Scottish Sanitary Survey Report

Sanitary Survey Report
Forth Estuary: Anstruther
SIN: FF 068
March 2013

Cefas

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Report Distribution – Forth Estuary Anstruther

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Partner Organisations

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

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I. Executive Summary

Under (EC) Regulation 854/2004, which sets forth specific rules for the organisation of official controls on products of animal origin intended for human consumption, sanitary surveys of production areas and their associated hydrological catchments and coastal waters are required in order to establish the appropriate representative monitoring points (RMPs) for the monitoring programme.

The purpose of the sanitary survey is to demonstrate compliance with the requirements stated in Annex II (Chapter II Paragraph 6) of Regulation (EC) 854/2004. The sanitary survey results in recommendations on the location of RMPs, the frequency of sampling for microbiological monitoring, and the boundaries of the production areas deemed to be represented by the RMPs.

A sanitary survey was undertaken on the classified surf clam fishery at Forth Estuary: Anstruther on the basis recommended in the European Union Reference Laboratory publication: “Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application” (http://www.crlcefas.org/gpg.asp). This production area was selected for survey at this time based on a risk-based ranking of the area amongst those in Scotland that have yet to receive sanitary surveys.

The Forth Estuary: Anstruther surf clam fishery is located along the east coast of Scotland, on the north side of the outer Forth Estuary approximately 40 km NE of Edinburgh. Surf clams are dredged from the seabed in an area extending from Crail westward along the coastline into an adjacent production area at Forth Estuary: Pittenweem. Harvesting may be undertaken at any time of year, in accordance with weather conditions and market prices for the clams. The shoreline area includes heavily populated areas at Anstruther Easter and Crail and large areas of agricultural land.

The principal sources of faecal contamination to the fishery are

- Continuous discharges of screened sewage from wastewater treatment works (WWTW) within and adjacent to the production area waters
- Discharges from combined sewage overflows (CSO) within and adjacent to the production area
- Direct discharge of pig slurry from the pig farm at Caiplie
- Diffuse and point source contamination to watercourses, particularly Dreel and Kilrenny Burns

They hydrographic assessment showed that contaminants may be carried up to 6 km from source and therefore discharges from well outside the production area boundaries may contribute to background contamination levels there. The outfall from Cornceres WWTW discharges screened sewage effluent directly to waters

overlying the clam bed. As the clams are subtidal, contaminants associated with particulate matter sinking to the sea bed are likely to be an important mechanism of contamination to the shellfish.

Sewage contamination from CSOs will be highly variable and risks from these sources cannot be adequately controlled via the monthly monitoring programme. As there is one harbour, Skinfast Haven, within the production area boundaries, it is recommended that the boundaries be redrawn to exclude it. Although the Cornceres sewage outfall is located within the bed area, excluding it would create a production area that would be complex and unenforceable under the current system. Due to the nature of the fishery (dredged by a number of harvesters) it is recommended that a monitoring zone approach be taken.

The recommended monitoring zone and production area boundaries are presented in tabular form overleaf and graphically in Section 16, Recommendations.

Sampling Plan

Production Area	Forth Estuary: Anstruther
Site Name	Anstruther surf clams
SIN	FF 068-184-19
Species	Surf clams
Type of Fishery	Wild - dredged
NGR of RMZ East North	The area within lines drawn between the following points: NO 5863 0354, NO 5953 0474, NO 5976 0456 and NO 5887 0336
Tolerance (m)	None
Depth (m)	Not applicable
Method of Sampling	Dredge
Frequency of Sampling	Monthly
Local Authority	Fife Council
Authorised Sampler(s)	Sandy Duncan
Local Authority Liaison Officer	Laura Gray
Recommended Production Area	The area bounded by lines drawn between NO 5700 0348 and NO 5700 0200 and NO 6400 0200 and NO 6400 0700 and NO 6108 0700 and between NO 5773 0375 and NO 5770 0374, extending to MHWS

II. Report

1. General Description

The Forth Estuary: Anstruther production area is located off the eastern coastline of Scotland (See Figure 1.1) near the mouth of the Firth of Forth. The Firth of Forth the is approximately 50 km Its width at the production area is approximately 18 km. Anstruther is located on a stretch of coastline open to the North Sea. The area surrounding the production area is moderately populated while the Firth in general is heavily populated with several large settlements lying on its shores, such as Edinburgh, Falkirk, Dunfermline and Kirkcaldy.

The production area is 7 km by 5 km and encompasses the coastline between the villages of Anstruther and Kilrenny to the west and Crail to the east. The depth ranges from 0 – 30 m. The adjoining land is mainly arable fields with a band of rough ground between the field and shore. The popular Fife coastal path, which runs along the Fife coast from Kincardine in the south to Newburgh in the north, follows the shore of the production area.

An adjacent production area; Forth Estuary: Pittenweem was the subject of a sanitary survey in 2008.

The sanitary survey at Forth Estuary: Anstruther is being undertaken due to the ranking for the area in a risk matrix.

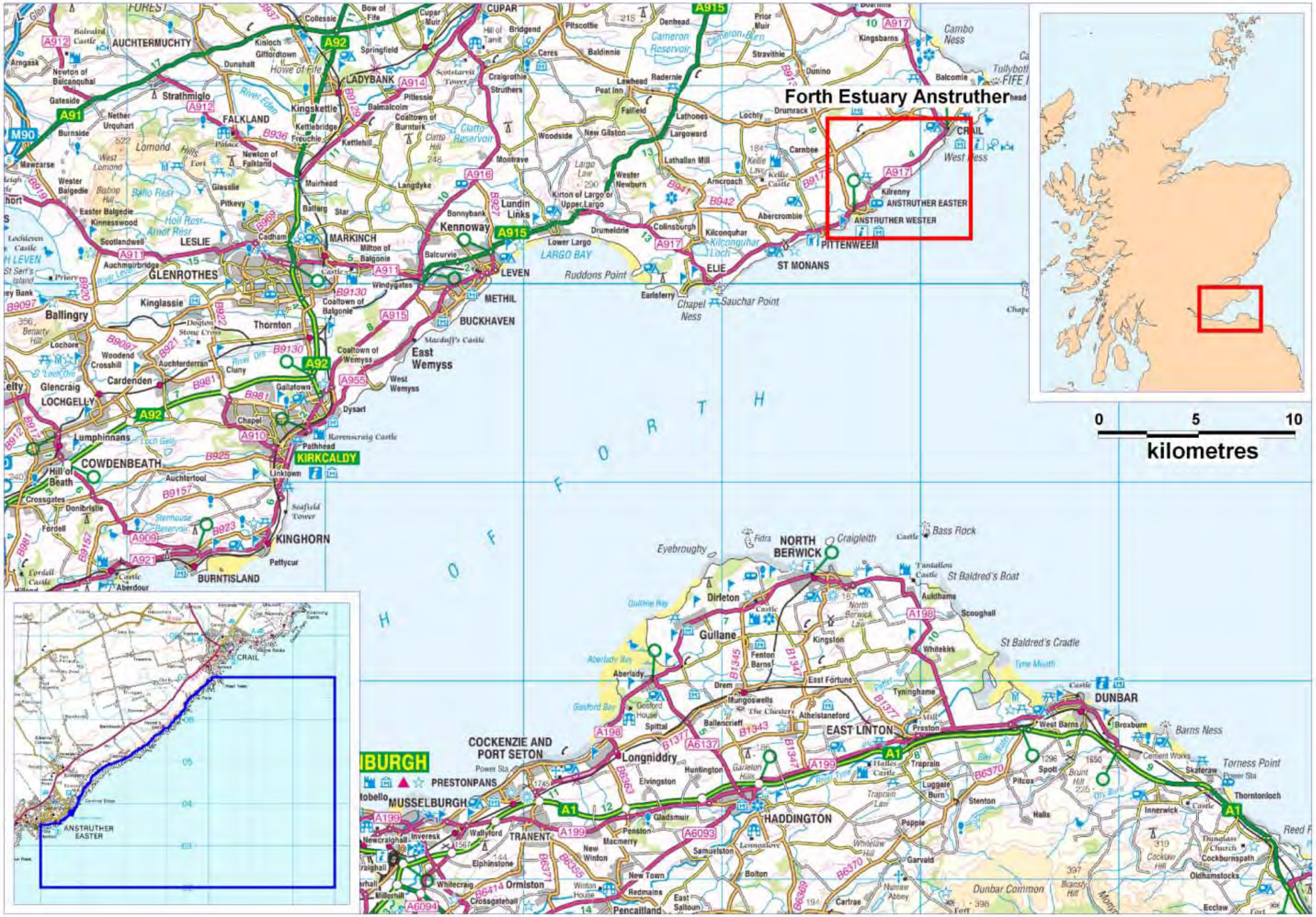

Forth Estuary Anstruther
0
5
10
kilometres
FIRTH OF FORTH
CRAIL
ANSTRUTHER EASTER
ANSTRUTHER WESTER
PITTENWEEM
ST MONANS
ELIE
LEVEN
METHIL
BUCKHAVEN
KIRKCALDY
KINGHORN
BURNTISLAND
GLENROTHES
CUPAR
NORTH BERWICK
DUNBAR
HADDINGTON
MUSSELBURGH
PRESTONPANS
COCKENZIE AND PORT SETON
EAST LINTON
COWDENBEATH
LOCHGELLY

Figure 1.1 Location of survey area

2. Fishery

Forth Estuary: Anstruther is a wild fishery of surf clam (*Spisula solida*) (SIN: FF-068-184-19) and has been in classification since 2002. It fell out of classification in 2007 due to insufficient sample submissions, returning to classification in 2008.

Boundaries for the currently classified production area lie inshore of the following lines: NO 5700 0348 and NO 5700 0200 and between NO 5700 0200 and NO 6400 0200 and between NO 6400 0200 and NO 6400 0700 and between NO 6400 0700 and NO 6108 0700 extending to MHWS.

The nominal RMP is located at NO 5930 0450. The production area boundary and RMP are shown in Figure 2.1

The shoreline survey identified that there are three areas where fishing is possible and regularly done so: the Pittenweem area (which falls in a separate production area) the Anstruther area and further northeast, the Caiplie Cave area. Due to the varying bottom topography, with rocky bottoms in places, dredging is not possible in all areas.

The exact limits of the surf clam bed are not known although it is known from previous sampling locations that the fishery classified in Pittenweem (SIN FF-073-819-19 and FF-073-189-19) is part of the same bed. For mapping purposes previous sampling locations have been used to derive the likely extent of the fishery in figure 2.1

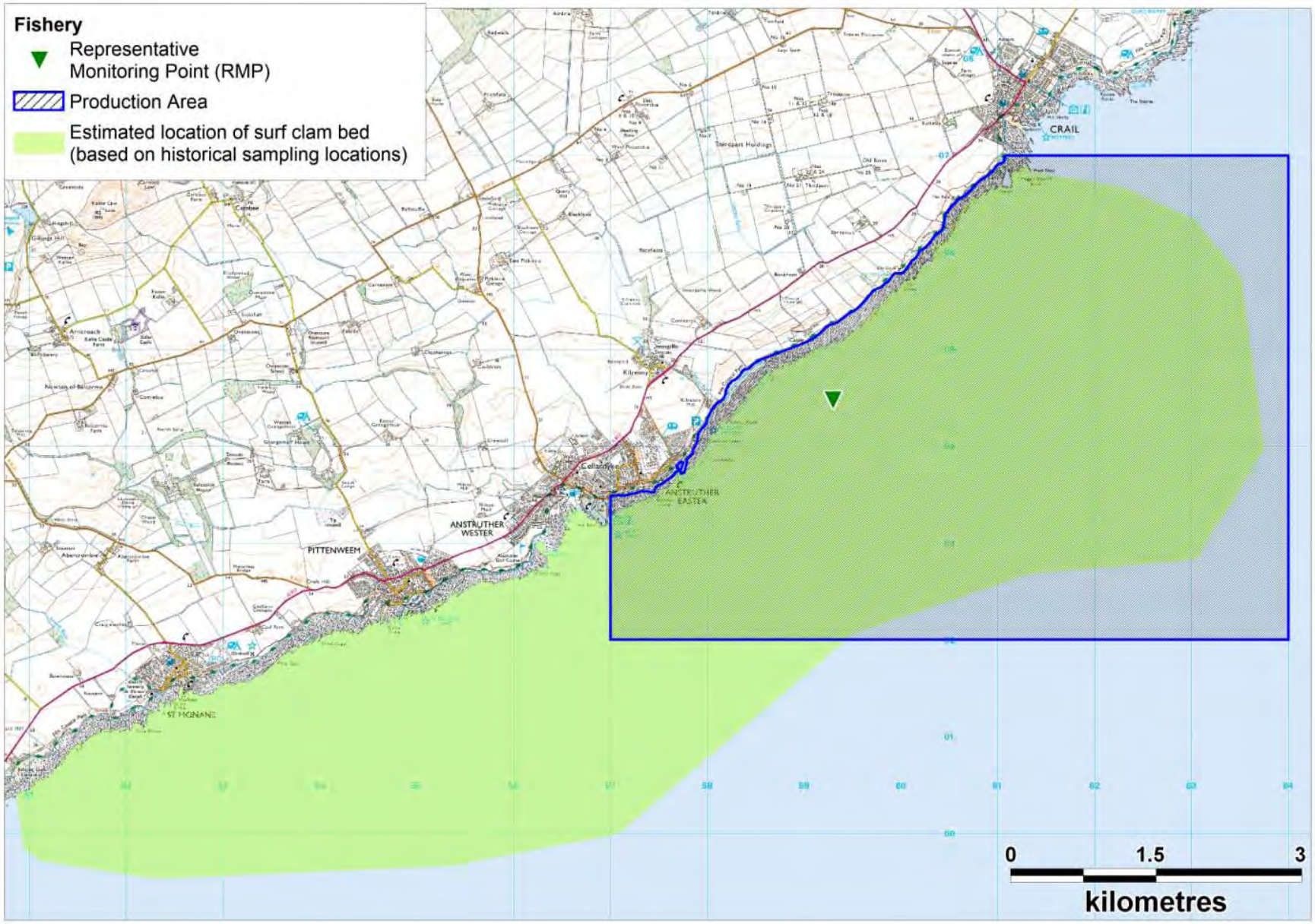

Fishery
Representative Monitoring Point (RMP)
Production Area
Estimated location of surf clam bed (based on historical sampling locations)
CRAIL
ANSTRUTHER WESTER
ANSTRUTHER EASTER
PITTENWEEM
ST MONANS
0
1.5
3
kilometres

Figure 2.1 Forth Estuary; Anstruther 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 Forth Estuary: Anstruther. The last census was undertaken in 2001. The 2011 census data was unavailable at the time of writing this report, however updated population totals for the towns of Crail, Anstruther (split into two boroughs Wester and Easter) and Pittenweem were available from the 2013 Fife Council website (www.fifedirect.org.uk). The census area data shown in Figure 3.1 is from the 2001 census and the town population totals are from the 2013 Fife council website.

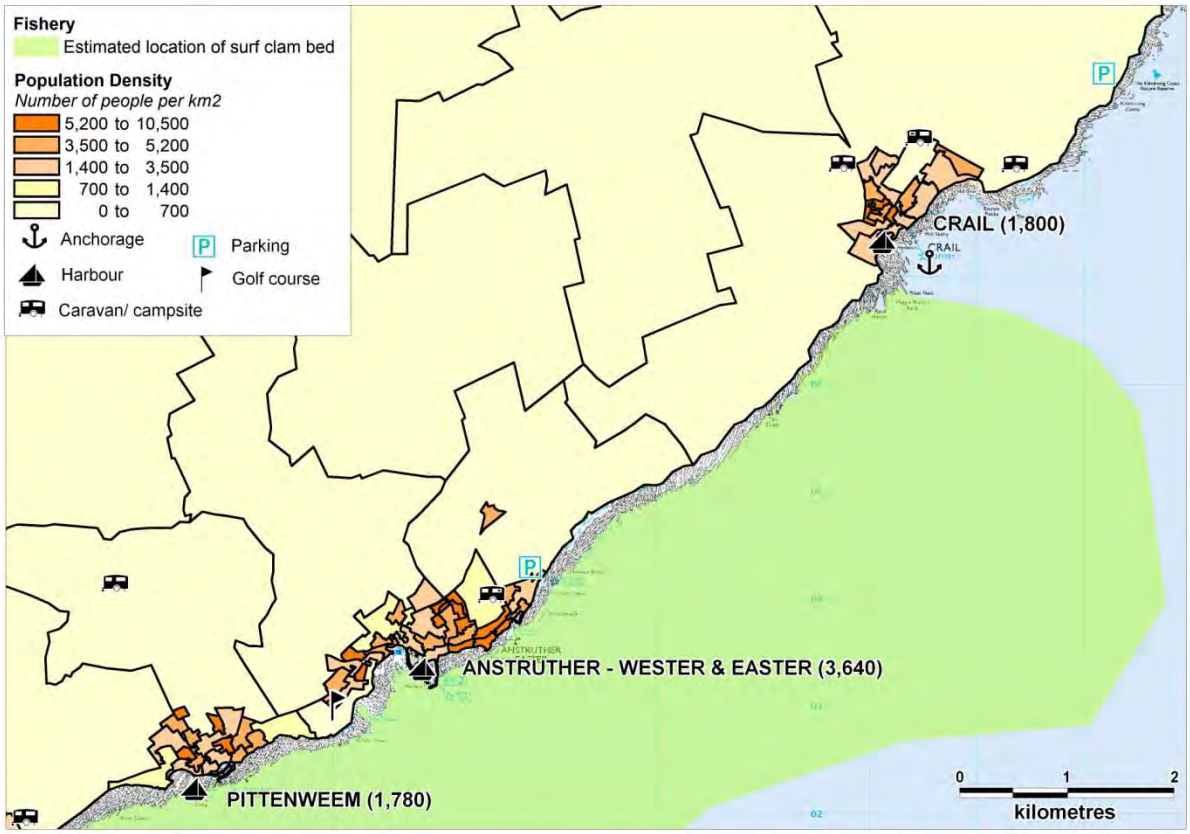


Figure 3.1 Population map of Forth Estuary: Anstruther

Figure 3.1 shows that population density is high for the census output areas representing the towns of Pittenweem, Anstruther Wester and Easter and Crail. The population density for the surrounding census output areas is low. Pittenweem and Crail lie just outside of the production area boundaries. Anstruther is located at the southwest end of the production area.

Anstruther has a primary and secondary school and tourist accommodation including hotels, bed & breakfasts and self-catering units. The area has lots of golf courses and is popular with tourists. The number of visitors to the area is expected to increase in the summer months.

Pittenweem, Anstruther and Crail have harbours. Pittenweem harbour is a primarily a commercial fishing harbour and is not normally visited by leisure boats (Fife Council, 2013). There is a fish market on the Pittenweem harbour side. Anstruther harbour has visitor facilities, approximately 400 metres of pier side berthing, 100 serviced berths for pleasure boats and 8 pontoon berths for visitors (Fife Council, 2013). Crail harbour is used by several fishing boats, approximately 12 seasonal craft and 2 berths for visitors. During the shoreline survey, 24 boats were observed 11 of which were identified as fishing boats. Approximately 100 boats were seen at Anstruther Harbour. Given that the shoreline survey was conducted in winter, it is likely that the numbers of boats present would be higher in summer during the traditional yachting season. There are no pump-out facilities for onboard sewage wastes at any of the three harbours. An anchorage lies just off the southeast end of Crail.

There are numerous caravan and campsites along the coastline. There are three caravan/campsites near Crail, two near Pittenweem and another in Anstruther Wester. The Anstruther Wester holiday park currently comprises of 30 touring pitches and 30 holiday home bases with plans to expand to 125 units in the future (Silverdyke Park, 2013).

Due to the large size of Anstruther and the close proximity of Pittenweem and Crail to the production area, it is likely that sewage discharges from both settlements will contribute to the faecal contamination of the shellfish bed. Due to the number of caravan sites in the area, it is expected that the population in the area will increase significantly during the summer holiday months. Any overboard discharges from boats using the Crail anchorage could have a significant impact on water quality at the northern end of the production area, which extends to the south end of Crail. Impacts from human sources to the water quality of the shellfish bed are likely to be seasonal, peaking during the summer months when visitor numbers are higher.

4. Sewage Discharges

Information on sewage discharges to the area around Forth Estuary: Anstruther was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Scottish Water identified 45 continuous and intermittent discharges for the area. Those that discharge to the Firth of Forth within 3 km of the production area and to watercourses discharging within or near the production area are considered of greatest significance to the fishery. Table 4.1 presents the details of the significant discharges.

Table 4.1 Scottish Water discharges, Anstruther area

Ref No.	NGR	Name	Discharge Type	Level of Treatment	Consent Flow (m^3/d)	Note
R7157	NO 6392 0835	Crail Kilminning WWTW	Continuous	6mm screen	1045	LSO
CAR/L/1001258	NO 5907 0390	Cornceres WWTW	Continuous	5 mm screen	1700	LSO
CAR/L/1001330	NO 5650 0208	Billowness WWTW and CSO	Continuous/ Intermittent	Screened (CSO 5mm screen)	2320	LSO
CAR/L/1001063	NO 538 017	ST Monans WWTW	Continuous	6mm screen	1150	LSO
CAR/L/1001316	NO 531 065	Carnbee ST	Continuous	Septic tank	9.1	To Dreel Burn
2425	NO 5374 0527	Ovenstone ST	Continuous	Septic tank	4.6	To Dreel Burn
CAR/L/1003755	NO 5203 0437	Arncroach WWTW and CSO	Continuous/ Intermittent	Secondary (CSO 6mm screen)	39	-
CAR/L/1087331	NO 6207 0782	Sauchope SPS CSO/EO	Intermittent	6mm screen	-	-
	NO 6164 0754	Kirk Wynd SPS CSO/EO	Intermittent	6mm screen	826	-
	NO 6105 0747	Lamont Terrace CSO	Intermittent	-	-	-
	NO 6130 0639	Crail Harbour CSO/EO	Intermittent	6mm screen	357	-
CAR/L/1084601	NO 5827 0436	Kilrenny Mill SPS CSO/EO	Intermittent	12 mm screen	398	-
	NO 5678 0436	Skinfast Haven SPS CSO/EO	Intermittent	10 mm screen	1301	-
	NO 5708 0349	Murray Square CSO	Intermittent	-	-	-
CAR/L/1026393	NO 5651 0311	Bankwell Road CSO/EO	Intermittent	5mm screen	209	-
	NO 5657 0333	Esplanade CSO/EO	Intermittent	12mm screen	740	-
	NO 5507 0246	Gyles SPS CSO/EO	Intermittent	-	-	-
	NO 5543 0225	Mayview SPS CSO/EO	Intermittent	12 mm screen	249	-
CAR/L/1026353	NO 5462 0222	West Shore CSO/EO	Intermittent	-	-	-

-No value given ; CSO=Combined Sewer Overflow; EO=Emergency Overflow; WWTW=Waste water treatment works; SPS= Sewage pumping station; LSO=Long Sea Outfall

Data was also requested for consented /design population equivalent (PE), predicted spill frequency, microbiological data, other effluent quality data, planned improvements, modelling studies and the proportion of the community on the

system. This data was not provided. The discharges in the table are shown mapped in Figure 4.1. Cornceres WWTW final effluent and Crail Harbour, Kilrenny Mill and Murray Square CSOs discharge directly to the production area. The Skinfast Haven CSO discharge location plots over 1 km inland and this considered to be an error as it is likely to discharge to sea at Skinfast Haven, within the production area boundaries. The large majority of discharges to this area receive preliminary treatment by screening. The three smallest continuous discharges receive septic tank or secondary treatment and discharge to Dreel Burn or its tributaries. No plans were identified for future improvement of any of the discharges. The continuous daily loading direct to sea within the production area would be 1.7×10^{14} *E.coli*/100 g, with that carried via Dreel Burn estimated at 1.1×10^{12} *E. coli*/day. Daily loadings were estimated based on the following assumptions:

- flow data provided by SW is consented DWF and representative of continuous flows,
- all discharges identified as screened are considered as crude,
- Bacteriological content of effluent is assumed to be 1.0×10^{7} *E. coli/*100 ml for crude sewage, 5.0×10^{6} *E. coli/*100 ml for primary treated (septic tank) sewage, and 1.0×10^{6} *E. coli*/100 ml for secondary treated sewage.

SEPA provided information on a large number (255) of consented discharges. A subset of 127 were located within the mapping area used in Figure 4.1. Table 4.2 presents a summary of the SEPA discharge data for the mapped area.

Table 4.2 Summary of discharge consents identified by SEPA

Type	Number of consents
Associated with public sewerage network	30
Private discharges to water	29
Private discharges to land or soakaway	68

Discharges associated with the public sewerage network are identified in Table 4.3. Not all discharges identified by Scottish Water were reflected in the SEPA dataset, and a number of assets identified as CSO or CSO/EO by Scottish Water were identified as Emergency Overflow (EO) by SEPA. Data on the geographic location of some discharges differed by up to 900 metres between the two datasets. Information provided in the Shellfish Growing Waters report, produced by SEPA, in some cases did not agree with other data provided by SEPA both in terms of consent reference and location. The most significant differences were for the Crail Harbour CSO, for which the three different sources gave three locations up to 2 km apart. It was not possible to cross validate flow volumes between the datasets, as SEPA did not report consented volumes, though PE information was obtained from the shellfish growing waters (SGW) report for a few discharges.

Table 4.3 Discharge consents identified by SEPA to Anstruther

No	Consent Ref.	NGR	Name	Discharge Type	Level of Treatment	PE or (DWF)*	Discharge to
1	CAR/L/1001337	NO 6339 0854	Crail Kilminning STW	FE	Preliminary	0	Coastal waters
2	CAR/L/1001258	NO 5908 0433	Cornceres STW Kilrenny	FE	Preliminary	0	Firth of Forth
3	CAR/L/1001330	NO 5606 0266	Billowness STW	FE	Preliminary	2320	Firth of Forth
4	CAR/L/1001063	NO 5385 0190	Pathhead STW, St. Monans	FE	Preliminary	1150	River Forth Estuary
5	CAR/L/1001316	NO 5317 0640	Carnbee Village STW	FE	Primary	1	U/T of Dreel Burn
6	CAR/L/1003755	NO 5204 0437	Arncroach Village STW, CSO/SSO	FE, CSO/SSO	Secondary	150 39	U/T of Dreel Burn
7	CAR/L/1087331	NO 6207 0782	Sauchope PS CSO, EO	CSO/EO	-	-	Firth of Forth
8	CAR/L/1003823	NO 6170 0764	Kirk Wynd PS CSO	CSO	-	-	-
9	CAR/L/1087331	NO 6105 0747	Lamont Terrace CSO	CSO	-	-	Firth of Forth
10	CAR/L/1087331	NO 6126 0731	Harbour PS CSO	CSO	-	-	-
11	CAR/L/1003823 CAR/L/1087331	NO 6110 0702	West Braes PS CSO, EO	CSO/EO	-	-	Firth of Forth
12	CAR/L/1003823 CAR/L/1087331	NO 6130 0739	Crail Harbour PS CSO, EO	CSO/EO	-	-	Firth of Forth
13	CAR/L/1003823 CAR/L/1087331	NO 6139 0749	Castle Walk PS CSO, EO	CSO/EO	-	-	Firth of Forth
14	CAR/L/1087331	NO 6161 0782	Kirk Wynd PS EO	EO	-	-	Firth of Forth
15	CAR/L/1003823	NO 6164 0754	Kirk Wynd PS CSO	CSO	-	-	Firth of forth
16	CAR/L/1084601	NO 5827 0436	Kilrenny Mill PS CSO	CSO	-	-	Firth of Forth
17	CAR/L/1084601	NO 5768 0371	Skinfasthaven PS CSO	CSO	-	-	Firth of Forth
18	CAR/L/1084601	NO 5708 0349	Murray Square CSO	CSO	-	-	Firth of Forth
19	CAR/L/1026393	NO 5651 0311	Bankwell Road PS CSO	EO	-	-	Firth of Forth
20	CAR/L/1026393	NO 5657 0333	Esplanade PS CSO	CSO	-	-	Firth of Forth
21	CAR/L/1026393	NO 5692 0380	St Andrews Rd PS CSO	CSO	-	-	U/T of Dreel Burn
22	CAR/L/1026393	NO 5543 0253	Mayview PS CSO	CSO	-	-	Firth of Forth
23	CAR/L/1026353	NO 5462 0222	West Shore CSO	CSO	-	-	Firth of Forth
24	CAR/L/1026353	NO 5274 0162	East Shore PS CSO	CSO	-	-	Firth of Forth
25	CAR/L/1026353	NO 5220 0150	Braehead PS CSO	CSO	-	-	St. Inverie Burn
26	CAR/L/1026353	NO 5226 0144	Burnside PS EO	EO			Inverie Burn

- No value given * PE=population equivalent, DWF = Dry Weather Flow (m^3/d) U/T=unnamed tributary FE=Final Effluent

A large number of private discharges to soakaway and to watercourses were identified for properties outside the villages served by the public sewerage network. Two of these, identified in Table 4.4, are located close to MHWS.

Table 4.4 Soakaways near shore

Licence	NGR	Description	Treatment	PE	Discharge to	Distance to MHWS
CAR/R/1054161	NO 5912 0523	Private property	ST	12	Soakaway	70 m
CAR/R/1063576	NO 5908 0515	7 properties	ST	40	Soakaway	20 m

The second of the two septic tank serves a relatively large population for a private tank and is situated very close to the high water line. There is a risk to water quality along the shore should higher than normal tides reach the soakaway field or should the soakaway field be too near the water table to operate efficiently.

One discharge consent was received for trade effluent associated with a dairy farm that also produces cheese and operates a cafe. No information was provided with regard to the consent conditions and therefore it is not clear whether this effluent includes septic waste from the farm and cafe.

Observations relating to sewerage infrastructure and discharges made during the shoreline survey are listed in Table 4.5. Observations were mainly clustered around the towns of Crail and Anstruther Wester. Although some pipes were observed in other locations along the shoreline, not all of these were clearly associated with discharges of human sewage and therefore are not presented here.

Table 4.5 Discharges and septic tanks observed during the shoreline survey

No	Date	NGR	Description
1	15/01/2013	NO 5638 0322	Large concrete structure leading out to the bay with no access to end of pipe.
2	15/01/2013	NO 5651 0311	End of large plastic discharge pipe with small flow (35 cm Ø ; ~10 ml/s flow rate)
3	15/01/2013	NO 5658 0333	Large concrete sewage pipe into the bay. Diver/workers fitting large hood to its end. Some visible discharge with no access to sample it.
4	15/01/2013	NO 5652 0355	Overflow from manhole at Dreel burn - running into the bay- heavily overflowing. Strong smell of sewage.
5	15/01/2013	NO 5685 0346	Outfall pipe into harbour. Only visible at low tide but not sampled due to unsafe access.
6	15/01/2013	NO 5733 0356	Manhole cover in base rock/concrete on foreshore. Visible concrete section runs parallel to shoreline and connects to another built stone structure further south on the shore.
7	15/01/2013	NO 5766 0377	Two manhole covers on street, one on foreshore. Outflow could not be located.
8	15/01/2013	NO 5812 0448	Sewage collection chamber, possibly Scottish Water, not confirmed as no signs are visible.
9	16/01/2013	NO 6260 0804	Assumed sewage box in Sauchope Link Caravan Park, just outside Crail to the east.
10	16/01/2013	NO 6207 0787	Scottish water sewage chamber.

No	Date	NGR	Description
11	16/01/2013	NO 6195 0791	Discharge on beach, cement block with 3 discharge pipes 2 plastic diameter 10cm 1 metal diameter 20cm. Sample taken from 20cm pipe, strong smell, estimate flow rate 75ml/s.
12	16/01/2013	NO 6190 0787	2 metal discharge pipes one 20cm one 12cm, no flow
13	16/01/2013	NO 6139 0749	Discharge pipe into bay, rusted and possibly disused.
14	16/01/2013	NO 6137 0752	Scottish water manholes and service box by castle.
15	16/01/2013	NO 6124 0741	Scottish water manholes and service box at head of discharge pipe on pier, no access to end of discharge.
16	16/01/2013	NO 6127 0740	Plastic discharge pipe 30cm width. Unable to measure flow because of high sea level, estimated flow of 600-800ml/s
17	16/01/2013	NO 6113 0742	Discharge from 20cm lidded valve flow estimated 25ml/s Immediately adjacent large orange pipe with little flow- no sample taken no photo taken.
18	16/01/2013	NO 6110 0742	Stream or possibly discharge running down hill through pipe. The pipe is broken above beach water/discharge running freely into sand. Flow variable estimated at 300-600ml/s in pulses.
19	16/01/2013	NO 6106 0717	Sewage discharge pipe running down from hillside, no flow observed width 25cm.

Observation 4 related to an apparent overflow at a manhole cover adjacent to Dreel Burn. This location did not correspond with any of the reported CSOs. It was noted to be heavily overflowing into the bay, which suggests a system malfunction occurring at the time of the shoreline survey. A water sample taken from the overflow returned a result of 800000 *E. coli cfu*/100 ml, confirming that the overflow was significantly contaminated with faecal waste which was presumed to be sewage.

Observation 18 was identified as possibly being a stream flow, however the variable ‘pulse’ to the flow suggested it was being pumped. A water sample taken from the outflow returned a result of 4200000 *E. coli cfu*/100 ml, which showed significant faecal content that may have been sewage. The observed flow was located at the shoreline approximately 70 m SE of the Lamont Terrace PS CSO, and may have been overflow from that source.

Observation 11 did not appear to correlate with any of the sewage infrastructure previously identified. A water sample taken from this flow was found to be only moderately contaminated (1000 *E. coli cfu*/100 ml).

No significant precipitation was recorded in the 48 hours prior to shoreline survey; therefore it is not clear whether the overflows were due to failures in the system or whether rainfall more than 2 days prior had contributed to storm system overflows.

Overall, the production area is subject to significant input of screened sewage from both continuous and intermittent sewage discharges. While the screening will remove gross solids, it will not significantly reduce the amount of microorganisms or chemical contaminants in the effluent. Most of the outfalls discharge at or near the shore, with exception of the long sea outfalls from Crail, Cornceres and Billowness

sewage treatment works (STW), which all discharge within 1 km of shore, and within the shellfish production area. The southwestern quadrant of the production area is likely to be more acutely impacted due to the presence of the Cornceres STW outfall and Dreel Burn, as well as the proximity of the Billowness STW outfall.

Due to the large number of CSOs and the observed overflows seen during the shoreline survey, it is highly unlikely that the monthly monitoring regime will accurately reflect worst case contamination levels at the shellfish bed.

Sewage-Related Acronyms

WWTW/STW	Wastewater (Sewage) treatment works	LSO	Long sea outfall
CSO	Combined sewer overflow	SSO	Settled storm overflow
EO	Emergency overflow	PE	Population equivalent
SPS/PS	Sewage pumping station	DWF	Dry weather flow
FE	Final effluent	ST	Septic tank

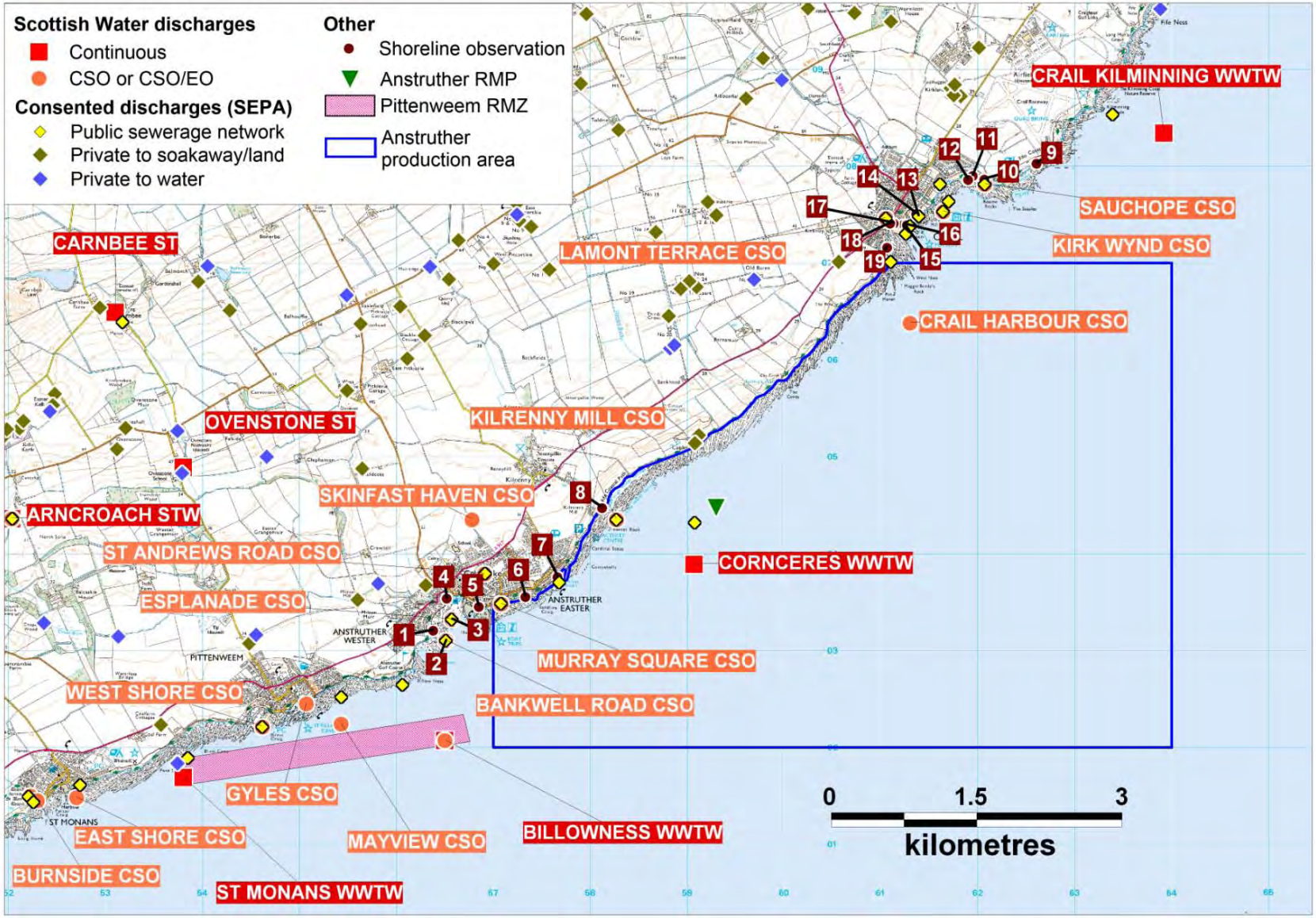


Figure 4.1 Map of discharges for Forth Estuary Anstruther

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 Pittenweem, Anstruther Wester and Easter, Kilrenny and Crail parishes. 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 agricultural parishes along the Anstruther coastline 2012

	Pittenweem		**Anstruther Wester & Easter**		**Kilrenny**		**Crail**	
	2.6 km^2		4.4 km^2		15.5 km^2		26.6 km^2	
	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers
Pigs	0	0	0	0	*	*	0	0
Poultry	0	0	0	0	10	4,124	5	8,673
Cattle	0	0	0	0	6	422	5	292
Sheep	0	0	0	0	*	*	*	*
Other horses and ponies	0	0	*	*	6	18	*	*

The agricultural parishes of Pittenweem and Anstruther Wester & Easter are very small in area and located west of the production area and no farms with livestock were reported for these parishes (see Table 5.1). The Kilrenny and Crail parishes border the production area, encompassing a total land area of over 42 km^2 (shown in the inset of Figure 5.1) and livestock were reported to be present in both areas. Relatively small numbers of cattle were reported. In the Kilrenny parish, numbers of sheep and pigs were not reported due to the small number of holdings. In the Crail parish, numbers of sheep and horses were not reported. Kilrenny and Crail parishes both host large poultry farms, though the locations of these relative to the fishery are not known.

The SEPA Ellie to Fife Ness Shellfish Growing Waters report (2011) identifies that the area is very fertile and almost exclusively used for arable farming. Slurry is spread on arable fields in the area (Pittenweem Shoreline Survey Report, 2008), though no information is available regarding location, timing or amount.

An additional 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 on 15th January 2013 (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.

During the shoreline survey a large pig farm was seen on the shoreline east of Anstruther Easter and over 100 pigs (not including piglets) were observed. The weather was bad during the shoreline survey so it is possible more pigs were present in the pens at the pig farm. A small number of sheep were seen in a fenced area near a burn further east of the pig farm (see Table 5.2).

Table 5.2 Livestock observations during shoreline survey

No.	Date	NGR	Livestock observation	Sample result (*E. coli cfu*/100ml)
1	15/01/2013	NO 5812 0448	Pig farm site with about 20 pig huts visible. Due to bad weather only about 6-8 pigs were out.	n/a
2	15/01/2013	NO 5871 0498	Another part of pig farm with smaller huts (approximately 100) with sows and piglet in nearly all of them. Plastic outfall pipe to shoreline from pig farm. Water sample taken	51000
3	15/01/2013	NO 5975 0563	8-10 sheep in a fenced area very close to burn.	n/a
4	15/01/2013	NO 5826 0468	Old, concrete outfall pipe with a broken end discharging onto shore from pig farm. Water sample taken.	41000
5	15/01/2013	NO 5836 0477	Old concrete discharge pipe, possibly land drain from pig farm. Insufficient flow to sample.	no sample

Sows breed all year round (Living Countryside , 2013) and photographs taken of the farm showed the land to be heavily waterlogged. Several drains appeared to carry run-off from the area of the pig farm to the shore. Water samples were collected from the outflow of two of these, while the third was not flowing sufficiently to sample. Both samples returned high results consistent with heavy faecal contamination.

The pig farm is likely to be the most significant source of agricultural contamination to the fishery. Due to the location of the farm directly adjacent to the shoreline, rainfall is likely to lead to significant drained and overland flow of pig waste directly to the waters of the Firth.

Sows breed all year round (Living Countryside , 2013), therefore numbers of pigs are not anticipated to show significant seasonal variation. NetRegs government website states that livestock slurry must not be spread on waterlogged, snow covered or frozen land (NetRegs, 2013) so it is likely that slurry will be spread more in spring and summer. However, where slurry is generated directly adjacent to the coast (as at the pig farm) it is likely to be washed into watercourses and the sea when it rains.

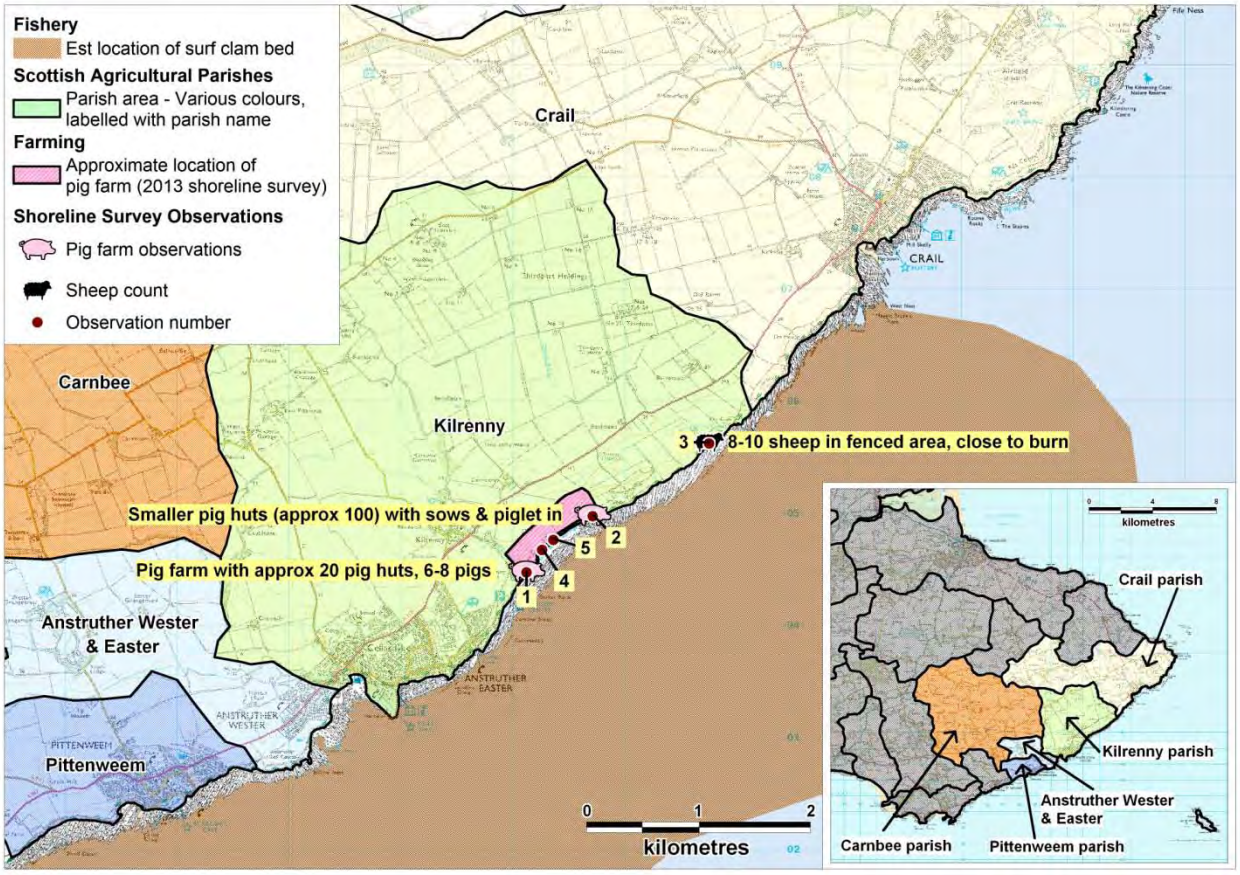


Figure 5.1 Agricultural parish boundary and livestock observations

Risk Table

Production area	Site	Factor - Livestock	Risk
Forth Estuary: Anstruther	Anstruther	Overall low numbers of livestock; however pig farm is situated right on the production area coastline. Inland areas are almost used exclusively for arable farming. Slurry spreading occurs.	Low – medium Varies spatially across the fishery.

6. Wildlife

Pinnipeds

The common/harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*) are commonly found in the Forth Estuary. No population estimates were available for seals around Anstruther at the time of this report.

The Isle of May to the southeast of Anstruther is a designated Special Area of Conservation (SAC) for grey seals and holds the fifth largest grey seal breeding colony in the UK. The population is estimated to be around 100 seals, though during the pupping season (autumn-winter) the population surges to around 4,000, with 4,249 grey seal pups born in 2010 (Special Committee on Seals, 2011). There are also two minor grey seal colonies further into the Firth of Forth (Duck, 2010). Common seals are also regularly spotted further into the Forth Estuary, preferring the sheltered shorelines for hauling out. It is likely that they will also forage around Anstruther waters.

No seals were observed at the time of the shoreline survey. However, the foraging behaviour of both grey and common seals suggests that they are likely to use the waters around Anstruther from time to time.

Cetaceans

The harbour porpoise (*Phocoena phocoena)* is commonly seen in the Forth Estuary. Also common are Bottlenose dolphins (*Tursiops truncatus*) which form a distinct population known as the north-east Scotland group. This group is estimated to be made up of 130 individuals and its home range includes the Forth Estuary (Wildlife Extra, 2012)

Twenty different cetacean species in total have been seen in the Forth Estuary, including Killer whales, Pilot whales, Sperm whales and White beaked dolphins (SeaWatch Foundation, 2007). Numbers of cetaceans around Anstruther are hard to predict, and as it is unlikely that they will come close to the shallow shoreline their faecal contamination risk is assumed to be small. No cetaceans were observed during the shoreline survey.

Seabirds

Seabird 2000 census data (Mitchell, et al., 2004) was queried for the area within a 5 km radius of the Anstruther production area and is summarised in Table 6.1 below. This census was undertaken between 1998 and 2002 covered the 25 species of seabird that breed regularly in Britain and Ireland.

Table 6.1 Seabird counts within 5 km of Anstruther

Common name	Species	Count*	Method
Northern fulmar	*Fulmaris glacialis*	42	Occupied sites

There were four separate observations of Northern fulmar occupied sites around Anstruther, which are shown in Figure 6.1. These observations were found to the north of the Anstruther production area, surrounding the town of Crail. It is likely that these nesting birds will use the shoreline along Anstruther, though they will have a significant contamination impact on the area around their nests.

The Isle of May (an island adjacent to Anstruther) is also an important area for many seabirds. It is reported that there are 50,000 puffin breeding pairs and is stated as the UK's top puffin breeding area. Other birds that breed on the Isle of May include: the European shag, guillemot, herring gull, gannet, kittiwake, razorbill, fulmar, lesser black-backed gull, common eider, Arctic tern, sandwich tern and the common tern (Anstruther Pleasure Cruises , 2013). Species potentially impacting on Anstruther include a number of different seabirds and seals. However, the impacts of these on the fishery will be unpredictable, and deposition of faeces by wildlife is likely to be widely distributed around the area and so will not be considered in the determination of sampling plans.

During the shoreline survey five separate seabird observations were recorded to the west of the Anstruther fishery production area. These included several observations of flocks of gulls, unidentified seabirds and 45 mallards. No observations of bird droppings were made during the shoreline survey, though it is likely that such dense numbers of birds will have an impact on contamination entering the water surrounding the fishery.

Overview

Species potentially impacting on Forth Estuary: Anstruther include seals, cetaceans and seabirds as well as waders and waterfowl. However, the impacts of these on the fishery will be unpredictable, and deposition of faeces by wildlife is likely to be widely distributed around the area and so will not be considered in the determination of sampling plans.

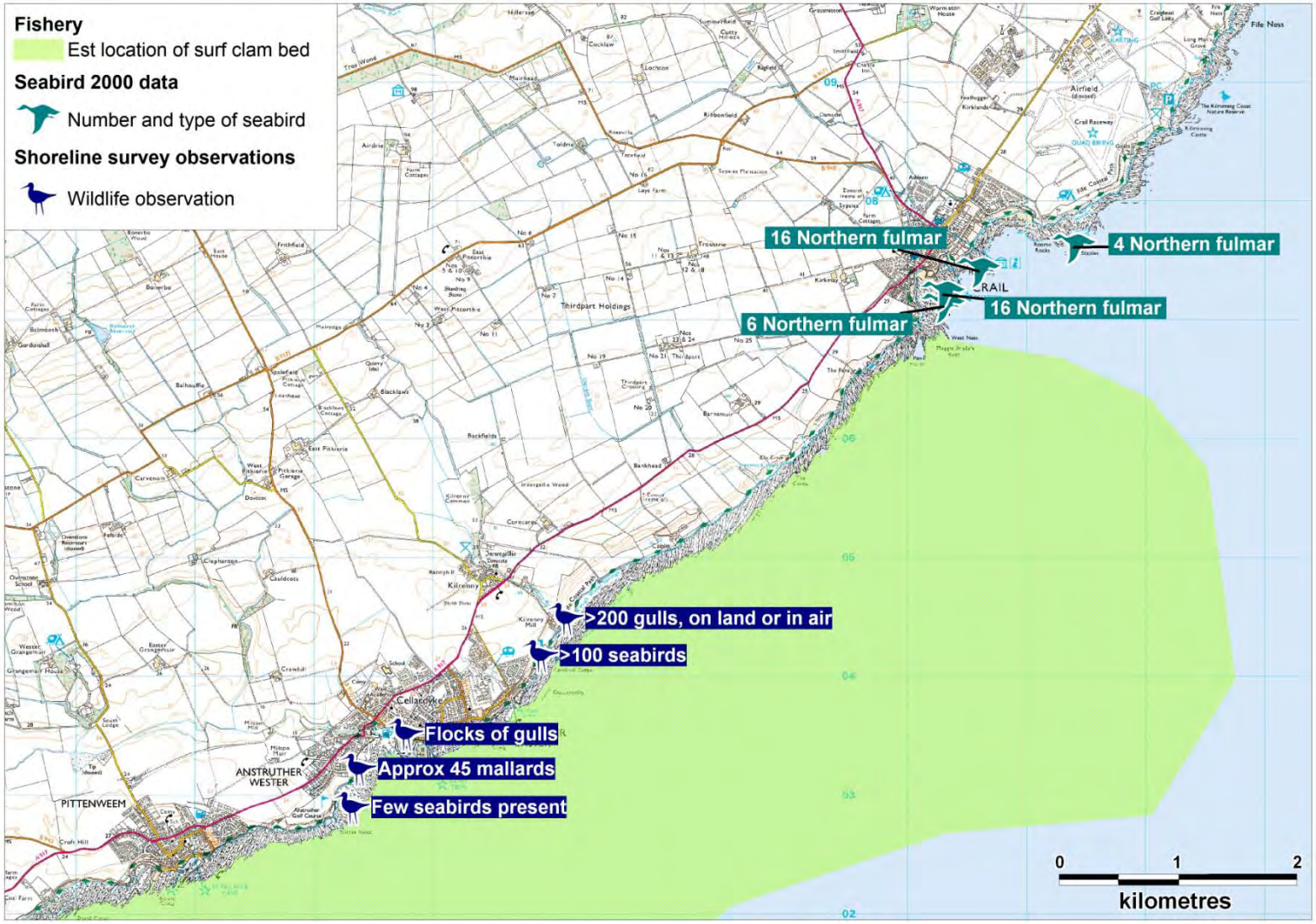


Figure 6.1 Wildlife observations around Forth Estuary: Anstruther

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 Anstruther

Arable, improved grassland and rough grassland are the predominant land cover types on the low-lying shoreline adjacent to the Anstruther shellfish bed. The towns of Pittenweem, Anstruther and Crail are shown as suburban, urban and urban industrial areas, surrounded by arable land and improved grassland. Crail race track is shown as an urban industrial area north east of Crail. The majority of the developed area of Anstruther Easter and strips of improved grassland border the production area.

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., 2008a). 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., 2008a).

The highest potential contribution of contaminated run-off to the Anstruther shellfish bed is from the suburban/urban areas of Anstruther, Pittenweem and Crail and the

areas of improved grassland located along the shoreline. The potential contribution of contaminated run-off to the shellfish farm would be highest in these areas and areas of rough grazing especially from the pig farm situated east of Anstruther. 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 current public river gauging stations on watercourses discharging to the Forth Estuary at Anstruther. The Shellfish Growing Water report for Fife Ness to Elie identified that the watercourses in the area drain catchments with significant arable farming and that Dreel Burn, Balmonth Burn (a tributary to Dreel Burn), and Kilrenny Burn are impacted by diffuse agricultural pollution, although one estate on the Dreel Burn had taken steps to reduce its impact on the burn.

The following 8 watercourses listed in Table 8.1 were observed during the shoreline survey and represent the largest freshwater inputs into the survey area. No significant precipitation fell in the two days prior to the survey, or during the two survey days. However, intermittent snow/sleet and rain showers fell on the first day of survey (15th January 2013), with heavy snow flurries falling intermittently on the final day (16th January 2013).

Table 8.1 Watercourse loadings for the Forth Estuary Anstruther

No	NGR	Description	Width (m)	Depth (m)	Flow (m/s)	Flow (m^3/d)	*E. coli* (cfu/100ml)	*E. coli* (Loading per day)
1	NO 5655 0352	Dreel Burn	7.00	0.15	0.275	24073	Not sampled	Not determined
2	NO 5812 0448	Kilrenny Burn	3.00	0.04	0.914	9471	< 1000*	$< 9.5x10^9$
3	NO 5929 0529	Stream	0.40	0.08	1.653	4570	200	$9.1x10^9$
4	NO 5975 0563	Dennet Burn	1.60	0.23	0.610	19395	4600	$8.9x10^{11}$
5	NO 6012 0596	Burn	1.18	0.34	0.317	10988	900	$9.9x10^{10}$
6	NO 6164 0777	Stream outflow over harbour wall	0.70	0.06	0.347	1259	1000	$1.3x10^{10}$
7	NO 6152 0759	Stream	0.90	0.08	2.205	13717	100	$1.4x10^{10}$
8	NO 6100 0692	Stream	Not measured or sampled					Not determined

*A nominal assumed value of 1000 *E. coli cfu*/100 ml was used to calculate a 'less than' potential loading. NGRs rounded to 10 m, full NGRs found in Appendix 1.

The geographical extent of the watercourses sampled stretch from Anstruther Easter to Crail. Two watercourses; 1 and 8, were not sampled and therefore it was not possible to determine the *E. coli* loading. Watercourse 1 (Dreel Burn) was measured, and is shown to be the watercourse with the greatest flow (24073 m^3/day) into the Forth Estuary at Anstruther at the time of the shoreline survey. Unfortunately, no sample was taken at that time. A water sample taken from this burn in September 2008 for a restricted sanitary survey at Forth Estuary: Pittenweem returned a result of 30000 *E. coli cfu*/100 ml with a loading of 6.3×10^{12} *E. coli*/day , indicative of significant faecal contamination at that time. It was not possible to measure Watercourse 8, located just west of Crail, at the time of the shoreline survey. *E. coli* loadings per day were found to be relatively high amongst all watercourses sampled, and varied between $9.1x10^9$ (watercourse 3) and $8.9x10^{11}$ (watercourse 4). These

two watercourses are located close to one another, however fenced sheep were observed close to the burn represented by watercourse 4, which may partly explain variation in overall loadings. The *E. coli* sample from watercourse 4 was far greater than that in watercourse 3 at 4600 and 200 *E. coli cfu*/100 ml respectively. Furthermore, watercourse 4 had a greater width, depth and flow than watercourse 3, which will also explain the variation in *E. coli* loading per day.

Watercourse 2 represents a stream that runs alongside a caravan site and a pig farm, with an unconfirmed sewage collection chamber also reported in close proximity. Despite these factors representing high faecal contamination risks, the overall loading from watercourse 2, is relatively low at $9.5x10^{9}$ at the time of the shoreline survey. The contamination impact from agriculture is also likely to be high from watercourses 3-5 and 8. These watercourses are likely to flow past fields inland that are used for either animal and/or crop based agriculture.

Watercourses 6 and 7 enter into the Forth Estuary outside the estimated extent of the surf clam bed, but within the Anstruther production area by the town of Crail. Both watercourses had relatively high *E. coli* loadings of $1.3x10^{10}$ and $1.4x10^{10}$ respectively. Watercourse 6 represents stream outflow over the Crail harbour wall, and green algae was noted as abundant around this watercourse.

It is likely that all watercourses noted in the shoreline survey will contribute to faecal contamination entering into the production area at Anstruther. In particular, watercourses 1-4 are on land lying adjacent to the estimated clam bed. These watercourses are expected to have the greatest contamination impact on the surf clam fishery, particularly those taken from close to shore.

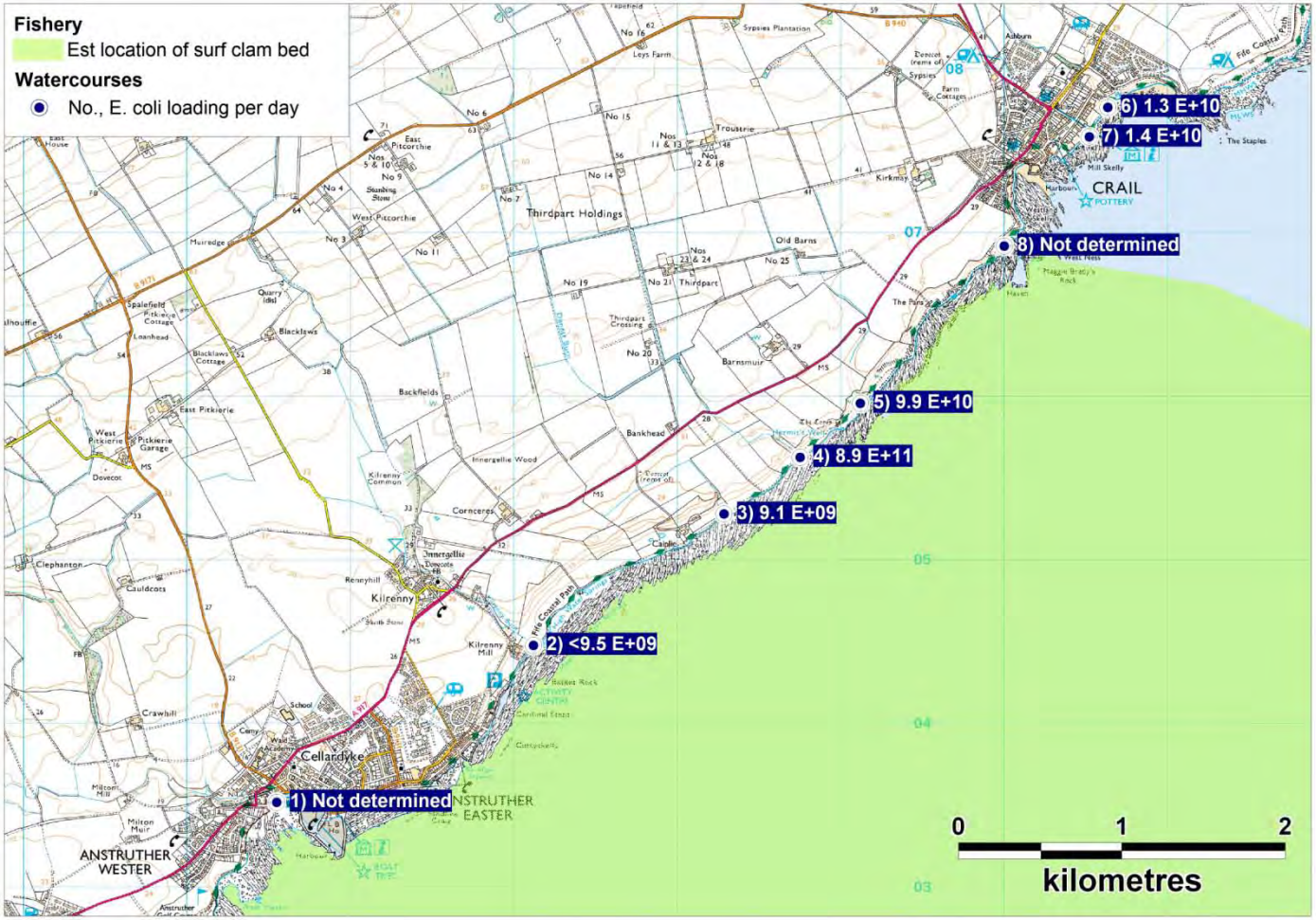


Figure 8.1 Map of watercourse loadings at Forth Estuary: Anstruther

Where the bacterial loadings is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So where normal scientific notation for 1000 is $1x10^3$, in digital format it is written as 1E+3

9. Meteorological data

The nearest weather station is located at Toldrie, situated approximately 3 km north of the production area; however data was unavailable for 22% of the days during January 2007 – August 2012. The second nearest weather station with a more complete rainfall data history is located at Belliston, situated approximately 7 km north west of the production area. Rainfall data was available for January 2007 – August 2012 at the time of writing this report. The nearest wind station is situated at Edinburgh Gogarbank, located 51 km south west of the production area. Conditions may differ between this station and the fisheries due to the 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 Forth Estuary: Anstruther.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003). 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 *.

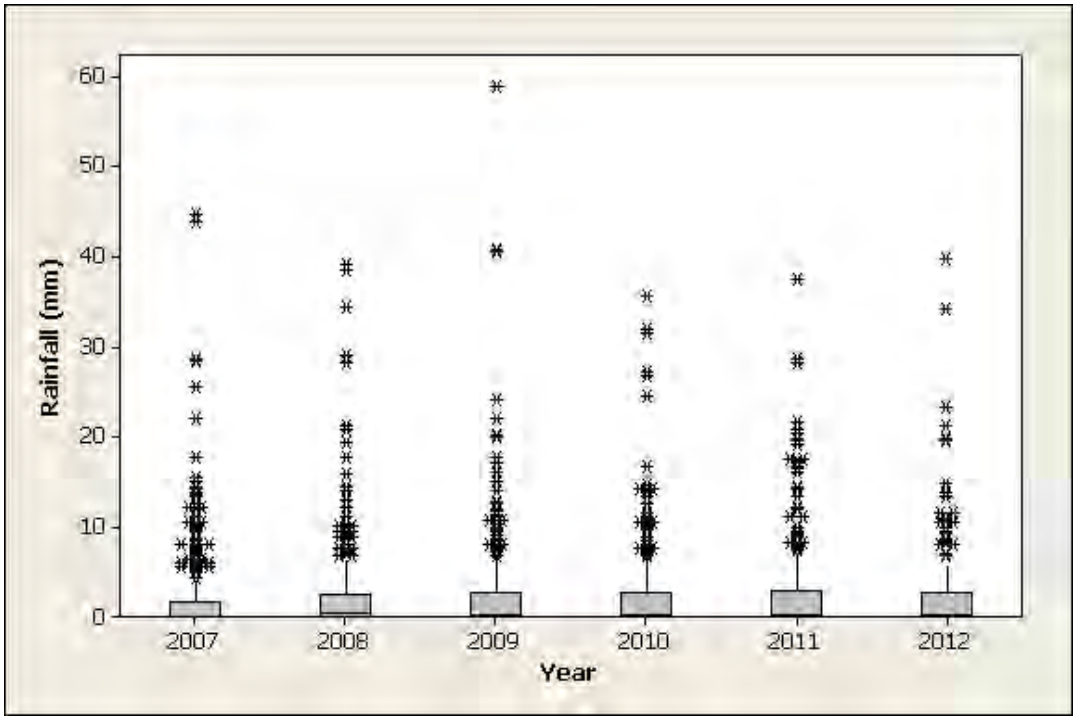


Figure 9.1 Box plot of daily rainfall values by year at Belliston (2007 – 2012)

Daily rainfall values varied from year to year, with 2007 being the driest year. The wettest year was 2011. High rainfall values of more than 30 mm/d occurred in all years but an extreme rainfall event of nearly 60 mm/d was seen in 2009.

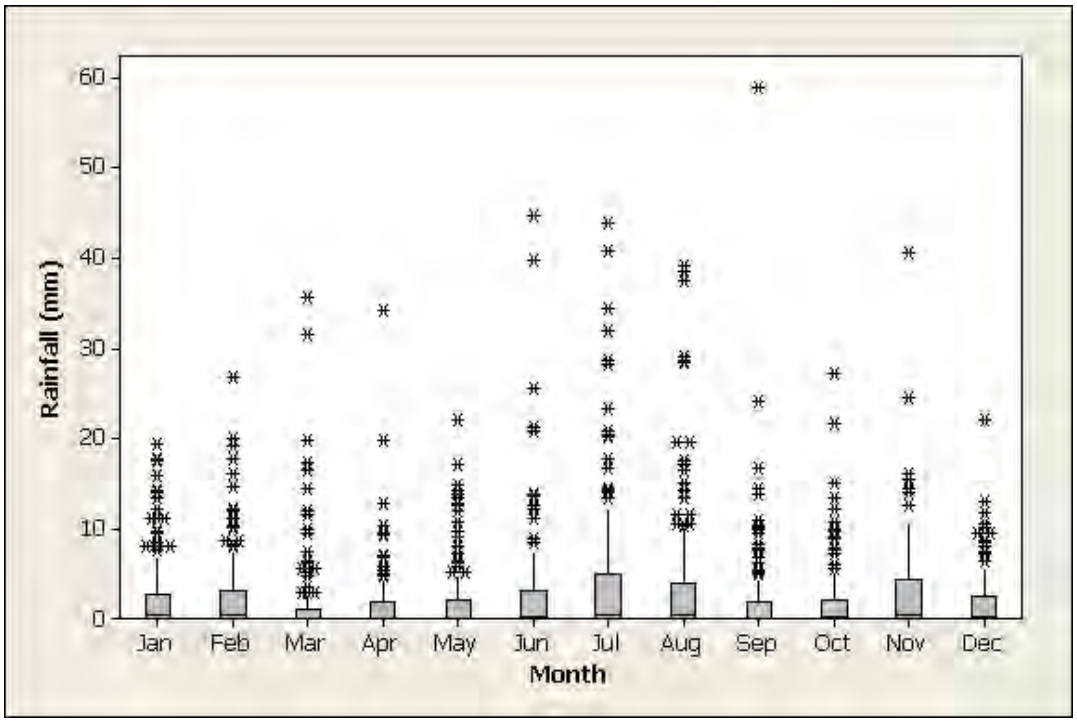


Figure 9.2 Box plot of daily rainfall values by month at Belliston (2007 – 2012)

Daily rainfall values were higher during the summer and winter. Rainfall increased from June to August and November to February and was highest in November. Weather was drier from March to May. Rainfall values exceeding 30 mm/d were

seen in all months except December, January and February (i.e. winter) and May. The 2009 extreme event occurred in September.

For the period considered here (2007 – 2012) 62% of days received daily rainfall of less than 1 mm and 6% of days received rainfall of over 10 mm.

It is therefore expected that run-off due to rainfall will be higher during the summer and winter months. However, extreme rainfall events leading to episodes of high run-off can occur in most months and when these occur during generally drier periods, 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 Edinburgh Gogarbank and summarised in seasonal wind roses in Figure 9.3 and annually in Figure 9.4.

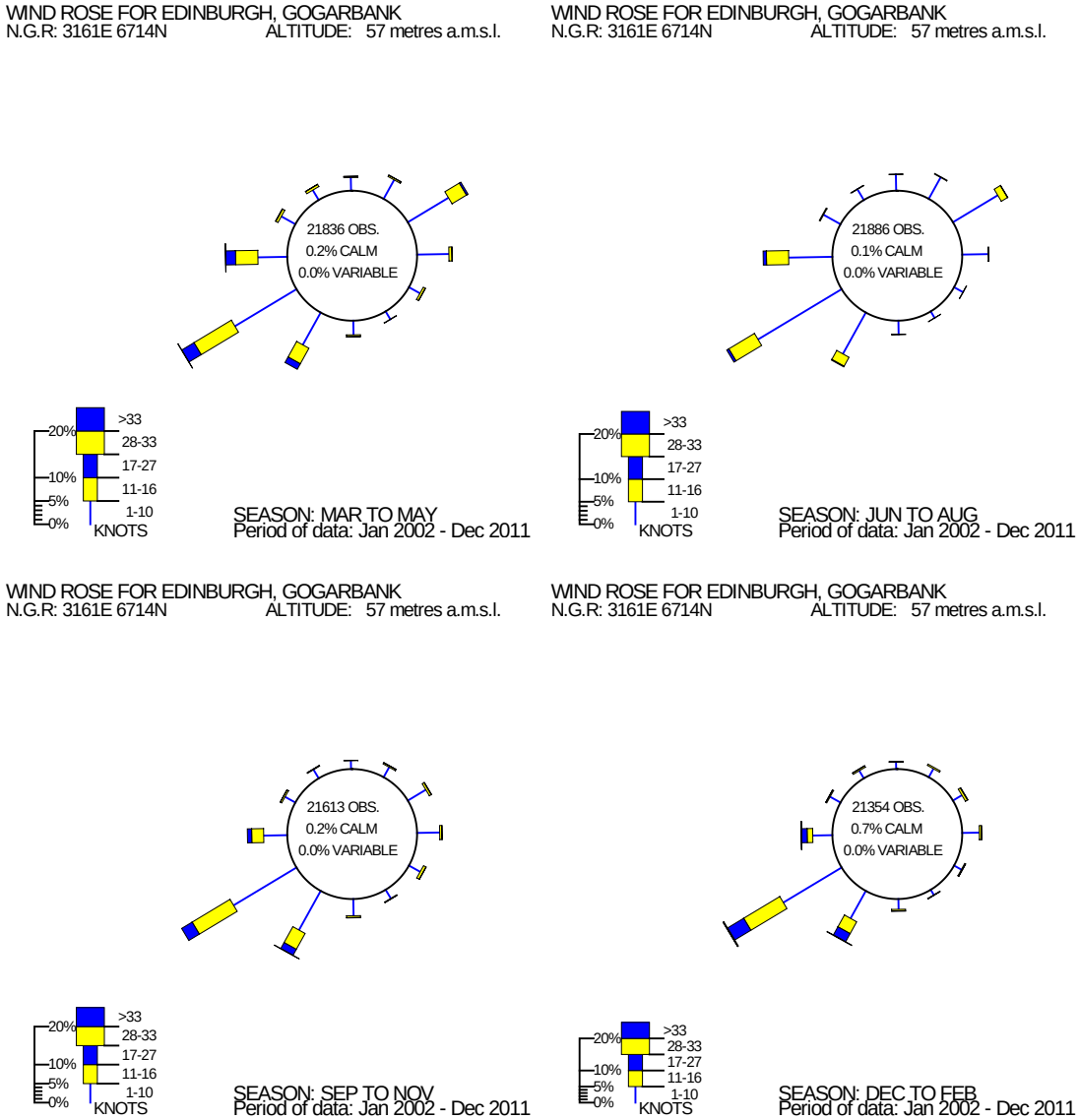


Figure 9.3 Seasonal wind roses for Edinburgh Gogarbank

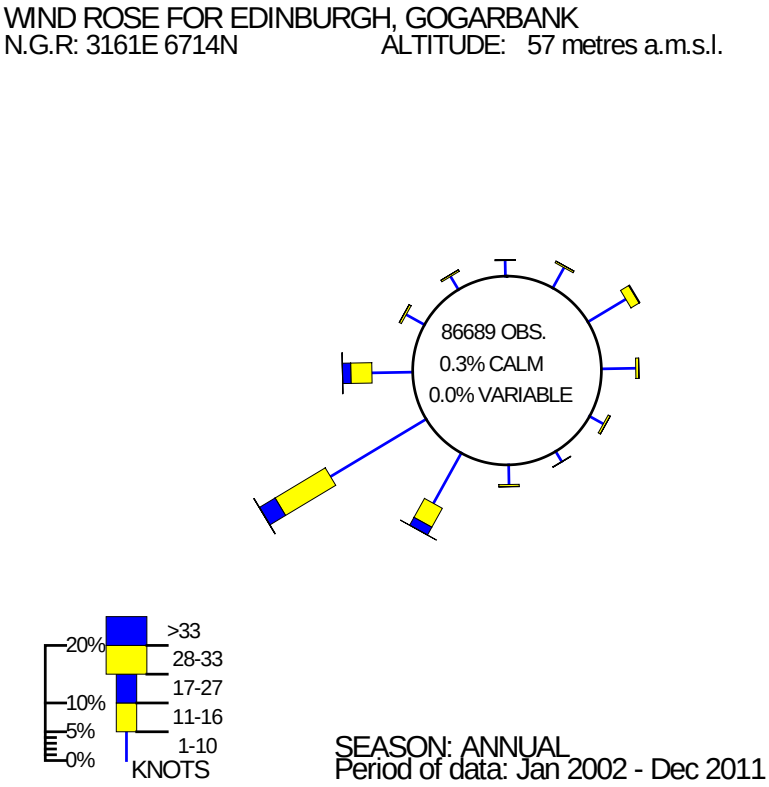


Figure 9.4 Annual wind rose for Edinburgh Gogarbank

Overall the predominant annual wind direction is WSW, along the axis of the firth. There is some wind from the ENE in the summer months. There was no marked change in wind direction throughout the months; however winds were stronger in the winter months than in the summer months.

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 surf clam production since 2008. The area has had a B classification year round both currently and historically.

The classification history since 2007 is listed in table 10.1.

Table 10.1 Forth Estuary; Anstruther (surf clam) classification history.

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

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned against Forth Estuary: Anstruther from the period 01/01/2007 to the 15/01/2013 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted from the database in January 2013. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid. One sample [VEROMARA_2011_FSA07-04871] was located in the Pittenweem Representative Monitoring Zone and was not included in the further geographical or statistical analysis.

In a previous report on sampling results from the Forth Estuary: Pittenweem production area, several samples were recorded as being taken in the Anstruther production area. Results for all samples assigned against Forth Estuary Pittenweem from the period 01/01/2007 to the 15/01/2013 were therefore extracted from the FSAS database and geographically mapped. One sample [VEROMARA_2011_FSA07-04870] was found within the Forth Estuary Anstruther production area, approximately 2.5 km southwest of the main group of results and nominal RMP. This sample will be included hereafter in the statistical analysis and geographical representation of data for the Forth Estuary Anstruther production area.

Six samples were recorded in the database as ‘rejected’ and were deleted. One sample plotted on land and was deleted. A total of 49 samples were collected and delivered to the laboratory within the 48 hr limit, and all samples had box temperatures < 8^{o}C.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results.

Sampling Summary	
Production area	Forth Estuary
Site	Anstruther
Species	Surf Clams
SIN	FF-068-184-19
Location	Anstruther
Total no of samples	49
No. 2007	9
No. 2008	6
No. 2009	7
No. 2010	4
No. 2011	10
No. 2012	13
Results Summary	
Minimum	50
Maximum	9100
Median	230
Geometric mean	331
90 percentile	2200
95 percentile	3900
No. exceeding 230/100g	13 (27%)
No. exceeding 1000/100g	9 (18%)
No. exceeding 4600/100g	2 (4%)
No. exceeding 18000/100g	0

A total of 49 samples were taken in the Forth Estuary Anstruther production area. The majority of samples were < 230 *E. coli* MPN/100g, with two samples exceeding 4600 *E. coli* MPN/100 g.

11.3 Overall geographical pattern of results

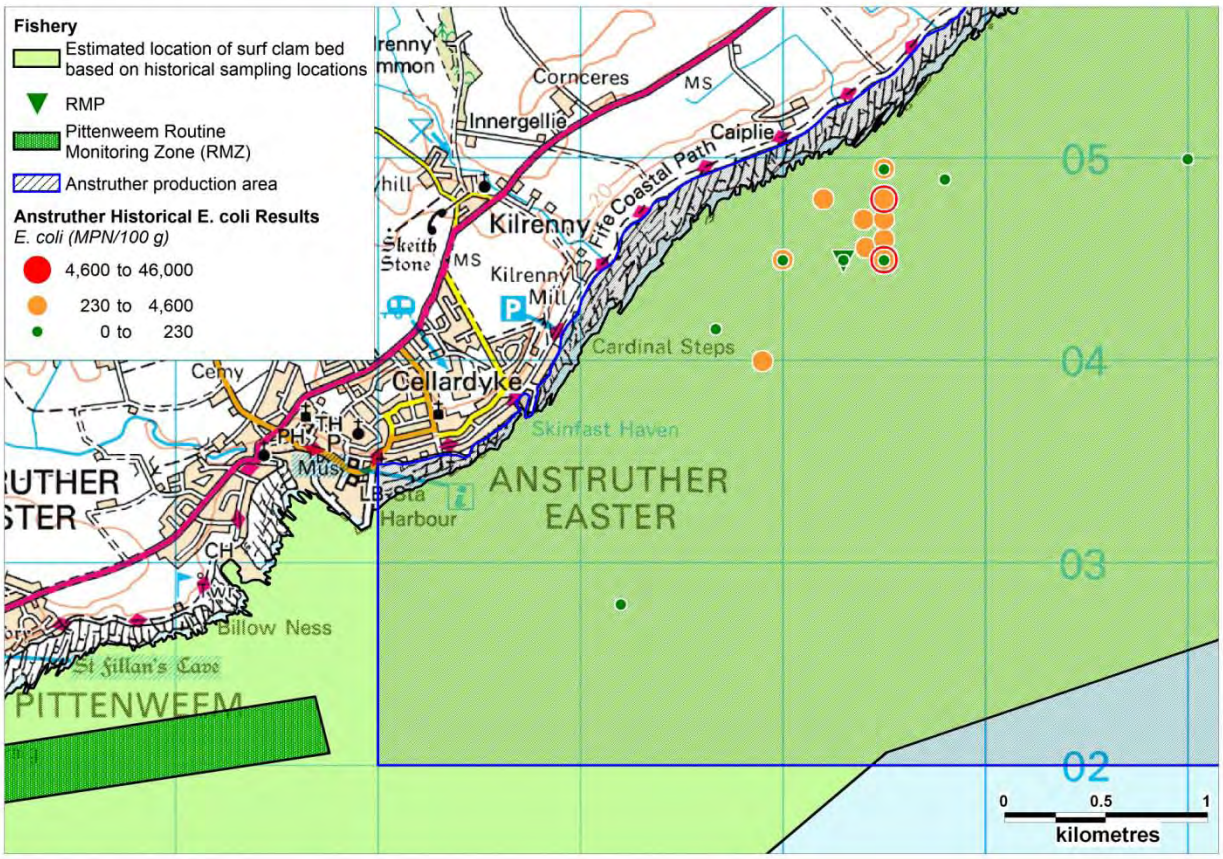


Figure 11.1 Map of Forth Estuary: Anstruther sampling result locations.

From the Forth Estuary: Anstruther historical *E. coli* data, a number of results had unverified NGRs (one sample in 2007 and all samples taken in 2012) and were therefore unable to be mapped.

Most samples were taken within a 1 km radius of the nominal RMP and there does not appear to be any geographical trend between high and low *E. coli* results. The majority of results were taken around the RMP, except for one which plotted approximately 2 km northeast [S00977-07-W] of the RMP.

A scatterplot of surf clam *E. coli* results against date is presented below. The dataset is fitted with a lowess trend line. Lowess trendlines allow 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.

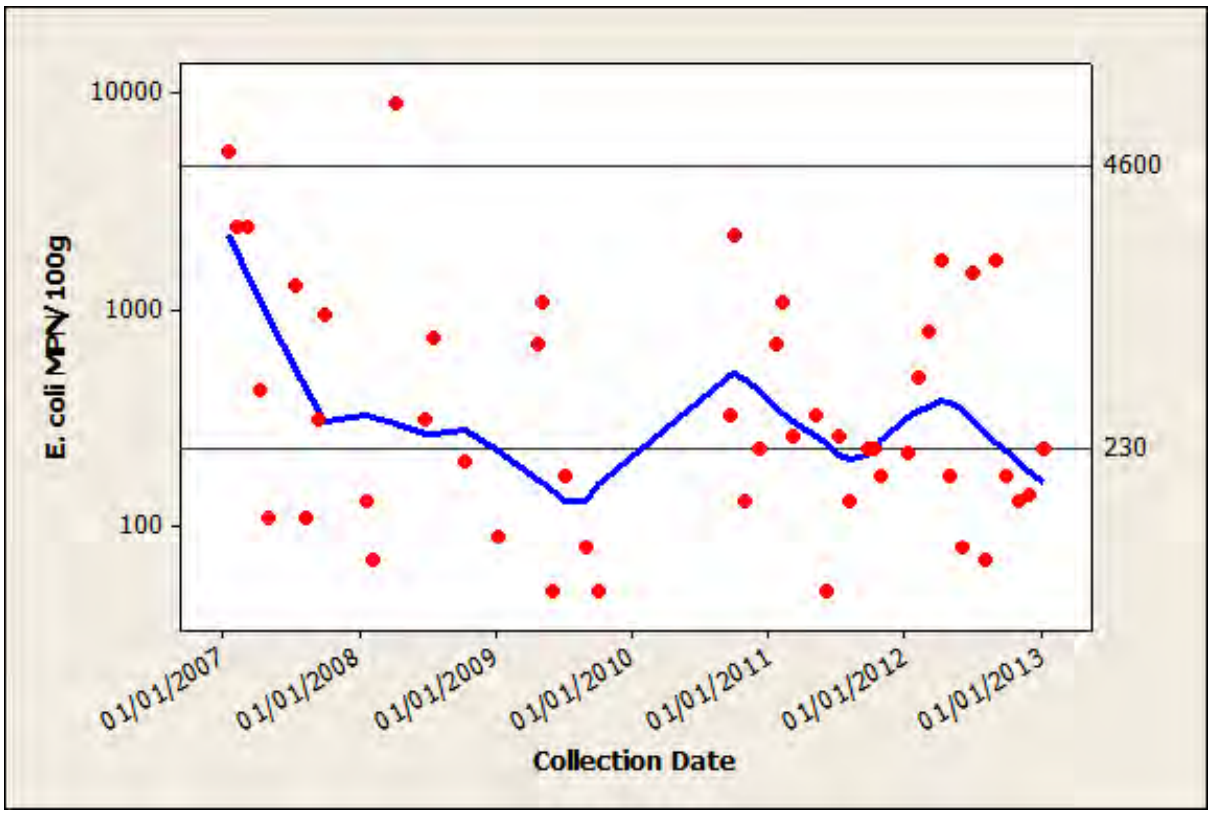


Figure 11.2 Scatterplot of surf clam *E. coli* results by date with a lowess line.

Contamination stays largely the same across years, with the majority of results < 1000 *E. coli* MPN/100 g. Two results (2007 and 2008) were > 4600 *E. coli* MPN/100 g. There appears to have been some trend of a reduction in the level of contamination, despite samples being taken from broadly the same area. The low number of samples taken during 2010 is apparent in Figure 11.2 and this will have affected the trend line either side of that period.

11.4 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. Figure 11.3 presents surf clam *E. coli* results by month, overlaid with a lowess line to highlight trends.

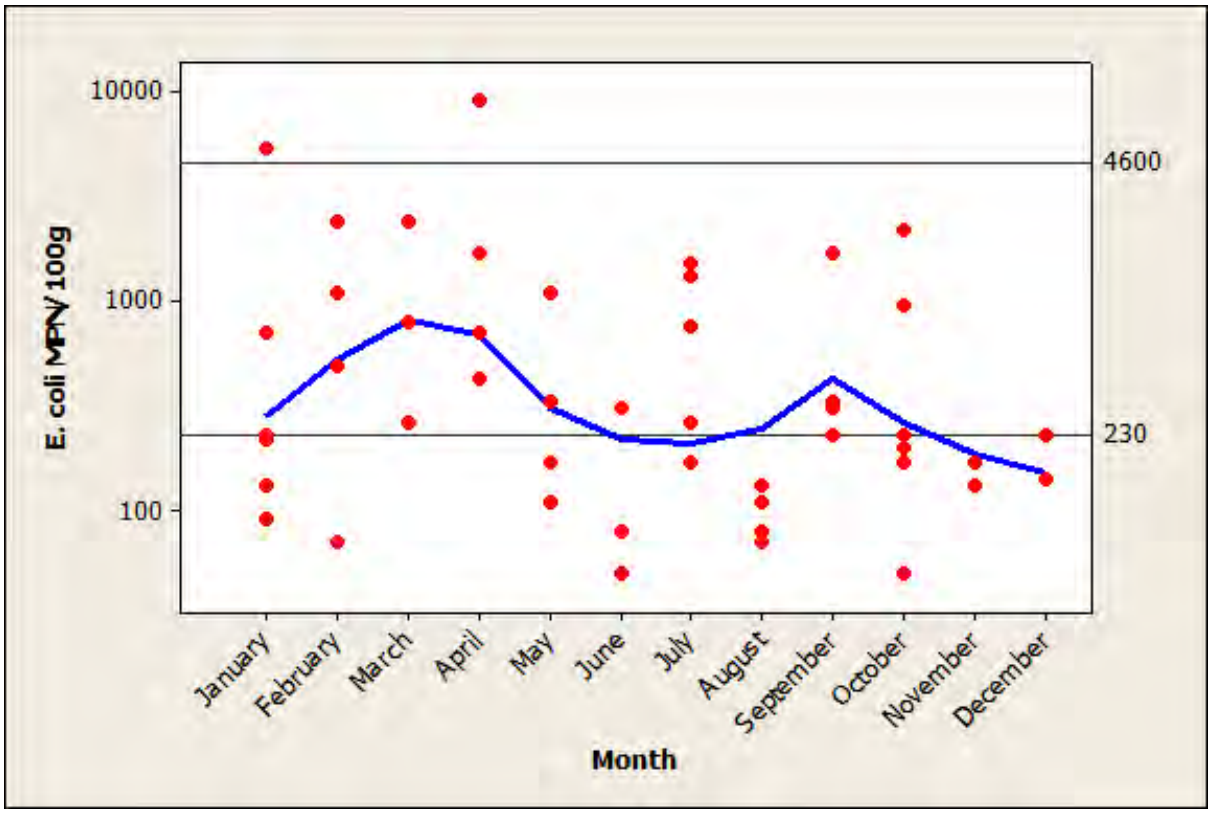


Figure 11.3 Scatterplot of surf clam *E. coli* results by month, fitted with a lowess line.

Sampling across months has not been even, with fewer samples taken in months of November and December. Results > 4600 *E. coli* MPN/ 100g occurred in January and April. Most of the results between February and April, as well as in July and September, were > 230 *E. coli* MPN/100 g. For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Figure 11.4 presents a boxplot of surf clam *E. coli* results by season.

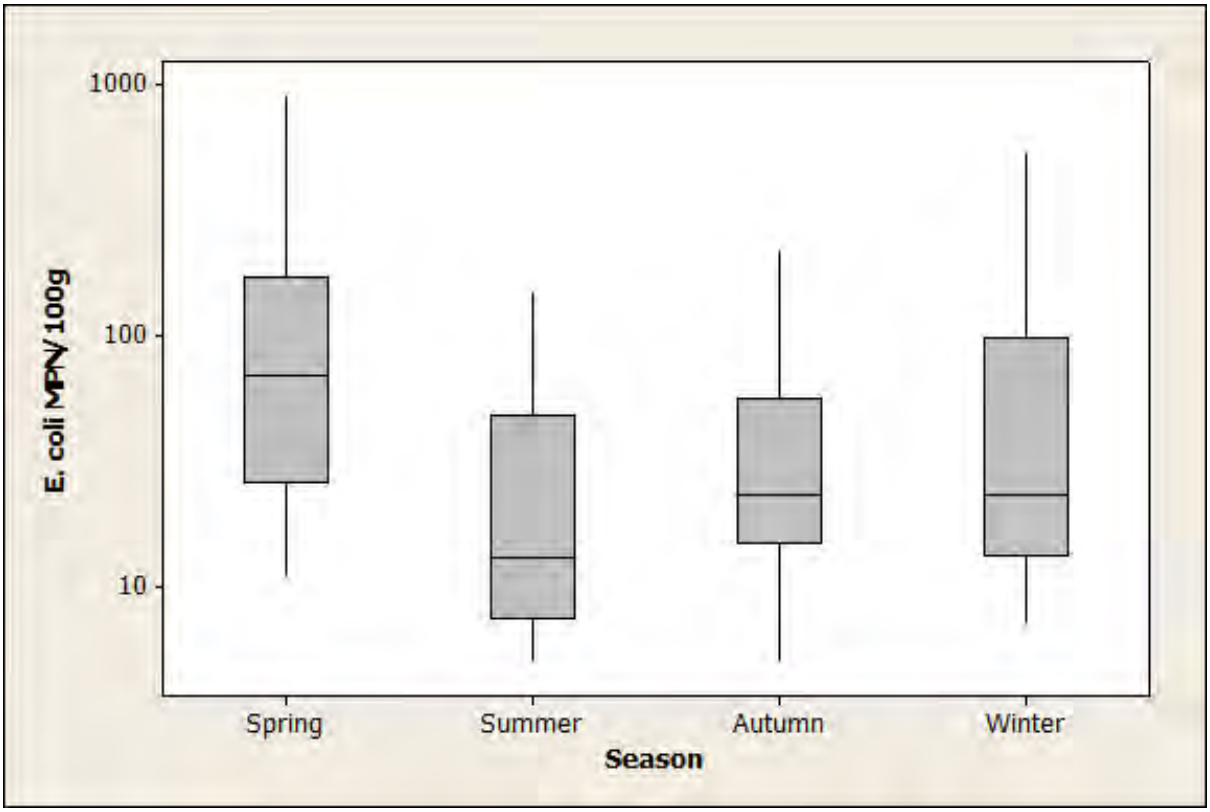


Figure 11.4 Boxplot of surf clam *E. coli* results by season.

No statistically significant difference was found between results by season (one-way ANOVA, F = 2.37, p = 0.083, Appendix 4).

11.5 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 & Morgan, 2003). The effects of these influences can be complex and difficult to interpret. This section aims to investigate and describe the influence of these factors individually (where appropriate environmental data is available) on the sample results using basic statistical techniques.

11.5.1 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Toldrie, approximately 5 km north-northwest of the production area. Rainfall data was purchased from the Meteorological Office for the period of 01/01/2007 to 31/08/2012 (total daily rainfall in mm). Rainfall data was extracted for the dates of surf clams *E. coli* results between the period 01/01/2007 and 31/08/2012.

Two-day rainfall

A scatterplot presents individual surf clam *E. coli* results against total rainfall recorded on the two days prior to sampling.

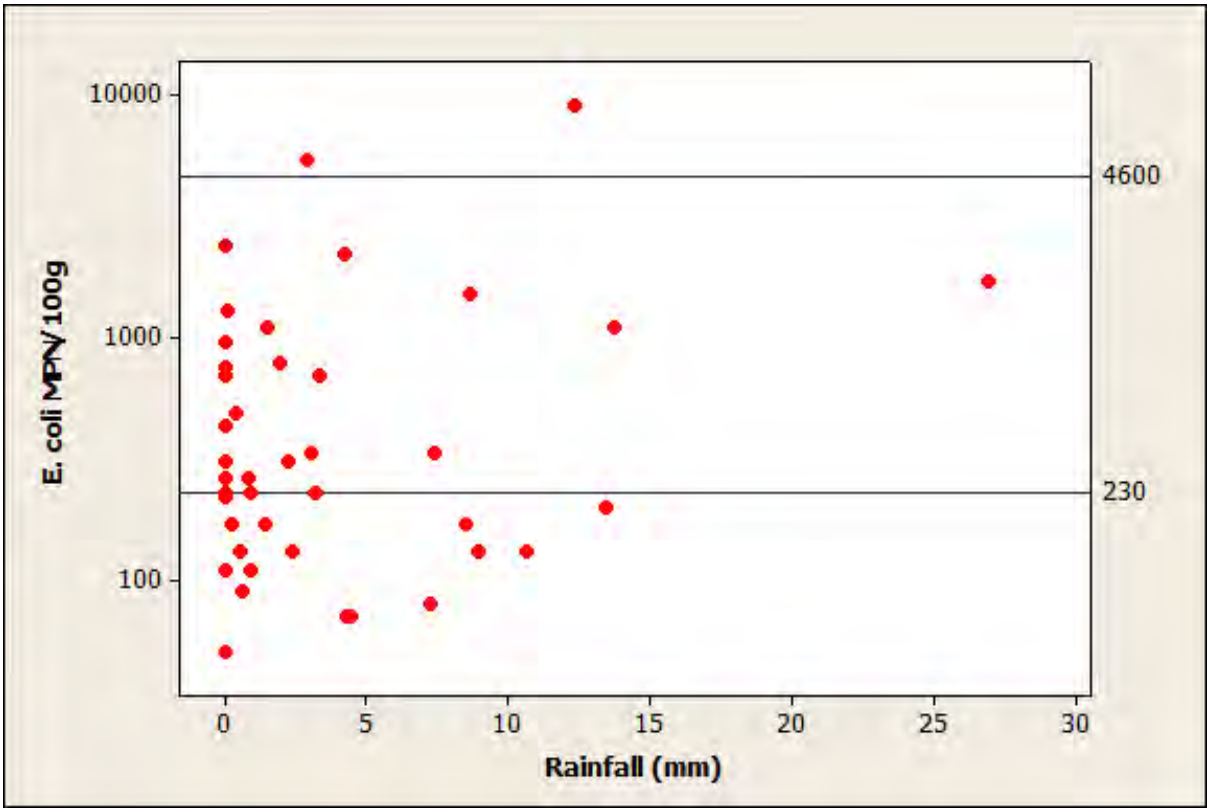


Figure 11.5 Scatterplot of surf clam *E. coli* results against rainfall in the previous two days.

No statistically significant correlation was found between the surf clam results and the previous two day rainfall (Spearman's rank correlation $r = 0.007$, $p = 0.963$). *E. coli* results > 230 *E. coli* MPN/100 g predominantly occurred when rainfall levels were low, between 0-5 mm. However, lowest recorded results increased with increasing rainfall.

Seven-day rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different system, the relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. Figure 11.6 presents a scatterplot of surf clam *E. coli* results against total rainfall recorded for the seven days prior to sampling.

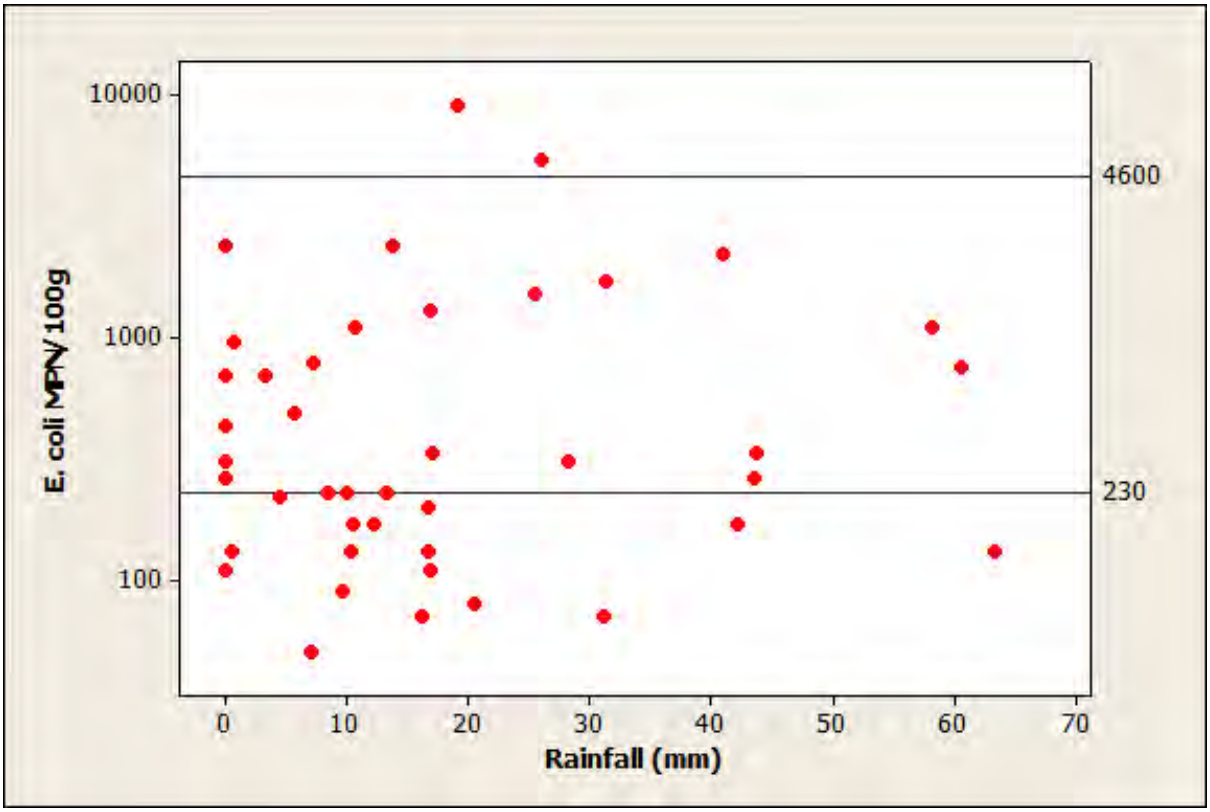


Figure 11.6 Scatterplot of surf clam *E. coli* results against rainfall in the previous seven days.

No statistically significant correlation was found between the surf clam results and the previous seven day rainfall (Spearman's rank correlation r = 0.116, p = 0.466). *E. coli* results > 230 *E. coli* MPN/100 g occurred between rainfall levels 0-65 mm.

11.5.2 Analysis of results by tidal height

Spring/neap tidal state

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. The largest spring tides occur approximately two days after the full moon about 45^{o}, then decrease to the smallest neap tides at about 225^{o}, before increasing back to spring tides. 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.

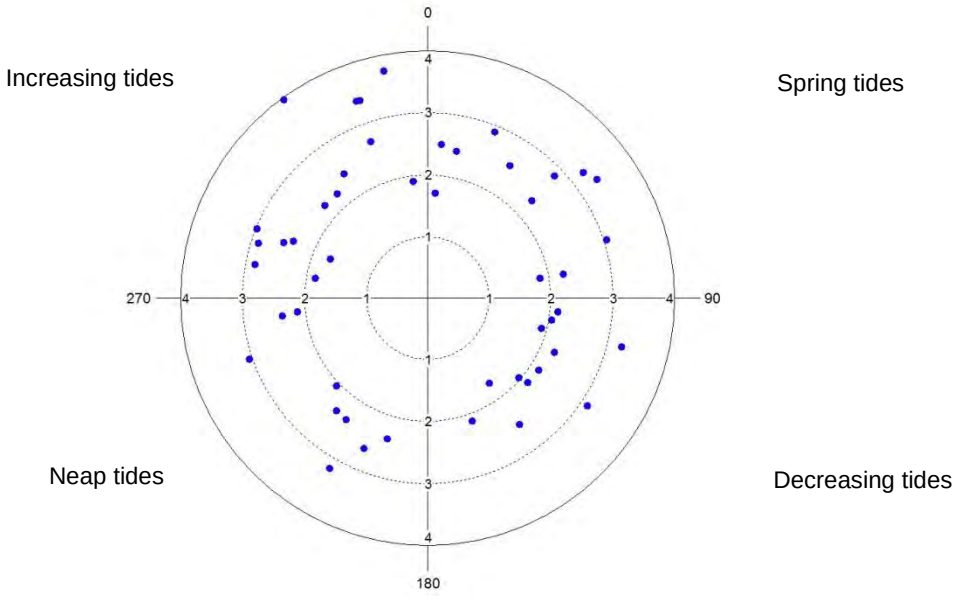


Figure 11.7 Polar plots of surf clam Log_{10} *E. coli* results on the spring/neap tidal cycle.

A significant correlation was found between surf clam log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r =0.287, p = 0.022). As shown by Figure 11.7 higher results occurred on increasing tides compared to spring, neap and decreasing tides.

High/low 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, where high water is at 0^o and low water at 180^o.

High and low water data from Anstruther-Easter was extracted from POLTIPS-3 in January 2013. This site was within the production area.

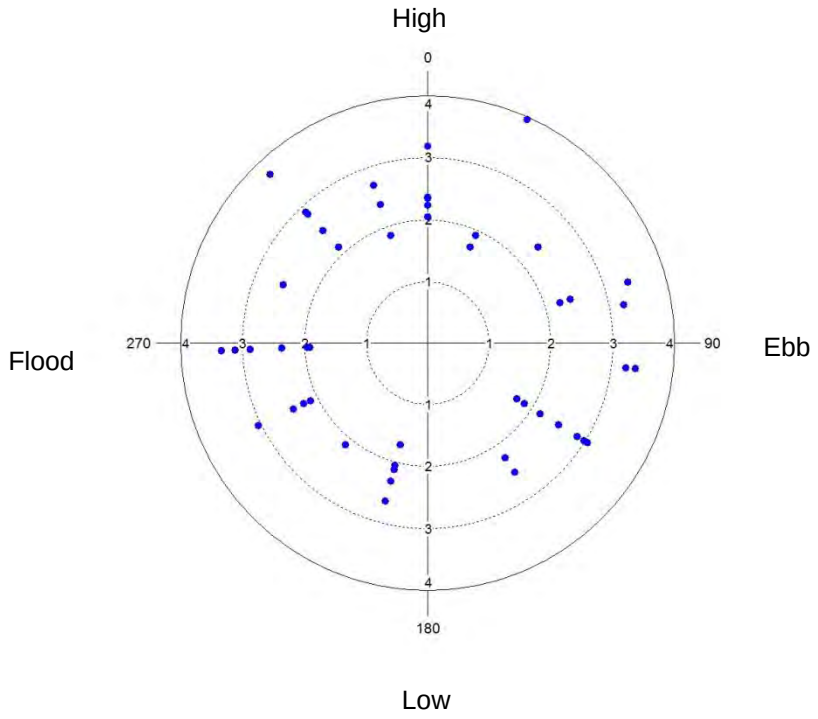


Figure 11.8 Polar plots of surf clam log10 *E. coli* results on the high/low tidal cycle.

No statistically significant correlation was found between surf clam $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.177, p = 0.235).

11.5.3 Analysis of results by water 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. Due to a lack of water temperature measurements taken at the time of sampling, the analysis of influence of water temperature on sampling results was unable to be conducted.

11.5.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater borne contamination at a site. No salinity measurements were taken at the time of sampling, preventing the analysis of an association between salinity and *E. coli* results.

11.6 Evaluation of results over 1000 *E. coli MPN*/100g

Sampling results exceeding 1000 *E. coli* MPN/100 g are listed in Table 11.2.

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

Collection Date	*E. coli* (MPN/100g)	Location	2day rainfall (mm)	7day rainfall (mm)	Water Temp (^{o}C)	Salinity (ppt)	Tidal state (high/low)	Tidal State (spring/neap)
16/01/2007	5400	NO 5950 0480	2.9	25.9	-	-	Flood	Increasing
05/02/2007	2400	NO 5900 0450	0.0	0.0	-	-	High	Increasing
07/03/2007	2400	NO 5900 0450	0.0	13.8	-	-	Ebb	Increasing
11/07/2007	1300	Unverified	0.1	16.8	-	-	Low	Decreasing
07/04/2008	9100	NO 5950 0450	12.3	19.1	-	-	High	Increasing
05/05/2009	1100	NO 5920 0480	1.5	10.6	-	-	Low	spring
04/10/2010	2200	NO 5950 0495	4.2	41.0	-	-	Low	spring
08/02/2011	1100	NO 5950 0495	13.7	58.2	-	-	Ebb	neap
10/04/2012	1700	Unverified	26.9	31.4	7	-	Ebb	Decreasing
03/07/2012	1500	Unverified	8.6	25.4	16	-	High	neap
04/09/2012	1700	Unverified	-	-	14	-	High	spring

-No available data

Samples yielding results > 1000 *E. coli* MPN/100 g occurred across all sampling years, with the majority (n=4) in 2007 and (n=3) in 2012. Only one sample > 1000 *E. coli* MPN/100 g was found in each of thesampling years 2008, 2009, 2010 and 2011. The highest result of 9100 *E. coli* MPN/100 g occurred in 2008. Location was unverified for four of the results, which represented all of the 2012 samples and one of the 2007 samples. Of the results with NGRs stated, all were located approximately < 0.2 km east of the nominal RMP. Water temperature was only present for the 2012 data and therefore trends are unable to be identified. However, temperature varied between 7-16^{o}C. No salinity was recorded for any of the samples. Rainfall for the two days prior to sampling varied between 0.0 – 26.9 mm, and data was unavailable for the last result on 04/09/2012. Rainfall from seven days prior to sampling also varied from 0.0 – 58.2 mm. However, very high rainfall levels of 25 mm and above were found for five of the samples. There was no clear trend found between high results and tidal cycle with regards to high/low tidal state or spring/neap.

11.7 Summary and conclusions

The majority of sampling locations plotted within a 1 km radius of the nominal RMP towards the northwest of the Anstruther production area, with all but one sample taken within the Anstruther production area. No clear geographical trend in high or low *E. coli* results was evident.

Over the sampling period (01/01/2007 – 08/01/2013) 27% of the samples had a result > 230 *E. coli* MPN/100 g, 18% had results > 1000 *E. coli* MPN/100 g and 4% had results > 4600 *E. coli* MPN/100 g. The highest sample (2007) had a result of 9100 *E. coli* MPN/100 g. Four out of the 11 results that > 1000 *E. coli* MPN/100 g was taken in 2007. The sampling rate was particularly low in 2010, with only four samples taken, compared to 2012 when 13 samples were taken. No significant statistical difference was found in results between seasons.

No significant statistical correlations were found between two and seven day rainfall and *E. coli* results. A significant statistical correlation was found between spring/neap tidal state and *E. coli* results, specifically with an increasing tide and higher *E. coli* results. No correlation was found between high/low tidal states.

12. Designated Waters Data

The Fife Ness to Ellie designated Shellfish Waters stretches from Sauchar Point in the southwest to Foreland Head in the northeast. The area was designated in 1998 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 Forth Estuary: Anstuther production area, RMP and the SGW monitoring point are shown in Figure 12.1. Since 2007, SEPA have based the SGW assessment on FSAS *E. coli* results. The *E. coli* results have been reviewed in Section 11 of this report.

The shellfish growing water report for the area identified that the Dreel Burn and Kilrenny Burn drain considerable arable agricultural catchments and reach the coast at Anstruther. Levels of arsenic exceeded guideline values in 2006 and 2007 and the source is thought to be the local geology. The waters have consistently failed to comply with the guideline standards for faecal coliforms from 1999 to 2010. The most recent SGW report for Fife Ness to Ellie was published in 2011 and did not have faecal coliform compliance results post 2010.

With regard to chemical contaminants, the report identified that in 2006, 2007 and 2010, the guideline value for arsenic was exceeded. It was further identified that “there are no point sources of arsenic in the area of the monitoring site at Ardross.” This does not correspond with the NGR given for the monitoring point in the SGW report, which plots at the opposite end of the SGW, near a car park at Kilminning Castle. However, the location does correspond with the monitoring point location shown on the map given in the SGW report. Therefore, it is not clear whether one or both locations were monitored. Both locations are shown in Figure 12.1.

The report noted a large discharge of ground water laden with high concentrations of iron on the coast between St. Monans and Pittenweem, though no geographic reference was given for this discharge. This discharge was observed during the 2008 shoreline survey for Forth Estuary: Pittenweem production area at NO 5350 0189, near Coal Farm.

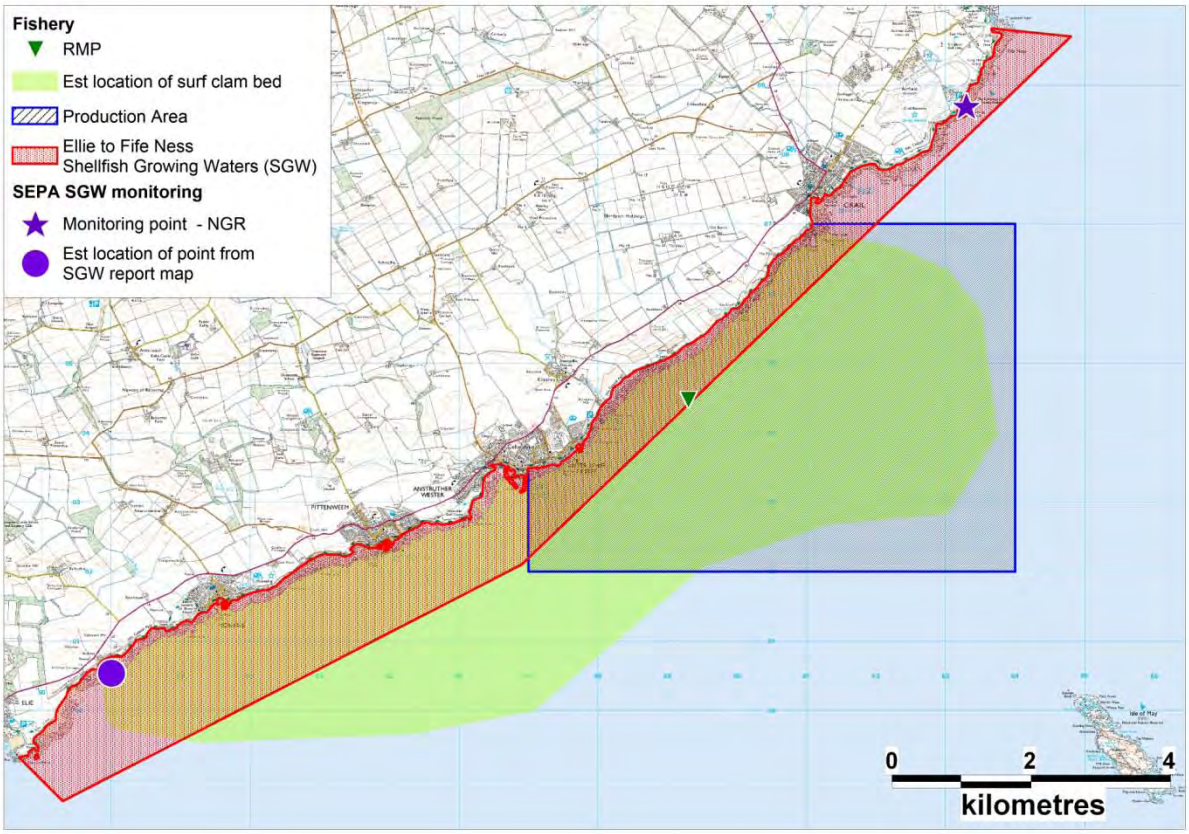


Figure 12.1 Designated shellfish growing water – Ellie to Fife Ness

13. Bathymetry and Hydrodynamics

13.1 Introduction

The Study Area

The Forth Estuary: Anstruther is situated on a section of the eastern coastline of Scotland where the entrance of the Firth of Forth joins the North Sea. For the purpose of this report the hydrographic study area extends from the headland of Fife Ness on the extreme east coast and continues south down the coast to Elie shown in Figure 1.1. This is a relatively large area compared to most other locations for hydrographic assessment. The area contains several villages, the largest being Anstruther Wester and Easter. This former fishing village is mostly reliant on tourism now and pleasure craft and tour boats regularly use the harbour. The Isle of May is a National Nature Reserve situated 8 km south-east of Anstruther Easter and is within the study area. Other smaller villages include the tourist destination of St Monans (St Monance on Admiralty chart), the active fishing village of Pittenweem and the harbour village of Crail.

Figure 13.1 Extent of hydrographic study area

Coordinates for Firth of Forth: Anstruther Harbour
56° 13.3’ N 002° 42.1’ W NO 56576 03543

13.2 Bathymetry and Hydrodynamics

Bathymetry

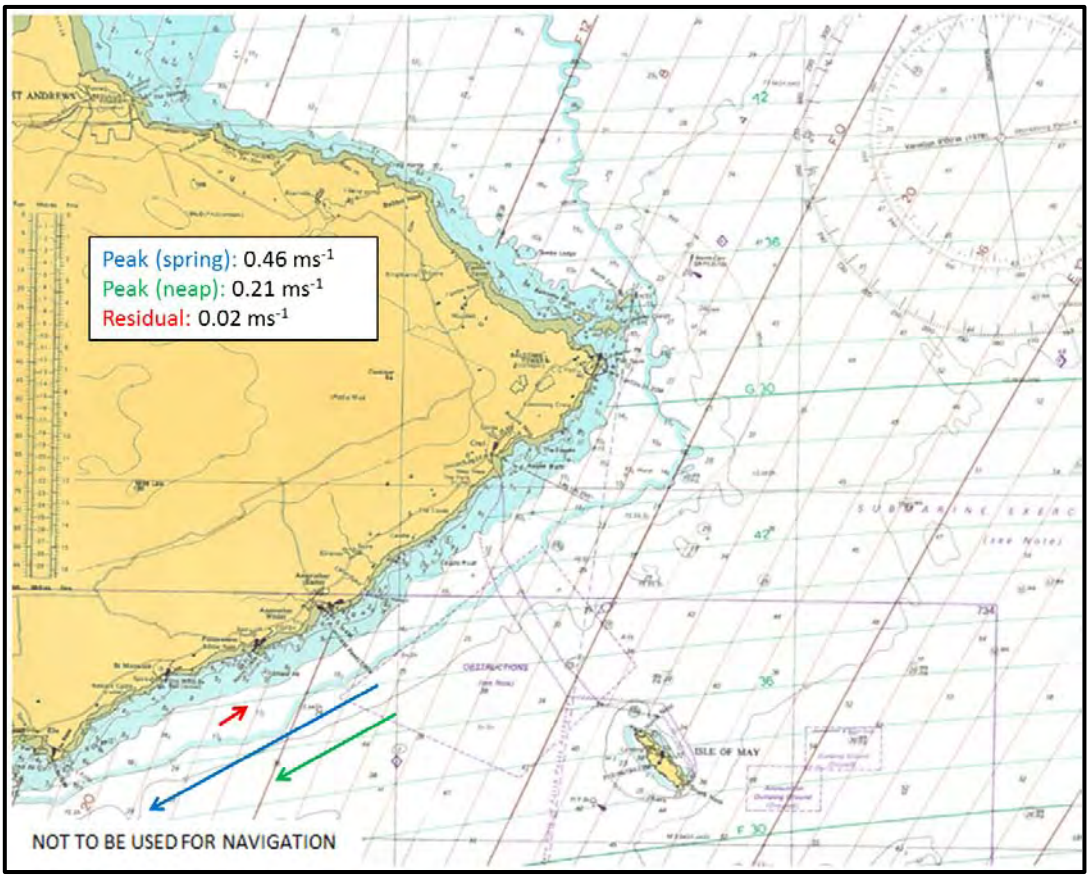


Figure 13.2 Admiralty chart extract for The Forth Estuary: Anstruther. Note that the length of the peak flow arrows approximately equate with the transport distance during the flood or ebb phases of the tide.

The Forth (the Estuary and Firth) as a whole has a length of approximately 100 km from the North Sea and eventually narrows to a width of approximately 2.5 km to the west at the far point of the estuary at Stirling (Neill & Elliott, 2004). The Firth is about 50 km in length and approximately vee-shaped and commonly divided into the inner, middle and outer Firth (Dyke, 1987). The inner part is referred to as the Estuary, extending from the bridges at Queensferry to Stirling.

Figure 2.1 shows the bathymetry of the Forth around the study area. The main entrance of the Firth of Forth faces NE, around 30 km wide (Balls & Topping, 1987) and connects directly to the North Sea. The exchange between the two areas is free with only the Isle of May being a relatively insignificant obstacle. Depths are typically around 25 - 40 m with maximum depths charted as reaching up to 60 m to the east of the Isle of May. There is a uniform gradual increase in depth from the coastline to offshore areas.

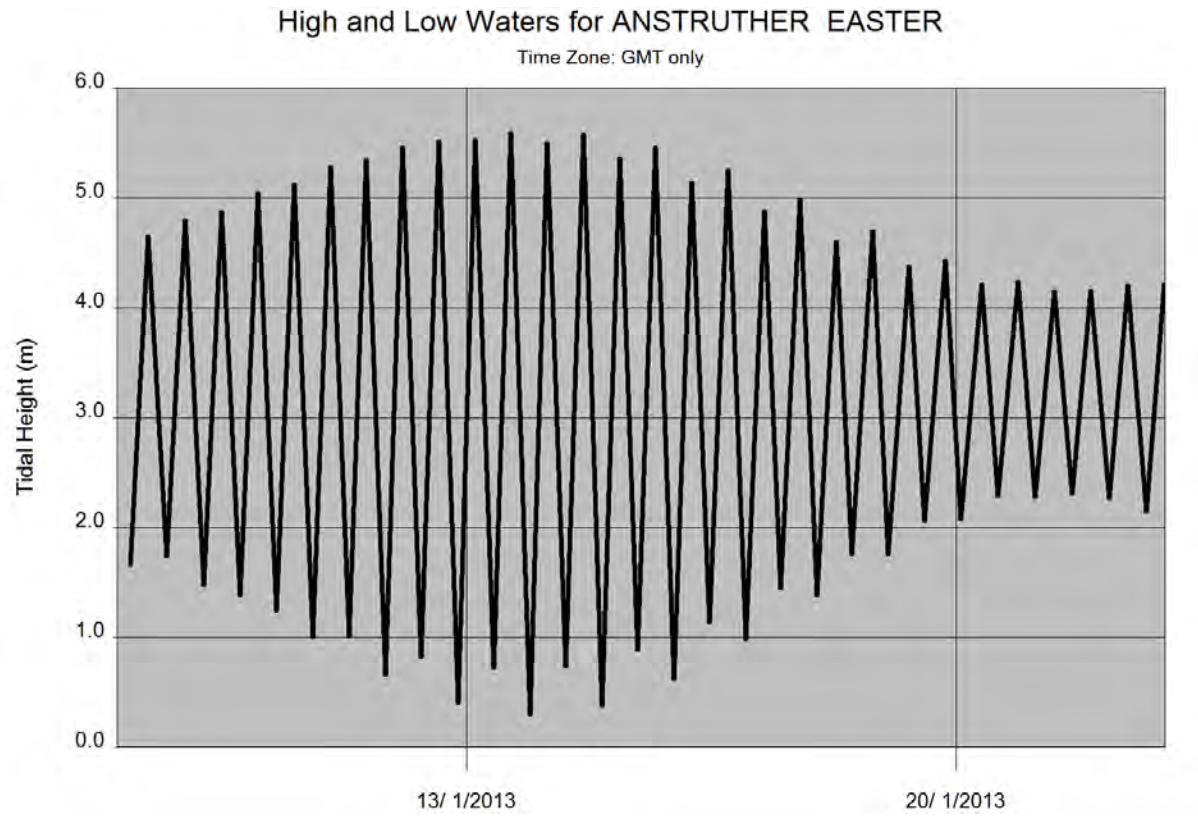
Within the study area the 20 m contour runs uniformly approximately 2.5 km offshore and there is an average depth of around 40 m (Elliot & Clarke, 1998).

Tides

The study area in the outer Firth has the typical semi-diurnal tidal characteristic. Data on tidal information is given from charted information.

Within the Forth Estuary the tides are more complex with a double high and double low water effect (Elliot & Clarke, 1998). The prevailing flows are predominantly tidal and the input of freshwater has a comparatively low influence on the overall flow movement. The bathymetry within the estuary causes stronger flood tides to the north of the estuary and stronger ebb currents towards the south.

Standard tidal data for Anstruther Easter are given below and the spring/neap cycle of tidal height around the time of the survey (15th January 2013) is shown in figure 2.2:



Reproduced from Poltips3 [www.pol.ac.uk/appl/poltips3]

Figure 13.3 Two week tidal curve for Forth Estuary: Anstruther.

Tidal Heights (from Admiralty Chart 190):
Mean High Water Springs = 5.5 m
Mean Low Water Springs = 0.7 m
Mean High Water Neaps = 4.4 m
Mean Low Water Neaps = 2.0 m
Tidal Ranges averaged for Forth Estuary:
Mean Spring Range = 4.8 m
Mean Neap Range = 2.4 m

Tidal Streams/Currents

Meaningful current data to determine long term mean flows are difficult to obtain in this area because (i) the currents are relatively small, (ii) long instrument deployments are difficult due to the operational challenges associated with an area having significant shipping movements and (iii) the size of the Firth of Forth makes it costly to cover the area (Dyke, 1987). No consistent information exists on time-dependent circulation.

For the Firth of Forth as a whole, the maximum tidal currents recorded are 0.5 m/s with residual and wind-induced currents at the surface reaching around 0.05 m/s or less (Elliot & Clarke, 1998) with residuals probably less than 1 cm/s (Dyke, 1987).

There is a tidal diamond south of Anstruther Easter, approximately 4.5 km offshore 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 and Carlin, 1998).

The flow is aligned parallel to the coast in the directions of 060°/240. The flood tide flows generally southwest (SW) and the ebb flows northeast (NE). The tidal flow is typically rectilinear (back and forth) rather than elliptical suggesting it is strongly constrained by the coastline. The maximum rates are 0.9 knots (0.46 m/s) at springs and 0.4 knots (0.21 m/s) at neaps, shown in Figure 2.1. There will be variations to these values across the assessment area in the vicinity of bays and headlands.

The cumulative transport that might be expected during each phase of the tide is 6.3 km (springs) and 3.3 km (neaps).

A residual flow in the study area 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 both springs and neaps the residual flow was found to be negligible meaning that the total transport is equal on both flood and ebb.

However, further information on the circulation in the study area was extracted from published literature. The general circulation of coastal flow in the outer Firth is described by Dyke (1987) which shows a residual outflow along the southern shore and a residual inflow along the central axis. This illustrates the classical concept of circulation in the Firth of Forth with landward net motion in the north side and seaward net motion on the south side (Lindsay, et al., 1996). A weak residual outflow was indicated close to the Anstruther coast based on current meter measurements for a duration of 40 days made by the Forth River Purification Board (Dyke, 1987). This east to west residual flow had a maximum value of 0.02 ms^1 between Pittenweem and St Monans, shown in Figure 2.1. The cause of the weak residual flow has been identified as either a dynamical effect during periods of weak stratification or as a gyre set up by flow around the shore line (Dyke, 1987) or wind driven (Balls & Topping, 1987).

River/Freshwater Inflow

The Forth sits within a 4655 km^3 drainage basin (Elliot & Clarke, 1998). Whilst quantitative data for this specific study area are sparse, the mean annual rainfall for the estuary as a whole is roughly 700 mm (Lindsay, et al., 1996). The significant river discharges are the Forth and Teith rivers which combine to give an input of 5.4 x 10^6 m^3/day and also the waters of Leith with an input of 2.2 x 10^6 m^3/day (Balls & Topping, 1987).

Even within the estuary, tidal movement is reported to dominate the flow, with freshwater influence being a relatively small component, reported to be 0.33% of the tidal flux at springs and 1.65% at neaps (Jacobs Arup on behalf of Transport Scotland, 2009). Freshwater discharge is not considered to have a significant impact on the hydrodynamics.

The outer Firth salinity is considered to be fully marine (Augley, et al., 2007) and virtually homogeneous (Dyke, 1987) with characteristic salinity values around 34 psu compared to the inner Firth which is typically 30-33 psu. Any freshwater outflow will tend to hug the south shore for most of the year giving slightly lower salinity values (~0.5) than the north (Jacobs Arup on behalf of Transport Scotland, 2009; Bell & Carlin, 1998).

The relatively low fresh water influence in the Firth of Forth, and the strongly marine nature of the water means that it is more like a coastal embayment than an estuary. A defined fresher surface layer can be present intermittently, usually in February and March when river flow is usually at its strongest (Dyke, 1987).

Within the specific study area of this report, the salinity of water will be affected by the Firth of Tay situated to the north of Fife Ness which generally has a lower salinity and which will flow into the north east of the Firth of Forth (Dyke, 1987). This can lead to weak stratification in the study area. On a smaller scale, fresh water inflow

into the study area includes Dreel Burn, Inverie Burn and Dennett Burn with other smaller waterways also present.

Meteorology

There is predominantly (over 50%) western airflow in the winter (Harrison, 1987) and corresponding summer data show not only a predominant westerly airflow but also north-easterly and easterly airflows (over 35%), explained by the proximity of the North Sea and the development of sea breezes (Lindsay, et al., 1996).

Model Assessment

Due to the paucity of data for this location and the unconstrained nature of the study area, it was not considered appropriate to set up a box model run for the outer Firth.

An extensive modelling study was conducted for the Forth (Jacobs Arup on behalf of Transport Scotland, 2009), but the model domain was concentrated on the inner Firth and the Estuary. The study area for this assessment was not included within the model. However, some elements of the model have been used to establish some of the broad characteristics of the Firth of Forth and are reported above.

13.3 Hydrographic Assessment

Surface flow

The site and the information from the literature indicate that freshwater is likely to be rather minimal in its impact. Indeed, the outer Firth of Forth can be viewed as having more marine characteristics than that of an estuary because the hydrography is more greatly influenced by the North Sea rather than freshwater discharge from the land. The greater influence of freshwater is found to the south, and even this is weak and seasonal.

There may be some sporadic influence of fresh water from the Firth of Tay which might enhance the stratification periodically. However, it is clear that flows in this site are tidally dominated and estuarine effects are minimal.

The principal current direction of the surface water flows in alignment with the shore line. The tidal excursion during a flood or ebb phase of the tide is typically 6.3 km and 3.3 km at mean springs and mean neaps respectively. This should be considered to be the best estimate of surface transport. It is therefore likely that any contaminant in the surface layers would follow the bathymetric contours of the site.

Whilst there is no residual flow apparent from the tidal diamond information, data in the literature show there to be a weak west to east residual flow in the study area of order 0.02 m/s. Over 12 hours this would result in a net transport of around 1 km.

The dominance of the westerly winds is likely to sustain the residual flow and may even be the underlying cause. The wind will also tend to enhance vertical mixing, though it has been reported that these waters are typically homogeneous which suggests effective vertical mixing conditions.

There are no direct measures of dispersion in the Firth, however, one might anticipate shear in the currents flowing along the shore, setting up a dispersive environment. This might be enhanced by downstream turbulence generated by the Isle of May.

Exchange Properties

Due to the close proximity to the North Sea, and the dominance of the tidal flow, the outer Firth of Forth has a relatively short flushing time (Anderson and Read, 1974) of order a few days. It is expected that the study site will be a moderately-well flushed system throughout most of the year with surface contaminants being dispersed in the residual flow.

There are rather few current meter data series available for the site and there is a lack of long term hydrographic data coverage for this area, particularly data sets with seasonal resolution. However, the site is relatively simple and the current meter records that do exist substantiate simple circulation schemes proposed in the literature. Therefore the confidence level of this assessment is MEDIUM.

14. Shoreline Survey Overview

The shoreline survey was conducted between the 15th and 16th January 2013. Prevailing weather conditions were cold, with light winds and snow/sleet on the first day turning to heavy snow showers on the second day. No significant precipitation fell in the 48 hrs prior to the survey.

The fishery is located off the east coast of Scotland where the mouth of the Forth Estuary meets the North Sea. Fishermen in the area have confirmed that there are three main areas where fishing is possible and regularly undertaken: the Pittenweem area, Anstruther area and, further northeast, the Caiplie Cave area.

Public sewerage systems operate in both the towns Anstruther/Cellardyke (southwest) and Crail (northeast). These towns are relatively densely populated and discharges include both continuous discharges from public WWTW and private septic tanks, as well as intermittent discharges from CSOs and EOs. The land outside the villages has only one active habitation and no visible septic tanks or sewage pipes. This habitation lies between the shoreline and the main road (A917) which runs parallel to the shore, northeast of Kilrenny.

The two towns of Anstruther and Crail are densely populated with a number of B&Bs, guest houses and hotels. At the time of sampling many of these hostelries were closed, though during the peak tourism time during the summer months it is likely that these will become very busy.

There are quite a few caravan parks along the boundary of the production area both directly along the shore or further inland. One of the two caravan sites observed along the shore is the Kilrenny Mill Caravan Park, where there was a playpark with a public toilet. Both the public toilet and the caravan park were closed at the time of the survey. Another caravan site was seen to the east of Crail which was also closed for the season at the time of survey.

There are three harbours in the production area, with the main harbours being Anstruther and Crail which are used by local fishermen on a regular basis for berthing and also for landing their catch. These two harbours also housed pleasure boats and yachts, whilst the third harbour at Cellardyke contained no boats at all. In Anstruther harbour there were around 100 vessels moored at the time of the survey. Crail harbour had 24 boats altogether out of which 11 were fishing boats, mainly small ones (around 3-5m in length).

Very little livestock was observed in the area during the survey with the exception of a large pig farm just outside Kilrenny to the east of Anstruther and a small fenced area with a hut and 9 sheep in the area roughly halfway between Anstruther and Crail. The pig farm is located exactly next to the Kilrenny Mill Caravan Park to the northeast. The pig farm appeared to be in two parts. One with about 15 larger huts

further up from the shore with only a few (5-6) large animals outside due to bad weather and the second part further to the east with around 100 smaller huts, with sows and piglets in nearly all of them. No waste heaps were visible but the area slopes slightly, ending in a flat area closest to the shore. The ground was soaked and covered in deep mud from precipitation and animal waste and most likely draining onto the shore where increased algae growth was evident on the rocks. The surrounding land was mainly used for agriculture with a few small patches of grazing land between the agricultural land and the shoreline. Indications of goat grazing were found on signs at gates at boundaries but no animals were observed apart from 8-10 sheep in a fenced area.

Seabirds were noted and counted during the survey. Their numbers were exceptionally high around the pig farm. At low tide in the bays and among the seaweed bird droppings were noted, but none were noted as resting on the shores in large number probably due to adverse weather conditions at the time. Species observed included curlews, oystercatchers, goosanders, ducks (eider and mallards), red shanks, gulls (black backed, herring and common) and fulmars.

Numerous watercourses of different sizes were observed discharging into the sea within the production area. The largest of these, Dreel Burn, was measured but not sampled. Freshwater samples taken from the other watercourses had varying levels of contamination, which varied between 100 and 4600 *E. coli cfu*/100 ml. Samples were also taken from discharge pipes that were identified as being contaminated. Results from these samples varied greatly, ranging from < 100 to 4200000 *E. coli cfu*/100 ml. Seawater samples had moderate levels of contamination ranging from 35 to 200 *E. coli cfu*/100 ml.

Shellfish samples could not be taken at the time of the shoreline survey.

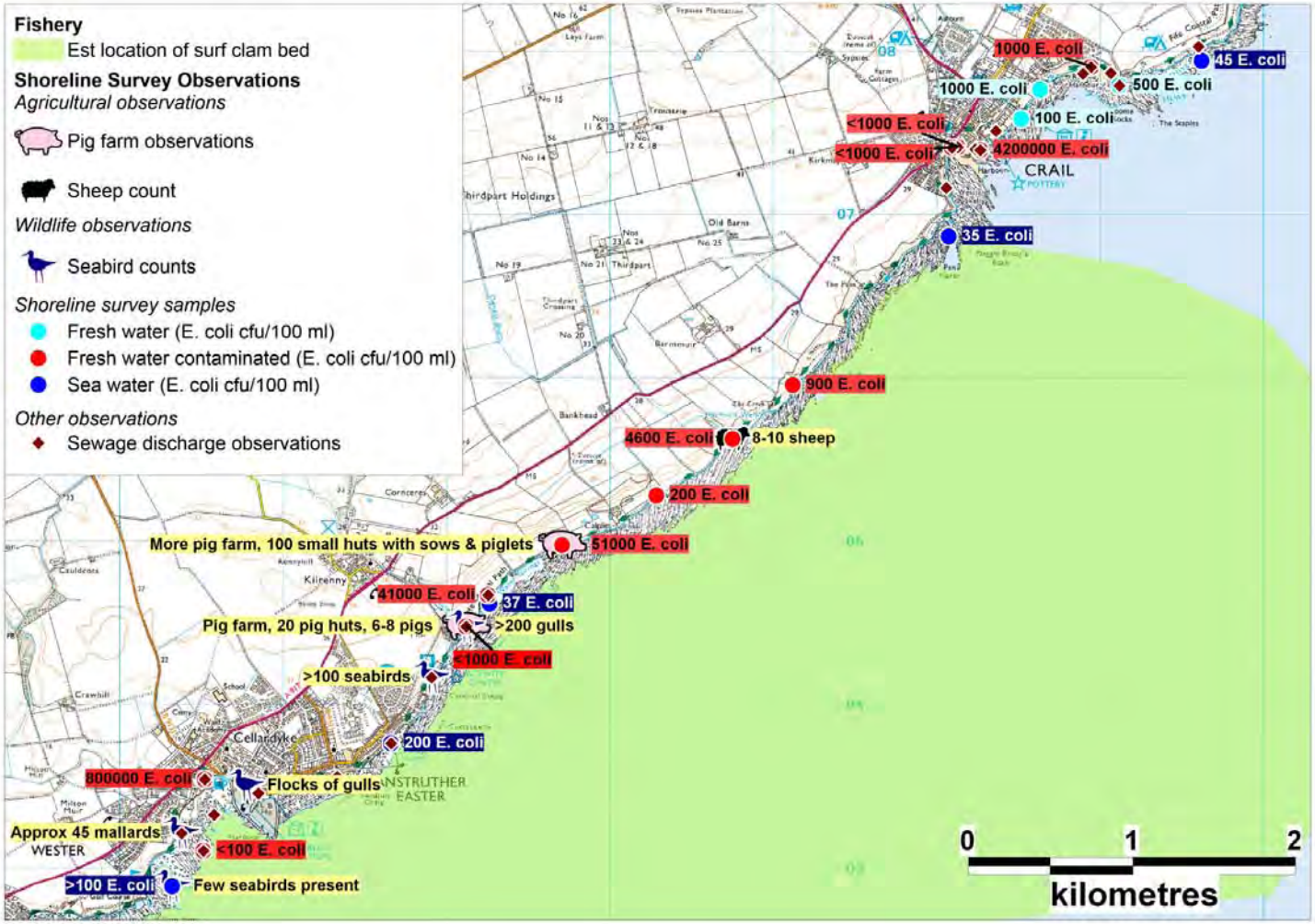


Figure 14.1 Summary of shoreline survey findings for Anstruther, Forth Estuary

15. Overall Assessment

Human sewage impacts

The waters of the shellfishery received continuous discharge of screened effluent from the Cornceres sewage outfall as well as storm overflows and both continuous and intermittent discharges carried via Dreel Burn. Six continuous and 19 intermittent outfalls discharge within 3 km of the production area, which is slightly less than the predicted surface transport distance at neap tides (not considering wind effects).

Although the majority of the urban population near the shore is connected to mains sewerage, the majority of properties outwith the urban centres are connected to private septic tanks. Two properties with reported septic tanks discharging to soakaway are located relatively near the shore, however any contamination arising from these is likely to be dwarfed by contamination coming from the main community outfalls.

Further discharges of sewage are likely to occur in and near the harbours at Crail and Anstruther, as well as at the anchorage site south of Crail. However, these inputs would be expected to be relatively minor in comparison to the other sources of sewage in the area.

One spill was observed during the shoreline survey arising from a part of the system not associated with a designed overflow point. This was flowing into the lower end of Dreel Burn. At Crail, an overflow was observed at the shoreline that may have originated from the Lamont Terrace CSO, approximately 100 m inland to the NW. Most community discharges are located to the northeast and southwest of the production area; however the larger population served appears to be to the southwest. Discharges from all the identified outfalls would impact on water quality at the fishery. Whilst the Crail Kilminning sewage outfall lies north of the likely extent of the shellfish bed, the remaining long sea outfalls discharge within the fished area identified by the harvesters.

As the shellfish are subtidal, and sewage effluent would be buoyant in comparison to the surrounding seawater, impact on water quality may be higher at the surface than at the seabed. However, particulate matter fine enough to pass through a 5mm-7mm screen would still be expected to eventually sink and settle on the seabed from where it could become resuspended by disturbance to the seabed, e.g. through dredging or storms.

Agricultural impacts

Agriculture is reported to be a significant activity in the area, especially inland of the towns. A pig farm located adjacent to shore northeast of Anstruther Easter is a significant source of faecal contamination to the fishery. Piped drainage from the farm discharges to the shore and water samples taken of the effluent were found to be highly contaminated with faecal bacteria. Photographs taken during the shoreline survey showed that the fields in which the pigs were kept were saturated, with standing water. This suggests that slurry from the farm drains from the field and into the sea.

Diffuse contamination arising from other farms in the area are likely to further contribute to loadings of faecal contaminants within the shellfishery waters. Dreel Burn and its tributaries and Kilrenny Burn were both identified as being affected by diffuse agricultural pollution. However, the shoreline survey showed Dennet Burn and watercourses discharging along the shore at the northern end of the production area to carry higher loadings of faecal contaminants than Kilrenny Burn. These watercourses also drain agricultural areas.

The shellfishery waters are impacted by significant point source agricultural contamination from the pig farm as well as significant diffuse contamination from agricultural sources carried in watercourses draining the area.

Wildlife impacts

Although a number of wildlife species are found in the Firth of Forth, due to the proximity of the shellfishery to shore and inhabited areas wildlife are unlikely to contribute significantly to faecal contamination in the area.

Seasonal variation

There is likely to be an increase in human population in the area during the summer months, as supported by the large number of campsites and other forms of tourist accommodation. Therefore, it is expected that the volume of sewage discharged to area waters would likewise increase during this time.

Historical daily rainfall values were higher in summer and winter months, though particularly heavy rainfall occurred across all months. Application of slurry is likely to be seasonal, and dependent on ground conditions. However, no reliable information was found on practices in the area of the fishery.

Analysis of historical monitoring data showed some variation in results by month, with peaks spring and autumn though highest results occurred in January and April. When the months were grouped into seasons, however, no significant correlation was found between results and season.

Watercourses

Watercourses discharging to the production area drain a mix of agricultural and urban areas and are subject to significant contamination from both agricultural and urban sources. Dreel Burn receives treated and untreated sewage effluent from septic tanks as well as diffuse run-off from agricultural areas.

The majority of watercourses discharging to the northern end of the production area showed higher calculated spot loadings than those discharging to the middle of the production area. However, no sample was taken from Dreel Burn, and given its size, both known and observed sewage discharge to the burn, and a sample result obtained in 2008 that showed high levels of faecal contamination, it is likely that this burn contributes the highest loading of faecal contamination to the fishery. As with all the burns, impacts are likely to be highest nearer shore where there has been less opportunity for dispersion and dilution.

Movement of contaminants

Hydrographic analysis suggests that movement of contaminants is likely to be largely tidally driven, with a maximum tidal excursion at the surface of 6.3 km at spring tides and just over 3 km at neap tides. This suggests that sources much further afield than those assessed within this report are likely to contribute to levels of faecal contamination in production area waters. Movement is most likely to be in line with the coast, moving toward the northeast on the ebb tide and the southwest on the flood. As the shellfish are actually subtidal, contaminants reaching waters near the seabed would be of greatest concern. Therefore, it is anticipated that contamination levels will be higher around the sewage outfall pipes and near the mouths of burns, where particulate-bound contaminants are likely to settle. Therefore, highest levels of contamination are anticipated toward the southern end of the production area between the mouth of Dreel Burn and along an area extending NE-SW from the Cornceres outfall.

Temporal and geographical patterns of sampling results

Analysis of historical monitoring results suggests that contamination levels have not changed markedly over time. Mapping of results by location shows reported sampling locations to be clustered mainly to the east of the RMP. Results in this cluster were higher than those taken from other parts of the fishery. Caution must be used in interpreting results by location, as the sampling from this fishery is unverified. However, highest results appear to have come from locations approximately 700-800 m northeast of the nearest sewage outfall (Cornceres). This suggests that faecal contamination from the

outfall travels in the water column some distance before settling toward the seabed and the shellfish.

No statistically significant correlations were found between *E. coli* results in surf clams and rainfall or the high/low tidal cycle. A statistically significant correlation was found between results and the spring/neap tidal cycle, with highest results occurring as tides were increasing, between neap and spring. The reason for this correlation is not clear.

Conclusions

The production area at Forth Estuary: Anstruther is subject to significant human and agricultural faecal contamination. Screened sewage is discharged directly to waters over the shellfish bed as well as to adjacent waters. Considering the predicted movement of contaminants and the observed geographic pattern of monitoring results, the impact from the sewage outfalls is likely to carry some distance away from source. Watercourses discharging to the area also carry significant loads of faecal contaminants, however as their impact on the fishery is likely to be dependent upon the level of mixing and distance from shore, as the freshwater is likely to be concentrated at the surface until mixing can occur. Levels of contamination in the water are likely to be higher near shore, while levels at or near the seabed, where the shellfish are filtering, may be higher some distance from recorded sources.

Due to the large number of intermittent discharges near the fishery, it is likely that monthly monitoring does not accurately reflect impacts from these discharges.

Overall Risk Table

Risk	
Sewage discharges from WWTW and CSOs	High
Overboard discharges from yachts	Moderate
Rainfall-dependent diffuse sources	Low
Wildlife sources	Low
Seasonal variability	Moderate

16. Recommendations

Production area

It is recommended that the production area remain largely as is, however with the area of Skinfast Harbour excluded. Therefore, it is recommended that the boundaries be described as the area bounded by lines drawn between NO 5700 0348 and NO 5700 0200 and NO 6400 0200 and NO 6400 0700 and NO 6108 0700 and between NO 5773 0375 and NO 5770 0374, extending to MHWS. It was not feasible to exclude all discharges from the production area boundaries in this case.

RMP

Given that this is a dredged fishery, it is recommended that a monitoring zone approach be applied in order to allow for movement of the bed and to allow sufficient scope for dredging. It is recommended that the monitoring zone be established adjacent to the Cornceres outfall as this is the largest continuous source of faecal contamination to the fishery. Therefore, the recommended monitoring zone is the area within lines drawn between the following: NO 5863 0354, NO 5953 0474, NO 5976 0456 and NO 5887 0336. This area is 1.5 km by 300 m, extending to the northeast and southwest of the sewage outfall location.

Frequency

Due to observed variation by month in results, it is recommended that monthly monitoring be continued.

Depth of sampling

Not applicable as this is a subtidal fishery.

Tolerance

No tolerance is recommended as there should be sufficient scope for sampling within the RMZ.

Other

It is further recommended that the production area be redesignated Firth of Forth: Anstruther as it does not lie within the Forth Estuary.

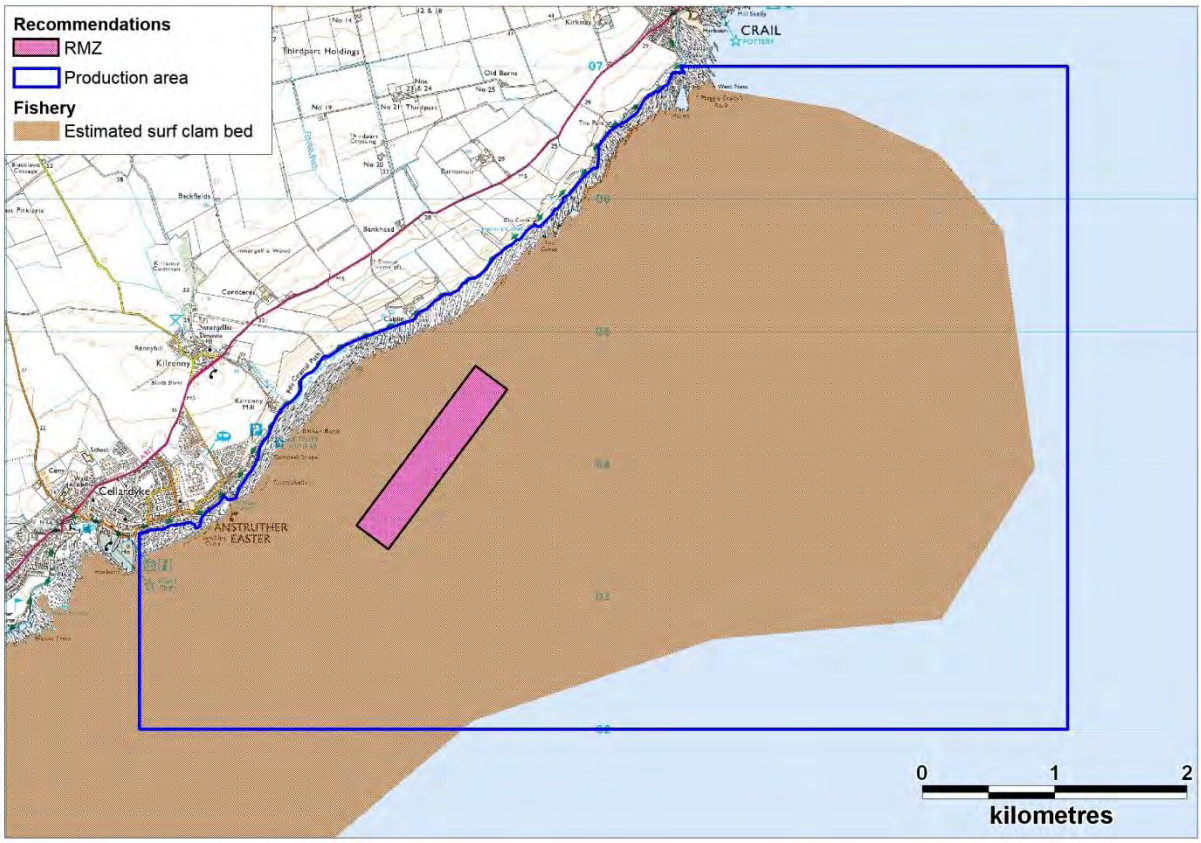


Figure 16.1 Map of recommendations at Forth: Anstruther

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18. List of Figures and Tables

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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 1.21×10^4 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.

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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

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

(Cis), and results of t-tests comparing base- and high-flow GMs for each group and type.

Source: (Kay, et al., 2008)

Geometric mean (GM) and 95% confidence intervals (CIs) of the GM faecal indicator organism (FIO) concentrations (cfu 100ml$_{-1}$) under base- and high-flow conditions at the 205 sampling points and for various subsets, and results of paired t-tests to establish whether there are significant elevations at high flow compared with base flow

FIO	*n*	Base Flow			High Flow		
Subcatchment land use		Geometric mean	Lower 95% CI	Upper 95% CI	Geometric mean[a]	Lower 95% CI	Upper 95% CI
Total coliforms							
All subcatchments	205	5.8×10^{3}	4.5×10^{3}	7.4×10^{3}	7.3×10^{4}**	5.9×10^{4}	9.1×10^{4}
Degree of urbanisation							
Urban	20	3.0×10^{4}	1.4×10^{4}	6.4×10^{4}	3.2×10^{5}**	1.7×10^{5}	5.9×10^{5}
Semi-urban	60	1.6×10^{4}	1.1×10^{4}	2.2×10^{4}	1.4×10^{5}**	1.0×10^{5}	2.0×10^{5}
Rural	125	2.8×10^{3}	2.1×10^{3}	3.7×10^{3}	4.2×10^{4}**	3.2×10^{4}	5.4×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	6.6×10^{3}	3.7×10^{3}	1.2×10^{4}	1.3×10^{5}**	1.0×10^{5}	1.7×10^{5}
≥75% Rough Grazing	13	1.0×10^{3}	4.8×10^{2}	2.1×10^{3}	1.8×10^{4}**	1.1×10^{4}	3.1×10^{4}
≥75% Woodland	6	5.8×10^{2}	2.2×10^{2}	1.5×10^{3}	6.3×10^{3}*	4.0×10^{3}	9.9×10^{3}
Faecal coliform							
All subcatchments	205	1.8×10^{3}	1.4×10^{3}	2.3×10^{3}	2.8×10^{4}**	2.2×10^{4}	3.4×10^{4}
Degree of urbanisation							
Urban	20	9.7×10^{3}	4.6×10^{3}	2.0×10^{4}	1.0×10^{5}**	5.3×10^{4}	2.0×10^{5}
Semi-urban	60	4.4×10^{3}	3.2×10^{3}	6.1×10^{3}	4.5×10^{4}**	3.2×10^{4}	6.3×10^{4}
Rural	125	8.7×10^{2}	6.3×10^{2}	1.2×10^{3}	1.8×10^{4}**	1.3×10^{4}	2.3×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	1.9×10^{3}	1.1×10^{3}	3.2×10^{3}	5.7×10^{4}**	4.1×10^{4}	7.9×10^{4}
≥75% Rough Grazing	13	3.6×10^{2}	1.6×10^{2}	7.8×10^{2}	8.6×10^{3}**	5.0×10^{3}	1.5×10^{4}
≥75% Woodland	6	3.7×10	1.2×10	1.2×10^{2}	1.5×10^{3}**	6.3×10^{2}	3.4×10^{3}
Enterococci							
All subcatchments	205	2.7×10^{2}	2.2×10^{2}	3.3×10^{2}	5.5×10^{3}**	4.4×10^{3}	6.8×10^{3}
Degree of urbanisation							
Urban	20	1.4×10^{3}	9.1×10^{2}	2.1×10^{3}	2.1×10^{4}**	1.3×10^{4}	3.3×10^{4}
Semi-urban	60	5.5×10^{2}	4.1×10^{2}	7.3×10^{2}	1.0×10^{4}**	7.6×10^{3}	1.4×10^{4}
Rural	125	1.5×10^{2}	1.1×10^{2}	1.9×10^{2}	3.3×10^{3}**	2.4×10^{3}	4.3×10^{3}
Rural subcatchments with different dominant land uses							
≥75% Imp. pasture	15	2.2×10^{2}	1.4×10^{2}	3.5×10^{2}	1.0×10^{4}**	7.9×10^{3}	1.4×10^{4}
≥75% Rough Grazing	13	4.7×10	1.7×10	1.3×10^{2}	1.2×10^{3}**	5.8×10^{2}	2.7×10^{3}
≥75% Woodland	6	1.6×10	7.4	3.5×10	1.7×10^{2}**	5.5×10	5.2×10^{2}

[a] Significant elevations in concentrations at high flow are indicated: **po0.001, *po0.05.

[b] Degree of urbanisation categorised according to percentage built-up land: 'Urban' (X10.0%), 'Semi-urban' (2.5–9.9%) and 'Rural' (o2.5%).

Source: (Kay, et al., 2008a)

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 x 108
Cow	230,000	23,600	5.4 x 109
Duck	33,000,000	336	1.1 x 1010
Horse	12,600	20,000	2.5 x 108
Pig	3,300,000	2,700	8.9 x 108
Sheep	16,000,000	1,130	1.8 x 1010
Turkey	290,000	448	1.3 x 108
Human	13,000,000	150	1.9 x 109

Source: (Gauthier & Bedard, 1986)

3. Statistical Data

One-way ANOVA: log10EC versus Season

```
Source DF SS MS F P
Season 3 1.788 0.596 2.18 0.103
Error 45 12.275 0.273
Total 48 14.063

S = 0.5223 R-Sq = 12.71% R-Sq(adj) = 6.89%

 Individual 95% CIs For Mean Based on
 Pooled StDev
Level N Mean StDev ---+---------+---------+---------+------
1 11 2.8357 0.5546 (----------*---------)
2 13 2.3016 0.4860 (---------*--------)
3 13 2.4594 0.4667 (---------*---------)
4 12 2.5679 0.5839 (----------*---------)
 ---+---------+---------+---------+------
 2.10 2.40 2.70 3.00

Pooled StDev = 0.5223

Grouping Information Using Tukey Method

Season N Mean Grouping
1 11 2.8357 A
4 12 2.5679 A
3 13 2.4594 A
2 13 2.3016 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 -1.1044 -0.5340 0.0363 (----------*-----------)
3 -0.9466 -0.3763 0.1941 (----------*-----------)
4 -0.8490 -0.2678 0.3134 (-----------*----------)
 --+---------+---------+---------+-------
 -1.00 -0.50 0.00 0.50

Season = 2 subtracted from:

Season Lower Center Upper --+---------+---------+---------+-------
3 -0.3883 0.1578 0.7039 (----------*----------)
4 -0.2911 0.2662 0.8236 (----------*----------)
 --+---------+---------+---------+-------
 -1.00 -0.50 0.00 0.50


Season = 3 subtracted from:

Season Lower Center Upper --+---------+---------+---------+-------
4 -0.4489 0.1084 0.6658 (----------*----------)
 --+---------+---------+---------+-------
 -1.00                -0.50                0.00                0.50
```

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

Report Title	Anstruther Shoreline Survey Report Draft
Project Name	Shellfish Sanitary Surveys
Client/Customer	Cefas
SRSL Project Reference	00561_B0067

Document Number	B0067_Shoreline 0004
Revision	Issue 02
Date	12/03/2013

Revision History

Revision	Changes	Date
A	Issue for internal review	03/02/2013
01	First draft issue to Cefas	04/02/2013
02	Second draft issue to CEFAS resolving comments in revision 01	12/03/2013

	Name & Position	Date
Author	Andrea Veszelovszki	03/02/2013
Checked	John Hausrath	12/03/2013
Approved	John Hausrath	12/03/2013

SRSL, Scottish Marine Institute, Oban, Argyll, PA37 1QA, tel 01631 559 470, www.samsrsl.co.uk

Shoreline Survey Report

Production area:	Forth Estuary: Anstruther
Site name:	Anstruther
SIN:	FF-068-184-19
Species:	Surf clams – *Spisula solida*
Harvester:	John Wilson
Local Authority:	Fife Council, Sandy Duncan (local sampling officer, discussed in advance, but could not attend the survey)
Status:	Existing area
Date Surveyed:	15-16 January 2013
Surveyed by:	Lars Brunner (survey leader), Andrea Veszelovszki and Debi Brennan
Existing RMP:	NO 5930 0450

Area Surveyed: From Anstruther Golf Course SW of Anstruther to Sauchope Links Caravan Park NE of Crail. Most of the coastal area covered by the survey is included in the Forth Estuary - Anstruther Production Area. Shellfish samples were not collected during this survey as cooperation with local fishermen was not found in the given timeframe.

18.1.1 Weather

Changeable weather with short snow shower the night before the survey but no significant precipitation was recorded in the 48 hours prior to survey. Cold overnight with low temperatures between 0 and -2 ˚C, resulting in frosty, partially frozen ground.

15th of January: During the day: about 70% scattered cloud cover, easterly wind with variable wind speed of 15-18km/h. Temperature 5.9 ˚C with considerable wind chill. Sea state was relatively calm. Changeable weather throughout the day with snow/sleet/rain showers, intermittently with sunshine.

16th of January: Very cold overnight. Dry and sunny start with wind speeds of 6-16 km/h. Temperature 2.7˚C. Sea state was relatively calm. Intermittently heavy snow.

18.1.2 Fishery

The fishery is located off the east coast of Scotland where the mouth of the Forth Estuary meets the North Sea. The area has been classified for the harvest of surf clams (*Spisula solida*) since 2008 and the production area is a 7x5 km zone encompassing the coastline between Anstruther and Crail.

The depth of the coastal zone ranges from 0-30 metres with varied bottom topography (in places rocky bottom). As a result of this, the otherwise traditional dredging is not possible in all areas. Fishermen in the area have confirmed that there are three main areas where fishing is possible and regularly done so: the Pittenweem area, Anstruther area and further northeast the Caiplie Cave area.

18.1.3 Sewage Sources

18.1.4 The production area is bordered at both ends by two densely populated villages, with Anstruther and Cellardyke (virtually merged into one village and refer to here as Anstruther) at the south end and Crail to the north. Both villages have public sewerage provisions, with both including continuous discharges and a number of pumping stations and overflows, most of which have been confirmed during the survey.

Three large outflows were identified running into Anstruther Bay. In the area of Cellardyke, further concrete structures running parallel to the shoreline indicate the existence of a Waste Water Treatment Works (WWTW), however the outflow could not be located.

18.1.5 Seasonal Population

The villages of Anstruther and Crail are densely populated with a number of B&Bs, guest houses and hotels present, with the area likely to experience a significant increase in population during the summer months due to tourism, however at the time of sampling many of the hostelries were closed.

There are quite a few caravan parks along the boundary of the production area both directly along the shore or further inland. One of the two main caravan sites along the shore is by Kilrenny, the Kilrenny Mill Caravan Park, where there is a playpark with a public toilet. Both the public toilet and the caravan park were closed at the time of the survey.

Another caravan site is located to the east of Crail which was also closed for the season, at the time of survey.

18.1.6 Boats/Shipping

There are three harbours in the production area, with the main harbours being Anstruther and Crail which are used by local fishermen on a regular basis for berthing and also for landing their catch. These two harbours also housed pleasure boats and yachts, whilst the third harbour at Cellardyke contained no boats at all. In Anstruther harbour there were around 100 vessels moored at the time of the survey. Crail harbour had 24 boats altogether out of which 11 were fishing boats, mainly small ones (around 3-5m in length).

Farming and Livestock

Very little livestock was observed in the area during the survey with the exception of a large pig farm just outside Kilrenny to the east and a small fenced area with a hut and 9 sheep in the area roughly halfway between Anstruther and Crail. The pig farm is located exactly next to the Kilrenny Mill Caravan Park to the northeast. The pig farm appeared to be in two parts. One with about 15 larger huts further up from the shore with only a few (5-6) large animals outside due to bad weather and the second part further to the east with around 100 smaller huts, with sows and piglets in nearly all of them. No waste heaps were visible but the area slopes slightly, ending in a flat area closest to the shore. The ground is soaked and covered in deep mud from

precipitation and animal waste and most likely draining onto the shore where increased algae growth was evident on the rocks.

18.1.7 Land Use

The shoreline between the two villages at both ends of the production area is mainly rocky. There are a few small sandy inlets along the shoreline. Inland from the shore, the land is steeply elevated with no dramatic changes in the landscape along the coast except in both villages where access to the shoreline is difficult or in some cases impossible due to steepness. The land is mainly used for agriculture with a few small patches of grazing land between the agricultural land and the shoreline. Indications for grazing of goats were found on signs at gates at boundaries but no animals were observed apart from 8-10 sheep in a fenced area. The land outside the villages has only one active habitation with a large unused garden and no visible septic tanks or sewage pipes. This habitation lies between the shoreline and the main road (A917) which runs parallel to the shore, northeast of Kilrenny.

Land Cover

The predominant landcover along the shoreline between Anstruther to Crail is crop land. There was no evidence of the use of poly tunnels in the area. Areas not used for crops were often found to be boggy.

Watercourses

There are numerous watercourses of different sizes discharging into the sea within the production area with the largest two being the Dreel and Dennett Burns. There are also other smaller watercourses/streams discharging into the production area with a few seepages through rocks and boulders as well.

18.1.8 Wildlife/Birds

Seabirds were noted and counted during the survey. Their numbers were exceptionally high around the pig farm. At low tide in the bays and among the seaweed bird droppings were noted, but none were noted as resting on the shores in large number probably due to adverse weather conditions at the time. Species observed included curlews, oystercatchers, goosanders, ducks (eider and mallards), red shanks, gulls (black backed, herring and common) and fulmars.

Shoreline Maps

Map image is Powered by Esri Inc.

Figure 1. Anstruther shoreline survey waypoints

Map image is Powered by Esri Inc.

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	15/01/2013	10:00	NO 56322 02892	356322	702892	3	ANS1 (SW)	Bay by Anstruther Golf Club. It was not possible to get to the planned seawater sampling position due to sea state/waves. Few seabirds were present but from droppings is concluded that it's a frequented location.
2	15/01/2013	10:23	NO 56380 03215	356380	703216	4,5		Scottish water discharge - large concrete structure leading out to the bay with no access to the end of the pipe. Surface drains in bay wall, but no visible discharges. Around 45 mallards present in the area.
3	15/01/2013	10:29	NO 56514 03109	356514	703110	6,7	ANS2 (FW)	End of large plastic discharge pipe with small discharge (35 cm Ø ; ~10 ml/s flow rate)
4	15/01/2013	10:44	NO 56577 03330	356577	703331	8,9		Large concrete sewage pipe into the bay. Diver/workers fitting large hood to its end. Some visible discharge with no access to sample it.
5	15/01/2013	10:54	NO 56521 03546	356522	703547	10	ANS3 (FW)	Sewage discharge manhole at Dreel Burn - running into the bay-heavily overflowing. Strong smell of sewage.
6	15/01/2013	11:03	NO 56550 03523	356551	703523			Dreel Burn measurements: Total width of burn is 7m, very fast flowing and turbulent at places. Depth1: 14 cm; Flow 0.344 m/s; SD 0.097 Depth2: 15 cm; Flow 0.205 m/s; SD 0.110
7	15/01/2013	11:20	NO 56774 03509	356774	703509	11,12		Anstruther Harbour. About 100 boats berthed here with a mix of pleasure, fishing and yachts. Flocks of gulls were present too.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
8	15/01/2013	11:34	NO 56850 03461	356850	703462	13		Outfall pipe onto harbour, possibly land drainage. Only visible at low tide but not sampled due to unsafe access - deep mud in harbour and steep overgrown wall ladder.
9	15/01/2013	11:42	NO 57005 03496	357005	703496			Access to shore difficult, continued survey on road until next possible access to shore.
10	15/01/2013	11:50	NO 57333 03564	357333	703564	14,15		Manhole cover in base rock/concrete on foreshore. Visible concrete section runs parallel to shoreline and connects to another stone built structure further south on the shore. Also visible land drainage from harbour wall.
11	15/01/2013	12:03	NO 57661 03768	357662	703769		ANS4 (SW)	Two manhole covers on street, one on foreshore. Outflow could not be located.
12	15/01/2013	12:17	NO 57910 04170	357911	704171			Anstruther Caravan site. Over 100 seabirds in the area. Public toilet and playpark. All closed for winter.
13	15/01/2013	12:26	NO 58122 04482	358123	704483	16,17,18	ANS5 (FW)	Pig farm site with about 20 pig huts visible. Due to bad weather only around 6-8 pigs were visible. Hundreds of gulls in the area, either on land or in air. Sewage collection chamber, possibly Scottish Water, not confirmed as no signs were visible. Stream runs onto shore between caravan site and pig farm. Green algae growing on rocks. Concrete pipe from caravan site runs onto shore next to burn, no discharge. Stream width: 3m, Depth: 4 cm; Flow: 1.031 m/s; SD: 0.016 Depth: 4 cm; Flow: 0.796 m/s; SD: 0.017
14	15/01/2013	12:47	NO 58265 04622	358266	704623	19	ANS6 (SW)	Rocks are green on shore possibly from land run-off from pig farm.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
15	15/01/2013	12:58	NO 58255 04675	358256	704675	20	ANS7 (FW)	Old, concrete outfall pipe with a broken end discharging onto shore from pig farm. (37 cm Ø; Depth: 5 cm; Flow: was not possible to measure due to large amount of sediment in pipe).
16	15/01/2013	13:02	NO 58356 04771	358356	704771	21		Old concrete discharge pipe, possibly land drain from pig farm. 16cm Ø; very small trickle out of it, not sufficient to measure or sample. Pipe also full of sediment.
17	15/01/2013	13:13	NO 58709 04982	358710	704983	22,23	ANS8 (FW)	Another part of pig farm with smaller huts (~100) with sows and piglets in nearly all of them. Plastic outfall pipe from pig farm. (Pipe Ø: 27 cm; Flow: 0.966 m/s; SD: 0.005)
18	15/01/2013	13:30	NO 59288 05286	359288	705286	24	ANS9 (FW)	Stream running onto shore through a culvert (40cm Ø; Depth: 8cm, Flow: 1.653 m/s; SD: 0.017)
19	15/01/2013	13:47	NO 59754 05633	359754	705633	25	ANS10 (FW)	Burn flowing onto shore (Width: 160cm; Depth: 23cm; Flow: 0.610m/s; SD: 0.015). 8-10 sheep in a fenced area very close to burn, no houses nearby.
20	15/01/2013	14:16	NO 60122 05962	360123	705963	26	ANS11 (FW)	Burn flowing onto shore (Width: 118 cm; Depth: 34cm; Flow: 0.317 m/s; SD: 0.021)
21	16/01/2013	9:56	NO 62604 08036	362605	708037	27		Manhole and electrical switch box in Sauchope Link Caravan Park, just outside Crail to the east.
22	16/01/2013	10:01	NO 62626 07949	362626	707949		ANS12 (SW)	Seawater sample taken by caravan park
23	16/01/2013	10:13	NO 62289 07850	362290	707850			Old 12cm iron discharge pipe not connected to shore but still running 100m to low water- no discharge

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
24	16/01/2013	10:19	NO 62120 07796	362120	707796	28	ANS13 (FW)	Groundwater drain running out from under west end of caravan park. Showing signs of green algal growth on shore.
25	16/01/2013	10:26	NO 62068 07874	362069	707874			Scottish water sewage chamber
26	16/01/2013	10:32	NO 61947 07910	361948	707911	29	ANS14 (FW)	Discharge on beach, cement block with 3 discharge pipes, 2 number plastic diameter 10cm and 1 number metal diameter 20cm. Sample taken from 20cm pipe, strong smell, estimated flow rate 75ml/s. Heavy algal growth from plastic pipes but flow insufficient to collect sample.
27	16/01/2013	10:39	NO 61898 07870	361898	707871			2 metal discharge pipes, one 20cm and one 12cm, no flow
28	16/01/2013	10:48	NO 61637 07773	361637	707773	30	ANS15 (FW)	Stream outflow over wall at harbour, lots of green algal growth (Width 70cm; Depth 6cm;flow 0.347m/s; SD 0.010)
29	16/01/2013	11:03	NO 61522 07592	361522	707592	31	ANS16(FW)	Stream running down to bay (Width 90cm; Depth 8cm; Flow 2.205m/s; SD 0.052)
30	16/01/2013	11:12	NO 61389 07493	361390	707493			Discharge pipe into bay, rusted disused.
31	16/01/2013	11:14	NO 61365 07518	361365	707519			Scottish water manholes and service box by castle.
32	16/01/2013	11:23	NO 61239 07408	361239	707409			Scottish water manholes and service box at head of discharge pipe on pier, no access to end of discharge.
33	16/01/2013	11:38	NO 61270 07401	361270	707402	32	ANS17 (FW)	Plastic discharge pipe 30cm diameter. Unable to measure flow because of high sea level, estimated flow of 600-800ml/s
34	16/01/2013	11:41	NO 61209 07414	361210	707415	33		Crail harbour 24 boats of which 11 fishing boats, no discharge into bay

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
35	16/01/2013	11:46	NO 61131 07420	361132	707421	34	ANS18 (FW)	Discharge from 20cm lidded valve, flow estimated 25ml/s Immediately adjacent large orange pipe with little flow- no sample taken no photo taken.
36	16/01/2013	11:50	NO 61095 07418	361095	707419	35	ANS19(FW)	Stream or possibly discharge running downhill through pipe. Pipe broken above beach water/discharge running freely into sand. Flow variable estimated at 300-600ml/s in pulses.
37	16/01/2013	12:02	NO 61062 07170	361062	707171			Sewage discharge pipe running down from hillside, no flow observed width 25cm.
38	16/01/2013	12:14	NO 61078 06873	361078	706873		ANS20 (SW)	Seawater sample taken just SW of Crail
39	16/01/2013	12:18	NO 61002 06924	361002	706925			Natural stream, clean looking no livestock in proximity, no pipes visible.

Photographs referenced in the table can be found attached as Figures 3-35.

Sampling

Water 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 and all of them were received and analysed the following day. The sample temperatures on arrival to the laboratory ranged between 2.4 ˚C and 5.6 ˚C.

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

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

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	15/01/2013	ANS1	NO 56322 02892	Seawater	> 100	36.0
2	15/01/2013	ANS2	NO 56514 03109	Fresh water - contaminated	< 100	
3	15/01/2013	ANS3	NO 56521 03546	Fresh water - contaminated	800000	
4	15/01/2013	ANS4	NO 57661 03768	Seawater	200	36.1
5	15/01/2013	ANS5	NO 58122 04482	Fresh water - contaminated	< 1000	
6	15/01/2013	ANS6	NO 58265 04622	Seawater	37	35.6
7	15/01/2013	ANS7	NO 58255 04675	Fresh water - contaminated	41000	
8	15/01/2013	ANS8	NO 58709 04982	Fresh water - contaminated	51000	
9	15/01/2013	ANS9	NO 59288 05286	Fresh water	200	
10	15/01/2013	ANS10	NO 59754 05633	Fresh water	4600	
11	15/01/2013	ANS11	NO 60122 05962	Fresh water	900	
12	16/01/2013	ANS12	NO 62626 07949	Seawater	45	35.8

13	16/01/2013	ANS13	NO 62120 07796	Fresh water	500	
14	16/01/2013	ANS14	NO 61947 07910	Fresh water - contaminated	1000	
15	16/01/2013	ANS15	NO 61637 07773	Fresh water	1000	
16	16/01/2013	ANS16	NO 61522 07592	fresh water	100	
17	16/01/2013	ANS17	NO 61270 07401	Fresh water - contaminated	4200000	
18	16/01/2013	ANS18	NO 61131 07420	Fresh water - contaminated	< 1000	
19	16/01/2013	ANS19	NO 61095 07418	Fresh water - contaminated	< 1000	
20	16/01/2013	ANS20	NO 61078 06873	Seawater	35	35.6

Photographs

Figure 3. Seawater sample taken in Anstruther bay (Waypoint 1, ANS1)

Figure 4. Sewage outfall pipe in Anstruther bay (WP2)

Figure 5. Sewage outfall pipe in Anstruther bay (WP2)

Figure 6. End of outfall pipe (Waypoint 3, ANS2)

Figure 7. End of outfall pipe (Waypoint 3, ANS2)

Figure 8. Concrete sewage pipe running into bay. Workers fitting a large hood at the end (Waypoint 4)

Figure 9. The end of concrete sewage pipe with fitted a large hood at the end (Waypoint 4)

Figure 10. Dreel Burn with overflowing sewage drain next to it (Waypoint 5, ANS3)

Figure 11. Anstruther harbour

Figure 12. Anstruther harbour

Figure 13. Discharge from harbour wall (Waypoint 8)

Figure 14. Manhole cover on shoreline (Waypoint 10)

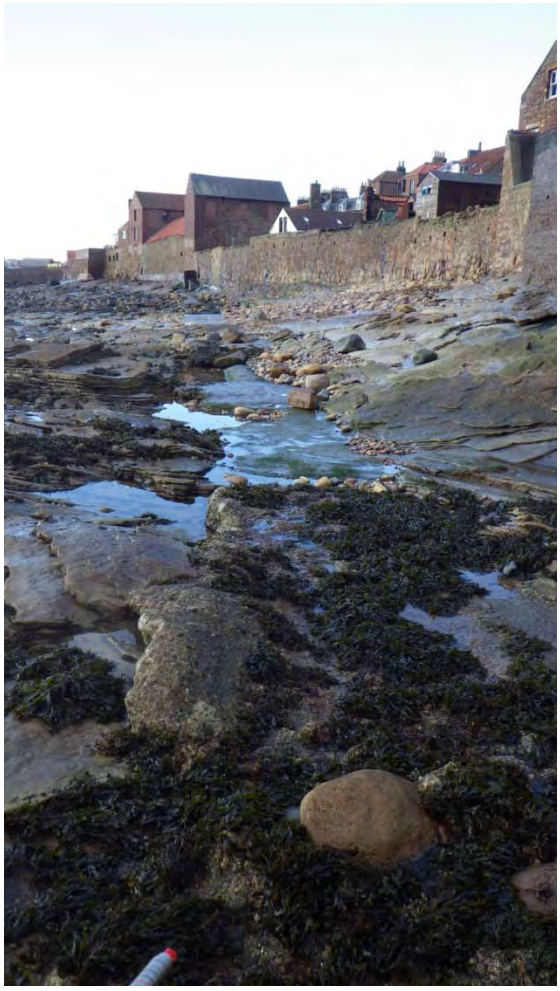

Figure 15. Concrete structure running parallel to shoreline (Waypoint 10)

Figure 16. Sewage collection chamber at pig farm/caravan site (Waypoint 13)

Figure 17. Burn between pig farm and caravan site (Waypoint 13, ANS5)

Figure 18. Old concrete outfall pipe next to sampled burn with no visible discharge (Waypoint 13)

Figure 19. Green rocks due to enhanced algae growth next to pig farm (Waypoint 14, ANS6)

Figure 20. Broken outfall pipe by pig farm discharging onto shore (Waypoint 15, ANS7)

Figure 21. Old concrete pipe, possibly land drain from pig farm (Waypoint 16)

Figure 22. Pig farm with smaller huts (Waypoint 17)

Figure 23. Large plastic outfall pipe by pig farm (Waypoint 17, ANS8)

Figure 24. Stream running through culvert onto shore (Waypoint 18, ANS9)

Figure 25. Burn flowing onto shore, sheep in fenced area nearby (Waypoint 19, ANS10)

Figure 26. Burn running down onto shore (Waypoint 20, ANS11)

Figure 27. Manhole and electrical switchbox, in Sauchope Link Caravan Park, just outside Crail to the east (Waypoint 21)

Figure 28. Groundwater drain running out from under west end of caravan park (Waypoint 24, ANS13)

Figure 29. Discharge on beach, cement block with 3 discharge pipes (Waypoint 26, ANS14)

Figure 30. Stream outflow over wall at harbour increased algal growth on shore rock (Waypoint 28, ANS15)

Figure 31. Stream running onto bay (Waypoint 29, ANS16)

Figure 32. Plastic discharge pipe (Waypoint 33, ANS17)

Figure 33. Crail harbour with boats (Waypoint 34)

Figure 34. Discharge from lidded valve on beach by Crail harbour (Waypoint 35, ANS18)

Figure 35. Stream or possibly discharge running downhill through pipe. The pipe is broken above beach, water/discharge running freely into sand (Waypoint 36, ANS19)