Scottish Sanitary Survey Project

Sanitary Survey Report
Cromarty Shoremill/Cromarty Bay Mussels
RC 473
March 2010

Report Distribution – Cromarty Shoremill/Cromarty Bay

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

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1. General Description

Cromarty Bay is located on the south shore of the outer end of Cromarty Firth, which is an enclosed estuary adjacent to the Moray Firth on the east coast of Scotland. The main channel of the Cormarty Firth is up to 30 m deep in places, but Cromarty Bay is gently sloping and shallow, with a maximum depth of about 5 m. This sanitary survey was undertaken in response to an application to classify this area for the harvest of common mussels and Pacific oysters.

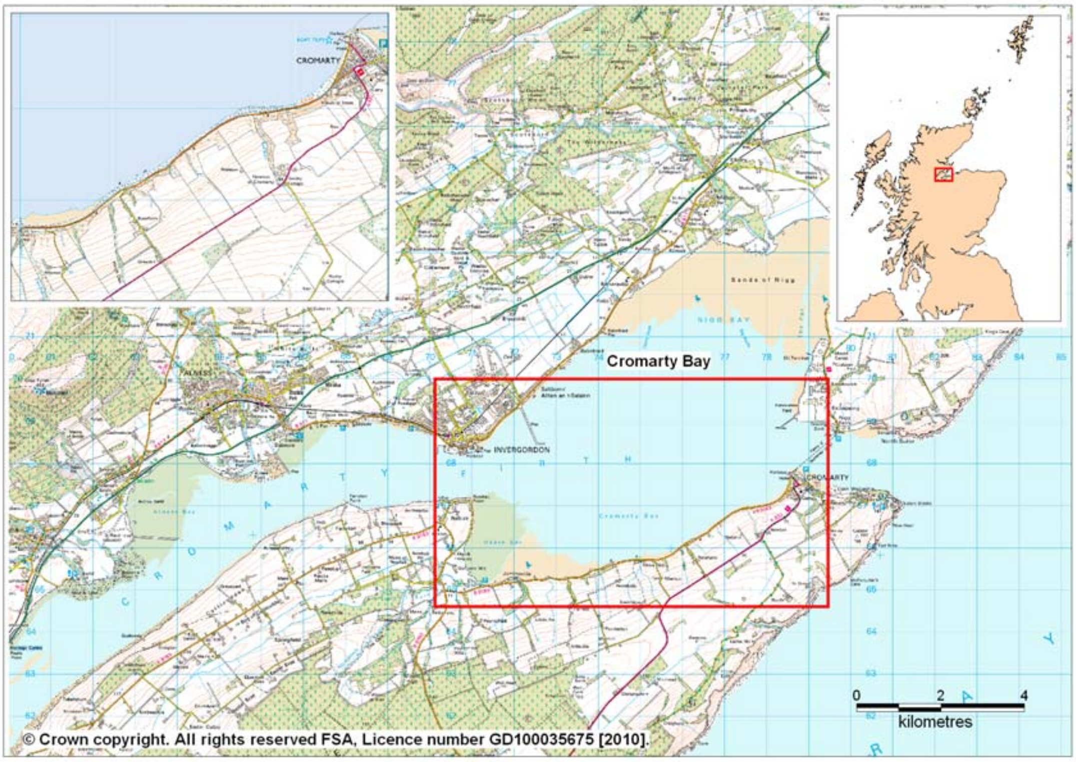

Figure 1.1 Location of Cromarty Bay

2. Fishery

There is currently no production area or Representative Monitoring Point (RMP) located in the Cromarty Bay/Shoremill area.

A stretch of the foreshore at Shoremill is privately owned. The eastern part of this foreshore has been recently sold by the original owners (Cromarty Mussels) to investors who plan to develop the historic oyster fishery here, which has not been operated in over a decade. At the time of survey, an area of damaged trestles measuring approximately 110 m x 110 m was seen, and this fell within the area of foreshore which has recently been sold. Planning permission for renovation and extension of these trestles has been granted, and it is anticipated that this will be carried out during the spring of 2010. Therefore the earliest likely harvest of stock here is autumn 2012 or 2013 unless plans change and part-grown oysters are bought in for on growing.

In addition to this, it is probable that a planning application for an additional oyster farm within the area of foreshore remaining under the ownership of Cromarty Mussels will be submitted in 2010 or 2011.

In addition to the oyster operations, mussel culture is planned just offshore from the oyster site on an area of seabed where an area of seabed has been leased from the Crown Estates by Cromarty Mussels. A planning application has been submitted by for a total of 75 mussel lines of 126 m each but permission has yet to be determined. Lengths of netting will be suspended from these, on which the mussels will be grown. It is anticipated there will be an element of seasonality to harvesting, with no harvesting during the post spawning period in the spring. First harvest here is anticipated in autumn 2012, although locally harvested mussels from either the Cromarty or Dornoch Firth may be on-grown here, so the time of first harvest may possibly be a year or so earlier. At the time of shoreline survey, no stock or tackle for mussel harvesting was present on site.

Table 2.1 Cromarty Shoremill/Cromarty Bay fisheries

Production Area	Site	SIN	Species
Cromarty Shoremill/ Cromarty Bay Mussels	Shoremill oysters	RC 473 884 13	Pacific oysters
Cromarty Shoremill/ Cromarty Bay Mussels	Shoremill mussels	RC 473 883 08	Common mussels

Figure 2.1 shows the relative positions of the area of trestles, privately owned foreshore, Crown Estates lease area and approximate boundaries within which planning permission for the renovation/extension of existing trestles has been granted.

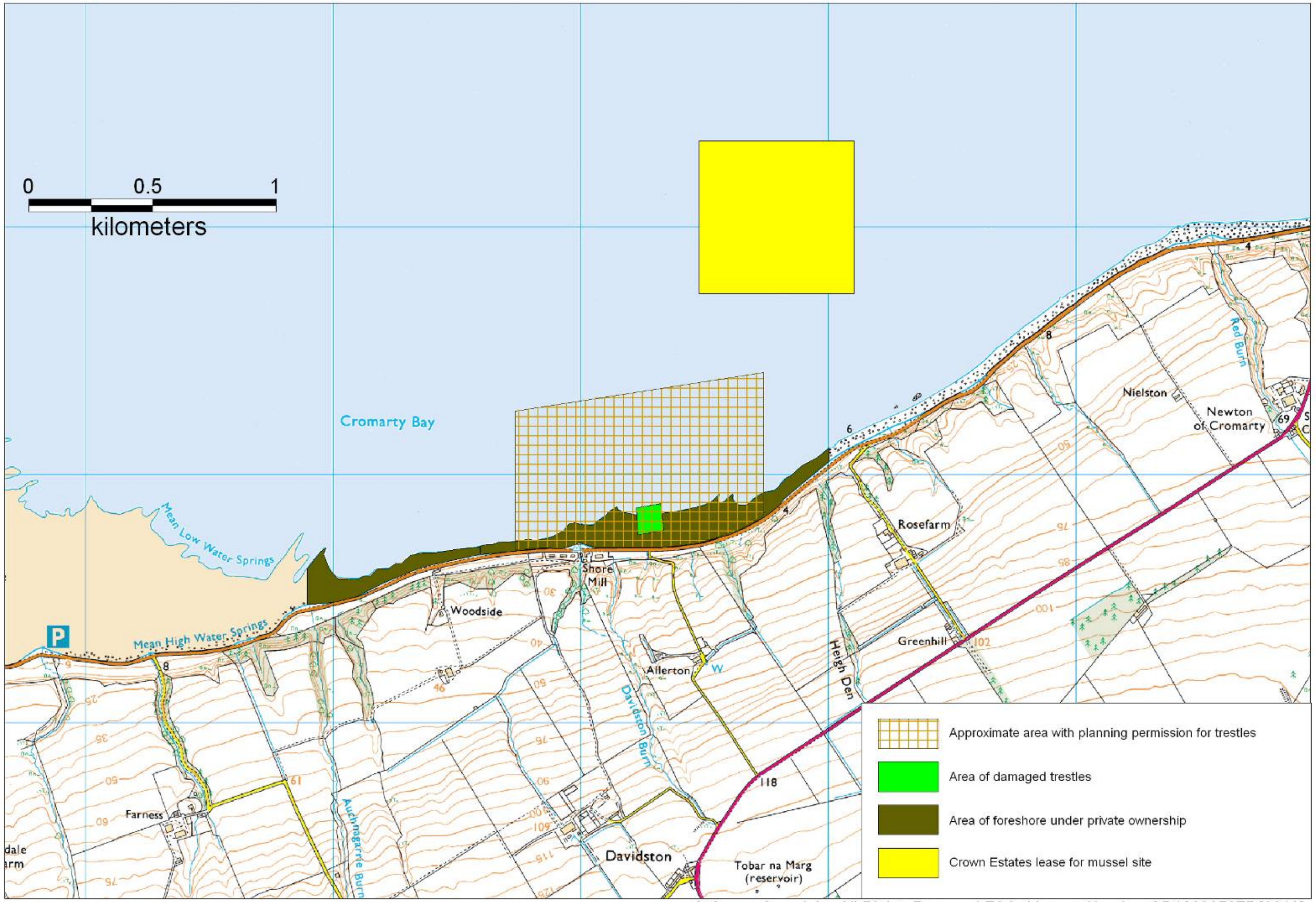

Figure 2.1 Cromarty Shoremill/Cromarty Bay Fishery

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Cromarty Bay at the time of last census (2001).

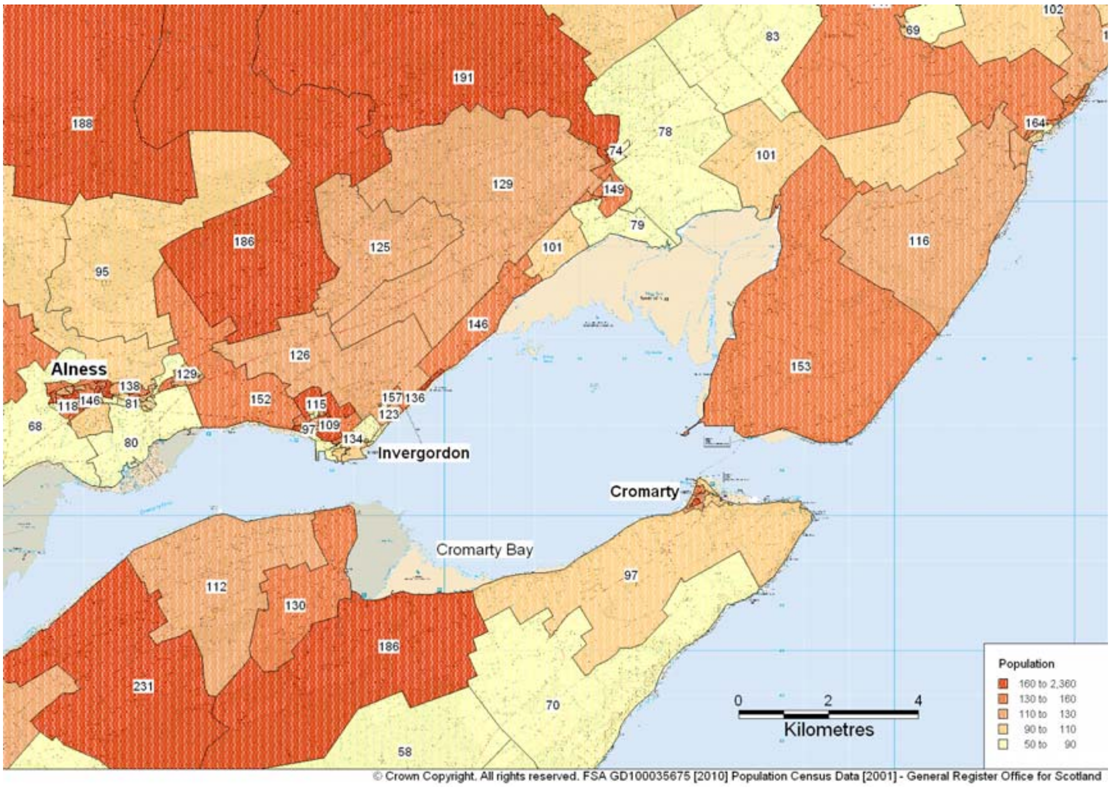

Figure 3.1 Population map for Cromarty Bay

Alness lies to the north-west of Cromarty bay, and encompasses several census areas with a combined population of 5186 (Census 2001). Invergordon lies to the north of Cromarty Bay, and has a combined population of 3890 (Census 2001). Cromarty is a smaller town at the eastern end of Cromarty Bay, with a population of 719 (Census 2001). Contamination to the firth in general from human sources would be expected to be mainly associated with these towns, and others further up the firth.

4. Sewage Discharges

Major discharges to the firth

A total of 67 discharges were identified by Scottish Water in the Cromarty Firth area, and a total of 34 discharge consents were reported by SEPA within 10 km of the site. Several of these are major discharges to Cromarty Firth that will increase levels of contamination within the firth as a whole, but their effects on the fishery are likely to depend on their size and location and the hydrography of the area. Figure 4.1 presents the location and size of the main continuous Scottish Water discharges (those serving populations greater than 50) around Cromarty Firth. Table 4.1 presents further details of these discharges.

Table 4.1 Continuous discharges to Cromarty Firth serving populations > 50 people

Discharge Name	Receiving Water	NGR of discharge	Level of Treatment	Consented flow (DWF) m^3/d	Population equivalent	Q&S III/IV Planned improvements?
Alness (Dalmore Pier)	Cromarty Firth	NH 66676772	None	None stated	8000	Yes
Arabella	Fearn Canal	NH 8128 7552	Septic tank & reed beds	17.7	85	No
Conon Bridge	River Conon	NH 551564	Secondary	1036	4000	No
Contin	Black Water	NH 456561	Septic tank	130	500	No
Cromarty WWTW	Cromarty Firth	NH 7995 6742	Secondary MBR	309	1550	No
Culbokie	Cromarty Firth	NH 59466085	Secondary		670	No
Dingwall	River Peffery	NH 56055850	Secondary	1591	8000	Yes
Evanton	River Sgitheach	NH 611658	Secondary	471	2107	No
Evanton Ind Estate	Cromarty Firth	NH 62906728	None	49	181	Yes
Invergordon	Cromarty Firth	NH 69066797	None		14999	Yes
Jemimavile WWTW	Cromarty Firth	NH 7212 6520	Secondary	27.7	160	No
Marybank	River Conon	NH 483548	Septic tank	75	300	Possibly
Milton of Kildary	Balnagown River	NH 769738	Secondary	227.5	1500	No
Strathpeffer WWTP - Peffery	River Peffery	NH 49305870	Secondary	994	3000	No

All these sewerage systems have associated overflows, some of which may operate following heavy rainfall. The most significant of the discharges listed in Table 4.1 are Invergordon and Alness (Dalmore Pier), both of which are raw discharges consented to serve populations of 8000 and 14999 respectively. The population numbers shown for these two discharges in Table 4.1, particularly Invergordon, are considerably higher than the resident population for these towns at the last census presumably due in part to significant inputs from industry. The Invergordon discharge is located in about 15 m of water at the northern edge of the main channel, about 6.5 km from Shoremill. The Alness discharge is located in between 5 and 10 m of water at the northern edge of the main channel just off the end of Alness pier, about 8.5 km from Shoremill. The extent to which these discharges affect levels of contamination at Shoremill will largely depend on water circulation patterns within the firth. Improvement works are underway to these two discharges. Both will be routed to a new sewage works incorporating secondary treatment, and then discharged via the existing Invergordon long sea outfall, and it is anticipated these works will be completed some time in 2010. This should result in an approximately 1-log (10 fold) reduction in the *E. coli* loading from these two discharges.

Other discharges located towards the head of the firth to the west are likely to have some effect on water quality in the firth as a whole, increasing background levels of contamination at Shoremill to some extent. Whether the discharges at Nigg Bay have any effect on water quality at Shoremill will depend on water circulation patterns within the firth.

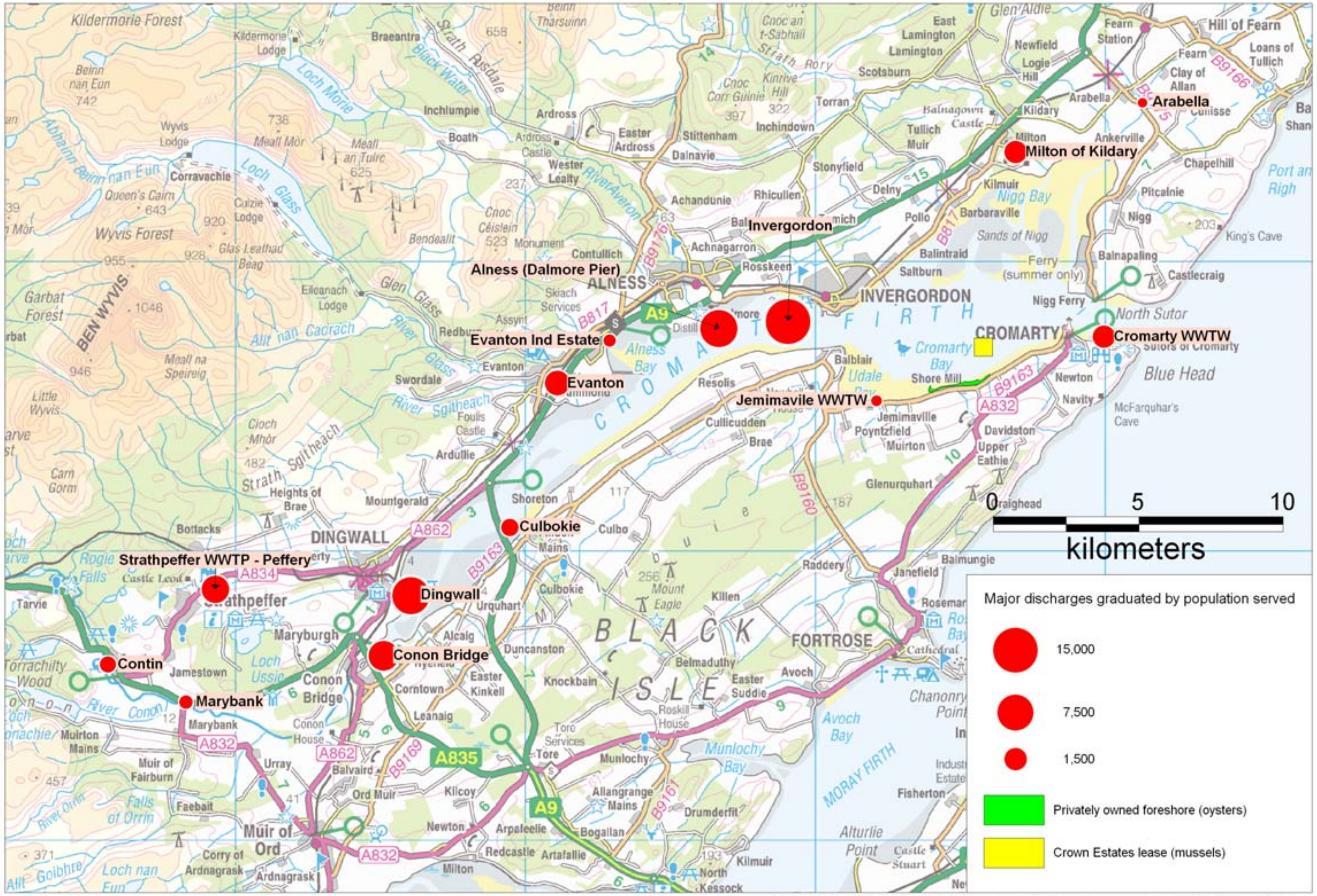

Figure 4.1 Continuous discharges to Cromarty Firth serving populations of over 50 people

Discharges in the vicinity of the fisheries

Figure 4.1 presents a map of those discharges which lie along the shore of Cromarty Bay, together with discharge observations from this area made during the shoreline survey. Tables 4.2 to 4.4 present details of Scottish Water discharges, SEPA consents and shoreline survey observations respectively in the area shown in Figure 4.1.

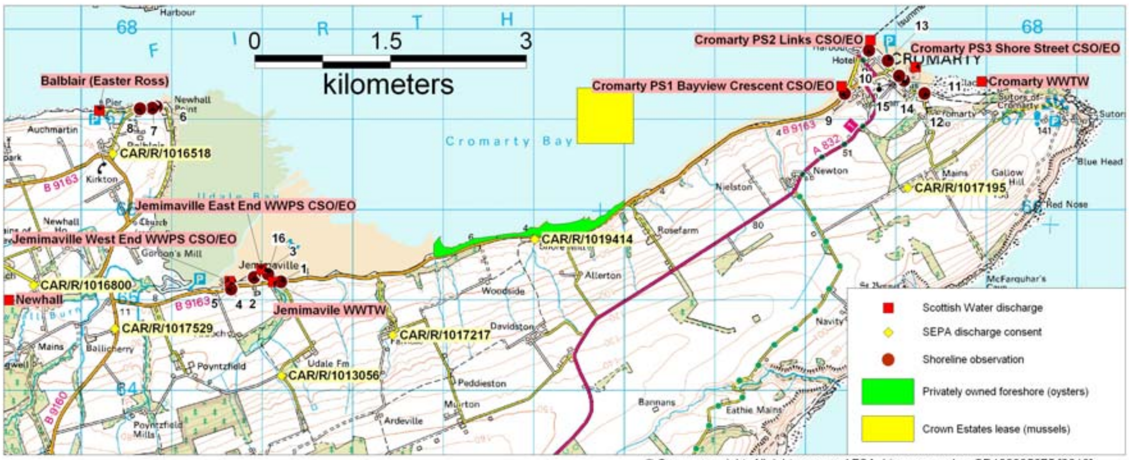

Figure 4.2 Discharges to Cromarty Bay

Table 4.2 Scottish Water discharges to Cromarty Bay

Discharge Name	Receiving Water	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Population equivalent	Planned improvements?
Balblair (Easter Ross)	Cromarty Firth	NH 702671	Continuous	Septic tank	None stated	30	No
Cromarty PS1 Bayview Crescent CSO/EO	Cromarty Firth	NH 7840 6737	Intermittent	6mm screening	75.2	376	No
Cromarty PS2 Links CSO/EO	Cromarty Firth	NH 7872 6788	Intermittent	6mm screening	73.4	367	No
Cromarty PS3 Shore Street CSO/EO	Cromarty Firth	NH 7922 6758	Intermittent	6mm screening	160.7	803	No
Cromarty WWTW	Cromarty Firth	NH 7995 6742	Continuous	Secondary MBR	309	1550	No
Jemimavile WWTW	Cromarty Firth	NH 7212 6520	Continuous	Secondary	27.7	160	No
Jemimaville East End WWPS CSO/EO	Cromarty Firth	NH 7199 6534	Intermittent	Settlement & 6mm screening	35.2		No
Jemimaville West End WWPS CSO/EO	Cromarty Firth	NH 7164 6521	Intermittent	6mm screening	7.3		No
Newhall	Newhall Burn	NH 692650	Continuous	Septic tank	30	20	Yes - ST & Reed bed treatment

No discharge consents were received from SEPA relating to the discharges in Table 4.2.

Table 4.3 Consents supplied by SEPA for discharges at Cromarty Bay

Consent no.	Grid ref	Discharges to	Sewage type	Level of treatment	Population equivalent
CAR/R/1013056	NH 7221 6416	Land	Domestic	Septic tank	5
CAR/R/1016518	NH 7035 6662	Land via soakaway	Domestic	Package plant	12
CAR/R/1019414	NH 7501 6567	Davidston Burn	Domestic	Septic tank	5
CAR/R/1017529	NH 7037 6468	Land via soakaway	Domestic	Septic tank	10
CAR/R/1017217	NH 7344 6461	Land via soakaway	Domestic	Septic tank	10
CAR/R/1017195	NH 7913 6624	Land via soakaway	Domestic	Septic tank	8
CAR/R/1016800	NH 6947 6516	Land via soakaway	Domestic	Septic tank	17

Table 4.4 Discharge observations made during the shoreline survey

No.	Position	Description
1	NH 72209 65209	Jemimaville WWTP
2	NH 71910 65256	Black ribbed 15cm plastic pipe, dripping, sewage fungus.
3	NH 72020 65316	20 cm metal pipe, not flowing, points back up shore to Jemimaville WWTP
4	NH 71650 65201	Metal 15cm pipe not flowing, overflow from Scottish Water pumping station
5	NH 71657 65128	Scottish Water pumping station - Jemimaville West End PS
6	NH 70833 67148	10cm cast iron sewage pipe, dripping
7	NH 70786 67134	Septic tank, overflow buried in beach
8	NH 70650 67127	Orange 12cm pipe, encased in concrete, end buried in beach
9	NH 78439 67295	Scottish Water pumping station with overflow pipe (underwater) - Cromarty PS1
10	NH 78704 67774	Scottish Water pumping station - Cromarty PS2
11	NH 79089 67425	Scottish Water pumping station - Probably Cromarty PS3
12	NH 79320 67294	Scottish Water pumping station
13	NH 78916 67660	Cast iron 15cm broken pipe to underwater
14	NH 79092 67441	Concrete pipe casing heading out for at least 100m also 2 storm drains in rocks.
15	NH 79040 67490	3 storm drains in rocks
16	NH 72064 65294	Scottish Water pumping station - Jemimaville East End PS

None of the observed discharges are covered by the consents listed in Table 4.3, however the majority relate to Scottish Water assets listed in Table 4.2.

One discharge consent (CAR/R/1019414) is listed for a private septic tank discharge with a population equivalent of 5 to the Davidson Burn, which flows across the foreshore just to the west of where the derelict trestles are located at Shoremill. This discharge may therefore impact water quality locally around the mouth of the Davidson Burn. This discharge was not seen during the shoreline survey.

About 3 km to the west of Shoremill is the small settlement of Jemimaville. This is served by a small sewage treatment works (population equivalent 160) with secondary treatment which is reported to discharge direct to Cromarty Firth, although the main discharge pipe was not seen during the shoreline survey. There are two CSO/EO discharges associated with the Jemimaville sewerage system. It is not known how frequently spills occur from these two overflows, but as they incorporate CSOs it is likely that spills of untreated sewage occur during wet weather. An additional private discharge was seen at Jemimaville during the shoreline survey (observation 2, Table 4.4).

The town of Cromarty, which lies about 4 km to the east of Shoremill is served by a membrane bioreactor (MBR) treatment works designed for a population of 1550. MBRs combine activated sludge with a low-pressure ultrafiltration step, and due to the small pore size in the membrane they are very effective at removing bacteria. MBR plants typically achieve a > 5 log reduction in bacteria, but are slightly less effective for removing viruses due to their smaller size (typically > 4 log reduction). Therefore, the effluent from the continuous discharge will be almost free of bacteria, and contain only low levels of virus. The main discharge from this treatment works is within the mouth of the Cromarty Firth rather than in Cromarty Bay. Also associated with the Cromarty sewerage system are three CSO/EO discharges. It is not known how frequently spills occur from these overflows, but the CSOs are likely to result in spills of untreated sewage occur during wet weather. Two discharge within the mouth of Cromarty Firth, and one discharges to Cromarty Bay.

At Newhall, there is a Scottish Water septic tank discharge serving a population of 20. This is discharged to the Newhall Burn, which in turn discharges to Udale Bay, just to the west of Jemimaville. This septic tank is to have an additional reedbed treatment step added in the future.

Just outside of the western end of Cromarty Bay at Newhall Point is the settlement of Balblair. This is served by a Scottish Water septic tank designed for a population of 30. Also, three private septic tank discharges were seen at Balblair (observations 6-8, Table 4.4).

Ships and boats

Cromarty Firth has a deepwater port at Invergordon, which receives significant traffic from the oil industry. Cruise liners also visit dock at Invergordon between April and September, with 46 scheduled visits in 2009. They generally dock for about 12 hours before sailing. At Nigg there is an oil terminal and a mothballed industrial area, both of which have docks. A small Ferry sails twice every hour between Nigg and Cromarty during the day in the summer months. At Cromarty there is a small harbour where small fishing boats operate from, and some yacht moorings just to the west of here at the eastern end of Cromarty Bay. Whether any of this ship/boat traffic discharges waste water within Cromarty Firth is uncertain, but it is suspected that any occupied yachts on the moorings by Cromarty would probably be the most important source of overboard discharges within Cromarty Bay.

Conclusions

In summary, there is a septic tank discharge to the privately owned stretch of foreshore, which is likely to cause a localised increase in levels of contamination in any oysters cultured here. Discharges to the western end of Cromarty Bay (Jemimaville, Newhall and possibly Balblair) are also likely to affect water quality in Cromarty Bay, with greater impacts towards the western end. The main discharge at Cromarty is MBR treated, and discharges to the mouth of Cromarty Firth rather than within Cromarty Bay so is likely to be of much less significance to water quality within Cromarty Bay, although may be of significance when any overflow discharges here are in operation. Outside of Cromarty Bay there are several large discharges to Cromarty Firth, most notably those from Invergordon and Alness, which are raw discharges consented for a total population of about 23,000. They are being upgraded to secondary treatment and this is due for completion some time in 2010. Although these discharges will affect levels of contamination within Cromarty Firth as a whole, the exact effects of each of these discharges on water quality at Shoremill will depend on water circulation patterns within the 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 and the areas shaded blue indicate freely draining soils.

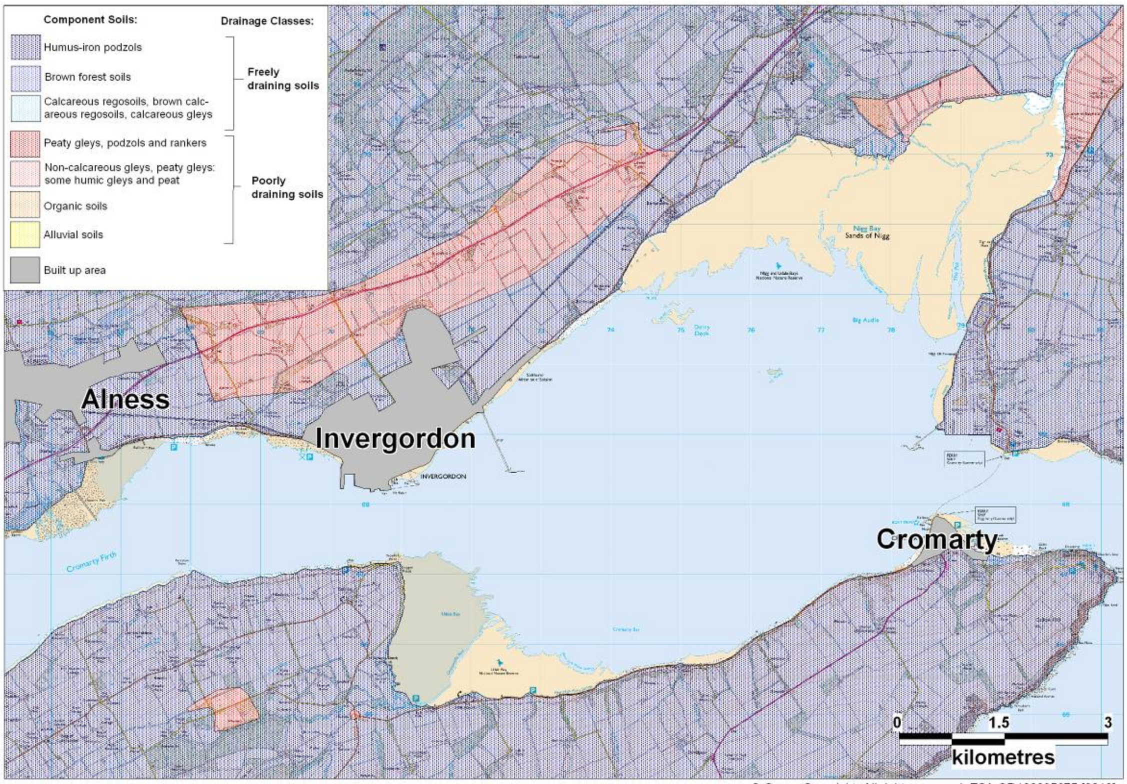

Figure 5.1 Component soils and drainage classes for Cromarty Firth

Two types of component soils are present in the area: peaty gleys, podzols and rankers and humus iron podzols. The humus iron podzols are freely draining; therefore the potential for runoff is reduced. These cover the majority of the land surrounding Cromarty Firth. The peaty gleys, podzols and rankers are poorly draining. Most of this soil type is found around the north shore of the survey area, with only a very small patch some distance back from the south shore. In addition to these two soil types, there are built up areas shown at Alness, Invergordon and Cromarty. These built-up zones have the highest runoff potential as they will contain extensive impermeable areas. Overall, outside of the built-up zones, the potential for runoff attributable to impermeable soils is low for this area.

6. Land Cover

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

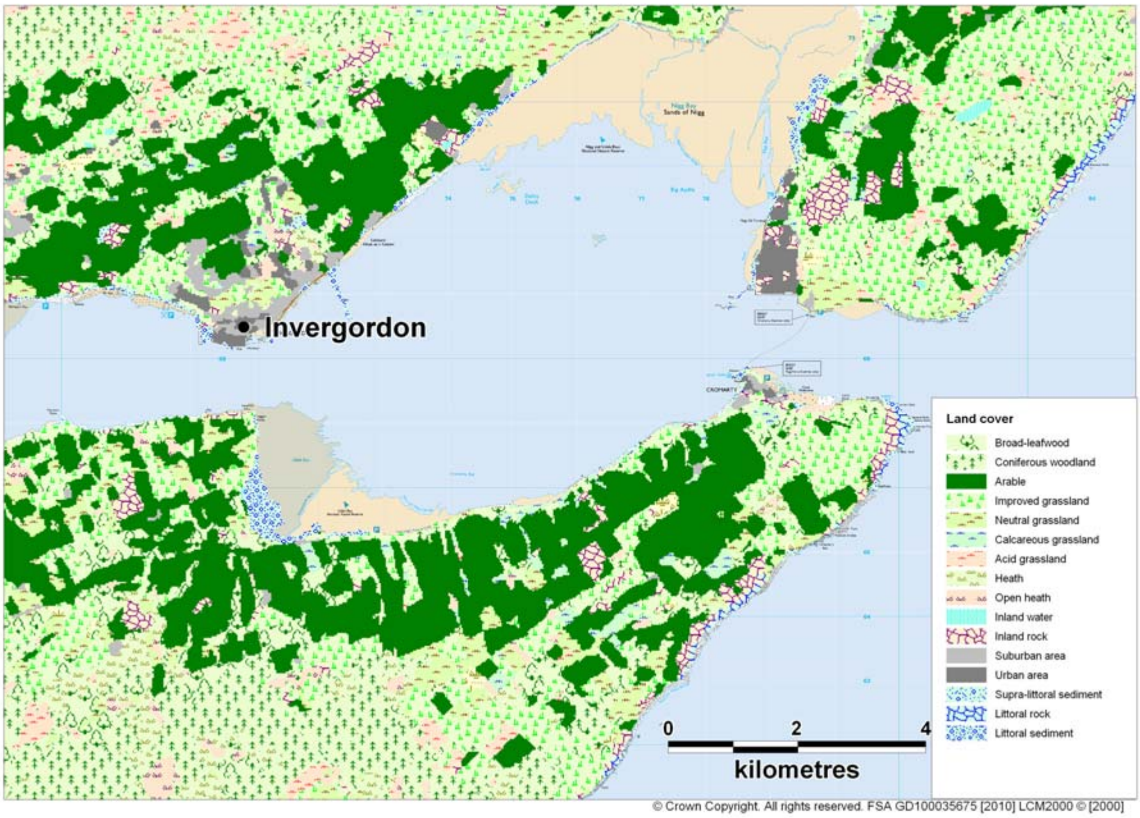

Figure 6.1 LCM2000 class land cover data for Cromarty Firth

There are a large variety of land cover types surrounding Cromarty Firth. On all sides of the shoreline there are large areas of arable land with patches of improved grassland, coniferous and broadleaf woodland. There are also a few areas of inland rock. There is a large built-up area located on the north-western shoreline at the town of Invergordon and a smaller one on the south-eastern shore at Cromarty. The Nigg oil terminal and associated dock area, located on the opposite side of the firth to Cromarty, also shows as urban area in Figure 6.1.

The faecal coliform contribution would be expected to be highest from developed areas (approx 1.2 – 2.8x10^{9} cfu km^{-2} hr^{-1}), with intermediate contributions 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. Although the expected contributions from arable land are generally low, slurry or manure may be used as fertiliser on these areas, so contributions may be relatively high following a recent application combined with significant rainfall.

Therefore, the overall predicted contribution of contaminated runoff from these land cover types would range from low to high, and would be expected to increase significantly following rainfall events. It is likely that parts of immediate shoreline with improved grassland and built-up areas, such as Invergordon and Cromarty, to the west and east of the fisheries, will be subject to higher levels of contamination.

7. Farm Animals

Agricultural census data was received from the Scottish Government Rural and Environment Research and Analysis Directorate (RERAD) for the Cromarty, Resolis, Nigg, Logie Easter, Kilmuir Easter, Rosskeen and Alness parishes, a total area of 521.1 km^2. Of this, 79.6 km^2 was classified as ‘total crops, fallow and setaside, 133.6 km^2 was classified as ‘total crops and grass’ (i.e. total crops, fallow and setaside together with improved grassland), and 165.6 km^2 was classified as ‘rough grazings’. Recorded livestock populations for these 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 the vicinity of Cromarty Bay, 2008

	Nigg	Cromarty	Resolis	Logie Easter	Rosskeen	Alness	Kilmuir Easter
Pigs	*	0	0	*	*	0	*
Poultry	*	*	179	1889	540	*	206
Cattle	956	1224	1156	994	1357	*	1019
Sheep	6447	*	*	3565	5699	*	2725
Deer	0	*	0	0	0	*	0
Horses and Ponies	*	*	32	31	72	27	25
Other livestock	0	*	*	*	*	0	0

*Data withheld for confidentiality

Numbers of sheep were highest (more than 18436 animals, with data undisclosed for Cromarty, Resolis and Alness), with numbers of cattle also significant (at least 6706 animals with data undisclosed for Alness). Cattle are dominant in the parishes that lie on the shoreline of Cromarty Bay (Cromarty and Resolis).

Due to large area of these parishes, this data does not provide localised information on the livestock numbers in the area immediately surrounding the production areas. However, it shows the general trend in the area surrounding the outer firth. In Figure 7.1, parishes have been thematically coloured by total livestock numbers. This shows that numbers of animals are generally greater on the north side of the firth. However, these could be located some way from the shore but could be near to watercourses that discharge into the firth.

The only significant source of localised information was the shoreline survey (see Appendix), which only relates to the time of the site visit on 12-14th 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), only selected parts of the land surrounding Cromarty Firth were surveyed.

The shoreline survey identified that arable farming dominates the land use on the shores of Cromarty Firth. A few areas of pasture where livestock were present were also recorded. Thirty cattle/calves were seen just under 1.5 km to the west of the oyster site and 12 sheep were recorded about 1.8 km to the east of the fisheries. Therefore, it is likely that streams draining these small areas of pasture carry contamination from livestock into Cromarty Bay. Further afield, approximately 250 sheep were recorded on pastures to the north of Nigg, and approximately 100 sheep were seen on the North Sutor. The livestock on the north shore are likely to make localised contributions to levels of contamination within Cromarty Firth but are not likely to have any significant impact on the microbiological quality of the fishery. The spreading of slurry on fields is likely to occur in the area. This may happen on any arable fields or improved pasture and at any time of the year, depending on a farms storage capacity, ground conditions and the growing cycle. Should heavy rain follow soon after slurry is spread, this can result in large amounts of contamination being carried into watercourses.

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. Therefore higher impacts from livestock may to be expected during this period.

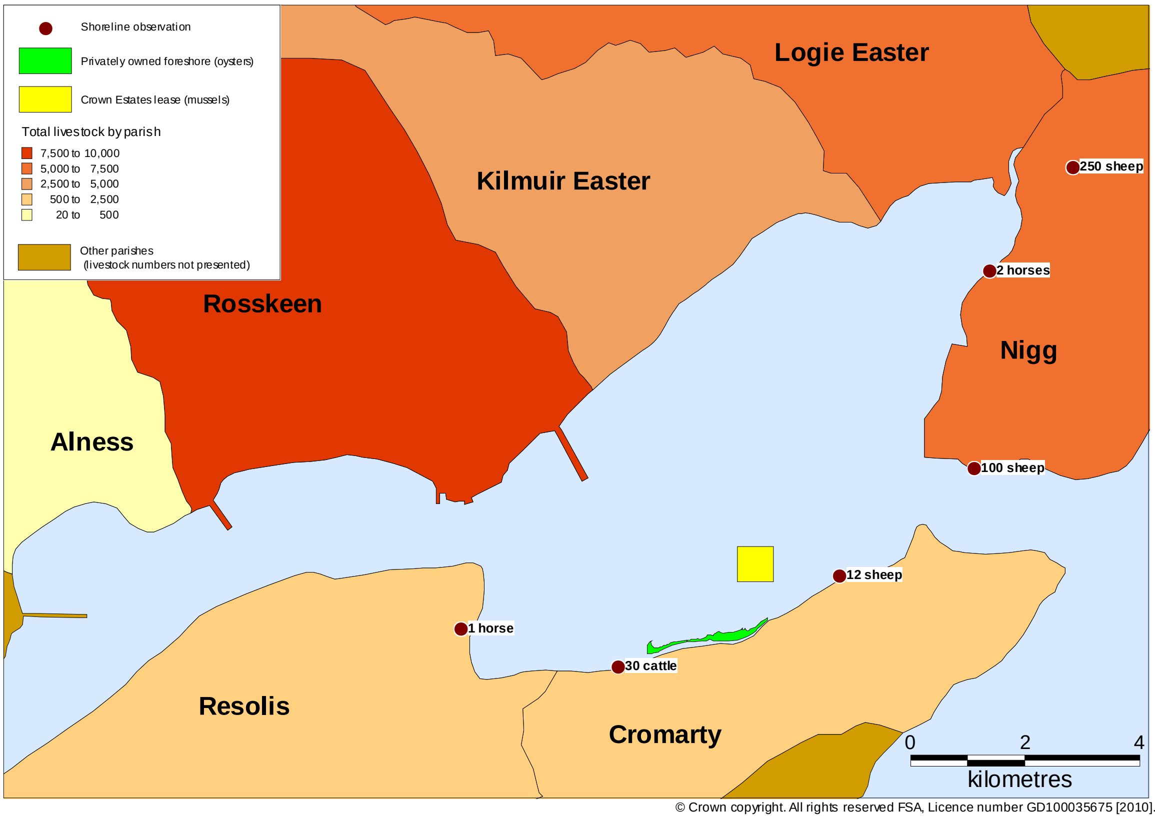

Figure 7.1 Shoreline survey livestock observations and total livestock numbers by agricultural parish

8. Wildlife

General information related to potential risks to water quality by wildlife can be found in Appendix 4. A number of wildlife species present or likely to be present at Cromarty Bay 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.

An estimated 138-286 common seals utilise sandbanks in the Cromarty Firth, but grey seals rarely occur here (Middlemas, 2003). Haulout sites were mainly in the Inner Firth, in the vicinity of the A9 road bridge, with one haulout site also identified in Nigg Bay. Therefore it is likely that common seals are a regular presence in the vicinity of the fishery. No seals were seen during the course of the shoreline survey.

Whales/Dolphins

The inner Moray Firth, which includes Cromarty Firth, is recognised as an internationally important area for bottlenose dolphins and was designated in 2005 as a Special Area of Conservation (SAC) under the EU Habitats Directive (92/43/EEC). Hammond & Thompson (1991) report a minimum estimate of 62 bottlenose dolphins in the Inner Moray Firth, with significant numbers of sitings around the mouth of Cromarty Firth. Wilson *et al* (1997) reports that this species is more frequently found in the inner areas of the Moray Firth during the summer months. Other smaller species such as harbour porpoises are likely to frequent the Cromarty Firth from time to time. It is uncertain whether the larger species commonly enter Cromarty Firth, although three Northern Bottlenose Whales (*Hyperoodon ampullatus*) were seen in Cromarty Firth recently, two of which became stranded on between Cormarty and Jemimaville (reported in the Daily Record, 3rd August 2009) so it is likely that these animals were unwell and not behaving normally.

Despite their presence in the area, their numbers are small relative to the area, and they are highly mobile, so their impacts on the fishery are likely to be minor and unpredictable.

Birds

Cromarty Firth contains a range of high-quality coastal habitats which provide important food sources for large numbers of wintering and migrating waterbirds (swans, geese, ducks and waders). It is part of a Special Protection Area (SPA) classified in accordance with the EC Birds Directive

(79/409/EEC), as well as a Ramsar site. There are RSPB reserves at Udale Bay and Nigg Bay. Wetland Birds Survey (WeBS) high tide counts are undertaken annually during the winter and published by the British Trust for Ornithology (BTO). Species recorded include swans, ducks, geese, waders and some other minor species. The five year average total count of overwintering waterbirds within Cromarty Firth from 2002/3 to 2006/7 was 33,038 (Austin *et al*, 2008). Of most significance to the fishery is Udale Bay, which host large numbers (thousands) of wigeon and pink footed geese during autumn and winter. Smaller populations of some species of waterbirds (e.g. swans, shelducks and oystercatchers) breed here during the summer. A similar pattern is observed at Nigg Bay.

In addition to waterbirds, there are significant numbers of breeding seabirds (gulls, terns, razorbills etc.) in Cromarty Firth. These were the subject of a detailed census carried out in sections during the late spring of 1999 (Mitchell *et al*, 2004). Total counts of all species recorded within 5 km of the site were 20 pairs of common gulls, 4 pairs of northern fulmar, 4 pairs of herring gull, and 2 pairs of great black-backed gull. More significant numbers (hundreds of pairs) of a variety of seabird species nest around the Nigg Ferry area and on the Sutors, but overall numbers are very low in relation to wintering waterbirds.

Deer

Although there was no specific information on numbers of deer in the vicinity of the production area, they are known to be present, and two were seen during the shoreline survey at the RSPB reserve at Nigg Bay.

Otters

No otters were observed during the course of the shoreline survey, although signage within the RSPB hides indicate that they are present in Cromarty Firth. However, the typical population densities of coastal otters are.

Summary

The main wildlife species potentially impacting on the production areas are likely to be waterbirds, which are only present in large numbers from October to April, with a high concentration of these birds at Udale Bay, just to the west of the fishery. Other species, such as seals, dolphins and seabirds are likely to frequent the area of the fishery, but as these animals are highly mobile, the impacts of these on the fishery will be unpredictable and widely spread temporally and geographically.

9. Meteorological data

The nearest weather station for which uninterrupted rainfall records for 2003-2008 are available is located at Geanies House, approximately 20 km to the north-east of the fishery. The nearest weather station for which wind data is available is Kinloss, approximately 33 km to the east of the fishery. It is likely that overall wind patterns are broadly similar at the fishery and at Kinloss, but local topography may result in some differences in patterns, and conditions at any given instant may differ due to the distance between them. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within Cromarty Bay.

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 midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

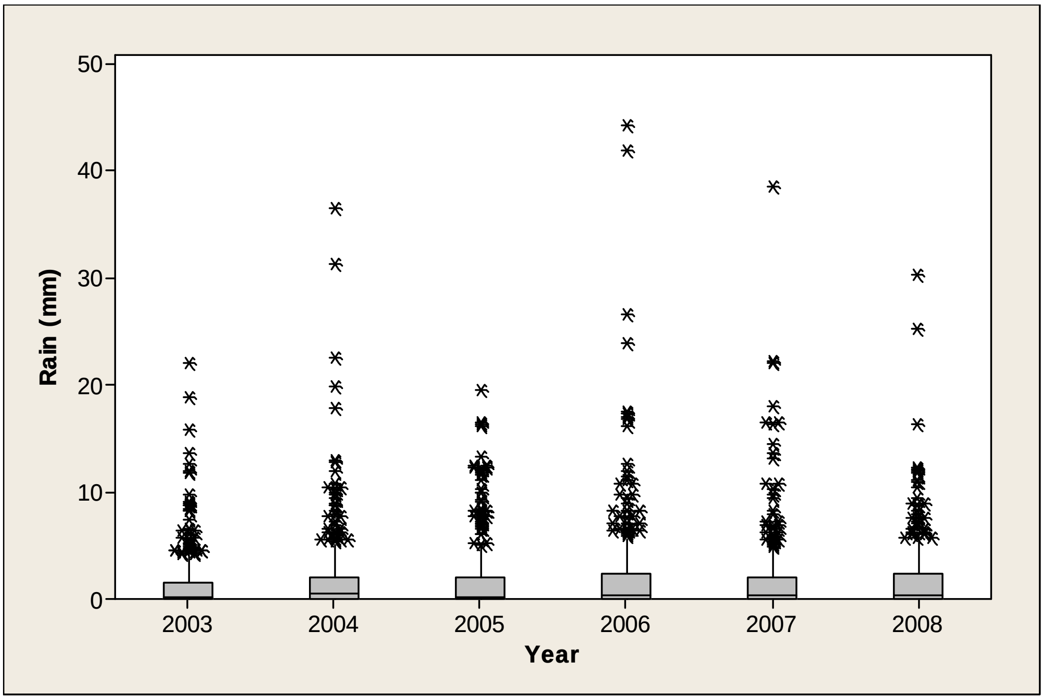

Figure 9.1 Box plot of daily rainfall values by year at Geanies House, 2003-2008

Figure 9.1 shows that 2003 appeared drier than other years and peak rainfall events in 2003 and 2005 were not as high as in other years.

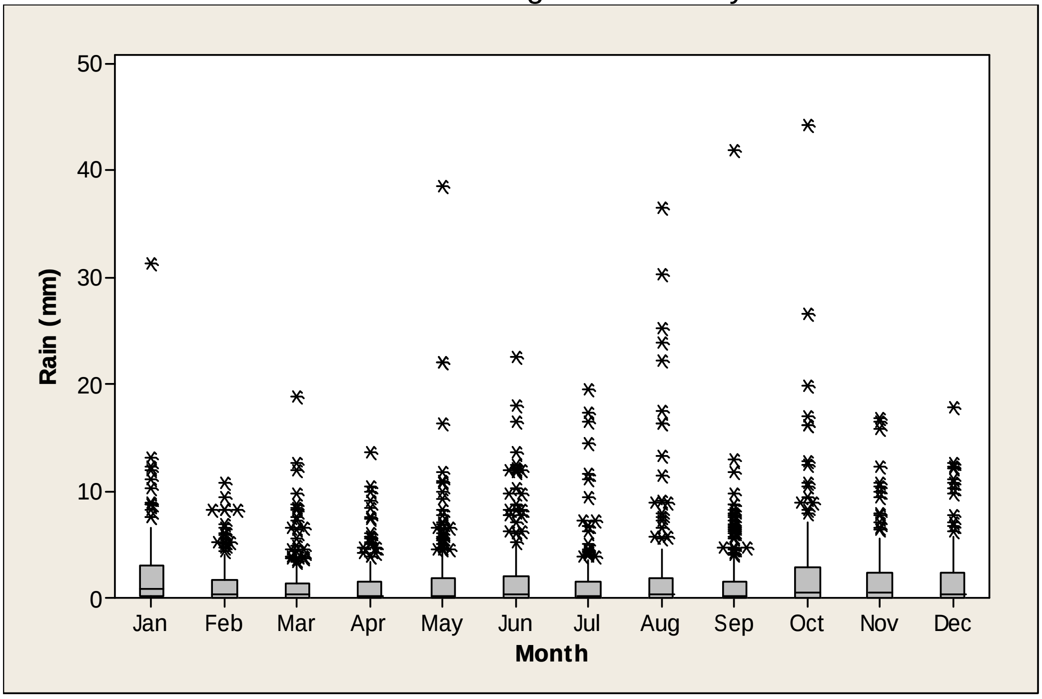

Figure 9.2 Box plot of daily rainfall values by month Geanies House, 2003-2008

The wettest months were October, November, December and January. The highest daily rainfall values were seen in January, May and August to October, although many of these represented single events. For the period considered here (2003-2008), 64% of days experienced rainfall less than 1 mm, and 3% of days experienced rainfall of 10 mm or more.

It can therefore be expected that levels of rainfall dependent faecal contamination entering the production area from these sources will be higher on average during the autumn and winter months. High rainfall events can occur at any time of year, perhaps with the exception of February to April, and these may result in a 'first flush' of highly contaminated runoff from pastures. This effect may be particularly acute during the summer, when livestock numbers are likely to be highest, and any preceding dry periods result in a build-up of faecal contamination on pastures.

9.2 Wind

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

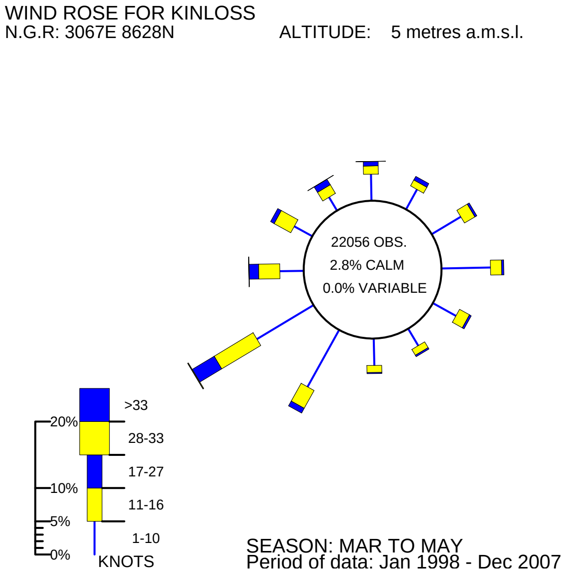

Figure supplied by the Meteorological Office under licence. ©Crown copyright 2010.

Figure 9.3 Wind rose for Kinloss (March to May)

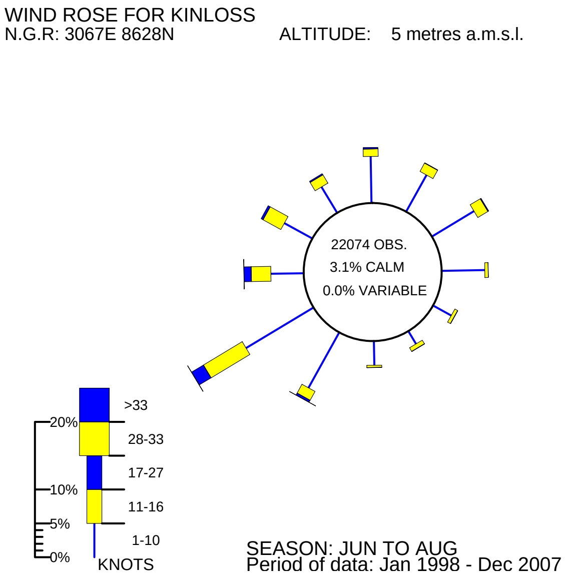

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Figure 9.4 Wind rose for Kinloss (June to August)

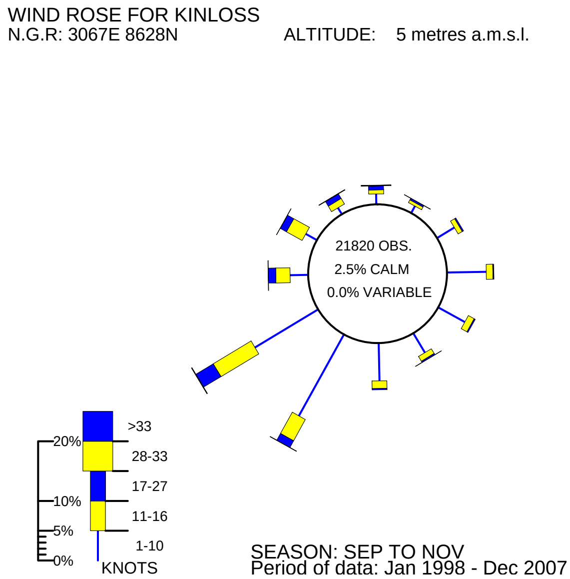

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Figure 9.5 Wind rose for Kinloss (September to November)

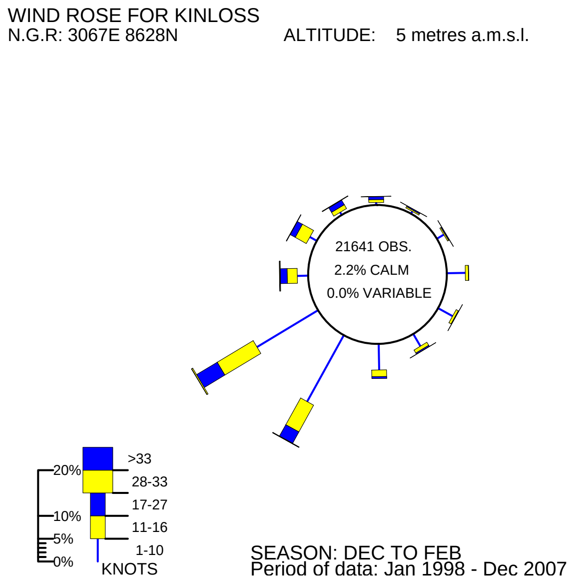

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Figure 9.6 Wind rose for Kinloss (December to February)

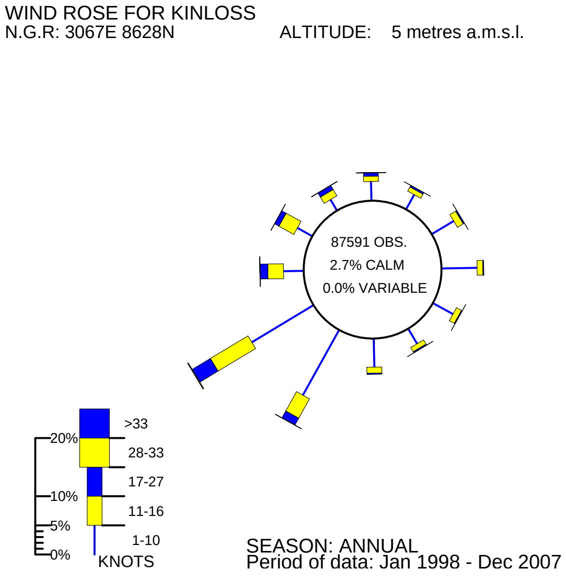

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Figure 9.7 Wind rose for Kinloss (Annual)

Wind direction is strongly skewed towards the south west at Kinloss, and there is a relatively low frequency of gales here compared to places such as Shetland. Winds are lightest during the summer months, and there is a higher frequency of winds from the north and east during spring and summer. The very skewed patterns of wind direction may be influenced by local topography. The station is located within the airfield at Kinloss, which is situated on low lying coastal land with the Moray Firth to the north, and Findhorn Bay to the west, but its exact siting in relation to minor topographical features is not known.

Cromarty Bay is located on the southern shore of Cromarty Firth, and is most exposed to winds from the north east, and most sheltered from winds blowing from the south. The Firth as a whole has an east-west aspect. However, the Udale Bay to Nigg Bay area has a large south-west to north-east aspect and thus may be more subject to the effects of prevailing winds coming from the south-west. 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. These surface water currents create return currents which may travel along the bottom or sides of the water body depending on bathymetry. Strong winds will increase the circulation of water and hence dilution of contamination from point sources within the sound. Winds from a northerly and north easterly direction are likely to result in the most significant changes to circulation and induce onshore wave action at the fishery, which may resuspend any contamination within the sediment. Also, winds blowing from the west or east, along the length of the firth as a whole are likely to alter patterns of water circulation within the firth.

10. Current and historical classification status

In 2001, three areas within Cromarty Firth were classified for the harvest of cockles. Cromarty Firth was given a provisional B classification while Nigg Bay and Udale Bay were given a full B classification. The areas classified are shown in Figure 10.1. No RMP was assigned for these production areas. Up until about the mid 1990s oysters were cultured at the area of old trestles at Shoremill, but at this time classifications were assigned by Fisheries Research Services (FRS) and records of these are no longer available. No part of Cromarty Firth has been classified for the harvest of shellfish since 2001.

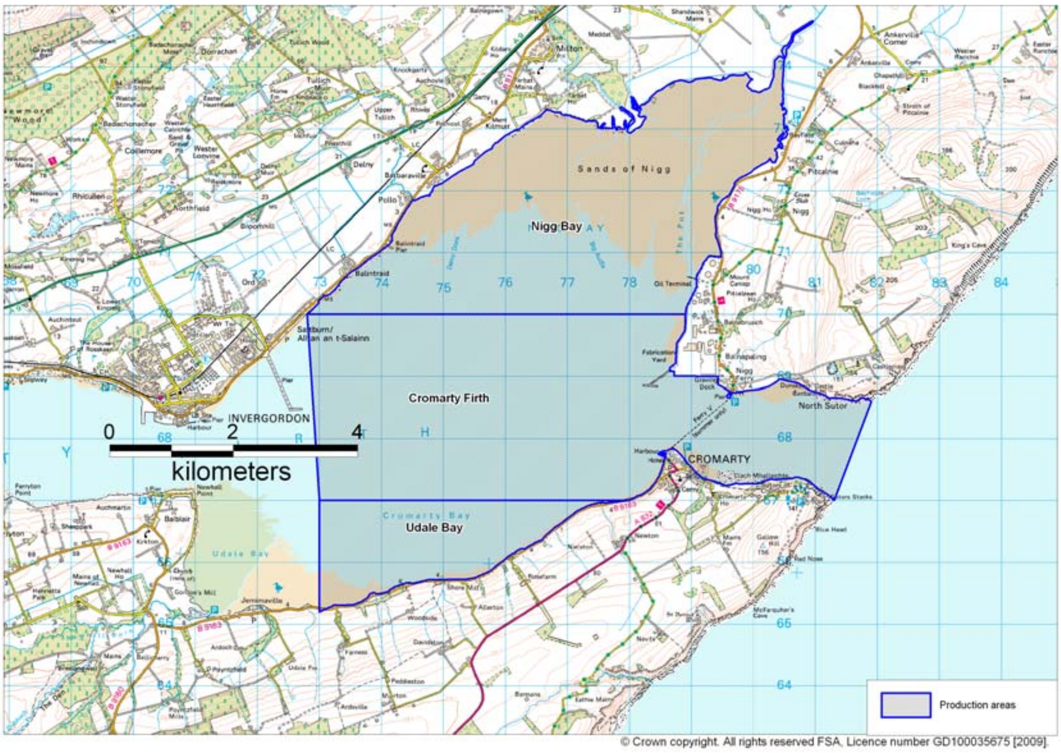

Figure 10.1 Areas classified for cockles in 2001

11. Historical *E. coli* data

11.1 Validation of historical data

While the available database covered the period from 2002 to 2009 inclusive, *E. coli* results for samples taken in Cromarty Firth only covered a period of six months in 2009. These were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

One Pacific oyster sample had no *E. coli* result as some of the shells were dead when opened at the laboratory, and so could not be used in the analysis.

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

11.2 Summary of microbiological results

Individual sample details are presented in Table 11.1. All samples were collected in 2009, following the receipt of the application to classify the area. The mussels were not grown *in situ*, but gathered from around Cromarty Harbour, and deployed in bags at least 2 weeks before they were sampled. The Pacific oysters were old stock from the previous oyster culture operation at the site, and believed to be more than a decade in age.

Table 11.1 Individual sample results from Cromarty Firth

Collection date	Production area	Site	SIN	Species	Grid reference	*E. coli* (MPN/100g)
10/03/2009	Cromarty Bay Mussels	Shoremill Mussels	RC-473-883-08	Common mussels	NH 75104 66334	1300
28/04/2009	Cromarty Bay Mussels	Shoremill Mussels	RC-473-883-08	Common mussels	NH 75187 67197	1400
27/05/2009	Cromarty Bay Mussels	Shoremill Mussels	RC-473-883-08	Common mussels	NH 75370 67137	330
17/06/2009	Cromarty Bay Mussels	Shoremill Mussels	RC-473-883-08	Common mussels	NH 75551 67197	230
03/08/2009	Cromarty Bay Mussels	Shoremill Mussels	RC-473-883-08	Common mussels	NH 75371 67133	170
29/09/2009	Cromarty Bay Mussels	Shoremill Mussels	RC-473-883-08	Common mussels	NH 75393 67129	270
10/03/2009	Cromarty Shoremill	Shoremill Oysters	RC-473-884-13	Pacific oysters	NH 75291 65781	130
12/05/2009	Cromarty Shoremill	Shoremill Oysters	RC-473-884-13	Pacific oysters	NH 75262 65757	80

E. coli results for mussels ranged from 170 to 1400 *E. coli* MPN/100 g, with a geometric mean of 430 *E. coli* MPN/100 g. Four of 5 samples gave results of 230 *E. coli* MPN/100 g or over. Highest results arose in March and April.

Both Pacific oyster samples gave results of less than 230 *E. coli* MPN/100 g.

11.3 Overall geographical pattern of results

Figure 11.1 presents a map showing *E. coli* results by reported sampling locations.

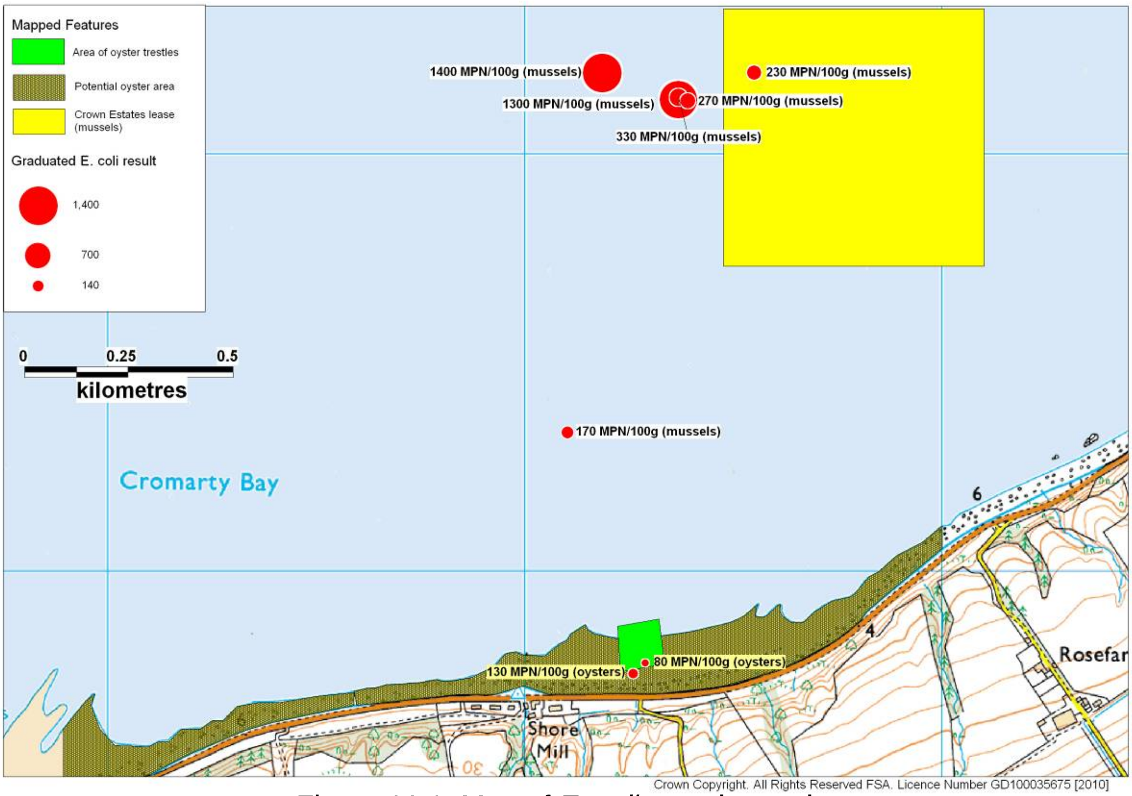

Figure 11.1 Map of *E. coli* sample results

The two highest results were seen in mussel samples taken further offshore, although whether it is not known whether this was a spatial or temporal effect as they occurred in samples taken in adjacent months. Higher results were seen in oysters but this may be due to species differences rather than spatial effects (Younger *et al*., 2003). On the one occasion when both mussels and oysters were sampled on the same day, oysters from the area of trestles gave a result of 130 *E. coli* MPN/100g, whereas mussels from the more offshore location gave a result of 1300 *E. coli* MPN/100g.

11.4 Further analysis of results

There was insufficient data to conduct meaningful analyses of the effects of season and environmental variables on *E. coli* levels in shellfish at Cromarty Bay.

12. Designated Shellfish Growing Waters Data

The area considered in this report coincides with a shellfish growing water that was designated in 1998. The extent of the growing water and the location of monitoring points is shown on Figure 12.1.

The monitoring requires the following testing:

- Quarterly for salinity, dissolved oxygen, pH, temperature, visible oil
- Twice yearly for metals in water
- Annually for metals and organohalogens in mussels
- Quarterly for faecal coliforms in mussels

Monitoring results for faecal coliforms in shore mussels to the end of 2008 have been provided by SEPA. These results are presented in Table 12.1.

Two points were sampled, both about 1.5 km to the east of the area of trestles at Shoremill. The geometric mean result of all shore mussel samples was 382 faecal coliforms /100 g. Results ranged from 40 to 16000 faecal coliforms/100 g, showing the potential for high levels of contamination at times. Geometric mean result for quarters 1 and 2 were very similar (180 and 182 faecal coliforms/100 g), as were results for quarter 3 and 4 (760 and 711 faecal coliforms/100 g), but differences between results by quarter were not significant (One-way ANOVA, p=0.158, Appendix 6). Levels of faecal coliforms are usually closely correlated to levels of *E. coli* often at a ratio of approximately 1:1. The ratio depends on a number of factors, such as environmental conditions and the source of contamination. However, the results show that the shellfish in Cromarty Bay are exposed to significant levels of faecal contamination on occasions in the past. There is some indication in Table 12.1 that this effect may have reduced since 2006.

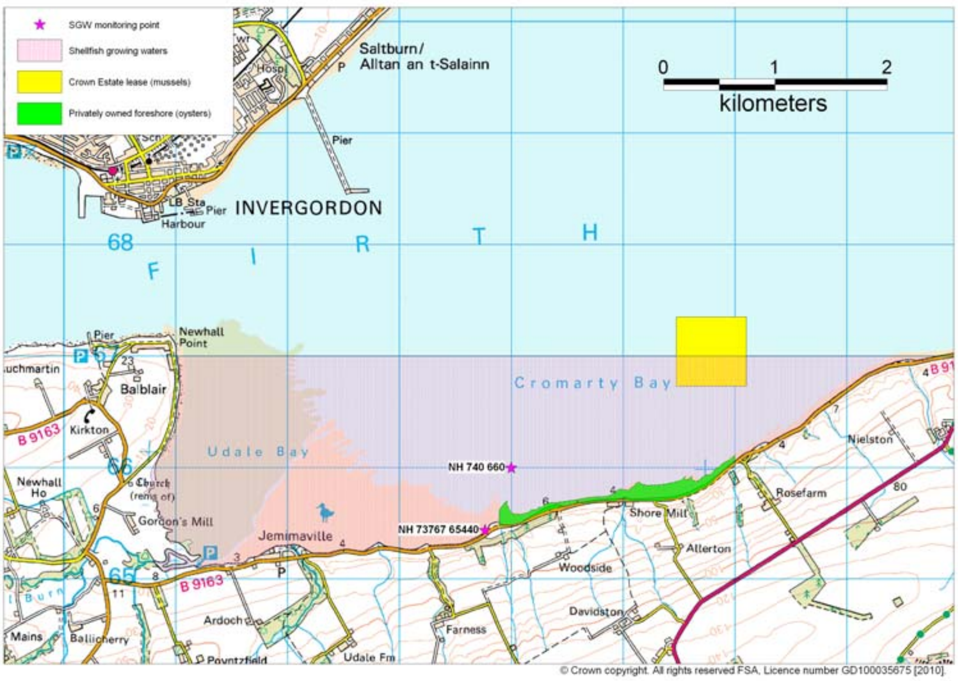

Figure 12.1 Shellfish growing waters and monitoring points

Table 12.1 SEPA Faecal coliform results (faecal coliforms/100g) for shore mussels gathered from Cromarty Bay.

	Site	Cromarty Bay	Cromarty Bay
	OS Grid Ref	NH 740 660	NH 73767 65440
2000	Q1	500	
	Q2		
	Q3		
	Q4		
2001	Q1		
	Q2		
	Q3	750	
	Q4	750	
2002	Q1	500	
	Q2	110	
	Q3	320	
	Q4	200	
2003	Q1	50	
	Q2		
	Q3		16000
	Q4		750
2004	Q1		90
	Q2		40
	Q3		160
	Q4		9100
2005	Q1		40
	Q2		220
	Q3		160
	Q4		500
2006	Q1		50
	Q2		2400
	Q3		1300
	Q4		16000
2007	Q1		700
	Q2		220
	Q3		3500
	Q4		160
2008	Q1		700
	Q2		70
	Q3		250
	Q4		50

13. Rivers and streams

The following rivers and streams within Cromarty Bay were measured and sampled during the shoreline survey. The survey was undertaken under dry conditions.

Table 13.1 Stream loadings for Cromarty Bay

No.	Position	Width (m)	Depth (m)	Flow (m/s)	Discharge (m^3/d)	*E. coli* (cfu/100ml)	*E. coli* loading (cfu/day)
1	NH 75277 65700	0.3	0.02	0.145	75	<100	$<7.5\times10^{7}$
2	NH 75140 65695	0.15	0.01	0.576	75	22000	1.6×10^{10}
3	NH 75003 65712	0.48	0.05	0.388	805	<100	$<8.0\times10^{8}$
4	NH 73900 65465	0.28	0.08	0.419	811	<100	$<8.1\times10^{8}$
5	NH 73256 65265	0.45	0.07	0.348	947	<100	$<9.5\times10^{8}$
6	NH 72826 65291	0.98	0.12	0.069	701	100	7.0×10^{8}
7	NH 72020 65316	1.63	0.12	0.146	2467	100	2.5×10^{9}
8	NH 71337 65134	5.75	*	*	11362	100	1.1×10^{10}
9	NH 75562 65738	0.6	0.02	0.3	311	<100	$<3.1\times10^{8}$
10	NH 76790 66525	1.12	0.03	0.335	973	<100	$<9.7\times10^{8}$

*Measured at several points across the transect, individual measurements not shown

Generally, streams discharging to the shore of Cromarty Bay had low levels of faecal contamination at the time of survey (100 or <100 *E. coli* cfu/100ml). This included the Davidston Burn (3) which is reported to receive a private septic tank discharge, and the Newhall Burn, which receives a small Scottish Water septic tank discharge. The exception to this was a very small stream discharging to the area of privately owned foreshore. This contained 22,000 *E. coli* cfu/100 ml and, despite its small size, gave the highest calculated *E. coli* loading. Growth of sewage fungus was noted within this stream suggesting it receives continuous or regular inputs of waste water, presumably from one of the houses at Shoremill. The location of this stream will probably result in differences in the level of contamination in oysters grown in the intertidal zone along this shore, but is of less significance to the mussel fishery which will be located over 500 m offshore.

On a larger scale, the Cromarty Firth receives surface runoff from a catchment area of 962 km^2. Land use within the catchment is 10% grazing, 10% arable, 1% rural residential/roads and 79% natural/semi natural vegetation (Eyre and Balls, 1999). The largest river input is the River Conon, which discharges at the head of the firth. Median discharge from the River Conon is about 3.5×10^6 m^3/d (CEH, 2005) and the flow is therefore many times larger than any of the watercourses listed in Table 13. It is regulated to some extent by the presence of hydroelectric schemes. Several smaller rivers and numerous streams also discharge to Cromarty Firth. These inputs are likely to increase background levels of contamination within Cromarty Firth and thus have a general impact on the microbiological quality of the shellfish at Cromarty Bay.

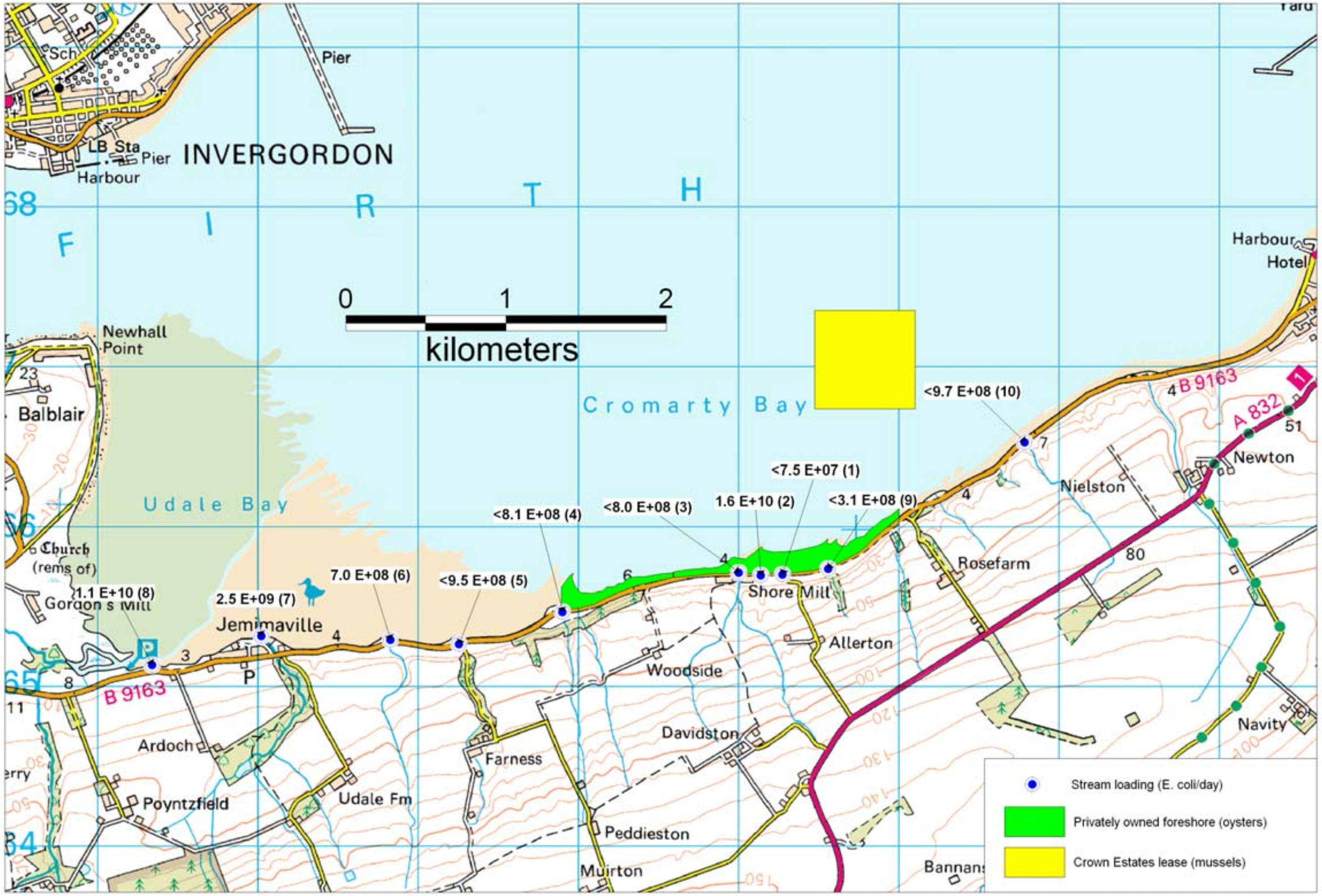

Figure 13.1 Stream loadings around Cromarty Bay

14. Bathymetry and Hydrodynamics

14.1 Physical characteristics

Figure 14.1 Bathymetry of Cromarty Firth

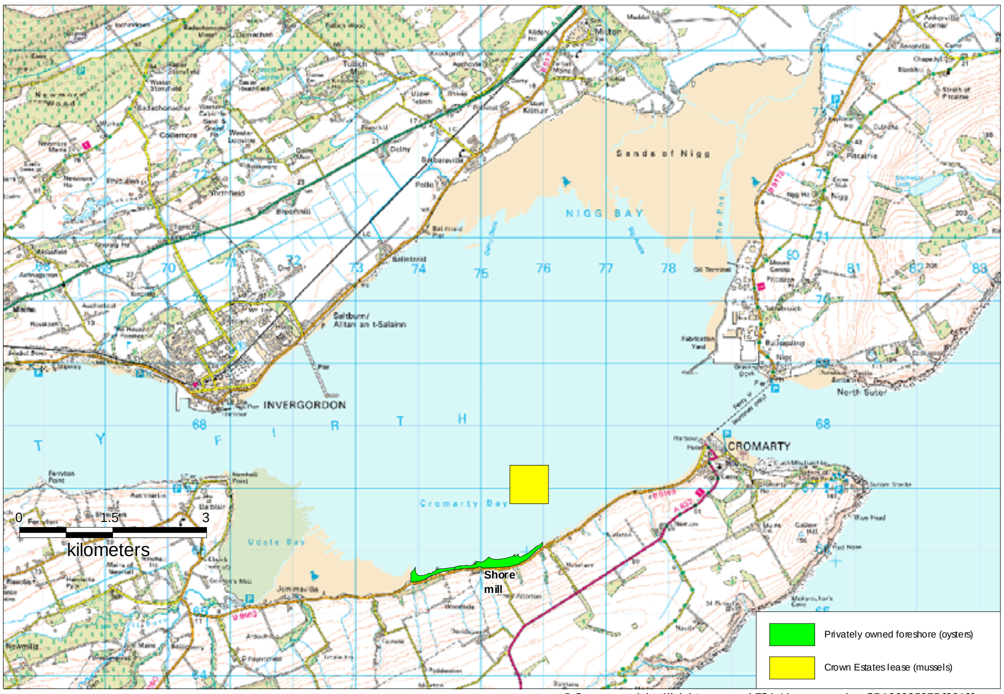

Figure 14.2 OS map of Cromarty Firth

Figures 14.1 and 14.2 only show the outer section of Cromarty Firth in which Cromarty Bay is located. Cromarty Firth is an enclosed estuary of about 30 km in length, with a maximum depth of about 50 m at its mouth. A deep channel runs along the centre of the firth. To the north of this channel is Nigg

Bay, and to the south is Cromarty Bay, both of which are shallow and gently sloping. There are large intertidal areas in the Udale Bay/ Cromarty Bay area on the south side of the firth and at Sands of Nigg on the north.

14.2 Tides

The two tidal curves below are for Cromarty. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 10/5/09 and the second is for seven days beginning 00.00 GMT on 29/8/09. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

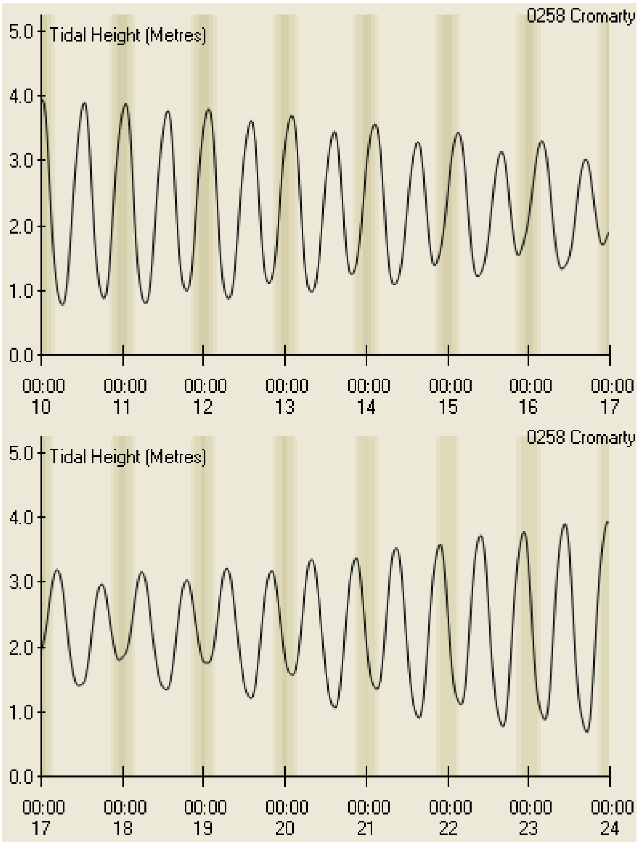

Figure 14.3 Tidal curves for Cromarty

The following is the summary description for Cromarty from TotalTide:

Cromarty is a Secondary Harmonic port. The tide type is Semi-Diurnal. Predicted heights are in metres above Chart Datum.

HAT	5.0 m
MHWS	4.3 m
MHWN	3.3 m
MSL	2.46 m
MLWN	1.6 m
MLWS	0.7 m

The tidal range at spring tide is therefore approximately 3.6 m and at neap tide 1.7 m.

The nearest locations for which tidal stream information was available was for two locations just off Invergordon, three locations at the mouth of Cromarty Firth and one location in the main channel about half way between the two. Tidal stream information for these locations is presented in Figure 14.4 for flooding and ebbing spring tides.

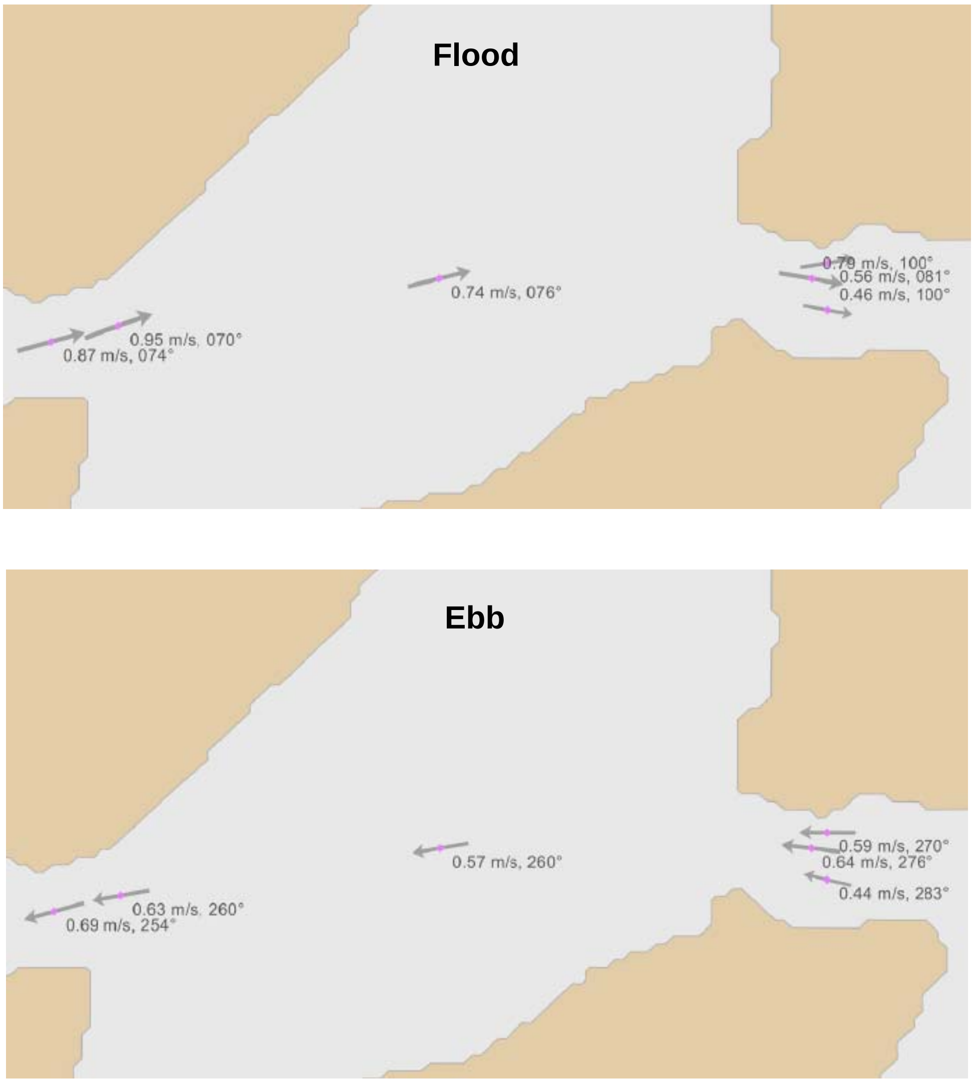

Figure 14.4 Tidal flows and direction during flooding and ebbing spring tides at Cromarty Firth (taken from TotalTide)

Figure 14.4 indicates that there is a strong bi-directional tidal flow along the main central channel of the outer reaches or Cromarty Firth. The tidal diamonds (not shown) indicate that flows can exceed 1 m/s at some locations on ebbing spring tides, and are roughly twice as strong on spring tides compared to neap tides. This information however does not provide a firm indication of the pattern of tidally driven currents within Udale Bay/Cromarty

Bay, and is probably more relevant to the mussel fishery than the oysters. Figure 14.1 suggests scouring has occurred at the mouth of the firth and at the constriction at Invergordon as is consistent with the relatively strong tidal flows here. A raised sand bar protrudes into Cromarty Bay from Newhall point at its western end, suggesting that sediment is deposited here by a slowing current.

14.3 Wind driven flows

The nearest weather station for which wind data was available was at Kinloss (Figures 9.3 to 9.7). Wind direction is strongly skewed towards the south west, and there is a relatively low frequency of gales. Winds are lightest during the summer months, and there is a higher frequency of winds from the north and east during spring and summer. The skewed patterns of wind direction at Kinloss may be influenced by local topography.

Cromarty Firth as a whole has an east west aspect, but Cromarty Bay itself is most exposed to north and north-easterly winds, which cross up to 10 km of open water before reaching Shoremill. Wind driven currents have the potential to significantly alter flows around the firth, creating surface currents flowing in the same direction as the wind, with the path of return currents depending on bathymetry. The predominant south-westerly winds blowing across the reltively open area from Udale Bay to Sands of Nigg, would tend to modify currents in such a way as to keep contamination from most sources away from the oyster area and could also deflect contamination from several sources to pass to the north of the mussel area. However, there is the potential for such winds to enhance travel of contamination from the stream at Shore Mill towards the mussel area.

14.4 Density driven flows

The catchment area of the Cromarty Firth is 962 km^2. The largest river input is the River Conon, which discharges at the head of the estuary, and there are some other significant rivers and many smaller watercourses discharging to the firth. Surface seawater samples taken from Cromarty Bay during the shoreline survey generally had salinities of between 30 and 34 ppt, indicating some freshwater influence at the time, although these measurements were taken under dry conditions. As well as carrying contamination from land runoff, freshwater can create density driven currents. Density driven currents are likely to be of significance within Cromarty Firth following high rainfalls. Simplistically, a net seaward flow of fresh water will occur at the surface of the firth, with return currents of more saline water at depth. Mixing of saline and fresh water and disruption of any stratification is more likely to occur at constrictions where currents are flowing fastest.

14.5 Other information

An hydrographic survey of the Cromarty Firth was carried out by the Marine Laboratory, Aberdeen (now Fisheries Research Services) in 1966 (Craig & Adams, 1967). Salinity profiles at various depths and states of the tide were taken at transects at Alness, Invergordon and Shoremill. This identified that density dependent effects were in operation, with a net outflow of less saline water at the surface and a net inflow of more saline water at the bottom. This had the effect of prolonging the ebb tide at the surface. The salinity reduction was highest towards the south shore, where surface ebb currents were prolonged the most. The skipper of the fishing boat used during the shoreline survey indicated that the current usually flows from west to east at Shoremill (where the oyster trestles were located), even on a flooding tide. This would appear to be consistent with the observations and deductions of Craig and Adams (1967).

14.6 Modelling assessment

This site was chosen for a full hydrodynamic modelling using the Hydrotrack model described in the Hydrography Methods Document. This document can be consulted for background information on the model and the methods applied.

14.6.1 Set-up

The area covered by the model is shown in Figure 14.5. Approximate depths relative to Mean Sea Level were obtained from Chart Datum values (Figure 14.1) by adding a uniform 2-metre correction. The model was set up with a resolution (grid size) of 125 m. Separate spring and neap tide simulations were run with semi-diurnal (12.4 hour period) tidal current forcing applied at the sea boundary to reproduce the observed spring and neap tidal range of approximately 3.5 and 1.7 m respectively (Figure 14.3). Inputs from the river Conon at the head of the firth was included and set at 50 $m^3 s^{-1}$ to approximate the annual average flow rate. The magnitude of the tidal velocities (Figure 14.6) indicated that tidal flows were the dominant currents and therefore attention was focussed on these rather than wind driven flows.

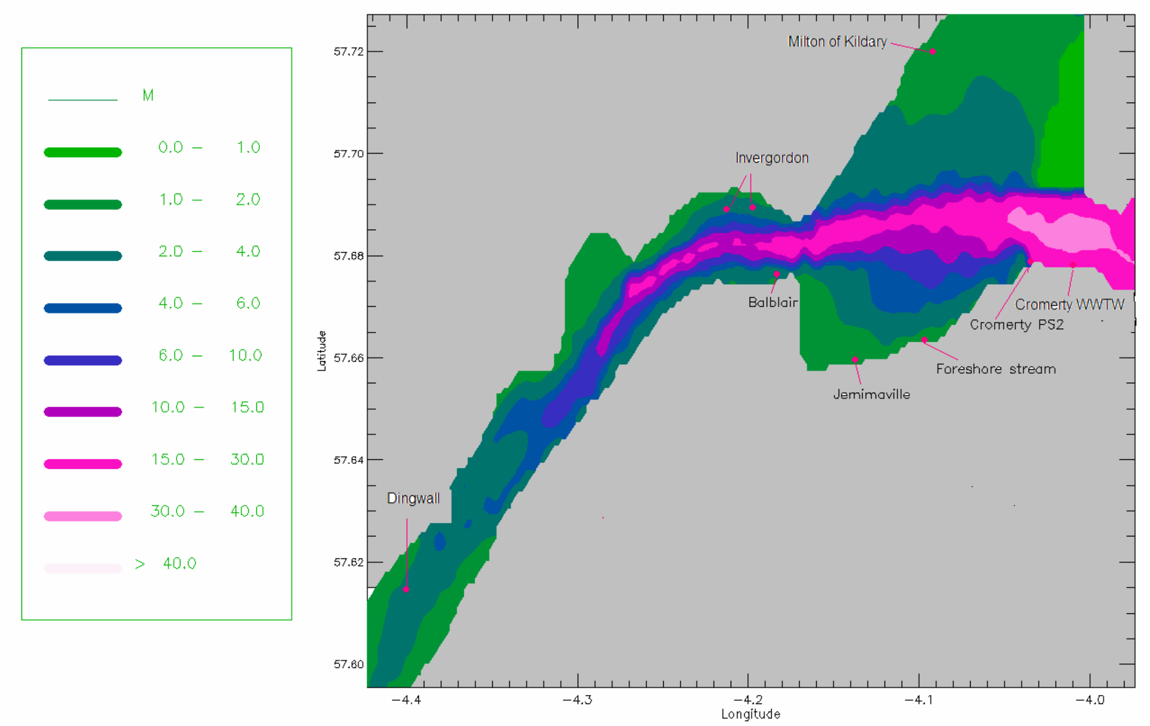

Figure 14.5 Model domain with depths (m).
With permission SeaZone Ltd. Also shown are the locations of main contaminant sources used in the model runs.

Flow fields were tidally analysed into a residual flow together with the principal diurnal tide and three higher harmonics. Particle paths calculated using the recombined tide. This procedure does lose some information contained in the higher harmonics. However tests including further harmonics showed only minor changes to predicted paths.

A large number of potential sources of contamination can be identified for this water body. For the modelling study a subset were selected based on magnitude of the consented discharges, proximity to the leased area or by the bacterial loads sampled during the shoreline survey. Eight potential sources were considered, and these are indicated in Figure 14.5. The 'foreshore stream' was identified during the shoreline survey as having a particularly high bacterial load (observation 2, Table 13.1). At each modelled source, particles were released at different states of the tide and followed for a number of tidal cycles. For clarity, particle paths were plotted only for the 1st tidal cycle as most impact is likely to occur soon after discharge because both dilution and bacterial decay will tend to mitigate impacts over time.

Ideally the model domain should include a significant portion of the surrounding coastal area outside the region of interest. This has not been possible here because of the model has limitations in size of the region it can cover at high resolution. Thus only the Cromarty Firth itself has been modelled with the sea boundary placed at the entrance to the Firth. This means that the net flow through the entrance is strongly controlled by the imposed tidal forcing rather than being calculated by the modelled physical processes. Studies were therefore carried out to assess the sensitivity of results to the open boundary conditions, and in particular to imposing a net flow across the seaward boundary. Sensitivity runs were also undertaken to investigate the effect of small changes (1-2 grid points) in the modelled location of the source positions.

Using a depth-integrated (2D) model does not allow the incorporation of density driven effects such as those described in section 14.5. Therefore, although tidally driven currents are dominant, and the modelling results are likely to describe the average throughout the whole water column with reasonable accuracy, there are likely to be significant differences in particle paths between the top and bottom of the water column in places, particularly at times of high freshwater input.

14.6.2 Results

Modelled tidal currents at spring tides (Figure 14.6) were found to be in reasonable agreement with tidal diamond information (Figure 14.4). In the main channel these velocities correspond to tidal excursions of the order of 10 km at spring tides and perhaps 7 km at neap tides.

An initial investigation of particle paths from all modelled sources was made. From this it was found that impacts within Cromarty Bay were primarily associated with particles released around high water. For sources to the west of the bay (e.g. Balblair) this is expected since particles released near high water will move east on the subsequent ebb tide. However potential impact were also found for particles released at high water from sources at Cromarty. The reasons for this are discussed later. In general it was found that after a few tidal cycles most particles tended to move into the main channel where they bypass Cromarty Bay and are eventually expelled from the firth. Because of the observed importance of high water releases, results are focussed on particles released a few hours on either side of high water. This has an additional advantage of ensuring that particles are released into water rather than an exposed foreshore. Also for continuous discharges, highest concentrations occur at slack water when flow induced dilution is low. Thus when high and slack water occur close together (generally the case in most estuaries, including Cromarty Firth) high water releases are also associated with higher initial concentrations.

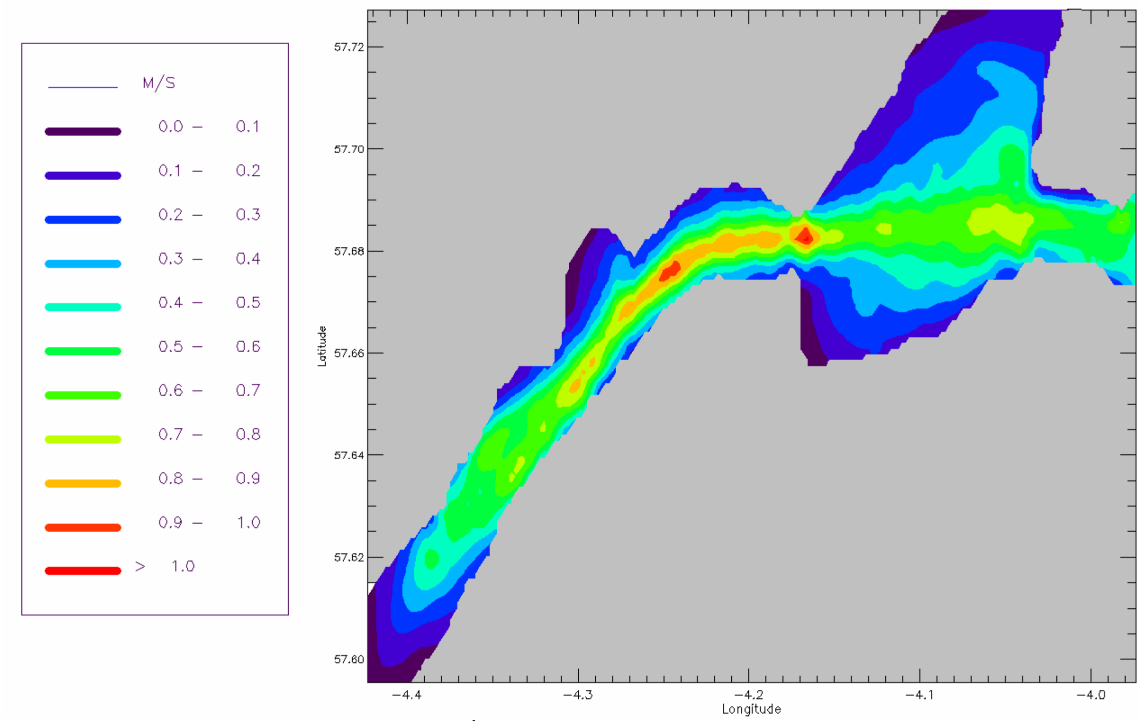

Figure 14.6 Tidal speed (ms^{-1}) for the principal diurnal tidal constituent.

To give an overall impression of model predictions for spring and neap tides, Figures 14.7 and 14.8 show summary plots of particle paths over a 12.4 hour tidal period, superimposed from all start locations with particles released within a 2-hour window around high water. These suggest a strong influence of the spring-neap cycle, with impacts mainly associated with the greater tidal excursions at spring tides. No impacts at either the mussel or the oyster sites were predicted for inputs from Invergordon, Milton Kildary or from the head of the estuary (represented by Dingwall) over a period of at least several tidal cycles. These start locations were therefore not investigated further. The sources at Cromarty, Jemimaville, Balblair, and the stream at Shoremill are considered in more detail below.

Studies were carried out to assess the sensitivity of results to the open boundary. The baseline calculations used sinusoidal tidal forcing only at the boundary. Calculations were also carried out with a uniform eastward 0.02 ms^{-1} residual current superimposed on the tidal forcing at the boundary. The results showed some changes, in particular paths tended to extend further to the east, but did not change the overall picture in terms of which sources impacted within Cromarty Bay. Tests of the sensitivity to small changes in start locations of the particles showed that the particle paths from the Cromarty town discharges (both the WWTW and the PS2 site) were rather sensitive to the assumed start position. Other sources showed rather less (but not negligible) sensitivity to small (1-2 grid points) changes in assumed start position.

The source at Balblair (Easter Ross) is a continuous septic tank treatment level discharge with a population equivalent of 30 (see Section 4). Material released near high water at spring tides was predicted to potentially impact the mussel lease area (Figure 14.9). As already noted, releases around high water slack are likely to be at higher concentrations because flow induced dilution is low. Material was predicted to reach the lease area near low water slack so contaminated water could persist there for a number of hours. No impact was predicted for neap tides.

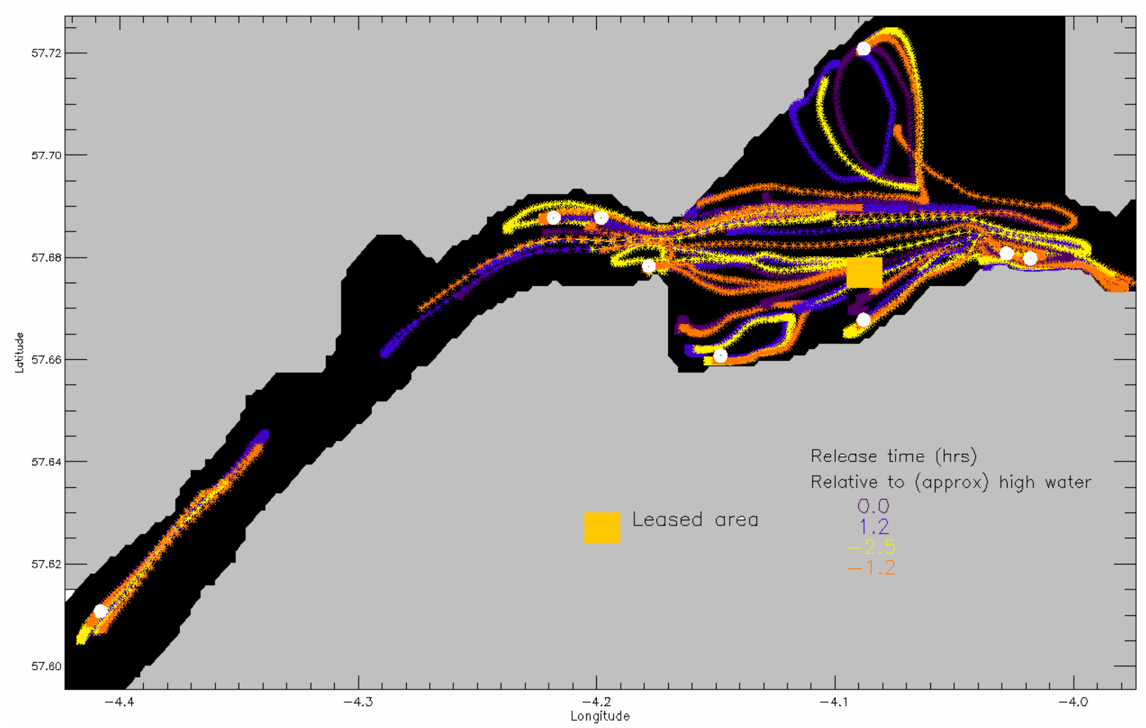

Figure 14.7 Tidal particle paths at Spring tides. White dots are release positions.

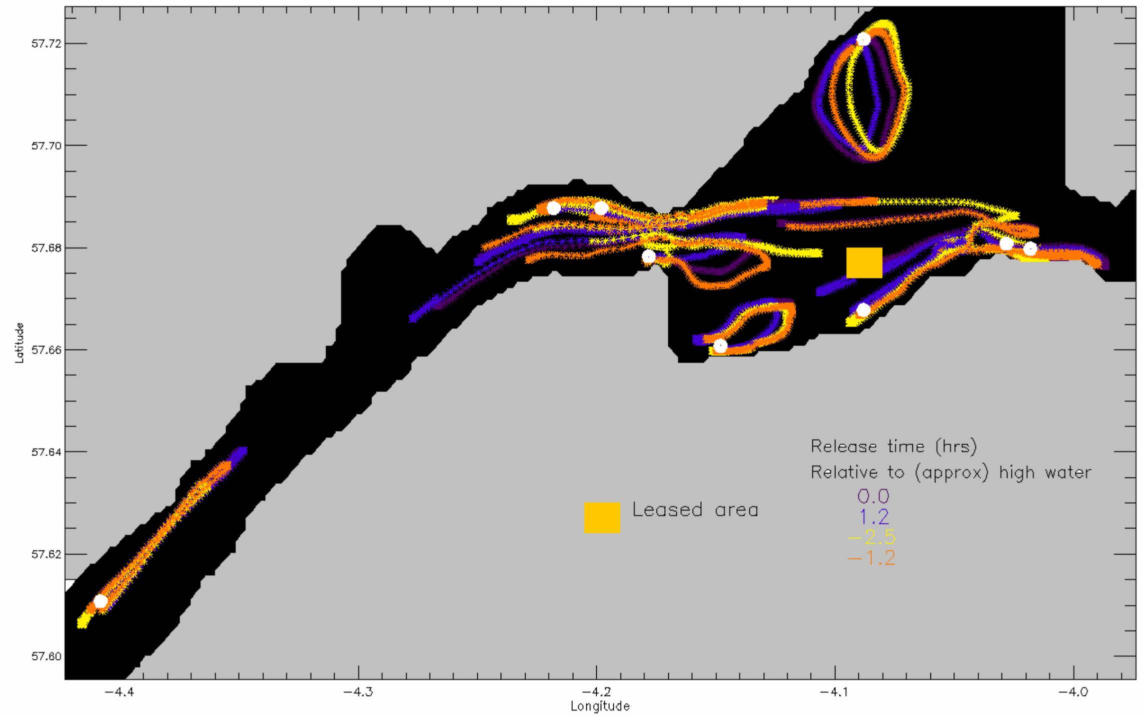

Figure 14.8 Tidal particle paths at Neap tides. White dots are release positions

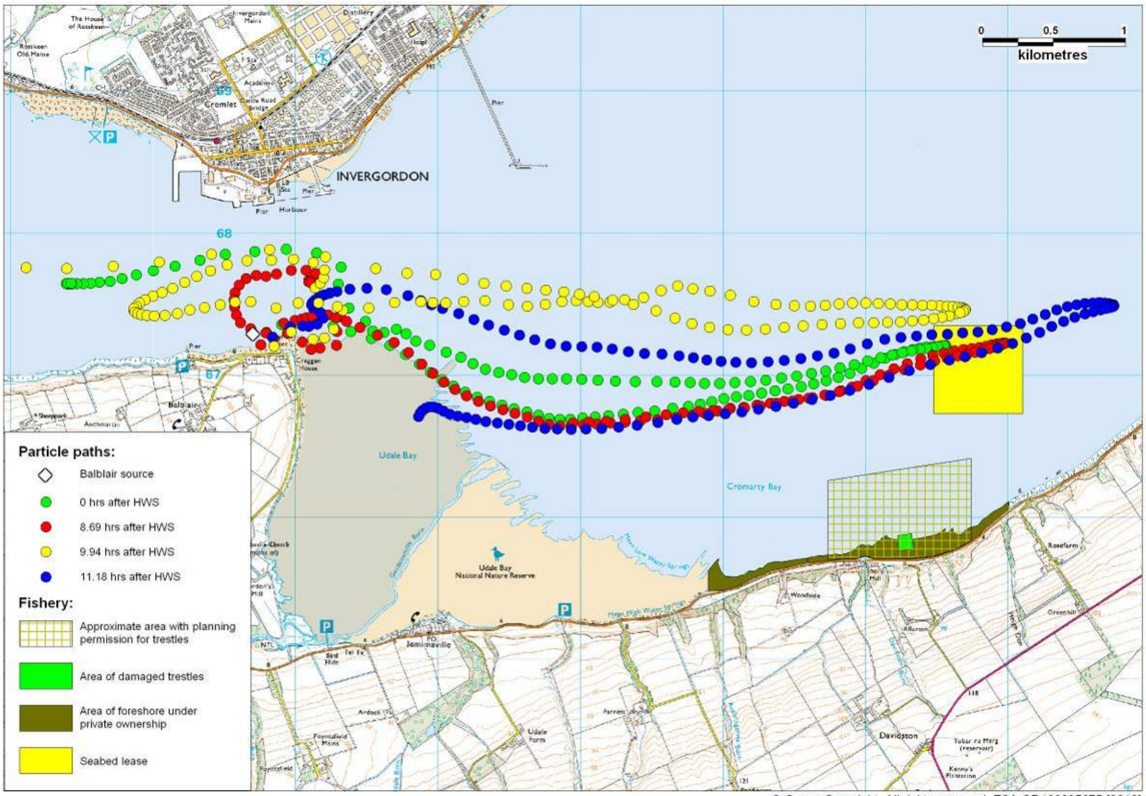

Figure 14.9 Tidal particle paths from Balblair at Spring tides.

The modelled source at Jemimaville actually represents a number of sources with varying treatment levels (see Section 4), associated with a population equivalent in excess of 160. It may also be considered to approximately represent the Newhall Burn (see section 13). Material released near high water is predicted to move northward up the coast toward Newhall point, impacting on the western end of the oyster area on the way, where it eventually joins the flow in the main channel (Figure 14.10). These results appear to be somewhat at odds with evidence of a predominantly eastward circulation along the southern shore in Cromarty Bay presented in Section 14.5.

The source on the foreshore at Shoremill represents the contaminated stream found on the shoreline survey (Table 13.1). Material released near high water on both spring and neaps tides is predicted to remain near the shore on the ebb tide, thus impacting on the eastern end of the oyster area (Figure 14.11). Normally, the material would pass to the north of the mussel on the following flood tide but uncertainties in the modelling, and the effect of any northerly wind, cannot rule out some predicted impact on occasions. However, it is likely that the material would be too dilute by that time to affect the microbiological quality of the shellfish.

Sources associated with Cromarty town are a WWTW with membrane treatment and a series of intermittent overflow discharges. The hydrodynamic behaviour of particles released from both these sources is unusual in that a high water discharge would be expected to impact only areas to the east.

However the model predicts a strong westward residual along the southern shore of the entrance to Cromarty Firth that causes particles to be carried well to the west of the source on the following flood tide at both spring and neap tides with a predicted impact at the mussel lease (Figures 14.12 and 14.13). Sensitivity testing of the effect of the nearby open boundary yielded similar particle paths, increasing somewhat the confidence that the result is not an artificial. However the predicted impacts were found to be sensitive to changes in the location of the release points and therefore the possibility of impact from sources at Cromarty is considered to be tentative. It should be noted that the high level of treatment at the Cromarty WWTW (but not the overflows) should strongly mitigate against contamination from the continuous discharge there, although there could be effects from the CSO under rainfall conditions.

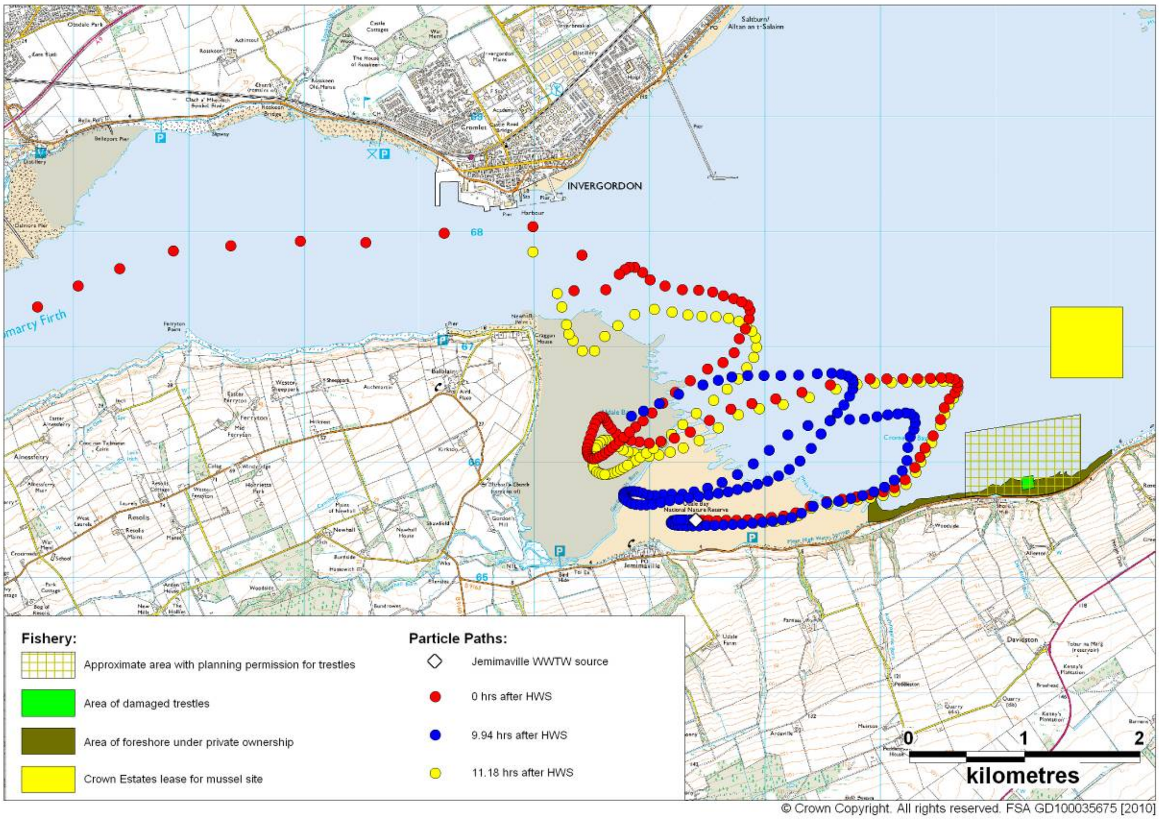

Figure 14.10 Tidal particle paths from Jemimaville at Spring tides.

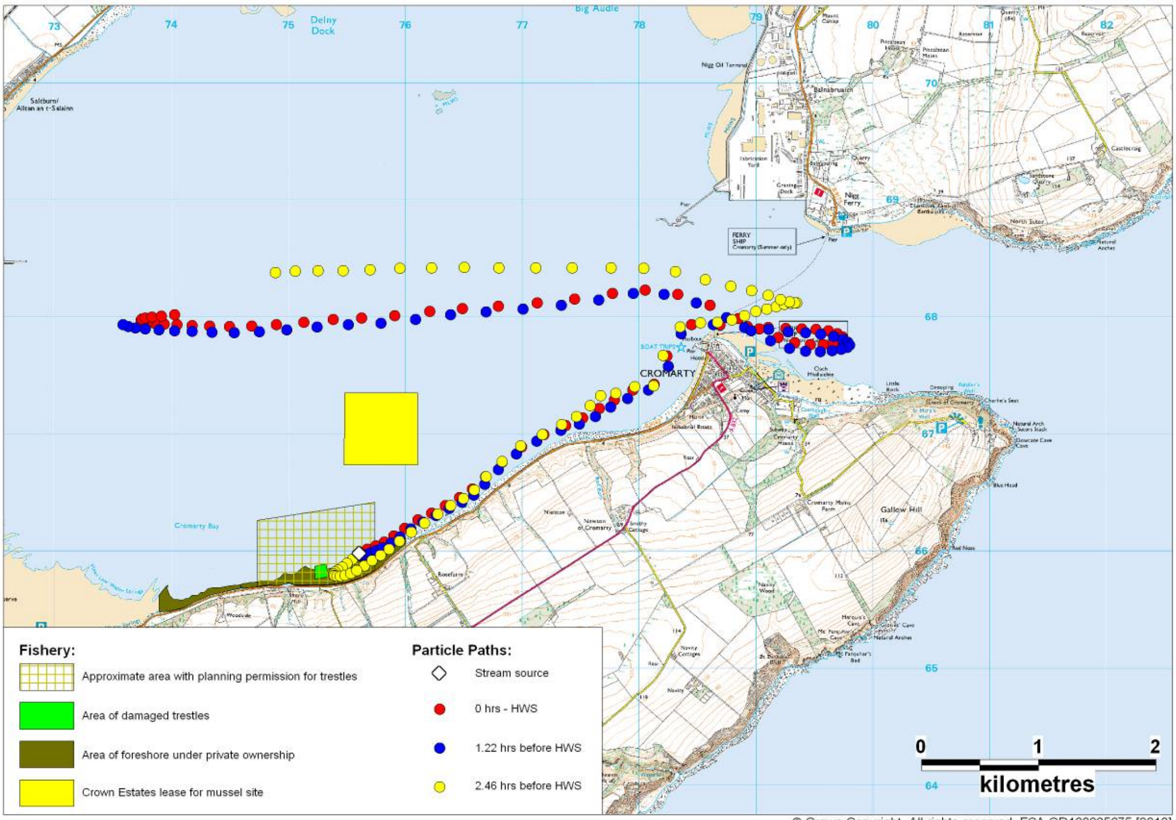

Figure 14.11 Tidal particle paths from a foreshore stream at Spring tides.

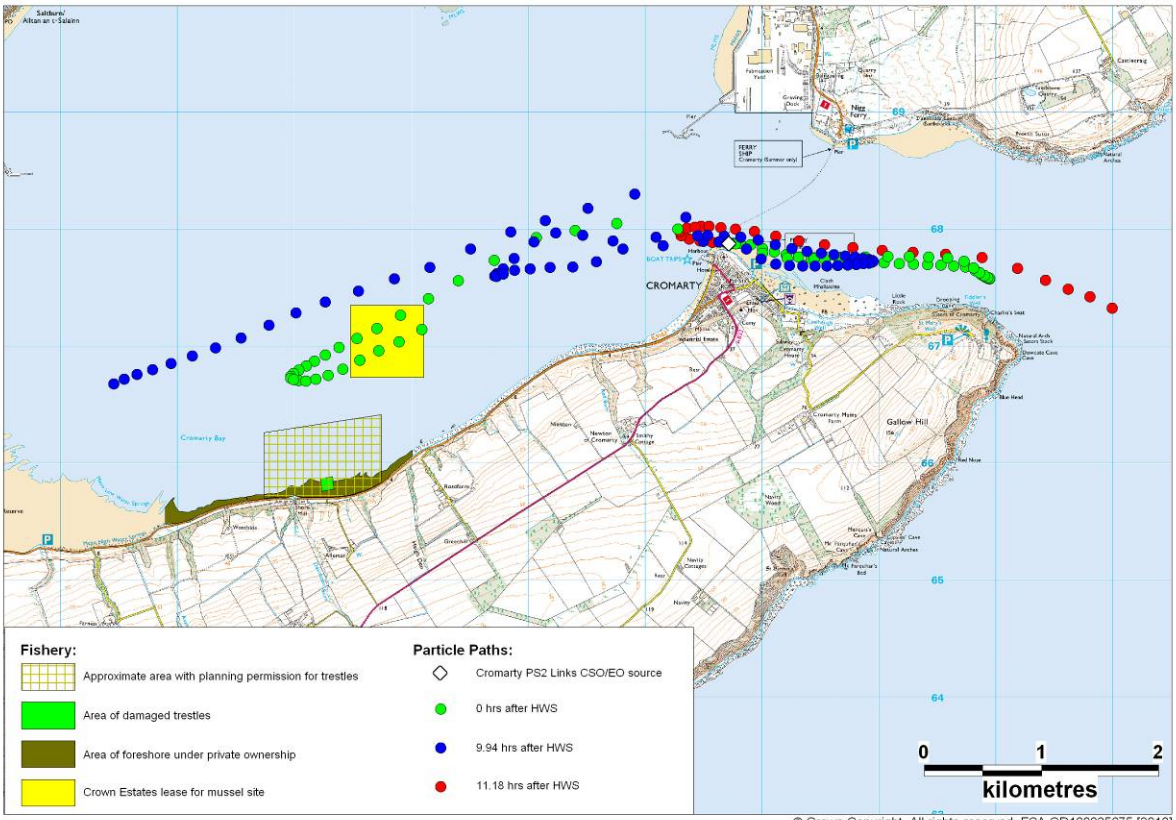

Figure 14.12 Tidal particle paths from Cromarty CSOs at Spring tides.

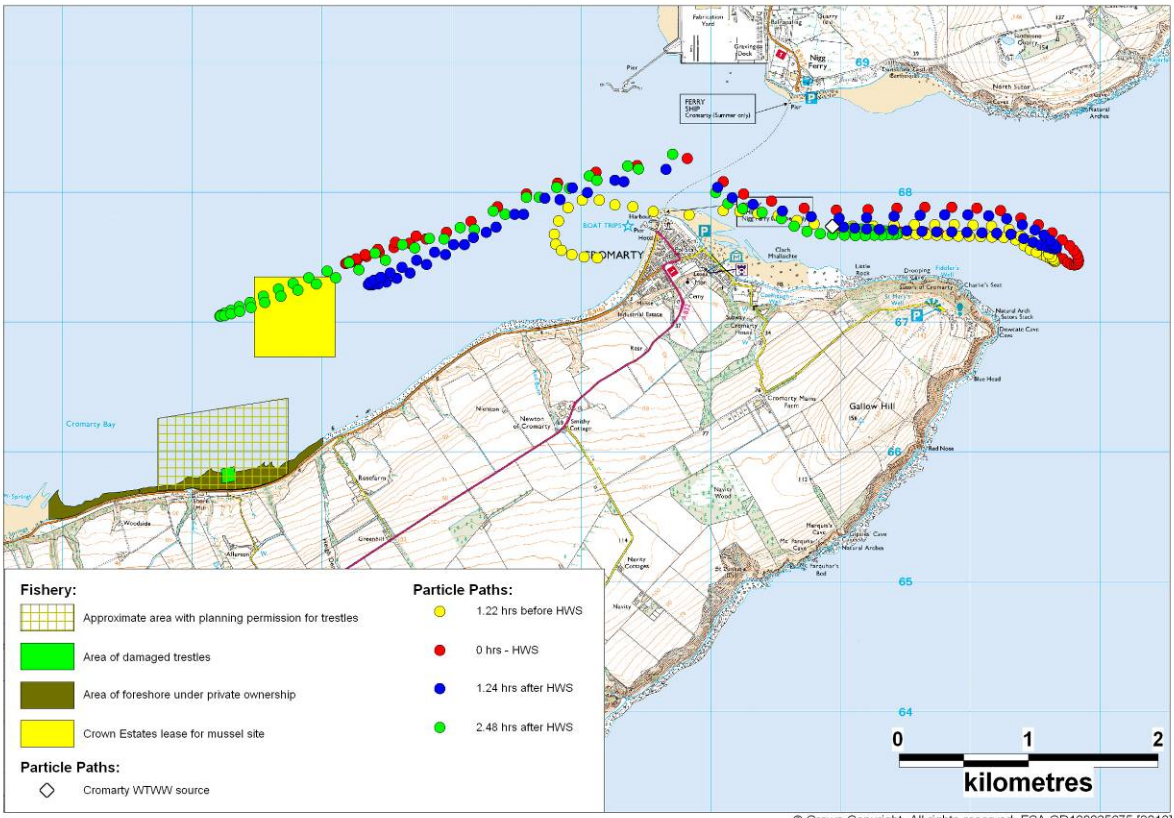

Figure 14.13 Tidal particle paths from Cromarty WWTW at Spring tides.

14.6.3 Summary of modelling results

Considering the modelling results overall, some useful conclusions can be reached. Impacts are predicted to be most likely at Spring tides. The large discharges from Invergordon and further up near the head of the firth are not expected to cause impact significantly within Cromarty bay as material tends to remain in the main channel. Sources at and near to Jemimaville may impact on the oyster area but are not predicted to reach the mussel lease. The modelling would suggest (tentatively) that the relatively small Balblair discharge represents the main source of potential contamination at the mussel lease, possibly together with intermittent discharges from Cromarty CSOs. However, it must be noted that the model does not incorporate density effects that are likely to prolong surface ebb flows within Cromarty Bay, thereby increasing the importance of sources at Jemimaville at both the oyster area and possibly to a lesser extent the mussel site. Wind effects may also modify flow patterns significantly but in a much less predictable way.

14.7 Overall conclusions

Tidally driven circulation is dominant with a strong bi-directional flow along the main central channel, and weaker flows in the shallower areas. A previous hydrographic study indicates that density effects prolong surface ebb flows within Cromarty Bay, although these density effects could not be incorporated into modelled particle paths from important identified contamination sources.

The modelling results suggest that impacts on the fisheries from these sources are most likely to occur for particles released around high water. The large discharges at Invergordon and Alness both lie on the northern edge of the central deepwater channel. Contamination from these sources was predicted to remain in the main channel although they could impact on the mussel area under some conditions. Assuming that these discharges are well mixed at the point of discharge, density effects may retard the eastward flow of these slightly..

Discharges at Balblair are likely to impact on the mussel lease site only. Density effects are likely to accentuate the eastward flow shown on the modelling results, with the particle paths remaining generally similar. Therefore, it is likely that particles released from Balblair impact on the mussel lease at a slightly greater range of tidal states than the modelling suggests.

Despite modelled particle paths suggesting otherwise, discharges at Jemimaville are likely to impact on both the oyster and the mussel fishery, but probably more so at the oyster fishery as contamination from here is likely to travel along the shoreline with the predominantly easterly flow.

The stream at Shoremill will impact mainly at the eastern end of the oyster site as shown in the particle path map, as flow is eastwards for the greater part of the tidal cycle. It will however also impact on the western end of the oyster site for the parts of the flood tide where flows are in a westerly direction here.

Although modelling suggests that discharges at Cromarty may impact on the mussel site, the continuous discharge is membrane treated, should contain very low levels of *E. coli,* and so should have negligible effects. It is not known under what rainfall conditions, and therefore how often, the CSO at Cromarty operates - following heavy rainfall, and this could therefore impact on the mussel site.

Strong winds have the potential to significantly alter the pattern of surface flows within the firth, dependent on wind strength and direction.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 12th to 14th May 2009 under dry conditions.

The oyster site consisted of a stretch of privately owned foreshore within which there was an area of 110 m x 110 m of derelict trestles where oysters were cultured up until about a decade ago. Small numbers of oysters which were old stock from and therefore more than 10 years old ago were found amongst the trestles in small numbers. Renovation of the site is planned, starting in 2010 and following this oyster seed will be laid in bags on trestles. Good growth was previously reported here, with oysters reaching market size in about 2 ½ years. Harvesting may take place at any time of the year.

It is planned that mussels will be cultured on a Crown Estates lease just offshore from Shoremil in about 6-7 m of water. No tackle or stock was present on site at the time of survey. It is anticipated that the mussel lines will be deployed some time in 2010. It is intended that harvesting will occur through most of the year, apart from during the post-spawning period when meat yields are lower.

There are several towns and villages on the shores of Cromarty Firth. The town of Cromarty, to the east of the site is served by a small sewage works, and the outfall is to the east of the town. There are also three intermittent discharges from pumping stations in Cromarty. To the west of the site a small sewage treatment plant and two associated overflow pipes were seen at Jemimaville. The main discharge pipe was not seen here, and was presumably buried in the sand and discharges to below the low tide mark. Also at Jemimaville one small suspected private sewage discharge was seen. Also on the south shore, to the west of Jemimaville three small discharges were seen at Balblair. On the north shore of Cromarty Firth lies the town of Invergordon, the largest town within the survey area. Five pumping stations and associated overflow pipes were seen here. The main discharge pipe was not seen, but is reported to discharge untreated sewage just over 1 km offshore at the western end of the town.

The town of Cromarty is picturesque and hosts several hotels and tourist attractions, so its population is likely to be higher during the summer months. Elsewhere, there is little in the way of attractions, although there are RSPB hides at Udales Bay and Nigg Bay, and Invergordon has a distillery and a golf course.

Cromarty Firth has a major deepwater port centred at Invergordon, which primarily serves the oil industry, but also receiving significant numbers of visits from cruise liners during the summer. There is also an oil terminal and mothballed industrial area at Nigg, both of which have ports. A small ferry sails between Nigg and Cormarty twice an hour during the summer months. There is also a small harbour at Cromarty, serving small shallow draft boats such as small fishing vessels, and 9 yachts were recorded on an area of moorings just off Cromarty.

Arable farming dominates the land use on the shores of Cromarty Firth. A few areas of pasture where livestock were present were also recorded. Just under 1.5 km to the west of the site, 30 cattle/calves were seen. About 1.8 km to the east of the site, 12 sheep were recorded. Further afield, about 250 sheep were recorded on pastures to the north of Nigg, and about 100 sheep were seen on the North Sutor. Two wild deer were seen at Nigg Bay. Cromarty Firth is an important habitat for overwintering waders and waterfowl, which congregate at the RSPB reserves at Udales Bay amd Nigg Bay from September to April. Porpoises, dolphins, seals and otters are also present in the firth.

Seawater samples taken within Cromarty Bay all had low levels of *E. coli* of 4 or less cfu/100 ml. One seawater sample taken at Balblair on a stretch of shore where three private discharges were recorded gave a result of 500 *E. coli* cfu/100ml. Two samples taken from the shore at Invergordon gave results of <1 and 9 *E. coli* cfu/100ml.

Mussel samples taken from the four corners of the trestles gave results of 20, 40, 20 and 70 *E. coli* MPN/100g, and a mussel sample taken about 700 m offshore gave a result of <20 *E. coli* MPN/100g. An oyster sample collected from within the trestles gave a result of 80 *E. coli* MPN/100g.

Freshwater samples taken from streams discharging to Cromarty Bay generally had low levels of faecal contamination (100 or <100 *E. coli* cfu/100ml). The exception to this was a very small stream discharging about 100 m to the west of the trestles which contained 22,000 *E. coli* cfu/100ml. Growth of sewage fungus was noted suggesting it receives inputs of waste water.

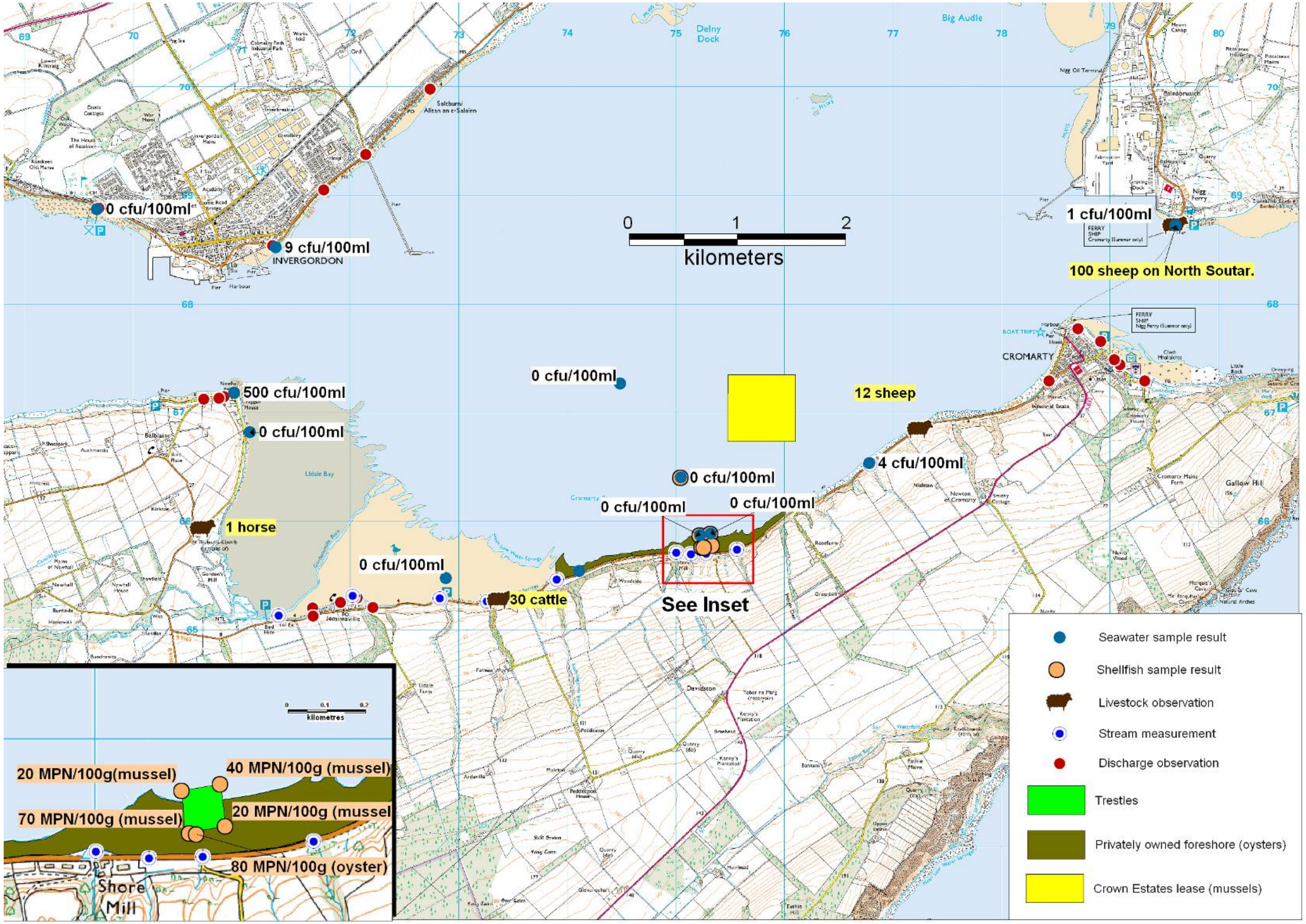

Figure 15.1 Summary of shoreline observations

16. Overall Assessment

Human sewage impacts

Discharges to the western end of Cromarty Bay (Jemimaville, Newhall and probably Balblair) are likely to affect water quality in Cromarty Bay, with greater impacts towards the western end. The main discharge at Cromarty is MBR treated, and discharges to the mouth of Cromarty Firth rather than within Cromarty Bay so is likely to be of much less significance to water quality within Cromarty Bay, although may be of significance when any overflow discharges here are in operation. Outside of Cromarty Bay there are several large discharges to Cromarty Firth, most notably those from Invergordon and Alness, which are raw discharges consented for a total population of about 23,000. Both of these discharge at the northern edge of the main deepwater channel running through the firth. They are being upgraded to secondary treatment and this is due for completion some time in 2010. Although these discharges will affect levels of contamination within Cromarty Firth as a whole, the exact effects of each of these discharges on water quality at Shoremill will depend on water circulation patterns within the firth.

At a more local level, there is a septic tank discharge consented by SEPA (but not seen during the shoreline survey) to a stream draining to the privately owned stretch of foreshore, which is likely to cause a localised increase in levels of contamination in the proposed oyster area. However, this stream contained very low levels of *E. coli* when sampled during the shoreline survey, whereas another nearby stream showed signs of receiving a sewage discharge (sewage fungus and high levels of *E. coli*) so it is possible that this septic tank actually discharges to the latter watercourse.

Cromarty Firth has a deepwater port at Invergordon, which receives significant traffic from the oil industry. Cruise liners also visit Invergordon between April and September. At Cromarty there is a small harbour from where small fishing boats operate. There are also some yacht moorings just at the eastern end of Cromarty Bay. Given the volume of traffic it is probable that waste water is discharged within Cromarty Firth by boats on occasion, although how often, where and when are uncertain.

Agricultural impacts

Arable farming dominates the land use on the shores of Cromarty Firth, although there are some areas of pasture present. Agricultural census data indicates cattle are the dominant livestock species in the parishes that lie on the shoreline of Cromarty Bay. During the shoreline survey, 30 cattle/calves were recorded just under 1.5 km to the west of the oyster site, and 12 sheep were recorded about 1.8 km to the east of the site. Therefore, it is likely that streams draining these small areas of pasture carry contamination from livestock into Cromarty Bay. Livestock was recorded in other locations such as Nigg and the North Sutor, but these were probably too far away to have any significant impact on the fishery. Given the presence of cattle, the spreading of slurry on fields is likely to occur in the area and contamination would be carried into watercourses following any rainfall. However, in the absence of information on the location of slurry spreading, it is not possible to predict the potential effects on the fisheries.

Wildlife impacts

The main wildlife species potentially impacting on the production areas are likely to be waterbirds (i.e. waders and wildfowl) which are only present in large numbers from October to April. Over 30,000 overwinter in Cromarty Firth, with a high concentration at Udale Bay, just to the west of the fishery. Therefore diffuse inputs from these birds may be expected at the fisheries, possibly more so at the oyster fishery as it is in the intertidal zone, and at its western end.

Other wildlife species, such as seals, dolphins and seabirds are likely to frequent the area of the fishery, albeit in much smaller numbers, and so may be responsible for a small proportion of contamination found at the shellfishery. However, as these animals are highly mobile, the impacts of these on the fishery will be unpredictable and widely spread temporally and geographically.

Seasonal variation

The town of Cromarty is picturesque and hosts several hotels and tourist attractions, so its population is likely to be higher during the summer months. Elsewhere, there is little in the way of attractions, although there are RSPB hides at Udales Bay and Nigg Bay, and Invergordon has a distillery and a golf course. Visiting cruise liners are likely to significantly, but briefly increase the population of Invergordon whist they are docked there. They visit during the summer months.

Livestock numbers are likely to be higher in the summer, so inputs from livestock may be higher during the summer, particularly following high rainfall events. Livestock are likely to access watercourses to drink more frequently during warmer weather.

A fairly consistent (but not statistically significant) seasonal pattern in shellfish growing waters monitoring results was seen at Cromarty Bay, with results higher on average for quarters 3 and 4 compared to 1 and 2. Insufficient classification monitoring samples have been taken from the fisheries to assess any seasonality in levels of contamination.

In conclusion, human population is likely to increase at Cromarty during the summer months. There is also likely to be an increase in contamination of livestock (sheep/cattle) origin during the summer months as livestock numbers are likely to be higher at this time. However, higher results in the shellfish growing waters monitoring have tended to be seen in both quarters 3 and 4 (July to December inclusive).

Rivers and streams

Cromarty Firth receives surface runoff from a catchment area of 962 km^2. Land use within its catchment area is 10% grazing, 10% arable, 1% rural residential/roads and 79% natural/semi natural vegetation. The largest river input is the River Conon, which discharges at the head of the estuary. Several smaller rivers and numerous streams also discharge to Cromarty Firth. These riverine inputs are likely to increase background levels of contamination within Cromarty Firth, and they are likely to significantly affect hydrography within the firth at times but it assumed that the impact from these will be relatively even across the fisheries. However, any resulting stratification causing higher levels of contamination towards the surface at the mussel lease.

On a more local scale, the streams discharging to the shore of Cromarty Bay generally had low levels of faecal contamination at the time of survey. This included the Davidston Burn, which is reported to receive a private septic tank discharge, and the Newhall Burn, which receives a small Scottish Water septic tank discharge. The one exception was a very small stream discharging to the area of privately owned foreshore which contained 22,000 *E. coli* cfu/100ml and despite its small size it gave the highest *E. coli* loading of any of the sampled streams. Growth of sewage fungus was noted within this stream suggesting it receives continuous or regular inputs of waste water. The location of this stream is likely to cause a distinct but very localised hotspot of contamination where it discharges and thus affect any oysters grown in that immediate area. It is probably of little significance to the mussel fishery, which will be located about 1 km offshore.

Meteorology, hydrology, and movement of contaminants

Tidally driven circulation is dominant with a strong bi-directional flow along the main central channel, and weaker flows in the shallower areas. Particle paths from significant identified sources were produced using a depth integrated tidal flow model. The sources considered included sewage discharges at Balblair, Jemimaville, Cromarty and Invergordon/Alness, and the contaminated stream discharging at the oyster site. The modelling results suggested that impacts on the fisheries from these sources are most likely to occur for particles released around high water. Discharges at Balblair and Cromarty were predicted to impact at the mussel lease, whereas discharges from Jemimaville and the contaminated stream at Shoremill were predicted to impact on the oyster area. Also of significance, contamination from the Invergordon/Alness discharges, which are located at the northern edge of the central channel was predicted to remain in the channel and not impact on either of the fisheries.

Although water movements are dominated by tides, the firth also receives significant freshwater inputs, the vast majority of which are upstream of Invergordon. As a consequence, stratification occurs within the firth, which is reported to prolong surface ebb flows within Cromarty Bay so surface flows in the vicinity of both fisheries is eastwards most of the time. The strength of this effect will depend on recent rainfall. The model used to produce the particle paths did not incorporate density effects so it is likely that the actual particle paths differ slightly from the modelled ones in some cases. Therefore, the Jemimaville discharges and Newhall Burn are likely to impact on the oyster area, and to a lesser extent the mussel area, and the discharges at Cromarty are less likely to impact on the mussel lease than suggested by the modelling. The contaminated stream at Shoremill will have the most impact on the oyster fishery immediately to the east of where it discharges, although it will impact immediately to its west when the tide is flowing in that direction. Density effects will probably result in little change to the predicted particle paths for Invergordon/Alness and Balblair.

Strong winds may significantly alter surface currents within the firth, depending on wind strength and direction. Stratification may result in higher levels of contamination being entrained in the fresher water at the surface, and this is likely to be reflected higher levels of contamination of mussels near the surface.

Temporal and geographical patterns of sampling results

Following the receipt of the application to classify the area, a total of six mussel samples and two oyster samples were taken from March to September 2009. The mussels were not grown *in situ*, but gathered from Cromarty Harbour, and deployed in bags at least 2 weeks before they were sampled. The Pacific oysters were old stock from a previous oyster culture operation at the site, and were believed to be more than a decade in age. *E. coli* results for mussels ranged from 170 to 1400 *E. coli* MPN/100g, with a geometric mean of 430 *E. coli* MPN/100g. Four of 5 samples gave results of 230 *E. coli* MPN/100g or over. Highest results arose in March and April, although this is possibly as a result of contamination carried over from the location from which they originated. Both Pacific oyster samples gave results of less than 230 *E. coli* MPN/100g. Highest results arose in mussel samples taken further offshore, although it is uncertain whether this was a spatial or temporal effect.

Seawater samples taken within Cromarty Bay during the shoreline survey all yielded low levels of *E. coli*, giving results of 4 or less cfu/100 ml. One seawater sample taken at Balblair on a stretch of shore where three private discharges were recorded gave a result of 500 *E. coli* cfu/100 ml. Mussel samples were taken from the four corners of the trestles during the shoreline survey, and gave results of 20, 40, 20 and 70 *E. coli* MPN/100 g, and a mussel sample taken about 700 m offshore gave a result of <20 *E. coli* MPN/100 g. An oyster sample collected from within the trestles gave a result of 80 *E. coli* MPN/100g. Therefore, low levels of contamination were consistently found in shoreline survey shellfish samples. Levels of contamination were slightly higher in the intertidal zone than at the mussel lease. It is possibly worthy of note that results were marginally higher (70 and 80 *E. coli* MPN/100g) on the inshore western corner of the trestle area, which is closest to the contaminated stream which discharges at Shoremill.

Higher levels of contamination have been observed on occasion in shore mussels collected to the west of Shoremill as part of the shellfish growing waters monitoring programme (up to 16000 faecal coliforms/100 g).

In summary, there no strong evidence of geographical patterns in levels of contamination at the fisheries based on the very limited data available, so it is desirable for a bacteriological survey to be carried out to assist in the determination of the RMPs.

Overall conclusions

There are currently no active fisheries for either oysters or mussels at Cromarty Bay, and planning permission is yet to be awarded for the construction of the mussel lines. Work on renovating the oyster site is due to start in spring 2010 or possibly later, so the time of first harvest for both oysters and mussels is unlikely to be before autumn 2012. Therefore there is no need for classification sampling to be undertaken before 2011 at the earliest.

Distant sources such as the River Conon and the Invergordon discharge may contribute to background levels of contamination within Cromarty Bay but they are unlikely to result in differences of contamination across either of the fishery sites.

Sources at the western end of Cromarty Bay are likely to be of more impact on the fishery due to the predominance of an easterly flow. Sources at Jemimaville lie 1.7 km to the west of the western end of the area of privately owned foreshore, which itself is over 2 km in length. Therefore, there may be a gradient in levels of contamination along this stretch of shoreline as a result of the discharges at Jemimaville. During the winter, large aggregations of waterbirds will be present at Udales Bay, also to the west of the fishery. There may also be a hotspot of contamination within the oyster area caused by the contaminated stream at Shoremill. High levels of contamination have been observed on occasion in shore mussels collected to the west of Shoremill as part of the shellfish growing waters monitoring programme.

Sources of contamination to the west of the mussel site are also expected to be the most significant. It is likely that there is stratification within Cromarty Bay, so there probably will be a noticeable difference in levels of contamination between the top and bottom of the water column, with higher levels being expected towards the surface.

There is likely to be an element of seasonality to some sources of contamination, namely human population, livestock and waterbirds. An element of seasonality has been found in mussels collected from Cromarty Bay under the shellfish growing water monitoring programme. Therefore, any classification sampling should be conducted on a monthly basis.

17. Recommendations

Given that there are currently no commercial oysters or mussels at this site, it is not relevant to recommend either the production area boundaries or the contents of the sampling plan. The information in this report should be reviewed when stock has been placed on site and recommendations based on the actual locations that apply at that point in time.

It is currently anticipated that classification sampling will need to start in 2011, to allow sufficient samples to be gathered to classify the fisheries by April 2012. An assessment should therefore be undertaken towards the end of 2010 to determine progress with the plans for both fisheries.

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8. **Shoreline Survey Report**

Sampling Plan for Cromarty Bay

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISH-ERY	NGR OF RMP	EAST	NORTH	TOLER-ANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Cromarty Shoremill	Shoremill oysters	RC 473 884 13	Pacific oysters	Trestle (not yet constructed)	TBA	TBA	TBA	TBA	N/a	Hand	Monthly	Highland Council	Bill Steven Hamish Spence	Bill Steven
Cromarty Bay mussels	Shoremill mussels	RC 473 883 08	Common mussels	Longline (not yet constructed)	TBA	TBA	TBA	TBA	TBA	Hand	Monthly	Highland Council	Bill Steven Hamish Spence	Bill Steven

Table of Proposed Boundaries and RMPs

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Cromarty Shoremill	Pacific oysters	RC 473 884 13	None	None	To be determined following development of the fishery	To be determined following development of the fishery	Site yet to be constructed. Earliest possible harvest is Autumn 2012.
Cromarty Bay mussels	Common mussels	RC 473 883 08	None	None	To be determined following development of the fishery	To be determined following development of the fishery	Site yet to be constructed Earliest possible harvest is Autumn 2012.

Geology and Soils Information

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.

References

Macaulay Institute. http://www.macaulay.ac.uk/explorescotland. Accessed September 2007.

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 x 10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al* 2004).

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

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

Cetaceans

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

A variety of cetacean species are routinely observed around the coast of Scotland. Where possible, information regarding recent sightings or surveys is gathered for the production area. As whales and dolphins are broadly free ranging, this is not usually possible to such fine detail. It is reasonable to expect that whales would not routinely affect shellfisheries located in shallow coastal areas. It is more likely that dolphins and harbour porpoises would be found in or near fisheries due to their smaller physical size and the larger numbers of sightings near the coast.

Birds

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

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

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

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

Deer

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

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

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

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

Otters

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, which may be washed into the water during periods of rain.

References:

Alderisio, K.A. and N. DeLuca (1999). Seasonal enumeration of fecal coliform bacteria from the feces of Ring-billed gulls (*Larus delawarensis*) and Canada geese (*Branta canadensis*). *Applied and Environmental Microbiology*, 65:5628-5630.

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

Lisle, J.T., Smith, J.J., Edwards, D.D., andd McFeters, G.A. (2004). Occurrence of microbial indicators and *Clostridium perfringens* in wastewater, water column samples, sediments, drinking water and Weddell Seal feces collected at McMurdo Station, Antarctica. *Applied and Environmental Microbiology*, 70:7269-7276.

Poppe, C., Smart, N., Khakhria, R., Johnson, W., Spika, J., and Prescott, J. (1998). Salmonella typhimurium DT104: A virulent drug-resistant pathogen. Canadian Veterinary Journal, 39:559-565.

Scottish Natural Heritage. http://www.snh.org.uk/publications/on-line/wildlife/otters/biology.asp. Accessed October 2007.

Stoddard, R. A., Gulland, F.M.D., Atwill, E.R., Lawrence, J., Jang, S. and Conrad, P.A. (2005). Salmonella and Campylobacter spp. in Northern elephant seals, California. *Emerging Infectious Diseases* www.cdc.gov/eid 12:1967-1969.

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 bacterial count data was log transformed prior to statistical tests.

Section 12. One-way ANOVA comparison of shellfish growing waters results by quarter

One-way ANOVA: log f coli versus q

```
Source  DF      SS     MS     F      P
q        3   2.779  0.926  1.88  0.158
Error   26  12.814  0.493
Total   29  15.593

S = 0.7020   R-Sq = 17.82%   R-Sq(adj) = 8.34%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  -------+---------+---------+---------+--
Q1     8  2.2553  0.5639    (---------*---------)
Q2     6  2.2589  0.6199  (-----------*-----------)
Q3     8  2.8811  0.7107                (----------*---------)
Q4     8  2.8520  0.8562                (---------*---------)
                          -------+---------+---------+---------+--
                               2.00      2.50      3.00      3.50

Pooled StDev = 0.7020
```

Hydrographic Methods

1.0 Introduction

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. This document collects together information common to all hydrographic assessments avoiding the repetition of information in each individual report.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only and is not discussed in any detail in this document. 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 focus on this more detailed hydrographic assessment and describes the common methodology applied to all sites.

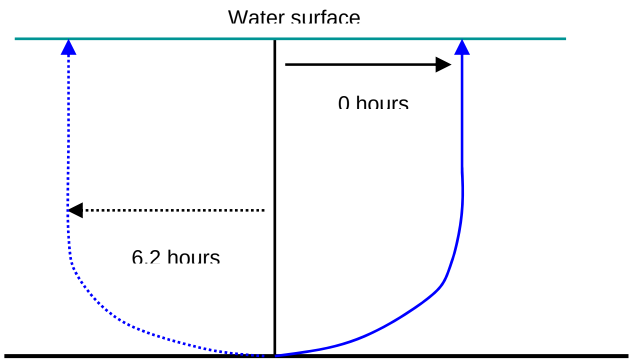
The regulations require an appreciation of the hydrography and currents within a region classified for shellfish production.

1.1 Background processes

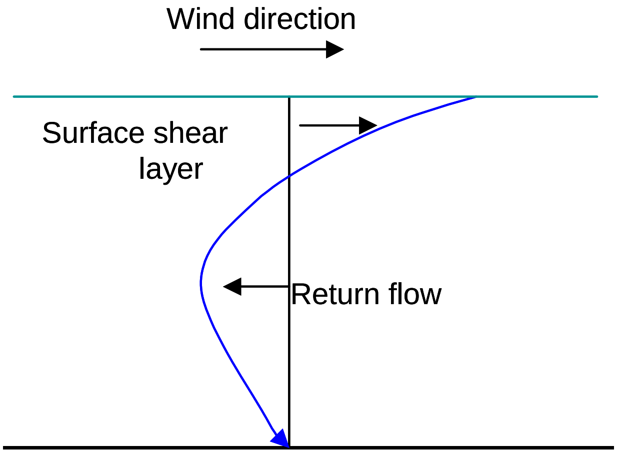
This section gives an overview of the hydrographic processes relevant to sanitary surveys.

Movement in the estuarine and coastal waters is generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences. Unless tidal flows are weak they usually dominate over the short term (~12 hours) and move material over the length of the tidal excursion. The tidal residual flow acts over longer time scales to give a net direction of transport. 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.

a)



b)



c)

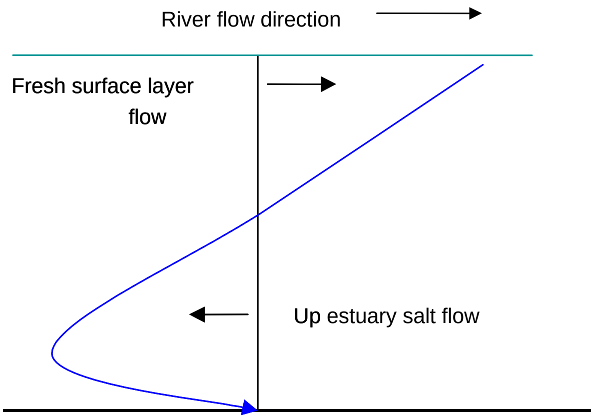


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

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.

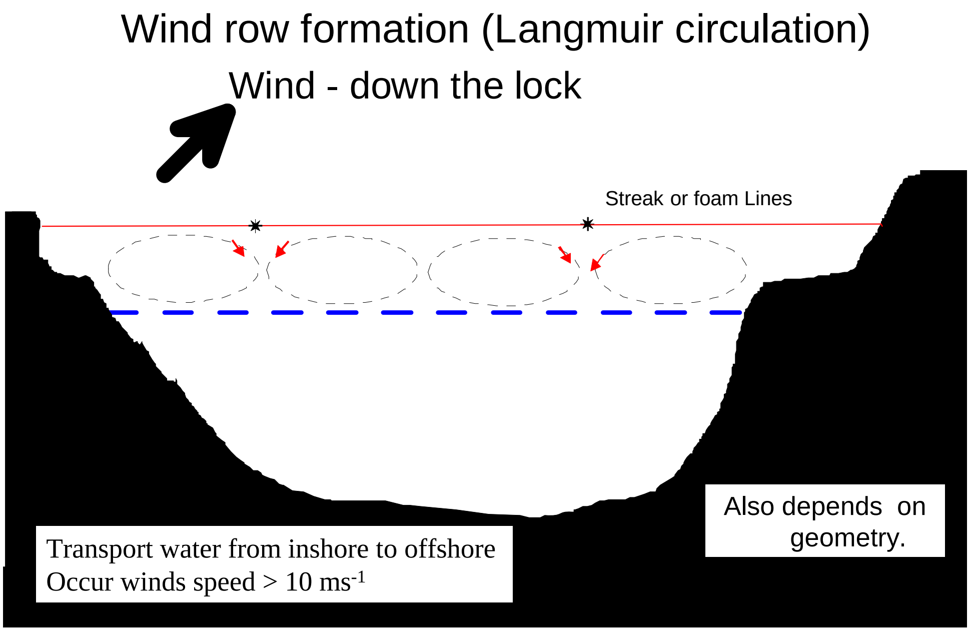


Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

2.0 Basic Assessment

This will be applied to most sites and consists of a description of bathymetry and the tidal regime obtained from admiralty charts and tidal diamonds and is not described in detail here.

3.0 More Detailed Assessment

This is applied at the request of the regulator (FSAS) when particular circumstances apply. Typically this will be at sites where production areas regular fail or where unusual results have been reported.

3.1 Modelling approach

The Hydrotrack computer model is used. This is able to simulate depth averaged tidal currents and give some indication of wind driven currents. Model output from the model is analysed to provide information on:

- Particle paths due to tides and winds.
- Residual current patterns due to tide and winds.

Tidal forcing is a simple sinusoidal current applied at the model boundary. Where possible the assumption is made that the change in tidal phase across the boundary is negligible. Basic checking of the model is limited to the available data. In most cases this is limited to reproducing the observed tidal range. If tidal diamond or current meter observations are available, model results are checked against these.

Model calculations are carried out for five cases: tides only and tides plus winds from north, south east and west directions. The resulting winds patterns are for winds blowing constantly for 48 hours so that a steady current pattern is produced. In reality of course winds are highly variable. For each of these cases the results over the last two tidal periods are analysed to provide tidal phase and amplitude and the residual current. The paths of particles moving with the water and starting from known sources of contamination are calculated using the analysed currents. For point sources very near the shore, model release points may be moved slightly offshore out to ensure particles are caught by the prevailing current and not trapped at the release point.

For a given water body, the strength of the applied wind is chosen to ensure wind driven currents are large relative to the tidal currents so that particle paths clearly show the wind driven movement.

Although Hydrotrack calculates currents over the spatial area of a water body, it cannot calculate the vertical profile of currents. Although adequate for tidal flows this has limitations for wind and density driven systems characteristic of many sea lochs. Therefore the modelling approach is more usefully applied to tidally dominated systems or shallow regions where vertical structure may be less significant.

3.2 Non-modelling approach

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’.
7. Estimates of flow speed combined with T_{90} will give a ‘region of influence’.
8. The ratio of river run-off to tidal prism gives an indication of the importance of density effects.

Many Scottish shell fish 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.

For the more detailed assessment of sea loch regions, the “Sea Loch catalogue” 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.

Dilution calculations in regions with steep and variable bathymetry typical of sea lochs are extremely difficult. The following methods are applied.

For class A and B classifications, correlation data (European Commission 1996) suggest the following water concentration need to be achieved:

Class A: 1 *E. coli* per 100 ml = 10^4 m^{-3}
Class B: 100 *E. coli* per 100 ml = 10^6 m^{-3}

3.2.1 Integrated Inputs

Given *E. coli* loadings and estimates of water body volume and flushing time, the *E. coli* concentration averaged over the entire water body can be estimated from:

$$C = S T_f / V$$

C = number *E. coli* m^{-3}
S = Sum of all loadings (number of *E. coli* per day)
T_f = Flushing time (days)
V = Water body volume (m^3)

This can then be compared with the Class A and B requirements.

3.2.2 Individual inputs

For a source with a loading M *E. coli* per second, discharging into water flowing at speed u (ms^{-1}), the number of *E. coli* per meter in the flow direction is given by M/u (*E. coli* m^{-1}). To achieve a target concentration of T, the cross sectional area that the material needs to be mixed over is given by

$$A = M/(u\ T)$$

Assuming an average depth for the water body this can be converted to a distance offshore. A subjective judgement can then made as to whether this is likely to occur over the relevant time scales (< 3 days). That is, will the required dilution occur quickly enough that only localised impacts would be expected? For sea lochs the assumption is made that away from the sills, mixing is likely to be quite weak.

4.0 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.

5.0 Glossary

The following technical terms 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

Cromarty Shoremill/Cromarty Bay mussels
RC 473

Scottish Sanitary Survey Project

Shoreline Survey Report

Prod. area:	Cromarty Shoremill/Cromarty Bay mussels
Site name:	Shoremill oysters (RC 473 884 13) Shoremill mussels (RC 473 883 08)
Species:	Pacific oysters and common mussels
Harvester:	Alan MacKenzie
Local Authority:	Highland Council (Ross & Cromarty)
Status:	New application
Date Surveyed:	12-14th May 2009
Surveyed by:	Bill Steven, Hamish Spence, Alastair Cook
Existing RMP:	None assigned
Area Surveyed:	See Map in Figure 1

Weather observations

12/5/09 Sunny, dry. Winds ESE (Force 2), but rising to Force 4 later in the day. Temp 12C.
13/5/09 Sunny, dry. Winds ENE (Force 3), but rising to Force 5 later in the day. Temp 13C.
14/5/09 Sunny, dry. Winds NE (Force 3). Temp 12C.

Site Observations

Fishery

The site consists of a stretch of privately owned foreshore and seabed at Shoremill, just to the west of the town of Cromarty, the approximate boundaries of which are indicated on Figure 1. A representative of the grower indicated that the eastern third of this area had recently been sold, but was not aware of any plans to establish any shellfish farms on this property.

Shoremill oysters. At the time of survey, an area of damaged trestles measuring approximately 110 m x 110 m was present on the intertidal area, with a very small amount of mostly dead old stock. Oysters were grown on this site up until about a decade ago, and at one point it is reported that there were up to 13 million oysters on site. Good growth was experienced, with oysters attaining a marketable size within 2 ½ years. Year round harvesting of oysters is planned. Renovation of the site is planned, and following this oyster seed will be laid in bags on the trestles. A timetable for this has not yet been set.

Shoremill mussels. At the time of survey, no stock or tackle was present on site. It is planned that mussel longlines will be deployed towards the northern extremity of the site, where the water is around 6-7m in depth. Lengths of netting will be supended from these, on which the mussels will be grown. Again, a timetable for this has not yet been set. Good spatfall and growth is reported here. It is anticipated there will be an element of seasonality to harvesting, with no harvesting during the post spawning period when meat yields are lower.

Currently, there are no depuration facilities associated with the site, although they are likely to be needed once the site is in commercial scale production.

Sewage/Faecal Sources

The shores of Cromarty Firth are quite heavily populated, with several towns and villages. The sewage infrastructure in the area is extensive, with the majority of houses connected to mains sewerage. The town of Cromarty, to the east of the site is served by a small sewage works, and the outfall is to the east of the town. There are also three intermittent discharges from pumping stations in Cromarty. To the west of the site a small sewage treatment plant and two associated overflow pipes were seen at Jemimaville. The main discharge pipe was not seen here, and was presumably buried in the sand and discharges to below the low tide mark. Also at Jemimaville one small suspected private sewage discharge was seen. Also on the south shore, to the west of Jemimaville three small discharges were seen at Balblair.

On the north shore of Cromarty Firth lies the town of Invergordon, the largest town within the survey area. Five pumping stations and associated overflow pipes were seen here. The main discharge pipe was not seen, but is reported to discharge untreated sewage just over 1 km offshore at the western end of the town. Another discharge was seen at Barbaraville.

In addition to the multiple sources of human sewage, a few areas of pasture where livestock were present were also recorded. Just under 1.5 km to the west of the site, 30 cattle/calves were seen. About 1.8 km to the east of the site, 12 sheep were recorded. Further afield, about 250 sheep were recorded on pastures to the north of Nigg, and about 100 sheep were seen on the North Sutor.

Seasonal Population

Inverness is the tourism centre for the region, and is used as a base and transit point for visitors to the Highlands. Cromarty is a picturesque town, and has several attractions such as Hugh Millers house, Cromarty Courthouse Museum, several gift shops, and an annual exhibition. Some self catering accommodation and a few hotels were seen. Two coach parties were seen visiting the Royal Hotel in Cromarty. There was little else in the way of recognised attractions on the south shore of the survey area, although one Bed and Breakfast was seen at Balblair, and there was an RSPB hide at Udale Bay.

On the north shore, there is little in the way of obvious attractions. Invergordon is mainly an industrial town, although it does have a golf course and a distillery, and is regularly visited by cruise liners between April and September. Also, there is an RSPB reserve and hide at Nigg Bay.

Boats/Shipping

Cromarty Firth has a deepwater port at Invergordon, which receives significant traffic from the oil industry. Two oil rigs were anchored in the Firth at the time of survey. Additionally, significant numbers of cruise liners visit Invergordon, with 46 scheduled to dock here during 2009. They generally remain for about 12 hours before sailing again. One was seen docked on 14/05/2009.

There is an oil terminal at Nigg, and a mothballed industrial area, both of which have docks. A small ferry sails between Nigg and Cromarty twice every hour during the day in the summer months.

At Cromarty, there is a small harbour where 14 small craft were tied up, mainly small fishing boats. Also at Cromarty, 9 yachts on moorings were counted. No other boating activity close to the south shore between Cromarty and Balblair was observed.

Land Use

Cromarty Firth is surrounded by low lying fertile soils, and arable farming dominates the land use in the area, with crops such as cereals, rape and potatoes seen during the survey. In addition to this there were areas of pasture, and some urban areas.

The land immediately adjacent to the fishery site consisted of a thin strip of gorse with some small areas of pasture, with arable fields further behind. This was drained by a series of small streams, and any of these with a measurable flow were sampled and measured.

Wildlife/Birds

There are two RSPB reserves in the survey area, one at Udale Bay, and a larger one at Nigg Bay. Both consist of areas of wet grassland, saltmarsh and intertidal sand/mud flats. Large numbers (thousands) of waders and waterfowl are present on these reserves from September to April. Smaller populations of some species (e.g. swans, shelducks and oystercatchers) breed here during the summer.

Signeage within the RSPB hides otters are present in Cromarty Firth, and that porpoises and dolphins are frequently sighted. Seals are reported to frequent the area around Foulis, on the north shore of the inner firth. Two roe deer were seen from the RSPB hide at Nigg Bay.

Other information

The skipper of the fishing boat used to access the offshore mussel samples indicated that the tide along the shore at Shoremills usually flows from west to east, even on a flooding tide, due to the formation of an eddy current during the flood. The site is most exposed to north easterly winds, and under these conditions significant onshore wave action can result causing the water to become very turbid.

A representative of the harvester indicated that when the fishery was previously in production, around a decade ago, microbiological results from shellfish were generally good. The one exception to this occurred following very heavy rain, and was attributed to contaminated runoff from arable fields to which slurry had been applied. Results of microbiological testing may be available from the harvester on request.

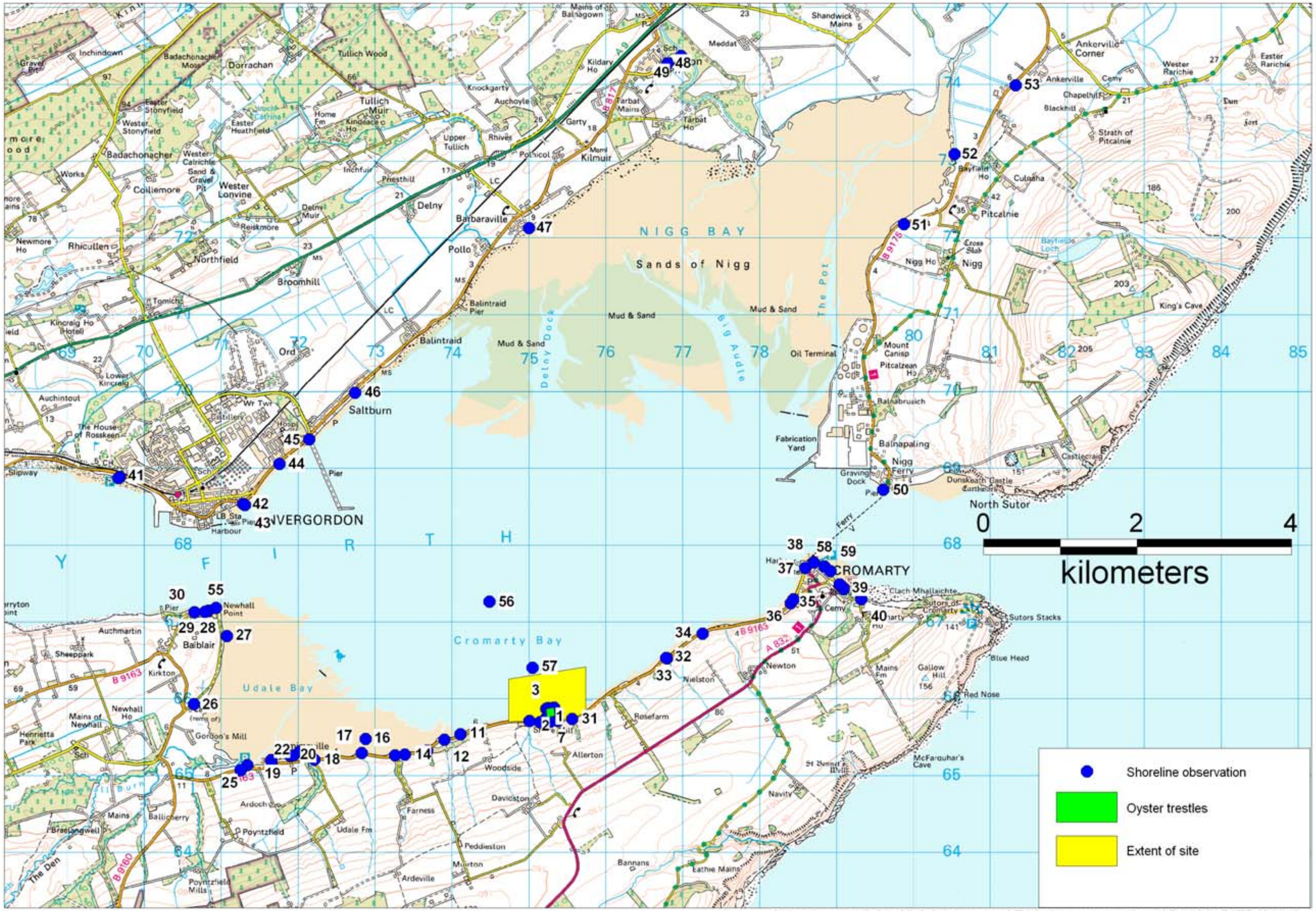


Figure 1 Map of Shoreline Observations

Table 1 Shoreline Observations

No.	Date and time	Position	Photograph	Description
1	12-MAY-09 8:47:21AM	NH 75230 65759	Figure 4	Corner of trestles
2	12-MAY-09 8:53:10AM	NH 75224 65868		Corner of trestles, seawater sample 1, mussel sample 1
3	12-MAY-09 9:12:44AM	NH 75251 65877		Oyster norovirus sample
4	12-MAY-09 9:15:46AM	NH 75323 65885		Corner of trestles, seawater sample 2, mussel sample 2
5	12-MAY-09 9:26:01AM	NH 75336 65777		Corner of trestles, mussel sample 3
6	12-MAY-09 9:36:37AM	NH 75243 65759		Mussel sample 4
7	12-MAY-09 9:46:29AM	NH 75277 65700		Stream 30cmx2cmx0.145m/s, freshwater sample 3
8	12-MAY-09 9:59:23AM	NH 75377 65709		Line of rocks heading out to sea but no pipe underneath
9	12-MAY-09 10:16:02AM	NH 75140 65695	Figure 5	Stream 15cmx1cmx0.576m/s, some sewage fungus, freshwater sample 4
10	12-MAY-09 10:24:02AM	NH 75003 65712		Stream 48cmx5cmx0.388m/s, freshwater sample 5
11	12-MAY-09 10:33:51AM	NH 74107 65537		Seawater sample 6
12	12-MAY-09 10:43:20AM	NH 73900 65465		Stream 28cmx8cmx0.419m/s, freshwater sample 7
13	12-MAY-09 10:52:10AM	NH 73674 65323		Land drain not flowing
14	12-MAY-09 10:54:28AM	NH 73385 65271	Figure 6	30 cattle/calves
15	12-MAY-09 10:56:58AM	NH 73256 65265		Stream 45cmx7cmx0.348m/s, freshwater sample 8
16	12-MAY-09 11:09:32AM	NH 72878 65475		Seawater sample 9
17	12-MAY-09 11:15:54AM	NH 72826 65291		Stream 98cmx12cmx0.069m/s, freshwater sample 9a
18	12-MAY-09 11:23:25AM	NH 72209 65209	Figure 7	Jemimaville WWTP
19	12-MAY-09 11:35:20AM	NH 71897 65253		Orange 12cm pipe probably land drain (not flowing)
20	12-MAY-09 11:36:40AM	NH 71910 65256	Figure 8	Black ribbed 15cm plastic pipe, dripping, sewage fungus.
21	12-MAY-09 11:37:50AM	NH 71936 65263		White ribbed 10cm land drain
22	12-MAY-09 11:41:59AM	NH 72020 65316	Figure 9	20 cm metal pipe, not flowing, points back up shore to Jemimaville WWTP. Also stream 163cmx12cmx0.146m/s, freshwater sample 10
23	12-MAY-09 11:53:10AM	NH 71650 65201		Metal 15cm pipe not flowing, presumable overflow from adjacent Scottish Water pumping station
24	12-MAY-09 12:03:13PM	NH 71657 65128		Scottish Water pumping station
25	12-MAY-09 12:10:15PM	NH 71337 65134		Stream, measured in 2 channels, 345cmx8cmx0.246m/s and 2130cmx6cmx0.461m/s, freshwater sample11. About 60 gulls and 5 swans further down channel.
26	12-MAY-09 12:25:37PM	NH 70644 65929		Paddock with one horse
27	12-MAY-09 12:29:54PM	NH 71071 66818		Seawater sample 12 (onshore wind, water turbid)
28	12-MAY-09 12:48:27PM	NH 70833 67148	Figure 10	10cm cast iron sewage pipe, dripping
29	12-MAY-09 12:51:19PM	NH 70786 67134	Figure 11	Septic tank, overflow buried in beach
30	12-MAY-09 12:54:02PM	NH 70650 67127	Figure 12	Orange 12cm pipe, encased in concrete, end buried in beach
31	12-MAY-09 1:20:26PM	NH 75562 65738		Stream 60cmx2cmx0.300m/s, freshwater sample 13
32	12-MAY-09 2:02:30PM	NH 76790 66525		Stream 112cmx3cmx0.335m/s, freshwater sample 14

No.	Date and time	Position	Photograph	Description
33	12-MAY-09 2:06:13PM	NH 76782 66533		Seawater sample 15
34	12-MAY-09 2:10:39PM	NH 77256 66847		12 sheep in field behind, possibly more not visible from this point
35	12-MAY-09 2:16:24PM	NH 78401 67244		9 yachts and some more empty moorings
36	12-MAY-09 2:18:13PM	NH 78439 67295		Scottish Water pumping station with overflow pipe (underwater)
37	12-MAY-09 2:32:37PM	NH 78590 67700	Figure 13	Harbour with 14 craft, mainly small fishing vessels
38	12-MAY-09 2:42:05PM	NH 78704 67774		Scottish Water pumping station
39	12-MAY-09 2:50:17PM	NH 79089 67425		Scottish Water pumping station
40	12-MAY-09 2:55:36PM	NH 79320 67294		Scottish Water pumping station
41	13-MAY-09 8:56:21AM	NH 69680 68887		Large broken concrete pipe to underwater
42	13-MAY-09 9:16:33AM	NH 71281 68538		Scottish Water pumping station
43	13-MAY-09 9:18:40AM	NH 71309 68521		Seawater sample 17
44	13-MAY-09 9:29:45AM	NH 71756 69056		Scottish Water pumping station, large concerte pipe to about 100m offshore
45	13-MAY-09 9:37:53AM	NH 72144 69380		Scottish Water pumping station
46	13-MAY-09 9:44:11AM	NH 72736 69982		Scottish Water pumping station, pipe to underwater, one pleasure craft (cabin cruiser) moored up
47	13-MAY-09 10:01:01AM	NH 74997 72129		Scottish Water pumping station, pipe running out about 200m across beach
48	13-MAY-09 10:12:19AM	NH 76796 74275		Scottish Water pumping station
49	13-MAY-09 10:18:55AM	NH 76978 74372	Figure 14	River 1250cm wide, 10cm and 0.334m/s at 2.5m across, 19cm and 0.243m/s at 5m across, 21cm and 0.217m/s at 7.5m across, 20cm and 0.394m/s at 10m across. Freshwater sample 18.
50	13-MAY-09 10:53:59AM	NH 79605 68721		Seawater sample 19. About 100 sheep seen up on the North Soutar.
51	13-MAY-09 11:07:12AM	NH 79874 72177		2 horses
52	13-MAY-09 11:19:52AM	NH 80529 73093	Figure 15	RSPB hide, 2 roe deer seen here
53	13-MAY-09 11:26:47AM	NH 81325 73989		About 250 sheep over several fields
54	13-MAY-09 11:47:21AM	NH 69664 68873		Seawater sample 20
55	13-MAY-09 12:27:47PM	NH 70929 67184		Seawater sample 21
56	13-MAY-09 2:16:38PM	NH 74486 67266		Seawater sample 22, salinity profile taken here
57	13-MAY-09 2:27:14PM	NH 75044 66402		Seawater sample 23, mussel sample 5 (1m depth), too rought to take salinity profile cable swinging everywhere
58	14-MAY-09 10:25:09AM	NH 78842 67721		Sanitary debris on beach
59	14-MAY-09 10:27:41AM	NH 78916 67660		Cast iron 15cm broken pipe to underwater
60	14-MAY-09 10:31:32AM	NH 79092 67441		Concrete pipe casing heading out for at least 100m (presumably main cromarty outfall) also 2 storm drains in rocks.
61	14-MAY-09 10:33:31AM	NH 79040 67490		3 storm drains in rocks
62	14-MAY-09 11:05:34AM	NH 72064 65294		Scottish Water pumping station
63	14-MAY-09 11:16:33AM	NH 71250 65068		Udales Bay RSPB hide, cruise liner now docked over at Invergordon

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 firth.

Sampling

Water and shellfish samples were collected at sites marked on the map. Four bags of mussels were suspended from floats covering the approximate planned position of the fishery several weeks prior to the survey, with the intention that samples be taken from these as part of the survey. On the day of survey however, only one of these could be found. The remaining mussel samples were collected from the corners of the empty oyster trestles. One oyster sample was gathered from old stock found lying around the trestles.. Samples were transferred to cool boxes for transport to the laboratory. All samples were analysed for *E. coli* content. Seawater sampled at the site was also tested for salinity by the laboratory. Bacteriology results follow in Tables 2 and 3.

Table 2. Water Sample Results

No.	Date and time	Position	Type	***E. coli* result (cfu/100ml)**	Salinity (ppt)
1	12-MAY-09 8:53:10AM	NH 75224 65868	Seawater	0	32.0
2	12-MAY-09 9:15:46AM	NH 75323 65885	Seawater	0	31.6
3	12-MAY-09 9:46:29AM	NH 75277 65700	Freshwater	<100	
4	12-MAY-09 10:16:02AM	NH 75140 65695	Freshwater	22000	
5	12-MAY-09 10:24:02AM	NH 75003 65712	Freshwater	<100	
6	12-MAY-09 10:33:51AM	NH 74107 65537	Seawater	0	31.8
7	12-MAY-09 10:43:20AM	NH 73900 65465	Freshwater	<100	
8	12-MAY-09 10:56:58AM	NH 73256 65265	Freshwater	<100	
9	12-MAY-09 11:09:32AM	NH 72878 65475	Seawater	0	32.2
9a	12-MAY-09 11:15:54AM	NH 72826 65291	Freshwater	100	
10	12-MAY-09 11:41:59AM	NH 72020 65316	Freshwater	100	
11	12-MAY-09 12:10:15PM	NH 71337 65134	Freshwater	100	
12	12-MAY-09 12:29:54PM	NH 71071 66818	Seawater	0	31.8
13	12-MAY-09 1:20:26PM	NH 75562 65738	Freshwater	<100	
14	12-MAY-09 2:02:30PM	NH 76790 66525	Freshwater	<100	
15	12-MAY-09 2:06:13PM	NH 76782 66533	Seawater	4	28.0
17	13-MAY-09 9:18:40AM	NH 71309 68521	Seawater	9	31.6
18	13-MAY-09 10:18:55AM	NH 76978 74372	Freshwater	100	
19	13-MAY-09 10:53:59AM	NH 79605 68721	Seawater	1	33.2
20	13-MAY-09 11:47:21AM	NH 69664 68873	Seawater	0	32.0
21	13-MAY-09 12:27:47PM	NH 70929 67184	Seawater	500	32.0
22	13-MAY-09 2:16:38PM	NH 74486 67266	Seawater	0	32.5
23	13-MAY-09 2:27:14PM	NH 75044 66402	Seawater	0	33.2

Table 3. Shellfish Sample Results

Sample	Description	Position	*E. coli* result (MPN/100g)
Mussel sample 1	12-MAY-09 8:53:10AM	NH 75224 65868	20
Mussel sample 2	12-MAY-09 9:15:46AM	NH 75323 65885	40
Mussel sample 3	12-MAY-09 9:26:01AM	NH 75336 65777	20
Mussel sample 4	12-MAY-09 9:36:37AM	NH 75243 65759	70
Oyster sample 1	12-MAY-09 9:42:00AM	NH 75262 65757	80
Mussel sample 5 (1m depth)	13-MAY-09 2:27:14PM	NH 75044 66402	<20

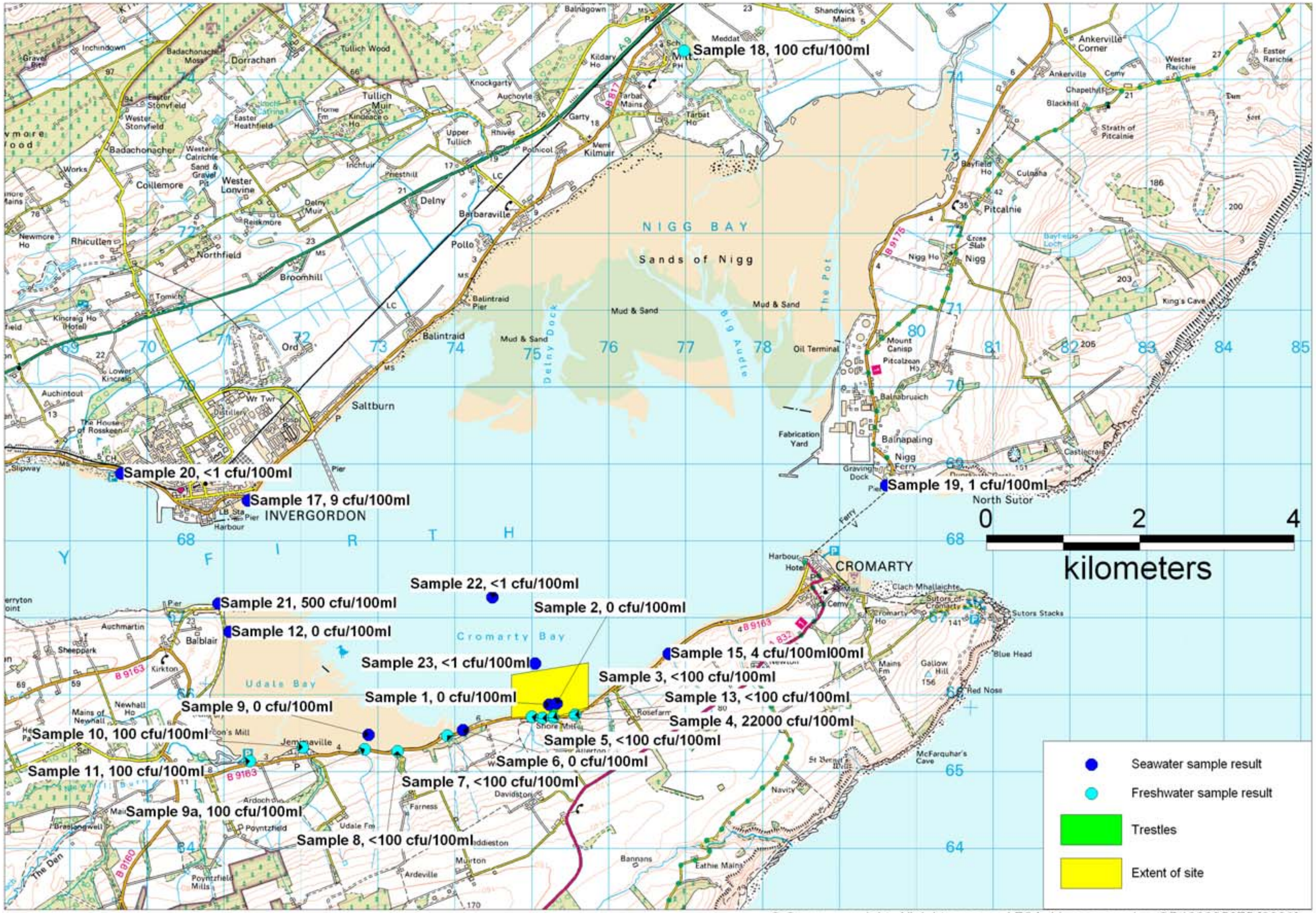


Figure 2 Water sample results map

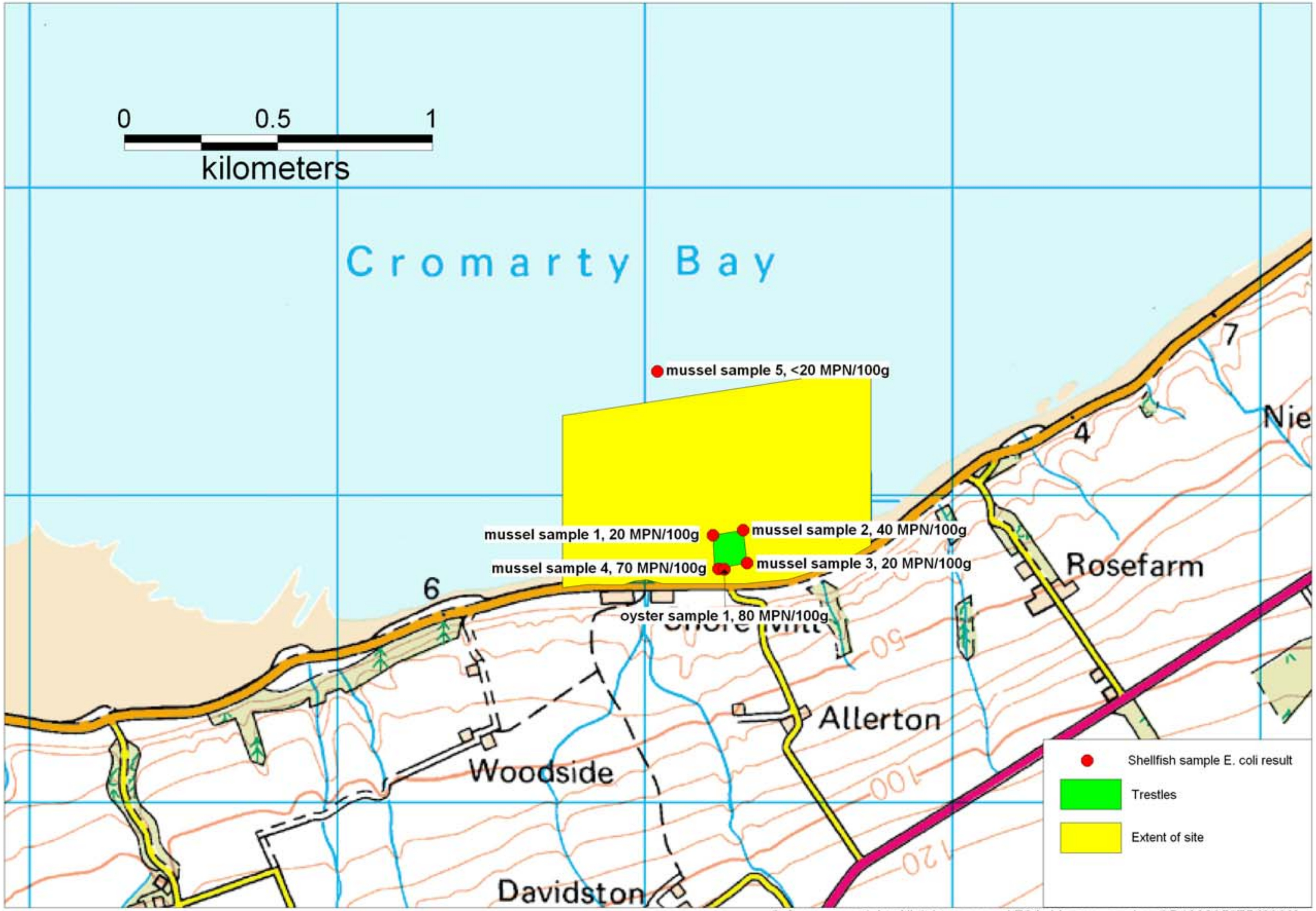


Figure 3 Shellfish sample results map


Figure 4. Trestles at low tide


Figure 5. Small stream with sewage fungus

Figure 6. Cattle in field by Jemimaville

Figure 7. Jemimaville STW


Figure 8. Private discharge at Jemimaville


Figure 9. Jemimaville STW overflow


Figure 10 Discharge pipe at Balblair


Figure 11. Septic tank at Balblair

Figure 12. Discharge pipe at Balblair

Figure 13. Cromarty harbour

Figure 14. Balnagown River

Figure 14. Balnagown River

Figure 15. Roe deer on RSPB reserve at Nigg Bay