Scottish Sanitary Survey Report

Sanitary Survey Report
Sound of Mull: Tobermory
Tobermory: Port na Coite
AB 258/AB 624
January 2013

Cefas

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Report Distribution – Sound of Mull: Tobermory and Tobermory: Port na Coite

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The hydrographic assessment and the shoreline survey and its associated report were undertaken by SRSL, Oban.

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I. Executive Summary

A sanitary survey at the Sound of Mull: Tobermory production area was undertaken due to the ranking for the area in a risk matrix. Subsequent to selection, a standard application was received for classification of common mussels at Port na Coite. The new site was situated within the Sound of Mull: Tobermory production area boundaries, and therefore was considered as part of this survey.

Tobermory Bay contains two long-line mussel farms. An established site, Aros Park, comprised two mussel long lines in the southern end of the bay at the time of survey. The new site, Port na Coite, comprised a single mussel long-line to the north east of the ferry terminal along the northern shore of the bay. This area was historically used for the production of Pacific oysters.

The main sources of contamination are associated with the town of Tobermory. The wastewater treatment works for the town, as well as its combined sewer overflow, lie in close proximity to the Port na Coite mussel farm. Three watercourses passing through the town to the bay were all found to contain significant loadings of *E. coli* based on measurements and spot samples taken on the day of survey. A number of homes on private septic tanks are situated along the Erray Burn immediately north of Port na Coite, as well as a small number of livestock and a golf course. The other two watercourses, Tobermory River and an unnamed watercourse, pass through agricultural land before reaching the town and then the bay. The town of Tobermory, which lies at the north end of the bay, is densely populated. Tobermory Bay is a centre of yachting on the west coast, and much of its area is devoted to moorings and anchorages for both resident and visiting yachts. A distillery on the south shore of the town attracts visitors and has a separate outfall for wastes.

Further watercourses drain the land around the central and southern reaches of the bay. Of these, the highest loadings of *E. coli* were found in measurements and spot samples taken from the Aros Burn, which discharges south of the Aros Park mussel farm. This burn drains woodland and flows past a picnic area and car park.

Outside the town, much of the area is wooded with relatively little agricultural land, though there is a dairy farm inland along the Tobermory River and a children's farm to the south of town. Limited numbers of sheep were observed grazing both inland and on Calve Island.

Port na Coite is situated near the main entrance to the bay, while Aros Park is situated within an anchorage in the southern end of the bay. Therefore, both mussel farms are subject to sewage contamination, although the Port na Coite

site is closer to a continual source of sewage whilst the Aros Park site is exposed to seasonal, intermittent sources (yachts) within 50 metres of the mussel lines.

Differences were seen in the pattern of historical monitoring results between the two areas, with results in mussels at Aros Park significantly influenced by rainfall and while those in Pacific oysters at Port na Coite showed no such influence.

Given the large continual sewage source near Port na Coite, and the difference in response to rainfall between the two sites, it is recommended that the production area be split and the two monitored separately. It is noted that sewage contamination from yachts will be highly variable and localised and that risks from these sources cannot be adequately controlled via the monitoring programme.

Recommended sampling points and production area boundaries are presented in tabular form overleaf and graphically on page 72.

II. Sampling Plan & Recommended Boundaries

Production Area	Sound of Mull: Tobermory	Tobermory: Port na Coite
Site Name	Aros Park	Port na Coite
SIN	AB 258 076 08	AB 624 128 08
Species	Common mussels	Common mussels
Type of Fishery	Longline aquaculture	Longline aquaculture
NGR of RMP	NM 5137 5423	NM 5097 5553*
East	151370	150970
North	754230	755530
Tolerance (m)	20	20
Depth (m)	1	1
Method of Sampling	Hand	Hand
Frequency of Sampling	Monthly	Monthly
Local Authority	Argyll & Bute Council	Argyll & Bute Council
Authorised Sampler(s)		
Local Authority Liaison Officer	Fraser Anderson William MacQuarrie Ewan McDougall Allison Hardie	Fraser Anderson William MacQuarrie Ewan McDougall Allison Hardie
Recommended Production Area	The area bounded by lines drawn between NM 5157 5429 and NM 5102 5438 and between NM 5159 5410 and NM 5134 5413 and extending to MHWS	The area bounded by lines drawn from NM 5090 5550 to NM 5105 5550 to NM 5111 5557 to NM 5123 5564 to NM 5115 5572 and extending to MHWS

* As there were no spat settled at this farm, it will be necessary to place bagged shellfish at the RMP for sampling purposes. Bagged shellfish should be in place for at least 2 weeks prior to sampling in order to ensure they are representative of water quality at that location.

III. Report

1. General Description

Tobermory Bay is a partially enclosed, north-easterly facing bay on the east coast of the Isle of Mull, western Scotland. The bay is approximately 2.5 km long and 1 km wide with a maximum depth of 60 m at the mouth of the bay. The bay is partially enclosed by Calve Island, which is separated from the Island from Mull by a narrow tidal channel. The northern end of the bay opens to the Sound of Mull. A regular ferry service operates between Tobermory to Kilchoan on the peninsula of Ardnamurchan on the mainland.

The sanitary survey at Tobermory is being undertaken due to the ranking for the area in a risk matrix. Subsequent to selection, a standard application was received for classification of common mussels at Port na Coite. The new site was situated within the Sound of Mull: Tobermory production area boundaries, and therefore was considered as part of this survey.

Figure 1.1 Location of survey area

2. Fishery

The fishery at Sound of Mull: Tobermory is comprised of two long line mussel (*Mytilus.*sp) farms as listed in Table 2.1 below:

Table 2.1 Area shellfish farms

Production area	Site	SIN	Species
Sound of Mull: Tobermory	Aros Park	AB 258 076 08	Common Mussels
Tobermory: Port na Coite	Port na Coite	AB 624 128 08	Common Mussels

The currently classified production area is described in the 2012/13 classification document as follows: area bounded by lines drawn between NM 5116 5600 and NM 5300 5600 and then to NM 5300 5318. Although not explicity stated in the document, this area then extends westward to MHWS from the boundary line. The nominal RMP is located at NM 5142 5416, which lies within 20 metres of the Aros Park site.

Figure 2.1 shows the relative positions of the mussel farm sites, the Food Standard Agency Scotland designated Production Area and the Crown Estates lease areas.

Three Crown Estate leases fall within this production area: one in the vicinity of the Aros Park, one at Port na Coite, and a third lease in Acarseid Mhor on Calve Island. The lease in Acarseid Mhor did not appear to be in use, although a small marine cage finfish farm was observed in that vicinity from a hill above Port na Coite.

Although Tobermory: Port na Coite has been assigned a separate production area number, it lies within the currently classified area. Separate production area boundaries have not yet been established, and monitoring had not commenced at the time of writing this report.

The area was also previously classified for Pacific oyster production at Port na Coite, however it was declassified for this species in 2010.

At the time of shoreline survey, the Aros Park mussel farm had 2 long lines with rope droppers in place. It is anticipated that harvesting will take place year round.

The Port na Coite site consisted of a single long line. At the time of the shoreline survey there was no stock available for sampling as there had been no spat settlement on the lines. It is anticipated that it will be at least two years before any harvesting can take place, if future spat settlement is successful.

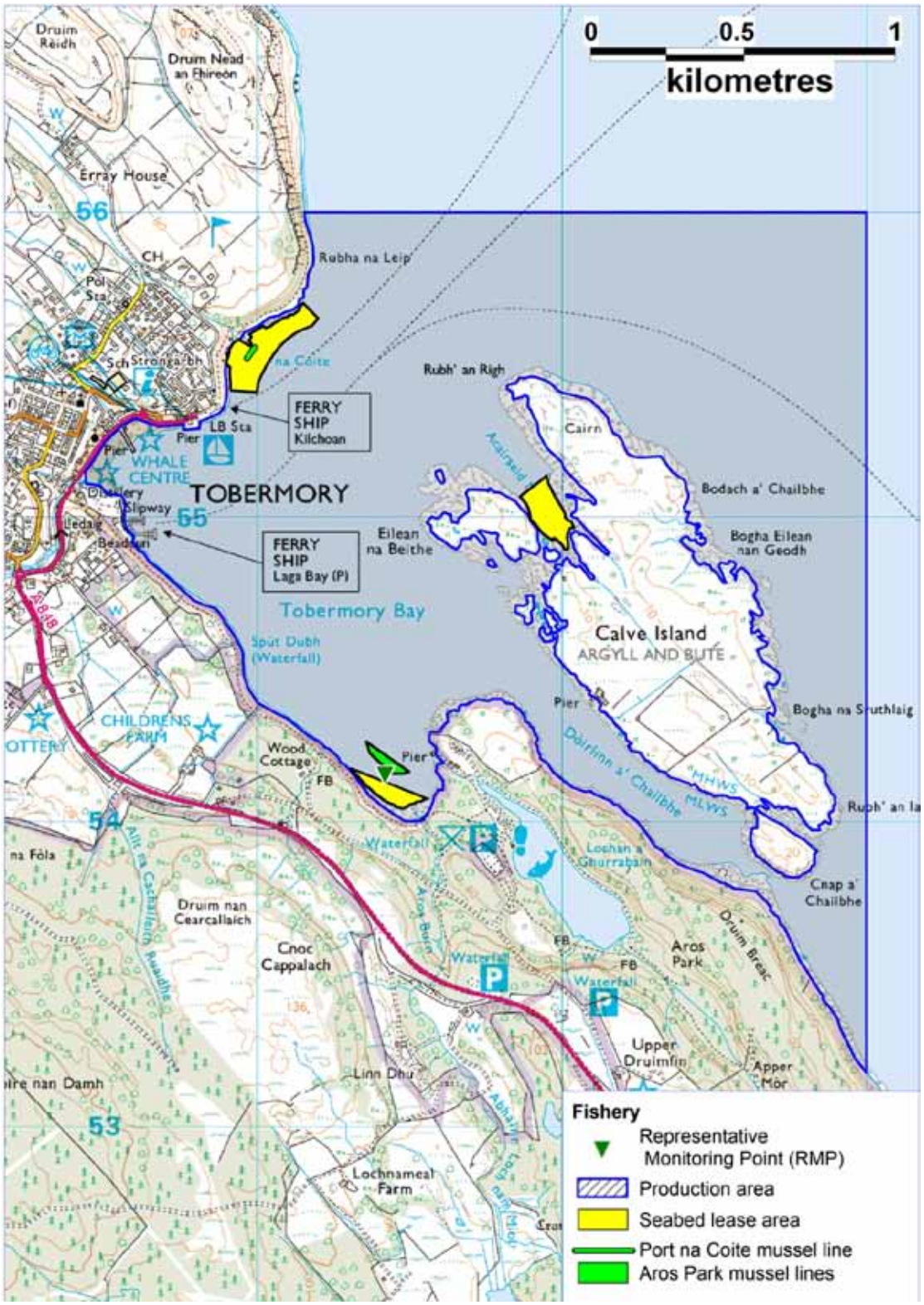

Figure 2.1 Sound of Mull: Tobermory fishery

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Tobermory. The last census was undertaken in 2011. However, this 2011 census data was unavailable at the time of writing this report and therefore data from the 2001 census was used.

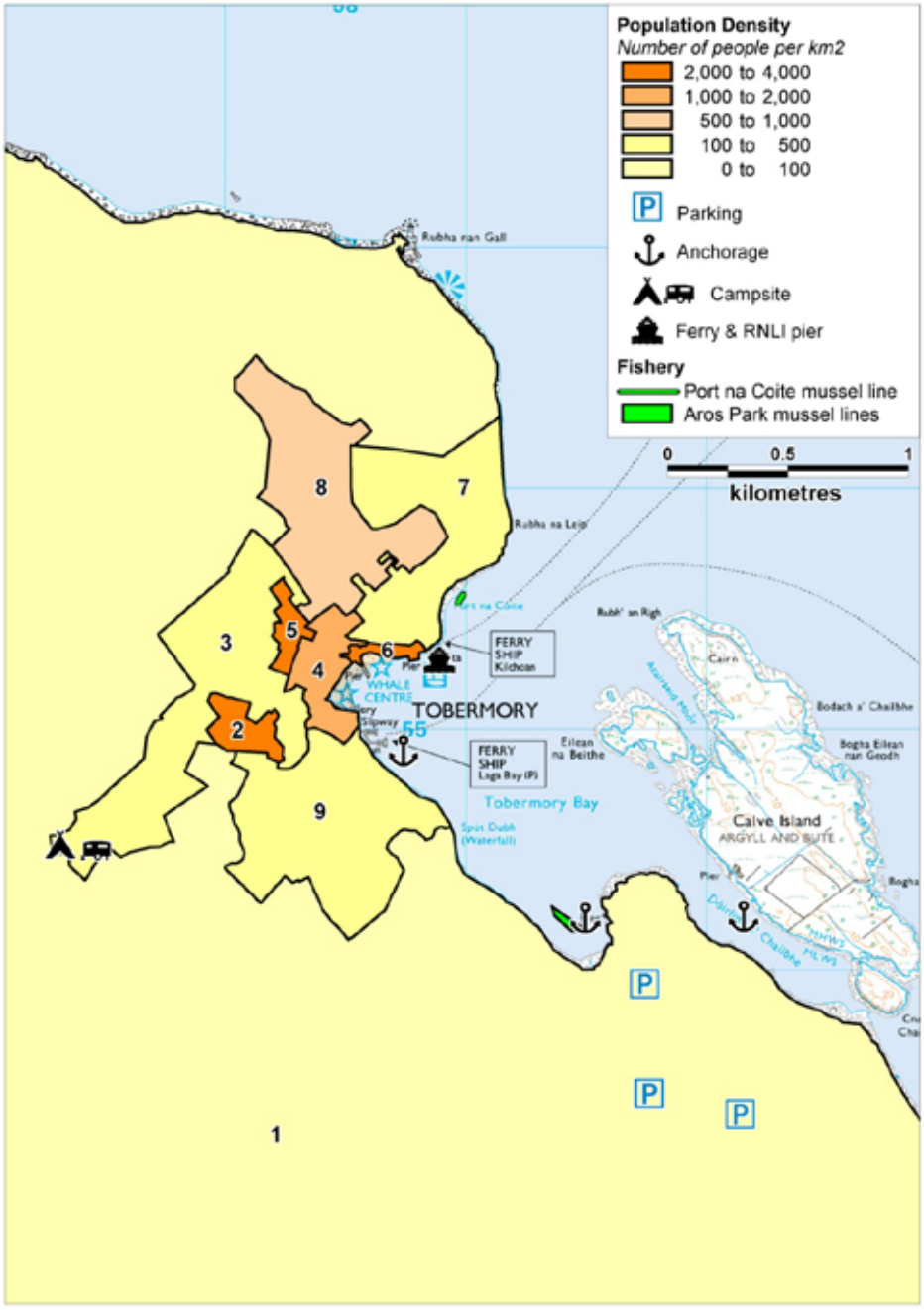

Figure 3.1 Population map of Tobermory

Figure 3.1 shows that population density is high for the census output areas representing the town of Tobermory and very low elsewhere around the bay.

The population figures for the nine output areas around Tobermory Bay area shown in Table 3.1.

Table 3.1 Census output areas: Tobermory

No.	Output area	Population	Area (km^2)	Population density (per km^2)
1	60QD000123	79	51.5	1.5
2	60QD000549	192	0.05	38.40
3	60QD000550	94	0.48	196
4	60QD000551	150	0.09	1666
5	60QD000552	124	0.04	3100
6	60QD000553	54	0.02	2700
7	60QD000554	81	0.36	225
8	60QD000555	199	0.39	510
9	60QD000556	86	0.45	191
Total		1059	53.38	

The large majority of the population for the area is located in the town of Tobermory, on the northwest shore of the bay. An updated estimate for the population of Tobermory only was obtained via the internet from Argyll & Bute Council (http://www.argyll-bute.gov.uk/node/31503). This identified a 2010 estimated population of 970, however did not provide a breakdown by census area.

Tobermory is a popular tourist destination due to its wildlife, landscapes and being the well known filming location of a children's television series. The town has a large number of bed and breakfasts, self catering accommodation, a few hotels and a caravan/campsite is located on the southwest outskirts of town.

The Tobermory marina has a Marine Visitor Centre, shower and toilet facilities and an estimated 73 local moorings and 31 visitor moorings. One pier provides alongside berthing for local fishing boats, the second pier provides alongside berthing for ferries, small ships, charter boats and fishing vessels and the third slipway is occupied by the local RNLI vessel. An anchoring area is provided on the south side of Tobermory harbour in addition to two other anchorages, one of which is located at the south east end of the bay and the other in the narrow channel between Mull and Calve Island. At least seven tour boats and charter vessels operate out of Tobermory harbour. There are no pump out facilities for onboard sewage wastes, and the harbour authority website contains no guidance on avoiding overboard discharges inside the bay.

At least two cruising clubs host visits to Tobermory in July. These are likely to bring a higher than usual number of yachts into the harbour during that time, resulting in an increased risk of faecal contamination to fisheries.

At the southern end of the bay, Aros Park is maintained as a recreational woodland with a car park, footpaths, barbecues and toilets (http://www.tobermory.co.uk/attractions/arospark/aros_park.htm). The main season for visitors is during the summer months when there is an additional passenger ferry service to/from Drimnin, Morven. In addition to the seasonal Drimnin passenger ferry there is a regular car ferry to/from Kilchoan, Ardnamurchan. Buses connect to ferry services elsewhere on the island. A seaplane operates between Glasgow and Tobermory Bay once a week, depending on weather conditions.

Overall, there is likely to be a significant impact to the water quality at the Port na Coite site due to its close proximity to the densely populated settlement of Tobermory and its marina.

There are a small number of dwellings adjacent to the shoreline near the Aros Park mussel farm, many of which may only be seasonally occupied. Aros Park itself will draw seasonal visitors to the area, particularly as it is so accessible. The mussel farm is located within 100 metres of a frequently used anchorage area. Any overboard discharges from boats using the anchorage could have a significant impact on water quality at the site.

Impacts from human sources to the water quality at both sites is likely to be seasonal, peaking during the summer months when visitor numbers are higher.

4. Sewage Discharges

Information on sewage discharges to the area was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Scottish Water identified three community sewage discharges for the area surrounding Tobermory, which are listed in Table 4.1.

Consent No.	Discharge Name	NGR	Discharge Type	Level of Treatment	DWF (m3/d)	PE
CAR/L/1010651	Tobermory WWTW	NM 5102 5536	Continuous	Secondary	802	2447
CAR/L/1010666	Tobermory Glengorm WWPS	NM 5090 5532	Intermittent CSO/EO	6 mm screen	787	-
CAR/L/1019929	Tobermory Ledaig WWPS	NM 5057 5502	Intermittent EO	6 mm screen	-	-

Table 4.1 Sewage discharges identified by Scottish Water

(DWF) Dry weather flow (PE) Population Equivalent, (FE) Final Effluent, (ST) Septic Tank, (WWTW) Wastewater Treatment Works, (CSO) Combined Sewage Overflow, (EO) Emergency Overflow, (WWPS) Wastewater Pumping Station. - Data not supplied or not applicable.

Information was sought on location, type, treatment level, consented flow or population equivalent, spill frequency, and performance. No sanitary or microbiological performance data were provided for the Scottish Water discharges. All three sites discharge directly into Tobermory Bay. Tobermory Waste Water Treatment Works (WWTW) was upgraded in 2007. Sewage is pumped to Tobermory WWTW, where it flows through 6 mm inlet screens, before flowing into the specialised Aero Fac® Facultative Lagoons (http://www.waterprojectsonline.com/case_studies/2007/Scottish%20Tobermory%20STW%202007.pdf. Accessed 27/01/2013). The system incorporates a pumping station (Glengorm WWPS) with storm storage tank and CSO at the ferry slipway that pumps to a booster station which then forwards flows on to the WWTW treatment lagoons. Ledaig WWPS pumps from a local catchment into the sewer network.

Once at the lagoons, effluent undergoes primary and secondary treatment before being discharged into Tobermory Bay (Figure 4.1). In addition to sewage flow from the village of Tobermory, the treatment lagoons receive tankered sludge from a number of other septic tanks on the Isle of Mull. The system is designed to digest the majority of solids, accumulating only a very small residual amount of solid sludge that is not anticipated to require regular removal .

The final effluent from the Tobermory WWTW discharges to an outfall ENE of the ferry pier at the northern end of Tobermory Bay, approximately 170 m south of the recorded location of the mussel line at Port na Coite and 54 m from the SE corner of the associated Crown Estate lease area.

Seasonal differences in flow and local population will vary the impact of contamination from the Tobermory WWTW. The total PE recorded for Tobermory WWTW in 2012 (including tourists) was 1653 (pers. communication, Fiona Garner, Scottish Water).

Tobermory Glengorm and Tobermory Ledaig Waste Water Pumping Stations (WWPS) will discharge intermittently. Scottish Water report significant storage capacity at the Glengorm WWPS, which is designed to limit the predicted number of spills per year to <10. There is no CSO at Ledaig WWPS. The emergency overflows at both sites will only flow during equipment failure. Flows from both the CSO and EOs will result in spills containing screened, untreated sewage. No data were available on the frequency or volume of flows from either Glengorm or Ledaig WWPS. The CSO outfall from Glengorm lies 97 m south of the Crown Estate lease and 215 m south of the mussel line at Port na Coite, and all three outfalls lie between 1 and 1.2 km north of the mussel lines at Aros Park.

Overall it is expected that the shellfishery at Port na Coite will be most at risk from contamination from the discharges associated with the Tobermory sewerage system, due to its close proximity to the discharge outfalls.

SEPA provided information on twenty consented private and community septic discharges, which are detailed in Table 4.2, overleaf.

There were some discrepancies between the consented flow volumes provided by SEPA and Scottish Water. However, the population equivalents are the same. Copies of the relevant CAR licences were requested from SEPA and the flow data specified on them was found to match that provided by Scottish Water.

Three of the sewage discharge consents identified by SEPA relate to privately owned septic tanks that discharge to Tobermory Bay or to watercourses that feed into the Bay. Of these, one relates to filter backwash from a potable water treatment plant. Although this may contain contaminants from faecal sources, it is not expected to contribute high loadings of bacteria to the water environment. The other two discharges relate to very small treatment works that provide a higher level of treatment and therefore would be expected to significantly reduce the loadings of faecal bacteria discharged in the effluents.

Consent number CAR/R/1089416 (Table 4.2, No. 3) discharges to Erray Burn a short distance north of the fishery at Port na Coite. This discharge receives secondary treatment, which would be expected to result in a two-log reduction in faecal coliform content over crude effluent, to approximately 3.3×10^5 organisms per 100ml (see Appendix 2).

Table 4.2 Sewage discharges identified by SEPA

No.	Consent No.	NGR	Discharge Type	Level of Treatment	Flow (m^3/d)	PE	Discharges to
1	CAR/R/1040743	NM 5040 5616	Continuous	Septic Tank	-	15	Soakaway
2	CAR/S/1080993	NM 5054 5592	Continuous	Tertiary	5.58	25	Land
3	CAR/R/1089416	NM 5064 5578	Continuous	Secondary	-	5	Erray Burn
4	CAR/R/1028979	NM 5073 5575	Continuous	Septic Tank	-	31	Soakaway
5	CAR/R/1101704	NM 5077 5573	Continuous	Septic Tank	-	6	Land
6	CAR/L/1010651	NM 5102 5536	Continuous	Secondary	1003	2447	Tobermory Bay
7	CAR/L/1010666	NM 5090 5532	Intermittent	EO	297	-	Tobermory Bay
8	CAR/L/1010666	NM 5090 5532	Intermittent	CSO	297 (802?)	-	Tobermory Bay
9	CAR/L/1019929	NM 5057 5502	Intermittent	EO	-	162	Tobermory Bay
10	CAR/R/1021006	NM 5012 5509	Continuous	Septic Tank	-	7	Soakaway
11	CAR/L/1000457	NM 4979 5509	Unspecified	Other Effluent Potable Water Treatment and Supply	1	-	Allt Torrbeg
12	CAR/R/1098755	NM 4937 5468	Continuous	Tertiary	-	6	Tobermory River
13	CAR/R/1090031	NM 5009 5438	Continuous	Secondary	-	12	Soakaway
14	CAR/R/1024145	NM 5072 5429	Continuous	Septic Tank	-	10	Soakaway
15	CAR/R/1096265	NM 5086 5412	Continuous	Septic Tank	-	5	Soakaway
16	CAR/R/1060865	NM 5174 5403	Continuous	Septic Tank	-	20	Land

Four consented discharges to land or soakaway (Table 4.2, Nos. 1-5) lie along the Erray Burn, and two additional septic tanks were observed along this burn during the shoreline survey. Of these, CAR/R/1028979 (Table 4.2, No. 4) appears to be located very near to the burn (< 10 meters) and therefore may pose a higher risk of contamination to the burn and by extension the fishery at Port na Coite. The total population equivalent for consented discharges along the burn is 82, and the observed presence of other septic tanks in the area suggests that it would be higher if all were considered. Given the close proximity of the reported soakaways to the burn, there is a risk that should the systems fail, contamination would be carried via overland flow to the burn and on to the bay at Port na Coite. A spot water sample taken from Erray Burn on the day of shoreline survey returned a result of 1200 *E. coli CFU*/100 ml, suggesting significant faecal input to the stream (for further discussion, see Section 8).

Several consented discharges are also present on the western shoreline of Tobermory Bay, with one situated in the southwest corner near to the Aros Park mussel fishery (No. 16, Figure 4.1). This has a PE of 20, and discharges to land near Lochan a' Ghurrabain, and may be associated with the public toilets near the Aros Park car park. Three pipes were observed adjacent to the

river, though none were flowing at the time of survey. It is not known for certain whether these would have septic content when in use.

Table 4.3 Discharges and septic tanks observed during the shoreline survey

No.	Date/Time	NGR	Description
1	29/10/2012	NM 4877 5559	Tobermory WWTW. Smell of sewage. No discharge at this location.
2	29/10/2012	NM 4971 5517	Pumping station and 2 storage chambers. Smell of sewage. No discharge at this location.
3	30/10/2012	NM 5066 5577	Septic tank next to house, on opposite side of burn to waypoint.
4	30/10/2012	NM 5071 5570	Metal cover in house garden, possibly of septic tank.
5	30/10/2012	NM 5072 5578	Metal cover in house garden, possibly of septic tank.
6	30/10/2012	NM 5092 5561	Port na Coite Bay. Pipe 10 cm diameter coming from one building, not flowing
7	30/10/2012	NM 5084 5533	Tobermory Glengorm Pumping Station (WWPS), six metal covers on ground next to pumping station building
8	30/10/2012	NM 5045 5509	Unidentified pipe – 10 cm diameter.
9	30/10/2012	NM 5048 5508	Distillery outflow pipe.
10	30/10/2012	NM 5055 5504	Ledaig Pumping Station, South bay, near Visitor Centre.
11	31/10/2012	NM 5164 5417	3 pipes by river, no flow. Two disused buildings

No consents were received for discharges from the distillery, which is reported to have a separate outfall and is not connected to the Tobermory WWTW (http://www.waterprojectsonline.com/case_studies/2007/Scottish%20Tobermory%20STW%202007.pdf). It is not clear whether waste from the distillery visitor centre toilets discharges through this outfall. The outfall related to the distillery was observed during the shoreline survey (No. 9, Table 4.3). This is located nearer to the north end of the bay and the Port na Coite fishery.

No consent information was received for Ledaig landfill site, which is located near the WWTW. According to a SEPA report, it receives domestic and industrial waste, including septic sludge, and leachate is passed through a treatment lagoon and reedbed before discharging to a tributary of the Tobermory River ((http://apps.sepa.org.uk/shellfish/pdf/99.pdf Last edited 01/06/11, Accessed 29/1/2013).

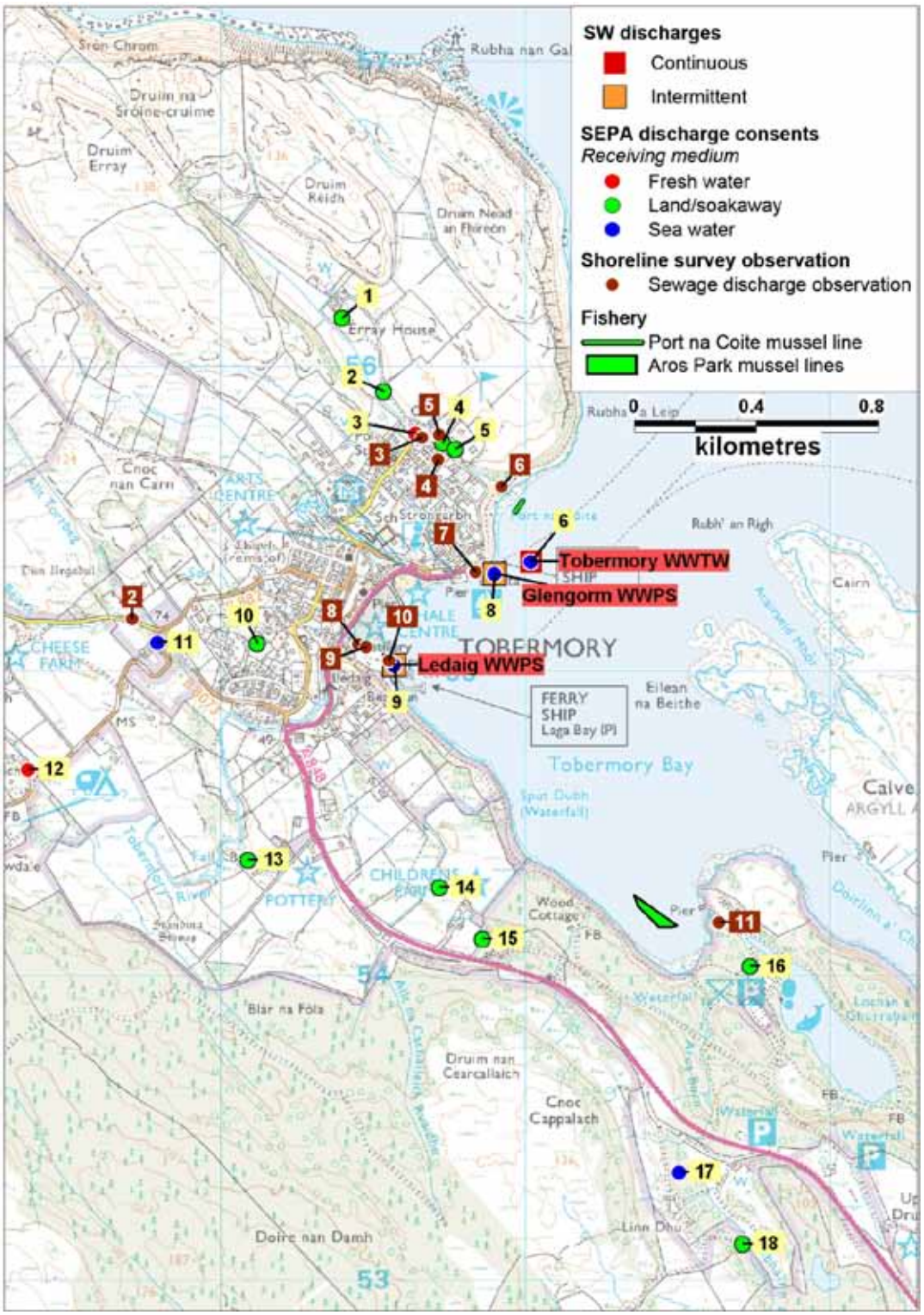

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Figure 4.1 Map of sewage discharges at Tobermory

5. Agriculture

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish production area. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Kilninian and Kilmore parish. Reported livestock populations for the parish in 2012 are listed in Table 5.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 5.1 Livestock numbers in Kilninian and Kilmore parish 2012

	Kilninian and Kilmore	
	308 km^2	
	2012	
	Holdings	Numbers
Pigs	*	*
Poultry	16	442
Cattle	24	1366
Sheep	36	16184
Other horses and ponies	10	48

Kilninian and Kilmore parish covers the northern end of the island, encompassing a land area of over 300 km^2 (shown in the inset of Figure 5.1). Because the livestock census numbers relate to such a large parish area, it is not possible to determine the spatial distribution of the livestock in relation to the Tobermory area or identify how many animals are likely to impact the catchment around Tobermory Bay. Therefore the figures are of little use in assessing the potential impact of livestock contamination to the fishery; however they do give an idea of the total numbers of livestock over the broader area.

Sgriob-ruadh Farm is a dairy farm and cheese factory situated near an unnamed tributary of the Tobermory River to the southwest of Tobermory. According to the Tobermory shellfish growing water report (http://apps.sepa.org.uk/shellfish/pdf/99.pdf Last edited 01/06/11, Accessed 29/1/2013) there have been pollution incidents in past caused by poor management of slurry and dirty yard water. SEPA report one other farm, with the remainder of the land area as managed forestry. Any farm-related runoff would be carried via the Tobermory River to the bay.

A Children's Farm is identified on the OS map south east of the town, however no information was available on the number and type of animals kept there. It is situated next to a drainage ditch near the edge of the woodland north west of the Aros Park mussel farm, therefore water in this ditch may carry any diffuse pollution arising from agricultural activity in this area.

The only significant source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 5) which only relates to the time of the site visit during 29th October to the 31st October 2012 (see Table 5.1). Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been obscured by the terrain. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 5.1.

The shoreline survey identified that there is a variety of livestock (sheep, cattle, ponies and pigs) in the area surrounding Tobermory. In total approximately 48 sheep, 6 cattle, 2 ponies and 3 pigs were observed on the mainland. Some of the livestock observed were in unfenced fields adjacent to burns leading down to the shoreline. Approximately nine sheep were observed grazing on Calve Island from the mainland.

Table 5.2 Livestock observations during shoreline survey

No.	Date	Time	NGR	Livestock observation
1	29/10/2012	14:17	NM 48945 55449	1 cow in unfenced field. 5 sheep in distance
2	29/10/2012	14:31	NM 49709 55172	Approx 10 sheep fenced off in field at the bottom of a burn. Five cattle in unfenced field next to burn. A further 10 sheep in adjacent field unfenced next to burn.
3	30/10/2012	09:43	NM 50854 55543	On Calve Island - Approx 9 sheep grazing
4	31/10/2012	15:30	NM 50375 54323	8 sheep and 2 ponies approx 200 m NNE
5	31/10/2012	15:32	NM 50640 54094	Approx 15 sheep & 3 pigs

There is no local information available for the area surrounding Sound of Mull: Aros concerning the seasonal numbers of livestock, but Argyll and Bute Council advise that an increase in numbers following lambing in the spring would be expected, and numbers would then decrease from autumn as animals are sent to market.

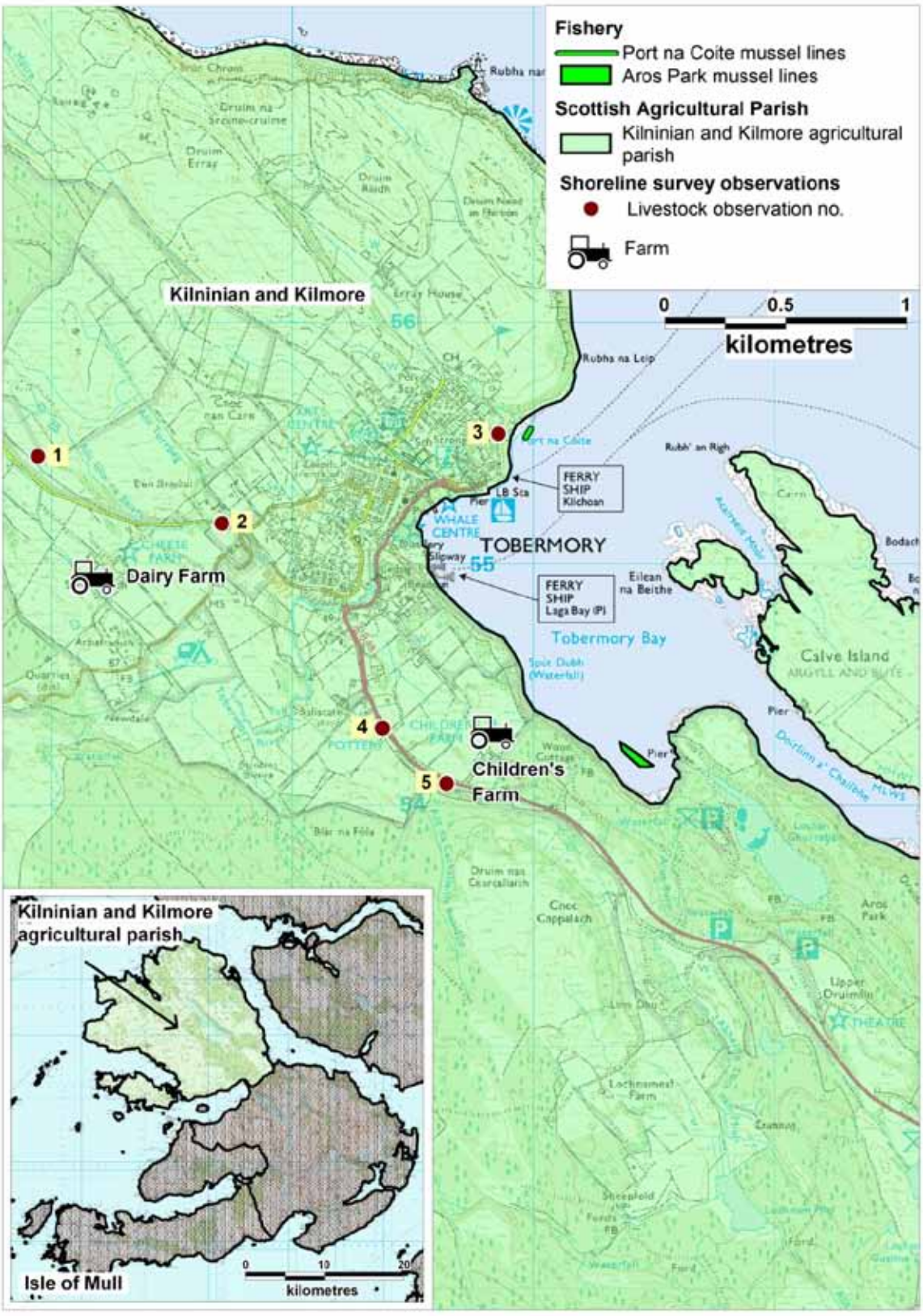

Figure 5.1 Agricultural parish boundary and livestock observations at Tobermory

6. Wildlife

Pinnipeds

Two species of seals are found in the waters surrounding Tobermory. These are the common/harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*).

Calve Island hosts a colony of common seals. These seals use the area as a haul out site, feeding in Tobermory Bay and the surrounding Sound of Mull. At present there is no data on population size of the common seal colony at Calve Island and it is not clear what areas of the island shoreline are used for hauling out. No seals were observed during the shoreline survey.

Cetaceans

Two types of cetaceans are regularly spotted in waters around the Isle of Mull. These are the harbour porpoise (*Phocoena phocoena*) and the common bottlenose dolphin (*Tursiops truncatus*). The Hebridean Whale and Dolphin Trust (HWDT) are based in Tobermory and operate whale and dolphin watching cruises around the island.

The rich waters of the Sound of Mull attract many marine mammals. In the past there have been sightings of marine mammals in Tobermory Bay. However, these mammals are not resident and their impact on the fishery is likely to be minor and sporadic. No cetaceans were observed during the shoreline survey.

Seabirds

Seabird 2000 census data (Mitchell, et al. 2004) was extracted from a 3 km radius around Tobermory Harbour and is presented in Table 6.1.

Table 6.1 Seabird counts within a 3 km radius of Tobermory.

common Name	Species	Count*	Method
European shag	*Phalacrocorax aristotelis*	14	Occupied nests
European herring gull	*Larus argentatus*	1	Occupied nests
common gull	*Larus canus*	3	Occupied nests

*Counts for occupied nests were doubled to reflect the number of individuals.

Tobermory harbour is a relatively busy area, with ferries, pleasure boats and fishing boats mooring along the intertidal shore. This high human usage prevents waterfowl and wading birds utilising this habitat. As a result, these birds are not found near the Port na Coite oyster farm.

Lochan a' Ghurrabain is an enclosed water body in Aros Park that is used by the angling community. It also holds a nesting barge. Waterfowl common to this area include; grey heron, goosander, mallard, merganser, and goldeneye.

Although no population estimates are available for these species, there may be significant numbers as the lochan is stocked with fish for the angling community.

During the shoreline survey gulls were observed in two locations: In the centre of Tobermory town (approximately 20 gulls) and out towards the Tobermory WWTW (no estimate). Gulls are scavengers and likely to be present much of the time around the densely populated Tobermory seafront, where food will be plentiful. Studies have also shown that gulls are commonly found around sewage works (Ferns and Mudge 2000) where they can feed directly off the sewage. No estimates on total number of gulls are available for the Tobermory area, so level of contamination risk from gulls remains largely unknown. Large numbers of gulls were not observed during the shoreline survey, but this only gives a snapshot of presence in the area on those particular survey days.

A single cormorant was observed towards the Port na Coite fishery to the northeast. Cormorants are known to be solitary feeders, with large home ranges (BirdLife International 2012) and are therefore unlikely to pose a significant contamination risk to the shellfisheries.

Deer

Red deer (*Cervus elaphus*) are found throughout the Isle of Mull. During summer months they live at higher elevations, migrating to lower grounds and shorelines during the winter. It is estimated that 6000 red deer live on the Isle of Mull. There is also a much smaller population of the smaller roe deer (*Capreolus capreolus*) (Webwork Mull 2011) and reports of fallow deer residing in woodland (Woodhouse n.d.). There are no specific reports of deer spp. around Tobermory, though anecdotal evidence suggests the thick forest habitat around Aros Park supports a small red deer population. The open fields near to Port na Coite are also said to be ideal grazing pasture for deer spp. Any faecal contamination coming from deer droppings is unlikely to be caused by runoff into streams, however it is not possible to quantify. No deer were observed during the shoreline survey.

Otters

The Eurasian otter (*Lutra lutra*) is common around the Isle of Mull. A new Tobermory Otter Fund has been set up (May 2012) to support future otter conservation work on Mull and Skye. Currently there are no population estimates for otters in Tobermory and only anecdotal reports state otter sightings around Aros Park. However, although otters are likely to be present around the Tobermory shoreline, their faecal contamination is likely to be low. Kruuk and Moorh (1991) showed that up to four adult females were found in a 4.5km range. However it should also be noted that the conservation initiative

for otters may lead to population increases, which will increase their overall impact as a faecal source. No otters were observed during the shoreline survey.

Overall

Species potentially impacting Tobermory fisheries include birds, otters, red and roe deer and seals. There is little information on which to base an assessment of impact, as so little is known about the numbers of animals present and their distribution. Deer and birds are most likely to contribute to faecal contamination levels at Aros Park, whereas gulls and seals may be most likely contributors at Port na Coite.

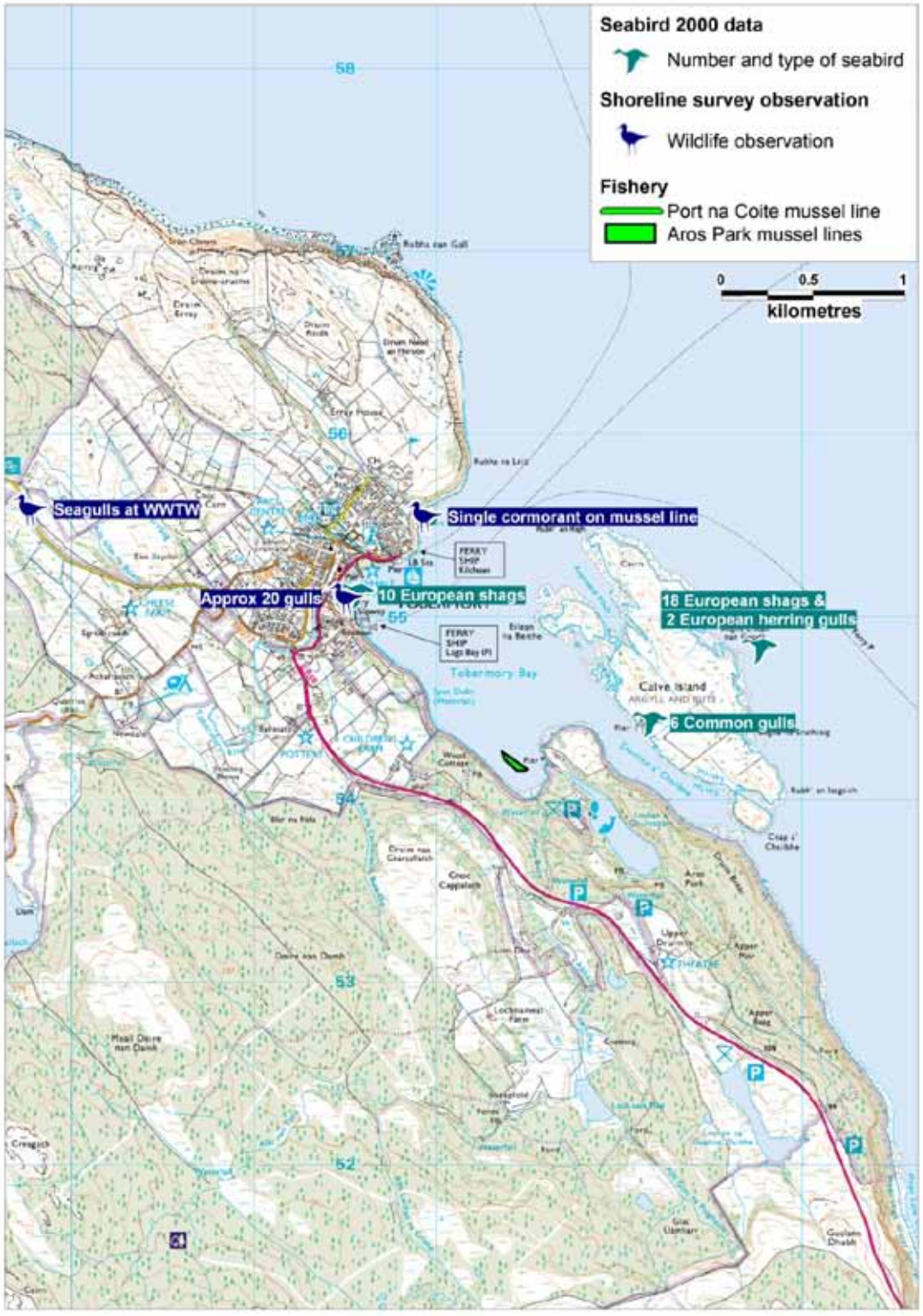

Figure 6.1 Map of wildlife at Tobermory.

7. Land Cover

The Land Cover Map 2007 data for the area is shown in Figure 7.1 below:

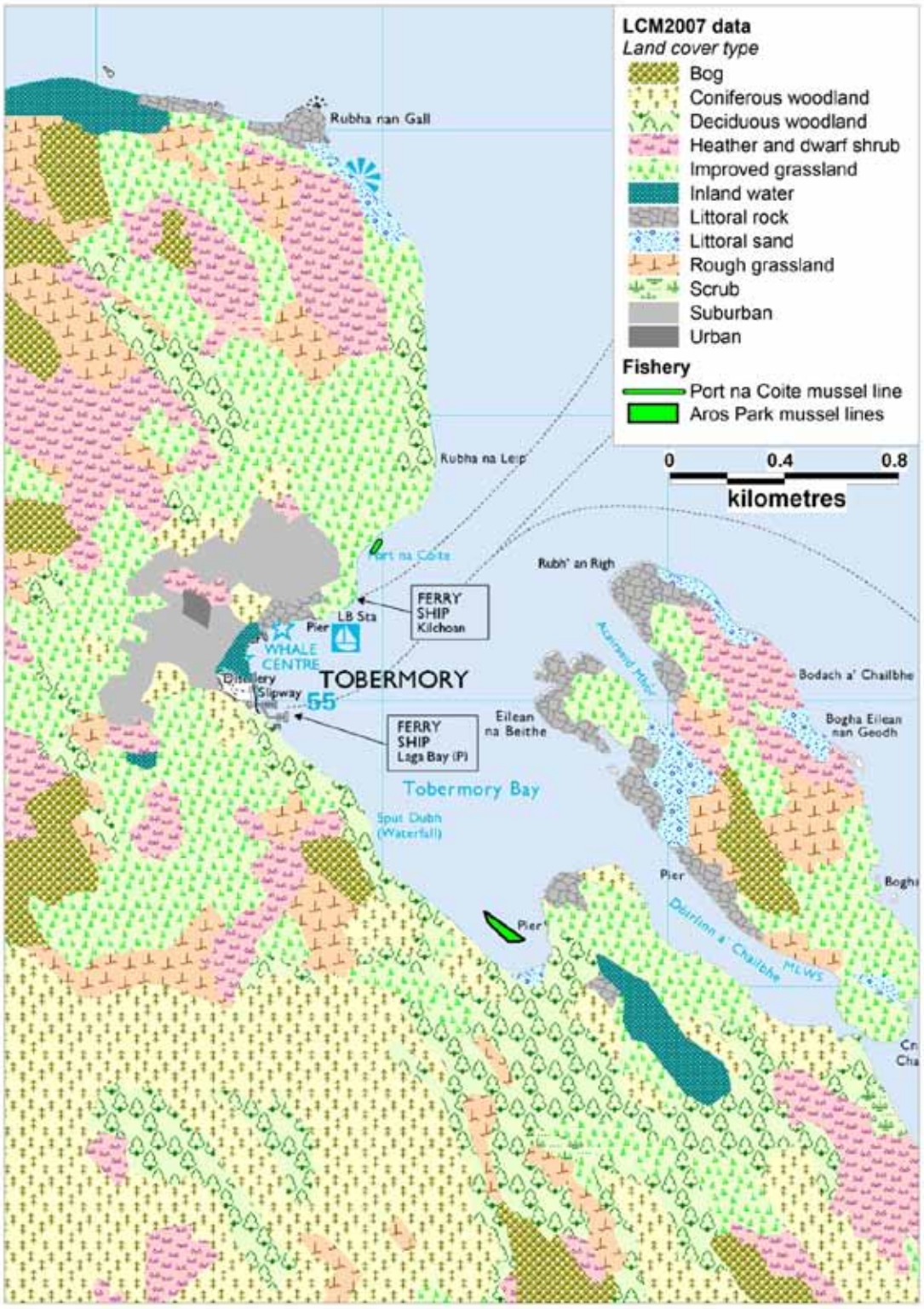

Figure 7.1 LCM2007 land cover data for Sound of Mull:Tobermory

Woodland, improved grassland and heather are the predominant land cover types on the shoreline adjacent to the Tobermory shellfish farms. Tobermory is shown as a suburban and urban area, surrounded by improved grassland and small patches of coniferous and deciduous woodland. The western shoreline of Tobermory Bay is lined with a strip of deciduous woodland and some coniferous woodland. The southern shoreline of Tobermory Bay where the Sound of Mull: Tobermory fishery is located is also improved grassland, deciduous and coniferous woodland. Further inland from the bay are larger areas of bog and heather and dwarf shrub. Calve Island is composed of a mixture of improved grassland, littoral sand, rough grassland, bog and heather and dwarf shrub. The areas classified as inland water north of the slipway at Tobermory and along the shoreline west of the Rubha nan Gall headland are misrepresented by the LCM2007 dataset. The Tobermory inland water areas are likely to be intertidal area adjacent to the town and harbour and the strip on the northern shoreline identifiable by Google Earth as cliffs. Further comparison with satellite imagery and shoreline survey observations identified that areas classed as improved grassland around Aros Park are actually mainly woodland and scrub. Improved grassland to the north of Port na Coite coincides with the location of the Tobermory golf course.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately 1.2 – 2.8×10^9 CFU km-2 hr-1 for urban catchment areas, approximately 8.3×10^8 CFU km-2 hr -1 for areas of improved grassland and approximately 2.5×10^8 CFU km-2 hr-1 for rough grazing (Kay, et al. 2008). The contributions from all land cover types would be expected to increase significantly after rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay, et al. 2008).

The highest potential contribution of contaminated runoff to the Port na Coite shellfish farm is from the suburban/urban area of Tobermory. and the area of improved grassland including the golf course adjacent to the fishery. The potential contribution of contaminated runoff to the Aros Park mussel farm would be highest to the north west of the farm where there is an area of rough grazing. Areas utilised for rough grazing would be expected to contribute significantly to faecal contaminant loading carried in watercourses and overland flow draining the area during rainfall.

8. Watercourses

There are no river gauging stations on rivers or burns discharging to Tobermory Bay. Following the shoreline survey, it was noted that Scottish Hydro operated a Hydro-Electric station on Tobermory River. Due to the structural engineering of this station, no viable information was available on flow velocity for Tobermory River from the station.

The rivers and streams listed in Table 8.1 were recorded during the shoreline survey. These represent the largest freshwater inputs into the survey area. Moderate rain fell throughout most of the shoreline survey, with heavy downpours on the afternoon and evening of the 30th November 2012. No rain fell on the last day of survey (31st November 2012).

Table 8.1 Watercourse loadings for Tobermory

No.	Shoreline observation	NGR	Width (m)	Depth (m)	Flow (m/s)	Flow (m3/d)	*E. coli* (cfu/100ml)	Loading (*E. coli*/day)
1	Erray Burn	NM 5094 5557	1.18	0.08	0.47	3866	1200	$4.6x10^{10}$
2	Stream	NM 5058 5526	0.80	0.10	1.87	12946	4000	$5.2x10^{11}$
3	Tobermory River	NM 5052 5508	3.70	0.35	0.52	58461	1050	$6.1x10^{11}$
4	Outflow from Lochan a' Ghurrabain	NM 5165 5416	1.90	0.47	0.65	49617	< 100*	$< 5.0x10^{10}$
5	Aros Burn	NM 5154 5399	6.10	0.63	1.48	486524	300	$1.5x10^{12}$
6	Stream	NM 5122 5417	0.75	0.17	0.54	5938	< 100*	$< 5.9x10^{9}$
7	Surface drainage	NM 5098 5433	0.60	0.13	0.84	5647	700	$4.0x10^{10}$
8	Sput Dubh	NM 5093 5458	2.00	0.19	0.28	8919	100	$8.9 x10^{9}$
9	Stream	NM 5077 5472	0.07	0.03	1.16	210	< 100*	$< 2.1x10^{8}$
10	Stream	NM 5145 5397	0.27	0.02	0.27	126	< 100*	$< 1.3x10^{8}$
11	Allt Torrbeg	NM 4971 5517	Not measured or sampled					Not determined

*A nominal assumed value of 100 CFU E. coli/100ml was used to calculate loading. NGRs were rounded to 10 m, with full NGRs found in Appendix 1.

Water samples taken from four of the measured watercourses were found to have fewer than 100 *E. coli CFU*/100 ml. Actual *E. coli* concentrations in the samples may have been significantly lower than 100 CFU/100 ml. Loadings were therefore calculated as 'less than' values and should be considered an outside estimate.

Allt Torrbeg (No. 11, Table 8.1) was observed during the shoreline survey (see Table 8.1) but not measured. This small burn was observed to run along part of Tobermory WWTW and was not measured as it is a tributary to the Tobermory River.

Watercourses enter into Tobermory Bay from around the shoreline as shown in Figure 8.1. The first three watercourses listed in Table 8.1 discharge to the north end of the bay, within approximately 500 metres of the Port na Coite mussel line. Water samples taken from these three watercourses all returned results in excess of 1000 *E. coli CFU*/100 ml, higher than any of the other water samples taken during the shoreline survey. These results suggest significant faecal contamination. The combined calculated loading based on these spot samples was 1.2×10^{12} *E. coli* per day. Erray Burn flows into the bay directly north of the Port na Coite mussel farm and would be expected to affect water quality in the vicinity of the farm most directly. An unnamed watercourse discharges adjacent to the pier, and drains open fields in its upper reaches and urban area in its lower half. This watercourse had the highest *E. coli* concentration of all the spot samples taken. Tobermory River discharges to the southwest of Port na Coite, and although the least contaminated of the three, had the highest loading due to its volume. This river has several tributaries receiving treated leachate from Ledaig landfill and runoff from the dairy farm. It then flows through the southern end of the town where Scottish Hydroelectric use it to provide power to Tobermory Distillery, which returns cooling water to the tidal part of the Tobermory River. This would be expected to cause an increase seawater temperatures around the mouth of the river. All of these watercourses would be expected to have a significant impact on water quality in the bay and due to their proximity to Port na Coite are likely to contribute to faecal bacterial loadings in shellfish grown there.

The remaining watercourses discharge to the western and southern shores of the bay, south of the town. Five of these (Nos. 4, 5, 6, 7 and 10 in Table 8.1) discharge within 500 metres of the Aros Park mussel farm; four discharge within 200 metres of the farm. Aros Burn, which discharges to the head of the small bay south of the mussel farm, had the highest calculated loading of all the measured watercourses largely due to its volume. This burn contributes by far the largest volume of fresh water to the bay and it likely to constitute an important source of contamination to the fishery. It flows through an area of woodland, and to the south of the car park and toilets at Aros Park, although it is not clear to what extent these features may contribute to faecal indicator concentrations in the burn. The Aros Park mussel farm is likely to be affected by faecal contamination arising from all of the watercourses at the south end of the bay and the largest impact would be from the Aros Burn. Due to the large amount of freshwater influx, contaminants may be concentrated near the surface and would be expected to affect the south and west of the Aros Park

mussel farm more strongly, although in light of the distances involved the entire farm would be subject to contamination from this source.

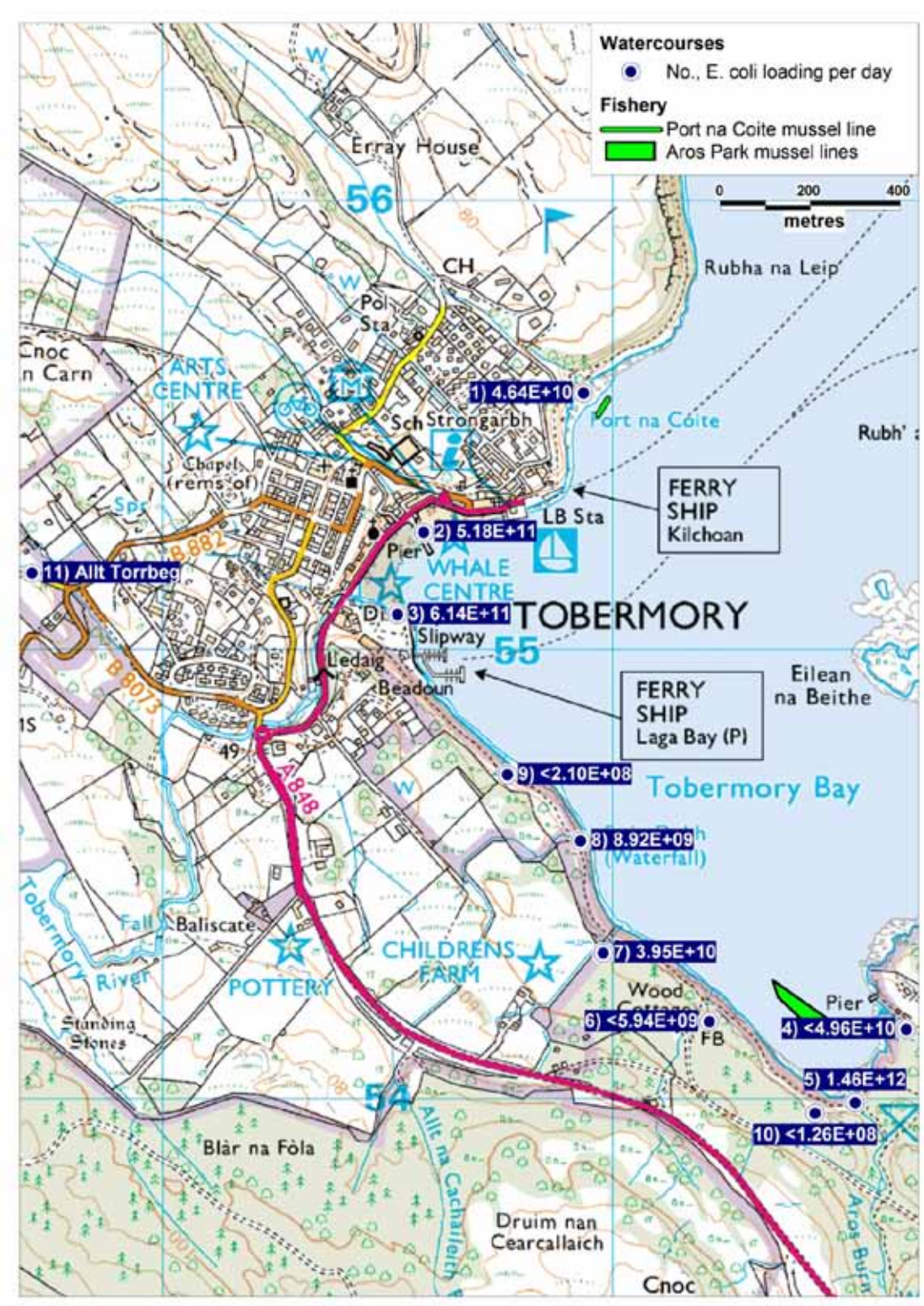

Figure 8.1 Map of river/stream loadings at Tobermory

9. Meteorological data

The nearest weather station for which rainfall data was available is located at Mull: Gruline, situated approximately 14 km to the south of the production area. Rainfall data was available for January 2007 – August 2012. At the time of writing this report rainfall data was only available up until August 2012. The nearest wind station is Tiree, located 53 km west of the production area. Conditions may differ between this station and the fisheries due to the large distances between them. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

Data for these stations was purchased from the Meteorological Office. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas. This section aims to describe the local rain and wind patterns in the context of the bacterial quality of shellfish at Tobermory.

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 and Morgan 2003)). The box and whisker plots in Figures 9.1 and 9.2, present a summary of 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 *.

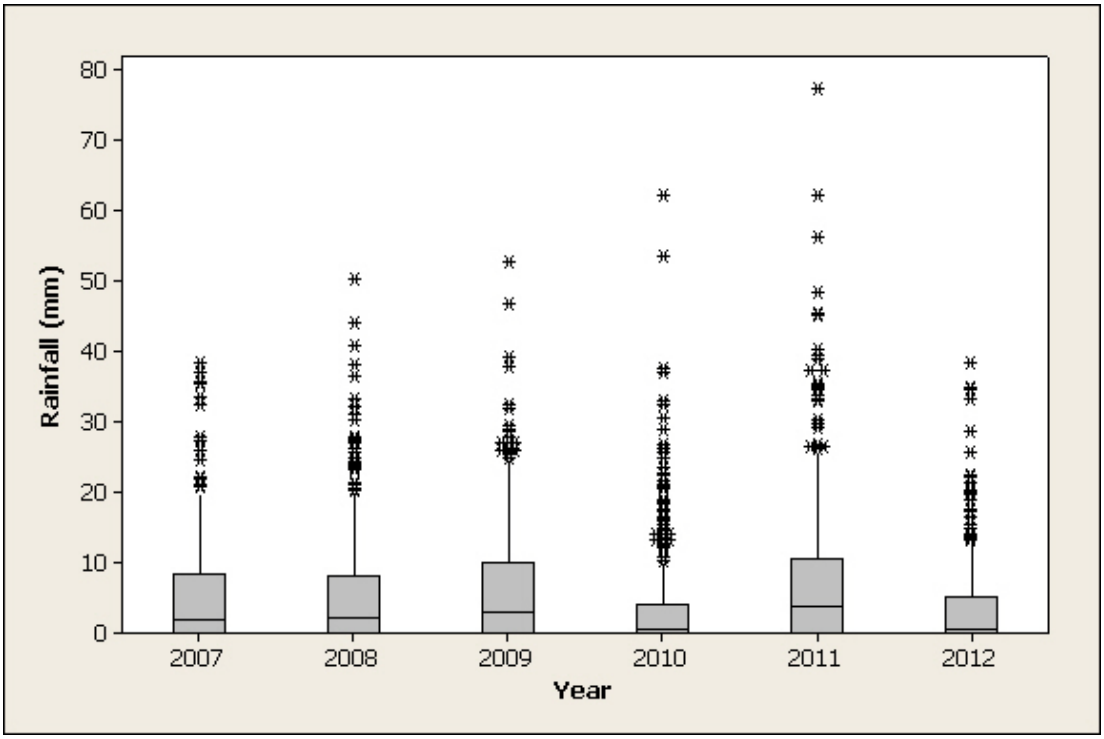

Figure 9.1 Box plot of daily rainfall values by year at Mull: Gruline (2007 – 2012)

Daily rainfall values varied from year to year, with 2010 being the driest year. The wettest year was 2011.

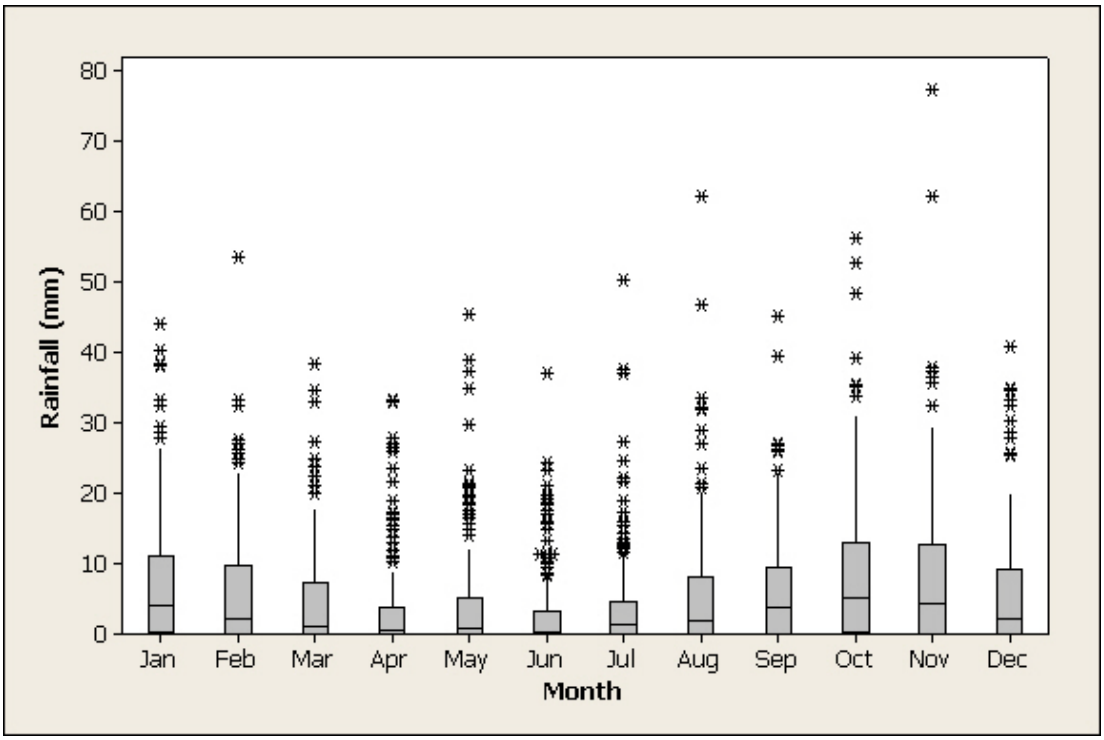

Figure 9.2 Box plot of daily rainfall values by month at Mull: Gruline (2007 – 2012)

Daily rainfall values were higher during the autumn and winter. Rainfall increased from August onward and was highest in October and November. Weather was drier from March to July.

For the period considered here (2007 – 2012) 42% of days received daily rainfall of less than 1 mm and 20% of days received rainfall of over 10 mm.

It is therefore expected that run-off due to rainfall will be higher during the autumn and winter months. However, extreme rainfall events leading to episodes of high runoff can occur in most months and when these occur during generally drier periods in summer and early autumn, they are likely to carry higher loadings of faecal material that has accumulated on pastures when greater numbers of livestock were present.

9.2 Wind

Wind data was collected from Tiree and summarised in seasonal wind roses in Figure 9.3 and annually in Figure 9.4.

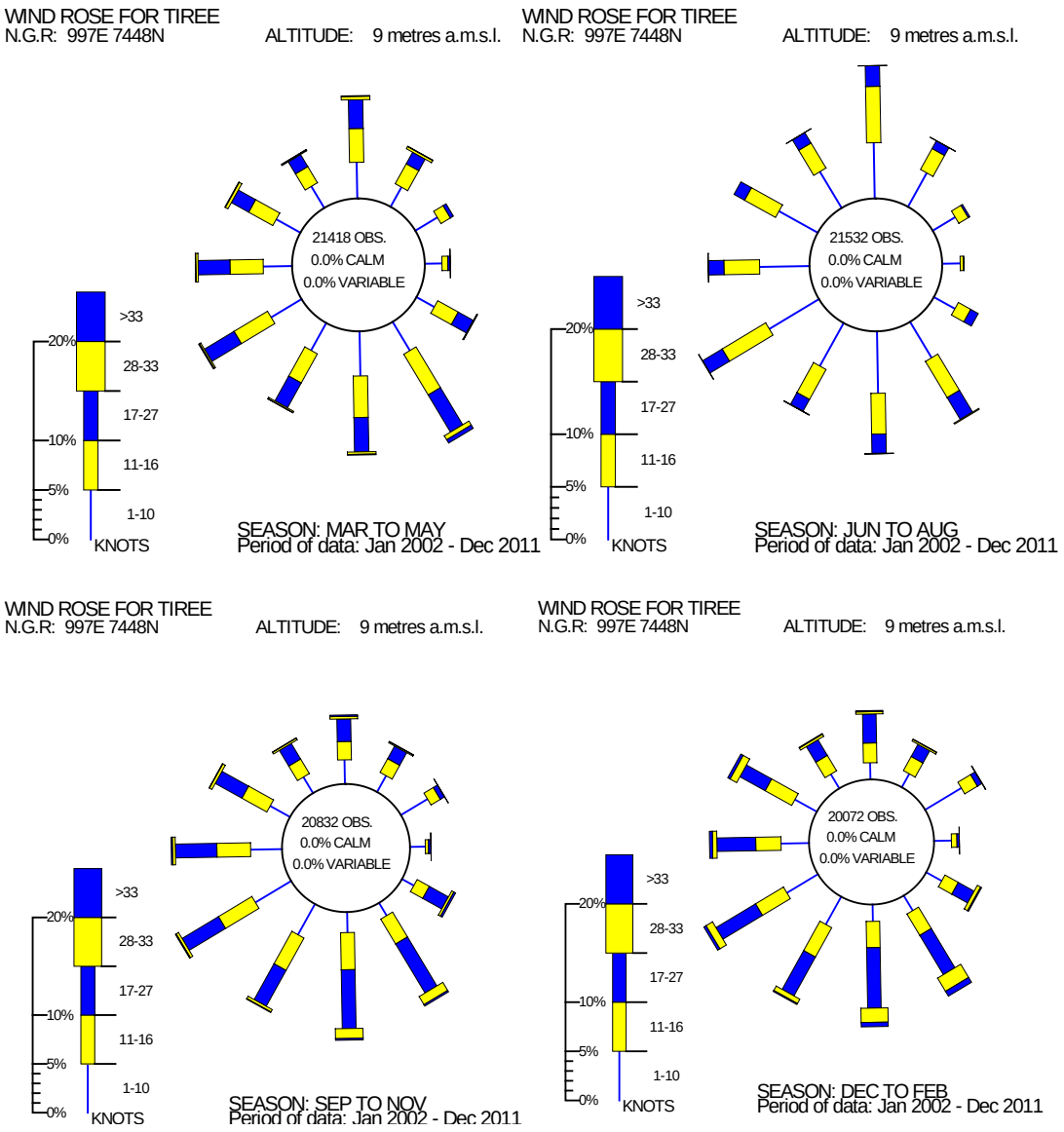

Figure 9.3 Seasonal wind roses for Tiree

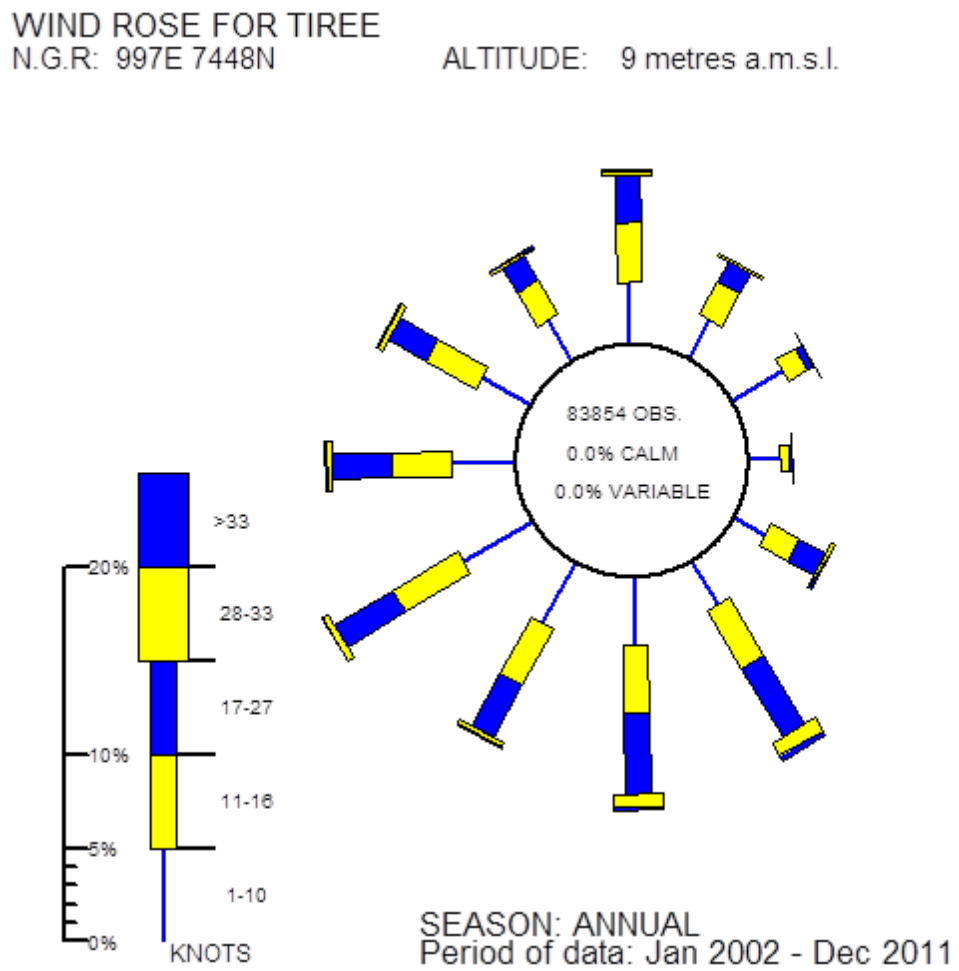

Figure 9.4 Annual wind rose for Tiree

Overall the annual wind rose showed that wind was stronger when coming from the west than the east, and winds from the southerly direction were stronger than those from the north. There was no marked change in wind direction throughout the months; however winds were much stronger in the winter months than in the summer months, when moderate to strong northerly winds were more frequent.

Wind is an important factor in the spread of contamination as it has the ability to 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. Therefore strong winds can significantly alter the pattern of surface currents. Strong winds also have the potential to affect tide height depending on wind direction and local hydrodynamics of the site. A strong wind combined with a spring tide may result in higher than usual tides, which will carry any accumulated faecal matter at and above the normal high water mark into the production area.

10. Classification Information

The area has been classified for mussel production since before 2007. The classification history since 2007 is listed in Table 10.1. Currently the site is classified as seasonal A/B.

Table 10.1 Sound of Mull Tobermory, (common mussels)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	A	A	A	B	B	B	B	B	B	B	B	B
2008	A	A	A	B	B	B	B	B	B	B	A	A
2009	A	A	A	B	B	B	B	B	B	B	A	A
2010	A	A	A	A	A	A	A	B	B	A	A	A
2011	A	A	A	A	A	A	B	B	B	A	A	A
2012	A	A	A	A	A	A	A	A	A	B	B	B
2013	A	A	A									

Until 2012, B classifications tended to be awarded during the summer and autumn months. August and September were classed B from 2007 to 2011. The remainder of the year has tended to be classed A. In 2012 the summer months that had previously always been classed B were awarded A class, and the B months shifted out to October to December.

The area had previously been classified for production of Pacific oysters at the Port na Coite site, but was declassified in 2011. The classification history for oyster is detailed in Table 10.2

Table 10.2 Sound of Mull Tobermory, (Pacific oysters)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	B	B	B	B	B	B	B	B	B	B	B	B
2008	B	B	B	B	B	B	B	B	B	B	B	B
2009	B	B	B	C	C	C	C	C	C	B	B	B
2010	B	B	B	B	B	C	C	C	C	B	B	B
2011	B	B	B									
2012												

Months classified as C tended to occur during the summer.

11. Historical *E. coli* Data

11.1 Validation of results

Results for all samples assigned against Sound of Mull: Tobermory and Port na Coite from the 01/01/2007 to the 10/11/2012 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. No historical results were available for mussels at the Port na Coite site. Pacific oysters were sampled at this site from prior to 2007 until 2010, and therefore these results are presented here. No samples had been submitted for either site in August or September 2012. All *E. coli* results were reported as most probable number (MPN) per 100g of shellfish flesh and intravalvular fluid.

Aros Park common mussel sample results were taken between 6th February 2007 and 26th June 2012. No samples were classified as rejected and were all included in the analysis. All samples arrived within 48 hours of collection and with box temperatures ≤ 8°C. Upon mapping sample INTEGRIN_2008_304 was deleted as the point lay outside the normal sample distribution. Sample CEFAS_12/926 was also omitted as meteorological data was unavailable. Four mussel samples had *E. coli* values of < 20, so were assigned a value of 10 for the purposes of statistical assessment and graphical representation. No *E. coli* levels exceeded 4600/100 g.

Port na Coite Pacific oyster sample results were taken between 2nd June 2007 and 9th July 2010. Two samples were recorded as rejected and were omitted from analysis. The remaining samples were validated, arriving within 48hrs of collection and with box temperatures < 8°C. Geographic distribution of samples was within the production area boundaries and therefore no samples were excluded due to location. Sample INTEGRIN_2008_959 had an *E. coli* value of > 18000, which was reassigned a value of 36000/100 g for the purposes of statistical assessment and graphical representation. Five samples had an *E. coli* level > 4600 MPN/100 g.

A summary of sample results for both locations is presented in Table 11.1.

Table 11.1 Summary of historical sampling results for the two locations at Tobermory.

Sampling summary		
Production area	Sound of Mull: Tobermory	
Site	Aros Park	Port na Coite
Species	common mussels	Pacific oysters
SIN	AB 258 076 08	
Location	NM 514 542	NM 510 555
Total no of samples	46	34
No. 2007	7	8
No. 2008	7	12
No. 2009	8	10
No. 2010	8	4
No. 2011	10	0
No. 2012	5	0
Results Summary		
Minimum	< 20	40
Maximum	2400	36000
Median	110	500
Geometric Mean	91.7	634
90 percentile	594	7250
95 percentile	1135	21000
No. Exceeding 230/100 g	6 (13%)	24 (67%)
No. Exceeding 1000/100 g	2 (4%)	12 (33%)
No. Exceeding 4600/100 g	0	5 (14%)
No. Exceeding 18000/100 g	0	1 (3%)

Results for Pacific oysters at Port na Coite show a higher level of contamination than mussels at Aros Park, even though some studies have shown that mussels concentrate *E. coli* to a greater extent than do Pacific oysters. This suggests that the Port na Coite site is generally more contaminated than the Aros Park site.

11.2 Overall geographical pattern of results

All sampling locations for Pacific oysters at the Port na Coite production area were recorded in relatively close proximity. Highest results were found within the main cluster of sampling locations in the intertidal shoreline north of the mussel line(Figure 11.1). The reported sample locations for this cluster all fell within 10m of NM 5097 5558. The reported locations for seven samples lay outside the main sampling location, with six on the MHW mark southeast of the main cluster. One sample was reported at NM 510 550, which was the nominal RMP at the time and is located to the southeast of the main area of samples.

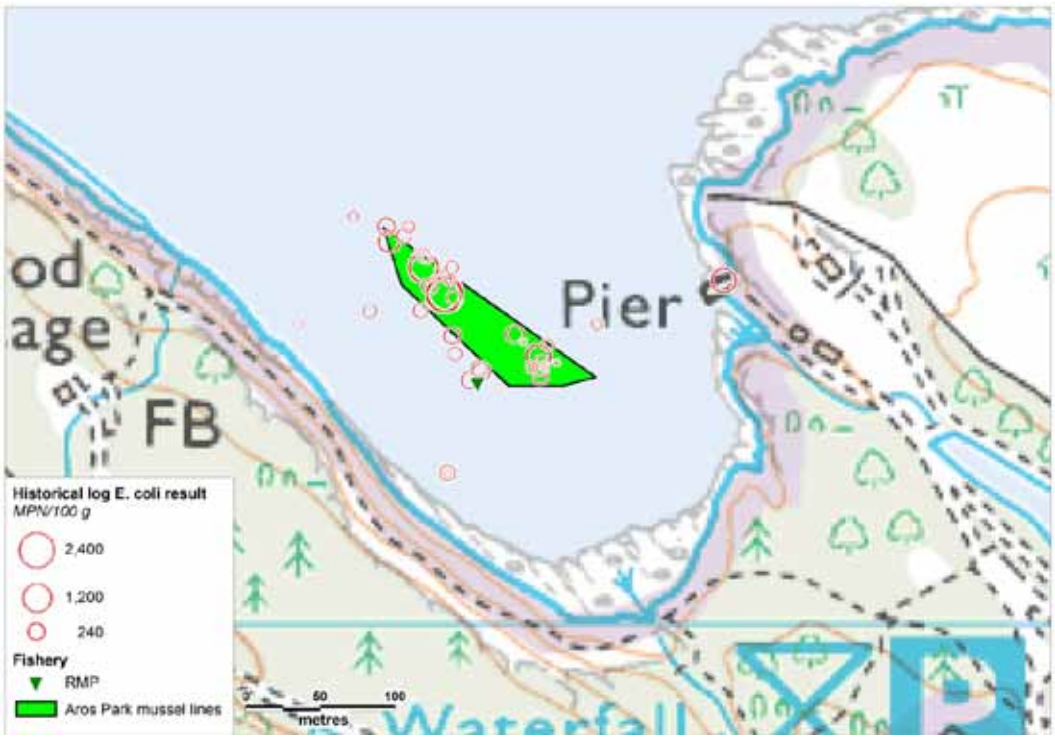

Figure 11.1 Map of reported sampling locations and *E. coli* results for mussels at Tobermory

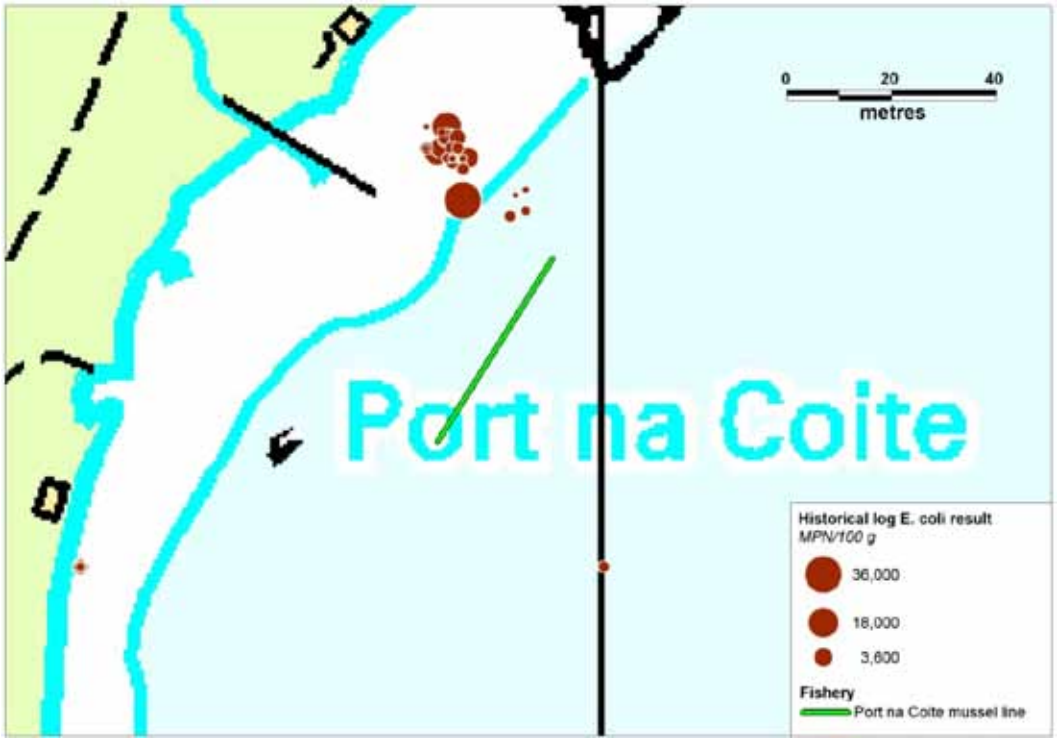

Figure 11.2 Map of reported sampling locations and *E. coli* results for Pacific oysters at Tobermory

1.1.1 Overall temporal pattern of results

Scatterplots of individual *E. coli* results against date are presented for common mussels in Figure 11.3 and Figure 11.4 for Pacific oysters. Both sets of results are fitted with a lowess trend line. Lowess trendlines allows for locally weighted regression scatter plot smoothing. At each point in the dataset an estimated value is fitted 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 lowess line is influenced more by the data close to it (in time) and less by the data further away. The trend line helps to highlight any apparent underlying trends or cycles.

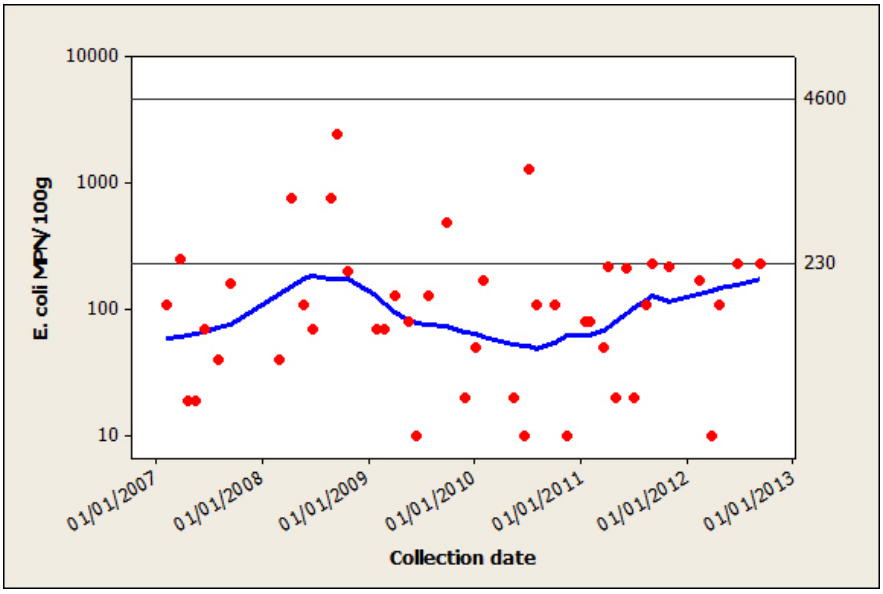

Figure 11.3 Scatterplot of mussel *E. coli* results by date with trend line

The majority of contamination in mussels is low with only a few results greater than 230 *E. coli MPN*/100 g between 2007 and 2010. There were also fewer very low results between 2008 and 2009. Overall, levels of contamination appear relatively stable across assessment years, with results remaining at or below 230 *E. coli MPN*/100 g since mid 2010.

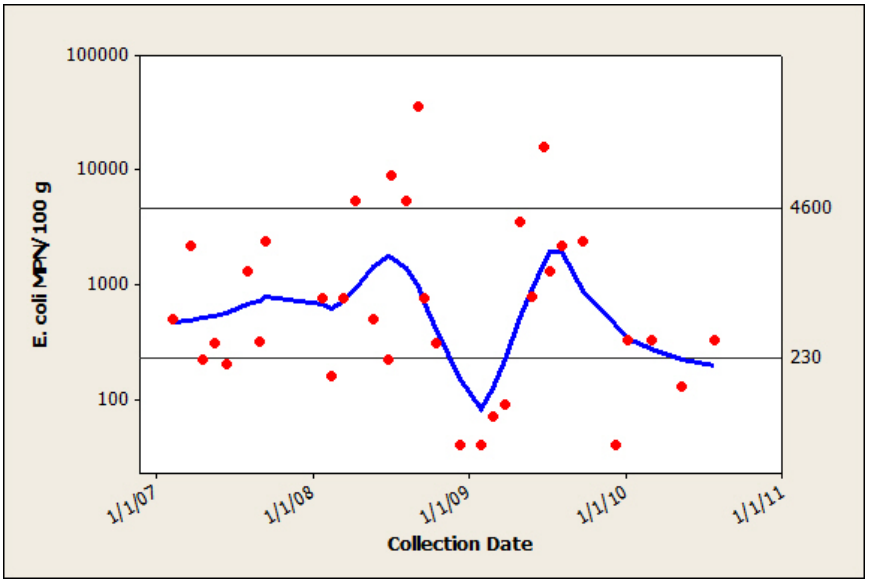

Figure 11.4 Scatterplot of Pacific oyster *E. coli* results by date with trend line

The dip in the trend line in early 2009 was resultant of several low results of between 40 - 70 *E. coli MPN*/100 g. The sharp decline and incline either side of the dip suggests that these levels are unusual. Levels before and after the dip also appear elevated, with the highest recorded results of > 18000 *E. coli MPN*/100 g before the dip. Overall there appears to be high levels of *E. coli* recorded between late 2008 and mid 2009, with the majority of contamination between 230 - 4600 *E. coli MPN*/100 g.

1.1.2 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns in human distribution. All of these can affect levels of microbial contamination, causing seasonal patterns in results. Scatterplots are presented for individual *E. coli* results by month, overlaid with a lowess line to highlight trends.

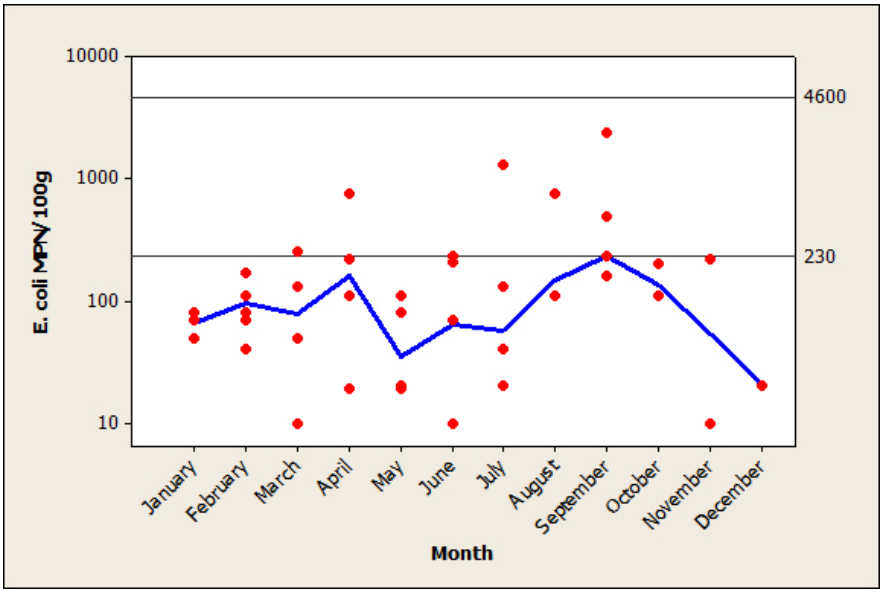

Figure 11.5 Scatterplot of mussel *E. coli* results by month with trend line

Two apparent peaks can be seen in the trend line in common mussel results. These occur in April and September. Results above 1000 *E. coli MPN*/100 g occurred in July and September.

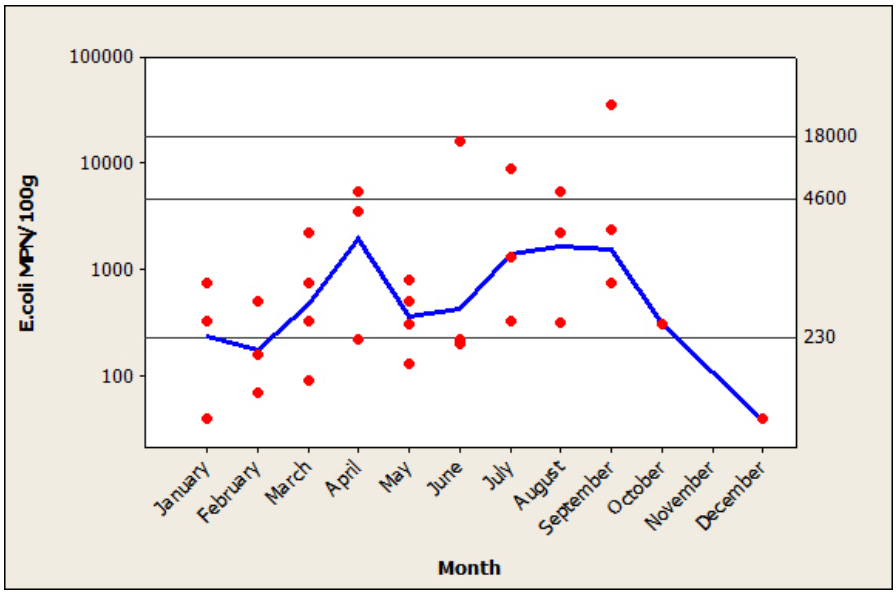

Figure 11.6 Scatterplot of Pacific oyster *E. coli* results by month with trend line

One distinct peak can be observed in results for the Pacific oyster in Figure 11.6, occurring in April. There is another evident peak, with a plateau between July and September. These two peaks correlate with results above 4600 *E. coli MPN*/100 g. The second peak also correlates with much higher results than those in the first peak in April. No results were recorded during November, and only one was recorded in October and December. Overall Pacific oyster *E. coli* results showed a similar seasonality to the common mussels.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Boxplots of results by season are shown in Figure 11.7 for common mussels and Figure 11.8 for Pacific oysters.

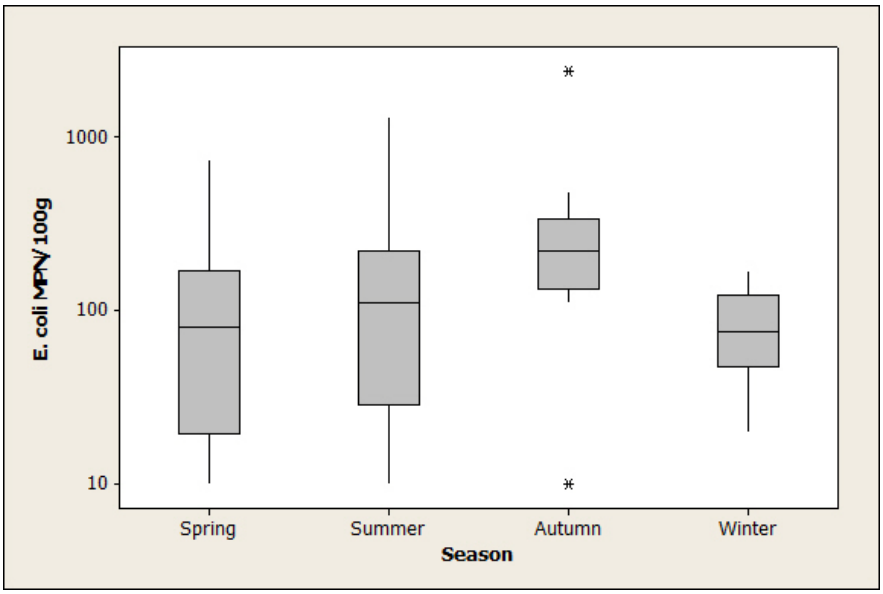

Figure 11.7 Box plot of mussel *E. coli* results by season

No statistically significant difference was found between results by season in mussels (one-way ANOVA, p = 0.218, Appendix 3). A post-ANOVA analysis (Tukey's method) confirmed that the results between seasons did not vary significantly. Fewer low results appear to have occurred in autumn and fewer high results in winter.

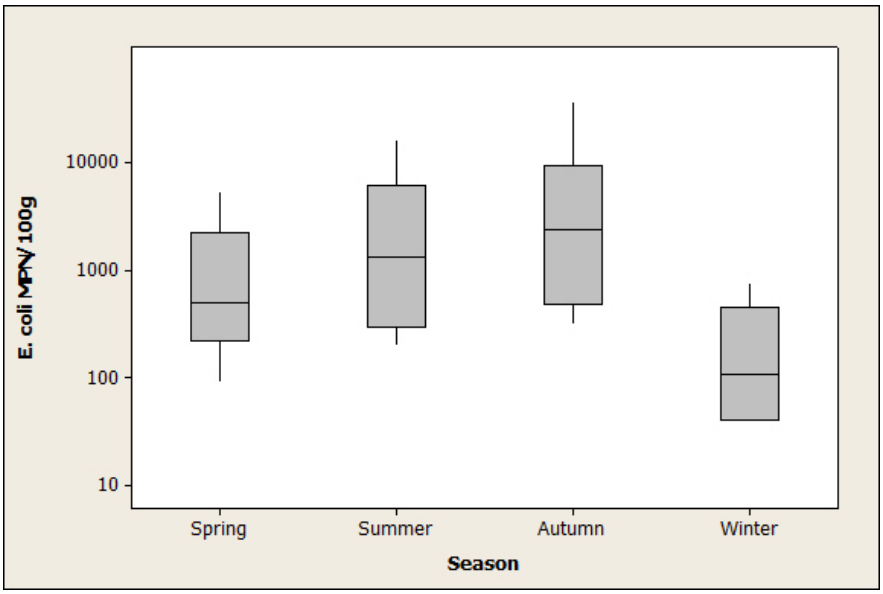

Figure 11.8 Box plot of Pacific oysters *E. coli* results by season

There was a statistically significant difference found between results by season in Pacific oysters. (One-way ANOVA, p = 0.006). A post-ANOVA analysis (Tukey's method) showed that results in the summer and autumn were significantly higher than those in winter.

11.3 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, wind, sunshine and temperature can all influence the flux of faecal contamination into growing waters (Mallin et al, 2001; Lee and 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.

1.1.3 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Gruline, approximately 14 km south of the production area. Rainfall data was purchased from the Meteorological Office for the period of 01/01/2007 – 12/09/2012 (total daily rainfall in mm). Data was extracted from this for common mussels between 06/02/2007-11/09/2012 and for Pacific oysters 06/02/2007-27/07/2010.

1.1.4 Two-day antecedent rainfall

Scatterplots are presented with individual *E. coli* results against total rainfall recorded on the two days prior to sampling.

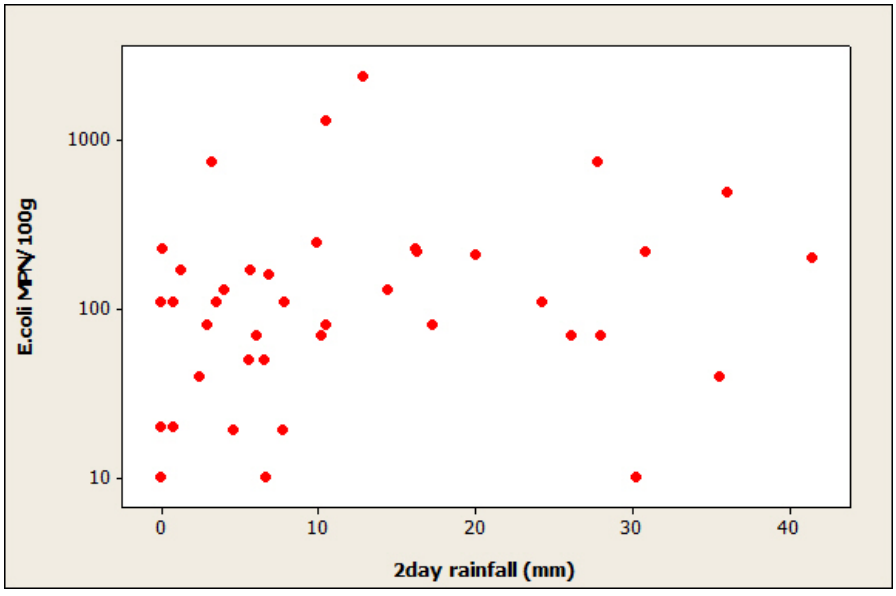

Figure 11.9 Scatterplot of mussel *E. coli* results against 2-day rainfall

A statistically significant correlation was found between the common mussel results and the previous two day rainfall (Spearman's rank correlation r = 0.349, p = 0.020). From Figure 11.9 it is evident that *E. coli* results varied over a wide range (from < 20 to > 1000 *E. coli MPN*/100 g) when rainfall was < 10 mm. However, fewer low results occurred at rainfall levels exceeding 10mm.

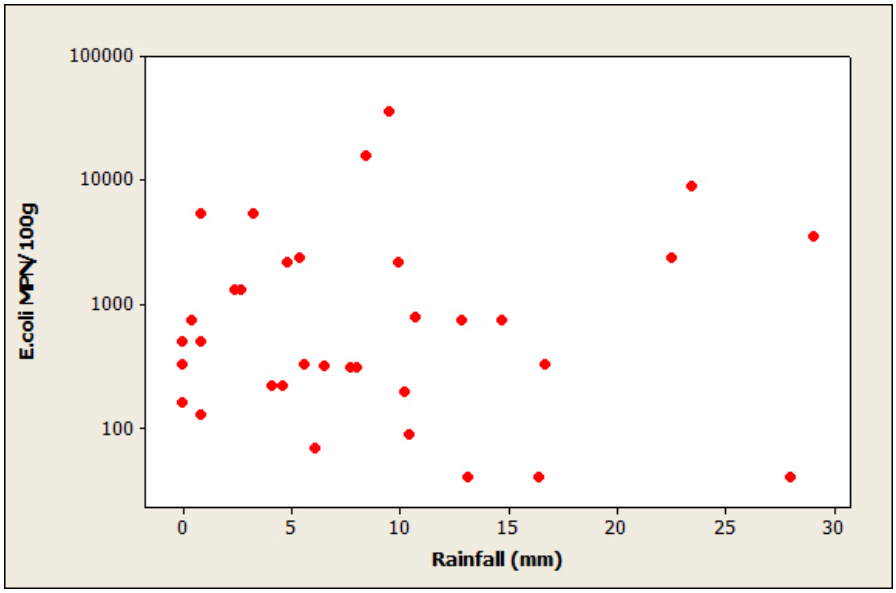

Figure 11.10 Scatterplot of Pacific oyster *E. coli* results against 2-day rainfall

No statistically significant correlation was found between the Pacific oyster results and the previous two day rainfall (Spearman's rank correlation r = 0.002, p = 0.993).

1.1.5 Seven-day antecedent rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different systems. The relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. Scatterplots are presented for *E. coli* results against total rainfall recorded for the seven days prior to sampling.

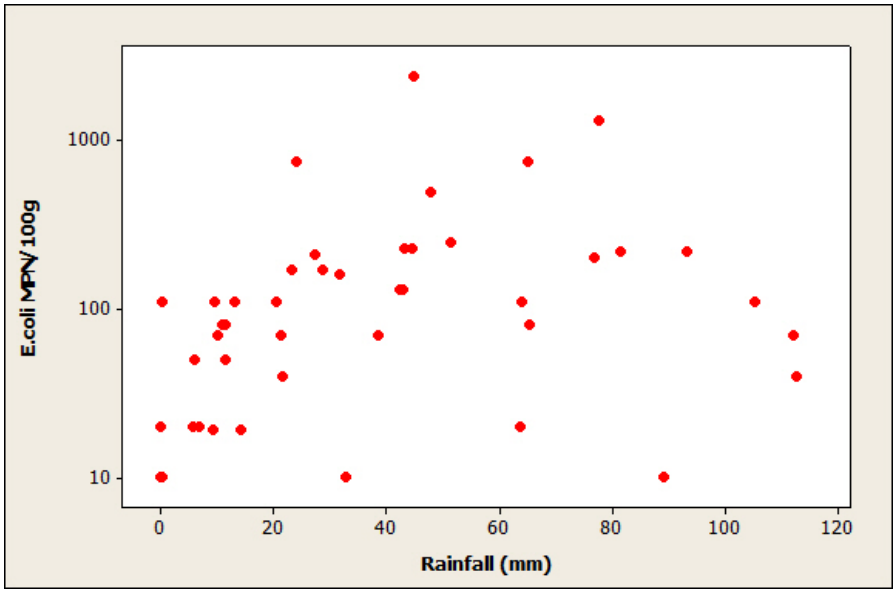

Figure 11.11 Scatterplot of mussel *E. coli* results against 7-day rainfall

A statistically significant correlation was found between the common mussel results and the previous seven day rainfall (Spearman's rank correlation

r = 0.449, p = 0.002). Figure 11.1 suggest that results increased as rainfall increased up to 60 mm. Above 60 mm, results appeared to level off and then decrease.

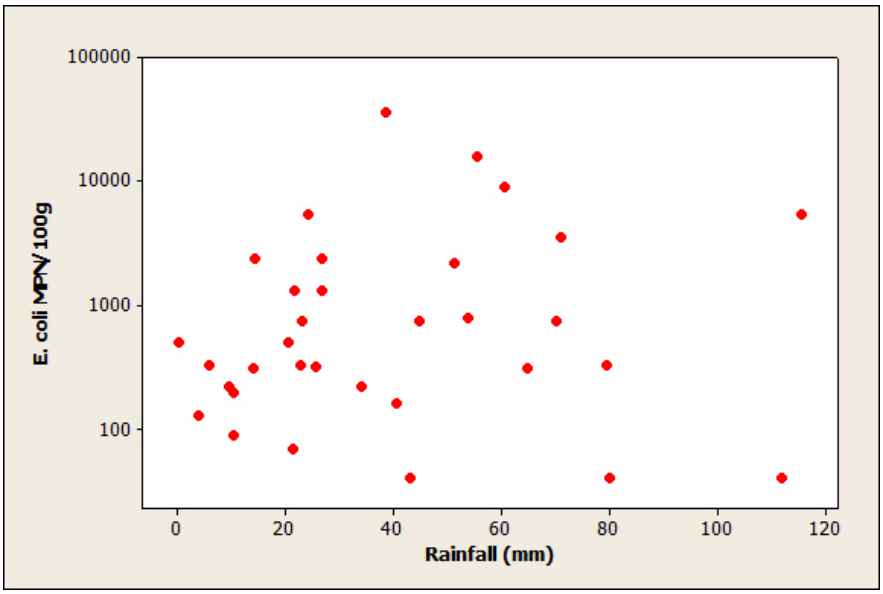

Figure 11.12 Scatterplot of Pacific oyster *E. coli* results against 7-day rainfall

No statistically significant correlation was found between the Pacific oyster results and the previous seven day rainfall (Spearman's rank correlation r = 0.228, p = 0.196).

11.4 Analysis of results by tidal height and state

1.1.6 Results by Tidal Height

Spring tides are large tides that occur fortnightly and are influenced by the state of the lunar cycle. They reach above the mean high water mark and therefore increase circulation and particle transport distances from potential contamination sources on the shoreline. In the figures below, Spring tides occur when the full moon is approximately at 45° and neap tides at about 225°. Polar plots are presented below showing *E. coli* results against the lunar cycle. It should be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but is not taken into account in this section.

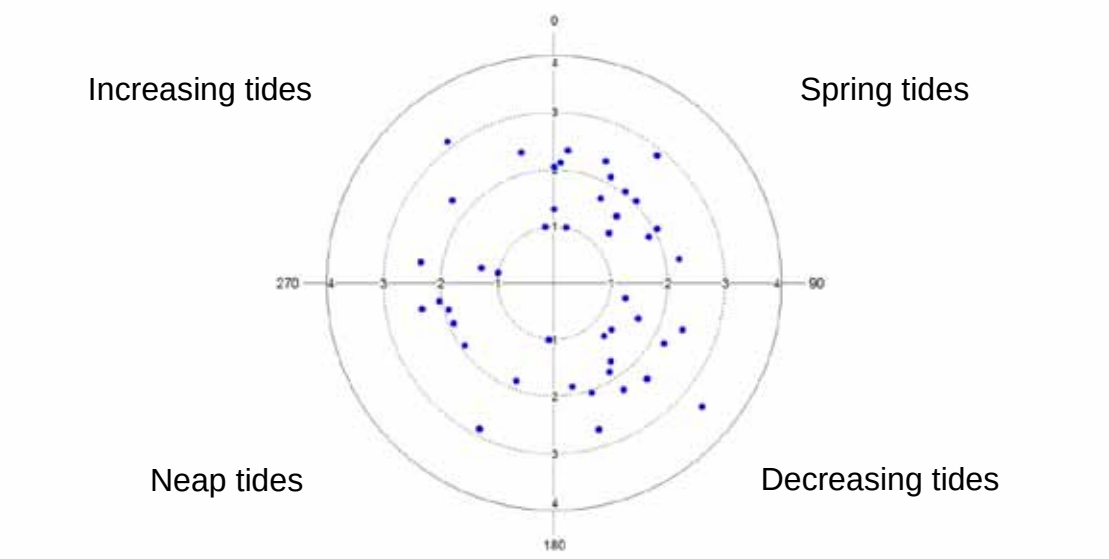

Figure 11.13 Polar plots of mussel log_{10} *E. coli* results on the spring/neap tidal cycle

No statistically significant correlation was found between common mussel log_{10} *E. coli* result and the spring/neap cycle (circular-linear correlation, r = 0.047, p = 0.910).

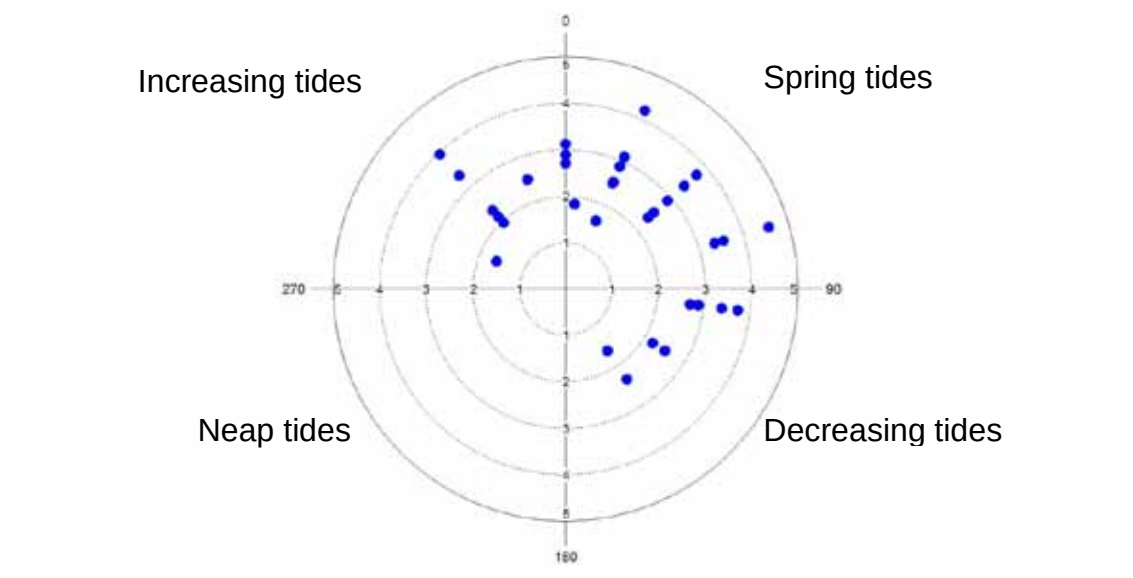

Figure 11.14 Polar plots of Pacific oyster log_{10} *E. coli* results on the spring/neap tidal cycle

A statistically significant correlation was found between Pacific oyster log_{10} *E. coli* result and the spring/neap cycle (circular-linear correlation, r = 0.396, p = 0.007). Sampling effort focused on spring tides when trestles were accessible.

1.1.7 Results by Tidal State

Tidal state (high/low tide) changes the direction and strength of water flow around production areas. Depending on the location of contamination sources, tidal state may cause marked changes in water quality near the vicinity of the farms. Shellfish species response time to *E. coli* levels can vary from within an hour to a few hours. Polar plots present *E. coli* results against lunar tidal cycle. High water is located at 0° and low water at 180°.

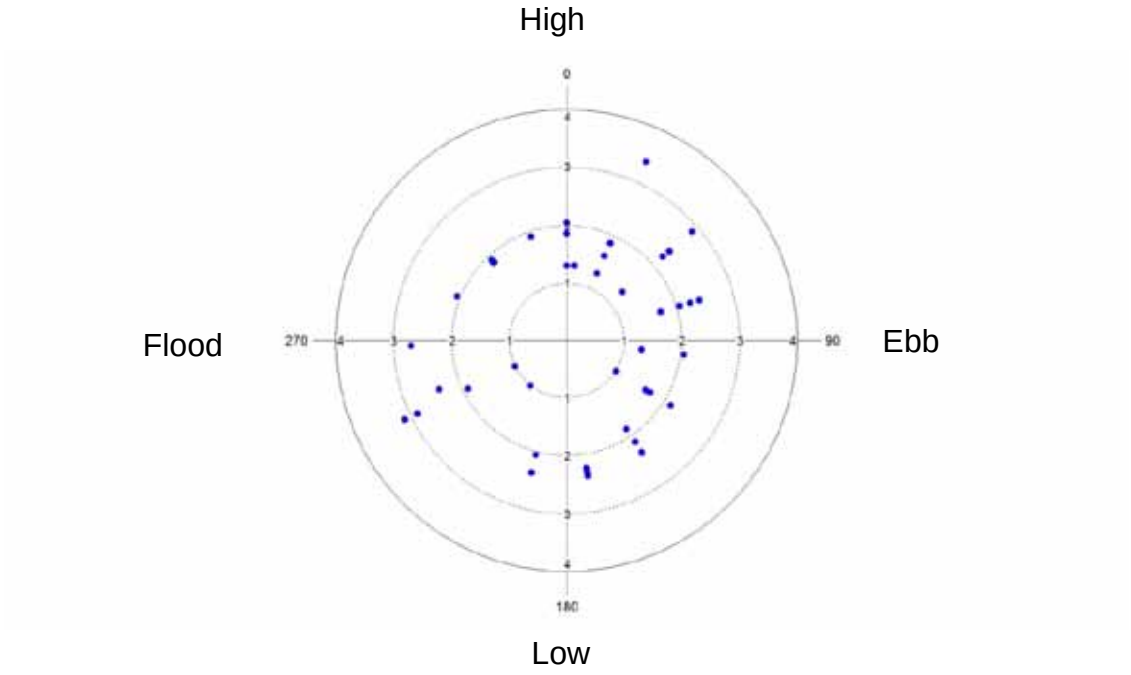

Figure 11.15 Polar plots of mussel $\log_{10}$ *E. coli* results on the high/low tidal cycle

No statistically significant correlation was found between common mussel $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation, r = 0.094, p = 0.688).

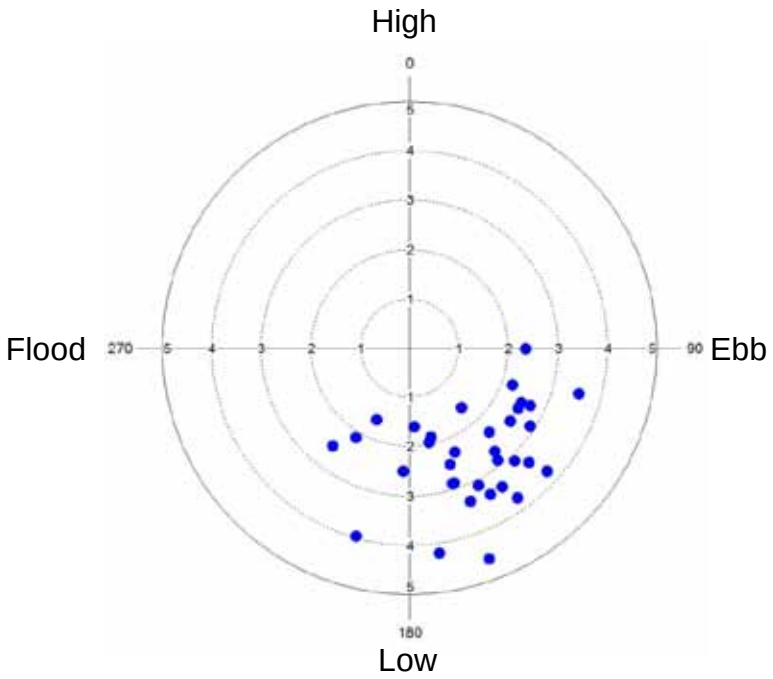

Figure 11.16 Polar plots of Pacific oyster log_{10} *E. coli* results on the high/low tidal cycle

No statistically significant correlation was found between Pacific oyster log_{10} *E. coli* results and the high/low tidal cycle (circular-linear correlation, $r = 0.258$, $p = 0.127$). All samples were taken below the half tide and the majority were sampled on an ebbing tide.

11.5 Analysis of Results by Seawater Temperature

Water temperature can affect survival time of bacteria in seawater (Burkhardt, et al. 2000). It can also affect the feeding and elimination rates in shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. Water temperature is obviously closely related to season. Any correlation between temperatures and *E. coli* levels in shellfish flesh may therefore not be directly attributable to temperature, but to the other factors e.g. seasonal differences in livestock grazing patterns. Scatterplots present *E. coli* results against water temperature.

Water temperatures were recorded against forty three of the sampling occasions for common mussels and thirty three for Pacific oysters.

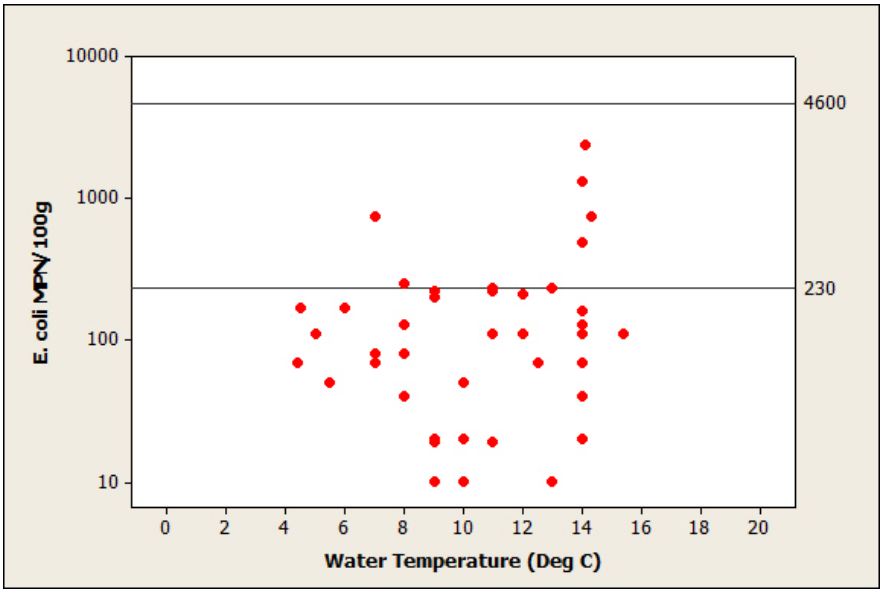

Figure 11.17 Scatterplot of mussel *E. coli* results against seawater temperature

No statistically significant correlation was found between common mussel *E. coli* results and water temperature (Spearman's rank correlation r = 0.166, p = 0.280). A cluster of high results occurred at temperatures of 14.0-14.5°C.

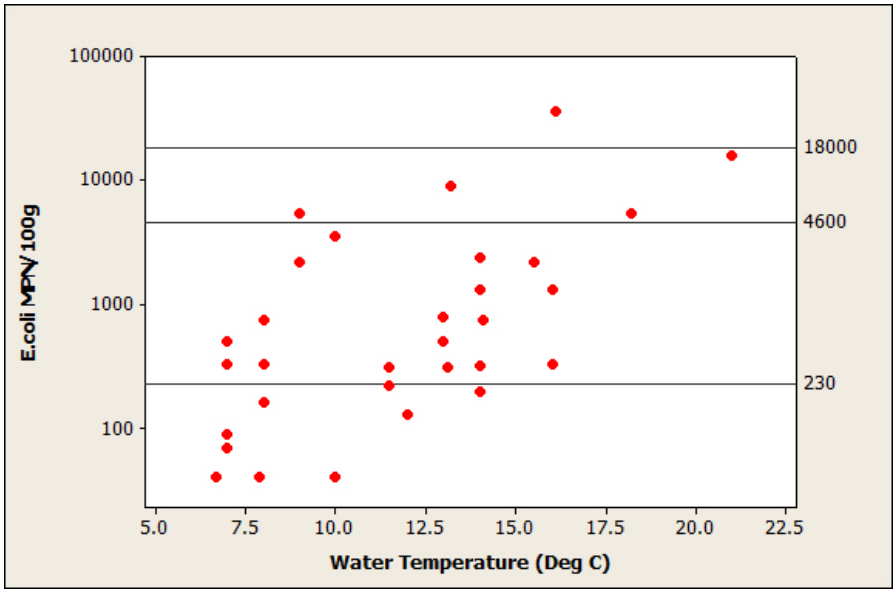

Figure 11.18 Scatterplot of Pacific oyster *E. coli* results against seawater temperature

A statistically significant correlation was found between Pacific oyster *E. coli* results and water temperature (Spearman's rank correlation r = 0.569, p = 0.001). As shown by Figure 11.18 there is a strong positive correlation with increasing water temperature and increasing *E. coli* results. Results of > 230 *E. coli MPN*/100 g were found to occur at all recorded water temperatures. However, no results < 230 *E. coli* /100 g were associated with temperatures greater than 15°C.

11.6 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater-borne contamination at a site. Scatter plots are presented of *E. coli* results against salinity.

Water salinity was recorded against 41 of the sampling occasions for common mussels and for 33 Pacific oysters.

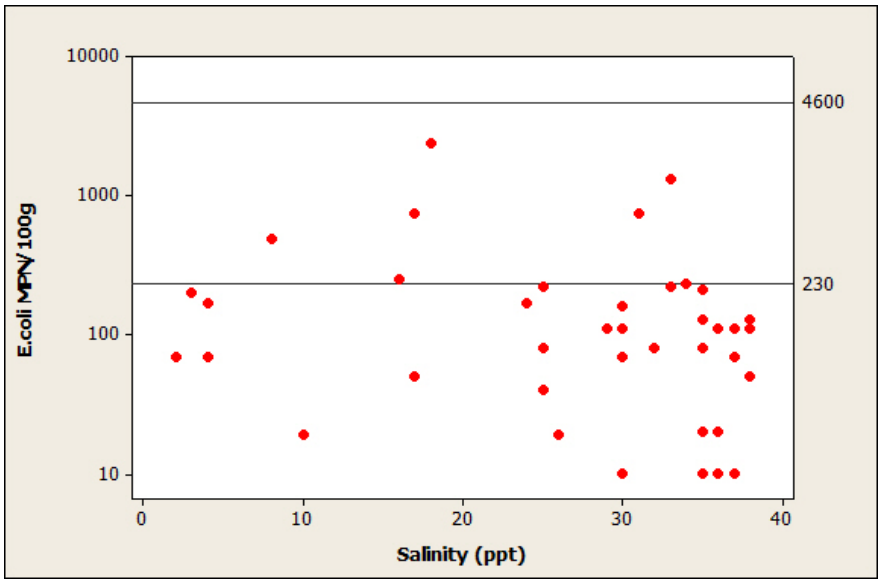

Figure 11.19 Scatterplot of mussel *E. coli* results against salinity

No statistically significant correlation was found between common mussel *E. coli* results and salinity (Spearman's rank correlation r = -0.292, p = 0.064). Figure 11.19 shows that samples were taken under a wide range of reported salinities. Fewer very low results were found at salinities below 20ppt.

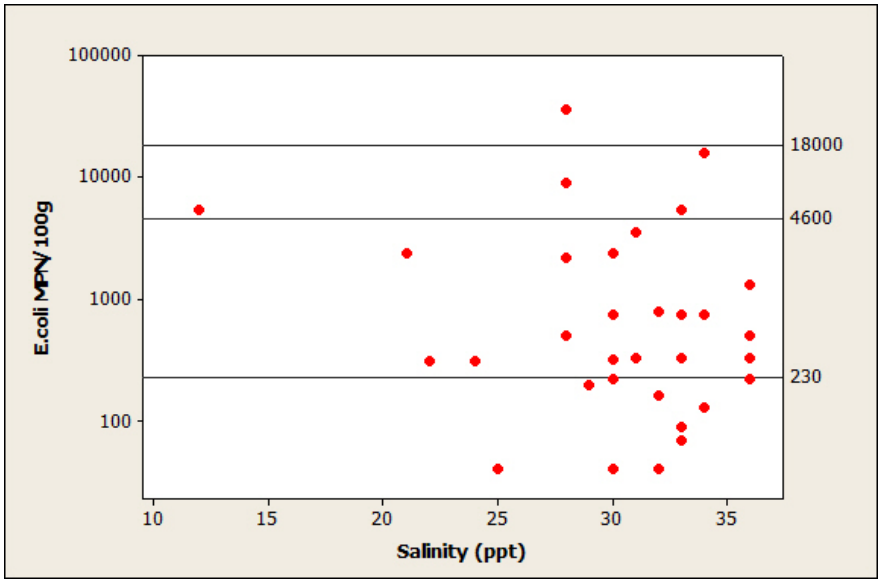

Figure 11.20 Scatterplot of Pacific oyster *E. coli* results against seawater salinity

No statistically significant correlation was found between Pacific oyster *E. coli* results and salinity (Spearman's rank correlation r = -0.145, p = 0.421). The majority of samples were taken at salinity values of ≥30 ppt.

11.7 Evaluation of results over 230 *E. coli MPN*/100 g

In the common mussel samples, five had results > 230 *E. coli MPN*/100 g. These are presented in Table 11.2.

Table 11.2 Historic common mussel *E. coli* sampling results > 230 *E. coli MPN*/100 g

Collection Date	*E. coli* (MPN/100 g)	Location	2 Day Rainfall (mm)	7 Day Rainfall (mm)	Water Temp (°C)	Salinity (ppt)	Tidal State (high/low)	Tidal State (spring/neap)
22/03/2007	250	NM 514 541	9.9	51.4	8	16	Ebb	Spring
26/08/2008	750	NM 5159 5423	27.8	65.1	14.3	17	Flood	Spring
16/09/2008	2400	NM 5140 5422	12.8	44.8	14.1	18	Ebb	Spring
29/09/2009	490	NM 5136 5425	36	48	14	8	Ebb	Spring
06/07/2010	1300	NM 5138 5424	10.5	77.6	14	33	Flood	Neap

Samples were collected in March, July, August and September from 2007 - 2010. High results occurred across a variety of rainfall, salinity and temperature readings. Four of the samples were taken during spring tides, with three of these on the ebb tide.

In the Pacific oyster samples, the majority of results were > 230 *E. coli MPN*/100 g. Table 11.3 therefore considers samples > 4600 *E. coli MPN*/100 g.

Table 11.3 Historic Pacific oyster *E. coli* sampling results > 4600 *E. coli MPN*/100 g

Collection Date	*E. coli* (MPN/ 100 g)	Location	2 Day Rainfall (mm)	7 Day Rainfall (mm)	Water Temp (°C)	Salinity (ppt)	Tidal State (high/low)	Tidal State (spring/neap)
08/04/2008	5400	NM 5097 5558	3.2	24.1	9	33	Ebb	Spring
01/07/2008	9100	NM 5097 5558	23.4	60.5	13	28	Flood	Neap
05/08/2008	5400	NM 5097 5558	0.8	115.5	18	12	Ebb	Spring
02/09/2008	36000	NM 5097 5557	9.5	38.7	16	28	Ebb	Spring
23/06/2009	16000	NM 5097 5558	8.4	55.6	21	34	Flood	Spring

Four out of the five samples with *E. coli* results > 4600 MPN/100 g were recorded in 2008. One sample was taken in April, and the remainder spread across the summer and early autumn months. The 2009 sample was also taken in summer. Most samples were taken during spring tides, however

sampling effort was concentrated on this tidal state due to access restrictions. Rainfall, temperature and salinity varied greatly, with no discernable pattern

11.8 Summary and Conclusions

1.1.8 Aros Park mussels

The majority of the sampling locations had been reported to the northwest of the RMP. The nominal RMP lies toward the southeast end and within 20 m of the mussel farm location recorded during the shoreline survey. Samples with the highest *E. coli* results were taken toward the northwest end of the mussel farm.

Over the review period for common mussels 13% of samples yielded results > 230 *E. coli MPN*/100 g, and no samples results exceeded 4600 MPN/100 g. The samples were predominantly sampled across the year, though fewer were recorded during December. There was no seasonal difference in *E. coli* results. No statistically significant difference was found between water temperature or salinity and *E. coli* results. A significant correlation was found between two and seven day rainfall and *E. coli* results. No significant correlation was found between tidal height or tidal state and *E. coli* results.

Overall, monitoring results suggest that levels of contamination may be higher toward the northwest end of the mussel farm. Wide variation in sample locations suggests that it may be necessary to place a sampling bag at the RMP to ensure tolerances can be met. Correlation with rainfall prior to sampling suggests that rainfall-dependent sources are an important driver of contamination levels at this site. Although there was no statistically significant association between seawater salinity and results, the graph showed fewer low results and the majority of high results coincided with recorded salinities of less than 20 ppt. This seems to further indicate that freshwater-borne sources of faecal contamination predominate at this site.

1.1.9 Port na Coite Pacific oysters

All but two of the reported sampling locations were in close proximity to one another. One of the locations related to the nominal RMP in use when the oyster fishery was active, which did not correspond with the location of the majority of samples.

The majority (67%) of Pacific oyster samples yielded results exceeding 230 *E. coli MPN*/100 g. Samples that exceeded 4600 *E. coli MPN*/100 g were also relatively common at 14%. The significant difference found between sampling seasons is likely to be resultant of markedly fewer samples taken in winter, and is unlikely to reflect the *E. coli* results. There was a significant correlation found between water temperature and *E. coli* results where an increase in temperature generally correlated with an increase in

elevated *E. coli* results. No correlation was found between salinity and *E. coli* results. No significant correlation was found for either two day or seven day rainfall and *E. coli* results. A significant correlation was also found between *E. coli* results and the spring/neap tidal cycle, although sampling effort was focused on spring tides. No correlation was found between the high/low tidal cycle and *E. coli* results.

Overall, monitoring results suggest that levels of contamination at Port na Coite are higher than those found at Aros Park and that these levels are not rainfall-dependent but rather more seasonally influenced. Higher results occurred within the main cluster of samples on the intertidal shore.

12. Designated Shellfish Growing Waters Data

The Tobermory designated Shellfish Waters lies in the Calve Island bay Acairseid Mhor. The area was designated in 2002 and has been monitored by SEPA since then. Under the Shellfish Waters Directive (European Communities 2006), designated waters must be monitored quarterly for faecal coliforms in the shellfish flesh and intervalvular fluid, as well as for a variety of chemical parameters. SEPA is responsible for ensuring that this monitoring is undertaken, and have used common mussels for this purpose.

The relative positions of the SGW boundary, the Sound of Mull: Tobermory production area, RMP and the SGW monitoring points are shown in Figure 12.1. SEPA stopped routinely monitoring the sampling point in the Tobermory designated shellfish growing water in 2006. Since then, FSAS *E. coli* data has been used to assess compliance. However, faecal coliform results were provided for three sampling occasions in 2009 and these gave results of:

Table 12.1 Shellfish Growing Waters data

Date of sample	Faecal coliforms MPN/100 ml
28/04/2009	310
15/07/2009	600
18/11/2009	26000

The November 2009 result indicates that mussels in the area can be contaminated to a relatively high level.

The shellfish growing water report for the area identified that effluent from the distillery is likely to have a wide range of pH and high levels of dissolved copper and zinc, as well as un-ionised ammonia. The report also identified that a section of the Tobermory Bay coastal water is classified as being of poor quality due to sewage-related discharges and that the designated shellfish area at Acardseidh Mor is likely to be “at risk from inappropriate discharges to Tobermory Bay or to the catchment that discharges to the bay”.

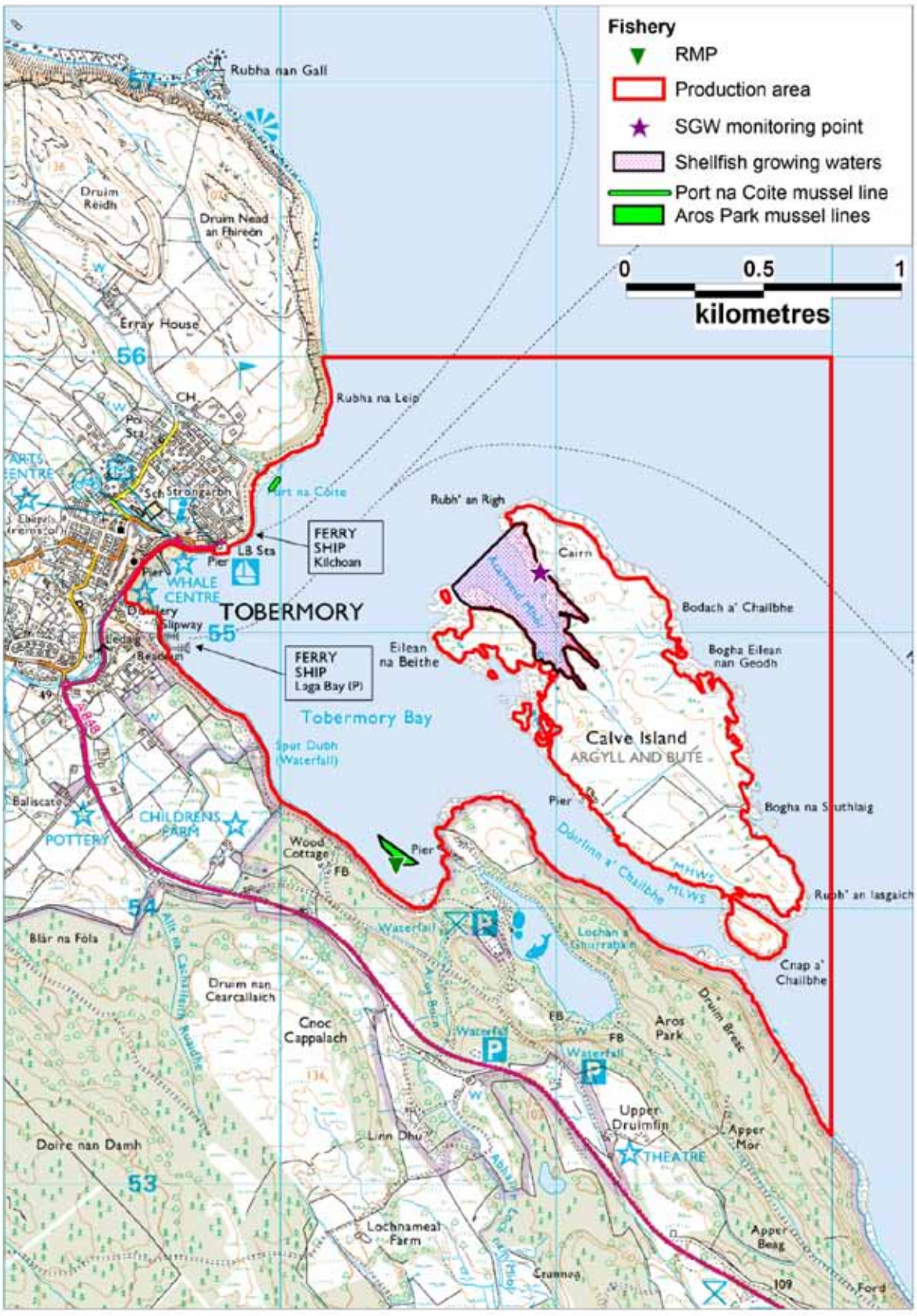

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Figure 12.1 Designated shellfish growing water – Tobermory

13. Bathymetry and Hydrodynamics

Tobermory harbour is a semi-enclosed bay at the north end of the Sound of Mull, Argyll. It is a commercial harbour which has local moorings, ferry traffic, a small fishing fleet and in the summer is a primary location for yachts on the west coast. The study area comprised the area of the Sound of Mull located between the yellow lines shown in Figure 1 plus Tobermory Bay.

Coordinates for Tobermory harbour

56° 37.3’ N 006° 03.7’ W

NM 50810 55038

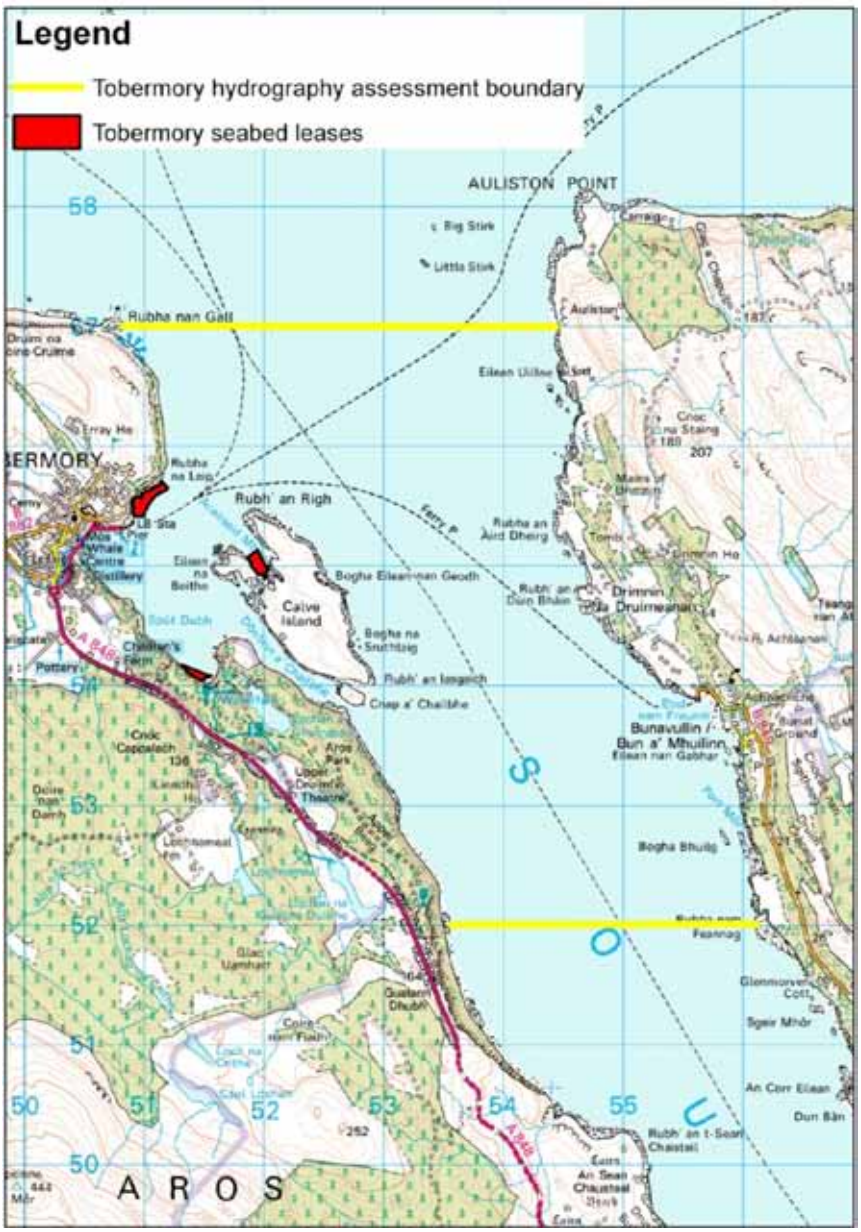

Figure 13.1 Extent of hydrographic study area

13.1 Bathymetry

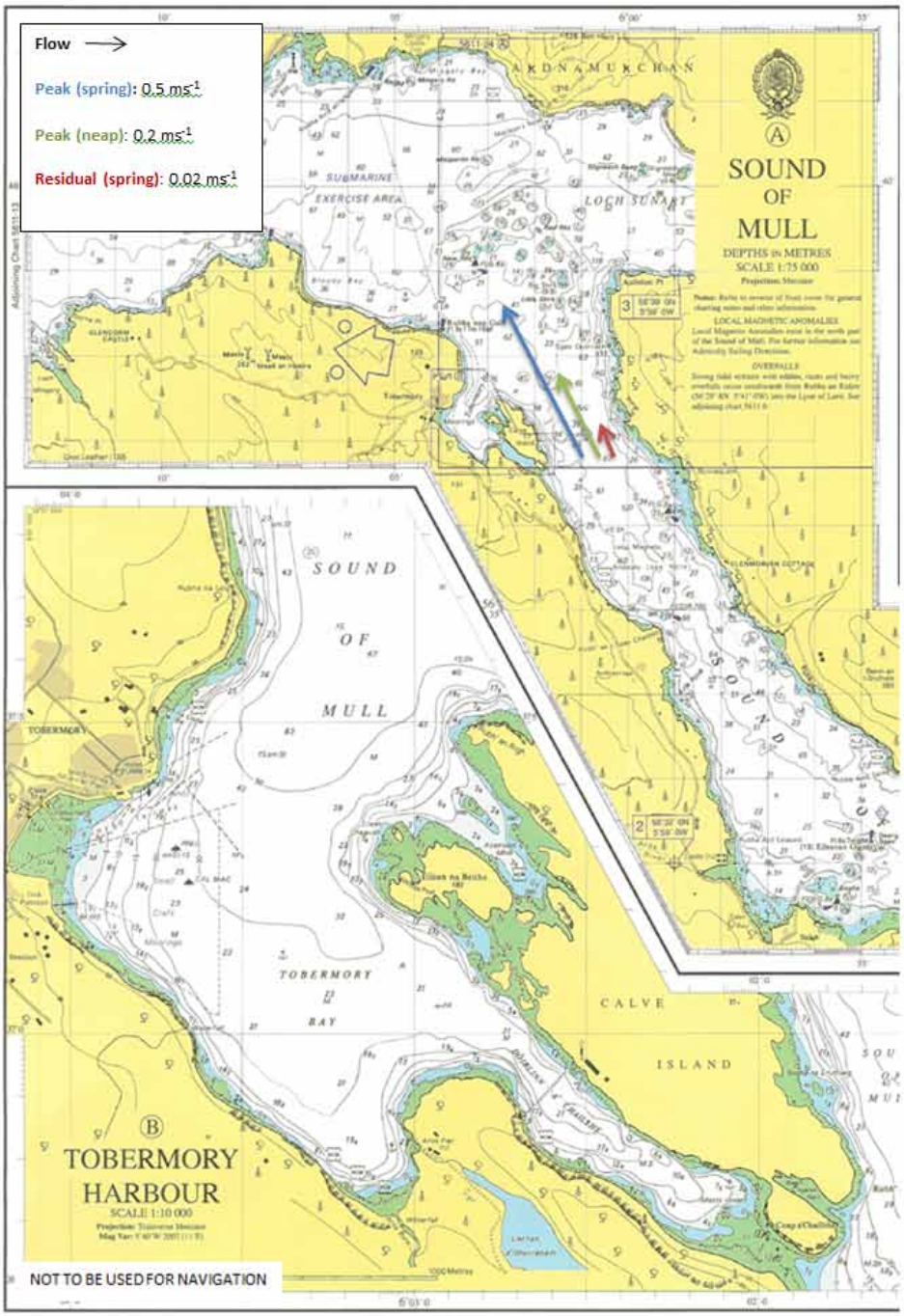

Figure 13.2 Admiralty chart extract for Tobermory Bay

Figure 13.2 shows the bathymetry of Tobermory Bay within the study area. Tobermory Bay covers an area of around 1.5 km x 0.7 km with an estimated mean depth of about 25 m. This gives an estimated volume of 2.6 x 10^8 m^3. The bay is generally steep sided with depths increasing to > 20 m within about 50-100 m of the shore. The exceptions are the more gently sloped areas around Tobermory harbour and Aros Bay to the south. The main entrance to the bay is in the NE with a width of 700 m and a depth of > 50 m, the

maximum charted depth is ~ 70 m. There is no sill at the entrance that would restrict horizontal exchange with the adjacent Sound of Mull. To the SE of the Bay, there is another entrance used by small craft at half tide. The 'Doirlinn' channel is < 100 m wide and dries at low water Springs. The depth of water in the channel at mean high water springs is around 3.5 m. The Bay is bounded to the east by Calve Island which has a small anchorage at its north end with a depth of around 5 m.

13.2 Tides

Tobermory Bay has the typical semi-diurnal tidal characteristic. Data on tidal information is given from local pilot books or charted information.

Standard tidal data for Tobermory are given below (Laurence 1987) and the spring/neap cycle of tidal height around the time of the survey (29-31 October 2012) is shown in Figure 13.3:

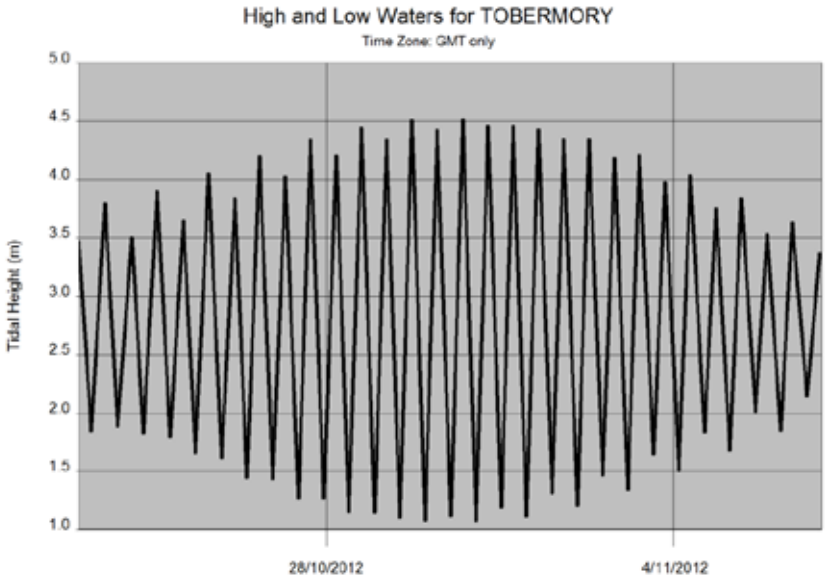

Figure 13.3 Two week tidal curve for Tobermory.
Reproduced from Poltips3 [www.pol.ac.uk/appl/poltips3]

Tidal Heights

Mean High Water Springs = 4.4 m

Mean Low Water Springs = 0.7 m

Mean High Water Neaps = 3.3 m

Mean Low Water Neaps = 1.8 m

Tidal Ranges

Mean Spring Range = 3.7 m

Mean Neap Range = 1.5 m

This will give a tidal volume of water during each tidal cycle of approximately:

Springs: 3.9×10^7 m^3

Neaps: 1.6×10^7 m^3

13.3 Tidal Streams/Currents

There are no accessible current meter records available from SEPA, British Oceanographic Data Centre (BODC) or records collected by SAMS. There is a single tidal diamond to the east of Calve Island in the Sound of Mull from which the following statements are derived. However, it should be remembered that data at tidal diamonds may only be relatively crude indications of flow characteristics derived from short current records (e.g. Bell & Carlin, 1998)

The flow is aligned with the Sound approximately 330°/150° and the maximum rates are 1.0 knots (0.5 m/s) at Springs and 0.4 knots (0.2 m/s) at Neaps. There will be variations to these values across the assessment area in the vicinity of bays and headlands. The flood tide flows generally northwest (NW) and the ebb flows southeast (SE). The tidal flow is typically rectilinear (back and forth) rather than elliptical suggesting it is strongly constrained by the coastline (Black, 2010).

In the Sound of Mull the cumulative transport that might be expected during each phase of the tide is 6.5 km (springs) and 2.2 km (neaps). It is likely that total transport will be less in Tobermory Bay but may still result in transport of distances of order 1 km.

A residual flow in the Sound of Mull has been estimated using the tidal diamond data. The tidal diamond provides a drift rate and direction for each hour of the tide. By summing the vectors for both spring flow and neap flow it is possible to calculate the residual flow, or net flow, over a tidal cycle. At neaps the residual flow is negligible, at springs the residual flow amounts to a displacement of 1.1 km to the NW over the tidal cycle giving a residual current speed of approximately 0.02 m/s.

Dispersion is an important property of a water body with respect to redistribution of contaminants over time. Information on the dispersive nature of the Sound of Mull is given by Black *et al*. (2005) which reports that dispersion in the Sound of Mull is relatively high (e.g. values of > 10 m2/s compared to values typically < 1 m2/s for other neighbouring sea lochs where

0.1 m2/s is a typical default value for SEPA management purposes for particulate deposition modelling (SEPA, 2005)).

There are no instrumental data for circulation within Tobermory Bay. However, the dimension and characteristics of the bay are such that it can be approximated to a rather small, shallow, sea loch. In such cases, there will often be an estuarine type flow, with the surface flow predominantly towards the mouth. Further, the distribution of fresh water may invoke a counter-clockwise flow around the bay. However, there may be some tidal and wind conditions where the flow may reverse to give a clockwise circulation, for example a strong NE wind. The broad assessment of flow can only be given based on the dominant characteristics of the site.

There are no reported flow rates for the 'Doirlinn' channel. However, it is likely that this would be a source of tidal turbulence to the southern part of the Bay to promote vertical mixing and increase the complexity of flow within the southern part of Tobermory Bay.

13.4 River/Freshwater Inflow

Fresh water inflow into Tobermory Bay is one of the factors that will determine the hydrographic conditions and their seasonal variation. There is no published information on the combined freshwater volume input to Tobermory Bay but the shoreline survey undertaken by SRSL in October 2012 to accompany this assessment sampled all freshwater discharges. The three most significant sources of fresh water comprising > 90% of the discharge are.

Aros River (NM 5154 5398): 5.5 m^3/s

Aros Brook (NM 5165 5415): 0.8 m^3/s

Tobermory River (NM 5052 5508): 0.6 m^3/s

All other freshwater sources were measured to 0.1 m^3/s or less. It is clear that the Aros River (TOW13 in the report) is the single biggest source of freshwater to the Bay and will dominate. However, it is clear from the local meteorology of the area that the input is highly seasonal. The discharge from the Aros River is approximately 5 x 105 m^3 per day. This is approximately 0.2% of the total volume of the Bay or about 1% of the spring tidal volume or 3% of the neap tidal volume. This fresh water contribution is focused on the southern part of the Bay. This is compatible with observations of brackish subsurface waters measured at location TOW9 (salinity 24.2). Further, the

distribution of the freshwater sources along the western and southern shore of Tobermory Bay would mean that the fresh water influence would be greatest at that side, this is confirmed with the subsurface salinity in the vicinity of the Tobermory river at location TOW8 of 22.4. This slightly fresher value of salinity is consistent with local observations (harbourmaster).

From observations of salinity made during the survey, the Bay is capped with a fresh surface layer of varying depth, sometimes in excess of 5 m such as at site TOW8 with a more saline layer beneath. This layering is referred to as stratification and provides a measure of how isolated the surface waters are from the deeper water. During periods of strong wind and low run off the stratification may be completely broken down, whilst during periods of high rain fall and weak winds the stratification could develop substantially. Therefore, there is considerable temporal and spatial variation in the stratification of the Bay.

13.5 Meteorology

The meteorological section of this area indicates that the prevailing winds and the strongest winds are found in the SW quadrant. In relation to Tobermory Bay, this direction provides rather effective shelter due to the high, wooded slopes to the west. It is also relevant to note that Tobermory bay is exposed to wind from the NE. Wind from this quadrant blows for approximately 10-15% of the time and often for sustained periods of time (in excess of a week).

13.6 Model Assessment

Due to the paucity of data for this location relating particularly to fresh water, basic elements of the model are missing, including sufficiently controlled boundary conditions. Therefore, it was not considered appropriate to set up a model run for Tobermory Bay.

A hydrodynamic model was developed for a project focussed on impacts of aquaculture further south in the Sound of Mull at Fiunary (Black *et al*, 2010). The northern boundary of the model was just within the area of the current hydrographic assessment area so is of limited value, particularly as the model was tuned to the local site at Fiunary. However, the model did indicate that there can be considerable sheer across the Sound as the tidal flow reverses closer inshore before that in the main channel which would lead to enhanced dispersion in the Sound.

13.7 Hydrographic Assessment

Surface flow

Surface flow can be strongly influenced by wind either by moving (forcing) the surface or by mixing the surface waters. The site is well sheltered from the prevailing winds from the SW and therefore wind forcing and mixing in the surface would probably be rather limited, certainly close to the Mull shore. The fetch over towards Calve Island and at the NE entrance would increase the level of surface mixing in that part of the Bay. When the wind is in the more exposed NE quadrant, then wind forcing and mixing will be much greater and could change the dispersion and circulation of water considerably.

The tidal range is such that there is a relatively large exchange of water through the Bay, constituting typically 10% of the total volume across spring and neap tides. Further, there is no shallow sill at the entrance acting as a barrier such that the Bay would be an effectively exchanged environment. The broad characteristics of the Bay are similar to a small, shallow sea loch with a substantial freshwater discharge towards the head and significant tidal excursion. Therefore, a tidal system with additional estuarine type circulation with the surface flow moving in a generally counter-clockwise direction can be anticipated.

In terms of dispersion of surface water, previous studies have been identified that note a highly dispersive environment in the Sound of Mull (Black et al, 2005) and it is likely that the tidal flow through Tobermory Bay would suggest a similarly effective dispersive environment. With the additional element of the Doirlinn Channel, this will provide additional complexity to the circulation and probably enhance dispersion in the southern part of the Bay. When the Channel is dry it is likely that this will promote circulatory flow within the bay rather than a through flow.

The inflow of fresh water, whilst a relatively small proportion of the total volume, is probably the single most significant influence on salinity and stratification within Tobermory Bay. The run-off is likely to set up rather strong stratification in the surface waters, particularly at times of high rainfall and low wind speeds. This may effectively isolate the surface from the intermediate waters for prolonged periods in areas of the Bay, potentially to 3-5 m deep. It is likely that this fresh layer will tend to spread as a plume across the Bay with a sharp front at the leading edge. Given the strong stratification, it is likely that the direction of surface flow and consequent transport pathways of any contaminants it may contain will be highly variable and is most likely determined by the wind direction.

Exchange Properties

The Sound of Mull has been shown to have a rather effective total and net transport at springs and is a dispersive environment compared to many neighbouring sea lochs. The precise pathways of transport will depend on the

tidal state and the wind direction but in general the north part of the Sound of Mull will provide a well flushed environment throughout the year.

Tobermory Bay has the characteristics of a small tidal sea loch with relatively well developed conditions for estuarine flow. Given the tidal characteristics it is likely that transport and exchange will be relatively effective in this environment, with surface flow assessed to take on a counter-clockwise flow. However, there is complexity in the system, particularly with respect to variability in freshwater runoff and wind direction so there is potential for a wide variety of transport pathways and surface flows to develop.

Long term hydrographic data coverage for this area is very low, particularly with reference to seasonal data sets. There are no in-situ measurements beyond that measured during the accompanying SRSL survey in October 2012 and no reliable model output. Therefore the confidence level of this assessment is **LOW**.

14. Shoreline Survey Overview

The shoreline survey was conducted between the 29th and the 31st October 2012. Prevailing weather conditions during these days were mostly wet and cloudy with very little wind.

Aros Park: The fishery at Aros Park is situated at the southern shore of Tobermory Bay next to the Forestry Commission site. Common mussels (*Mytilus* sp.) are grown on ropes suspended from two lines of surface floats. No lifting equipment is used to harvest the mussels, the site owner does this himself. It is thought that it will take approximately 2 years to get the farm fully up and running according to the site owner. Once this happens, it is hoped that the mussels will be harvested all year round.

Port na Coite: Mussel spat settlement at this new site was unsuccessful this year therefore it was not possible to collect shellfish samples. Only one mussel line consisting of eleven floats was present at this site. The floats were very high in the water consistent with there being no mussel settlement at present. Calve Island is not currently in use for shellfish production. No mussel lines were visible at this site from Tobermory bay. Only one very small fish farm consisting of 1 cage was observed.

The area surrounding the north part of Tobermory Bay is densely populated. Tobermory is a large tourist attraction, with a visitor centre, cafes, shops, restaurants and houses all found in the centre of the town. Fewer dwellings and buildings were found at the south end of Tobermory Bay, which is predominantly woodland. The shoreline area directly above Port na Coite fishery is also predominantly comprised of deciduous woodland.

The Tobermory WWTW discharge and Glengorm WWPS were on the north end of Tobermory Bay. Ledaig WWPS was located midway down the shoreline. Three possible septic tanks associated with private properties were observed on the north end of the bay.

Little in the way of farmland was observed during the shoreline survey. Some livestock (< 5 sheep and cows) was noted inland around Tobermory WWTW and some further southward along Tobermory Bay, which included sheep, ponies and several pigs further inland. Livestock were unable to access the shoreline, but land drainage and runoff from inland areas where animals kept could enter streams that enter Tobermory Bay, particularly to the south.

Several gulls were observed during the shoreline survey, around the Tobermory WWTW and the Visitor centre. Little in the way of other wildlife was observed.

A number of watercourses were observed during the shoreline survey, with discharge measurements made for some of those that were deemed a contamination risk to the fisheries. Tobermory River represented the largest watercourse, though significant input also came from several streams and land runoff/seepage was also common. Freshwater samples *E. coli* levels varied between: < 100 – 8900 *E. coli CFU*/100 ml. Seawater samples contained relatively low levels of *E. coli*, ranging from 1 to 9 per 100 ml. Highest results were from samples taken at the pontoons and at the Aros Park mussel farm.

Two shellfish samples were taken at Aros Park mussel farm, with *E. coli* levels low, recorded at < 20 and 50 *E. coli CFU*/100 ml respectively. Mussels taken at a depth of 3m had the lower *E. coli* level, compared to the shellfish sample taken at 2-3m depth.

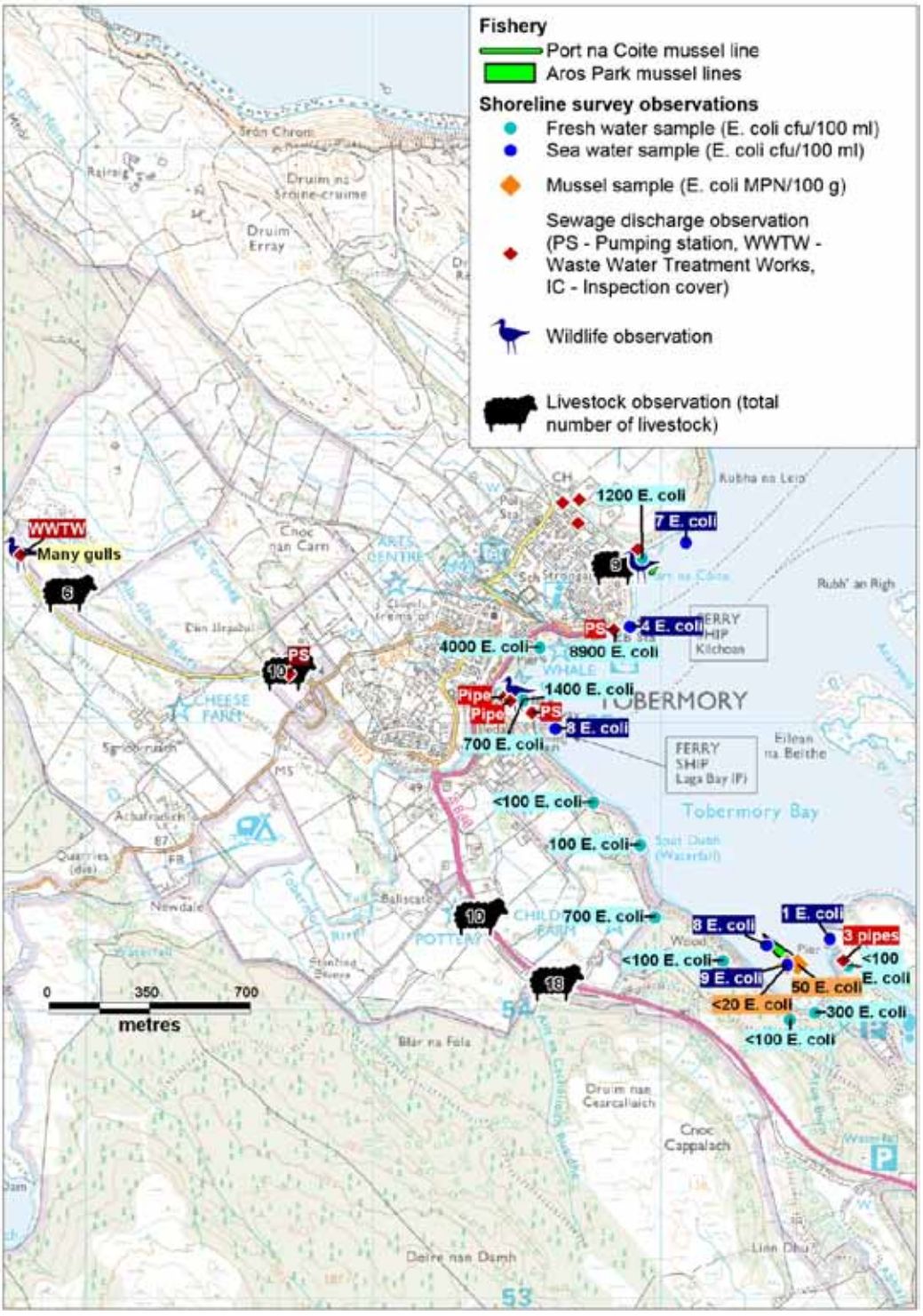

Figure 14.1 Summary of shoreline survey findings for Tobermory

15. Overall Assessment

Human sewage impacts

The final effluent from the Tobermory WWTW discharges to an outfall near the ferry pier at the northern end of Tobermory Bay, approximately 170 metres south of the recorded location of the mussel line at Port na Coite. It is only 50 metres from the nearest boundary of the Crown Estate lease area for the fishery.

The Glengorm CSO outfall lies approximately 210 metres from the mussel line and 100 metres from the CE lease area. No information was provided on predicted spill frequency, but the CSO is designed to operate when heavy rainfall overwhelms the capacity of the drainage system. Analysis of meteorological data in Section 9 showed that during the years 2007-2012, rainfall in excess of 10 mm occurred on 20% of days and that rainfall exceeding 30 mm/day occurred in all years and could occur during any month of the year. Without knowing how much rainfall is likely to trigger an overflow, it is not possible to assess how often this is likely to compromise water quality at the fishery. However, it is reasonable to presume that it would flow at least once a year. The CSO is expected to have a significant impact on bacteriological water quality at the Port na Coite farm whenever it is in operation.

Subsequent to circulation of the draft sanitary survey report, Scottish Water provided a copy of a draft assessment of the impact of the proposed upgrade to facultative lagoon treatment at Tobermory from 2006. This assessment suggested that compliance with a standard of 2000 faecal coliforms/100 ml during the bathing season would be met by the new works. Regarding compliance with the Shellfish Growing Water standard of 300 faecal coliforms/100 g in shellfish, the assessment identified that:

> "As predicted at the outset, despite the high pathogen removal rates afforded by Facultative Lagoons the quality of the final effluent will not meet the Shellfish Waters Standard at the end of the outfall. However, even when using conservative assumptions the Shellfish Waters Standard will be met at the edge of the mixing zone. As this point is remote from where the shellfish are actually harvested this should ensure that the underlying intentions behind the Shellfish Hygiene directive 91/492/EEC are met, namely that the shellfish flesh is protected from Faecal contamination."

No representation or information about the extent and location of the mixing zone was presented. The area was given seasonal C classification for Pacific oysters (grown at Port na Coite) in 2009 and 2010, indicative of high

levels of faecal contamination at that location and consistent with the presence of a significant point source in the vicinity.

Five consented discharges, as well as at least two additional septic tanks, are situated along Erray Burn, which in turn discharges into the seabed lease area for the Port na Coite fishery. Only one of these discharges directly to the burn, with the remainder discharging to soakaway. The total population equivalent for consented discharges along the burn is 82, and the observed presence of other septic tanks in the area suggests that it would be higher if all were considered. Given the close proximity of the reported soakaways to the burn, there is a risk that should the drain fields become clogged or waterlogged, contamination would be carried via overland flow to the burn and on to the bay at Port na Coite. A water sample taken during the shoreline survey was found to contain elevated levels of faecal bacteria (1200 *E. coli CFU*/100 ml). This is likely to be a significant contributor to contamination at the fishery, though relatively minor compared to other nearby sources.

Tobermory Bay has a large number of yacht moorings (> 100). The large proportion of these are for local yachts, with 31 visitor moorings. When these are occupied, there may be considerable contamination from overboard disposal of sewage waste yachts. An annual yacht cruise of western Scotland, usually held in July, visits Tobermory bringing additional yachts into the bay during peak season. The presence of these, as well as any other visiting yachts on moorings or anchorages, is likely to result in an increase in overboard discharges of contaminated wastewater and sewage to the bay. The risk posed by this source will not necessarily be reflected in normal monitoring and therefore will not be adequately controlled via the sampling plan.

Impacts from human sewage sources at Aros Park are anticipated to be lower generally than at Port na Coite as it lies further from the outfalls associated with Tobermory (approx 1.1 km from WWTW outfall). The nearest outfall, at Ledaig, is an Emergency Overflow and would not be expected to flow except in rare circumstances. However, the Aros Park farm does lie within the yacht anchorage at the south end of the bay. When present, occupied yachts on this anchorage would be expected to discharge largely untreated waste overboard in close vicinity to the mussel farm. Satellite images viewed on the internet showed yachts moored within 50 metres inshore (to the south) of the mussel lines. This presents a high risk to the fishery, though it is anticipated to be largely seasonal, with highest risk when more yachts are likely to be present during the main yachting season of April to October.

Agricultural impacts

Much of the area around Tobermory Bay is either densely populated or forested, therefore there is relatively little agricultural activity in the vicinity of the fisheries. The majority of livestock observed were located either south or west of Tobermory, although a small number of sheep were seen on Calve Island. Any diffuse pollution from agricultural activity in the area is likely to be carried to the fishery via watercourses, in particular the Tobermory River and land drains or small streams discharging along the western side of the bay south of the town. A history of poor waste management practices at the dairy suggests this may be a significant source of faecal contamination from cattle to the Tobermory River. A small number of sheep were observed grazing on the north end of Calve Island, and therefore runoff and streams flowing from the island may also contribute to background faecal contamination in the bay. Impacts from diffuse agricultural sources are likely affect water quality to some extent in the whole of the bay, mainly through output from watercourses. It is not clear whether one site would be more affected than the other, although the Aros Park mussel farm is situated further from the main potential sources than Port na Coite.

Wildlife impacts

Relatively little is known about wildlife populations in the vicinity of the mussel farms. Gulls were observed at Port na Coite, and frequent the WWTW ponds to the north of the bay. These may pose a risk of contamination to the fishery, but it is unlikely that they would outweigh the risk from the WWTW discharge itself. An unknown number of seals use Calve Island as a haulout, however it is not known whether and how great an impact this might have on water quality at the two mussel farms. Deer and waterfowl are likely to contribute to faecal contamination levels at the southern end of the bay, where Sput Dubh drains Lochan a'Ghurrabain. A water sample taken from Sput Dubh returned a result of 700 *E. coli CFU*/100 ml, suggesting that there is moderate faecal contamination of these waters.

Seasonal variation

Seasonal variation is seen in historical rainfall patterns, with much less rainfall occurring from March to July, inclusive. However, extreme rainfall events with daily recorded rainfall of over 30 mm have occurred in all months. Although no spill data was available, it is likely that while CSO overflows can occur in any month, the weather is wetter overall between August and February and therefore spills may occur more often during this period.

Seasonal increases are expected in human population, with an attendant increase in demand on the sewerage network and an increase in discharge of sewage from yachts.

Analysis of historical monitoring results in mussels at Aros Park showed two peaks in the trend of results, one occurring in April and the other around September. Results greater than 1000 *E. coli MPN*/100 g occurred in July and September. Analysis of results by season showed no statistically significant variation in results by season. Results of monitoring at the Pacific oyster fishery showed similar trends to the mussel results, with a distinct peak in April and highest results occurring from July to September with no statistically significant variation seen by season. April usually coincides with Easter and school holidays, though the date of these varies. July to September are peak tourism months in the area, suggesting that the levels of contamination seen in shellfish are higher during periods of highest human visitation to the area.

Rivers and streams

Erray Burn discharges close to the mussel farm at Port na Coite, receives discharge from one private septic tank and passes close to the soakaway fields for at least four others. It also had a relatively high *E. coli* loading at the time of the shoreline survey and flows into the bay immediately north of the Port na Coite mussel farm. It also flows past Tobermory Golf Course. Any organic fertilisers used at the golf course could also contribute to faecal contamination levels in the burn and by extension at the fishery.

The Tobermory River is likely to carry diffuse faecal contamination from the dairy as well as from the landfill. It flows into Tobermory Bay between the two mussel farms and it likely to contribute to overall loadings of faecal bacteria found within the bay.

Aros Burn, which discharges to the south of the Aros Park mussel farm, was found to contain significant levels of faecal contamination. The source of this is not clear, however the car park and associated toilets at Aros Park are nearby and there are also likely to be wildlife in this area. This and other watercourses discharging along the south and west shores of the bay are likely to be significant sources of faecal contaminants to the Aros Park fishery. Impacts are expected to be highest along the western and southern ends of the fishery.

Movement of contaminants

A hydrographic assessment of the bay suggests that contamination entering the bay from various freshwater sources is likely to be well dispersed within the bay on the whole. Particle transport distances are likely to be in the order of 1km or more, therefore given the size of the bay and distances between sources and shellfish farms, most sources are capable of impacting at both farms.

If a counter clock-wise circulation is caused by fresh water flow into the bay, then any contamination arising from the Tobermory River will be likely to have a greater impact at the Aros Park mussel farm than at Port na Coite, and this would affect the northern end of the Aros Park lines first. This pattern of circulation would also take contamination arising from the WWTW discharges toward Aros Park. It was further noted that the bay is exposed to winds from the north east, and that sustained strong winds from this direction may reverse circulation. Winds blow from this quadrant up to 15% of the time, and often for sustained periods of time. If seasonal patterns observed in wind data at Tiree hold true for Tobermory, then this is most likely to happen from March to August. Clockwise flow would tend to take contaminants from the Tobermory River flow around toward the entrance to the bay and away from Aros Park. During calmer conditions, freshwater flow into the bay is likely to cause a cap of lower salinity water at the surface, which was observed in salinity profiles taken during the shoreline survey. Contaminants are likely to be more concentrated in this layer. This effect, when present, is likely to be most pronounced along the western side of the bay and may be more likely to affect Aros Park than Port na Coite, which lies nearer the mouth of the bay. Sources of freshwater-borne contamination south and west of Aros Park are most likely to affect the fishery there, with higher impacts along the west side of the lines nearer to sources arising at the shoreline.

Temporal and geographical patterns of sampling results

Overall, the trend in Aros Park mussel *E. coli* results has been stable over the period assessed (2007-2012). Results exceeded 230 MPN/100 g on only five sampling occasions, all of these occurred prior to 2011 and four of these during spring tides. Sampling effort was slightly skewed toward this tidal state, which complicates interpretation. The highest results came from the northern end of the mussel farm, and contaminants arising from the north of the bay will travel farther on spring tidal flows, which could potentially explain the association of high results and spring tides. A statistically significant correlation was found between results in mussels and rainfall for both 2 and 7 days prior to sampling, and a small but statistically significant correlation was found with salinity. This suggests that rainfall-dependent sources of faecal contamination are likely to predominate at this site. No significant correlations were found with temperature or tidal state.

No results were available for mussels at Port na Coite, therefore results from the now declassified Pacific oyster fishery were considered. Sample results came from a very small geographic area, therefore it was not possible to assess spatial variation across the fishery. Over time, the results in Pacific oysters showed marked variation, with a very distinct trough occurring in late 2008 and early 2009. During this period, all results were lower than 230 *E. coli MPN*/100 g. The occurrence of exceptionally high results in the periods

preceding and following this trough further accentuated the trend. In general, results showed that overall contamination levels at the Port na Coite oyster farm were relatively high, with the majority of results exceeding 230 *E. coli MPN*/100 g. Five results of greater than 4600 *E. coli MPN*/100 g were recorded in 2008 and 2009 during the periods flanking the trough in results. While these results cannot be directly compared to those in mussels, they do suggest moderate to sometimes very high levels of faecal contamination at this location. Analysis of results against environmental factors showed no correlation with rainfall. This suggests that rainfall dependent sources, such as diffuse runoff from land and CSO overflows, may have been less important than continuous sources at this fishery. As mussels and oysters respond differently to freshwater input, it is not clear whether this would hold true for the new mussel farm. A statistically significant correlation was found between *E. coli* results and seawater temperatures, with no results < 230 MPN/100 g occurring when seawater temperatures were reported above 15°C. However, it is not clear whether this happened to coincide with warmer water temperatures found during the summer tourist season. There was also a significant association between results and spring tides, however, due to the nature of the fishery sampling effort was targeted at spring tides and therefore this association is likely to be spurious. The Aros Park mussel farm is situated within an anchorage and therefore the presence of yachts in the anchorage is expected to result in higher levels of contamination at these times due to overboard discharge of sewage. As with the Port na Coite fishery, the monitoring programme cannot adequately control for this risk and therefore other measures may need to be applied during periods when yachts are present. Highest risk for this occurring is summer, with a distinct rise in July when there are various cruising club visits to the area.

Conclusions

The Port na Coite fishery is at significant risk of faecal contamination from human sources arising primarily from the continuous sewage discharge and the CSO to the west of the mussel farm, but also from sources along the Erray Burn which discharges to Tobermory Bay immediately to the north. It will also be subject to contamination from visiting yachts anchored or moored in Tobermory Bay. It is highly unlikely that routine monitoring of shellfish at this site will adequately reflect the risks from these variable sources. Impacts from the identified sources will be subject to seasonal variation, with increases from all sources between April and October.

Analysis of monitoring results suggests that the Aros Park mussel farm is more strongly affected by rainfall dependent diffuse sources of faecal contamination. However, it lies within a yacht anchorage area and is also likely to be subject to significant human faecal contamination during times when yachts are present and discharging overboard in the vicinity of the

fishery. This is most likely to occur in summer, and particularly in July. As with the Port na Coite fishery, peaks in contamination resulting from these variable discharges is unlikely to be reflected adequately in the routine monitoring results.

Overall Risk Table

Risk	Port na Coite	Aros Park
Sewage discharges from WWTW, private septic systems	High	Medium
Overboard discharges from yachts	High	High
Rainfall-dependent diffuse sources	Medium	Medium
Wildlife sources	Low	Low
Seasonal variability	High	High

16. Recommendations

The main influences affecting contamination levels at the two sites are different and therefore one sampling point will not adequately represent both. Therefore, it is recommended that the production area be split with Port na Coite and Aros Park monitored separately.

Port na Coite

Production area

The southern extent of the seabed lease area associated with this fishery lies only 54 metres from the Tobermory WWTW outfall. Therefore, it is recommended that the boundary of the production area be curtailed to as far as possible from the outfall whilst still allowing sufficient buffer to allow for any shifting of the mussel long line on its anchors. Therefore it is recommended that the production area be established as the area bounded by lines drawn between NM 5090 5550 to NM 5105 5550 to NM 5111 5557 to NM 5123 5564 to NM 5115 5572 and extending to MHWS.

It was not feasible to exclude the area surrounding the mouth of Erray Burn from the production area.

RMP

Both the sewage discharge and Erray Burn constitute sources of human faecal contamination. The current mussel line is only 40 metres long, and any point on this line would be within the standard 40 metre tolerance normally allowed for sampling from long lines. Therefore, it is recommended that the RMP be established at the southern end line at NM 5097 5553. As there is not currently stock on site, it is recommended that a sampling bag be placed at this location. Mussels placed in the bag for sampling purposes must be left in place for at least 2 weeks prior to sampling in order to ensure that they reflect the surrounding water quality.

If the mussel line is shifted or expanded southward, the location of the RMP should be reevaluated.

Frequency

Standard monthly sampling is recommended.

Depth of sampling

The majority of contaminant input is likely to be in freshwater or sewage, both of which are less dense than seawater and so therefore may be more concentrated at or near the surface. Therefore, it is recommended that monitoring samples be taken at a depth of one meter.

Tolerance

A sampling tolerance of 20 metres is recommended to allow some scope for movement of the line on the anchors.

Aros Park

Production Area

Due to the relative abundance of potential sources of contamination within the bay, it is recommended that the production area boundaries for the Aros Park fishery be curtailed to include just the small embayment within which the farm is situated, excluding the head of the bay where the Aros River discharges. The recommended boundaries are the area bounded by lines drawn between NM 5157 5429 and NM 5102 5438 and between NM 5159 5410 and NM 5134 5413 and extending to MHWS. This excludes the anchorage area, moorings and sewage outfalls to the north. Should the fishery be moved to the southwest, it will be necessary to re-evaluate the production area boundaries.

RMP

As the highest monitoring results were obtained at the northern end of the fishery and the most significant freshwater source of contamination is situated to the west of the farm, it is recommended that the RMP be relocated to the northern end of the westernmost mussel line, at NM 5137 5423, in order to reflect significant contamination sources to the north and west of the fishery. This will not reflect adequately contamination arising from yachts anchored to the south of the fishery during the yachting season. As the presence of yachts is not continual it is not possible to adequately reflect this source via monthly monitoring. Should the fishery be moved to the southwest, it will be necessary to re-evaluate the RMP location.

Frequency

Standard monthly sampling is recommended.

Depth

Due to the influence of freshwater sources at this site, at the association found between higher *E. coli* results and reduced salinity, it is recommended that samples be taken from a depth of one meter.

Tolerance

A sampling tolerance of 20 metres is recommended to allow for some movement of the lines, as the area is relatively sheltered. Due to the large amount of locational variability seen in historical monitoring results at this site, it is recommended that bagged shellfish be considered in order to ensure that samples can be collected from within the tolerance range.

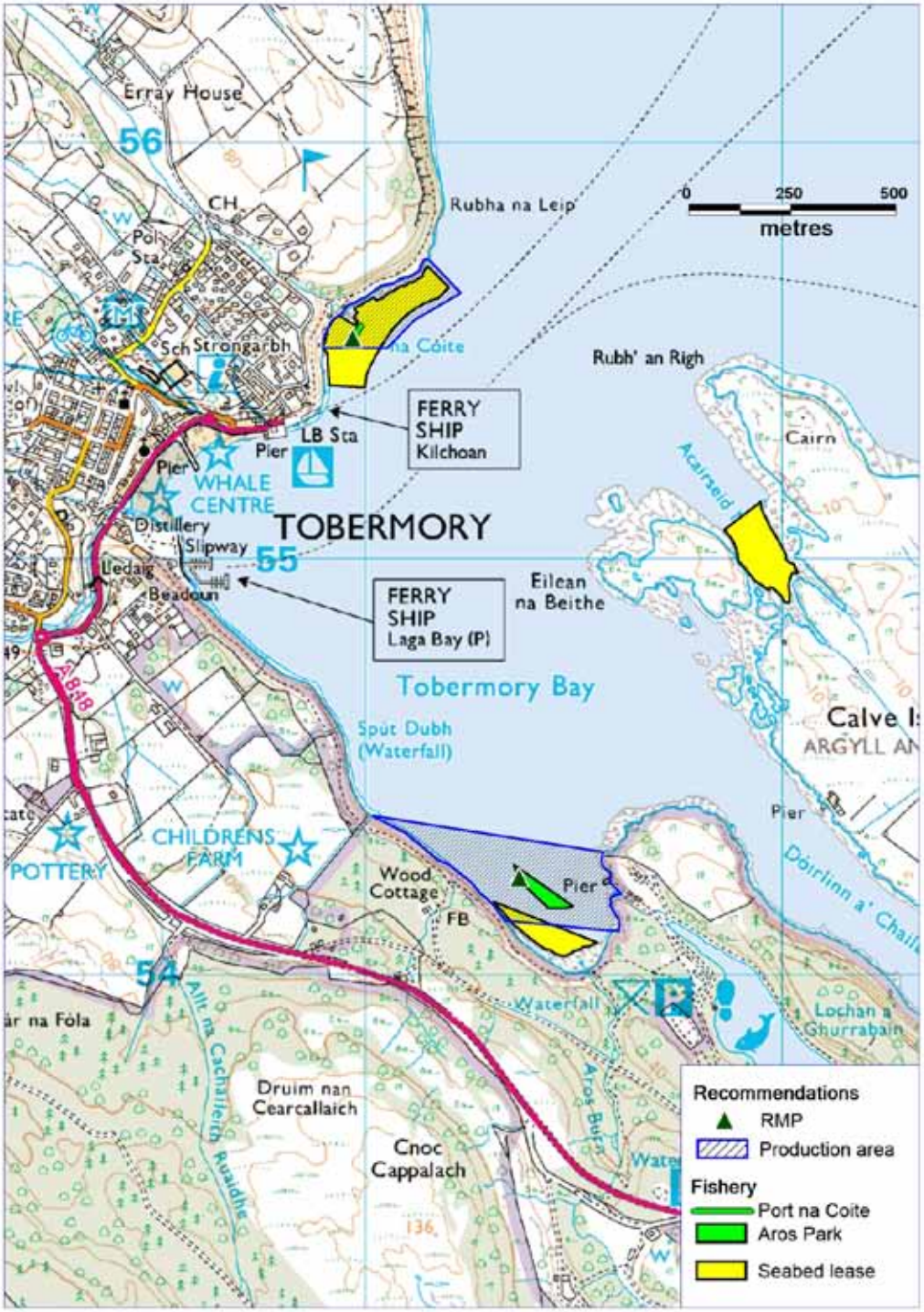

Figure 16.1 Map of recommendations for Tobermory

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4. **Hydrographic Section Glossary**
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1. 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 50-170 kg. 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 x 10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al* 2004).

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

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

Cetaceans

As mammals, whales and dolphins would be expected to have resident populations of *E. coli* and other faecal indicator bacteria in the gut. Little is known about the concentration of indicator bacteria in whale or dolphin faeces, in large part because the animals are widely dispersed and sample collection difficult.

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

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

Birds

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

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

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28×10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77×10^8 FC per faecal deposit to a local reservoir (Alderisio & 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 (Gauthier & Bedard, 1986)

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

Deer

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

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

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

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

Other

The European Otter (*Lutra lutra*) is present around Scotland with some areas hosting populations of international significance. Coastal otters tend to be more active during the day, feeding on bottom-dwelling fish and crustaceans among the seaweed found on rocky inshore areas. An otter will occupy a home range extending along 4-5km of coastline, though these ranges may sometimes overlap (Scottish National Heritage, n.d.). 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 treams, which may be washed into the water during periods of rain.

Alderisio, K. A. & DeLuca, N., 1999. Seasonal enumeration of fecal coliform bacretia from the feces of ring-billed gulls (Larus delawerensis) and Canada geese (Branta canadensis). *Applied and Environmental Microbiology,* 65(12), pp. 5628-5630.

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Scottish National Heritage, n.d. *Otters and Development.* [Online] Available at: http://www.snh.org.uk/publications/on-line/wildlife/otters/biology.asp
[Accessed 10 10 2012].

Stoddard, R. A. et al., 2005. Salmonella and Campylobacter spp. in Northern Elephant Seals, California. *Emerging Infections Diseases,* 11(12), pp. 1967-1969.

2. Tables of Typical Faecal Bacteria Concentrations

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

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	282	2.8×10^{6} * (-)	2.3×10^{6}	3.2×10^{6}
Crude sewage discharges	252	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	79	3.5×10^{6} * (-)	2.6×10^{6}	4.7×10^{6}
Storm sewage overflows					203	2.5×10^{6}	2.0×10^{6}	2.9×10^{6}
Primary	127	1.0×10^{7} * (+)	8.4×10^{6}	1.3×10^{7}	14	4.6×10^{6} (-)	2.1×10^{6}	1.0×10^{7}
Primary settled sewage	60	1.8×10^{7}	1.4×10^{7}	2.1×10^{7}	8	5.7×10^{6}		
Stored settled sewage	25	5.6×10^{6}	3.2×10^{6}	9.7×10^{6}	1	8.0×10^{5}		
Settled septic tank	42	7.2×10^{6}	4.4×10^{6}	1.1×10^{7}	5	4.8×10^{6}		
Secondary	864	3.3×10^{5} * (-)	2.9×10^{5}	3.7×10^{5}	184	5.0×10^{5} * (+)	3.7×10^{5}	6.8×10^{5}
Trickling filter	477	4.3×10^{5}	3.6×10^{5}	5.0×10^{5}	76	5.5×10^{5}	3.8×10^{5}	8.0×10^{5}
Activated sludge	261	2.8×10^{5} * (-)	2.2×10^{5}	3.5×10^{5}	93	5.1×10^{5} * (+)	3.1×10^{5}	8.5×10^{5}
Oxidation ditch	35	2.0×10^{5}	1.1×10^{5}	3.7×10^{5}	5	5.6×10^{5}		
Trickling/sand filter	11	2.1×10^{5}	9.0×10^{4}	6.0×10^{5}	8	1.3×10^{5}		
Rotating biological contactor	80	1.6×10^{5}	1.1×10^{5}	2.3×10^{5}	2	6.7×10^{5}		
Tertiary	179	1.3×10^{3}	7.5×10^{2}	2.2×10^{3}	8	9.1×10^{2}		
Reed bed/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, et al. 2008)

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: (Gauthier and Bedard 1986)

3. Statistical Data

One-way ANOVA: Log EC versus Season Aros Park Common mussels

Source DF SS MS F P
Season 3 1.408 0.469 1.54 0.218
Error 41 12.464 0.304
Total 44 13.872

S = 0.5514 R-Sq = 10.15% R-Sq(adj) = 3.57%

S = 0.5514 R-Sq = 10.15% R-Sq(adj) = 3.57%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev	+---------+---------+---------+---------
1	13	1.8134	0.5570	(---------*---------)
2	13	1.9587	0.6410	(---------*---------)
3	9	2.2981	0.6219	(----------*----------)
4	10	1.8601	0.2821	(----------*----------)

+---------+---------+---------+---------
1.50 1.80 2.10 2.40

Pooled StDev = 0.5514

Grouping Information Using Tukey Method

Season	N	Mean	Grouping
3	9	2.2981	A
2	13	1.9587	A
4	10	1.8601	A
1	13	1.8134	A

Means that do not share a letter are significantly different.

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

Individual confidence level = 98.94%

Season = 1 subtracted from:

Season	Lower	Center	Upper	---------+---------+---------+---------+
2	-0.4342	0.1453	0.7249	(--------*---------)
3	-0.1560	0.4847	1.1255	(----------*----------)
4	-0.5748	0.0467	0.6682	(----------*---------)

---------+---------+---------+---------+
-0.60 0.00 0.60 1.20

Season = 2 subtracted from:

```
Season   Lower   Center   Upper  ---------+---------+---------+---------+
3       -0.3013  0.3394  0.9801             (----------*---------)
4       -0.7201  -0.0986  0.5229        (---------*----------)
                          ---------+---------+---------+---------+
                              -0.60      0.00      0.60      1.20
```

Season = 3 subtracted from:

```
Season   Lower   Center   Upper  ---------+---------+---------+---------+
4       -1.1169  -0.4380  0.2409  (-----------*----------)
                          ---------+---------+---------+---------+
                              -0.60      0.00      0.60      1.20
```

One-way ANOVA: log EC versus season Port na Coite Pacific oysters

```
Source  DF     SS     MS     F      P
season   3   6.144   2.048  5.12  0.006
Error    30  11.994  0.400
Total    33  18.138
```

S = 0.6323 R-Sq = 33.88% R-Sq(adj) = 27.26%

```
                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level   N    Mean   StDev  --+---------+---------+---------+-------
1      11  2.7737  0.5749            (-----*------)
2      10  3.1133  0.6927                (------*------)
3       5  3.3366  0.7776                (---------*--------)
4       8  2.1185  0.5280  (------*-------)
                        --+---------+---------+---------+-------
                        1.80      2.40      3.00      3.60
```

Pooled StDev = 0.6323

Tukey 95% Simultaneous Confidence Intervals

All Pairwise Comparisons among Levels of season

Individual confidence level = 98.93%

season = 1 subtracted from:

```
season    Lower   Center   Upper  --------+---------+---------+---------+-
2       -0.4125   0.3396  1.0917              (-----*-----)
3       -0.3655   0.5629  1.4913              (-------*------)
4       -1.4551  -0.6552  0.1446       (------*-----)
                         --------+---------+---------+---------+-
                            -1.2       0.0       1.2       2.4
```

season = 2 subtracted from:

```
season    Lower   Center    Upper  --------+---------+---------+---------+-
3       -0.7195   0.2233   1.1661           (-------*-------)
4       -1.8113  -0.9948  -0.1783     (------*------)
                         --------+---------+---------+---------+-
                            -1.2       0.0       1.2       2.4
```

season = 3 subtracted from:

```
season    Lower   Center    Upper  --------+---------+---------+---------+-
4       -2.1994  -1.2181  -0.2368  (-------*-------)
                         --------+---------+---------+---------+-
                            -1.2       0.0       1.2       2.4
```

4. Hydrographic Assessment 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.

MHW. Mean High Water, The highest level that tides reach on average.

MHWN. Mean High Water Neep, The highest level that tides reach on average during neep tides.

MHWS. Mean High Water Spring, The highest level that tides reach on average during spring tides

MLW. Mean Low Water, The lowest level that tides reach on average.

MLWN. Mean Low Water Neep, The lowest level that tides reach on average during neep tides.

MLWS. Mean Low Water Spring, The lowest level that tides reach on average during spring tides.

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. Spring tides occur during or just after new moon and full moon when the tide-generating force of the sun acts in the same direction as that of the moon, reinforcing it. The tidal range is greatest and tidal currents strongest during spring tides.

Neep tides occur during the first or last quarter of the moon when the tide-generating forces of the sun and moon oppose each other. The tidal range is smallest and tidal currents are weakest during neep 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. A surface flow at the surface may be accompanied by a compensating flow in the opposite direction at the bed.

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.

5. Shoreline Survey Report

Production area:	Sound of Mull Tobermory/Tobermory Port na Coite
Site name:	Aros Park/Port na Coite
SIN:	AB-258-076-08/AB-624-128-08
Species:	Common mussel (*Mytilus sp.*)
Harvester:	Mr. Creon Carmichael/Mr. Skeith Cloete
Local Authority:	Argyll & Bute
Status:	Existing area-Aros Park/New application-Port na Coite
Date Surveyed:	29 – 31 October 2012
Surveyed by:	Ron Lee, Eilidh Cole, Lars Brunner, Andrea Veszelovszki
Existing RMP:	NM 5142 5416
Area Surveyed:	Inland at the North of the Bay. The northern half of shoreline plus the shellfish farm at Aros Park. The southern half of Tobermory Bay plus additional observations at Aros Park.

Mr Carmichael kindly provided boat access to the Aros Park site.

Weather

29th October: Moderate rain for 24 hrs prior to survey. Moderate showers at around 20:30 for most of the night. 100% cloud cover; calm throughout day with very little wind. Sea state-calm.

30th October: Moderate rain previous evening, throughout the night and continuing until early morning. No rain at beginning of survey. A few moderate showers throughout the day and then heavy rain at approximately 15:45. 100% cloud cover; calm throughout day-1.1m/s wind speed. Wind north-westerly. Temp-10ºC. Sea state-calm.

31st October: Very heavy rain during previous evening and through the night. No rain during survey. Temp. 6.5ºC, wind speed - 0.8m/s, very calm. 100% cloud cover. Sea state-calm.

Fishery

Aros Park: The fishery at Aros Park is situated at the southern shore of Tobermory Bay next to the Forestry Commission site. Common mussels (*Mytilus sp.*) are grown on ropes suspended from two lines of surface floats. No lifting equipment is used to harvest the mussels, the site owner does this himself. It is thought that it will take approximately 2 years to get the farm fully up and running according to the site owner. Once this happens, it is hoped that the mussels will be harvested all year round.

Port na Coite: Mussel spat settlement at this new site was unsuccessful this year therefore it was not possible to collect shellfish samples. Only one mussel line consisting of eleven floats was present at this site. The floats were very high in the water consistent with there being no mussel settlement at present.

Calve Island: It was not possible to gain access to the seabed lease area at the north end of Calve Island. It is not in use at present for shellfish production. No mussel lines were visible at this site from Tobermory bay. Only one very small fish farm consisting of 1 cage was noticed.

Sewage Sources

There are three main sewage discharges to Tobermory Bay. These include the Tobermory Waste Water Treatment Works and Glengorm Waste Water Pumping Station to the north of the bay as well as Ledaig Waste Water Pumping Station near the middle of the bay next to the marina. Three possible septic tanks were observed associated with properties close to a stream that discharges into the northern end of the bay. No other septic tanks were observed at other locations during the survey. The population is more concentrated at north end of the bay. Tobermory itself has several cafes and restaurants especially along the waterfront and there are public toilets, shower and laundry facilities at the Harbour visitor centre next to the marina.

Seasonal Population

Tobermory is densely populated, and experiences seasonal fluctuations in population, with a large influx of tourists during the summer months. There are a large number of B&Bs, self-catering accommodation and hotels in Tobermory itself and these were observed but not specifically recorded in the table of observations. No caravan or campsites were observed during the survey. The Harbour Visitor Centre is located at the marina midway down the bay and is open all year round to provide shower, toilet and laundry facilities.

Boats/Shipping

There is a ferry pier at the north end of the town, just southwest of Port na Coite and a slipway at Aros Park. Tobermory Harbour provides a visitor centre incorporating toilets, showers and laundry facilities located near to the distillery to the south. There are many mooring blocks in Tobermory Harbour but these were not specifically recorded in the table of observations. Approximately 17 boats were seen on the third day of the survey in the mooring area and approximately 18 at the pontoon.

Farming and Livestock

Little in the way of farmland was noticed during the survey. Some sheep and cows (approximately 5 of each) were noticed on the first day of the survey further inland near to Tobermory Waste Water Treatment Works. These are noted in the table of observations. On the final day of the survey, 8 sheep and 2 ponies in a field were observed further inland midway down Tobermory Bay along with approximately 15 sheep and 3 pigs in a field slightly south of this also inland. These are noted in the table of observations. Drainage from these locations could enter the observed streams and land run-off that were measured and sampled further down the hill and contribute to their loadings.

Land Use

Tobermory Bay is approximately 2.5km long and faces north-east. The mouth of the bay is partially enclosed by Calve Island. Tobermory is heavily populated but also caters for a high level of tourism particularly during the summer months. There are several shops, cafes, pubs and restaurants in the town itself as well as housing. There is a distillery just inland from Tobermory Harbour next to the Visitor Centre. Little in the way of farmland was noted on the survey possibly because any farmland would be further inland from the shoreline walk. However, a small number of farm animals were observed during the survey and these are noted in the table of observations.

Land Cover

The southern half of the shoreline is densely wooded and there is a Forestry Commission area at Aros Park. This area has very little foreshore and the banks are steep sided. Access to the shore was limited and impossible in some cases.

The shoreline at Port na Coite is a rocky intertidal area and is also steep banked. The land above the shore is mainly deciduous woodland. The northern half of Tobermory Bay is more densely populated than the southern half.

Further inland, apart from housing, forestry or farmland the land cover appeared to be mainly rough moorland.

Watercourses

A number of watercourses of various sizes were observed discharging into Tobermory Bay throughout its length. Of these, Tobermory River was the largest and flows under a road and then past the distillery before reaching the bay. Waterfalls were also evident as were land drainage and areas of land seepage, some of which were sampled.

Wildlife/Birds

Several seagulls were seen in and around Tobermory during the survey as would be expected at a seaside town. They were seen mainly at Tobermory Waste Water Treatment Works and by the end of Tobermory River as noted in the table of observations. Only one cormorant and one robin were noted at Port na Coite and the Visitor Centre respectively. No other birds or wildlife were seen during the survey.

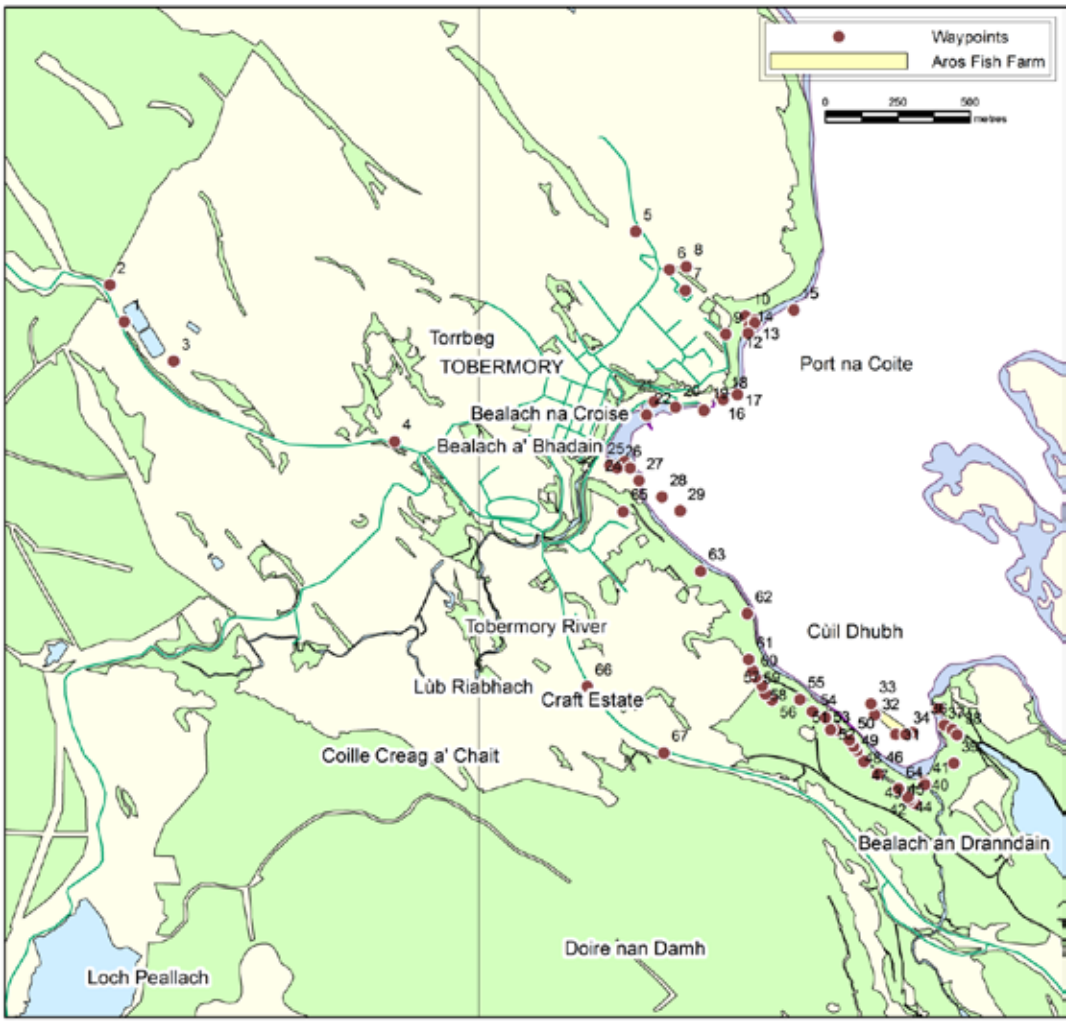

Figure 1. Map of shoreline observations marked as waypoints.

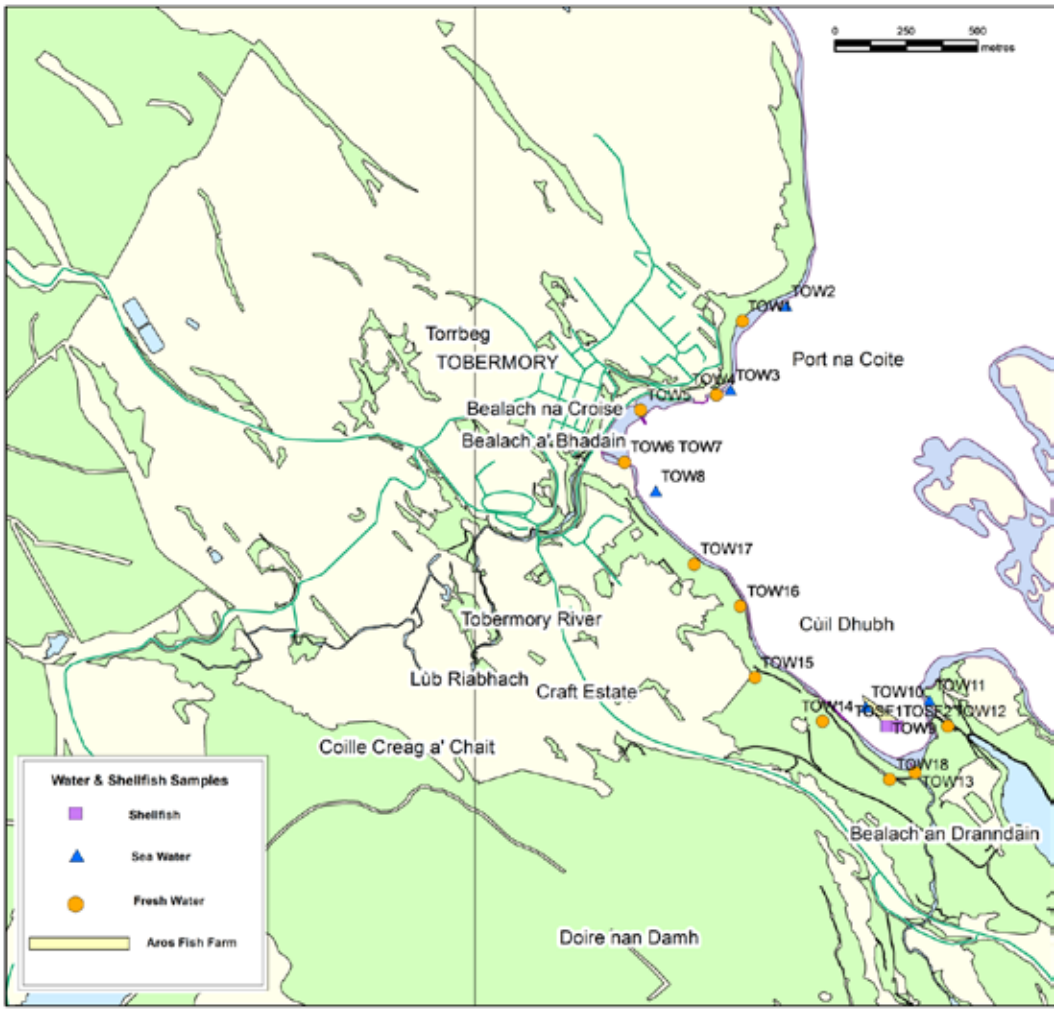

Figure 2. Map showing locations of samples taken during shoreline survey.

Table 1. Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	29/10/2012	14:02:52	NM 48773 55586	148773	755586			Start of survey, Tobermory Waste Water Treatment Works. Many seagulls at WWTW.
2	29/10/2012	14:06:38	NM 48723 55714	148723	755714	Figure 3		Glengorm Landfill Site & Recycling Centre. Location of landfill site in relation to WWTW.
3	29/10/2012	14:17:02	NM 48945 55449	148945	755449			Landscape from below WWTW into Tobermory Bay, mainly moorland, heather and bog, few trees. No pipes or outflows noticed at WWTWs although smell of sewage present. 1 cow grazing in nearby field (no fence) plus 5 sheep in distance.
4	29/10/2012	14:31:19	NM 49709 55172	149709	755172	Figure 4 Figure 5		Pumping station next to road. Small burn running next to it. Sheep (approx. 10 seen) fenced off in field at bottom of burn. 2 storage chambers on ground next to pumping station. Smell of sewage. 5 cows in field next to burn (no fence) beside road next to pumping station. Approx. 10 more sheep in adjacent field also next to burn and no fence.
5	30/10/2012	9:23:02	NM 50542 55899	150542	755899			No discharge pipes observed flowing into burn.
6	30/10/2012	9:27:38	NM 50660 55767	150660	755767			Septic tank seen next to house on opposite side of burn to where waypoint taken.
7	30/10/2012	9:31:50	NM 50714 55695	150714	755695			Metal cover in house garden, possibly of septic tank.
8	30/10/2012	9:37:02	NM 50718 55777	150718	755777			Metal cover in house garden, possibly of septic tank.
9	30/10/2012	9:43:47	NM 50854 55543	150854	755543	Figure 6		Waypoint taken looking SE from Tobermory to Calve Island. Seen on Calve Island is a house, small fish farm (1 cage) and grazing sheep (approx. 9).

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								Floats near to shore of mainland (mussel lines).
10	30/10/2012	9:54:45	NM 50922 55606	150922	755606	Figure 7		River running into bay at Port na Coite. Pipes seen scattered but not attached or flowing.
11	30/10/2012	9:57:13	NM 50954 55591	150954	755591			3 buildings on shore at Port na Coite. Pipe 10 cm diameter not running, coming from one building. Buildings now possibly disused. One mussel line offshore consisting of 11 floats at Port na Coite, very high in water.
12	30/10/2012	10:01:58	NM 50936 55573	150936	755573	Figure 8	TOW1	Burn running into Port na Coite. Freshwater sample. Width - 118 cm Depth - 6 cm Depth - 10 cm (opposite side) Flow - 0.498 m/s Flow - 0.450 m/s SD - 0.017 SD - 0.026 Land cover: Steep banked mainly deciduous woodland. Rocky shores (relates to Figure 8).
13	30/10/2012	10:15:33	NM 50954 55581	150954	755581			Sighting compass used to measure extent of mussel lines as could not get out on boat. 126º angle on l side; 137º angle on R side.
14	30/10/2012	10:19:22	NM 50932 55546	150932	755546			Sighting compass used to measure extent of mussel lines as could not get out on boat. 122º angle on l side; 133º angle on R side. No mussels visible on shore to sample. No evidence of mussel shells. Single cormorant on float on mussel line. Few shells on beach, only winkles & limpets.
15	30/10/2012	10:31:33	NM 51089 55627	151089	755627		TOW2	Seawater sample from bay near Port na Coite.
16	30/10/2012	10:46:35	NM 50838 55325	150838	755325			Possibly Tobermory Glengorm Pumping Station (WWPS). 6 metal covers on ground next to pumping station building next

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								to stream.
17	30/10/2012	10:50:35	NM 50894 55334	150894	755334		TOW3	Seawater sample from ferry slipway (Tobermory to Ardnamurchan ferry).
18	30/10/2012	10:53:56	NM 50845 55317	150845	755317	Figure 9	TOW4	Freshwater sample from outflow pipe. Diameter - 90 cm Flow - 2.410 m/s Depth - 6 cm SD - 0.070
19	30/10/2012	11:06:39	NM 50778 55280	150778	755280			Boats observed offshore at Tobermory Bay.
20	30/10/2012	11:13:24	NM 50680 55290	150680	755290			No outflow pipes observed at bay wall.
21	30/10/2012	11:19:07	NM 50607 55310	150607	755310			Surface drainage pipes on bay wall, no flow at present from any of them.
22	30/10/2012	11:21:51	NM 50580 55263	150580	755263	Figure 10	TOW5	Freshwater sample. Smell of sewage from culvert stream. Width - 80 cm Flow - 1.873 m/s Depth - 10 cm SD - 0.033
23	30/10/2012	11:33:40	NM 50503 55100	150503	755100			Approx. 20 gulls sitting on beach by major river in flow.
24	30/10/2012	11:36:52	NM 50522 55080	150522	755080	Figure 11	TOW6	Tobermory River. Freshwater sample. Width - 3.7 m Flow - 0.362 m/s Depth - 35 cm SD - 0.184
							TOW7	Freshwater sample. (From opposite side of Tobermory River as TOW6) Width - 3.7 m Flow - 0.683 m/s Depth - 35 cm SD - 0.039
25	30/10/2012	11:50:26	NM 50453 55089	150453	755089			Unidentified pipe - 10cm diameter.
26	30/10/2012	11:52:55	NM 50477 55079	150477	755079			Distillery outflow pipe.
27	30/10/2012	12:00:42	NM 50553 55036	150553	755036	Figure 12		Ledaig Pumping Station, south bay, near Visitor Centre. Photos showing boat distribution. Pontoon.
28	30/10/2012	12:09:23	NM 50634 54980	150634	754980		TOW8	Seawater sample taken from end of pontoon.
29	30/10/2012	14:31:05	NM 50696 54931	150696	754931			End of larger branch of pontoon, salinity profile measurements taken from edge.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								Meter examined against 0.9% saline solution and found to be acceptable. 5m depth - 23.5 ppt 3m depth - 22.8 ppt 1m depth - 23.3 ppt Subsurface - 22.4 ppt
30	30/10/2012	15:54:14	NM 51499 54164	151499	754164			Extent of mussel lines.
31	30/10/2012	15:54:41	NM 51441 54158	151441	754158		TOSF1 TOW9	Extent of mussel lines. Shellfish sample taken basket at from approx. 3m depth. Seawater sample. Salinity profile: 5m - 27.39 3m - 26.87 1m - 26.92 Subsurface - 24.23 Harvester normally uses 10m droppers.
32	30/10/2012	16:02:20	NM 51369 54226	151369	754226		TOW10	Extent of mussel lines. Seawater sample.
33	30/10/2012	16:06:42	NM 51357 54264	151357	754264			Furthest edge of inner mussel line.
34	30/10/2012	16:09:10	NM 51477 54158	151477	754158	Figure 13	TOSF2	Nearest edge of inner mussel line. Shellfish sample from the top 2-3 m of the line only. Not many mussels present. Will take shellfish harvester approx. 2 years to get the farm fully running. Once it is up and running, he plans to harvest all year round.
35	31/10/2012	09:27:39	NM 51589 54248	151589	754248	Figure 14	TOW11	Seawater sample taken from end of pier at Aros Park. River running into bay plus two others on opposite shore (not shown in photos).

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
36	31/10/2012	09:34:24	NM 51611 54190	151611	754190			Surface water run-off down towards pier into bay.
37	31/10/2012	09:35:59	NM 51638 54174	151638	754174			3 pipes by river, nothing coming out of pipes; 2 disused buildings.
38	31/10/2012	09:37:52	NM 51654 54156	151654	754156		TOW12	Freshwater sample from river under bridge. River flowing heavily. Width - 1.9 m Depth - 45 cm Depth - 48 cm (opposite side) Flow - 0.817 m/s Flow - 0.483 m/s SD - 0.085 SD - 0.079
39	31/10/2012	09:47:44	NM 51643 54058	151643	754058			Land seepage, pipe under path.
40	31/10/2012	10:03:08	NM 51540 53993	151540	753993	Figure 15	TOW13	Freshwater sample from wide, heavily flowing river with waterfall (taken below bridge). Width - 6.1 m Flow - 1.229 m/s Depth - 65 cm SD - 0.184
41	31/10/2012	10:15:18	NM 51543 53984	151543	753984			Measurements of river on opposite bank. Width - 6.1 m Flow - 1.724 m/s Depth - 60cm SD - 0.161 Land cover; Steep sided deciduous forest until bay; rocky shores heavily covered with seaweed.
42	31/10/2012	10:21:14	NM 51507 53919	151507	753919			Surface drainage pipe - not flowing.
43	31/10/2012	10:21:42	NM 51490 53930	151490	753930			Surface drainage pipe - not flowing.
44	31/10/2012	10:21:56	NM 51483 53940	151483	753940			Surface drainage pipe - not flowing.
45	31/10/2012	10:23:03	NM 51455 53972	151455	753972	Figure 16		Surface drainage - flowing.
46	31/10/2012	10:26:00	NM 51381 54021	151381	754021			Surface drainage - flowing.
47	31/10/2012	10:27:18	NM 51332 54065	151332	754065			Surface drainage - flowing.
48	31/10/2012	10:28:28	NM 51308 54101	151308	754101			Surface drainage - not flowing.
49	31/10/2012	10:29:18	NM 51296 54116	151296	754116			Surface drainage - not flowing.
50	31/10/2012	10:30:00	NM 51283 54138	151283	754138			Surface drainage - not flowing.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
51	31/10/2012	10:30:55	NM 51237 54172	151237	754172			Surface drainage - flowing.
52	31/10/2012	10:31:30	NM 51216 54173	151216	754173		TOW14	Freshwater sample. Width - 75 cm Flow - 0.539 m/s Depth - 17 cm SD - 0.014 White house on bank above waterfall.
53	31/10/2012	10:36:30	NM 51198 54216	151198	754216			Surface drainage - flowing.
54	31/10/2012	10:37:36	NM 51154 54236	151154	754236			Surface drainage - flowing.
55	31/10/2012	10:38:41	NM 51110 54279	151110	754279			Surface drainage - flowing.
56	31/10/2012	10:40:24	NM 51013 54277	151013	754277			Surface drainage - flowing.
57	31/10/2012	10:40:55	NM 50991 54298	150991	754298			Surface drainage - not flowing.
58	31/10/2012	10:41:36	NM 50980 54326	150980	754326		TOW15	Surface drainage - flowing heavily. Freshwater sample. Width - 60 cm culvert Flow - 0.838 m/s Depth - 13 cm SD - 0.024
59	31/10/2012	10:49:10	NM 50957 54355	150957	754355			Surface drainage - not flowing
60	31/10/2012	10:49:44	NM 50947 54378	150947	754378			Surface drainage - flowing a little.
61	31/10/2012	10:51:00	NM 50933 54416	150933	754416			House seen just above path above bay along with 4 chalets. One large, new looking house with barn only just visible behind hill and trees.
62	31/10/2012	10:56:54	NM 50929 54576	150929	754576		TOW16	River and waterfall flowing into bay. Freshwater sample. Width - 2 m Depth - 19 cm Depth - 18cm (opposite bank) Flow - 0.457 m/s Flow - 0.101 m/s SD - 0.086 SD - 0.061
63	31/10/2012	11:08:41	NM 50767 54723	150767	754723		TOW17	Small stream with waterfall. Freshwater sample. Width - 7 cm Flow - 1.156 m/s

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								Depth - 3 cm SD - 0.013
64	31/10/2012	11:36:50	NM 51451 53969	151451	753969		TOW18	This stream was re-marked (see Figure 15) on the way back to the car so that measurements could be taken. Width - 27 cm Flow - 0.269 m/s Depth - 2 cm SD - 0.005
65	31/10/2012	15:23:59	NM 50498 54929	150498	754929	Figure 17		Photos taken from top of bay for boat and mooring distribution.
66	31/10/2012	15:30:30	NM 50375 54323	150375	754323			8 sheep and 2 ponies in field approx. 200m NNE.
67	31/10/2012	15:32:25	NM 50640 54094	150640	754094			Approx. 15 sheep and 3 pigs in field.

Photographs referenced in the table can be found attached as Figures 3 – 17.

(Note: Table 1 contains observations not associated with a waypoint).

Sampling

Water and shellfish samples were collected at sites marked on the map shown in Figure 2. Samples were transferred to either Biotherm 10 or Biotherm 25 boxes with ice packs and shipped to Glasgow Scientific Services (GSS) for *E.coli* analysis. All samples were shipped on the day of collection except for water samples TOW9 and TOW10 and shellfish samples TOSF1 and TOSF2 which were shipped the following day. All samples were received and analysed by GSS on the day following collection, except for water samples TOW9 and TOW10 and shellfish samples TOSF1 and TOSF2 which were analysed two days following collection. Sample temperatures on arrival at GSS ranged between 0.2 ºC and 2.0 ºC. The results are presented in Tables 2 and 3.

Seawater samples were tested for salinity by GSS and results reported in mg Chloride per litre. These results have been converted to parts per thousand (ppt) using the following formula:

$$\text{Salinity (ppt)} = 0.0018066 \times Cl^{-} \text{ (mg/L)}$$

As the fishery salinity and temperature were recorded at the surface, 1 meter, 3 meters and 5 meters depth at two locations using a YSI ProPlus CT probe. The locations are shown in Figure 2 and the resulting profiles are reported in Table 4. All salinity values have been rounded up to one decimal place.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	30/10/2012	TOW1	NM 50936 55573	Fresh	1200	-
2	30/10/2012	TOW2	NM 51089 55627	Sea	7	34.9
3	30/10/2012	TOW3	NM 50894 55334	Sea	4	35.2
4	30/10/2012	TOW4	NM 50845 55317	Fresh	8900	-
5	30/10/2012	TOW5	NM 50580 55263	Fresh	4000	-
6	30/10/2012	TOW6	NM 50522 55080	Fresh	700	-
7	30/10/2012	TOW7	NM 50522 55080	Fresh	1400	-
8	30/10/2012	TOW8	NM 50634 54980	Sea	8	35.2
9	30/10/2012	TOW9	NM 51441 54158	Sea	9	27.6
10	30/10/2012	TOW10	NM 51369 54226	Sea	8	35.2
11	31/10/2012	TOW11	NM 51589 54248	Sea	1	34.7
12	31/10/2012	TOW12	NM 51654 54156	Fresh	< 100	-
13	31/10/2012	TOW13	NM 51540 53993	Fresh	300	-
14	31/10/2012	TOW14	NM 51216 54173	Fresh	< 100	-
15	31/10/2012	TOW15	NM 50980 54326	Fresh	700	-
13	31/10/2012	TOW16	NM 50929 54576	Fresh	100	-
14	31/10/2012	TOW17	NM 50767 54723	Fresh	< 100	-
15	31/10/2012	TOW18	NM 51451 53969	Fresh	< 100	-

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	Location on Line	E. coli (MPN/100g)
1	30/10/2012	TOSF1	NM 51441 54158	Common Mussel	Approx. 3m depth	< 20
2	30/10/2012	TOSF2	NM 51477 54158	Common Mussel	Top 2-3m	50

Table 4. Salinity profiles

Profile	Date and time	Position	Depth (m)	Salinity (ppt)	Temperature (°C)*
1	30/10/2012	NM 50696 54931	0	22.4	-
			1	23.3	-
			3	22.8	-
			5	23.5	-
2	30/10/2012	NM 51441 54158	0	24.2	-
			1	26.9	-
			3	26.9	-
			5	27.4	-

*Only two salinity profiles were taken as the salinity metre malfunctioned after this. Temperature readings were not taken as temperature probe was giving erroneous readings.

Photographs

Figure 3. Location of Glengorm landfill site in relation to Tobermory WWTW.

Figure 4. Pumping station beside burn next to road.

Figure 5. Cows in field next to burn, no fence.

Figure 6. Calve Island looking SE from Tobermory with fish farm cage and grazing sheep.

Figure 7. River running into bay at Port na Coite. Pipes scattered but not attached or flowing.

Figure 8. Land cover at Port na Coite.

Figure 9. Outflow from pipe, sample TOW4 taken here.


Figure 10. Smell of sewage from this stream, location of sample TOW5.

Figure 11. Tobermory River. Site of TOW6 & TOW7 (opposite banks).

Figure 12. Tobermory Harbour pontoon.

Figure 13. Mussel lines at Aros Park high in the water.

Figure 14. River running into bay at Aros Park.

Figure 15. Heavily flowing river with waterfall. Location of TOW13.

Figure 16. Surface drainage with pipe.

Figure 17. Tobermory Bay.