Scottish Sanitary Survey Project

Sanitary Survey Report

Papa Little Voe and Gon Firth

SI 235 and SI 076

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Cefas

FOOD STANDARDS AGENCY SCOTLAND
Buidheann Inbhe-Bìdhe an Alba

Report Distribution – Papa Little Voe & Gon Firth

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

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Table of Contents

1. General Description

The Papa Little Voe production area lies within the Sound of Houbansetter, which is a small body of water located to the east of Papa Little Island on the western mainland. It is fairly sheltered and is 1.6km wide at its widest point. Its maximum depth of 50m is found across the northern part of the voe. This sanitary survey was conducted in response to receipt of an application for classification of Papa Little Voe for mussels. The Gon Firth production area abuts the northern boundary of the Papa Little Voe production area and so was surveyed at the same time. The water body of Gon Firth lies to the east of the production area and the two do not overlap.

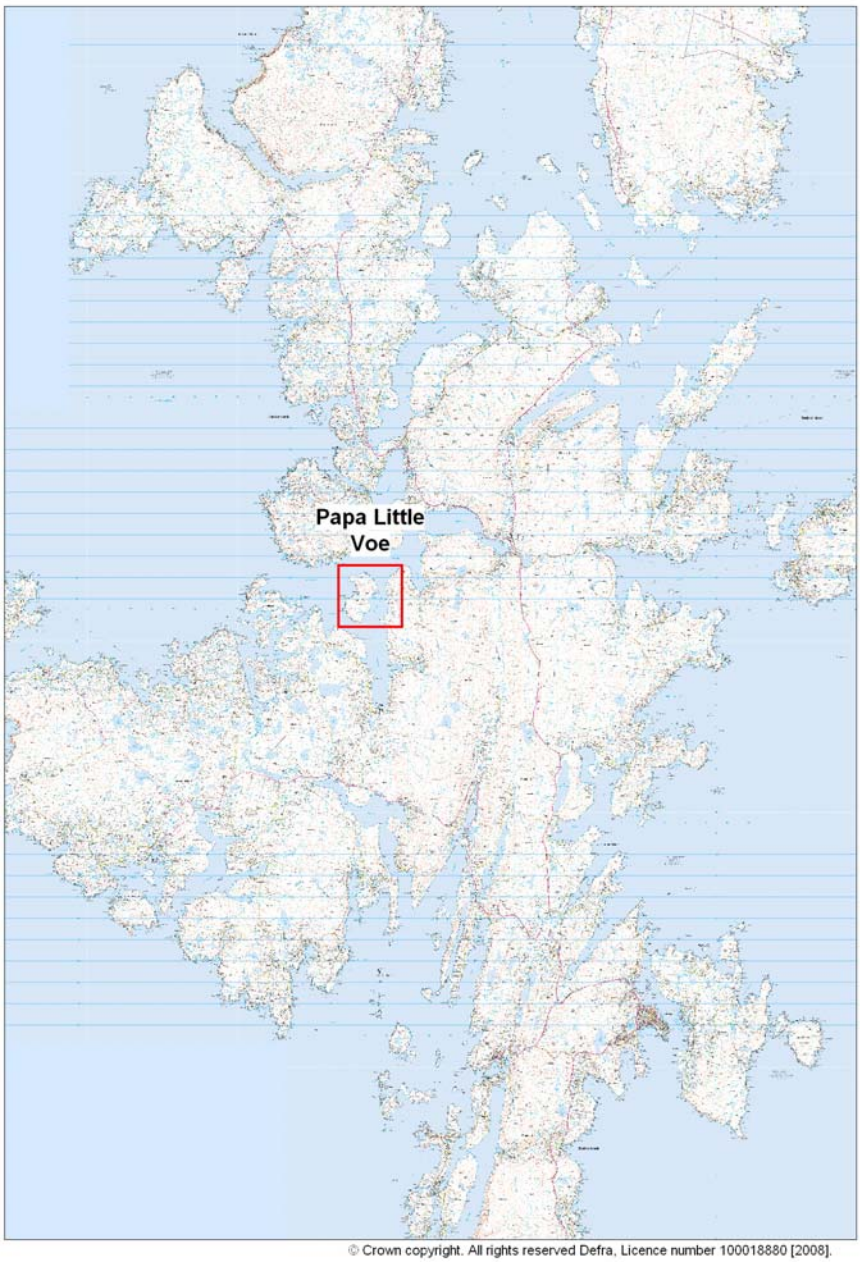


Figure 1.1 Location of Papa Little Voe and Gon Firth

2. Fishery

The fishery at Gon Firth:Cole Ness is comprised of one active long line mussel (*Mytilus* sp.) farm. The fishery at Papa Little Voe is comprised of two long line mussel sites, the smaller of which had been recently added, and its owner is unknown. Since the survey, the sampling officer reported the line appeared to be falling into disrepair. It is unknown whether this site will come into production.

Table 2.1. Papa Little Voe and Gon Firth shellfish farms

Area	Site	SIN	Species	Description
Papa Little Voe	Papa Little Voe	SI 235 440 08	Common Mussels	4 Longlines
Papa Little Voe	Unnamed	SI 235 TBA 08	Common Mussels	1 longline, recently deployed
Gon Firth	Cole Ness	SI 076 423 08	Common Mussels	4 longlines

Papa Little Voe

The current production area boundaries for Papa Little Voe are given as the area bounded by lines drawn between HU 3458 6140 to HU 3492 6150 and HU 3377 5990 to HU 3500 5966. There is currently no assigned RMP for the Papa Little Voe production area, though the local authority collects samples from grid reference of HU 3397 6005.

The Papa Little Voe production area consists of an active mussel farm (Papa Little Voe) which is located toward the southern end of the production area. This site contains four double-headed long lines with 10 metre droppers. A further single mussel line has been placed off the eastern shore of the voe, approximately 0.5 km north northeast of the existing farm. It is not known to whom this line belongs, though it appeared to have been put in place recently and the sampling officer had been unaware of it.

Gon Firth: Cole Ness

The current production area boundaries for Gon Firth:Cole Ness are given as the area bounded by lies drawn between HU 3398 6225 to HU 3570 6253 and between HU 3458 6140 to HU 3491 6150. The nominal RMP for the production area is currently located at grid reference HU 354 623. As this is only defined to 100 metre accuracy, the local authority uses a more precise grid reference of HU 3542 6236.

This production area contains an active long line mussel farm at Cole Ness consisting of four double-headed long lines with 10 metre droppers. This farm contains lines with stock at different maturities to allow for rotational harvest within the site.

In addition, there were the remains of a mussel farm in the southern half of the production area that at the time of survey appeared to consist of one mussel line that had slipped anchor and formed a tangled ball.

Figure 2.1 shows the relative positions of the RMP, production area boundaries, mussel sites and the seabed lease areas. The boundaries of the

two production areas overlap slightly where they meet. Permitted seabed lease areas were reported by both Shetland Island Council and the Crown Estate and as they differ somewhat, both are mapped in Figure 2.1.

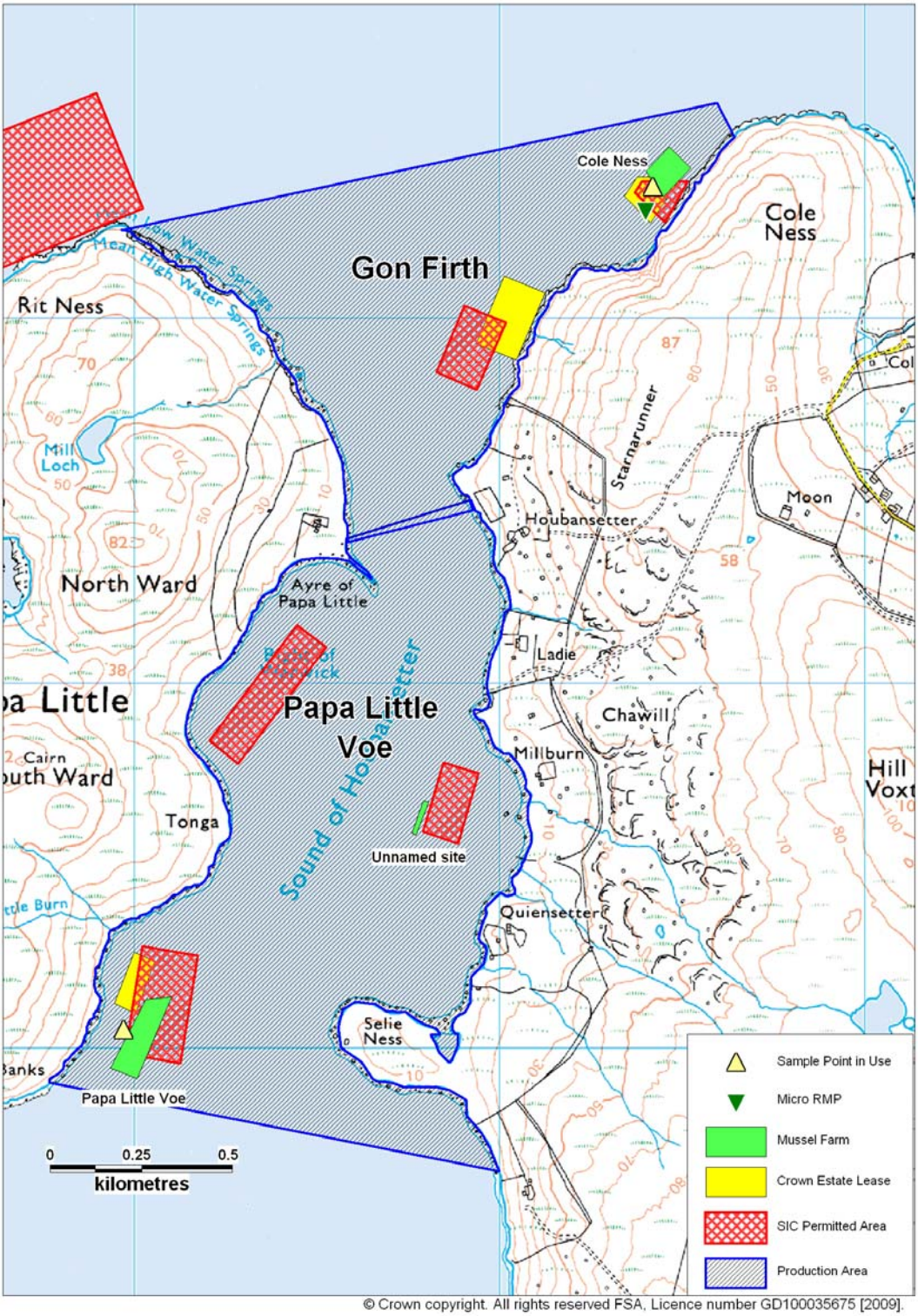


Figure 2.1 Papa Little Voe and Gon Firth fishery

3. Human Population

Information on the human population in the vicinity of the production areas was obtained from the General Register Office for Scotland.

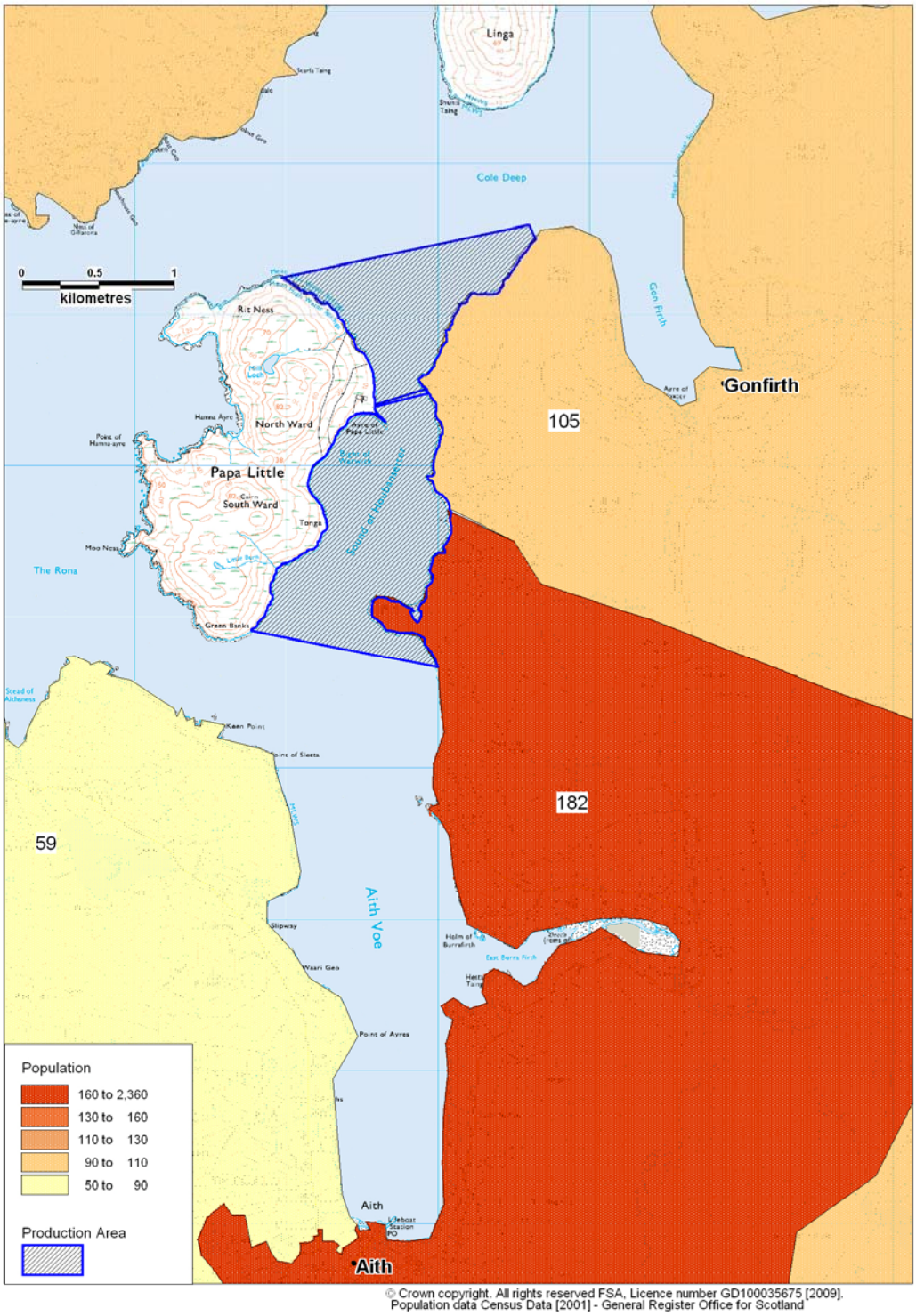


Figure 3.1 Population map for Papa Little Voe and Gonfirth

Four census output areas bordered on the Papa Little Voe and Gon Firth production areas. These are represented on the map in Figure 3.1. Population figures for these areas are listed below:

60RD000047	105
60RD000036	182
60RD000034	59
60RD000037	104

The area is sparsely populated overall and there are no significant settlements directly adjacent to the fishery. The shoreline survey identified that the dwellings on the east coast of the Papa Little Voe production area are uninhabited. The island of Papa Little is also uninhabited. There is a small settlement at Gonfirth, around a headland to the east of the fishery.

No campgrounds or other tourist facilities were noted during the shoreline survey and it is unlikely that the area is significantly impacted by tourism. According to local information, many of the old abandoned houses on the island lie beyond the extent of electric service and so are unlikely to be reoccupied, even seasonally.

The nearest settlement of significant size is Aith, located approximately 4 km south of the southernmost production area boundary. Aith had a population of 165 at the 1991 Census, comprising most of the population of the entire census output area. Any human sewage impacts to the production area would be expected to originate from discharges either from individual dwellings or from discharges associated with population centres further afield, such as those at Aith. It is anticipated that the impact from these would be relatively minor.

4. Sewage Discharges

There are no known Scottish Water discharges or SEPA consented discharges directly to the Papa Little Voe and Gon Firth: Cole Ness production areas. Community sewage discharges were reported by Scottish Water in Aith Voe, 3.8 km south of the production areas. The Aith septic tank discharges 3.8 km south of the southern end of the Papa Little Voe mussel farm. A further two community septic tanks are reported within 10 km of the production area, one in Olna Firth to the east, one in Busta Voe to the north. None of these was viewed during the shoreline survey.

Table 4.1 Discharge identified by Scottish Water

SEPA Permit	Discharge Name	NGR of discharge	Discharge Type	Level of Treatment	Consented flow m^3/day	Consented Design PE
S59A, S16B	Aith East WWPS	HU 3478 5587	EO only	8hrs storage	-	-
S59B, S16C	Aith West WWPS	HU 3457 5601	EO only	8hrs storage	-	-
S59X	Aith Septic Tank	HU 3495 5624	Continuous	Septic Tank	70	300
SD2	Voe Septic Tank	HU 403 636	Continuous	Septic Tank	80	400
-	Voe WWPS	HU 4082 6327	EO	-	-	-
WPC/N/60950(01)	Brae Septic Tank	HU 3566 6757	Continuous	Septic Tank	242	1000

SEPA have issued consents for the community discharges listed above as well as four additional private septic discharges in the area. None of these is located immediately within, or adjacent to, the Papa Little Voe or Gon Firth: Cole Ness production areas. These consents are listed in Table 4.2.

Table 4.2 Discharge consents issued by SEPA

Ref No.	NGR of discharge	Discharge Type	Discharges To	Level of Treatment	Consented flow (DWF) m3/d	Consented/ design PE
S59X	HU 3495 5624	Continuous	Aith Voe	Septic Tank	70	-
S16B	HU 3478 5587	Council ST/ PS	Aith Voe	Septic Tank	-	230
S16C	HU 3457 5601	Intermittent/PS	Aith Voe		-	120
SD2	HU 403 636	Continuous	Olna Firth	Septic Tank	80	400
WPC/N/(60950(01)	HU 3570 6750	Continuous	Busta Voe	Septic Tank	242	1000
CAR/R/1020320	HU 3623 5769	Continuous	Land	Septic Tank	-	5
CAR/R/1014050	HU 3562 5760	Continuous	Aith Voe	Septic Tank	-	5
CAR/R/1013090	HU 3522 5683	Continuous	Land	Septic Tank	-	5
CAR/R/1018415	HU 3435 6512	Continuous	Busta Voe	Pkg plant	-	5

The dwellings marked on the ordnance survey map on the east shore of the production areas appeared to be uninhabited at the time of shoreline survey. Several dwellings and a farm were identified during the shoreline survey around the headland at Cole Ness, so septic tanks may be present here but not registered. Only one outfall pipe was recorded here during the shoreline survey and it is identified in Table 4.3. The discharge flow from the pipe was very low and was not measured. A sample taken from it contained very high concentrations of faecal bacteria.

Table 4.3 Discharges observed during shoreline survey

No	NGR	Description	Sample No	*E.coli* cfu/100ml
1	HU 36175 61916	Dribbling pipe (raw sewage)	9	1.0×10^5

All discharges noted in the above tables are mapped in Figure 4.1. Human sewage inputs originate from well outside the production areas. Inputs from the community septic tanks within the wider area could potentially impact water quality at the identified fisheries, depending upon meteorological conditions and local hydrography. Of these, the discharges at Aith may be sufficiently close to the Papa Little Voe mussel farm to have an impact water quality there. The other two discharges are sufficiently far away that impact to the Cole Ness mussel farm is less likely than from the closer septic discharge observed in Gon Firth, though it still possible.

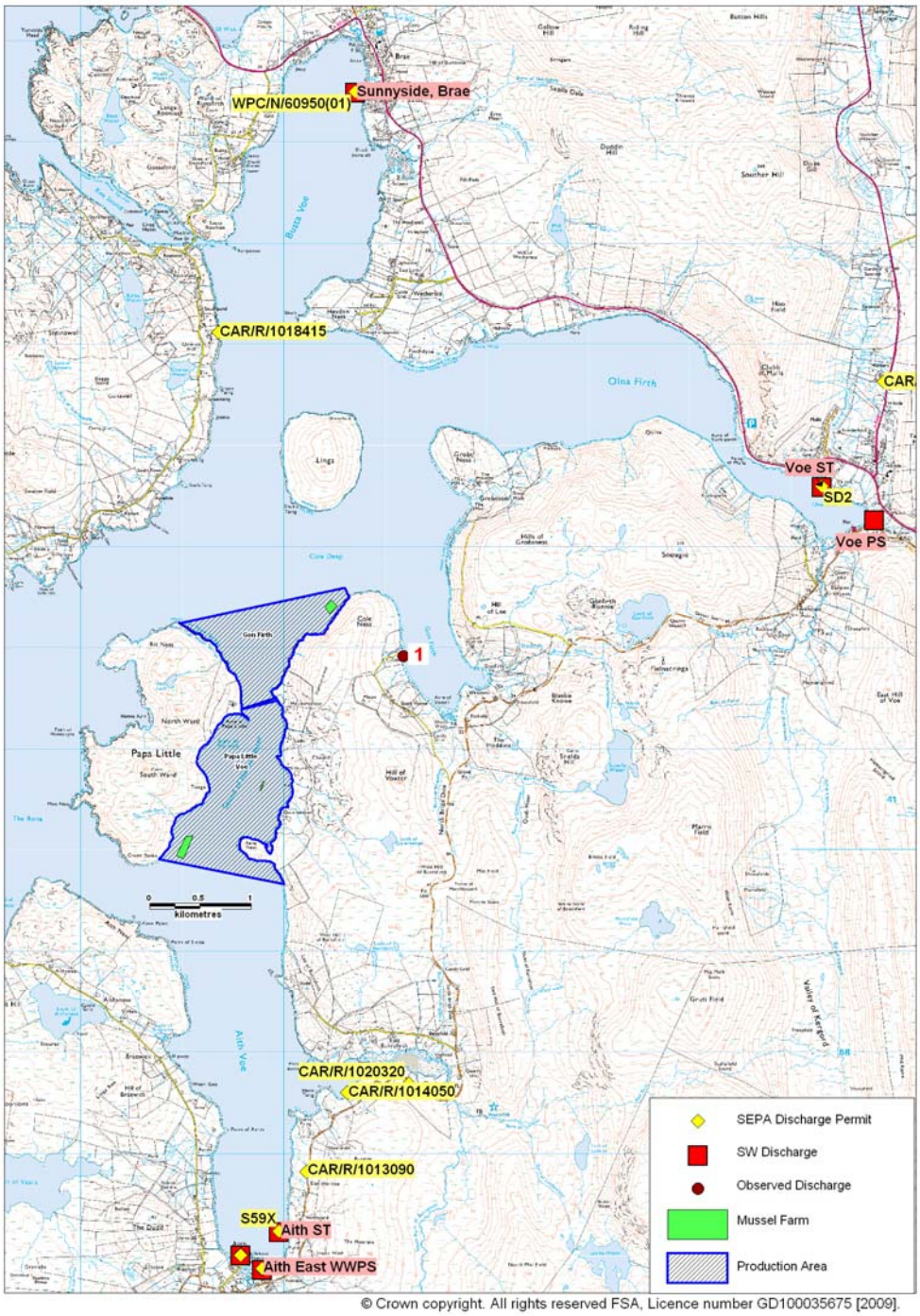


Figure 4.1 Sewage discharges near Papa Little Voe and Gon Firth

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 indicate poorly draining soils while areas shaded blue indicate more freely draining soils.

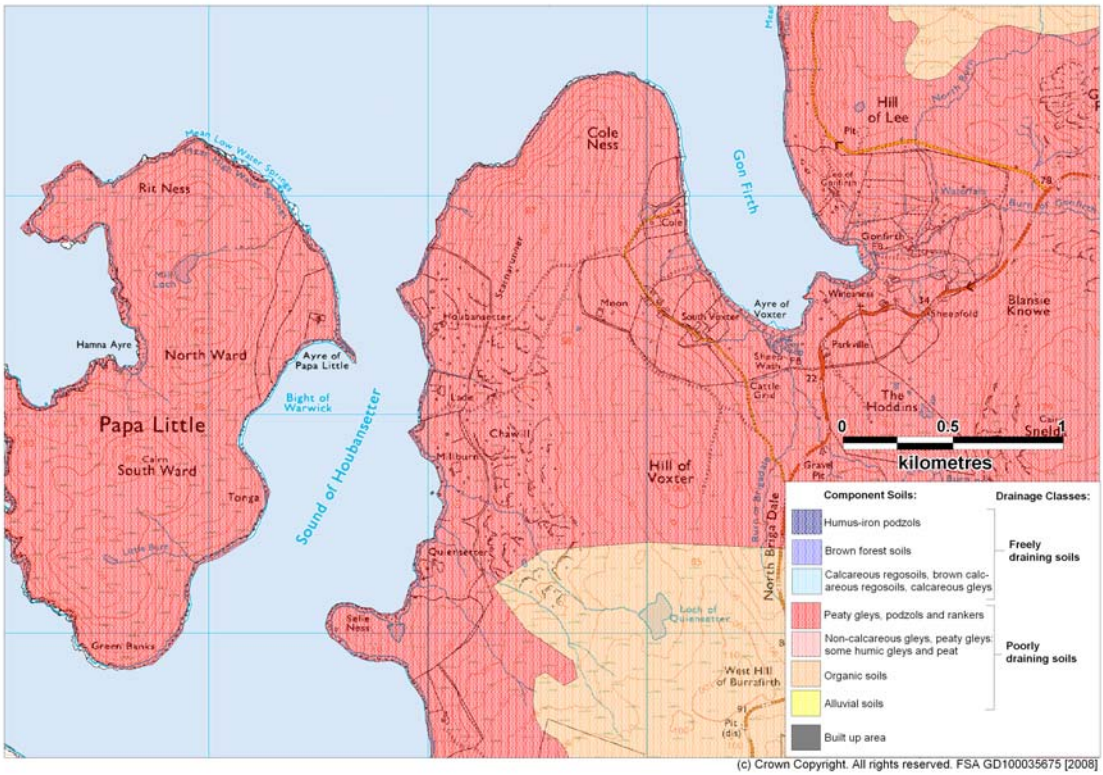


Figure 5.1 Component soils and drainage classes for Papa Little Voe and Gon Firth.

There are two types of component soils visible in this area. The most dominant is composed primarily of peaty gleys, podzols and rankers. This soil type covers the majority of the coastline surrounding Papa Little Voe and Gon Firth. The second dominant soil type is composed of organic soils and this occupies an area further inland.

The potential for runoff contaminated with *E. coli* from human and/or animal waste is high along the immediate coastline of the production areas. Soakaway systems located within these types of soils may not function efficiently, leading to contaminated runoff. The land surrounding the production areas is steeply sloping, further increasing the runoff potential.

The potential for contaminated runoff containing sheep or other animal droppings is high immediately adjacent both production areas. As there likely to be septic tanks within Gon Firth itself, any contamination from malfunctioning septic systems may impact the shellfish farm in the Gon Firth: Cole Ness production area. Impacts from livestock contaminated runoff is likely to equally impact both areas over time.

6. Land Cover

The Land Cover Map 2000 data for the area is shown in Figure 6.1 below:

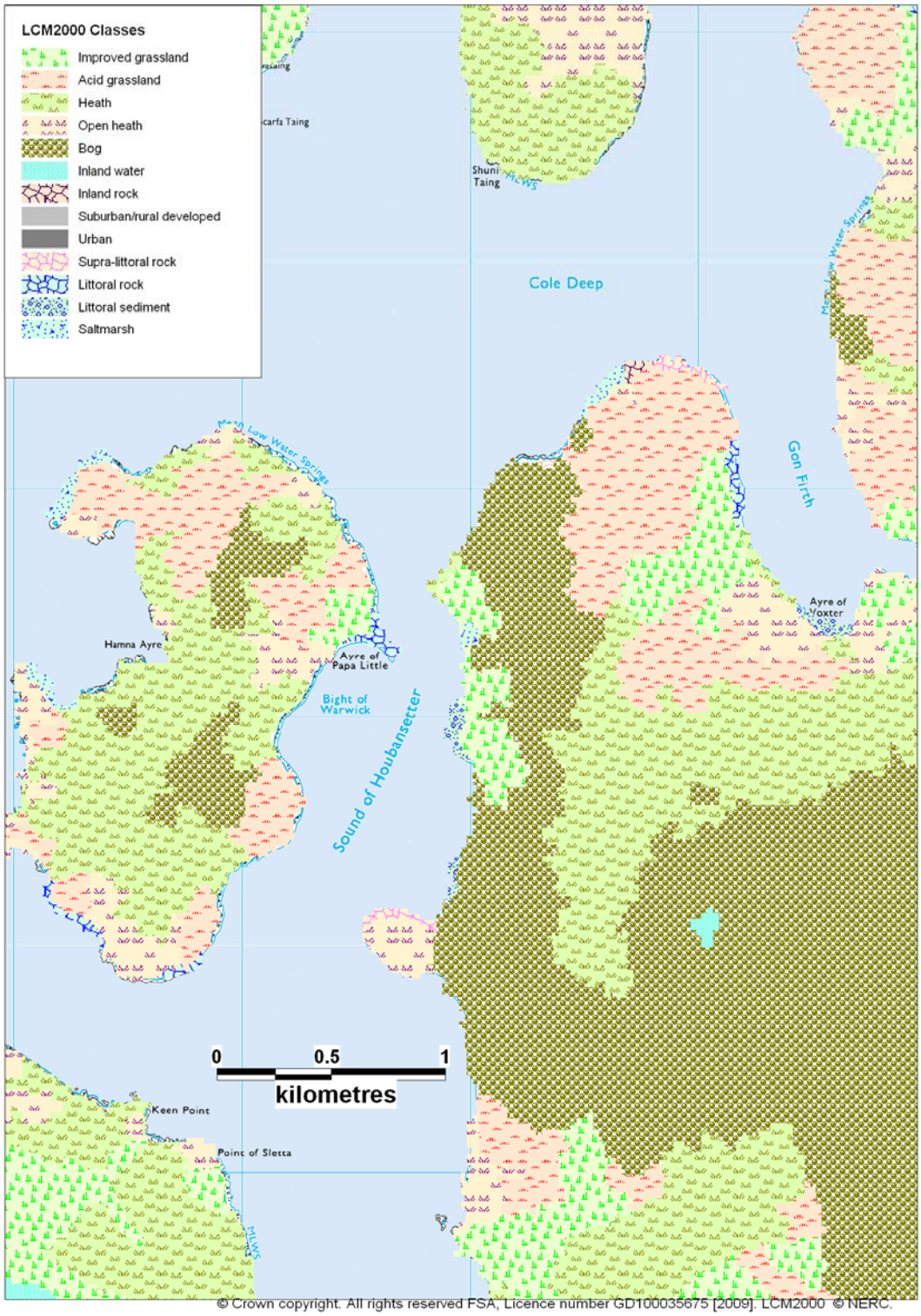


Figure 6.1 LCM2000 class land cover data for Papa Little Voe and Gon Firth

Land on the island of Papa Little to the west of the Sound of Houbansetter is predominantly heath land and bog with some acid grassland, improved grassland. The land east of the Papa Little Voe and Gon Firth: Cole Ness production areas is mainly bog and heath with some areas of improved and acid grassland. The northern end of the headland is predominantly acid grassland with some salt marsh along the coastline. Along the coastline of Gon Firth on the eastern side of the headland the land cover is improved grassland and open heath land. There are no heavily developed urban areas directly adjacent to the production areas.

The faecal coliform contribution would be expected intermediate from the improved grassland (approximately $8.3x10^{8}$ cfu km^{-2} hr^{-1}) and lowest from the other land cover types (approximately $2.5x10^{8}$ 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 being expected to be highest, at more than 100-fold, for the improved grassland.

As the majority of land surrounding the production areas is bog or unimproved grassland, with a few small patches of improved grassland, the land cover types mainly fall into the category giving the lowest contribution of faecal coliforms. However, contributions may be expected to increase following heavy rainfall. Higher potential for contaminated runoff exists from the strip of improved grassland on the east shore of the production areas and the smaller area on the west shore around Ayre of Papa Little.

7. Farm Animals

Agricultural census data was received from the Scottish Government Rural and Environment Research and Analysis Directorate (RERAD) for Aithsting and Delting parishes, which both border on the Papa Little Voe and Gon Firth production areas. The Aithsting parish covers an area of 93 km^2, extending 13 km east to west and 17 km north to south. The larger Delting parish covers an area of 148 km^2 extending 15 km east to west and 20 km north to south. 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 Aithsting and Delting Parishes, 2008

	Aithsting (93 km^2)		Delting (148 km^2)	
	Holdings	Numbers	Holdings	Numbers
Total pigs	*	*	*	*
Total poultry	15	215	14	211
Total cattle	12	302	11	369
Total sheep	72	19764	65	22644
Horses and ponies	8	37	5	27

*Data withheld on confidentiality basis

Because these figures relate to large parish areas, they are of relatively little use in assessing the potential impact of livestock contamination at the fishery. However, in general they give an idea of the total numbers of livestock over the broader area. The most significant population of farm animals in the area is of sheep, with a rough average of 275 animals per holding in Aithsting and 348 animals per holding in Delting. This equates to an average of 2 sheep per hectare, if the entire parish area is assumed to be used for sheep grazing. Cattle, poultry and horses are present, however not in substantial numbers given the size of the parish area. The only information specific to the area near the shellfishery was that obtained during the shoreline survey (see Appendix 7), which only relates to the time of the site visit on 17th June 2008. The spatial distribution and numbers of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. This information is dependent upon the point of view of the surveyor so not all animals present would have necessarily been visible.

The shoreline survey identified that sheep grazed widely around Papa Little Voe and Gon Firth. There were active farms at Cole and South Voxter on the eastern side of Cole Ness with improved pasture and evidence of recent muck spreading. Sheep were observed on the shoreline east of Cole Ness, though none were observed directly on the shoreline along the Sound of Houbansetter. There were also a horse, a pen of turkeys and chickens at Cole and several domestic ducks along the coastline. The most significant

concentrations of livestock were sheep on the western coastline of Gon Firth and southeast coastline of Papa Little Voe.

Numbers of sheep will be approximately double during May following the birth of lambs, and decrease in the autumn as they are sent to market. Therefore larger amounts of livestock droppings will be deposited during this period, though it may not impact the fishery until washed into the sea during and/or after rainfall unless deposited directly on the shoreline.

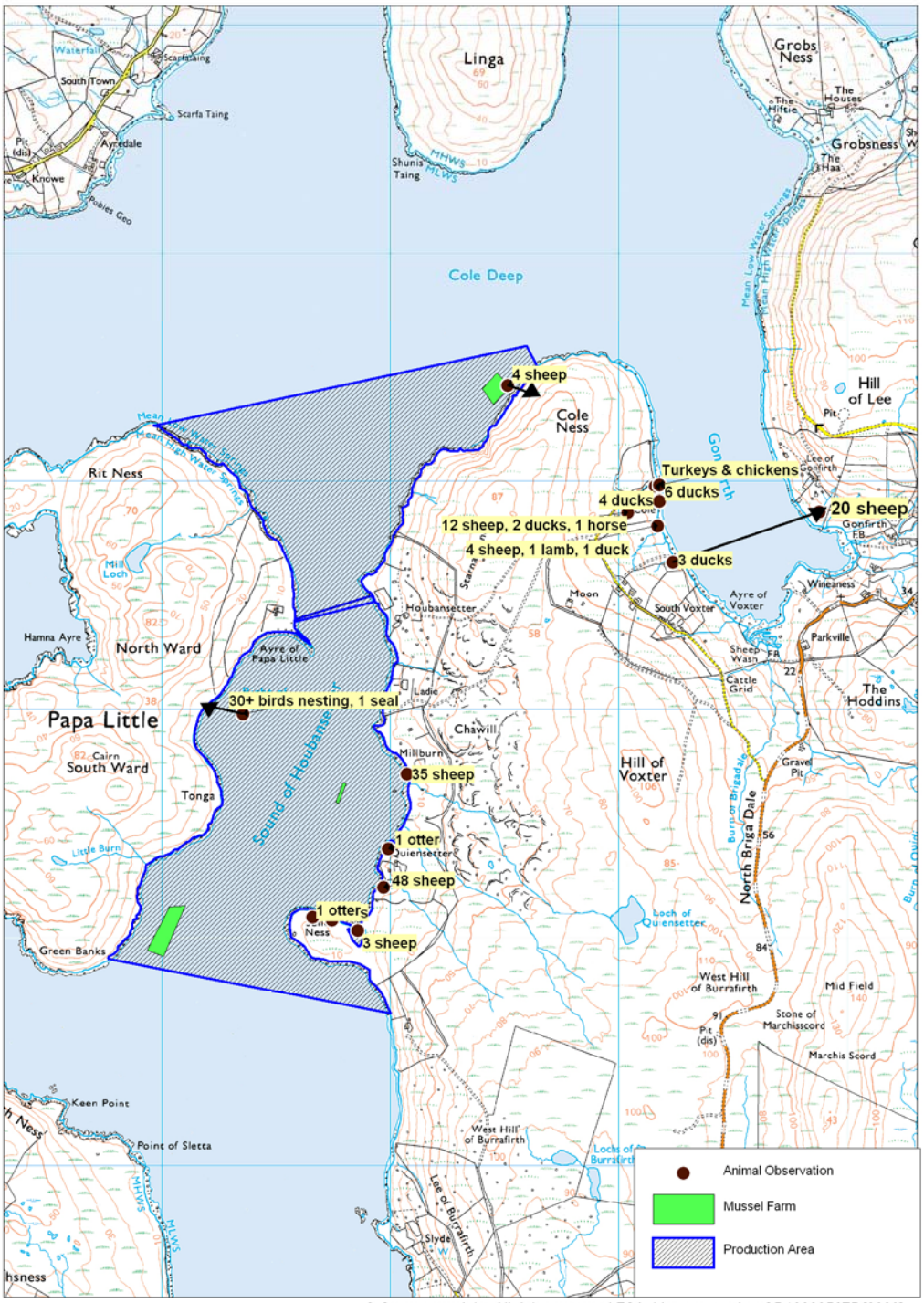


Figure 7.1 Animal observations at Papa Little Voe and Gon Firth

8. Wildlife

General information related to potential risks to water quality by wildlife can be found in Appendix 3. A number of the wildlife species present or likely to be present in and around Papa Little Voe and Gon Firth could potentially affect water quality in the vicinity of the fishery.

Seals

Common seals surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage. The Shetland-wide count in 2006 was 3021 harbour seals, though this was anticipated to be an underestimation of the total population (Sea Mammal Research Unit 2007). More detailed information from the previous count (2001) identified a haulout site for this species on the island of Papa Little.

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). A breeding colony was reported on Muckle Roe, with an estimated pup production of 23 in 2004.

A total of four seals were observed during the course of the shoreline survey, and the locations of these are mapped in Figure 7.1 on page 12. Seals will forage widely for food so it is likely they will feed near the mussel farms at some point in time. Seals have been observed lying between mussel floats in other parts of Shetland (R. Anderson, personal communication) so it is possible that there could be some direct impact to the fisheries from time to time. However, the population is fairly small in relation to the size of the area concerned and is highly mobile therefore it is likely that any impact will be limited and unpredictable.

Whales and Dolphins

A variety of cetacean species are routinely observed near Shetland. It is highly likely that whales and dolphins will be found from time to time in the area, although the larger species are less likely to pass near the shore. As with seals, these are highly mobile animals and any impact from their presence is likely to be limited in duration and unpredictable.

Birds

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 1998, 1999, 2000 and 2002 (Mitchell et al. 2004). Total counts of all species recorded within 5km of the mussel lines are presented in Table 8.1. For most species, each count represents a breeding pair of birds.

Table 8.1 Seabird counts within 5km of Papa Little Voe.

Common name	Species	Count	Method	Individuals/ Pairs
Northern Fulmar	*Fulmarus glacialis*	2837	Occupied sites	Pairs
Arctic Tern	*Sterna paradisaea*	937	Occupied nests/individuals on land	Pairs
Black Guillemot	*Cepphus grylle*	466	Individuals on land	Individuals
Herring Gull	*Larus argentatus*	347	Occupied nests/territories/individuals on land	Pairs
Common Gull	*Larus canus*	252	Occupied territories/individuals on land	Pairs
Great Black-backed Gull	*Larus marinus*	160	Occupied nests/territories/individuals on land	Pairs
Black-headed Gull	*Larus ridibundus*	139	Occupied territories/individuals on land	Pairs
Kittiwake	*Rissa tridactyla*	123	Occupied nests	Pairs
European Shag	*Phalacrocorax aristotelis*	49	Occupied nests	Pairs
Atlantic Puffin	*Fratercula arctica*	46	Individuals on land	Pairs
Great Skua	*Stercorarius skua*	23	Occupied territory	Pairs
Common Tern	*Sterna hirundo*	22	Individuals on land	Pairs
Lesser Black-backed Gull	*Larus fuscus*	10	Individuals on land	Pairs
Arctic skua	*Stercorarius parasiticus*	4	Occupied territory	Pairs

There is a high density of breeding seabirds in the general area. Some large aggregations of breeding birds have been found close to the production areas. On Papa Little a total of 363 northern fulmar pairs, 63 guillemot individuals, 111 common gull pairs, 312 herring gull pairs and 150 Arctic tern pairs were counted, together with a few birds of other species. Also, 67 northern fulmar pairs were recorded on Selie Ness. A map of total counts (assuming that a pair equates to two individuals) are presented in Figure 8.1. Nesting seabirds were noted on Papa Little Island during the course of the shoreline survey. Significant inputs from seabirds may be expected, particularly during the breeding season. Faecal material from the nesting areas will be carried to the sea via rainfall runoff, and birds will also deposit faeces directly to the sea whilst feeding or flying. Both impacts would tend to be seasonal, with a lag between direct impacts and those carried via runoff from land. Direct inputs from feeding birds will be spatially diffuse while impacts from the nesting areas will tend to be concentrated around the nests and any streams carrying runoff from the nesting areas.

Breeding occurs during the summer, after which some species disperse though others, such as gulls, remain in the area throughout the year.

The waters adjacent the central eastern coastline of Papa Little Island would be the most impacted, as this area has the highest concentration of nesting sites. The waters around Selie Ness, nearer the Papa Little Voe shellfish

farm, may also be impacted though to a lesser extent due to smaller numbers of nesting birds recorded there. The mussel farm at Gon Firth is unlikely to be significantly impacted by faecal contamination from nesting areas.

Figure 8.1 Seabird 2000 survey counts (total number of individual birds)

Waterfowl (ducks and geese) are present in Shetland at various times of the year. Eider ducks feed on mussel lines and are present in the Shetlands

throughout the year, although none was observed during the shoreline survey. Geese tend to pass through the Shetlands during migrations but do not linger in very large numbers as they do further south.

Otters

There is a significant population of European Otters (*Lutra lutra*) present in Shetland, and two were seen around Selie Ness during the shoreline survey (see Figure 7.1). Overall densities of otters are low relative to livestock and seabirds, so it is unlikely that otter faeces will be a significant source of contamination to the fishery.

Summary

The main wildlife species potentially impacting on the production areas are seabirds, of which there are large breeding colonies on Papa Little, and seals. The impacts of these on the fishery will be largely unpredictable and deposition of faeces by most wildlife is likely to be widely distributed around the area.

However, impacts from nesting seabirds may be concentrated near the nesting areas and watercourses draining those areas. Contamination carried from seabird nest sites via runoff would be most likely to impact the main farm at Papa Little Voe as it lies within 1km of two significant nesting areas. Any resulting increase in contamination levels at the fishery is most likely to occur during and immediately after the summer breeding season (May-July) and would most likely impact the northeastern end of the farm.

9. Meteorological data

The nearest weather station is located at Lerwick, approximately 22 km to the south east of the production areas, for which uninterrupted rainfall data is available for 2003-2007 inclusive. It is likely that the rainfall patterns at Lerwick are similar but not identical to those at Papa Little Voe and Gon Firth and surrounding land due to their proximity, but it is not certain whether the local topography may result in differing wind patterns (Lerwick is on the east coast, Papa Little Voe and Gon Firth are on the west coast).

This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within Papa Little Voe and Gon Firth.

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 summarise the pattern of rainfall at Lerwick by year and by month respectively.

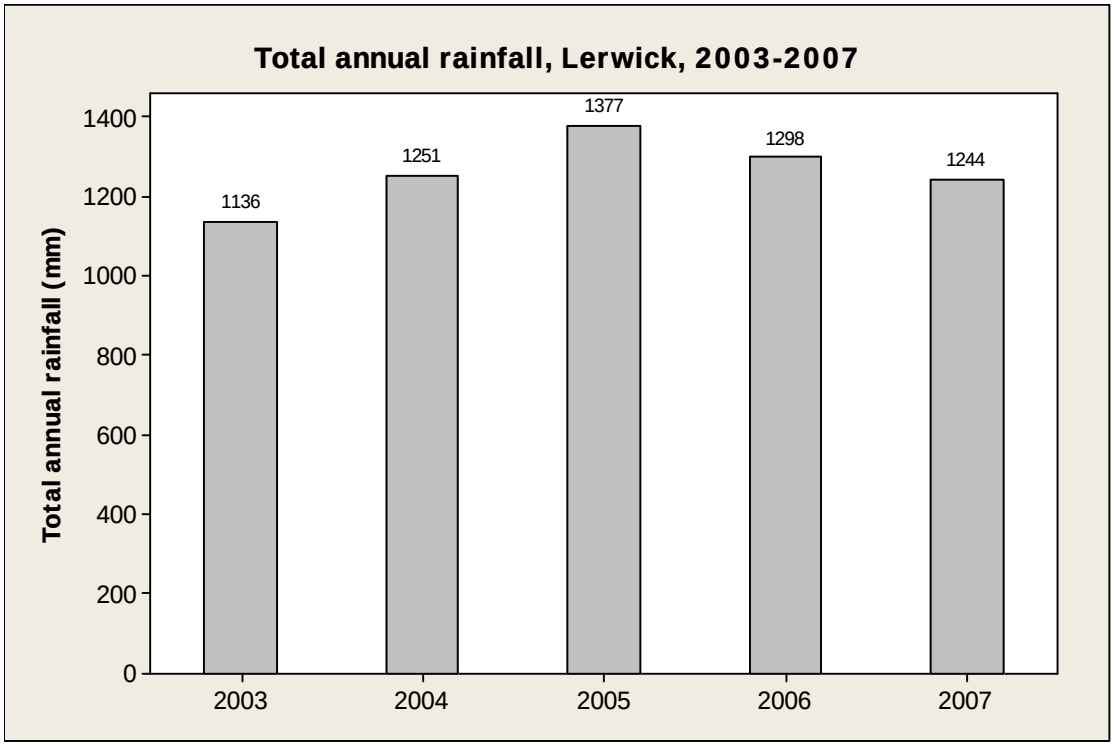


Figure 9.1 Bar chart of annual rainfall at Lerwick 2003-2007

Total rainfall over the period examined peaked in 2005, for which recorded rainfall amounts represented a 21% increase over those recorded in 2003.

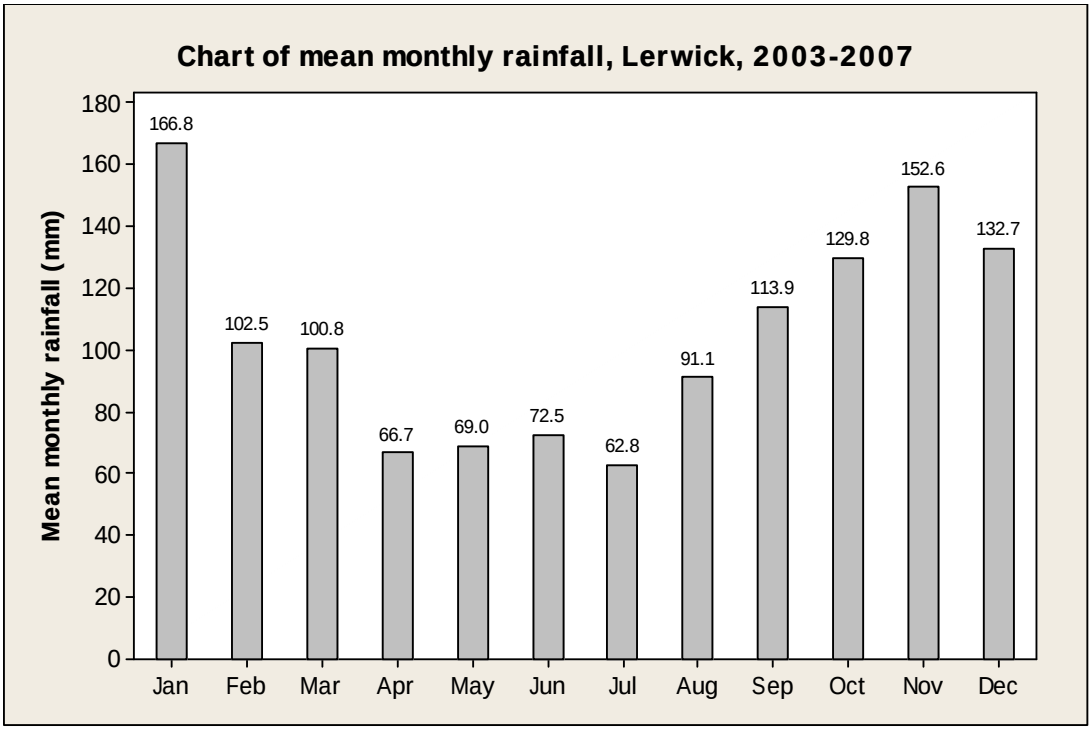


Figure 9.2 Bar chart of mean monthly rainfall at Lerwick 2003-2007

Mean monthly rainfall was highly seasonal, with the wettest months being October through January, inclusive. Rainfall increased steadily from July to November, then dropped off sharply after January. For the period considered here (2003-2007), 12.9% of days experienced no rainfall and 44.6% of days experienced rainfall of 1mm or less.

A comparison of Lerwick rainfall data with Scotland average rainfall data for the period of 1970-2000 is presented in Table 9.3. Although there were more wet days in Lerwick during the autumn, winter and spring, total rainfall in Lerwick was lower than the average for the whole of Scotland for every month of the year.

Table 9.1 Lerwick mean monthly rainfall vs Scottish average, 1970-2000*.

Month	Scotland rainfall (mm)	Lerwick rainfall (mm)	Scotland - days of rainfall >= 1mm	Lerwick - days of rainfall >= 1mm
Jan	170.5	135.4	18.6	21.3
Feb	123.4	107.8	14.8	17.8
Mar	138.5	122.3	17.3	19
Apr	86.2	74.2	13	14.4
May	79	53.6	12.2	10.1
Jun	85.1	58.6	12.7	11.3
Jul	92.1	58.5	13.3	11
Aug	107.4	78.3	14.1	12.5
Sep	139.7	115.3	15.9	17.4
Oct	162.6	131.9	17.7	19.4
Nov	165.9	152.4	17.9	21.5
Dec	169.6	150	18.2	22.2
Whole year	1520.1	1238.1	185.8	197.9

*Data © Crown Copyright, Met Office

It is anticipated that levels of rainfall dependant faecal contamination entering the production area from these sources will be higher during the autumn and winter months.

Periods of increased rainfall are generally associated with higher levels of contaminated surface water runoff. However, the catchment area for the sound and its streams is small and contamination via these sources may be present at any time of year after a rainfall.

Faecal contaminants from other sources may be independent of rainfall and so episodes of contamination may occur outside identified periods of higher rainfall, for example when livestock are present on the shoreline.

9.2 Wind

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

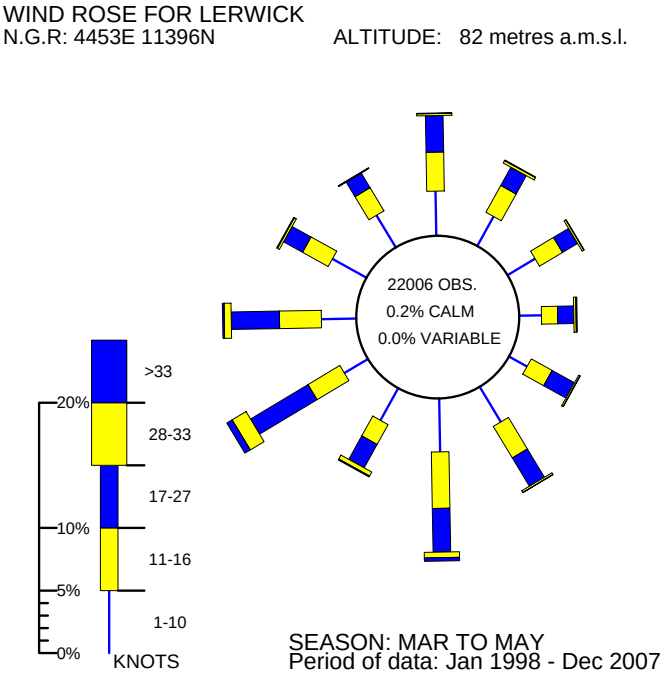


Figure 9.3 Wind rose for Lerwick (March to May)

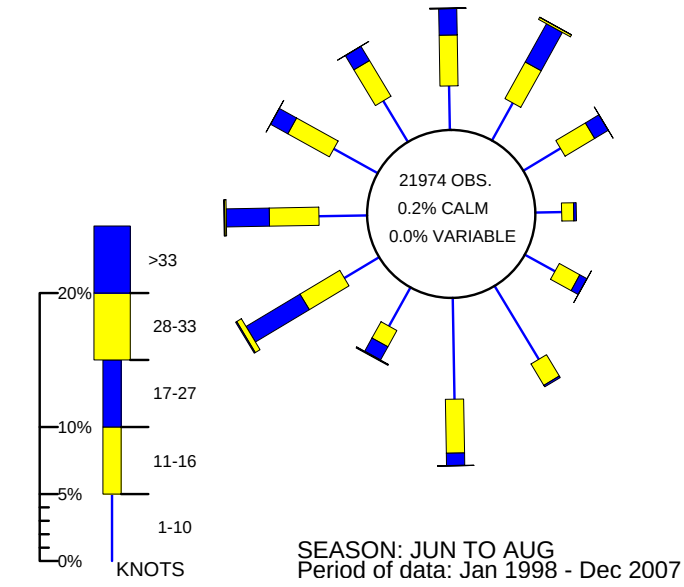


Figure 9.4 Wind rose for Lerwick (June to August)

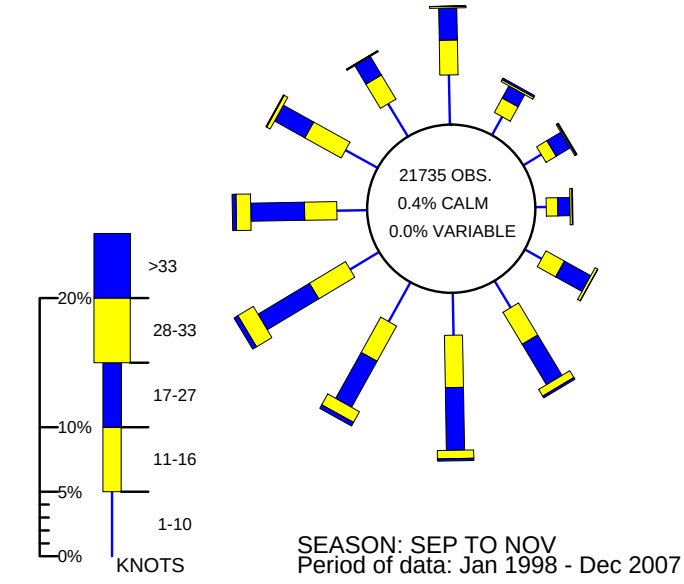


Figure 9.5 Wind rose for Lerwick (September to November)

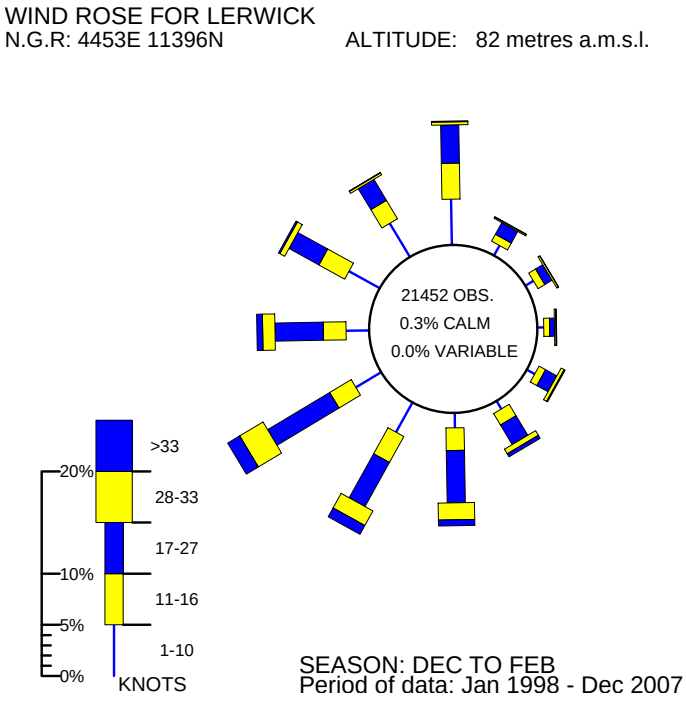


Figure 9.6 Wind rose for Lerwick (December to February)

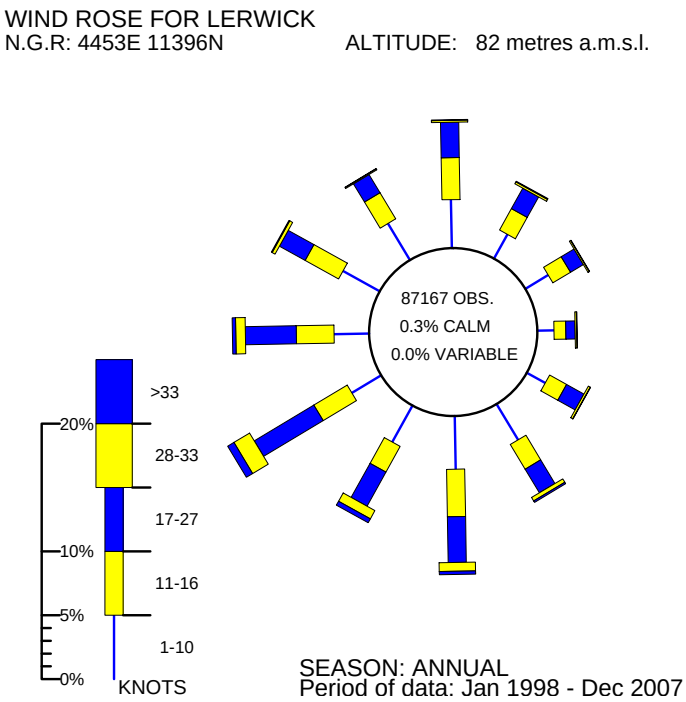


Figure 9.7 Wind rose for Lerwick (Annual)

Shetland is one of the windier 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.

Papa Little Voe and Gon Firth are part of the same water body, which has a north-south aspect, and is sheltered from the open sea from all directions by the mainland, Papa Little and Muckle Roe, which rise to over 100 m in places. The surrounding land may have the effect of channelling northerly or southerly winds up or down the Voe.

Wind effects are likely to cause significant changes in water circulation within the voe as tidally influenced movements of water are relatively weak. Winds typically drive surface water currents 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. These surface water currents create return currents which may travel along the bottom or sides of the water body depending on bathymetry. Exact effects will be difficult to predict given the complex shape of the voe.

Strong winds will increase the circulation of water and hence dilution of contamination from point sources within the voe. Wind effects are likely to be greatest with either a northerly or southerly wind which will blow along the length of the voe. High winds from the south may result in transportation of contamination from the discharge at Aith toward the mussel farm at Papa Little Voe.

10. Current and historical classification status

Papa Little Voe was first classified for the production of mussels in 2004. It was declassified in 2007 due to a lack of samples, then reclassified in 2008. The classification history is presented in Table 10.1. Throughout the first period of classification, it was classified as a seasonal A/B, although the timing of the B months has varied from year to year. In 2008 it was classified as an A. The local authority reports a sampling location of HU 3397 6005 for Papa Little Voe.

Table 10.1. Classification history, Papa Little Voe

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2004	A	A	A	A	A	A	A	B	A	A	A	A
2005	B	B	B	A	A	A	B	B	B	B	B	B
2006	A	A	A	A	A	A	B	B	A	A	A	A
2007	A	A	A									
2008				A	A	A	A	A	A	A	A	A
2009	A	A	A									

Gon Firth: Cole Ness was first classified for the production of mussels in 2006. The classification history is presented in Table 10.2. Throughout the period of classification, it was classified as a seasonal A/B, with very little variation in the timing of the B months from year to year. The nominal RMP lies within 100m of the southern end of the mussel farm as mapped during the shoreline survey and the actual sampling location identified by the local authority lies within 10 metres of it.

Table 10.2. Classification history, Gon Firth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	A	A	A	A	A	A	B	B	B	A	A	A
2007	A	A	A	A	A	A	B	B	B	B	A	A
2008	A	A	A	A	A	A	B	B	B	A	A	A
2009	A	A	A									

A map of the production areas is presented in Figure 10.1.

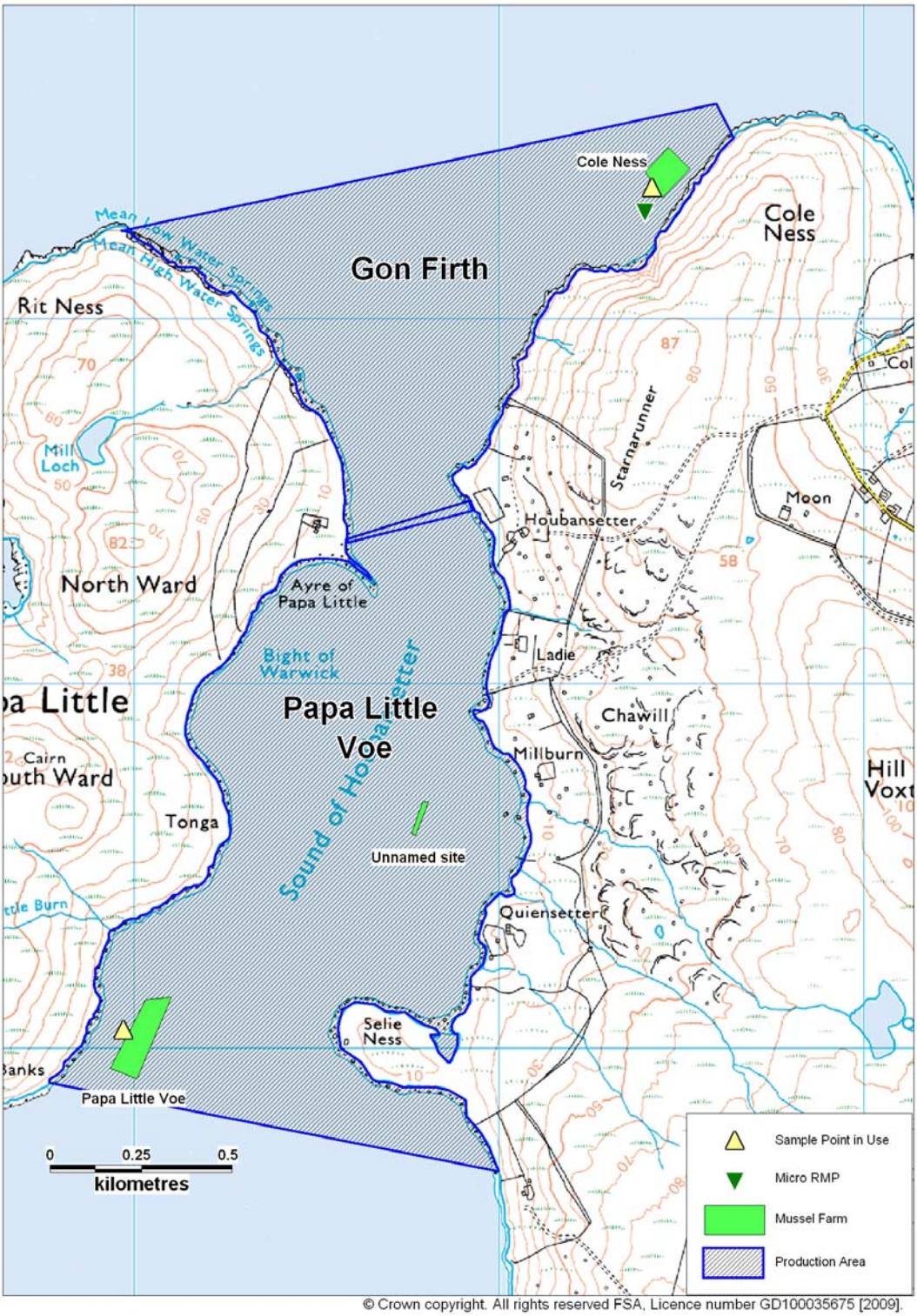


Figure 10.1 Map of current production areas

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken from Papa Little Voe and Gon Firth: Cole Ness from the beginning of 2002 up to the end of 2008 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

Two samples had an invalid test result reported and so were excluded from the analysis. No samples were excluded from the analysis on the basis of geographical or date discrepancies.

7 samples from Papa Little Voe and 14 from Gon Firth: Cole Ness had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. One sample from Gon Firth: Cole Ness had the result reported as >18000, and the result was assigned a nominal value of 36000 for statistical assessment and graphical presentation.

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

11.2 Summary of microbiological results by production area

A summary of all sampling and results by is presented in Table 11.1.

Table 11.1 Summary of historical results from Papa Little Voe and Gon Firth

Sampling Summary			
Production area	Papa Little Voe	Papa Little Voe	Gon Firth: Cole Ness
Site	Papa Little Voe	Papa Little Voe	Cole Ness
Species	Common mussels	Common mussels	Common mussels
SIN	SI-235-440-8	SI-235-440-8	SI-76-423-8
Location	HU340602	HU342603	HU354623 (RMP)
Total no of samples	42	4	34
No. 2002	3	0	0
No. 2003	9	4	0
No. 2004	13	0	1
No. 2005	8	0	11
No. 2006	2	0	11
No. 2007	7	0	11
Results Summary			
Minimum	<20	90	<20
Maximum	16000	500	>18000
Median	70	190	20
Geometric mean	93.6	199	41.1
90 percentile	1310	*	604
95 percentile	1700	*	1330
No. exceeding 230/100g	9 (21%)	1 (25%)	6 (18%)
No. exceeding 1000/100g	5 (12%)	0	2 (8%)
No. exceeding 4600/100g	1 (2%)	0	1 (3%)
No. exceeding 18000/100g	0	0	1 (3%)

* not calculated due to small sample size

11.3 Overall geographical pattern of results

The nominal RMP for Gon Firth: Cole Ness lies within a Crown Estates lease, and 60 m from the location of the nearest mussel line. According to the local authority, samples are taken from Grid Reference HU 3542 6236. Though there is currently no designated RMP for Papa Little Voe, the local authority reports a sampling location of HU 3397 6005.

A comparison of all results by production area indicates there is a significant difference between the two areas (T-test, T=-2.17, p=0.034, Appendix 5), with higher mean results at Papa Little Voe. A boxplot of results by production area is presented in Figure 11.1.

Figure 11.2 presents a map showing geometric mean result by reported sampling locations (with OS grid reference, site, number of samples and sampling dates).

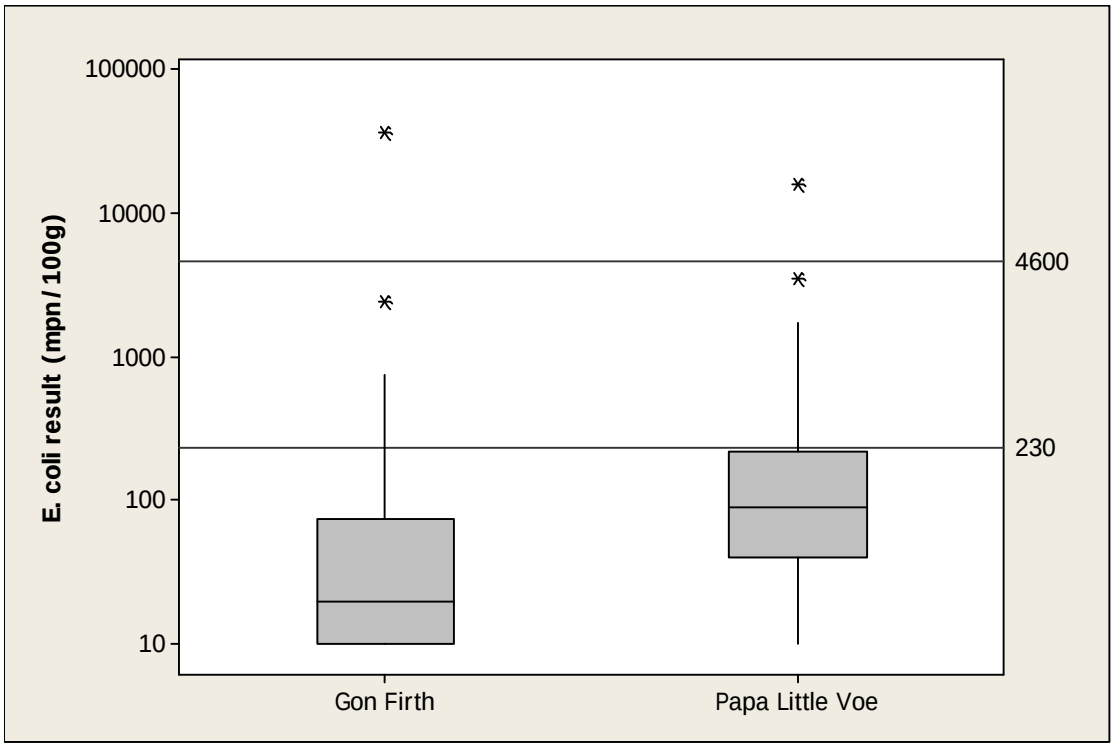


Figure 11.1. Box plot of *E. coli* result by production area

A total of 16 results of over 230 *E. coli* mpn/100g were reported from the two production areas. Proportions of these higher results occurring by production area are presented in Table 11.4

Table 11.2 Proportion of historic *E. coli* sampling results over 230 mpn/100g by production area

	Gon Firth	Papa Little Voe (both locations)
No. results > 230 mpn/100g	6 (18%)	10 (22%)
No. results < 230 mpn/100g	28 (82%)	36 (78%)

No significant difference was found in the proportion of results over 230 *E. coli* mpn/100g between the production areas (Chi-Sq = 0.205, DF = 1, P-Value = 0.651, Appendix 5).

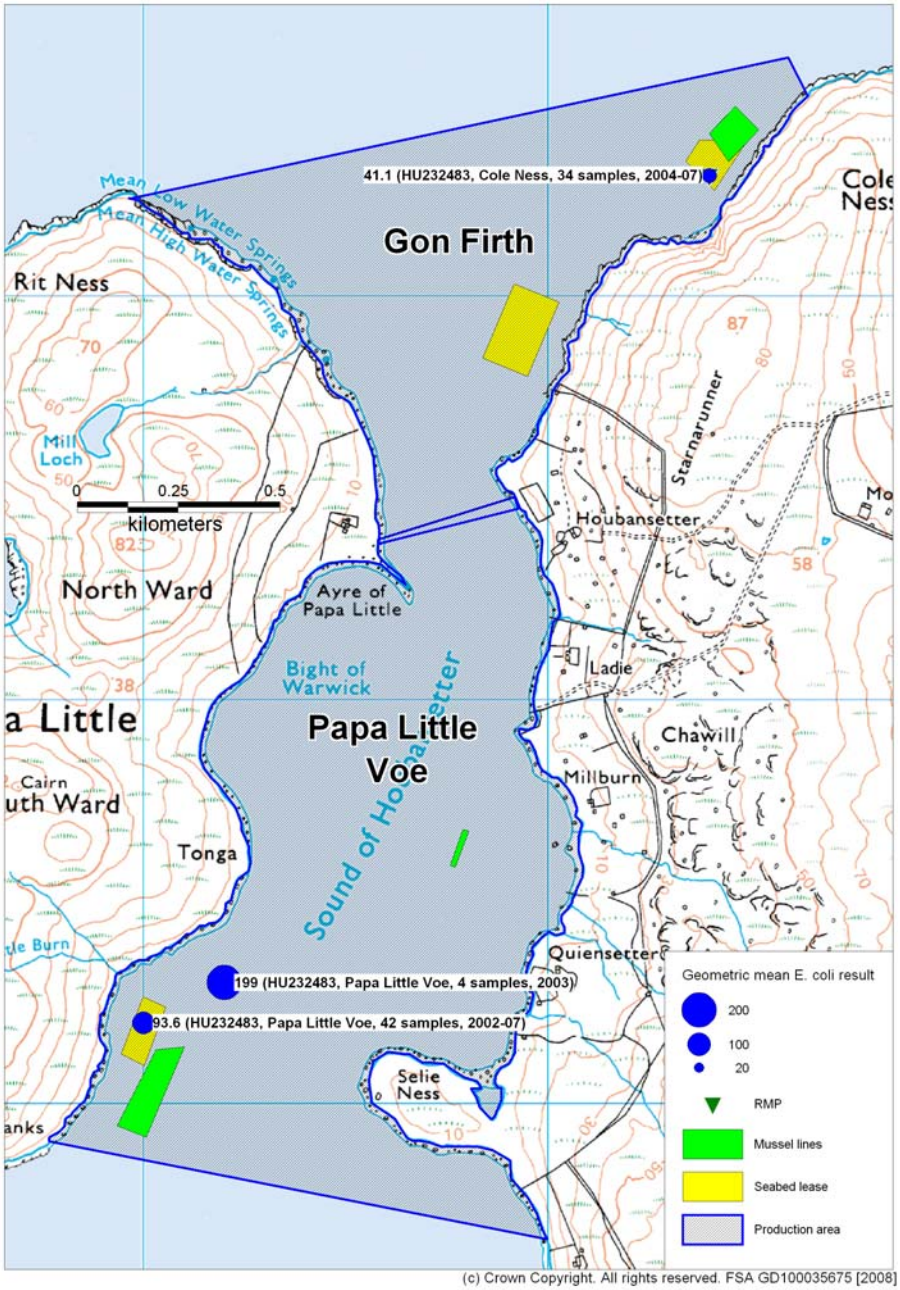


Figure 11.2 Map of sampling points and geometric mean *E. coli* result

11.4 Overall temporal pattern of results

Figures 11.2 and 11.3 present scatter plots of individual results against date for all mussel samples taken from the two production areas. Both are fitted with trend lines to help highlight any apparent underlying trends or cycles. Figure 11.3 is fitted with lines indicating the geometric mean of the previous 5 samples for each site, the current sample and the following 6 samples. Figure 11.4 is fitted with loess smoothers for each site, a regression based smoother line calculated by the Minitab statistical software.

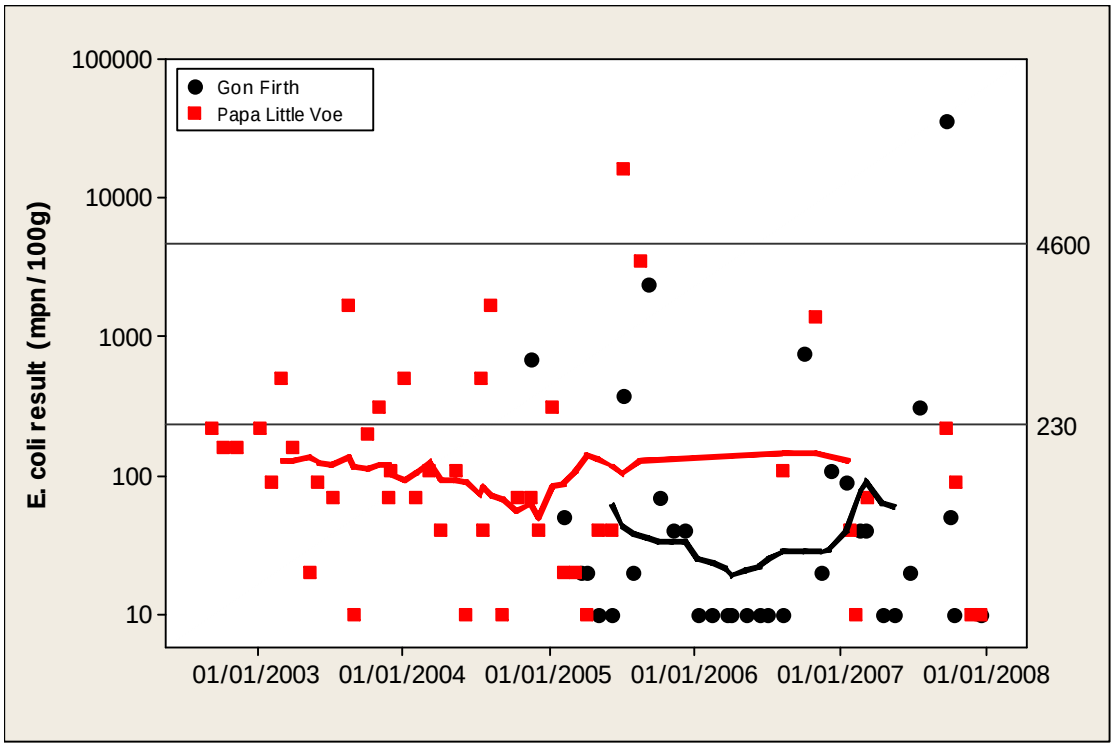


Figure 11.3 Scatterplot of *E. coli* results by date with rolling geometric mean

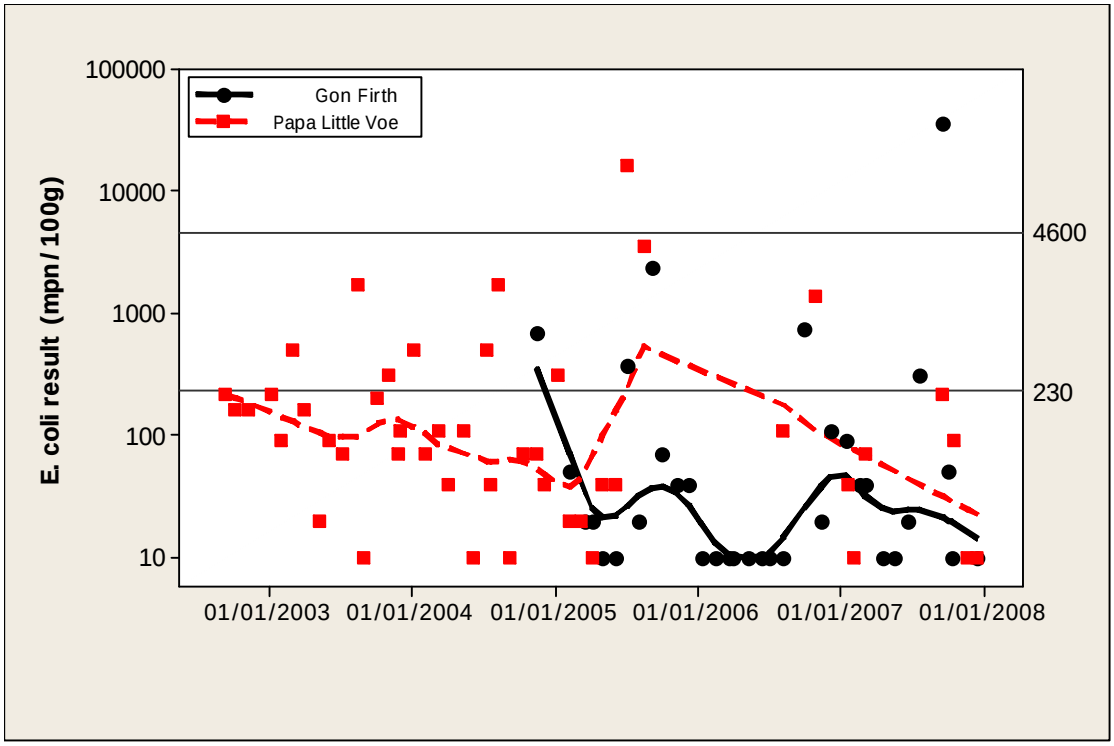


Figure 11.4 Scatterplot of *E. coli* results by date with loess smoother

No trends or cycles are apparent in Figure 11.3. Figure 11.4 suggests a peak in results for Papa Little Voe in late 2006, but this may be misleading as the timing of the apparent peak coincides with a period when no samples were taken, either side of which happened to be relatively high results. Overall, results for Papa Little Voe appear to have improved since 2003. Results for Gon Firth: Cole Ness appear to display a cyclical pattern, with a long period of very low results (<20 *E. coli*/100g) occurring over the first half of 2006. Outside of this period, results were more variable.

11.5 Seasonal pattern of results

Season dictates 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 11.5 and 11.6 present the geometric mean shellfish *E. coli* results by month (+ 2 times the standard error) for Papa Little Voe and Gon Firth: Cole Ness respectively.

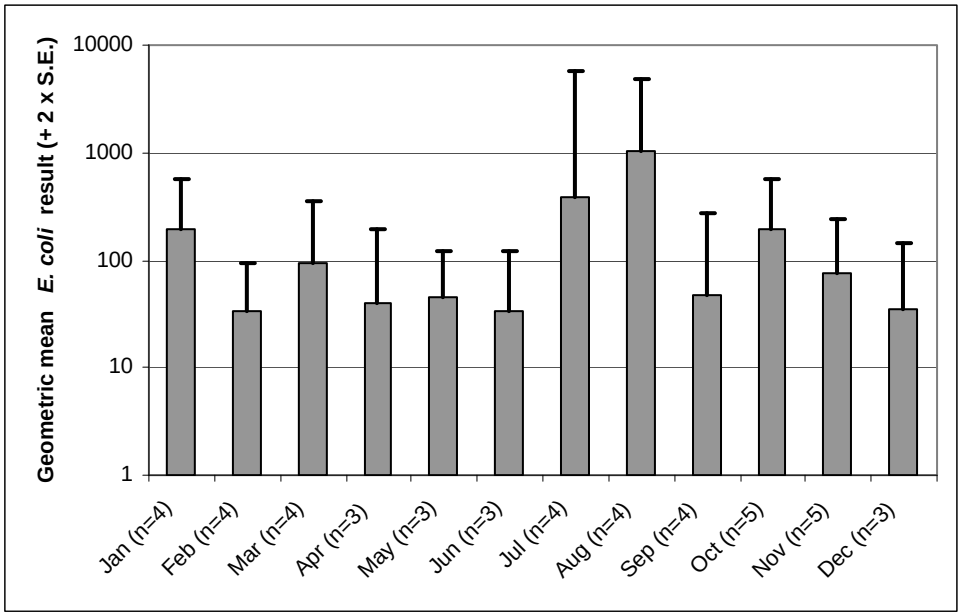


Figure 11.5 Geometric mean *E. coli* result by month (Papa Little Voe)

Highest mean results occurred in July and August, indicating summer seasonality to monitoring results here. Lowest mean results occurred during February, April, May, June, and December.

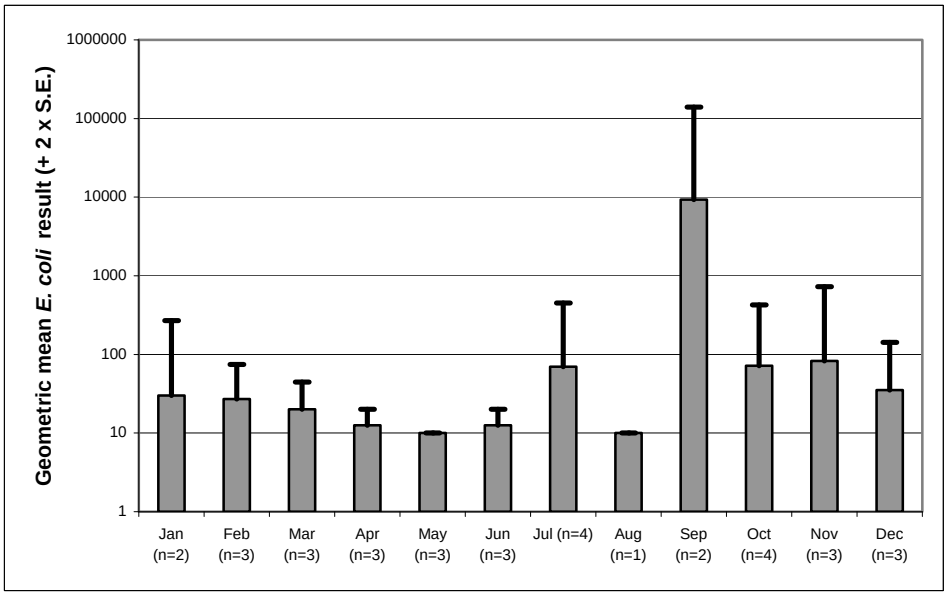


Figure 11.6 Geometric mean *E. coli* result by month (Gon Firth)

Highest mean results for occurred in September. It must be noted that sample numbers for each month are relatively low and single high results could have a disproportionate effect on the geographic means.

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

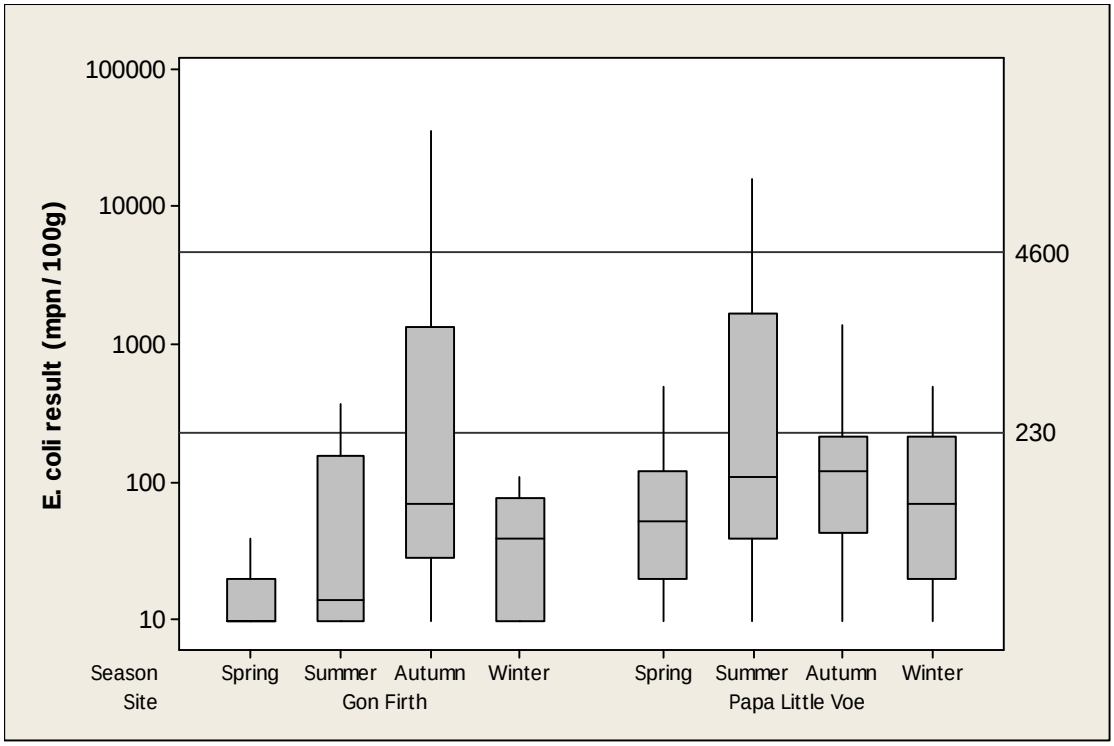


Figure 11.7 Boxplot of *E. coli* result by season

For Papa Little Voe, no significant difference was found between results by season using analysis of variance (One-way ANOVA, p=0.102, Appendix 5). However, it is clear from the box plot above that the range of results obtained in the summer was much higher, even though the means were not statistically different. For Gon Firth: Cole Ness, a significant difference was also found between results by season (One-way ANOVA, p=0.009, Appendix 5). A post ANOVA test (Tukeys comparison, Appendix 5) indicates that results for the autumn were significantly higher than those in the spring. These results indicate that the two areas may be influenced by different contaminant sources.

11.6 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, wind, sunshine and temperature can all influence the flux of faecal contamination into shellfish production areas (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. This analysis considers

11.6.1 Analysis of results by recent rainfall

The nearest weather station is Lerwick, approximately 22 km to the south east of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily rainfall in mm). Pearsons correlations were carried out for ranked *E. coli* results and ranked

rainfall in the previous 2 days at Lerwick. Figure 11.8 presents a scatterplot of *E. coli* results against rainfall for both production areas.

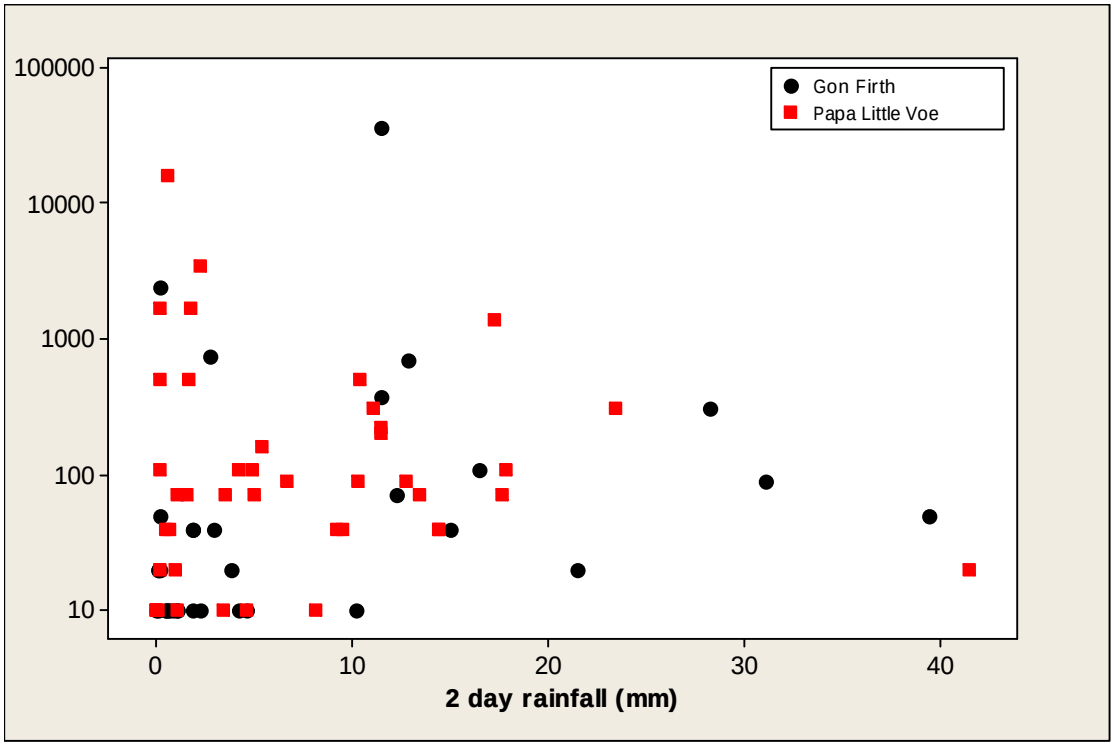


Figure 11.8 Scatterplot of *E. coli* result against rainfall in previous 2 days

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous two days for Papa Little Voe (Pearson correlation=0.172, p=0.275, Appendix 5). A significant positive correlation between the ranked *E. coli* result and the ranked rainfall in the previous two days for Gon Firth: Cole Ness (Pearson correlation=0.467, p=0.005, Appendix 5)

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.

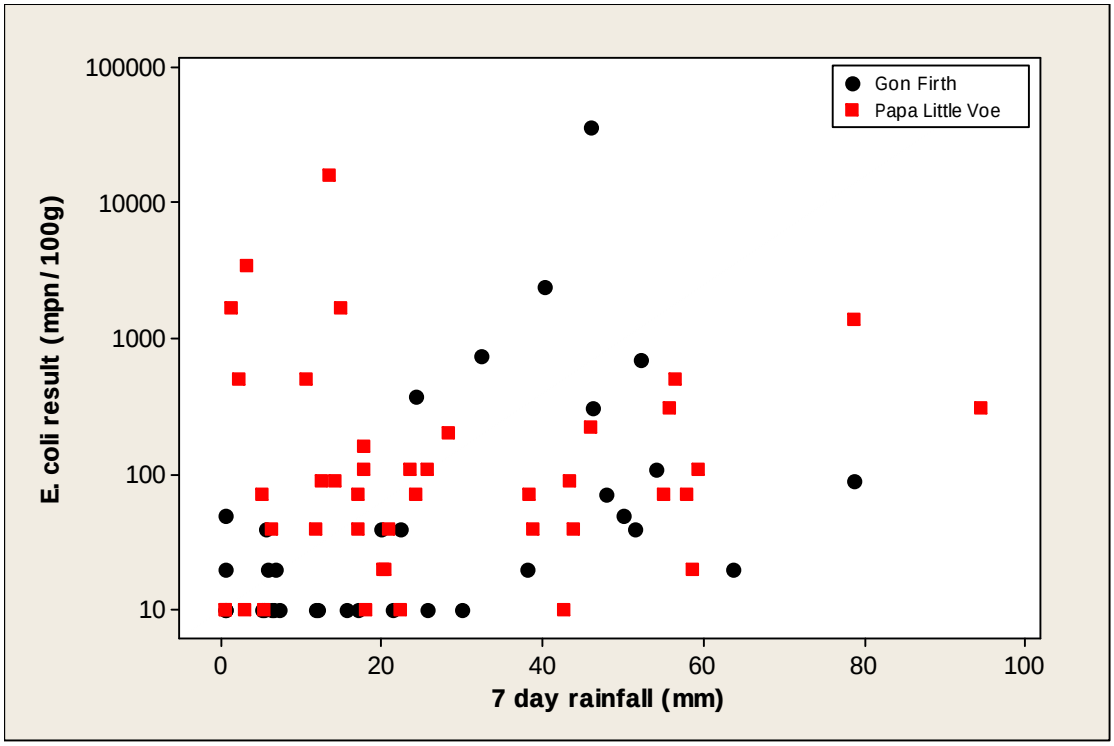


Figure 11.9 Scatterplot of *E. coli* result against rainfall in previous 7 days

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous seven days for Papa Little Voe (Pearson correlation=0.122, p=0.443, Appendix 5). A significant positive correlation between the ranked *E. coli* result and the ranked rainfall in the previous seven days for Gon Firth: Cole Ness (Pearson correlation=0.592, p=0.000, Appendix 5).

11.6.2 Analysis of results by tide 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 and wildlife into the voe. Figure 11.12 presents a scatterplot of *E. coli* results by predicted height of the previous high water at Scalloway (predictions from TotalTide tidal prediction software in meters above chart datum). It should be noted that local meteorological conditions such as wind and barometric pressure can influence the height of tides and this is not taken into account.

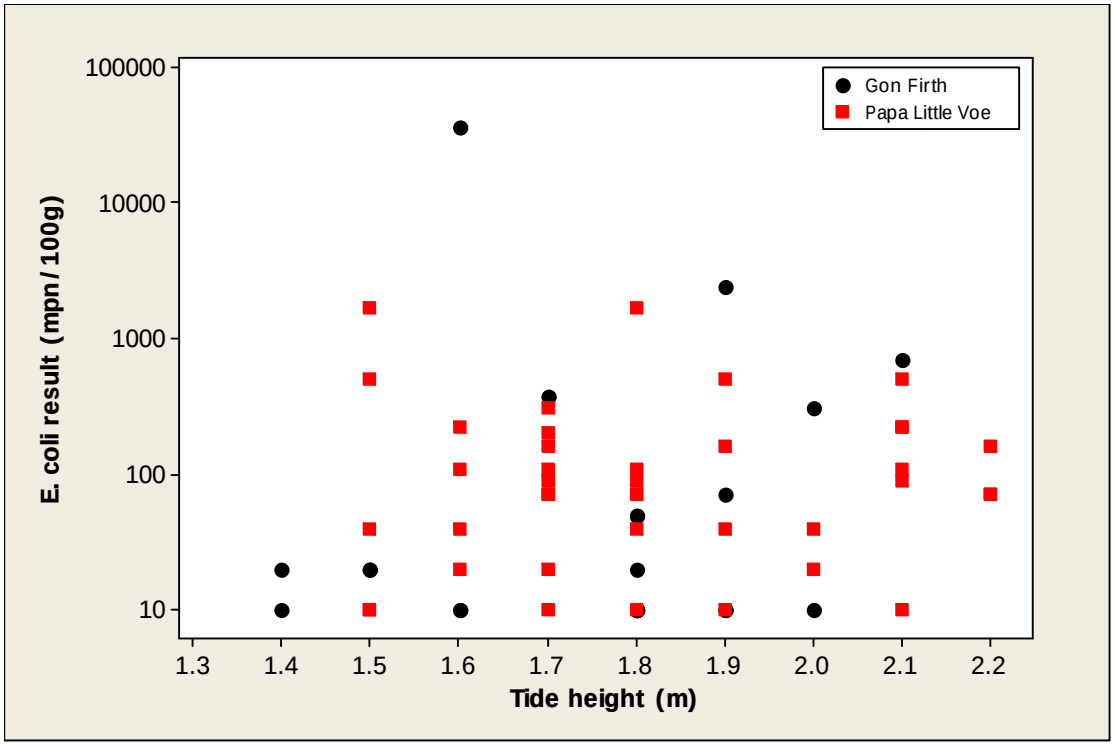


Figure 11.10 Scatterplot of *E. coli* result by tide height

The coefficient of determination indicates that there was no relationship between the *E. coli* result and predicted height of the previous tide for Papa Little Voe (Adjusted R-sq=0.0%, p=0.759, Appendix 5) or for Gon Firth: Cole Ness (Adjusted R-sq=0.0%, p=0.470, Appendix 5).

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 mussels can respond within an hour or less to changes in *E. coli* levels in water (Marino et al. 2004), tidal state at time of sampling (hours post high water) was compared with *E. coli* results.

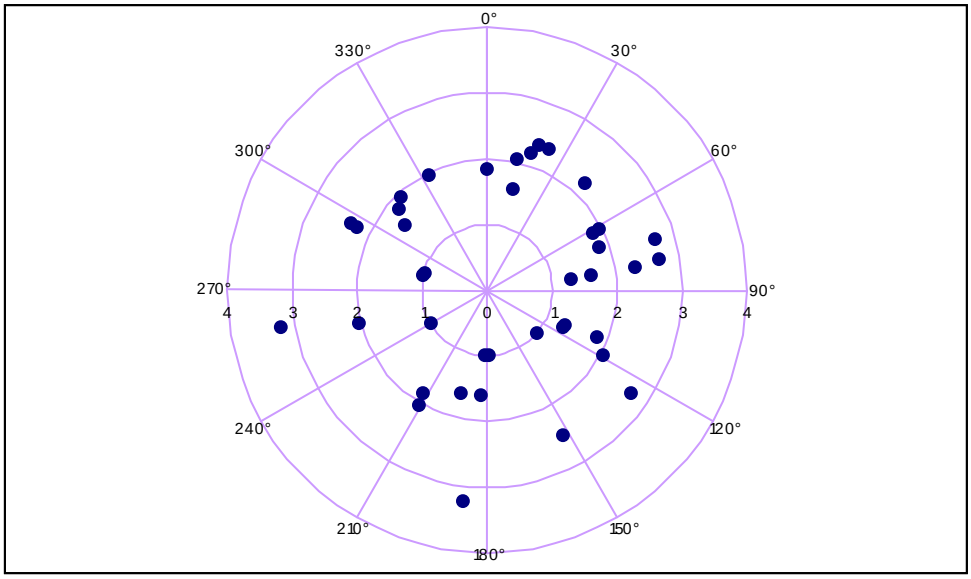


Figure 11.11 Polar plot of log10 *E. coli* result by tidal state (Papa Little Voe). High water is at 0 degrees, low water is at 180 degrees.

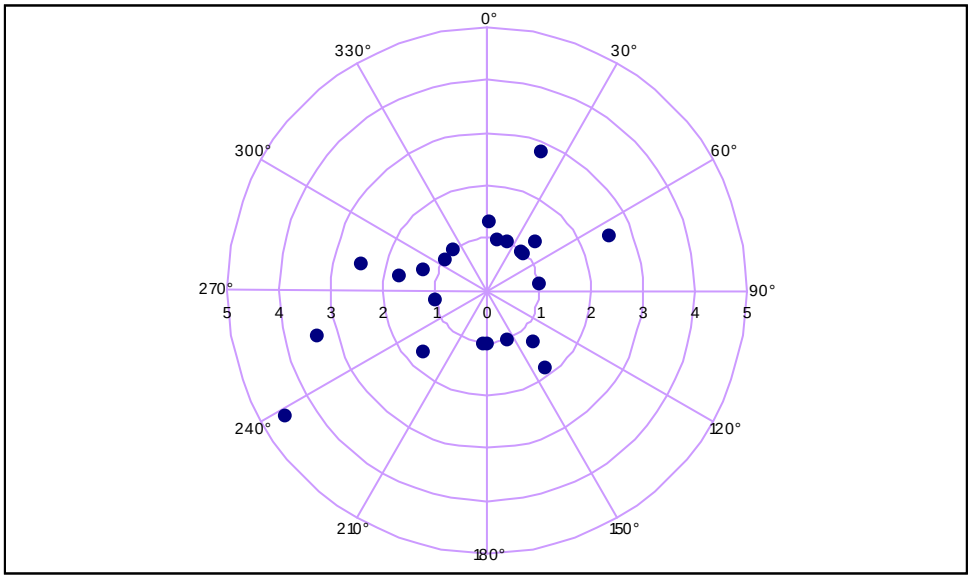


Figure 11.12 Polar plot of log10 *E. coli* result by tidal state (Gon Firth) High water is at 0 degrees, low water is at 180 degrees.

No significant correlation was found between tidal state and *E. coli* result at either Papa Little Voe (circular-linear correlation, r=0.175, p=0.323, Appendix 5) or Gon Firth: Cole Ness (circular-linear correlation, r=0.306, p=0.153, Appendix 5).

Overall, neither tide size nor tidal state appears to have an influence on result. Tidal currents in the area are relatively weak and there is little foreshore in the area to wash accumulate faecal matter. Larger tides usually result in increased particle transport distances, however this increase may be insignificant in areas with little current.

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 and 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 factors such as seasonal differences in livestock grazing patterns.

A record of water temperature at time of sampling was only available for a one sample, so no investigation of the relationship between water temperature and *E. coli* result could be carried out.

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns in the production areas. Mean wind direction for the 7 days prior to each sample being collected was calculated from wind data recorded at the Lerwick weather station, and mean result by mean wind direction in the previous 7 days is plotted in Figure 11.13 for Papa Little Voe, and 11.14 for Gon Firth: Cole Ness.

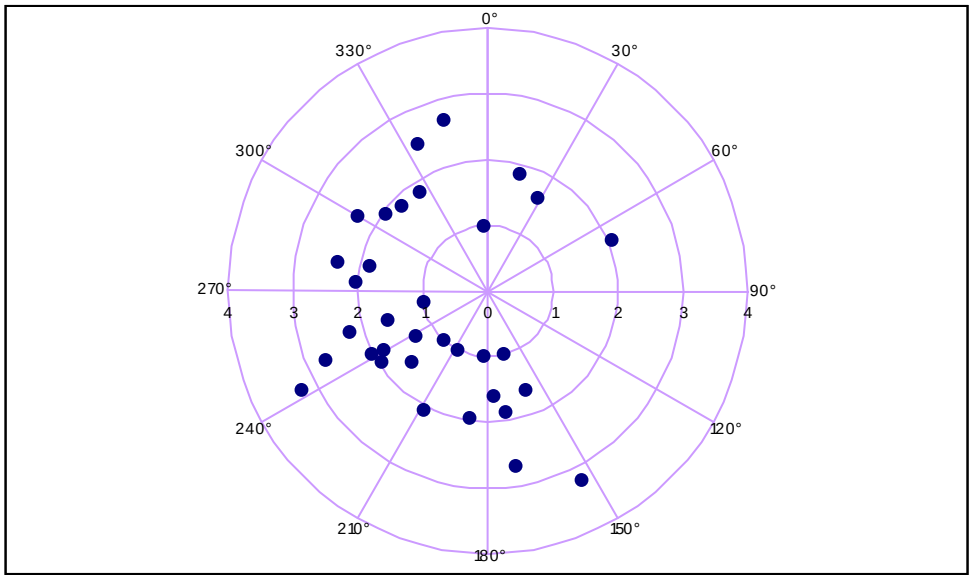


Figure 11.13 Polar plot of log10 *E. coli* result *E. coli* result by wind direction (Papa Little Voe)

No significant correlation was found between wind direction at Lerwick and *E. coli* result for Papa Little Voe (circular-linear correlation, r=0.123, p=0.626, Appendix 5).

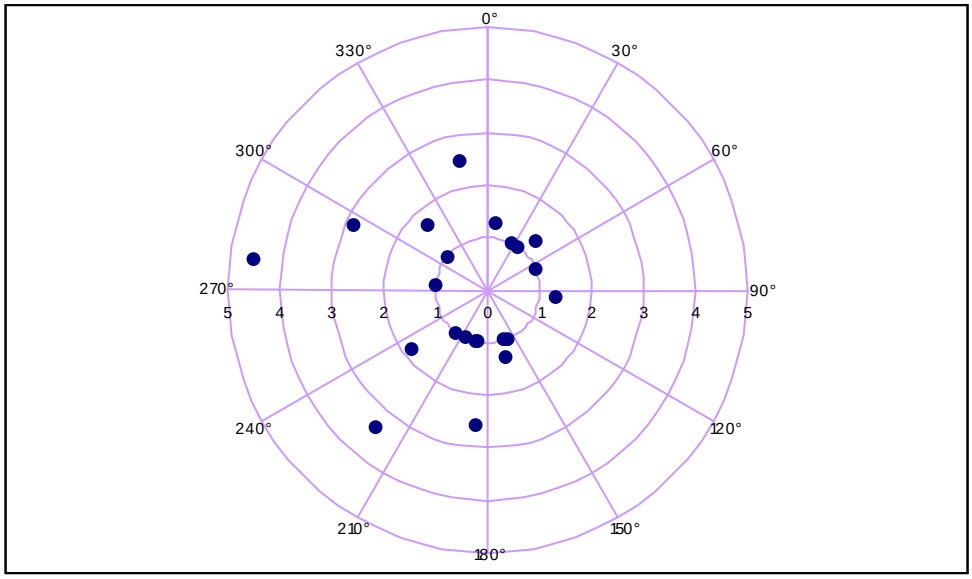


Figure 11.14 Polar plot of log10 *E. coli* result *E. coli* result by wind direction (Gon Firth)

A significant correlation was found between wind direction and *E. coli* result for Gon Firth: Cole Ness (circular-linear correlation, r=0.476, p=0.012, Appendix 5). Higher results occurred when the wind was blowing from the northwest. It must also be noted that sample numbers were relatively low and wind speeds and variability of wind direction not taken into consideration.

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

Two results over 4600 *E. coli* mpn/100g were reported. One originated from Papa Little Voe and one from Gon Firth: Cole Ness. The high result from Papa Little Voe occurred during July 2005 following a relatively dry period (quartile 1 for 2 day rainfall, and quartile 2 for 7 day rainfall). The one from Gon Firth: Cole Ness arose during September 2007 following a wet week (the highest quartile for both 2 and 7 day rainfall) on a mid sized tide just after low water.

Table 11.3 Historic *E. coli* sampling results over 4600 mpn/100g

Collection Date	*E. coli* result (mpn/100g)	Location Sampled	Area	2 day rain quartile	7 day rain quartile	7 day wind direction	Previous tide height	Time since high water
04/07/2005	16000	HU340602	Papa Little Voe	Q1	Q2	*	*	*
19/09/2007	>18000	HU354623	Gon Firth	Q4	Q4	278º	1.6 m	08:17

* Time of collection not recorded

11.8 Summary and conclusions

Mean results were significantly higher within the Papa Little Voe production area compared to Gon Firth: Cole Ness. There was no significant difference between the areas in the proportion of results over 230 *E. coli* mpn/100g.

A statistically significant seasonal effect was found for Gon Firth: Cole Ness only, where results for the autumn were significantly higher than those in the spring.

No relationship was found between *E. coli* results and levels of recent rainfall for Papa Little Voe. For Gon Firth: Cole Ness, positive relationships were found between *E. coli* result and rainfall in the previous two and seven days.

No significant influence of either tide size (i.e. spring or neap) or tidal state (i.e. high/low/ebb/flood) was found. This may be expected as tidal currents in the area are relatively weak.

A correlation was found between wind direction and magnitude of *E. coli* results for Gon Firth: Cole Ness only, with highest mean results occurring when the wind was blowing from the northwest quarter. As the sample size was small for this type of analysis, it is difficult to draw firm conclusions from this result. There are no apparent point sources of contamination in this direction from the shellfish farm.

The two highest individual results occurred in the late summer/early autumn following different rainfall conditions, one in each production area. It is difficult to say whether these individual results are indicative of any overall pattern.

It should be noted that the relatively small amount of data available 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 production area as they have both held seasonal classifications for the last three years.

12. Designated Shellfish Growing Waters Data

Papa Little Voe and Gon Firth: Cole Ness do not lie within designated shellfish growing waters.

13. River Flow

There are no river gauging stations on rivers or burns along the Papa Little Voe and Gon Firth coastline.

The following rivers and streams were measured and sampled during the shoreline survey. These represented the largest freshwater inputs into the Papa Little Voe and Gon Firth: Cole Ness area at the time of shoreline survey.

Table 13.1 Stream loadings at Papa Little Voe and Gon Firth

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Discharge (m^3/day)	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	HU 35102 60700	Stream	0.33	0.05	0.4	570	30	1.7×10^8
2	HU 35163 60618	Stream	0.85	0.3	0.1	2203	30	6.6×10^8
3	HU 35068 60469	Stream	0.5	0.3	0.1	1296	20	2.6×10^8
4	HU 34974 60198	Stream	0.4	0.08	0.1	276	10	2.8×10^7
5	HU 34972 60033	Stream	0.16	0.05	0.06	41	<1	$<4.1 \times 10^5$
6	HU 36158 61980	Stream	0.1	0.4	0.16	553	210	1.2×10^9
7	HU 36169 61808	Stream	0.25	0.3	0.03	194	40	7.8×10^7
8	HU 36205 61672	Stream	0.75	0.4	0.06	1555	40	6.2×10^8
9	HU 36234 61648	Stream	0.5	0.01	0.08	35	<1	$<3.5 \times 10^5$
10	HU 33921 60318	Stream	0.4	0.06	0.07	145	9	1.3×10^7

In addition to the ten streams listed, several others were also observed but were too small to measure and sample at the time. There were two main areas where a number of small streams discharged to the sea. One was on the east shore of the Papa Little Voe production area, the other was to Gon Firth, on the other side of Cole Ness, outside of both production areas. No streams discharging to the Gon Firth: Cole Ness production area were measured, although two very small watercourses can be seen on the ordnance survey map.

Despite draining areas of pasture where high densities of sheep were present, *E. coli* levels and associated loadings were generally fairly low (maximum 210 cfu/100ml, all but one < 50 cfu/100ml). The eastern side of the Papa Little Voe production area, and the new mussel line in place there, would be more highly impacted by these sources than the established farm on the west side.

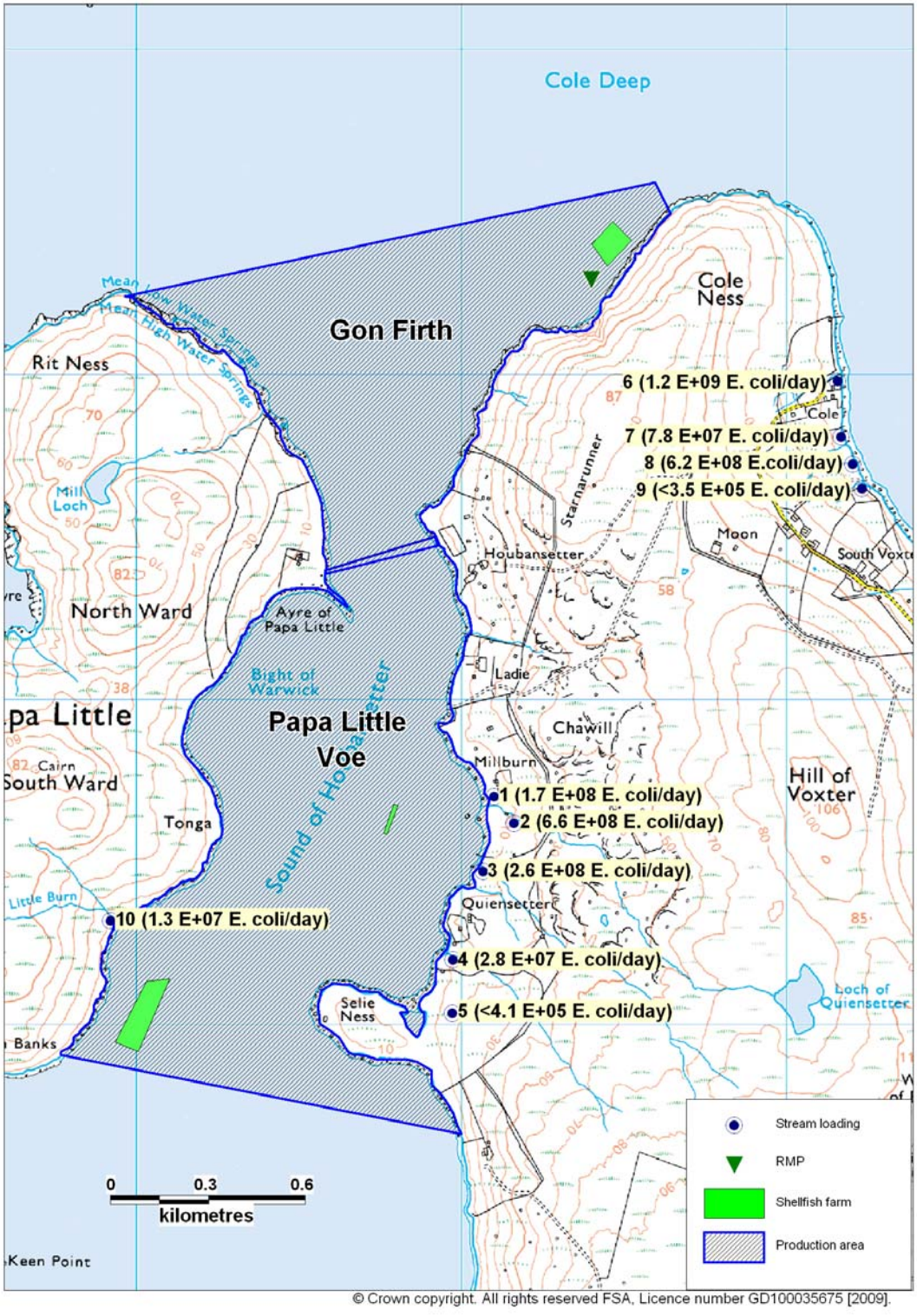


Figure 13.1 Significant streams and loadings at Papa Little Voe and Gon Firth

14. Bathymetry and Hydrodynamics

This site was chosen for assessment using full hydrodynamic modelling. It is recommended that the Hydrography Methods Document be consulted for background information on the methods applied.

14.1 Physical Characteristics

The Papa Little Voe is located on the north island of Shetland and comprises the Sound of Houbansetter located between the main shore and the island of Papa Little and also some neighbouring waters. The area is contained within a larger inlet containing other Voes, some with bivalve production areas (Figure 14.1). No separate entry for this water body exists in the Sea Loch Catalogue (SLC) (Edwards and Sharples, 1986) and basic information is therefore obtained from admiralty charts or with reference to the nearby Aith Voe that is contained within the SLC. The Sound of Houbansetter is approximately is 3.0 km long with a maximum depth of 26m (relative to Lowest Astronomical Tide - LAT). A sill exists at the northern entrance to the sound with a maximum depth of 9m (LAT) and an average depth of approximately 4m. The sill also corresponds with a constriction in the width of the water body. Average depth at low water is estimated to be 15m.

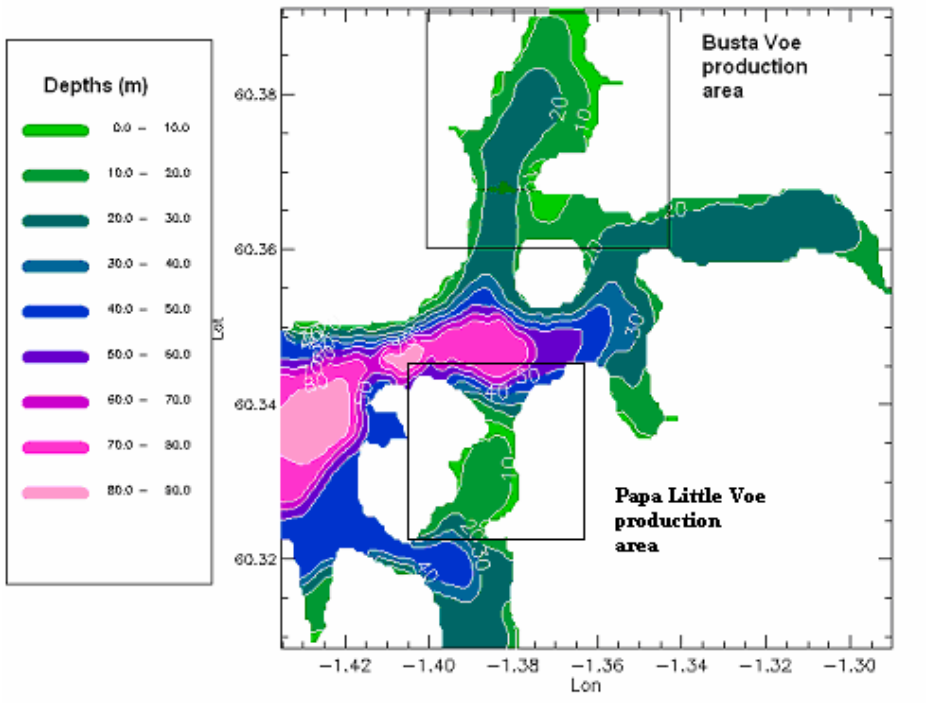


Figure 14.1 Complete model domain with depths (m).

Tides

Based on the tidal range given in the SLC for Busta and Aith Voes, spring tidal range is assumed to be 1.7m. Based on the model simulations, tidal currents are predicted to be very low (Figure 14.2) even over the sills and at constrictions.

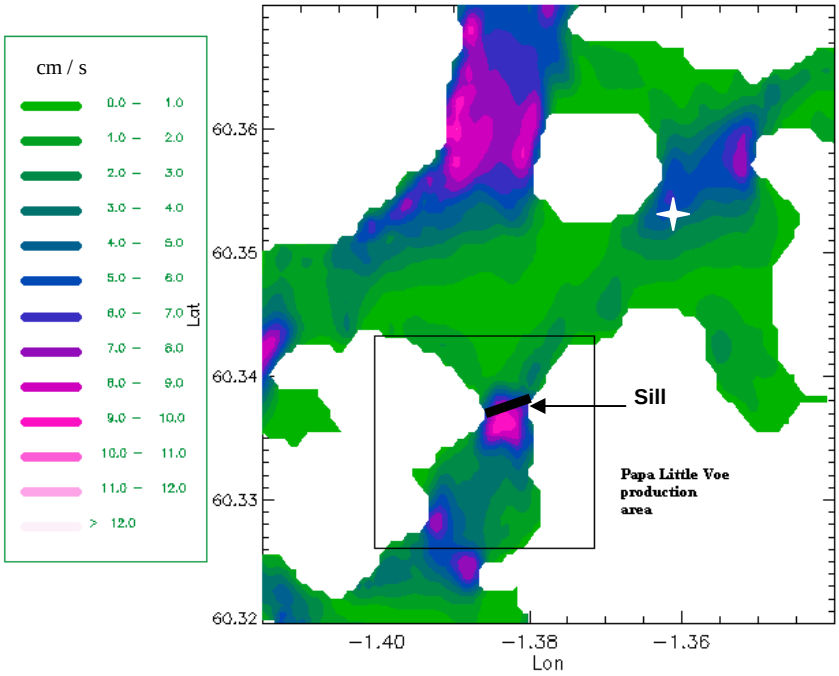


Figure 14.2: Maximum north-south tidal velocity from the model. Note this gives speeds of only 10 cm/s, even over the sill to the north of the Sound of Houbansetter in the Papa Little Voe production area. White cross indicates current meter deployment.

Wind driven flows

Winds measured at Lerwick (figure 14.3) should be representative of the wind speed and directions experienced at the Papa Little Voe. There is a clear predominance of winds from a south-westerly direction and these are generally rather strong, being above 17 knots (8 ms-1) for about 60% of the time.

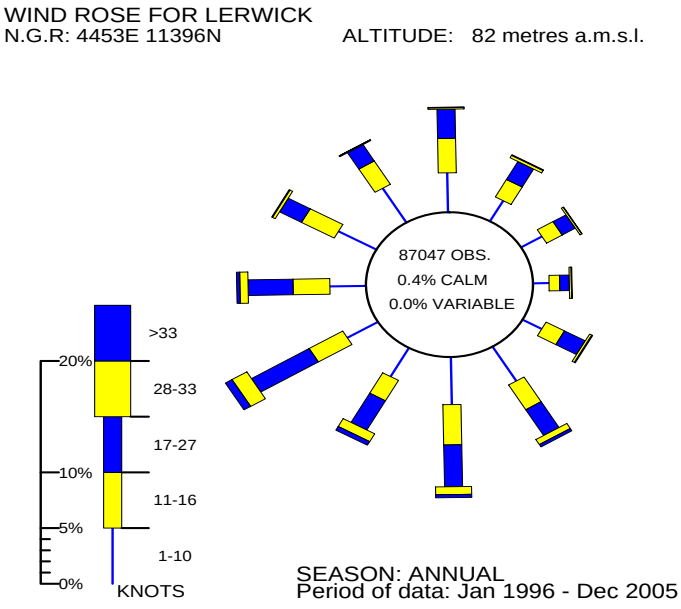


Figure 14.3: Annual wind rose for Lerwick.

Density driven flows
No significant freshwater flows enter the water body. For the nearby Aith Voe the SLC gives the ratio of freshwater runoff to tidal exchange as 1:114, which is moderate to low, implying annual freshwater inputs are relatively small compared to tidal exchange. Nevertheless, because the tides are so weak, there is the possibility of thermal stratification in summer because the tides are unable to mix the water column. If this occurs, a layer of warm water on top of colder dense water will form generating a density driven current. For the purposes of modelling, we consider only wind and tide driven flows.

14.2 Related studies

Currents were measured in the Cole Deep off the Isle of Linga (Figure 14.2) during 2001 in support of a discharge consent application to SEPA (SSQC, 2001). The results showed considerable scatter consistent with wind dominated flows and relatively weak tides, which concurred with the results of modelling described later in this report.

14.3 Model study

Set-up
The area covered by the model is shown in Figure 14.1. The resolution of the model (the grid spacing) was around 50 m so that features down to this length can be represented. The tidal forcing was set to reproduce the observed spring tidal range of approximately 1.7 m in the region, as given in the Scottish Sea Loch Catalogue.

In addition to tidal flows, the response to constant winds blowing from the north, south, east and west directions at a speed of 5 m/s (gentle to moderate breeze) was calculated. The effect of the south-westerly wind that predominates on Shetland was analysed by considering combination of the separate south and west cases. In each wind scenario, winds were applied for 48 hours so that a constant (equilibrium) current pattern was reached.

The shoreline survey indicated two groups of potential contamination sources. A group of streams located on the eastern shore of the Sound of Houbansetter and streams and a septic discharge around to the east in the waters of Gon Firth. Two particle release points were used as representative inputs from these two general locations.

Simulated particles were released into the combined tidal and wind generated currents and followed within the model for 2 days. For the wind driven runs it should be noted that this is an idealised scenario, since winds are unlikely to blow persistently from a given direction for this length of time. Nevertheless, within the limitations of the model, they illustrate the general types of current pattern set up by wind forcing within the water body.

Limitations of using a simple depth integrated model are discussed in the hydrographic methods document (Appendix 6). These concern the inability of

the model to describe vertical structure within the water column and will effect the modelling of wind and density driven flows in particular.

Results

Modelled tidal currents were found to be very weak throughout, with speeds generally less than 5cm/s (Figure 14.2). Slightly stronger tidal currents are associated with narrow constrictions and sills such as that between Linga and Hevden Ness. However, even here peak tidal current speeds were generally predicted to be less than 15cm/s. Consequently the tidal residual flow is also predicted to be very weak, generally of the order of a few millimetres per second. Thus tidal currents lead to modest transport distances (Figure 14.4). Consideration of the particles paths and the tidal residual circulation (Figure 14.6) suggest that none of the Papa Little Voe production areas are likely to be impacted by material transport from the identified sources by tidal flows alone.

Imposing even a modest wind was found to have a large effect on water movement and particle paths. For all the wind simulations the state of the tide at which particles were released (particles released 6.2 hours apart) had little effect - consistent with the relatively weak tidal influence. Particle tracks in response to North, South, East and West winds are shown in Figures 14.5 a-d. The unnamed mussel line in the northern entrance to the Sound of Houbansetter shows a clear potential to be impacted although only from the relatively lightly contaminated sources from the eastern shore of the Sound.

The paths for a predominant south-easterly wind are shown in Figure 14.6. Again this shows potential for the unnamed mussel line to be impacted.

The particle paths predicted for both the tide and wind driven situations can generally be understood by reference to the underlying water circulation patterns generated by the model in each case (Figure 14.7, 14.8 a-e). Visual inspection confirms that particles move in a way consistent with these patterns.

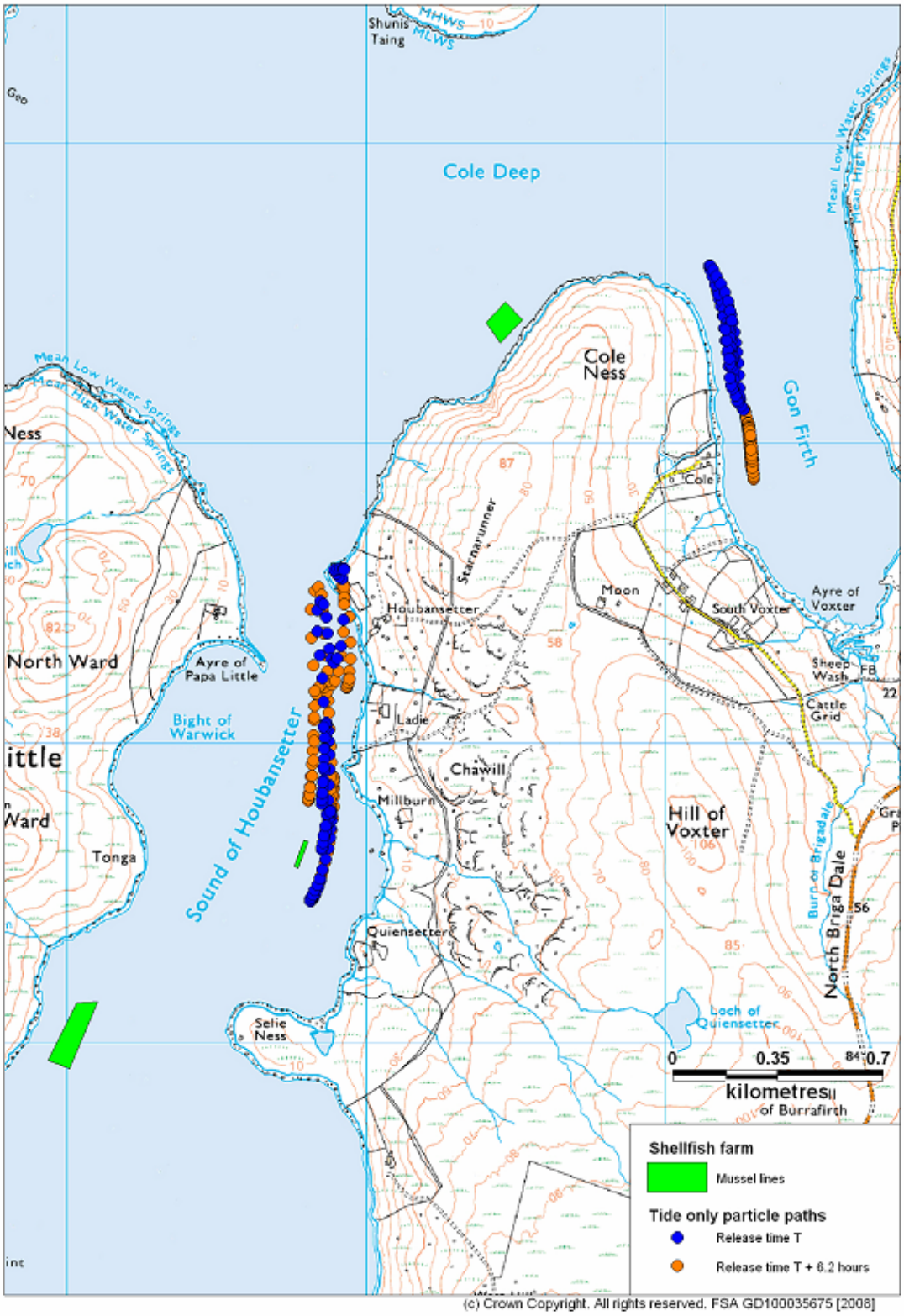
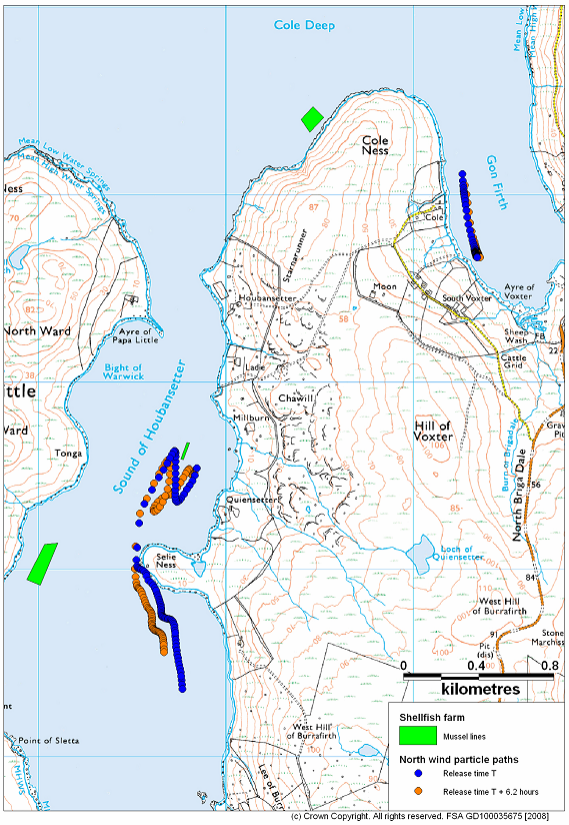
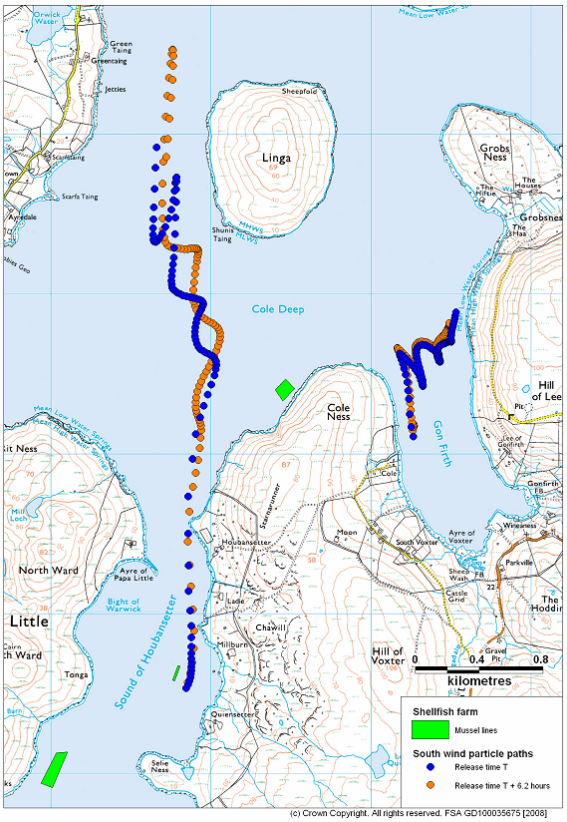


Figure 14.4 Particle paths for tidal motion only. The black circle shows the start location. The two paths shown in orange and blue represent particles released 6.2 hours apart to catch different states of the tide.





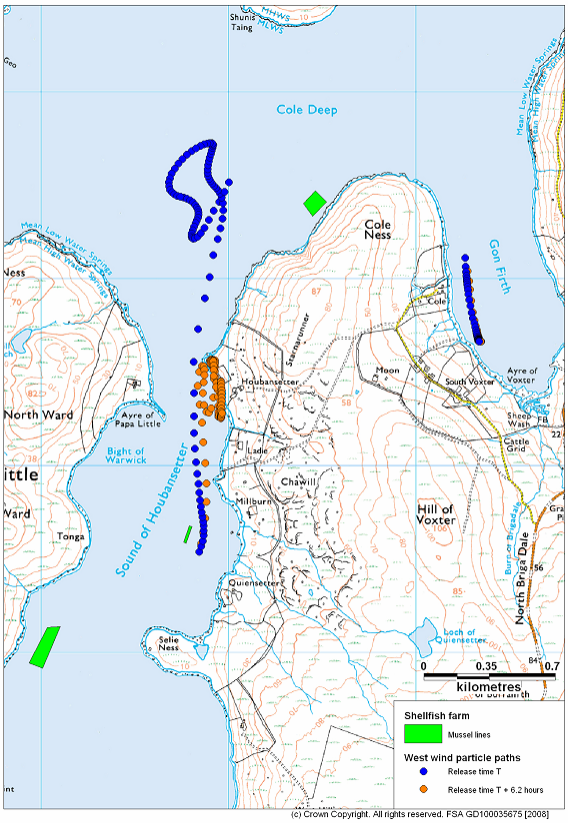


Figure14.5a-d Wind + tide-generated residual particle paths for North, South, East and West winds.

Figure14.6 Wind + tide-generated residual particle paths for south-westerly winds.

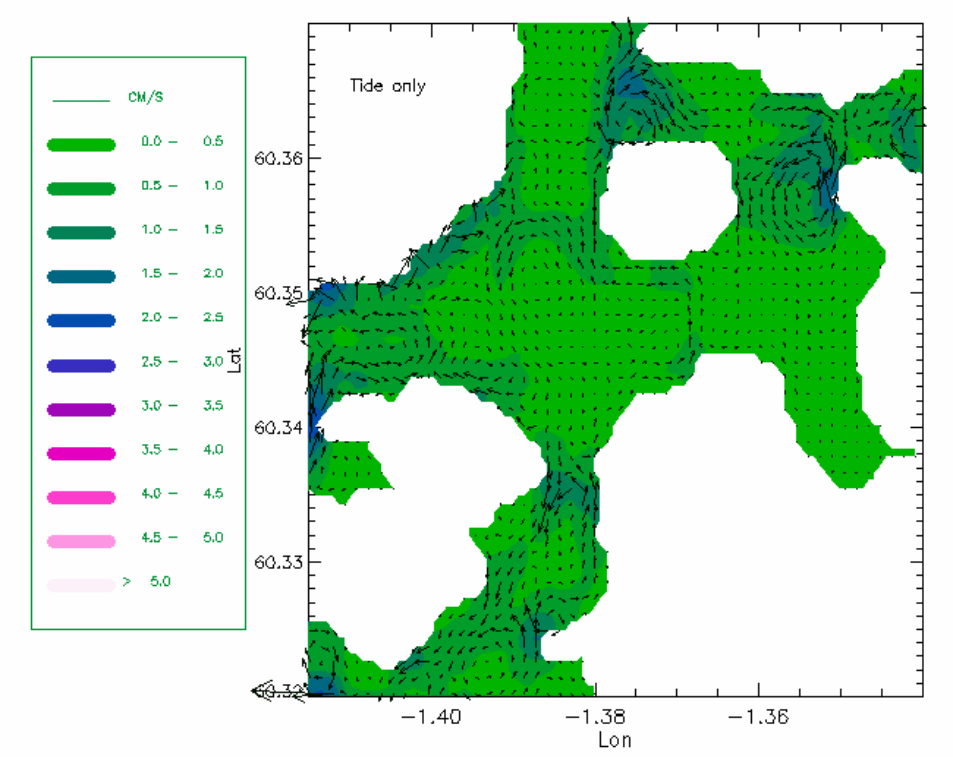


Figure14.7 Tidal residual currents. Colour scale indicates current speed (cm/s)

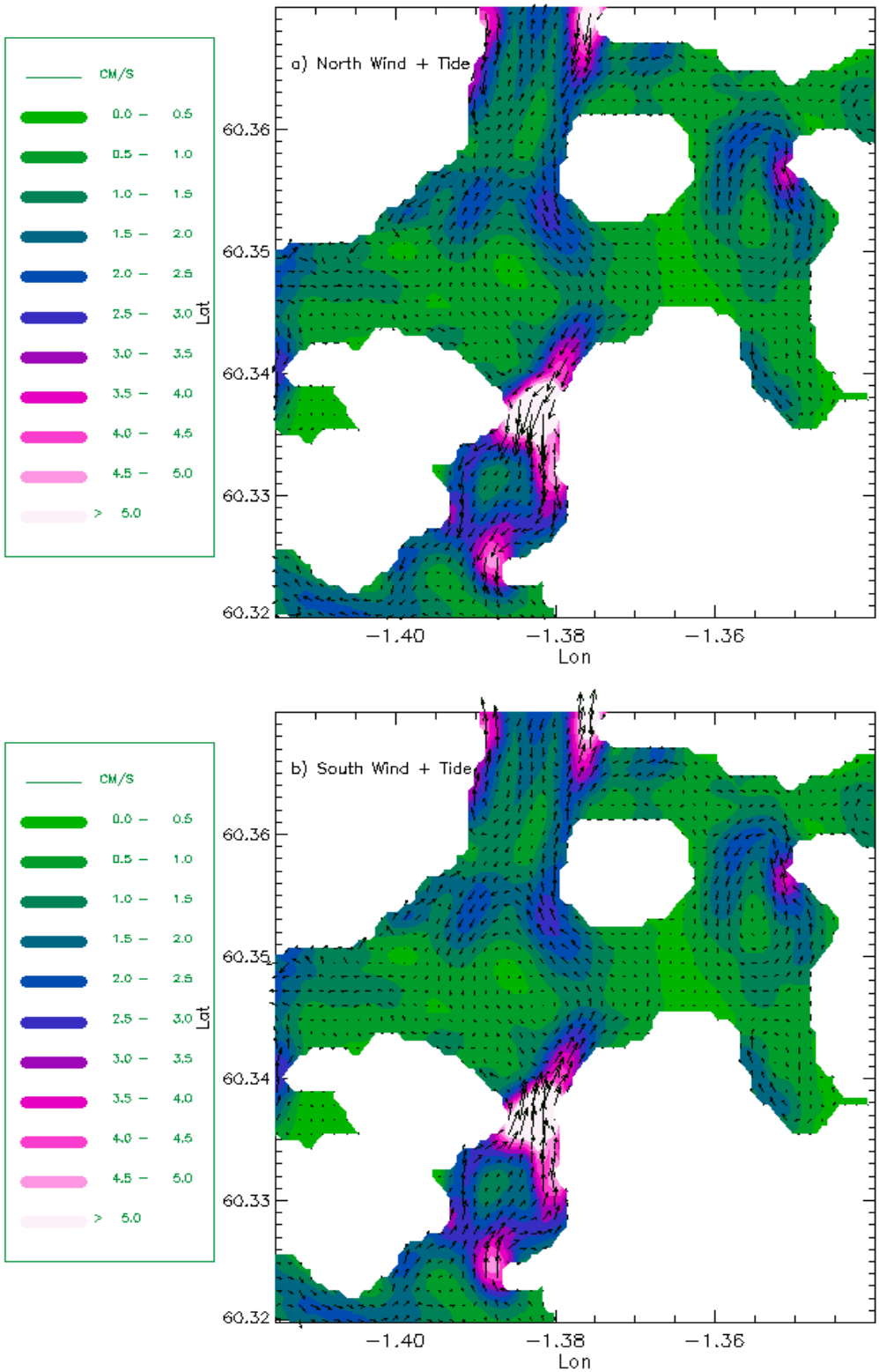


Figure14.8 a,b Wind + tide-generated residual currents; a) north and, b) south winds. Colour scale indicates current speed (cm/s)

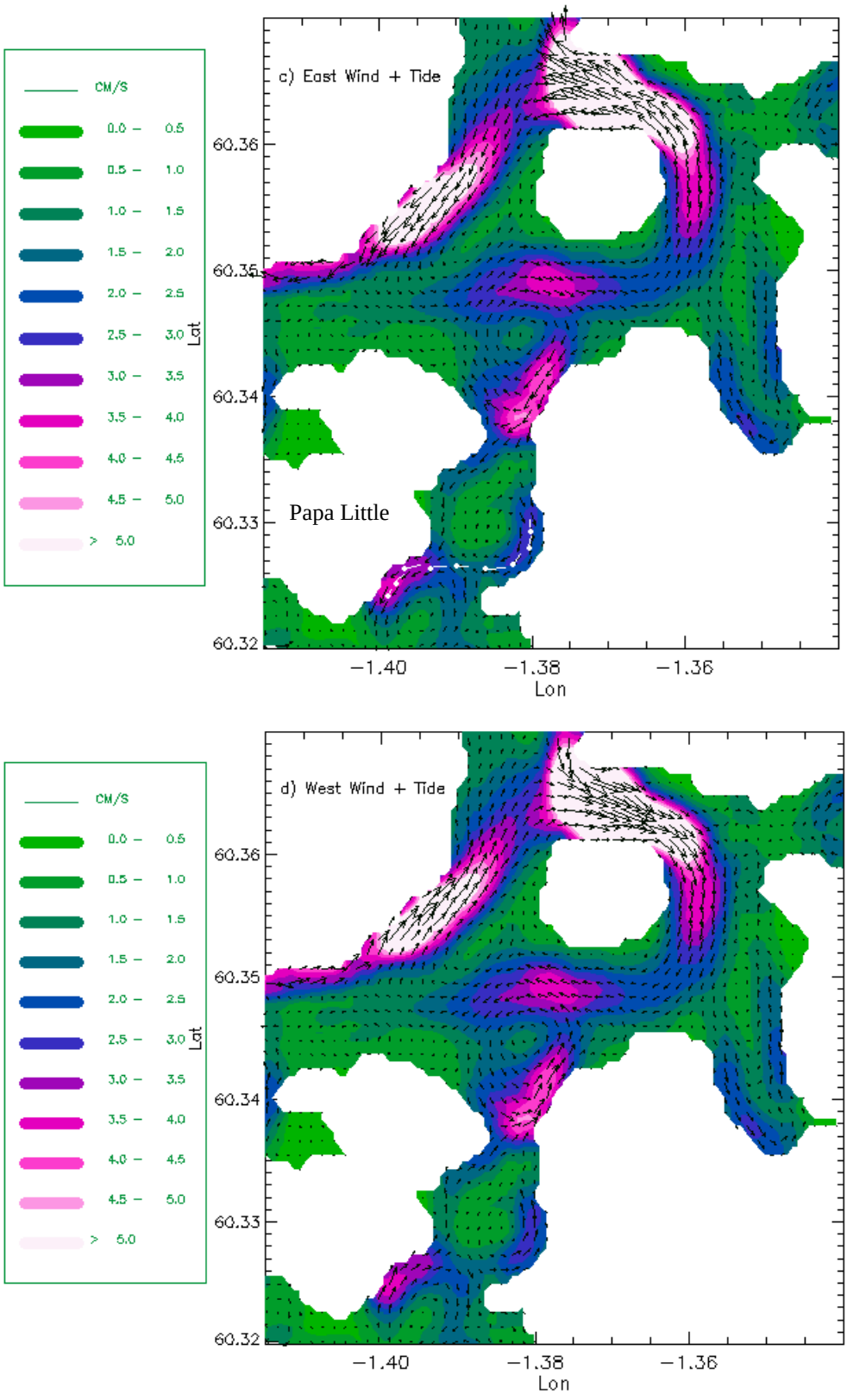


Figure14.8c,d Wind + tide-generated residual currents; c) east and, d) west winds. Colour scale indicates current speed (cm/s). Note the path indicated in white for the east wind case. This is referred to in the discussion and summary below.

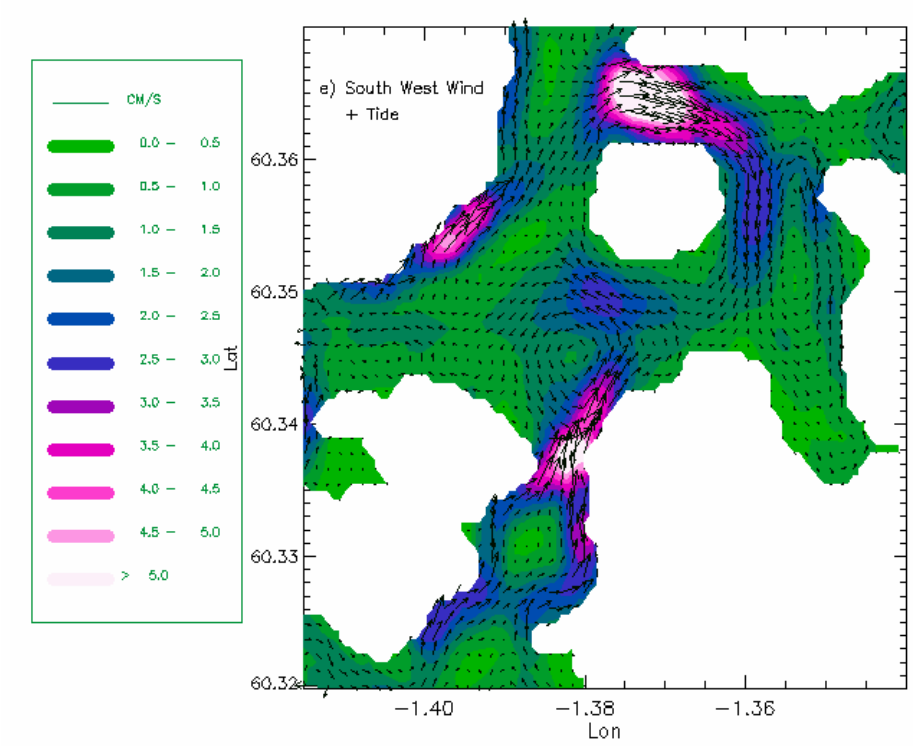


Figure14.8e Wind + tide-generated residual current for south westerly wind. Colour scale indicates current speed (cm/s)

14.4 Discussion and Summary

In general tidal flows are weak and wind-generated currents have a major influence on water movement. Particle paths for idealised wind scenarios suggest that the unnamed mussel line at the northern entrance to the Sound of Houbansetter is likely to be impacted by contaminants entering along the eastern shore of the Sound. Water movements generated by persistent easterly winds also suggest a possible path (figure 12.7c, marked in white) from these sources to the leased area offshore of Papa Little and opposite Selie Ness. For this case the modelled particle paths (Figure 12.5c) show particles being retained in a region of low current speed near Selie Ness rather than continuing further along the path indicated in Figure 12.7c. However, it is not unreasonable to assume that at least some of the particles would not retained here and that some could indeed reach the leased area opposite Selie Ness on the east shore of the Island of Papa Little.

Based on concentrations of *E. coli* in water measured during the shoreline survey, and taking account of dilution, only the septic discharge near Cole Farm in Gon Firth appears to be a significant source. This assumes that the concentrations measured on the day of the survey are representative, which may not be the case. With regard to the particle paths from the Gon Firth source in particular, although they are not predicted to impact the production areas in this survey, it is interesting that under easterly winds particles move toward the production areas in Busta Voe. The calculated dilutions suggest that they will not dilute significantly over this distance and may conceivably act as a source of contamination to Busta Voe Lee North production area. However, any such impacts are likely to be rather intermittent and dependent on particular wind conditions.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 29th and 30th April 2008 following a prolonged period of dry weather.

The fishery at Gon Firth consists of a longline mussel site with four individual lines (Cole Ness). Stock of a variety of sizes were present to allow for rotational harvest. Two sites were present in the Papa Little Voe production area. Harvesting was underway at the time of survey at the larger of these sites (Papa Little Voe) which consisted of four individual longlines. The smaller site (unnamed) consisted of a single longline which had been recently deployed, and its owner is not currently known.

No sources of human sewage within the immediate vicinity of the production area were identified. A small private discharge around the headland to the northeast of the production areas was sampled and found to be highly contaminated. No caravans, car parks or campsites were observed in the vicinity. Only one boat was observed during the survey, and it was harvesting mussels at the Papa Little Voe site.

Land use in the area is predominantly sheep grazing on rough grassland. Active farms were located at Cole and South Voxter on the eastern side of Cole Ness with improved pasture and evidence of recent muck spreading. A total of 133 sheep, 12 domestic ducks, one horse and a small number of poultry were recorded. The majority of these were either at Quiensetter or at Cole. Although no live sheep were seen, there was evidence of sheep grazing on Papa Little. Two otters and four seals were observed, mostly around Selie Ness. At least 30 seabirds were seen nesting on Papa Little.

Seawater samples collected from the surface by the mussel lines at both Papa Little Voe and Gon Firth returned results of <1 *E. coli* cfu/100 ml. Mussel samples taken from these locations also showed very low levels of contamination irrespective of depth, with all samples giving an *E. coli* result of <20 or 20 MPN/100 g. *E. coli* levels in streams sampled were generally fairly low (maximum 210 cfu/100 ml, all but one were < 50 cfu/100 ml), and the stream sizes small so loading contributed from these sources was relatively low overall.

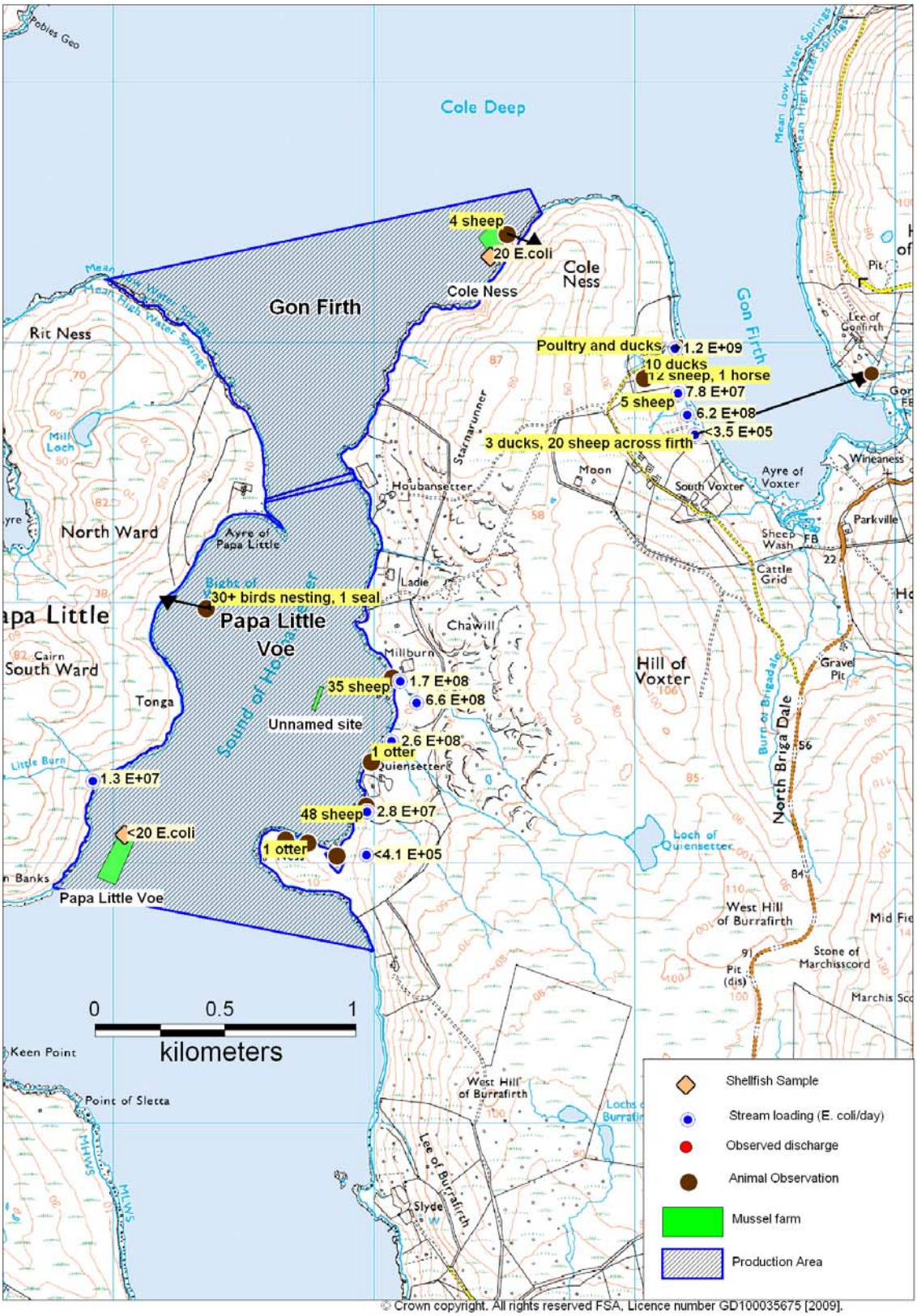


Figure 15.1 Summary of shoreline survey findings

16. Overall Assessment

Human sewage impacts

There are no known Scottish Water or SEPA consented discharges directly to the Papa Little Voe and Gon Firth: Cole Ness production areas, and there are no inhabited dwellings on their adjacent shorelines. The only discharge observed during the shoreline survey was a small private discharge located on the east side of the headland at Cole Ness. There are larger settlements on the shores of Aith Voe to the south, Olna Firth to the east and Busta Voe to the north, all of which are more than 3km away from the production areas. The Aith Voe discharges, however, are much closer to the Papa Little Voe mussel farm than

There is little in the way of boat traffic in the area. The only boat observed during the shoreline survey was harvesting mussels from the Papa Little Voe site. Whether this boat constitutes a risk to the fishery depends upon whether sewage waste from the head onboard discharges directly overboard, or whether any holding tank onboard is discharged in or near the fishery. This type of impact is likely to be variable and may not occur at all in this fishery, so it will not be considered in establishing a sampling plan.

Primary sources of human sewage originate from outside the production area and may be less likely to impact the fishery consistently. The Gon Firth: Cole Ness production area is likely to be impacted by sewage impacts to the east within Gon Firth. The Papa Little Voe production area is most likely to be affected by sewage discharged within Aith Voe to the south. However, it should be noted that dilution calculations undertaken as part of the hydrographic modelling indicated that even small sources in this water body could impair water quality over a very wide area.

Agricultural impacts

Agricultural census data for 2008 identified that livestock kept within the two parishes bordering on the production areas is predominantly sheep. The shoreline survey confirmed the presence of extensive sheep grazing in the area. Animals were mainly seen along the eastern shore of the Papa Little Voe production area and at Cole, southeast of the headland at Cole Ness. These locations relate only to the date of shoreline survey, and it is probably that the sheep graze throughout this area, including on Papa Little island. Contamination of livestock origin will mostly be carried to the production areas via the streams draining the surrounding land. Most of the streams discharging to the production areas were found on the eastern shore of the Sound of Houbansetter, with another aggregation of small streams at Cole, however additional streams and land runoff may be present during wetter weather than that observed during the shoreline survey. Therefore, contamination from grazing livestock will be assumed to be evenly distributed for the purposes of recommending an RMP.

Overall numbers of livestock will increase in late spring following the birth of lambs, and decrease from the autumn as animals are sent to market leading to a seasonal increase in deposition of faecal matter during the summer and potentially higher levels of contamination when rainfall increases in early autumn and begins to wash these deposits into streams and watercourses.

Wildlife impacts

Large numbers of seabirds are reported to breed on the island of Papa Little. Therefore, inputs from seabirds may be expected, particularly during the summer. Contamination from faeces deposited on the island would be carried into the production area via land runoff and this could be expected to have the greatest impact north and east of the mussel farm at Papa Little Voe, and primarily during July and August..

Seals are present in the area, but not at particularly high densities (four were seen during the shoreline survey). Seals will forage widely for food so it is likely they will feed near the mussel farms at some point in time. They are highly mobile therefore it is likely that any impact will be limited and unpredictable.

Seasonal variation

No tourist facilities were recorded in the area during the shoreline survey, so it is not anticipated that the human population in the immediate area increases during the summer months. Livestock numbers will be higher in the summer, so contamination from livestock sources may be higher during the summer.

A statistically significant seasonal effect was found in the historical *E. coli* monitoring data for Gon Firth: Cole Ness only, where results for the autumn were significantly higher than those in the spring. Mean results were higher in the summer and autumn at Papa Little Voe (specifically July and August), but this effect was not statistically significant when results were grouped into three-month seasons.

In conclusion, there is the potential for seasonal variation in levels of contamination due to varying livestock and seabird numbers as well as differing meteorological conditions, so monthly monitoring would be advisable. A statistically significant seasonal effect was found in historical *E. coli* monitoring results for Gon Firth: Cole Ness but not Papa Little Voe.

Rivers and streams

The catchment area for these production areas is very small, so overall direct freshwater inputs are low, limited to a few small streams draining areas of pasture. Most of the streams discharging to the production areas were found at around Quiensetter on the east shore of the Sound of Houbansetter, with another aggregation of small streams at Cole. Two small streams discharge to the east coast of Papa Little, one to the Gon Firth: Cole Ness production area, and one to the Papa Little Voe production area which might affect the

Papa Little Voe site. None of the streams measured on the shoreline survey were large or particularly contaminated, although the *E. coli* loading of these streams is likely to increase following rainfall events.

Contamination resulting from streams is likely to most acutely impact areas near the shoreline with highest impacts likely within body of Gon Firth and slightly lower impacts to the eastern shore of the Sound of Houbansetter. This would be most likely to affect the new mussel line observed along this section of shoreline.

Meteorology, hydrology, and movement of contaminants

The weather is wetter and windier during the autumn and winter months, and the prevailing wind direction is from the south west.

No significant influence of either spring/neap tide height or tidal state (i.e. high/low/ebb/flood) was found. This may be expected as tidal currents in the area are relatively weak, and there are no major point sources of contamination in the immediate area.

A correlation was found between wind direction and magnitude of *E. coli* results for Gon Firth: Cole Ness only, with higher results occurring during periods of north westerly winds. A positive relationship was found between *E. coli* result and rainfall in the previous 2 days for Gon Firth: Cole Ness, and a slightly stronger positive relationship was found when rainfall in the previous 7 days was considered. The two highest individual results occurred in the late summer/early autumn following a wet week with westerly winds. Thus, the correlation with wind direction may actually be due to rainfall.

No relationship was found between *E. coli* results and levels of recent rainfall for Papa Little Voe.

Movement of contaminants within the area is likely to be predominantly wind driven and hydrographic modelling of residual surface currents indicates that contamination of the Gon Firth: Cole Ness production area from the private septic discharge at Cole is unlikely. While larger septic discharges are present more than 3 km from the shellfish farms, it is unlikely that these will significantly affect the shellfish farms. Contamination levels are sometimes very high at both sites, indicative of high levels of faecal bacteria in the water despite the lack of significant point sources of pollution. There did not appear to be significant background levels of contamination present during the shoreline survey, so it is presumed that any faecal contaminants are coming from diffuse sources closer to the fisheries.

Temporal and geographical patterns of sampling results

In terms of overall temporal patterns in historical *E. coli* monitoring results, a possible peak in results may be seen for Papa Little Voe in late 2006. Seasonal patterns in these results are described in the assessment of seasonal variation.

A significant difference in was found mean historical *E. coli* monitoring results between the two production areas, supporting their continued classification as separate production areas. No significant difference was found in the proportion of results over 230 *E. coli* mpn/100g between the two production areas however.

Seawater samples collected during the shoreline survey at the mussel lines at both Papa Little Voe and Gon Firth gave results of <1 *E. coli* cfu/100 ml. Mussel samples taken from these locations also showed very low levels of contamination irrespective of depth, with all samples giving an *E. coli* result of <20 or 20 mpn/100g. Sampling results from the shoreline survey must be treated with caution as they are specific to the conditions on the day.

17. Recommendations

Papa Little Voe

Based upon the assessment of movement of contaminants and consideration of closest sources of faecal contamination, it is recommended that the production area boundaries be retained essentially as established with a small correction to eliminate the overlap with the Gon Firth production area. The recommended boundaries are the area within lines drawn between HU 3458 6139 to HU 3493 6147 and HU 3377 5991 to HU 3500 5966 and extending to MHWS. Waters within this area are subject to relatively little direct pollution, primarily of animal source.

The local authority has been submitting samples from HU 3397 6005. It is recommended that an RMP be established at HU 3404 6012. This point lies closest to the burn on Papa Little Island that is the nearest source of faecal contamination to the fishery. The sampling tolerance is recommended to be 20 m. Sampling depth is recommended to be 1 m as any contaminants reaching the fishery are likely to be carried in freshwater runoff and may be poorly mixed and more concentrated at the surface.

Should the mussel farm on the eastern side of the production area be further developed, the sampling plan should be reviewed as the location of this farm may be subject to higher levels of contamination due to the livestock and streams found along the eastern shoreline near the mussel line. Relocation of the RMP to this site should be considered at that point in time.

Gon Firth: Cole Ness

As the historical monitoring results indicated that the two areas were significantly different in terms of seasonal variation in contamination levels, it is recommended that Papa Little Voe and Gon Firth: Cole Ness be maintained as separate production areas.

It is recommended that the production area boundaries at Gon Firth: Cole Ness be retained essentially as established with a small correction to eliminate the overlap between it and the Papa Little Voe production area. The amended description is the area bounded by lines drawn between HU 3398 6225 to HU 3570 6253 and between HU 3458 6139 to HU 3493 6147.

Samples are collected by the local authority at HU 3542 6236, whilst the RMP is identified as HU 354 623, which lies just over 100 m from the identified mussel farm. The farm itself only covers an area of 100 m x 80 m and only the southern end of it lies on the lease. As the known sources of contamination lie east and north of the mussel farm and higher contamination levels are found when winds are blowing from the northwest, it is not clear what the contaminating sources are at this location. Given the lack of point sources of contamination and the size of the farm, there is no compelling reason to move the RMP from the southern end of the lines. It is, however, recommended

that the RMP be restated as HU 3543 6237 as this point lies 20 m in from the end of the lines (to allow for a sampling tolerance). The sampling tolerance is recommended to be 20 m. Sampling depth is recommended to be 1 m as any contaminants reaching the fishery are likely to be carried in freshwater runoff and may be poorly mixed and more concentrated at the surface.

Recommendations for both production areas are represented in Figure 17.1.

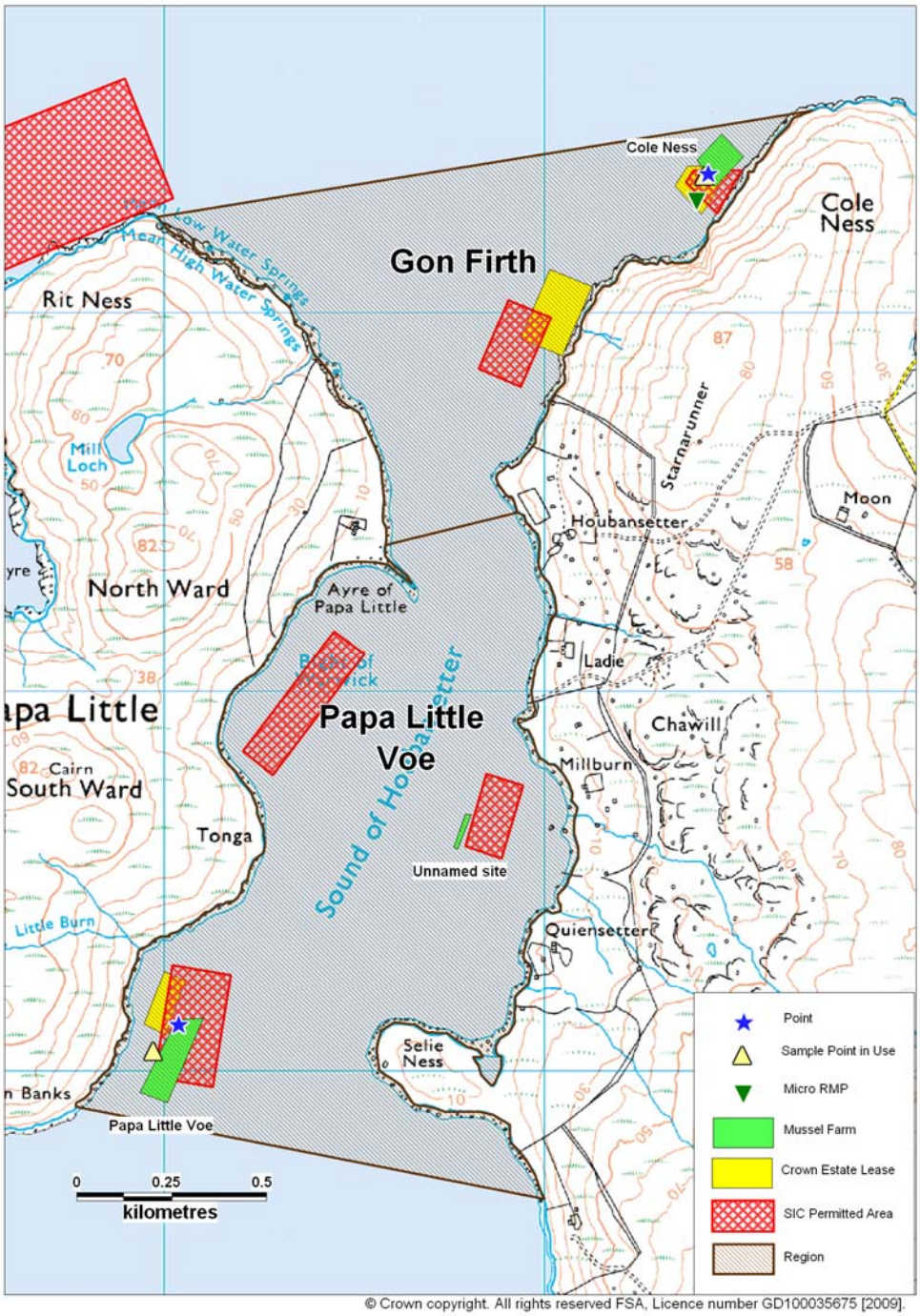


Figure 17.1 Map of recommendations for Papa Little Voe and Gon Firth

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19. List of Tables and Figures

Tables

Figures