Centre for Environment Fisheries & Aquaculture Science

www.cefas.gov.uk

Silloth Sanitary Survey

Review

November 2014

Food Standards Agency

Cover photo: Lees Scar and Glen Craig from just south of Silloth

This document/publication is also available on our website at:

https://www.cefas.co.uk/publications-data/food-safety/sanitary-surveys/england-and-wales/

Contacts

For enquires relating to this report or further information on the implementation of sanitary surveys in England and Wales:

Simon Kershaw
Food Safety Group
Cefas Weymouth Laboratory
Barrack Road
The Nothe
Weymouth
Dorset
DT4 8UB

☎ +44 (0) 1305 206600
✉ fsq@cefas.co.uk

For enquires relating to policy matters on the implementation of sanitary surveys in England:

Karen Pratt
Hygiene Delivery Branch
Enforcement and Delivery Division
Food Standards Agency
Aviation House
125 Kingsway
London
WC2B 6NH

☎ +44 (0) 207 276 8970
✉ shellfishharvesting@foodstandards.gsi.gov

Statement of use

Under EC Regulation 854/2004 which lays down specific rules for official controls on products of animal origin intended for human consumption, a sanitary survey relevant to bivalve mollusc beds in Silloth was undertaken in 2009. This provided an appropriate hygiene classification zoning and monitoring plan based on the best available information with detailed supporting evidence. The Food Standards Agency (FSA) is committed to reviewing sanitary surveys every six years or sooner if significant changes in pollution sources or the fishery have occurred that may require revision of the sampling plan. This report provides a six year review of information and recommendations for a revised sampling plan. The Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook this work on behalf of the FSA.

Report prepared by

David Walker, Rachel Parks, Fiona Vogt, Owen Morgan.

Revision history

Version	Details	Approved by	Approval date
1	Draft for internal review	David Walker	03/10/2014
2	Draft for external review	Simon Kershaw	18/03/2015
Final	Final report post consultation	Simon Kershaw	10/06/2015

Consultation

Consultee	Date of consultation	Date of response
Allerdale Borough Council	18/03/2015	20/04/2015
Defra	18/03/2015	None
Environment Agency	18/03/2015	19/03/2015 & 20/04/2015
Natural England	18/03/2015	17/04/2015
NW Inshore Fisheries & Conservation Authority	18/03/2015	14/04/2015
Shellfish Association of Great Britain	18/03/2015	None
United Utilities	18/03/2015	02/04/2015

Dissemination

Food Standards Agency and Allerdale District Council. The report is available publicly via the Cefas website.

Recommended Bibliographic Reference

Cefas, 2014. Review of the Silloth 2009 Sanitary Survey. Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under EC Regulation No. 854/2004.

Contents

1. Introduction

1.1. Background

The Centre for Environment, Fisheries & Aquaculture Science (Cefas) is carrying out sanitary surveys for bivalve mollusc production areas (BMPAs) in England and Wales, on behalf of the Food Standards Agency (FSA). The purpose of the sanitary surveys is to demonstrate compliance with the requirements stated in Annex II (Chapter II paragraph 6) of EC Regulation 854/2004, whereby 'if the competent authority decides in principle to classify a production or relay area it must:

(a) make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production areas;
(b) examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste-water treatment, etc.;
(c) determine the characteristics of the circulation of pollutants by virtue of current patterns, bathymetry and the tidal regime in the production area; and
(d) establish a sampling programme of bivalve molluscs in the production area which is based on the examination of established data, and with a number of samples, a geographical distribution of the sampling points and a sampling frequency which must ensure that the results of the analysis are as representative as possible for the area considered.'

In line with the Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2014), Cefas is contracted to undertake reviews of sanitary surveys on behalf of the Food Standards Agency. Reviews are to be undertaken at six yearly intervals after the original sanitary survey or sooner and where there are changes to the type and locations of the shellfisheries or significant changes in sources of pollution.

1.2. Silloth Review

This report reviews available information and makes recommendations for a revised sampling plan for the existing cockles, mussels and Pacific oyster classification zones in the Silloth production area. This review identifies changes to the information presented in the sanitary survey through a desk based study and updates the assessment and sampling plan where necessary.

Specifically, the review will consider:

(a) changes to the shellfishery
(b) changes in microbiological monitoring results

(c) changes in sources of pollution impacting the production area or new evidence relating to the actual or potential impact of sources
(d) changes in land use in the area
(e) change in environmental conditions

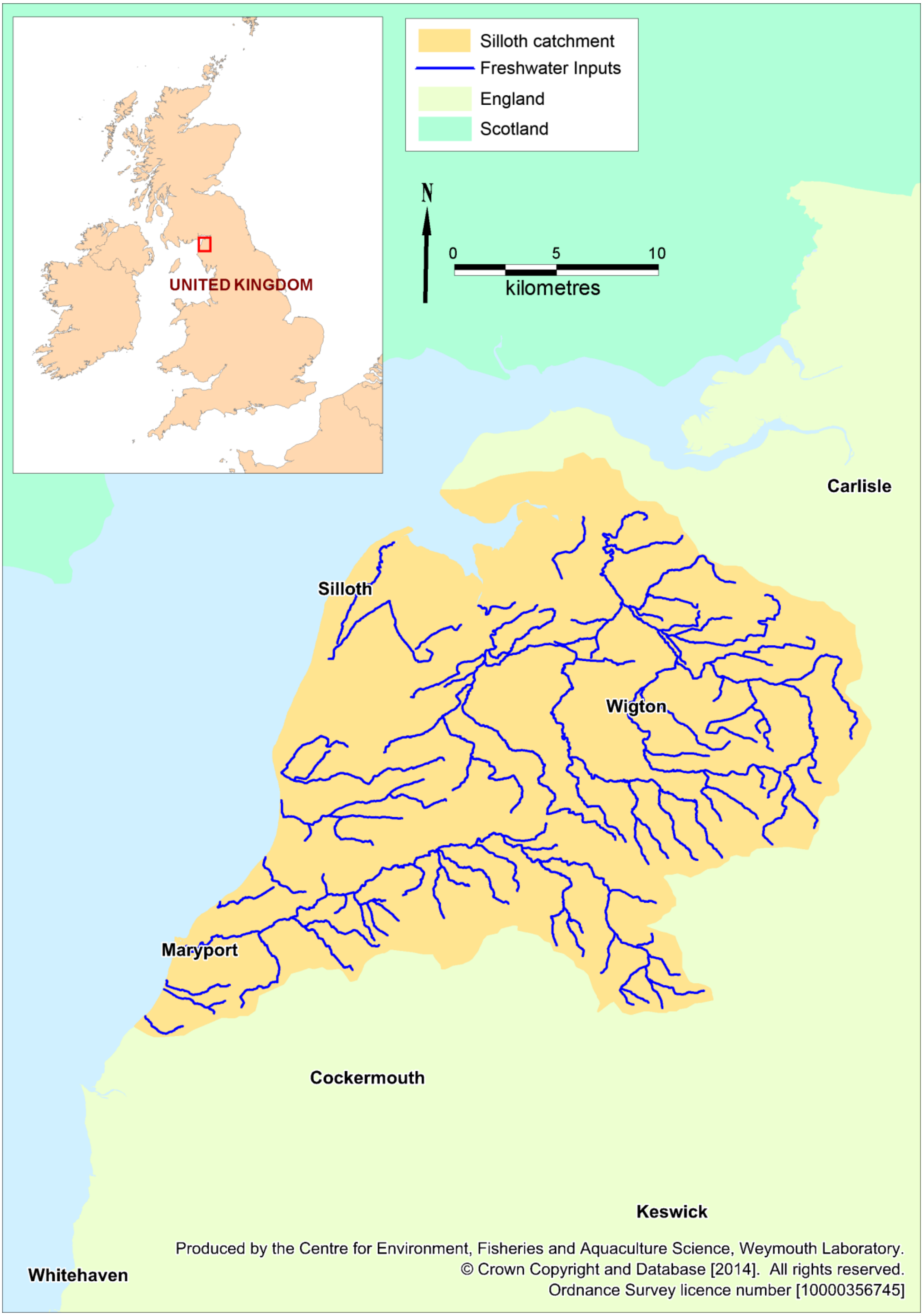


Figure 1.1: Location of Silloth

2. Shellfisheries

2.1. Description of shellfishery

The locations and extents of the cockle and mussel beds as surveyed in the most recent published stock assessments (Lancaster, 2009a & 2009b) are shown in Figure 2.1. The location of the Pacific oyster farm also is shown.

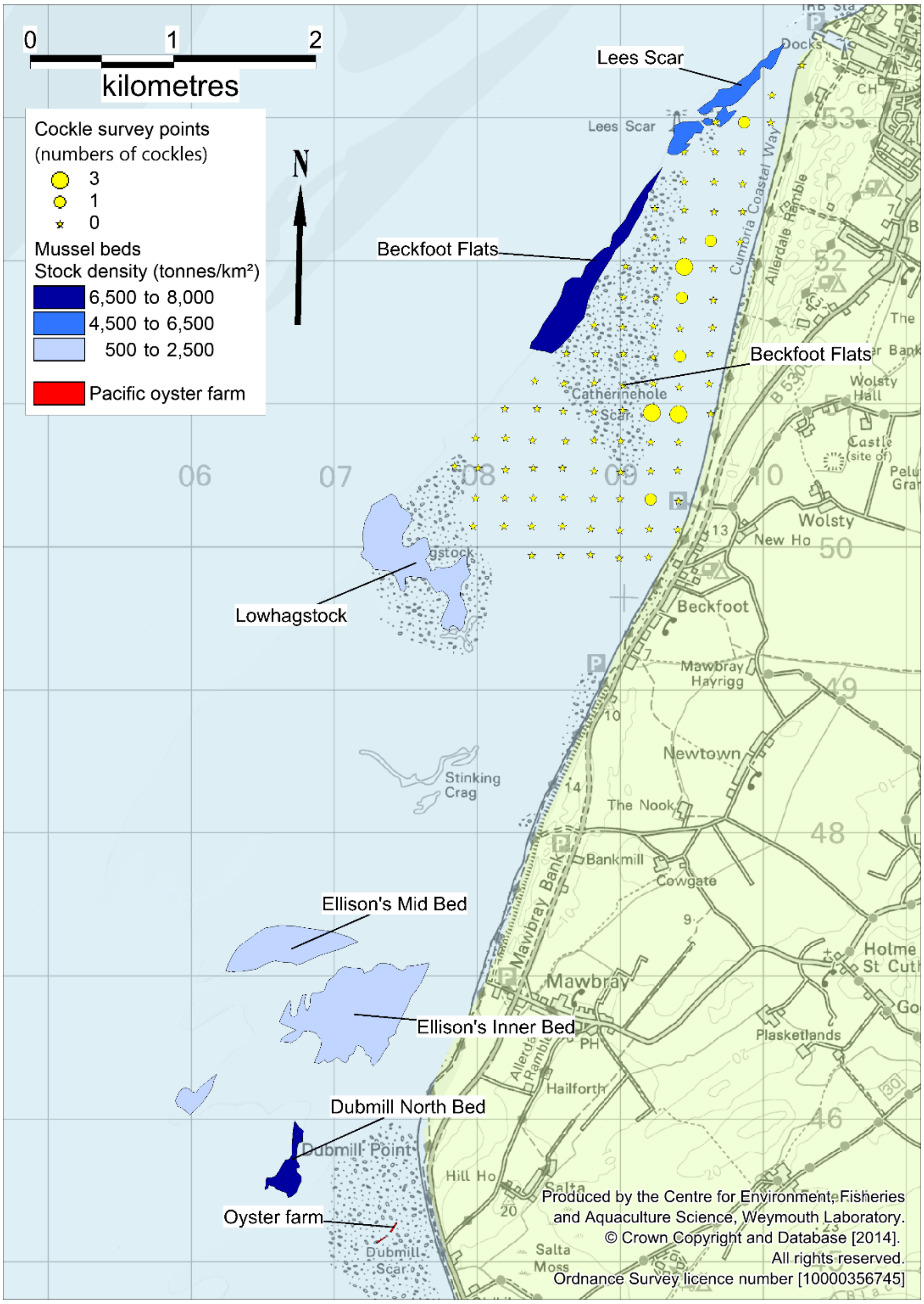


Figure 2.1: Locations of the mussel and cockle beds and the Pacific oyster farm in the Silloth production area.
Data from Lancaster 2009a and 2009b.

All harvesting of cockles and mussels in the North West IFCA region requires a permit under North West IFCA Byelaw 3 (North West IFCA, 2012). Paragraph 7 of Byelaw 3 also states that cockles and mussels must also be gathered by hand or rake. However, suction dredging of cockles, which has been used here previously could be authorised by North West IFCA if there was sufficient stock and environmental assessments showed no adverse environmental impacts.

In the most recently published stock assessment for cockles (Lancaster 2009a), 75 stations were sampled at Beckfoot Flats and the stock densities of cockles were estimated to be 1.47 cockles/m^2.

Due to the low stock densities, cockle beds in the English Solway Firth have been closed to harvesting, Cumbria Sea Fisheries Committee byelaw 18, which is administered by North West IFCA.

A recent survey has shown that stock levels are still very low at Beckfoot Flats and the cockle beds are not likely to reopen for the foreseeable future (North West IFCA, pers comm., 2014).

Table 2.1 shows the mussel stock levels and densities in the Silloth production area according to the most recent published stock assessment, which was carried out in 2009 (Lancaster, 2009b).

Table 2.1: Mussel densities in the English Solway Firth mussel beds in 2009.

Bed name	Estimated commercial sized mussels (tonnes)	Density of commercial sized mussels (tonnes/km^2)
Dubmill North Bed	364.04	6,990
Ellison's Inner Bed	567.26	1,310
Ellison's Mid Bed	117.89	690
Lowhagstock	420.69	1,560
Beckfoot Flats	1,380.97	7,970
Lees Scar	425.07	4,650
Total	3,275.95	-

Data from Lancaster, 2009b

The mussel beds are open for harvesting in the Solway Firth, however due to relatively low stock densities the mussels are not currently exploited. Following a high spatfall in 2009 (Lancaster 2009b), there were indications that marketable size mussel populations were beginning to recover. However, there is currently very little interest in harvesting mussels in the Solway Firth due to the present low stock densities (North West IFCA, pers comm., 2014). A classification area within the Solway Firth Channel was recommended for mussels in the 2009 sanitary survey. However, this area did not become classified, and we are not aware of any renewed commercial interest here.

The pacific oyster farm at Dubmill Point was set up in 2008 using the BST adjustable longline system (BST, 2009). This system uses baskets suspended from lines in which oysters are grown to maturity. The oysters are grown on a five yearly cycle. Currently there are three pairs of lines and the first harvest from this farm was expected in 2014. Originally 150,000 oysters were laid in the baskets and it is not known how many will be available for harvest.

The oysters will be depurated in the harvester's own depuration tanks before being sold both to local restaurants and on the Internet within the UK (W. Morgan, pers comm., 2014). However, it is understood from the local authority that growth has been slower than anticipated and as of May 2015 no oysters had been harvested.

2.2. Hygiene Classification

Table 2.2: Historical hygiene classifications, 2004 to present

Bed name	Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Beckfoot Flatts	Cockles	B	B	B-LT	B-LT	B-LT	B-LT	-	-	-	-	-
Silloth - South	Cockles	-	-	-	-	-	-	B-LT	B-LT	B-LT	B-LT	B-LT
Beckfoot	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	-	-	-	-	-
Dubmill Point	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	DC	-	-
Lees Scar	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	-	-	-	-	-
Mawbray	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Silloth - South	Mussels	-	-	-	-	-	-	B-LT	B-LT	B-LT	B-LT	B-LT
Skinburness	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	-	-	-	-	-
Dubmill Scar	Pacific oysters	-	-	-	-	-	B	B-LT	B-LT	B-LT	B-LT	B-LT

DC = Declassified, B-LT = Long term B

All of the currently classified zones are have long term B classifications.

Table 2.3: Criteria for classification of bivalve mollusc production areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A[2]	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) of *E. coli* 100 g^{-1} Fluid and Intravalvular Liquid (FIL)	None
B[3]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 4,600 *E. coli* 100 g^{-1} FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* 100 g^{-1} FIL	Purification, relaying or cooking by an approved method
C[4]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 46,000 *E. coli* 100 g^{-1} FIL	Relaying for, at least, two months in an approved relaying area or cooking by an approved method
Prohibited[6]	>46,000 *E. coli* 100 g^{-1} FIL[5]	Harvesting not permitted

[1] The reference method is given as ISO 16649-3.
[2] By cross-reference from EC Regulation 854/2004, via EC Regulation 853/2004, to EC Regulation 2073/2005.
[3] From EC Regulation 1021/2008.
[4] From EC Regulation 854/2004.
[5] This level is not specifically given in the Regulation but does not comply with classes A, B or C. The competent authority has the power to prohibit any production and harvesting of bivalve molluscs in areas considered unsuitable for health reasons.
[6] Areas which are not classified and therefore commercial harvesting of LBMs cannot take place. This also includes areas which are unfit for commercial harvesting for health reasons e.g. areas consistently returning prohibited level results in routine monitoring and these are included in the FSA list of designated prohibited bed.

3. Overall Assessment

Figure 3.1 shows an overview of contamination sources for the Silloth production area, and these are discussed below.

Shellfishery

Harvesting of cockles is currently prohibited due to low stock densities. This is likely to continue for the foreseeable future depending on variable spatfall.

The mussel beds are open, however due to low stock densities there is currently no interest in harvesting mussels at this time. However, if stock densities increase to feasible levels, harvesting is likely to resume.

Growth of Pacific oysters at the farm at Dubmill was established in 2008, but no harvest has been taken yet. The operator's depuration plant will need to be approved before harvesting takes place.

Population

Between the 2001 census (data used in the 2009 sanitary survey) and the 2011 census (most recent), the population of the catchment has increased by 0.9%. This small increase is unlikely to have a significant effect on the volume of sewage discharged. However, the level of reported tourism has increased considerably (166%) since the sanitary survey. It is not clear whether this is due to differences in reporting methods or whether this is a genuine change. Analyses of seasonal differences in *E. coli* levels in shellfish before and after the sanitary survey was written show that at the Beckfoot flats cockle RMP, there were generally higher levels of *E. coli* in cockle flesh during the summer months following the sanitary survey. Additionally, at the Dubmill Point mussel RMP there were significantly higher *E. coli* levels in flesh during the summer months following the sanitary survey, while no such pattern existed before the sanitary survey. This may indicate that the reported increase in tourism in the area has led to an increase in seasonal sewage discharges. However, not enough data are available to investigate this fully.

Sewage discharges

The main sources of sewage contamination in this production area are likely to be Allonby Sewage Works to the south and Silloth Screen House WwTW to the north. Since the 2009 sanitary survey, Allonby Sewage works has increased its dry weather flow (DWF) by 107%. Conversely, Silloth Screen House WwTW has reduced its DWF by 62%. Information received immediately prior to the publication of this report also suggests that the Raby Cote trade effluent discharge is "a dominant bacteriological contributor, in particular for *E. coli*, at locations assessed within Silloth shellfish water" (Environment Agency, pers. comm. 2015).

Agriculture

Overall numbers of livestock in the Allerdale District increased between 2007 and 2010 by 27.7%. Nearly all (99%) of the increase in livestock numbers was due to chickens. It was not possible to determine the increases in livestock at the levels of individual farms/holdings and/or associated discharges. Therefore the increase in livestock will not directly influence the position of RMPs. As was reported in the original sanitary report, there are manure piles in the farms near to the shoreline. These could be a source of contamination following rainfall due to run-off into water courses and/or directly into tidal waters.

Freshwater inputs

Water samples taken from Crookhurst Beck, Black Dub and Mawbray Beck (Appendix I), which discharge in close proximity to the shellfish beds, had *E. coli* concentrations of between 3,600 and 6,800 cfu/100 ml. This indicates that these watercourses are likely to be significant contamination sources for the shellfish in this area.

Wildlife

There has been some potential decrease in the number of birds in the Silloth production area. However, due to the highly dispersed nature of birds and other wildlife (including seals), this will not influence the position of RMPs.

Hydrography

There have been no significant changes in the bathymetry of the production area and so its influence of contaminant circulation is also assumed to have remained the same since the 2009 sanitary survey.

There have been no significant differences in the average levels of contamination at any of the cockle or mussel RMPs since the sanitary survey. There has been a slight but significant decrease in *E. coli* levels at the Dubmill Oysters RMP. The relative steadiness of the contamination levels in the shellfish is reflected by the stable long-term B classifications in most of the classification zones. However, as discussed above there does appear to be higher levels of contamination during the summer.

Figure 3.1: Overview of the main sources of contamination to the Silloth production area.

4. Sampling Plan

4.1. Recommendations

Cockles

Cockle stocks are currently too low to take samples for classification. However, in the event that cockle stocks increase, the following classification arrangements are recommended.

Silloth South - As in the 2009 sanitary survey, the main source of contamination to this bed is likely to be the Silloth Screen House WwTW which is to the north of the bed, with additional contamination from the upper Solway Firth. While the dry weather flow at this WwTW had reportedly reduced since the sanitary survey, no other significant changes in contamination sources or circulation have occurred. Therefore both the classification zone and RMP should remain unchanged.

Mussels

Mussels are not currently harvested due to low stock densities. However, the fishery is open for permit holders. It is therefore recommended that monthly sampling continues, to maintain classification if harvesting resumes.

Mawbray - The current classification zone at Mawbray does not extend to the shoreline, and the RMP is currently located outside of the classification zone. The main source of contamination for this bed is likely to be Mawbray Beck, which had a calculated daily *E. coli* loading of $5x10^{11}$ cfu during the shoreline survey. It is therefore recommended that the classification zone is extended to the shoreline as recommended in the sanitary survey, and the RMP remains unchanged.

Silloth South - Contamination sources for the Silloth South mussel zone are similar to the Silloth South cockle zone. Therefore, the RMP should be located towards the north of the bed as it currently is. This zone and RMP should remain unchanged.

Pacific oysters

Dubmill Scar Oysters - The Dubmill Scar Oysters classification zone is larger than the extent of the oyster farm. This allows for future development. The main sources of contamination for this area are likely to be from Allonby Sewage Works, Crookhurst Beck and Black Dub to the south. The RMP should therefore be located as far to the south and inland of the beds as possible. For this reason, while the classification zone should not change, the RMP should be moved to the south-eastern end of the farm. If there are future developments to the south or east of the farm, the RMP should be moved accordingly to take into account the closer proximity to contamination sources.

4.2. General information

Location Reference

Production area	Silloth
Cefas main site reference	M059
Ordnance survey 1:25,000 map	Explorer 314 (The English Lakes, North-western area) Explorer OL4 (Solway Firth)
Admiralty / Imray charts	No 2013 / No C62 *Mostly un-surveyed*

Shellfishery

Species/culture	Cockles (*Cerastoderma edule*) Mussels (*Mytilus spp.*) Pacific oysters (*Crassostrea gigas*)	Wild Wild Cultured
Seasonality of harvest	Year round	

Local Enforcement Authority

Name	Allerdale Borough Council
Environmental health officer	Pam Shepherd
Telephone number ☎	01900 702580
Fax number	01900 702787
E-mail	environmental.health@allerdale.gov.uk

Requirement for review

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2014) indicates that sanitary assessments should be fully reviewed every six years. This assessment is therefore due for formal review in 2020. The assessment may require review in the interim should any significant changes in sources of contamination come to light.

Table 4.1: Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones within the Silloth estuary

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Sampling species	Tolerance	Frequency	Comments
Silloth South	B059M	Catherinehole Scar	NY09865256	54°51.581'N 03°24.346'W	Cockles	Wild	Hand	Hand	Cockles	100 m	Monthly	-
Mawbray	B059N	Mawbray	NY07574704	54°48.580'N 03°26.380'W	Mussels	Wild	Hand	Hand	Mussels	100 m	Monthly	-
Silloth South	B059L	Lees Scar	NY10055345	54°52.062'N 03°24.185'W	Mussels	Wild	Hand	Hand	Mussels	100 m	Monthly	-
Dubmill Scar Oysters	TBA*	Dubmill Oysters 2	NY07384520	54°47.586'N 03°26.522'W	Pacific oysters	Cultured	Hand	Hand	Pacific oysters	10 m	Monthly	-

**RMP code will be generated once the report has been agreed and finalised.*

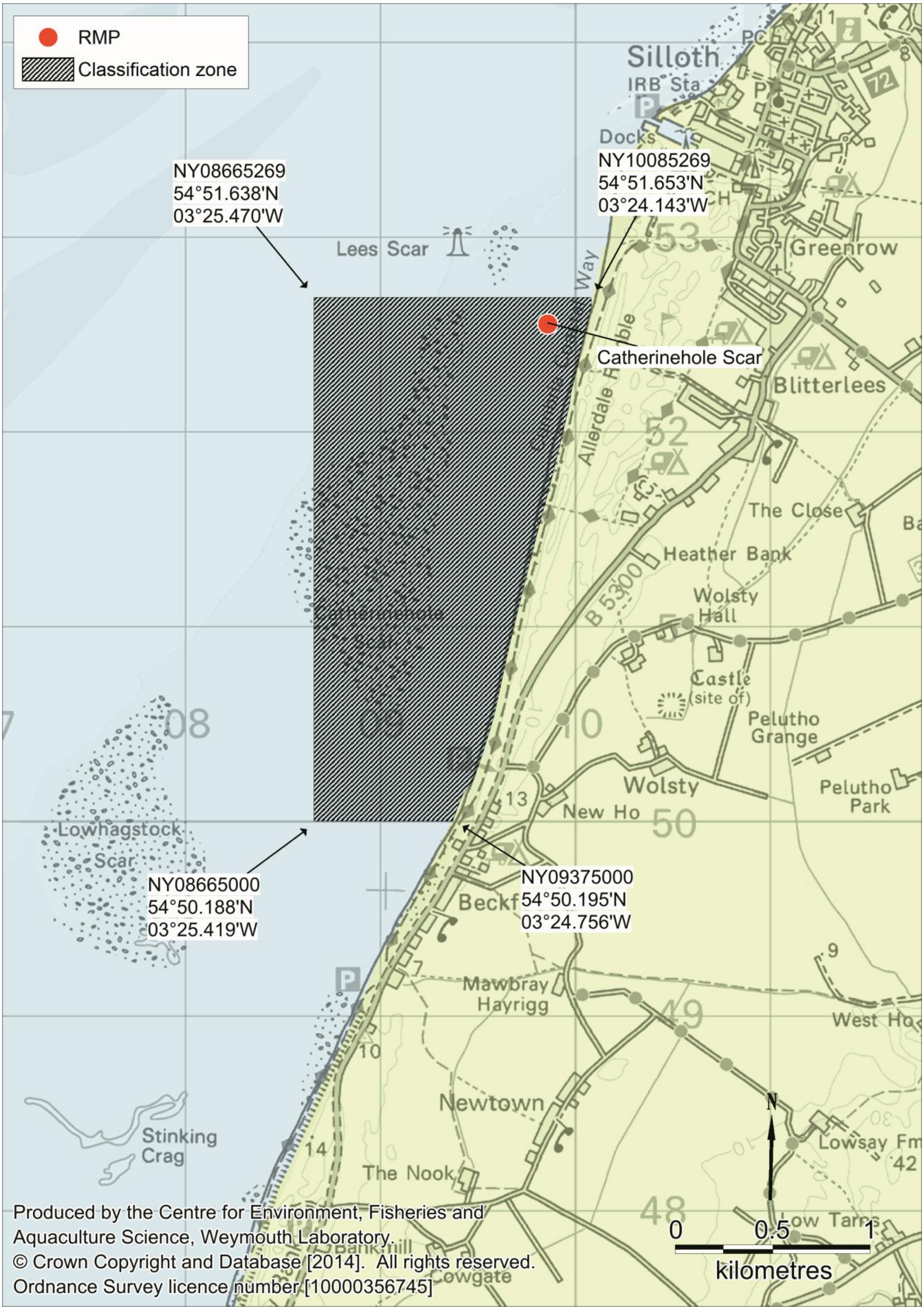


Figure 4.1: Recommended zoning and monitoring arrangements (cockles).

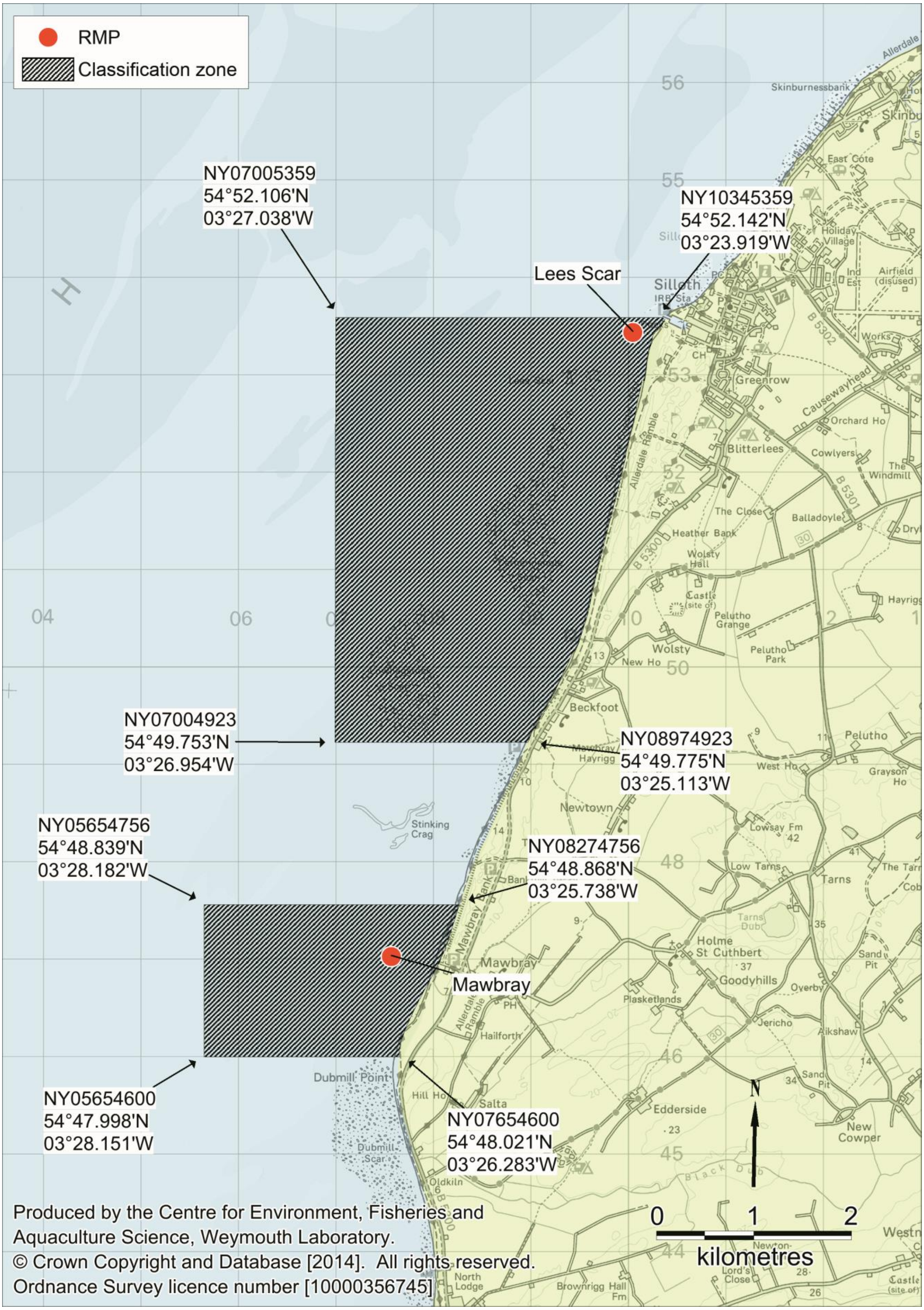


Figure 4.2: Recommended zoning and monitoring arrangements (mussels).

Figure 4.3: Recommended zoning and monitoring arrangements (Pacific oysters).

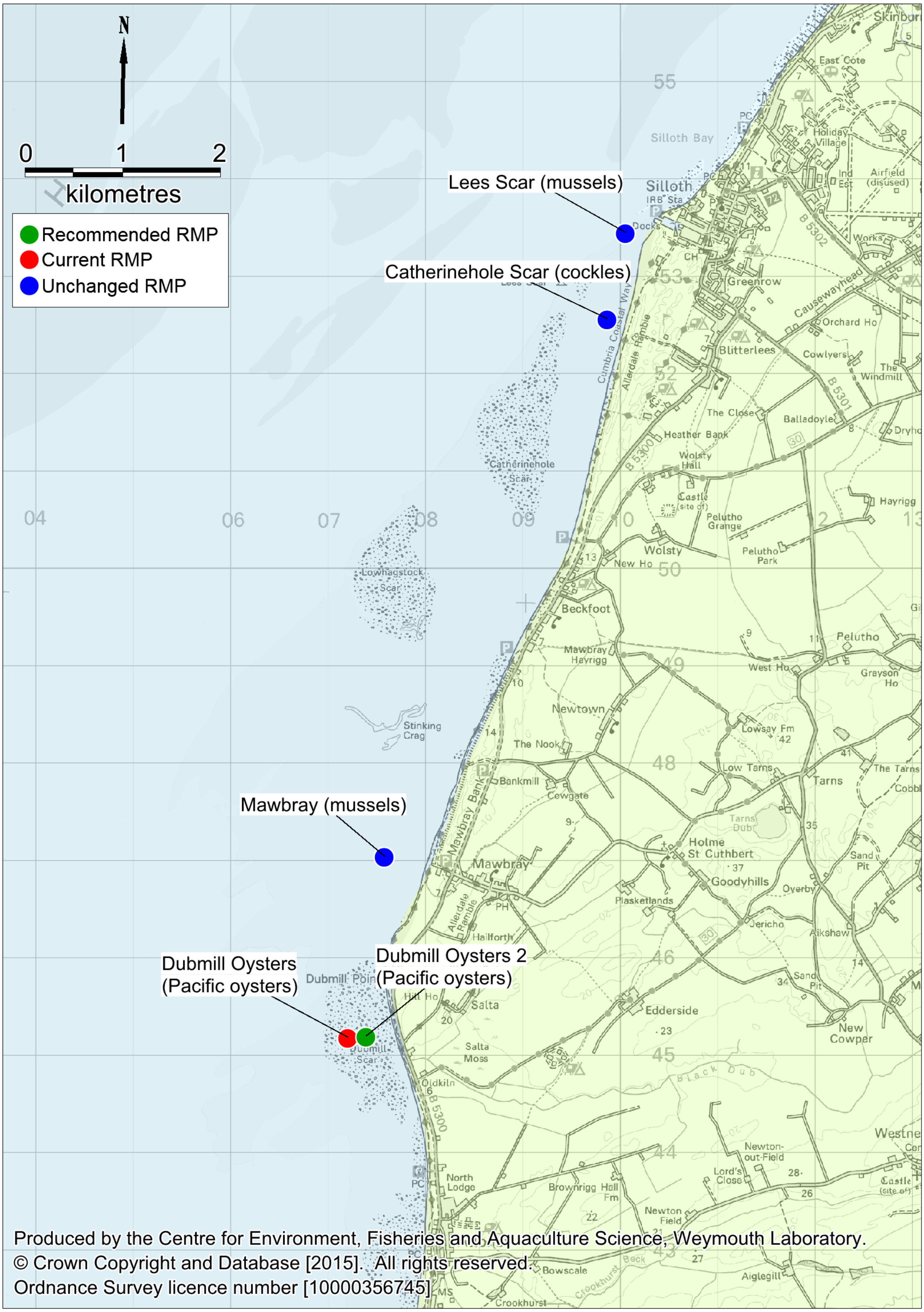


Figure 4.4: Current and recommended RMPs. Cockle and mussel RMPs remain unchanged.

5. Pollution sources

5.1. Population

In the 2009 Silloth Sanitary Survey Report, the population data presented were collected in the 2001 census. Another census was conducted in 2011.

Figure 5.1 shows population densities in census Lower Layer Super Output Areas (LSOAs) within or partially within the Silloth catchment area, derived from data collected from the 2011 census. The population density within the catchment is predominantly low (<1,100 people/km²). Since the 2001 census, the population density has remained similar throughout the catchment, with the highest population densities situated in and around the towns of Maryport, Dearham and Wigton. The total population in the catchment area increased from 57,800 to 58,300 (0.9% increase) between 2001 and 2011.

In Allerdale the number of tourists (including day visitors) has increased considerably from 2.5 M (Allerdale Borough Council, 2005) to 6.64 M between 2002 and 2013 (Cumbria Tourism).

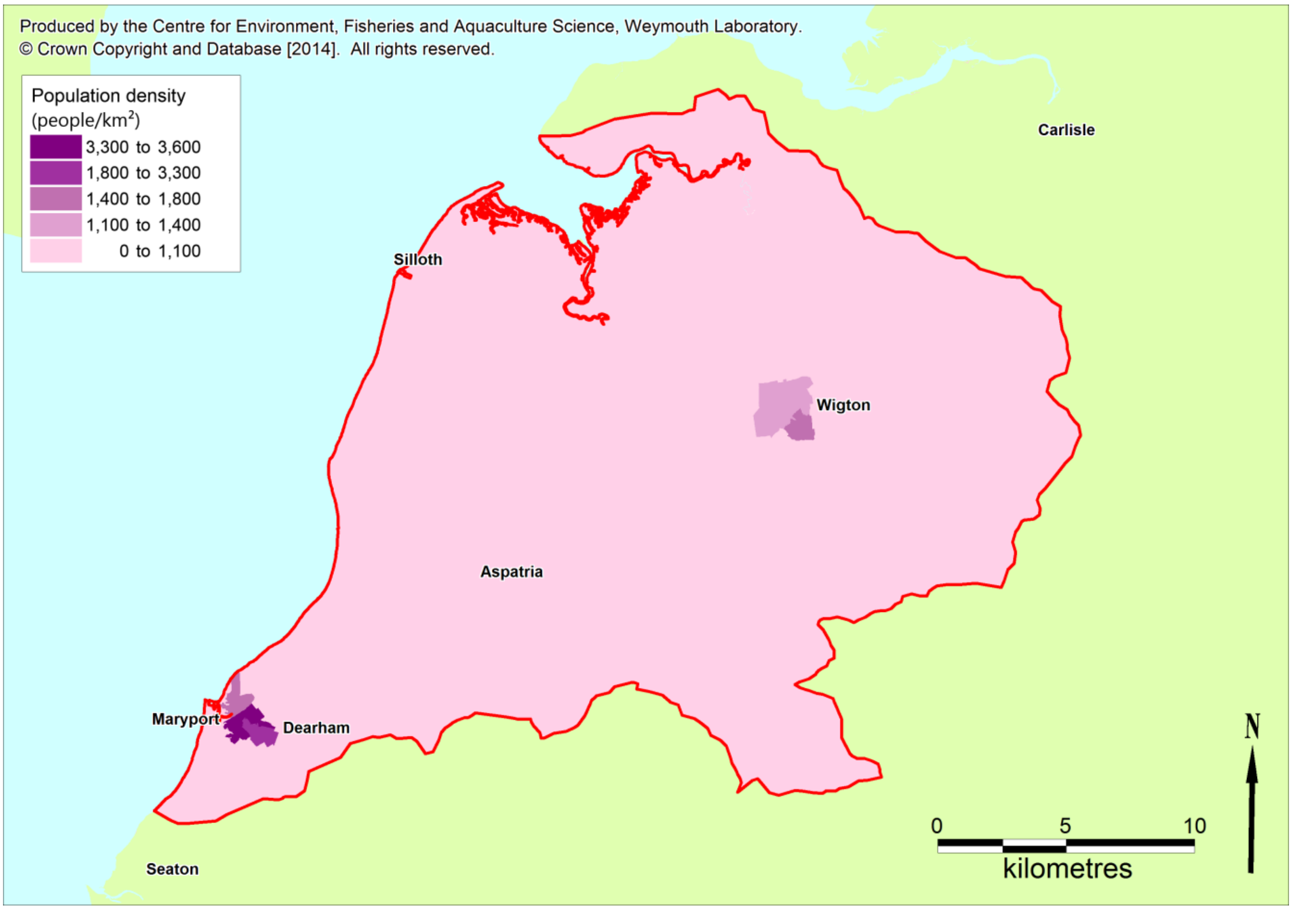


Figure 5.1: Human population density in census LSOAs in the Silloth catchment

5.2. Sewage

Figure 5.2 shows the locations of all of the current discharges identified in the Environment Agency (EA) national permit database (July 2014) which fall within the catchment area for the Silloth production area.

The 2009 sanitary survey only reported a very small number of discharges and did not include those in the upper catchment. The only discharge reported in the 2009 report that is no longer consented is the Greenrow PS CSO (Appendix II, Table 4.3).

There are a total of 38 water company owned, continuous discharges (Table 5.1) within the catchment, six of which were reported in the 2009 sanitary survey report. Three of these discharges had dry weather flows (DWF) reported in the current Environment Agency (EA) national permit database. The 2009 sanitary survey reported that Allonby Sewage Works had a DWF of 112 m^3/day (recent information from United Utilities states this was in fact 103 m^3/day), but this has since increased to 232 m^3/day. The Silloth Screen House WwTW has reduced its DWF from 2,298 m^3/day reported in the 2009 sanitary survey to 880 m^3/day currently. Additionally, while there is no reported DWF for Hayton STW, its treatment level has been upgraded from secondary to tertiary biological treatment since 2009.

A total of 58 water company owned intermittent discharged are consented in the Silloth production area catchment (Table 5.2). Seven of these were reported in the 2009 report. The Maryport Sewage Pumping Station was associated with poor bathing water results at Allonby. Additional storage was built at Maryport Sewage Pumping Station in September 2012 to reduce the number of spills from this discharge.

Table 5.4 and Figure 5.3 show the spills from the Allonby Sewage Works intermittent discharges. Much of the spill data for this period were unavailable at the time of writing. While the discharge does not appear to spill often, there were occasional large spills in 2011.

There are also 33 private discharges in the catchment with consented DWFs equal to or greater than 5 m^3/day (Table 5.3). Three of these were reported in the 2009 sanitary survey report: The Vicarage Field Caravan Park discharge, maximum daily flow previously unknown, has a maximum daily flow of 18 m^3 recorded in the current database; The maximum daily flow from Mealo House Caravan Site has increased from 51 to 58 m^3 and Tanglewood Caravan Park, does not have a maximum daily flow reported in the current database. Information received immediately prior to the publication of this report also suggests that the Raby Cote trade effluent discharge is “a dominant bacteriological contributor, in particular for *E. coli*, at locations assessed within Silloth shellfish water” (Environment Agency, pers. comm. 2015).

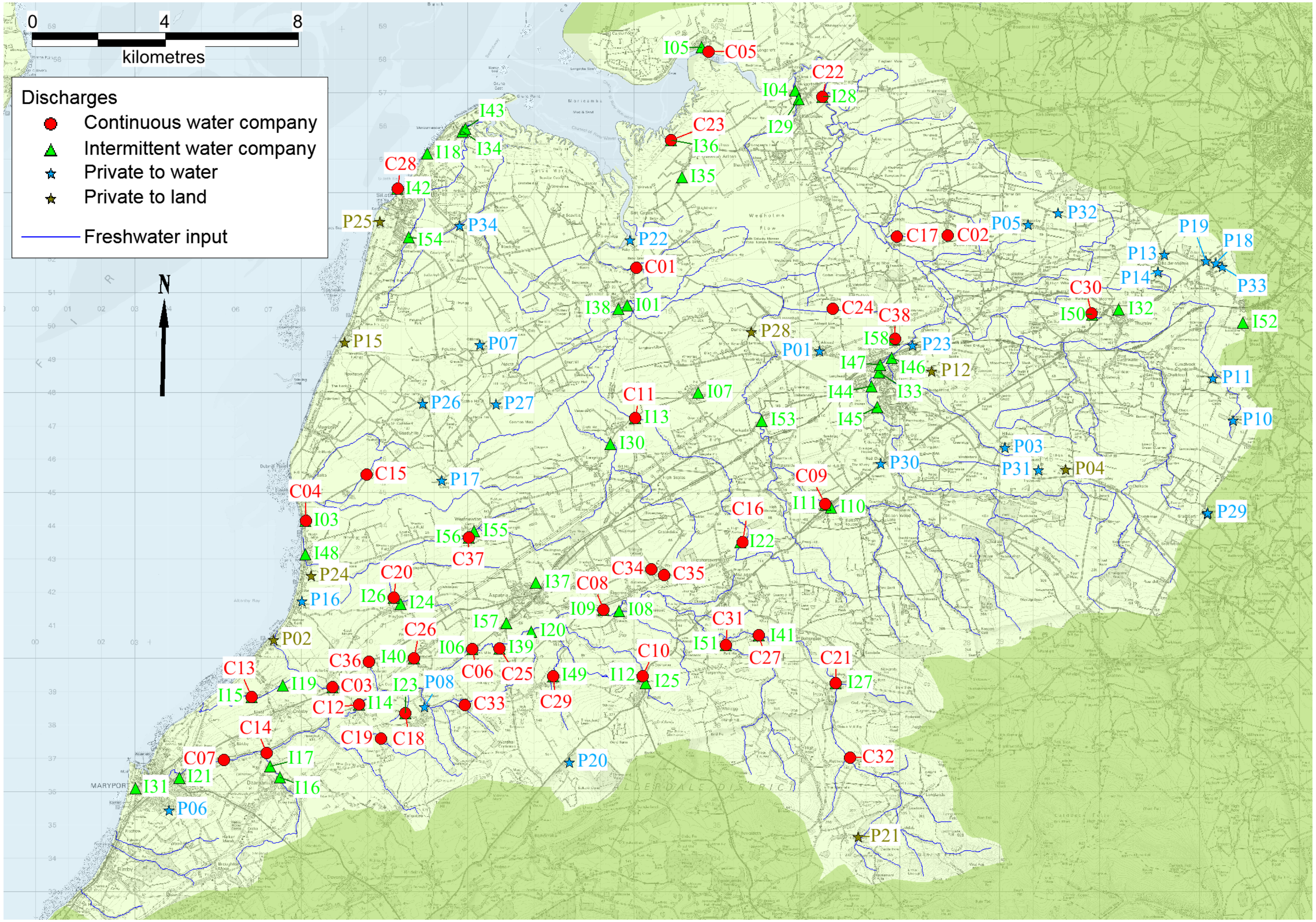


Figure 5.2: Discharges in the Silloth production area catchment (Table 5.1, Table 5.2, and Table 5.3 for details)

Contains Environment Agency information © Environment Agency and database right

Table 5.1: Continuous water company discharges within the Silloth production area catchment.

Number on map	Name in current database	Name in 2009 report	NGR	Reported in 2009 sanitary survey?	Treatment	Dry weather flow (m³/day)	Receiving environment
C01	Abbey Town WwTW		NY1805051750	No	2° (Biological)	206	Freshwater river
C02	Aikton WwTW		NY2742052710	No	2° (Biological)	112	Freshwater river
C03	Allerby STW	Allerby STW	NY0892039130	Yes	2° (Biological)	85	Freshwater river
C04	Allonby Sewage Works	Allonby STW	NY0812044130	Yes	2° (Biological)	232	Controlled sea
C05	Anthorn STW		NY2023058240	No	2° (Biological)	NR	Saline Estuary
C06	Aspatria STW		NY1312040280	No	2° (Biological)	NR	Freshwater river
C07	Birkby STW		NY0565036950	No	2° (Biological)	NR	Freshwater river
C08	Blennerhasset STW		NY1706041460	No	2° (Biological)	NR	Freshwater river
C09	Bolton Low Houses STW		NY2374044640	No	2° (Biological)	NR	Freshwater river
C10	Bothel STW		NY1825039470	No	2° (Biological)	106	Freshwater river
C11	Bromfield STW		NY1802047230	No	2° (Biological)	NR	Freshwater river
C12	Bullgill STW		NY0972038620	No	2° (Biological)	7	Freshwater river
C13	Crosscanonby STW		NY0649038840	No	3° (Biological)	215	Freshwater river
C14	Dearham STW		NY0693037150	No	2° (Biological)	710	Freshwater river
C15	Edderside STW	Edderside STW	NY0994045520	Yes	2° (Biological)	NR	Freshwater river
C16	Fletchertown STW		NY2125043500	No	2° (Biological)	NR	Freshwater river
C17	Gamelsby STW		NY2589052690	No	1° (Settlement)	NR	Freshwater river
C18	Gilcrux STW		NY1110038360	No	2° (Biological)	NR	Freshwater river
C19	Greengill STW		NY1038037580	No	2° (Biological)	NR	Freshwater river
C20	Hayton STW	Hayton STW	NY1076041830	Yes	3° (Biological)	NR	Freshwater river
C21	Ireby WwTW		NY2405039260	No	2° (Biological)	117	Freshwater river
C22	Kirkbride ETW		NY2365056890	No	2° (Biological)	112	Freshwater river
C23	Newton Arlosh WwTW		NY1909055590	No	2° (Biological)	54	Freshwater river
C24	Oulton STW		NY2396050520	No	2° (Biological)	NR	Freshwater river
C25	Plumbland STW		NY1394040300	No	2° (Biological)	NR	Freshwater river

Number on map	Name in current database	Name in 2009 report	NGR	Reported in 2009 sanitary survey?	Treatment	Dry weather flow (m³/day)	Receiving environment
C26	Prospect/Oughterside STW		NY1137040010	No	2° (Biological)	120	Freshwater river
C27	Quarry Hill WTW		NY2173040690	No	Unknown	NR	Freshwater river
C28	Silloth Screen House WwTW	Silloth STW	NY1088054120	Yes	3° (UV)	880	Freshwater river
C29	Threapland STW		NY1555039470	No	2° (Biological)	NR	Freshwater river
C30	Thursby STW		NY3175050370	No	2° (Biological)	220	Freshwater river
C31	Torpenhow STW		NY2075040410	No	2° (Biological)	NR	Freshwater river
C32	Uldale STW		NY2449037010	No	2° (Biological)	NR	Freshwater river
C33	Wardhall Guards STW		NY1290038600	No	2° (Biological)	NR	Freshwater river
C34	Watch Hill STW		NY1850042670	No	2° (Biological)	NR	Freshwater river
C35	Watchhill (West) WwTW		NY1889042510	No	1° (Settlement)	10	Freshwater river
C36	Westmoor End STW		NY1002039890	No	2° (Biological)	NR	Freshwater river
C37	Westnewton STW	West Newton STW	NY1302043630	No	2° (Biological)	NR	Freshwater river
C38	Wigton STW		NY2584049600	No	2° (Biological)	2515	Freshwater river

Contains Environment Agency information © Environment Agency and database right
NR=Not Reported

Table 5.2: Intermittent water company discharges within the Silloth production area catchment. Grey cells indicate discharges used in Figure 5.3.

Number on map	Name in current database	Name in 2009 report	NGR	Reported in 2009 sanitary survey?	Receiving environment
I01	Abbeytown PS		NY1777050610	No	Freshwater river
I02	Allerby STW		NY0892039130	No	Freshwater river
I03	Allonby Sewage Works		NY0811044130	No	Controlled sea
I04	Angerton PS		NY2284057080	No	Freshwater river
I05	Anthorn PS		NY2002058380	No	Freshwater river
I06	Aspatria STW		NY1312040280	No	Freshwater river
I07	Blencogo PS		NY1991048000	No	Freshwater river
I08	Blennerhasset SPS		NY1753041430	No	Freshwater river
I09	Blennerhasset STW		NY1706041460	No	Freshwater river
I10	Bolton Low Houses CSO		NY2391044530	No	Freshwater river

Number on map	Name in current database	Name in 2009 report	NGR	Reported in 2009 sanitary survey?	Receiving environment
I11	Bolton Low Houses STW		NY2374044630	No	Freshwater river
I12	Bothel STW		NY1825039470	No	Freshwater river
I13	Bromfield STW		NY1802047230	No	Freshwater river
I14	Bullgill STW		NY0972038620	No	Freshwater river
I15	Crosscanonby STW		NY0649038840	No	Freshwater river
I16	Dearham Hall		NY0733036430	No	Freshwater river
I17	Dearham STW		NY0704036760	No	Freshwater river
I18	East Cote PS		NY1177055190	No	Freshwater river
I19	Eastland Farm		NY0742039190	No	Freshwater river
I20	Ellen Vale		NY1490040800	No	Freshwater river
I21	Ellenborough Rd(Rail B)		NY0431036400	No	Freshwater river
I22	Fletchertown STW		NY2118043490	No	Freshwater river
I23	Gilcrux STW		NY1110038360	No	Freshwater river
I24	Grange Farm Combined Sewer Overflow	Grange Farm CSO	NY1096041640	Yes	Freshwater river
I25	Greyhound Inn		NY1833039250	No	Freshwater river
I26	Hayton STW		NY1076041830	No	Freshwater river
I27	Ireby WwTW		NY2405039260	No	Freshwater river
I28	Kirkbride ETW		NY2365056890	No	Freshwater river
I29	Kirkbride PS		NY2293056810	No	Freshwater river
I30	Langrigg PS		NY1728046450	No	Freshwater river
I31	Maryport Sewage Pumping Station	Maryport SPS CSO	NY0299036090	Yes	Controlled sea
I32	Meadow Croft Pumping Station		NY3256050490	No	Freshwater river
I33	Meeting House Lane CSO		NY2535048600	No	Freshwater river
I34	Moricambe Park PS	Moricambe Park PS	NY1282055840	Yes	Saline Estuary
I35	Newton Arlosh West PS		NY1942054480	No	Freshwater river
I36	Newton Arlosh WwTW		NY1909055590	No	Freshwater river
I37	North Rd/North View		NY1504042270	No	Freshwater river
I38	Opp West View		NY1752050520	No	Freshwater river
I39	Plumbland STW		NY1394040300	No	Freshwater river

Number on map	Name in current database	Name in 2009 report	NGR	Reported in 2009 sanitary survey?	Receiving environment
I40	Prospect/Oughterside STW		NY1137040010	No	Freshwater river
I41	Quarry Hill Wtw		NY2173040690	No	Freshwater river
I42	Silloth Screen House WwTW	Silloth STW storm tank	NY1087054120	Yes	Freshwater river
I43	Skinburness Hotel SPS		NY1291055930	No	Saline Estuary
I44	South End Road CSO		NY2512048180	No	Freshwater river
I45	Springfields PS		NY2530047560	No	Freshwater river
I46	Stampery PS		NY2574049030	No	Freshwater river
I47	Station Hill CSO		NY2539048820	No	Freshwater river
I48	The Square		NY0810043120	No	Not reported
I49	Threapland STW		NY1555039470	No	Freshwater river
I50	Thursby STW		NY3177050330	No	Freshwater river
I51	Torpenhow STW		NY2075040410	No	Freshwater river
I52	Townhead SPS		NY3629050100	No	Freshwater river
I53	Waverton PS		NY2182047150	No	Freshwater river
I54	West Silloth PS	West Silloth PS	NY1122052670	Yes	Freshwater river
I55	Westnewton PS	West Newton PS	NY1318043820	Yes	Freshwater river
I56	Westnewton STW	West Newton STW storm tank	NY1302043630	Yes	Freshwater river
I57	White Horse Yard		NY1414041070	No	Freshwater river
I58	Wigton STW		NY2581049590	No	Freshwater river

Table 5.3: Private discharges within the Silloth production area catchment with maximum daily flows above 5 m³.

Number on map	Name in current database	Name in 2009 report	NGR	Reported in 2009 sanitary survey?	Maximum daily flow (m^3) 2014	Receiving environment
P01	Aikhead Farm		NY2356049250	No	5	Water
P02	Blue Dial Caravan Park	Blue Dial Caravan Park	NY0715040550	Yes	20	Land
P03	Brackenthwaite House		NY2913046340	No	5	Water
P04	Causa Court		NY3095845682	No	7.5	Land
P05	Croft House Farm		NY2984053050	No	5	Water
P06	Ewanrigg Minewater Treatment Scheme		NY0401035430	No	864	Water

Number on map	Name in current database	Name in 2009 report	NGR	Reported in 2009 sanitary survey?	Maximum daily flow (m³) 2014	Receiving environment
P07	Foulsyke Farm		NY1334049430	No	6.4	Water
P08	Gilcrux Trout Farm		NY1168038550	No	4320	Water
P09	Green View Lodges		NY3522044350	No	10.4	Water
P10	Hawksdale Pastures Package STP		NY3600047164	No	5.2	Water
P11	Kingswood Educational Centre		NY3539048430	No	32	Water
P12	Kirkland Farm Barns		NY2694048640	No	5	Land
P13	Land Adj To Linden Farm		NY3393052150	No	5	Water
P14	Linden Farm		NY3375051630	No	7	Water
P15	Mayfair Caravan Park		NY0929149510	No	20	Land
P16	Mealo House Caravan Site	Mealo House Caravan Park	NY0799641730	Yes	58	Water
P17	New Cowper Farm		NY1220245345	No	7.5	Water
P18	Orton Grange Caravan Park		NY3548051890	No	20	Water
P19	Orton Grange Farm		NY3519051950	No	5	Water
P20	Osprey Hotel		NY1603536869	No	65	Water
P21	Overwater Hall Hotel		NY2472034630	No	5	Land
P22	Raby Cote Trade Effluent		NY1787052621	No	4000	Water
P23	Spittal Farm Estate		NY2636049420	No	17	Water
P24	STP @ Vicarage Field Caravan Park	Vicarage Field	NY0828142478	Yes	18	Land
P25	STS & UV Treated Effluent @ Siloth		NY1034553133	No	18.5	Land
P26	Tarnside Caravan Park		NY1162047660	No	31.5	Water
P27	The Bog Farm		NY1383047640	No	5	Water
P28	The Limes Farm		NY2152049820	No	7	Land
P29	The Royal Oak		NY3523644381	No	20	Water
P30	The Sun Inn		NY2540045860	No	7.5	Water
P31	Tracentree Low House		NY3015045670	No	5	Water
P32	Watchtree		NY3074053390	No	289	Water
P33	Westwood Nurseries		NY3566451784	No	20	Water
P34	Tanglewood Caravan Park	Tanglewood Caravan Park	NY1273853009	Yes	NR	Water

Contains Environment Agency information © Environment Agency and database right
NR=Not reported

Table 5.4: Spills from intermittent discharges in the Silloth production area catchment.

	Number of spills				% time spilling*			
Discharge	**2008**	**2009**	**2010**	**2011**	**2008**	**2009**	**2010**	**2011**
Allonby Sewage Works	7	6	1	12	1.06	1.46	0.23	0.85

Contains Environment Agency information © Environment Agency and database right
*% time spilling were adjusted to account for missed reporting days.
Missing data from 12/01/2009-30/06/2009, 01/10/2009-30/09/2010 & 01/10/2011-31/12/2011 (not available at time of writing)
Spills assessment derived using EA 12/24 hour block counting method

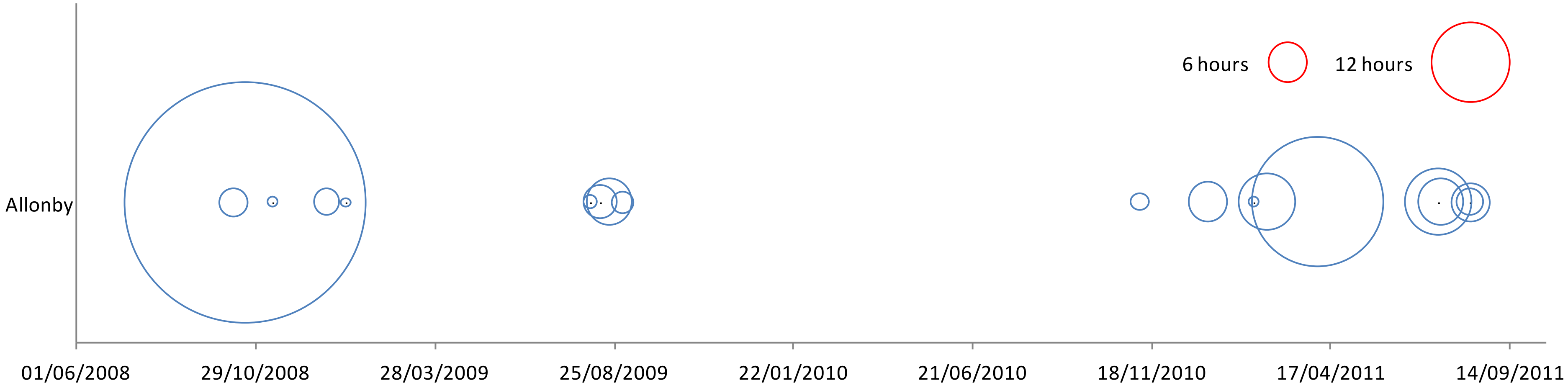


Figure 5.3: Bubble plot of spills from intermittent discharges in the Silloth production area catchment.
Contains Environment Agency information © Environment Agency and database right
Missing data from 12/01/2009-30/06/2009, 01/10/2009-30/09/2010 & 01/10/2011-31/12/2011 (not available at time of writing)

5.3. Agriculture

No livestock data were freely available for the same area assessed in the sanitary survey report (Ellen and Waver catchments). However, the livestock numbers for the Allerdale district area were available for both 2007 and 2010. Ninety six percent of the Silloth production area catchment lies within the Allerdale district, but only makes up 40% of the total area of the district. Therefore, the changes in livestock numbers shown in Table 5.5 may not be truly representative of the catchment.

There has been an overall increase in livestock in the Allerdale district. Chickens accounted for 99% of the total increase in livestock numbers.

Table 5.5: Livestock data for the Allerdale District in 2007 and 2010.

	2007	2010	% difference
Cattle	121,495	118,213	-2.7
Sheep	307,056	307,047	<-0.01
Pigs	4,876	7,234	+48.4
Poultry	387,336	615,560	+58.9
Sum	820,763	1,048,054	+27.7

Data from Defra (2010)

5.4. Wildlife

The Solway Firth hosts internationally important migratory and overwintering populations of wading birds and wildfowl. Since the 2009 sanitary survey the number of birds residing in the Firth has decreased slightly. An average of 122,602 waders and wildfowl were recorded for the five winters up to 2007/2008 (Holt *et al*, 2009) in the Solway Firth compared to an average of 113,765 waders and wildfowl over the five winters running up to 2012/2013 (Austin *et al*, 2014). However, it is unclear whether these are significant changes or due to natural fluctuation. There are no official data available to suggest that numbers of waders, wildfowl, gull or terns within the survey area have changed since the last survey but it is expected that they will be of similar numbers. As concluded in the 2009 survey, birds are likely to be a source of contamination to shellfish beds, predominantly in the winter months when migratory birds are present. However, due to the diffuse and spatially unpredictable nature of contamination from birds it is difficult to select specific monitoring locations to account for this.

Seals were not assessed as a source of microbiological contamination to the shellfish beds in the 2009 survey. Seals are present within the Solway Firth, often hauled out on sand flats. However no formal counts or haul out locations have been identified within the survey area (Natural England; The Wildlife Trusts; The Solway Firth Partnership, 2012). A survey undertaken in 2007, recorded 23 harbour seals in South West Scotland between Loch Ryan and the English Border at Carlisle (including the northern section of the Solway Firth) (SCOS, 2013). The moulting and pupping season for harbour seals is between June and August and in these months they will spend more time at their haul out sites. Therefore, harbour seals may enter the survey area from time to time but given the small numbers and large area over which they are likely to forage, their impacts are likely to be minor and unpredictable in spatial terms. Consequently, the presence of seals will not influence the sampling plan.

6. Hydrodynamics

Bathymetry within the Silloth survey area remains largely unchanged since the 2009 survey. Comparison of Admiralty Chart No. 2013, 2001 edition (up to date with 2005 Notice to Mariners) and the 2010 edition (up to date with Notice to Mariners 2012) showed there have been minor changes to the depths throughout the survey area. There have also been some minor movements to sand banks such as the Beckfoot Flats. These changes are unlikely to have modified surface currents considerably.

As detailed in the 2009 survey, residual currents off the Cumbrian coast flow in a north to south orientation. However, inshore currents are likely to be modified by coastal features and wind direction. It was concluded that onshore currents generated during the dominant flood tide and subject to the effect of dominant westerly winds will promote the onshore retention of microbiological contamination.

7. Rainfall

There were no freely available rainfall data available that were relevant to this report.

8. Microbial Monitoring Results

8.1. Summary statistics and geographical variation

There are a total of 10 representative monitoring points (RMPs) in the Silloth production area that have been sampled between 2003 and 2014. Two of these RMPs are for cockles, seven are for mussels and one is for Pacific oysters. Five of these RMPs have been sampled both before and after the 2009 sanitary survey.

The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2003 onwards are presented in Figure 8.1. Summary statistics are presented in Table 8.1 and boxplots for sites are shown in Figure 8.2 to Figure 8.4.

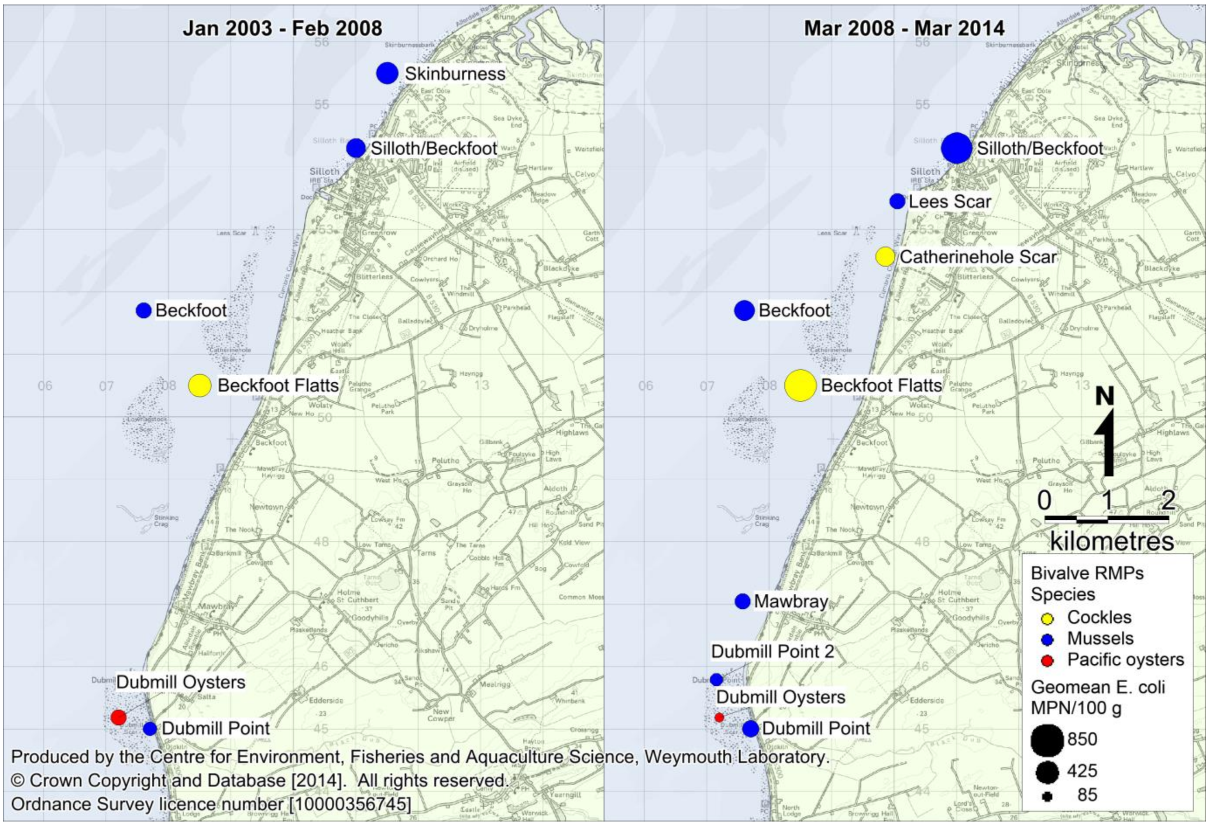


Figure 8.1: Bivalve RMPs active since 2003

Table 8.1: Summary statistics of *E. coli* results (MPN/100 g) from RMPs sampled from 2003 onwards

Site	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4,600	% over 46,000
Catherinehole Scar	Cockle	41	05/01/2010	04/03/2014	319.9	<20	5,400	58.5	4.9	0.0
Beckfoot Flatts (2003-2008)	Cockle	44	20/01/2003	27/11/2007	459.1	20	91,000	68.2	9.1	2.3
Beckfoot Flatts (2008-2014)	Cockle	17	11/03/2008	07/12/2009	819.9	80	9,200	70.6	17.6	0.0
Skinburness	Mussel	1	30/08/2006	30/08/2006	430.0	430	430	100.0	0.0	0.0
Silloth/Beckfoot (2003-2008)	Mussel	56	20/01/2003	11/02/2008	335.9	<20	9,100	62.5	5.4	0.0
Silloth/Beckfoot (2008-2014)	Mussel	15	11/03/2008	21/09/2009	779.2	50	54,000	73.3	20.0	6.7
Lees Scar	Mussel	43	05/01/2010	04/03/2014	238.7	<20	2,400	58.1	0.0	0.0
Beckfoot (2003-2008)	Mussel	42	20/01/2003	11/02/2008	233.5	20	3,500	42.9	0.0	0.0
Beckfoot (2008-2014)	Mussel	14	21/04/2008	07/12/2009	360.1	<20	3,500	64.3	0.0	0.0
Mawbray	Mussel	42	19/10/2009	04/03/2014	235.6	<20	5,400	59.5	2.4	0.0
Dubmill Point 2	Mussel	20	16/02/2010	13/03/2012	161.1	20	2,400	45.0	0.0	0.0
Dubmill Point (2003-2008)	Mussel	50	20/01/2003	11/02/2008	174.7	<20	2,400	44.0	0.0	0.0
Dubmill Point (2008-2014)	Mussel	15	11/03/2008	07/12/2009	242.5	<20	2,400	60.0	0.0	0.0
Dubmill Oysters (2003-2008)	Pacific oyster	13	25/06/2007	28/01/2008	222.3	<20	2,400	53.8	0.0	0.0
Dubmill Oysters (2008-2014)	Pacific oyster	66	11/03/2008	04/03/2014	86.7	<20	3,500	37.9	0.0	0.0

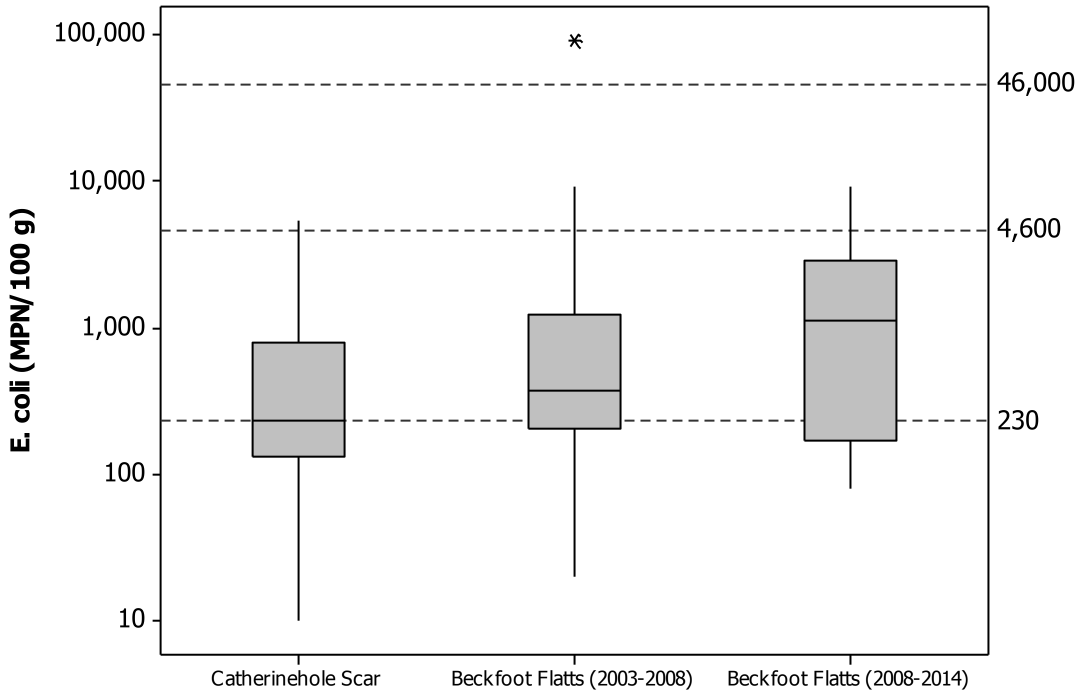


Figure 8.2: Boxplots of *E. coli* results from cockle RMPs from 2003 onwards.

E. coli levels at both Catherinehole Scar and Beckfoot Flatts (before and after the sanitary survey) exceeded 230 MPN/100 g in over 50% of samples. Between 2003 and 2008, 9.1% of samples taken from Beckfoot Flatts had *E. coli* levels greater than 4,600 MPN/100 g and 2.3% exceeded 46,000 MPN/100 g. Since 2008, no samples have exceeded 46,000 MPN/100 g, but the proportion of samples with greater than 4,600 MPN/100 g has risen to 17.6%. One-way ANOVAs showed no differences in *E. coli* levels between cockle RMPS (p=0.121) and two-sample T-tests showed no differences in *E. coli* levels at Beckfoot Flatts before and after the sanitary survey (p=0.261).

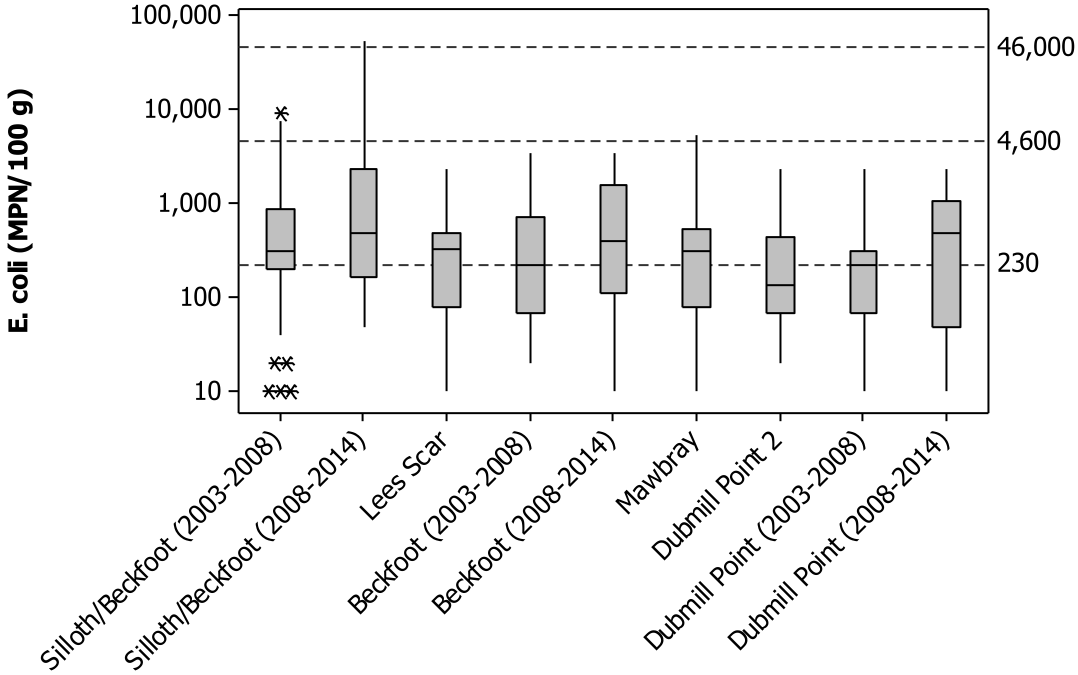


Figure 8.3: Boxplots of *E. coli* results from mussel RMPs from 2003 onwards.

Between 2003 and 2006, three mussel RMPs were sampled, but only two sites were sampled on more than 10 occasions (Silloth/Beckfoot and Dubmill Point). Both of these sites had samples with *E. coli* levels of over 230 MPN/100 g, but only Silloth/Beckfoot had levels above 4,600 (5.4%). Since 2008, seven mussel RMPs have been sampled. All sites have had samples exceeding 230 *E. coli* MPN/100 g, but only two (Silloth/Beckfoot and Mawbray) have had samples exceeding 4,600 *E. coli* MPN/100 g (20% and 2.4% respectively) and only Silloth/Beckfoot had samples exceeding 46,000 *E. coli* MPN/100 g (6.7%). One-way ANOVAs revealed no differences in *E. coli* levels between mussel sites. Two sample T-tests revealed that there were no differences in *E. coli* levels before and after the sanitary survey at those sites sampled in both periods (Silloth Beckfoot [p=0.130], Beckfoot [p=0.404] and Dubmill Point [p=0.541]).

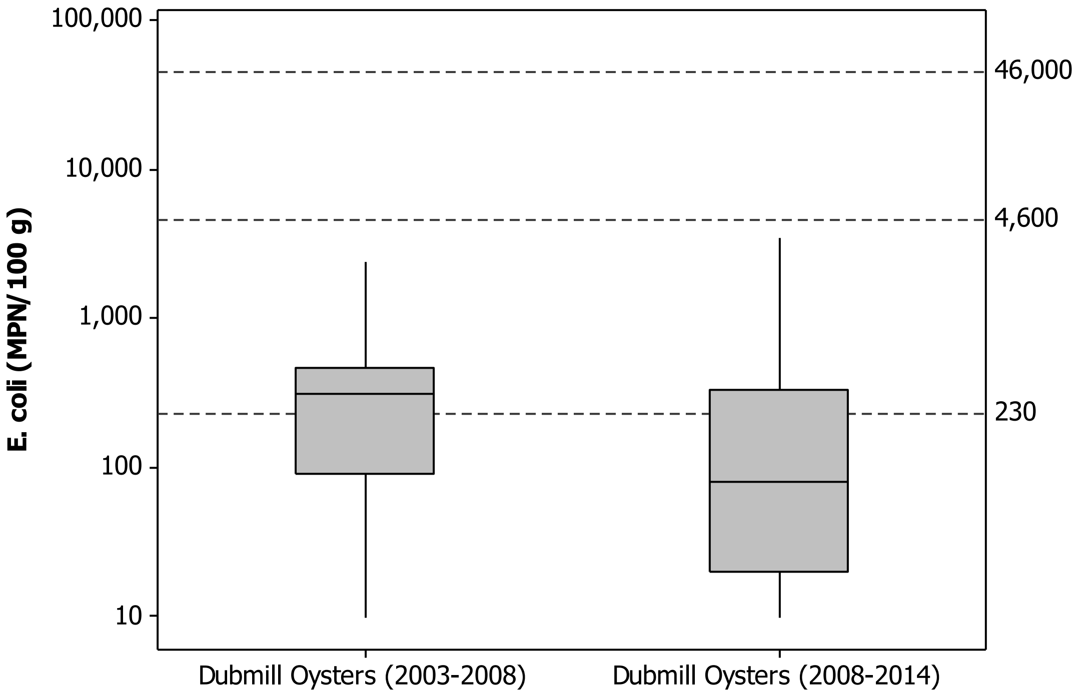


Figure 8.4: Boxplots of *E. coli* results from Pacific oyster RMPs from 2003 onwards.

At Dubmill Oysters, there were slightly fewer samples that exceeded 230 *E. coli* MPN/100g after the sanitary survey (37.9%) than before (53.8%). Two sample T-tests revealed a significant difference between *E. coli* levels before and after the sanitary survey (p=0.041) with a reduction from a geometric mean of 222.3 *E. coli* MPN/100 g to 86.7 *E. coli* MPN/100 g.

8.2. Overall temporal pattern in results

The overall variation in *E. coli* levels found in bivalves is shown in Figure 8.5 to Figure 8.7.

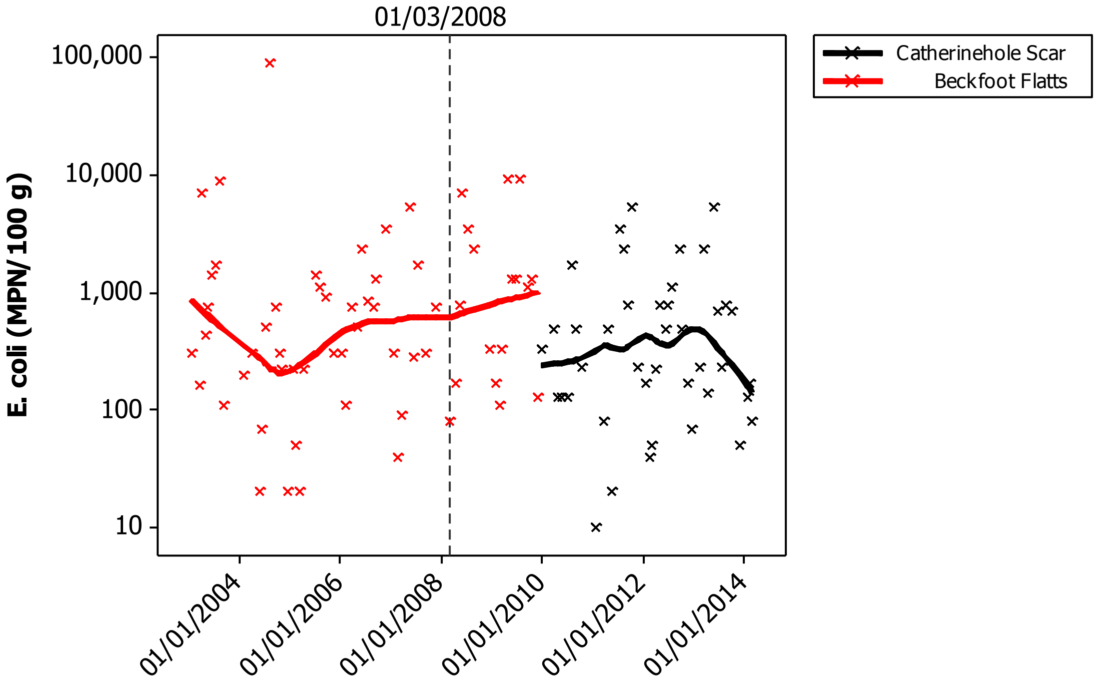


Figure 8.5: Scatterplot of *E. coli* results for cockles overlaid with loess line.

There was a slight increase in *E. coli* levels at Beckfoot Flatts between 2004 and the end of sampling in 2010. At Catherinehole Scar, *E. coli* levels have remained fairly stable since 2010.

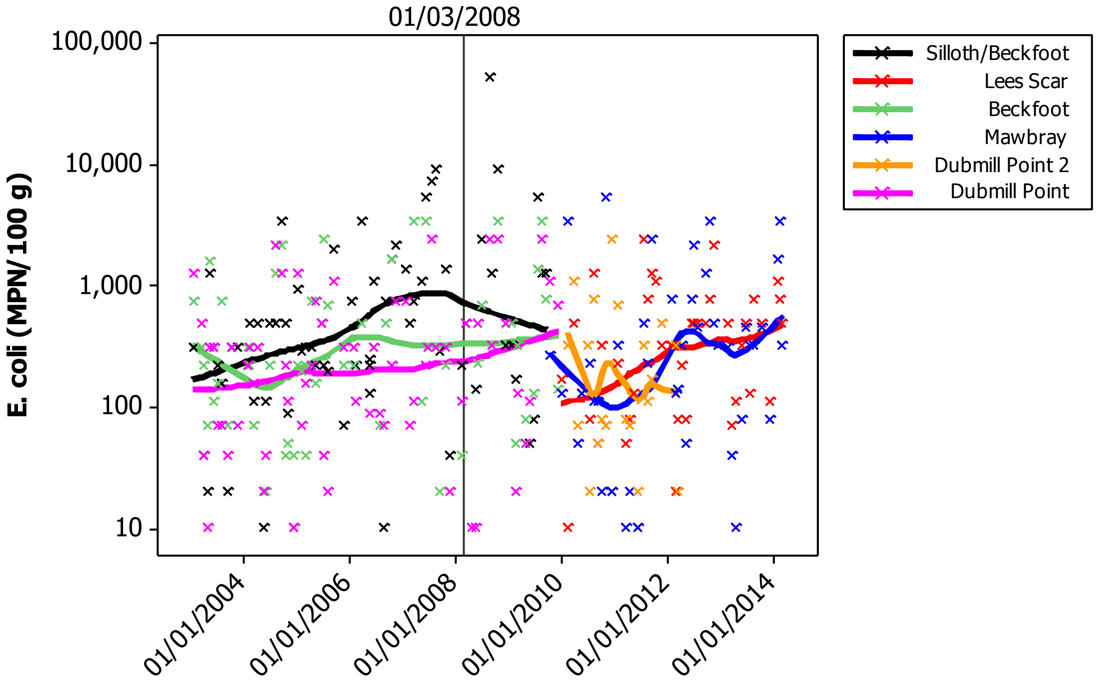


Figure 8.6: Scatterplot of *E. coli* results for mussels overlaid with loess line.

At all mussel RMPs *E. coli* levels have remained fairly stable since 2003.

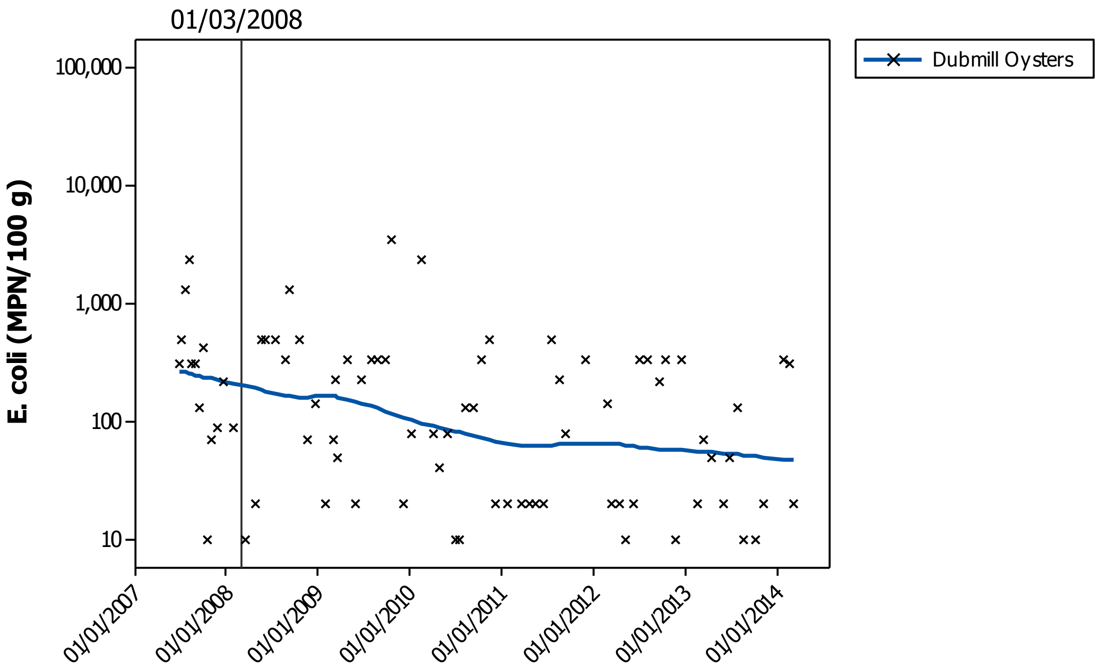


Figure 8.7: Scatterplot of *E. coli* results for Pacific oysters overlaid with loess line.

There has been an overall decline in *E. coli* levels at Dubmill Oysters.

8.3. Seasonal patterns of results

The seasonal patterns of results from 2003 to 2013 were investigated by RMP. Figure 8.8 to Figure 8.10 show box plots of *E. coli* levels at each site by season.

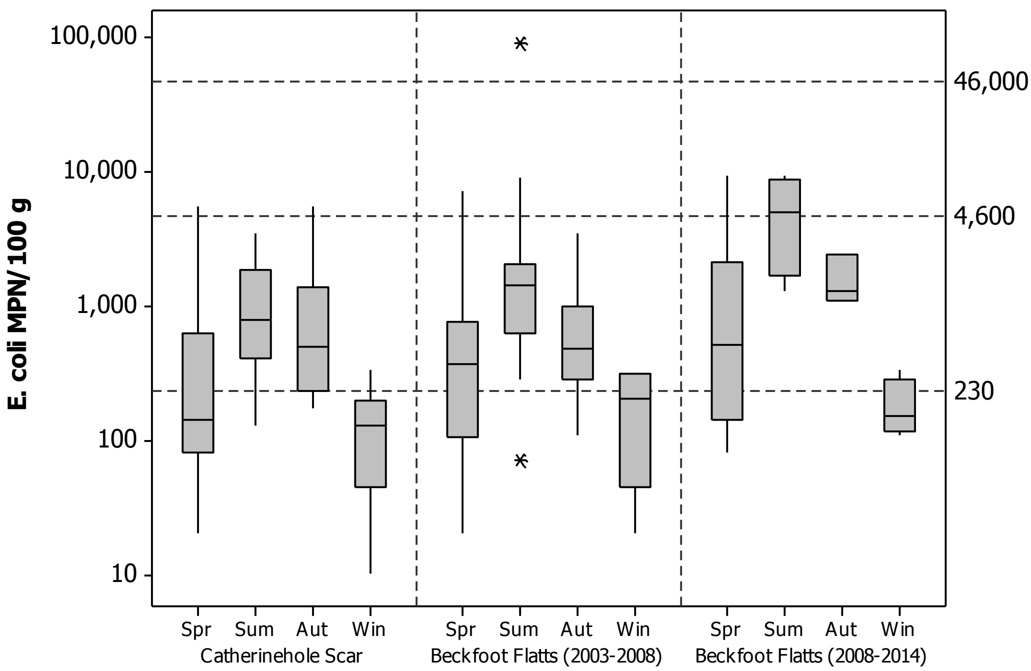


Figure 8.8: Boxplot of *E. coli* results for cockles by RMP and season

One-way ANOVAs showed that there were significant variations in *E. coli* levels between seasons at both the Catherinehole Scar (p=0.002) and Beckfoot Flatts (p=0.005 before 2008 and p=0.011 after 2008) cockle RMPs. Post-ANOVA Tukey tests revealed that at Catherinehole Scar, *E. coli* levels were significantly higher during the summer and autumn than during the winter. At Beckfoot Flatts, *E. coli* levels were significantly higher during the summer than during the winter both before and after the sanitary survey.

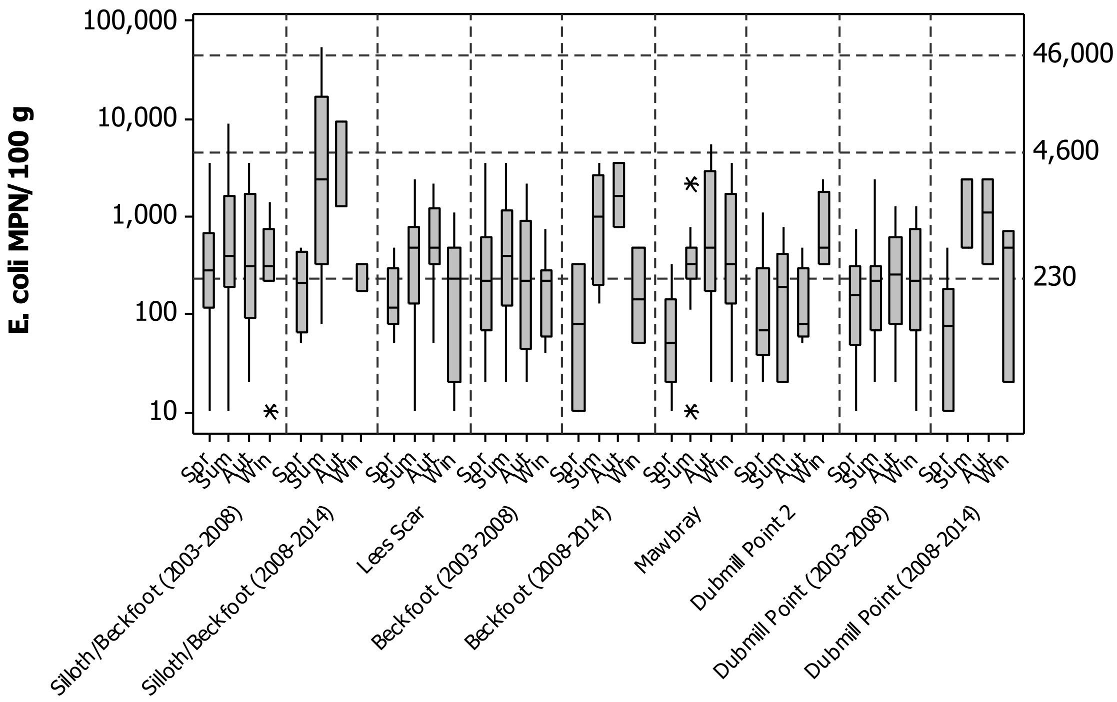


Figure 8.9: Boxplot of *E. coli* results for mussels by RMP and season

One-way ANOVAs showed that there were no significant variations in *E. coli* levels between seasons at any of the mussel RMPs (p=0.056 to 0.792) except at Mawbray (p=0.008) and Dubmill Point after 2008 (p=0.029). Post ANOVA Tukey tests showed that at Mawbray, *E. coli* levels were significantly higher during the autumn and winter than during the spring. At Dubmill Point, *E. coli* levels were significantly higher in summer than in spring.

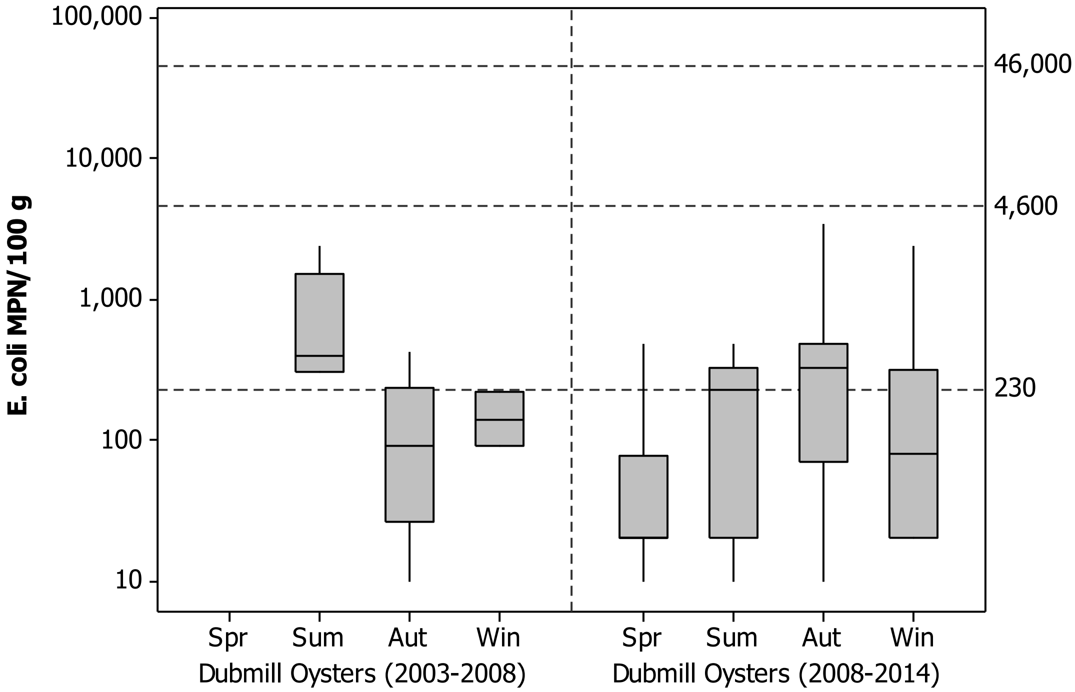


Figure 8.10: Boxplot of *E. coli* results for Pacific oysters by RMP and season

While no samples were taken in spring before 2008, one-way ANOVAs revealed that there were significant variations in *E. coli* levels between seasons both before and after 2008 at Dubmill Oysters (p=0.033 and p=0.024 respectively). Post ANOVA Tukey tests showed that between 2003 and 2008, there were significantly higher *E. coli* levels in summer than in autumn. Between 2008 and 2014, there were significantly higher *E. coli* levels in autumn than in spring.

8.4. Influence of tide

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the high/low and spring/neap tidal cycles for each RMP where more than 30 samples had been taken. Results of these correlations are summarised in Table 8.2, and significant results are highlighted in yellow.

Table 8.2: Circular linear correlation coefficients (r) and associated p values for *E. coli* results against the high/low and spring/neap tidal cycles

		High/low tides		Spring/neap tides	
Site Name	**Species**	**r**	**p**	**r**	**p**
Catherinehole Scar	Cockle	0.222	0.152	0.283	0.047
Beckfoot Flatts (2003-2008)	Cockle	0.066	0.839	0.203	0.185
Silloth/Beckfoot (2003-2008)	Mussel	0.241	0.046	0.404	<0.001
Lees Scar	Mussel	0.175	0.293	0.107	0.630
Beckfoot (2003-2008)	Mussel	0.031	0.963	0.228	0.131
Mawbray	Mussel	0.163	0.353	0.193	0.234
Dubmill Point (2003-2008)	Mussel	0.257	0.044	0.246	0.057
Dubmill Oysters (2008-2014)	Pacific oyster	0.214	0.056	0.195	0.090

Figure 8.11 presents polar plots of log_{10} *E. coli* results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Silloth is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100g or less are plotted in green, those from 231 to 4,600 are plotted in yellow, and those exceeding 4,600 are plotted in red.

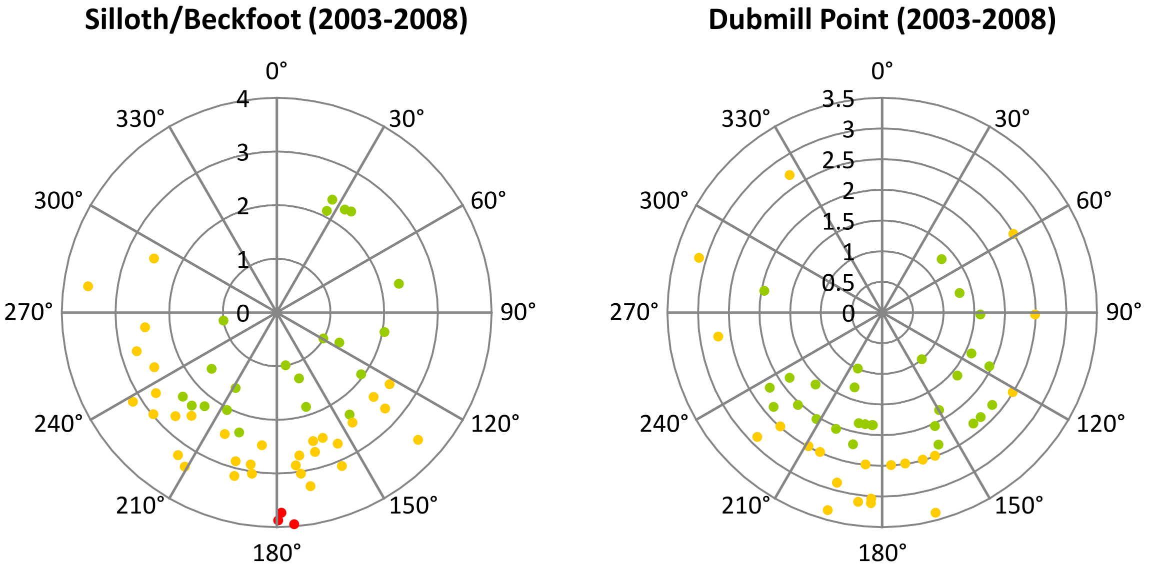


Figure 8.11: Polar plot of log_{10} *E. coli* results (MPN/100 g) at mussel RMPs against high/low tidal state

The majority of the sampling effort for mussels occurred around low tide. However, it appears that proportionally more high results occurred around low tide than during the ebb at both sites.

Figure 8.12 and Figure 8.13 present polar plots of log_{10} *E. coli* results against the spring neap tidal cycle for each RMP where correlations indicated a statistically significant effect. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 230 *E. coli* MPN/100 g or less are plotted in green, those from 231 to 4,600 are plotted in yellow, and those exceeding 4,600 are plotted in red.

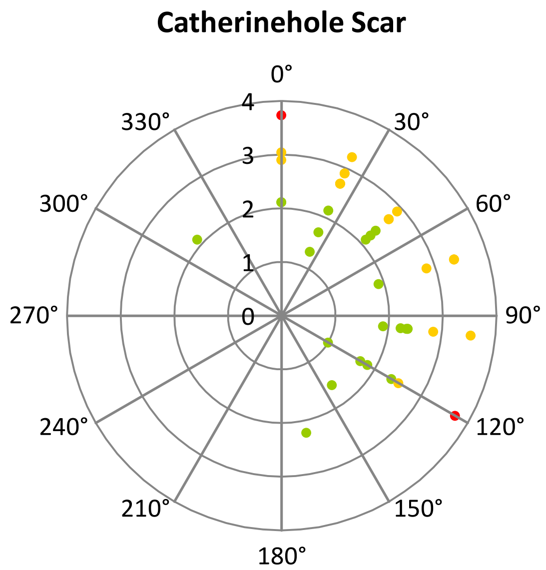


Figure 8.12: Polar plot of $\log_{10}$ *E. coli* results (MPN/100 g) at cockle RMPs against spring/neap tidal state

While the correlations showed a significant effect of spring/neap tidal state on *E. coli* levels at Catherinehole Scar, no effect is apparent in the polar plot.

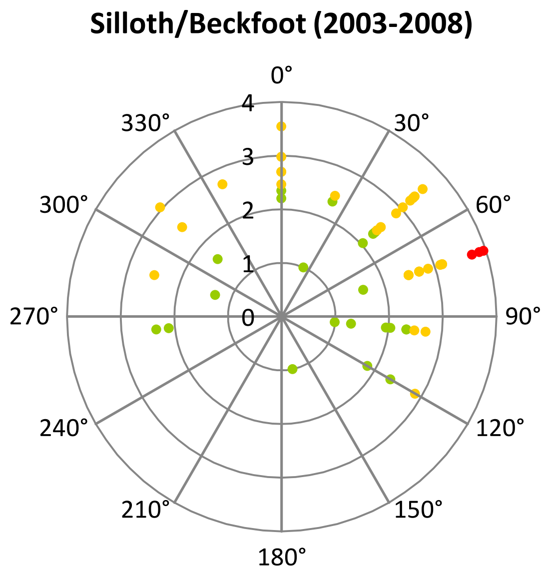


Figure 8.13: Polar plot of log10 *E. coli* results (MPN/100 g) at mussel RMPs against spring/neap tidal state

At Silloth/Beckfoot, there appeared to be proportionally more high results around the spring tide. This indicates that a significant source of contamination for this site may be located some distance away.

9. References

Allerdale Borough Council, 2005. Allerdale Borough Council. A strategy for Tourism 2005-2015. Available from: http://www.allerdale.gov.uk/downloads/page992/tourismstrategyfinalversion.pdf. Accessed October 2008.

Austin, G.E., Calbrade, N.A., Mellan, H.J., Musgrove, A.J., Hearn, R.D., Stroud, D.A., Wotton, S.R. and Holt, C.A. 2014. Waterbirds in the UK 2012/13: The Wetland Bird Survey. BTO/RSPB/JNCC

BST, 2009. BST Oyster Supplies. Available from: http://www.bstoysters.com/index.php?id=home. Accessed August 2014.

Cumbria Tourism, Research in Cumbria. Available from: http://www.cumbriatourism.org/research/surveys-data.aspx. Accessed July 2014

Defra, 2010. Local Authority breakdown for key crops areas and livestock numbers on agricultural holdings. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/183111/defra-stats-foodfarm-landuselivestock-june-results-localauthority2010-120608.xls. Accessed August 2014

EU Working Group on the Microbiological Monitoring of Bivalve Harvest Areas, 2014. Microbiological Monitoring of Bivalve Harvest Areas. Guide to Good Practice: Technical Application. Issue 5, June 2014.

Holt, C.; Austin, G.; Calbrade, N.; Mellan, H.; Thewlis, R.; Hall, C.; Stroud, D.; Wotton, S. and Musgrove, A. 2009. Waterbirds in the UK 2007/08: The Wetland Bird Survey. BTO/WWT/RSPB/JNCC

Lancaster, J. 2009a. Cockle Stock Assessment: Survey of the English Solway Cockle Grounds 28th October 2009. Produced by Solveno on behalf of Cumbria Sea Fisheries Committee. Available from: http://councilportal.cumbria.gov.uk/Data/Cumbria%20Sea%20Fisheries%20Committee/20091204/Agenda/(item%2011)%20Cockle%20Stock%20Survey%202009.pdf. Accessed August 2014

Lancaster, J. 2009b. Mussel Stock Assessment: Annual Stock Survey of the Littoral Mussel (Mytilus edulis) stock in the Solway Firth, 20th October 2009. Produced by Solveno on behalf of Cumbria Sea Fisheries Committee. Available from: http://councilportal.cumbria.gov.uk/Data/Cumbria%20Sea%20Fisheries%20Committee/20091204/Agenda/(item%2010)%20Mussell%20Stock%20Survey%20Report%202009.pdf. Accessed August 2014

Natural England. Solway Coast. Available from: http://www.naturalengland.org.uk/ourwork/conservation/designations/aonb/solway.aspx. Accessed August 2014

North West IFCA, 2012. NWIFCA Byelaw 3: Permit to fish for cockles (Cerastoderma edule) and mussels (Mytilus edulis). Available from: http://www.nw-ifca.gov.uk/contents/images/File/Byelaws/NWIFCA%20Byelaw%203%20(final)%20poster.pdf. Accessed August 2014

SCOS, 2013. Scientific Advice on Matters Related to the Management of Seal Populations: 2013

Solway Firth Partnership, 2012. Tidelines Newsletter of the Solway Firth Partnership. Issue 37. Available from: http://148.252.128.13/modules/guardian3/cgi-bin/download/download.cgi?id=1409137657,4132,2,e5944a8c31528a1c1616dc6b139bb3a58a22732c. Accessed August 2014

The Wildlife Trusts. Solway Firth Recommended MCZ. Available from: http://www.wildlifetrusts.org/MCZ/solway-firth. Accessed August 2014

10. Acknowledgements

David Copeland (Allerdale Borough Council), Wilf Morgan (Dubmill Oysters).

Appendices

Appendix I. Shoreline Survey

Date (time):
22nd May 2014 (08:30-13:50)

Cefas Officers:
David Walker

Local Enforcement Authority Officers:
David Copeland, Allerdale Borough Council

Area surveyed:
Allonby to Silloth

Weather:
Overcast, 12°C, wind bearing 32° at 17 km/h

Tides:
Admiralty TotalTide© predictions for Silloth (54°52'N 3°24'W). All times in this report are BST.

22/05/2014		
High	06:33	8.0 m
High	19:16	7.6 m
Low	00:45	1.7 m
Low	13:27	1.4 m

I.1. Objectives:

The shoreline survey aims to obtain samples of freshwater inputs to the area for bacteriological testing; confirm the location of previously identified sources of potential contamination; locate other potential sources of contamination that were previously unknown and find out more information about the fishery. A full list of recorded observations is presented in Table I.1 and the locations of these observations are shown in Figure 10.1. The shoreline survey was undertaken on one day by foot. Additional observations were made in the car journey to site.

I.2. Description of Fishery

During the visit to Silloth it was possible to meet with Mr Wilf Morgan, the operator of the Pacific oyster farm towards the south of the production area. Mr Morgan cultures oysters using the BST adjustable longline system (BST, 2009[1]). This system uses baskets

[1] BST, 2009. Oyster Farming Products & Solutions. Available from: http://www.bstoysters.com/index.php?id=home. Accessed June 2014.

suspended from lines in which oysters are grown to maturity. Currently there are three pairs of lines and the first harvest from this farm is expected this year. Originally 150,000 oysters were laid in the baskets and it is not known how many will be available for harvest. The oysters will be taken straight to Mr Morgan's own UV depuration facility. After depuration the oysters will be sold both to local restaurants and on the Internet within the UK. Mr Morgan plans to grow oysters on a five year cycle.

During the shoreline survey, there was mussel dead shell seen at observations 8, 12, 13 and 16. However, according to Mr Morgan there is currently no interest in harvesting mussels as the stock density is too low.

I.3. Sources of contamination

Sewage discharges

No sewage discharges were sampled during the survey. The Allonby Sewage Treatment Works was not visible at the time of survey. Markers for the Silloth Screen House waste water treatment works and associated overflows were observed at observation 24, but the outfalls were covered by the tide. Cotton buds were seen at observations 1 and 11, indicated that there may have been some sewage contamination that had washed on to the beach in the recent past.

Freshwater inputs

Four streams, two of which were culverted were observed (observations 2, 4, 6 and 9). These streams had *E. coli* loadings of between $1.81x10^{11}$ and $6.45x10^{11}$ cfu/100 ml. Much of the contamination in these streams is likely to be from runoff from grazing land.

Livestock

Much of the land adjacent to the shellfish beds is used for grazing. While the numbers of livestock in each field were quite low, a large manure pile seen at observation 26 may serve as a point of contamination following rainfall.

Wildlife

Many birds were observed (observations 3, 5, 7, 10 and 14) and a large patch of inter tidal heavily deposited with bird faeces was seen at observation 15.

Sediment sampling

During the survey, sampling was conducted to determine whether sediment contamination in a channel flowing over a beach declined with distance away from the channel. The results from six sediment samples are shown in Table I.3. A single water sample was taken from the water channel itself (observation 23, sample S05). Both transects showed slightly higher levels of *E. coli* away from the channel. Additionally, as the level of *E. coli* in the channel water was so low (20 cfu/100 ml), it would not be expected that a significant change in sediment contamination would be seen across the transect.

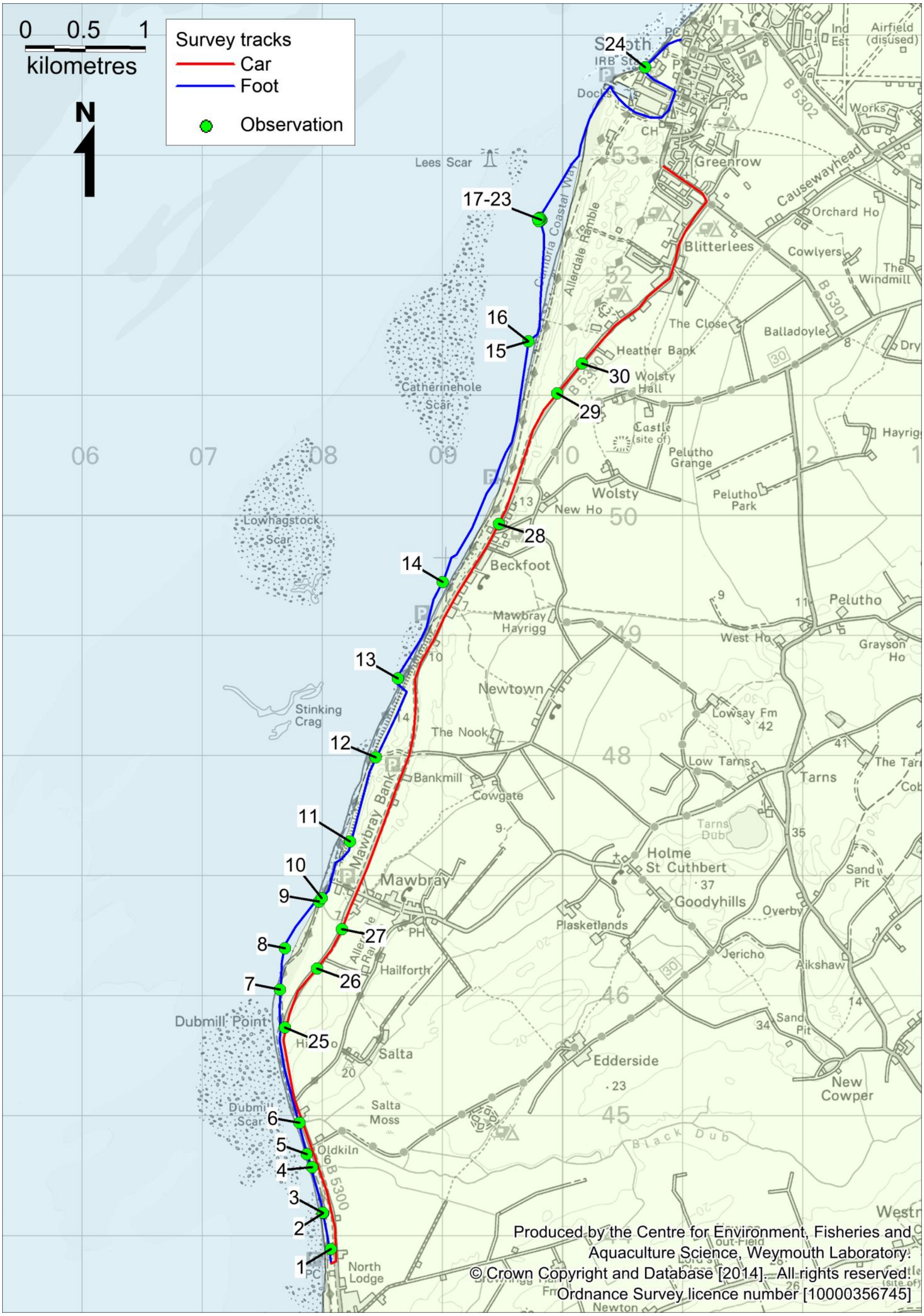


Figure 10.1: Locations of shoreline observations (Table I.1 for details)

Table I.1: Details of shoreline observations

Observation no.	NGR	Date	Time	Description	Photo
1	NY0806943889	22/05/2014	08:38	Cotton buds	
2	NY0800544187	22/05/2014	08:46	Crookhurst Beck running on to beach (1.4m width, 0.2m depth, 0.606m/s)	Figure 10.4
3	NY0800444190	22/05/2014	08:46	Gulls all along beach in clusters of 50 birds	
4	NY0791444571	22/05/2014	08:55	Culverted stream through concrete discharge flowing under road and over beach (1.1m diameter, 0.1m flow depth, 0.877m/s)	Figure 10.5
5	NY0787044680	22/05/2014	08:56	Around 200 gulls	
6	NY0764546044	22/05/2014	09:16	Culverted Black Dub stream through concrete discharge flowing under road and over beach (1.1m diameter, 0.15m flow depth, 2.445m/s)	Figure 10.6
7	NY0764546048	22/05/2014	09:16	Around 200 gulls	
8	NY0768646394	22/05/2014	09:21	Mussel deadshell	
9	NY0797146784	22/05/2014	09:28	Mawbray Beck flowing over beach, running past filed with around 30 sheep (1.5m width, .15m depth, 0.717m/s)	Figure 10.7
10	NY0799346811	22/05/2014	09:31	Around 100 birds	
11	NY0823047283	22/05/2014	09:40	Cotton buds	
12	NY0844447984	22/05/2014	09:51	Mussel deadshell	
13	NY0862948642	22/05/2014	10:02	Mussel deadshell	
14	NY0900249446	22/05/2014	10:14	Around 300 gulls	
15	NY0971651449	22/05/2014	10:57	Bird faeces	
16	NY0971651449	22/05/2014	10:57	Mussel deadshell	
17	NY0982352461	22/05/2014	11:14	Sediment transect +20m	
18	NY0981452459	22/05/2014	11:14	Sediment transect +10m	
19	NY0980252452	22/05/2014	11:14	Sediment transect origin	
20	NY0981152481	22/05/2014	11:18	Sediment transect +20m	
21	NY0980552476	22/05/2014	11:19	Sediment transect +10m	
22	NY0979552471	22/05/2014	11:19	Sediment transect origin	
23	NY0979552471	22/05/2014	11:19	Water sample of channel, no flow (3m width, 0.1m depth)	Figure 10.8& Figure 10.9
24	NY1068953732	22/05/2014	12:01	Silloth Screen House WwTW outfall markers near RNLI station – covered by tide	Figure 10.10
25	NY0768745735	22/05/2014	13:37	Around 20 cows landward of road	
26	NY0795446224	22/05/2014	13:38	Manure pile	
27	NY0816346552	22/05/2014	13:38	Around 10 sheep landward of road	
28	NY0946949931	22/05/2014	13:42	Around 10 cows landward of road	
29	NY0995551018	22/05/2014	13:43	Around 50 sheep seaward of road	

30	NY1016251265	22/05/2014	13:43	Two cows and 10 sheep seaward of road

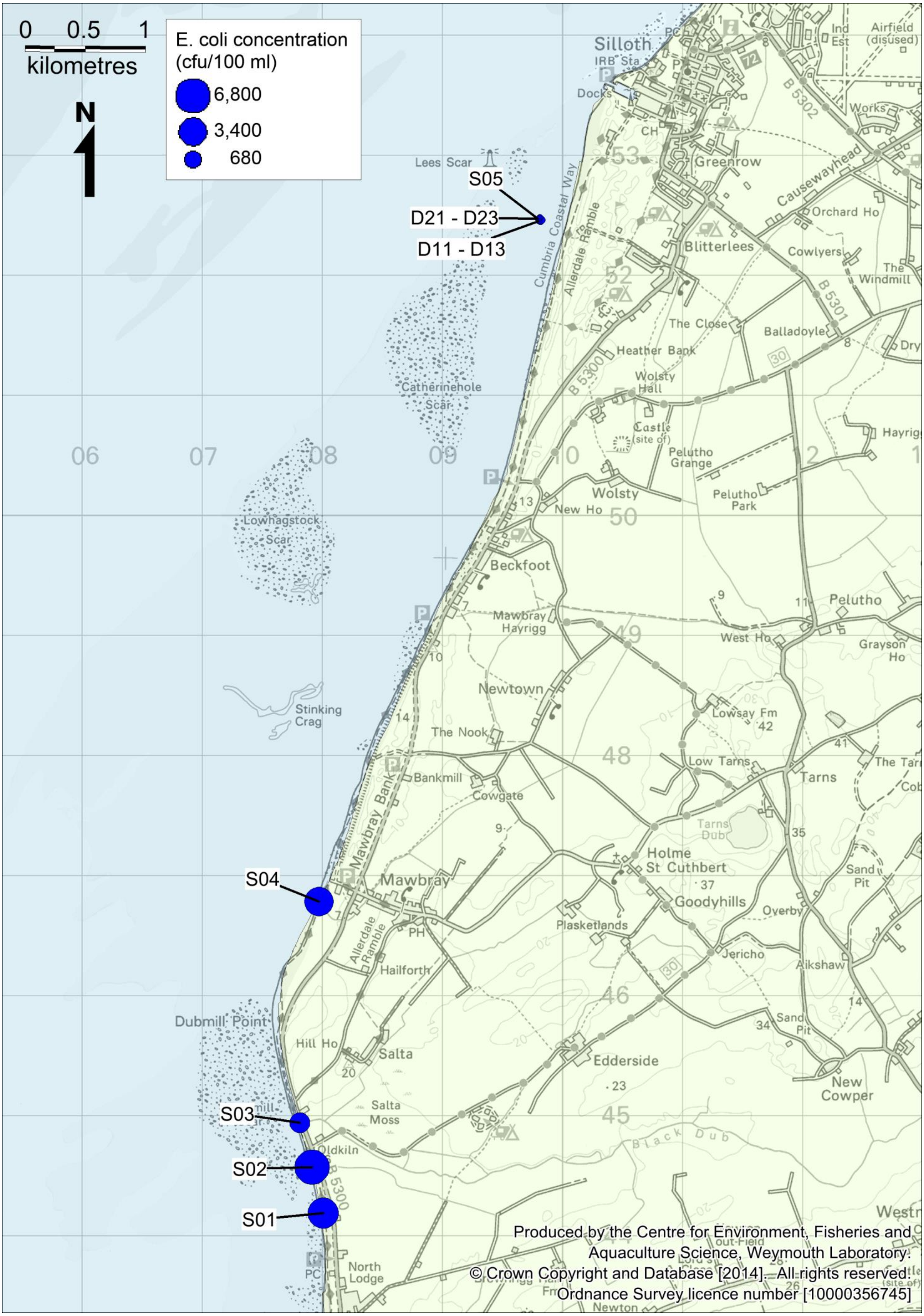


Figure 10.2: Water sample results (Table I.2 and Table I.3 for details)

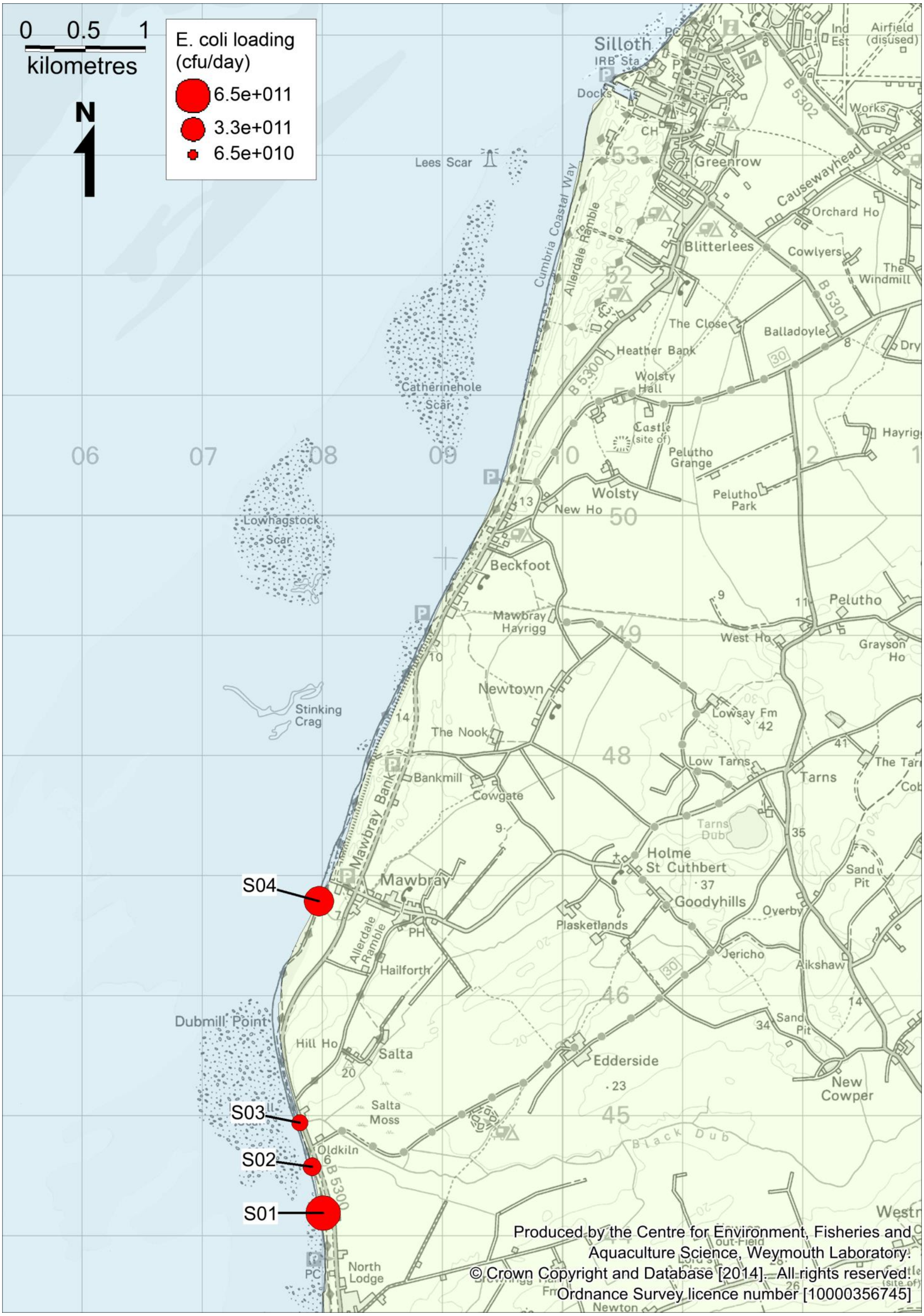


Figure 10.3: *E. coli* stream loadings (Table I.2 for details).

Table I.2: Water sample *E. coli* results, spot flow gauging results and estimated loadings.

Sample ID	Observation number	Date and time	Description	Flow (m^3/s)	*E. coli* concentration (cfu/100 ml)	*E. coli* loading (cfu/day)	NGR
S01	2	22/05/2014 08:46	Stream	0.169	4400	$6.45x10^{11}$	NY0800544187
S02	4	22/05/2014 08:55	Culvert	0.037	6800	$2.22 x10^{11}$	NY0791444571
S03	6	22/05/2014 09:16	Culvert	0.190	1100	$1.81 x10^{11}$	NY0764546044
S04	9	22/05/2014 09:28	Stream	0.161	3600	$5.02 x10^{11}$	NY0797146784
S05	23	22/05/2014 11:19	Water sample of channel	0	20	n/a	NY0979552471

Table I.3: Sediment sample *E. coli* results.

Sample ID	Observation number	Date and time	Description	*E. coli* concentration (cfu/100 ml)	NGR
D13	17	22/05/2014 11:14	Sediment transect 1 +20m	40	NY0982352461
D12	18	22/05/2014 11:14	Sediment transect 1 +10m	80	NY0981452459
D11	19	22/05/2014 11:14	Sediment transect 1 origin	10	NY0980252452
D23	20	22/05/2014 11:18	Sediment transect 2 +20m	30	NY0981152481
D22	21	22/05/2014 11:19	Sediment transect 2 +10m	20	NY0980552476
D21	22	22/05/2014 11:19	Sediment transect 2 origin	<20	NY0979552471

Figure 10.4

Figure 10.5


Figure 10.6


Figure 10.7


Figure 10.8


Figure 10.9

Figure 10.10

Appendix II. Silloth Sanitary Survey Report 2009

EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Silloth (Cumbria)

2009

Cover photo: Production area for Pacific oysters at Dubmill Point.
Courtesy of David Copeland (Allerdale Borough Council).

CONTACTS:

For enquires relating to this report or further information on the implementation of sanitary surveys in England and Wales:

Simon Kershaw/Carlos Campos
Food Safety Group
Cefas Weymouth Laboratory
Barrack Road, The Nothe
Weymouth
Dorset
DT43 8UB

☎ +44 (0) 1305 206600
✉ fsq@cefas.co.uk

For enquires relating to policy matters on the implementation of sanitary surveys in England and Wales:

Linden Jack
Hygiene & Microbiology - Hygiene 1
Food Standards Agency
Room 808C Aviation House
125 Kingsway
London
WC2B 6NH

☎ +44 (0) 20 7276 8955
✉ shellfish_hygiene@foodstandards.gsi.gov.uk

STATEMENT OF USE: This report provides information from a study of the information available relevant to perform a sanitary survey of bivalve mollusc production areas in Silloth. Its primary purpose is to demonstrate compliance with the requirements for classification of bivalve mollusc production areas, determined in EC Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption. The Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook this work on behalf of the Food Standards Agency (FSA).

DISSEMINATION: Food Standards Agency, Allerdale Borough Council, Cumbria Sea Fisheries Committee, Environment Agency.

CONTENTS

Executive Summary

Under EC Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption, there is a requirement for competent authorities intending to classify bivalve mollusc production and relaying areas (BMPAs) to undertake a number of tasks collectively known (in England and Wales) as 'sanitary surveys'. The main purpose of these surveys is to inform the sampling plans for the microbiological monitoring and classification of BMPAs.

This report documents the qualitative assessment made of microbiological contamination of bivalve mollusc harvesting areas at Silloth (West coast of Cumbria). The sanitary survey was prompted by an application for monitoring and classification of farmed Pacific oysters (*Crassostrea gigas*) at Dubmill Point. The report presents the recommended sampling plan for this new area and existing beds for cockles (*Cerastoderma edule*) and mussels (*Mytilus* spp.) as a result of a sanitary survey undertaken by Cefas on behalf of the Food Standards Agency (FSA).

The assessment is supported by published information for Waver and Ellen river catchment areas and information obtained from a shoreline survey performed in the vicinity of the proposed new harvesting area at Dubmill Point.

Both catchments are used for livestock production and the overall potential risk of contamination was found to be significantly higher from pollution sources of animal origin than sources from human origin. However, human impact is significantly increased during summer due to tourism related activities.

The most significant water company continuous sewage discharges are Silloth STW and Allonby STW, which receive year round UV disinfection. These were considered to have a low contribution as pollution sources impacting on the levels of contamination in BMPAs for most of the time. There have however been episodes of low operational efficiency indicating the potential for a much higher impact. There are other small STW and a number of intermittent sewage discharges to coastal streams that flow to the sea between Allonby and Silloth.

Bivalve mollusc harvesting areas off Silloth are shallow (<2m depth at chart datum) and dominated by mixing and sedimentation processes. Prevailing westerly winds combined with dominant flood tide currents will promote retention of land runoff inshore.

Analysis of historical *E. coli* data suggested a decreasing gradient of microbiological contamination from north to south along Silloth/Beckfoot, Beckfoot and Dubmill Point mussel beds.

Statistically significant linear relationships were obtained between *E. coli* levels in mussels from Dubmill Point and Silloth/Beckfoot and river flows monitored on the River Ellen. This indicates that the variation of microbiological contamination in commercially harvested mussels is affected by contaminated run-off water or storm overflows following rainfall.

Recommendations are made with regard to (a) assigning separate classification zones for each species (b) relocating representative monitoring points towards the northern, inshore boundaries of these classification zones. This will target monitoring of the worst-case scenario of microbiological contamination from pollution sources impacting on these areas.

1 INTRODUCTION

1.1 Background

Under EC Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption, sanitary surveys of bivalve mollusc production areas (BMPAs) 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 Centre for Environment Fisheries & Aquaculture Science (Cefas) is performing sanitary surveys for new BMPAs in England and Wales, on behalf of the Food Standards Agency (FSA). The purposes of the sanitary surveys are to demonstrate compliance with the requirements stated in Annex II (Chapter II paragraph 6) of EC Regulation 854/2004, whereby 'if the competent authority decides in principle to classify a production or relay area it must:

(a) make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production areas;

(b) examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste-water treatment, etc.;

(c) determine the characteristics of the circulation of pollutants by virtue of current patterns, bathymetry and the tidal regime in the production area; and

(d) establish a sampling programme of bivalve molluscs in the production area which is based on the examination of established data, and with a number of samples, a geographical distribution of the sampling points and a sampling frequency which must ensure that the results of the analysis are as representative as possible for the area considered.'

The present report documents information relevant to undertake a sanitary survey of a new production area for Pacific oysters and existing production areas for mussels and cockles in Silloth (Cumbria).

A desk-based assessment of existing information has been made and the results are presented in Sections 2 to 5. The results from a shoreline survey undertaken in the adjacent coastal area are set out in the Appendix. In Section 6, the results of the desk study and shoreline survey are drawn together in an overall assessment of the potential sources of pollution likely to constitute sources of microbiological contamination for the harvesting areas. The overall assessment informs the sampling plan for microbiological monitoring, which includes recommendations for the location of the RMPs and required sampling frequency for the new harvesting area for Pacific oysters at Dubmill Point and existing BMPAs for cockles and mussels in Silloth.

1.2 Site description

The town of Silloth is situated on the Cumbrian coast, in the mouth of Solway Firth (54°52.11'N, 03°23.9'W). The area covered by this assessment, which encompasses the new production area for Pacific oysters and existing production areas for mussels and cockles, includes the stretch of coast extending for approximately 11.5km between Skinburness in the North to Dubmill Point in the South. The coast is predominantly impacted by pollution sources from Waver (total area=18,640ha) and Ellen (19,134ha) catchments and, to a lesser degree, from catchments bordering the upper Solway Firth (Figure 1.1).

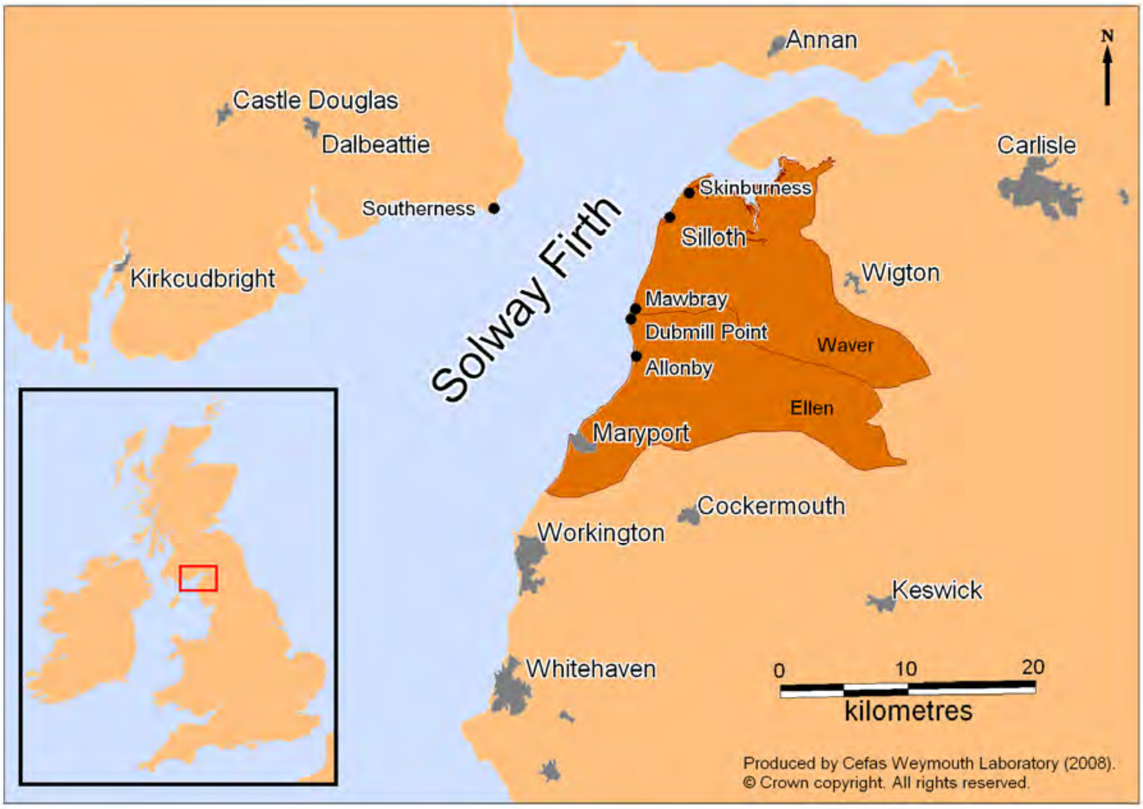


Figure 1.1 Location of Dubmill Point showing main localities in coastal area of Cumbria.

The Firth is approximately 12.5km wide from Dubmill Point on the English Cumbrian coast to Southerness on the Scottish at Dumfries and Galloway coast.

The Solway Coast Area of Outstanding Natural Beauty (AONB) follows 59 km of the Cumbrian coast between Rockcliffe (within the boundaries of Carlisle City Council) and Maryport, covering an area of 115km^2. The designated area excludes the town of Silloth. Most of the coastal area between Silloth Harbour and Dubmill Point also covers the Site of Special Scientific Interest (SSSI) of Silloth Dunes and Mawbray, consisting largely of dune heath and grassland. Two County Wildlife Sites and a Regionally Important Geological and Geomorphological Site (RIGS) are located within this stretch of coast. The area is also within the Upper Solway Flats and Marshes SSSI. Conservation designations covering this stretch of coast are shown in Figure 1.2.

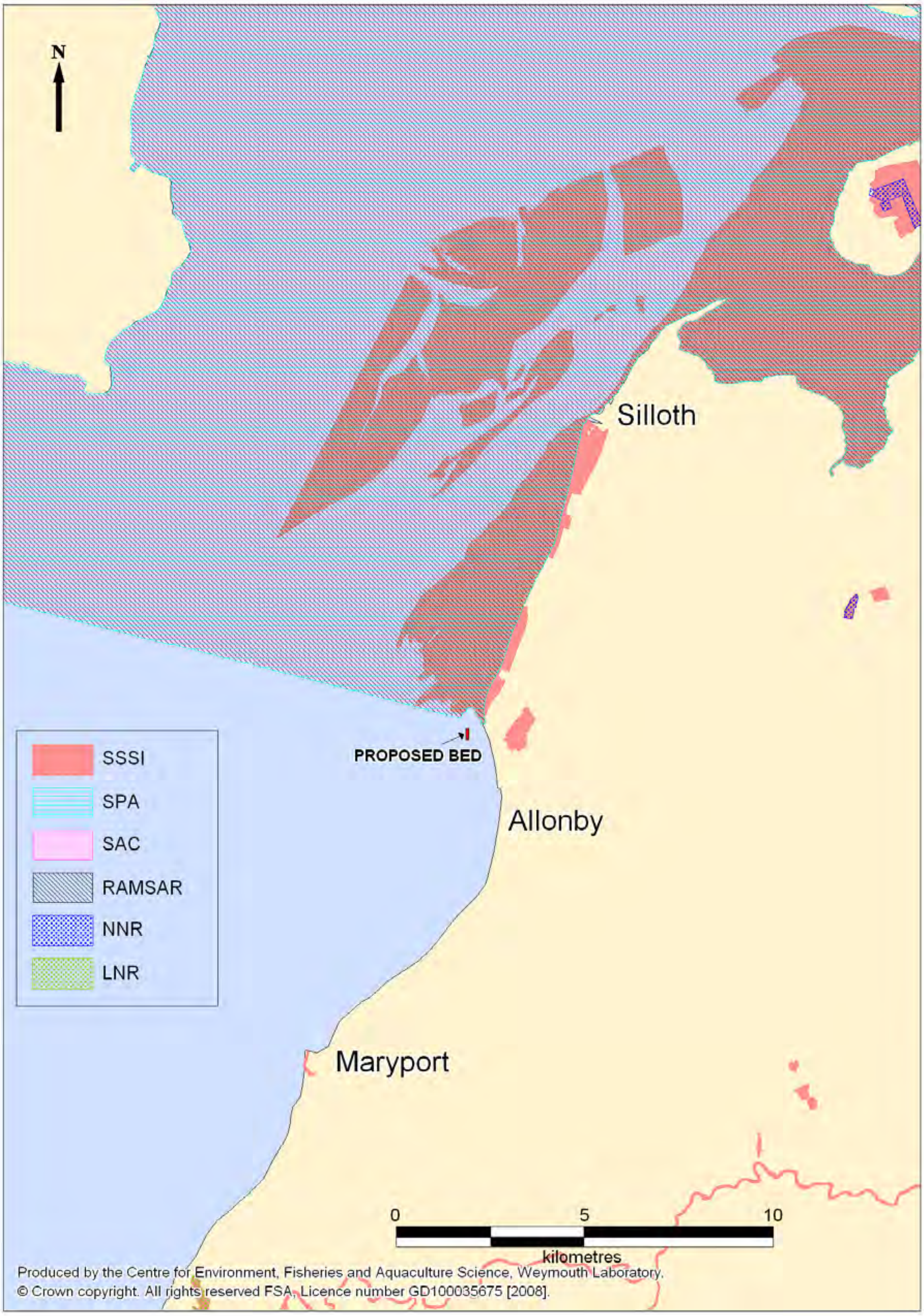


Figure 1.2 Conservation designations along the coast in the vicinity of Silloth.
Boundary data from and regularly updated by Natural England (2008).
(http://www.naturalengland.org.uk).

The coast of Dubmill Point to Allonby is fronted by improved grassland and arable land, with a small strip of dunes in the South (Figure 1.3). The SSSI of Salta Moss is approximately 600m inland of the coast where the new production area for Pacific oysters lies.

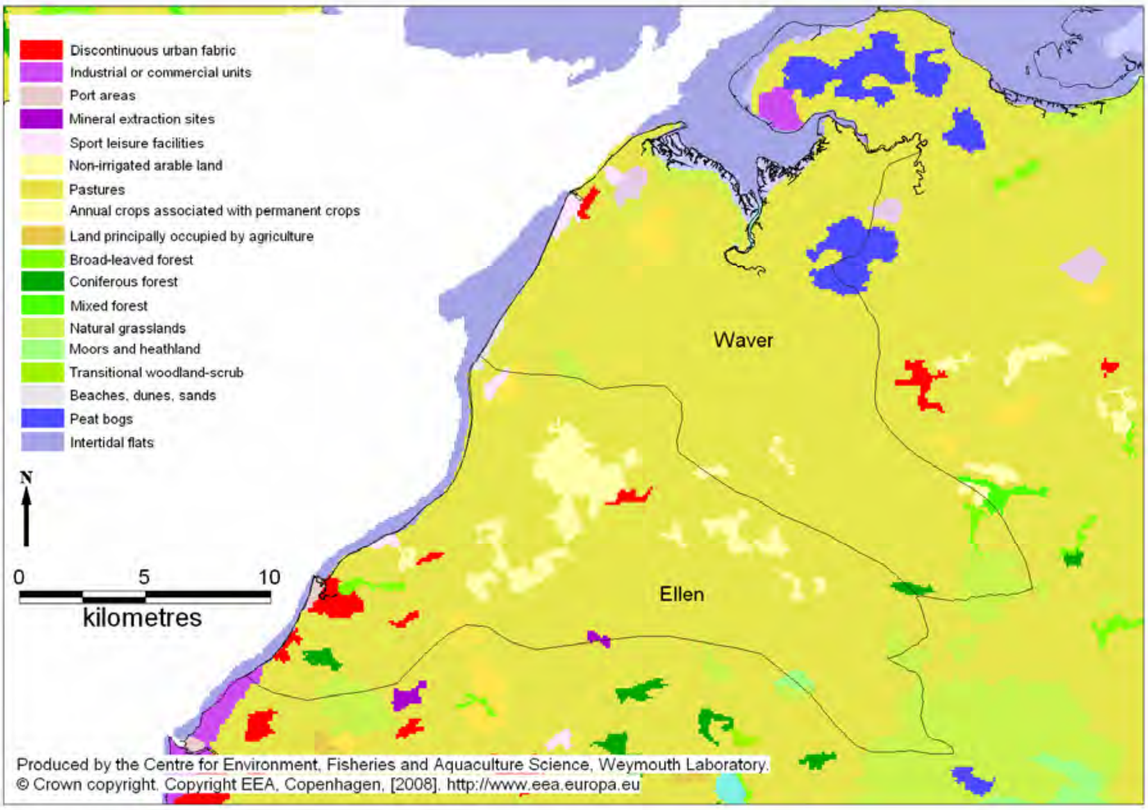


Figure 1.3 Land use in Waver and Ellen catchments.

The seaward coastal area of Allonby to Maryport is mostly constituted by dunes and pasture land, whilst the landward area is dominated by grassland and land principally occupied by agriculture (Figure 1.3). The surrounding catchment is flat, open and largely pastoral, with key features including raised beaches, mudflats and salt marshes (Environment Agency, 2007). The coast is largely rural in nature with the exceptions of the towns of Silloth, Mawbray, Allonby and Maryport (Figure 1.4A–D).

The coastline receives sediment from the West to East erosion and transportation of the glacial tills, which make up the bed of the Irish Sea. The central and more exposed coastal areas of Solway Firth are formed of mobile sand and mudflats. These experience erosion with the littoral process forcing a net Northerly drift of the sand and shingle, which forms the coast. At Dubmill Point, the groynes seem to be effective at trapping sediment and further erosion of the cliff line is constrained by the presence of a sea wall (Bullen Consultants Ltd, 1998).

Figure 1.4 Aerial views of the coastal area of Silloth (A), Mawbray (B), Allonby (C) and Maryport (D).
Permitted use by VisitCumbria (2008).

1.3 Human population and tourism activities

The Waver and Ellen catchments are predominantly rural and sparsely populated (see Figure 1.1). The total resident population in these catchments are 22,294 in Ellen and 6,736 in Waver; total population = 29,030 people; mid-2005 estimates for river catchment areas; Office for National Statistics, 2007). The major population centres and villages are listed in Table 1.1. The coastal area includes other small settlements, such as Mawbray, Allonby and Skinburness.

Table 1.1 Coastal population centres in Waver and Ellen river catchments.

Town	Resident population
Maryport	9,617
Allonby	444
Silloth	2,900

Data from Office for National Statistics.
© Crown Copyright 2008.
Census 2001 - urban area mid-2006 population estimates.
Population centres with more than 20 hectares in total area.

Resident human population in the Allerdale District is concentrated in Keswick, Wigton, All Saints in Cockermouth, Seaton, St. Michael's, St. John's and Moss Bay in Workington. Silloth (3,442 people) and Ewanrigg (3,478 people) are the coastal most populated areas in Waver and Ellen catchments in the vicinity of currently classified BMPAs (Figure 1.5).

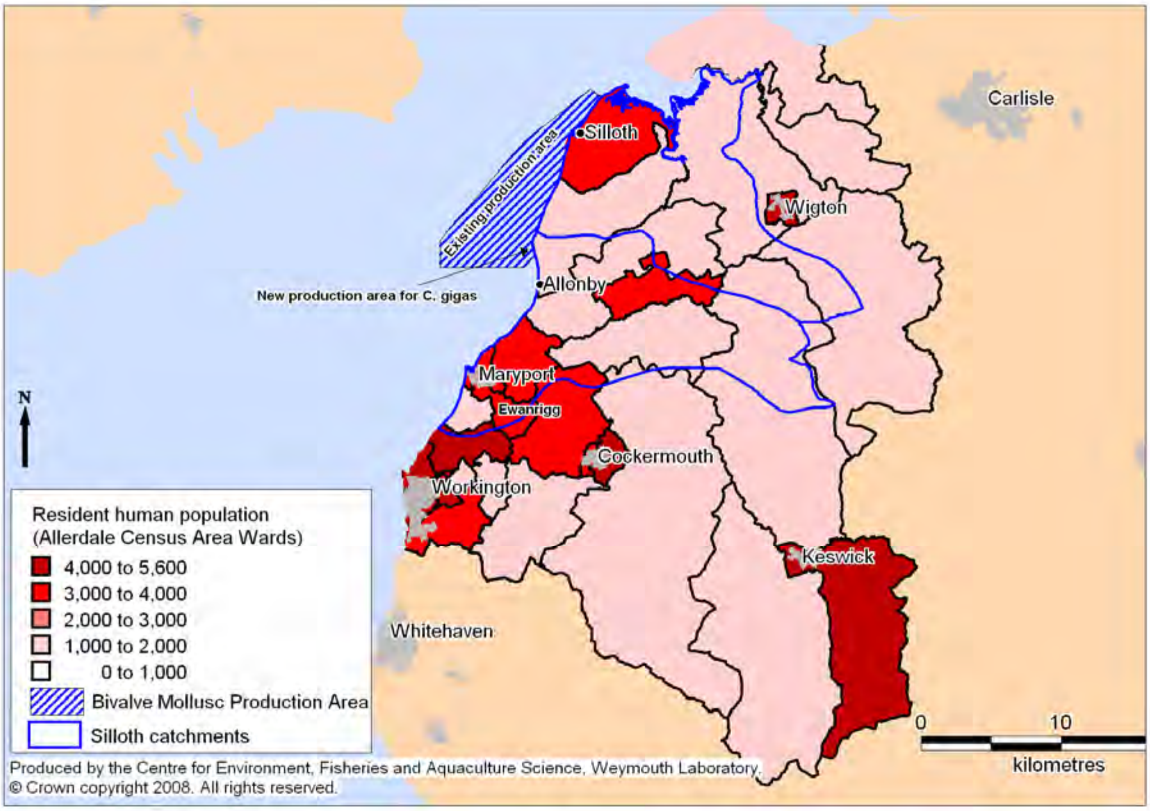


Figure 1.5 Human population in Allerdale by Census Area Wards.
Data provided by the Office for National Statistics, Census Area Statistics (England and Wales).
© Crown Copyright.
Catchment boundaries (blue line) refer to Mean High Water.
Census Area Ward boundaries refer to Mean Low Water.

Tourism is one of the dominant human activities in Allerdale District, representing approximately 17% of total tourist numbers to Cumbria (Cumbria Tourism, 2007). Tourism related activities have long been associated with the wildlife/nature, arts and crafts, history and heritage, parks and gardens and water-based attractions (Allerdale Borough Council, 1999, 2007).

Allerdale attracts more than 2.5M visitors per year, most of them day visitors (Allerdale Borough Council, 2005; number for 2002). There is a golf course at Silloth and the coastal area is used for a number of other recreational activities.

In 2007, the Lake District Coast Aquarium at Maryport received over 46,700 visitors (Cumbria Tourism, 2007). Other locally important tourism attractions are Bank Mill Nurseries at Silloth and The Wave Centre and Ventures West Boat Trips & RIB rides at Maryport (Allerdale Borough Council, 2007).

Figure 1.6 shows an increase in the number of tourists to Silloth area from January to August and the popularity of summer months. Increased human impact during summer months has the potential to increase levels of microbiological contamination discharged to coastal waters and therefore to impact on the levels of contamination in BMPAs.

Seasonal variation of *E. coli* levels in bivalve molluscs from currently classified BMPAs in Silloth has been analysed and the results are shown in Section 5.2.5.

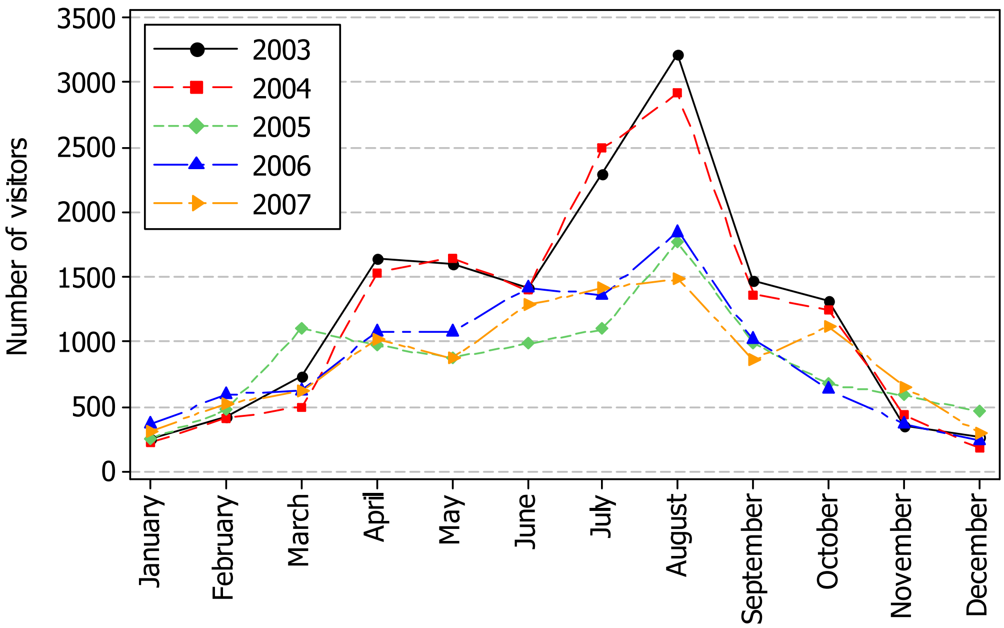


Figure 1.6 Monthly variation in numbers of visitors in Silloth.
Figures indicate recorded visitors to Silloth Tourist Information Centre.
Data from Allerdale Borough Council (2008).

Edwards *et al*. (2008) discussed that farmyards (including farm buildings, adjacent livestock collecting areas, access tracks and overflows from domestic wastewater systems) can contribute significantly to catchment faecal indicator organisms when (a) they have a ready or renewable source of faecal material; (b) a direct hydrological connection with open water channels and (c) a sufficient proportion of livestock farms in the catchment.

Livestock figures (346,404 farmed animals) represent approximately ten times that of the human population in the Waver and Ellen catchments, indicating the potential for a high microbiological load from livestock production areas.

2. SHELLFISHERIES

2.1 Species, location and extent

Harvesting of the common cockle (*Cerastoderma edule*) and mussels (*Mytilus* spp.) for human consumption has a long tradition along the English Solway Firth coast. The cultivation of the Pacific oyster (*Crassostrea gigas*), a non-native species in the United Kingdom (JNCC, 1997), is to be undertaken at Dubmill Point (Figure 2.1). No natural spatfalls of this species have been reported along the Cumbrian coast. The proposed new operation is dependent on the regular supply of juveniles (seed) from commercial hatcheries.

Cockles and mussels often occur on the intertidal sandflats and mudflats of the Cumbrian coast (Lancaster, 2007; Lancaster and Davies, 2007). Mussels usually colonise intertidal beds of shingle (known as scars or skears) or other natural intertidal hard substrates (English Nature, 1997). Dense spatfalls of mussels often occur at Lees Scar, Beckfoot Flats, Lowhagstock Scar and Ellison's Bed. Figure 2.1 shows the location of mussel and cockle beds following stock assessments undertaken by the Cumbria Sea Fisheries Committee (CSFC) in 2006 and the location of the new production area for Pacific oysters at Dubmill Scar.

Densities of commercial sized mussels and cockles vary considerably between years or even between seasons. These variations have been attributed to limited settlement and low survival rates. This represents potential problems for sample collection and continuity of microbiological monitoring where RMPs are established close to the edges of beds that may be liable to change.

High densities of commercial sized mussels (above 45mm) Beckfoot Flats (391.17 mussels/m^2), Lees Scar (194.6 mussels m^{-2}) and landward area of Ellison's Bed (71.9 mussels m^{-2}) were found in the 2006 mussel stock assessment (Lancaster and Davies, 2007).

Cockles were also surveyed in Beckfoot Flats in July 2007. Very low densities of commercial sized cockles (above 24mm) were found in this survey, with the mid to upper mid shore zones of this sandbank reaching an overall density of 2.6 cockles m^{-2} (Davies and Lancaster, 2007).

The coastal intertidal and subtidal areas between Skinburness (North of Silloth) and South of Dubmill Point encompass the currently classified production area for mussels (Figure 2.2A); the area from Lees Scar to Lowhagstock Scar constitutes currently classified area for cockles (Figure 2.2B).

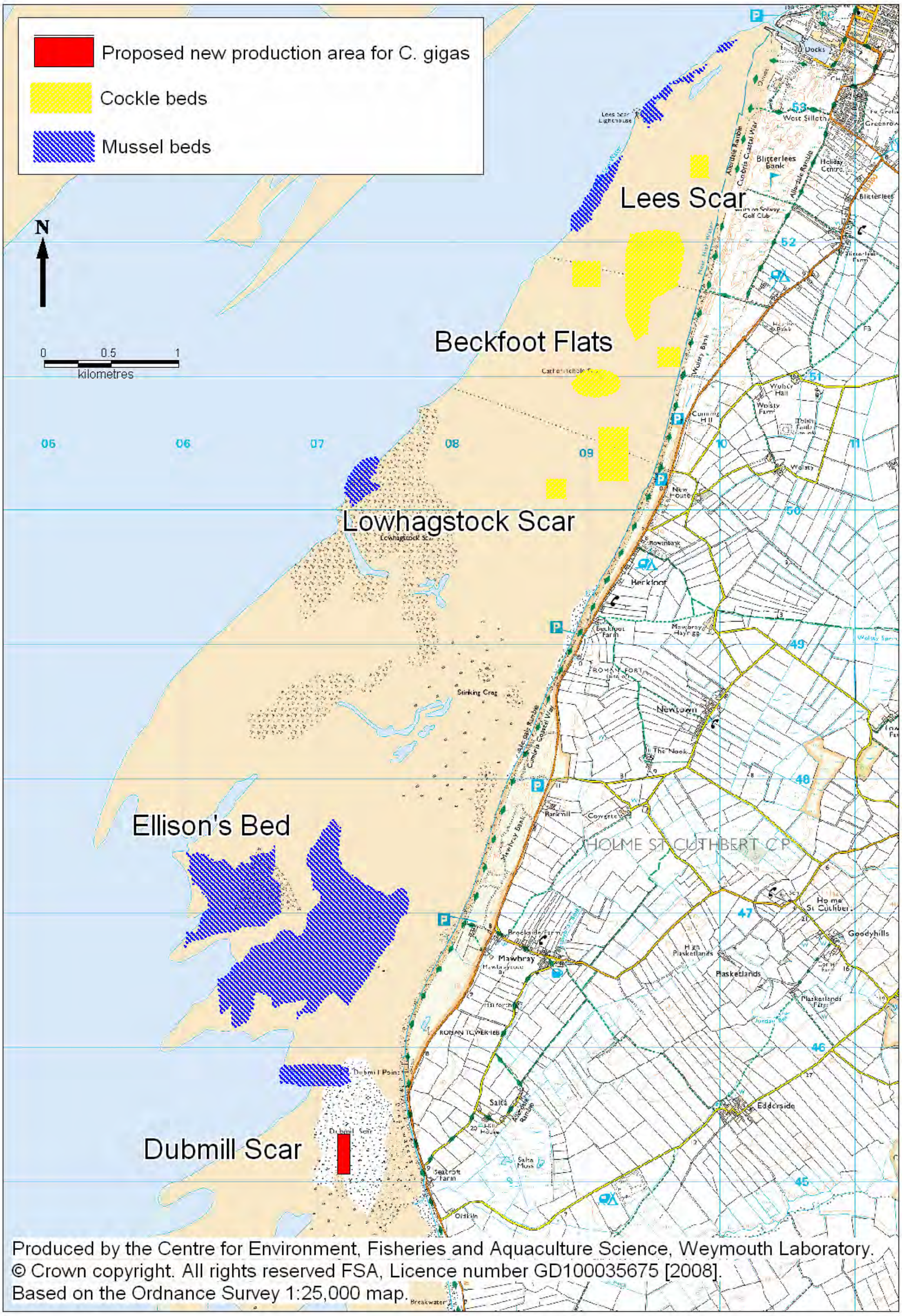
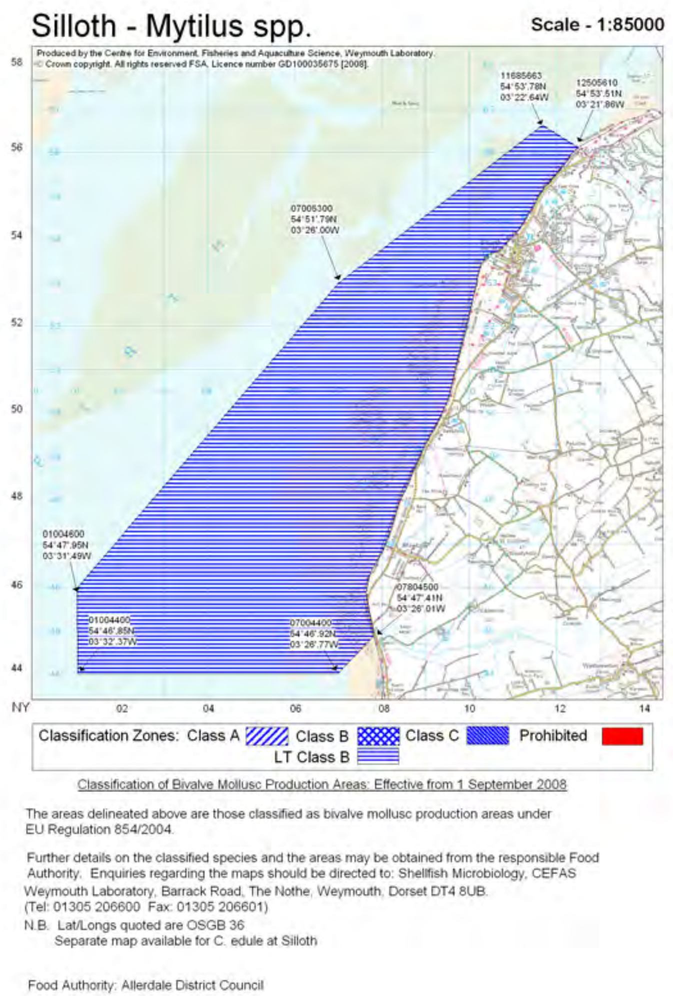


Figure 2.1 Location of wild harvested cockle and mussel beds and new aquaculture operation for Pacific oysters in Silloth.
Location of cockle and mussels beds verified and confirmed by the Chief Officer of the Cumbria Sea Fisheries Committee on 03 Nov 2008.

A



B

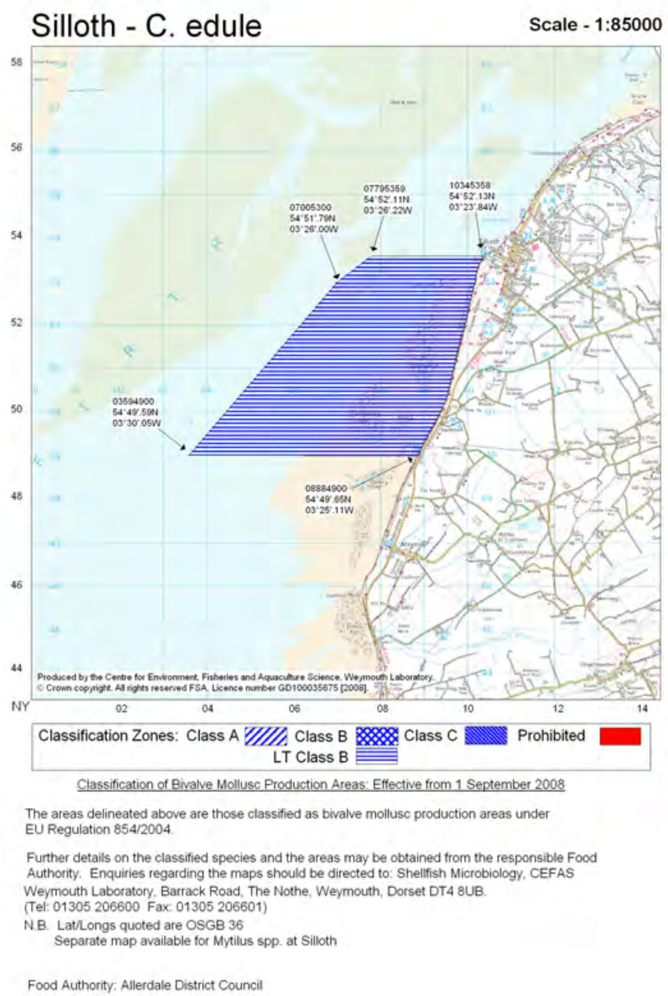


Figure 2.2 Classification status of mussels (A) and cockles (B) in Silloth.

2.2 Growing methods and harvesting techniques

Hand-picking has been the main harvesting technique employed for mussels and cockles since the development of a fully commercial activity in the 1990s on the English Solway Firth (Figure 2.3A). Small scale harvesting of cockles using dredging by boat (using hydraulic dredgers) (Figure 2.3B–C) or tractor have also been authorised on the Solway Firth by the Cumbria Sea Fisheries Committee (CSFC) (Cumbria Sea Fisheries Committee, 2008). Some boats started to dredge for mussels in the early 1990's (Bullen Consultants Ltd., 1998). Three dredging boats are currently in operation for cockles in Silloth (Figure 2.3C).

Mussel harvesting has traditionally been undertaken by hand raking and dredging by boat. During the 2005–2006 season, 190 tonnes were removed by up to 30 hand gatherers (Lancaster and Davies, 2006).

Figure 2.3 Hand gathering of mussels (A, B), cockle suction dredger (C) and bags of cockles (D) in the Solway Firth.
Permitted use by Cumbria Sea Fisheries Committee (2008).

The application for classification of the new production area for Pacific oysters at Dubmill Point proposes the use of the adjustable longline system (Figure 2.4). The operation has currently two sets of 'dripper tubes'. Cefas has been informed that the applicant intends to expand the number of longlines in Dubmill Scar over time, although it is unlikely that this will occur in the foreseeable future (David Copeland, pers. com., 05 Nov. 2008).

Cefas aims to review the sanitary survey before the normal period (see Requirement for Review in the Appendix II - Sampling Plan) in light of any changes on the location will be necessary in order to ensure that recommendations on boundaries for the new production area considered and the new sampling regime are as representative as possible for the new area.

Figure 2.4 Illustrative adjustable longline oyster farming system showing two 'dripper' tubes with suspended baskets (A), each basket secured at either end to a end-cap (B).
Permitted use by BST International and BST Oyster Supplies.

2.3 Seasonal controls

Cumbria Sea Fisheries Committee regulates harvesting of bivalve molluscs under the byelaws summarised in Table 2.1.

Table 2.1 Summary of byelaws relating to the regulation of bivalve mollusc harvesting at Silloth.

Byelaw	Species	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
21	Cockles				Authorisations for cockle harvesting issued by SFC valid from the 1st April to 31st December								
23	Mussels	Harvesting permitted 1st January to 31st December											
16	Cockles				Harvesting not permitted 15 April to 14 September								
18	All species	Cumbria SFC may issue temporary closures within its jurisdiction											

Annual permit schemes are issued by the CSFC, these include daily catch restrictions for mussels and cockles. Under byelaw No 21, permits for harvesting cockles are valid from 1 August to 31 December in the same year, whilst under byelaw No 23, permits for harvesting mussels are valid from 1 January to 31 December in the same year (Cumbria Sea Fisheries Committee, 2008).

The CSFC has also the responsibility to issue annual closures of bivalve molluscs harvesting areas on conservation grounds. Under byelaw No 16, cockle harvesting is not allowed between 15 April and 14 September (both days inclusive) within the jurisdiction limits of the CSFC.

Between 1993 and 2003, all cockle beds remained closed on the English Solway Firth due to poor recruitment and increased fishing pressure. Since then, harvesting of this species has been authorised for relatively short periods.

Between 6 December 2005 and 24 February 2006, the fishery was opened to seven vessels, which removed 26 tonnes of cockles from the offshore bank. Since then, the fishery has remained closed (Davies and Lancaster, 2007).

The CSFC has also the responsibility to issue temporary closures to harvesting of bivalve molluscs within its jurisdiction area, in accordance with byelaw No 18 Cumbria Sea Fisheries Committee, 2008).

The CSFC has currently published public notices for temporary closure for harvesting of cockles (all beds) and mussels (Beckfoot Flats, Dubmill Scar, Ellison Scar, Lees Scar, Lowhagstock Scar, Skinburness). The notices were published on 30 November 2007 and are into force until further notice. The temporary closures were implemented to protect small and immature stocks (see also Byelaw No 18 in Cumbria Sea Fisheries Committee, 2007).

The Chief Fishery Officer of the CSFC informed Cefas that temporary closures for mussel harvesting are mussel harvesting at Ellison's Scar and Dubmill Point (D. T. Dobson, pers. com., 20 Oct. 2008) were re-evaluated in December 2008. Following expressions of interest from members of industry for mussel harvesting on sublittoral beds at Silloth a mussel stock assessment has been undertaken. The results of the assessments evidenced low mussel and cockle densities along the Silloth channel (D. T. Dobson, pers. com., 21 Jan. 2009). The Chief Officer also confirmed the accuracy of the information on location and extent of mussel and cockle beds currently held by Cefas.

3. HYDRODYNAMICS

3.1 Bathymetry

The Solway Firth is an embayment estuary (Type 5). It gradually widens towards the west and its seaward extent is situated between Southerness Point and Dubmill Point (Figure 1). The mouth of the Firth is large (approx. 13km) compared with its channel length (approximately 23km from Annan to Southerness Point). The relative depth to width ratio is low at 0.66 for the tidal range (see Section 3.2), indicating potential for further sedimentation (Futurecoast, 2002; see Section 3.2).

The bathymetry of much of the Solway Firth Cumbrian coast including part of the intertidal area of Lees Scar and Lowhagstock Scar between Silloth and Dubmill Point, is largely unsurveyed (see UKHO Admiralty Chart No 2013). However, the adjacent sub-tidal surveyed areas from where mussels and cockles are harvested for commercial purposes are within the 2 metres depth contour line (UKHO Admiralty Chart No 2013).

Mixing and sedimentation processes are expected to dominate and significantly contribute to variations in the levels of microbiological contaminants in shallower depths. Representative monitoring points situated in these areas would therefore be more representative of contaminating inputs from pollution sources of human and animal origin discharging directly to the sea or transported via watercourses.

3.2 Tides and tidal currents

Tidal levels for the nearest ports to the proposed new harvesting area at Dubmill Point are shown in Table 3.1.

Table 3.1 Tide levels and ranges along the Cumbrian coast (TotalTide, 2008).

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Silloth	9.2	7.1	2.3	0.8	8.4	4.8
Maryport	8.6	6.6	2.5	0.9	7.7	4.1

Predictions for these secondary ports are based on Liverpool (Alfred Dock).

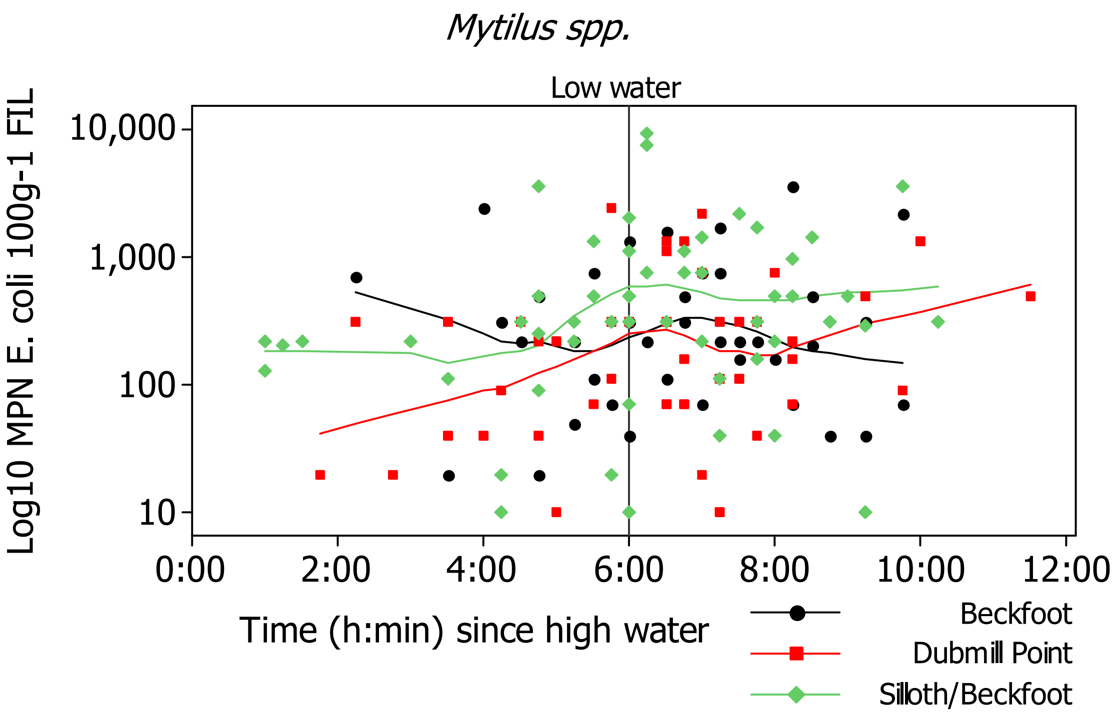
The predicted tidal range at Silloth Port (approximately 8km to the North of Dubmill Point) is approximately 8.4 metres on spring tides and 4.8 metres on neap tides. The spring tide flood lasts for approx. 5 hours, whilst the ebb tide lasts for approx. 7 hours (Bullen Consultants Ltd., 1998).

At Maryport (approximately 10km to the South of Dubmill Point), the predicted range is approximately 6.1 metres on spring tides and 5.7 metres on neap tides.

Tidal currents in the Solway Firth are flood dominant (Futurecoast, 2002). This dominance is given by the flood tidal stream entering through the North Channel and flowing East towards the headland of St Bees. Residual near-bed currents at Silloth indicate maximum recorded flood and ebb velocities of 2m s^{-1} and 1.5m s^{-1}, respectively (Ove Arup and Partners, 1993). Off Dubmill Point, the flood tide reaches a mean flow rate of 1m s^{-1} and a mean ebb flow rate of 0.9m s^{-1} (Bullen Consultants Ltd, 1998).

Mounsey (1998, 1998a) found that elevated concentrations of faecal coliforms in Silloth bathing water coincided with the highest tides of those sampled (1,500 and 2,200CFU 100 ml^{-1} on 7.9 and 7.6m tides, respectively). These results suggest that tides are a factor accounting for significant variations in the levels of microbiological contamination of shellfisheries in Silloth.

The state of tide at which sampling for mussels from Beckfoot, Dubmill Point and Silloth/Beckfoot and cockles from Beckfoot Flatts occurred was analysed for the period 2003–2007. Figure 3.1 indicates that the majority of samples were collected within 2 hours of low water. An apparent albeit small increase (<1 Log) in levels of *E. coli* occurs in both species during the first hour of the incoming tide. This could be due to an increase in filtration rates derived from increased water flows, or due to re-suspension of contaminated sediment, or as a consequence of the effect of water temperature and/or salinity of seawater on the physiological activity of bivalve molluscs.



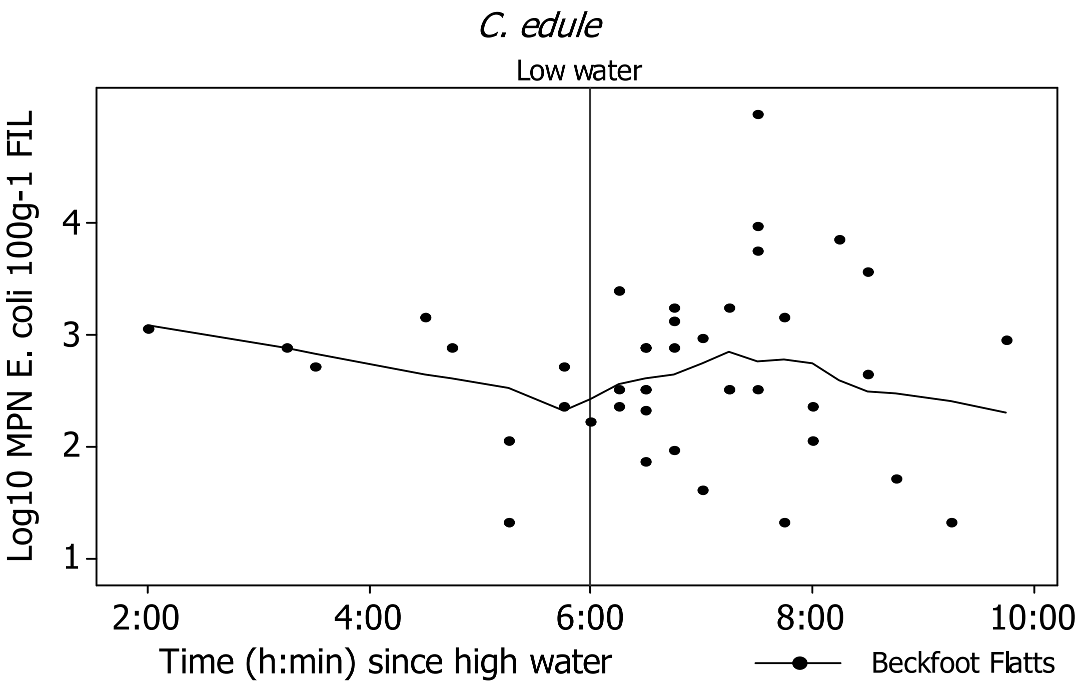


Figure 3.1 Variation of levels of* E. coli *in bivalve molluscs from four beds during the tidal cycle for the period 2001–2007.
Tidal predictions for Silloth from POLTIPS-3 (Proudman Oceanographic Laboratory).

Consideration could be given by the LEA to sampling mussels during the first hour and sampling cockles during the first two hours after low water time in order to reflect the worst-case scenario of microbiological contamination, if this aspect of the Good Practice Guide for Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (Cefas-CRL, 2007) is adopted in the UK at some time in the future.

Wind acting on sea surface generates waves and water movement. Wind-driven surface currents are known to play an important role on mixing processes on sediment resuspension in the shallow areas of the Eastern Irish Sea, particullarly during storm periods (Defra, 2000).

The high-resolution three-dimensional hydrodynamic tidal model developed by Aldridge and Davies (1993) evidenced the existence of depth averaged residual tidal currents running down the Cumbrian coast (Figure 3.2). This model shows the prevalent residual current running on a north-south orientation between Silloth and Dubmill Point (Figure 3.1). These tidal currents are likely to promote transport of microbiological contamination discharged from sources located along the coasts of Silloth and to a lesser extent, sources from the upper Solway Firth over the shellfish beds. However, the directions of tidal currents tend to be modified in inshore areas (Davies and Lawrence, 1995). No detailed data on these inshore modifications could be found in the course of this assessment.

The water company, United Utilities (UU), has been asked by the EA to conduct a detailed investigation in the next water company investment period which will involve a first time detailed model of the Solway, including first time full bathymetry collection. This should enable a model to be constructed with a finer resolution and help understanding the impact of remote pollution sources, such as those discharging to the Rivers Eden, Annan and Nith and any sewage discharges in Carlisle and Dumfries.

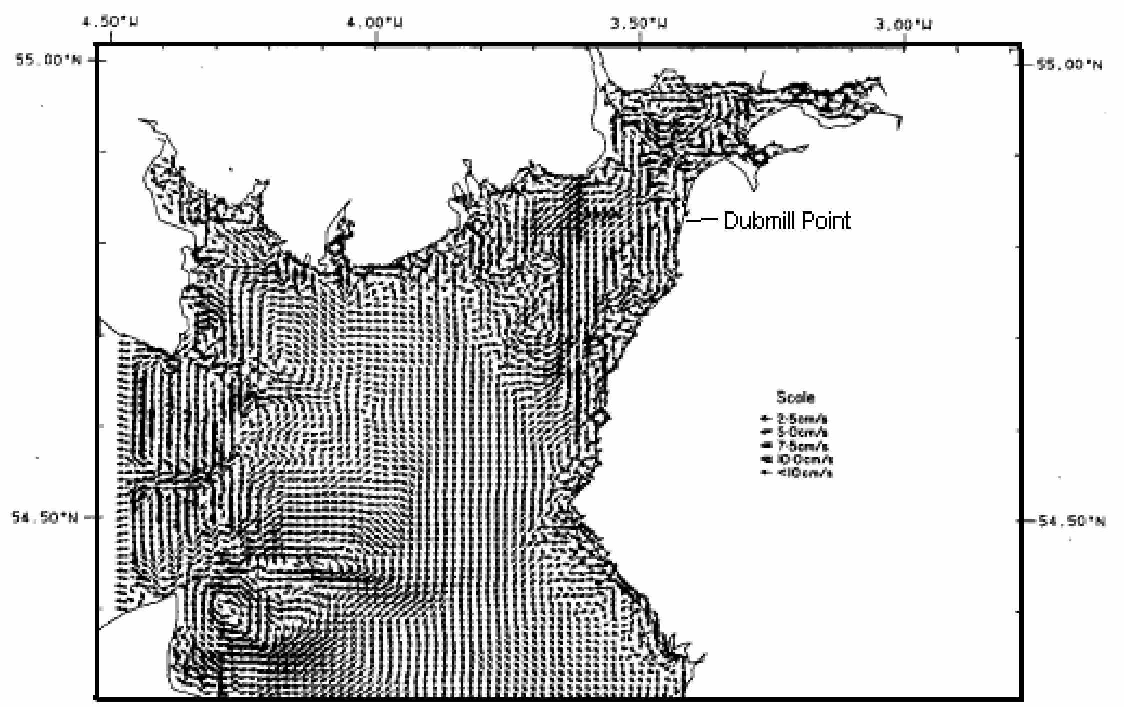


Figure 3.2 Depth averaged tidal residuals in the Solway Firth and Eastern Irish Sea.
Modified from Aldridge and Davies (1993).

Intertidal beds between Silloth and Dubmill Point are predominantly sandy, whilst intertidal beds between Maryport and Dubmill Point are predominantly gravelly. At seabed level, tidal currents for the Solway Firth and Eastern Irish Sea area show their maximum values in the Eastern Solway Firth along the Silloth Channel (Figure 3.3). Bacteria tend to associate with fine sediments and sediment pathways represent one potential route of contamination.

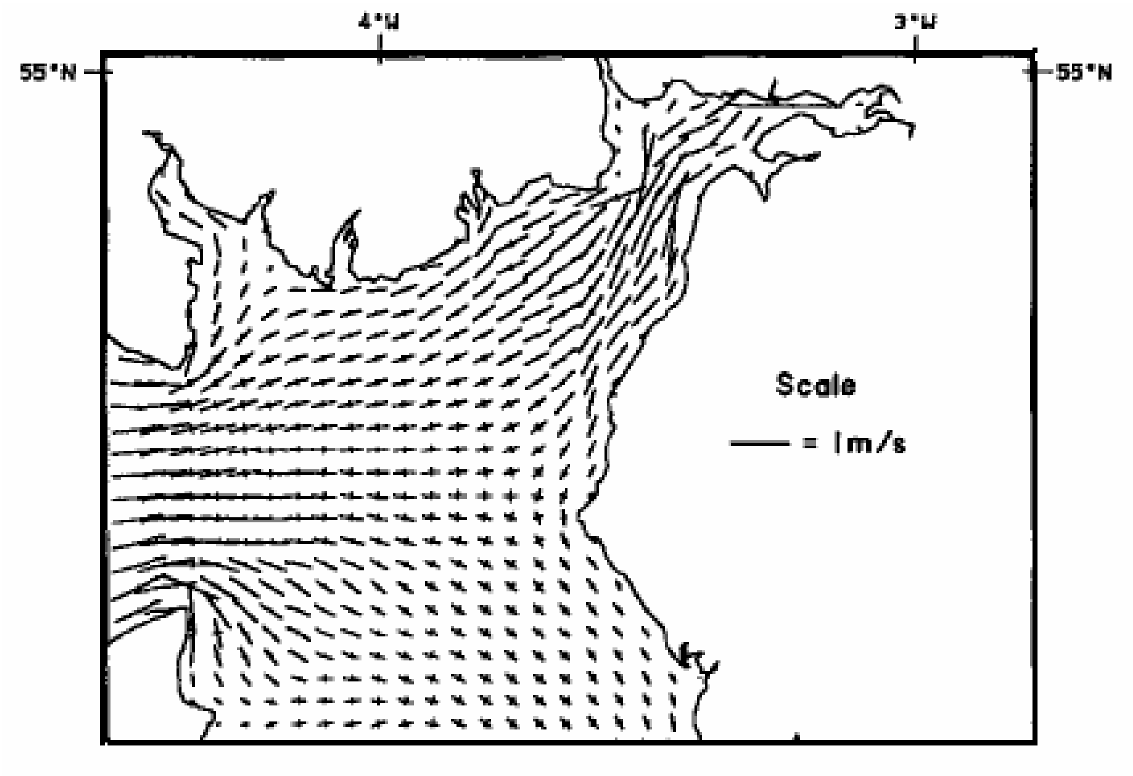


Figure 3.3 Near-bed current ellipses (major and minor axis) in the Solway Firth and Eastern Irish Sea.
Modified from Davies and Lawrence (1995).

Sediment transport modelling undertaken for the Irish Sea indicates that the pattern of sediment distribution tends to follow the distribution of tidal current speeds (Hartnett, 2007). Gravels are transported where currents are stronger and muddy sediment where current speeds are weakest. Sediment transport circulation paths along the eastern Solway Firth tend to be directed southward in near-surface waters and northwards in near-bottom waters.

The coast of Silloth is subject to sediment erosion (Bullen Consultants Ltd., 1998). Near-bed sediment from the upper Solway Firth is likely to be transported down the coast during the ebb stage of the tide (Figure 3.3). In the event of this sediment being contaminated this may affect cockles and mussels during the initial periods of the flood tide should filtration rates increase significantly, as indicated in Figure 3.1.

Information presented in this section indicates that under predominant flood tide conditions combined with onshore westerly winds, land based sources of pollution (i.e. form outfalls and fresh watercourses) would be constrained inshore. In contrast, off-shore, deeper water areas provide more available dilution for dispersion of contamination. Therefore, RMPs situated in offshore areas are not likely to reflect worst-case contamination.

Analysis of historical *E. coli* data for existing shellfish beds at Silloth, potentially impacted by pollution souces from the upper Solway Firth is presented in Section 5.2.

4. SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION

4.1 Sewage discharges

Sewage discharges that may impact on the Pacific oyster production area at Dubmill Point and the wider Silloth BMPAs are shown in Figure 4.1.

The most significant water company continuous sewage discharges are those from Silloth STW [population equivalent (p.e.) = 2,298)] and Allonby STW (p.e. = 422) (Table 4.1). There are also several smaller STW discharges to coastal streams that flow to the sea between Allonby and Silloth.

Table 4.1 Continuous sewage discharges with a potential impact on the levels of microbiological contamination for bivalve mollusc production areas in Silloth.

Name	Treatment level	DWF (m^3 day^{-1})	NGR of outfall	Distance (km) from BMPA at Dubmill Point
Allonby STW	Tertiary (UV)	112	NY 0773 4407	1.3
Edderside STW	Secondary	11 (max.)	NY 0994 4552	3.3
Hayton STW	Secondary	90 (max)	NY 1076 4183	6.8
Allerby STW	Secondary	85	NY 0892 3913	7.4
West Newton STW	Secondary	60 (max.)	NY 1302 4363	7.9
Silloth STW	Tertiary (UV)	2,298	NY 1087 5412	9.5

STW - sewage treatment works.
DWF - dry weather flow.
UV - ultraviolet.
NGR - national grid reference system.

The effluents from both Allonby and Silloth STW receive year round UV disinfection.

Table 4.2 summarises the results from the microbiological control undertaken in Allonby and Silloth sewage treatment works.

Table 4.2 Summary of faecal coliform data for final effluents in two sewage treatment works during the period 2003–2007.

		Faecal coliforms (CFU $100ml^{-1}$)		
	No samples	Geometric mean	Minimum	Maximum
Allonby STW	111	76	<10	87,000
Silloth STW	93	72	<10	14,000

United Utilities efficacy data provided by the Environment Agency (2008).
Faecal coliform results qualified as less-than a numerical value were assigned half that numerical value before calculation of geometric mean.

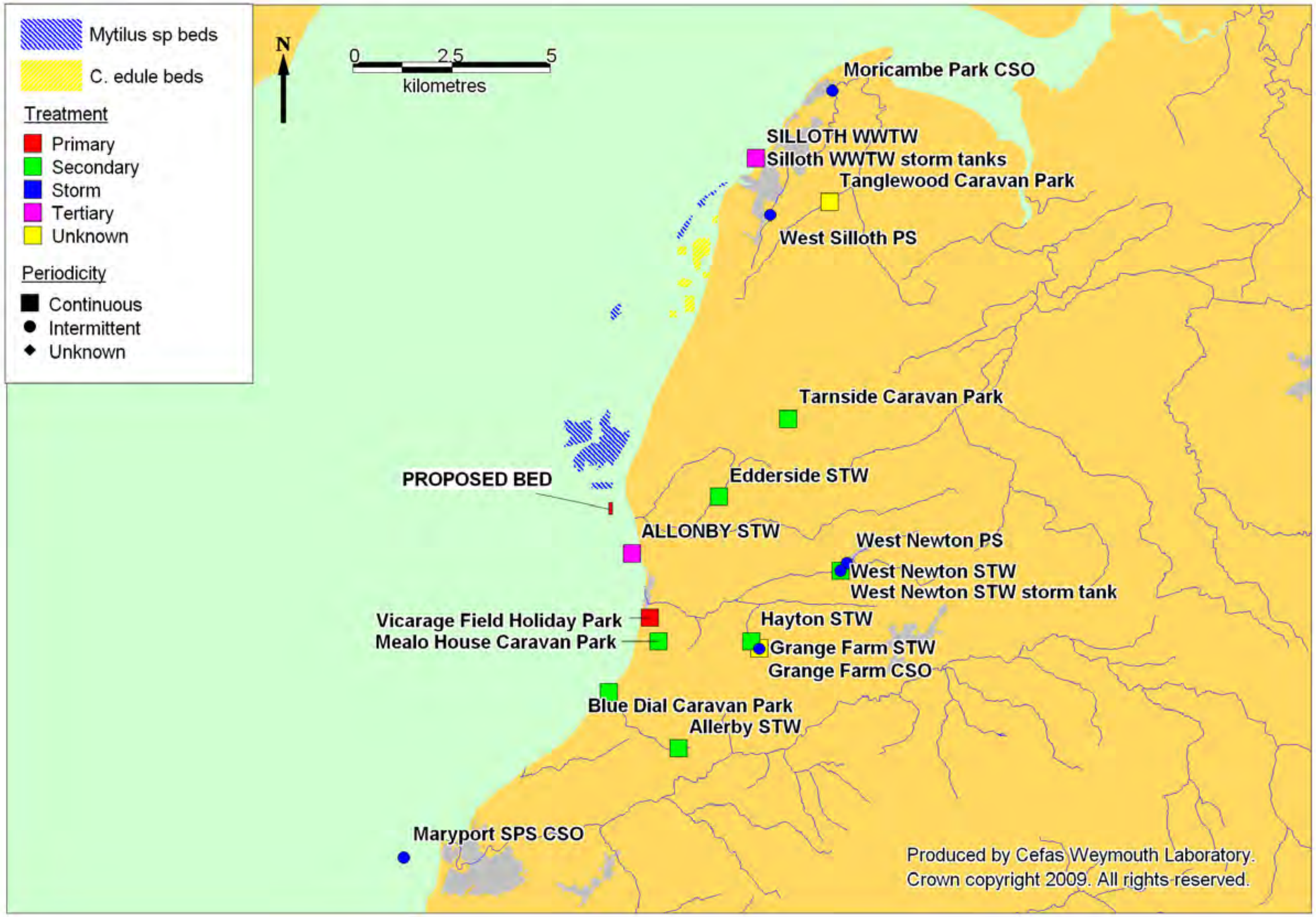


Figure 4 Sewage discharges with a potential impact on the levels of microbiological contamination for bivalve mollusc production areas in Silloth.

The variability of levels of faecal coliforms in these results indicates episodes of low efficiency in these STWs. The geometric means correspond to typical values reported for UV-treated effluents reported by Kay *et al.* (2007)[1]. In general, it is considered that for most of the time the contribution of these tertiary-treated effluents as sources of microbiological contamination impacting on BMPAs is low when compared with other sewage discharges or sources of contamination of diffuse origin. However, under certain hydrodynamic conditions discussed in Section 3, both discharges seem to have the potential for a much more significant impact on the levels of contamination in BMPAs.

Intermittent sewage discharges from storm overflows that may impact on the Silloth production area are listed in Table 4.3.

Table 4.3 Intermittent sewage discharges with a potential impact on the levels of microbiological contamination for bivalve mollusc production areas in Silloth.

Name	Receiving water	NGR of outfall	Distance (km) from BMPA at Dubmill Point
Grange Farm CSO	Patten Beck	NY 1096 4164	7.0
West Newton STW storm tank	Crookhurst Beck	NY 1302 4363	7.9
West Newton PS	Crookhurst Beck	NY 1318 4382	8.2
Silloth STW storm tank	Solway Firth	NY 1087 5412	9.5
Moricambe Park PS	Great Gutter	NY 1282 5584	16.8
West Silloth PS	Tributary of Great Gutter	NY 1124 5268	20.7
Greenrow PS CSO	Tributary of Great Gutter	NY 1123 5265	20.7
Maryport SPS CSO	Irish Sea	NY 0194 3636	10.3

PS - pumping station.
CSO - combined storm overflow.
STW - sewage treatment works.
NGR - national grid reference system.

Environment Agency (EA) monitoring data and modelling work carried out by Metoc plc on behalf of the water company (UU) has shown an association between discharges from Maryport PS CSO and poor bathing water quality at Allonby. The EA informed Cefas that improvements (reduction in spill to 10 spills a year on average by construction of a 6,000m^3 storage tank) have been included by UU in a recent 'Change Protocol'[2] submission. These improvements will not be completed until 2013.

None of the other intermittent discharges are in close proximity (i.e. within 5km) to Dubmill Point. Sewerage network modelling has shown that the storm discharges from Silloth STW and West Silloth PS have sufficient storage to meet the design criteria for protection of the designated Shellfish Waters

[1] The indicative levels of faecal coliforms in UV-disinfected effluents from a number of STW around the UK reported by Kay *et al.* (2007) were 2.8 x 10^2 (n=108) during base-flow conditions and 3.6 x 10^2 (n=6) during high flow conditions. The same study reported a reduction in 3 Log_{10} orders of magnitude for UV-disinfected effluents relative to concentrations in effluents providing the input to analysed treatment plants.

[2] Change Protocol is a procedure whereby water company investment schemes may be substituted or brought forward. In the case of waste water improvements these would be agreed with the Environment Agency and would require consultation with the water companies' regulator OFWAT and Defra to agree a new delivery date and for the water company to get any funding adjustments agreed.

(Environment Agency, 2007). These discharges are therefore not considered significant sources of contamination to bivalve molluscs.

There are several camping and caravan parks along the coast between Allonby and Silloth and sewage discharges from these sites may be a source of contamination of coastal waters (Jones, 2006). Caravan parks for which details are known, that are not connected to main sewer are listed in Table 4.4. There are more caravan parks in the area which are currently under investigation by the EA. Details of and an assessment of these will be incorporated in the next review.

Table 4.4 Camping and caravan park sewage discharges with a potential impact on the levels of microbiological contamination for bivalve mollusc production areas in Silloth.

Name	Treatment	Flow ($m^3 day^{-1}$)	NGR of outfall	Distance (km) from BMPA at Dubmill Point
Vicarage Field (unconsented)	Primary	Unknown	NY 0819 4243	3.0
Mealo House Caravan Park (unconsented)	Primary	51 (maximum)	NY 0840 4183	3.9
Tanglewood Caravan Park	Secondary	5.5	NY 1274 5301	19.8
Blue Dial Caravan Park	Secondary	20	NY 0715 4055	4.8

NGR - national grid reference system.

Failing septic systems have been mentioned as potentially significant pollution sources impacting on coastal waters. As part of a collaborative project aiming to improve water quality in catchments impacting on designated bathing waters (ICREW Project), 305 septic tanks were identified in the Ellen catchment. Of these, only 32 were within 50 metres from a watercourse. However, this figure was considered to be an underestimation by the fact that only major watercourses were considered in the analysis (Jones, 2006). More information on septic tanks impacting on bathing waters in the Ellen catchment was requested from the Environment Agency. This data were not available at the time of writing this report.

4.2 Farming activities

Agriculture is important within Waver and Ellen catchments. It accounts for 65% of the land use within the Solway Coast AONB.

The density of farms in the Waver and Ellen catchments are shown in Figure 4.2.

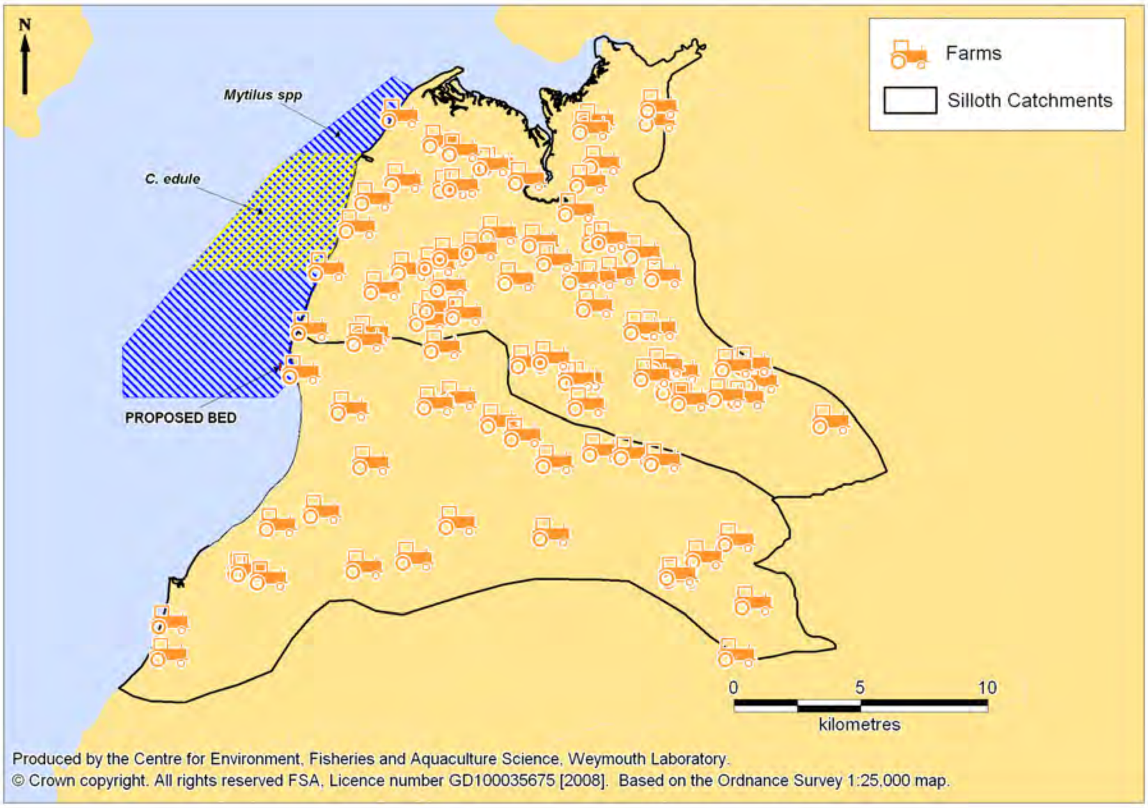


Figure 4.2 Farms in Waver and Ellen catchment areas.

The total number of farmed animals in these catchments is 346,404. Approximately 41% of livestock are cattle and sheep (Figure 4.3). Numbers of sheep are higher in the Ellen catchment. The high number of poultry in the Waver catchment is due to a poultry unit in Silloth.

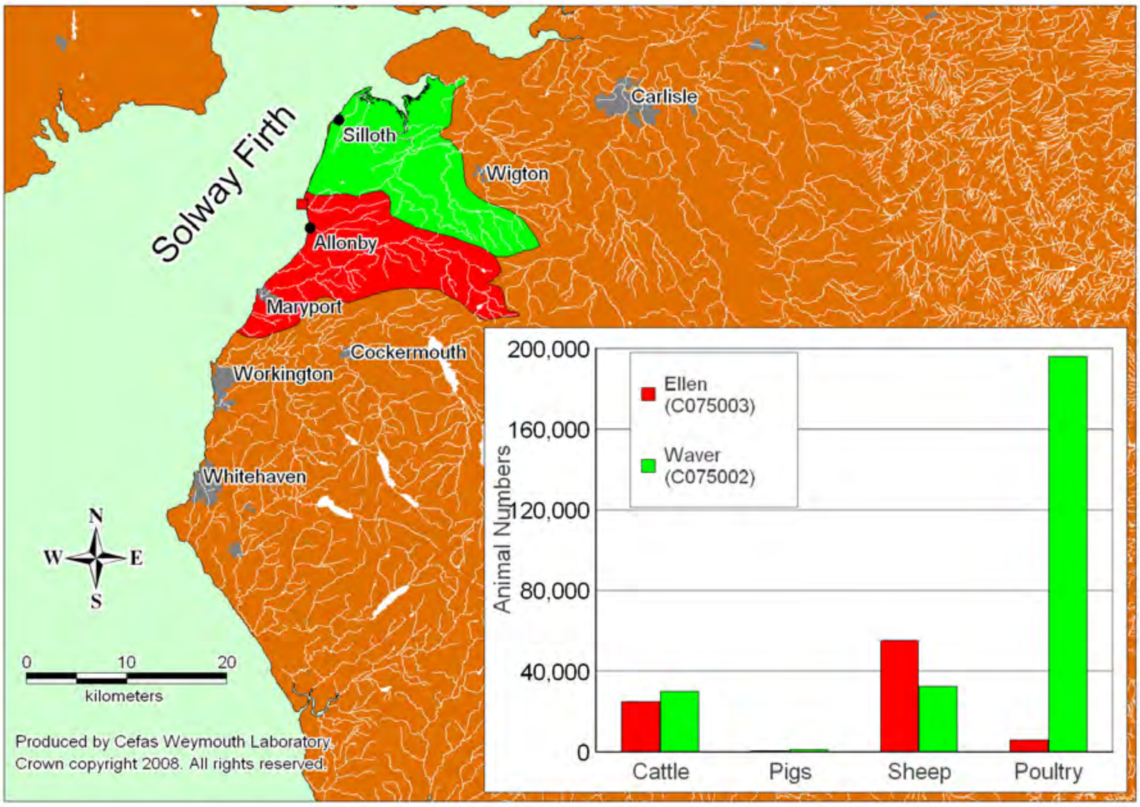


Figure 4.3 Livestock numbers in Waver and Ellen catchment areas.

Dairy farms predominate in the upper reaches of both catchments, whilst beef, beef and sheep and dairy and beef farms are more abundant in the lower reaches of both catchments, especially at Dubmill Point. Extensive livestock production occurs both on grassland and areas occupied by dunes (see Figure 1.2). A number of farms in the lower reaches of these catchments have cattle access points to watercourses (Jones, 2006). These farms represent a higher risk of diffuse pollution impacting on the levels of microbiological contamination in BMPAs.

The overall potential microbiological load from pollution sources of animal origin in the Waver and Ellen catchments is potentially higher than the load from pollution sources of human origin[3]. However, source apportionment and source tracing work, especially during and following high rainfall events, would be needed to better assess the relative significance of each in terms of their potential to impact on Silloth BMPAs.

Detailed information on specific sites where farmyard manure or slurry are applied to land and corresponding spreading regimes in the proximity of shellfish beds was requested from Defra. These data were not available at the time of finalising this report.

[3] Published literature quotes excreted thermotolerant coliforms in humans ranging between 10^5 and 4×10^8 coliforms per g, for an excretion rate of 150 g per day.) Whilst in cows the excretion of those microorganisms ranges between 2×10^5 and 7×10^7 coliforms per g, for an excretion rate of 23,600 g per day (see Pommepuy *et al.*, 2005). These figures indicate that contamination from cattle is potentially higher than contamination from human sources.

As part of the ICREW Project, inspections were undertaken to farms within the Ellen catchment between May and August 2005. These inspections focused on the identification of pollution sources around the farm steading area (e.g. slurry stores), slurry and manure spreading practices and animal access to watercourses and fenced stretches of rivers. Of the 127 farms visited in the catchment, more than 60% were classed as 'low risk' with respect to the existence of slurry and solid manure stores and dirty areas. Results also indicated that of the 76 farms having slurry stores, 63% have at least three months storage and 37% two months storage or less. A survey of farmers also indicated that the period October–March is when most of the slurry[4] is spread on a daily, weekly or monthly basis or dependent from the weather. However, the majority of farmers indicated they did not spread farmyard manure during winter but during the summer after cropping (Jones, 2006).

Bivalve molluscs harvested on a year-round basis (particularly mussels and Pacific oysters from Dubmill Point) would be vulnerable to microbiological contamination from agricultural land run-off in catchments where both slurry and manure are frequently applied. As indicated by the results from farm inspections, the periods of higher risk of contamination would be winter months for slurry and summer months for manure.

Cockles are only harvested during the autumn-winter months and are therefore most vulnerable to receive contamination delivered from areas where slurry is spread.

4.3 Birds and domestic animals

The Upper Solway Flats and Marshes supports large communities of migratory waterfowl (ducks, geese, swans) and is a vital resting and wintering area for birds migrating along the Eastern Atlantic. The intertidal mudflats and sandflats are particularly important habitats for large populations of curlews, oystercatcher and redshank (English Nature and Scottish Natural Heritage, 2000). The intertidal rocky scar grounds are also important habitats for breeding and wintering wading birds. The high cliffs support populations of seabirds. Table 4.5 summarises counts of seabirds in four coastal sites along the coasts of Waver and Ellen catchments. Locations of these sites are shown in Figure 4.4.

Table 4.5 Number of occupied nests by seabird species monitored in three sites in Ellen and Waver catchments.

		Number of occupied nests per site (site counts per 1km length)		
Species	Common name	Siddick Beach (NY 005325)	Allonby (NY080430)	Grune Point (NY152572)
Sterna albifrons	Little Tern	12	4	-
Phalacrocorax carbo	Great Cormorant	-	-	54

Data from Seabird 2000 supplied by Joint Nature Conservation Committee.

[4] In this context, slurry is understood as the liquid fraction of manure or fraction with low concentrations of solids.

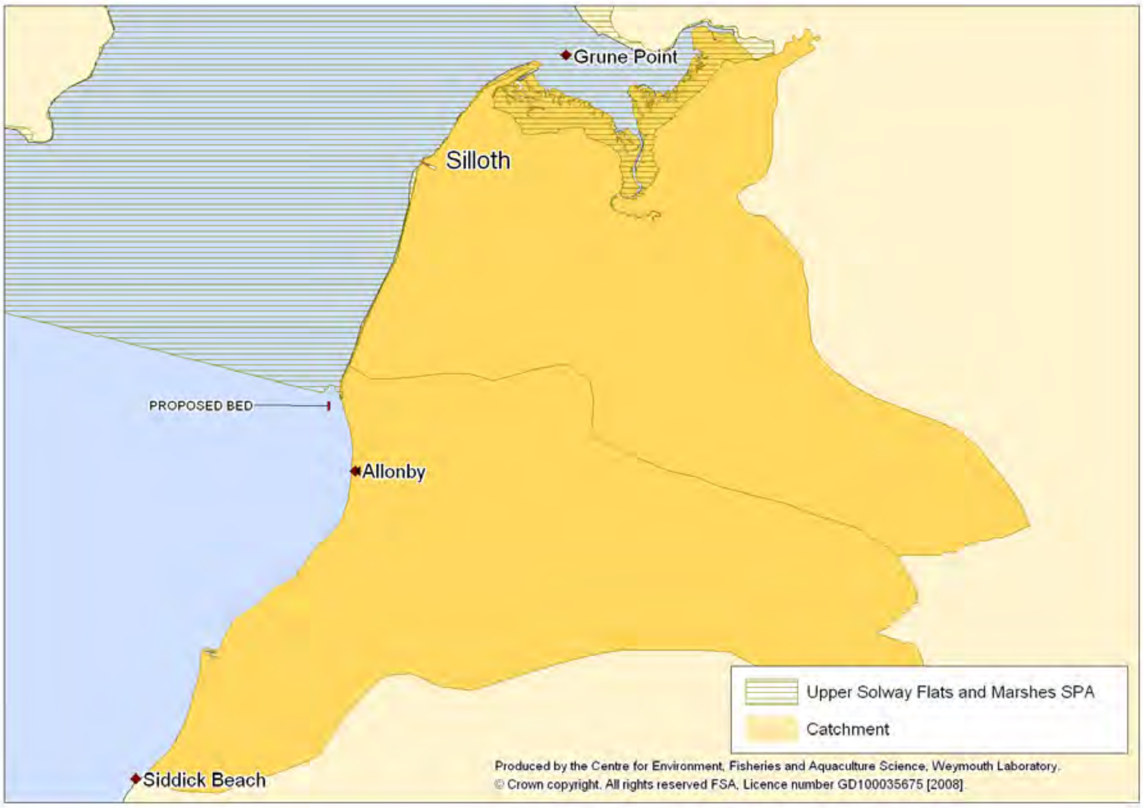


Figure 4.4 Locations of sites referred in this section.

Table 4.6 summarises the numbers of birds recorded in the wider Upper Solway Flats and Marshes Special Protection Area (see Figure 1.2).

Table 4.6 Numbers of birds recorded in the Upper Solway Flats and Marshes.

Species	Common name	Number of individuals
Limosa lapponica	Bar-tailed Godwit	2,367
Branta leucopsis	Barnacle Goose	13,595
Pluvialis apricaria	Golden Plover	6,121
Pluvialis squatarola	Grey Plover	1,036
Cygnus cygnus	Whooper Swan	117
Charadrius hiaticula	Ringed Plover	729
Numenius arquata	Curlew	5,881
Calidris alpina alpina	Dunlin	14,566
Calidris canutus	Knot	12,271
Calidris alba	Sanderling	212
Haematopus ostralegus	Oystercatcher	34,694
Tadorna tadorna	Shelduck	2,196
Bucephala clangula	Common Goldeneye	190
Aythya marila	Greater Scaup	1,544
Arenaria interpres	Ruddy Turnstone	600
Anser brachyrhynchus	Pink-footed Goose	15,983
Anas acuta	Pintail	2,253
Anas clypeata	Northern Shoveler	48
Anas crecca	Common Teal	1,248
Tringa totanus	Redshank	3,088

Data from JNCC (2006).

High numbers of birds were observed during the shoreline survey (see Appendix I). Previous studies in the UK have indicated significant concentrations of microbiological contaminants (thermophilic campylobacters, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). Birds therefore will both contribute to background levels and constitute a potentially significant source of localised contamination to BMPAs at Silloth.

The shores of Silloth are also very popular for horse-riding and dog walking. This was observed during the shoreline survey in the vicinity of the new production area for Pacific oysters (see Appendix I). Dog walking is allowed throughout the year along Silloth shores (David Copeland, Allerdale Borough Council, Environmental Health Unit, pers. com., 26 January, 2009). These represent a localised source of faecal contamination to the inshore areas of shellfish beds.

During the 2008 bathing season, the Environment Agency collected eight water samples at Silloth Bathing Water for DNA microbial source tracking (MST) analysis. The DNA/MST method highlighted human pollution, ruminant and bird sources as being significant (Table 4.7).

Table 4.7 Levels of faecal coliforms and results from the Bacteroidetes and mitochondrial DNA markers from water samples taken during the 2008 bathing season at Silloth.

		Bacteroidetes marker			mtDNA marker			
Date	Faecal coliforms (CFU 100ml^{-1})	Human presence	Ruminant presence	Other sources	Human	dog	bird	Direct bird
06-Jun-08	231	No	Yes	Yes	Yes	No	No	N/A
22-Jul-08	1,560	Yes	Yes	Yes	Yes	No	Yes	Yes
05-Aug-08	462	Yes	Yes	Yes	Yes	No	Yes	Yes
19-Aug-08	920	28%	72%	No	Yes	No	No	N/A
22-Aug-08	308	Yes	Yes	Yes	Yes	Yes	Yes	Yes
29-Aug-08	231	Yes	Yes	Yes	Yes	No	Yes	Yes
03-Sep-08	338	Yes	Yes	Yes	Yes	No	Yes	Yes
18-Sep-08	308	Yes	Yes	Yes	Yes	No	Yes	unknown

Data from Environment Agency (2009).
N.B. Direct bird means whether markers are from birds directly impacting on the BW or whether there is some element of bird DNA contained in the human sewage.

5 MICROBIOLOGICAL DATA

5.1 Bathing waters monitoring programme

There are four bathing waters in Waver and Ellen catchments designated under Directive 76/160/EEC (European Communities, 1976, 2006)[5]: Skinburness and Silloth (Waver) and Allonby Westwinds and Allonby South (Ellen), all in close proximity to BMPAs (Figure 5.1).

Figure 5.1 Bathing and Shellfish Waters Monitoring Points in the vicinity of Silloth shellfish beds.

[5] The bathing season runs from 15 May to 30 September. Water is sampled throughout the season. Levels of bacteria must not exceed the Imperative (I) value (2000 faecal coliforms $100ml^{-1}$) and the Guideline (G) value (100 faecal coliforms $100ml^{-1}$) represents the ideal maximum value. Bathing waters in England and Wales are classified as:
Poor - fails at least one coliform I standard;
Good - passes coliform I standards but fails at least one coliform G standard;
Excellent - passes coliform G standard and faecal streptococci standards.

The overall quality of these Bathing Waters (BWs) is summarised in Table 5.1 below.

Table 5.1 Quality of Bathing Waters for the period 2003–2008.

Compliance	Bathing Water	Bathing Season					
		2003	2004	2005	2006	2007	2008
Excellent (Guideline Pass)	Skinburness	√	√				
	Silloth				√		
	Allonby Westwinds				√		
	Allonby South				√		
Good (Mandatory Pass)	Skinburness		√	√	√	√	√
	Silloth	√	√	√		√	√
	Allonby Westwinds	√	√	√		√	
	Allonby South	√	√	√		√	√
Poor (Mandatory Fail)	Skinburness						
	Silloth						
	Allonby Westwinds						√
	Allonby South						

Data from Environment Agency (2009).
N.B. The descriptions in this table are based on compliance monitoring and assessment against the current Bathing Water Directive. This will be replaced by assessment against the Directive in 2014.

In 2008, Allonby West winds failed to meet the mandatory standards. The other BWs were mandatory passes.

Under the revised BW Directive, the four BWs do not meet good or excellent status during the period (Table 5.2). They are a mixture of poor and risky sufficient.

Table 5.2 Quality of Bathing Waters for the period 2003–2008 under the revised Bathing Waters Directive.

	2003 to 2006	2004 to 2007	2005 to 2008
Allonby South	Risky sufficient	Sufficient	Risky sufficient
Allonby	Poor	Risky sufficient	Poor
Silloth	Risky sufficient	Poor	Poor
Skinburness	Sufficient	Risky sufficient	Risky sufficient

Data from Environment Agency (2009).

The median and geometric mean values in Skinburness are lower than those in Allonby and Silloth bathing waters (Table 5.3). Although these results seem to suggest that impact from pollution sources in the vicinity of Allonby and Silloth is more significant than contamination derived from sources further up the Solway Firth, it should be pointed out that the large tidal range in the area and the fact that sampling is undertaken within 2h of high water would account for extreme variations between years.

Skinburness achieved overall classifications of ‘excellent’ in 2003 and ‘good’ during the period 2004–2007; Silloth, Allonby Westwinds and Allonby South achieved classifications of ‘excellent’ in 2006 and ‘good’ in 2003–2005 and in 2007.

Levels of faecal coliforms from the bathing waters monitoring programme for the period 2003–2007 were analysed and represented by box-and-whisker plots[6]. The similar sizes of top and bottom halves and similar lengths of whiskers for levels of faecal coliforms from all bathing waters indicate similar variation on the levels of microbiological contamination in all bathing waters (Figure 5.2).

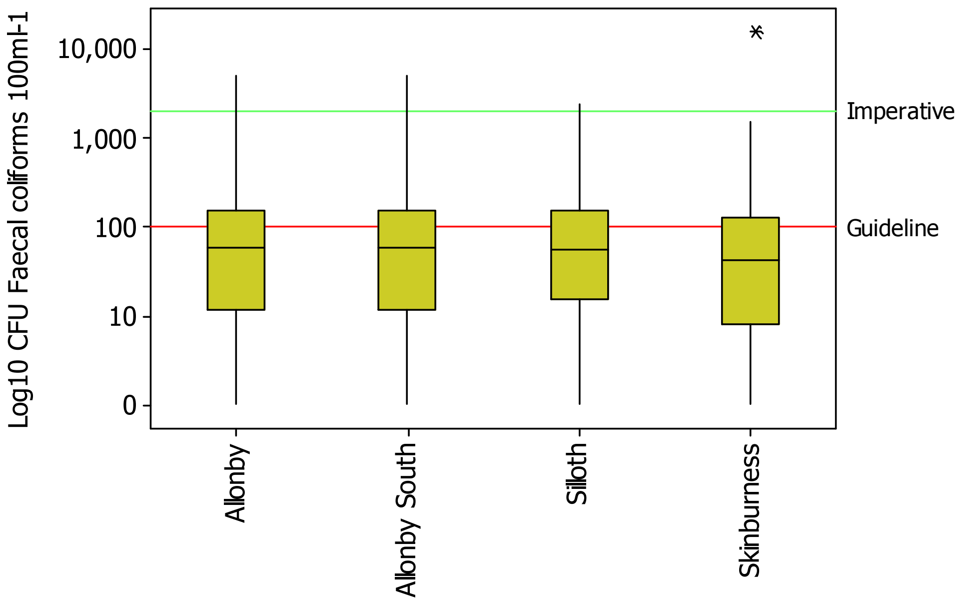


Figure 5.2 Box-and-whisker plots of levels of faecal coliforms in four designated bathing waters in Waver and Ellen catchment areas for the period 2003–2007.

A similar sampling effort was maintained for all bathing waters. The median and geometric mean values in Skinburness are lower than those in Allonby and Silloth bathing waters (Table 5.3). Considering that samples are taken semi-randomly through the day to reflect a range of tidal states (Environment Agency, 2008), these results suggest that impact from pollution sources in the vicinity of Allonby and Silloth are more significant than contamination derived from sources further up the Solway Firth.

Table 5.2 shows deterioration in the microbiological water quality for all bathing waters in 2007, when compared to results detected in 2004–2006 as evidenced by the lower geometric means. In particular, results of faecal coliforms results above guideline values were detected in June–August, e.g. Allonby South (CFU=5,000 100ml^{-1}) 29 June 2007.

Geometric means of faecal coliforms in water would be equivalent to levels of *E. coli* in shellfish within class A.

[6] Box-and-whisker plots depict the distribution (central tendency and spread) of a data set. These plots show (a) the centre or median of the data (centre line of the box), (b) the spread or inter-quartile range (box height), (c) quartile skew (relative size of box halves) and (d) the presence of extreme values or outliers (asterisks).

The deterioration in the microbiological quality of these bathing waters is consistent with elevated levels of *E. coli* detected in bivalve molluscs during the same period, namely high results in mussels from Silloth/Beckfoot (MPN=9,100 100g^{-1} on 15 August 2007) and Beckfoot (MPN=3,500 100g^{-1} on 21 March 2007) and in Pacific oysters from Dubmill Point (MPN=2,400 100g^{-1} on 1 August 2007) (Figure 5.3).

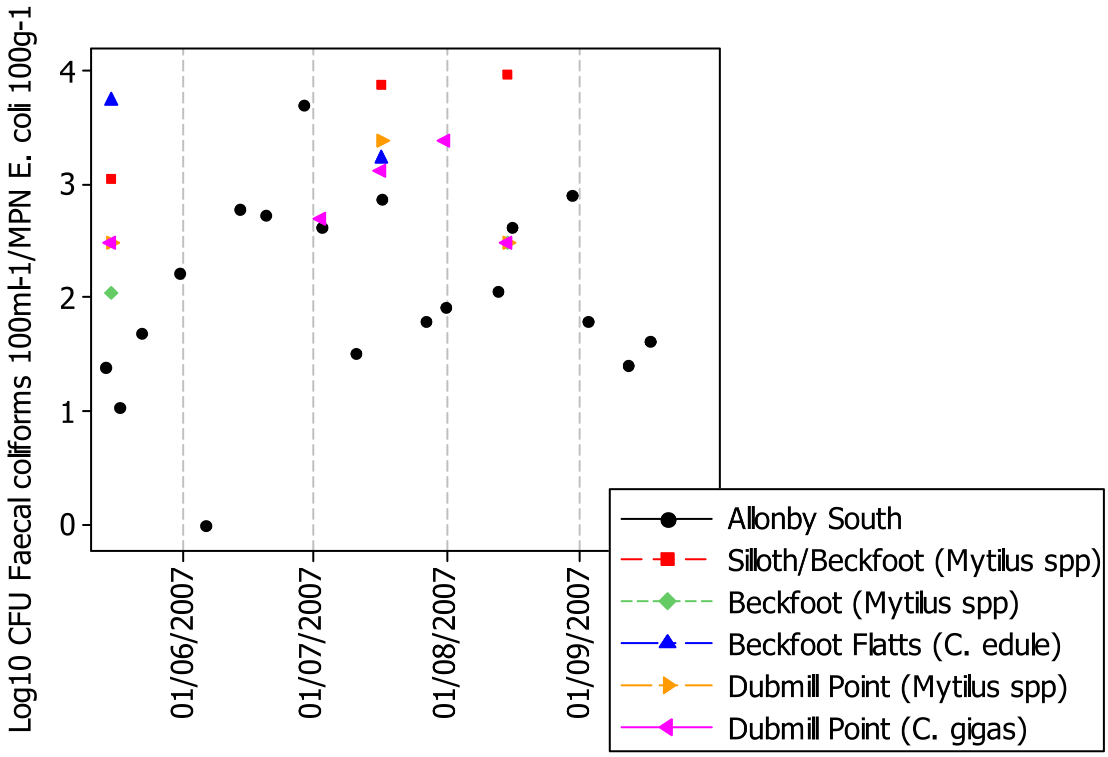


Figure 5.3 Scatterplot of faecal coliform levels in Allonby South bathing water and* E. coli *levels in bivalve molluscs from five representative monitoring points in Silloth during the bathing season.

Table 5.3 Summary statistics of faecal coliforms in four designated bathing waters in Waver and Ellen catchment areas for bathing seasons 2003–2007.

Year	Range (Min.–Max. CFU Faecal coliforms 100ml^{-1}) (number of samples)				Geometric mean (CFU Faecal coliforms 100ml^{-1})				Median (CFU Faecal coliforms 100ml^{-1})			
	Allonby	Allonby South	Silloth	Skinburness	Allonby	Allonby South	Silloth	Skinburness	Allonby	Allonby South	Silloth	Skinburness
2003	4–1,160 (17)	4–4,231 (20)	5–1,360 (20)	5–654 (20)	122	88	40	28	160	104	45	26
2004	8–308 (16)	<2–416 (20)	<2–1,080 (20)	<2–1,280 (20)	64	28	38	30	70	40	40	46
2005	8–3,981 (18)	<2–1,360 (20)	<2–2,120 (20)	5–523 (20)	76	52	75	32	55	73	87	30
2006	8–202 (18)	<2–166 (20)	<2–2,440 (20)	<2–16,000 (20)	49	13	32	32	59	14	55	41
2007	2–1,360 (20)	<2–5,000 (20)	<2–1,800 (20)	<2–1,480 (20)	104	100	62	75	100	73	66	106
2003–2007	<2–3,981 (89)	<2–5,000 (100)	<2–2,440 (100)	<2–16,000 (100)	79	44	47	37	74	58	55	42

Faecal coliform results qualified as less-than (<) or greater-than (>) a numerical value were assigned half or double that numerical value, respectively, before log transformation and calculation of the geometric mean and median values.

5.2 Shellfish hygiene monitoring programme

5.2.1 Hygiene classification

Following introduction of hygiene controls in 1992, several beds of both mussels and cockles have been classified in Silloth. Table 5.4 shows individual bed classifications for the period 1993–2007 in Silloth production area and two adjacent beds on the English Solway Firth (Cardurnock Flats and Moricambe Bay).

All BMPAs at Silloth have shown stable class B classifications during the last decade.

Table 5.4 Classifications of bivalve mollusc production areas in Silloth, Cardunock Flats and Moricambe Bay 1993–2008.

RMP	Bed name	Species	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
B059A	Beckfoot	*Mytilus* spp.	B	B	B	B	B	B	B	B	B	B	B	B	B-LT	B-LT[1]	B-LT	B-LT[1*]
B059H	Lees Scar	*Mytilus* spp.	-	B	B	B	B	B	B	B	B	B	B	B	B-LT	B-LT	B-LT	B-LT
B059F	Skinburness	*Mytilus* spp.	-	B	B	B	B	B	B	B	B	B	B	B	B-LT	B-LT	B-LT	B-LT
B059E	Dubmill Point	*Mytilus* spp.	-	-	-	B	B	B	B	B	B	B	B	B	B-LT	B-LT	B-LT	B-LT
B059B	Beckfoot Flats	*C. edule*	B	B	B	B	B	B	B	B	B	n/c	B	B	B[4]	B-LT[1]	B-LT[1]	B-LT
Not Known	Mawbray	*Mytilus* spp.	-	-	B	B	B	B	B	B	B	B	B	B	B-LT	B-LT	B-LT	B-LT
B049B	Cardurnock Flats	*C. edule*	C	C	C	B	B	B	B	B	B	n/c	B	B	B-LT	n/c	n/c	n/c
B049C	Moricambe Bay	*C. edule*	-	-	-	-	-	B	B	B	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c

n/c - not classified.
LT - Long-Term classification system applies.
** Classification is provisional due to minimum number of samples or new status of bed.*
Note: Long-Term (LT) classification system was introduced in England and Wales alongside the annual classification system, and applies to class B areas only. New class B areas will initially be given annual classification until they meet criteria for a long-term classification. Seasonal - class B only for the period 1 June–30 November, reverting to class C at all the other times.
1 - Classification is provisional due to insufficient sample results, either in number or period of time covered.

Bivalve molluscs from class B areas need to be purified, relayed or cooked by an approved method before sold for human consumption.

5.2.2 Historical *Escherichia coli* data

Table 5.5 summarises data from the shellfish hygiene monitoring programme in terms of sampling effort, geometric mean and range of *E. coli* levels in bivalves sampled from beds in the wider Silloth production areas and non-currently classified beds (Cardunock Flats and Moricambe Bay). Locations of these beds and RMPs are shown in Figure 5.4.

The median (or 50th percentile) is the central value of the distribution when the data are ranked in order of magnitude, i.e. for an odd number of observations, is the data point, which has an equal number of observations both above and below it. The geometric mean is often reported for positively skewed data sets, those with a relatively few high values (Helsel and Hirsch, 2002).

Table 5.5 Summary statistics of* E. coli *levels in bivalve molluscs from seven RMPs in Silloth classification zone for the period 2003–2008.

				Date		MPN *E. coli* $100g^{-1}$ FIL			
RMP	Bed name	Species	n	First sample	Last sample	GM	Median	Min.	Max.
B049B	Cardunock Flats	*C. edule*	26	01/04/2003	19/10/2005	369	310	20	24,000
B049C	Moricambe Bay	*C. edule*	22	29/04/2003	29/11/2006	463	300	20	160,000
B059D	Skinburness	*Mytilus* spp.	1	30/08/2006	-	-	-	430	-
B059H	Silloth/Beckfoot	*Mytilus* spp.	53	28/04/2003	11/02/2008	351	220	<20	9,100
B059A	Beckfoot	*Mytilus* spp.	39	28/04/2003	11/02/2008	225	220	20	3,500
B059B	Beckfoot Flats	*C. edule*	41	28/04/2003	27/11/2007	445	430	20	91,000
B059K	Dubmill	*C. gigas*	13	25/06/2007	28/01/2008	222	310	<20	2,400
B059E	Dubmill Point	*Mytilus* spp.	47	28/04/2003	11/02/2008	169	430	<20	2,400

n - number of samples.
GM - geometric mean.
FIL - flesh and intravalvular liquid.
Note: Samples are be assumed to be taken from exact locations (as defined by grid references) shown in Figure 5.4 below.

The similar number of mussel samples from most of the RMPs indicates a continued and consistent sampling effort in Silloth over the period.

The lower number of cockle samples from some of the RMPs indicates a more intermittent microbiological monitoring of this species. This is due to temporary closures applied on harvesting by the Cumbria Sea Fisheries Committee (CSFC) (see Section 2.3). Cockle harvesting from all beds within the jurisdiction of this authority was prohibited from 30 November 2007 until further notice and for this reason, monitoring for cockles from Beckfoot Flats has not been undertaken since November 2007.

Microbiological monitoring of Pacific oysters at Dubmill Point was initiated in June 2007, following the receipt of an application for monitoring and classification of this new area. A bacteriological survey was then initiated in order to clarify the potential impact of pollution sources on the levels of contamination in the new species. Given the small scale of the operation (see Section 2), only one possible location from which representative samples could be obtained was identified (RMP B059K). Parallel monitoring for mussels has also been undertaken from a RMP at Dubmill Point (B059E), in close proximity to B059K.

It was agreed between Cefas and LEA that a provision of a formal recommendation for classification of Pacific oysters at Dubmill Point to the FSA to be made when the full sanitary survey has been carried out including a review of the existing BMPAs.

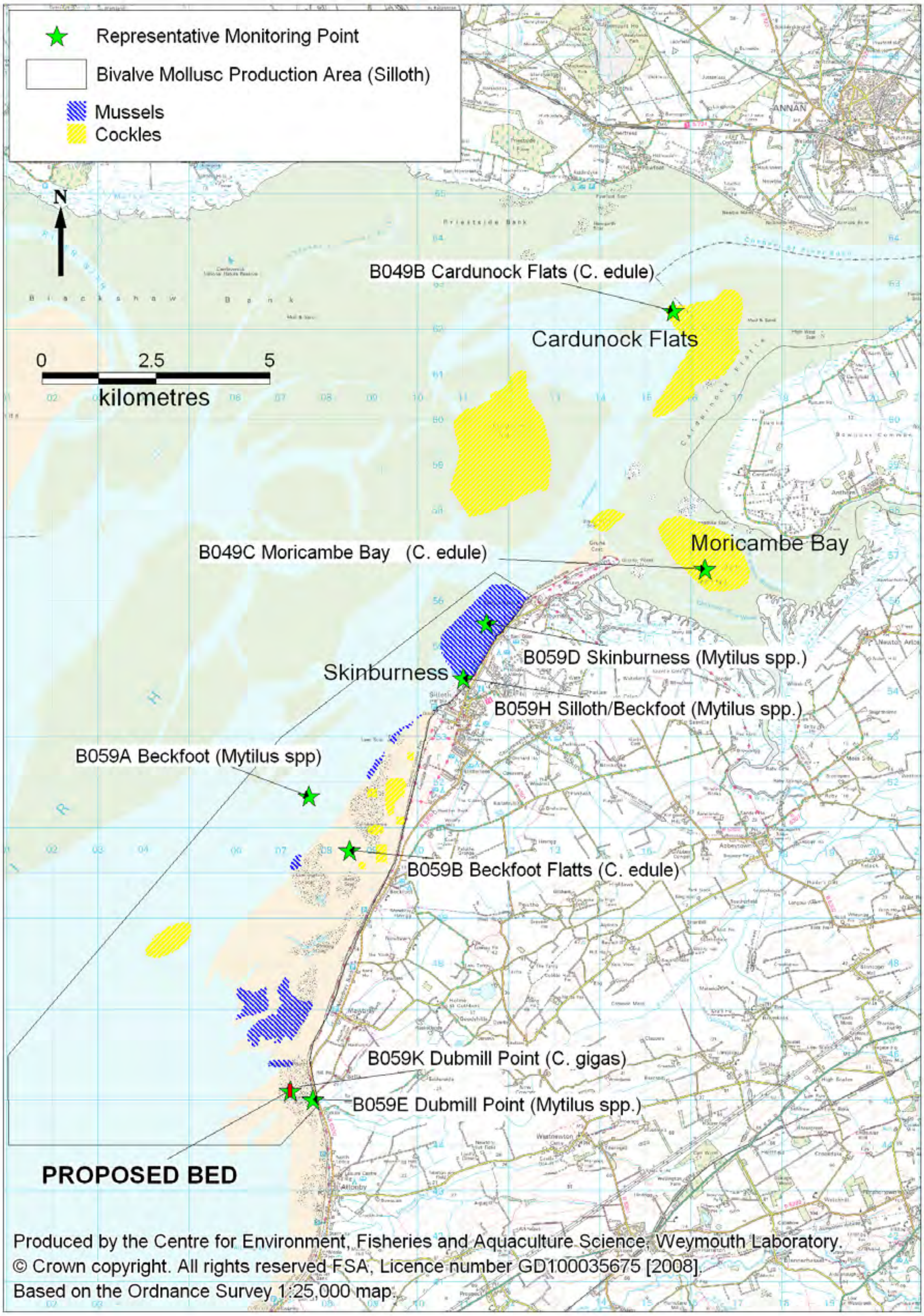


Figure 5.4 Location of beds and representative monitoring points in Silloth, Moricambe Bay and Cardunock Flats.

Location of beds corresponds to information as supplied to Cefas by October 2008. For updated information, please refer to Figure 2.1.

Although only a low number of samples were obtained, similar geometric means of *E. coli* were obtained in mussels (231; n=7) and Pacific oysters (222, n=13) during the period of parallel monitoring (June 2007–February 2008) at Dubmill Point.

Higher levels of *E. coli* in cockles from two RMPs in currently unclassified areas (Cardunock Flats and Moricambe Bay) and the high levels detected in cockles from the currently classified bed Beckfoot Flats indicate an increased gradient of contamination to the North of Dubmill Point.

Geometric mean values and box-and-whisker plots of *E. coli* in mussels from existing RMPs suggest a decreasing gradient of microbiological contamination on a north–south direction along Silloth/Beckfoot, Beckfoot and Dubmill Point mussel beds (see Table 5.4; Figure 5.5).

The position of the median line within the box box-and-whisker plots in Figure 5.5 indicate a skewed distribution of *E. coli* levels in Pacific oysters from Dubmill Point and cockles from Beckfoot Flatts i.e. a higher number of low results of *E. coli* from these RMPs relative to those detected in bivalves from the other RMPs.

Box-and-whisker plots[7] also show the occurrence of outliers or high *E. coli* results in cockles from Beckfoot Flats, Cardunock Flats and Moricambe Bay.

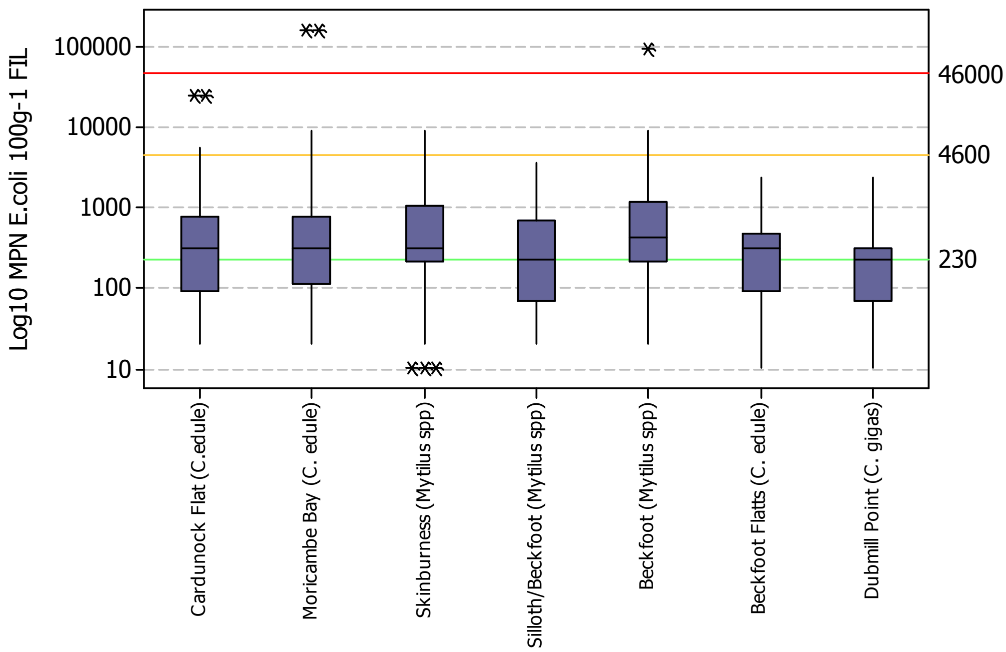


Figure 5.5 Box-and-whisker plots of levels of* E. coli *in bivalve molluscs from bivalve mollusc beds in Silloth for the period 2003–2008.

[7] Box-and-whisker plots depict the distribution (central tendency and spread) of a data set. These plots show (a) the centre or median of the data (centre line of the box), (b) the spread or inter-quartile range (box height), (c) quartile skew (relative size of box halves) and (d) the presence of extreme values or outliers (asterisks).

Monthly *E. coli* levels in bivalve molluscs from these RMPs were also plotted together with LOWESS lines (degree of smoothing=0.5; number of steps=6) (Figure 5.6). LOWESS can be used to (a) emphasize the shape of the relationship between variables, aiding the judgement of how these could be related; (b) compare and contrast multiple large data sets demonstrating both linear or non-linear relationships (Helsel and Hirsch, 2002).

The shape of LOWESS lines indicates that improved microbiological quality has been detected in mussels from Beckfoot Flatts. This tendency is not apparent in mussels from Dubmill Point and Silloth/Beckfoot and cockles from Beckfoot Flats. The low number of results obtained to date in Pacific oysters from Dubmill Point does not allow a judgement as to whether *E. coli* levels have increased/decreased with time.

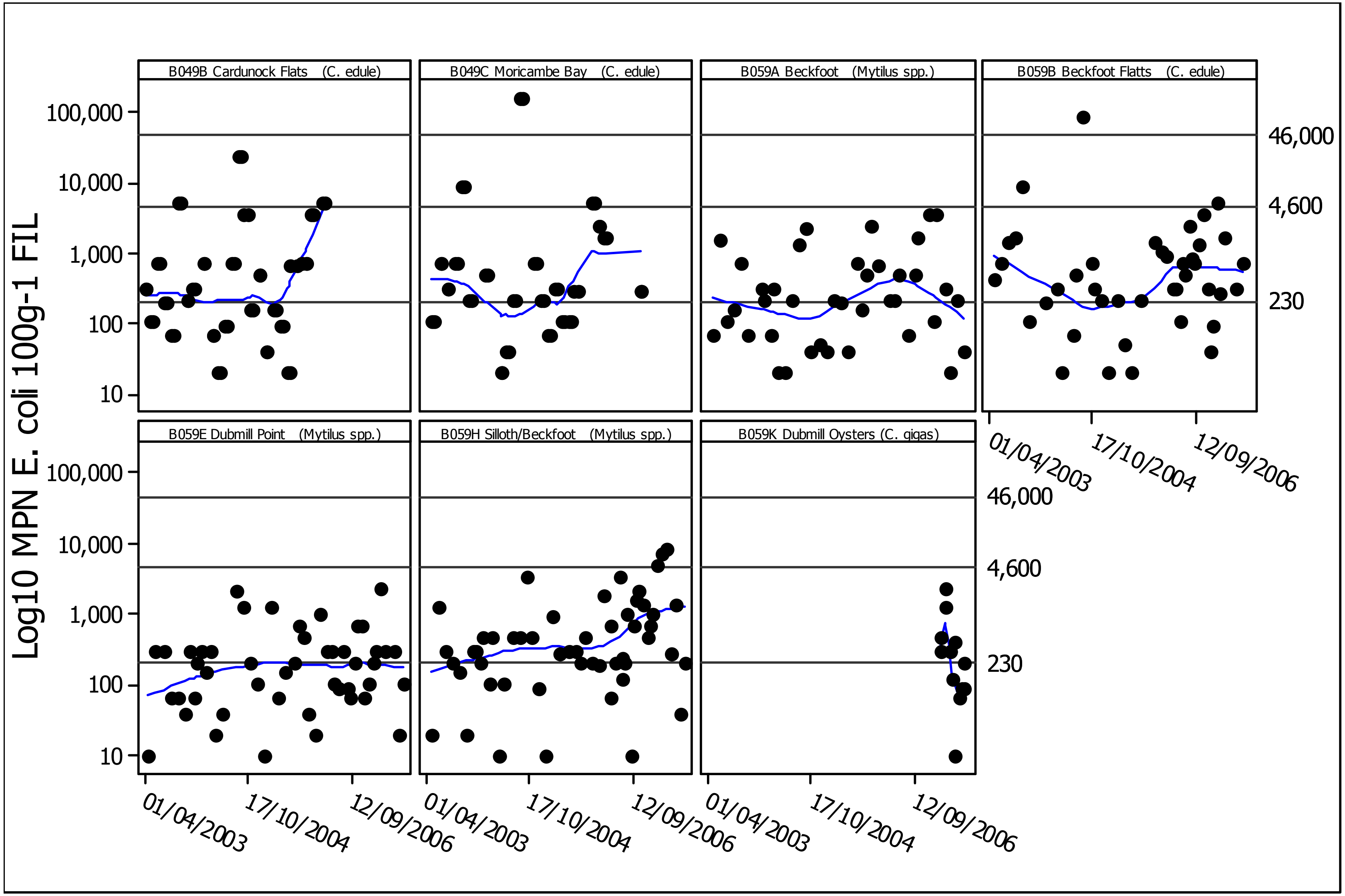


Figure 5.6 Locally weighted scatterplot smoothing of monthly variation in* E. coli *levels in bivalve molluscs from seven monitoring points for the period April 2003–February 2008.

5.2.3 Variation of *Escherichia coli* according to rainfall

Monthly variation in total rainfall for a rainfall gauge in the lower Waver catchment at Mawbray shown in Figure 5.7 follows the general pattern found in Northwest England, in which there is an increase in rainfall levels from June-July to peak in late autumn-winter months (October–January). October was typically the wettest month over the studied period (average rainfall=123 mm).

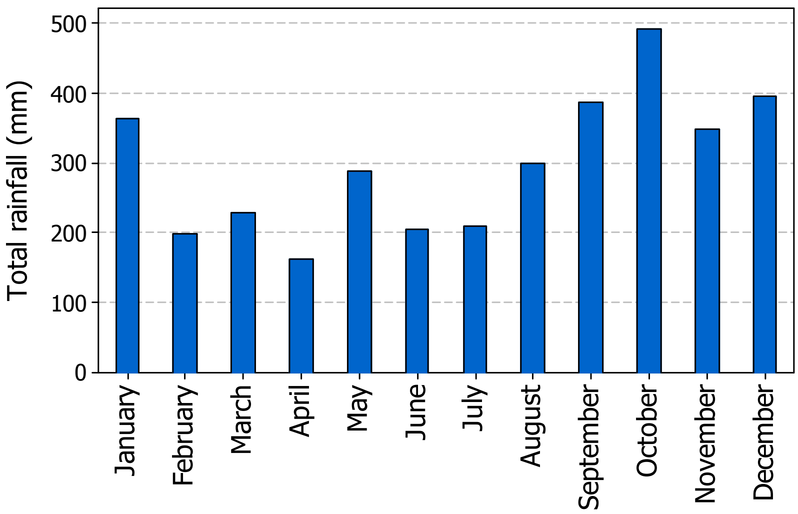


Figure 5.7 Monthly variation in total rainfall in Mawbray for the period January 2000–June 2007.
Data from the Environment Agency (2008).

Total annual rainfall for Mawbray (711 mm in 2003, 1,004 mm in 2004, 893 mm in 2005, 977 mm in 2006) is representative of total annual averages found along the coastal area of NW England (871–1,060 mm) for the period 1971-2000 (see Met Office, 2008).

Rainfall data from Mawbray rain-gauge station was correlated with *E. coli* levels in bivalve molluscs from six RMPs in Silloth for the period January 2000-June 2007.

Pearson correlation coefficient (*r*) was used to estimate correlations between MPN *E. coli* 100 g^{-1} FIL and daily and total rainfall up to seven days before sampling. Pearson coefficient is a measure of the linear association between variables and is based on the assumption that the data follow a bivariate normal distribution (Helsel and Hirsch, 2002). Because *E. coli* levels frequently approximate a log-normal distribution, these were Log_{10}-tranformed before correlation analyses.

Statistically significant correlations were obtained between *E. coli* levels and daily rainfall six days before sampling of cockles from Cardunock Flats and Moricambe Bay and between *E. coli* levels and total rainfall seven days before sampling mussels from Silloth and cockles from Moricambe Bay (Table 5.6).

Table 5.6 Pearson correlation coefficients between rainfall recorded at Mawbray rain-gauge station and levels of* E. coli *in bivalves from Silloth for the period January 2000–June 2007.

		MPN *E. coli* 100g⁻¹ FIL					
	RMP	B059A	B059B	B059E	B059H	B049B	B049C
	Bed name	Beckfoot	Beckfoot	Dubmill Point	Silloth/ Beckfoot	Cardunock Flats	Moricambe Bay
	Species	*Mytilus* sp.	*C. edule*	*Mytilus* sp.	*Mytilus* sp.	*C. edule*	*C. edule*
	Number of samples	35	38	42	45	26	22
Rainfall (mm)							
Daily rainfall	Day of sampling	0.275	0.222	0.023	0.246	0.211	0.045
	p	0.110	0.181	0.884	0.103	0.301	0.844
	- 1 day	0.127	0.023	0.040	0.061	0.357	0.486
	p	0.468	0.892	0.800	0.690	0.074	0.022
	- 2 days	0.287	0.045	0.275	0.342	0.145	0.205
	p	0.095	0.789	0.077	0.021	0.480	0.359
	- 3 days	0.239	0.204	0.310	0.365	0.261	0.052
	p	0.167	0.220	0.046	0.014	0.198	0.819
	- 4 days	0.234	0.323	0.326	0.498	0.302	0.262
	p	0.175	0.048	0.035	0.000	0.134	0.238
	- 5 days	0.277	0.339	0.387	0.264	0.245	0.405
	p	0.107	0.037	0.011	0.079	0.228	0.061
	- 6 days	0.332	0.373	0.308	0.377	0.584*	0.621*
	p	0.051	0.021	0.048	0.011	0.002	0.002
	- 7 days	0.082	0.098	0.155	0.064	0.396	0.305
	p	0.638	0.558	0.326	0.675	0.045	0.167
Total rainfall	2 days	0.293	0.157	0.039	0.214	0.327	0.195
	p	0.087	0.346	0.806	0.157	0.103	0.385
	3 days	0.339	0.118	0.211	0.283	0.320	0.150
	p	0.046	0.480	0.180	0.059	0.111	0.505
	4 days	0.360	0.185	0.331	0.393	0.326	0.136
	p	0.034	0.266	0.032	0.008	0.105	0.546
	5 days	0.383	0.232	0.366	0.450	0.340	0.254
	p	0.023	0.161	0.017	0.002	0.089	0.253
	6 days	0.409	0.319	0.449	0.492	0.370	0.324
	p	0.015	0.051	0.003	0.001	0.063	0.142
	7 days	0.448	0.366	0.487	0.524*	0.486	0.531*
	p	0.007	0.024	0.001	0.000	0.012	0.011

Pearson correlation coefficient (*r*) ranges between +1 and -1. The significance of *r* is tested by determining whether its value differs from 0. * Statistically significant (p<0.05).
A correlation of +1 means that there is a perfect positive linear relationship between rainfall and Log_{10} MPN of *E. coli* $100g^{-1}$ FIL.
A correlation of -1 means that there is a perfect negative linear relationship between rainfall and Log_{10} MPN of *E. coli* $100g^{-1}$ FIL.
A correlation of 0 means that there is no linear relationship between rainfall and Log_{10} MPN of *E. coli* $100g^{-1}$ FIL.
Correlation analysis performed using Log_{10}-transformed *E. coli* concentrations. Less-than *E. coli* results were assigned half the numerical value before transformation. Greater-than *E. coli* results were assigned double the numerical value before transformation.

5.2.4 Variation of *Escherichia coli* according to river flow

There are eight main rivers discharging to southern shore of the outer Solway Firth[8], but none of these has very large flows (Gurbutt, 1993). The Waver catchment (total area=186km^2) drains through the River Waver, which discharge to Moricambe Bay. The River Ellen (approximately 34km in total length) is the major watercourse in the Ellen catchment (total area=19,134ha) draining in the vicinity of BMPAs. There are other less significant watercourses discharging to the sea in close proximity to BMPAs (Figure 5.8).

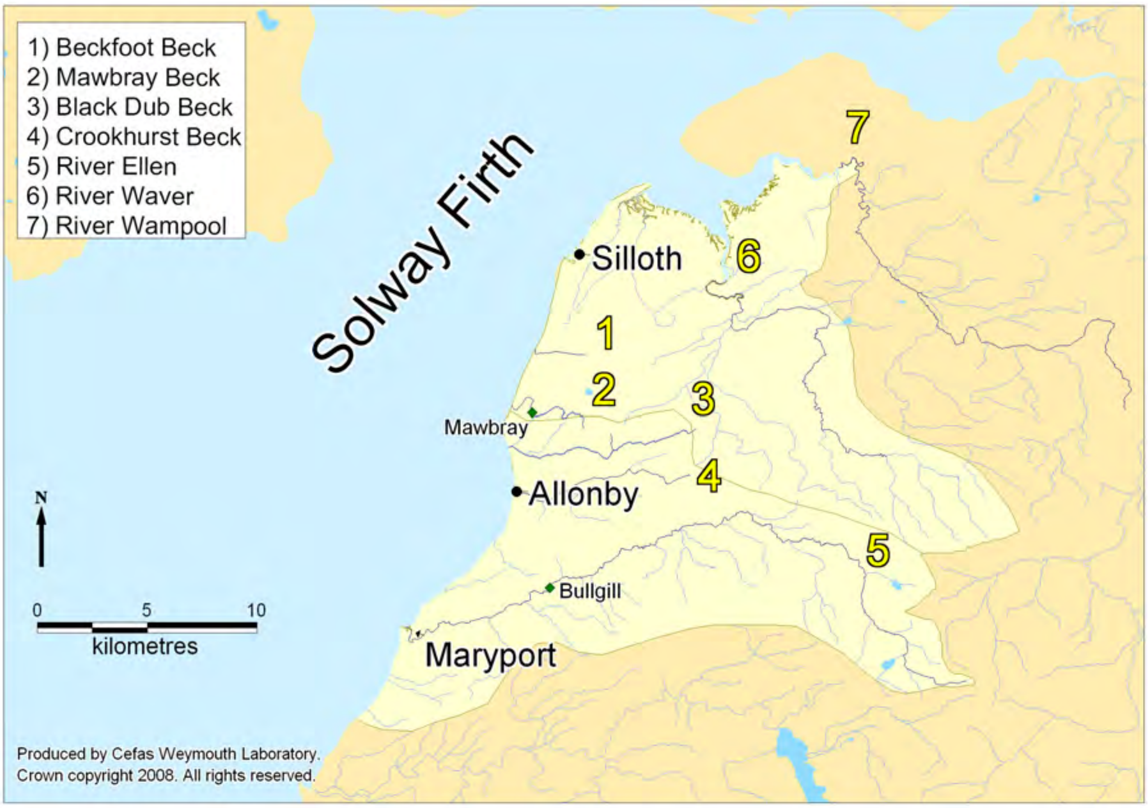


Figure 5.8 Rivers and location of river gauging station in Waver and Ellen catchments.

The River Ellen, which drains a catchment area of approximately 191km^2, has a mean flow of 2.1m^3 s^{-1} recorded at Bullgill gauging station (altitude=26.6 m relative to Ordnance Datum) (Figure 5.9).

The Q_{95} (averaged flow that is exceeded for 95% of the time) in the River Ellen is 0.28 m^3 s^{-1}) (National River Flow Archive, 2008). Figure 5.8 indicates that water levels in the River Ellen respond rapidly to rainfall.

[8] Other rivers (e.g. Eden and rivers discharging on the Scottish Solway) would contribute to background levels of contamination. For the purposes of the present sanitary survey, only those discharging on the English side are analysed in detail.

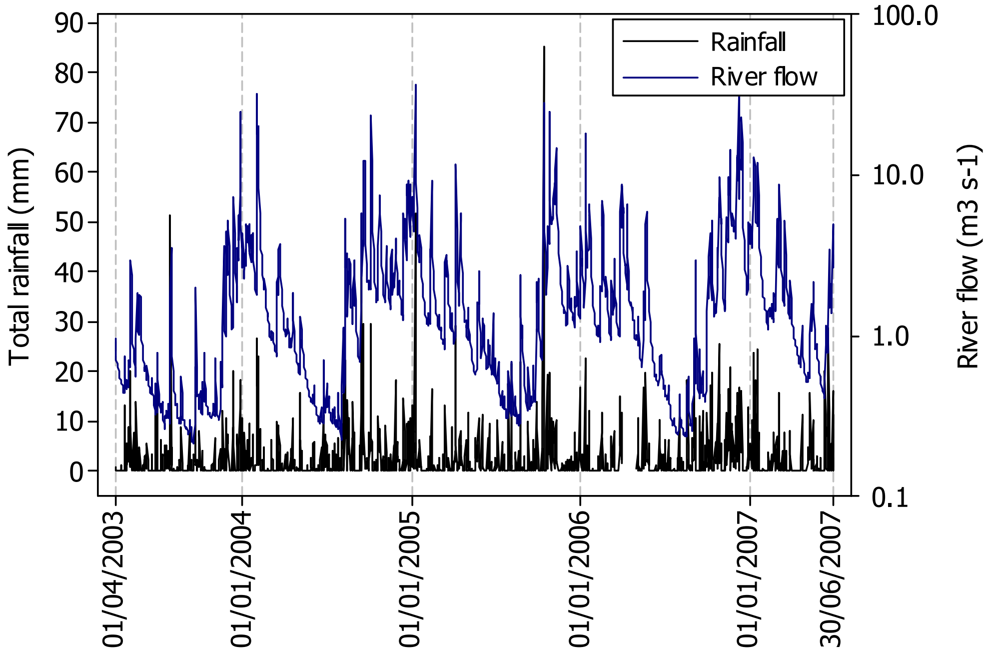


Figure 5.9 Hydrograph for the River Ellen recorded at Bullgill gauging station.

In 2005, the Environment Agency undertook a dye tracing study aimed at analysing the impact of Brunsow Beck and Allonby Beck on the water quality of Allonby Westwinds and Allonby South bathing waters. The study showed that freshwater inputs had little impact on the water quality of either bathing water. Although contributions to elevated faecal indicator organisms can be detected during high river flow conditions, these did not result in bathing water failing to meet Imperative standard (Environment Agency, 2005 *in* Jones, 2006). However, the Bathing Water Imperative standard is relatively high when considering Shellfish Water quality.

In order to investigate the effect of river flows on the levels of microbiological contamination in bivalve molluscs, river flow data recorded at Bullgill was correlated with *E. coli* levels monitored in bivalve molluscs from six existing RMPs during the period April 2003–June 2007. Pearson correlation coefficient (*r*) was used to estimate correlations between MPN *E. coli* 100g^{-1} FIL and daily and total river flows.

Statistically significant linear relationships were obtained between *E. coli* levels in mussels from Dubmill Point and daily mean river flows between the first and fifth day before sampling and between *E. coli* levels and total daily flows between the second and seventh day before sampling (Table 5.7).

Statistically significant linear relationships were also obtained between *E. coli* levels in mussels from Silloth/Beckfoot and daily river flows from the day of sampling to the third day before sampling; significant relationships were also obtained between *E. coli* levels and total river flows from the second to the seventh day before sampling (Table 5.7).

Table 5.7 Pearson correlation coefficients between total and daily river flow recorded at Mawbray rain-gauge station and levels of* E. coli *in bivalves from Silloth for the period April 2003–June 2007.

		MPN *E. coli* 100g^{-1} FIL					
	RMP	B059A	B059B	B059E	B059H	B049B	B049C
	Bed name	Beckfoot	Beckfoot	Dubmill Point	Silloth/ Beckfoot	Cardunock Flats	Moricambe Bay
	Species	*Mytilus* spp.	*C. edule*	*Mytilus* spp.	*Mytilus* spp.	*C. edule*	*C. edule*
	Number of samples	35	38	42	45	26	22
Daily river flow	Day of	0.241	-0.111	0.438	0.442	0.153	0.027
	p	0.164	0.506	0.004	0.002	0.457	0.906
	- 1 day	0.303	-0.093	0.518*	0.465*	0.211	0.039
	p	0.077	0.579	0.000	0.001	0.301	0.864
	- 2 days	0.300	-0.018	0.521*	0.474*	0.284	0.075
	p	0.080	0.916	0.000	0.001	0.159	0.739
	- 3 days	0.253	-0.008	0.501*	0.419	0.297	0.147
	p	0.143	0.960	0.001	0.004	0.141	0.513
	- 4 days	0.122	-0.058	0.458*	0.349	0.305	0.195
	p	0.486	0.730	0.002	0.019	0.130	0.385
	- 5 days	0.112	-0.024	0.471*	0.287	0.253	0.135
	p	0.523	0.885	0.002	0.056	0.213	0.550
	- 6 days	0.054	-0.121	0.358	0.210	0.297	0.178
	p	0.758	0.470	0.020	0.165	0.141	0.428
	- 7 days	-0.046	-0.219	0.320	0.179	0.224	0.086
	p	0.792	0.186	0.039	0.238	0.271	0.704
Total river flow	2 days	0.279	-0.101	0.482*	0.458*	0.166	0.024
	p	0.105	0.546	0.001	0.002	0.417	0.917
	3 days	0.289	-0.071	0.499*	0.469*	0.203	0.035
	p	0.093	0.673	0.001	0.001	0.321	0.877
	4 days	0.288	-0.050	0.508*	0.462*	0.225	0.063
	p	0.094	0.765	0.001	0.001	0.268	0.782
	5 days	0.270	-0.052	0.509*	0.452*	0.248	0.094
	p	0.117	0.755	0.001	0.002	0.223	0.677
	6 days	0.256	-0.043	0.513*	0.438	0.260	0.103
	p	0.138	0.799	0.001	0.003	0.199	0.647
	7 days	0.240	-0.054	0.498*	0.419	0.283	0.123
	p	0.165	0.749	0.001	0.004	0.161	0.585

Pearson correlation coefficient (*r*) ranges between +1 and -1. The significance of *r* is tested by determining whether its value differs from 0.
A correlation of +1 means that there is a perfect positive linear relationship between rainfall and Log_{10} MPN of *E. coli* 100g^{-1} FIL.
A correlation of -1 means that there is a perfect negative linear relationship between rainfall and Log_{10} MPN of *E. coli* 100g^{-1} FIL.
A correlation of 0 means that there is no linear relationship between rainfall and Log_{10} MPN of *E. coli* 100g^{-1} FIL.
* Statistically significant ($p<0.05$).
Correlation analysis performed using Log_{10}-transformed *E. coli* concentrations. Less-than *E. coli* results were assigned half the numerical value before transformation. Greater-than *E. coli* results were assigned double the numerical value before transformation.

These results indicate that elevated concentrations of *E. coli* are detected in mussels from beds receiving microbiological contamination from Beckfoot Beck and Mawbray Beck during high river flow conditions. Both RMPs are in close proximity to rainfall dependent sewage discharges, which discharge directly to the sea or to watercourses in Waver catchment. Similarly, Pacific oysters at Dubmill Point would potentially be impacted by contamination discharged via Beckfoot Beck and Mawbray Beck under high river flow conditions.

It is interesting to note that *E. coli* levels in mussels from Beckfoot did not show significant relationship with river flow. This is probably due to the fact that this RMP is in a more off-shore location and therefore any potential impact of contamination from watercourses is minimised by factors promoting dispersion and dilution of contaminants discussed in Section 3.

These results show that RMPs in in-shore positions of the beds better reflect the impact of microbiological contaminants delivered from watercourses. This impact is likely to decrease significantly with distance from the coast and, therefore, recommendations for classification zone boundaries should take this factor into account.

5.2.5 Seasonal variation of *Escherichia coli*

Investigation of seasonal variation of microbiological contamination in bivalve molluscs was undertaken for currently classified BMPAs in Silloth. Historical *E. coli* data from mussels (B059A, B059H and B059E) and cockles (B059B) was analysed period April 2003–February 2008 (mussels) and April 2003–November 2007 using two methods. Levels of *E. coli* in Pacific oysters from Dubmill Point were not analysed due to the low number of results obtained to date.

The first method consisted of the analysis of monthly geometric means of *E. coli* together with the percent of *E. coli* results > 4,600 MPN100g^{-1} FIL. The second method consisted of the analysis of the seasonal variation of *E. coli* levels, as represented by box-and-whisker plots. Data was amalgamated by season considering spring (March–May), summer (June–August), autumn (September–November) and winter (December–February). One-way Analysis of Variance (ANOVA) was undertaken to test differences in *E. coli* levels between seasons followed by a Tukey HSD test using a significance level (α) of 0.05.

Cockles show higher prevalence of *E. coli* results>4,600 MPN 100g^{-1} FIL. In general, August is the month when elevated *E. coli* results are detected. This pattern is consistent for cockles from the three RMPs analysed in detail in Section 5.2.2.

There is an increase in geometric means of *E. coli* in mussels from later summer to early winter (Figure 5.10). However, maximum geometric means in this species were obtained in different months throughout the year in different RMPs. When data was amalgamated by season, median levels of *E. coli* in mussels did not show statistically significant differences (Figure 5.12).

The decreasing gradient of microbiological contamination along Silloth/Beckfoot, Beckfoot and Dubmill Point mussel beds suggested in Section 5.2.2 is corroborated by the magnitude of monthly geometric means shown in Figure 5.10 and by the relative position of median values in box-and-whisker plots of *E. coli* shown in Figure 5.12.

The different magnitudes of microbiological contamination found in mussels from three RMPs indicate that this species is heavily affected by pollution sources located along the coast of Waver catchment. Therefore, recommendation for situating RMPs at the northward boundary of the mussel production area would potentially be more representative of the worst-case scenario of contamination. The detection of maximum geometric means in different months and the similar seasonal variations of *E. coli* in this species also indicate that a minimum monthly sampling would be the most appropriate frequency for mussels at Silloth.

A decrease in more than 1 Log_{10} was detected in *E. coli* levels between summer and winter in cockles from Beckfoot Flatts (Figure 5.13). Although less evident, similar tendencies were detected in cockles from Moricambe Bay and Cardunock Flats.

Differences in *E. coli* levels in cockles from Beckfoot Flatts between summer and winter were statistically significant (ANOVA; F=5.73; $p<0.003$) at the 0.05 significance level (α). This falls within the period of seasonal closure issued by the CSFC (15 April–14 September). As the area has been class B for some time, it would be appropriate to consider reducing or suspending monitoring during the closed period. However, given that the highest results tend to occur during part of the closed period, it would be pertinent to investigate an increased monitoring frequency two months prior to the active season. This would assist in assessing whether the underlying level of contamination has changed. Therefore, the sampling plan for microbiological monitoring of cockles in Beckfoot Flats (see Appendix II) recommends beginning of sampling on a fortnightly basis between July and August and continued sampling on a monthly basis from September to April, when the season is active and *E. coli* levels are relatively stable.

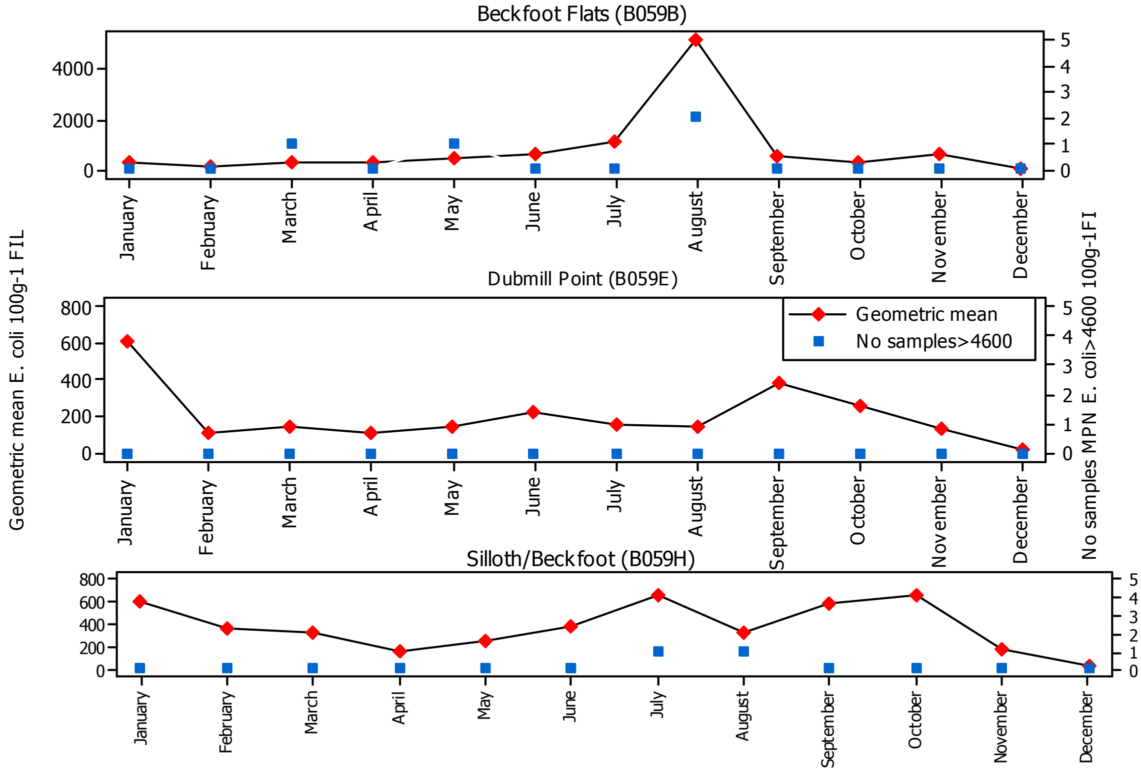


Figure 5.10 Monthly variation of geometric means and number of results of* E. coli *higher than 4,600 in mussels from three RMPs in Silloth for the period 2003–2008.

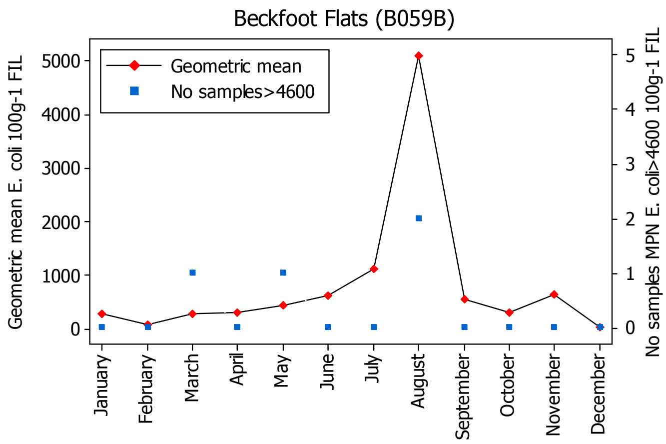


Figure 5.11 Monthly variation of geometric means and number of results of* E. coli *higher than 4,600 in cockles from Beckfoot Flats (Silloth) for the period 2003–2008.

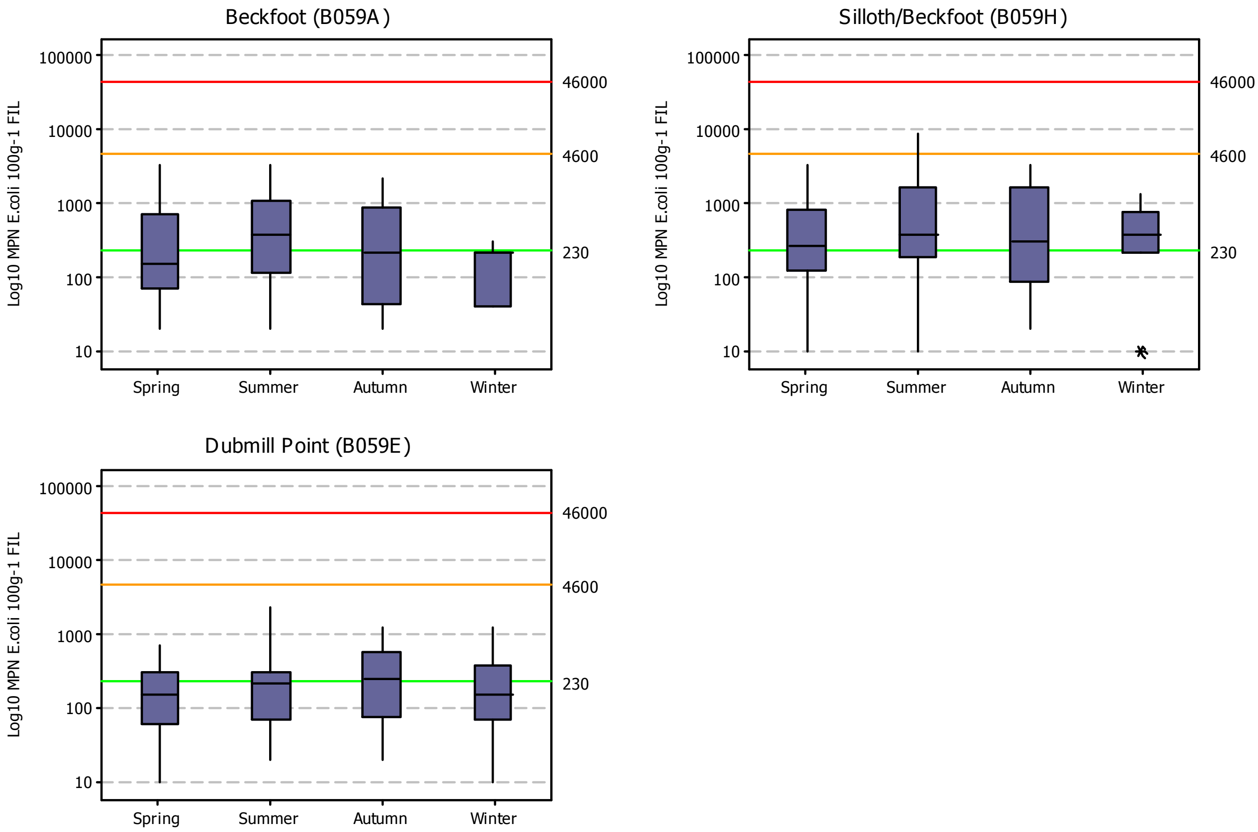


Figure 5.12 Box-and-whisker plots of seasonal variation of* E. coli *levels in mussels from three RMPs in Silloth for the period 2003–2007.

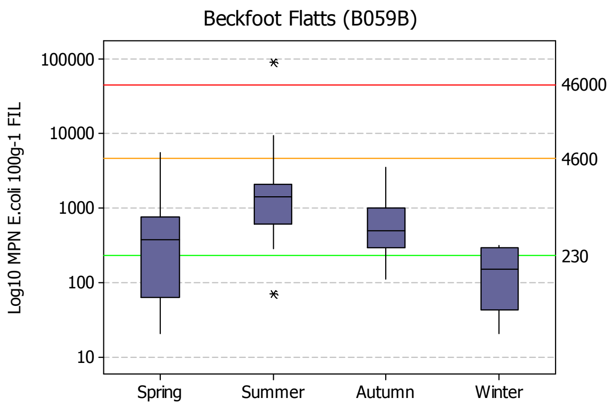


Figure 5.13 Box-and-whisker plots of seasonal variation of* E. coli *levels in cockles from Beckfoot Flats (Silloth) for the period 2003–2007.

6. OVERALL ASSESSMENT

The bivalve mollusc production areas (BMPAs) in Silloth assessed for the purposes of the present sanitary survey receive inputs of microbiological contamination from pollution sources located predominantly in Waver and Ellen catchments and, to a lesser extent, catchments bordering the Upper Solway Firth. These catchments have low levels of urbanisation and significant areas predominantly used for agriculture.

Resident human population in the Ellen and Waver catchments is approximately 29,000. Silloth (2,900) and Maryport (9,617) are the most populated coastal towns in the vicinity of currently classified BMPAs. There is however a significant increase in human population during summer due to tourism, which represents a significant factor accounting for high loads of microbiological contaminants from sources of human origin.

The most significant continuous sewage discharges are Silloth STW, which discharges to the sea and directly impact on the wider Silloth BMPA and Allonby STW, which also discharges to the sea to the South of the BMPA. Effluents from both STW receive year round UV disinfection. Although levels of faecal coliforms have generally corresponded to typical values for UV-treated effluents reported in the literature, episodes of low efficiency have been recently identified indicating the potential for a much more significant impact on the levels of contamination in BMPAs.

In addition, there are several small STW and a number of intermittent sewage discharges to coastal streams that flow to the sea between Allonby and Silloth and potentially constitute significant sources of microbiological contamination.

In contrast to the relatively sparse human population there are high numbers of animals in the Waver and Ellen catchments (24,891 cattle and 55,432 sheep in Ellen and 30,213 cattle and 32,494 sheep in Waver).

Farms with slurry or solid manure stores and dirty areas or with cattle access points to watercourses constitute potentially significant sources of microbiological contamination, particularly during winter months. The existence of manure storage sites and dirty areas was observed during the shoreline survey in a few areas of Wolsty Bank, Mawbray Bank and Dubmill Point. However, it was also observed that many of these farms have fences preventing direct access of livestock to watercourses. More than 60% of farms in the Waver catchment were classified in 2005 by the Environment Agency as being of 'low risk' of diffuse pollution to bathing waters with respect to slurry and solid manure stores and dirty areas.

During the last decade, all BMPAs in Silloth have shown stable class B classifications. Analysis of historical *E. coli* data suggested a decreasing gradient of microbiological contamination in a north–south direction along Silloth/Beckfoot, Beckfoot and Dubmill Point mussel beds. A similar tendency was also identified for cockles, although in this species the analysis was limited by the low number of samples analysed from beds located to the North of Silloth due to the lack of commercially viable stocks in recent years. Splitting the existing BMPA into separate production areas will allow a more effective assessment of the underlying level of contamination of each bed and therefore more effective management of risk of contamination. Boundaries for the revised BMPAs in the wider Silloth are proposed in Figure A1 of the Sampling Plan (Appendix II).

A level of correspondence was identified between high levels of faecal coliforms detected in Allonby South bathing water and high levels of *E. coli* detected in mussels from currently classified Silloth/Beckfoot and Beckfoot beds and in Pacific oysters from the new production area at Dubmill Point in the summer of 2007. This indicates that episodes of high contamination impacting on Allonby South could potentially provide an indication of deteriorated microbiological quality in mussels and Pacific oysters at those beds.

The River Ellen is known to respond with rapid run-off following rainfall. Statistically significant linear relationships were obtained between *E. coli* levels in mussels from Dubmill Point and Silloth/Beckfoot and river flows recorded at Bullgill gauging station suggesting that the variation of microbiological contamination in commercially harvested mussels is affected by deteriorating water quality during wet weather.

The sub-tidal area within the current Silloth BMPA is shallow (<2m relative to Chart Datum contour line). The area is considered to be subject to sediment erosion. Mixing and sedimentation processes are expected to dominate in these areas and contribute to resuspension of potentially contaminated particulates over the shellfish beds. Hydrodynamic modelling studies indicate residual tidal currents running down the Cumbrian coast. However, this pattern tends to be modified near the coast, where prevalent conditions are determined by the geography of the coast and wind direction. Onshore currents generated during the dominant flood tide and subject to the effect of dominant westerly winds will promote the onshore retention of microbiological contaminants.

High historical *E. coli* levels detected in cockles from Moricambe Bay and Cardurnock Flatts suggested that pollution sources in the upper Solway Firth have a high impact on shellfish beds. The impact decreases significantly in southern beds along the shores of Silloth. Overall, the hydrodynamic information and microbiological data collated for the purposes of this assessment suggest that RMPs located in inshore positions of the northward boundaries of BMPAs would better reflect the worst-case scenario of contamination from pollution sources discharging to the sea.

Cockles from Beckfoot Flats show deteriorated microbiological quality during the summer, with a decrease in median *E. coli* levels of more than 1 Log_{10} between summer and winter. Recommendations are made in the sampling plan (Appendix II) for an increased sampling frequency (fortnightly) between July and August (two months before the beginning of the active harvesting season for cockles as determined by the Cumbria Sea Fisheries Committee) followed by sampling on a monthly basis, when data show relatively stable *E. coli* levels. This increased frequency would assist the assessment of whether the underlying level of contamination in cockles is changed during summer to be undertaken at the time of the next review of the sanitary survey. Consideration could be given by the LEA to reduce sampling frequency during the period of annual closure for cockles (see Cefas, 2007). Details of this reduced frequency monitoring should be agreed between LEA and Cefas.

A schematic representation showing the most significant pollution sources likely to cause microbiological contamination to the BMPAs is shown in Figure 6.1.

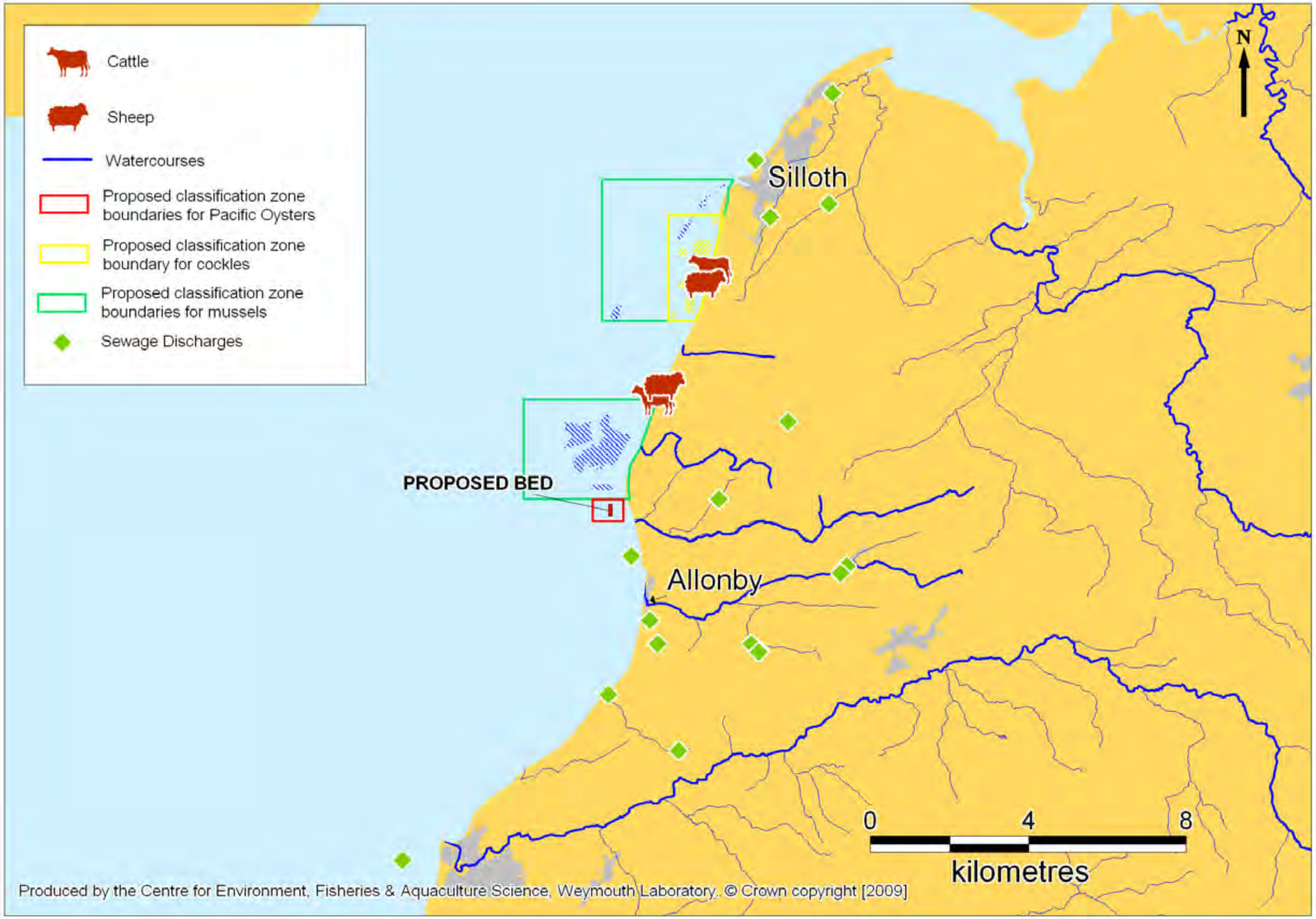


Figure 6.1 Overview of sources of pollution likely to affect the levels of microbiological contamination in bivalve molluscs at Silloth.

6.1 Recommendations for production area boundaries and monitoring points

Boundaries for a BMPA at *C. gigas* at Dubmill Scar and revised BMPAs in the wider Silloth area are proposed in Figure A1 of the Sampling Plan (Appendix II).

- Boundaries of three classification zones for mussels should be defined: one encompassing beds in Lees Scar, Beckfoot Flats and Lowhagstock Scar, the second classification zone encompassing beds at Mawbray and a third classification zone encompassing beds at Dubmill Point.

- The RMP for mussels at Dubmill Point should be relocated to the Eastern edge of the bed to adequately reflect the impact of pollution sources, as summarised above. Due to low density of commercial sized mussels in this bed relative to other beds in the wider Silloth production area, the maximum recommended tolerance for this RMP is 50 metres.

- A new RMP for mussels in Lees Scar is necessary to adequately reflect the impact of microbiological contamination of diffuse origin from agricultural land in the Waver catchment and sewage discharged directly to the sea or to watercourses in the Silloth area and transported down the coast during the ebb tide. The recommended maximum tolerance for this RMP is 20 metres due to significant decrease in the density of commercial sized mussels found in consecutive surveys undertaken by the CSFC on this bed from 2006 to 2007. It is considered that this tolerance minimises the effect of spatial variability in the extent of contamination whilst preserves the fixed location concept.

- Boundaries of the classification zone for cockles should encompass beds in Lees Scar, Beckfoot Scar and Catherinehole Scar.

- The RMP for cockles at Beckfoot Flats (B059B) should be replaced by a new RMP at Catherinehole Scar, located in an inshore position near the northern edge of the bed in order to adequately reflect the impact of contamination from pollution sources mentioned above and inputs of contamination discharged via Beckfoot Beck. The recommended maximum tolerance for the new RMP is 50 metres by virtue of the low density of commercial sized cockles found on this bed in recent stock assessment surveys undertaken by the CSFC.

- A new RMP for mussels at the Eastern edge of the bed at Mawbray is necessary to adequately reflect the impact of contamination from the Waver catchment transported down the coast during the ebb tide and contamination from agricultural land discharged via Mawbray Beck and Black Dub Beck. Although the low density of commercial sized mussels found in this bed at the last stock assessment undertaken by Cumbria SFC in 2006, the high commercial and total tonnages of mussels obtained in further stock assessments (2006, 2007) indicate that there is likely to be no constraint in obtaining sufficient animals for sampling and therefore the recommended maximum tolerance for this RMP is 10 metres.

- Owing to the very small size of aquaculture operation for Pacific oysters at Dubmill Scar and the limited scope for selection of alternative sampling points within that area, an RMP (B059K) was identified for monitoring towards preliminary classification at an earlier stage of this assessment. Subsequently, the applicant has indicated plans to extend the operation in the future such that a larger area will be required for production. This larger area is reflected in the recommended boundaries for the classification zone at Dubmill Scar and has been considered in our final assessment of RMP location, which has recommended that RMP B059K should be maintained since this adequately reflects the impact of contamination from discharges at Allonby and contamination of diffuse origin discharged via Black Dub Beck and River Ellen. The recommended maximum tolerance for this RMP is 10 metres in virtue of the restricted area of the operation and no foreseeable difficulties in obtaining sufficient numbers of oysters for sampling.

- The recommended new sampling plan presented in the Appendix II represents a decrease in the number of RMPs for mussels from 4 to 2 and the same number (1) of RMPs for cockles.

- The new sampling plan represents the same number of samples per year relative to the plan used before the sanitary survey. Fortnightly sampling was initially recommended for cockles at Catherinehole Scar. However, during the period of consultation of the sanitary survey, the LEA informed Cefas that it will not be possible to undertake this sampling regime due to financial constraints. It was agreed that monthly monitoring will be undertaken for all RMPs.

7. References

ALDRIDGE, J. N. AND DAVIES, A. M., 1993. A high-resolution three-dimensional hydrodynamic tidal model of the Eastern Irish Sea. Journal of Physical Oceanography 23(2):207–224.

ALLERDALE BOROUGH COUNCIL, 1999. Allerdale Local Plan. Available from: http://www.allerdale.gov.uk/environment-and-planning/planning/planning-policy/the-local-plan.aspx. Accessed October 2008.

ALLERDALE BOROUGH COUNCIL, 2005. Allerdale Borough Council. A strategy for Tourism 2005-2015. Available from: http://www.allerdale.gov.uk/downloads/page992/tourismstrategyfinalversion.pdf. Accessed October 2008.

ALLERDALE BOROUGH COUNCIL, 2007. Local attractions. Available from: http://www.allerdale.gov.uk/leisure-and-culture/tourism-and-travel/local-attractions.aspx. Accessed October 2008.

BULLEN CONSULTANTS LTD. 1998. Shoreline management plan: St Bees Head to River Sark. Data Collection, Analysis, Interpretation and Objective Setting. Volume III: Supporting Information. November 1998. 89 pp.

CENTRE FOR ENVIRONMENT FISHERIES AND AQUACULTURE SCIENCE, 2007. Cefas protocol for the classification of shellfish harvesting areas - England and Wales. Annual and Long Term classification systems. 46 pp.

CENTRE FOR ENVIRONMENT FISHERIES AND AQUACULTURE SCIENCE - COMMUNITY REFERENCE LABORATORY (CEFAS-CRL), 2007. Microbiological monitoring of bivalve mollusc harvesting areas. Guide to good practice: technical application. EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas. Issue 3: February 2007.

CUMBRIA SEA FISHERIES COMMITTEE, 2007. Byelaws in force in the Cumbria Sea Fisheries District. Made under Section 5 of the Sea Fisheries Regulation Act, 1966 and the Salmon Act, 1986. D Claxton Secretary to the Cumbria Sea Fisheries Committee, January 2007. 12 pp. Available from: http://www.cumbriasfc.org.uk/ContentDetails.aspx. Accessed October 2007.

CUMBRIA SEA FISHERIES COMMITTEE, 2008. Notices and updates. Cockles - Closure Notice. Available from: http://www.cumbriasfc.org.uk/ContentDetails.aspx. Accessed October 2007.

CUMBRIA SEA FISHERIES COMMITTEE, 2008. Notices and updates. Mussels -Closure Notice - Littoral beds. Available from: http://www.cumbriasfc.org.uk/ContentDetails.aspx. Accessed October 2007.

CUMBRIA TOURISM, 2007. Tourism volume and value 2007. Cumbria Tourism Research Department, 13 pp. Available from: http://www.cumbriatourism.org/press/intelligence/CumbriaTrends2005-2007.pdf. Accessed October 2008.

CUMBRIA TOURISM, 2008. Cumbria - top 20 visitor attractions 2007. Visitor attractions monitor. Available from: http://www.cumbriatourism.org/press/intelligence/Top20VisitorAttractions2007.pdf. Accessed October 2008.

DAVIES, A.M. AND LAWRENCE, J. 1995. Modeling the effect of wave-current interaction on the three-dimensional wind-driven circulation of the Eastern Irish Sea. Journal of Physical Oceanography 25:29–45.

DAVIES, M. and LANCASTER, J. 2007. Cockle stock assessment 2007. Survey of the English intertidal Solway cockle grounds. 10th October 2007. Solenvo Marine Environmental Consultants, on behalf of Cumbria Sea Fisheries Committee. 17 pp.

DEFRA, 2000. Chapter 2. Geography and physical oceanography. Quality status report of the Marine and Coastal Areas of the Irish Sea and Bristol Channel. Available from: http://www.defra.gov.uk/environment/water/marine/uk/science/irishbristol/03.htm. Accessed 07 October 2008.

EDWARDS, A. C., KAY, D., MCDONALD, A. T., FRANCIS, C., WATKINS, J., WILKINSON, J. R., WYER, M. D., 2008. Farmyards, an overlooked source for highly contaminated runoff. Journal of Environmental Management 87:551–559.

ENGLISH NATURE. 1997. Cumbrian coast natural area profile. NA 119. 45 pp.

ENGLISH NATURE AND SCOTTISH NATURAL HERITAGE, 2000. Solway European Marine Site. English Nature's and Scottish Natural Heritage's advice given in compliance with Regulation 33(2) and in support of the implementation of The Conservation (Natural Habitats &c.) Regulations 1994.

ENVIRONMENT AGENCY, 2007. Directive (79/923/EEC) on the quality required of Shellfish Waters. Article 5 Programme. Silloth. 10 pp.

ENVIRONMENT AGENCY, 2008. Bathing Waters Directive: monitoring and reporting, 2008. Operational Instruction 140_07. Version 2.

EUROPEAN COMMUNITIES, 1976. Council Directive of 8 December 1975 concerning the quality of bathing water (76/160/EEC). Official Journal of the European Communities L31, 05.02.1976: 1–9.

EUROPEAN COMMUNITIES, 2004. Regulation (EC) No 854/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption. Official Journal of the European Communities L226, 25.06.04: 83–127.

EUROPEAN COMMUNITIES, 2006. Directive 2006/113/EC of the European Parliament and of the Council of 12 December 2006 on the quality required of shellfish waters (codified version). Official Journal of the European Union L376, 27.12.06: 14–20.

EUROPEAN COMMUNITIES, 2006. Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC. Official Journal of the European Union L64; 04.03.06: 37–51.

FUTURECOAST, 2002. Department of Environment, Food and Rural Affairs (Defra), Halcrow Group Ltd 3 CD set.

GURBUTT, P.A., 1993. Ituna: a model of the Solway Firth. Fisheries Research Technical Report, Ministry of Agriculture, Fisheries and Food, Directorate of Fisheries Research, Lowestoft 93. 13 pp.

HARNETT, M., 2007. Sediment transport model. In Elliott, A, Harnett, M., O'Riain, G., Dollard, B. (eds). The PRISM project. Predictive Irish Sea Models. Final Report EU INTERREG IIIA.

HELSEL, D. R. AND HIRSCH, R. M., 2002. Techniques of water-resources investigations of the United States Geological Survey. Book 4, hydrologic analysis and interpretation. Chapter A3, statistical methods in water resources. US Geological Survey. Available at: http://water.usgs.gov/pubs/twri/twri4a3/. Accessed October 2007.

JONES, A. 2006. Ellen catchment report focussing on Allonby bathing waters. 48 pp.

JOINT NATURE CONSERVATION COMMITTEE, 1997. Non-native marine species in British waters: a review and directory. Eno, N.C., Clarck, R.A., Sanderson, W.G. (Eds). JNCC, Peterborough. 136 pp.

JOINT NATURE CONSERVATION COMMITTEE, 2006. Available at: http://www.jncc.gov.uk/pdf/SPA/UK9005012.pdf. Accessed 26 January 2009.

KAY, D., CROWTHER, J., STAPLETON, C. M., WYER, M. D., FEWTRELL, L., EDWARDS, A., FRANCIS, C. A., MCDONALD, A. T., WATKINS, J. AND WILKINSON, J., 2008. Faecal indicator organism concentrations in sewage and treated effluents. Water Research 42: 442–454.

LANCASTER, J. AND DAVIES, M. 2006. Annual stock assessment of the littoral mussel (*Mytilus edulis*) stocks in the Solway Firth. 16th November 2006. 26 pp.

LANCASTER, J. AND DAVIES, M. 2007. Annual stock assessment of the littoral mussel (*Mytilus edulis*) stocks in the Solway Firth 2007. 29th October 2007. Solenvo Marine Environmental Consultants, on behalf of Cumbria Sea Fisheries Committee. 24 pp.

MET OFFICE, 2008. UK climate and weather statistics. 1971-2000 mapped averages. Available from: http://www.metoffice.gov.uk/climate/uk/averages/19712000/mapped.html. Accessed 11 August 2008.

MOUNSEY, S. 1998. An investigation into bacterial water quality at designated bathing water beaches in Cumbria 1997 - Volume I. Environment Agency.

Mounsey, S. 1998a. An investigation into bacterial water quality at designated bathing water beaches in Cumbria 1997 - Volume II - Appendices. Environment Agency.

NATIONAL RIVER FLOW ARCHIVE, 2008. 75017 - Ellen at Bullgill. Available from: http://www.nwl.ac.uk/ih/nrfa/station_summaries/075/017.html. Accessed August 2008.

OFFICE FOR NATIONAL STATISTICS, 2007. Provisional mid-2005 population estimates for river catchment areas in England and Wales.

OFFICE FOR NATIONAL STATISTICS, 2008. KS01 Usual resident population: Census 2001, Key Statistics for urban areas. Available from: http://www.statistics.gov.uk/StatBase/ssdataset.asp?vlnk=8271&Pos=2&ColRank=1&Rank=224. Accessed October 2008.

OVE ARUP AND PARTNERS, 1993. Chapelcross Hydrographic Survey. Report commissioned by British Nuclear Fuels.

POMMEPUY, M., HERVIO-HEAT, D., CAPRAIS, M. P., GOURMELON, M., LE SAUX, J. C. AND LE GUYADER, F., 2005. Fecal contamination in coastal areas: an engineering approach. In Belkin and Colwell (Eds). Oceans and Health: Pathogens in the Marine Environment, pp. 331–359.

VISITCUMBRIA, 2008. The Western Lakes and Coast of Cumbria. Available at: http://www.visitcumbria.com/wc/index.htm. Accessed 07 August 2008.

Acknowledgements

Cefas would like to thank Keira Armstrong (Environment Agency), David Copeland (Allerdale Borough Council), D. T. Dobson (Cumbria Sea Fisheries Committee), Paul Simmons (Environment Agency), Julian (Visit Cumbria), Ann Sumpton (Silloth Tourist Information Centre), Michelle Whibley (BST Oyster Supplies), Vaughan Williams (Boddingtons Ltd.).

List of Abbreviations

AONB	Area of Outstanding Natural Beauty
BMPA	Bivalve Mollusc Production Area
CD	Chart Datum
Cefas	Centre for Environment, Fisheries & Aquaculture Science
CFU	Colony Forming Units
CSO	Combined Sewer Overflow
Defra	Department for Environment, Food and Rural Affairs
DWF	Dry Weather Flow
EA	Environment Agency
E. coli	*Escherichia coli*
EC	European Commission
EEC	European Economic Community
EO	Emergency Overflow
ESA	Environmentally Sensitive Area
FIL	Fluid and Intravalvular Liquid
FSA	Food Standards Agency
HAT	Highest Astronomical Tide
ISO	International Organization for Standardization
km	Kilometre
LEA	Local Enforcement Authority
M	Million
m	Metres
ml	Millilitres
mm	Millimetres
MPN	Most Probable Number
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
OSGB36	Ordnance Survey Great Britain 1936
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SSSI	Site of Special Scientific Interest
UU	United Utilities
UV	Ultraviolet
WGS84	World Geodetic System 1984

Glossary

Bathing Water	Element of surface water used for bathing by a large number of people. Bathing waters may be classed as either EC designated or non-designated OR those waters specified in section 104 of the Water Resources Act, 1991.
Bivalve mollusc	Any marine or freshwater mollusc of the class Pelecypoda (formerly Bivalvia or Lamellibranchia), having a laterally compressed body, a shell consisting of two hinged valves, and gills for respiration. The group includes clams, cockles, oysters and mussels.
Bathymetry	Depths below and drying heights above Chart Datum.
Classification of bivalve mollusc production or relaying areas	Official monitoring programme to determine the microbiological contamination in classified production and relaying areas according to the requirements of Annex II, Chapter II of EC Regulation 854/2004.
Coliform	Gram negative, facultatively anaerobic rod-shaped bacteria which ferment lactose to produce acid and gas at 37 °C. Members of this group normally inhabit the intestine of warm-blooded animals but may also be found in the environment (e.g. on plant material and soil).
Combined Sewer Overflow	A system for allowing the discharge of sewage (usually dilute crude) from a sewer system following heavy rainfall. This diverts high flows away from the sewers or treatment works further down the sewerage system.
Discharge	Flow of effluent into the environment.
Dry Weather Flow (DWF)	The average daily flow to the treatment works during seven consecutive days without rain following seven days during which rainfall did not exceed 0.25 mm on any one day (excludes public or local holidays). With a significant industrial input the dry weather flow is based on the flows during five working days if production is limited to that period.
Ebb tide	The falling tide, immediately following the period of high water and preceding the flood tide. Ebb-dominant estuaries have asymmetric tidal currents with a shorter ebb phase with higher speeds and a longer flood phase with lower speeds. In general, ebb-dominant estuaries have an amplitude of tidal range to mean depth ratio of less than 0.2.
EC Directive	Community legislation as set out in Article 189 of the Treaty of Rome. Directives are binding but set out only the results to be achieved leaving the methods of implementation to Member States, although a Directive will specify a date by which formal implementation is required.
Emergency Overflow	A system for allowing the discharge of sewage (usually crude) from a sewer system or sewage treatment works in the case of equipment failure.
Escherichia coli (E. coli)	A species of bacterium that is a member of the faecal coliform group (see below). It is more specifically associated with the intestines of warm-blooded animals and birds than other members of the faecal coliform group.
E. coli O157	E. *coli* O157 is one of hundreds of strains of the bacterium *Escherichia coli*. Although most strains are harmless, this strain produces a powerful toxin that can cause severe illness. The strain O157:H7 has been found in the intestines of healthy cattle, deer goats and sheep.
Faecal coliforms	A group of bacteria found in faeces and used as a parameter in the Hygine Regulations, Shellfish and Bathing Water Directives, *E. coli* is the most common example of faecal coliform. Coliforms (see above) which can produce their characteristic reactions (e.g. production of acid from lactose) at 44 °C as well as 37 °C. Usually, but not exclusively, associated with the intestines of warm-blooded animals and birds.
Flood tide	The rising tide, immediately following the period of low water and preceding the ebb tide.
Flow ratio	Ratio of the volume of freshwater entering into an estuary during the tidal cycle to the volume of water flowing up the estuary through a given

	cross section during the flood tide.
Geometric mean	The geometric mean of a series of N numbers is the N^{th} root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the anti-log of that mean. It is often used to describe the typical values of a skewed data set such as one following a log-normal distribution.
Hydrodynamics	Scientific discipline concerned with the mechanical properties of liquids.
Hydrography	The study, surveying, and mapping of the oceans, seas, and rivers.
Microbial source tracking	The concept that the origin of faecal pollution can be traced using microbiological, genotypic, phenotypic and chemical methods
Secondary Treatment	Treatment to applied to breakdown and reduce the amount of solids by helping bacteria and other microorganisms consume the organic material in the sewage or further treatment of settled sewage, generally by biological oxidation.
Sewage	Sewage can be defined as liquid, of whatever quality that is or has been in a sewer. It consists of waterborne waste from domestic, trade and industrial sources together with rainfall from subsoil and surface water.
Sewage Treatment Works (STW)	Facility for treating the waste water from predominantly domestic and trade premises.
Sewer	A pipe for the transport of sewage.
Sewerage	A system of connected sewers, often incorporating inter-stage pumping stations and overflows.
Storm Water	Rainfall which runs off roofs, roads, gulleys, etc. In some areas storm water is collected and discharged to separate sewers, whilst in combined sewers it mixes with foul sewage from domestic properties and trade premises.
Waste water	Any waste water but see also “sewage”.

APPENDICES

Appendix I: Shoreline survey

General information

A shoreline survey was conducted on the 11 October 2007 along the west coast of Cumbria between the southern area of Allonby and The Green at Silloth by Cefas staff and the Environmental Health Officer of the Allerdale Borough Council. A Shoreline Survey Record Form which documented information recorded at the time of this survey is appended at the end of this section.

The objectives of the survey were to (a) confirm the existence of pollution sources identified during the desk study likely to constitute sources of microbiological contamination for the BMPAs, (b) identify any additional pollution sources in the area and (c) confirm the extent of the new production area.

The survey took place between 7:15 and 12:30 British Summer Time (BST) under showers (3.6mm, daily total rainfall) and SW wind (~16mph). The maximum air temperature recorded at Carlisle meteorological station was 13℃. The survey was undertaken over the low water and flood stages of the tide. The predicted tidal curve for the day is given in Figure A1.

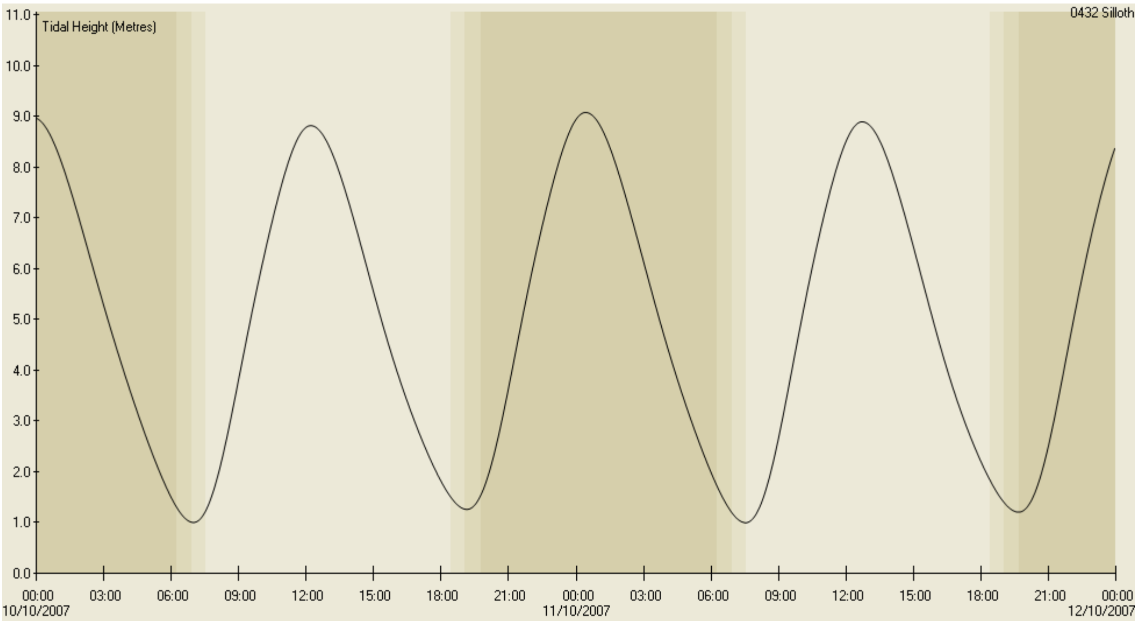


Figure A1 Tidal curve at Silloth on 11 October 2007.

Republished with permission from Admiralty Total Tide (United Kingdom Hydrographic Office) by permission of Her Majesty's Stationery Office and the UK Hydrographic Office.

Observations and results

The survey started at Dubmill Scar, in the vicinity of the new production area for Pacific oysters (Figure A2). For health and safety reasons, it was not possible to access the longline systems.

Figure A2 New production area for Pacific oysters at Dubmill Scar.
Area of adjustable longlines marked with white brackets.

Three stretches of coast were surveyed (Figure A3). The first stretch included the sand and shingle littoral of Allonby Bay to the West End of Allonby. The second stretch of coast surveyed was the littoral of Mawbray and Mawbray Bank from the Brookside Farm area. The third stretch of coast surveyed was Silloth Bay at The Green leisure park.

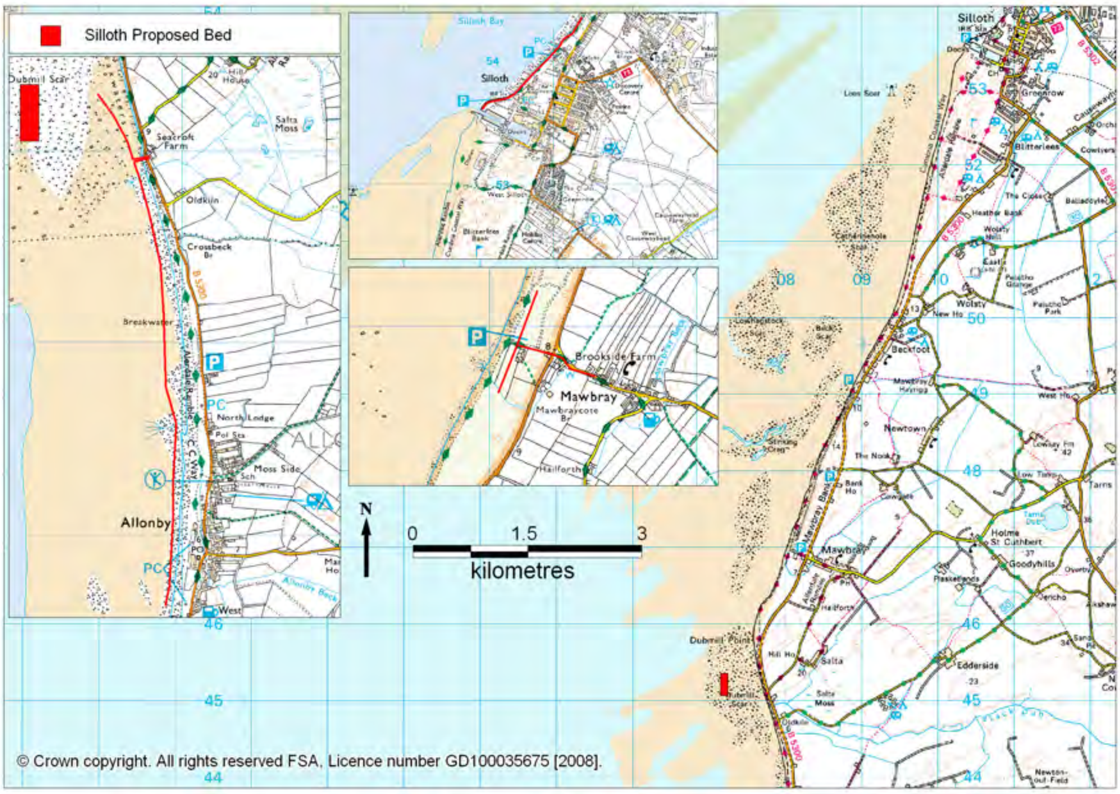


Figure A3 Area surveyed (red line) in Silloth on 11 October 2007.

The high sediment and water dynamics in the area encompassing the BMPA were noted by the high turbidity of water. Large areas of sandflats exposed at low water were completely covered by water during the flood tide (Figure A4A, B).

Figure A4 Sandflats at low water (A) and high water (B) in Dubmill Point.

Agricultural activities

Cattle were seen grazing on farmland and dunes along Wolsty Bank and Mawbray Bank. Evidence of manure application was observed at Wolsty farm, Beckfoot Farm and Seacroft farm (Dubmill Point) (Figure A5). Approximately 70 cattle were counted at Mawbray Bank, 20 sheep in the vicinity of Mawbray and 22 cattle and 26 sheep at Wolsty Bank. Many farms in these areas have fences preventing access of livestock to watercourses (Figures A5, A7D).

Figure A5 Manure storage site in a farm at Dubmill Point.

A dirty area with chicken and one horse was observed in Mawbray Bank, in the vicinity of the car park at Mawbray.

Animals

Dog owners use both the beach and the coastal footpath to exercise dogs. Three dogs and dog faeces were seen in the shores of Allonby (Figure A6).

Approximately 50 seabirds were seen in various locations along the shore in the vicinity of Allonby Stream and at The Green park at Silloth.

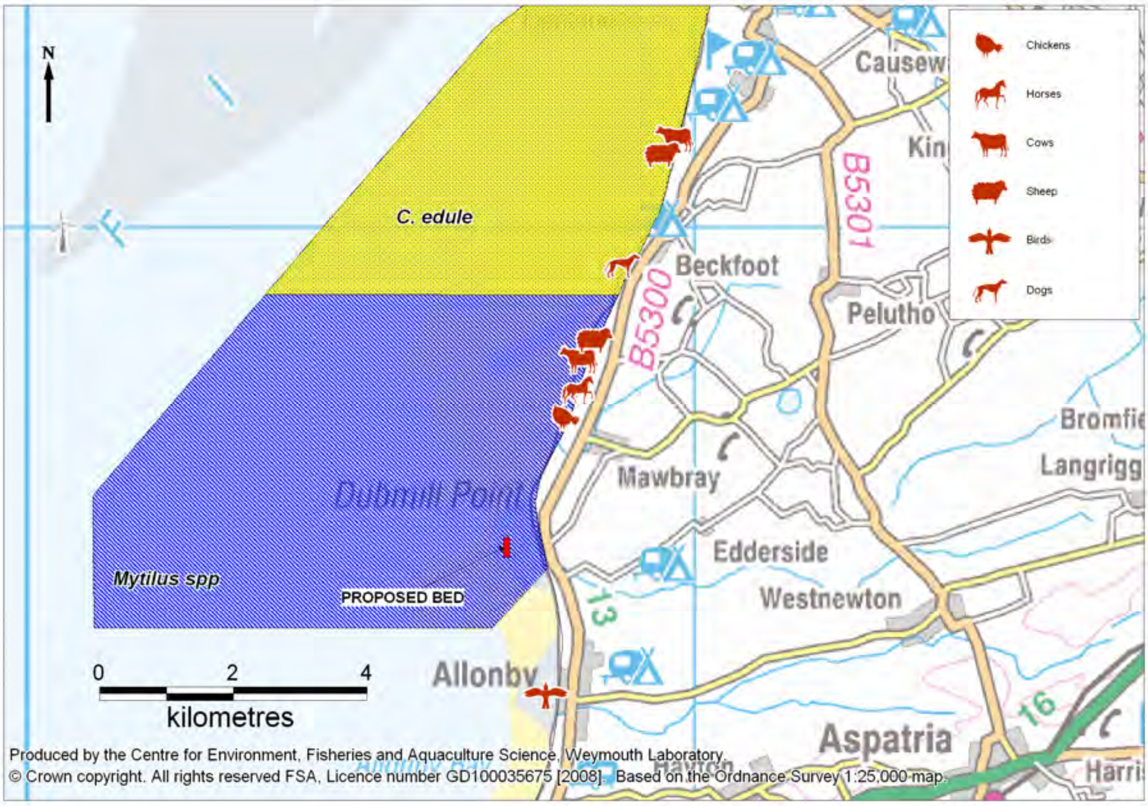


Figure A6 Locations where animals were observed in Dubmill Point.

Tourism activities

The coastal area between Silloth and Allonby is well-known as holiday destination. There is a holiday centre and golf course at West Silloth and caravan parks at Blitterlees and Beckfoot, near Salta Moss and Allonby.

No boating activities were observed during the survey.

Sewage discharges and water quality

The locations of sewage discharges inspected during the survey are shown in Table A1.

Table A.1 Sewage discharges inspected during the shoreline survey.

Name	Treatment level	NGR of outfall
Silloth STW	Tertiary (UV)	NY 1087 5412
Allonby STW	Tertiary (UV)	NY 0773 4407

UV-ultraviolet.
NGR - national grid reference system.

Freshwater samples were collected from four watercourses discharging to the sea for quantification of *E. coli* (Figure A7). Locations and microbiological results for these samples are shown in Table A2.

Figure A7 Sites sampled during the shoreline survey.

Table A2. Levels of* E. coli *in samples collected during the shoreline survey.

Site	Location (Eastings/Northings)	Time	CFU *E. coli* 100ml^{-1}
A	Black Dub (07809/44898)	08:00	887
B	Cross Beck (07926/44550)	08:12	415
C	Allonby Stream (08056/43619)	08:36	1,160
D	Mawbray Stream (08005/46763)	09:38	1,095

Conclusion

The shoreline survey highlighted the small scale of the new production area for Pacific oysters at Dubmill Point. The survey also allowed confirming the potential contribution of Allonby Stream and Mawbray Stream as routes of microbiological contamination impacting shellfish beds. Despite the high number of farms and wildlife and the existence of dirty areas and manure storage sites in the coastal area, no evidence of direct access of animals to the shore or watercourses was observed.

Shoreline Survey Record Form

General Information			
1	**Bed ID**	B059K	
2	**Bed Name/Coordinates**	Dubmill (Eastings/Northings) (307250/545350; 307250/545049; 307150/545049; 307150/307150) (see Figure A2)	
3	**Production Area**	M059 - Silloth	
4	**Area of Bed**	Approximately 0.3km^2	
5	**SWD Flesh Point**	n/a	
6	**SWD Water Point**	n/a	
7	**BWD**	Allonby, Allonby South, Silloth, Skinburness	
8	**Cefas Officer**	Carlos Campos	
9	**Local Enforcement Authority Officer**	David Copeland (Allerdale Borough Council)	
10	**Dates/times of survey:**	11 October 2007 (shore) 07:15-12:30 BST	
11	**Extent of Survey Area**	From South of Allonby to The Green at Silloth (see Figure A2)	
12	**Map/Chart References**	Explorer 314: Solway Firth (Wigton & Silloth) 1:25 000 2013 (St. Bees Head to Silloth)	
13	**Predicted Tides 0432 Silloth** Totaltide (BST) See Figure A1	High Water (time/height)	11 October 2007 - 13:00 (8.8m)
		Low Water (time/height)	11 October 2007 - 07:30 (1.0m)
14	Weather Forecast	Max. air temp=15℃ at 19:00 Max. wind speed=16.1 knots at 07:00 Wind direction=SW Rain=1 mm at 07:00 (Silloth Beach)	
15	**Air temperature (measured)**	Maximum air temp=13℃	
16	**Wind (measured)**	16mph (SW) Beaufort Scale- moderate breeze.	
17	**Precipitation**	3.6mm	
18	**Rivers/streams/springs observed**	Water appearance: Black Dub (brown, turbid) Cross Beck (brown) Allonby Stream (dark brown) Mawbray Stream (clear)	

<table>
<tr><td>19</td><td>Key Discharges (Cefas database)</td><td>
<table>
<tr><th>Name</th><th>Treatment level</th><th>NGR of outfall</th></tr>
<tr><td>Allonby STW</td><td>Tertiary (UV)</td><td>NY 0773 4407</td></tr>
<tr><td>Edderside STW</td><td>Secondary</td><td>NY 0994 4552</td></tr>
<tr><td>Hayton STW</td><td>Secondary</td><td>NY 1076 4183</td></tr>
<tr><td>Allerby STW</td><td>Secondary</td><td>NY 0892 3913</td></tr>
<tr><td>West Newton STW</td><td>Secondary</td><td>NY 1302 4363</td></tr>
<tr><td>Silloth STW</td><td>Tertiary (UV)</td><td>NY 1087 5412</td></tr>
<tr><td>Grange Farm CSO</td><td>-</td><td>NY 1096 4164</td></tr>
<tr><td>West Newton STW storm tank</td><td>-</td><td>NY 1302 4363</td></tr>
<tr><td>West Newton PS</td><td>-</td><td>NY 1318 4382</td></tr>
<tr><td>Silloth STW storm tank</td><td>-</td><td>NY 1087 5412</td></tr>
<tr><td>Moricambe Park PS</td><td>-</td><td>NY 1282 5584</td></tr>
<tr><td>West Silloth PS</td><td>-</td><td>NY 1124 5268</td></tr>
<tr><td>Greenrow PS CSO</td><td>-</td><td>NY 1123 5265</td></tr>
</table>
</td></tr>
<tr><td>20</td><td>Discharges (observed)</td><td>
<table>
<tr><th>Name</th><th>Treatment level</th><th>NGR of outfall</th></tr>
<tr><td>Silloth STW</td><td>Tertiary (UV)</td><td>NY 1087 5412</td></tr>
<tr><td>Allonby STW</td><td>Tertiary (UV)</td><td>NY 0773 4407</td></tr>
</table>
</td></tr>
<tr><td>21</td><td>Boats/Port</td><td>None at time of survey.</td></tr>
<tr><td>22</td><td>Dogs</td><td>3 dogs and dog faeces in the shores of Allonby (Figure A6).</td></tr>
<tr><td>23</td><td>Birds</td><td>Approx. 50 seabirds in various locations along the shore in the vicinity of Allonby Stream and at The Green park (Silloth).</td></tr>
<tr><td>24</td><td>Other animals</td><td>Cattle grazing on farmland and dunes along Wolsty Bank and Mawbray Bank.
Evidence of manure application at Wolsty farm, Beckfoot Farm and Seacroft farm (Dubmill Point) (Figure A5).
Approx. 70 cattle at Mawbray Bank
Approx. 20 sheep in the vicinity of Mawbray
22 cattle and 26 sheep at Wolsty Bank. Farms in these areas with fences preventing access of livestock to watercourses (Figures A5, A7D).
Dirty area with chicken and one horse at Mawbray Bank, in the vicinity of the car park at Mawbray.</td></tr>
<tr><td>25</td><td>Strand line SRD</td><td>None observed at the time of survey.</td></tr>
</table>

26	**Samples Taken**	Location (Eastings/Northings) / Time / CFU *E. coli* 100ml^{-1} Black Dub (07809/44898) / 08:00 / 887 Cross Beck (07926/44550) / 08:12 / 415 Allonby Stream (08056/43619) / 08:36 / 1,160 Mawbray Stream (08005/46763) / 09:38 / 1,095
27	**Bivalve Harvesting Activity**	None at time of survey.
28	**Water Appearance**	Turbid seawater during flood tide (see Figure A4B).

Appendix II: SAMPLING PLAN

EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SAMPLING PLAN

Silloth (Cumbria)

2009

GENERAL INFORMATION

Location Reference

Production Area	Silloth
Cefas Main Site Reference	M059
Cefas Area Reference	FDR 3584
Ordnance survey 1:25,000 map	Explorer TM 314: Solway Firth (Wigton & Silloth)
Admiralty Chart	2013 (St. Bees Head to Silloth)

Shellfishery

Species/culture	Mussels (*Mytilus* spp.)	Wild
	Cockles (*C. edule*)	Wild
	Pacific oysters (*Crassostrea gigas*)	Farmed
Seasonality of harvest	Pacific oysters - year round Mussels - year round* Cockles: seasonal closure* 15 April–14 September inclusive *Additional temporary closures may be imposed on conservation grounds from time to time at the discretion of the Sea Fisheries Committee.	

Local Enforcement Authority

Local Enforcement Authority	Allerdale Borough Council Food & Occupational Health Department Environmental Health Unit
Telephone number ☎	01900 702590
Environmental Health Officer	Mr David Copeland
Telephone number ☎	01900 702588
Fax number	01900 702787
E-mail	david.copeland@allerdale.gov.uk
Sampling Officer	Mrs Gillian Scotter
E-mail	gillian.scotter@allerdale.gov.uk

REQUIREMENT FOR REVIEW

The need for this sampling plan to be reviewed will be assessed by the competent authority within six years or in light of any obvious known changes in sources of pollution of human (e.g. improvements in sewage treatment works) or animal origin likely to be a source of contamination for bivalve mollusc production areas.

Table A1. Number and location of representative monitoring points (RMPs) and frequency of sampling in Silloth classification zones.

Classification zone			Silloth - South	Silloth - South	Silloth - Mawbray	Silloth - Dubmill Point	Silloth	Silloth - Dubmill Scar
RMP			B059L	B059M	B059N	B059O	B059P	B059K
RMP name			Lees Scar	Catherinehole Scar	Mawbray	Dubmill Point	Silloth Channel	Dubmill Scar
Geographic grid references (datum) of sampling points	**OSGB36**	**Eastings**	310,046	309,858	307,570	307,150	306,780	307,198
		Northings	553,448	552,557	547,040	545,788	526,280	545,182
	NGR		NY 1005 5345	NY 0986 5256	NY 0757 4704	NY 0715 4579	NY 0678 5262	NY 0720 4518
	WGS84	**Latitude**	54°52.05'	54°51.57'	54°48.57'	54°47.89'	54°51.35'	54°47.57'
		Longitude	03°24.19'	03°24.35'	03°26.38'	03°26.75'	03°27.13'	03°26.69'
Species			*Mytilus* spp.	*C. edule*	*Mytilus* spp.	*Mytilus* spp.	*Mytilus* spp.	*C. gigas*
Growing method			Wild	Wild	Wild	Wild	Wild	Adjustable longline system
Harvesting technique			Hand-picking	Hand-picking	Hand-picking	Hand-picking	Boat-dredged	Hand-picking
Sampling method			Hand-picking	Hand-picking	Hand-picking	Hand-picking	Boat-dredged	Hand-picking
Depth			Seabed	Seabed	Seabed	Seabed	Seabed	Depth of suspended baskets
Tolerance for sampling points (m)			20	50	20	10	50	10
Frequency of sampling (PRELIMINARY Classification)			Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	10 samples taken over at least 3 months (interval between sampling not less than 1 week).
Frequency of sampling (FULL Classification)			At least monthly	At least monthly	At least monthly	At least monthly	At least monthly	At least monthly over one year

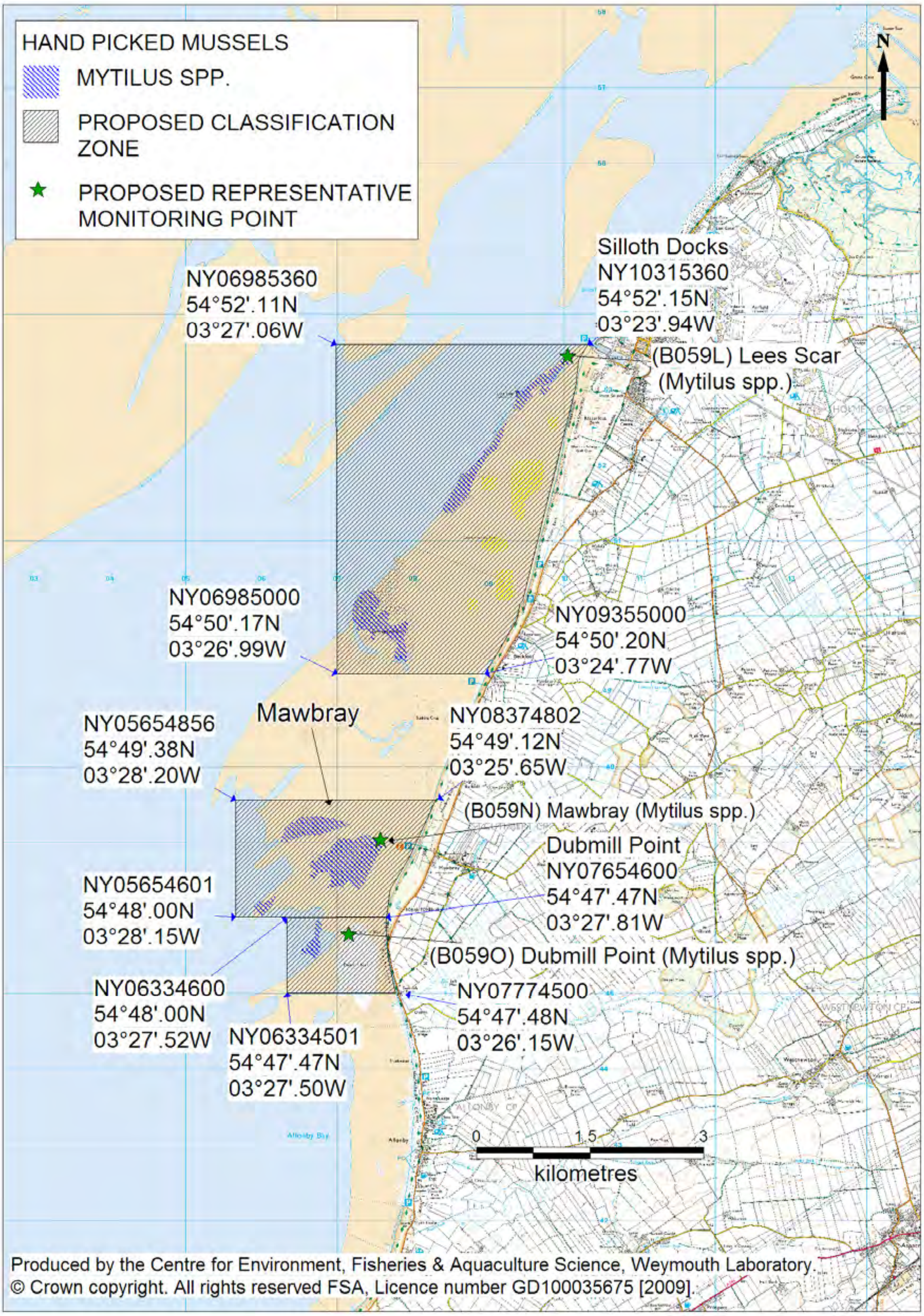


Figure A1. Location of representative monitoring points (RMPs) and recommended boundaries of classification zones for hand-picked mussels in Silloth.

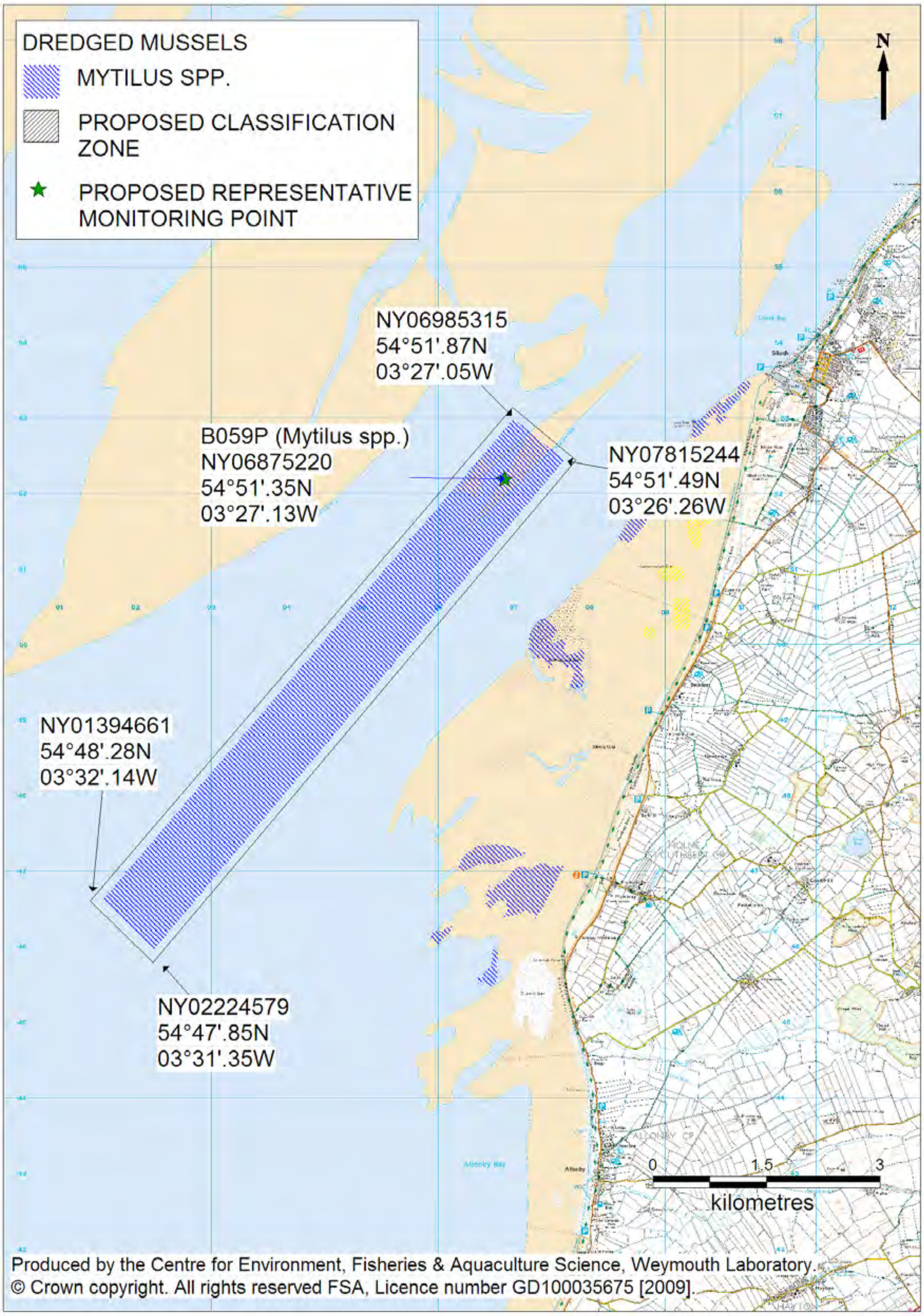


Figure A2. Location of representative monitoring points (RMPs) and recommended boundaries of classification zones for dredged mussels in Silloth.

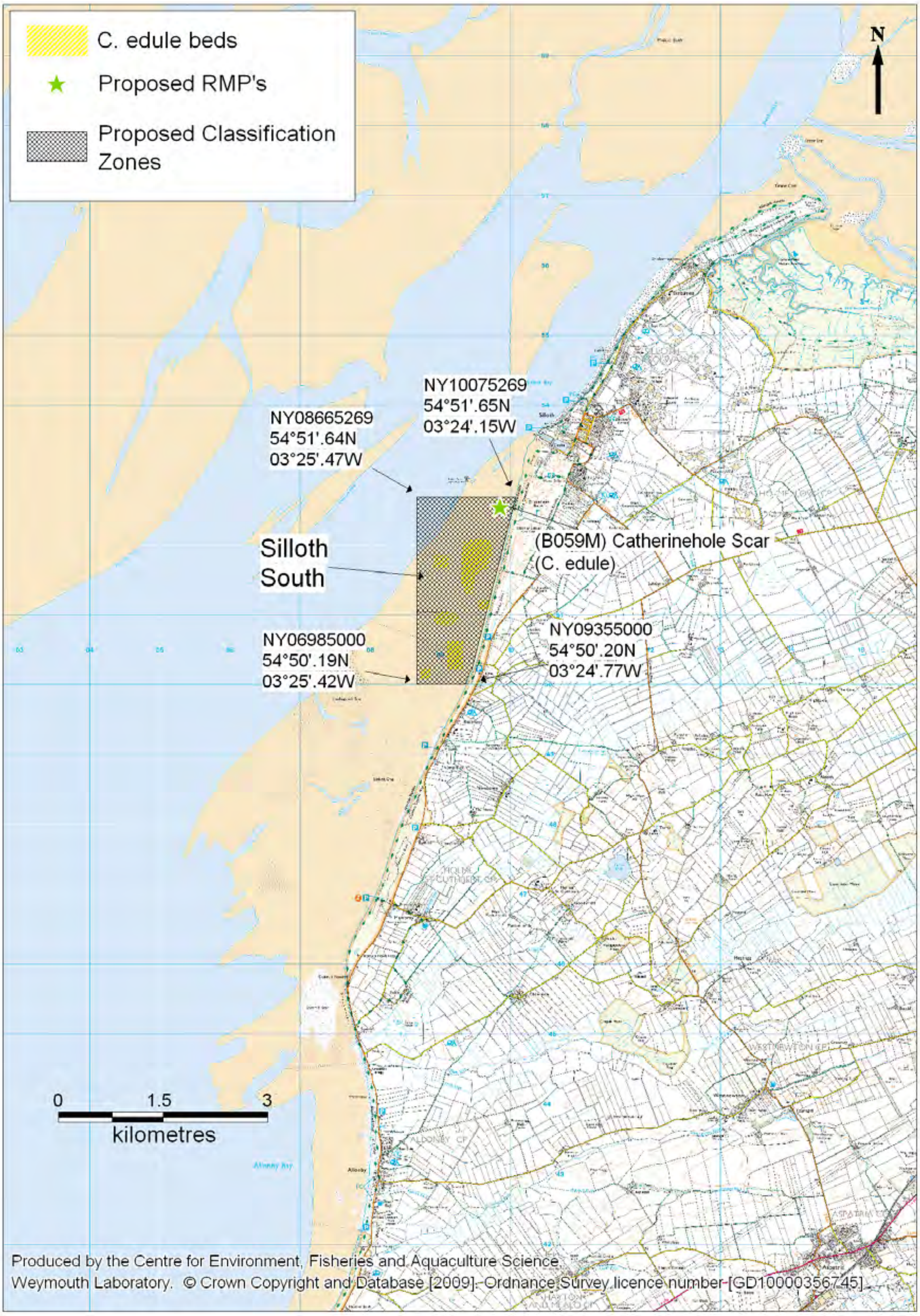


Figure A3. Location of representative monitoring point (RMP) and recommended boundaries of classification zone for cockles in Silloth.

Figure A4. Location of representative monitoring point (RMP) and recommended boundaries of classification zone for Pacific oysters in Silloth.