day cumulative rainfall

21 - GM E.Coli vs. 21 - 7 Day Rain mm
Observations per sample = 180

Spearman's rank correlation coefficient (Rho) = 0.249734

95% CI for rho (Fisher's Z transformed) = 0.107394 to 0.382043

Upper side P = 0.0004 (H_1: positive correlation)
Lower side P = 0.9996 (H_1: negative correlation)
Two sided P = 0.0007 (H_1: any correlation)

Area 21 - Spearman's rank correlation - antecedent seven day sunshine hours

21 - GM E.Coli vs. 21 - 7 Day Sun hrs
Observations per sample = 180

Spearman's rank correlation coefficient (Rho) = -0.266259

95% CI for rho (Fisher's Z transformed) = -0.39706 to -0.124859

Upper side P = 0.9998 (H_1: positive correlation)
Lower side P = 0.0002 (H_1: negative correlation)
Two sided P = 0.0003 (H_1: any correlation)

Area 24 - Spearman's rank correlation - antecedent seven day cumulative rainfall

24 - GM E.Coli vs. 24 - 7 Day Rain mm
Observations per sample = 164

Spearman's rank correlation coefficient (Rho) = 0.297547

95% CI for rho (Fisher's Z transformed) = 0.151191 to 0.431138

Upper side P < 0.0001 (H_1: positive correlation)
Lower side P > 0.9999 (H_1: negative correlation)
Two sided P = 0.0001 (H_1: any correlation)

Area 24 - Spearman's rank correlation - antecedent seven day sunshine hours

24 - GM E.Coli vs. 24 - 7 Day Sun
Observations per sample = 164

Spearman's rank correlation coefficient (Rho) = -0.157981

95% CI for rho (Fisher's Z transformed) = -0.303873 to -0.004848

Upper side P = 0.9783 (H_1: positive correlation)
Lower side P = 0.0217 (H_1: negative correlation)
Two sided P = 0.0434 (H_1: any correlation)

Area 6 - Spearman's rank correlation - antecedent seven day cumulative rainfall

6 - GM E.Coli vs. 6 - 7 Day Rain mm
Observations per sample = 204

Spearman's rank correlation coefficient (Rho) = 0.224705

95% CI for rho (Fisher's Z transformed) = 0.090116 to 0.351234

Upper side P = 0.0006 (H_1: positive correlation)
Lower side P = 0.9994 (H_1: negative correlation)
Two sided P = 0.0013 (H_1: any correlation)

Area 6 - Spearman's rank correlation - antecedent seven day sunshine hours

6 - GM E.Coli vs. 6 - 7 Day Sun hrs
Observations per sample = 204

Spearman's rank correlation coefficient (Rho) = -0.075882

95% CI for rho (Fisher's Z transformed) = -0.211053 to 0.062137

Upper side P = 0.8598 (H_1: positive correlation)
Lower side P = 0.1402 (H_1: negative correlation)
Two sided P = 0.2805 (H_1: any correlation)

Area 27 - Spearman's rank correlation - antecedent seven day cumulative rainfall

27 - GM E.Coli vs. 27 - 7 Day Rain mm
Observations per sample = 145

Spearman's rank correlation coefficient (Rho) = 0.074614

95% CI for rho (Fisher's Z transformed) = -0.089484 to 0.234767

Upper side P = 0.186 (H_1: positive correlation)
Lower side P = 0.814 (H_1: negative correlation)
Two sided P = 0.372 (H_1: any correlation)

Area 27 - Spearman's rank correlation - antecedent seven day sunshine hours

27 - GM E.Coli vs. 27 - 7 Day Sun hrs
Observations per sample = 145

Spearman's rank correlation coefficient (Rho) = 0.029933

95% CI for rho (Fisher's Z transformed) = -0.133729 to 0.192005

Upper side P = 0.3602 (H_1: positive correlation)
Lower side P = 0.6398 (H_1: negative correlation)
Two sided P = 0.7205 (H_1: any correlation)

Area 8 - Spearman's rank correlation - antecedent seven day cumulative rainfall

8 - GM E.Coli vs. 8 - 7 Day Rain mm
Observations per sample = 200

Spearman's rank correlation coefficient (Rho) = 0.2808

95% CI for rho (Fisher's Z transformed) = 0.147818 to 0.403809

Upper side P < 0.0001 (H_1: positive correlation)
Lower side P > 0.9999 (H_1: negative correlation)
Two sided P < 0.0001 (H_1: any correlation)

Area 8 - Spearman's rank correlation - antecedent seven day sunshine hours

8 - GM E.Coli vs. 8 - 7 Day Sun hrs
Observations per sample = 200

Spearman's rank correlation coefficient (Rho) = -0.337634

95% CI for rho (Fisher's Z transformed) = -0.455059 to -0.208668

Upper side P > 0.9999 (H_1: positive correlation)
Lower side P < 0.0001 (H_1: negative correlation)
Two sided P < 0.0001 (H_1: any correlation)

Area 12 - Spearman's rank correlation - antecedent seven day cumulative rainfall

12 - GM E.Coli vs. 12 - 7 Day Rain mm
Observations per sample = 96

Spearman's rank correlation coefficient (Rho) = 0.150388

95% CI for rho (Fisher's Z transformed) = -0.051656 to 0.340604

Upper side P = 0.0717 (H_1: positive correlation)
Lower side P = 0.9283 (H_1: negative correlation)
Two sided P = 0.1434 (H_1: any correlation)

Area 12 - Spearman's rank correlation - antecedent seven day sunshine hours

12 - GM E.Coli vs. 12 - 7 Day Sun hrs
Observations per sample = 96

Spearman's rank correlation coefficient (Rho) = -0.046218

95% CI for rho (Fisher's Z transformed) = -0.244439 to 0.155711

Upper side P = 0.6729 (H_1: positive correlation)
Lower side P = 0.3271 (H_1: negative correlation)
Two sided P = 0.6543 (H_1: any correlation)

Area 20 - Spearman's rank correlation - antecedent seven day cumulative rainfall

20 - GM E.Coli vs. 20 - 7 Day Rain mm
Observations per sample = 73

Spearman's rank correlation coefficient (Rho) = 0.074862

95% CI for rho (Fisher's Z transformed) = -0.157925 to 0.299766

Upper side P = 0.2641 (H_1: positive correlation)
Lower side P = 0.7359 (H_1: negative correlation)
Two sided P = 0.5281 (H_1: any correlation)

Area 20 - Spearman's rank correlation - antecedent seven day sunshine hours

20 - GM E.Coli vs. 20 - 7 Day Sun hrs
Observations per sample = 73

Spearman's rank correlation coefficient (Rho) = 0.139028

95% CI for rho (Fisher's Z transformed) = -0.094047 to 0.357656

Upper side P = 0.1201 (H_1: positive correlation)
Lower side P = 0.8799 (H_1: negative correlation)
Two sided P = 0.2401 (H_1: any correlation)

Area 26 - Spearman's rank correlation - antecedent seven day cumulative rainfall

26 - GM E.Coli vs. 26 - 7 Day Rain mm
Observations per sample = 148

Spearman's rank correlation coefficient (Rho) = 0.020535

95% CI for rho (Fisher's Z transformed) = -0.141277 to 0.181278

Upper side P = 0.4021 (H_1: positive correlation)

Lower side P = 0.5979 (H_1: negative correlation)
Two sided P = 0.8041 (H_1: any correlation)

Area 26 - Spearman's rank correlation - antecedent seven day sunshine hours

26 - GM E.Coli vs. 26 - 7 Day Sun hrs
Observations per sample = 148

Spearman's rank correlation coefficient (Rho) = 0.04435

95% CI for rho (Fisher's Z transformed) = -0.117837 to 0.204233

Upper side P = 0.296 (H_1: positive correlation)
Lower side P = 0.704 (H_1: negative correlation)
Two sided P = 0.5921 (H_1: any correlation)

Area 25 - Spearman's rank correlation - antecedent seven day cumulative rainfall

25 - GM E.Coli vs. 25 - 7 Day Rain mm
Observations per sample = 40

Spearman's rank correlation coefficient (Rho) = 0.171946

95% CI for rho (Fisher's Z transformed) = -0.147462 to 0.458877

Upper side P = 0.1437 (H_1: positive correlation)
Lower side P = 0.8563 (H_1: negative correlation)
Two sided P = 0.2873 (H_1: any correlation)

Area 25 - Spearman's rank correlation - antecedent seven day sunshine hours

25 - GM E.Coli vs. 7 Day Sun hrs
Observations per sample = 40

Spearman's rank correlation coefficient (Rho) = -0.506814

95% CI for rho (Fisher's Z transformed) = -0.706744 to -0.231919

Upper side P = 0.9995 (H_1: positive correlation)
Lower side P = 0.0005 (H_1: negative correlation)
Two sided P = 0.001 (H_1: any correlation)

SPATIAL ANALYSIS OF MUSSEL FLESH *E. COLI* COUNTS

Mussels ANOVA - One way analysis of variance

Variables: 24B [no gaps], 28 [no gaps], 27 [no gaps], 8 [no gaps], 25 [no gaps]

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	13.182257	4	3.295564
Within Groups	117.488202	288	0.407945
Corrected Total	130.670459	292	

F (variance ratio) = 8.078449 P < 0.0001

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.882212, $|q^*|$ = 2.745207
Pooled standard deviation = 0.638706

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
24B [no gaps] vs. 27 [no gaps]	-0.540971 (-0.834393 to -0.247549)	7.157485	P < 0.0001
24B [no gaps] vs. 28 [no gaps]	-0.458987 (-0.757045 to -0.16093)	5.97833	P = 0.0003
27 [no gaps] vs. 25 [no gaps]	0.372593 (0.048816 to 0.696371)	4.467539	P = 0.015
28 [no gaps] vs. 25 [no gaps]	0.29061 (-0.037374 to 0.618594)	3.43983	P = 0.1097 stop
24B [no gaps] vs. 8 [no gaps]	-0.281236 (-0.644499 to 0.082027)	3.005581	P = 0.2122
27 [no gaps] vs. 8 [no gaps]	0.259735 (-0.107649 to 0.627119)	2.744669	P = 0.2982
24B [no gaps] vs. 25 [no gaps]	-0.168378 (-0.487472 to 0.150717)	2.048538	P = 0.5968
28 [no gaps] vs. 8 [no gaps]	0.177751 (-0.193345 to 0.548848)	1.859539	P = 0.6822
8 [no gaps] vs. 25 [no gaps]	0.112858 (-0.275337 to 0.501054)	1.128661	P = 0.931
28 [no gaps] vs. 27 [no gaps]	-0.081984 (-0.385049 to 0.221082)	1.050197	P = 0.9463

Mussels ANOVA - Two way randomized block analysis of variance

Treatments: 24, 28, 27

Source of Variation	Sum Squares	DF	Mean Square
Between blocks (rows)	44.743003	62	0.721661
Between treatments (columns)	10.331925	2	5.165963
Residual (error)	37.064706	124	0.298909
Corrected total	92.139633	188	

F (VR between blocks) = 2.414319 P < 0.0001

F (VR between treatments) = 17.282731 P < 0.0001

Tukey multiple comparisons

Critical value (Studentized range) = 3.341262, $|q^*|$ = 2.362703
Pooled standard deviation = 0.546726

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
24 vs. 27	-0.539594 (-0.769743 to -0.309445)	7.83372	P < 0.0001
24 vs. 28	-0.43601 (-0.66616 to -0.205861)	6.329912	P < 0.0001
28 vs. 27	-0.103584 (-0.333733 to 0.126566)	1.503808	P = 0.538 stop

TEMPORAL ANALYSIS OF MUSSEL FLESH *E. COLI* COUNTS

Season Effect - Area 24 - One way analysis of variance

Variables: Winter, Spring, Summer, Autumn

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	0.261927	3	0.087309
Within Groups	38.388346	70	0.548405
Corrected Total	38.650273	73	

F (variance ratio) = 0.159205 P = 0.9234

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.721978, $|q^*|$ = 2.631903
Pooled standard deviation = 0.740544

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Spring vs. Autumn	-0.150355 (-0.793296 to 0.492585)	0.870405	P = 0.9268 stop
Winter vs. Autumn	-0.12529 (-0.749672 to 0.499091)	0.746865	P = 0.952
Spring vs. Summer	-0.09486 (-0.754008 to 0.564287)	0.535644	P = 0.9813
Winter vs. Summer	-0.069796 (-0.710854 to 0.571262)	0.405233	P = 0.9917
Summer vs. Autumn	-0.055495 (-0.688708 to 0.577718)	0.326195	P = 0.9956
Winter vs. Spring	0.025065 (-0.625603 to 0.675733)	0.143377	P = 0.9996

Season Effect - Area 27 One way analysis of variance

Variables: Winter, Spring, Summer, Autumn

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	3.614879	3	1.20496
Within Groups	21.024373	65	0.323452
Corrected Total	24.639252	68	

F (variance ratio) = 3.725313 P = 0.0155

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.728941, $|q^*|$ = 2.636827
Pooled standard deviation = 0.568728

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Spring vs. Summer	-0.64156 (-1.156811 to -0.126309)	4.643058	P = 0.0088
Winter vs. Summer	-0.407409 (-0.914573 to 0.099756)	2.995485	P = 0.1582 stop
Summer vs. Autumn	0.350094 (-0.149773 to 0.84996)	2.611653	P = 0.2613
Spring vs. Autumn	-0.291466 (-0.806717 to 0.223784)	2.109382	P = 0.4484
Winter vs. Spring	0.234151 (-0.288183 to 0.756485)	1.671605	P = 0.6403
Winter vs. Autumn	-0.057315 (-0.56448 to 0.449849)	0.421412	P = 0.9907

Season Effect - Area 28 - One way analysis of variance

Variables: Winter, Spring, Summer, Autumn

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	1.320559	3	0.440186
Within Groups	22.748613	61	0.372928
Corrected Total	24.069173	64	

F (variance ratio) = 1.180352 P = 0.3247

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.735351, $|q^*|$ = 2.641359
Pooled standard deviation = 0.610678

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Spring vs. Summer	-0.386185 (-0.973272 to 0.200901)	2.457115	P = 0.3136 stop
Spring vs. Autumn	-0.35283 (-0.933401 to 0.227741)	2.270082	P = 0.3834
Winter vs. Spring	0.272732 (-0.338479 to 0.883942)	1.666772	P = 0.6426
Winter vs. Summer	-0.113454 (-0.677356 to 0.450449)	0.751531	P = 0.9511

Winter vs. Autumn	-0.080099 (-0.637215 to 0.477018)	0.537044	P = 0.9812
Summer vs. Autumn	0.033355 (-0.497183 to 0.563894)	0.234844	P = 0.9984

Season Effect - Area 8 - One way analysis of variance

Variables: Winter, Spring, Summer, Autumn

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	1.276135	3	0.425378
Within Groups	15.032609	30	0.501087
Corrected Total	16.308743	33	

F (variance ratio) = 0.848911 P = 0.4781

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.845401, $|q^*|$ = 2.719173
Pooled standard deviation = 0.707875

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Winter vs. Spring	0.537223 (-0.411323 to 1.48577)	2.177899	P = 0.4272 stop
Spring vs. Summer	-0.44072 (-1.469563 to 0.588124)	1.647232	P = 0.6531
Spring vs. Autumn	-0.313569 (-1.262116 to 0.634977)	1.271209	P = 0.8055
Winter vs. Autumn	0.223654 (-0.637138 to 1.084446)	0.999124	P = 0.8937
Summer vs. Autumn	0.12715 (-0.821396 to 1.075697)	0.515466	P = 0.9831
Winter vs. Summer	0.096504 (-0.852043 to 1.04505)	0.391225	P = 0.9924

Season Effect - Area 25 - One way analysis of variance

Variables: Winter, Spring, Summer, Autumn

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	0.600628	3	0.200209
Within Groups	13.220133	47	0.281279
Corrected Total	13.820761	50	

F (variance ratio) = 0.711781 P = 0.5499

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.766601, $|q^*|$ = 2.663455
Pooled standard deviation = 0.530358

Comparison	Mean difference L (95% CI)	|L/SE(L)|	
Winter vs. Summer	0.324119 (-0.278194 to 0.926432)	2.026898	P = 0.4855 stop
Winter vs. Spring	0.205481 (-0.355242 to 0.766204)	1.3803	P = 0.7637
Summer vs. Autumn	-0.168801 (-0.737933 to 0.400332)	1.117147	P = 0.8587
Winter vs. Autumn	0.155318 (-0.413814 to 0.724451)	1.02792	P = 0.8859
Spring vs. Summer	0.118638 (-0.442085 to 0.679361)	0.796938	P = 0.9424
Spring vs. Autumn	-0.050163 (-0.575083 to 0.474757)	0.359946	P = 0.9941

ANALYSIS OF MUSSEL FLESH *E. COLI* COUNTS - ENVIRONMENTAL INFLUENCES

Area 24 - Spearman's rank correlation - antecedent seven day cumulative rainfall

24 Count vs. 24 - 7 Day Rain
Observations per sample = 74

Spearman's rank correlation coefficient (Rho) = 0.245975

95% CI for rho (Fisher's Z transformed) = 0.018517 to 0.449225

Upper side P = 0.0174 (H_1: positive correlation)
Lower side P = 0.9826 (H_1: negative correlation)
Two sided P = 0.0349 (H_1: any correlation)

Area 24 - Spearman's rank correlation - antecedent seven day sunshine hours

24 Count vs. 24 - 7 Day Sun
Observations per sample = 74

Spearman's rank correlation coefficient (Rho) = -0.13953

95% CI for rho (Fisher's Z transformed) = -0.356658 to 0.091899

Upper side P = 0.8824 (H_1: positive correlation)
Lower side P = 0.1176 (H_1: negative correlation)
Two sided P = 0.2351 (H_1: any correlation)

Area 28 - Spearman's rank correlation - antecedent seven day cumulative rainfall

28 Count vs. 28 - 7 Day Rain
Observations per sample = 65

Spearman's rank correlation coefficient (Rho) = 0.458338

95% CI for rho (Fisher's Z transformed) = 0.241427 to 0.631628

Upper side P < 0.0001 (H_1: positive correlation)
Lower side P > 0.9999 (H_1: negative correlation)
Two sided P = 0.0001 (H_1: any correlation)

Area 28 - Spearman's rank correlation - antecedent seven day sunshine hours

28 Count vs. 28 - 7 Day Sun
Observations per sample = 65

Spearman's rank correlation coefficient (Rho) = -0.232014

95% CI for rho (Fisher's Z transformed) = -0.450424 to 0.012599

Upper side P = 0.9685 (H_1: positive correlation)
Lower side P = 0.0315 (H_1: negative correlation)
Two sided P = 0.0631 (H_1: any correlation)

Area 27 - Spearman's rank correlation - antecedent seven day cumulative rainfall

27 Count vs. 27 - 7 Day Rain
Observations per sample = 69

Spearman's rank correlation coefficient (Rho) = 0.20854

95% CI for rho (Fisher's Z transformed) = -0.029601 to 0.42428

Upper side P = 0.0428 (H_1: positive correlation)
Lower side P = 0.9572 (H_1: negative correlation)
Two sided P = 0.0855 (H_1: any correlation)

Area 27 - Spearman's rank correlation - antecedent seven day sunshine hours

27 Count vs. 27 - 7 Day Sun
Observations per sample = 69

Spearman's rank correlation coefficient (Rho) = 0.03172

95% CI for rho (Fisher's Z transformed) = -0.206511 to 0.266401

Upper side P = 0.3976 (H_1: positive correlation)
Lower side P = 0.6024 (H_1: negative correlation)
Two sided P = 0.7952 (H_1: any correlation)

Area 8 - Spearman's rank correlation - antecedent seven day cumulative rainfall

8 - Count vs. 8 - 7 Day Rain
Observations per sample = 34

Spearman's rank correlation coefficient (Rho) = 0.634702

95% CI for rho (Fisher's Z transformed) = 0.377578 to 0.800955

Upper side P < 0.0001 (H_1: positive correlation)
Lower side P > 0.9999 (H_1: negative correlation)
Two sided P < 0.0001 (H_1: any correlation)

Area 8 - Spearman's rank correlation - antecedent seven day sunshine hours

8 - Count vs. 8 - 7 Day Sun
Observations per sample = 34

Spearman's rank correlation coefficient (Rho) = -0.449194

95% CI for rho (Fisher's Z transformed) = -0.68353 to -0.130915

Upper side P = 0.9959 (H_1: positive correlation)
Lower side P = 0.0041 (H_1: negative correlation)
Two sided P = 0.0082 (H_1: any correlation)

Area 25 - Spearman's rank correlation - antecedent seven day cumulative rainfall

25 - Count vs. 25 - 7 Day Rain
Observations per sample = 51

Spearman's rank correlation coefficient (Rho) = 0.14955

95% CI for rho (Fisher's Z transformed) = -0.131451 to 0.408306

Upper side P = 0.1469 (H_1: positive correlation)
Lower side P = 0.8531 (H_1: negative correlation)
Two sided P = 0.2938 (H_1: any correlation)

Area 25 - Spearman's rank correlation - antecedent seven day sunshine hours

25 - Count vs. 25 - 7 Day Sun
Observations per sample = 51

Spearman's rank correlation coefficient (Rho) = -0.313689

95% CI for rho (Fisher's Z transformed) = -0.542385 to -0.041711

Upper side P = 0.9873 (H_1: positive correlation)
Lower side P = 0.0127 (H_1: negative correlation)
Two sided P = 0.0254 (H_1: any correlation)

TEMPORAL ANALYSIS OF OYSTER AND MUSSEL FLESH *E. COLI* COUNTS BETWEEN YEARS 2010, 2011 AND 2012

Oysters by year - One way analysis of variance

Variables: 2010, 2011, 2012

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	13.013574	2	6.506787
Within Groups	158.024334	362	0.436531
Corrected Total	171.037908	364	

F (variance ratio) = 14.90566 P < 0.0001

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.328202, $|q^*| = 2.343701$
Pooled standard deviation = 0.660705

Comparison	Mean difference L (95% CI)	|L/SE(L)|	P
2011 vs. 2012	-0.428108 (-0.622973 to -0.233244)	7.311903	P < 0.0001
2010 vs. 2012	-0.353866 (-0.557913 to -0.149818)	5.771873	P = 0.0002
2010 vs. 2011	0.074243 (-0.126494 to 0.274979)	1.230937	P = 0.6593 stop

Mussels by Year - One way analysis of variance

Variables: 2010, 2011, 2012

Source of Variation	Sum Squares	DF	Mean Square
Between Groups	2.350358	2	1.175179
Within Groups	55.352573	155	0.357113
Corrected Total	57.702931	157	

F (variance ratio) = 3.290773 P = 0.0398

Tukey-Kramer multiple comparisons

Critical value (Studentized range) = 3.346659, $|q^*| = 2.366519$
Pooled standard deviation = 0.59759

Comparison	Mean difference L (95% CI)	|L/SE(L)|	P
2010 vs. 2012	-0.254193 (-0.526536 to 0.01815)	3.123627	P = 0.0728 stop
2010 vs. 2011	-0.255786 (-0.530938 to 0.019367)	3.111104	P = 0.0743
2011 vs. 2012	0.001593 (-0.278507 to 0.281693)	0.019033	P > 0.9999