Scottish Sanitary Survey Project

Sanitary Survey Report

Baltasound (SI 010)

May 2010

Report Distribution – Baltasound

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* Distribution of both draft and final reports to relevant agency personnel is undertaken by FSAS.

** Distribution of draft and final reports to harvesters is undertaken by the relevant local authority.

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Appendices

1. General Description

The production area for Baltasound is located within Balta Sound on the eastern side of the Isle of Unst, the most northerly island of Shetland.

Balta Sound is fairly sheltered by the island of Balta on the eastern side. The inner sound lies in a west-east direction and is 3 km in length, 0.08 km at its narrowest point and 1 km at its widest point. The depth varies from 0 to 20 m, with the shallower areas at the western end of the sound. The outer sound lies in a north-south direction and is situated on the Unst side of the island of Balta.

This sanitary survey was triggered by the risk matrix score achieved for the Baltasound production area due to monitoring results outwith its classification.

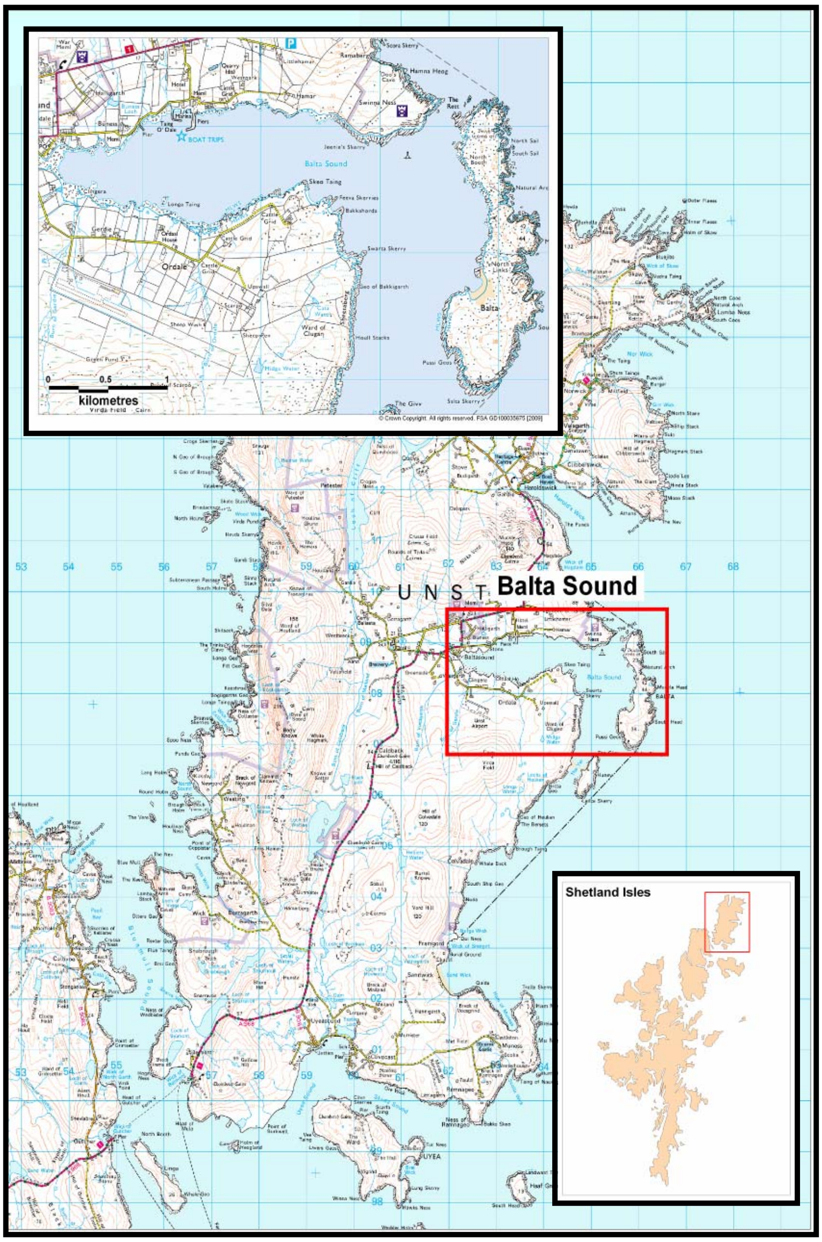

Figure 1.1 Location of Balta Sound

2. Fishery

The fishery at Baltasound is composed of a Pacific oyster farm and two long line mussel (*Mytilus* sp.) farms, as listed in Table 2.1 below:

Table 2.1 Baltasound shellfish farms

Production area	Site	SIN	Species
Baltasound	Baltasound	SI 010 394 13	Pacific oysters
	Baltasound harbour	SI 010 395 08	Mussels
	TBA	SI 010 TBA 08	Mussels

The production area boundaries for both species are currently a line drawn between HP 6535 0900 to HP 6482 0793 extending to MHWS. The nominal Representative Monitoring Point (RMP) grid reference for Pacific oysters is HP 625 087 and for mussels is HP 643 089. Neither falls within the actual fisheries or Crown Estates lease areas. Both mussel sites are under the same ownership.

<u>Baltasound</u>
The Baltasound site consisted of an area of 41 oyster trestles, inshore of and smaller than the Crown Estates lease for this site. The trestles were of a cage type, with up to 6 layers of bagged Pacific oysters inside each cage. Additionally, a few bags of oysters were found on the substrate at the inshore side of the fishery. Stock of a range of sizes was present, including that of a harvestable size. Harvesting may occur at any time of the year. Oysters grow slowly at this site, taking around 6 or 7 years to reach a harvestable size, making the viability of their culture here marginal. It is believed that the fishery may be sold on or wound down in the next few years.

<u>Baltasound harbour</u>
The Baltasound harbour site consisted of 3 double and one single headed long lines, all with 8 m droppers. The owner reported poor spatfall and relatively low yields from this site. There was little stock present, although there were some mussels, including of a harvestable size on some lines. The tackle was deployed about 3 years ago, and the first harvest was planned for the second half of 2009. However, the owner has decided to postpone harvest until 2010 due to the poor growth.

<u>New mussel site</u>
In addition to the Baltasound site, the same owner also deployed one double headed longline closer to the head of the sound in mid 2008. The two headropes had been pulled apart in the middle to form an elongated diamond shape. No stock was available for sampling from this line. It is anticipated that this line will be harvested in 2011. The owner has a processing shed with depuration unit on the south shore of the sound. This serves the mussel

culture operation in Balta Sound, as well as another mussel culture operation in nearby Uyeasound, which is under the same ownership.

Figure 2.1 shows the relative positions of the shellfisheries, Food Standard Agency Scotland designated production area, Crown Estates lease areas, and RMPs.

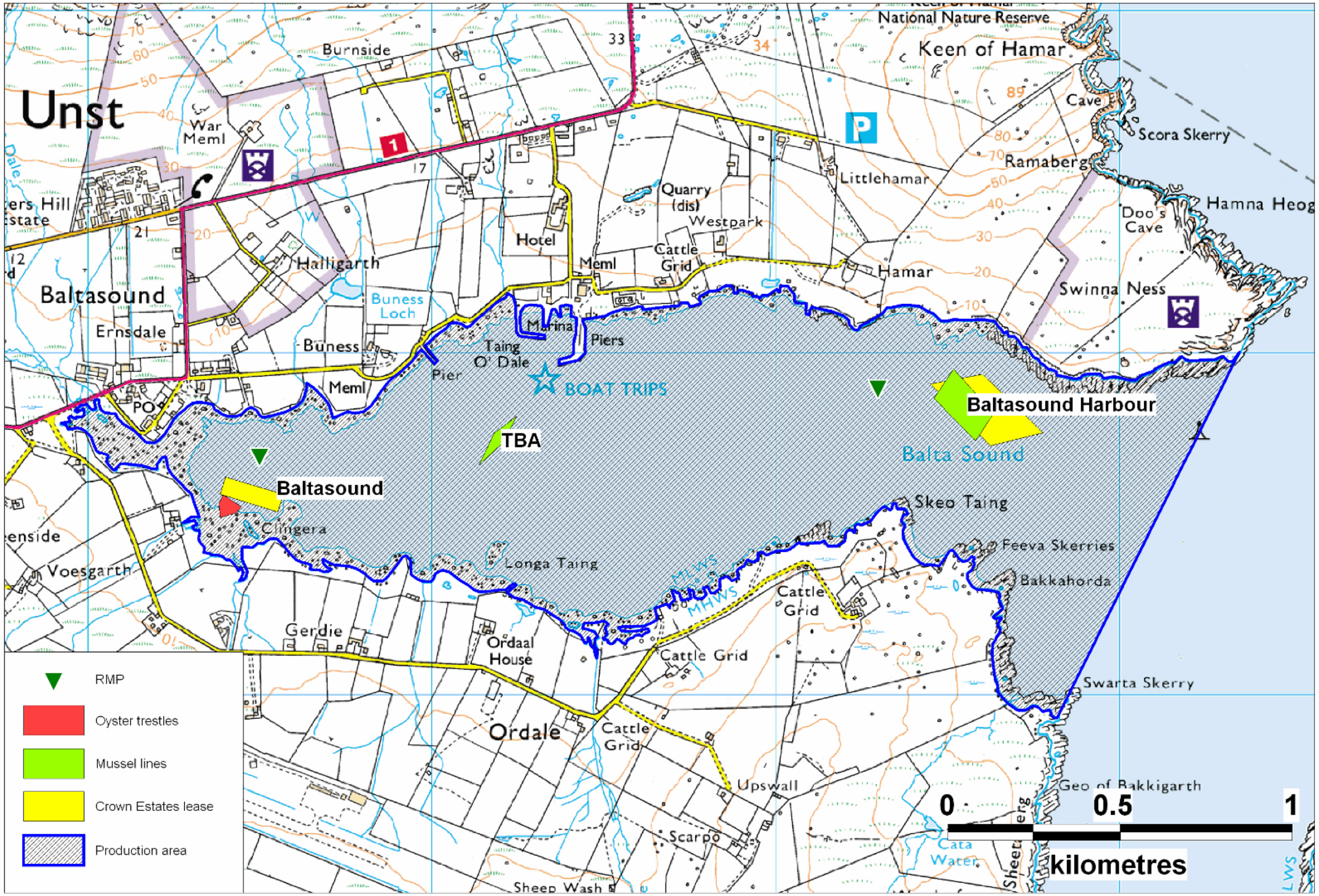

Figure 2.1 Fishery at Balta Sound

3. Human Population

The figure below shows information on population within the census output areas in the vicinity of Balta Sound. The data was obtained from the General Register Office for Scotland and is based on the 2001 census returns.

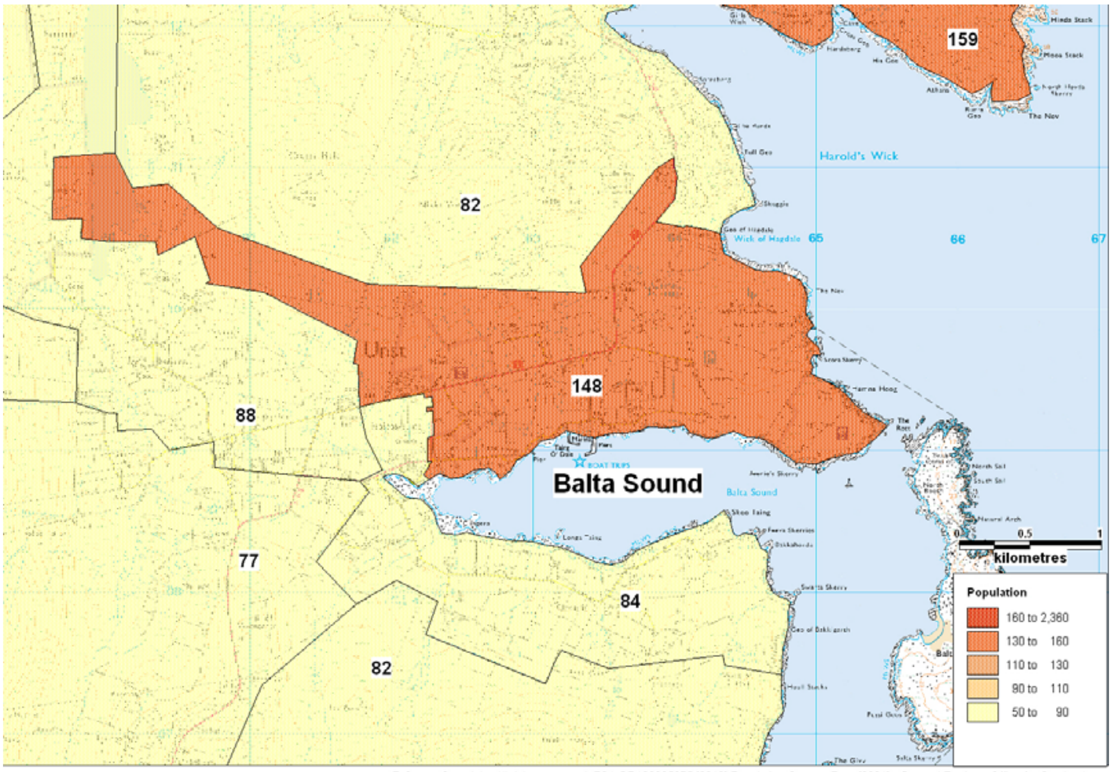

Figure 3.1 Human population surrounding Balta Sound

Baltasound is the largest community on Unst but is spread out, located around the coastal area adjacent to Balta Sound. A large proportion of this community live at the eastern end and on the north-eastern side of Balta Sound but there is also a concentration around Ordale on the south side. Any contribution of faecal contamination from human sources will therefore tend to be greatest around these areas.

There is a pier and harbour on the north side of the inner sound and the area is also used as an anchorage. There is thus the potential for the release of waste from boats.

Tourism on Unst is currently limited although there are plans to develop this further in the future (Shetland Local Plan – Ulst Community Council Area Statement). There is a guest house and hotel in Baltasound. There may therefore be some increase in anthropogenic contamination in the summer months. This is likely to increase if the development plans are successful.

4. Sewage Discharges

One community septic tank was identified by Scottish Water for the area, which is consented to serve 504 people and discharges to the north shore of Balta Sound. This system also has an emergency overflow at the head of Balta Sound. Details are presented in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

NGR	Discharge Name	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consent/ design pop	Q&S III Planned improve-ment?	Discharge consent reference number
HP 6372 0912	Baltasound	continuous	septic tank	135	504	no	CAR/L/1002233
HP 6195 0885	Baltasound EO	intermittent	none	none stated	504	no	CAR/L/1002233

No sanitary or microbiological data is available for these discharges. Six discharge consents have been issued by SEPA, details of which are presented in Table 4.2. The first two entries in Table 4.2 relate to the Scottish Water discharges given in Table 4.1.

Table 4.2 Discharges identified by SEPA

Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
CAR/L/1002233	HP 6372 0912	Treated Sewage Effluent	Septic tank	135	504	Balta Sound
CAR/L/1002233	HP 6195 0885	Emergency Overflow	None		504	Balta Sound
CAR/R/1015148	HP 6343 0915	Domestic	Septic tank		14	Balta Sound
CAR/R/1035036	HP 62490 09620	Domestic	Septic tank		15	Land via soakaway
CAR/R/1037418	HP 6247 0933	Domestic	Septic tank		5	Land via soakaway
CAR/R/1036528	HP 62480 09520	Domestic	Septic tank		15	Land via soakaway
CAR/R/1036517	HP 62580 09270	Domestic	Septic tank		15	Land via soakaway

Apart from the Scottish Water septic tank and its associated EO, and a private discharge by Baltasound marina, all of these discharge to soakaway and so are likely to be of no impact on water quality within Balta Sound. As there has not historically been a requirement to register septic systems in Scotland, this list is unlikely to cover all septic tanks in the area. A physical survey of the shoreline was undertaken and observations of septic tanks and/or potential outfall pipes present along the shoreline of Balta Sound are presented in Table 4.3.

Observations 1, 4 and 8 in Table 4.3 apply to Scottish Water infrastructure. The emergency overflow actually discharges to the head of Balta Sound about 300 m to the southeast of the pumping station rather than at the pumping station itself. The private discharge at Baltasound marina (SEPA consent no CAR/R/1015148) was not seen during the shoreline survey, although this section of the shore was walked. A further 5 private discharges to Balta Sound were seen (observations 2, 6, 7, 9 and 10) as well as one private discharge to a stream at the head of the sound which in turn flows over the oyster trestles (observation 5) and one septic tank to soakaway (observation 3).

Table 4.3 Discharges and septic tanks observed during the shoreline survey

No.	Date	NGR	Observation
1	26-MAY-09	HP 63708 09126	Scottish Water septic tank. Boil from outflow visible about 20m offshore.
2	26-MAY-09	HP 63826 09182	Private 12cm cast iron sewer pipe to underwater. 1 house behind.
3	26-MAY-09	HP 63650 09168	Septic tank with obvious soakaway.
4	27-MAY-09	HP 62205 08703	Scottish Water Emergency overflow (not flowing).
5	27-MAY-09	HP 62254 08477	Septic tank discharge pipe to stream. Not flowing. Serves 1 house.
6	27-MAY-09	HP 62433 08800	20 cm cast iron sewer pipe, not flowing. Looked old and possibly not in use.
7	27-MAY-09	HP 62366 08833	15 cm faded orange plastic sewer pipe, dripping, septic tank cover in field behind, probably serves one house
8	27-MAY-09	HP 61949 08843	Scottish water pumping station.
9	27-MAY-09	HP 63231 08276	Orange 110mm plastic sewer pipe (1 house behind)
10	27-MAY-09	HP 63669 08246	Septic tank with pipe to underwater (serves mussel shed)

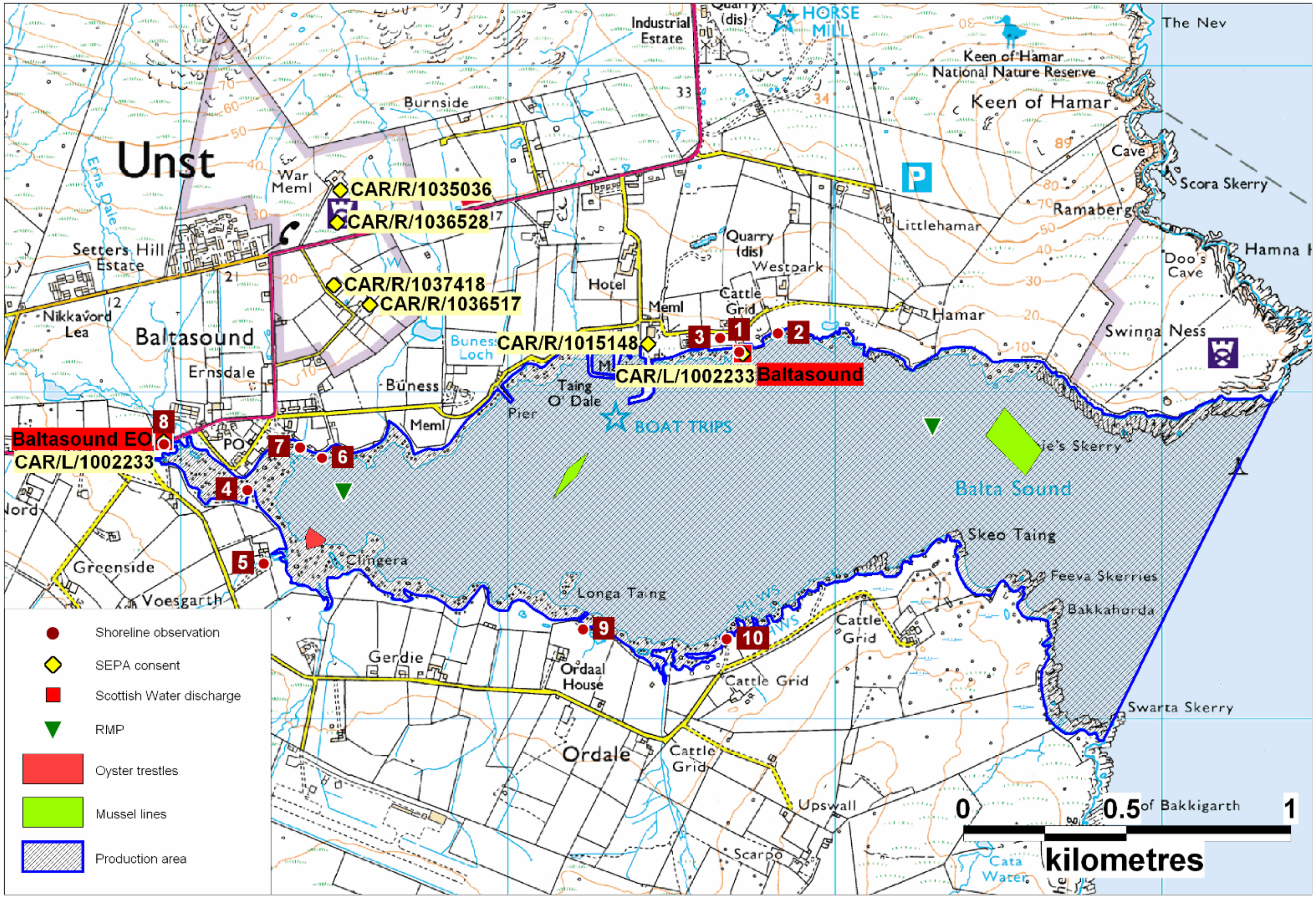

Figure 4.1 Sewage discharges at Balta Sound

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 2. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red indicates poorly draining soils and the areas shaded in different tones of blue indicate freely draining soils.

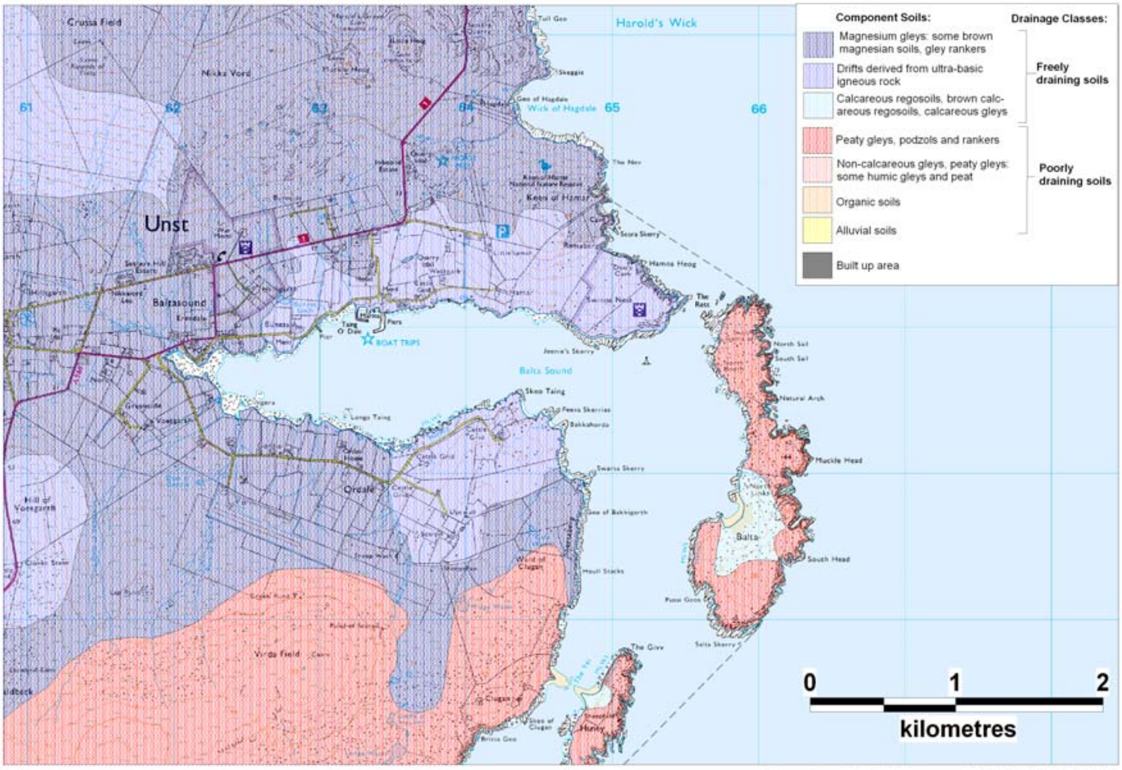

Figure 5.1 Component soils and drainage classes for Balta Sound

Four types of component soil are present in the area: peaty gleys, podzols and rankers, alluvial soils, calcareous regosoils, brown calcareous regosoils and calcareous gleys, magnesium gleys, some brown magnesium soils, gley rankers and drifts derived from ultra basic igneous rock. The peaty gleys, podzols and rankers are poorly draining and the other soil types are freely draining. Therefore, the potential for runoff contaminated with *E. coli* from human and/or animal waste will be reduced in the areas with freely draining soil, this includes the majority of land surrounding Balta Sound.

6. Land Cover

No Land Cover Map 2000 data was available for this area, and no similar substitute data sources could be identified, so no detailed land cover maps could be produced for this area.

The Ordnance Survey map indicates that the land surrounding Balta Sound has a gradual gradient. The Ordnance Survey map of the area indicates that there is ‘bracken, heath or rough grassland’ at the shoreline at the far eastern and far western ends of the sound. The shoreline survey identified that the land surrounding Balta Sound is primarily improved pasture which is grazed by sheep, cattle and ponies. The more elevated land appeared to be heathland located further back from this low lying area of pasture. There is also several small developed areas at Baltasound around the head and northern side and Ordale located on the southern coastline of the sound.

The faecal coliform contribution would be expected to be highest from developed areas (approx 1.2 – 2.8×10^9 cfu km^{-2} hr^{-1}), with intermediate contributions from the improved grassland (approximately 8.3×10^8 cfu km^{-2} hr^{-1}) and lowest from the other land cover types (approximately 2.5×10^8 cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to increase significantly after marked rainfall events. This increase would be highest, at more than 100-fold, for the improved grassland.

Therefore, on the basis of observed land cover, the potential for contaminated runoff would be highest close to the developed areas of Baltasound and Ordale, low to intermediate around the rest the sound. Contamination is likely to increase most after rainfall in the areas of pastureland.

7. Farm Animals

Agricultural census data was received from the Scottish Government Rural and Environment Research and Analysis Directorate (RERAD) for the Unst parish, which covers the entire of Unst, an area of 123 km^2. Recorded livestock populations for the parishes for 2008 are presented in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reported would have made it possible to discern individual farm data.

Table 7.1 Livestock numbers in Unst, 2008

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Pigs	0	-	*	*
Poultry	15	257	13	303
Cattle	13	321	13	326
Sheep	115	25938	116	25306
Horses and Ponies	27	237	25	225

*Data withheld for the purpose of confidentiality

Livestock kept within this parish are predominantly sheep. Due to large area of the parish, this data does not provide information on the livestock numbers in the area immediately surrounding the production areas. The only significant source of local information was therefore the shoreline survey (see Appendix), which only relates to the time of the site visit on 25-26th May 2009. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. This information should be treated with caution, as it applies only to the survey dates and is dependent upon the point of view of the observer (some animals may have been obscured from view by the terrain).

The shoreline survey confirmed that agriculture in the area is dominated by sheep grazing. The band of low lying crofts and fields surrounding the production area appeared to be improved pastures, which supported fairly high densities of a variety of livestock. This band extended about 1 km inland from the shore. Not all fields had livestock on them at the time of survey. In most places fences prevented livestock from accessing the shoreline, although there was a notable exception to this adjacent to the main area of mussel lines, where cattle had access to the beach. A total of 519 sheep, 82 cattle, 37 ponies and 3 chickens were recorded on these pastures. In addition to this, approximately 100 sheep were recorded on the island of Balta, at the mouth of Balta Sound (not shown on map). Therefore, all streams draining into the production area are likely to carry some contamination of livestock origin.

Numbers of sheep and cattle will approximately double during May following the birth of lambs and calves, and decrease in the autumn as they are sent to market. Animals are also likely to access streams to drink and cool off more frequently during the warmer months. Therefore higher impacts from livestock may be expected during this period.

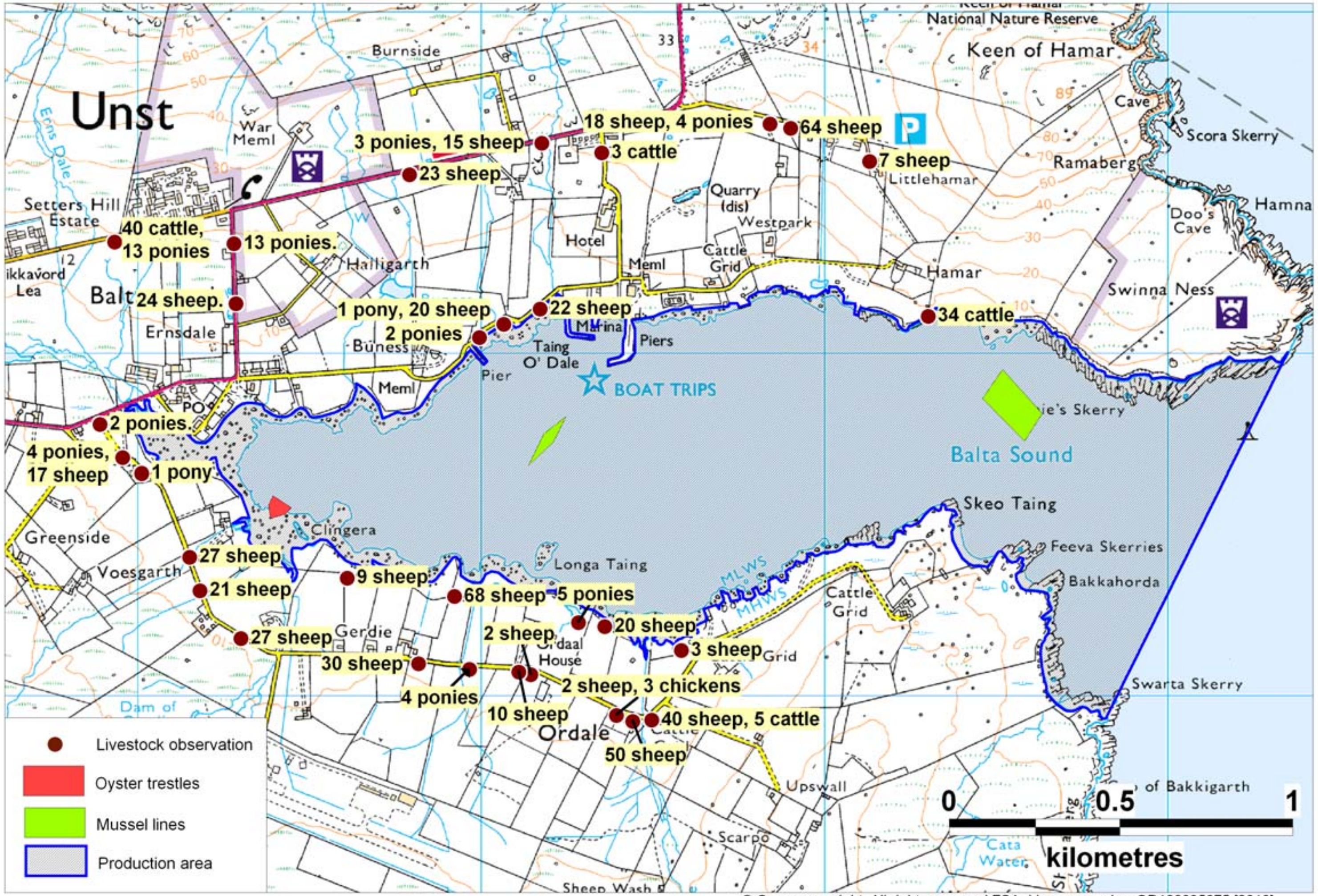

Figure 7.1 Shoreline survey livestock observations

8. Wildlife

General information related to potential risks to water quality by contamination from wildlife sources can be found in Appendix 4. A number of wildlife species present or likely to be present at Balta Sound could potentially affect water quality around the fishery.

Seals

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*). Scotland hosts significant populations of both species.

A survey conducted by the Sea Mammal Research Unit in 2001 estimated a population of 140 common seals on Unst. No haulout sites were reported at Balta Sound, and the majority of haulout sites on Unst were on its west coast.

Minimum grey seal pup production in Shetland was estimated as 943 in 2004. Adult numbers are estimated to be 3.5 times the pup population (Callan Duck, Sea Mammal Research Unit, personal communication). No breeding colonies were reported for grey seals in Balta Sound, but a large colony is located at Uyea (producing at least 114 pups in 2006), just to the south of Unst.

Therefore it is likely that both species of seals may be present in the area from time to time. No seals were seen during the course of the shoreline survey.

Whales/Dolphins

A variety of whales and dolphinsare routinely observed near Shetland. It is possible that cetaceans will be found from time to time in the area, although the larger species will not visit this area as it is fairly shallow and enclosed. Any impact of their presence is likely to be fleeting and unpredictable.

Birds

A number of bird species are found around Balta Sound, but seabirds and waterfowl may be expected to occur around or near the fisheries. A number of seabird species breed in Shetland. These were the subject of a detailed census carried out in sections during the late spring of 1999, 2000, 2001 and 2002 (Mitchell et al, 2004). Total counts of all species recorded within 5 km of the mussel lines are presented in Table 8.1. Where counts were of occupied sites/nests/territories, actual numbers of birds breeding in the area will be higher.

The seabird census indicated a high density of breeding seabirds in the general area, but not within Balta Sound itself. Within and on the shores of Balta Sound only a one pair of gulls and 9 guillemots were recorded. A significant colony of breeding seabirds was recorded on the island of Balta at the mouth of Balta Sound, with 154 guillemot individuals and 98 pairs of terns and gulls.

Table 8.1 Counts of breeding seabirds within 5 km of Balta Sound

Common name	**Species**	**Total count**	**Method**	**Individuals / pairs**
Northern Fulmar	*Fulmarus glacialis*	1732	Occupied sites	Pairs
Black Guillemot	*Cepphus grylle*	464	Individuals on land	Individuals
Atlantic Puffin	*Fratercula arctica*	220	Occupied burrows	Pairs
Arctic Tern	*Sterna paradisaea*	140	Occupied territory	Pairs
Great Skua	*Stercorarius skua*	127	Occupied territory	Pairs
Arctic skua	*Stercorarius parasiticus*	124	Occupied territory	Pairs
European Shag	*Phalacrocorax aristotelis*	66	Occupied nests	Pairs
Great Black-backed Gull	*Larus marinus*	58	Occupied territory	Pairs
Herring Gull	*Larus argentatus*	51	Occupied territory	Pairs
Common Gull	*Larus canus*	49	Occupied territory	Pairs
Common Guillemot	*Uria aalge*	36	Individuals on land	Individuals
Lesser Black-backed Gull	*Larus fuscus*	28	Occupied territory	Pairs
Razorbill	*Alca torda*	2	Individuals on land	Individuals

Waterfowl (ducks and geese) may be present in the area at various times, either to overwinter, or briefly during migration, or possibly to breed during the summer. No ducks or geese were seen during the course of the shoreline survey.

Wading birds would be concentrated on intertidal areas, but no aggregations were noted during the shoreline survey. Generally, few birds were seen during the course of the shoreline survey.

Otters

No otters were observed during the course of the shoreline survey, although it is believed that they are present in the area. However, the typical population densities of coastal otters are low and their impacts on the shellfishery are expected to be very minor.

Summary

The bird census data of seabirds do not record the presence of seabirds within the sound itself but a significant colony was located on Balta Island. At that location, they would not be expected to impact on water quality at the fisheries. However, they may periodically feed within the inner sound and could then have an effect. The same would apply to the other species recorded by the bird censuses.

9. Meteorological data

The nearest weather station is located at Baltasound, approximately 600 m to the south of the fishery, for which uninterrupted rainfall data was available for 2003-2008 inclusive. The nearest weather station for which wind data was available was Lerwick, approximately 70 km to the south of the fishery. It is likely that overall wind patterns are broadly similar at the fishery and at Lerwick, but local topography may result in some differences. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within Balta Sound.

Rainfall and wind data were supplied to Cefas/FSAS by the Meteorological Office under licence. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas.

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). Figures 9.1 and 9.2 present box and whisker plots summarising 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 line within the box. 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 shows that rainfall patterns were broadly similar between the years presented here. One relatively extreme rainfall event occurred in 2005. There appears to be a general upward trend in the magnitude of extreme events.

Figure 9.2 shows that the wettest months were September to March and the driest months were April to August. Extreme rainfall events (>30 mm/day) occurred during June to October and in December in this data set. For the period considered here (2003-2008), 43% of days experienced rainfall less than 1 mm, and 8% of days experienced rainfall of 10 mm or more.

It can therefore generally be expected that levels of run-off will be higher during the autumn and winter months. However, it is likely that associated faecal contamination entering the production area will be greatest when extreme rainfall events occur during summer or early autumn after a build-up of faecal matter on pastures during the drier summer months when stock levels are at their highest.

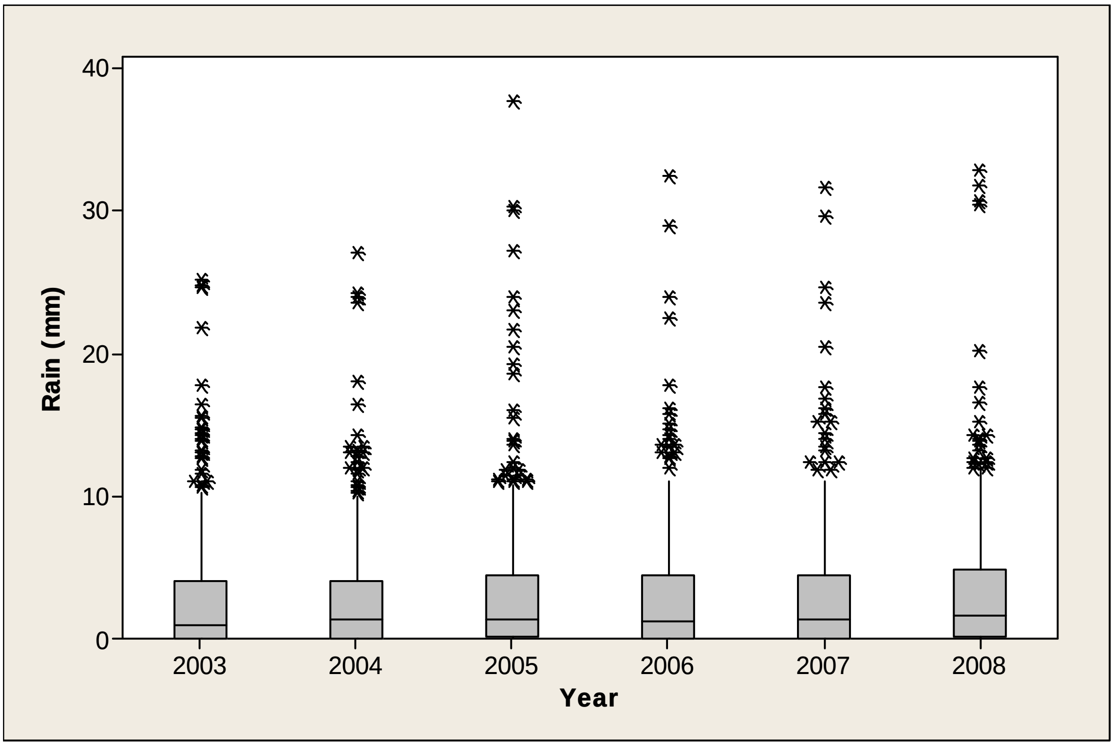

Figure 9.1 Box plot of daily rainfall by year at Baltasound, 2005-2008

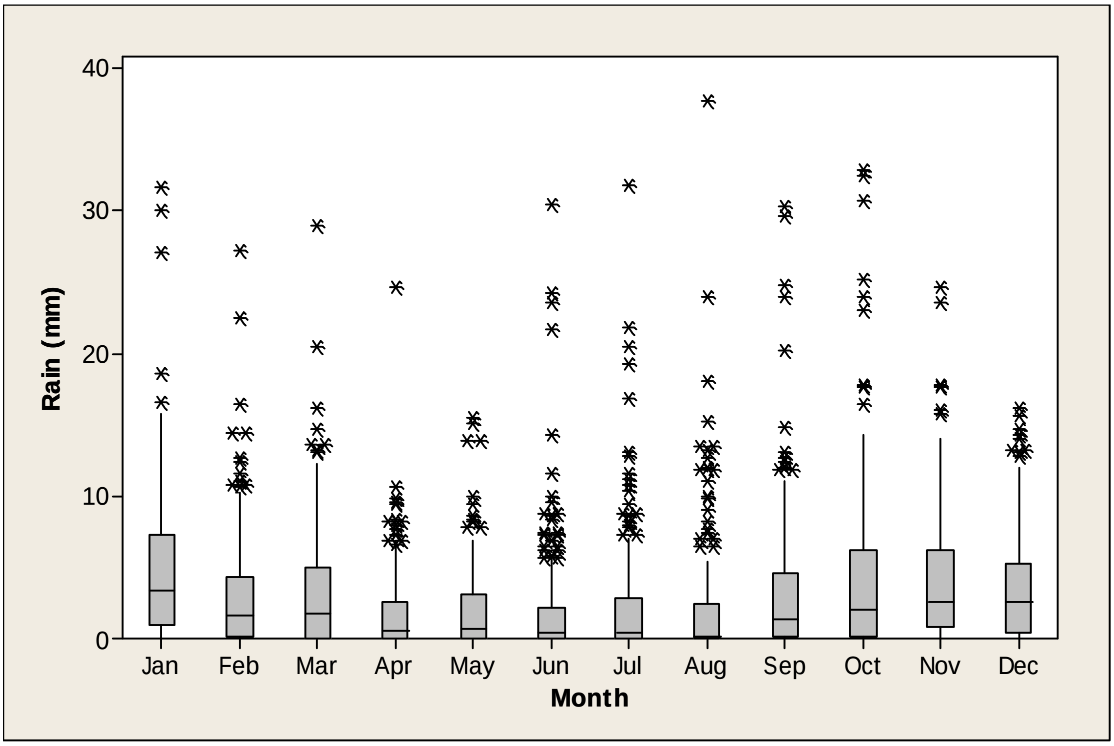

Figure 9.2 Box plot of daily rainfall by month at Baltasound, 2005-2008

9.2 Wind

Wind data collected at the Lerwick weather station is summarised by season and presented in figures 9.3 to 9.7.

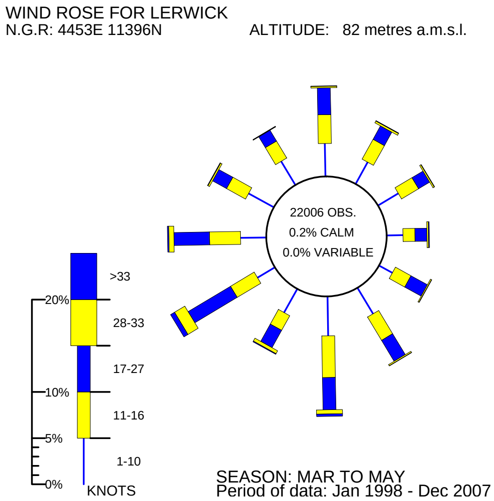

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Figure 9.3 Wind rose for Lerwick (March to May)

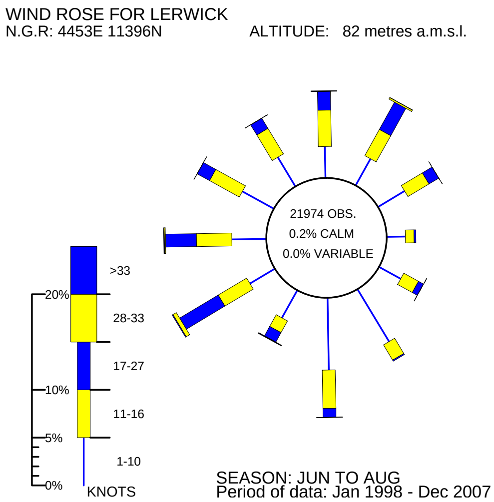

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Figure 9.4 Wind rose for Lerwick (June to August)

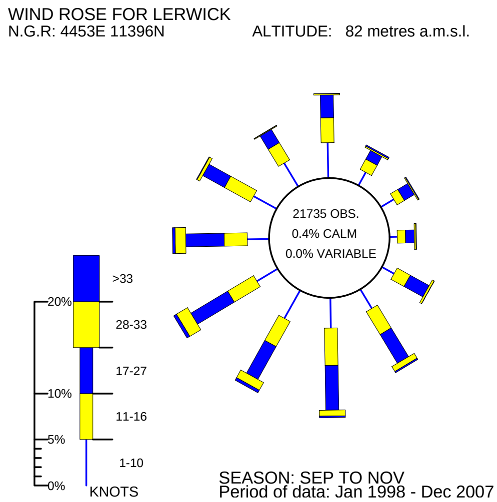

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Figure 9.5 Wind rose for Lerwick (September to November)

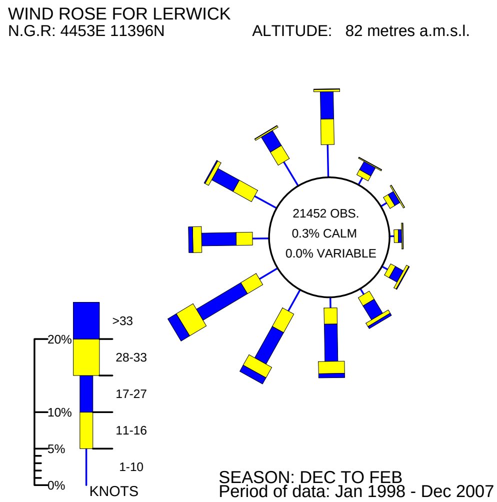

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Figure 9.6 Wind rose for Lerwick (December to February)

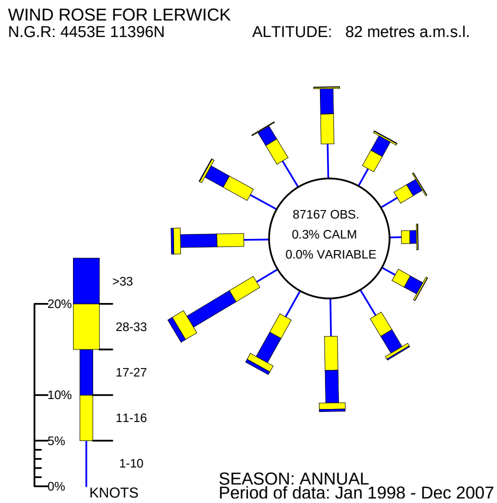

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Figure 9.7 Wind rose for Lerwick (Annual)

Shetland is one of the more windy areas of Scotland with a much higher frequency of gales than the country as a whole. The wind roses show that the overall prevailing direction of the wind is from the south and west, and when it is blowing from this direction it is likely to be stronger than when blowing from other directions. Winds are generally lighter during the summer months and strongest in the winter.

Balta Sound faces the east, with the island of Balta lying across its mouth so will receive some shelter from winds from all directions. As it has an east-west asspect it is likely that winds from the east and west will cause the most significant changes to circulation here. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. This is large compared to the tidal currents expected in the area. Strong winds will increase the circulation of water and hence dilution of contamination from point sources within the sound. Winds from a north westerly direction may transport contamination from the Scottish Water septic tank (the main point source identified in the area) towards the larger mussel site. Winds from the predominant southerly and south-westerly directions would tend to keep contamination from that source closer to the northern shore and away from the fisheries.

10. Current and historical classification status

Baltasound has been classified for the production of both mussels and Pacific oysters since 2002. Classification histories for these species are presented in Tables 10.1 to 10.2. A map of the current production area can be found in Section 2, Figure 2.1.

Table 10.1 Classification history, Baltasound, mussels

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	A (P)	A (P)	A (P)	A (P)	-	-	B (P)	B (P)	B (P)	B (P)	B (P)	B (P)
2003	A	A	A	A	A	A	A	A	A	A	A	A
2004	A	A	A	A	A	A	A	A	A	A	A	A
2005	A	A	A	A	A	A	A	A	A	A	A	A
2006	A	A	A	A	A	A	A	A	A	A	A	A
2007	A	A	A	A	A	A	A	B	B	B	A	A
2008	A	A	A	A	A	A	A	B	B	B	A	A
2009	A	A	A	A	A	A	B	B	B	A	A	A
2010	A	A	A									

(P) = provisional

For mussels, the area received a provisional A/B classification in 2002, with May and June not classified. From 2003 to 2006 the area received an A classification. From 2007 onwards the area received seasonal A/B classifications, with the B months falling in the summer/autumn.

Table 10.2 Classification history, Baltasound, Pacific oysters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	B (P)	B (P)	B (P)	B (P)	B (P)	B (P)	B (P)	B (P)	B (P)	B (P)	B (P)	B (P)
2003	A	A	A	A	A	A	A	B	B	B	B	A
2004	B	B	A	A	A	B	B	B	B	B	B	B
2005	B	A	A	A	A	A	A	B	B	B	B	B
2006	B	A	A	A	A	A	A	B	B	B	B	B
2007	B	A	A	A	A	A	A	B	B	B	B	B
2008	A	A	A	B	B	B	B	B	B	B	B	B
2009	A	A	B	A	A	A	B	B	B	B	B	B
2010	B	A	A									

(P) = provisional

For Pacific oysters, the area received a provisional B classification in 2002. Since then it has held seasonal A/B classifications, with the timing of varying from year to year. The months of August to December have always received B classifications.

The Pacific oysters have therefore tended to be classified B over a wider period than the mussels.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken from the Baltasound production area from the beginning of 2002 up to the 22nd September 2009 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

Four Pacific oyster and 4 mussel samples had the wrong prefix to their reported grid reference, and these were corrected. One mussel and one Pacific oyster sample had an extra '0' in their reported grid reference, and these were also corrected. Following these corrections, all sampling locations fell within the production area.

Two mussel samples and one Pacific oyster sample had invalid laboratory results and these were excluded from the analysis.

Eight Pacific oyster and 16 common mussel samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. One Pacific oyster had a reported result of >18000, and this was assigned a nominal value of 36000 for statistical assessment and graphical presentation.

One mussel sample had a reported collection date after the laboratory received date, and this was excluded from the analysis. All other samples were analysed within 48 hours of collection.

All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intravalvular fluid.

11.2 Summary of microbiological results

A summary of all sampling and results by location is presented in Table 11.1. In addition to these samples, one native oyster sample was submitted from the Pacific oyster RMP in Nov 2002, and gave a result of 20 *E. coli* MPN/100 g. This sample will not be considered further in this analysis.

Table 11.1 Summary of historical sampling and results

Sampling Summary			
Production area	Baltasound	Baltasound	Baltasound
Site	Baltasound	Baltasound Harbour	Baltasound Harbour
Species	Pacific oysters	Common mussels	Common mussels
SIN	SI-010-394-13	SI-010-395-08	SI-010-395-08
Location	HP 625087	HP 645088	HP 643089
Total no of samples	81	19	64
No. 2002	11	0	12
No. 2003	13	0	12
No. 2004	11	0	13
No. 2005	11	0	10
No. 2006	10	0	11
No. 2007	9	4	6
No. 2008	9	8	0
No. 2009	7	7	0
Results Summary			
Minimum	<20	<20	<20
Maximum	>18000	1700	1300
Median	140	130	40
Geometric mean	159	98.6	52.3
90 percentile	1300	1140	283
95 percentile	2400	1340	487
No. exceeding 230/100g	29 (36%)	5 (26%)	7 (11%)
No. exceeding 1000/100g	10 (12%)	3 (16%)	1 (2%)
No. exceeding 4600/100g	3 (4%)	0 (0%)	0 (0%)
No. exceeding 18000/100g	1 (1%)	0 (0%)	0 (0%)

11.3 Overall geographical pattern of results

Figure 11.1 presents a map showing geometric mean result by reported sampling locations (with OS grid reference, species, number of samples and sampling years). All Pacific oyster samples were reported from the nominal RMP (although this does not coincide with the location of the fishery) so no spatial analysis of results could be undertaken for this species. Prior to June 2007, all mussel samples were reported from HP 643 089 (the nominal RMP), which falls outside the current boundaries of the fisheries, so there is some uncertainty about the location of sampling during that period. From July 2007, all mussel samples were recorded as being taken from HP 645 088, which falls within the fishery.

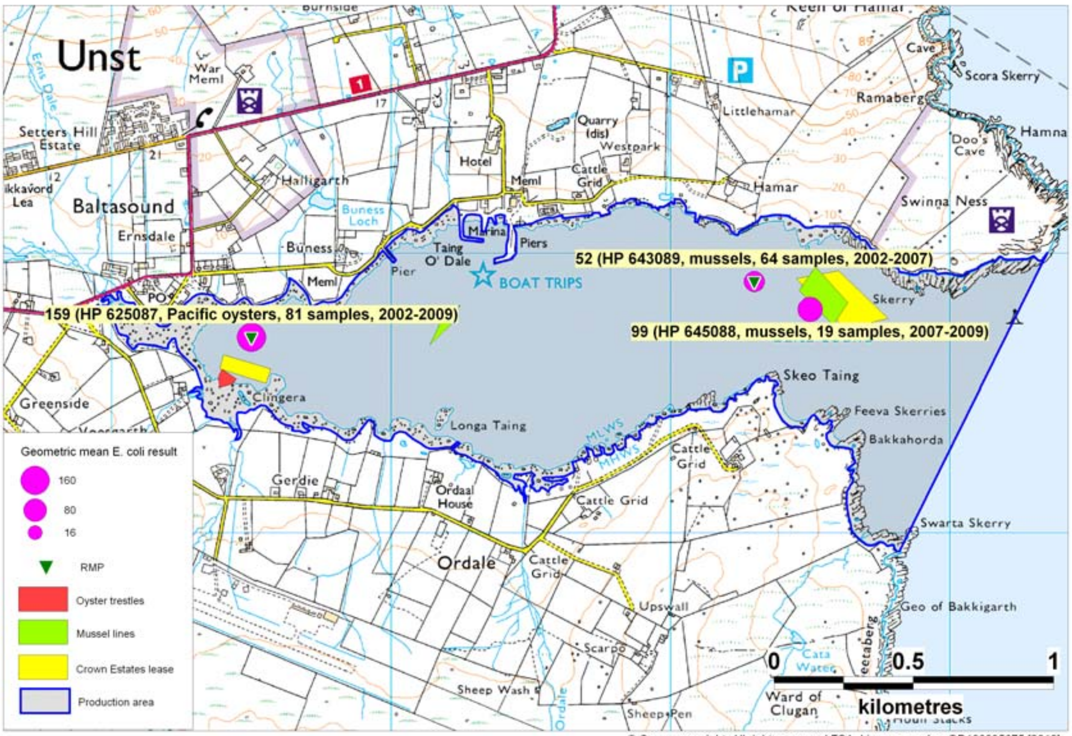

Figure 11.1 Map of sampling points and geometric mean result

Table 11.1 shows that, for mussels, both the geometric mean *E. coli* result and the proportion of results exceeding 230 *E. coli* MPN/100g was higher for samples taken from HP 645 088. However, a comparison of results for mussels taken from HP 643 089 and HP 645 088 revealed no significant difference in mean result between the two reported sampling locations (T-test, t=-1.49, p=0.150, Appendix 6). There was also no significant difference in the proportion of results over 230 *E. coli* MPN/100g (Fisher's exact test, p=0.134, Appendix 6). Therefore, mussel samples from both reported sampling locations will be considered together in the further analyses presented below.

11.4 Overall temporal pattern of results

Figures 11.2 and 11.3 present scatter plots of individual results against date for each species, fitted with trend lines calculated using two different techniques. The first is a rolling geometric mean, with the line following the geometric mean of the previous 5 samples, the current sample and the following 6 samples. The second is a loess line which stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away. These trend lines help to highlight any apparent underlying trends or cycles. For each of the figures, the rolling geometric mean is plotted with a heavy black line and the Loess line is plotted as a fine blue line.

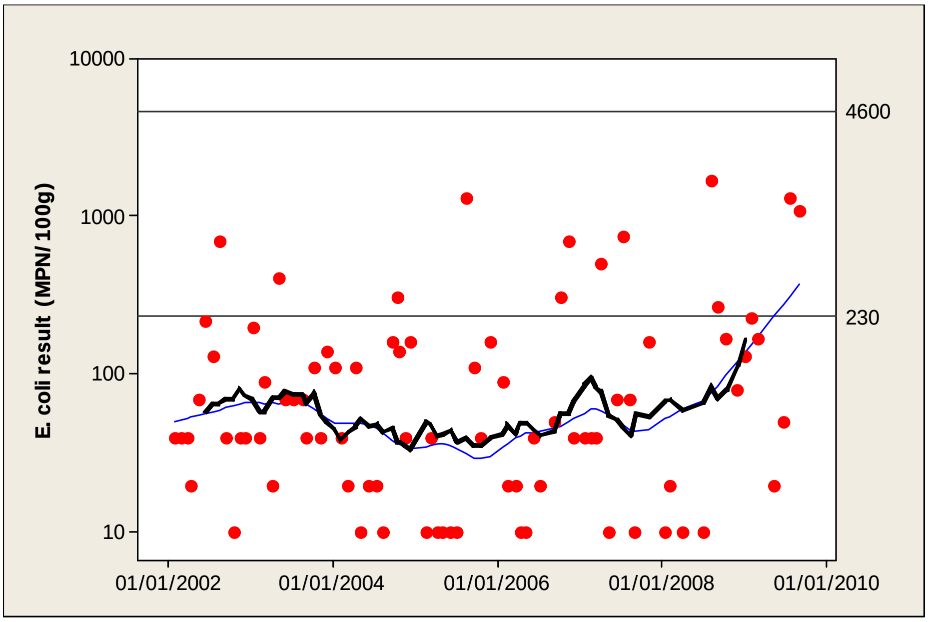

Figure 11.2 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line) (mussels)

Figure 11.2 shows that results above 1000 *E. coli* MPN/100 g have only been seen since the second half of 2005.

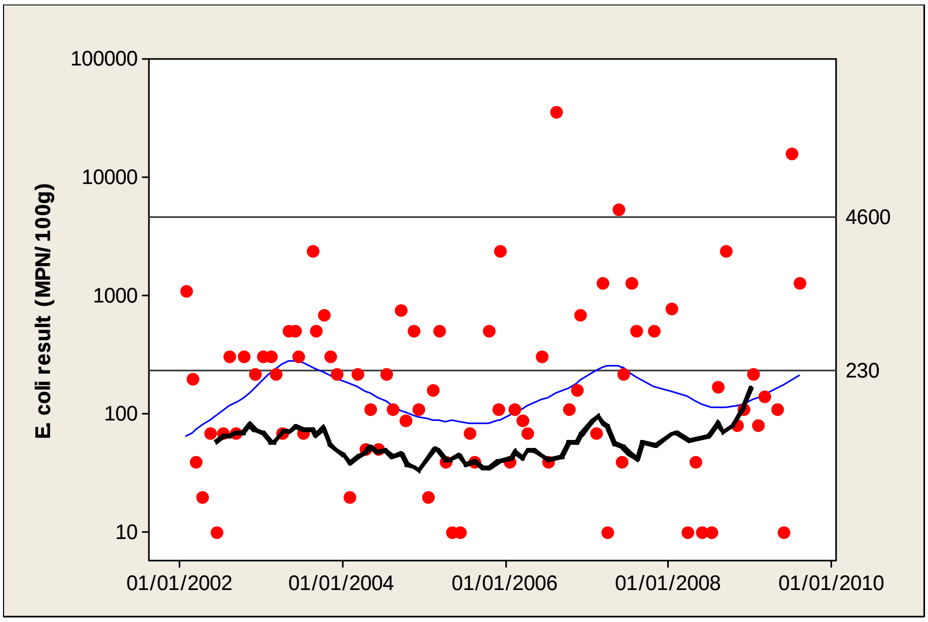

Figure 11.3 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line) (Pacific oysters)

Figure 11.3 shows that results greater than 4600 *E. coli* MPN/100 g have only been seen since the second half of 2006. The loess line shows two peaks in the trend in results at least 4 years apart. This is not reflected in the geometric mean trend line.

11.5 Seasonal pattern of results

Season affects not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figures 11.4 and 11.5 present boxplots of *E. coli* result by month for mussels and Pacific oysters respectively.

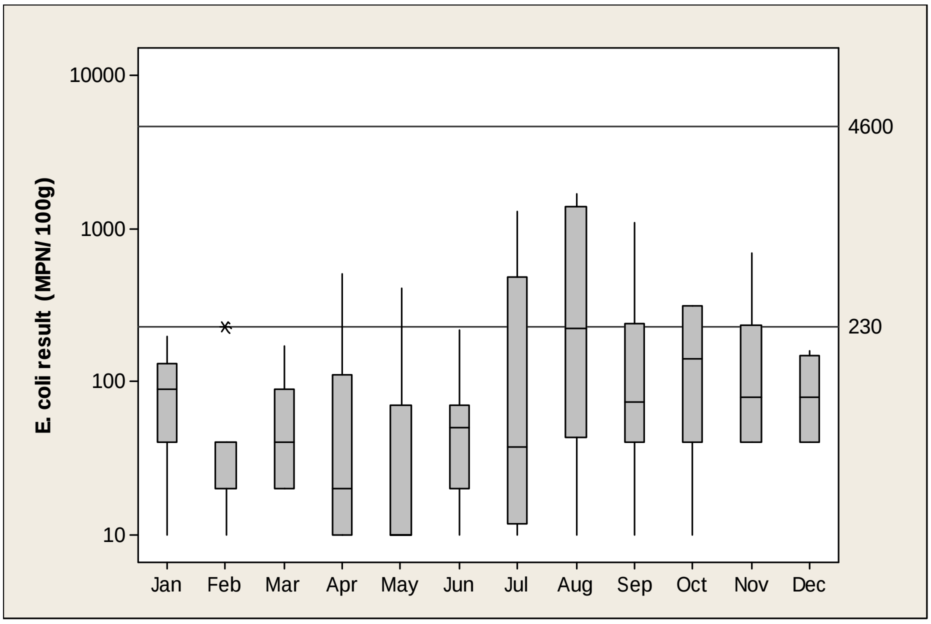

Figure 11.4 Boxplot of results by month (mussels)

Higher results for mussels generally occurred during the second half of the year, particularly during July and August. A greater proportion of results over 230 *E. coli*/100 g occur in those two months.

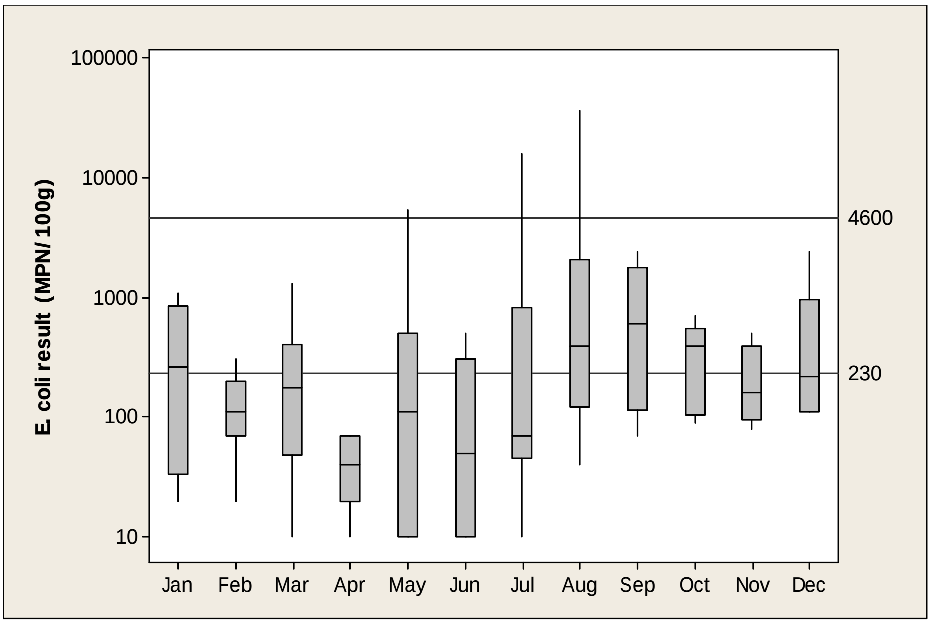

Figure 11.5 Boxplot of results by month (Oysters)

Higher results for oysters generally occurred during the second half of the year, particularly during July, August and September. Results above 4500 *E. coli* MPN/100 g were seen in May, July and August. Results >230 *E. coli* MPN/100 g occurred in all months except April. Lower results generally arose in the first half of the year.

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February).

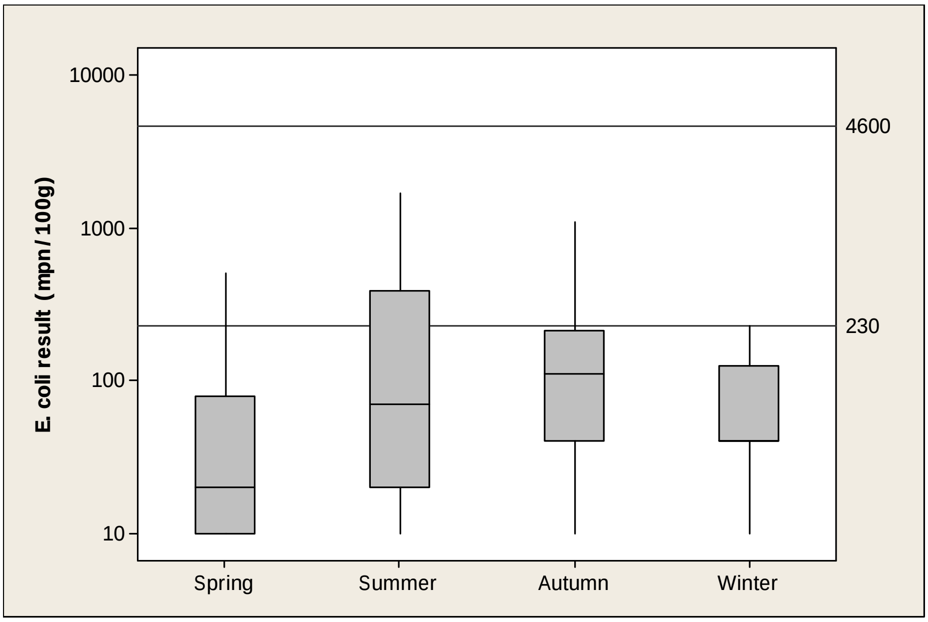

Figure 11.6 Boxplot of result by season (mussels)

A significant difference was found between results by season for mussels (One-way ANOVA, p=0.041, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the autumn were significantly higher than those in the spring.

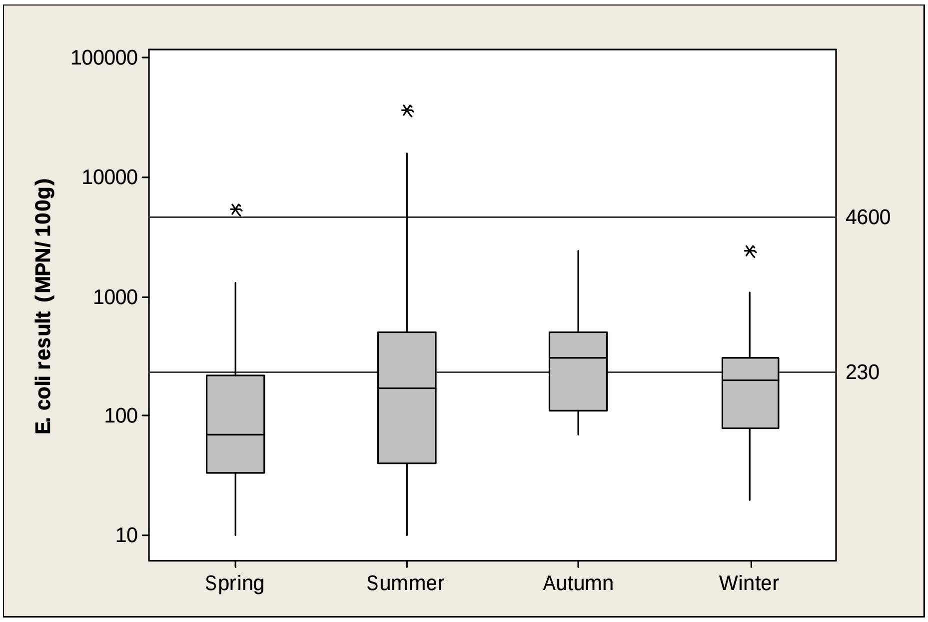

Figure 11.7 Boxplot of result by season (oysters)

No significant difference was found between results by season for oysters (One-way ANOVA, p=0.162, Appendix 6).

11.6 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, winds, sunshine and temperatures can all influence the flux of faecal contamination into growing waters (e.g. Mallin et al, 2001; Lee & Morgan, 2003). The effects of these influences can be complex and difficult to interpret. This section aims to investigate and describe the influence of these factors individually (where appropriate environmental data is available) on the sample results using basic statistical techniques.

11.6.1 Analysis of results by recent rainfall

The nearest weather station is Baltasound, approximately 600 m to the south of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2008 (total daily rainfall in mm). Spearman's Rank correlations were carried out between shellfish *E. coli* results and total rainfall over 2 and 7 days prior to sampling.

<u>Two-day antecedent rainfall</u>
Figure 11.8 presents a scatterplot of *E. coli* results against 2-day antecedent rainfall for mussels, Figure 11.9 presents the same for oysters.

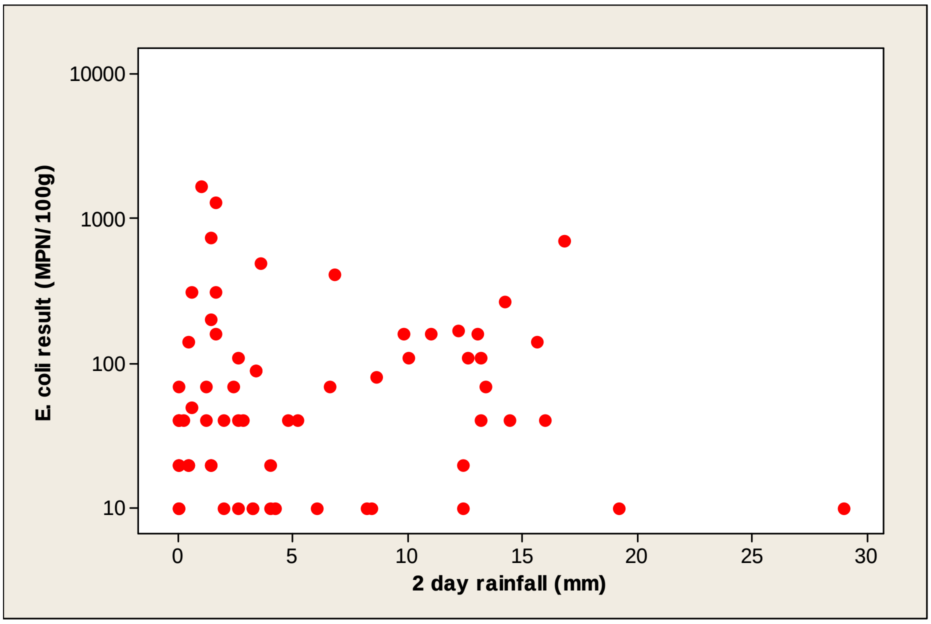

Figure 11.8 Scatterplot of result against rainfall in previous 2 days (mussels)

No correlation was found between *E. coli* result in mussels and rainfall in the previous 2 days (Spearman's rank correlation =0.080, p=0.528, Appendix 6). The highest rainfall value corresponded to a very low *E. coli* result.

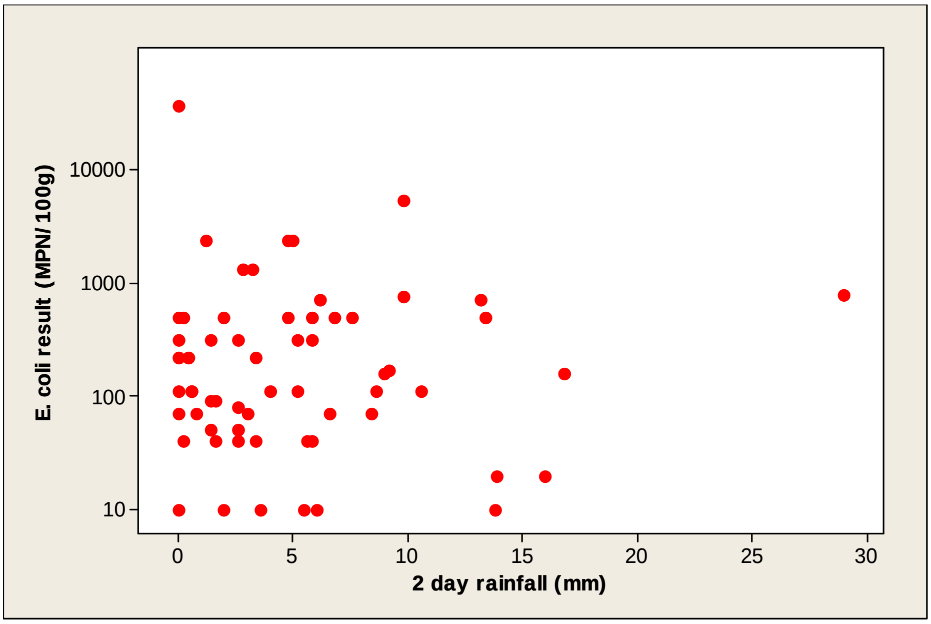

Figure 11.9 Scatterplot of result against rainfall in previous 2 days (oysters)

No correlation was found between *E. coli* result in oysters and rainfall in the previous 2 days (Spearman's rank correlation =0.033, p=0.796, Appendix 6). The highest rainfall value corresponded to a moderately high *E. coli* result and the highest *E. coli* value was seen after no rainfall in the preceding two days.

<u>Seven-day antecedent rainfall</u>

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results was investigated in an identical manner to the above. Figure 11.10 presents a scatterplot of *E. coli* results against 7-day antecedent rainfall for mussels, Figure 11.11 presents the same for oysters.

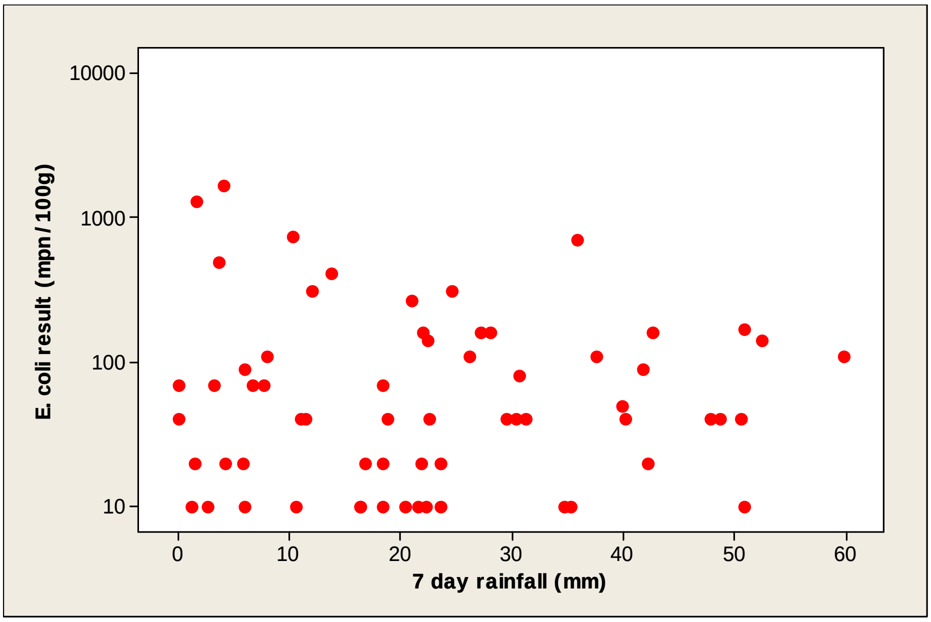

Figure 11.10 Scatterplot of result against rainfall in previous 7 days (mussels)

No correlation was found between *E. coli* result in mussels and rainfall in the previous 7 days (Spearman's rank correlation = 0.061, p=0.634, Appendix 6). *E. coli* results were relatively low at the highest 7-day rainfall values (>40 mm rain).

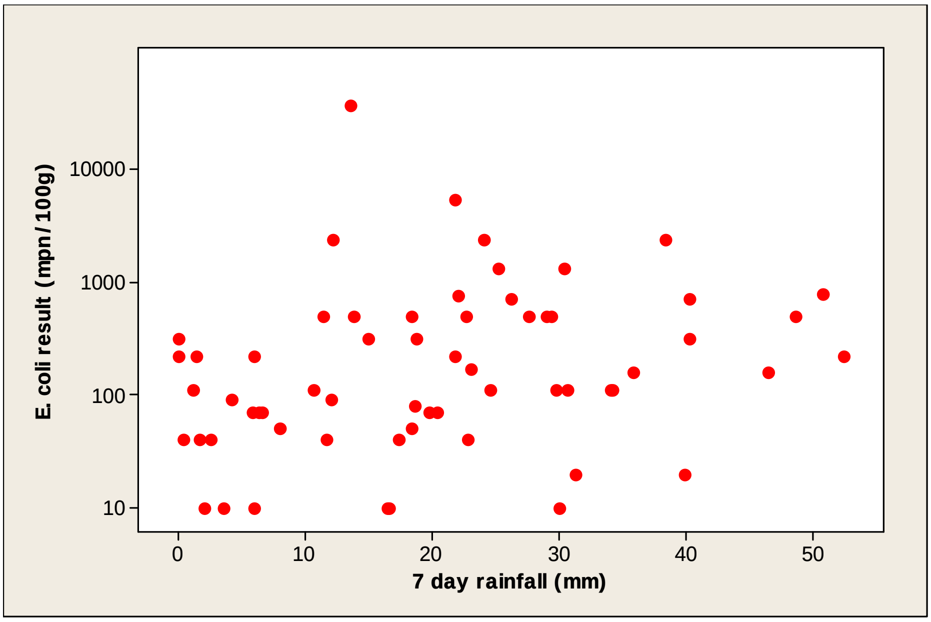

Figure 11.11 Scatterplot of result against rainfall in previous 7 days (oysters)

A positive correlation was found between *E. coli* result in oysters and rainfall in the previous 7 days (Spearman's rank correlation = 0.339, p=0.007, Appendix 6). However, no results >1000 *E. coli* MPN/100 g were seen at the highest 7-day rainfall values (>40 mm rain).

11.6.2 Analysis of results by tidal height and state

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the loch. Figures 11.12 and 11.13 present polar plots of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle for mussels and oysters respectively. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results under 230 *E. coli* MPN/100 g are plotted in green, those between 230 and 1000 *E. coli* MPN/100 g are plotted in yellow, and those over 1000 *E. coli* MPN/100 g are plotted in red. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and these are not taken into account.

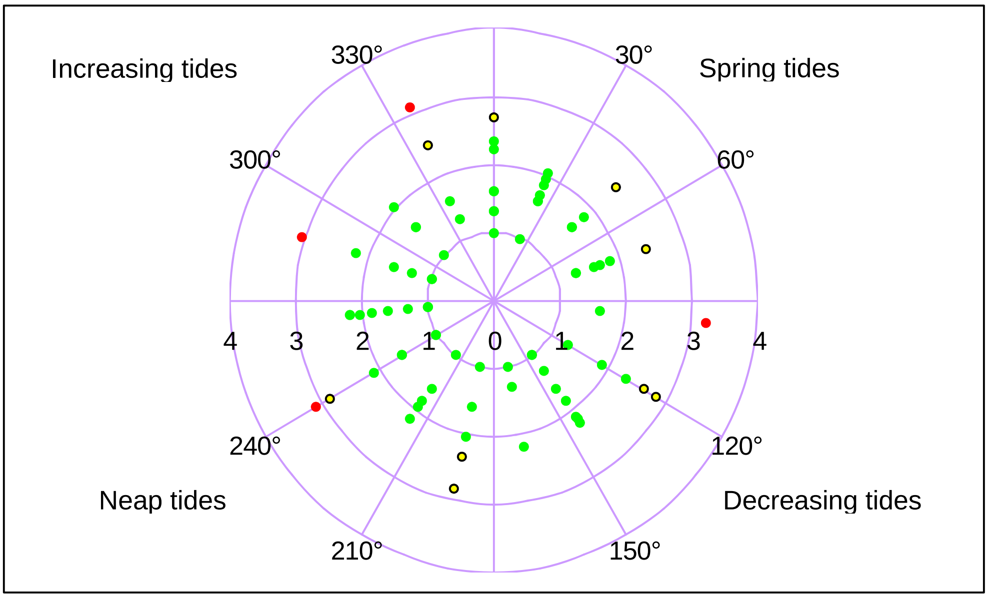

Figure 11.12 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (mussels)

No correlation was found between *E. coli* results and the spring/neap cycle for mussels (circular-linear correlation, r=0.105, p=0.416, Appendix 6), and no pattern in results is apparent in Figure 11.12.

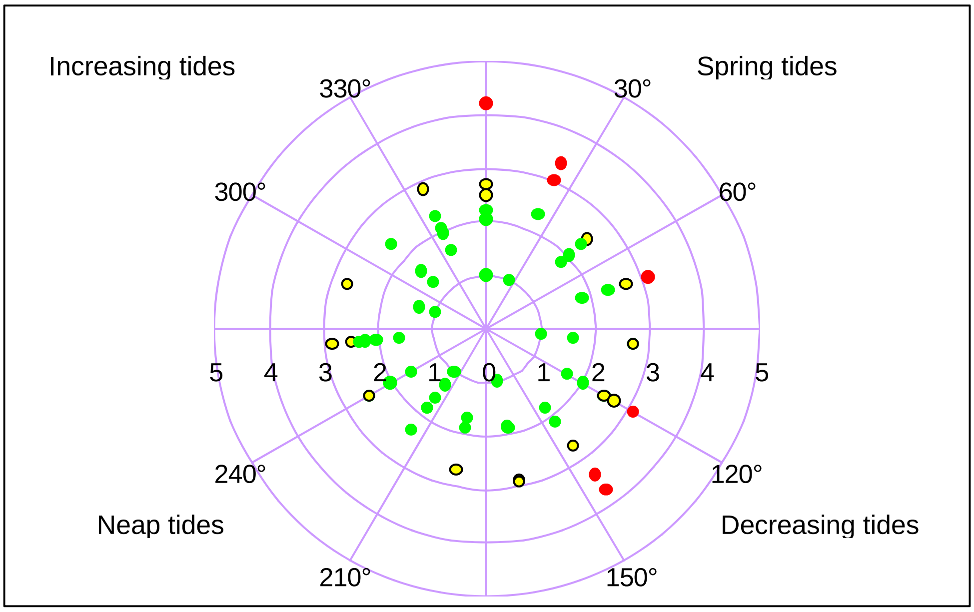

Figure 11.13 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (oysters)

A weak correlation was found between *E. coli* results and the spring/neap cycle for oysters (circular-linear correlation, r=0.261, p=0.009, Appendix 6). Figure 11.13 suggests that higher results occurred at spring tides or when they were decreasing towards neaps.

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figures 11.14 and 11.15 present polar plots of $\log_{10}$ *E. coli* results on the lunar high/low tidal cycle for mussels and oysters respectively. High water is at 0º, and low water is at 180º. Again, results of under 230 *E. coli* MPN/100 g are plotted in green, those between 230 and 1000 *E. coli* MPN/100 g are plotted in yellow, and those over 1000 *E. coli* MPN/100 g are plotted in red.

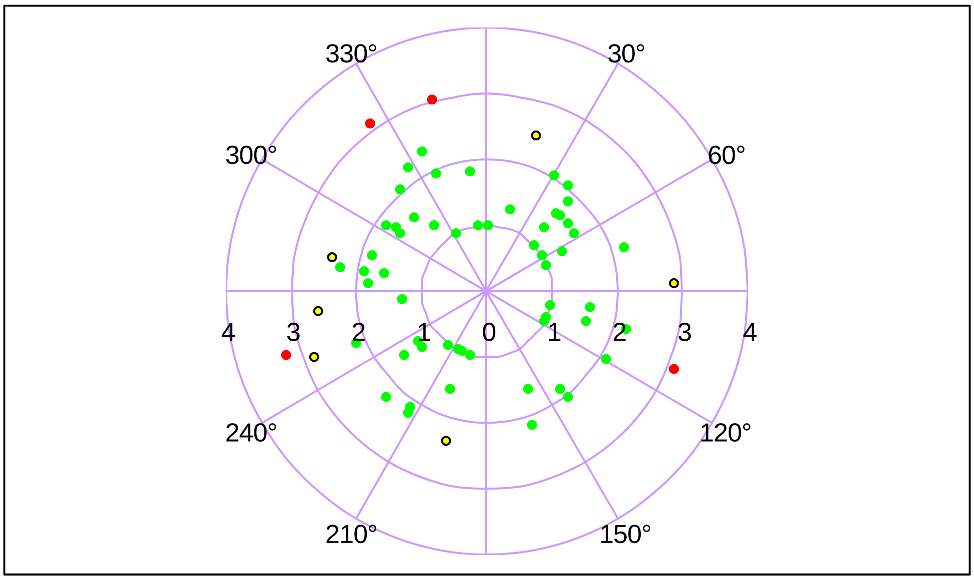

Figure 11.14 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (mussels).

No correlation was found between *E. coli* results and the high/low tidal cycle for mussels (circular-linear correlation, r=0.180, p=0.129, Appendix 6).

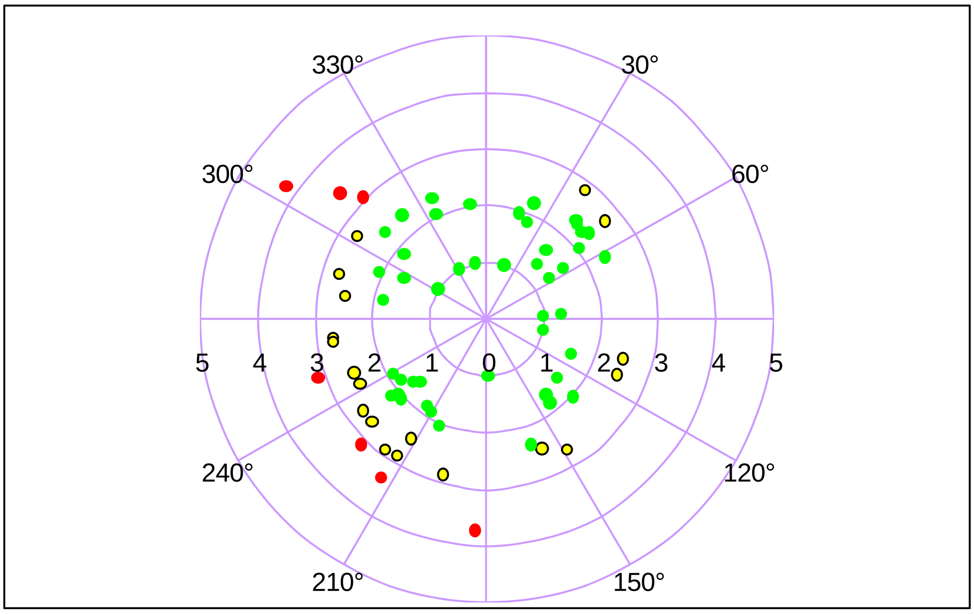

Figure 11.15 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (oysters).

A correlation was found between *E. coli* results and the high/low cycle for oysters (circular-linear correlation, r=0.341, p<0.001, Appendix 6). Figure 11.15 shows that the highest results (red) all occurred on a flooding tide.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish. It therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other seasonal factors. Figure 11.16 presents a scatterplot of *E. coli* results against seawater temperature for mussels, Figure 11.17 presents the same for Pacific oysters. Note that the seawater temperature at time of sampling was only reported for a proportion of sampling occasions.

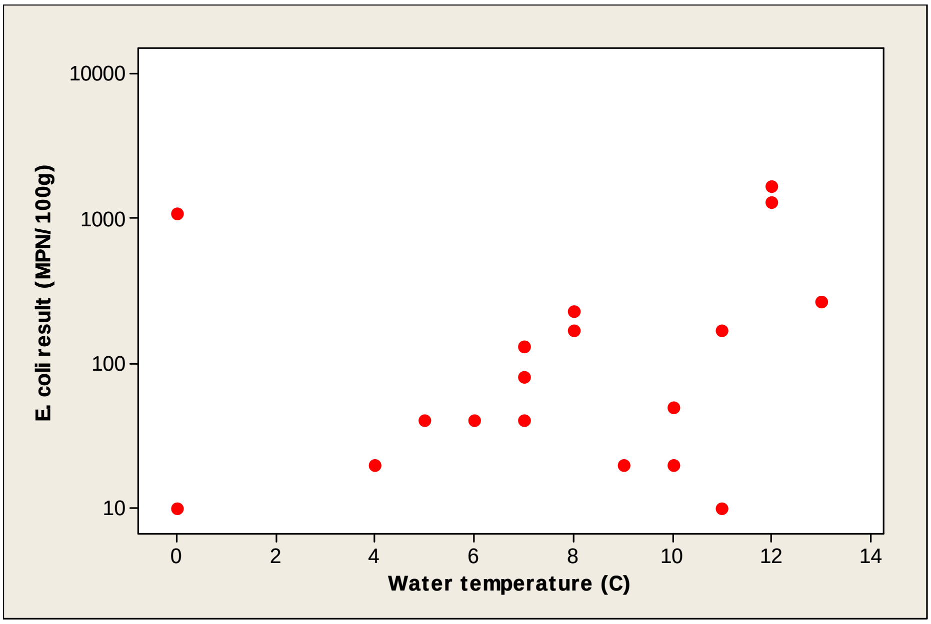

Figure 11.16 Scatterplot of result by water temperature (mussels)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and water temperature for mussels (Adjusted R-sq=0.3%, p=0.319, Appendix 6)

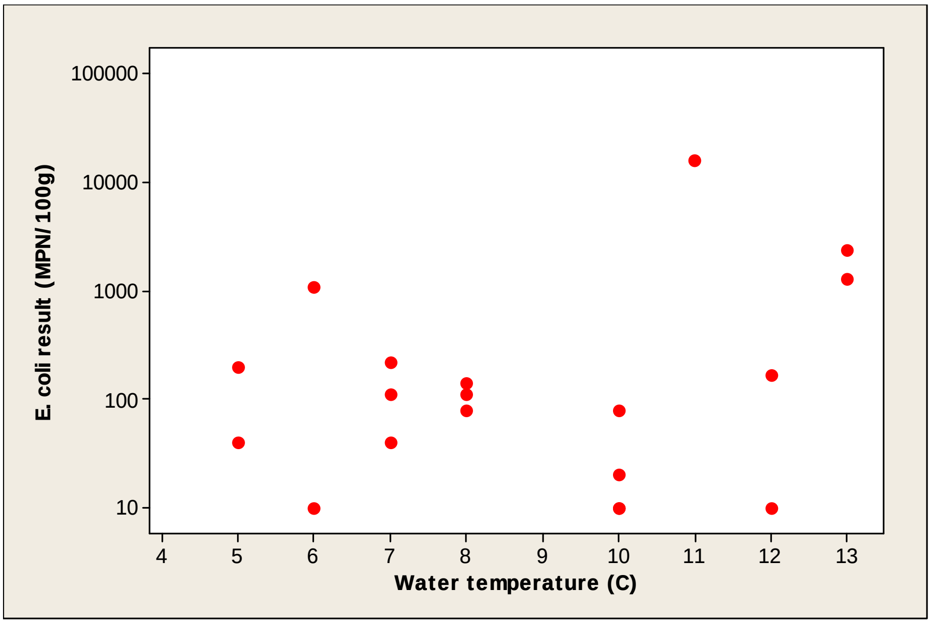

Figure 11.17 Scatterplot of result by water temperature (oysters)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and water temperature for oysters (Adjusted R-sq=0.0%, p=0.339, Appendix 6)

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns within the production area. However, the nearest wind station for which records were available was Lerwick, approximately 70 km to the south. Although it is likely that wind speed and direction will be broadly similar at the two locations, potential local differences meant that it was not considered appropriate to compare *E. coli* results at Baltasound with wind readings taken at Lerwick.

11.6.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.18 and 11.19 present scatter plots of *E. coli* result against salinity for mussels and oysters respectively, where salinity readings were available. Salinities of over 40 ppt were recorded on four occasions (twice for mussels, twice for oysters) and these results were not included in the analysis as these salinities were greater than that expected for full strength seawater in Shetland.

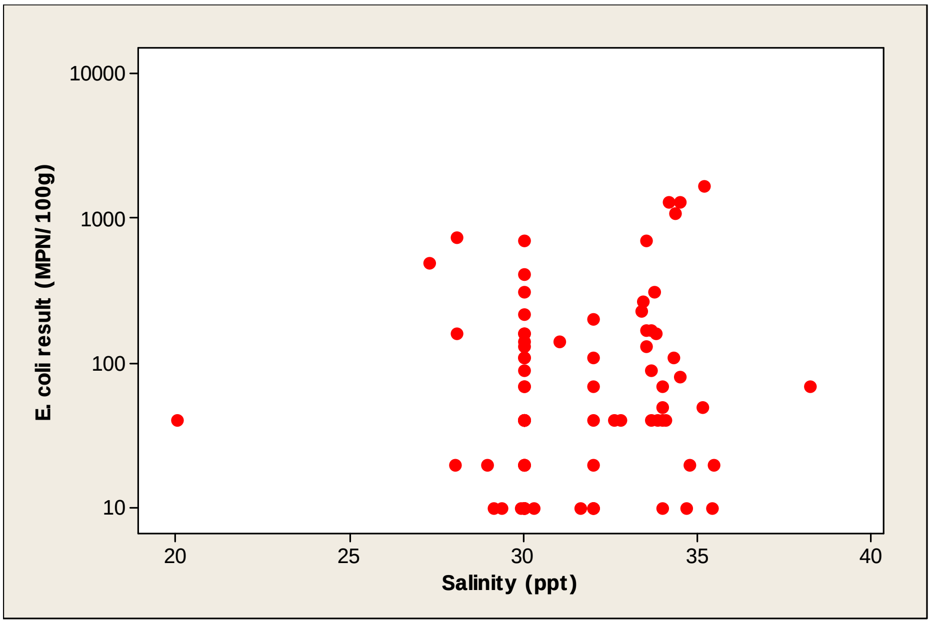

Figure 11.18 Scatterplot of result by salinity (mussels)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity for mussels (Adjusted R-sq=0.3%, p=0.269, Appendix 6).

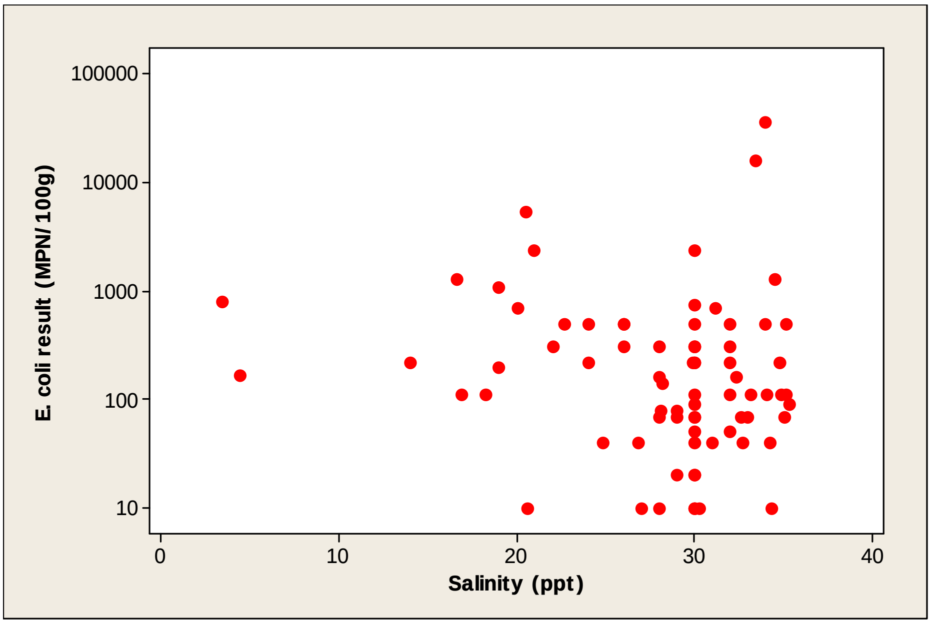

Figure 11.19 Scatterplot of result by salinity (oysters)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity for oysters (Adjusted R-sq=1.1%, p=0.178, Appendix 6). A greater range of salinities were recorded at this site, which is in the intertidal zone at the head of the sound.

11.7 Evaluation of results over 4600 E. coli MPN/100g

Throughout its classification history, Baltasound has received A classifications in most months for mussels, although from 2007-09 it has been classified B for several months of the year in summer/early autumn. A total of 12 samples (14% of all mussel samples) gave a result of over 230 *E. coli* MPN/100g, and these are listed in Table 11.2.

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

Collection date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
13/08/2002	700	HP 643 089	*	*	*	30	Flood	Decreasing to neap
06/05/2003	410	HP 643 089	6.8	13.8	*	30	Flood	Decreasing to neap
12/10/2004	310	HP 643 089	1.6	12.0	*	30	High	Increasing to spring
15/08/2005	1300	HP 643 089	1.6	1.6	*	34.19	Ebb	Neap
09/10/2006	310	HP 643 089	0.6	24.6	*	33.74	*	Spring
13/11/2006	700	HP 643 089	16.8	35.8	*	33.51	*	Neap
02/04/2007	500	HP 643 089	3.6	3.6	*	27.29	*	Spring
10/07/2007	750	HP 645 088	1.4	10.2	*	28.05	Ebb	Neap
05/08/2008	1700	HP 645 088	1.0	4.0	12	35.18	Flood	Decreasing to neap
02/09/2008	270	HP 645 088	14.2	21.0	13	33.45	Flood	Decreasing to neap
21/07/2009	1300	HP 645 088	*	*	12	34.48	High	Increasing to spring
01/09/2009	1100	HP 645 088	*	*	*	34.34	High	Increasing to spring

* Data unavailable

Results over 230 *E. coli* MPN/100g arose in April (1), May (1), July (2), August (3), September (2), October (2) and November (1) and so were clearly centred on the late summer/early autumn period. As noted previously, a higher proportion of results over 230 MPN/100 g were found at HP645088, the location sampled from mid 2007 onwards, but whether this was a temporal or spatial effect is uncertain. These results arose under a broad range of rainfalls, salinities and tidal states, although none occurred around low water.

A much higher proportion of results for oysters were over 230 *E. coli* MPN/100g (36%), and this is reflected in its classification history (these results are not detailed here). A total of three results (4%) were over 4600 *E. coli* MPN/100 g, and these are listed in Table 11.3.

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

Collection date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
14/08/2006	>18000	HP625087	0	13.6	*	33.93	*	Decreasing to neap
22/05/2007	5400	HP625087	9.8	21.8	*	20.52	Low	Decreasing to neap
07/07/2009	16000	HP625087	*	*	11	33.43	Flood	Spring

* Data unavailable

These samples were taken in May, July and August, all from the same nominal RMP, at a range of salinities, and tidal states. Two were obtained following low to moderate rainfall (rainfall not available for one sampling occasion). The high/low tidal state could not be determined for one sample.

11.8 Summary and conclusions

Two locations were recorded as being sampled for mussels, although it is not clear whether this reflects an actual difference in sampling location. There was no significant difference in results between the two recorded locations, either in terms of mean result or proportion of results over 230 *E. coli* MPN/100 g. It was not possible to investigate geographical patterns in levels of contamination in oysters as all oyster samples were reported from the same location.

Mussel results >1000 *E. coli* MPN/100 g have only been seen since the second half of 2005. For oysters, results >4600 *E. coli*/100 g have only been seen since the second half of 2006. It is not known whether this reflects a true deterioration in water quality in the area over time. A significant difference was found between results by season for mussels, with results in the autumn were significantly higher than those in the spring. No significant difference was found between results by season for oysters. There was no relationship between water temperature and *E. coli* results for either species.

No correlation was found between *E. coli* result and recent rainfall for mussels. For oysters, a positive correlation was found between rainfall in the previous 7 days and *E. coli* results, but not with rainfall in the previous 2 days. No relationship between salinity and *E. coli* result was found for either species.

For mussels, no correlation was found between *E. coli* results and either the spring/neap or high/low tidal cycle. For oysters, a weak correlation with the spring/neap tidal cycle was found, with higher results arising on spring or decreasing tides. A stronger correlation with tidal state on the high/low cycle was found for this species, with higher results generally occurring on a flooding tide.

It should be noted that the relatively small amount of data precluded the assessment of the effect of interactions between environmental factors on the *E. coli* concentrations in shellfish.

11.9 Sampling frequency

When a production area has held the same (non-seasonal) classification for 3 years, and the geometric mean of the results falls within a certain range it is recommended that the sampling frequency be decreased from monthly to bimonthly. This is not appropriate for either species within this production area they have held seasonal classifications within the last three years.

12. Designated Shellfish Growing Waters Data

Baltasound is not within a designated Shellfish Growing Water.

13. Rivers and streams

The following streams were measured and sampled during the shoreline survey. These represent the largest freshwater inputs into the production area. The weather had been relatively dry in the days preceding the survey, and not all streams were flowing.

Table 13.1 Stream loadings for Balta Sound

No.	Position	Width (m)	Depth (m)	Flow (m/s)	Discharge (m^3/d)	*E. coli* result (cfu/100ml)	*E. coli* loading (cfu/day)
1	HP 6228 0850	0.37	0.03	0.448	430	330	1.4×10^9
2	HP 6244 0838	1.15	0.02	0.089	177	90	1.6×10^8
3	HP 6305 0908	0.88	0.02	0.119	181	60	1.1×10^8
4	HP 6259 0893	0.64	0.07	0.282	1092	30	3.3×10^8
5	HP 6197 0885	1.00	0.05	0.392	1693	50	8.5×10^8
6	HP 6199 0877	1.10	0.03	0.327	932	<10	$<9.3 \times 10^7$
7	HP 6297 0828	1.25	0.05	0.024	130	1400	1.8×10^9
8	HP 6349 0810	1.4.0	0.12	0.019	276	800	2.2×10^9

Stream inputs had levels of *E. coli* up to 1400 cfu/100ml. The combined loading contributed by these streams was 7×10^9 *E. coli* cfu/day. Of particular significance to the oyster site is stream 1, to which a private septic tank discharges. This septic tank was not flowing at the time of sampling, but this may have been be due to the hour (06:30), and it appeared to have been in recent use. This stream flows directly through the oyster trestles. Streams 2, 5 and 6 may also have some impact on the oyster fishery given their proximity. No particular stream is likely to specifically impact on the mussel fisheries, but their combined effects will contribute to levels of contamination within Balta Sound, although their contribution at the time of survey was low relative to that of sewage discharges.

The catchment area of Balta Sound is small at 15 km^2. Streams draining to Balta Sound drain rough pastures/moorland on the hills further back, then flow through a coastal strip of improved pasture which supports relatively high densities of livestock. These streams will be an important pathway for the transport of contamination from livestock sources into the sound. It is therefore expected that the loadings contributed by these streams will increase following periods of heavy rainfall.

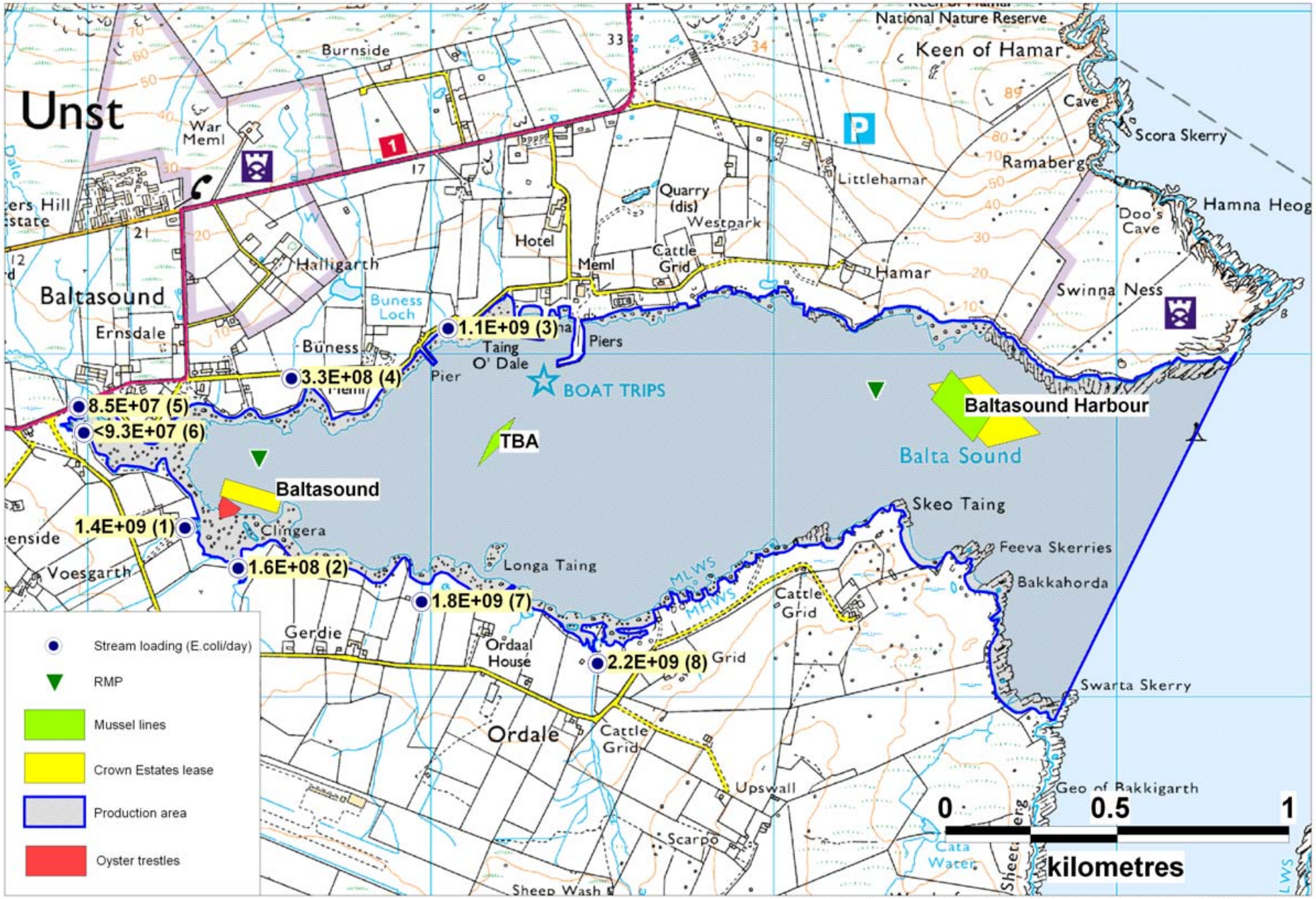

Figure 13.1 Location and loadings of significant streams in Balta Sound

14. Bathymetry and Hydrodynamics

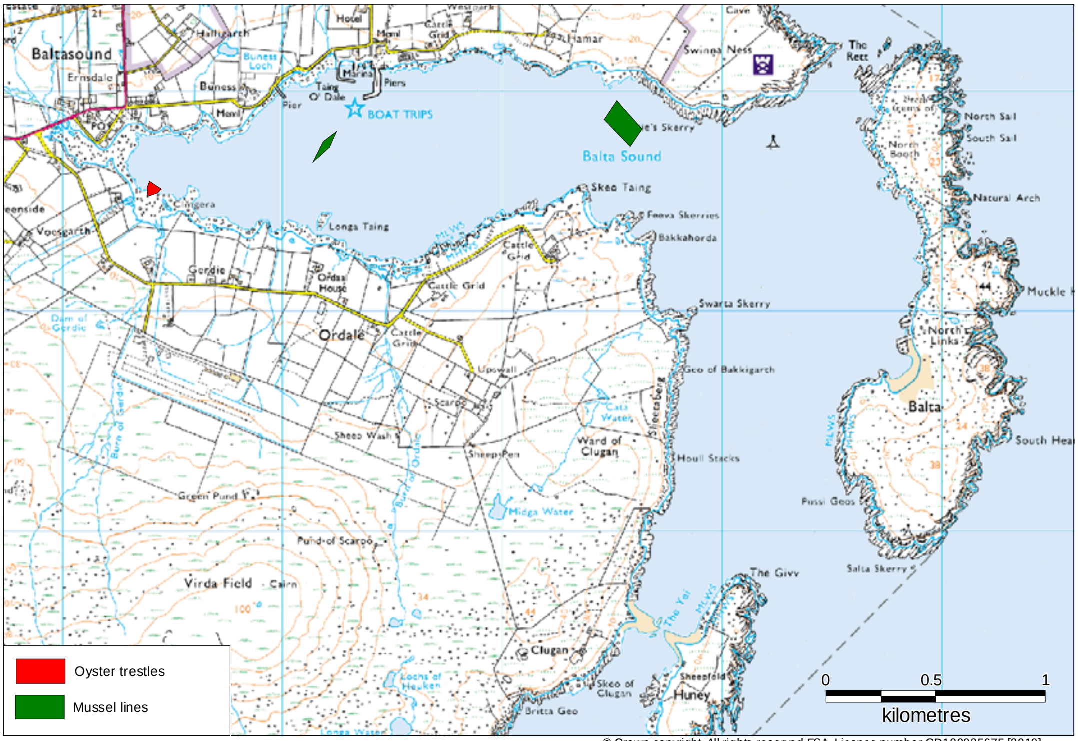

Figure 14.1 OS map of Balta Sound

Figure 14.2 Bathymetry at Balta Sound

The area of Balta Sound which constitutes the production area lies in a west to east orientation with the mouth at the eastern end. This is protected from the open sea by the presence of the island of Balta. Balta Sound itself continues to the south between the islands of Unst and Balta (with the island of Huney on the Unst side at the southern end). That part of the sound is more open to the south than the north as the gap between Unst and Balta is very narrow at the northern end.

In the part covered by the present production area, the depth ranges from more than 10 m at the eastern end to an intertidal area at the western end. There are other intertidal areas around the sound. One set of mussel lines is located in more than 10 m of water while the other is located at between 5 and 10 m depth. The oyster trestles are located in the drying area at the western end of the sound.

14.1 Tidal Curve and Description

The two tidal curves given in Figure 14.3 are for Balta Sound. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 25/05/09 and the second is for seven days beginning 00.00 BST on 01/06/09. The shoreline survey was undertaken during the first two days of this two week period. Together the curves show the predicted tidal heights over high/low water for a full spring/neap tidal cycle.

The following is the summary description for Balta Sound from TotalTide:

0290B Balta Sound is a Secondary Non-Harmonic port.
The tide type is Semi-Diurnal.

HAT	2.8 m
MHWS	2.3 m
MHWN	1.8 m
MSL	1.32 m
MLWN	0.9 m
MLWS	0.4 m
LAT	-0.2 m

Predicted heights are in metres above Chart Datum. The location for the predictions lies on the northern side of the inner sound.

The average tidal range is therefore 2.4 m at spring tides and 0.9 m at neap tides. It can be seen from Figure 13.3 that the predicted range can differ markedly between the two tides on a single day.

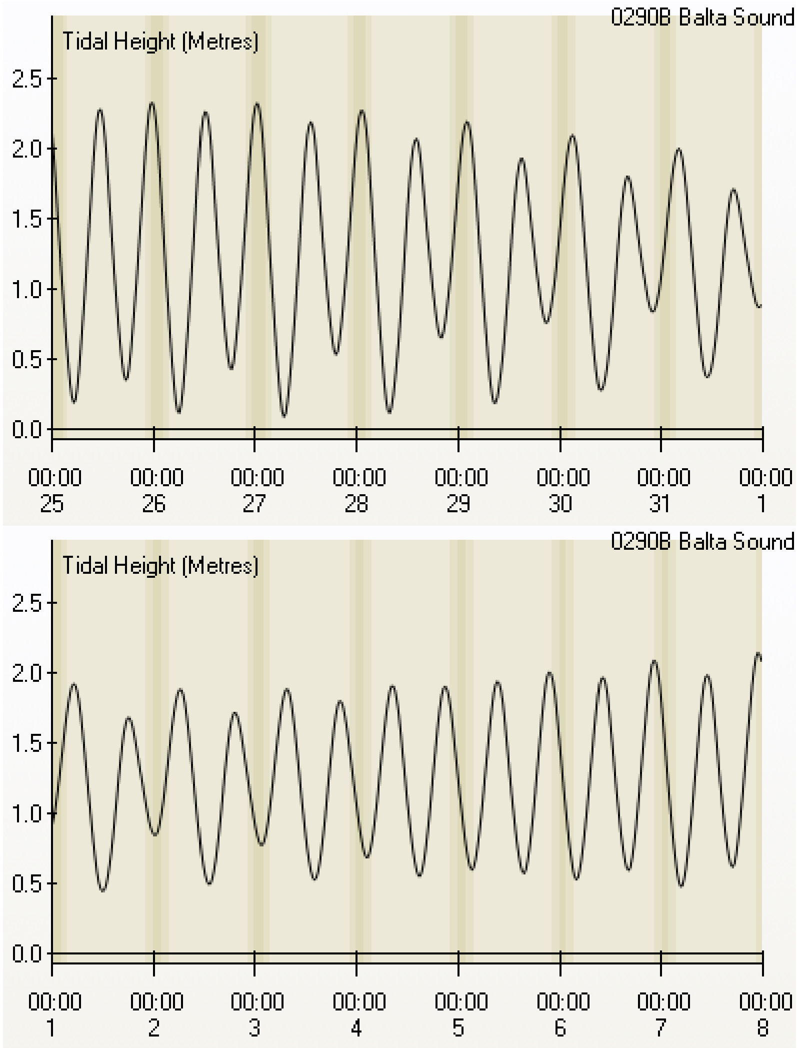

Figure 14.3 Tidal curves for Balta Sound

14.2 Currents

The Admiralty Tidal Steam Atlas for Orkney and Shetland gives current information offshore of the east coast of Unst but not in the near vicinity of Balta Sound. The direction and speed of the offshore currents will not be relevant to the situation within the sound itself. It is expected that the tide will flood from, and ebb towards, the gap between Huney and Balta and then up into the west-east lying part of the sound. From the topography and bathymetry, it is likely that the currents will follow the deeper channel towards the north of this part of the sound, which contains the present mussel lines.

Shetland Seafood Quality Control undertook current meter studies on behalf of Balta Island Seafare Ltd at three locations within Balta Sound to provide information in support of an application to SEPA to discharge from a marine cage fish farm. Data from the studies were provided to Cefas with the agreement of Balta Island Seafare Ltd.

The locations at which the current meters were deployed are shown in Figure 14.4. The survey periods were as given in Table 14.1.

Table 14.1 Survey periods for the fish farm current meter studies

Location	Survey period	Wind during survey period
Swarta Skerry	19th March 2003 – 16th April 2003	light to strong; direction variable
Balta South	28 September 2001 to 9 November 2001	light to moderate; direction variable
Huney	24th October 2003 – 16th November 2003	light to moderate; mainly north-west to southerly

Unfortunately, the deployment locations meant that the meter data would not yield information on water movements within the inner sound but should confirm whether the assumptions on water movements in the outer sound were correct. Polar plots of the current directions and speeds at the three locations are shown in Figure 14.5.

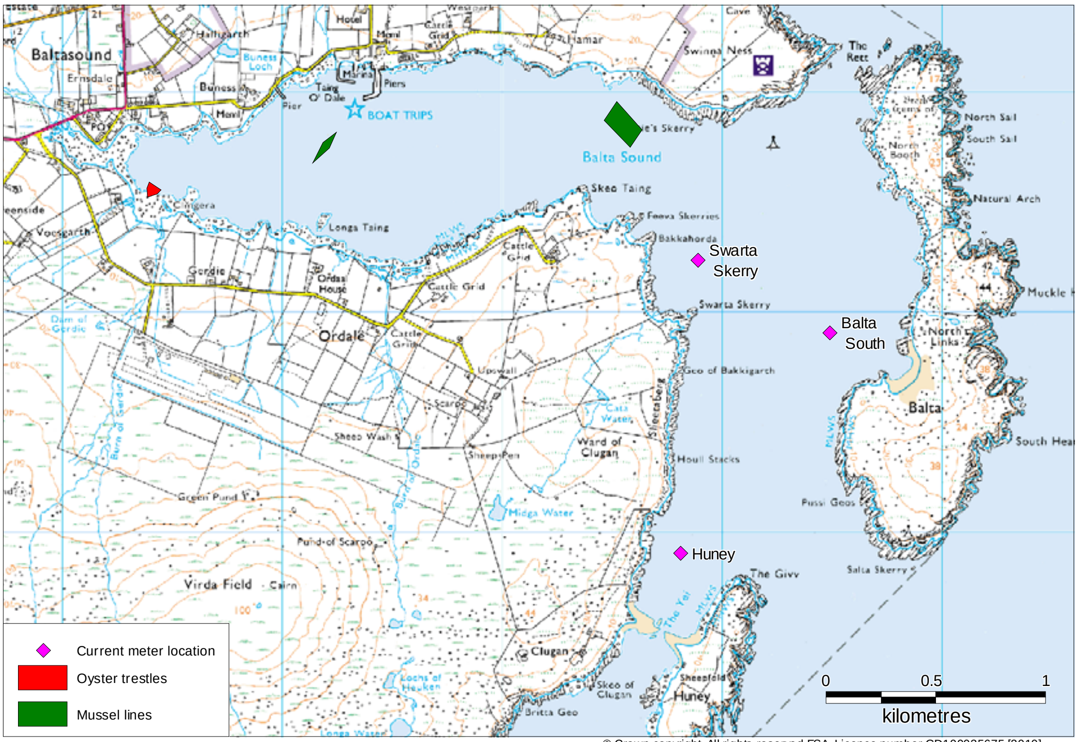

Figure 14.4 Current meter locations in Balta Sound

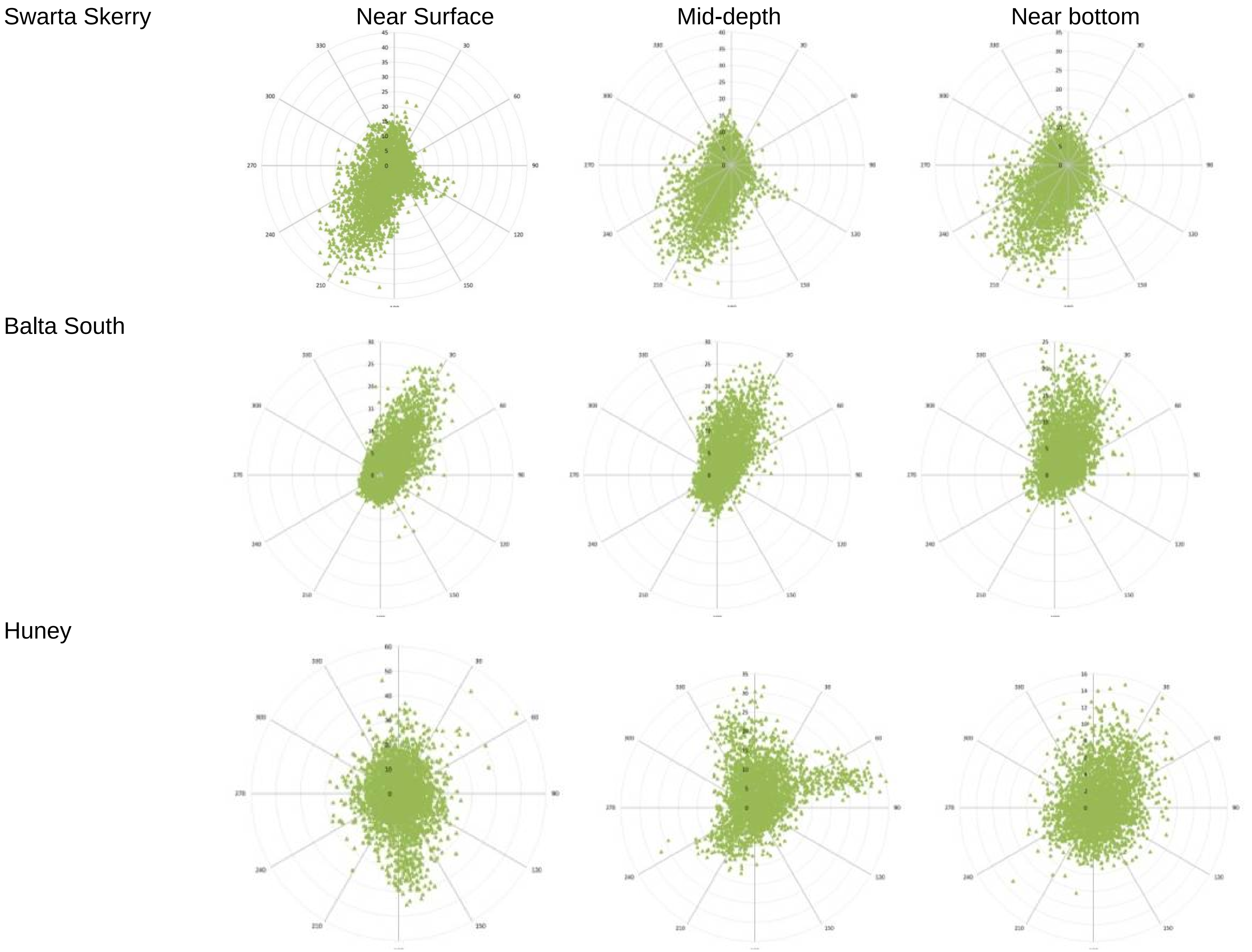

Figure 14.5. Polar plots of recorded currents in outer Balta Sound
(Directions in degrees clockwise from 0 (north) at the top. Current speed in cm/s.)

The recorded currents were less than 50 cm/s (0.5 m/s; 1 knot). They are therefore generally weak.

The predominant current direction at Swarta Skerry is south-south-west while at Balta South it is north-north-east. This indicates that the ebb tide is stronger on the west side of that part of the sound and the flood tide is stronger on the east side. At each of these two locations, the current pattern is similar at each depth although the directional component is slightly more clearly defined nearer the surface than at depth.

The current direction is more complex at Huney, presumably due to the location of the current meter between the north tip of Huney and Unst, with the possibility of flows through two channels when the tide is higher but principally though one channel when the tide is lower.

Winds in the area at the time of the three surveys were highly variable in both direction and strength. There does not seem to be an effect of wind evident in the plots, although this may be due to the variability at the time of the surveys.

14.3 Conclusions

In general, currents in the inner sound will flow parallel to the shore, with most flow in the main channel. However, currents in the area are weak.
The oyster site will mainly be impacted by sources at the head of the inner sound on the ebbing tide, and from further east along the southern side on the flooding tide. The mussel lines will be impacted by sources at the head of the inner sound, on the ebbing tide, with the lines nearest the head being most affected. Given the relatively weak currents in the area, those lines will also be affected by local sources on the northern shore around Baltasound Harbour. The mussel lines towards the outer sound could potentially be impacted by sources there on a flooding tide, although any contamination would be subject to significant dilution.

15. Shoreline Survey Overview

The survey was undertaken on 25 and 26 May 2009. The weather had been dry on the days preceding the survey but there were some showers on the first day and some heavy showers on the second.

The Baltasound site was relatively small but contained a large number of trestles with cages, each cage containing bags of Pacific oysters. There was a set of mussel longlines at the Baltasound Harbour mussel site and a single line off Baltasound marina.

Population is located around the inner sound. The Scottish Water community septic tank discharge was observed on the northern shore and a number of other private septic tanks were identified. These included one which discharged to a stream entering the sound near the oyster site.

Large numbers of sheep (519) and a significant number of cattle (82) and ponies (37) were observed at the time of the survey. These were widely located around the sound. Some seabirds were seen in the area as were a small number of domestic geese.

A number of streams were measured and sampled. The three yielding the highest concentrations of *E. coli* were located on the southern side of the sound, including one located close to the oyster trestles.

Seawater samples taken during the survey gave results ranging from <1 to 20 *E. coli* cfu/100 ml. The lowest concentrations were found in samples taken at the mussel lines while the higher concentrations were found in samples taken at various locations around the shore of the sound, including in the vicinity of the oyster trestles.

Four mussel samples taken from the established set of lines gave results ranging from <20 to 70 *E. coli* MPN/100 g and a single sample of oysters gave a result of 40 *E. coli* MPN/100 g. No stock was available for sampling from the single mussel line located off Baltasound marina.

Figure 15.1 shows the most significant observations from the shoreline survey. Sheep seen on the island of Balta are not shown.

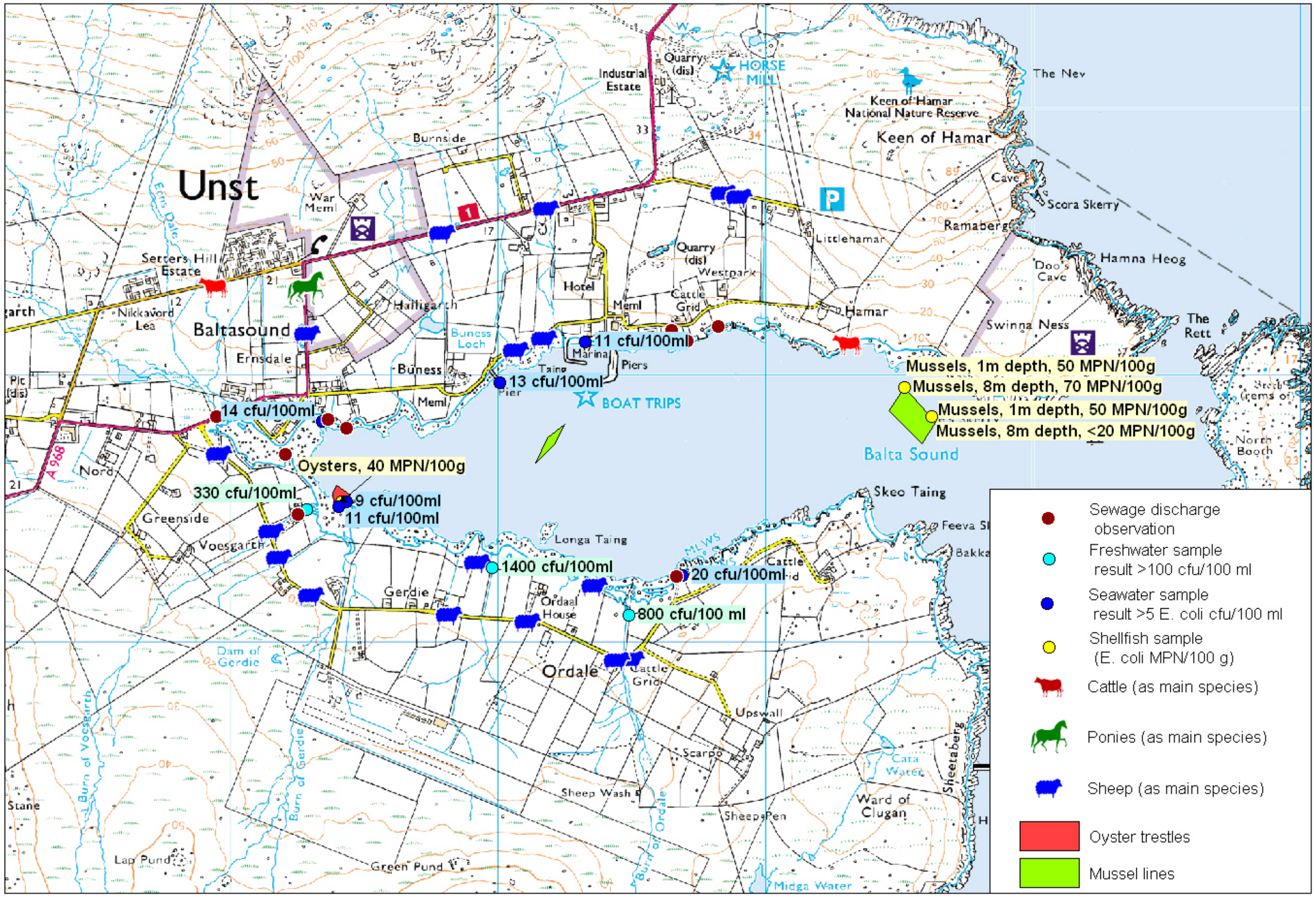

Figure 15.1 Summary of main shoreline survey findings for Balta Sound

16. Overall Assessment

Human sewage impacts

The main sewage input to the sound is the Scottish Water community septic tank discharge on the north side of the inner sound. This will have the potential to affect water quality over a wider area than the other septic discharges to the sound. The associated emergency discharge, located at the head of the sound, cause significantly impact on water quality if it were to discharge. This would significantly affect the microbiological quality of the oyster site.

A number of private septic tanks around the inner sound would be expected to cause local effects on water quality. Potentially, the most significant of these discharges to a stream that enters the sound near the oyster fishery.

Agricultural impacts

Farm animals, principally sheep but also cattle and ponies, occur widely around the shores and surrounding area of the sound. It will be expected that these will contribute to faecal contamination of the sound, either via stream or, in the case of cattle on the northern shore near Hamar, by direct deposition to the shore/seawater. The latter location was in the vicinity of the established mussel lines.

Wildlife impacts

Although bird census data identifies the historical presence of significant numbers of seabirds within 5 km of Balta Sound, they do not record breeding sites within the sound itself. A significant colony was located on Balta Island. At that location, the seabirds would not be expected to impact on water quality at the fisheries. However, they may periodically feed within the inner sound and could then have an effect. The same would apply to the other species recorded by the bird censuses.

Seasonal variation

At present, the human population is not expected to increase significantly in the area during the summer months as tourism is low. Boat activity is likely to be higher during that period and any associated discharges more likely. Farm animal numbers will tend to be higher during the summer and associated diffuse pollution more likely to occur during wet periods at that time of year. The 4 results over 1000 *E. coli* MPN/100 g in mussels were seen during the months of July, August and September. A seasonal analysis showed that results in autumn were statistically higher than results in spring. Higher results in oysters tended to be seen in the second half than the first half of the year, although seasonal analysis did not show any significant differences. The three results that were greater than 4600 *E. coli* MPN/100 g occurred in the months of May, July and August.

Rivers and streams

Three streams which were measured and sampled during the shoreline survey showed moderate levels of *E. coli* and calculated loadings for these streams were all >1.0 x 10^9 *E. coli* cfu/100 ml. These streams in particular will have the potential to cause local impact on water quality. They were all located along the southern shore of the inner sound. One of these streams entered the sound near to the oyster trestles. A septic tank discharged into this stream, and livestock were seen grazing nearby. It will therefore carry faecal contamination of both human and animal origin and will affect the microbiological quality of the oysters.

Meteorology, hydrology, and movement of contaminants

Rainfall patterns at Baltasound have tended to be generally similar over the past few years, both in terms of average daily rainfall and the occurrence of high rainfall events. Rainfall tends to be higher during the period September to March. More extreme events generally occur throughout the year although events >20 mm in 24 h were not seen during either May or December in the data set analysed. In analysing the association between *E. coli* in shellfish and rainfall, the only correlation found was with oysters and rainfall over the previous 7 days. This would conform to the nearby stream having an impact on the microbiological quality of the oysters. However, it should be noted that there was no significant association between *E. coli* levels in the oysters and salinity at time of sampling.

There is a main channel down the inner sound in which the mussel sites lie. Contamination arising at the head of the sound will therefore tend to impact on the sites although this should be significantly diluted by the time it reaches the outer, established mussel lines. The mussel lines nearer the head of the sound would be more likely to be impacted from such sources.

In general, tidal currents within the inner sound are expected to be weak and to travel parallel to shore. Wind-driven currents may therefore be significant relative to these. The prevailing winds in the area tend to be from the south and south-west. These may have the effect of constraining contamination from the community septic tank closer to the northern shore and away from the mussel lines. North-westerly winds would tend to take the contamination towards the mussel lines near the mouth of the inner sound and a north-easterly towards the mussel lines further inside the sound.

No correlation was found between spring/neap or high/low tidal state and *E. coli* results in mussels. With oysters, higher results tended to be found at spring and decreasing tides with respect to the spring/neap tidal cycle, and with flooding tides with respect to the high/low tidal cycle. This would lead to an inference that contamination in the oysters was arising to the east of the trestles. However, care needs to be taken in inferring this as Pacific oysters may take a relatively long time (at least hours) to equilibrate to the contamination in the surrounding seawater.

Temporal and geographical patterns of sampling results

In general, Pacific oysters tend to show lower levels of contamination than do mussels when exposed to the same surrounding water quality (Younger, *et al*., 2003). However, in Baltasound, the Pacific oysters show higher peak results, and a greater proportion of higher results, than the mussels. This implies that the oysters are exposed to water quality that is many times worse than the mussels. It was not possible to analyse results from the two species on a geographic basis since all of the oyster samples were reported against the same location and the two different locations recorded for the mussel samples may simply reflect a change in sampling arrangements and not a change in the actual location of sampling.

Results above 1000 *E. coli* MPN/100g in mussels have only been seen since August 2005. Results greater than that value have been seen occasionally in oysters throughout the sampling period analysed in this report (since 2002). However, results greater than 46000 per 100g have only been seen in oysters since August 2006. Therefore there does seem to be tendency towards higher results in both species in recent years. Seasonal patterns have been summarized above.

Only a single Pacific oyster sample was taken at the time of the shoreline survey and therefore this does not inform a geographical assessment of the contamination of that species. Four mussel samples were taken and the results were all generally low. There was some indication of a tendency towards higher results at the north-western end of the lines but no consistent pattern with depth.

Overall conclusions

There are a number of sources of animal and human faecal contamination around the inner sound. The Pacific oyster site is likely to be exposed more to these sources than the outer mussel site and this is borne out in the historical results. Of the two mussel sites, the inner one may be exposed to higher contamination than the outer one and, with each, the ends closer to the northern shore may be exposed to contamination from the community septic tank under some conditions.

17. Recommendations

It is recommended that the Pacific oysters and mussels are given different production areas as the fisheries are exposed to markedly different sources and levels of contamination. The recommendations are shown also shown in map form in Figure 17.1 and summarised in Appendices 1 and 2.

Oysters

Production area

The recommended production area is as follows: Area bounded by lines drawn between HP 6226 0863 and HP 6260 0863 and between HP 6260 0863 and HP 6260 0840 and extending to MHWS.

This covers the entire area of the present oyster fishery but excludes areas of potentially greater contamination to the north of this, including the area in the immediate vicinity of the emergency overflow.

RMP

The recommended location is at HP 6240 0854. This is in the area expected to be impacted by the identified sources of contamination, including the nearby stream.

Tolerance

The recommended tolerance is 10 m. Given that this is an aquaculture site, it should be possible to access stock within this tolerance. However, it allows for some variation in accessing animals of sufficient size. If there is a problem with regard to sampling within the recommended tolerance, consideration should be given to placing a bag of Pacific oysters at the recommend location specifically for sampling purposes. If this is done, the oysters should be placed *in situ* for at least two weeks prior to sampling to ensure that they have taken on the microbiological quality of the RMP.

Depth

Not applicable to specify for oyster trestles.

Frequency

It is recommended that the sampling frequency be monthly, given that the area is not suitable for analysis of stability, on the grounds of fluctuating and seasonal classifications.

Mussels

Production area

The recommended production area is as follows: Area bounded by lines drawn between HP 6300 0860 and HP 6300 0900 and between HP 6300 0900 and HP 6463 0900 and between HP 6463 0900 and HP 6486 0880 and between HP 6486 0880 and HP 6486 0860 and between HP 6486 0860 and HP 6300 0860.

This encompasses the locations of both sets of mussel lines, and known permitted areas, and limits the production area from the potentially more contaminated areas closer to shore and to the head of the sound. In practice, the location of the lines in the inner will be limited to the deeper water, covered by the recommended area.

RMP

The recommended location is at HP 6320 0876. This is located on the newer set of lines which is anticipated to be exposed to greater contamination from the head and north-western shore of the sound, and to the north-western extent of those lines, to reflect those sources.

Tolerance

The recommended tolerance is 20 m. Given that these are aquaculture sites, it should be possible to access stock within this tolerance. However, it allows for some variation in accessing animals of sufficient size and drift of the lines themselves. If either of these factors presents a problem with regard to sampling within the recommended tolerance, consideration should be given to placing a bag of mussels at the recommend location and depth specifically for sampling purposes. If this is done, mussels should be placed *in situ* for at least two weeks prior to sampling to ensure that they have taken on the microbiological quality of the RMP.

Depth

The recommended depth for sampling is from 1 to 3 m given that there was no evidence of a consistent difference in the extent of contamination with depth.

Frequency

It is recommended that the sampling frequency be monthly, given that the area is not suitable for analysis of stability, on the grounds of fluctuating and seasonal classifications.

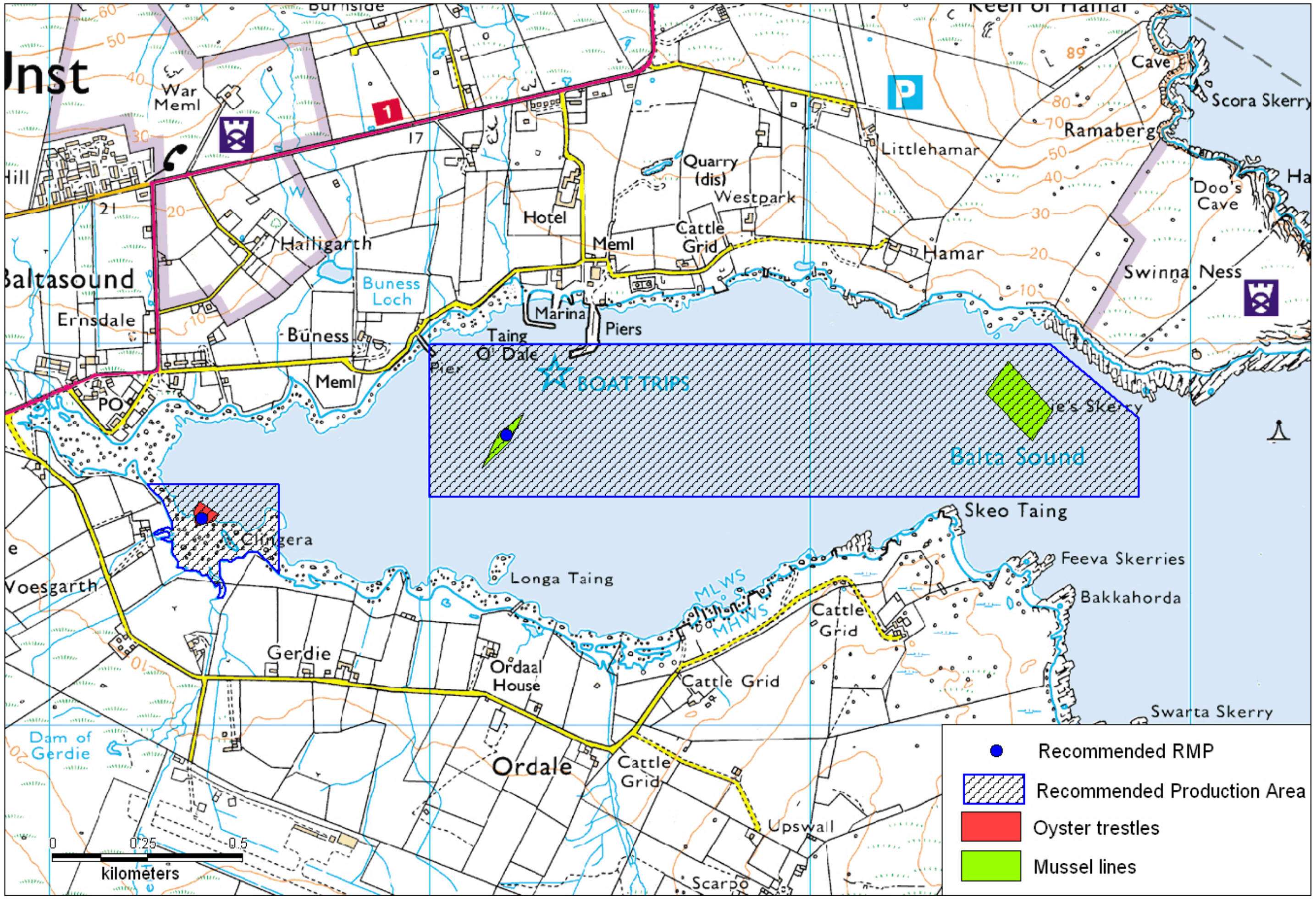

Figure 17.1 Map of recommendations at Balta Sound

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4. **General Information on Wildlife Impacts**
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6. **Statistical Data**
7. **Hydrographic Methods**
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Sampling Plan for Balta Sound

PRODUCTION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISHERY	NGR OF RMP	EAST	NORTH	TOLERANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Baltasound	Baltasound	SI 010 394 13	Pacific oysters	Oyster trestles	HP 6240 0854	462400	1208540	10	N/A	Hand	Monthly	Shetland Island Council	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson
Baltasound Harbour	Baltasound Harbour	TBA	Common mussels	Mussel lines	HP 6320 0876	463200	1208760	20	1-3	Hand	Monthly	Shetland Island Council	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson

Table of Proposed Boundaries and RMPs

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Baltasound	Pacific oysters	SI 010 394 13	Area bounded by lines drawn between HP 6535 0900 to HP 6482 0793 extending to MHWS	HP625087	Area bounded by lines drawn between HP 6226 0863 and HP 6260 0863 and between HP 6260 0863 and HP 6260 0840 and extending to MHWS.	HP 6240 0854	Revised production area boundary. Revised RMP.
Baltasound Harbour	Common mussels	TBA (currently SI 010 395 08)	Area bounded by lines drawn between HP 6535 0900 to HP 6482 0793 extending to MHWS	HP643089	Area bounded by lines drawn between HP 6300 0860 and HP 6300 0900 and between HP 6300 0900 and HP 6463 0900 and between HP 6463 0900 and HP 6486 0880 and between HP 6486 0880 and HP 6486 0860 and between HP 6486 0860 and HP 6300 0860.	HP 6320 0876	Revised production area boundary. Revised RMP.

Geology and Soils Assessment

Component soils and their associations were identified using uncoloured soil maps (scale 1:50,000) obtained from the Macaulay Institute. The relevant soils associations and component soils were then investigated to establish basic characteristics. From the maps seven main soil types were identified: 1) humus-iron podzols, 2) brown forest soils, 3) calcareous regosols, brown calcareous regosols, calcareous gleys, 4) peaty gleys, podzols, rankers, 5) non-calcareous gleys, peaty gleys: some humic gleys, peat, 6) organic soils and 7) alluvial soils.

Humus-iron podzols are generally infertile and physically limiting soils for productive use. In terms of drainage, depending on the related soil association they generally have a low surface % runoff, of between 14.5 – 48.4%, indicating that they are generally freely draining.

Brown forest soils are characteristically well drained with their occurrence being restricted to warmer drier climates, and under natural conditions they often form beneath broadleaf woodland. With a very low surface % runoff of between 2 – 29.2%, brown forest soils can be categorised as freely draining (Macaulay Institute, 2007).

Calcareous regosols, brown regosols and calcareous gleys are all characteristically freely draining soils containing free calcium carbonate within their profiles. These soil types have a very low surface % runoff at 14.5%.

Peaty gleys, peaty podzols and peaty rankers contribute to a large percentage of the soil composition of Scotland. They are all characteristically acidic, nutrient deficient and poorly draining. They have a very high surface % runoff of between 48.4 – 60%.

Non-calcareous gleys, peaty gleys and humic gleys are generally developed under conditions of intermittent or permanent water logging. In Scotland, non-calcareous gleys within the Arkaig association are most common and have an average surface % runoff of 48.4%, indicating that they are generally poorly draining.

Organic soils often referred to as peat deposits and are composed of greater than 60% organic matter. Organic soils have a surface % runoff of 25.3% and although low, due to their water logged nature, results in them being poorly draining.

Alluvial soils are confined to principal river valleys and stream channels, with a wide soil textural range and variable drainage. However, the alluvial soils encountered within this region have an average surface % runoff of 44.3%, so it is likely that in this case they would be poorly draining.

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and it's potential impact on runoff.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

Gley: A sticky, bluish-grey subsurface layer of clay developed under intermittent or permanent water logging.

Podzol: Infertile, non-productive soils. Formed in cool, humid climates, generally freely draining.

Rankers: Soils developed over noncalcareous material, usually rock, also called 'topsoil'.

Regosol: coarse-textured, unconsolidated soil lacking distinct horizons. In Scotland, it is formed from either quartzose or shelly sands.

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 50-170kg. 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

A variety of cetacean species are routinely observed around the west coast of Scotland.

Table 8.1 Cetacean sightings in 2007 – Western Scotland.

Common name	Scientific name	No. sighted*
Minke whale	*Balaenoptera acutorostrata*	28
Killer whale	*Orcinus orca*	183
Long finned pilot whale	*Globicephala melas*	14
Bottlenose dolphin	*Tursiops truncatus*	369
Risso's dolphin	*Grampus griseus*	145
Common dolphin	*Delphinus delphis*	6
Harbour porpoise	*Phocoena phocoena*	>500

*Numbers sighted are based on rough estimates based on reports received from various observers and whale watch groups. Source: Hebridean Whale and Dolphin Trust.

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 5km 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 per faecal deposit and ring-billedgulls (*Larus delawarensis*) approximately 1.77×10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). 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 and birds are known to carry *Salmonella*.

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 Natural Heritage website). 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.

Tables of Typical Faecal Bacteria Concentrations

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

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

Source: Kay, D. et al (2008) Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42, 442-454.

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: Adapted from Geldreich 1978 by Ashbolt et al in World Health Organisation (WHO) Guidelines, Standards and Health. 2001. Ed. by Fewtrell and Bartram. IWA Publishing, London.

Statistical data

All *E. coli* data was log transformed prior to statistical tests.

Section 11.3 T-test comparison of mussel results by sampling location

```
Two-sample T for Log E. coli

GridRef    N   Mean  StDev  SE Mean
HP643089  64  1.719  0.524    0.066
HP645088  19  1.994  0.752     0.17

Difference = mu (HP643089) - mu (HP645088)
Estimate for difference:  -0.275
95% CI for difference:  (-0.657, 0.107)
T-Test of difference = 0 (vs not =): T-Value = -1.49  P-Value = 0.150  DF =
23
```

Section 11.3 Fishers exact test comparison of proportion of mussel results over 230 MPN/100g by sampling location

```
Using frequencies in Count

Rows: result   Columns: Location

        HP643089  HP645088    All

<230          14        57     71
           16.25     54.75  71.00

>230           5         7     12
            2.75      9.25  12.00

All           19        64     83
           19.00     64.00  83.00

Cell Contents:      Count
                    Expected count

Pearson Chi-Square = 2.801, DF = 1, P-Value = 0.094
Likelihood Ratio Chi-Square = 2.502, DF = 1, P-Value = 0.114

* NOTE * 1 cells with expected counts less than 5

Fisher's exact test: P-Value =  0.134001
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (mussels)

```
Source  DF      SS     MS     F      P
Season   3   2.831  0.944  2.89  0.041
Error   79  25.785  0.326
Total   82  28.616

S = 0.5713   R-Sq = 9.89%   R-Sq(adj) = 6.47%

                           Individual 95% CIs For Mean Based on Pooled StDev
Level   N    Mean   StDev    +---------+---------+---------+---------
1      21  1.5093  0.5388    (---------*---------)
2      21  1.9078  0.7504                    (---------*---------)
3      21  1.9849  0.5342                       (---------*---------)
4      20  1.7222  0.3981             (---------*---------)
                             +---------+---------+---------+---------
                           1.25      1.50      1.75      2.00
Pooled StDev = 0.5713

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

Individual confidence level = 98.96%
```

```
Season = 1 subtracted from:

Season    Lower  Center   Upper  -----+---------+---------+---------+----
2       -0.0639  0.3986  0.8611              (--------*--------)
3        0.0132  0.4757  0.9382                (---------*--------)
4       -0.2553  0.2130  0.6812          (--------*---------)
                                 -----+---------+---------+---------+----
                                   -0.50      0.00      0.50      1.00
Season = 2 subtracted from:

Season    Lower   Center   Upper  -----+---------+---------+---------+----
3       -0.3854   0.0771  0.5396        (---------*--------)
4       -0.6539  -0.1856  0.2827   (--------*---------)
                                  -----+---------+---------+---------+----
                                    -0.50      0.00      0.50      1.00
Season = 3 subtracted from:

Season    Lower   Center   Upper  -----+---------+---------+---------+----
4       -0.7310  -0.2627  0.2055  (---------*--------)
                                  -----+---------+---------+---------+----
                                    -0.50      0.00      0.50      1.00
```

<u>Section 11.5 One way ANOVA comparison of *E. coli* results by season (oysters)</u>

```
Source  DF      SS     MS     F      P
Season   3   2.714  0.905  1.76  0.162
Error   77  39.567  0.514
Total   80  42.281

S = 0.7168   R-Sq = 6.42%   R-Sq(adj) = 2.77%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ----+---------+---------+---------+-----
1      22  1.9297  0.7070  (--------*--------)
2      25  2.2495  0.9321            (-------*-------)
3      15  2.4579  0.4438                (---------*----------)
4      19  2.2503  0.5507           (--------*---------)
                           ----+---------+---------+---------+-----
                             1.75      2.10      2.45      2.80
Pooled StDev = 0.7168

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

Individual confidence level = 98.95%

Season = 1 subtracted from:

Season    Lower  Center   Upper  ----+---------+---------+---------+-----
2       -0.2299  0.3198  0.8695           (--------*--------)
3       -0.1015  0.5282  1.1579             (----------*---------)
4       -0.2684  0.3206  0.9096           (--------*---------)
                                 ----+---------+---------+---------+-----
                                  -0.60      0.00      0.60      1.20
Season = 2 subtracted from:

Season    Lower  Center   Upper  ----+---------+---------+---------+-----
3       -0.4058  0.2084  0.8226        (---------*----------)
4       -0.5715  0.0008  0.5732     (---------*---------)
                                 ----+---------+---------+---------+-----
                                  -0.60      0.00      0.60      1.20
Season = 3 subtracted from:

Season    Lower   Center   Upper  ----+---------+---------+---------+-----
4       -0.8571  -0.2076  0.4420  (----------*---------)
                                  ----+---------+---------+---------+-----
                                    -0.60      0.00      0.60      1.20
```

<u>Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (mussels)</u>

```
Pearson correlation of logres 2 d ranked and 2 d rain ranked = 0.080
P-Value = 0.528
```

<u>Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (oysters)</u>

```
Pearson correlation of logres 2 d ranked and 2 d rain ranked = 0.033
P-Value = 0.796
```

<u>Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (mussels)</u>

```
Pearson correlation of logres 7d ranked and 7 d rain ranked = 0.061
P-Value = 0.634
```

<u>Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (oysters)</u>

```
Pearson correlation of logres 7d ranked and 7 d rain ranked = 0.339
P-Value = 0.007
```

<u>Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (mussels)</u>

CIRCULAR-LINEAR CORRELATION
Analysis begun: 19 November 2009 14:44:37

Variables (& observations)	r	p
Angles & Linear (83)	0.105	0.416

<u>Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (oysters)</u>

CIRCULAR-LINEAR CORRELATION
Analysis begun: 24 September 2009 10:03:46

Variables (& observations)	r	p
Angles & Linear (72)	0.261	0.009

<u>Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (mussels)</u>

CIRCULAR-LINEAR CORRELATION
Analysis begun: 19 November 2009 14:43:13

Variables (& observations)	r	p
Angles & Linear (66)	0.18	0.129

<u>Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (oysters)</u>

CIRCULAR-LINEAR CORRELATION
Analysis begun: 24 September 2009 10:02:17

Variables (& observations)	r	p
Angles & Linear (72)	0.341	3.14E-04

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (mussels)

```
The regression equation is
log e coli temperature = 1.59 + 0.0459 temperature

Predictor       Coef  SE Coef     T      P
Constant      1.5912   0.3841  4.14  0.001
temperature  0.04588  0.04465  1.03  0.319

S = 0.696236   R-Sq = 6.2%   R-Sq(adj) = 0.3%

Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  0.5118  0.5118  1.06  0.319
Residual Error  16  7.7559  0.4847
Total           17  8.2677

Unusual Observations
                   log e coli
Obs  temperature  temperature    Fit  SE Fit  Residual  St Resid
 18          0.0        3.041  1.591   0.384     1.450      2.50R

R denotes an observation with a large standardized residual.
```

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (oysters)

```
The regression equation is
log e coli temperature = 1.36 + 0.0789 temperature

Predictor       Coef  SE Coef     T      P
Constant      1.3634   0.7369  1.85  0.082
temperature  0.07887  0.08011  0.98  0.339

S = 0.886702   R-Sq = 5.4%   R-Sq(adj) = 0.0%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.7622  0.7622  0.97  0.339
Residual Error  17  13.3661  0.7862
Total           18  14.1282

Unusual Observations
                   log e coli
Obs  temperature  temperature    Fit  SE Fit  Residual  St Resid
 18         11.0        4.204  2.231   0.267     1.973      2.33R

R denotes an observation with a large standardized residual.
```

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (mussels)

```
The regression equation is
Log E. coli salinity = 0.869 + 0.0294 Salinity

Predictor     Coef  SE Coef     T      P
Constant    0.8693   0.8374  1.04  0.303
Salinity   0.02940  0.02643  1.11  0.269

S = 0.602795   R-Sq = 1.6%   R-Sq(adj) = 0.3%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.4497  0.4497  1.24  0.269
Residual Error  76  27.6155  0.3634
Total           77  28.0652
```

Unusual Observations

Obs	Salinity	Log E. coli salinity	Fit	SE Fit	Residual	St Resid
1	20.0	1.6021	1.4573	0.3137	0.1448	0.28 X
43	34.2	3.1139	1.8745	0.0969	1.2395	2.08R
61	38.3	1.8451	1.9938	0.1889	-0.1487	-0.26 X
68	35.2	3.2304	1.9036	0.1170	1.3269	2.24R
77	34.5	3.1139	1.8830	0.1025	1.2309	2.07R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (oysters)

The regression equation is
Log E. coli salinity = 2.69 - 0.0176 Salinity

Predictor	Coef	SE Coef	T	P
Constant	2.6906	0.3708	7.26	0.000
Salinity	-0.01756	0.01289	-1.36	0.178

S = 0.712919   R-Sq = 2.5%   R-Sq(adj) = 1.1%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.9421	0.9421	1.85	0.178
Residual Error	73	37.1025	0.5083		
Total	74	38.0446			

Unusual Observations

Obs	Salinity	Log E. coli salinity	Fit	SE Fit	Residual	St Resid
49	33.9	4.5563	2.0950	0.1120	2.4614	3.50R
61	3.5	2.8976	2.6299	0.3274	0.2677	0.42 X
65	4.4	2.2304	2.6136	0.3158	-0.3831	-0.60 X
74	33.4	4.2041	2.1037	0.1078	2.1004	2.98R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.

Hydrographic Methods

The new EU regulations require an appreciation of the hydrography and currents within a region classified for shellfish production with the aim to "determine the characteristics of the circulation of pollution, appreciating current patterns, bathymetry and the tidal cycle." This document outlines the methodology used by Cefas to fulfil the requirements of the sanitary survey procedure with regard to hydrographic evaluation of shellfish production areas. It is written as far as possible to be understandable by someone who is not an expert in oceanography or computer modelling. A glossary at the end of the document defines commonly used hydrographic terms e.g. tidal excursion, residual flow, spring-neap cycle etc.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only. Selected sites will be assessed in more detail using either: 1) a hydrodynamic model, or 2) an extended consideration of sources, available field studies and expert assessment. This document will consider the more basic hydrographic processes and describes the common methodology applied to all sites.

<u>Background processes</u>
Currents in estuarine and coastal waters are generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences.

Tidal flows often dominate water movement over the short term (approximately 12 hours) and move material over the length of the *tidal excursion*. Tides move water back and forth over the tidal period often leading to only a small net movement over the 12 hours tidal cycle. This small net movement is partly associated with the *tidal residual* flow and over a period of days gives rise to persistent movement in a preferred direction. The direction will depend on a number of factors including the bathymetry and direction of propagation of the main tidal wave.

Wind and density driven current also lead to persistent movement of water and are particular important in regions of relatively low tidal velocities characteristic of many of the water bodies in Scottish waters. Whilst tidal flows generally move material in more or less the same direction at all depths, wind and density driven flows often move material in different directions at the surface and at the bed. Typical vertical profiles are depicted in Figure 1. However, it should be understood that in a given water body, movement will often be the sum of all three processes.

In sea lochs, mechanisms such as "wind rows" can transport sources of contamination at the edge of the loch to production areas further offshore. Wind rows are generated by winds directed along the main length of the loch. An illustration of the waters movements generated in this way is given in Figure 2. As can be seen the water circulates in a series of cell that draw material across the loch at right angles to the wind direction. This is a particularly common situation for lochs with high land on either side as these tend to act as a steering mechanism to align winds along the water body.

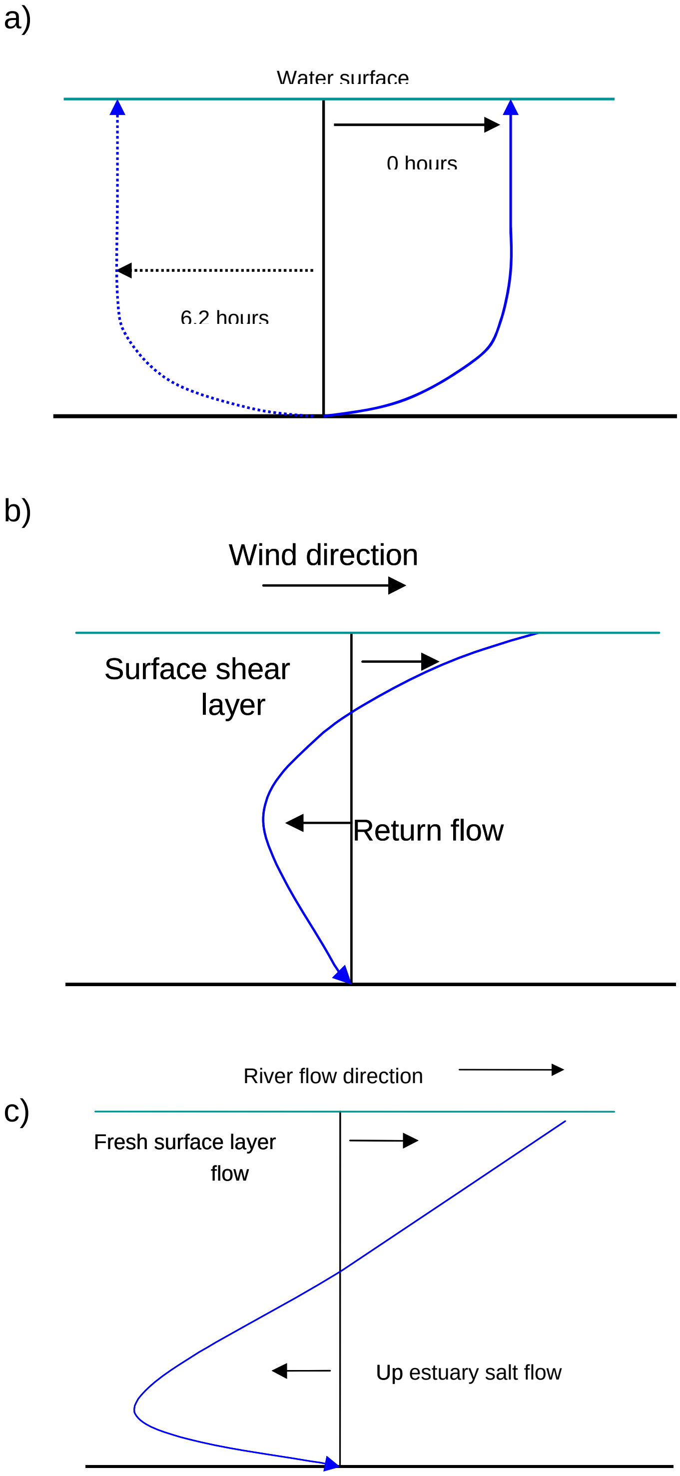

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction over a period of 6.2 hours. b) wind driven current profile, c) density driven current profile.

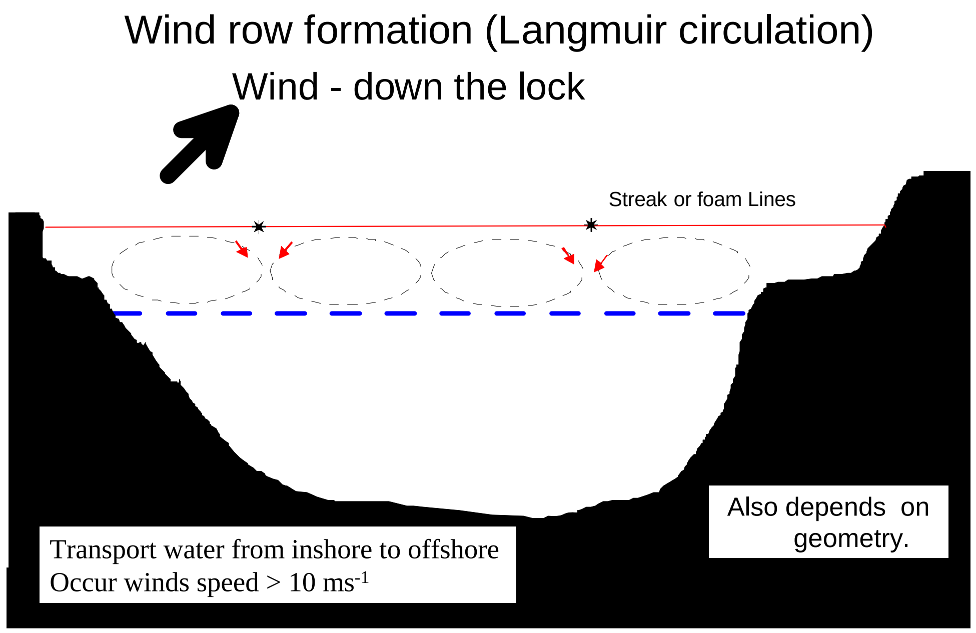

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

<u>Non-modelling Assessment</u>
In this approach the assessment requires a certain amount of expert judgment and subjectivity enters in. For all production areas, the following general guidelines are used:

1. Near-shore flows will generally align parallel to the shore.
2. Tidal flows are bi-directional, thus sources on either side of a production area are potentially polluting.
3. For tidal flows, the tidal excursion gives an idea of the likely main 'region of influence' around an identified pollutant source.
4. Wind driven flows can drive material from any direction depending on the wind direction. Wind driven current speeds are usually at a maximum when the wind direction is aligned with the principle axis of the loch.
5. Density driven flows generally have a preferred direction.
6. Material will be drawn out in the direction of current, often forming long thin 'plumes'.

Many Scottish shellfish production areas occur within sea lochs. These are fjord-like water bodies consisting of one or more basins, deepened by glacial activity and having relatively shallow sills that control the mixing and flushing processes. The sills are often regions of relatively high currents, while the basins are much more tranquil often containing higher density water trapped below a fresh lower density surface layer. Tidal mixing primarily occurs at the sills.

The catalogue of Scottish Sea Loch produced by the SMBA is used to quantify sills, volume fluxes and likely flow velocities. Because the flow is so constrained by the rapidly varying bathymetry, care has to be used in the extrapolation of direct measurements of current flow. Mean flow velocities can be estimated at the sills by using estimates of the sill area and the volume change through a tidal cycle. This in turn can be used to estimate the maximum distance travelled in a tidal cycle in the sill area. Away from the sill area, tidal velocities are general low and transport events are dominated by wind or density effects. Sea Lochs generally have a surface layer of fresher water; the extent of this depends on freshwater input, sill depth and quantity of mixing.

In addition to movement of particles by currents, dilution is also an important consideration. Dilution reduces the effect of an individual point source although at the expense of potentially contaminating a larger area. Thus class A production areas can be achieved in water bodies with significant faecal coliform inputs if no transport pathway exists and little mixing can occur. Conversely a poor classification might occur where high mixing causes high and permanent background concentrations arising from many weak diffuse sources.

References

European Commission 1996. Report on the equivalence of EU and US legislation for the Sanitary Production of Live Bivalve Molluscs for Human Consumption. EU Scientific Veterinary Committee Working Group on Faecal Coliforms in Shellfish, August 1996.

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.

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. The strongest tides in a month are called spring tides and the weakest are called neap tides. Spring tides occur every 14 days with neaps tides occurring 7 days after springs. Both tidal range and tidal currents are strongest at Spring 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. Often a surface flow at the surface is accompanied by a compensating flow in the opposite direction at the bed (see figure 1).

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.

Shoreline Survey Report

Survey Area: Baltasound (SI 010)

Scottish Sanitary Survey Project Cefas

Shoreline Survey Report

Production Area:

Production Area	Site	SIN	Species	Nominal RMP	Actual RMP
Baltasound	Baltasound	SI 010 394 13	Pacific oysters	HP 625 087	HP 6238 0852
Baltasound	Baltasound Harbour	SI 010 395 08	Mussels	HP 643 089	HP 6450 0885

Harvesters: Denis Buddle (Unst Oysters)
David Niven (Unst Shellfish)
Status: Both production areas are currently classified for harvest
Date Surveyed: 25/5/09 to 26/5/09
Surveyed by: Sean Williamson, Alastair Cook
Area Surveyed: See Figure 1

Weather observations

25/5/09 Wind NW force 3, 9°C, a few showers but generally bright.
26/5/09 Wind W force 5, 9°C, some heavy showers.
The weather had been relatively dry in the days preceding the survey.

Site Observations

Specific observations made on site are mapped in Figure 1 and listed in Table 1. Water and shellfish samples were collected at sites marked on Figures 2 and 3. Bacteriology results are given in Tables 2 and 3. Salinity profiles are presented in Table 4. Photographs are presented in Figures 4-25.

Fishery

Baltasound (SI 010 394 13). This consisted of an area of 41 oyster trestles, inshore of and smaller than the Crown Estates lease for this site. The trestles were of a cage type, with up to 6 layers of bagged Pacific oysters inside each cage. Additionally, a few bags of oysters were found on the substrate at the inshore side of the fishery. Stock of a range of sizes was present, including that of a harvestable size. Harvesting may occur at any time of the year. Oysters grow slowly at this site, taking around 6 or 7 years to reach a harvestable size, making the viability of their culture here marginal. A large number of clams (species uncertain) were seen on the substrate surrounding the trestles.

Baltasound harbour (SI 010 395 08). This site consisted of one single-headed and three double-headed long lines, all with 8 m droppers. The owner reported poor spatfall and relatively low yields from this site. There was little stock present, although there were some mussels, including of a harvestable size on some lines. The tackle was deployed about 3 years ago, and the first harvest was planned for later this year. However, the owner has decided to postpone harvest until next year due to the poor growth. In addition to this site, the same owner has also deployed one double headed longline closer to the head of the sound approximately a year ago. The two headropes had been pulled apart in the middle to form and elongated diamond shape. No stock was available for sampling from this line. It is anticipated that this line will be harvested in about 2 years. The owner has a processing shed on the south shore of the sound, which has a depuration unit. This serves the mussel culture operation in Balta Sound, as well as another mussel culture operation in nearby Uyeasound, which is under the same ownership.

Sewage/Faecal Contamination Sources

Human

The main population centre in the area is the settlement of Baltasound, which is centred around the head of the sound, but spreads along both the north and south shore. The majority of houses here are connected to mains sewerage, which is treated via septic tank and discharged just offshore just to the east of the marina on the north shore. At the time when this section was surveyed and the mussel lines were sampled, the wind appeared to be blowing the plume from this discharge directly towards the larger area of mussel lines. This system also incorporates a pumping station with an emergency overflow at the head of the sound, which was not flowing at the time of survey.

In addition to this, five private sewage discharges direct to the production area were found, although one of these may no longer be in use. A further private septic tank discharge serving one house was found discharging to a small stream which flows into Balta Sound where the oyster trestles were located. One further private discharge to soakaway was recorded. It is quite likely that other private discharges exist either discharging to soakaway or to small watercourses, as not all houses and gardens were investigated. No sanitary debris was found during the course of the survey.

Livestock

The band of low lying crofts and fields surrounding the production area appeared to be improved pastures, which supported fairly high densities of a variety of livestock. This band extended about 1 km back from the shore. Not all fields had livestock on them at the time of survey. In most places fences prevented livestock from accessing the shoreline, although there was a notable exception to this adjacent to the main area of mussel lines, where cattle had access to the beach. A total of 519 sheep, 82 cattle, 37 ponies and 3 chickens were recorded on these pastures. In addition to this, roughly 100 sheep were recorded on the island of Balta, at the mouth of Balta Sound.

A few small streams discharge into the voe and these drain areas of pasture. The catchment area of Balta Sound is small (roughly 15 km^2). Water samples were taken, and discharge estimated where the streams were of sufficient size for flow to be measured. It must be noted that water levels were low, and some of the smaller streams marked on the Ordnance Survey map, although wetted in places, had negligible flow. Stream inputs had low to moderate levels of *E. coli* (<10-1400 cfu/100ml). It is likely that land runoff is an important pathway for moving contamination from livestock into the sound.

E. coli levels in seawater taken offshore in the vicinity of the mussel lines was low (<1 *E. coli* cfu/100ml in all cases). Levels of *E. coli* in seawater samples taken from the shore were low, and ranged from 1 to 20 *E. coli* cfu/100ml. Lower levels were generally found towards the eastern end of the sound, but not consistently.

The four rope mussel samples gave *E. coli* results ranging from <20 to 70 MPN/100g. Salinity measurements taken during the survey indicated that there was little freshwater influence on the water body at the time, with salinities all around that of full strength seawater with very little or no stratification.

Seasonal Population

The main attractions in the area are wildlife watching and outdoor pursuits. One hotel with 17 chalets, and a Bed and Breakfast were recorded during the survey. Some dwellings, mainly in the Setters Hill estate, which used to house army personnel, are likely to be holiday homes. Therefore population is likely to be slightly higher during the summer months.

Boats/Shipping

Boat traffic in Balta Sound is relatively light, limited to small fishing boats, mussel and salmon boats, small pleasure boats, and a few visiting yachts. There is a marina for small boats, where a total of 24 small cabin cruisers and dinghies were seen at the time of survey, and a pontoon berth where visiting yachts can tie up, both on the north shore.

Land Use

The land surrounding Balta Sound is primarily improved pasture, which is grazed by sheep, cattle and ponies. Further back from this low lying area of pasture, the more elevated land appeared to be heathland. Additionally, there are houses and gardens dotted around the sound.

Wildlife/Birds

Gulls, waders and a few geese were seen during the survey, but no major aggregations of wildlife were recorded. A few rabbits were seen on pastures. Otters and seals are reported to frequent the area, although none was seen during the course of the survey.

Recorded observations apply to the date of survey only. Animal numbers were recorded on the day from the observer’s point of view. This does not necessarily equate to total numbers present as natural features may obscure individuals and small groups of animals from view.

Dimensions and flows of watercourses are estimated at the most convenient point of access and not necessarily at the point at which the watercourses enter the sound.

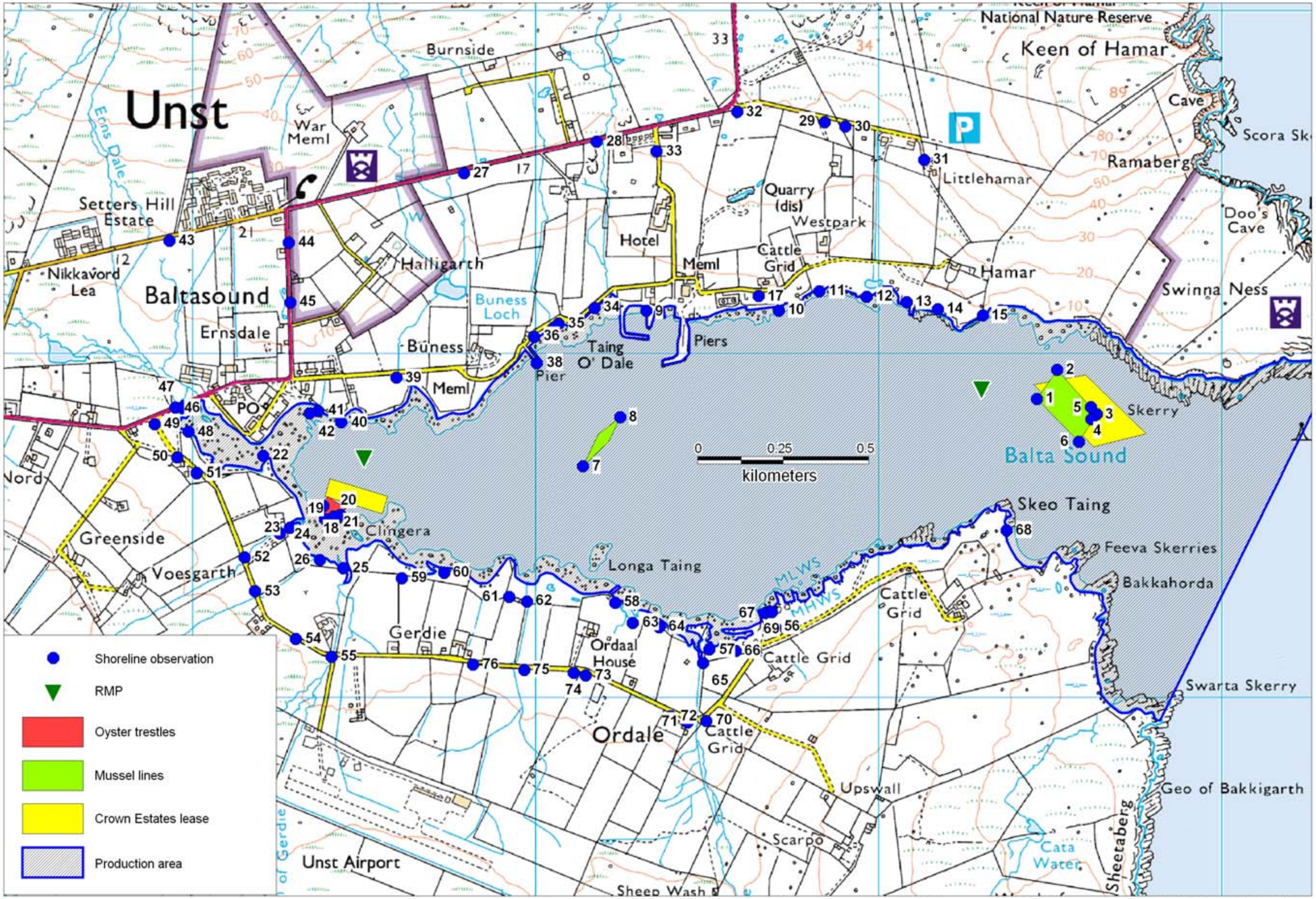

Figure 1. Map of Shoreline Observations

Table 1. Shoreline observations

No.	Date and time	Position	Photograph	Observation
1	26-MAY-09 12:12:46PM	HP 64461 08868		Corner of mussel lines (3 double and 1 single headed long lines with 8 m droppers)
2	26-MAY-09 12:14:38PM	HP 64519 08953		Corner of lines, seawater sample 1, mussel sample 1 (top) and 2 (bottom). Salinity profile 1.
3	26-MAY-09 12:26:02PM	HP 64635 08824		Corner of lines, 3 terns and 1 cormorant on floats
4	26-MAY-09 12:27:33PM	HP 64619 08809		Seawater sample 2. Salinity profile 2.
5	26-MAY-09 12:31:47PM	HP 64618 08844		Mussel sample 3 (top) and 4 (bottom)
6	26-MAY-09 12:41:40PM	HP 64583 08744		Corner of lines
7	26-MAY-09 12:49:10PM	HP 63138 08672	Figure 4	End of double headed line. Lines pulled apart to a diamond shape, about 10 m between them in the middle.
8	26-MAY-09 12:50:28PM	HP 63246 08815		Other end of line. Seawater sample 3. Salinity profile 3.
9	26-MAY-09 1:13:43PM	HP 63322 09125	Figure 5	Marina, 24 small boats tied up. Seawater sample 4.
10	26-MAY-09 1:22:57PM	HP 63708 09126	Figures 6 and 7	Scottish water septic tank. Boil from outflow visible about 20m offshore. Wind is pushing water from the boil in a plume directly towards the larger mussel site. Seawater sample 5 (not within plume)
11	26-MAY-09 1:29:03PM	HP 63826 09182	Figure 8	Private 12cm cast iron sewer pipe to underwater. 1 house behind.
12	26-MAY-09 1:32:53PM	HP 63964 09166		4 geese
13	26-MAY-09 1:36:40PM	HP 64081 09150		Small stream not flowing.
14	26-MAY-09 1:38:16PM	HP 64172 09130		Livestock feeder
15	26-MAY-09 1:40:58PM	HP 64303 09112		34 cattle in field which runs the length of the larger mussel site. No fence to shore
16	26-MAY-09 1:43:18PM	HP 64355 09127		Seawater sample 6, cowpats on beach.
17	26-MAY-09 1:57:14PM	HP 63650 09168	Figure 9	Septic tank with obvious soakaway.
18	27-MAY-09 5:53:20AM	HP 62385 08519	Figure 10	Corner of oyster site. 41 cages of trestles, each holding up to 6 layers of bags.
19	27-MAY-09 5:54:29AM	HP 62381 08558		Corner of site about 30 m further out (too deep to reach)
20	27-MAY-09 5:58:43AM	HP 62431 08532		Seawater sample 7. Corner of site about 15m further out from here.
21	27-MAY-09 6:01:29AM	HP 62411 08527		Oyster sample 5. Oyster sample also taken for norovirus testing. Seawater sample 8
22	27-MAY-09 6:28:11AM	HP 62205 08703	Figure 11	Presumed Scottish Water Emergency overflow (not flowing).
23	27-MAY-09 6:32:39AM	HP 62283 08495		Stream 37cmx6cmx0.448m/s. Freshwater sample 9.
24	27-MAY-09 6:35:44AM	HP 62254 08477	Figure 12	Septic tank discharge pipe to stream. Not flowing. Serves 1 house.
25	27-MAY-09 6:46:19AM	HP 62439 08377		Stream 115cmx2cmx0.089m/s. Freshwater sample 10
26	27-MAY-09 6:48:13AM	HP 62370 08401		Dry stream
27	27-MAY-09 6:55:50AM	HP 62791 09526		23 sheep.
28	27-MAY-09 6:56:53AM	HP 63177 09618		3 ponies and 15 sheep.
29	27-MAY-09 6:59:00AM	HP 63842 09675		18 sheep and 4 ponies.

No.	Date and time	Position	Photograph	Observation
30	27-MAY-09 6:59:59AM	HP 63902 09662		64 sheep.
31	27-MAY-09 7:01:25AM	HP 64132 09565		7 sheep.
32	27-MAY-09 7:05:03AM	HP 63587 09705		Bus shelter.
33	27-MAY-09 7:06:09AM	HP 63351 09590		3 cattle.
34	27-MAY-09 9:08:01AM	HP 63172 09133		22 sheep.
35	27-MAY-09 9:09:03AM	HP 63066 09088		1 pony and 20 sheep.
36	27-MAY-09 9:11:01AM	HP 62995 09050		2 ponies
37	27-MAY-09 9:11:56AM	HP 63051 09076		Stream 88cmx2cmx0.119m/s. Freshwater sample 11.
38	27-MAY-09 9:16:41AM	HP 63003 08972		Seawater sample 12.
39	27-MAY-09 9:24:08AM	HP 62594 08931		Stream 64cmx7cmx0.282m/s. Freshwater sample 13.
40	27-MAY-09 9:32:54AM	HP 62433 08800		20 cm cast iron sewer pipe, not flowing. Looked old and possibly not in use.
41	27-MAY-09 9:34:51AM	HP 62366 08833		15 cm faded orange plastic sewer pipe, dripping, setic tank cover in field behind, probably serves one house. Also small stream, not flowing.
42	27-MAY-09 9:36:57AM	HP 62341 08826		Seawater sample 14.
43	27-MAY-09 10:14:45AM	HP 61932 09329		40 cattle and 13 ponies.
44	27-MAY-09 10:17:31AM	HP 62280 09324		13 ponies.
45	27-MAY-09 10:19:09AM	HP 62285 09149		24 sheep.
46	27-MAY-09 10:24:33AM	HP 61949 08843	Figure 13	Scottish water pumping station.
47	27-MAY-09 10:26:30AM	HP 61974 08848		Stream 100cmx5cmx0.392m/s. Freshwater sample 15.
48	27-MAY-09 10:31:30AM	HP 61988 08773		Stream 110cmx3cmx0.327m/s. Freshwater sample 16.
49	27-MAY-09 10:40:20AM	HP 61889 08795		2 ponies.
50	27-MAY-09 10:41:50AM	HP 61955 08698		4 ponies and 17 sheep.
51	27-MAY-09 10:42:31AM	HP 62011 08653		1 pony.
52	27-MAY-09 10:43:36AM	HP 62151 08408		27 sheep.
53	27-MAY-09 10:44:23AM	HP 62181 08310		21 sheep.
54	27-MAY-09 10:45:39AM	HP 62300 08170		27 sheep.
55	27-MAY-09 10:46:24AM	HP 62404 08118		Bed and Breakfast.
56	27-MAY-09 10:51:22AM	HP 63698 08205		Mussel shed with depuration plant
57	27-MAY-09 10:57:08AM	HP 63506 08140		11 geese
58	27-MAY-09 11:03:56AM	HP 63231 08276		Orange 110mm plastic sewer pipe (1 house behind)
59	27-MAY-09 11:16:35AM	HP 62610 08347		9 sheep
60	27-MAY-09 11:18:57AM	HP 62733 08363		Seawater sample 17
61	27-MAY-09 11:24:49AM	HP 62922 08293		68 sheep
62	27-MAY-09 11:26:09AM	HP 62974 08279		Stream 125cmx5cmx0.024m/s. Freshwater sample 18.
63	27-MAY-09 11:37:10AM	HP 63283 08217		5 ponies

No.	Date and time	Position	Photograph	Observation
64	27-MAY-09 11:39:13AM	HP 63360 08205		20 sheep
65	27-MAY-09 11:42:55AM	HP 63487 08100		Stream 140cmx12cmx0.019. Freshwater sample 19.
66	27-MAY-09 11:46:51AM	HP 63583 08135		3 sheep
67	27-MAY-09 11:50:53AM	HP 63669 08246	Figure 14	Septic tank with pipe to underwater (serves mussel shed)
68	27-MAY-09 12:04:12PM	HP 64372 08486		Seawater sample 20m, about 100 sheep out on Balta
69	27-MAY-09 12:20:40PM	HP 63688 08249		Seawater sample 21
70	27-MAY-09 12:29:55PM	HP 63497 07931		40 sheep, 5 cows, 5 geese
71	27-MAY-09 12:31:02PM	HP 63442 07927		50 sheep
72	27-MAY-09 12:31:45PM	HP 63394 07945		2 sheep, 3 chickens
73	27-MAY-09 12:32:59PM	HP 63145 08064		2 sheep
74	27-MAY-09 12:33:09PM	HP 63110 08072		10 sheep
75	27-MAY-09 12:34:12PM	HP 62966 08080		4 ponies
76	27-MAY-09 12:34:54PM	HP 62817 08096		30 sheep

Table 2. Water sample *E. coli* results

Sample No.	Date and time	Position	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	26-MAY-09 12:26:02PM	HP 64635 08824	Seawater	<1	34.28
2	26-MAY-09 12:31:47PM	HP 64618 08844	Seawater	<1	34.34
3	26-MAY-09 12:50:28PM	HP 63246 08815	Seawater	<1	34.27
4	26-MAY-09 1:13:43PM	HP 63322 09125	Seawater	11	34.14
5	26-MAY-09 1:22:57PM	HP 63708 09126	Seawater	1	34.29
6	26-MAY-09 1:43:18PM	HP 64355 09127	Seawater	4	34.36
7	27-MAY-09 5:58:43AM	HP 62431 08532	Seawater	9	33.54
8	27-MAY-09 6:01:29AM	HP 62411 08527	Seawater	11	33.48
9	27-MAY-09 6:32:39AM	HP 62283 08495	Freshwater	330	
10	27-MAY-09 6:46:19AM	HP 62439 08377	Freshwater	90	
11	27-MAY-09 9:11:56AM	HP 63051 09076	Freshwater	60	
12	27-MAY-09 9:16:41AM	HP 63003 08972	Seawater	13	33.9
13	27-MAY-09 9:24:08AM	HP 62594 08931	Freshwater	30	
14	27-MAY-09 9:36:57AM	HP 62341 08826	Seawater	14	31.04
15	27-MAY-09 10:26:30AM	HP 61974 08848	Freshwater	50	
16	27-MAY-09 10:31:30AM	HP 61988 08773	Freshwater	<10	
17	27-MAY-09 11:18:57AM	HP 62733 08363	Seawater	4	34.06
18	27-MAY-09 11:26:09AM	HP 62974 08279	Freshwater	1400	
19	27-MAY-09 11:42:55AM	HP 63487 08100	Freshwater	800	
20	27-MAY-09 12:04:12PM	HP 64372 08486	Seawater	1	34.16
21	27-MAY-09 12:20:40PM	HP 63688 08249	Seawater	20	34.4

Table 3. Shellfish sample *E. coli* results

Sample	Date and time	Position	Species	Depth	Result
1	26-MAY-09 12:26:02PM	HP 64635 08824	Mussel	1m	50
2	26-MAY-09 12:26:02PM	HP 64635 08824	Mussel	8m	70
3	26-MAY-09 12:41:40PM	HP 64583 08744	Mussel	1m	50
4	26-MAY-09 12:41:40PM	HP 64583 08744	Mussel	8m	<20
5	27-MAY-09 6:01:29AM	HP 62411 08527	Pacific oyster	NA	40

Table 4. Salinity profiles

Profile	Date and time	Position	Depth (m)	Salinity (ppt)	Temperature (°C)
1	26-MAY-09 12:14:38PM	HP 64519 08953	0	35.2	10.9
1	26-MAY-09 12:14:38PM	HP 64519 08953	2.5	35.5	10.2
1	26-MAY-09 12:14:38PM	HP 64519 08953	5	35.5	10
1	26-MAY-09 12:14:38PM	HP 64519 08953	7.5	35.7	9.9
1	26-MAY-09 12:14:38PM	HP 64519 08953	10	35.8	9.8
2	26-MAY-09 12:27:33PM	HP 64619 08809	0	35.8	10.3
2	26-MAY-09 12:27:33PM	HP 64619 08809	2.5	35.8	9.9
2	26-MAY-09 12:27:33PM	HP 64619 08809	5	35.8	9.7
2	26-MAY-09 12:27:33PM	HP 64619 08809	7.5	35.8	9.6
2	26-MAY-09 12:27:33PM	HP 64619 08809	10	35.9	9.6
3	26-MAY-09 12:50:28PM	HP 63246 08815	0	35.6	11
3	26-MAY-09 12:50:28PM	HP 63246 08815	2.5	35.6	10.3
3	26-MAY-09 12:50:28PM	HP 63246 08815	5	35.9	10.1
3	26-MAY-09 12:50:28PM	HP 63246 08815	7.5	35.8	9.8

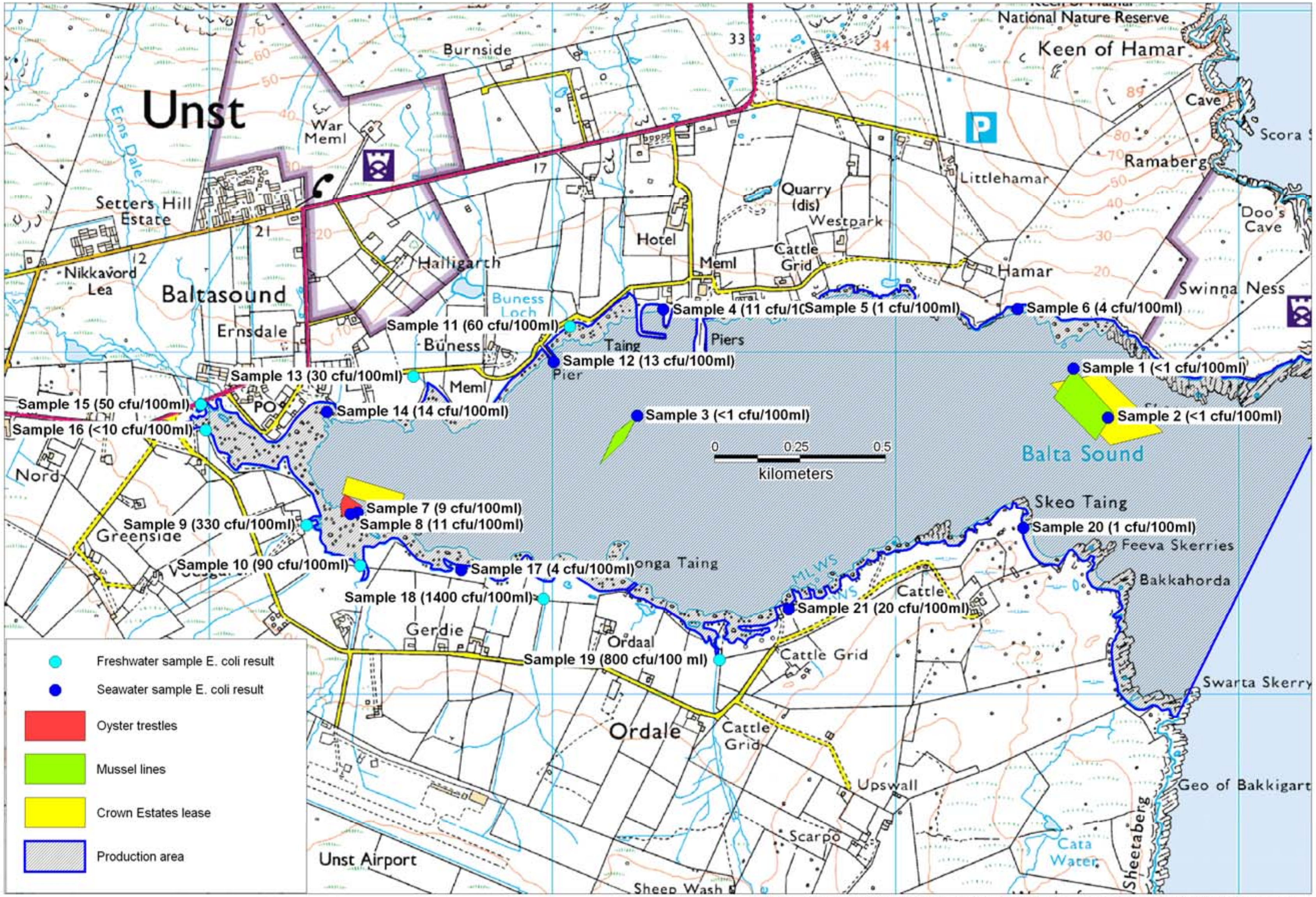

Figure 2. Water sample results map

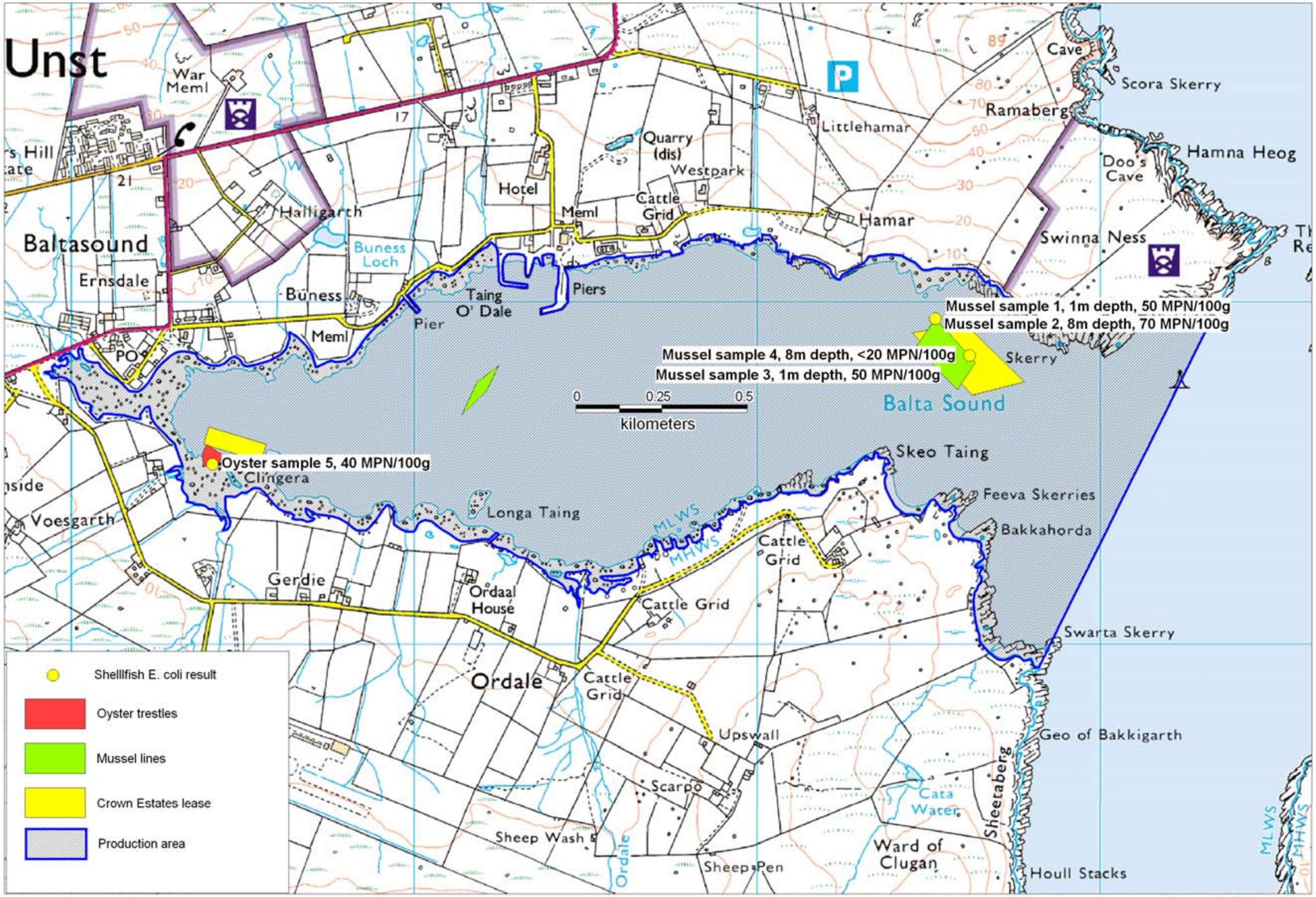

Figure 3. Shellfish sample results map


Figure 4. Double-headed mussel line


Figure 5. Baltasound marina

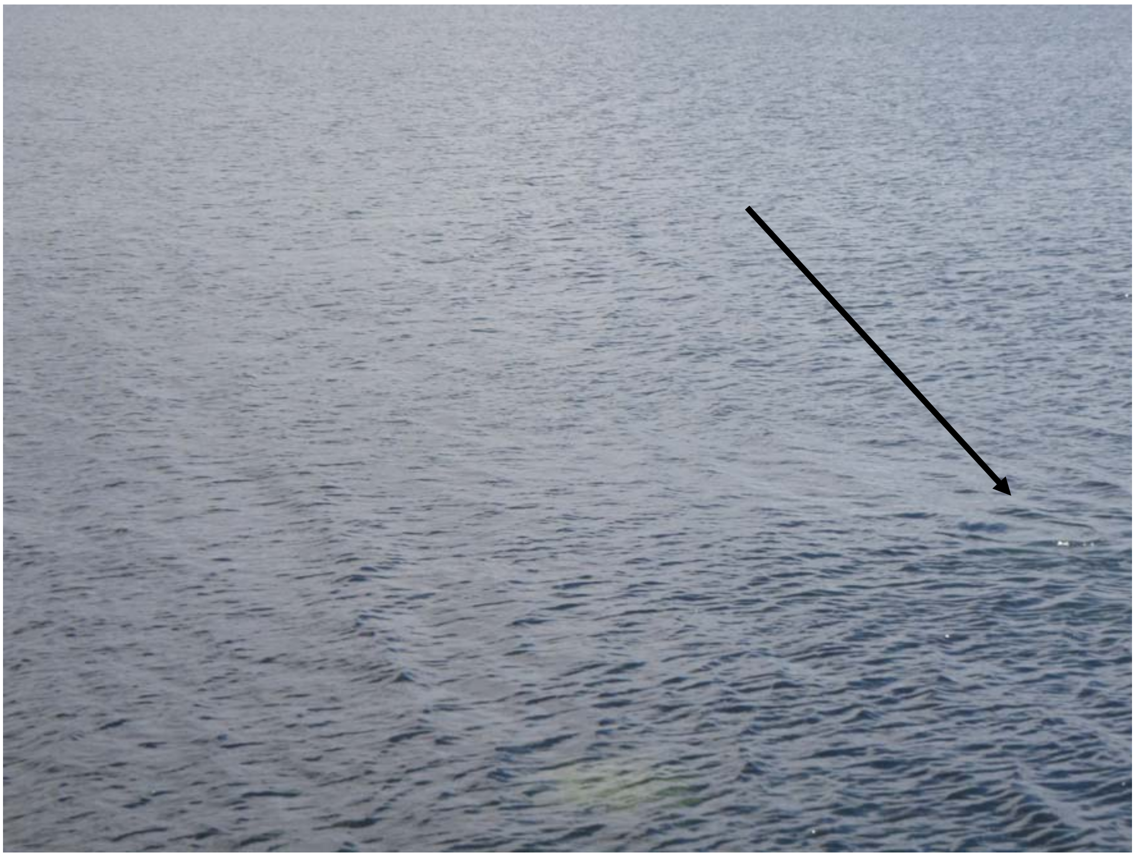

Figure 6. Boil at Scottish Water septic tank outfall

Figure 7. Scottish Water septic tank

Figure 8. Private sewer outfall

Figure 9. Septic tank with apparent soakaway

Figure 10. Oyster trestles with path of stream in foreground

Figure 11. Scottish water emergency overflow

Figure 12. Septic tank discharge to stream which flows toward trestles

Figure 13. Scottish Water pumping station

Figure 14. Septic tank at mussel shed