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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Amble

June 2014

Food Standards Agency

Cover photo: Derelict North Jetty where mussel cultivation is planned.

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Statement of use

This report provides a sanitary survey relevant to bivalve mollusc beds at Amble, as required under EC Regulation 854/2004 which lays down specific rules for official controls on products of animal origin intended for human consumption. It provides an appropriate hygiene classification zoning and monitoring plan based on the best available information with detailed supporting evidence. The Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook this work on behalf of the Food Standards Agency (FSA).

Report prepared by

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3	Final	Simon Kershaw	13/10/2014

Consultation

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Dissemination

Food Standards Agency, Northumberland County Council. The report is available publicly via the Cefas website.

Recommended Bibliographic Reference

Cefas, 2014. Sanitary survey of Amble. 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. Legislative Requirement

Filter feeding, bivalve molluscan shellfish (e.g. mussels, clams, oysters) retain and accumulate a variety of microorganisms from their natural environments. Since filter feeding promotes retention and accumulation of these microorganisms, the microbiological safety of bivalves for human consumption depends heavily on the quality of the waters from which they are taken.

When consumed raw or lightly cooked, bivalves contaminated with pathogenic microorganisms may cause infectious diseases (e.g. Norovirus-associated gastroenteritis, Hepatitis A and Salmonellosis) in humans.. In England and Wales, fish and shellfish constitute the fourth most reported food item causing infectious disease outbreaks in humans after poultry, red meat and desserts (Hughes *et al.*, 2007).

The risk of contamination of bivalve molluscs with pathogens is assessed through the microbiological monitoring of bivalves. This assessment results in the classification of BMPAs, which determines the level of treatment (e.g. purification, relaying, cooking) required before human consumption of bivalves (Lee and Younger, 2002).

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 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 area;

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 cycle 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.'

EC Regulation 854/2004 also specifies the use of *Escherichia coli* as an indicator of microbiological contamination in bivalves. This bacterium is present in animal and human faeces in large numbers and is therefore indicative of contamination of faecal origin.

In addition to better targeting the location of RMPs and frequency of sampling for microbiological monitoring, it is believed that the sanitary survey may serve to help to target future water quality improvements and improve analysis of their effects on shellfish hygiene. Improved monitoring should lead to improved detection of pollution events and identification of the likely sources of pollution. Remedial action may then be possible either through funding of improvements in point sources of contamination or as a result of changes in land management practices.

This report documents the information relevant to undertake a sanitary survey for mussels (*Mytilus* spp.) at Warkworth Harbour, Amble. The area was prioritised for survey in 2014-15 at the request of the Food Standards Agency.

1.2. Area description

Amble is a small town situated at the mouth of the Coquet estuary, on the North Northumberland coast (Figure 1.1). It supports a fishing fleet and some limited industry and tourism. Agriculture is also important to the local economy.

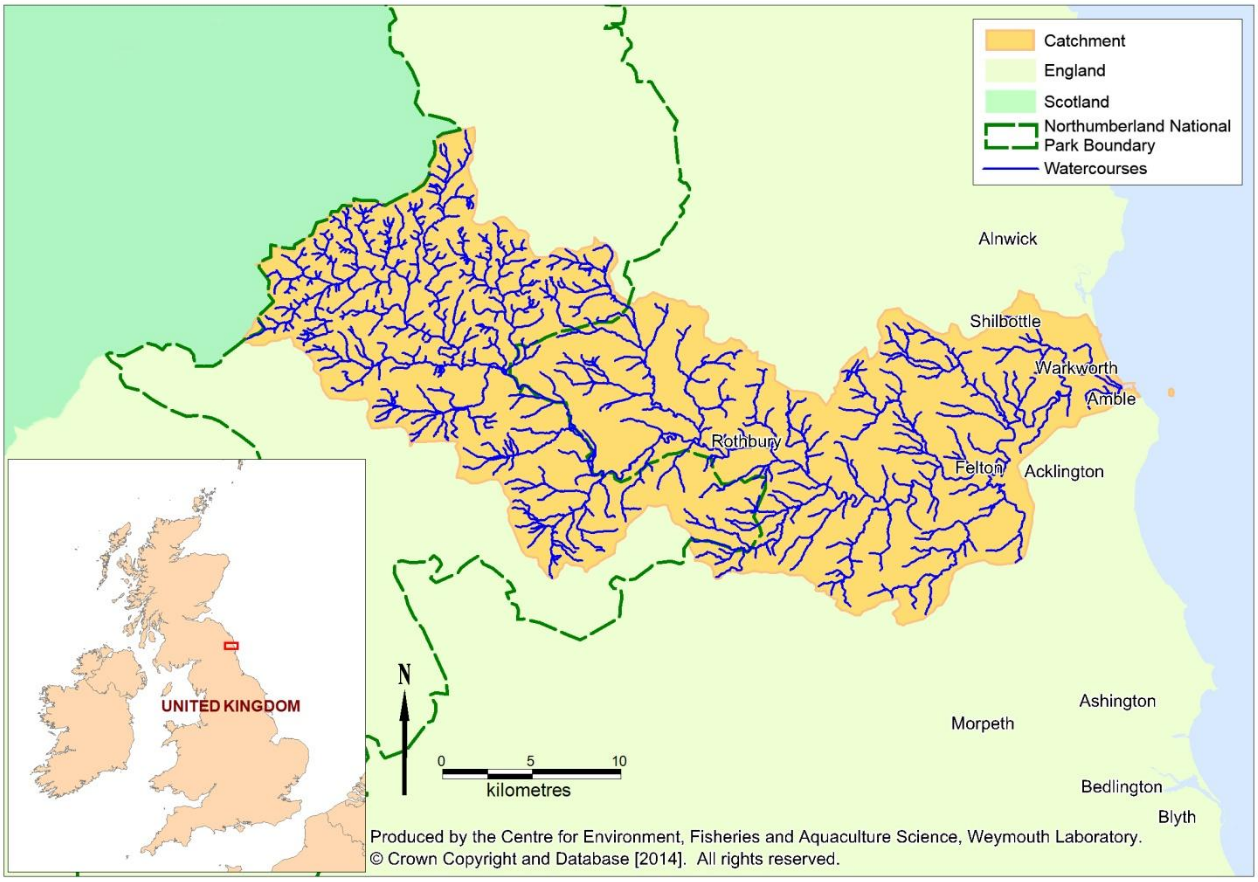

Figure 1.1: Location of the survey area

The Coquet estuary is about 5 km in length, narrow and meandering, covering an area of approximately 0.75 km^2. There is a harbour and marina within its outer reaches and a significant spate river drains to its head. Currently there is no active shellfishery in the estuary. The Amble Development Trust intends to run some mussel culture trials in the outer estuary at Amble as part of a wider scheme to stimulate the local economy.

1.3. Catchment

The Coquet estuary has a hydrological catchment of about 600 km^2, almost all of which drains to the head of the estuary via the River Coquet. The estuary itself lies in the Northumbrian coastal plain, a relatively flat and low lying strip of land bordering the coast. The Coquet catchment extends up into the Cheviot Hills, and its' maximum elevation is 777 m. Figure 1.2 shows land cover within this area.

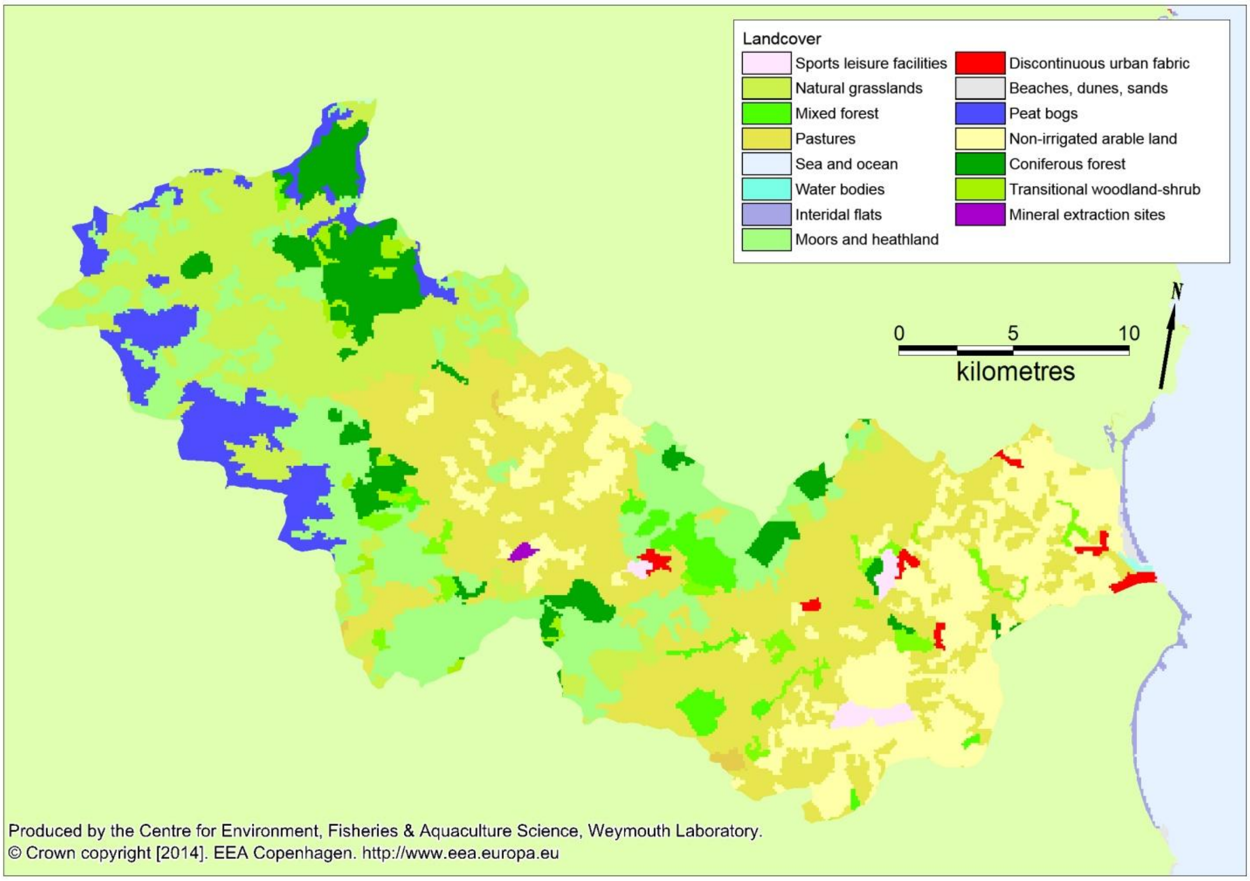

Figure 1.2: Landcover in the catchment area

The catchment is rural and sparsely populated with few urbanised areas, most of which are in the lower catchment. Arable farming with some pasture predominates in the lower reaches, with pasture and woodlands in the middle reaches. The upper reaches are a mix of heathland, peat bog and forest.

Different land cover types will generate differing levels of contamination in surface runoff. Highest faecal coliform contribution arises from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land types (Kay *et al*. 2008a). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, particularly for improved grassland which increase up to 100 fold.

Hydrogeology maps indicate that the catchment geology is mainly of moderate water permeability, with the upper reaches being of very low permeability (NERC, 2012). This, together with the generally hilly nature of the catchment suggests that watercourses will respond rapidly to rainfall, a high proportion of which will run off.

2. Recommendations

It is difficult to recommend a representative sampling plan when the layout of the fishery and culture methods are yet to be decided. The development of a commercial fishery would require further consideration given the results of the bacteriological survey described below. A sampling plan is nevertheless provided based on the area for which classification was requested, although it may require significant revision if a commercial fishery is developed at some point in the future.

The contaminating influences are mainly up-estuary from the area for which classification has been requested. The largest source is likely to be the River Coquet, which will deliver a highly variable bacterial loading. The caravan park discharge may also be a significant contaminating influence. There are a number of intermittent discharges to the estuary, all but one of which lie up-estuary from the shellfishery. Those located at Amble, including the one adjacent to the area requiring classification, lie on the opposite bank, so any effluent discharged will mainly impact along the south shore. It is possible that birds roosting on the remains of the North Jetty may also make some contribution to levels of faecal indicator bacteria at the site. It is therefore concluded that there may be a slight increase in average levels of contamination towards the upstream end of the fishery.

The bacteriological survey however found that levels of contamination were higher on average at the downstream end of the North Jetty, where 3 of the four samples exceeded 4,600 *E. coli* MPN/100g and one exceeded 46,000 *E. coli* MPN/100g. Whether the difference between the two monitoring points was related to their relative elevations, the presence of birds, or some other local influence is uncertain. The results indicate that the area may be prohibited for harvest, in which case it is possible that an upgrade may be issued following 2 years of monthly monitoring assuming no further results exceeding 46,000 are returned. Where known sewage discharge improvements have taken place then this period may be reduced with increased monitoring frequency..

Given the bacteriological survey results it is recommended that the RMP (if required at some point) should be located at the downstream end of the North Jetty where the highest results were recorded. The species sampled should be mussels of a harvestable size.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Amble
Cefas Main Site Reference	M093
Ordnance survey 1:25,000 map	Explorer 332
Admiralty Chart	1627

Shellfishery

Species/culture	Mussels	Culture methods yet to be established
Seasonality of harvest	Potentially year round	

Local Enforcement Authority

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3.2. 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 6 years, so this assessment is due a formal review in 2020. The assessment may require review in the interim should any significant changes in sources of contamination come to light or any changes to the shellfishery occur other than those currently planned.

Table 3.1: Location of representative monitoring point (RMP) and frequency of sampling for Amble production area

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency
North Jetty	B093C	North Jetty East	NU26940498	55°20.288'N 01°34.610'W	Mussels	To be decided	To be decided	Hand	10 m	Would usually be monthly, but will not be required until the proposed operator has shellfish of marketable size to be sampled.

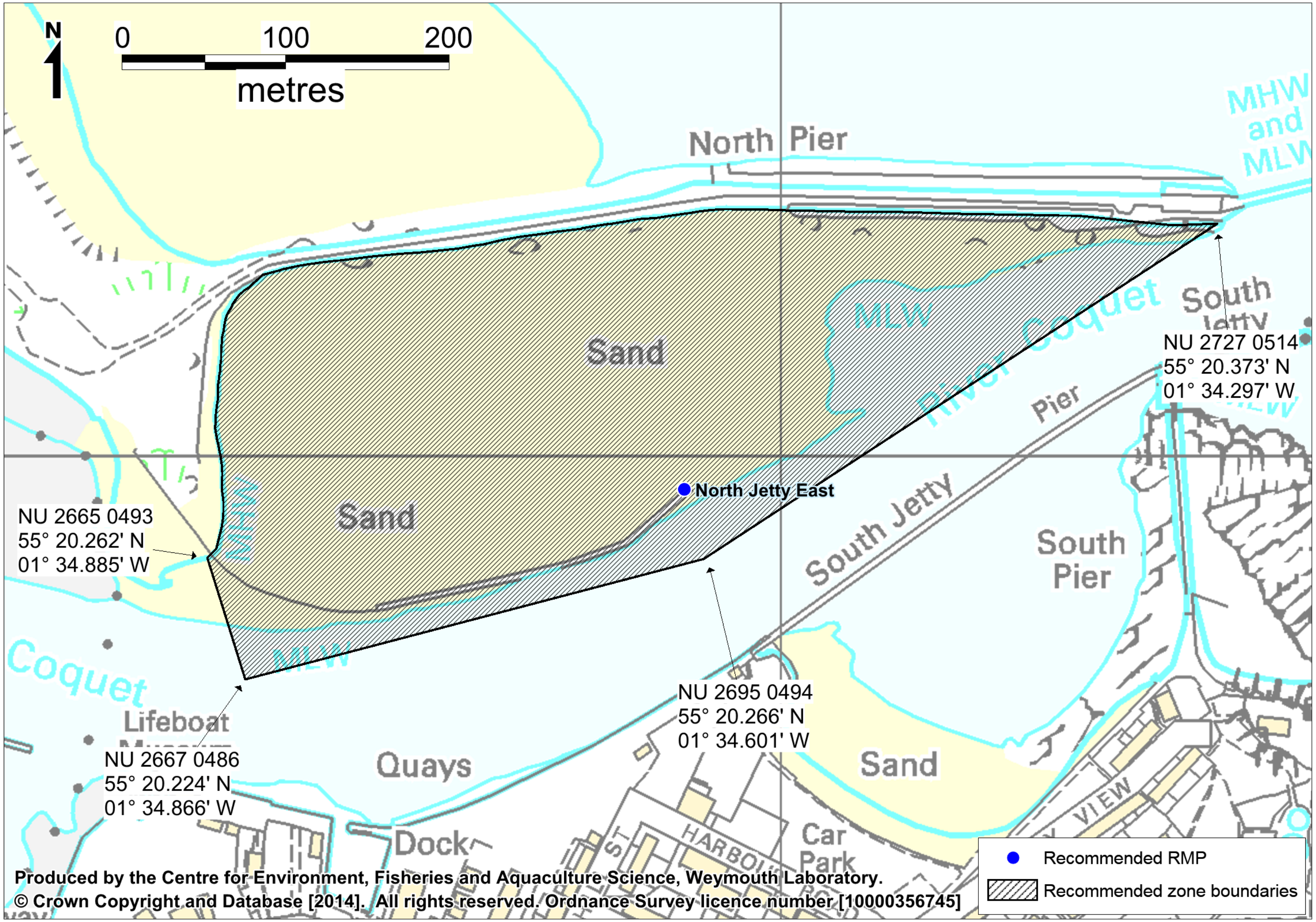

Figure 3.1: Recommended zoning and monitoring arrangements

4. Shellfisheries

4.1. Species, location and extent

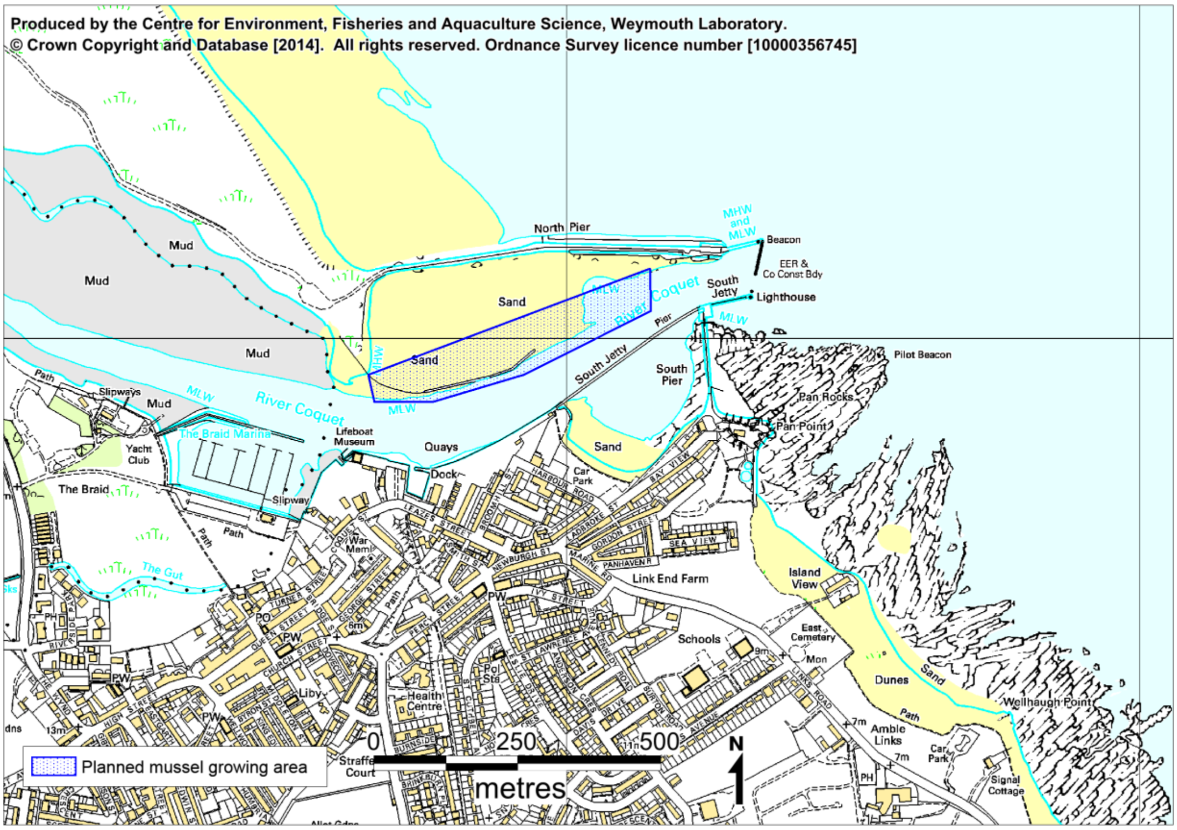

Figure 4.1: Planned fishery area

The Amble Development Trust has tentative plans to establish a small mussel cultivation operation within the outer reaches of the estuary around the remains of the old North Jetty. This is one of many parallel initiatives the trust is pursuing to stimulate the fisheries and aquaculture business in the area. At the time of writing, no attempts at mussel culture had occurred within this area and no stock was present on site. No wild stock was observed within the area during the shoreline survey.

4.2. Growing Methods and Harvesting Techniques

Growing methods are yet to be decided exactly, but may involve the use of either bouchot poles or mussel rafts. A supply of seed stock will need to be established as there does not appear to be any natural settlement in the harbour. It is likely that harvest would be by hand.

4.3. Seasonality of Harvest, Conservation Controls and Development Potential

No conservation controls apply to cultured mussels, and harvest may be at any time of the year. There are few potential seed sources locally and any collection of seed would require the authorisation of the Northumberland IFCA.

There are no projected production volumes for mussel culture at Amble, although the Amble Development Trust envisages that the operation will be on a relatively small scale, employing perhaps one or two people on a part time basis. Of critical importance to the future of the fishery is the classification it receives. A C classification would preclude the direct marketing of live mussels following depuration, so they would have to be relayed in class A or B waters for two months in order to be marketed live. Alternatively they could be marketed following an EC approved heat treatment process. The Amble Development Trust would need to consider the results from the sanitary survey and would need to proceed with their trial to ascertain whether the harbour is a suitable environment for mussel culture in terms of survival , growth and quality of product, and to establish the most suitable culture method, before any further sampling for classification purposes is initiated (as classification is not required until the shellfish are of marketable size).

4.4. Hygiene Classification

No bivalve mollusc classification has been issued within the survey area. From 2003 to 2005 24 mussel samples were taken from the opposite side of the outer harbour at Littleshore (Appendix XI) and tested for *E. coli* in order to establish a hygiene classification. The proportion of results exceeding 4,600 *E. coli* MPN/100g was 20.8%, which aligns with a C classification (Table 4.2). . More recently, the results of a bacteriological survey were consistent with an area which may be prohibited on hygiene grounds following initial monitoring (Appendix XII).

Table 4.1: 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* $100g^{-1}$ 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* $100g^{-1}$ FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* $100g^{-1}$ 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* $100g^{-1}$ FIL	Relaying for, at least, two months in an approved relaying area or cooking by an approved method

Prohibited[6]	>46,000 *E. coli* 100g^{-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 beds

5. Overall Assessment

5.1. Aim

This section presents an overall assessment of sources of contamination, their likely impacts, and patterns in levels of contamination observed in water and shellfish samples taken in the area under various programmes, summarised from supporting information in the previous sections and the Appendices. Its main purpose is to inform the sampling plan for the microbiological monitoring and classification of the bivalve mollusc beds in this geographical area.

5.2. Shellfisheries

The Amble Development Trust has tentative plans to develop a mussel culture fishery around the derelict North Jetty, on the north side of the outer reaches of the estuary. This is one of several parallel initiatives the trust is pursuing to stimulate business in the area via a new ‘harbour village and development the of the towns seafood industry.

There are no stocks of naturally occurring mussels within the survey area. Potential culture methods indicated on the application were rafts and bouchot poles, but as yet no source of seed has been identified, no stock has been introduced and no pilot trials have been undertaken. Although the area requiring classification was clearly delineated on the application, the sampling plan proposed in this report may require significant revision if and when the layout of the fishery is developed.

5.3. Pollution Sources

Freshwater Inputs

The Coquet estuary has a hydrological catchment of about 600 km². The vast majority of this (~98%) is drained by the River Coquet, which discharges to the head of the estuary. Its catchment is mainly rural, with rough grazing and natural areas in its upper reaches where elevations are higher and the hydrogeology is impermeable. The lower reaches are largely pasture and arable fields with some urban areas, and the land is less hilly and the hydrogeology more permeable. Flow gauging records indicate a mean discharge of about 9.5 m^3/sec, with base flows of about 1.4 m^3/sec. Discharge varies significantly in response to rainfall and other environmental factors, with flows exceeding 20 m^3/sec recorded about 10% of the time. There is a strong seasonal variation in discharge, which is highest on average in January, and lowest during May. Flood events were recorded in all months of the year, although only occasionally in May. During the shoreline survey, a spot flow measurement was made. Discharge at the time was 4.73 m^3/sec and the *E. coli* concentration was 460 cfu/100ml, indicating that the bacterial loading it was delivering at the time was $1.9x10^{12}$ *E. coli*/day.

There are also a few minor watercourses draining to other points in the estuary, all of which lie upstream of the fishery. The only minor watercourse that discharges to the lower is the Guilders Burn, which discharges to the south shore in the corner of the Marina. The bacterial loading carried by this watercourse at the time of shoreline survey was only $7.8x10^7$ *E. coli*/day.

It is therefore concluded that the vast majority of runoff-derived contamination will be delivered by the River Coquet, and the bacterial loading it delivers will vary significantly depending on rainfall, and possibly the time of year. As all freshwater inputs are up-estuary of the fishery, monitoring at the up-estuary end of any shellfishery would be most effective at capturing their impacts.

Human Population

Total resident population within census areas contained within or partially within the catchment area was approximately 37,000 at the time of the last census. The higher density areas within the catchment are around the Coquet estuary, including the town of Amble (population ~6,000) which lies adjacent to the lower estuary where the fishery is planned. The catchment includes part of the Northumberland National Park and the seaside town of Amble, both of which attract tourists. It is therefore likely that population in the area increases during the summer months. There is a large caravan park (228 units) in close proximity to the fishery which is open year round but is likely to be in peak occupancy during the summer holiday period.

Sewage Discharges

There are 16 water company owned sewage treatment works within the survey area, of which 15 discharge to the River Coquet and tributaries. These are a mixture of small to medium sized secondary treatment works, and a few smaller septic tanks. The total consented dry weather flow of these sewage works is 2,429.5 m^3/day, although this does not include five small works where consented dry weather flow is unspecified on the permit database. They will contribute to the bacterial loading delivered to the estuary by the River Coquet. The final water company sewage works (Amble STW) is the largest, providing secondary treatment for a dry weather flow of 2,512 m^3/day. It discharges about 350 m east of the harbour entrance to a depth of about 5 m relative to chart datum. Water circulation patterns in the area suggest this discharge should have no influence on water quality within the Coquet estuary.

There are a total of 40 intermittent (overflow) discharges associated with the water company sewerage networks within the survey area. Most of these are located inland, and discharge to the River Coquet and tributaries, and so may contribute from time to time to the bacterial loading delivered by the river. There are also clusters of intermittent discharges to the estuary at Warkworth and Amble. Additionally Amble STW has an overflow discharge at the same location as the main (continuous) outfall. Those discharging to the harbour at Amble all discharge to the opposite bank to which the fishery is located. No spill information was available for these at the time of writing. Without any spill records it is difficult to assess their potential impacts aside from noting their location and potential to spill storm or untreated sewage. Some sanitary debris (rag) was observed during the shoreline survey at Littleshore in Amble, but it is uncertain whether this originated from one of the intermittent discharges in the area or from another source.

Whilst the majority of the survey area is served by water company sewerage infrastructure, there are also a number of private discharges in the catchment. Of the permitted discharges with a sewage content, 23 discharge to soakaway and 130 discharge to water. Where specified, they are generally treated by small works such as package plants or septic tanks. Those discharging to soakaway should be of no impact on coastal waters assuming they are functioning correctly. Of those discharging to water, the vast majority discharge to the River Coquet and tributaries, and so will contribute to the bacterial loading delivered by this watercourse. There are only two private discharges to the estuary, both of which are located upstream of the fishery. One is a septic tank discharge from a small number of properties on the east bank at Warkworth, which is consented to discharge up to 5 m^3/day. The other is from the Coquet View caravan park, and this is consented to discharge up to 16 m^3/day of secondary treated effluent to the old river channel about 1.5 km upstream of the fishery. At the time of shoreline survey, an instantaneous measurement of discharge rate from this site was 77 m^3/day, much greater than the consented rate, although discharge rates will probably vary throughout the day with water usage by residents. The effluent contained 10,000 *E. coli* cfu/100ml, so the bacterial loading generated by this discharge at the time was 7.7×10^9 *E. coli*/day. The Environment Agency are aware that this discharge is not compliant with its permit and are working with the owner to rectify the situation. At present it discharges somewhere between 40-90 m^3/day. Revised permit conditions are to be decided, but may require an investigation of the feasibility of relocating this discharge. A planning application to expand the site from 228 to 352 units has been submitted recently. The park is open all year round, but peak occupancy and hence peak discharge volumes are likely to occur during the summer holidays.

Agriculture

Land cover within the Coquet catchment is principally pasture/grassland (53%), with significant areas also used for arable farming (18%). Arable land is mainly in the lower catchment, various grades of pasture are distributed throughout, and the natural areas are more extensive further inland. Livestock census data indicate that sheep are present in high numbers and densities (177,843 animals at 294 per km^2), with significant numbers of cattle also present (17,945 animals at 29.7 per km^2). Small numbers of pigs and poultry are also farmed. It is therefore concluded that there are likely to be significant fluxes of microbiological contamination of agricultural origin into the estuary.

Faecal matter from grazing livestock is either deposited directly on pastures, or collected from farmyards or livestock sheds then applied to agricultural lands as a fertilizer. Manure from pigs and poultry is typically stored and applied tactically to nearby farmland, and sewage sludge may be applied at certain times and places. Within the catchment composted manure is more common than slurry based systems, and the composting process reduces the bacterial content due to the heat it generates. Faecal matter deposited on farmland may be washed into watercourses by land runoff. The extent to which this occurs will depend on topography, soils and the degree of separation between fields and watercourses. All watercourses enter the estuary upstream of the fishery, so monitoring at the upstream end of the fishery would best capture contamination of agricultural origin. As the primary mechanism for mobilisation of faecal matter from agricultural land is via land runoff, fluxes of livestock related contamination into the estuary will be highly rainfall dependent.

There is likely to be seasonality in the fluxes of contamination originating from livestock. Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs calves, and decrease in the autumn when animals are sent to market. During the warmer months, cattle are likely to access watercourses more frequently to drink and cool off. During winter, cattle may be transferred from pastures to indoor sheds, and at these times manure will be collected and stored for later application to fields. Such applications are generally made in the winter, spring, or after the harvest of summer crops. Therefore, peak levels of contamination from grazing livestock may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period, which would allow a build up of faecal material on pastures, or on a more localised basis if wet weather follows a manure application, which mainly occur in the winter, spring and summer.

Boats

The discharge of sewage from boats is potentially a significant source of bacterial contamination within the Coquet estuary. There is a 250 berth marina and a significant resident fleet of 27 under 10 m and 5 over 10 m fishing vessels. Wildlife tours also operate from the estuary during the spring and summer months. These vessels are confined to the outer reaches of the estuary in the Amble area. Larger vessels such as merchant shipping do not use the estuary due to its shallow nature. There are no sewage pump out facilities within the area.

It is likely that the larger of the private vessels (yachts, cabin cruisers, and fishing vessels) which have onboard toilets make overboard discharges from time to time. This may occur whilst boats are on passage, and it is quite likely that any boats in overnight occupation on moorings will make a discharge at some point during their stay. Those on pontoon berths within the marina or berthed at the quay will have easier access to onshore facilities so may be considered less likely to make overboard discharges. The harbour wall where the fishing vessels berth lies opposite to the planned fishery site, the marina is also on the south bank but a short distance upstream of the fishery site, and the moorings lie off the marina. As such, it is not anticipated that any one part of the fishery site will be affected more than another. Peak pleasure craft activity will occur in the summer, so highest impacts are anticipated at this time. However, it is difficult to be more specific without any firm information about the locations, timings and volumes of such discharges, and as such boating will have little material bearing on the sampling plan.

Wildlife

The Coquet estuary encompasses a variety of habitats including intertidal mudflats, sand dunes, sand spit and limited saltmarsh. These and other coastal features support significant local populations of birds and other wildlife, which may contribute to levels of faecal indicator organisms within the estuary.

The main wildlife aggregation in the vicinity is a major seabird breeding colony at Coquet Island. In a survey undertaken during the breeding season in 2000, 23,362 pairs of birds were recorded, of which the majority (around 73%) were Atlantic Puffins with the rest made up of mainly gulls and terns. The puffins arrive from the open sea in March, and depart at the end of July, but as they forage in the open sea rather than within estuaries, they are unlikely to be much of an influence on the fishery site. Other species such as gulls are likely to forage in the vicinity of the estuary, but away from the breeding colony their impacts may be considered diffuse so will have no bearing on the sampling plan. Some of these species (e.g. terns) migrate away from the area outside of the breeding season, and it is likely that resident species disperse somewhat at these times.

The estuary itself provides habitat for a mixture of seabirds and waterbirds, but numbers are much lower than at Coquet Island. Bird numbers on the estuary appear to peak in September, and their spatial use of the area will vary from species to species. Some (such as waders) will tend to forage for invertebrates on intertidal areas, others such as wigeon will graze on any saltmarsh or eelgrass. Preferred foraging areas are uncertain. It is therefore concluded that impacts from foraging birds will be diffuse and widespread. Resting and roosting areas are likely to be situated in inaccessible and undisturbed locations. The contaminating influence of bird droppings is likely to be more intense in the immediate vicinity of any such areas in regular use. The remains of the North Jetty, around which the shellfishery may be constructed, may represent such an area. Gulls and cormorants were observed resting on the structure during the shoreline survey. Several eider ducks were also observed in the outer estuary, and these are likely to forage on mussels if they are introduced to the area. If rafts or bouchot poles are used in the fishery, these are also likely to be used for resting and roosting. However, until the cultivation methods and the layout of the fishery is decided, it is not possible to conclude which parts of it are likely to be most vulnerable to contamination of avian origin.

Up to 600 grey seals are regularly sighted hauled out or in the waters surrounding Coquet Island. No haul-out sites within the estuary have been identified. Seals will forage widely and it is highly likely that they enter the estuary on a regular basis, particularly during the main period of return migration of salmon and sea trout in summer and autumn. However, away from their haul-out sites their impacts may be considered as spatially diffuse and unpredictable, so their presence will have no bearing on the sampling plan. No other wildlife species which may have an influence on the sampling plan have been identified.

Domestic animals

Dog walking takes place on paths adjacent to the shoreline of the survey area and could represent a potential source of diffuse contamination to the near shore zone. The intensity of dog walking is likely to be higher closer to the more accessible paths, for example around Littleshore and on the footpath between the caravan park and the North Jetty. As a diffuse source, this will have little influence on the location of RMPs.

Summary of Pollution Sources

An overview of sources of pollution likely to affect the levels of microbiological contamination to the shellfish beds is shown in Table 5.1 and Figure 5.1.

Table 5.1: Qualitative assessment of seasonality of important sources of contamination.

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural runoff												
Urban runoff												
Continuous sewage discharges												
Intermittent sewage discharges	?	?	?	?	?	?	?	?	?	?	?	?
Birds												
Boats												

Red - high risk; orange - moderate risk; yellow - lower risk;

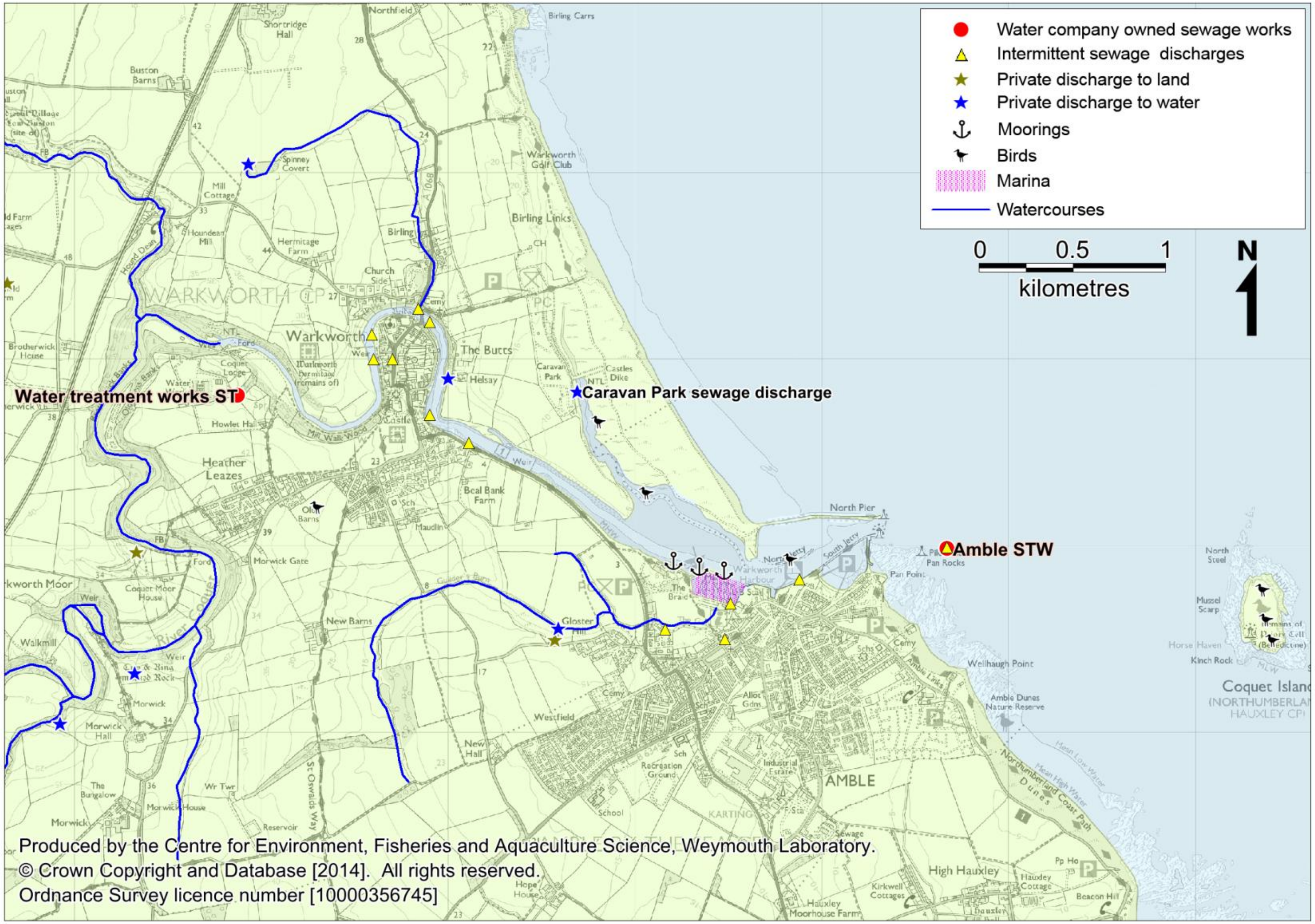

Figure 5.1: Summary of main contaminating influences

5.4. Hydrography

The Coquet estuary is a drowned river valley of about 5 km in length from its mouth to the tidal limit. It is narrow and shallow, with a maximum depth of 3.5 m relative to chart datum, and covers an area of 75 Ha, of which 45 Ha is intertidal. The intertidal areas are most extensive on the north shore of the outermost reaches. This includes that area around the derelict North Jetty where the fishery is planned. There is one side channel, which was formerly the main river channel until the present estuary mouth was opened during a storm 250 years ago. This emanates northwards and is located just upstream from the fishery area. There are solid breakwaters either side of the estuary mouth. Between Amble and Warkworth there is a weir that is covered at high water, but creates an impoundment at lower states of the tide. Outside of the estuary mouth the bathymetry generally slopes gently away to about 10 m around a kilometre offshore.

The tidal range at Amble is relatively large, at 4.2 m on spring tides and 2.0 m on neap tides, and this drives extensive water movements through the area. Tidal streams off the Northumberland coast flood in a southerly direction and ebb in a northerly direction. The plume from the Amble STW outfall, which lies to the south of the estuary mouth, will not therefore be carried into the estuary by the tides. Tidal streams will flood up the estuary, with the reverse occurring on the ebb. Therefore, shoreline sources will impact to either side of their location, along the bank to which they discharge. Impacts will decrease with distance as any plumes become more dilute. No information was found regarding current speeds or tidal excursions within the estuary so it is difficult to estimate the ranges across which they may impact. Sources of contamination discharging to the former river channel sidearm, and to the marina will principally impact the main channel down-estuary (in the vicinity of the planned fishery) as these areas will be filling during the flood tide. As such, the caravan park sewage discharge is likely to contribute to *E. coli* counts in shellfish there. Water draining from the marina and other sources on the south side of the estuary would primarily be an influence on the south shore.

Freshwater inputs may significantly modify the circulation of water around estuaries via density effects. Freshwater inputs are relatively high and may result in some stratification particularly at higher river flows. Any stratification will result in a shear in currents down the water column, with a net seaward flow in the upper layers and a net landward flow at depth. Perhaps more important in terms of contamination of shellfish, stratification will tend to entrain freshwater borne contamination in the surface layers meaning stocks at lower elevations may be more separated from such contamination. As such, if and when the fishery develops and rafts or poles are used, the RMP should at the top of the droppers or poles. Some turbulent mixing of the water column is likely to occur at the half tide weir, and there is likely to be a marked increase in average salinity downstream of this weir. Surface salinity measurements were taken during the shoreline survey during an ebbing tide under conditions of relatively low river flow. Salinities were 15.8 ppt in the outer estuary opposite the fishery, 12.1 ppt a short distance downstream of the half tide weir, and 4.5 ppt just upstream of the weir. They were accompanied by a gradient of increasing *E. coli* levels roughly aligning with the proportions of river and sea water represented by these salinities. This suggests that the river delivers the bulk of faecal indicator bacteria to the estuary, and demonstrates that low salinities occur in the vicinity of the fishery even at relatively low river discharge. It is likely that there are significant salinity fluctuations at the fishery across the high/low tidal cycle, but that the average salinity gradient across the length of the fishery is slight. Nevertheless, an RMP at the upstream end of the site would be most effective at capturing contamination carried into the estuary by the river.

The effects of wind may also modify tidally driven currents. Strong winds will typically drive surface currents, which will then create return currents at depth or along sheltered margins. The prevailing wind direction is from the southwest. The estuary is narrow and enclosed so is sheltered from winds from most directions. Strong easterly winds would blow up the estuary, thereby pushing surface flows in this direction. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great range of scenarios may arise. As well as driving surface currents, onshore winds will create wave action, which may resuspend contamination in sediments. However, the enclosed nature of the estuary, and the shelter afforded from North Sea swells by the breakwaters suggest that energetic wave action is unlikely to occur within it.

5.5. Summary of Existing Microbiological Data

The survey area has a limited microbiological monitoring history. This includes two bathing waters, and some limited mussel monitoring within the outer estuary. Figure 5.2 shows the locations of the monitoring points referred to in this assessment.

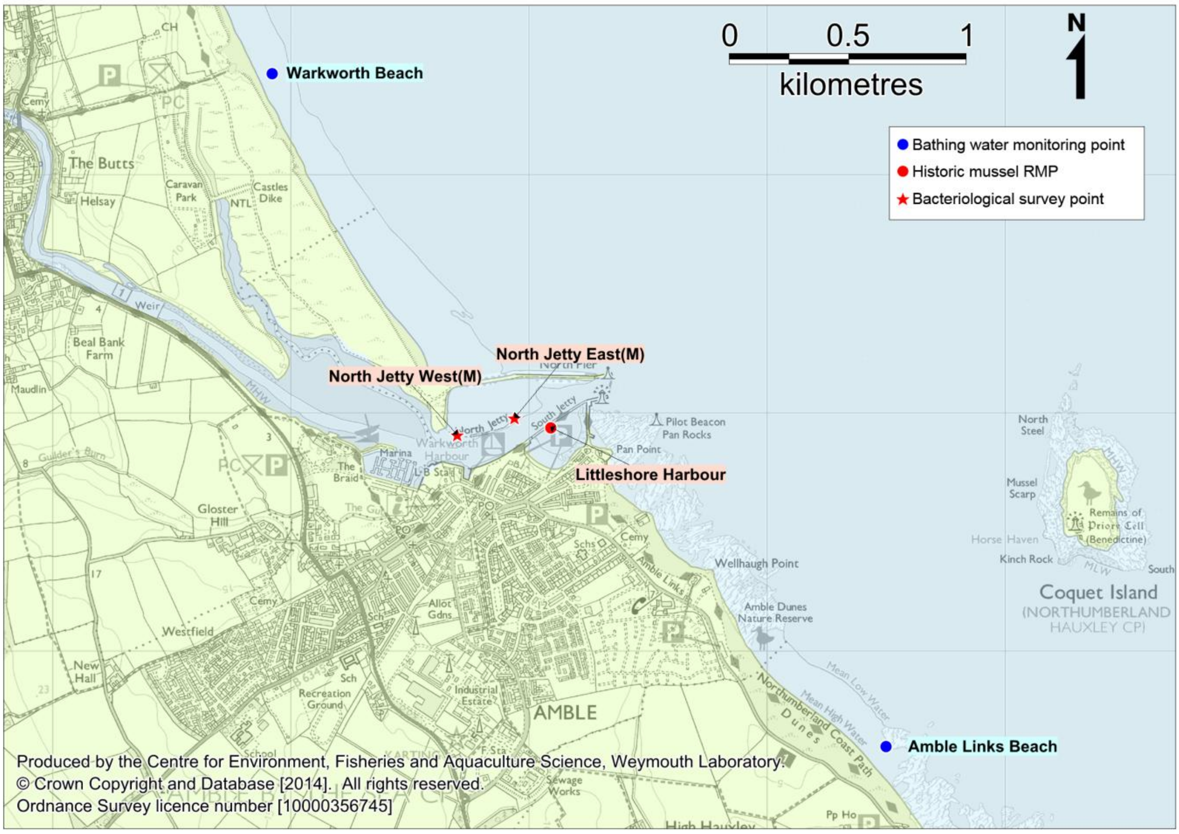

Figure 5.2: Microbiological sampling locations

Bathing waters

Around twenty water samples were taken from each of the bathing waters sites during each bathing season, which runs from May to September, and enumerated for faecal coliforms. The results are of limited relevance as both sites lie outside of the estuary on the open coast, about 2 km either side of its mouth. Faecal coliform concentrations were significantly higher on average at Amble Links Beach (geometric mean of 7.4 cfu/100ml) than at Warkworth Beach (geometric mean of 3.4 cfu/100ml). Occasional results exceeding 1000 cfu/100ml were recorded at both. The results of paired (same day) samples between the two were strongly correlated, suggesting they share similar sources of contamination.

During the period considered (2004-2011) results were similar each year, apart from in 2008 and 2009 when they were slightly higher on average. No significant correlations were found between faecal coliform levels and tidal state across both the spring neap and high low cycles. Significant correlations between faecal coliforms and rainfall were detected at both bathing water sites, where faecal coliform levels rapidly increased after rainfall, and remained higher for several days.

Shellfish Hygiene classification monitoring

There is one historic mussel RMP in the Amble production area that was sampled in 2004 and 2005, but has not been sampled since. It is located at Littleshore, opposite the planned fishery site. A total of 24 samples were taken, with a geometric mean result of 1,034 *E. coli* MPN/100g. Just over 20% of these samples returned a result exceeding 4600 *E. coli* MPN/100g, which would align with a C classification. This suggests that the possibility of a stable B classification at the planned fishery site is likely to be marginal. The maximum result was 18,000 *E. coli* MPN/100g.

Statistically significant correlations between *E. coli* levels and tidal state were found. Across the high low tidal cycle, sampling was targeted towards low water, but results were higher on average during the later stages of the ebb tide compared to the early stages of the flood. This suggests that upstream sources of contamination are the main influence. Across the spring/neap tidal cycle the correlation was weaker and the pattern less clear, but there appeared to be a tendency for higher results as the tide decreased in size from springs to neaps.

No relationships were found between rainfall or river flow and *E. coli* levels in mussels, apart from two positive correlations between rainfall and *E. coli* levels 3 and 5 days before sampling, which are suspected to be artefacts. This lack of influence is perhaps surprising given the River Coquet is likely to deliver most of the contamination the estuary receives. However, low salinities and abrupt fluctuations of salinity are likely to cause mussels to stop feeding, and shoreline survey measurements suggest that salinities even in the outer estuary and at low river flows are quite low. As such, there may be elevated levels of faecal indicator bacteria in the water column at times of high river discharge, but *E. coli* levels in mussels may not reflect this due to reduced feeding rates.

Bacteriological survey

Bagged mussels were deployed at the east and west ends of the North Jetty and allowed to equilibrate for two weeks. Northumberland County Council then sampled them on four occasions at intervals of around two weeks. The highest average and peak result was recorded at the more downstream site (North Jetty East), which was consistently more contaminated than the upstream site. The reasons for this difference are unclear, but may relate to either the slightly lower elevation at which North Jetty East is located resulting in increased immersion at lower states of tide when the water column is likely to be more contaminated. Alternatively, there may be a more regular presence of birds roosting towards the downstream end of the jetty. Three of the four results at North Jetty East exceeded 4,600 *E. coli* MPN/100g, and one exceeded 46,000 *E. coli* MPN/100g. This is not consistent with a B classification as preferred by the Amble Development Trust and the competent authority may denote the area as prohibited for harvest on hygiene grounds.

Appendices

Appendix I. Human Population

Figure I.1 shows population densities in census output areas within or partially within the survey catchment, derived from data collected from the 2011 census.

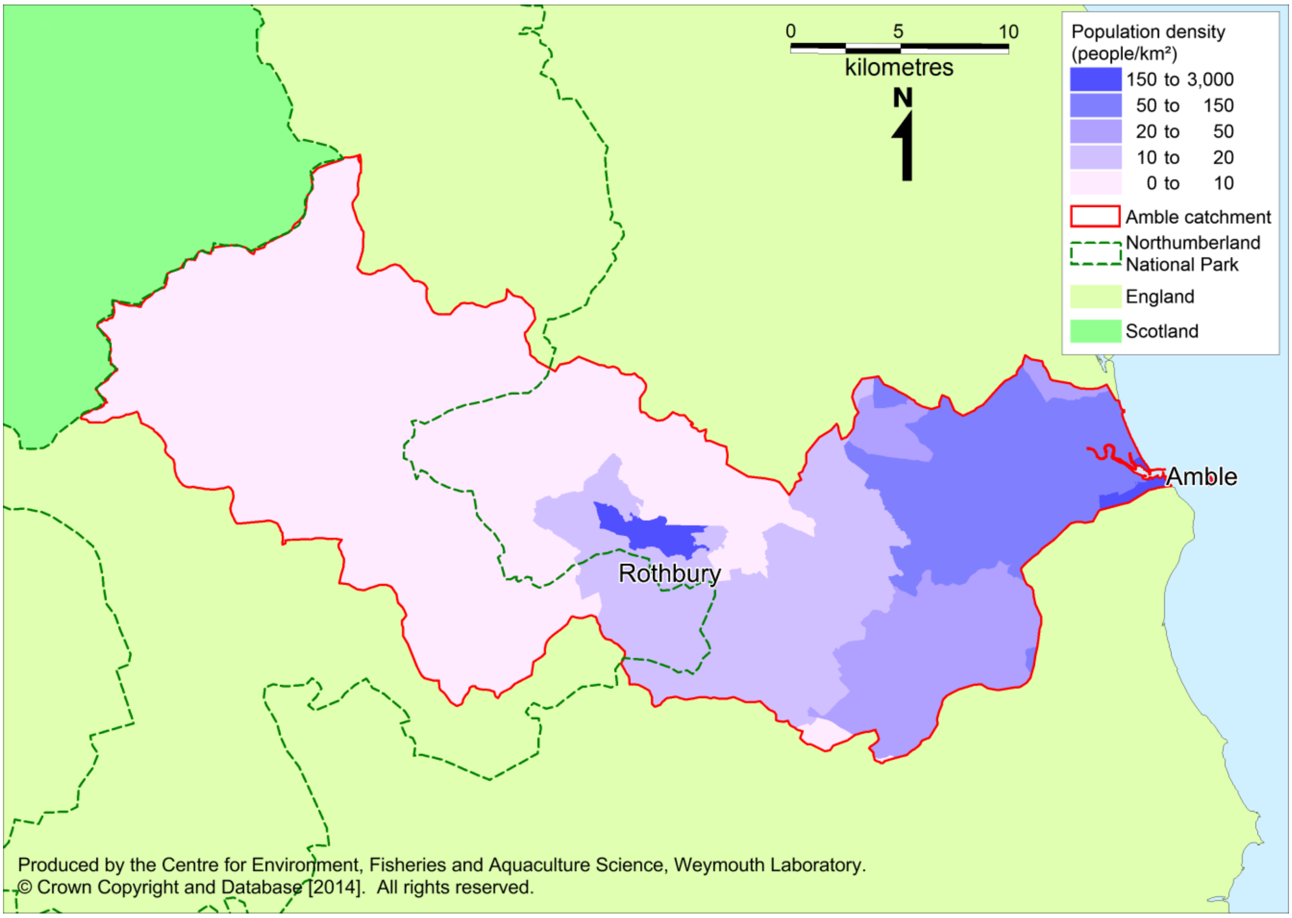

Figure I.1: Human population density in census areas in the survey catchment.

Total resident population within census areas contained within or partially within the catchment area was approximately 37,000 at the time of the last census. The largest settlements in the area are Rothbury (population ~1,500) and Amble (population ~6,000). The higher density areas within the catchment are around the Coquet estuary. With the exception of Rothbury and parts of Amble, the population density is below 100 people/km² throughout the catchment.

The Northumberland National Park makes up 45% of the survey catchment, and the catchment makes up 26% of the Northumberland National Park. The national park attracted 1.5 million visitors in 2012 (National Parks, 2012). It can therefore be expected that the population of the upper catchment will increase moderately during the warmer months with visitors to the national park. No tourism statistics are available for the lower catchment. However, there does not appear to be many tourist attractions in the area, and so while there may be an increase in population during the warmer months, this increase is not likely to be particularly large.

Of relevance to the survey because of its sewerage arrangements, the Coquet View holiday park hosts 228 static caravans (Northumberland County Council, 2012). Whilst it is open all year round peak occupancy is likely to occur during the summer months and around other holiday times.

Appendix II. Sources and Variation of Microbiological Pollution: Sewage Discharges

All permitted sewage discharges within the hydrological catchment are mapped in Figure II.1. Figure II.2 shows those local to the fishery. The source of this information was the Environment Agency permit database (October 2013 update).

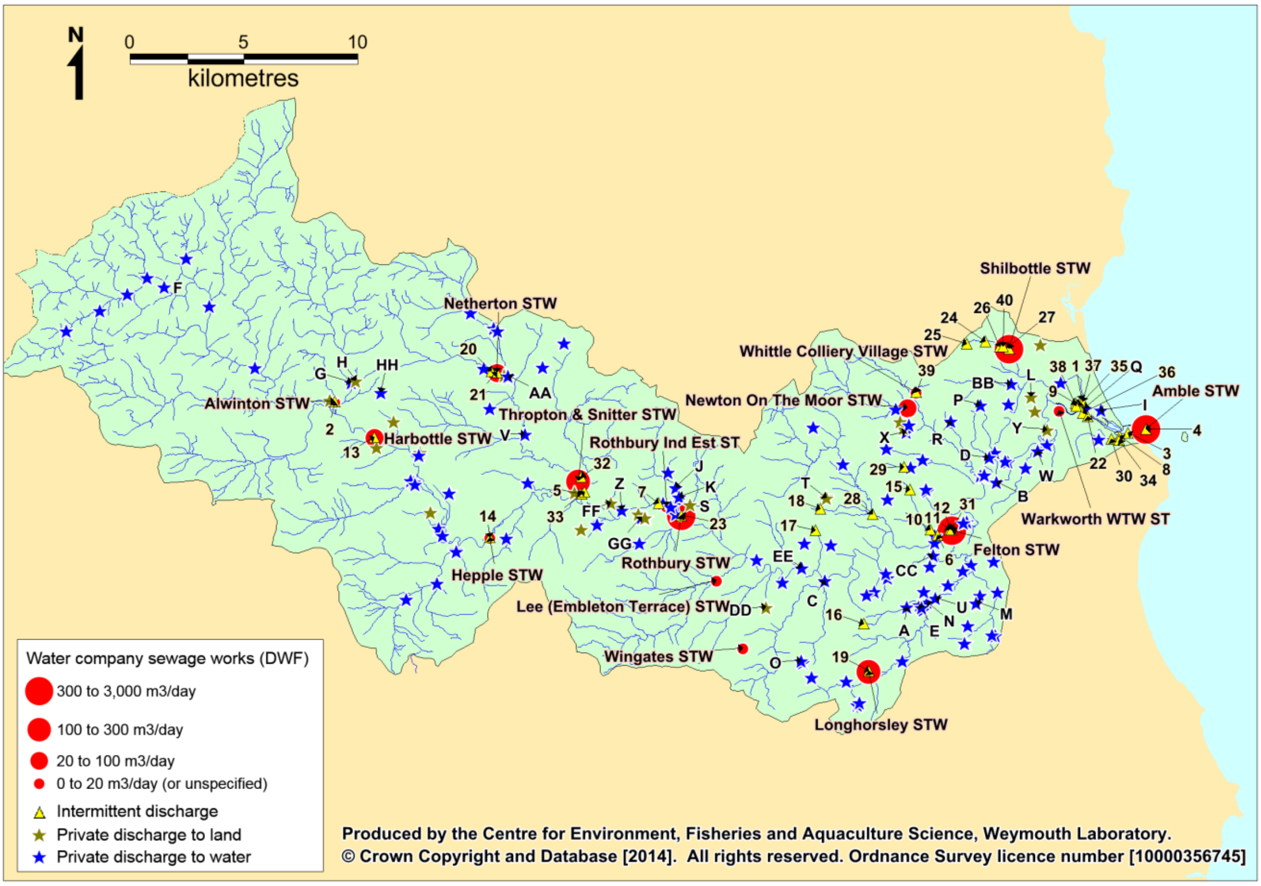

Figure II.1: All permitted sewage discharges in the Coquet catchment

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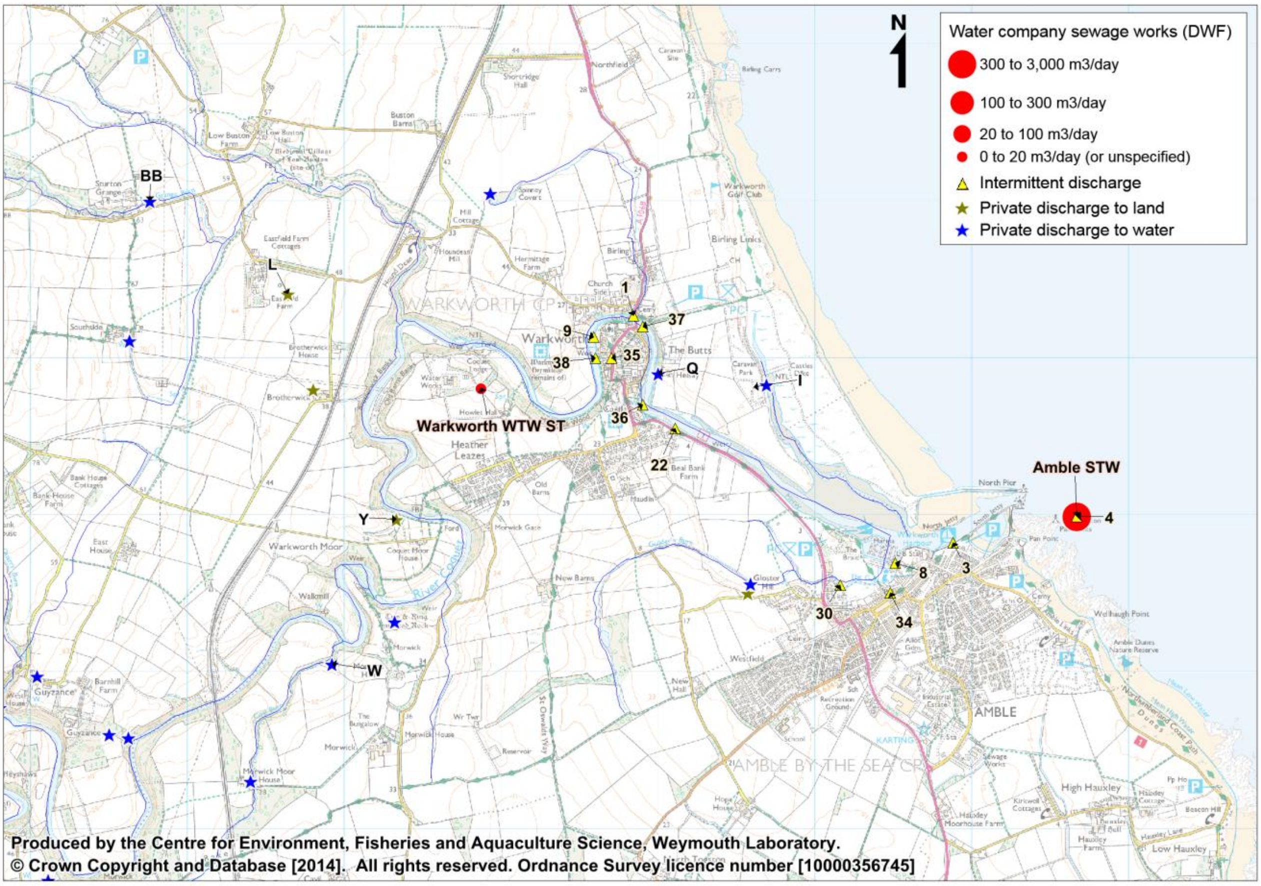

Figure II.2: Sewage discharges within the local area

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There are 16 water company owned sewage treatment works within the catchment, details of which are presented in Table II.1.

Table II.1: Details of continuous water company sewage works

Name	NGR	Treatment	Dry Weather Flow (m^3/day)	Estimated bacterial loading (cfu/day)*	Receiving environment
Alwinton STW	NT9209406188	Biological Filtration	9.5	2.7×10^{10}	Hosedon Burn
Amble STW	NU2767004990	Biological Filtration	2512	7.0×10^{12}	North Sea
Felton STW	NU1915000560	Biological Filtration	971	2.7×10^{12}	River Coquet
Harbottle STW	NT9384004630	Package Plant	29	8.1×10^{10}	River Coquet
Hepple STW	NT9890000250	Septic Tank	12	1.2×10^{12}	River Coquet
Lee (Embleton Terrace) STW	NZ0883098360	Septic Tank	Unspecified	-	Forest Burn
Longhorsley STW	NZ1552094390	Biological Filtration	213	6.0×10^{11}	Paxtondean Burn
Netherton STW	NT9921007480	Biological Filtration	30	8.4×10^{10}	Netherton Burn
Newton On The Moor STW	NU1721005940	Biological Filtration	35	9.8×10^{10}	Newton Burn
Rothbury Ind. Est. ST	NU0665001620	Septic Tank	Unspecified	-	River Coquet
Rothbury STW	NU0730001200	Biological Filtration	512	1.4×10^{12}	River Coquet
Shilbottle STW	NU2167008510	Biological Filtration	376	1.1×10^{12}	Tyelaw Burn

Name	NGR	Treatment	Dry Weather Flow (m^3/day)	Estimated bacterial loading (cfu/day)*	Receiving environment
Thropton & Snitter STW	NU0279102734	Biological Filtration	242	$6.8x10^{11}$	Wreigh Burn
Warkworth WTW ST	NU2387005810	Septic Tank & Filter	Unspecified	-	R. Coquet trib.
Whittle Colliery Village STW	NU1760006600	Unspecified	Unspecified	-	Ogle Letch
Wingates STW	NZ1000095400	Unspecified	Unspecified	-	Tod Burn Trib.

*faecal coliforms (cfu/day) based on geometric base flow averages from a range of UK STWs (Table II.2).

Table II.2: Summary of reference faecal coliform levels (cfu/100ml) for different sewage treatment levels under different flow conditions.

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
Storm overflow (53)	-	-	200	$7.2x10^6$
Primary (12)	127	$1.0x10^7$	14	$4.6x10^6$
Secondary (67)	864	$3.3x10^5$	184	$5.0x10^5$
Tertiary (UV) (8)	108	$2.8x10^2$	6	$3.6x10^2$

Data from Kay et al. (2008b).
n - number of samples.
Figures in brackets indicate the number of STWs sampled.

The largest of these works is Amble STW, which discharges about 350 m east of the harbour entrance in about 5 m depth of water. The extent of its influence on the shellfishery will depend largely on water circulation patterns. All other water company sewage works discharge to the Coquet or tributaries thereof. Their combined discharge volumes are roughly equal to that of Amble STW, although some of the smaller ones only provide septic tank treatment. Faecal indicator bacteria from these will therefore be delivered via the river. Depending on river transit times, some natural die-off of micro-organisms is likely to occur between the point of discharge and the shellfisheries, particularly for those further inland.

In addition to the continuous sewage discharges, there are various intermittent discharges associated with the water company sewerage networks. Details of these are shown in Table II.3.

Table II.3: Intermittent discharges in the Coquet hydrological catchment

Label	Name	Grid reference	Receiving water
1	A1086 Road Bridge SSO	NU2484006270	Coquet Estuary
2	Alwinton STW	NT9209406188	Hosedon Burn
3	Amble Harbour PS	NU2688004820	Coquet Estuary
4	Amble STW	NU2767004990	North Sea
5	Church Fields PS, Thropton	NU0293002140	River Coquet
6	CSO Main Street	NU1854000330	River Coquet
7	Rothbury PS & CSO	NU0631001740	River Coquet

Label	Name	Grid reference	Receiving water
8	CSO Turner Street	NU2651004690	Coquet Estuary
9	Ejector Station No 1	NU2459006130	Coquet Estuary
10	Felton Lodge PS	NU1822000570	Ditch To Back Burn
11	Felton Recreation Ground Combined	NU1905000590	River Coquet
12	Felton STW	NU1913000570	River Coquet
13	Harbottle STW	NT9384004630	River Coquet
14	Hepple STW	NT9890000250	River Coquet
15	Lanehead PS	NU1733002340	East House Burn
16	Linden Hall Sewage PS	NZ1530096460	Bywell Letch
17	Longframlington CSO	NU1319000550	Coquet Trib.
18	Longframlington SSO	NU1340001500	Fence Burn
19	Longhorsley STW	NZ1552094390	Paxtondean Burn
20	Netherton CSO	NT9897007530	Netherton Burn
21	Netherton STW	NT9921007480	Netherton Burn
22	Pumping Station No4	NU2510905551	Coquet Estuary
23	Rothbury STW	NU0730001200	River Coquet
24	Shilbottle CSO	NU2064008830	Tyelaw Burn
25	Shilbottle CSO A	NU1980008740	Tyelaw Burn
26	Shilbottle CSO D	NU2125008620	Tyelaw Burn
27	Shilbottle STW	NU2167008510	Tyelaw Burn
28	Swarland Fence PS	NU1568001260	Fence Burn
29	Swarland Old Sewage Works CSO	NU1707003330	Mere Burn
30	The Wynd PS	NU2616004550	The Gut
31	Thirston PS	NU1913000580	River Coquet
32	Thropton & Snitter STW	NU0290002900	Wreigh Burn
33	Thropton CSO	NU0304002241	Wreigh Burn
34	Turner Street SSO	NU2648004500	Coquet Estuary
35	Warkworth PS	NU2470006000	Coquet Estuary
36	Warkworth PS No3	NU2490005700	Coquet Estuary
37	Warkworth Sewerage System SSO	NU2490006200	Coquet Estuary
38	Warkworth Sewerage System SSO	NU2460006000	Coquet Estuary
39	Whittle Colliery Village STW	NU1760006600	Ogle Letch
40	Woodhouse Farm No 2	NU2141008620	Tyelaw Burn

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Most of these are located inland, and discharge to the River Coquet and tributaries. There are also clusters of intermittent discharges to the estuary at Warkworth and Amble. Additionally Amble STW has an overflow discharge at the same location as the main (continuous) outfall. Those discharging to the harbour at Amble all discharge to the opposite bank to which the fishery is located. Without any spill records it is difficult to assess their potential impacts aside from noting their location and potential to spill storm or untreated sewage.

Whilst the majority of the survey area is served by water company sewerage infrastructure, there are also a number of private discharges in the catchment. Of the permitted discharges with a sewage content, 23 discharge to soakaway and 130 discharge to water. Where specified, they are generally treated by small works such as package plants or septic tanks. Table II.4 details private discharges >5 m^3/day (max daily flow).

Table II.4: Details of private discharges over 5 m^3/day in the survey catchment

Label	Property served	Grid reference	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	7 Dwellings (Burgham)	NZ1734097070	Biodisc	5	Bywell Letch
B	Acklington Park Farm	NU2095002530	Septic Tank	5	Coquet trib.
C	Anglers Arms	NZ1371098570	Package Plant	10	River Coquet
D	Bankhouse Farm	NU2095005050	Biological Filtration	11	River Coquet
E	Burgham Golf & Country Club	NZ1716097050	Biological Filtration	17	Longdike Burn
F	Carshope Troop Shelter	NT8463011230	Septic Tank	5.23	River Coquet
G	Clennel Farm	NT9283007050	Septic Tank	5	Alwin
H	Clennell Hall Riverside Holiday Pak	NT9303007120	Package Plant	20	Groundwater
I	Coquet View Caravan Site	NU2568505830	Oxidation Ditch	16	Coquet Estuary
J	Cragside Estate	NU0710002470	Package Plant	52	Debdon Burn
K	Cragside House	NU0720002020	Septic Tank	5	Debdon Burn
L	Eastfield Hall	NU2258006470	Septic Tank & Filter	10	Groundwater
M	Eshott Hall Estate	NZ2022097409	Biodisc	45	Eshott Burn trib.
N	Felmoor Park Limited	NZ1811297419	Package Plant	50.4	Longdike Burn
O	Forget Me Not Caravan Park	NZ1256094830	Reedbed	20	Coquet trib.
P	Hartlaw Farm	NU2034006080	Package Plant	5	Quarry Burn
Q	Helsay Farm, Residential Properties	NU2500005900	Septic Tank	5	Coquet Estuary
R	High Hazon Farm	NU1922005720	Package Plant	5	Hazon Burn trib.
S	Lakeside Toilet Block	NU0768001680	Septic Tank	5	Groundwater
T	Leisure Centre	NU1365001970	Septic Tank	5	Groundwater
U	Longdyke Country Park	NZ1844097590	Reedbed	5	Longdike Burn
V	Low Trewhitt Farm	NU0044004770	Septic Tank	5	Wreigh Burn
W	Morwick House & Assoc'D Properties	NU2292004050	Septic Tank	5	Coal Burn trib.
X	Newton Hall	NU1691204791	Package Plant	20	Hazon Burn trib.
Y	Riverside Holiday Park	NU2333004970	Septic Tank	5	Groundwater
Z	Rothbury Golf Club	NU0470001440	Septic Tank	5	River Coquet
AA	STP Serving Burnfoot Holiday Cottages	NT9968707329	Package Plant	8	Scrainwood Burn
BB	Sturton Grange	NU2173007000	Package Plant	5	Grange Burn
CC	Thirston New Houses	NZ1820099250	Package Plant	5	Thirston Burn trib.
DD	Tindles Hill Caravan Park	NZ1100097200	Septic Tank	5	Groundwater
EE	Todstead Farm	NZ1258098920	Biodisc	7	Coquet trib.
FF	Westcliffe House	NU0424001770	Septic Tank	5	Groundwater
GG	Whittontower, Pele Tower & Coach House	NU0556001130	Septic Tank & Filter	5	Coquet trib.
HH	Wilkinson Park	NT9413006600	Biodisc	5	Coquet trib.

Those discharging to soakaway should be of no impact on coastal waters assuming they are functioning correctly. Of those discharging to water, the vast majority discharge to the River Coquet and tributaries. As such, they will contribute to the bacterial loading delivered to the estuary by this watercourse. There are two private discharges direct to the estuary. One is from a septic tank at Warkworth (Q) and the other is from the Coquet View Caravan Park (I). Both of these discharge up-estuary from the shellfishery, so as with all other private discharges monitoring at the up-estuary end of the shellfishery would be most effective at capturing their impacts. The caravan park is likely to be of more significance by virtue of its location. It includes 228 static caravans (Northumberland County Council, 2012) so if it is ever in full occupancy there may be somewhere between 500 and 1,000 people on site. The Environment Agency advised that this discharge is not compliant with its permit in terms of both effluent quality and volume. Effluent quality has been improved sufficiently following maintenance. Discharge volumes are actually in the region of 40-90 m^3/day rather than the 16m^3/day indicated on the permit, and that the owner has submitted a request for a permit variation to reflect this. The new permit conditions have yet to be determined, and may require an investigation of the feasibility of relocating this discharge. A recent planning application to extend the park to accommodate a further 124 caravans has been submitted, but no decision has been made yet. The park is open all year round, but peak occupancy is likely to occur during the summer holidays.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

Land cover within the Coquet catchment is principally grassland (53%), with significant areas used for arable farming (18%). The remainder comprises of a mix of woodland, heath and peat bog, with a very small amount of urbanised area (NERC, 2012). Arable land is mainly in the lower catchment, various grades of pasture are distributed throughout, and the natural areas are more extensive further inland. Table III.1 presents livestock numbers and densities for the catchment. These data were provided by Defra and are derived from the June 2010 census as this provides more details than censuses undertaken in subsequent years. Geographic assignment of animal counts in this dataset is based on the allocation of a single point to each farm, whereas in reality an individual farm may span the catchment boundary. Nevertheless, Table III.1 should give a reasonable indication of the numbers and types of livestock within the catchment.

Table III.1: Summary statistics from 2010 livestock census for the Coquet catchment

Cattle		Sheep		Pigs		Poultry	
No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)
17,945	29.7	177,843	294.2	1,206	2.0	3,439	5.7

Data from Defra

The concentration of faecal coliforms excreted in the faeces of animals and humans and corresponding loads per day are summarised in Table III.2.

Table III.2: Levels of faecal coliforms and corresponding loads excreted in the faeces of warm-blooded animals.

Animal	Faecal coliforms (No./g wet weight)	Excretion rate (g/day wet weight)	Faecal coliform load (No./day)
Chicken	1,300,000	182	2.3×10^8
Pig	3,300,000	2,700	8.9×10^8
Human	13,000,000	150	1.9×10^9
Cow	230,000	23,600	5.4×10^9
Sheep	16,000,000	1,130	1.8×10^{10}

Data from Geldreich (1978) and Ashbolt et al. (2001).

Table III.1 indicates that there are large numbers of sheep within the catchment, as well as significant numbers of cattle and a few pigs and poultry. No livestock was recorded in the immediate vicinity of the estuary during the shoreline survey.

Livestock manures will either be deposited directly on pastures by grazing animals, or collected from farmyards and poultry houses and spread on both arable land and pasture. Sheep, which are the dominant livestock type, deposit the majority of their droppings directly on pasture and generate little manure. Cattle farming is largely beef rather than dairy, so slurry based systems are not common. Manures are generally composted rather than applied as slurries, and the composting process reduces bacterial content due to the heat generated.

Faecal matter deposited on land may be washed into watercourses which will carry it to coastal waters. Watercourses which animals can access will be more vulnerable than those that are fenced off. Given the ubiquity of farmland throughout the survey area, all watercourses may potentially be affected at times. The geographical pattern of agricultural impacts are likely to closely mirror those of land runoff, with the vast majority delivered to the head of the estuary, and potential minor hotspots where any smaller watercourses join the lower estuary. As the primary mechanism for mobilisation of faecal matter deposited on pastures into watercourses is via land runoff, fluxes of agricultural contamination into coastal waters will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the 'first flush').

There is likely to be seasonality in levels of contamination originating from livestock. Numbers of sheep and cattle will increase significantly in the spring with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. During the warmer months, cattle are likely to access watercourses more frequently to drink and cool off, although sheep do not tend to do this. During winter cattle may be transferred from pastures to indoor sheds, and at these times manure will be collected and stored for later application to fields. There are peaks in spreading in the spring, then in the summer after crops and silage are harvested. Farms with smaller storage capacities (typically hill farms) also spread on frozen ground during the winter to empty their stores.

Therefore peak levels of contamination from grazing livestock may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures, or on a more localised basis if wet weather follows a manure application, which mainly occur in the spring and summer or winter.

Appendix IV. Sources and variation of microbiological pollution: Boats

The discharge of sewage from boats is a potential source of bacterial contamination to the survey area. Boat traffic in the area is limited to fishing boats and smaller recreational craft such as yachts, sailing dinghies and kayaks. Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

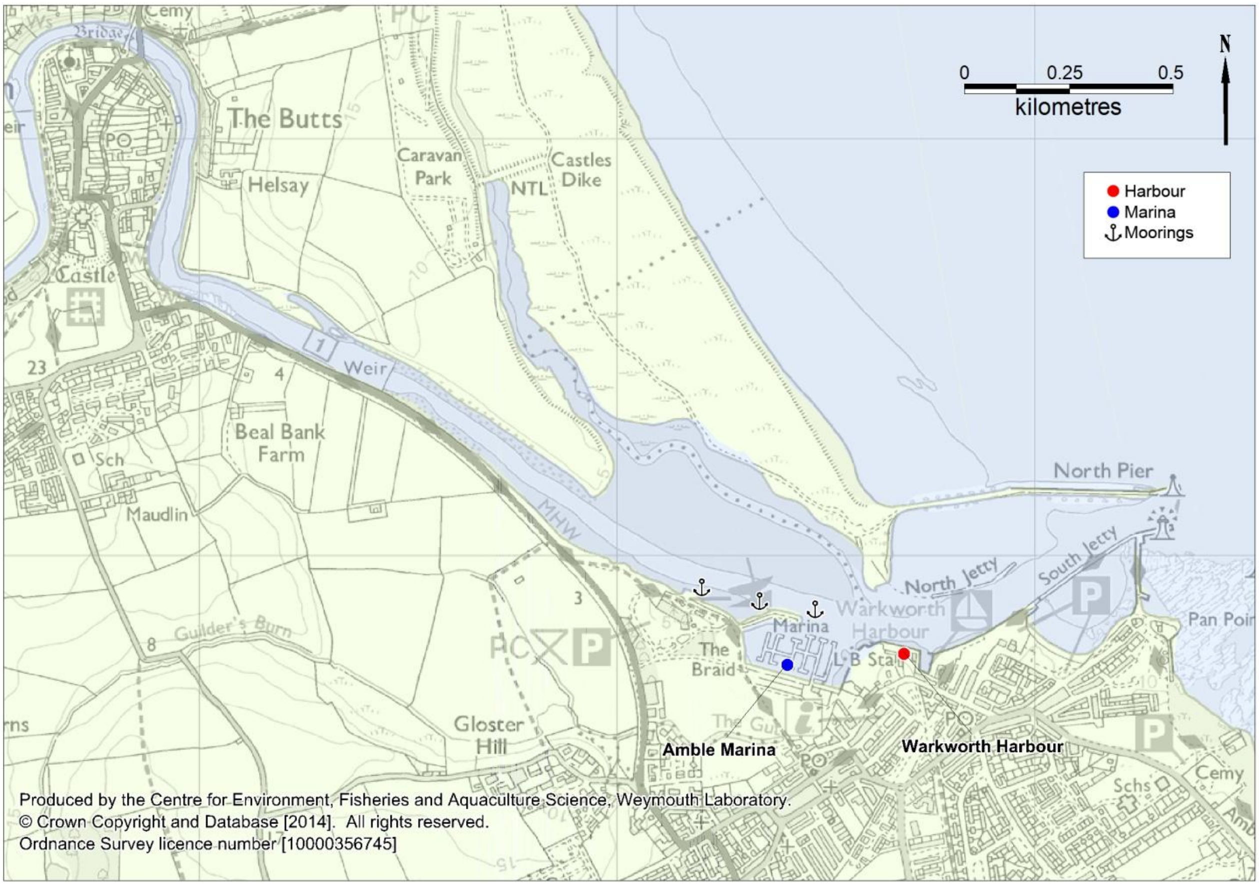

Figure IV.1 Boating Activity in the Coquet estuary

Amble marina is situated on the southern shore of the estuary close to its mouth and provides in excess of 250 berths (Amble Marina website, 2014). No sewage pump-out facilities are available here, with the closest located in the Sunderland Marina in the River Wear and St. Peters Marina in the Tyne River (The Green Blue, 2010). There are also numerous swinging and drying moorings located in the lower reaches of the estuary for recreational craft, the locations of which are shown in Figure IV.1.

Coquet Yacht Club offers a variety of cruising and racing throughout the year for both yachts and the smaller dinghies. Coquet Shorebase Trust, situated close to Warkworth Harbour offers a variety of watersports courses and training including dinghy sailing, canoeing, kayaking, windsurfing and power boating. Wildlife tours operate from Amble to Coquet Island during the spring and summer months.

The largest commercial fishing fleet in Northumberland operates from the estuary (NIFCA, 2012), of which 27 fishing vessels under 10 metres in length and 5 over 10 metres are listed as having Amble as their home port (MMO, 2014). Fishing efforts include trawling for prawns in the winter and fish in the summer, as well as potting for crabs and lobsters (NIFCA, 2012). There is no commercial port within the estuary and therefore merchant shipping is unlikely to enter the area so does not pose a threat in terms of microbiological contamination.

It is therefore concluded that boat traffic within the estuary is limited to pleasure craft and fishing vessels. Smaller pleasure craft such as sailing dinghies and windsurfers will not have onboard toilets and so are unlikely to make overboard discharges. Private vessels such as yachts and motor cruisers of a sufficient size are likely to make overboard discharges from time to time. This may occur either when the boats are moored or at anchor, particularly if they are in overnight occupation, or while they are navigating through the area. Occupied yachts on pontoon berths may be less likely to make overboard discharges as this is somewhat antisocial in the crowded marina setting, and facilities on land are easier to access. Therefore, whilst overboard discharges may be made anywhere within the survey area, it is likely that the moorings and the main navigation routes through the area are most at risk of contamination from this source. Peak pleasure craft activity is anticipated during the summer, so associated impacts are likely to follow this seasonal pattern. It is difficult to be more specific about the potential impacts from boats and how they may affect the sampling plan without any firm information about the locations, timings and volumes of such discharges.

Appendix V. Sources and Variation of Microbiological Pollution: Wildlife

The Coquet estuary encompasses a variety of habitats including intertidal mudflats, sand dunes, sand spit and limited saltmarsh. These and other coastal features support significant local populations of birds and other wildlife.

The main wildlife aggregation in the vicinity is the major seabird breeding colony at Coquet Island. Studies in the UK have found 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). In a survey undertaken during the breeding season in 2000, 23,362 pairs of birds were recorded, of which the majority (around 73%) were Atlantic Puffins (Mitchell *et al*, 2004). Other species included Black-headed Gull, Sandwich Tern, Common Tern, Black-legged Kittiwake and the Roseate Tern. The puffins are reported to arrive from the open sea in March, and depart at the end of July (Amble Puffin Festival, 2014). They range widely during foraging, but do not typically use estuarine habitats, preferring the open sea. As such, they are unlikely to be much of an influence on the fishery. Other species such as gulls are likely to forage in the vicinity of the estuary, but away from the breeding colony their impacts may be considered diffuse so will have no bearing on the sampling plan. Some of these species (e.g. terns) migrate away from the area outside of the breeding season, and it is likely that resident species disperse somewhat at these times.

The estuary itself provides habitat for a mixture of seabirds and waterbirds, but numbers are much lower than at Coquet Island. Gull species recorded during bird counts co-ordinated by the British Trust for Ornithology (Austin *et al*, 2014) included Black Headed, Herring and Greater Black-backed gulls. Their five-year average peak counts (2007/8 to 2011/12) were 629, 168 and 102 respectively, and their peak numbers all occurred in September. The main wildfowl species was Wigeon, with five-year average peak counts of 313 during February. Other wildfowl species with counts exceeding 50 were Eider (90, September), Teal (65, December) and Mute Swan (52, June). Waders with five-year average peak counts exceeding 50 were Lapwing (549, November), Golden Plover (156, September), Redshank (155, September) and Dunlin (129, February). Based on this information, bird numbers would appear to peak in September. The spatial use of the area will vary from species to species. Some (such as waders) will tend to forage for invertebrates on intertidal areas, others such as wigeon will graze on any saltmarsh or eelgrass. Preferred foraging areas are uncertain. It is therefore concluded that impacts from foraging birds will be diffuse and widespread, either being deposited directly on the intertidal areas, or washed into the estuary through tidal inundation of salt marsh or land runoff.

Resting and roosting areas are likely to be situated in inaccessible and undisturbed locations. The contaminating influence of bird droppings is likely to be more intense in the immediate vicinity of any such areas in regular use. The remains of the North Jetty, around which the shellfishery may be constructed, may represent such an area. Gulls and cormorants were observed resting on the structure during the shoreline survey. Several eider ducks were also observed in the outer estuary, and these are likely to forage on mussels if they are introduced to the area. If rafts or bouchot poles are used in the fishery, these are also likely to be used for resting and roosting. However, until the cultivation methods and the layout of the fishery is decided, it is not possible to conclude which parts of it are likely to be most vulnerable to contamination of avian origin.

Up to 600 grey seals are regularly sighted hauled out or in the waters surrounding Coquet Island (Visit Northumberland, 2014). No haul-out sites within the estuary have been identified. Seals will forage widely and it is highly likely that they enter the estuary on a regular basis, particularly during the main period of return migration of salmon and sea trout in summer and autumn. However, away from their haul-out sites their impacts may be considered as spatially diffuse and unpredictable, so their presence will have no bearing on the sampling plan. No other wildlife species which may have an influence on the sampling plan have been identified.

Appendix VI. Meteorological Data: Rainfall

The locations of the Linbriggs (upper catchment) and Warkworth (lower catchment) weather stations are shown in Figure VI.1. The monthly rainfall data for these stations are plotted in Figure VI.2 and Figure VI.3.

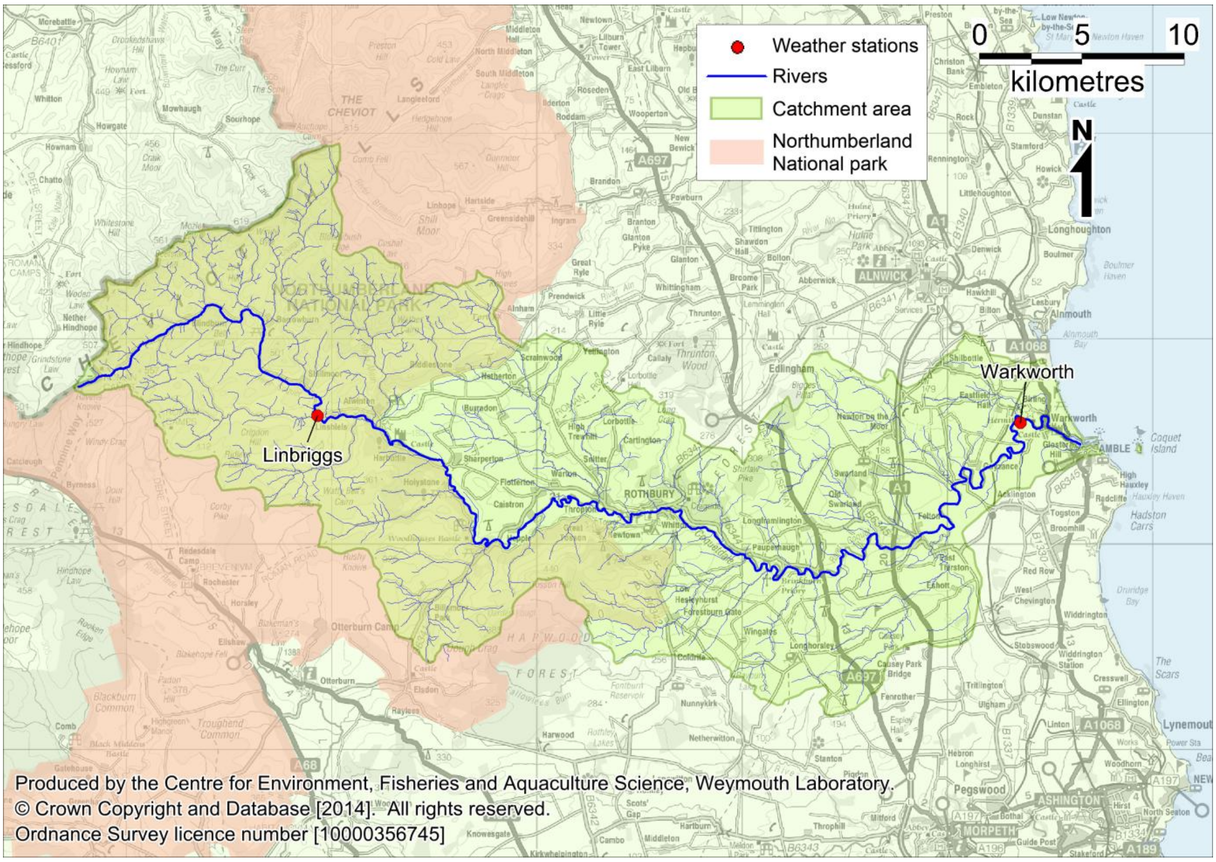

Figure VI.1: Locations of the Linbriggs and Warkworth weather stations

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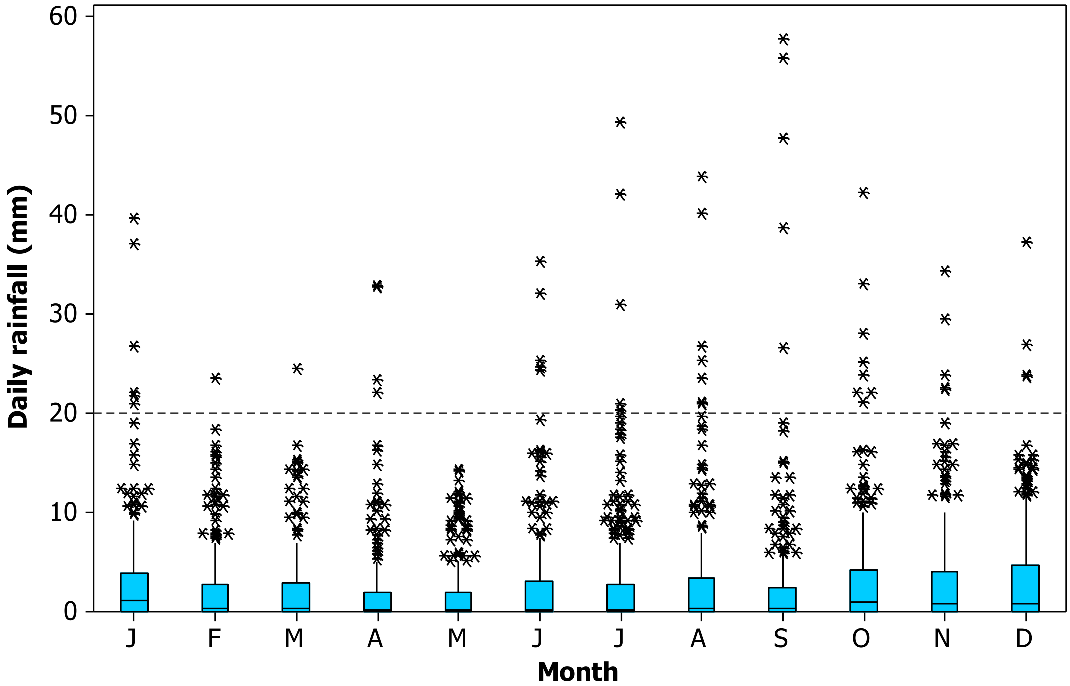

Figure VI.2: Boxplot of daily rainfall totals at Linbriggs, January 2004 to December 2013.
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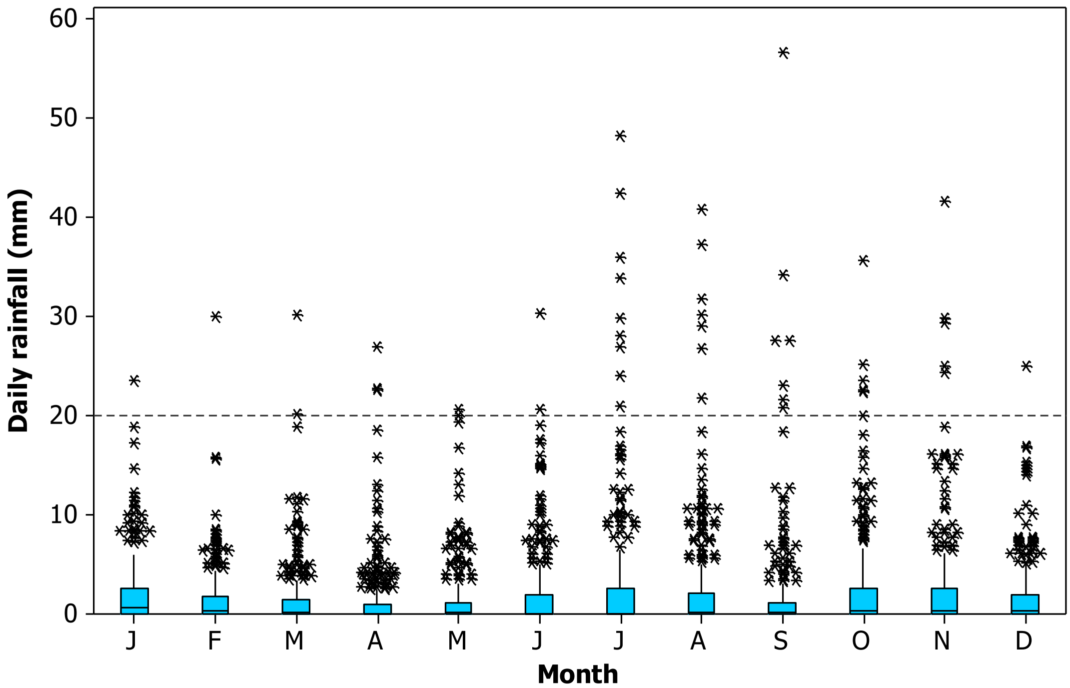

Figure VI.3: Boxplot of daily rainfall totals at Warkworth, January 2004 to December 2013.
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The Linbriggs and Warkworth weather stations received an average of 968 mm and 710 mm per year respectively between 2004 and 2014. Rainfall data from both stations indicate some seasonal variation with heavier rainfall in the second half of the year. At Linnbriggs, October had the highest average rainfall, whereas at Warkworth, July had the highest average rainfall. Daily totals of over 20 mm were recorded on 1.4% of days at Linbriggs and 1.2% of days at Warkworth. No rainfall was recorded on 36% and 44% of days between 2004 and 2014 at Linbriggs and Warkworth respectively.

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSO) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al*., 2003). Representative monitoring points located in parts of shellfish beds closest to rainfall dependent discharges and freshwater inputs will reflect the combined effect of rainfall on the contribution of individual pollution sources. Relationships between levels of *E. coli* and faecal coliforms in shellfish and water samples and recent rainfall are investigated in detail in Appendices XI and XII.

Appendix VII. Meteorological Data: Wind

The strongest winds are associated with the passage of deep depressions across or close to the UK. The frequency of depressions is greatest during the winter months so this is when the strongest winds normally occur (Met Office, 2012).

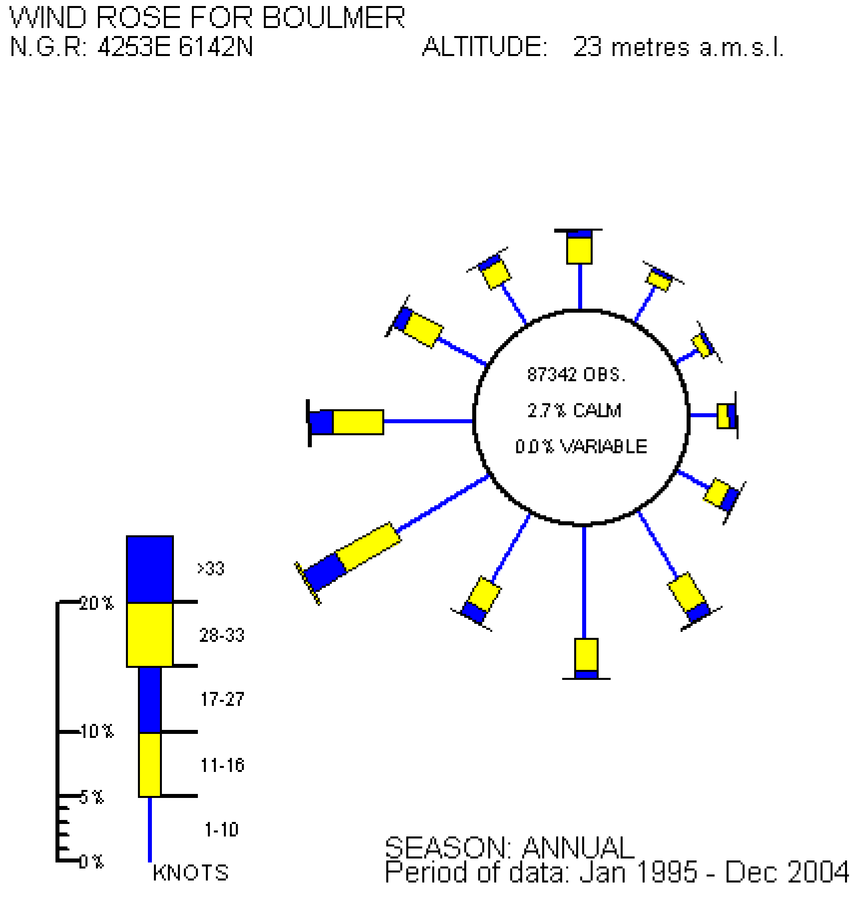

Figure VII.1: Wind Rose for Boulmer

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The wind rose for Boulmer is typical of open, level locations across the region. There is a prevailing south-westerly wind direction throughout the year. During spring there is also a high frequency of north to north-easterly wind's due to a build up of pressure over Scandinavia (Met Office, 2012). Periods of very light or calm winds are more prevalent inland, with coastal areas having similar wind directions to inland locations but higher wind speeds (Met Office, 2012). The Coquet estuary opens out to the east and has a narrow constricted mouth; it is therefore reasonably sheltered from the prevailing winds but will be exposed to winds from the eastern quadrant. It is surrounded by low lying land which will offer a limited amount of shelter to the prevailing winds.

Appendix VIII. Hydrometric Data: Freshwater Inputs

The Coquet estuary has a hydrological catchment of about 600 km² draining into it (Northumbrian Water, 2014). The vast majority of this area (~98%) is drained by the River Coquet, which discharges to the head of the estuary at Warkworth (Figure VIII.1). There are several further minor watercourses draining to the estuary at various locations.

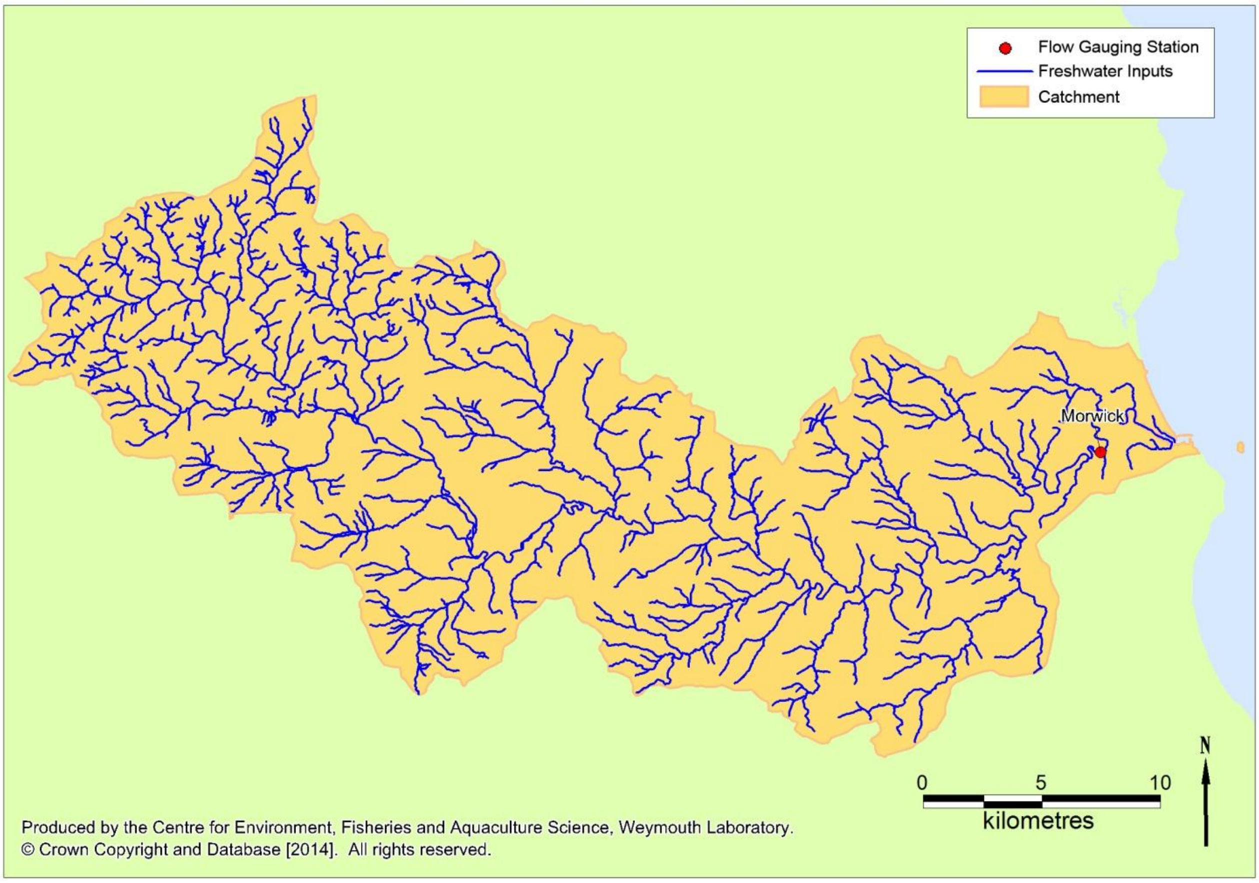

Figure VIII.1: Main Watercourses in the Coquet catchment

The River Coquet is a spate river of about 64 km in length that originates in the Cheviot Hills. Its upper reaches drain a mixture of blanket bog, heathland and grassland which are grazed by sheep and some cattle. Pasture and arable land dominate the lower catchment and urban areas are mainly located here. There are several sewage discharges to the Coquet and tributaries. It will therefore deliver contamination of both sewage and agricultural origin to the estuary. The upper reaches are hilly, with a maximum elevation of 777 m, but the topography becomes flatter and lower towards the Northumbrian coastal plain, which lies adjacent to the coast. The geology of the upper catchment comprises of impermeable Devonian and Igneous rocks. The lower catchment is underlain with a mixture of more permeable sedimentary limestone, shales and sandstones (English Heritage, 2012; Environment Agency, 2009). The river therefore responds rapidly to rainfall, a high proportion of which will run off, particularly in the upper catchment.

There are three flow gauging stations available for the River Coquet. For this survey, Morwick gauging station will be considered as it is situated the furthest downstream (~3.5 km upstream of the tidal limit) and will therefore be best representative of discharge volumes delivered to the estuary. Summary statistics for this station are presented in Table VIII.1 where data for mean flow, Q95 and Q10 cover the period from 2004-2014.

Table VIII.1 Summary flow statistics for the Morwick gauging station (2004-2014)

Watercourse	Station Name	Catchment Area (Km²)	Mean Annual Rainfall 1961-1990 (mm)	Mean Flow (m^3s^{-1})	Q95[1] (m^3s^{-1})	Q10[2] (m^3s^{-1})
Coquet	Morwick	569.8	850	9.53	1.38	20.61

[1]Q95 is the flow that is exceeded 95% of the time (i.e. low flow). [2]Q10 is the flow that is exceeded 10% of the time (i.e. high flow).
Data from NERC, 2012 and the Environment Agency.

Base flows (Q95) are less than 15% of mean flows, and the Q10 is just over double the mean flow indicating a variable discharge in response to rainfall events. Boxplots showing mean daily flow records for Morwick gauging station by month are presented in Figure VIII.2.

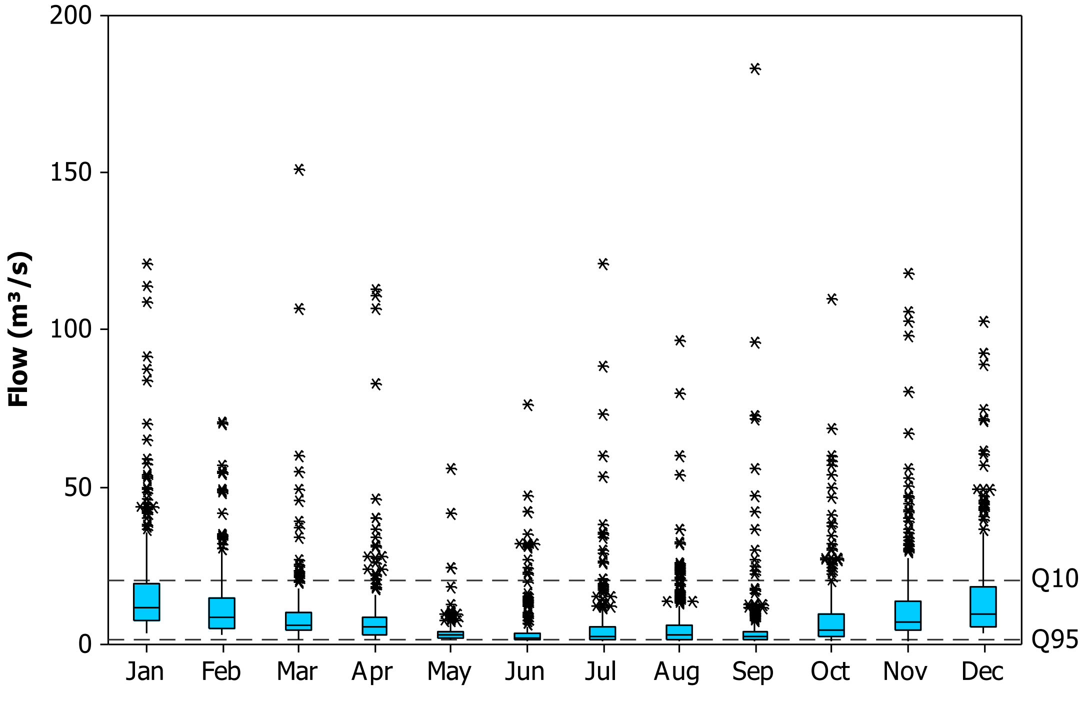

Figure VIII.2 Boxplots of mean daily flow records from the Morwick gauging station on the Coquet watercourse (2004 – 2014)
Two records from September where mean daily flows of 248 and 394 m^3/sec are omitted for clarity
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Strong seasonal variation in flow is apparent at this gauging station. Flows are highest on average in January, and lowest during May. High flow events were recorded in all months of the year, but only occasionally in May. The most extreme event averaged 394 m^3/sec over a 24 hour period in September 2008. The seasonal pattern of flows is not entirely dependent on rainfall as during the colder months there is less evaporation and transpiration. This in turn leads to a greater level of runoff immediately after rainfall. Increased levels of runoff are likely to result in an increase in the amount of microorganisms carried into coastal waters. Additionally, higher runoff will decrease residence time in rivers, allowing contamination from more distant sources to have an increased impact during high flow events.

During the shoreline survey, a spot flow gauging was made at a ford across the River Coquet about 2.3 km upstream of the tidal limit. Discharge at the time was 4.73 m^3/sec and the *E. coli* concentration was 460 cfu/100ml, indicating that the bacterial loading it was delivering at the time was 1.9×10^{12} *E. coli*/day. The only minor watercourse that discharges to the estuary downstream of the half tide weir is the Guilders Burn, which discharges to the south shore in the corner of the Marina. The bacterial loading carried by this watercourse at the time of shoreline survey was only 7.8×10^{7} *E. coli*/day.

It is therefore concluded that the vast majority of runoff derived contamination will be delivered by the River Coquet, and the bacterial loading it delivers will vary significantly depending on rainfall, and possibly the time of year. As all freshwater inputs are up-estuary of the fishery, monitoring at the up-estuary end of any shellfishery would be most effective at capturing their impacts.

Appendix IX. Hydrography

IX.1. Bathymetry

The Coquet estuary is a drowned river valley of about 5 km in length from its mouth to the tidal limit. It covers an area of 75 Ha, of which 45 Ha is intertidal (Futurecoast, 2002).

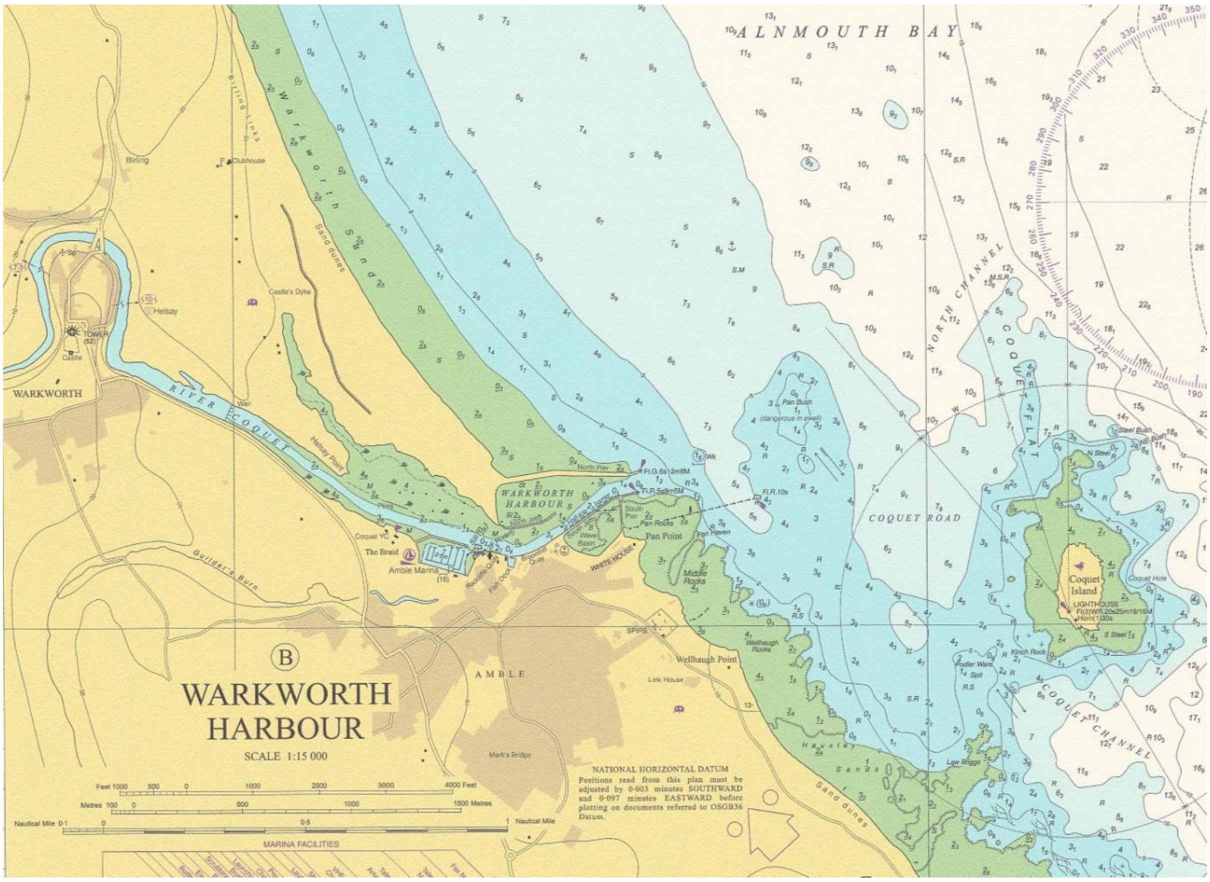

Figure IX.1: Bathymetric chart of the survey area.

The estuary is narrow, shallow, and meandering, with maximum depths of around 3.5 m relative to chart datum, and the entrance is shallow at <1 m deep relative to chart datum. The intertidal areas are most extensive on the north shore of the outermost reaches. This includes a sandy area to the south of the main (north) breakwater within which the mussel fishery is planned. Within this area there is a line of wooden pilings which are the remains of the north jetty around which the mussel farm is to be constructed. The remains of the former estuary channel[1] extend in a northerly direction just inshore of the North Jetty.

There is a smaller breakwater (South Pier) extending from the mouth on the south shore. Inside of this there is a small intertidal sandy bay (Littleshore) which lies behind the South Jetty. This jetty is on pilings, so there is little restriction to tidal movements underneath it. Upstream from here the south shore at Amble is fronted by harbour walls for about 500 m. Just upstream from here a marina has been constructed, which has a sill across the entrance to retain water which is 0.8 m above chart datum. Upstream of the marina and the old river channel, the estuary narrows to about 100 m or less in width. There are three weirs across the river channel. Between Amble and Warkworth there is a half-tide weir which impounds flow at lower states of the tide, but is covered towards high water. Further upstream there is a much lower weir at Warkworth, which has a much smaller impounding effect limited to low tide and low river flows (Environment Agency, pers. comm.). The third weir marks the tidal limit by Coquet Lodge.

Outside of the estuary mouth the bathymetry generally slopes gently away to about 10 m around a kilometre offshore. There is a shallower area about 700 m off the estuary mouth (Pan Bush) and a small rocky island (Coquet Island) lies about 2 km east south east of the estuary mouth.

IX.2. Tides and Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Tidal streams off the Northumberland coast flood in a southerly direction and ebb in a northerly direction. The plume from the Amble STW outfall, which lies to the south of the estuary mouth, will not therefore be carried into the estuary by tidal streams. Tidal currents along the coast are generally weak, with spring tides reaching 0.3 m/s while neap tides are about 0.15 m/s, although they do increase locally in the vicinity of islands and headlands (Royal Haskoning, 2009).

Table IX.1 Tidal levels and ranges at Amble and Coquet Island

Port	Height above chart datum (m)				Range (m)	
	MHWS	**MHWN**	**MLWN**	**MLWS**	**Spring**	**Neap**
Amble	5.00	3.90	1.90	0.80	4.20	2.00
Coquet Island	5.10	4.00	1.80	0.80	4.30	2.20

Data from the Proudman Oceanographic Laboratory.

The tidal range at Amble is 4.2 m on spring tides and 2 m on neap tides. Tidal streams will flood up the estuary, with the reverse occurring on the ebb. Therefore,

[1] The present position of the estuary mouth shifted a considerable distance south when the river broke through to the sea at a meander at Amble during a flood in March 1764 (Alnwick District Council, 2008).

shoreline sources will impact to either side of their location, along the bank to which they discharge. Impacts will decrease with distance as any plumes become more dilute. No information was found regarding current speeds or tidal excursions within the estuary so it is difficult to estimate the ranges across which they may impact. Sources of contamination discharging to the former river channel sidearm, and to the marina will principally impact the main channel down-estuary as these area will be filling during the flood tide.

Freshwater inputs may significantly modify the circulation of water around estuaries via density effects. The Futurecoast study (Futurecoast, 2002) calculated a mean flow ratio for the estuary of 0.027 and a maximum flow ratio of 0.580. This indicates that the freshwater inputs are quite high relative to tidal exchange and may result in some stratification particularly at higher river flows. Any stratification will result in a shear in currents down the water column, with a net seaward flow in the upper layers and a net landward flow at depth. Perhaps more important in terms of contamination of shellfish, stratification will tend to entrain freshwater borne contamination in the surface layers meaning stocks at lower elevations may be more separated from such contamination. As such, if and when the fishery develops and rafts or poles are used, the RMP should be located at the top of the droppers or poles. Some turbulent mixing of the water column is likely to occur at the half tide weir, and there is likely to be a marked increase in average salinity downstream of this weir.

The only salinity measurements available were those taken during the shoreline survey, which was undertaken at a time of relatively low freshwater input. Salinity and bacteriological samples were taken simultaneously at several locations (Table XIII.2). The *E. coli* concentration in the river was 460 cfu/100ml (fully fresh water), then decreased to 400 just upstream of the weir (with a salinity of 4.5 ppt). Downstream of the weir, where salinity increased to 12.1 ppt, the *E. coli* concentration decreased to 150 cfu/100ml. In the outer estuary (salinity 15.8ppt) the *E. coli* concentration decreased further to 94 cfu/100ml. These limited results suggest that there is a gradient of decreasing average salinity and increasing runoff borne contamination from the lower to the upper estuary, although it is likely that salinities will fluctuate significantly at any given location with tidal state and river discharge. The relative bacterial concentrations and salinities observed also suggest that the bulk of bacterial contamination in the estuary was being delivered by the River Coquet at the time. It is therefore concluded that an RMP at the up-estuary end of the shellfishery site would be most effective at capturing contamination from land runoff, although the difference between the east and west ends of the North Jetty is likely to be small on average.

Tidally driven currents may also be modified by the effects of wind. Strong winds will typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m s^{-1}) would drive a surface water current of about 1 knot or 0.5 m s^{-1}. Surface currents will create return currents at depth or along sheltered margins. The prevailing wind direction is from the south west. The estuary is narrow and enclosed so is sheltered from winds from most directions. Strong easterly winds would blow up the estuary, thereby pushing surface flows in this direction. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great range of scenarios may arise. As well as driving surface currents, onshore winds will create wave action. Waves may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides. The enclosed nature of the estuary, and the shelter afforded from North Sea swells by the breakwaters suggest that energetic wave action is unlikely to occur within it.

Appendix X. Microbiological data: Bathing Waters

Due to changes in the analyses of bathing water quality by the Environment Agency from 2012, only data produced up to the end of 2011 were used in these analyses. There are two bathing waters around Amble designated under the Directive 76/160/EEC (Council of the European Communities, 1975), the locations of which are shown in Figure X.1.

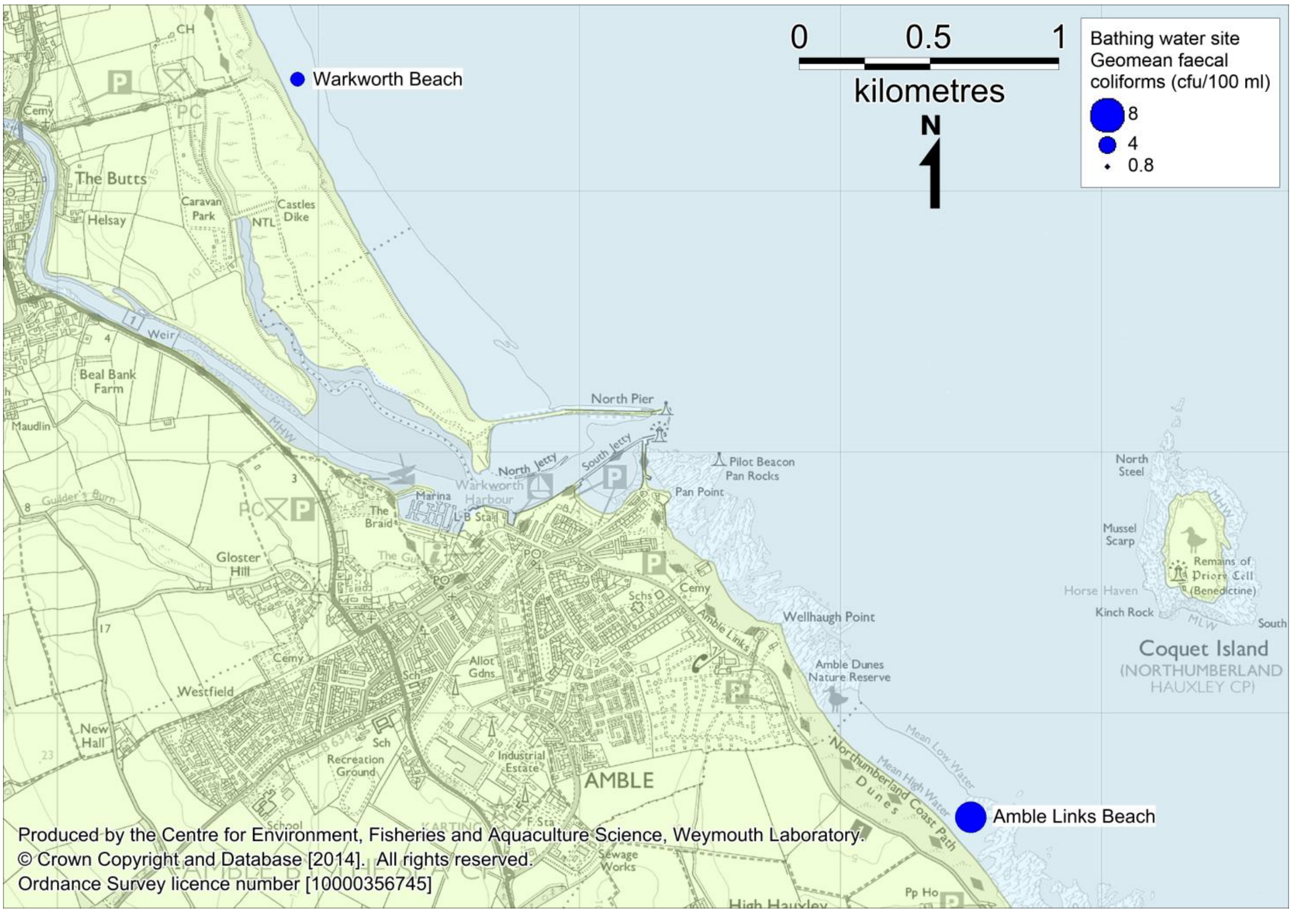

Figure X.1: Location of designated bathing waters monitoring points near Amble
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Around twenty water samples were taken from each of the bathing waters sites during each bathing season, which runs from the 15th May to the 30th September. Faecal coliforms were enumerated in all of these samples. Summary statistics of all results by bathing water are presented in Table X.1, and Figure X.2 presents box plots of these data.

Table X.1: Summary statistics for bathing waters faecal coliforms results, 2004-2011 (cfu/100ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
Warkworth Beach	160	05/05/2004	22/09/2011	3.4	<2	1,188	6.3	1.9
Amble Links Beach	160	05/05/2004	22/09/2011	7.4	<2	2,000	6.9	0.6

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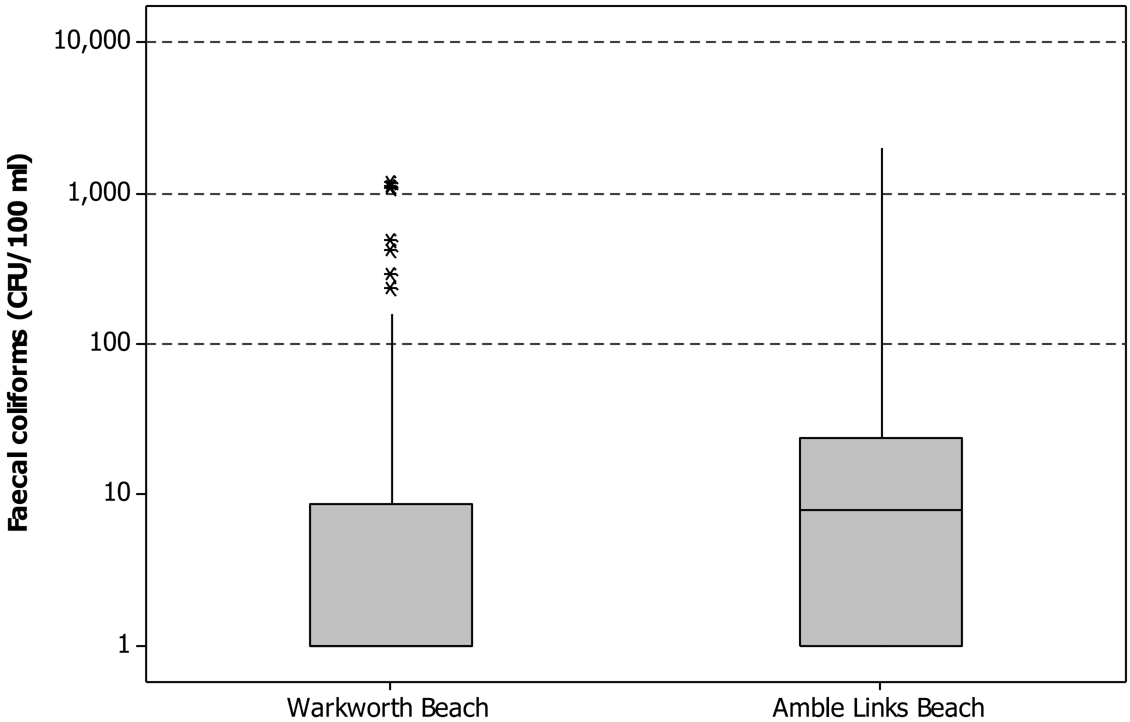

Figure X.2: Box-and-whisker plots of all faecal coliforms results by site
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Both sites had results exceeding 1,000 faecal coliforms/100 ml, but Warkworth Beach had more than Amble Links Beach. A two sample T test showed that Amble Links Beach had significantly higher results overall than Warkworth Beach ($p < 0.001$). Correlations (Pearson's) were run between samples at the two sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. There was a significant correlation ($r = 0.539$, $p < 0.001$) indicating that the sites are affected by similar sources, or by sources which respond in a similar manner to environmental variables.

Overall temporal pattern in results

The overall variation in faecal coliform levels found at bathing water sites is shown in Figure X.3.

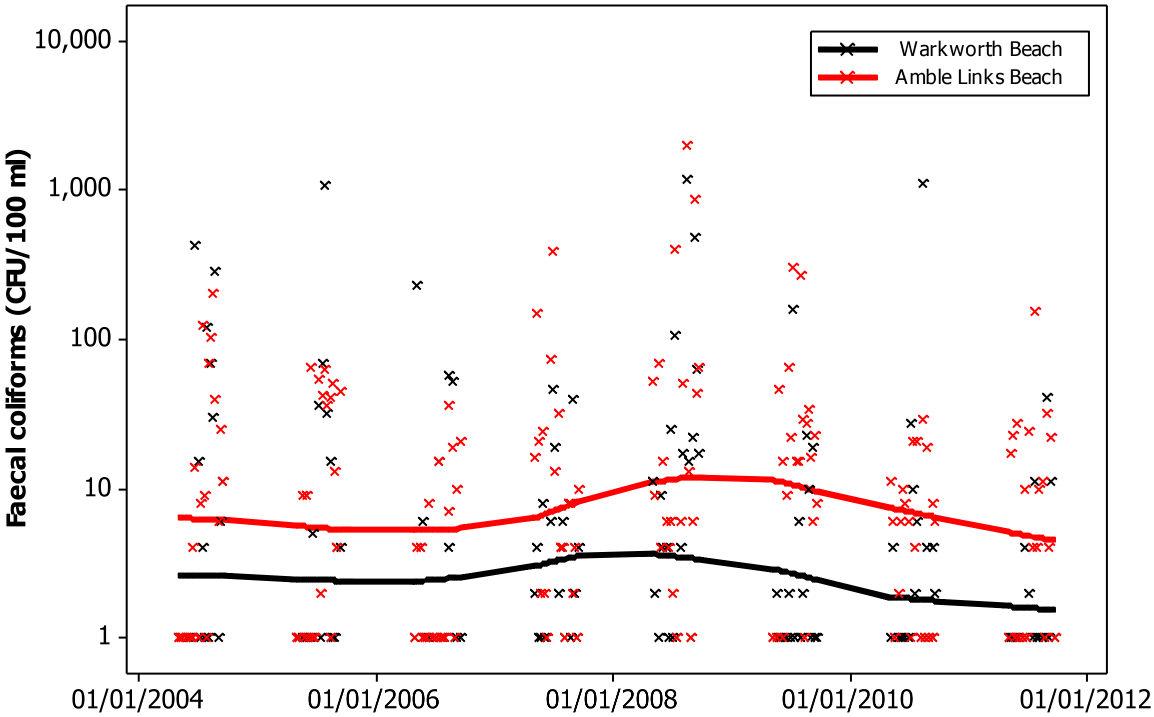

Figure X.3: Scatterplot of faecal coliform results for bathing waters near Amble overlaid with loess lines.

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Faecal coliform levels have remained fairly stable since 2004. However there was a slight increase in levels at both beaches during the 2008 and 2009 seasons.

Influence of tides

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles for each of these bathing water sampling points. Correlation coefficients are presented in Table X.2.

Table X.2: Circular linear correlation coefficients (r) and associated p values for faecal coliform results against the high low and spring/neap tidal cycles

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Warkworth Beach	0.036	0.817	0.076	0.408
Amble Links Beach	0.067	0.495	0.092	0.264

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No significant correlations were found between faecal coliform levels and tidal state.

Influence of Rainfall

To investigate the effects of rainfall on levels of contamination at the bathing waters sites, Spearman's rank correlations were carried out between rainfall recorded at the

Warkworth weather station (Appendix II for details) over various periods running up to sample collection and faecal coliforms results. These are presented in Table X.3 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.3: Spearmans Rank correlation coefficients for faecal coliforms results against recent rainfall

	Site	Warkworth Beach	Amble Links Beach
	n	160	160
24 hour periods prior to sampling	1 day	0.220	0.276
	2 days	0.289	0.204
	3 days	0.174	0.208
	4 days	0.175	0.164
	5 days	0.175	0.150
	6 days	0.138	0.128
	7 days	0.007	0.083
Total prior to sampling over	2 days	0.346	0.292
	3 days	0.352	0.330
	4 days	0.401	0.353
	5 days	0.422	0.352
	6 days	0.440	0.338
	7 days	0.425	0.350

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At both bathing water sites, faecal coliform levels rapidly increase after rainfall, and remain higher for several days.

Appendix XI. Microbiological Data: Shellfish Flesh Hygiene

XI.1. Summary statistics and geographical variation

There is one historic mussel RMP in the Amble production area that was sampled in 2004 and 2005, but has not been sampled since. The geometric mean results of shellfish flesh monitoring from this RMP is presented in Figure XI.1. Summary statistics are presented in Table XI.1 and a boxplot for site is show in Figure XI.2.

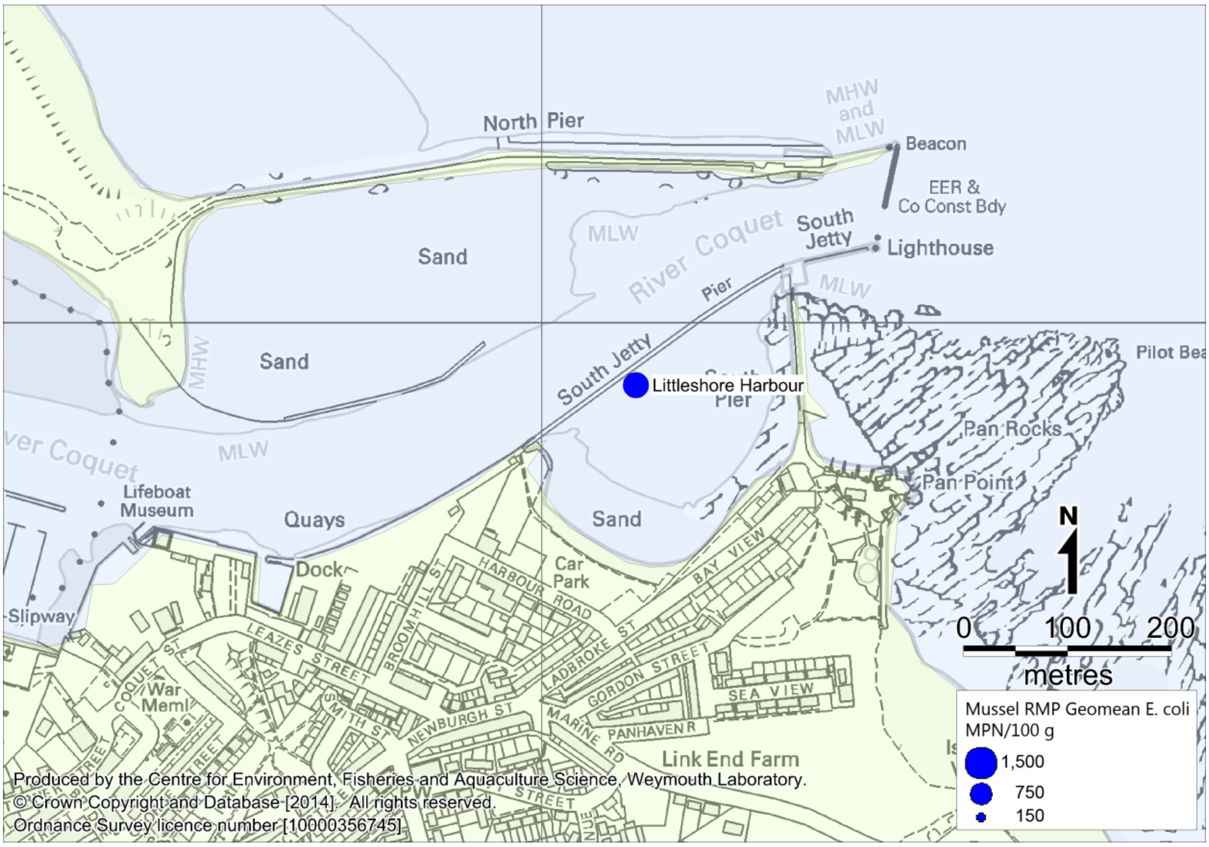

Figure XI.1: Mussel RMPs active since 2004

Table XI.1: Summary statistics of *E. coli* results (MPN/100 g) from 2004 onwards

Site	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4,600	% over 46,000
Littleshore Harbour	Mussel	24	05/05/2004	07/12/2005	1,034	40	18,000	87.5	20.8	0.0

Figure XI.2: Boxplots of *E. coli* results from 2004 onwards.

E. coli levels at Littleshore Harbour exceeded 4,600 MPN/100 g on more than 20% of sampling occasions. The maximum recorded result was 18,000 MPN/100 g.

XI.2. Overall temporal pattern in results

The overall variation in *E. coli* levels found in mussels is shown in Figure XI.3.

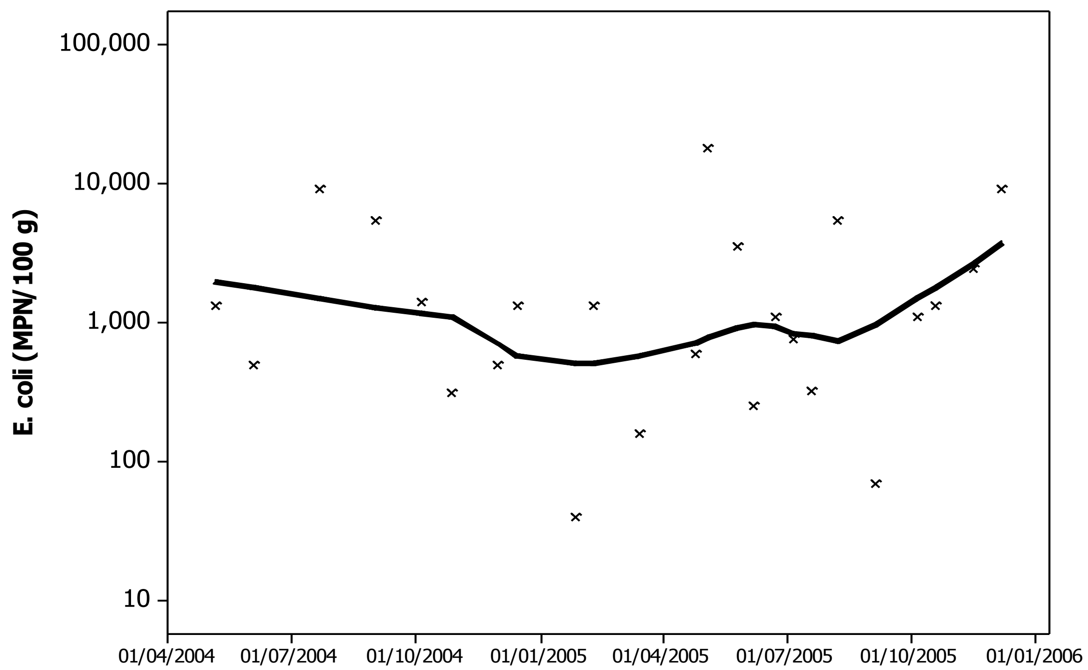

Figure XI.3: Scatterplot of *E. coli* results for mussels overlaid with loess line.

E. coli results at Littleshore Harbour remained fairly stable throughout the sampling period.

XI.3. Seasonal patterns of results

The seasonal patterns of results from mussels are shown in Figure XI.4.

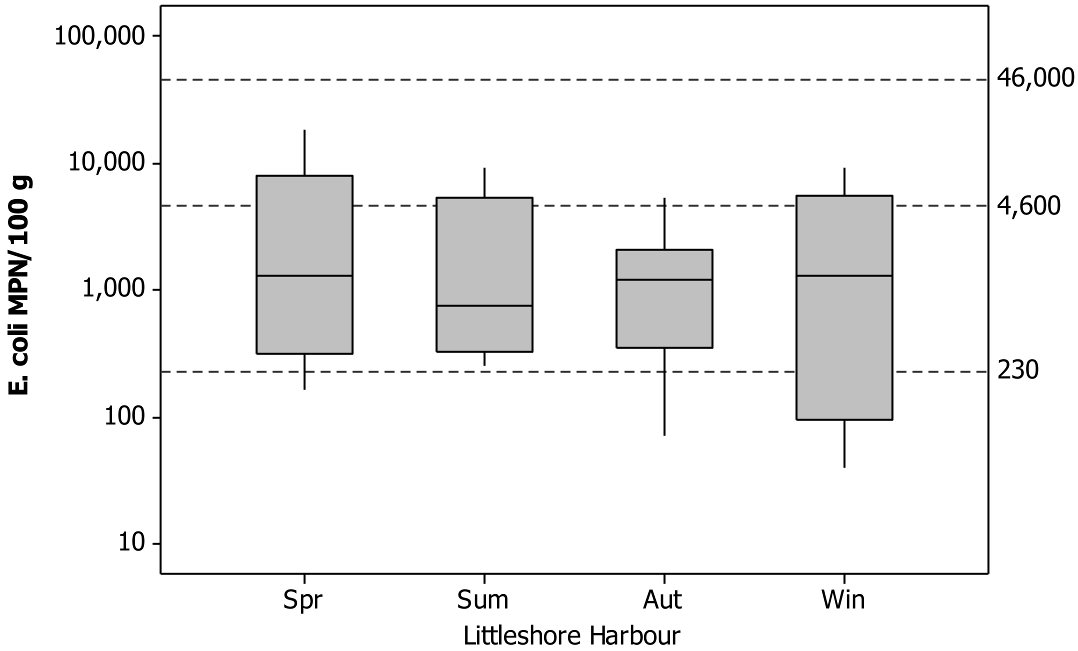

Figure XI.4: Boxplot of *E. coli* results for mussels by season

One-way ANOVAs showed that there were no significant variations in *E. coli* levels between seasons (p=0.933). Although relatively few samples are available to support this analysis, meaning the statistical analysis lacks power. However, the results do appear relatively consistent throughout the year.

XI.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. Results of these correlations are summarised in Table XI.2, and significant results are highlighted in yellow.

Table XI.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**
Littleshore Harbour	Mussels	0.595	<0.001	0.436	0.018

Figure XI.5 presents a polar plot 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 Amble is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100 g or less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

Figure XI.5: Polar plot of $\log_{10}$ *E. coli* results (MPN/100 g) against high/low tidal state

The polar plot shows sampling was targeted towards low water, and that results tended to be higher during the ebb tide. This suggests that up-estuary sources may be of influence.

Figure XI.6 shows a polar plot of $\log_{10}$ *E. coli* results against tidal state on the spring neap cycle. 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/100g less are plotted in green, those from 231 to 4,600 are plotted in yellow, and those exceeding 4600 are plotted in red.

Figure XI.6: Polar plot of $\log_{10}$ *E. coli* results (MPN/100 g) against spring/neap tidal state

Whilst the complete cycle is not represented, and the correlation was relatively weak, it appears that the higher results arose as tide size decreased from springs to neaps.

XI.5. Influence of rainfall

To investigate the effects of rainfall on levels of contamination within shellfish samples Spearman's rank correlations were carried out between *E. coli* results and rainfall recorded at the Warkworth and Linbriggs weather stations (Appendix II for details) over various periods running up to sample collection. These are presented in Table XI.3, and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XI.3: Spearman's Rank correlations between rainfall recorded at Warkworth and Linbriggs and shellfish hygiene results

	Weather station	Warkworth	Linbriggs
	n	**24**	**24**
24 hour periods prior to sampling	1 day	-0.253	-0.240
	2 days	0.199	0.199
	3 days	0.095	0.353
	4 days	-0.293	-0.131
	5 days	0.157	0.465
	6 days	0.162	0.053
	7 days	0.121	0.071
Total prior to sampling over	2 days	0.033	-0.050
	3 days	0.106	0.036
	4 days	-0.132	0.078
	5 days	-0.067	0.145
	6 days	0.014	0.173
	7 days	-0.017	0.121

There were no significant correlations between rainfall at Warkworth and *E. coli* levels. Significant correlations between upstream rainfall at Linnbriggs and *E. coli* levels at Littleshore Harbour three and five days after rainfall suggest that increased rainfall upstream may bring some contamination from the upper catchment to the shellfish in the estuary. It should however be noted that on average, one in twenty correlations will return an apparently significant r value by chance alone. The two apparent positive correlations lie either side of a negative r value at four days. If rainfall (and therefore river discharge) was a real influence three and five days after an event it may be expected that a similar influence would be detected after four days.

A similar analysis was undertaken comparing river discharge recorded at Morwick, on the River Coquet (Table XI.4).

Table XI.4: Spearman's Rank correlations between mean daily discharge at the Morwick gauging station on the River Coquet

Site Species n		Littleshore Harbour Mussel 24
24 hour periods prior to sampling	1 day	0.063
	2 days	0.100
	3 days	0.088
	4 days	0.126
	5 days	0.089
	6 days	0.130
	7 days	0.116
Total prior to sampling over	2 days	0.084
	3 days	0.098
	4 days	0.109
	5 days	0.121
	6 days	0.121
	7 days	0.094

No correlations between river flow and *E. coli* levels in mussels at Littleshore Harbour were detected. The lack of correlations with rainfall and river flow are surprising, given that the River Coquet is likely to be a highly significant source of faecal indicator bacteria to the estuary, and that high flow events are likely to be associated with higher levels of faecal indicator bacteria in the water column. It is possible that at times of reduced salinity or when abrupt changes in salinity occur the mussels stop feeding and accumulating *E. coli*. It is likely that there are complex interactions between river flow, salinity, temperature, tidal states and mussel feeding rates, and the small dataset considered is not sufficient to investigate this in a meaningful way.

Appendix XII. Bacteriological survey

Two bags of mussels were collected from Holy Island and deployed at each end of the North Jetty on 22/05/2014 (Figure XII.1). These were allowed to equilibrate *in situ* for two weeks, then sampled on four occasions each about two weeks apart.

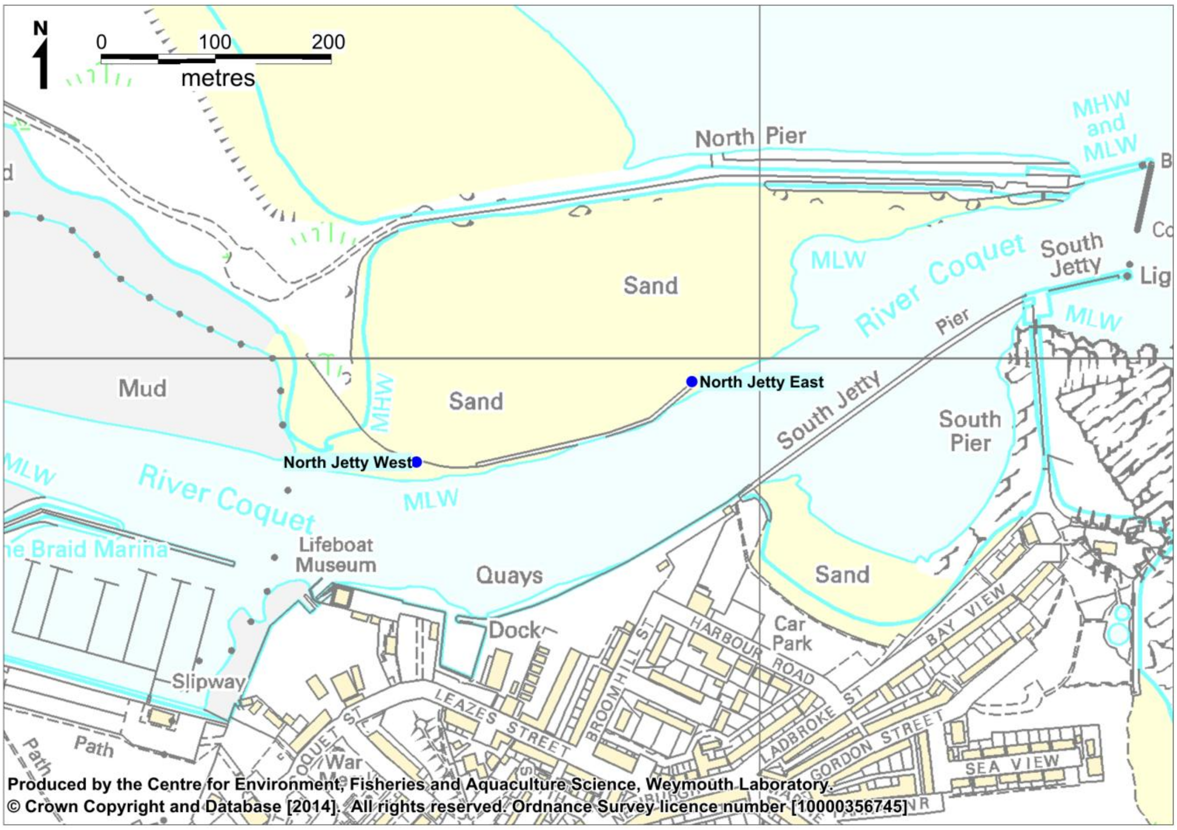

Figure XII.1: Bacteriological survey points

Table XII.1: Bacteriological survey results

	***E. coli* result (MPN/100g)**	
Date	**North Jetty West**	**North Jetty East**
11/06/2014	3,500	9,200
25/06/2014	1,700	1,700
10/07/2014	5,400	54,000
23/07/2014	3,500	11,000
Geometric mean	3,256	9,818
Maximum	5,400	54,000
No. exceeding 4,600	1 (25%)	3 (75%)
No. exceeding 46,000	0 (0%)	1 (25%)

The highest average and peak result was recorded at the more downstream site (North Jetty East), which was consistently more contaminated than the upstream site. The reasons for this difference are unclear, but may relate to either the slightly lower elevation at which North Jetty East is located resulting in increased immersion at lower states of tide when the water column is likely to be more contaminated.

Alternatively, there may be a more regular presence of birds roosting towards the downstream end of the jetty.

Three of the four results at North Jetty East exceeded 4600 *E. coli* MPN/100g, and one exceeded 46,000 *E. coli* MPN/100g.

Appendix XIII. Shoreline Survey Report

Date (time): 20/05/2014 (08:00 – 14:00)

Cefas Officers: Alastair Cook

Local Enforcement Authority Officers: Mark Mitchell, Charles Copeland.

Area surveyed: Outer Coquet estuary (Figure XII.1).

Weather: Dry, overcast, 11C, wind W force 3.

Tides:

Admiralty TotalTide© predictions for Amble. All times in this report are BST.

20/05/2014		
High	01:50	1.3 m
High	07:53	4.8 m
Low	14:25	1.0 m
Low	20:46	4.6 m

Objectives:

The shoreline survey aimed 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. A further objective was to deploy bagged mussels at the fishery site for subsequent bacteriological survey. A full list of recorded observations is presented in Table XIII.1 and the locations of these observations are mapped in Figure XIII.1. Photographs are presented in Figure XIII.3 – Figure XIII.7.

Description of Fishery

There are tentative plans for a mussel fishery in the vicinity of the derelict North Jetty at this stage. No trials have been undertaken as yet, no stock is present on site, and seed sources and culture methods are yet to be decided. No mussels were seen anywhere within the estuary during the shoreline survey.

Two sampling bags stocked with mussels sourced from Holy Island (with permission from the Northumberland IFCA) were deployed at the east and west ends of the North Jetty at about 18:00 on the 22/05/2014. These are were sampled on a weekly basis once they had equilibrated *in situ* for two weeks, and results are reported in the bacteriological survey section.

Sources of contamination

Sewage discharges

Inspection covers were seen at the location of the Amble Harbour PS, but the outfall could not be seen as it was presumably underwater (observation 2). The Turner Street CSO outfall could not be seen, again presumably, as it was underwater (observation 4). The location of the PS No. 4 outfall was confirmed (observation 6). The caravan park sewage outfall was located and sampled and measured (observation 10), although the *E. coli* loading it was generating at the time was not particularly large. There was fresh sewage related debris (rag, sweetcorn etc) in the vicinity of its outfall. Northumberland Council advised there are plans to extend the caravan park.

Freshwater inputs

There is little in the way of freshwater inputs in the vicinity of the fishery. Guilders Burn is the closest, and discharges in the vicinity of the Marina. Its outfall was not seen during the survey (presumably covered by the tide) but it was sampled and measured at an accessible point about 500 m inland from where it drains to the estuary (observation 17). A sample was taken and an approximate flow gauging was made on a ford across the River Coquet about 2.3 km upstream of its tidal limit (observation 14).

Boats and Shipping

There were several fishing boats alongside the harbour wall (observation 2) and many leisure craft in the Marina (observation 4).

Livestock

No livestock was observed during the course of the shoreline survey.

Wildlife

Birds (including ducks, gulls and waders) were commonly sighted, but no major aggregations were recorded. Of possible significance, around 20 gulls and cormorants were observed resting on the remains of the north jetty, which may be a favoured roosting area.

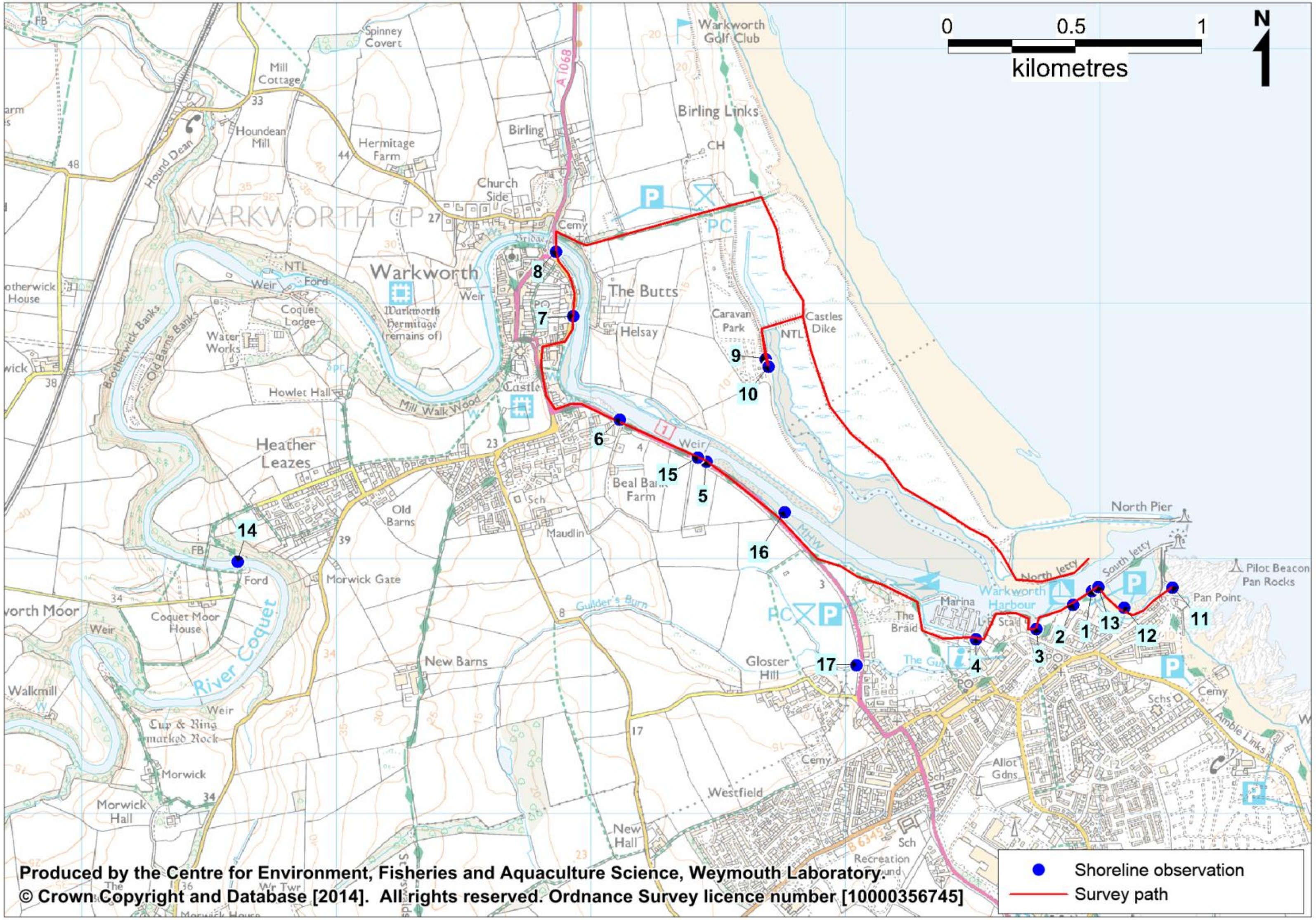

Figure XIII.1: Locations of shoreline observations

Table XIII.1. Details of Shoreline Observations

No	Time and Date	NGR	Photograph	Observation
1	20/05/2014 08:29	NU 26969 04875		Around 20 cormorants and gulls resting on the remains of the north jetty (opposite). About 15 eiders on the water.
2	20/05/2014 08:32	NU 26894 04821	Figure XIII.3	Storm tank inspection covers in car park, no outfall visible. Several fishing boats alongside harbour wall.
3	20/05/2014 08:36	NU 26750 04724		About 15 eider ducks in enclosed harbour area.
4	20/05/2014 08:52	NU 26513 04685		Marina. No outfall visible in the corner.
5	20/05/2014 09:10	NU 25453 05383	Figure XIII.4	Half tide weir
6	20/05/2014 09:17	NU 25111 05547	Figure XIII.5	CSO outfall
7	20/05/2014 09:32	NU 24929 05955	Figure XIII.6	Pipe to foreshore on opposite bank, location corresponds with consented private discharge.
8	20/05/2014 09:37	NU 24860 06208		No CSO outfall visible here
9	20/05/2014 10:04	NU 25685 05784		Fresh sanitary debris
10	20/05/2014 10:06	NU 25697 05755	Figure XIII.7	Caravan Park sewage outfall, 6cmx2cmx0746m/s, water sample 1 (sewage).
11	20/05/2014 10:51	NU 27285 04888		Water sample 2 (seawater outside estuary mouth)
12	20/05/2014 10:56	NU 27094 04809		Fresh sanitary debris (rag)
13	20/05/2014 10:58	NU 26994 04890		Water sample 3 (salinity 15.8 ppt)
14	20/05/2014 11:44	NU 23609 04990		River Coquet at Ford. 43mx10cmx0.889m/s + 1.5mx40cmx1.504m/s. Water sample 4 (fresh)
15	20/05/2014 12:09	NU 25418 05399		Water sample 5 (salinity 4.5 ppt)
16	20/05/2014 12:17	NU 25759 05184		Water sample 6 (salinity 12.1 ppt)
17	20/05/2014 12:29	NU 26043 04583		Guilders Burn. 22cmx4cmx0.412m/s. Water sample 7 (fresh)

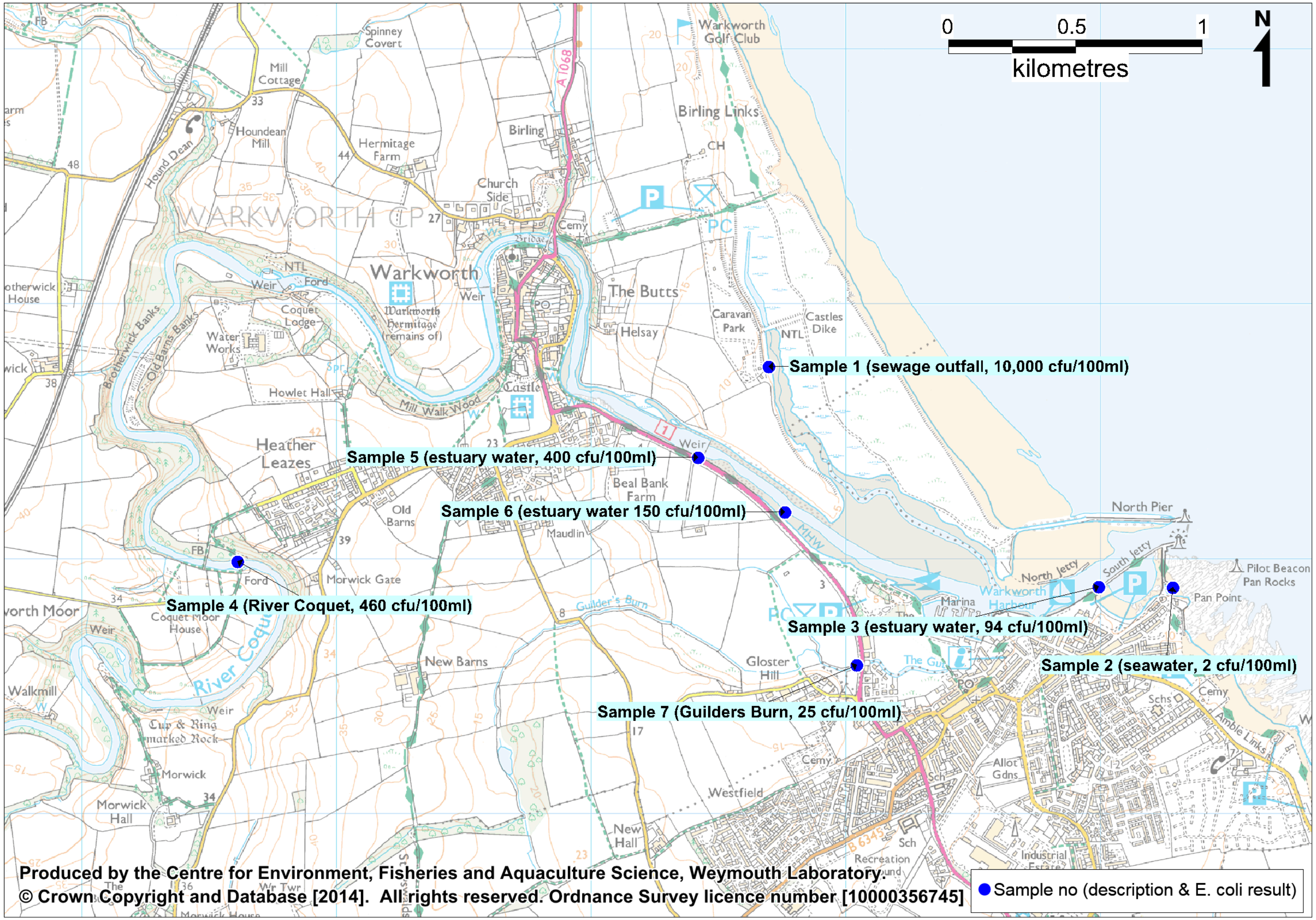

Figure XIII.2: Water sample results

Table XIII.2: Water sample *E. coli* results, salinity measurements, and spot flow gauging results

No.	Date and time	Position	Description	Salinity (ppt)	*E. coli* (cfu/100ml)	Discharge (m^3/sec)	Estimated *E. coli* loading (cfu/day)
1	20/05/2014 10:06	NU 25697 05755	Caravan Park sewage outfall	Freshwater	10000	$9.0x10^{-4}$	$7.7x10^{9}$
2	20/05/2014 10:51	NU 27285 04888	Seawater (outside estuary)	Not recorded	2		
3	20/05/2014 10:58	NU 26994 04890	Estuary water	15.8	94		
4	20/05/2014 11:44	NU 23609 04990	River Coquet	Freshwater	460	4.73	$1.9x10^{12}$
5	20/05/2014 12:09	NU 25418 05399	Estuary water	4.5	400		
6	20/05/2014 12:17	NU 25759 05184	Estuary water	12.1	150		
7	20/05/2014 12:29	NU 26043 04583	Guilders Burn	Freshwater	25	$3.6x10^{-3}$	$7.8x10^{7}$

At the time of survey, the volumes of land runoff entering the estuary were relatively low, with an estimated discharge of just under 5 m^3/sec from the River Coquet. Despite this, salinity in the outer reaches of the estuary was only 15.8 ppt in the middle stages of the ebb tide. A distinct drop in salinity was observed across the half tide weir. Within the estuary, *E. coli* concentrations increased with distance from the mouth further upstream. The lowest *E. coli* concentration was recorded in the North Sea, just outside the estuary. The Guilders Burn was of negligible significance in terms of discharge volumes and bacterial loading.

The *E. coli* concentration within the caravan park sewage discharge was not particularly high, although the sample was taken in off peak season and as such occupancy rates will be lower than in the peak summer holidays. The instantaneous discharge rate at the time was equivalent to 77 m^3/day, which is considerably higher than the consented maximum daily flow of 16 m^3/day. It is however recognised that discharge rates will fluctuate significantly according to the time of day due to patterns of water usage.

Figure XIII.3

Figure XIII.4

Figure XIII.5

Figure XIII.6

Figure XIII.7

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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
CZ	Classification Zone
Defra	Department for Environment, Food and Rural Affairs
DWF	Dry Weather Flow
EA	Environment Agency
E. coli	Escherichia coli
EC	European Community
EEC	European Economic Community
EO	Emergency Overflow
FIL	Fluid and Intravalvular Liquid
FSA	Food Standards Agency
GM	Geometric Mean
IFCA	Inshore Fisheries and Conservation Authority
ISO	International Organization for Standardization
km	Kilometre
LEA (LFA)	Local Enforcement Authority formerly Local Food Authority
M	Million
m	Metres
ml	Millilitres
mm	Millimetres
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MPN	Most Probable Number
NM	Nautical Miles
NRA	National Rivers Authority
NWSFC	North Western Sea Fisheries Committee
OSGB36	Ordnance Survey Great Britain 1936
mtDNA	Mitochondrial DNA
ppt	Parts per thousand
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SHS	Cefas Shellfish Hygiene System, integrated database and mapping application
SSSI	Site of Special Scientific Interest
STW	Sewage Treatment Works
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.
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.
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.
EC Regulation	Body of European Union law involved in the regulation of state support to commercial industries, and of certain industry sectors and public services.
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 Hygiene 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 Nth 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 skewed data such as those 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.
Lowess	Locally Weighted Scatterplot Smoothing, more descriptively known as locally weighted polynomial regression. At each point of a given dataset, a low-degree polynomial is fitted to a subset of the data, with explanatory variable values near the point whose response is being estimated. The polynomial is fitted using weighted least squares, giving more weight to points near the point whose response is being estimated and less weight to points further away. The value of the regression function for the point is then obtained by evaluating the local polynomial using the explanatory variable values for that data point. The LOWESS fit is complete after regression function values have been computed for each of the n data points. LOWESS fit enhances the visual information on a scatterplot.
Telemetry	A means of collecting information by unmanned monitoring stations (often rainfall or river flows) using a computer that is connected to the public telephone system.
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 forms a diluted sewage.
Waste water	Any waste water but see also “sewage”.

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