Scottish Sanitary Survey Report

Sanitary Survey Report
Ardcastle Bay
AB-634, AB-635, AB-636, AB-637
April 2014

Cefas

Food Standards Agency
food.gov.uk
Buidheann Inbhe-Bidhe

Report Title	Ardcastle Bay Sanitary Survey Report
Project Name	Scottish Sanitary Survey
Client/Customer	Food Standards Agency Scotland
Cefas Project Reference	C5792C
Document Number	C5792C_2013_16
Revision	1.0
Date	23/04/2014

Revision History

Revision number	Date	Pages revised	Reason for revision
0.1	10/02/2014	-	External draft for consultation
1.0	22/04/2014	2,3,6,11,14, 30,51, Appendix 4	Amended sampling plan to account for depth of urchin and scallop culture, incorporated information on additional discharge provided by Scottish Water, amended site names.

	Name	Position	Date
Author	Ron Lee, Jessica Larkham, Frank Cox, Liefy Hendrikz	Scottish Sanitary Survey Team	10/02/2014
Checked	Michelle Price-Hayward	Senior Shellfish Hygiene Scientist	23/04/2014
Approved	Ron Lee	Principal Shellfish Hygiene Scientist	23/04/2014

Centre for Environment, Fisheries & Aquaculture Science, Weymouth Laboratory, Barrack Road, The Nothe, Weymouth DT4 8UB. Tel 01305 206 600 www.cefas.defra.gov.uk

Report Distribution – Ardcastle Bay

Date	Name	Agency
	Joyce Carr	Scottish Government
	David Denoon	SEPA
	Douglas Sinclair	SEPA
	Hazel MacLeod	SEPA
	Fiona Garner	Scottish Water
	Alex Adrian	Crown Estate
	Fraser Anderson	Argyll & Bute Council
	Andrew MacLeod	Argyll & Bute Council
	David Attwood	Harvester

Partner Organisations

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

Table of Contents

I. Executive Summary

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

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

A sanitary survey was undertaken on the fishery at Ardcastle Bay on the basis recommended in the European Union Reference Laboratory publication: “Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application” (http://www.crlcefas.org/gpg.asp). This production area was selected for survey on the basis of the receipt of an application for standard classification of the area. The following is a summary of the main findings of the sanitary survey.

Ardcastle Bay is located on the northwestern shore of inner Loch Fyne. The aquaculture shellfishery consists of long lines with droppers for mussels and cages for the other species (Pacific oysters, queen scallops and green sea urchins) set adjacent to a marine cage fish farm in order to take advantage of nutrient waste arising from the fish farm. The area is generally sparsely populated with small settlements located at Minard and at Lochgair/Asknish northeast and southwest of the fishery respectively. A number of sewage discharges are associated with these communities, including a Scottish Water WWTW at Minard. Most of the land on the adjacent shoreline is woodland. The only agriculture observed during the shorline survey was at Lephinchapel on the shore opposite the shellfish farm.

Tidal currents are expected to flow along the axis of the loch. The maximum anticipated transport distance over an ebb or flood cycle is 1.7 km (not allowing for a difference between spring and neap tides). This is less than the distance between most of the identified pollution sources and the shellfish farm. However, there is a net residual outward flow from the loch and therefore contmaiantion arising from northeast of the shellfish farm will be transported towards it over successive tidal cycles.

Summary of recommendations

It is recommended that the production area boundary be limited to the north by the current fish farm and to the west by the shore. The eastern and southern boundaries have been defined to allow further expansion while not extending too close to other

known pollution sources. It is recommended that the RMP be located at NR 9534 9200 to reflect the pollution sources known to be located to the north of the shellfishery. Further details regarding recommendations can be found in the sampling plan on the next page or in Section 17 of this report.

II. Sampling Plan

Production Area	Ardcastle Bay
Site Name	Ardcastle Oysters Ardcastle Mussels Ardcastle Scallops Ardcastle Urchins
SIN	AB-634-1280-13 AB-635-1281-08 AB-636-1282-15 AB-637-1283-22
Species	Pacific oysters Common mussels Queen scallops Green sea urchins
Type of Fishery	Long lines Suspended cages
NGR of RMP	NR 9534 9200
East	195340
North	692000
Tolerance (m)	40 m
Depth (m)	Mussels/Pacific oysters: 1 – 3 m Queen scallops/sea urchins: 15 m
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	Argyll and Bute Council
Authorised Sampler(s)	Fraser Anderson William MacQuarrie Ewan McDougall Allison Hardie
Recommended Production Area	The area bounded by lines drawn from NR 9523 9221 to NR 9584 9200 to NR 9584 9132 to NR 9506 9132 and extending to MHWS.

III. Report

1. General Description

Loch Fyne is located on the west coast of Scotland, and is part of Argyll and Bute local authority. The loch opens to the Sound of Bute and the Clyde Sea and has a total length of 61 km and an average width of 3 km with a maximum depth of 189 m. There are two main sections to the loch. The outer part runs approximately south to north for 23 km. This section varies between 4 and 7 km in width. The inner part runs approximately southwest to northeast. It is a little over 40 km in length and the width varies between 0.5 and 3 km. Ardcastle Bay is located approximately 9 km northeast of Lochgilphead and roughly ¼ of the way into the inner part of the loch, on the northwestern shore.

Several settlements lie on its shore although none immediately adjacent to the production area. The villages of Lochgair and Asknish lie on the shores of Loch Gair, a small bay approximately 3 km to the southwest. The village of Minard lies approximately 5km to the northeast.

A sanitary survey was undertaken on the fishery at Ardcastle Bay on the basis recommended in the European Union Reference Laboratory publication: “Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application” (http://www.crlcefas.org/gpg.asp). The production area was identified for survey on the basis of a standard track application for classification.

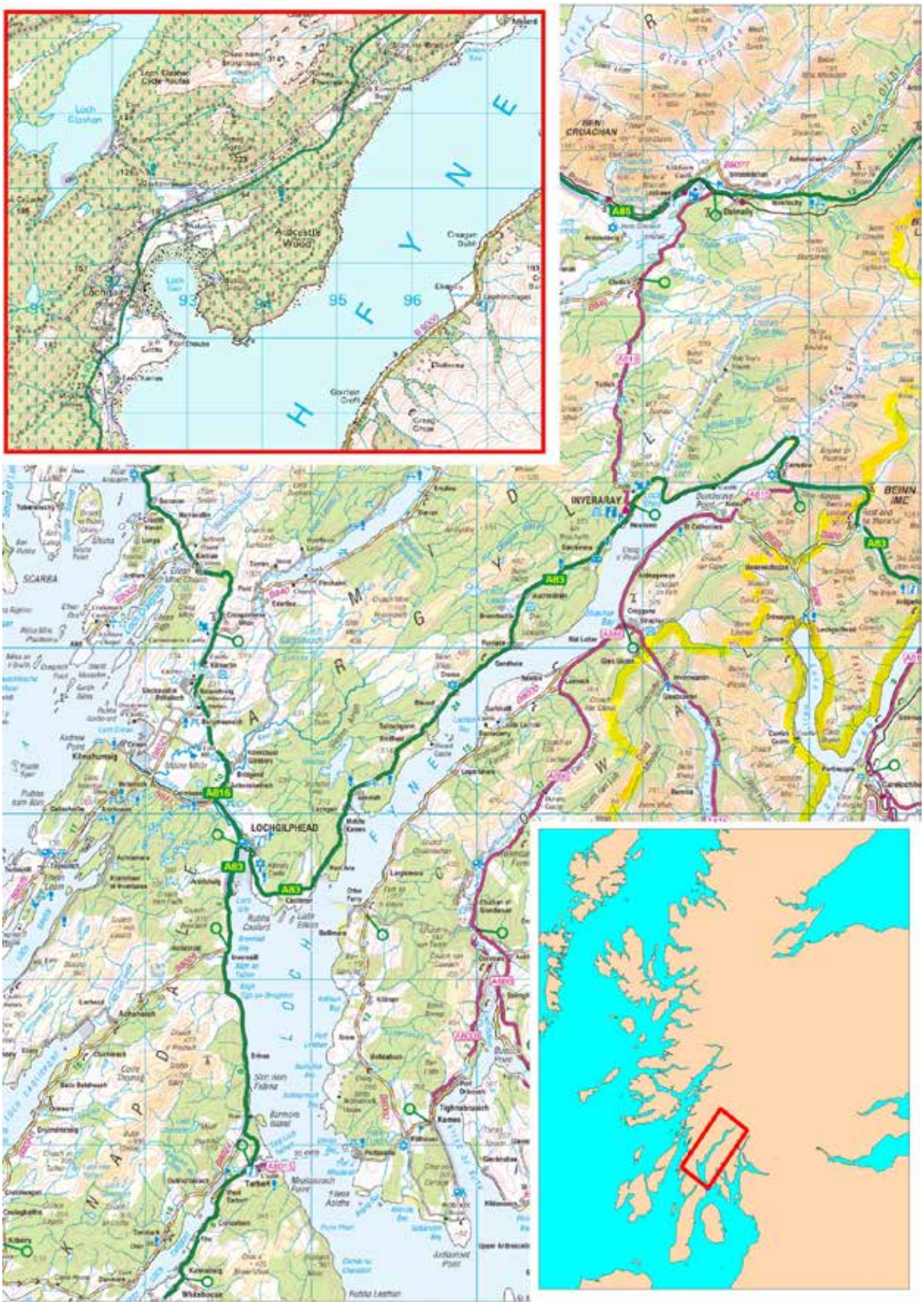


Figure 1.1 Location of Ardcastle Bay

2. Fishery

The fishery at Ardcastle Bay is a multi-species system, consisting primarily of mussels (*Mytilus edulis*) on dropper ropes. The site is also used for the culture of Pacific oysters (*Crassostea gigas*), queen scallops (*Aequipecten opercularis*) and green sea urchins (*Psammechinus miliaris*). The shellfish farm is situated approximately 300 m southwest of the Ardcastle Bay Marine Cage Fish Farm (MCFF), and the harvester's intention is that enrichment of the water from the finfish farm will support growth of the shellfish.

This is a new fishery currently submitting samples towards standard classification. Details of the site are presented in Table 2.1.

Table 2.1 Ardcastle Bay Area shellfish farms

Production area	Site	SIN	Species	Provisional RMP
Ardcastle Bay	Ardcastle Bay Mussels	AB-634-1280-13	Common mussels	NR 9529 9180
	Ardcastle Bay Oysters	AB-635-1281-08	Pacific oysters	
	Ardcastle Bay Scallops	AB-636-1282-15	Queen Scallops	
	Ardcastle Bay Urchins	AB-637-1283-22	Green Sea Urchin	

The most recent seabed lease information received from the Crown Estates (2012) did not indicate the presence of a shellfish seabed lease in the area. However, updated information has been sought and though not yet received at the time of drafting this report, any updated information received will be incorporated into the final report.

Previously recommended production area boundaries were: the area bounded by lines drawn from NR 9523 9221 to NR 9584 9200 to NR 9584 9132 to NR 9506 9132 and extending to MHWS. The present recommended provisional RMP, subject to review within this report, has not been used to date for classification sampling.

At the time of the shoreline survey, there were ten 220 m longlines on site, with the harvester reporting five thousand 10 m droppers present for mussel production: no mature mussels were present at the time. There were also two cage arrays used for Pacific oyster culture and 40 pyramid cages used for queen scallop culture.The harvester reported that these cages were suspended at 3 m and 15 m depths, respectively. No mention was made of sea urchins, however the harvester has subsequently identified that these are to be cultured at the same depth as the queen scallops. The plan is to culture all four species on the site, with the hope that nutrients and waste coming from the adjacent marine cage fish farm will provide food for the shellfish grown down-current. Most of the shellfish present on site was still under market size and the harvester identified that there were no plans to harvest until after 2014.

The fishery area recorded in the shoreline survey is shown in Figure 2.1, together with the locations of the provisional RMP, production area and fish farm.

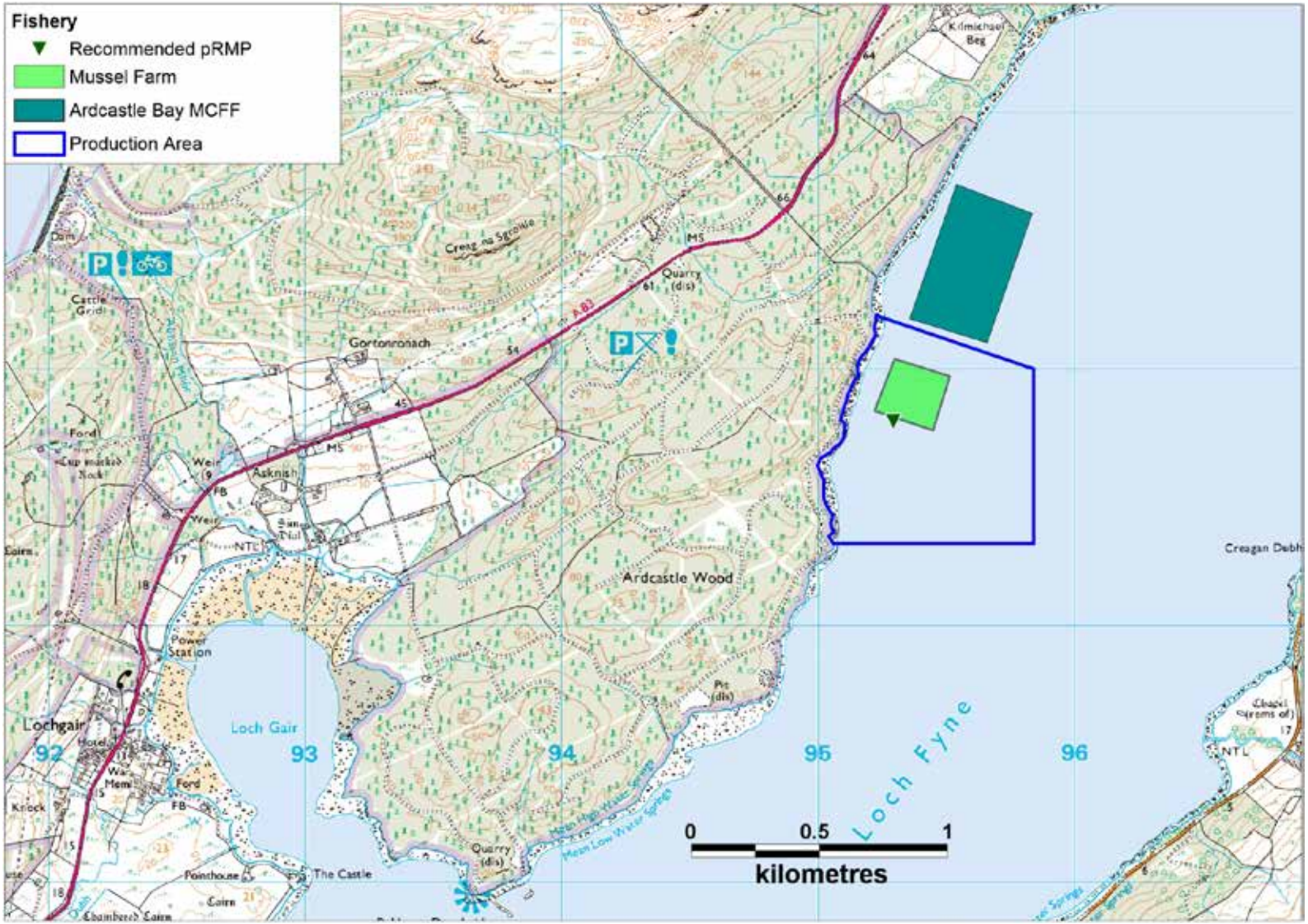


Figure 2.1 Ardcastle Bay Fishery

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the vicinity of Ardcastle Bay production area. The last census was undertaken in 2011. The census output areas surrounding Ardcastle Bay are shown thematically mapped by the 2011 population densities in Figure 3.1. The population density is low (< 11 people per km^2) on the coastline adjacent to the fishery.

A road runs inland (>400 m from the shoreline) adjacent to the western coastline of the fishery. At the small settlement of Lochgair the road runs close to the shoreline and there is a hotel (sleeps 24) and hydroelectric power plant. A second small settlement, Minard is located approximately 5 km north of the fishery. Minard Castle is a tourist attraction that also has associated accommodation to let.

During the shoreline survey a new build house and boat storage shed with gravel slipway were observed north of the fishery. There is an anchorage and moorings in Loch Gair (Clyde Cruising Club, 2007) and a second anchorage south of Loch Gair (United Kingdom Hydrographic Office, 2003). The shoreline west of the fishery is sparsely populated and accessible via a track running adjacent to the shoreline. A significant amount of boat traffic is expected to pass through the area towards and from the head of the loch (e.g. to Inverarary).

Larger settlements are located elsewhere in Loch Fyne. These are Inverarary, Lochgilphead and Tarbet (see Figure 1.1).

Overall, impacts from human sources to the water quality of the shellfish bed are likely to be low due to the low population density of the area, with any effects predominating to the south of the fishery where the settlement of Lochgair and the anchorages and moorings are located.

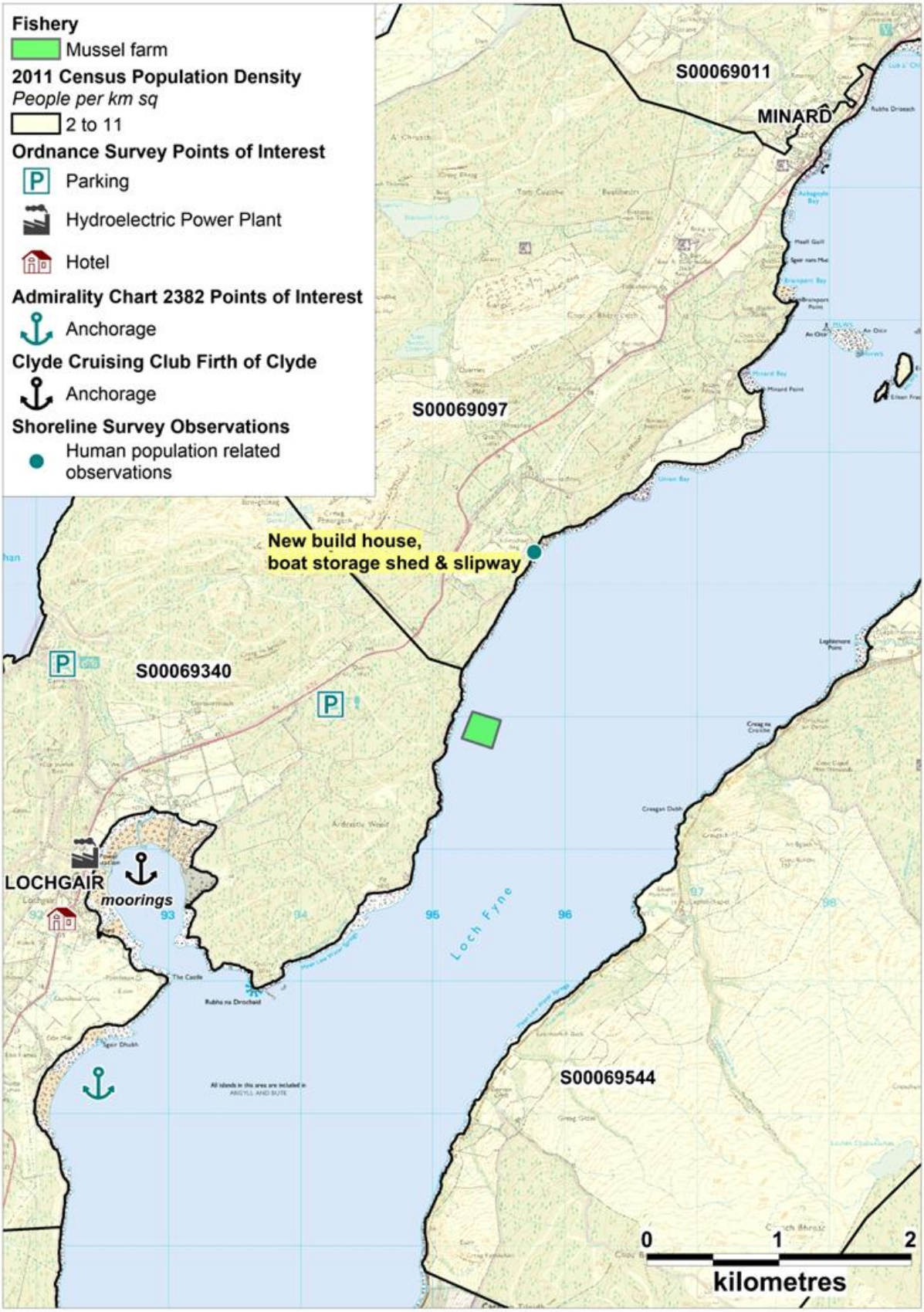


Figure 3.1 Population map for the area in the vicinity of Ardcastle Bay

4. Sewage Discharges

Information on sewage discharges 6 km around point NR 9540 9180 was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Data requested included the name, location, type, size (in either flow or population equivalent), level of treatment, sanitary or bacteriological data, spill frequency, discharge destination (to land, to waterbody or to sea), any available dispersion or dilution modelling studies, and whether improvements were in work or planned.

4.1 Scottish Water Discharges

Scottish Water provided information of 3 discharges within the area requested. These are shown in Table 4.1:

Table 4.1 Scottish Water discharges

Licence Number	Discharge Name	NGR	Discharge Type	Treatment Level	DWF (m^3/d)	Overflow l/sec	PE
WPC/W/71921	Minard, Minard ST	NR 982 961	Continuous	Septic Tank	117.5	*	178
WPC/W/71921	Minard, Minard WWPS EO	NR 982 961	Intermittent	6mm screen	*	1.36	*
WPC/W/71921	Minard, Minard CSO	NR 982 961	Intermittent	6mm screen	*	1.36	*

EO Emergency Overflow; CSO Combined Sewer Overflow; DWF Dry Weather Flow; PE Population Equivalent; *Not applicable [a] Assumed (per Scottish Water); [b] Connected population

Subsequent to release of the draft report for consultation, Scottish Water identified a further septic tank (Lochgair ST) serving 60 people and discharging to Loch Gair at NR 9256 9026. An assumed DWF of 12.6 m^3/day. Scottish Water also reported that an impact assessment carried out on the Lochgair septic tank showed no impact beyond the entrance to Loch Gair.

4.2 Consented Discharges

SEPA provided information on a relatively large number of consented discharges in the request area. Discharges considered explicitly in this report were those that lay within 6 km of the fishery. These, together with the location of the fish farm that holds a discharge consent, are listed in Table 4.2.

Table 4.2 SEPA discharge consents adjacent to Ardcastle Bay

Licence No.	NGR	Treatment type	Discharges to	PE
CAR/R/1010086	NR 92420 90550	Sewage (Private) Primary	Loch Gair	6
CAR/R/1013277	NR 98230 96600	Sewage (Private) Primary	Achagoyle Bay	8
CAR/R/1013460	NR 97881 96340	Sewage (Private) Primary	Auchgoyle Burn	11
CAR/R/1015591	NR 92382 90353	Sewage (Private) Primary	Soakaway	5
CAR/R/1018022	NR 92440 90870	Sewage (Private) Primary	Loch Gair	5
CAR/R/1018936	NR 95296 88856	Sewage (Private) Primary	U/N W/C	10
CAR/R/1019643	NR 93120 91965	Sewage (Private) Primary	U/N W/C	5
CAR/R/1020286	NR 93010 91500	Sewage (Private) Primary	Soakaway	6
CAR/R/1022292	NR 92096 89437	Sewage (Private) Primary	Soakaway	20
CAR/R/1024288	NR 92376 90458	Sewage (Private) Primary	Soakaway	5
CAR/R/1026866	NR 92390 90570	Sewage (Private) Primary	Loch Gair	5
CAR/R/1028918	NR 92570 90590	Sewage (Private) Primary	Loch Gair	0
CAR/R/1033020	NR 98120 96490	Sewage (Private) Primary	Loch Fyne	0
CAR/R/1037220	NR 91978 90006	Sewage (Private) Primary	Loch gair	5
CAR/R/1037270	NR 92299 90657	Sewage (Private) Primary	Loch Gair	5
CAR/R/1037298	NR 97882 96278	Sewage (Private) Primary	Auchagoyle Burn	11
CAR/R/1037341	NR 98090 96486	Sewage (Private) Primary	Loch Fyne	5
CAR/R/1037679	NR 92470 90557	Sewage (Private) Primary	Loch Gair	7
CAR/R/1037700	NR 92062 90375	Sewage (Private) Primary	U/T of Eas Dubh	5
CAR/R/1037715	NR 92414 90300	Sewage (Private) Primary	Eas Dubh	5
CAR/R/1037732	NR 98083 96471	Sewage (Private) Primary	Loch Fyne	5
CAR/R/1037885	NR 92405 90297	Sewage (Private) Primary	Eas Dubh	6
CAR/R/1038300	NR 92506 90494	Sewage (Private) Primary	Loch Gair	5
CAR/R/1038806	NR 98049 96631	Sewage (Private) Primary	U/N W/C	5
CAR/R/1038817	NR 98280 96750	Sewage (Private) Primary	Soakaway	25
CAR/R/1038822	NR 91740 89160	Sewage (Private) Primary	Soakaway	20
CAR/R/1038841	NR 92407 90357	Sewage (Private) Primary	Eas Dubh	11
CAR/R/1038848	NR 93222 91842	Sewage (Private) Primary	U/N W/C	15
CAR/R/1038850	NR 97782 96121	Sewage (Private) Primary	Loch Fyne	5
CAR/R/1038911	NR 96710 95180	Sewage (Private) Primary	U/N W/C	5
CAR/R/1038927	NR 92519 90393	Sewage (Private) Primary	Loch Gair	5
CAR/R/1038928	NR 97770 96570	Sewage (Private) Primary	Soakaway	15
CAR/R/1039076	NR 98070 96470	Sewage (Private) Primary	Loch Fyne	6
CAR/R/1039245	NR 96829 95245	Sewage (Private) Primary	Soakaway	5
CAR/R/1039314	NR 98011 96664	Sewage (Private) Primary	U/T of Loch Fyne	5
CAR/R/1039331	NR 92470 90520	Sewage (Private) Primary	Loch Gair	11
CAR/R/1039697	NR 97930 96670	Sewage (Private) Primary	Soakaway	5
CAR/R/1039814	NR 95443 93322	Sewage (Private) Primary	Soakaway	5
CAR/R/1040083	NR 97836 96033	Sewage (Private) Primary	Achagoyl Bay	7
CAR/R/1040154	NR 92450 90690	Sewage (Private) Primary	Loch Gair	5
CAR/R/1040523	NR 92340 90360	Sewage (Private) Primary	Soakaway	6
CAR/R/1042341	NR 96807 95189	Sewage (Private) Primary	U/N W/C	15
CAR/R/1057901	NR 97879 96662	Sewage (Private) Primary	Soakaway	5
CAR/R/1064501	NR 92957 91703	Sewage (Private) Primary	U/T of Abhainn Mhor	5
CAR/R/1064883	NR 97194 94350	Sewage (Private) Primary	Soakaway	5
CAR/R/1064952	NR 97443 94053	Sewage (Private) Primary	Loch Fyne	30

Licence No.	NGR	Treatment type	Discharges to	PE
CAR/R/1066990	NR 98025 96620	Sewage (Private) Primary	Soakaway	5
CAR/R/1067222	NR 95638 93739	Sewage (Private) Primary	Eas na Feannaige	8
CAR/R/1072285	NR 96077 94438	Sewage (Private) Primary	Soakaway	5
CAR/R/1078797	NR 98163 96738	Sewage (Private) Primary	Loch Fyne	6
CAR/R/1079545	NR 98200 96580	Sewage (Private) Primary	Lachlan Bay	7
CAR/R/1080373	NR 92470 90430	Sewage (Private) Primary	Loch Gair	7
CAR/R/1095852	NR 95193 88854	Sewage (Private) Primary	Loch Fyne	10
CAR/R/1105322	NR 96881 95406	Sewage (Private) Primary	Soakaway	8
CAR/R/1106453	NR 97675 96409	Sewage (Private) Primary	Achagoyle Burn	6
CAR/R/1106708	NR 92470 91410	Sewage (Private) Primary	Soakaway	10
CAR/R/1108000	NR 97580 95770	Sewage (Private) Primary	Loch Fyne	6
CAR/R/1067821	NR 97930 96350	Sewage (Private) Primary	Soakaway	5
CAR/R/1021321	NR 97764 96109	Sewage (Private) Secondary	Loch Fyne	6
CAR/R/1022222	NR 92085 89432	Sewage (Private) Secondary	U/T of Loch Fyne	7
CAR/R/1024782	NR 92295 90739	Sewage (Private) Secondary	U/N W/C	5
CAR/R/1035375	NR 92790 90070	Sewage (Private) Secondary	Loch Gair	0
CAR/R/1035833	NR 96768 95192	Sewage (Private) Secondary	U/N W/C	12
CAR/R/1089794	NR 95520 89260	Sewage (Private) Secondary	Soakaway	8
CAR/R/1075260	NR 98149 96536	Sewage (Private) Untreated	Loch Fyne	5
CAR/R/1111160	NR 98120 96500	Sewage (Private) Untreated	Loch Fyne	10
CAR/L/1010775	NR 95070 90777	Fish Farm Marine Cage	Loch Fyne	-

- No data provided; U/T Unnamed tributary; U/N W/C Unnamed watercourse

No information was received from SEPA regarding the Minard septic tank. Of the consent information provided by SEPA, 67 consents related to private discharge were recorded as being located within 6 km of the fishery. These included the Ardcastle marine cage fish farm (CAR/L/1010775), the given location of which plots approximately 1 km to the south of the shellfish farm. However, no other evidence was found of a fish farm in this location. According to the application information provided by the harvester, the Ardcastle marine cage fish farm is actually located approximately 300 m northeast of the shellfish farm. This location was confirmed by both internet-based satellite imagery (BingMaps, imagery date April 2012) and observation recorded during the shoreline survey (undertaken in November 2013).

Of the 66 sewage discharge consents, 58 related to septic tanks, 6 to some form of secondary treatment and two to untreated sewage effluent.

The large majority of consented discharges discharged to water, with 26 discharging directly to Loch Fyne or adjoining coastal water bodies such as Loch Gair, and a further 21 discharging to watercourses flowing into Loch Fyne.

There are likely to be additional, unregistered, septic tank discharges in the area. SEPA have also identified that in remote areas, discharge arrangements may no longer match the consent as private septic tank outfalls may be rerouted from failed soakaway systems to nearby watercourses or shoreline.

The majority of consents for private discharges were associated with the settlements of Minard and Lochgair, although there are a few discharges from premises located along the A83 which runs along the northwestern shore of the loch.

Shoreline Survey Discharge Observations

No sewage-related observations were noted during the shoreline survey. The shoreline survey route did not include Loch Gair or Minard. The shoreline adjacent to the fishery was unpopulated woodland. One observation identified a finfish farm with a manned feeding barge lying within one kilometre to the north of the mussel lines. The shoreline survey report stated that this barge is manned by two people during the day but that provision for sewage disposal was unknown and no details were found in planning applications for the site. This location is consistent with the fish farm lease area identified in Section 2.

Summary

The area directly adjacent to the fishery is largely unpopulated. The main sewage inputs are north of the production area at Minard and south, at Loch Gair. The majority of sewage discharges to either watercourses or to sea.

The only public sewage system discharges at Minard, northeast of the production area and serves a population equivalent of 178.

List of Acronyms

CSO	Combined Sewer Overflow	ST	Septic Tank
DWF	Dry weather flow	WWPS	Wastewater Pumping Station
EO	Emergency Overflow	WWTW	Wastewater Treatment Work
PE	Population Equivalent		

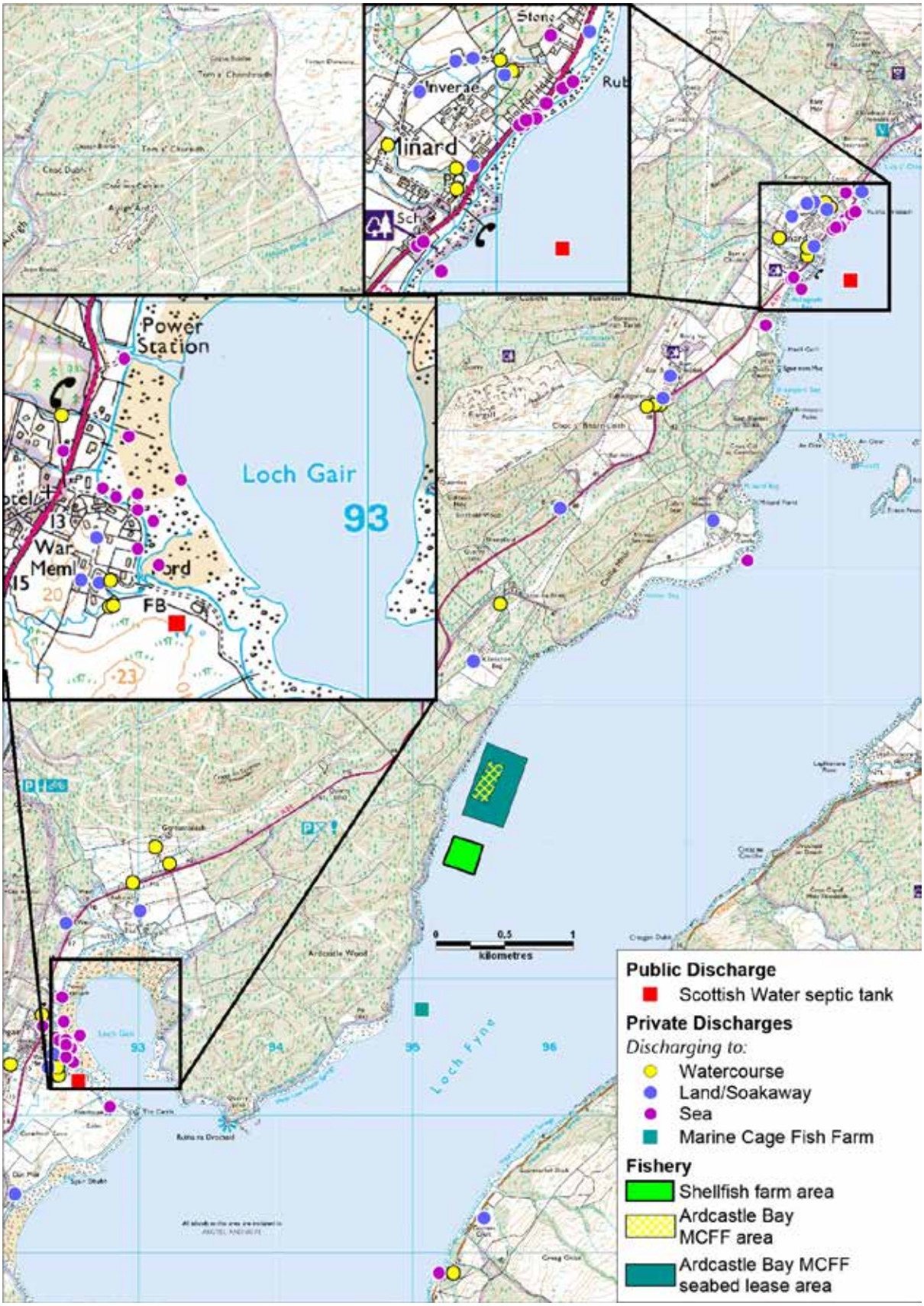


Figure 4.1 Map of discharges for Ardcastle Bay

5. Agriculture

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

Table 5.1 Livestock numbers in the Kilmichael Glassary and Strathlachlan agricultural parishes 2012

	Kilmichael Glassary		Strathlachlan	
	249 km^2		62 km^2	
	Holdings	Numbers	Holdings	Numbers
Pigs	0	-	0	-
Poultry	12	182	*	*
Cattle	12	1396	*	*
Sheep	18	13953	*	*
Other horses and ponies	5	10	*	*

* data withheld

The livestock census numbers for Kilmichael Glassary relate to very a large parish area, therefore it is not possible to determine the spatial distribution of the livestock on the west side of the loch in relation to the Ardcastle Bay area or identify how many animals are likely to impact the catchment around the fishery. Therefore the figures are of little use in assessing the potential impact of livestock contamination to the fishery; however they do give an idea of the total numbers of livestock over the broader area. There were no holdings of pigs and poultry, cattle and sheep were present in moderate numbers with other horses and ponies present in small numbers. The southeastern shoreline of the loch lies in the Strathlachlan agricultural parish: no holdings of pigs and less than five holdings of poultry, cattle, sheep and other horses and ponies were reported for this parish.

A source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 4) which only relates to the time of the site visit on the 19th November 2013. Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been obscured by the terrain. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 5.1.

During the shoreline survey, no livestock were observed along the northwestern shoreline closest to the fishery. Approximately 60 sheep were grazing close to a watercourse at Lephinchapel on the southeastern coastline of Loch Fyne. Lephinchapel Farm was observed at the same location and planning applications for the installation of a slurry pit (1997), erection of a sheep shed (1999) and separate cattle shed (2009) were approved by Argyll and Bute Council (Argyll and Bute Council, 2014). One sheep dip consent was identified in the area by SEPA, north of the farm and close to where the livestock had been observed during the shoreline survey.

Seasonal increases in the number of sheep are expected, with numbers expected to be approximately double during late spring following the birth of lambs before dropping back down again in the autumn after the lambs are sent to market.

Any contributions of faecal contamination from livestock grazing in the area potentially affect the side of the mussel farm closest to the eastern coastline; dependent on currents in the area.

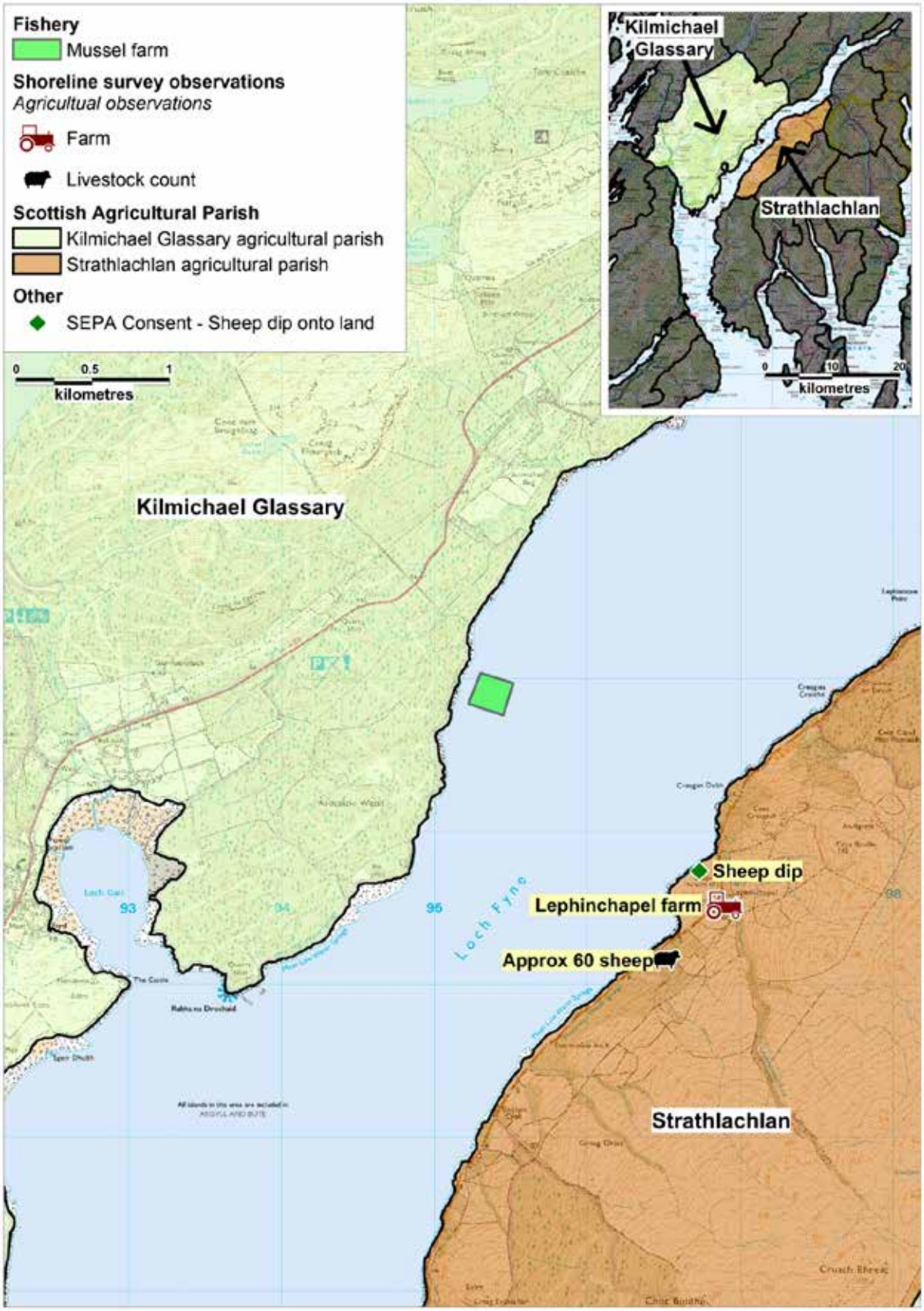


Figure 5.1 Livestock observations at Ardcastle Bay

6. Wildlife

Wildlife species present in and around the production area will contribute to background levels of faecal contamination at the fishery, and large concentrations of animals may constitute significant sources when they are present. Seals, cetaceans and some seabirds may deposit faeces directly into the sea, while birds and mammals present on land will contribute a proportion of any faecal indicator loading carried in diffuse run-off or watercourses.

The species most likely to contribute to faecal indicator levels at the Ardcastle Bay multi-trophic fishery are considered below.

Pinnipeds

In a study by the Special Committee on Seals (SCOS, 2012) between the years 2007-2011, approximately 10 harbour seals and five grey seals were observed in Loch Fyne, northeast and southwest of the Ardcastle Bay area (reported locations relate to 10 km squares). In the open seas around the entrance to Loch Fyne, high numbers of both seal species were observed, though harbour seals were more common, owing to the less exposed nature of the south west coast of Scotland.

There are anecdotal accounts that seals can often be seen around Ardcastle Bay (Walkhighlands.co.uk, 2013) though no seals were observed during the shoreline survey.

Cetaceans

In 2013 alone there have been at least one sighting reported of one or more harbour porpoise in the Loch Fyne (Hebridean Whale and Dolphin Trust, 2014). This indicates that these cetaceans will be travelling though the Ardcastle Bay area and may be having a contamination impact on the area. There are also anecdotal accounts of dolphins in the loch (Minard Castle, 2002). It is unlikely that larger cetaceans such as whales will be using the area, owing to the narrowness of the loch.

Birds

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

Table 6.1 Seabird counts within 5 km of Ardcastle Bay.

Common name	Species	Count*	Method
European herring gull	*Larus argentatus*	762	Occupied nests
Lesser Black-backed gull	*Larus fuscus*	86	Occupied nests
Great black backed gull	*Larus marinus*	66	Occupied nests
Common gull	*Larus canus*	2	Individuals on land
European shag	*Phalacrocorax aristotelis*	72	Occupied nests

*Counts have been adjusted where the method used was occupied nests to reflect the probable number of individual birds (i.e. counts of nests were doubled).

The densest colony of seabirds from the Seabird 2000 data was found to be located on Eilean Aoghainn, approximately 4 km northeast of the Ardcastle fishery. This was a breeding colony that consisted of *Larus* sp. and European shags. The location shown in Figure 6.1 lies southwest of the island, at the southwest corner of the 1 km grid containing the island. Breeding season varies somewhat, with shags breeding as early as February and fedging from June to October and gulls breeding between May and September.

Other information suggests that various species of birds use the surrounding area around Minard castle which lies approximately 7.5 km from the fishery (Minard Castle, 2002). Wading birds were also noted to be common on the intertidal area south of Ardcastle, at Loch Gair (Argyll and Bute Council, 2009).

Only approximately a dozen birds were seen in the area during the shoreline survey. The most significant of these observations are shown in Figure 6.1.

Deer

Deer are recognised as being present in large numbers on the hillsides around Tarbert. And there is also a deer farm located on the south side of Tarbert (Tarbert Loch Fyne, 2014). Anecdotal accounts of deer both red and roe deer in woodland around Minard Castle approximately 7.5 km southwest of the fishery suggest that there are deer in the close vicinity (Walkhighlands.co.uk, 2013; Minard Castle, 2002)

Otters

The Eurasian otter (*Lutra lutra*) is common in Scotland. There are anecdotal accounts of otters around Minard Castle, which is situated approximately 7.5 km southwest of the fishery (Walkhighlands.co.uk, 2013; Minard Castle, 2002). There is also information indicating otters are present on shores around Loch Gair, south of Ardcastle (Argyll and Bute Council, 2009).

Overall

Species potentially impacting on Ardcastle Bay include seals, seabirds, deer and otters. The most significant source is expected to lie the northeast of Ardcastle Bay, associated with the breeding colonies of *Larus* sp. and European shag.

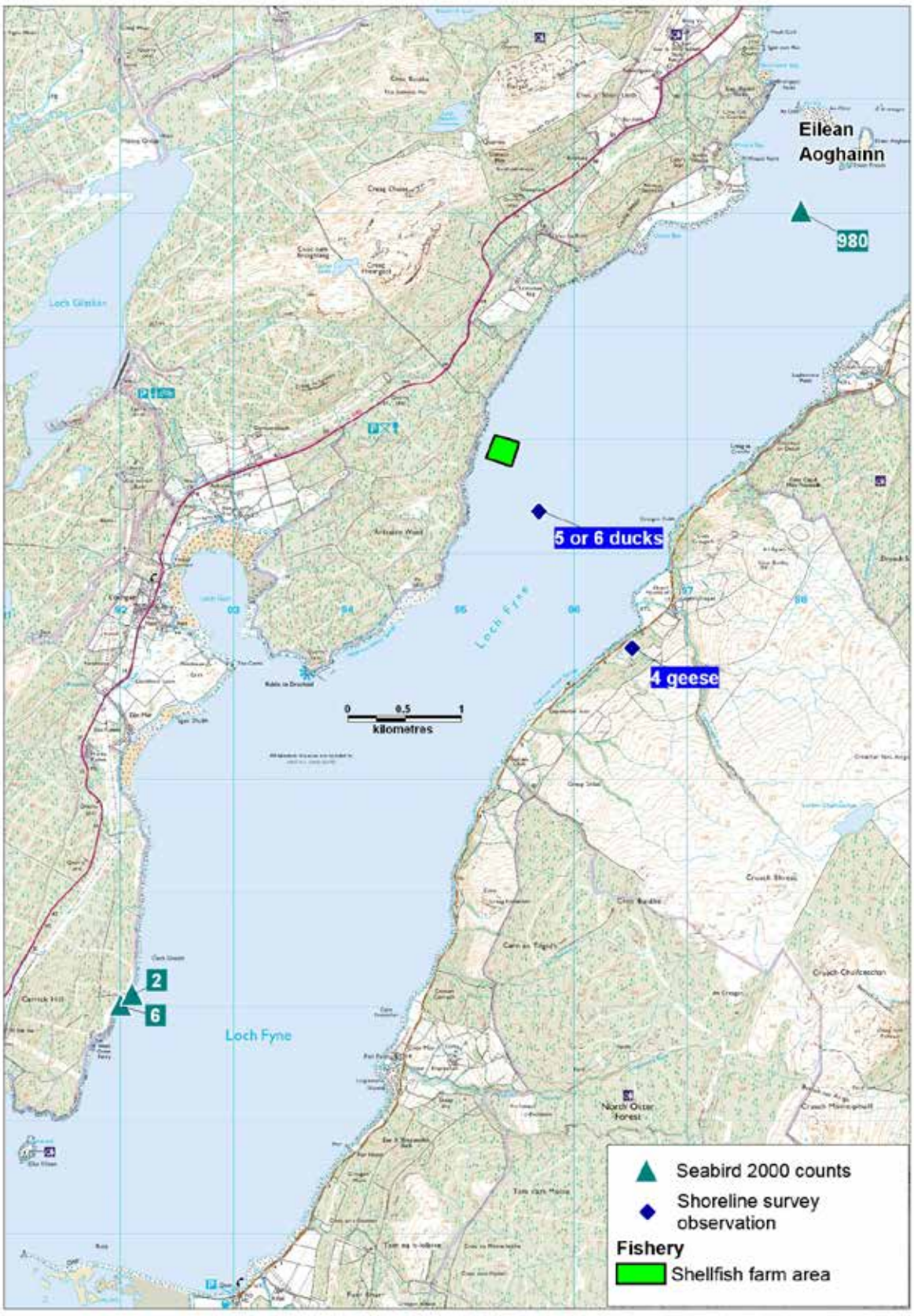


Figure 6.1 Map of wildlife around Ardcastle Bay

7. Land Cover

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

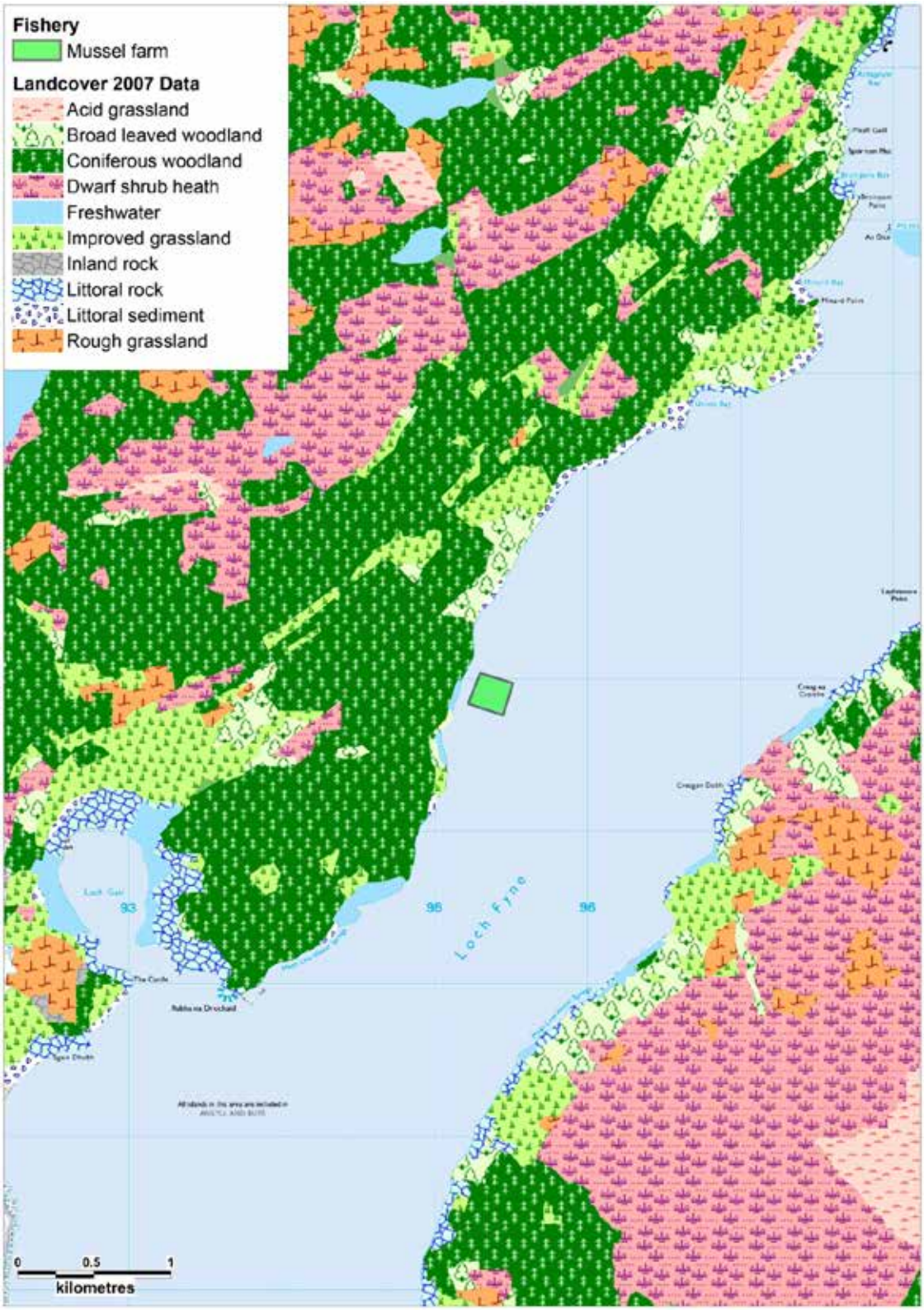


Figure 7.1 LCM2007 land cover data for the area around Ardcastle Bay

Coniferous woodland, dwarf shrub heath, rough grassland and improved grassland are the predominant land cover types on the coastlines adjacent to Ardcastle Bay fishery. There are also scattered small areas of broad leaved woodland and acid grassland. There are no built up or urban areas represented (the small settlements are principally located within parts of areas identified as improved grassland..

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately $8.3x10^8$ cfu/km^2/hr for areas of improved grassland and approximately $2.5x10^8$ cfu/km^2/hr for rough grazing (Kay, et al., 2008). The contributions from all land cover types would be expected to increase significantly after rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay, et al., 2008).

The highest potential contribution of contaminated run-off to the Ardcastle Bay mussel farm is from the areas of improved grassland located along the shoreline northeast and southwest of the fishery. The potential contribution of contaminated run-off to the shellfish bed would be highest in these areas.

8. Watercourses

There are no gauging stations on watercourses entering Loch Fyne in the vicinity of Ardcastle Bay.

Spot measurements of flow and microbial content were obtained during the shoreline survey conducted on the 19th November 2013. In the 24 hrs prior to the survey, 1.1 mm of rainfall was recorded at the nearest rain gauge at Oban, located approximately 39 km northwest of the fishery. The watercourses listed in Table 8.1 are those recorded during the shoreline survey.

No areas of land drainage were observed. Watercourse No. 2 was not sampled as the surveyor observed no potential sources of contamination (dwellings, livestock and/or outfalls) entering the watercourse or in the surrounding catchment area. No loading could therefore be estimated for this watercourse.

Table 8.1 Watercourses entering Ardcastle Bay

No.	NGR	Description	Width (m)	Depth (m)	Flow (m^3/d)	Loading (*E. coli* per day)
1	NR 9660 9057	Lephinchapel Burn	2.45	0.57*	20391*	3.5×10^{10}
2	NR 9520 9222	Watercourse	0.40	0.05**	291	Not determined
3	NR 9521 9237	Watercourse	1.60	0.09**	5053**	5.1×10^{8}
4	NR 9563 9304	Watercourse	1.45	0.09**	4089**	8.2×10^{8}

* Average taken from three measurements ** Average taken from two measurements

Three of the watercourses recorded in the area had significant flows at the time of survey. Lephinchapel Burn joins Loch Fyne southeast of the fishery and had the highest calculated loading. The remaining watercourses were observed to the north of the shellfish farm and had moderate calculated loadings.

Watercourse No. 3 discharges to Loch Fyne approximately 350 m northwest of the mussel farm. It is expected that contamination this watercourse will have a moderate impact on the northern extent of the mussel farm. Any loading from watercourse No. 2 would add to that impact. The locations and loadings of measured watercourses are shown in Figure 8.1.

Overall freshwater inputs are expected to provide moderate levels of contamination to the shellfish farm at Ardcastle Bay, and effects would be greatest at the northern part of the farm.

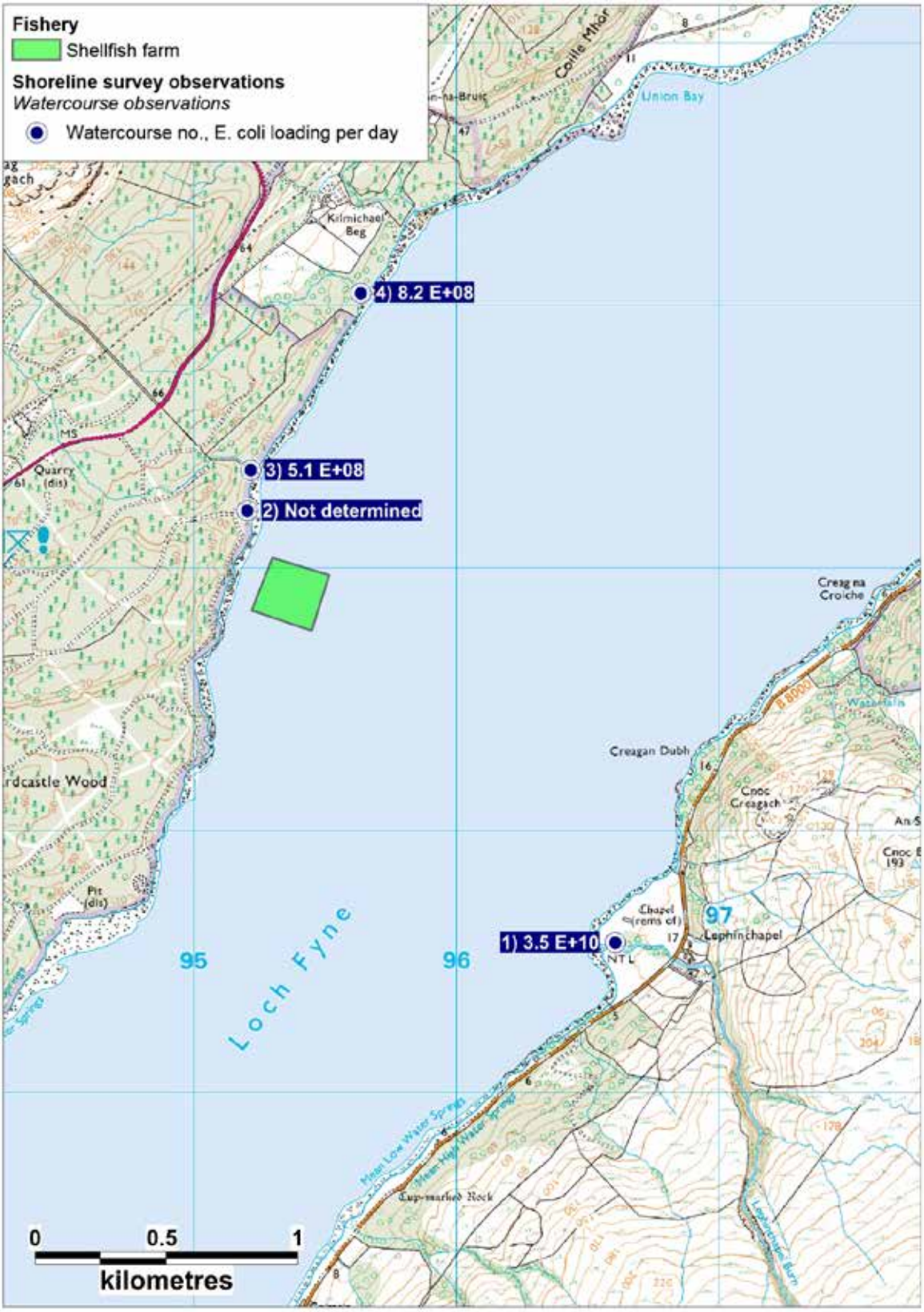


Figure 8.1 Map of watercourse loadings at Ardcastle Bay

9. Meteorological Data

The nearest weather station for which a near complete rainfall data set was available is located at Benmore, Younger Botantical Gardens, situated approximately 20 km to the south east of the fishery. Rainfall data was available for January 2007 – December 2012. The nearest wind station is situated in Glasgow, Bishopton, located 50 km east of the fishery. Data for these stations was purchased from the Meteorological Office. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas. This section aims to describe the local rain and wind patterns in the context of the bacterial quality of shellfish at Ardcastle Bay.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (e.g. (Mallin, et al., 2001; Lee & Morgan, 2003)). The box and whisker plots in Figures 9.1 and 9.2, present a summary of the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

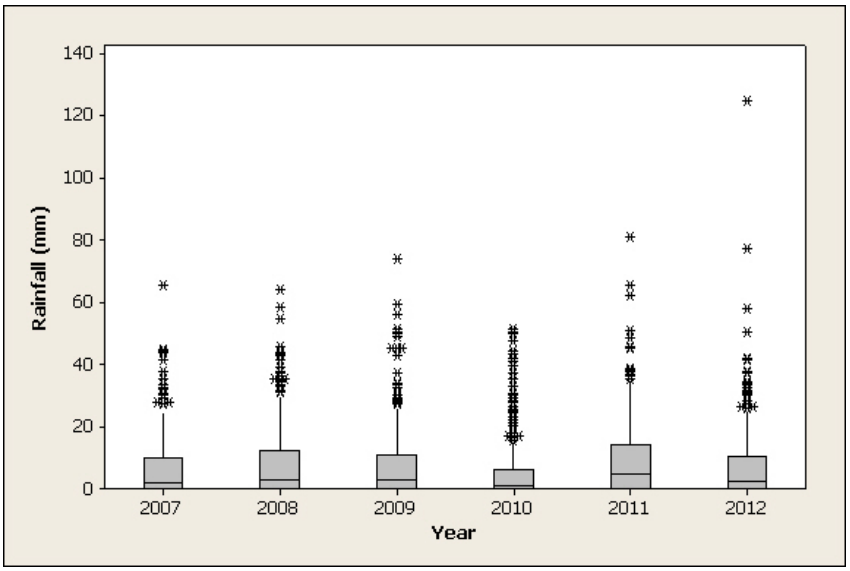


Figure 9.1 Box plot of daily rainfall values by year at Benmore, Younger Botanical Gardens (2007 – 2012)

Total rainfall values varied from year to year, with 2010 being the driest year so far (a total of 1957 mm). The wettest year was 2011 (a total of 3340 mm). Daily rainfall values of more than 50 mm/d occurred in all years but an extreme rainfall event of nearly 130 mm/d occurred 2012.

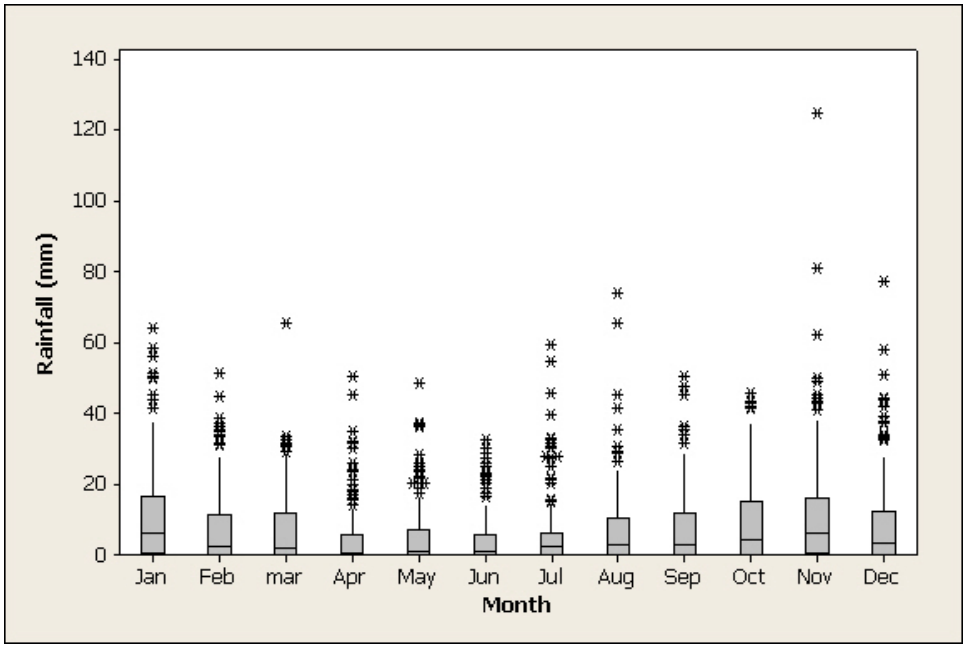


Figure 9.2 Box plot of daily rainfall values by month at Benmore, Younger Botanical Gardens (2007 – 2012)

Rainfall was lowest between April and July and highest between October and January. Rainfall values exceeding 50 mm/d were seen in all months apart from June and October. The 2012 extreme event occurred in November.

For the period considered here (2007 – 2012) 41 % of days received daily rainfall of less than 1 mm and 26 % of days received rainfall of over 10 mm.

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

9.2 Wind

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

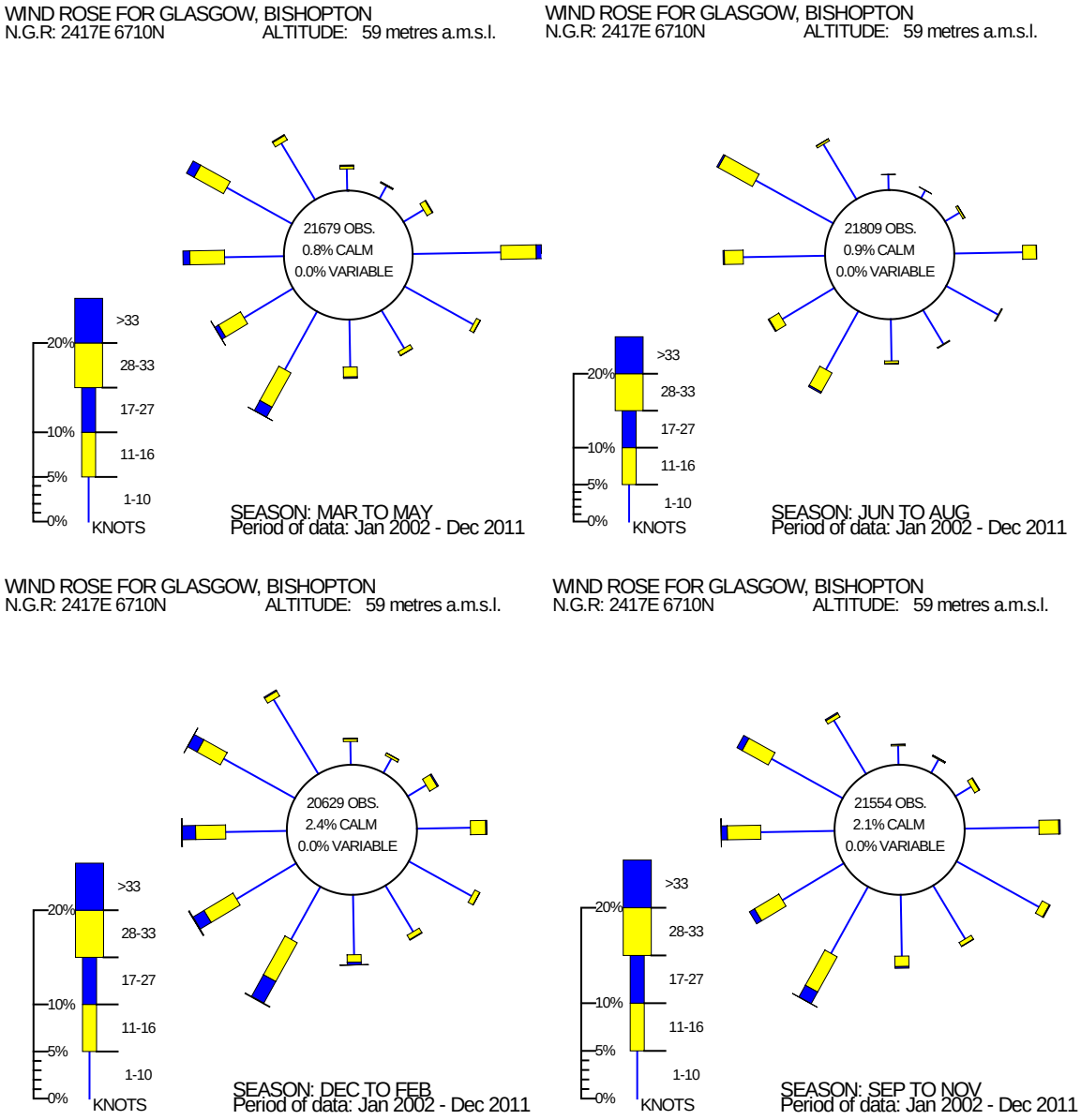


Figure 9.3 Seasonal wind roses for Glasgow, Bishopton

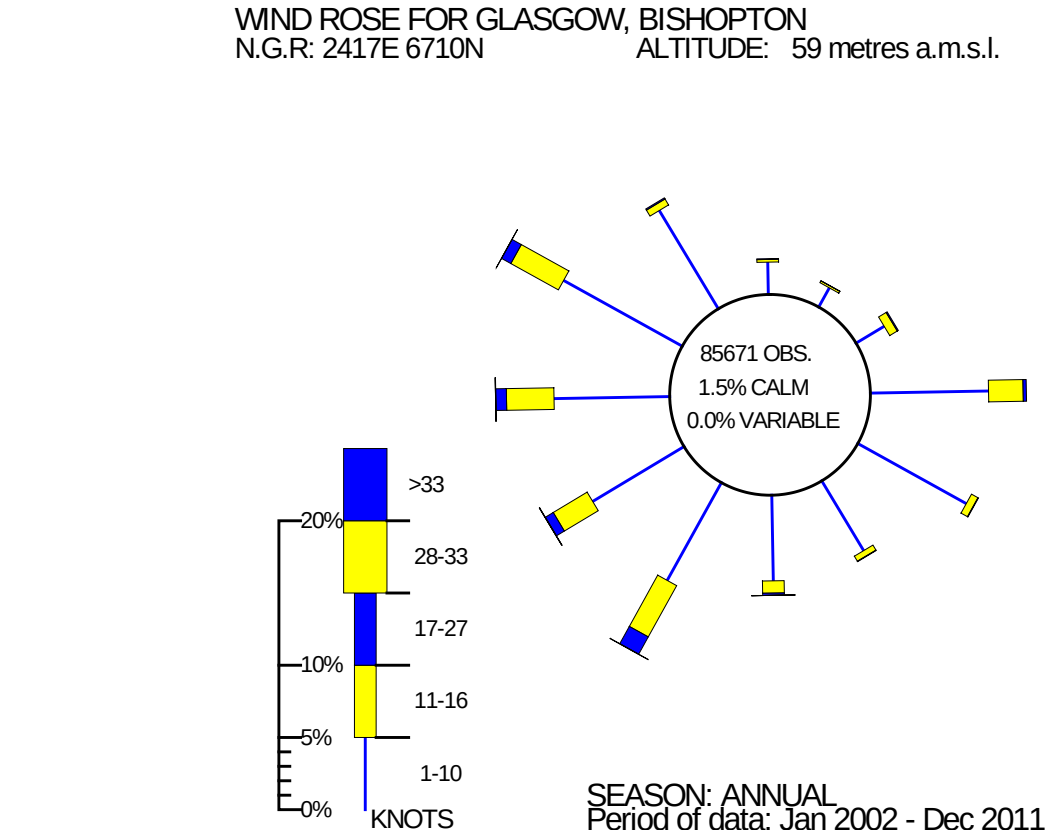


Figure 9.4 Annual wind rose for Glasgow, Bishopton

Overall the annual wind direction showed that wind was stronger when coming from the west than the east, and winds from the southerly direction were stronger than those from the north. Predominant winds were from the west south-west. There was no marked change in wind direction throughout the months; however winds were much stronger in the winter months than in the summer months.

Wind is an important factor in the spread of contamination as it has the ability to drive surface water at about (3%) of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore strong winds can significantly alter the pattern of surface currents. Strong winds also have the potential to affect tide height depending on wind direction and local hydrodynamics of the site. A strong wind combined with a spring tide may result in higher than usual tides, which will carry any accumulated faecal matter at and above the normal high water mark into the production area.

10. Classification Information

Ardcastle Bay is a new production area. Samples are currenly being submitted towards standard classification.

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples of all species assigned against the Ardcastle Bay site for the period 01/01/2008 to the 07/01/2014 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted on 07/01/2014. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

All sample results reported as <20 *E. coli* MPN/ 100 g were reassigned a value of 10 *E. coli* MPN/ 100 g for the purposes of statistical evaluation and graphical representation.

All mussel, oyster and scallop samples were reported as valid in the database. One urchin result was recorded as rejected and was excluded from further analysis. All remaining samples from all four species were received at the laboratory within 48 hours of collection, and were reported as having been taken within the boundaries of the recommended production area.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary				
Production area	Ardcastle Bay			
Site	Ardcastle Bay			
Species	Common mussels	Pacific oysters	Queen scallops	Green sea urchins
SIN	AB-635-1281-08	AB-634-1280-13	AB-637-1282-15	AB-637-1283-22
Location	Various			
Total no of samples	9	9	8	3
No. 2013	9	9	8	3
Minimum	<20	<20	<20	<20
Maximum	330	700	490	<20
Median	50	50	20	<20
Geometric mean	49	57	36	-
90 percentile	330	700	490	-
95 percentile	330	700	490	-
No. exceeding 230/100g	2	2	2	0
No. exceeding 1000/100g	0	0	0	0
No. exceeding 4600/100g	0	0	0	0
No. exceeding 18000/100g	0	0	0	0

-Too few results taken to calculate geometric means, 90 and 95 percentiles

Highest results were recorded in Pacific oysters. Mussels, oysters and scallops all had two results >230 *E. coli* MPN/ 100 g during the sampling period.

11.3 Overall geographical pattern of results

The reported sampling locations for all four species were located within 10 m of NR 9550 9189 eastern side of the fishery. This is presumed to be the location where the harvester originally placed a set of sampling cages prior to the assignment of a provisional RMP. The classification application showed a sampling box location at the northeastern corner of the farm. The location, however, does not coincide with that of the recommended pRMP. The approximate centre of the reported sampling points and the location of the pRMP are shown in Figure 11.1.

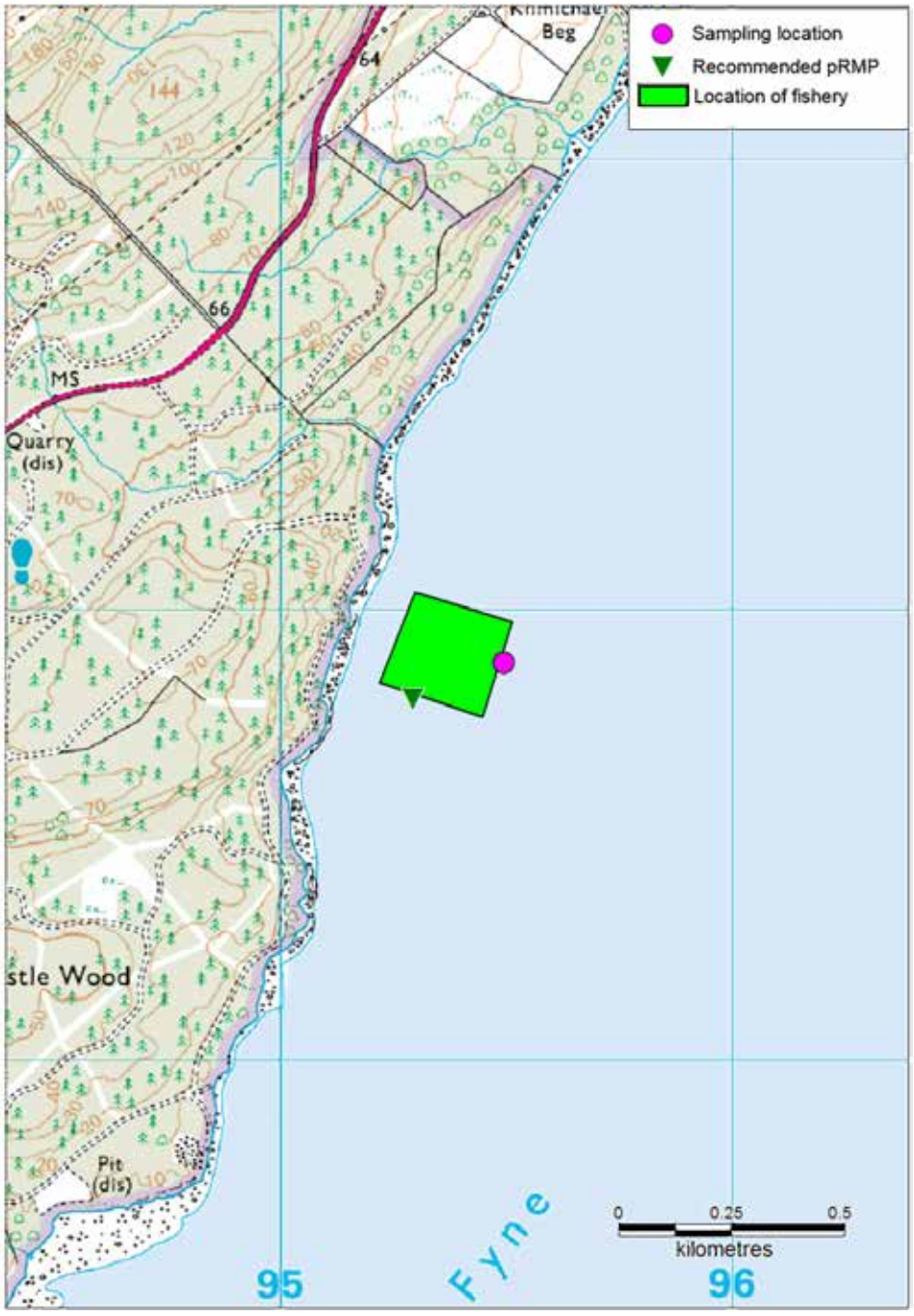


Figure 11.1 Sampling location at Ardcastle Bay

No spatial assessment of the results can be undertaken due to the use of a single sample location.

11.4 Overall temporal pattern of results

A scatterplot of all species *E. coli* results against date for Ardcastle Bay is presented in Figure 11.2. The dataset is fitted with a lowess trend line.

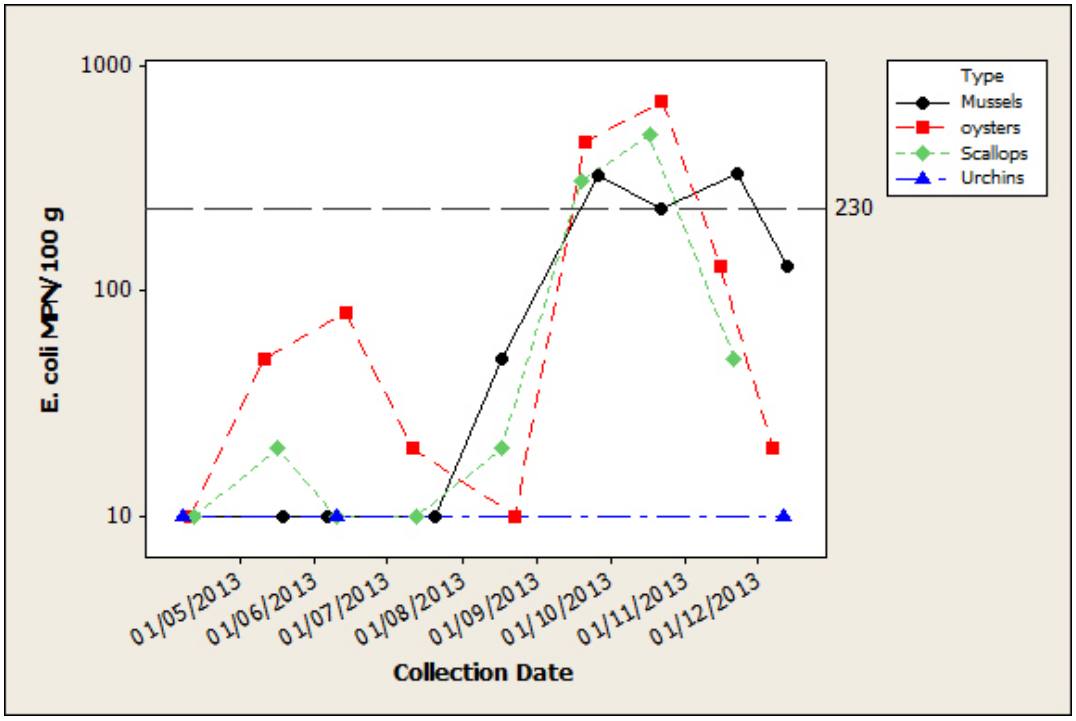


Figure 11.2 Scatterplot of all species *E. coli* results by collection date at Ardcastle Bay, fitted with a lowess line

Results above 230 MPN *E. coli*/100 g were seen between September and November. It will not be possible to properly assess seasonal trends until at least a further year's results are available.Table 11.2 lists results >230 *E. coli* MPN/100 g taken in mussel, oyster and scallop samples. The higher results occurred in all three species on one date and in two of the three species on another date. There was only one occasion when such a result was seen in only one species (mussels). Salinity data was not available for the sampling occasions: the seawater temperature was 9°C or higher on all occasions.

Table 11.2 Ardcastle Bay historic *E. coli* sampling results over 230 *E. coli* MPN/ 100g

Species	Collection Date	Location	*E. coli* (MPN/100g)	Sea temperature
Common mussel	23/09/2013	NR 95498 91886	330	13
Common mussel	18/11/2013	NR 95488 91889	330	9
Pacific oyster	23/09/2013	NR 95498 91886	460	13
Pacific oyster	21/10/2013	NR 95499 91887	700	12

Queen scallop	23/09/2013	NR 95498 91886	310	13
Queen scallop	21/10/2013	NR 95499 91887	490	12

11.5 Summary and conclusions

Two results >230 *E. coli* MPN / 100 g have been returned for each species except sea urchins over the 2013 sampling period. These occurred during the September to November inclusive. The highest result was reported in oysters in October. All samples were taken in broadly the same location on the eastern side of the shellfishery and so spatial assessment of the data is not possible.

12. Designated Waters

Shellfish Water Protected Areas

The Shellfish Waters Directive (2006/113/EC) has been repealed (as at 31 December 2013) and equivalent protection for areas previously designated under that Directive is given by The Water Environment (Shellfish Water Protected Areas: Environmental Objectives etc.) (Scotland) Regulations 2013. The Loch Fyne Shellfish Water Protected Area (SWPA) is an extension of the previous Loch Fyne Shellfish Growing Water (SGW), which only covered a coastal strip within the loch. The SWPA designation covers the majority of the loch and includes the Ardcastle Bay fishery. There is an historic SGW monitoring point located in Loch Gair at NR 924 908. Since 2007, SEPA has used the FSAS *E. coli* data for assessing microbiological quality. The designated SWPA in Loch Fyne is shown in Figure 12.1.

Bathing Waters

There are no designated bathing waters within Loch Fyne. The nearest is located at Ettrick Bay on the Isle of Bute, and any data relating to that location will not be relevant to the consideration of water quality at Ardcastle Bay.

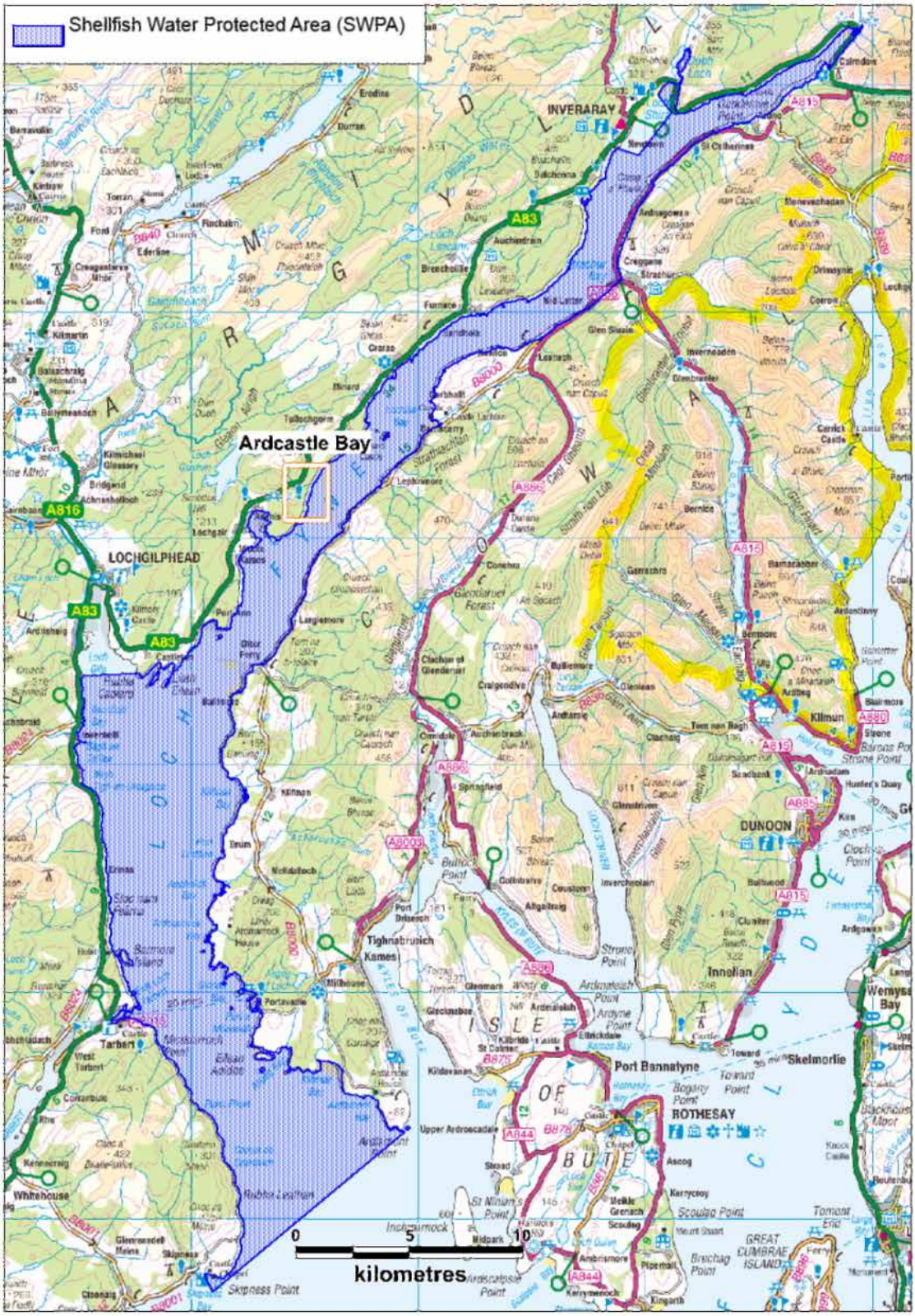


Figure 12.1 Designated shellfish water protected area – Ardcastle Bay

13. Bathymetry and Hydrodynamics

13.1 Introduction

13.1.1 The Study Area

Loch Fyne is the longest and deepest loch system in Scotland (Edwards & Sharples, 1986) which, at the mouth, opens up to the Sound of Bute and the Clyde Sea. Loch Fyne is situated in the Argyll and Bute District of the west coast of Scotland. It lies in a region away from industrial activities. The area is heavily forested with mountains surrounding the loch. The main townships are Inverary, Lochgilphead and Tarbert. The three towns are connected by the A85 trunk road which runs alongside the west coast of Loch Fyne. The region around Ardcastle Bay is sparsely populated.

The assessment area of Ardcastle Bay is within the middle reaches of Loch Fyne, between Lochgilphead to the south and Inverary to the north. The total length of Loch Fyne is 61 km but the hydrographic study area is a fraction of this at approximately 7 km. The average width of Loch Fyne is around 3 km and in the study area is typically 2 km. Thus, the assessment area is relatively confined in relation to the whole loch complex. The coastline is reasonably linear especially within the hydrographic assessment area.

Coordinates for the middle of Ardcastle Bay:

56° 4.54’ N 005° 16.70’ W
NR 96066 91830

The extent of the area considered in this hydgrographic assessment is shown in Figure 13.1.

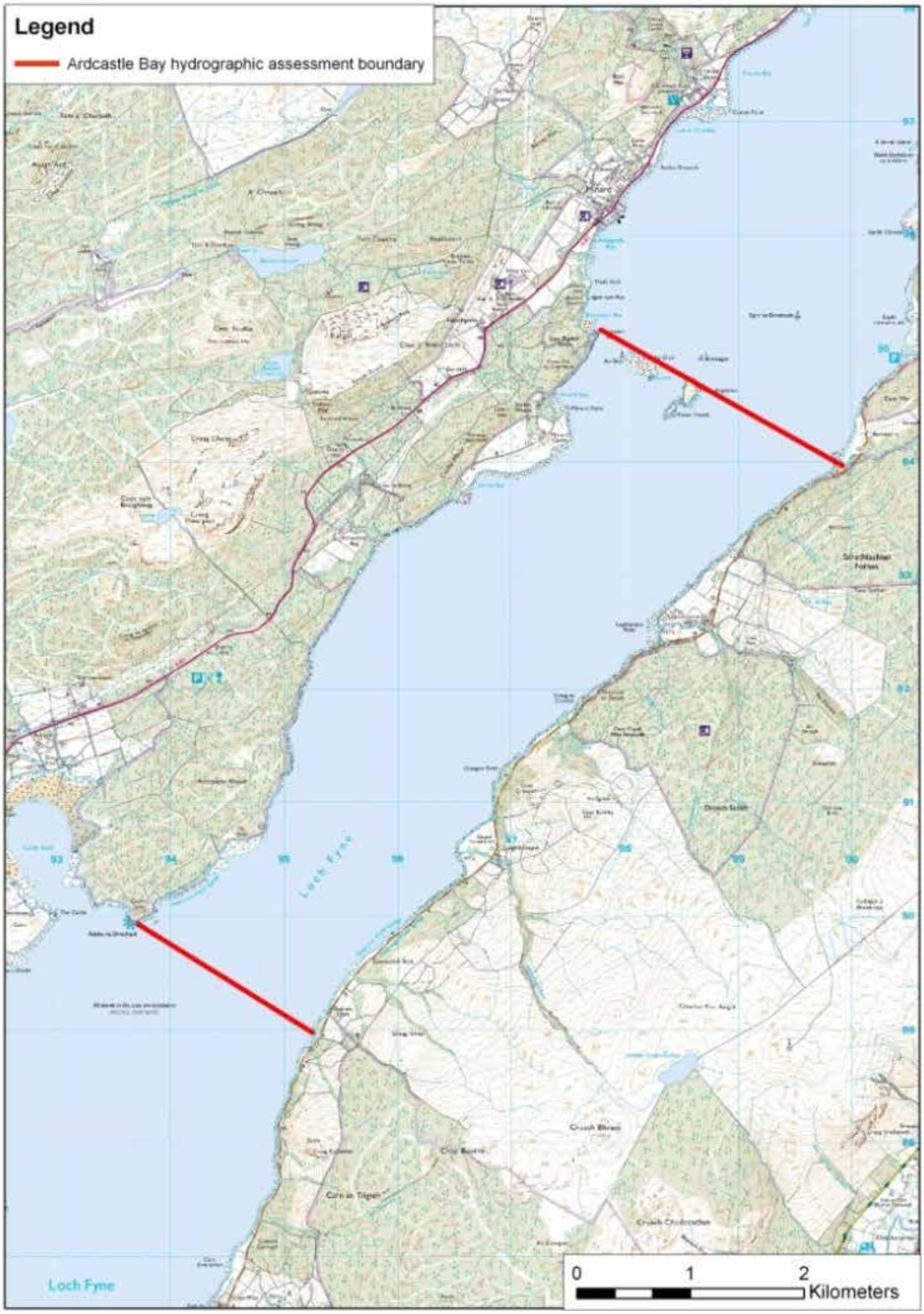


Figure 13.1 Extent of hydrographic study area

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

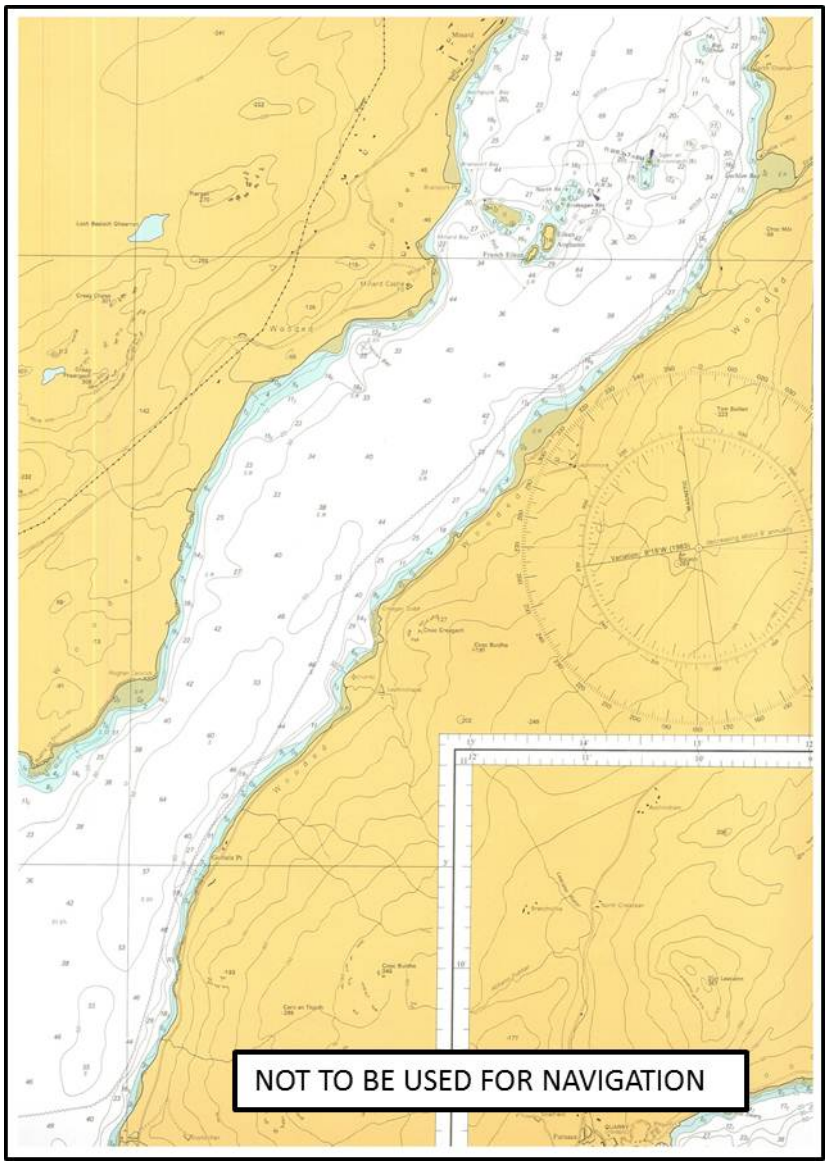


Figure 13.2 Admiralty chart (2382) extract for Loch Fyne.

Figure 13.2 shows the bathymetry of Ardcastle Bay. In general the bathymetry is rather uniform with gently sloping boundaries to deep water of approximately 40 m. There is a small island group at the northern boundary, the largest of which is Eilean Aoghainn. The maximum charted depth from Admiralty chart 2382 is 64m in the centre of the Loch adjacent to the southern boundary of the study area and another deep point of 64 m to the south east of Eilean Aoghainn.

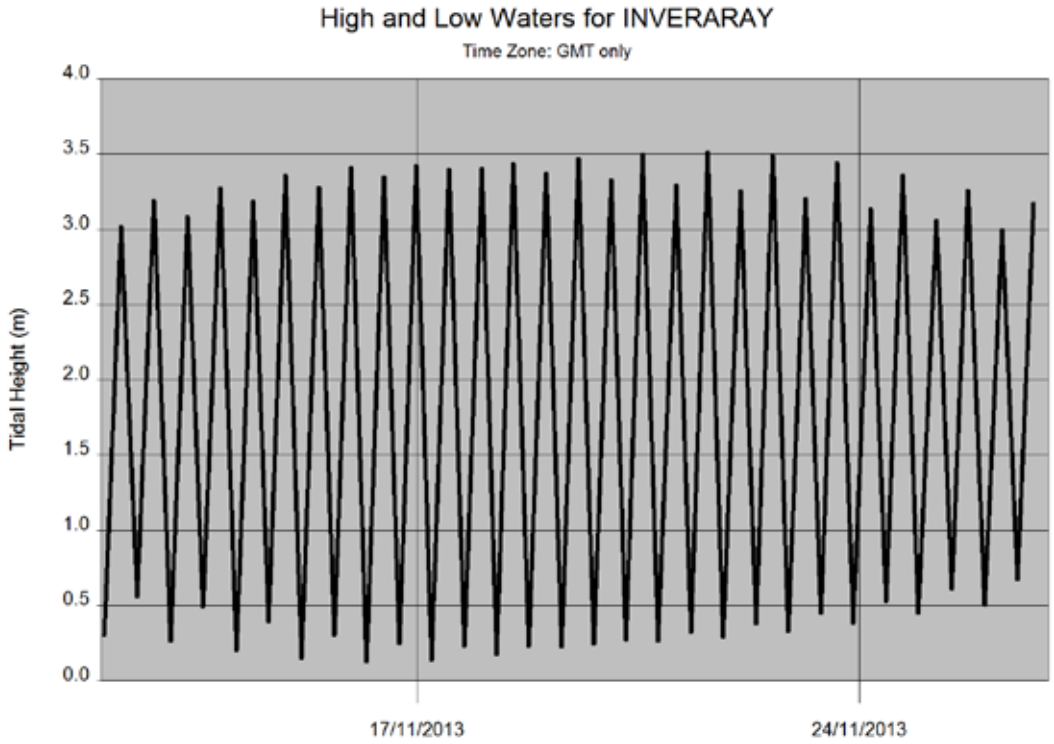
Loch Fyne contains two sills; the uppermost sill coincides with the northern boundary of the study area. This sill is 1.7 km in length with an average depth of 16 m. The lowermost sill is approximately 5 km to the south of the southern boundary of the assessment area and is 300 m in length with an average depth of 20 m (Edwards & Sharples, 1986). The

assessment area therefore lies between the two sills. The low water surface area for Loch Fyne is 173 km^2 with a mean depth through the loch of 55 m (Edwards & Sharples, 1986).

13.2.2 Tides

Ardcastle Bay has a typical semi-diurnal tidal characteristic. Data on tidal information is given from charted information. The nearest location for tidal predictions is Inverary, Loch Fyne [http://easytide.ukho.gov.uk].

Standard tidal data for Inverary, Loch Fyne, centred on the survey date of 19th November 2013, is shown in Figure 13.3.



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

Figure 13.3 Two week tidal curve for Inverary, Loch Fyne.

Tidal Heights at Inverary, Loch Fyne:

Mean High Water Springs = 3.3 m Mean Low Water Springs = 0.1 m Mean High Water Neaps = 2.9 m Mean Low Water Neaps = 0.5 m

Tidal Ranges:

Mean Spring Range = 3.2 m
Mean Neap Range = 2.4 m

This gives a tidal volume of water within the assessment area during each tidal cycle of approximately:

Springs: 4.3 x 10^7 m^3
Neaps: 3.2 x 10^7 m^3

Which is approximately 7% of the total tidal volume for Loch Fyne.

13.2.3 Tidal Streams and Currents

There are no published tidal diamonds for this area. Enhancement of tidal streams caused by straights and shallow areas will be important near the sill at the northern boundary of the study area, particularly around the islands along the sill, Eilean Aoghainn & Fraoch Eilean, which may cause localised effects.

There is a single site with current meter data available from a previous survey. Current meter data were obtained from SEPA which were collected from a site in Ardcastle Bay (Anderson, 2006). Figure 13.4 shows the location of this site. The Hydrographic survey spans 15 days. This being the half-lunar period to capture a spring-neap cycle.

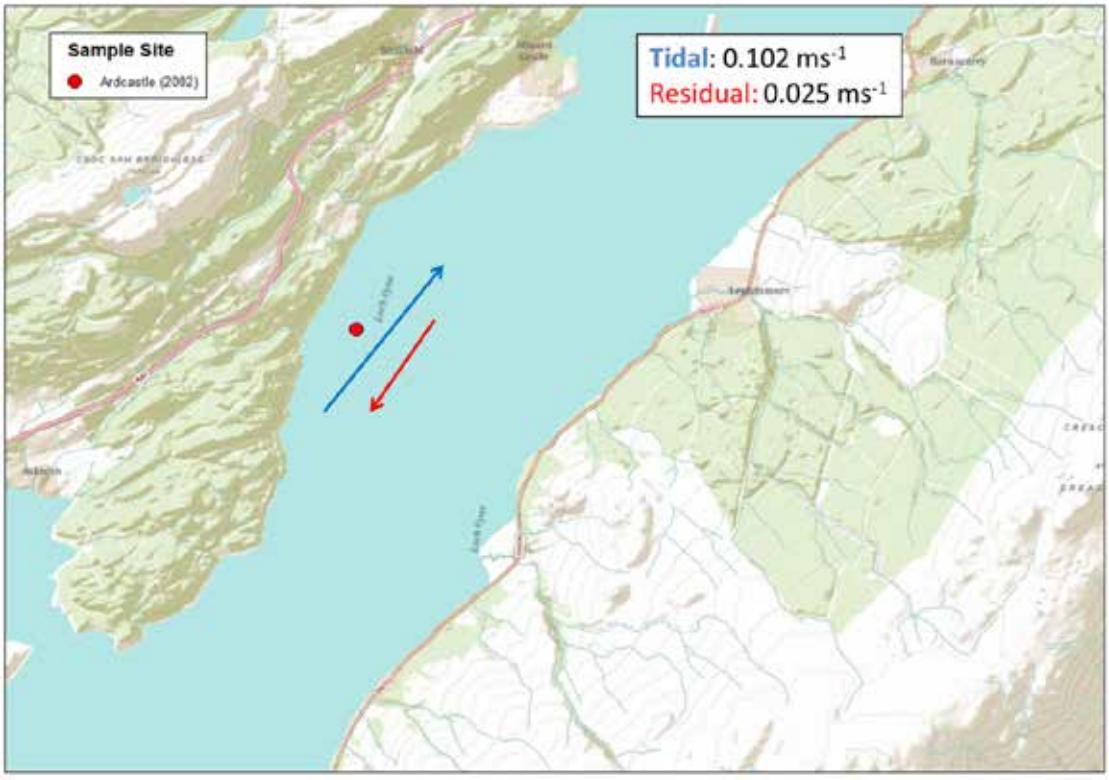


Figure 13.4 Map showing Ardcastle Bay sample site (data from 2002). Net cumulative displacement by tidal flow (ebb) and the estimated cumulative displacement through residual flow over a full tidal cycle at sample site are shown.

Data from Ardcastle Bay were collected between 4 July and 20 July 2002 and are summarised in Table 13.1. In general, the currents were of a moderate speed. Whilst the tabulated mean velocities are greatest in the mid-surface measurements, the report states that overall there was “similarity” between current velocity and direction throughout the water column (Anderson, 2006). The currents in all depths were strongly directional, aligned along the direction of the shore, with the most frequent current directions aligned in the NE-SW direction.

Table 13.1 Ardcastle current data measured in 2002

Height above seabed	Near-bed (2 m)	Mid (18 m)	Sub-surface (21 m)

Mean Speed (ms^{-1})	0.069	0.082	0.064
Maximum Speed (ms^{-1})	0.207	0.220	0.238
Principal Axis Amp & Dir (ms^{-1}) & (^oM)	0.115 (035)	0.125 (035)	0.102 (215)
Residual speed (ms^{-1})	0.007	0.013	0.026
Residual direction (^oM)	035	321	224

Current speeds were moderate, with a maximum recorded surface velocity of 0.238 m/s and a maximum 3h mean velocity of 0.176 m/s. Currents at all depths were strongly directional, with the most frequent current directions at 020>040ºT and 210>240ºT. The residual currents however did show some vertical structure. The residual current speed decreased with depth. The residual current was orientated towards the south-west at the surface and was more northerly at mid-water and near-bed depths. It is likely that the residual flow is driven by freshwater flow at the surface and/or wind forcing, although no wind directions are reported for the data.

Using a typical surface principal current amplitude of 0.102 m/s (Table 13.1) and the assumption of a uniform sinusoidal tide, the cumulative transport that might be expected during each phase of the tide (approximately 6 hours) has been estimated at approximately 1.4 km, illustrated in Figure 13.4. No distinction is made here for springs and neaps.

Dispersion is an important property of a water body with respect to redistribution of contaminants over time. There are no measurements or published data relating to dispersion in Ardcastle Bay. Without such data it is difficult to judge what the dispersive environment might be like. However, flow round the islands at the north of the assessment area might enhance dispersion.

13.2.4 River/Freshwater Inflow

There are several rivers surrounding Ardcastle which may or may not flow depending on the season. Within the hydrographic assessment boundary, the main watercourses on the eastern shore are Barnacarry Burn, Lephinmore Burn and Lephinchapel Burn. Other minor freshwater sources on the eastern shore are Allt Ceann na Coille, Allt Buidhe, Alltan Cleirich and Alltan Reil with other unnamed watercourses on the OS map. The main watercourses on the west shore are fewer and, again, unnamed on the OS map.

The annual precipitation in the Loch Fyne area is approximately 1750 mm and the annual freshwater run-off is estimated as 1340 x 10^6 m^3/yr (Edwards & Sharples, 1986). The ratio of freshwater flow to tidal flow in Loch Fyne is 1:205 (Edwards and Sharples, 1986) which is a rather small contribution relative to the tide compared to other sea lochs. This freshwater input will likely have substantial seasonal variability. Reported discharge during winter shows a mean discharge rate into Loch Fyne of around 50 m^3/s peaking at nearly 400 m^3/s (Gillibrand, et al., 2001).

13.2.5 Meteorology

Rainfall data were taken from Benmore, Younger Botanical Gardens which is situated roughly 20 km to the south east of the Ardcastle Bay fishery. These records spanned the time frame from January 2007 – December 2012.

The year with the highest rainfall was 2011 and the least rain fell in 2010. In 2012, extreme rainfall levels of approximately 130 mm/d were recorded but generally high rainfall values (>50 mm/d) were seen in all years. The highest daily rainfall values occurred throughout autumn and winter where rainfall increased from August onwards and peaked in January and November. There was rainfall of >30 mm/d in all months. For the duration of the data set, daily rainfall of below 1 mm occurred 41% of the time and daily rainfall of above 10 mm occurred 26% of the time.

It can be surmised from these data that run-off due to rainfall is expected to be higher in the autumn and winter months but it must also be noted that high rainfall and consequently high run-off can occur in most months.

Data about wind conditions were collected from Bishopton, Glasgow which is located approximately 50 km southeast of the production area. Due to the distance between the two areas, the wind rose statistics may not be directly transferrable to the specific production area in Ardcastle Bay but they can be used to give a general picture of the seasonal wind conditions in the area. The data from Bishopton shows that overall westerly winds were stronger than easterly winds and southerly winds were stronger than those from the north. There is a predominant west south-westerly airflow year round for the area. It is highly likely that the wind direction will be strongly influenced in Ardcastle, Loch Fyne by the morphology of the surrounding high ground.

13.2.6 Model Assessment

The exchange characteristics of Loch Fyne have been assessed in previous studies (Gillibrand, et al., 2001) using a two-dimensional circulation model, which provides a more sophisticated set-up than a simple box model approach. The model represents the main basins of Loch Fyne, with the assessment area located within the basin defined by the southern sill. The model is driven by surface winds, river run-off and surface oscillation and the outer boundary is set by the salinity profile in the adjacent coastal waters of the Clyde Sea. The model output has been compared to observations made between November 1994 and February 1995.

The model of Gillibrand (2001) was run for the full water column and for just the surface 10 m of water, often the region of relevance to contaminants. For the full water column, the exchange time is calculated as 30.9 days compared to the tidal prism estimate of 11.2 days Gillibrand (2001), or 12.4 days (Marine Scotland, 2012). The large difference in calculated exchange times is due to mixing and recirculation processes not represented in the tidal prism method which tends to retain water behind the shallow sills.

The exchange time for the surface waters in the assessment area is calculated at 3.8 days Gillibrand (2001). This compares with a value for Tidal Prism estimate of 2.5 days. Again

the discrepancy between these values relates to the retention of water behind the shallow sills.

Variations in these exchange rates will generally be related to wind forcing. Gillibrand (2001) notes that enhanced exchange occurs during strong northerly winds, driving the surface water out of the loch and reducing the exchange time by about a factor of 3.

13.3 Hydrographic Assessment

13.3.1 Surface Flow

The site and the meteorological data indicate that there is likely to be a rather small freshwater discharge into the surface waters of the loch, though the absolute value of discharge would have moderate seasonal variation.

The Loch is divided into distinct basins and so there is likely to be significant variation in surface properties between the basins of the loch, with the inner basin being less saline and more highly stratified than that which opens into the coastal waters. The freshwater discharge would suggest that stratification might dominate only under calm conditions and most likely in the upper basin.

From the single current meter record it shows that on the west side of the assessment areas the tidal flow appears to be aligned with the shore. We anticipate that the tidal flow would be similar on the east side, flowing into the loch on the flood and out of the loch on the ebb. The cumulative transport distance on each phase (flood/ebb) of the tide has been estimated at around 1.7 km based on a typical surface principal current amplitude of 0.12 m/s, section 13.2.3.

Surface flows are seen to be enhanced/retarded by winds blowing out of/into the loch. The winds would be generally funnelled by the surrounding hills creating winds blowing along the axis of the loch which would further enhance the mixing of the waters.

Net transport of contaminants is related to the residual flow presented in Figure 13.4 and documented in Table 13.1. The residual surface flows measured in the surface waters of the assessment have been reported as flowing out of the loch, probably in response to winds and/or estuarine flow. With the surface residual speed of order 0.025 m/s, the net transport over a tidal cycle of approximately 12 hours would around 1 km along the axis of the loch. The implication is that the cumulative transport on the ebb is greater than on the flood phase of the tide.

The dispersive characteristics of the site are unknown but there will be enhanced dispersion as the flow encounters islands of promontories along the path of the flow and in periods of strong wind.

13.3.2 Exchange Properties

The flushing time for the whole loch complex using a simple tidal prism approach is around 11-12 days, Section 13.2.6, but this is an underestimation due to the nature of the sills which can retain water and therefore contaminants within the loch.

A modelling study by Gillibrand (2001) has shown that a more realistic flushing time for the assessment area is 30.9 days but that this is further reduced to 3.8 days if just the upper 10 m of water is considered. This would expect to be even further reduced during periods of strong down-loch winds. Therefore, one might describe the flushing characteristics for the surface waters of the assessment area as being ‘well flushed’, with the potential for additional enhancement from the fresh water discharge and from winds.

There is a limited amount of available current meter data for Ardcastle Bay and there is a paucity of measured hydrographic data. However, there is a published model assessment of exchange available and a single current meter record in what is a relatively simple region of the Loch Fyne system. Therefore the confidence level of this assessment is MEDIUM.

14. Shoreline Survey Overview

The Ardcastle Bay shoreline survey was conducted on the 19/11/2013. The weather on the day of the survey was dry, with a temperature of 4^{o}C. Rainfall was recorded at 16.5 mm for the previous seven days and 1.1 mm for the preceding day to the survey.

The Ardcastle Bay fishery consisted of 10 x 220 m lines, with a total of 5000 dropper ropes to 10 m depth. Two small cage arrays for oysters and 30 pyramid pearl nets for queen scallops were also located at the fishery, at depths of approximately 3 m for the oyster cages and 15 m for the scallop nets, as indicated by the harvester. Sampling was only possible from the current stock of oysters and queen scallops as the mussels were <20 mm and therefore too small for sampling. Samples returned results of 20 *E. coli* MPN/ 100 g for both the queen scallop sample taken at 3 m depth and the Pacific oyster sample taken at 15 m depth. Seawater samples were taken at the northwest and southeast extents of the farm and returned results of 2 and 4 *E. coli* cfu/100 ml respectively. The harvester planned to culture mainly mussels and then progress to a multi-species site with oysters, queen scallops and sea urchins with no harvest of any species expected in 2014. The farm is situated to take advantage of nutrients coming from the adjacent fin fish farm, and the harvester hoped this would be beneficial to the growth of filter-feeding shellfish.

No sewage discharges were observed along the adjacent shoreline to the fishery. A finfish barge was seen to the north of the shellfishery and the barge was reported to be manned daily by two personnel. Septic arrangements on board were not known.

A small pier and base unit for the shellfish and finfish farms was located at Crarae Point, 6 km north of the fishery. No moorings, leisure or other boats were observed from, or in the vicinity of shellfish farm. All agricultural observations were made on the east shore; approximately 60 sheep were seen grazing at Lephinchapel, where a farm was also located.

Small hamlets of Tullochgorm and Minard lie approximately 3.5 km and 4.5 km north of the fishery respectively. The village of Loch Gair is also located approximately 3 km south of the fishery and a seawater sample taken on the southern side of the entrance to Loch Gair returned a high result of 600 *E. coli* cfu/100 ml. A seawater samples taken to the east of Loch Gair returned a result of 7 *E. coli* cfu/100 ml and a sample taken <1 km south of the fishery returned a result of 1 *E. coli* cfu/100 ml. There was a picnic area and marked trails at Ardcastle Wood. A conductivity, temperature and depth (CTD) recorded cast was made at the southeastern corner of the fishery (see Appendix 6). This showed a salinity of 32.2 psu and a temperature of 10.8°C at nearly 14 m and a salinity of 28.6 psu and a temperature of 8.3°C just under the surface.

The largest watercourse was at Lephinchapel, where a water sample returned a result of 170 *E. coli* cfu/100 ml. Two unnamed watercourses entered north of the fishery, and water samples returned results of 20 and 10 *E. coli* cfu/100 ml. A further stream was noted to enter the loch just norther of the fishery but this was not measured or sampled.

A small number of ducks were seen from a distance to the south of the fishery, whilst four geese were observed below Lephinchapel on a field above the shoreline. Relatively fresh crab remains were seen on exposed, high shore bedrock in a number of places indicating possible feeding areas for seabirds or other small predators.

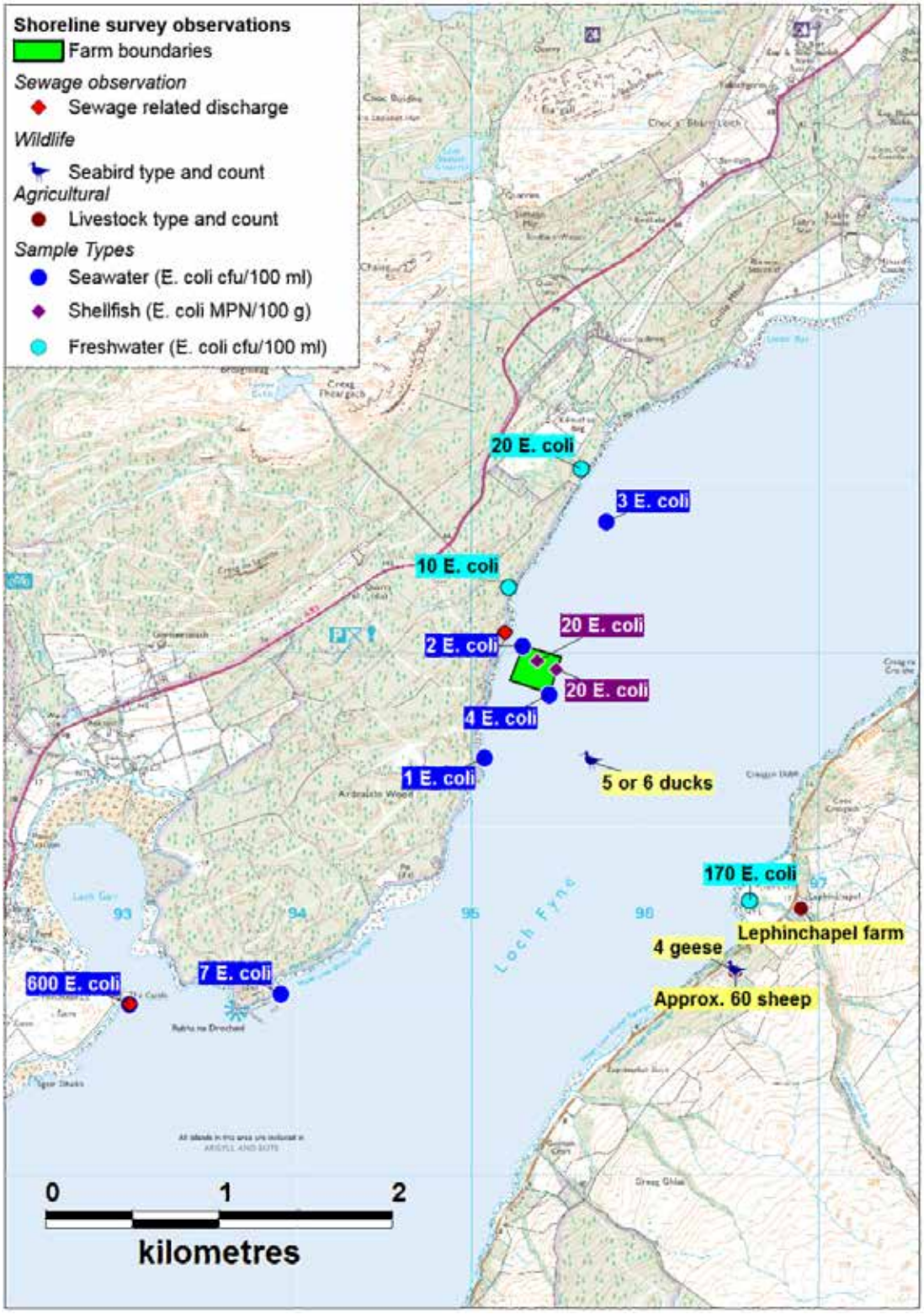


Figure 14.1 Summary of shoreline survey findings for Ardcastle Bay

15. Bacteriological Survey

A bacteriological survey was not undertaken at this site due to the uncertainty of the location of stock of appropriate size.

16. Overall Assessment

Human sewage impacts

The area around Ardcastle Bay is sparsely populated and the main sewage inputs are to north of the production area at Minard and to the south at Loch Gair. These lie more than 3 km from the shellfish farm and the nearest known individual private sewage discharges lie more than 1 km away. The service barge associated with the fin fish farm immediately north of the shellfish farm is manned during the day and presumably has toilet facilities onboard, though the discharge arrangements are not known.

Agricultural impacts

No agriculture was identified on the northeastern shore of the loch adjacent to the shellfish farm. The only significant agricultural sources identified during the shoreline survey were at Lephinchapel, on the southeastern shore, where a farmyard and approximately 60 sheep were seen. These are located more than 1.5 km from the shellfish farm on the opposite side of the loch and therefore any impact would be dependent upon the predicted movement of contaminants.

Wildlife impacts

Little wildlife was seen during the shoreline survey. Other information indicates that there is a significant seabird colony located to the northeast of the shellfish farm and large numbers of deer in the nearby hills. Both of these are likely to impact on the water quality at the fishery from time to time. Seals and cetaceans will pose additional, but infrequent, sources of contamination. Overall, wildlife sources are expected to contribute to background levels of contamination and there is no evidence to suggest that any one part of the shellfish farm will be significantly more affected than another.

Seasonal variation

The human population in the general area, both land-based (at Lochgait, Asknish and Minard) and associated with boating traffic, will be higher from late spring to early autumn due to increased visitor numbers. The different bird species present in the area have different breeding seasons. However, the greatest numbers are gulls and the breeding season for these is from late spring to mid-autumn. Deer numbers are likely to be lowest in winter due to greater mortality during that season. While sheep numbers will vary seasonally, the low number in the area covered by the assessment means that this is unlikely to be reflected in seasonal variaition in water quality.

Assessment of the limited shellfish monitoring data showed that results tend to be higher in autumn.

Rivers and streams

Assessment of information on the characteristics of the loch and the meterological data led to the conclusion that there will be a small amount of freshwater input into the immediate area. The input would be expected to vary by season, being highest in the winter. During the shoreline survey, only a small number of watercourses were observed in the vicinity of the shellfish farm. Estimated loadings derived from the shoreline survey data were low to moderate. However, salinity recorded during the shoreline survey showed significantly reduced salinities both at the surface and at depth, suggesting that there was significant freshwater influence in the vicinity. There are many watercourses further up the loch, though the predicted ratio of fresh to tidal flow given in Section 13 suggests that there is relatively little freshwater impact on the loch. Therefore, it is possible that watercourses from well outside the vicinity of the fishery will contribute to a reduction in salinity and potentially associated diffuse contamination at the shellfish farm. Any impacts on the water quality at the shellfish farm would be greatest at the northwestern corner.

Movement of contaminants

The Loch is divided into distinct basins and so there is likely to be significant variation in surface properties between the basins of the loch, with the inner basin being less saline and more highly stratified than that which opens into the coastal waters. The freshwater discharge would suggest that stratification might dominate only under calm conditions and would be most likely to occur in the upper basin (further towards the head of the loch than Ardcastle Bay). The CTD cast undertaken at the shellfish farm showed a diference in salinity of approximately 3.6 psu between depth and subsurface, which suggests that freshwater-borne contamination may be more concentrated in the lower salinity surface layer.

Tidal flows are expected to follow the orientation of the loch. The cumulative transport distance over each tidal phase (ebb/flood) was estimated as approximately 1.7 km (no distinction was made between spring and neap tides). Surface flows would be enhanced or retarded by winds blowing into/out of the loch. The effect of wind would also be to enhance the mixing of the waters. Residual flows (over consecutive tidal cycles) flow out of the loch. The estimated residual flow over a full tidal cycle of 12 hours is estimated to be approximately 1 km, along the axis of the loch. This implies that the transport distance on the ebb tide will be greater than on the flood tide.

Temporal and geographical patterns of sampling results

Classification monitoring data was available for 2013, principally from three species (mussels, oysters and scallops). Only three results were available from urchins. Results have been generally low with the highest at 700 *E. coli* MPN/100 g. The limited data indicates that results may be higher in autumn. However, further data will be needed to confirm this pattern. All samples to date have been taken in close proximity to each other (not at the recommended pRMP) and spatial analysis is not possible.

Due to the location of stocks on site, only two shellfish samples were taken during the shoreline survey. These both produced low results of 20 E. coli MPN/100 g.Six seawater samples were taken. Five of these gave relatively low E. coli results (up tp 7 cfu/100 ml). However, the sixth, taken on the southern side of the entrance to Loch Gair, yielded a result of 600 E. coli cfu/100 ml.

Conclusions

Due to the expected direction of tidal currents (along the axis of the loch), pollution sources on the same side of the loch as the shellfish farm are expected to influence the microbiological quality at the shellfish farm to a much greater extent than sources on the opposite side. The sewage discharges that could potentially impact at the shellfish farm are principally located at Minard (to the northeast), and within Loch Gair (to the southeast). Both lie a greater distance from the fishery than the expected maximum particle transport distance. However, net residual flow is out of the loch and therefore the discharges at Minard (including the community discharge) may have a greater effect than those at Loch Gair. The overall effect with respect to *E. coli* will depend on time of transport on the outward residual flow versus the rate of bacterial die off. The watercourses that are expected to have greatest impact at the fishery are those to the north of it. The evidence for some freshwater effect towards the surface means that the greatest level of contamination will tend to be located in the upper part of the water column.

17. Recommendations

The following recommendations apply to all four species to be classified: common mussels, Pacific oysters, queen scallops and green sea urchins.

Production area

It is recommended that the production area defined in the pRMP assessment is used for the standard classification. These boundaries are constrained along the north end by the adjacent fish farm and along the west by the shore. The other boundaries limit extension towards other known sources of pollution while covering the whole of the longline anchor area. The recommended production area is therefore: the area bounded by lines drawn from NR 9523 9221 to NR 9584 9200 to NR 9584 9132 to NR 9506 9132 and extending to MHWS.

RMP

It is recommended that the RMP be located at NR 9534 9200, at the northeast extent of the shellfish farm. This will reflect the pollution sources known to be located to the north of the shellfishery and also the predicted southward residual flow of surface waters in the loch. If stock of the correct size of each species are not present at the correct location and depth, a separate holding bag or bags or net (as appropriate) should be located here.

Tolerance

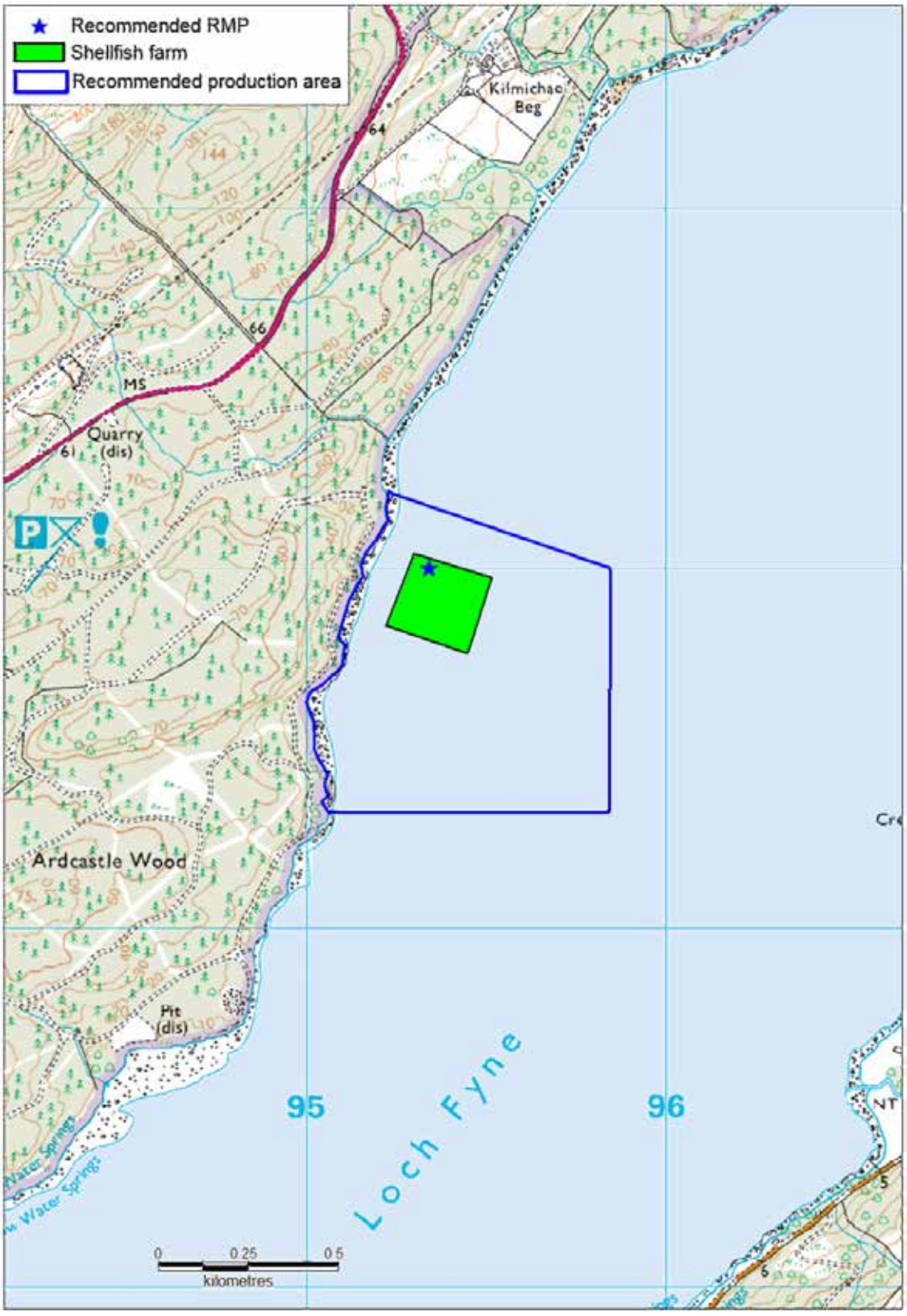
A 40 m tolerance is recommended to allow sufficient scope for variation in the position of the lines.

Depth of sampling

It is recommended that depth of sampling for mussels and Pacific oysters be between 1 and 3 m given the observed freshwater influence towards the surface. For the scallops and sea urchins, which are cultured between 10 and 15 metres depth, the recommended sampling depth is 15 m as this lies nearer the seabed and any settled contaminants present there.

Frequency

Given that there is very limited monitoring data for the area, monitoring for all four species should be undertaken monthly.



Produced by Cefas Weymouth Laboratory. © Crown Copyright and Database 2014. All rights reserved. Ordnance Survey licence number [GD100035675]

Figure 17.1 Map of recommendations at Ardcastle Bay

18. References

Anderson, S. J., 2006. *Ardcastle - revised site and hydrographic survey report AMSP Report No 06/4.5 rev0,* s.l.: s.n.

Argyll and Bute Council, 2009. *POLICY ZONE G: LOCH GAIR TO UNION BAY.* [Online]
Available at: http://www.argyll-bute.gov.uk/sites/default/files/planning-and-environment/Policy%20Zone%20G%20Loch%20Gair%20to%20Union%20Bay.pdf
[Accessed 21 01 2014].

Argyll and Bute Council, 2014. *Property History: Lephinchapel.* [Online]
Available at: http://publicaccess.argyll-bute.gov.uk/publicaccess/propertyDetails.do?activeTab=relatedCases&keyVal=IBPGGLCH40000
[Accessed 21 01 2014].

Brown, J., 1991. The final Voyage of Rapaiti:A measure of surface drift velocity in relation to the surface wind. *Marine Pollution Bulletin,* 22(1), pp. 37-40.

Clyde Cruising Club, 2007. *Sailing Directions and Anchorages - Part 1 Firth of Clyde including North Channel, Solway Firth and Isle of Man ,* Glasgow: Clyde Cruising Club Publications Ltd..

Edwards, A. & Sharples, F., 1986. *Scottish Sea Lochs: a Catalogue,* Oban: Scottish Marine Biological Association/Nature Conservancy Council.

Gillibrand, P. A., Inall, M. E., Portilla, E. & Tett, P., 2001. Calculating Exchange Times in a Scottish Fjord Using a Two-Dimensional, Latterally-intergrated Numerical Model. *Estuarine, Coastal and Shelf Science,* Volume 53, pp. 437-449.

Hebridean Whale and Dolphin Trust, 2014. *Recent Sightings.* [Online]
Available at: http://www.whaledolphintrust.co.uk/sightings-recent-sightings.asp
[Accessed 21 01 2014].

Kay, D. et al., 2008. Faecal indicator organism in concentration sewage and treated effluents. *Water Research,* 42(1/2), pp. 442-454.

Lee, R. J. & Morgan, O. C., 2003. Envrionmental factors influencing the microbial contamination of commercially harvested shellfish.. *Water Science and Technology,* Issue 47, pp. 65-70.

Mallin, M. A. et al., 2001. Demographis, landscape and meterological factors controlling the microbial pollution of coastal waters. *Hydrobiologica,* Issue 460, pp. 185-193.

Marine Scotland, 2012. *Locational Guidelines for the authorisation of marine fish farmes in Scottish waters.,* Edinburgh: Produced for Marine Scotland Science by the Marine Scotland Performance Graphics Group.

Minard Castle, 2002. *Wildlife around Minard Castle.* [Online] Available at: http://www.minardcastle.com/wildlife.html [Accessed 21 01 2014].

Mitchell, I. P., Newton, S. F., Ratcliffe, N. & Dunn, T. E., 2004. *Seabird populations of Britain and Ireland: results of the Seabird 2000 census (1998-2002),* London: T & A D Poyser.

Special Committee on Seals, 2012. *Scientific Advice on Matters Related to the Management of Seal Populations 2012,* St Andrews: St Andrews University; Sea Mammal Research Unit.

Tarbert Loch Fyne, 2014. *Tarbert Wildlife.* [Online] Available at: http://www.tarbertlochfyne.com/geography/wildlife.php [Accessed 21 01 2014].

United Kingdom Hydrographic Office, 2003. *Admiralty Chart 2382,* Taunton: United Kingdom Hydrographic Office.

Walkhighlands.co.uk, 2013. *Ardcastle Point, Loch Fyne.* [Online] Available at: http://www.walkhighlands.co.uk/argyll/ardcastle.shtml [Accessed 21 01 2014].

19. List of Figures and Tables

Appendices

1. **General Information on Wildlife Impacts**
2. **Tables of Typical Faecal Bacteria Concentrations**
3. **Hydrographic Section Glossary**
4. **Shoreline Survey Report**
5. **CTD Data**

1. General Information on Wildlife Impacts

Pinnipeds

Two species of pinniped (seals, sea lions, walruses) are commonly found around the coasts of Scotland: These are the European harbour, or common, seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). Both species can be found along the west coast of Scotland.

Common seal surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage.

According to the Scottish Executive, in 2001 there were approximately 119,000 grey seals in Scottish waters, the majority of which were found in breeding colonies in Orkney and the Outer Hebrides.

Adult Grey seals weigh 150-220 kg and adult common seals 50-170 kg. They are estimated to consume between 4 and 8% of their body weight per day in fish, squid, molluscs and crustaceans. No estimates of the volume of seal faeces passed per day were available, though it is reasonable to assume that what is ingested and not assimilated in the gut must also pass. Assuming 6% of a median body weight for harbour seals of 110kg, that would equate to 6.6kg consumed per day and probably very nearly that defecated.

The concentration of *E. coli* and other faecal indicator bacteria contained in seal faeces has been reported as being similar to that found in raw sewage, with counts showing up to 1.21×10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al* 2004).

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

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

Cetaceans

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

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

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

Birds

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

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

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28×10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77×10^8 FC per faecal deposit to a local reservoir (Alderisio & DeLuca, 1999). An earlier study found that geese averaged from 5.23 to 18.79 defecations per hour while feeding, though it did not specify how many hours per day they typically (Gauthier & Bedard, 1986)

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

Deer

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

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

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

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

Other

The European Otter (*Lutra lutra*) is present around Scotland with some areas hosting populations of international significance. Coastal otters tend to be more active during the day, feeding on bottom-dwelling fish and crustaceans among the seaweed found on rocky inshore areas. An otter will occupy a home range extending along 4-5km of coastline, though these ranges may sometimes overlap (Scottish National Heritage, n.d.). Otters primarily forage within the 10 m depth contour and feed on a variety of fish, crustaceans and shellfish (Paul Harvey, Shetland Sea Mammal Group, personal communication).

Otters leave faeces (also known as spraint) along the shoreline or along streams, which may be washed into the water during periods of rain.

References

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

Gauthier, G. & Bedard, J., 1986. Assessment of faecal output in geese. *Journal of Applied Ecology,* 23(1), pp. 77-90.

Lisle, J. T., Smith, J. J., Edwards, D. D. & McFeters, G. A., 2004. Occurence of microbial indicators and Clostridium perfringens in wastewater, water coloum samples, sediments, drinking water and weddel seal faeces collected at McMurdo Station, Antarctica. *Applied and Environmental Microbiology,* 70(12), pp. 7269-7276.

Poppe, C. et al., 1998. Salmonella typhimurium DT104: a virulent and drug-resistant pathogen. *The Canadian Veterinary Journal,* 39(9), pp. 559-565.

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

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

2. Tables of Typical Faecal Bacteria Concentrations

Summary of faecal coliform concentrations (cfu $100ml^{-1}$) for different treatment levels and individual types of sewage-related effluents under different flow conditions: geometric means (GMs), 95% confidence intervals (CIs), and results of t-tests

Indicator organism	**Base-flow conditions**				**High-flow conditions**			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	282	2.8×10^{6} * (-)	2.3×10^{6}	3.2×10^{6}
Crude sewage discharges	252	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	79	3.5×10^{6} * (-)	2.6×10^{6}	4.7×10^{6}
Storm sewage overflows					203	2.5×10^{6}	2.0×10^{6}	2.9×10^{6}
Primary	127	1.0×10^{7} * (+)	8.4×10^{6}	1.3×10^{7}	14	4.6×10^{6} (-)	2.1×10^{6}	1.0×10^{7}
Primary settled sewage	60	1.8×10^{7}	1.4×10^{7}	2.1×10^{7}	8	5.7×10^{6}		
Stored settled sewage	25	5.6×10^{6}	3.2×10^{6}	9.7×10^{6}	1	8.0×10^{5}		
Settled septic tank	42	7.2×10^{6}	4.4×10^{6}	1.1×10^{7}	5	4.8×10^{6}		
Secondary	864	3.3×10^{5} * (-)	2.9×10^{5}	3.7×10^{5}	184	5.0×10^{5} * (+)	3.7×10^{5}	6.8×10^{5}
Trickling filter	477	4.3×10^{5}	3.6×10^{5}	5.0×10^{5}	76	5.5×10^{5}	3.8×10^{5}	8.0×10^{5}
Activated sludge	261	2.8×10^{5} * (-)	2.2×10^{5}	3.5×10^{5}	93	5.1×10^{5} * (+)	3.1×10^{5}	8.5×10^{5}
Oxidation ditch	35	2.0×10^{5}	1.1×10^{5}	3.7×10^{5}	5	5.6×10^{5}		
Trickling/sand filter	11	2.1×10^{5}	9.0×10^{4}	6.0×10^{5}	8	1.3×10^{5}		
Rotating biological contactor	80	1.6×10^{5}	1.1×10^{5}	2.3×10^{5}	2	6.7×10^{5}		
Tertiary	179	1.3×10^{3}	7.5×10^{2}	2.2×10^{3}	8	9.1×10^{2}		
Reed bed/grass plot	71	1.3×10^{4}	5.4×10^{3}	3.4×10^{4}	2	1.5×10^{4}		
Ultraviolet disinfection	108	2.8×10^{2}	1.7×10^{2}	4.4×10^{2}	6	3.6×10^{2}		

comparing base- and high-flow GMs for each group and type.

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

Table 3 – Geometric mean (GM) and 95% confidence intervals (CIs) of the GM faecal indicator organism (FIO) concentrations (cfu/100ml) under base- and high-flow conditions at the 205 sampling points and for various subsets, and results of paired t-tests to establish whether there are significant elevations at high flow compared with base flow

FIO	*n*	**Base Flow**			**High Flow**		
Subcatchment land use		Geometric mean	Lower 95% CI	Upper 95% CI	Geometric mean[a]	Lower 95% CI	Upper 95% CI
Total coliforms							
All subcatchments	205	5.8×10^{3}	4.5×10^{3}	7.4×10^{3}	7.3×10^{4}**	5.9×10^{4}	9.1×10^{4}
Degree of urbanisation							
Urban	20	3.0×10^{4}	1.4×10^{4}	6.4×10^{4}	3.2×10^{5}**	1.7×10^{5}	5.9×10^{5}
Semi-urban	60	1.6×10^{4}	1.1×10^{4}	2.2×10^{4}	1.4×10^{5}**	1.0×10^{5}	2.0×10^{5}
Rural	125	2.8×10^{3}	2.1×10^{3}	3.7×10^{3}	4.2×10^{4}**	3.2×10^{4}	5.4×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	6.6×10^{3}	3.7×10^{3}	1.2×10^{4}	1.3×10^{5}**	1.0×10^{5}	1.7×10^{5}
≥75% Rough Grazing	13	1.0×10^{3}	4.8×10^{2}	2.1×10^{3}	1.8×10^{4}**	1.1×10^{4}	3.1×10^{4}
≥75% Woodland	6	5.8×10^{2}	2.2×10^{2}	1.5×10^{3}	6.3×10^{3}*	4.0×10^{3}	9.9×10^{3}
Faecal coliform							
All subcatchments	205	1.8×10^{3}	1.4×10^{3}	2.3×10^{3}	2.8×10^{4}**	2.2×10^{4}	3.4×10^{4}
Degree of urbanisation							
Urban	20	9.7×10^{3}	4.6×10^{3}	2.0×10^{4}	1.0×10^{5}**	5.3×10^{4}	2.0×10^{5}
Semi-urban	60	4.4×10^{3}	3.2×10^{3}	6.1×10^{3}	4.5×10^{4}**	3.2×10^{4}	6.3×10^{4}
Rural	125	8.7×10^{2}	6.3×10^{2}	1.2×10^{3}	1.8×10^{4}**	1.3×10^{4}	2.3×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	1.9×10^{3}	1.1×10^{3}	3.2×10^{3}	5.7×10^{4}**	4.1×10^{4}	7.9×10^{4}
≥75% Rough Grazing	13	3.6×10^{2}	1.6×10^{2}	7.8×10^{2}	8.6×10^{3}**	5.0×10^{3}	1.5×10^{4}
≥75% Woodland	6	3.7×10	1.2×10	1.2×10^{2}	1.5×10^{3}**	6.3×10^{2}	3.4×10^{3}
Enterococci							
All subcatchments	205	2.7×10^{2}	2.2×10^{2}	3.3×10^{2}	5.5×10^{3}**	4.4×10^{3}	6.8×10^{3}
Degree of urbanisation							
Urban	20	1.4×10^{3}	9.1×10^{2}	2.1×10^{3}	2.1×10^{4}**	1.3×10^{4}	3.3×10^{4}
Semi-urban	60	5.5×10^{2}	4.1×10^{2}	7.3×10^{2}	1.0×10^{4}**	7.6×10^{3}	1.4×10^{4}
Rural	125	1.5×10^{2}	1.1×10^{2}	1.9×10^{2}	3.3×10^{3}**	2.4×10^{3}	4.3×10^{3}
Rural subcatchments with different dominant land uses							
≥75% Imp. pasture	15	2.2×10^{2}	1.4×10^{2}	3.5×10^{2}	1.0×10^{4}**	7.9×10^{3}	1.4×10^{4}
≥75% Rough Grazing	13	4.7×10	1.7×10	1.3×10^{2}	1.2×10^{3}**	5.8×10^{2}	2.7×10^{3}
≥75% Woodland	6	1.6×10	7.4	3.5×10	1.7×10^{2}**	5.5×10	5.2×10^{2}
[a] Significant elevations in concentrations at high flow are indicated: **po0.001, *po0.05.							
[b] Degree of urbanisation categorised according to percentage built-up land: 'Urban' (X10.0%), 'Semi-urban' (2.5–9.9%) and 'Rural' (o2.5%).							

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

Table 4 - Comparison of faecal indicator concentrations (average numbers/g wet weight) excreted in the faeces of warm-blooded animals

Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers/day)
Chicken	1,300,000	182	2.3×10^8
Cow	230,000	23,600	5.4×10^9
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^8
Pig	3,300,000	2,700	8.9×10^8
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^8
Human	13,000,000	150	1.9×10^9

Source: (Gauthier & Bedard, 1986)

References

Gauthier, G. & Bedard, J., 1986. Assessment of faecal output in geese. *Journal of Applied Ecology,* 23(1), pp. 77-90.

Kay, D. et al., 2008a. Faecal indicator organism concentrations and catchment export coefficients in the UK. *Water Research,* 42(10/11), pp. 2649-2661.

Kay, D. et al., 2008b. Faecal indicator organism in concentration sewage and treated effluents. *Water Research,* 42(1/2), pp. 442-454.

3. Hydrographic Assessment Glossary

The following technical terms may appear in the hydrographic assessment.

Bathymetry. The underwater topography given as depths relative to some fixed reference level e.g. mean sea level.

Hydrography. Study of the movement of water in navigable waters e.g. along coasts, rivers, lochs, estuaries.

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

MHWN. Mean High Water Neap, The highest level that tides reach on average during neap tides.

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

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

MLWN. Mean Low Water Neap, The lowest level that tides reach on average during neap tides.

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

Tidal period. The dominant tide around the UK is the twice daily one generated by the moon. It has a period of 12.42 hours. For near shore so-called rectilinear tidal currents then roughly speaking water will flow one way for 6.2 hours then back the other way for 6.2 hours.

Tidal range. The difference in height between low and high water. Will change over a month.

Tidal excursion. The distance travelled by a particle over one half of a tidal cycle (roughly~6.2 hours). Over the other half of the tidal cycle the particle will move in the opposite direction leading to a small net movement related to the tidal residual. The excursion will be largest at Spring tides.

Tidal residual. For the purposes of these documents it is taken to be the tidal current averaged over a complete tidal cycle. Very roughly it gives an idea of the general speed and direction of travel due to tides for a particle over a period of several days.

Tidal prism. The volume of water brought into an estuary or sea loch during half a tidal cycle. Equal to the difference in estuary/sea loch volume at high and low water.

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

Neap tides occur during the first or last quarter of the moon when the tide-generating forces of the sun and moon oppose each other. The tidal range is smallest and tidal currents are weakest during neap tides.

Tidal diamonds. The tidal velocities measured and printed on admiralty charts at specific locations are called tidal diamonds.

Wind driven shear/surface layer. The top metre or so of the surface that generally moves in the rough direction of the wind typically at a speed that is a few percent (~3%) of the wind speed.

Return flow. A surface flow at the surface may be accompanied by a compensating flow in the opposite direction at the bed.

Stratification. The splitting of the water into two layers of different density with the less dense layer on top of the denser one. Due to either temperature or salinity differences or a combination of both.

4. Shoreline Survey Report

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

Document Number	B0067_Shoreline 0025

Revision History

Revision	Changes	Date
A	Issue for internal review	29/11/2013
B	Draft B for internal review	11/12/2013
01	First formal issue to Cefas	13/12/2013
02	Second issue to client incorporating correction in Issue01	09/01/2014
03	Third issue to client incorporating correction in Issue02	10/01/2014
04	Latest issue incorporating corrections from FSAS on names of production area and sites	22/04/2014

	Name & Position	Date
Author	Peter Lamont Alison Clarke	26/11/2013
Checked	Andrea Veszelovszki	09/01/2014
Approved	Andrea Veszelovszki	22/04/2014

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

Shoreline Survey Report

Production area:	Ardcastle Bay
Site name:	See below
SIN:	Ardcastle Oysters AB-634-1280-13
	Ardcastle Mussels AB-635-1281-08
	Ardcastle Scallops AB-637-1282-15
	Ardcastle Urchins AB-637-1283-22
Species:	Common mussels (*Mytilus edulis*)
	Pacific oysters (*Crassostrea gigas*)
	Queen scallops (*Aequipecten opercularis)*
	Green sea urchin (*Psammechinus miliaris*)
Harvester:	Mr David Attwood
Local Authority:	Argyll and Bute
Date Surveyed:	19/11/2013
Surveyed by:	Peter Lamont, Alison Clarke
Existing RMP:	NR 9521 9184

Area Surveyed

The shoreline was surveyed for about 1.5 km in total, from NR 9505 9168 southwest of the SW corner of the shellfish farm grid heading north, northeast along the shore towards Kilmichael farm to NR 9579 9324 terminating at an old fence line traversing the shore to the sea (Fig. 1, waypoints 24 to 37). The survey chronology and waypoints are listed in Table 1.

The shellfish farm was visited and sampled from the farm workboat, courtesy of the harvester. Seawater samples, distant from the farm, were also obtained on the same trip from the workboat as well as a freshwater sample and photographs taken at Lephinchapel directly across Loch Fyne to the east (Fig.1, waypoints 1 to 23).

Weather

Rainfall was recorded at 16.5 mm for the previous seven days (from 12/11/2013) leading up to the survey including 1.1 mm for the preceding day to the survey, from data recorded for the nearest gauge at Oban. During the survey, the weather was cold, dry and sunny.

Tuesday 19/11/2013 - Cloud cover was at approximately 10% at the start of the survey and increased only slightly during the day. Temperature was 4°C with no wind. Sea state 0 calm, no ripples.

Stakeholder engagement during the survey

Mr David Attwood (harvester) and Sampling Officer Mr William McQuarrie were both very helpful and cooperative during pre-survey arrangements. The Sampling Officer had visited the shellfish farm the day before the survey so was not present during the survey. The farm workboat was skippered by Mr Ian MacKay along with the harvester Mr David Attwood. The survey team also had the company of Mr Jack McGregor from Seil who was on a tour to see the new farm installation and some of the gear. Mr McGregor has a mussel farm in the Sound of Seil.

Fishery

This farm was constructed, according to the harvester, on a new site in January/February of 2013 with ten main lines of buoys and a total of 5000 dropper ropes across the site. (Fig. 3). The length of the ten main lines is 220 m and the depth of the mussel lines are 10 metres. All mussels were newly settled spats with none of suitable size (>20mm) for sampling. A dropper with the mussel spats present is illustrated in Fig. 5.

On the day of the survey, in addition to the mussel droppers, there were two small cage arrays for oysters one of which is illustrated in Fig. 4, and thirty pyramid cages known as ‘Pearl’ nets for queen scallops (Fig. 6). The harvester indicated the suspension depths for these cages, which are about 3 metres for the oysters and about 15 metres for the scallops. All species grown at the site were very small and sampling was only possible from the current stock of oysters and queen scallops, which were only available at one location each.

The plan is to culture mainly mussels with eventually also oysters, queen scallops and sea urchins. It is hoped that enrichment of the water from the finfish farm immediately to the north will benefit the filter feeding shellfish. The harvester stated that there are no harvest plans for the year 2014.

Sewage Sources

The shellfish farm lies off Ardcastle Wood, an uninhabited, relatively isolated section of shore bounded by the A83 to the west and north and Loch Gair to the south. A fin fish farm lies within one kilometre to the north of the shellfish site. This fish farm consists of a feed barge situated at the south side manned

during the day by two personnel, Fig. 12, with up to 12 circular fish cages each about twenty metres in diameter, arranged in pairs extending northwards (Fig. 13). The facilities arrangements on the barge for the occupants are not known.

There is another finfish farms in the vicinity of the shellfish growing area at Lephinmore (4 km northeast, NR 983 926). This observed as the team passed by in the boat during the site visit, though it is not known if it is active.

The farm house of Kilmichael Beg lies a few hundred metres beyond the northern limit of the surveyed shoreline and was not approached during the survey.

The surveyed shore at Ardcastle Wood was very clean and scarcely disturbed being composed of a rocky shore of boulders and pebbles with occasional bedrock outcrops extending into the sea. There was nowhere any sign of animal or human effluent contamination.

Seasonal Population

The A83 main road south of Inveraray was used for access as far as Ardcastle Wood permitting the following observations. On the west side, the nearest caravan park is 3 km south of Inveraray (>20 km by water from Ardcastle Wood).

There are few, if any, seasonally occupied dwellings off the A83 immediately bordering Ardcastle Wood. The hamlet of Tullochgorm, (3.5 km north) and Minard village (4.5 km north) have some seasonal (holiday) housing but the scale is not known. The village of Loch Gair, 1 km to the south, was not visited during the survey. Part of Loch Gair village can be seen in Fig. 8.

A forestry picnic area is signposted off the A83 in the middle of Ardcastle Wood at NR 942 921, uphill of the surveyed shore. There are marked walking trails through the wood bordering the shore. The picnic site was not visited on the survey and facilities are not known.

Boats/Shipping

Shore facilities (a small pier) at Crarae Point (6 km north of the site and 0.5 km north of Minard village) are used as a base both for the finfish farm and the shellfish farm. Biosecurity measures observed included dedicated footwear and wet weather gear provided in a portacabin changing room for visitors and a sterilizing bath for equipment situated at the top of the boat slipway.

No moorings, leisure or other boats were observed from, or in the vicinity of the shore survey by Ardcastle Wood.

Farming and Livestock

No livestock, or signs of livestock were observed on the shore survey apart from about 60 sheep grazing the alluvial river fan at Lephinchapel on the east side of Loch Fyne (Fig. 10), opposite the shellfish site.

Land Use

Ardcastle Wood is a managed forestry with mature trees above the shore and a patchwork of plantation areas at all stages of maturity (Fig. 13). Amenity use of the surveyed coast consisted of a forest walking trail coming close to the shore at the south end of the shore walk and a new boat house (presumed) at the north end (Fig 17).

Land Cover

The survey area inland of the shore walk consists of coniferous forest plantation with mature trees immediately above the shore at the south end of the survey and mixed, semi-native woodland cover at the north end of the survey. There is also improved grassland for grazing around Kilmichael Farm on the west shore just north of the production area and on the east shore around Lephinchapel and Lephinmore.

Watercourses

The largest watercourses in the area were Lephinchapel and Lephinmore Burns both on the eastern shore of the loch. From these Lephinchapel Burn was sampled and measured, as requested. Another two un-named Ardcastle Wood streams were also sampled on the shore walk to the west of the shellfish site as marked on the survey plan (Fig.15 and 16). The flow in one other small watercourse draining the wood was also measured but was not sampled as it was considered to be a low-risk source for contamination (Fig. 14, waypoint 29).

Wildlife/Birds

At the start of the shore survey (south end) a pair of robins was seen briefly on the shore but no other birds were observed during the shore walk. Relatively fresh crab remains (from sublittoral fauna) were seen on exposed, high shore bedrock in a number of places indicating possibly mink but more likely otter, however no spraint or regular otter trails were observed.

On approach by boat to Lephinchapel four wild geese were flushed and on the loch in the distance five or six ducks were seen (possibly eider).

Shoreline Survey Maps

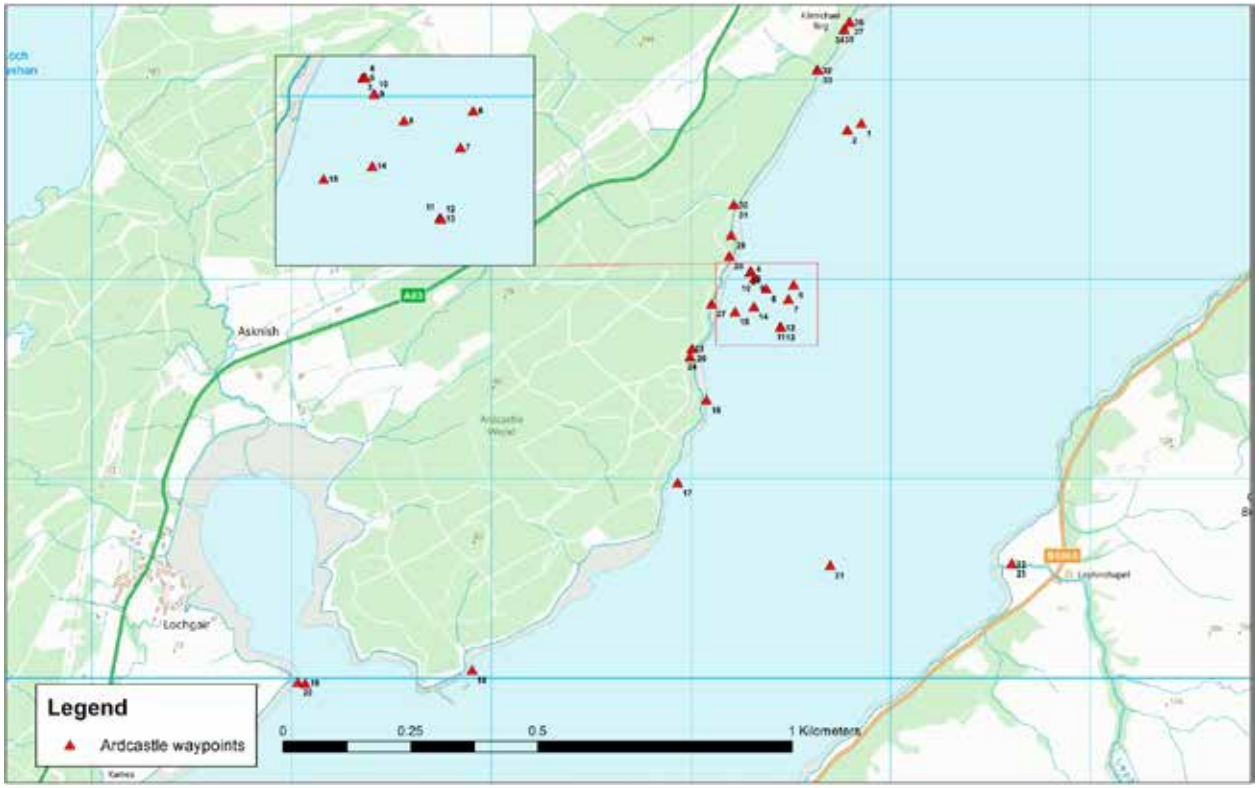
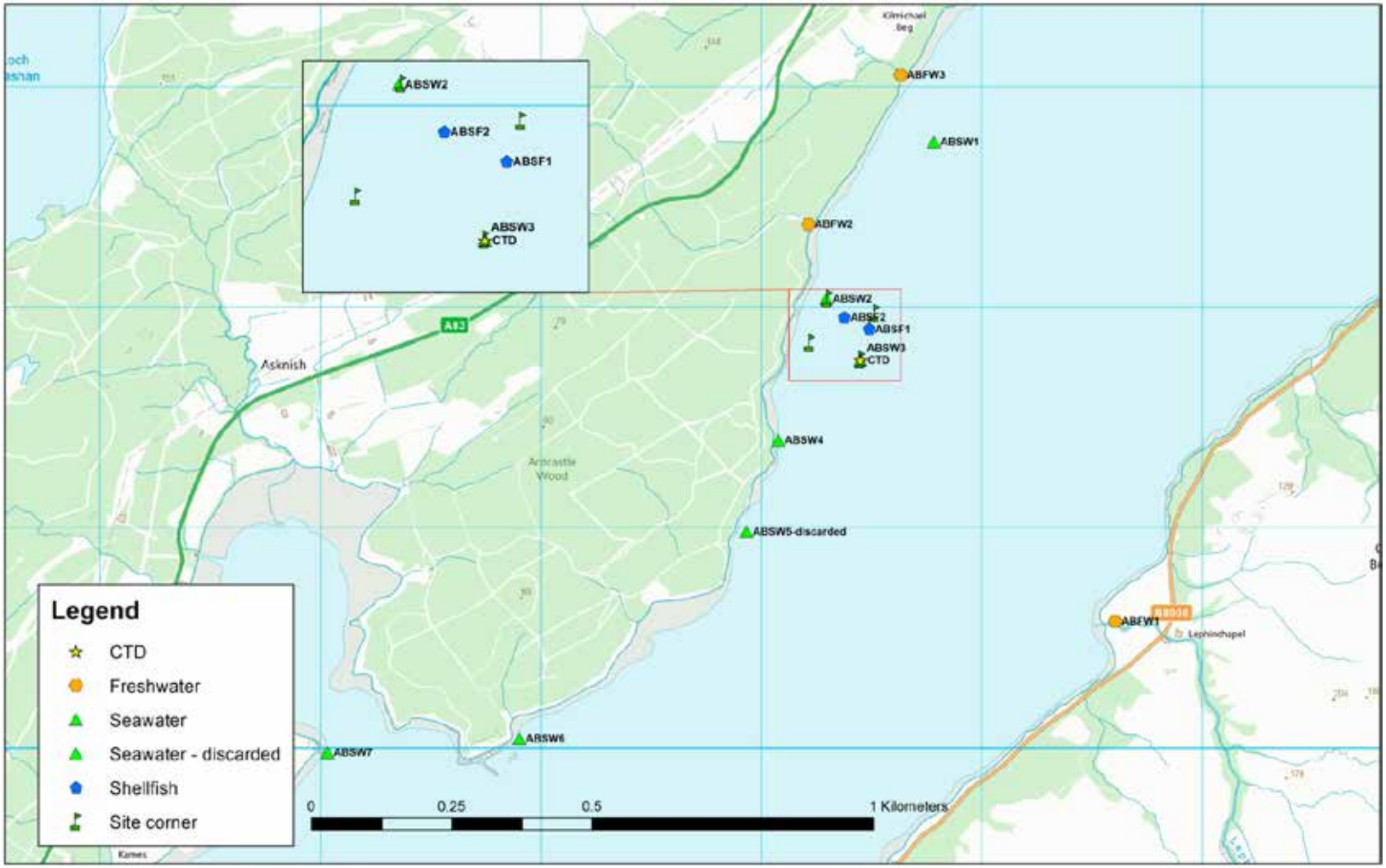


Figure 1. Ardcastle waypoints.



Contains Ordnance Survey data © Crown Copyright and Database right (2013)

Figure 2. Ardcastle samples and shellfish farm limits.

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	19/11/2013	9:44	NR 95853 92782	195854	692782			On board the harvester's boat. Approaching the MCFF lease area from the north to collect the planned seawater sample 1.
2	19/11/2013	9:45	NR 95782 92749	195783	692749		ABSW1	Planned seawater sample 1.
3	19/11/2013	9:51	NR 95296 92037	195296	692038		ABSW2	Planned seawater sample 2.
4	19/11/2013	9:56	NR 95300 92039	195300	692039	Figure 3		North west corner of mussel lines (10 lines in total).
5	19/11/2013	9:57	NR 95300 92036	195300	692037			The CTD was cast to 10m but data recording failed. No shellfish were available to sample because the site is in its first year (<10 months).
6	19/11/2013	10:00	NR 95513 91972	195514	691973			Northeast corner of mussel lines.
7	19/11/2013	10:02	NR 95488 91900	195489	691900		ABSF1	Queen scallop sample taken from 15 m depth. No mussels available to sample, only spats.
8	19/11/2013	10:09	NR 95377 91952	195377	691953		ABSF1	Pacific oyster sample taken from the middle of the grid at 3 metres depth. Named as auxiliary stock by the harvester for representative monitoring point (RMP).
9	19/11/2013	10:17	NR 95319 92005	195320	692005	Figure 4		Pacific Oyster cage lifted on board of harvester's boat. These were all the available oysters on site to sample.
10	19/11/2013	10:18	NR 95317 92005	195318	692005	Figure 5		The mussel lines are 10 m in depth and a line with mussel spats was photographed at 2 m depth. There are 10 main lines with a total of 5000 droppers on farm. (ABSF3 of spat <20 mm was taken but later discarded on advice from base).
11	19/11/2013	10:26	NR 95447 91762	195448	691762			Southeast corner of mussel lines.
12	19/11/2013	10:27	NR 95450 91760	195450	691760		ABSW3	Planned seawater sample 3 at SE corner.
13	19/11/2013	10:29	NR 95449 91759	195450	691760		ABCTD2	CTD cast. Harvester estimated depth at 30 meters.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
14	19/11/2013	10:41	NR 95314 91863	195315	691864	Figure 6		Queen scallops in Pearl nets brought up from 15 metres (animals too small for sampling).
15	19/11/2013	10:44	NR 95219 91837	195220	691838			Southwest corner of mussel lines. Rocky shoreline photographed with Ardcastle Wood approx. 0.6 km SSW of farm.
16	19/11/2013	10:52	NR 95077 91395	195077	691395		ABSW4	Planned seawater sample 4.
17	19/11/2013	10:56	NR 94933 90980	194933	690980	Figure 7	ABSW5	Seawater sample 5 collected and later discarded. Wrong location. A typical view of the Ardcastle Wood was photographed.
18	19/11/2013	11:02	NR 93903 90041	193903	690041		ABSW6	Planned seawater sample 6 at correct location. Estimated water depth 3 m.
19	19/11/2013	11:06	NR 93067 89975	193068	689975			Loch Gair. Location of final seawater sample.
20	19/11/2013	11:07	NR 93031 89979	193032	689979	Figure 8	ABSW7	Planned seawater sample 7. Photograph shows sample location and the castle with part of Loch Gair village in the background.
21	19/11/2013	11:14	NR 95696 90566	195697	690567			Aboard harvester's workboat approaching Lephinchapel on east side of loch. Approximately 60 sheep and 4 geese observed in field above the shoreline.
22	19/11/2013	11:23	NR 96605 90574	196606	690574		ABFW1	Planned freshwater sample 1 at Lephinchapel burn.
23	19/11/2013	11:31	NR 96605 90574	196606	690575	Figure 9		Lephinchapel burn measurements: Width 2.45 m. Measurement 1: depth 0.31 m, flow 0.179 m/s, SD 0.039. Measurement 2: depth 0.25 m, flow 0.158 m/s, SD 0.014. Measurement 3: depth 1.15 m, flow 0.170 m/s, SD 0.021.
24	19/11/2013	14:02	NR 94994 91612	194995	691613			Start of shoreline survey at Ardcastle Wood, south end of shoreline survey route. One pair of robins observed on the rocky shore.
25	19/11/2013	14:04	NR 94994 91614	194995	691614	Figure 10		Lephinchapel on the east side of the loch, viewed from the start of the shoreline survey.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
26	19/11/2013	14:08	NR 95005 91653	195005	691654	Figure 11		150 mm diameter plastic pipe section on shore (drift).
27	19/11/2013	14:16	NR 95103 91877	195103	691877			An overview of Ardcastle Bay and Lephinchaple farm from the shore.
28	19/11/2013	14:22	NR 95191 92116	195191	692116	Figure 12, 13		Finfish farm manned feeding barge and farm cages from the Ardcastle shore.
29	19/11/2013	14:28	NR 95200 92220	195201	692221	Fig. 14		Small stream: width 0.40 m. Measurement 1: depth 0.05 m, flow 0.168 m/s, SD 0.003. Measurement 2: depth 0.05 m, flow 0.169 m/s, SD 0.004. Clean forest drainage not on the sample plan, not sampled as considered low risk.
30	19/11/2013	14:41	NR 95214 92374	195214	692375		ABFW2	Planned freshwater sample 2. Sample associated with waypoint 31.
31	19/11/2013	14:41	NR 95214 92374	195214	692375	Fig 15		Un-named stream No. 1, width 1.6 m. Measurement 1: depth 0.08, flow 0.384 m/s, SD 0.008. Measurement 2: depth 0.09 m, flow 0.476 m/s, SD 0.020.
32	19/11/2013	15:05	NR 95632 93052	195633	693052		ABFW3	Planned freshwater sample 3. Sample associated with measurements at waypoint 33.
33	19/11/2013	15:06	NR 95635 93049	195635	693050	Figure 16		Un-named stream No.2, width 1.45 m. Measurement 1: depth 0.10 m, flow 0.197 m/s, SD 0.007. Measurement 2: depth 0.07 m, flow 0.187 m/s, SD 0.007.
34	19/11/2013	15:16	NR 95764 93251	195764	693252			New build, storage (boat?) shed with access to a gravel slipway.
35	19/11/2013	15:17	NR 95767 93254	195767	693254	Figure 17		Storage (boat?) shed
36	19/11/2013	15:20	NR 95792 93290	195793	693290			Photograph to show the end of survey line with photographic reference to the finfish farm.
37	19/11/2013	15:20	NR 95793 93291	195793	693291			End of survey at N end of shore walk.

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

Sampling

Seawater and freshwater samples were collected at the sites marked on the Ardcastle samples map shown in Figures 2. An additional seawater sample was mistakenly collected from the farm workboat at an incorrect location (waypoint 17) and subsequently discarded when the correct location was reached. No additional freshwater samples were taken as all other watercourses on the shore walk were minor drainage channels off the forestry and there was no reason to suspect human or animal contamination.

Due to the fact that the shellfish farm is a newly set up site, there were no mussels of a suitable size for testing for *E. coli* (Fig. 5) therefore the scheduled sampling plan could not be followed. Pacific oysters (Fig. 4) and native queen scallops (Fig. 6) as replacement for mussels were collected for analysis.

All the samples were transferred to a Biotherm 30 box with ice packs and posted to the Glasgow Scientific Services (GSS) for *E.coli* on the day of collection and were received by the laboratory the following day. The sample temperature on arrival at the laboratory was recorded as 3.6°C.

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

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

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	19/11/2013	ABFW1	NR 96605 90574	Freshwater	170	
2	19/11/2013	ABFW2	NR 95214 92374	Freshwater	10	
3	19/11/2013	ABFW3	NR 95632 93052	Freshwater	20	
4	19/11/2013	ABSW1	NR 95782 92749	Seawater	3	29.45
5	19/11/2013	ABSW2	NR 95296 92037	Seawater	2	29.81
6	19/11/2013	ABSW3	NR 95450 91760	Seawater	4	29.09
7	19/11/2013	ABSW4	NR 95077 91395	Seawater	1	29.45
8	19/11/2013	ABSW6	NR 93903 90041	Seawater	7	30.35
9	19/11/2013	ABSW7	NR 93031 89979	Seawater	600	23.85

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	Sample depths	E. coli (MPN/100g)
1	19/11/2013	ABSF1	NR 95488 91900	Queen scallops	3	20
2	19/11/2013	ABSF2	NR 95377 91952	Pacific oysters	15	20

Salinity Profiles

The two scheduled CTD casts were not completely successful as the first cast at the NW corner of the site (water depth about 10 m) was found not to have been registered when the records were examined at SAMS. The second cast at the SE corner (water depth about 30 m) was successfully recorded by the instrument.

The successful CTD cast profile will be issued to CEFAS separately.

Shoreline Survey Photographs

NB: photograph imprinted times are BST and therefore 1 hour ahead of GMT waypoint times in Table 1 (column 3).

Fig. 3. NW corner of mussel lines looking S. Waypoint 4.

Fig. 4. Pacific oysters in one of two cage arrays. Waypoints 7 and 8.

Fig. 5. Mussel spat on dropper line at waypoint 10.

Fig. 6. Queen scallops in Pearl net from 15 m water depth. Waypoint 14.

Fig. 7. View of typical shore vegetation of Ardcastle Wood. From waypoint 17.

Fig. 8. Location of ABSW7, Loch Gair castle with part of Loch Gair village in background. Waypoint 20.

Fig. 9. Lephinchapel Burn, E side Loch Fyne. Site of ABFW1, waypoint 23.

Fig. 10. Lephinchapel Burn view from start of shore walk on the west shore (S end). Photo taken from waypoint 25.

Fig. 11. ABS plastic pipe on shore. Waypoint 26.

Fig. 12. Finfish farm feed barge, N of shellfish farm site, from waypoint 28.

Fig. 13. Finfish farm cages (double row) and feed barge from waypoint 28.

Fig. 14. Small un-named watercourse measured for flow. Waypoint 29.

Fig. 15. Location ABFW2 plus flow measurements. Waypoint 31

Fig. 16. Final f/w sample ABFW3 plus flow measurements. Waypoint 31.

Fig. 17. Presumed storage/boat shed near N end of shore walk. Waypoint 34.

5. Ardcastle Bay CTD data

Data obtained during the shoreline survey. The location of the cast is shown in the figure below.

Figure. Location of CTD cast

CAST 2

Data Header

% Device	10G100653
% File name	10G100653_20131119_103007
% Cast time (local)	19/11/2013 10:30
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	56.0747579
% Start longitude	-5.288213
% Start GPS horizontal error(Meter)	5.409999847
% Start GPS vertical error(Meter)	7.679999828
% Start GPS number of satellites	5
% Cast duration (Seconds)	63.8
% Samples per second	5
Calibration Date	March 2013
Calibration offset for Temperature	-0.033
Calibration offset for Salinity	0.029

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.149498361	8.265524376	28.59247755
0.448474581	8.291462279	28.60846281
0.747450918	8.373518901	28.66273165
1.04641176	8.487869891	28.77597153
1.345329363	8.675732314	29.09255257
1.64418984	8.957666491	29.35965191
1.942999181	9.206856003	29.63773592
2.241772756	9.35570284	29.74681276
2.54053171	9.475918082	29.81566404
2.839288339	9.677437885	29.82810071
3.137997714	9.90657492	30.31458419
3.436641743	10.02502776	30.47029097
3.735240226	10.09180167	30.75054042
4.033796936	10.17056445	30.86523069
4.332323139	10.24830879	31.04905935
4.630828897	10.29421214	31.06843648
4.929316472	10.33683724	31.22507745
5.227784201	10.3582854	31.25392008
5.526239629	10.37173681	31.33793582
5.824681592	10.38804109	31.3759453
6.123112826	10.40153848	31.4358881
6.421533712	10.42656331	31.47244426
6.719938128	10.45695179	31.59002769
7.018327403	10.4921523	31.61713392
7.316707018	10.51922872	31.68573542
7.615077724	10.52646998	31.70015834
7.913445206	10.52505851	31.71244515
8.211810926	10.535812	31.71473648
8.510175104	10.53585322	31.72540213
8.808537344	10.54474474	31.73078945
9.106895366	10.55231818	31.76319508
9.405247688	10.55768506	31.78088937
9.703595332	10.56353784	31.80391892
10.00193876	10.57410902	31.81867098
10.30028005	10.57859527	31.82311673
10.59861799	10.58276294	31.84704107
10.89695231	10.60738076	31.85844414
11.1952757	10.6361301	31.95218876
11.49357483	10.6702095	32.08335419
11.79185283	10.71002252	32.15197753
12.09012026	10.73461689	32.18799096
12.38838197	10.74817961	32.20801894
12.68664261	10.75454998	32.19880707
12.98490535	10.73988304	32.18462583
13.28316405	10.73358915	32.22688742
13.58141561	10.76463697	32.25011419
13.82891435	10.76327957	32.24397501