SANITARY SURVEY

REPORT

Belfast Lough

2008

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Executive Summary

Under Regulation (EC) No. 854/2004 there is a requirement for competent authorities intending to classify bivalve mollusc production and realying areas to undertake a number of tasks collectively known as ‘sanitary surveys’. The main purpose of these surveys is to inform the sampling plans for the microbiological monitoring programme and classification of production areas. Other benefits of these surveys include the potential to improve identification of pollution events and the sources of those events such that in the future remedial action can be taken to the benefit of the fisheries.

This report documents the qualitative assessment made of the potential sources of microbiological contamination of bivalve molluscs in Belfast Lough and presents the recommended sampling plan as a result of the sanitary survey undertaken by AFBI, on behalf of the Food Standards Agency NI (FSANI). The assessment is supported by published information for Belfast Lough and new information obtained from a shoreline survey. The Recommendations of the report present information on the location of microbiological monitoring points and sampling frequency for classified harvesting areas in Belfast Lough.

Sanitary Survey of Belfast Lough

This text should be used in conjunction with the Arc Publisher Project Supplied with this report which allows combinations of maps to be created.

1. Introduction

With regard to the establishment of microbiological monitoring programmes for shellfish harvesting areas, EU Regulation 854/2004 Section 6 of Annex II stipulates that:

"If the competent authority decides in principle to classify a production or relaying area, it must:

1. make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area;
2. examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste water treatment etc;
3. determine the characteristics of the circulation of pollutants by virtue of current patterns, bathymetry and the tidal cycle in the production area; and
4. establish a sampling programme of bivalve molluscs in the production area which is based on the examination of established data, and with a number of samples, a geographical distribution of the sampling points and a sampling frequency which must ensure that the results of the analysis are as representative as possible for the area considered."

The activities included in points 1 to 3 above constitute a sanitary survey. The main elements of a sanitary survey are:

a. Desk survey – acquisition and analysis of relevant data and information.

b. Shoreline survey – practical survey to confirm information obtained during the desk study and to identify other potential sources of contamination.
c. Bathymetry and hydrodynamics – to determine whether the potential sources actually impact on the shellfishery and to what extent
d. Bacteriological survey – testing of samples from a number of points to determine differences in contamination across the shellfishery – this should only be undertaken if the outcome of the other elements are unclear.

2. Study Area – General description

Belfast Lough lies on a North East facing line on the East coast of Northern Ireland (Figure 1) straddling the border of Counties Antrim to the North, and Down, to the South.

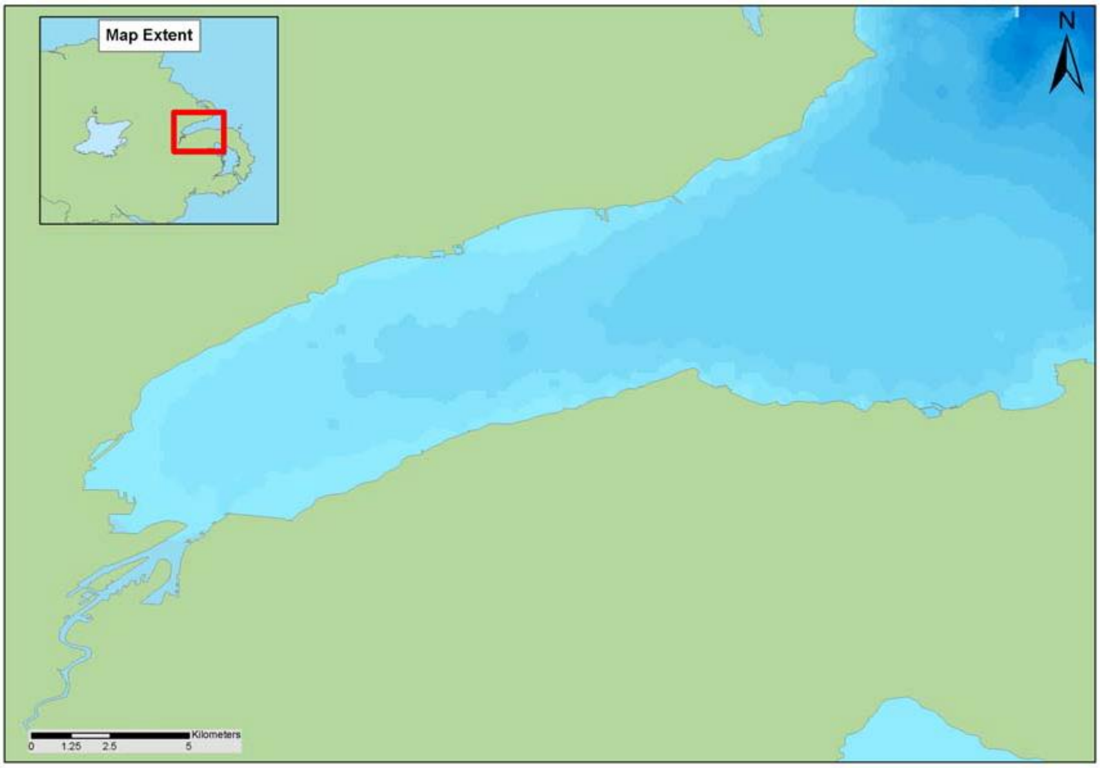


Figure 1: The Location of Belfast Lough

The catchment of Belfast Lough covers an area of just over 900 km^2 of which approximately 60% forms the drainage area of the River Lagan, Belfast Lough's primary freshwater source. The river is some 70 km in length and drains some of the most productive agricultural land in Northern Ireland. The remainder of the catchment is drained by a number of comparatively small rivers and streams. In terms of land use the Belfast catchment comprises 415 farms covering dairy, sheep, pig and arable farming (1993 Census data). The patterns of land use are shown in figure 2 and 3. There is a general predominance for pasture to the North of the Lough with more mixed agricultrual land with the higher urban density to the south. Most of the immediate fringing areas are classifed urban.

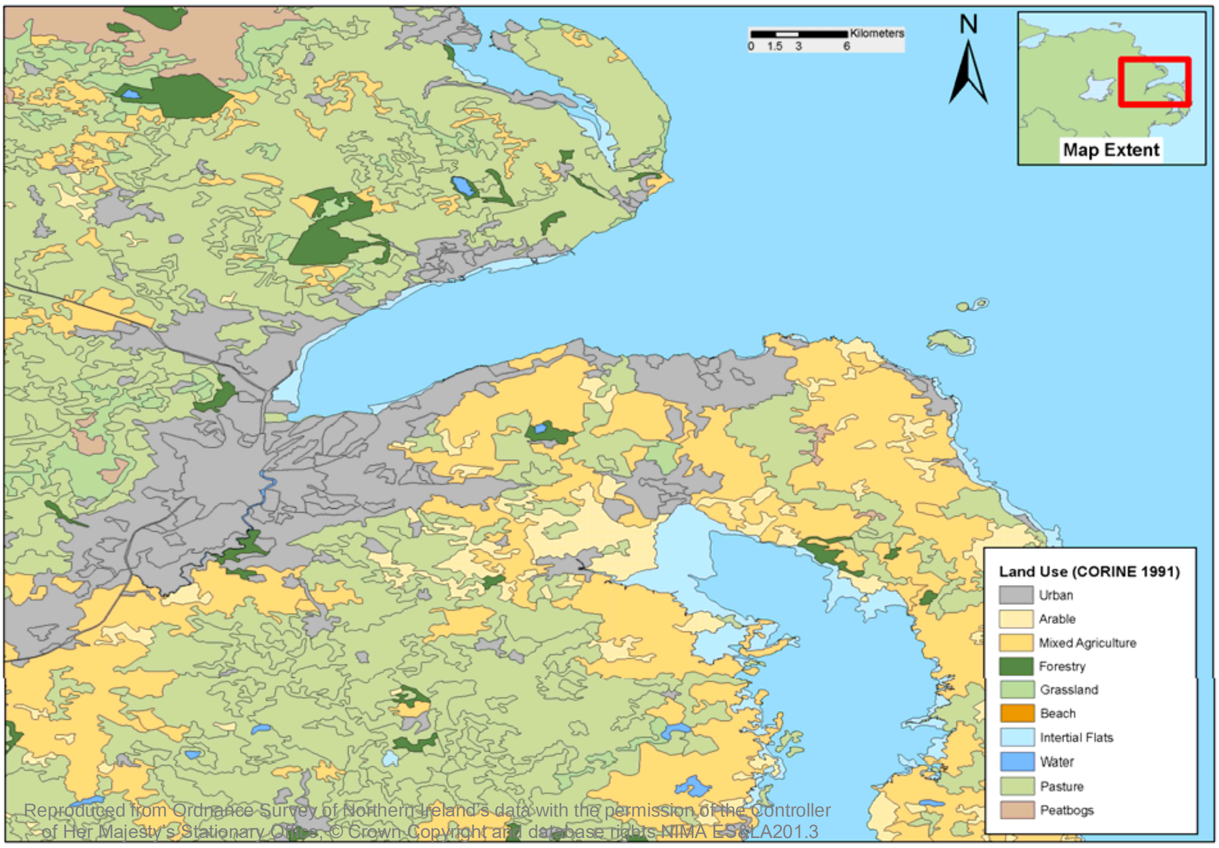


Figure 2: Land Use Classifcation- Antrim and North Down

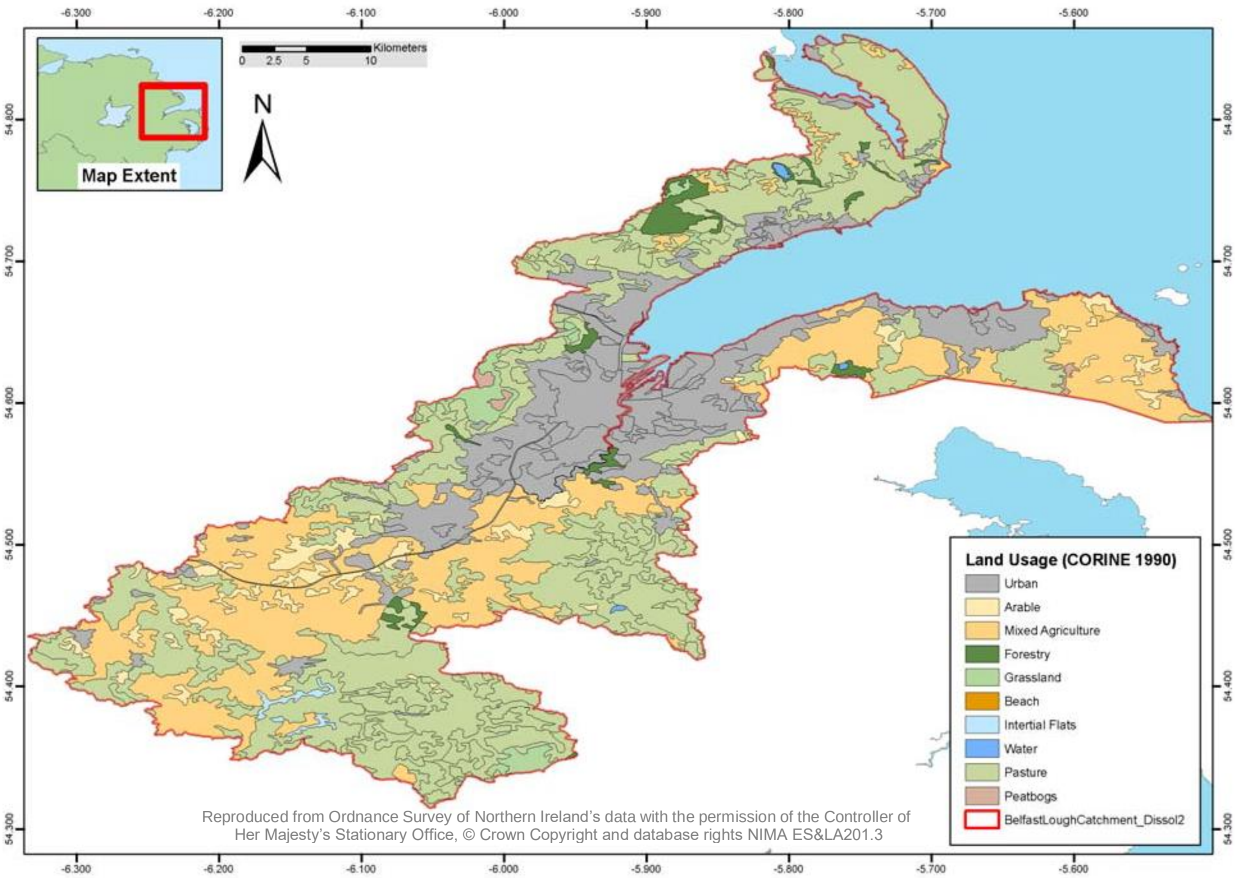


Figure 3: Land Use Classifcation- Belfast Catchment

At its head lies the city of Belfast, the capital of Northern Ireland and the home of approximately one third of its population. Along the Lough's shores the principal conurbations are Newtownabbey and Carrickfergus, to the North, with Holywood and Bangor, to the South (Figure 4).

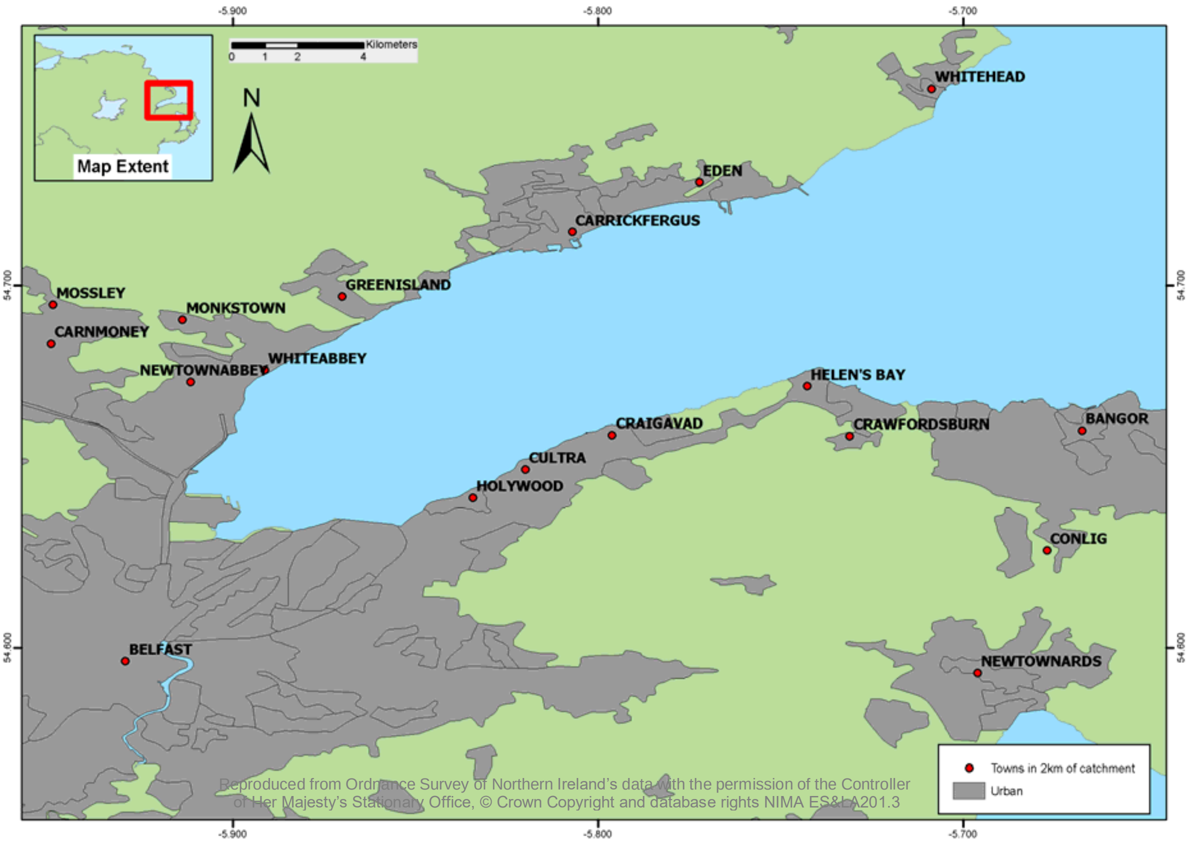


Figure 4: Settlements around the Lough

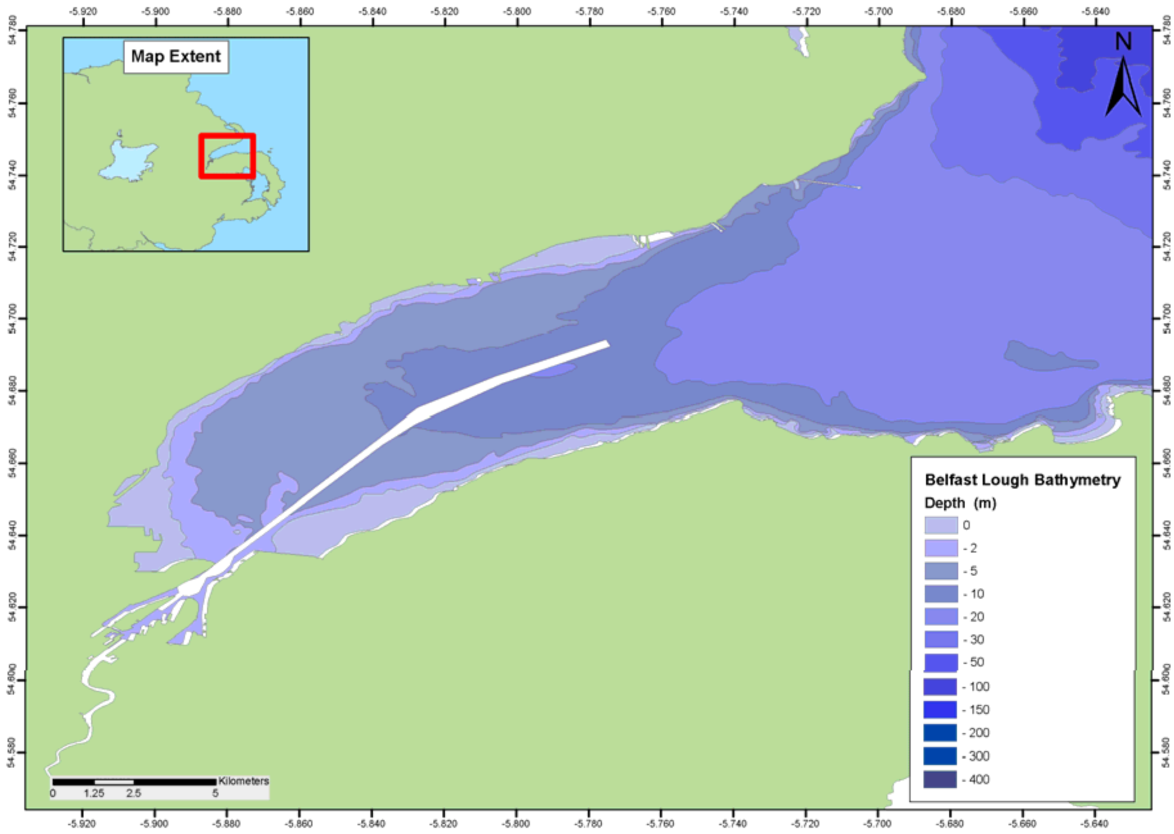


Figure 5: Bathymetry of Belfast Lough

3. Bathymetry and Hydrography

The Lough is a shallow semi-enclosed bay separated from the North Channel with a maximum depth of approximately 20m at its limit (figure 5). Hydrodynamic modelling of the Lough was undertaken by AFBI as part of the Sustainable Mariculture in Northern Irish Sea Loughs (SMILE) Project, Ferreira *et al* (2007) and this report should be consulted for a fuller explanation of the hydrodynamic studies discussed below. Two hydrodynamic models were used; the high resolution DELFT 3D model which defined boundary conditions outside the lough and provided detailed information on currents and the lower resolution Ecowin model which is more suitable for ecological studies. The SMILE study collated data from a number of water quality studies of the Lough and some summary statistics are presented in table one.

Table 1 General Characteristics of Belfast Lough

Volume	(millions m3)	1548
Total area	(km2)	130
Maximum depth	(m)	23
Catchment area	(km2)	900
Temperature range	(ºC)	2-21
Mean salinity	(psu)	28
Flushing time	(days)	1.8
Freshwater run-off	(millions m3 y-1)	1022

Nutrients

Mean nutrient concentration (μmol l-1)				Nutrient load (ton year-1)	
Ammonium	Nitrate	Phosphorus	Silicate	Nitrogen	Phosphorus
33	22	2.6	7.75	7 600	48

Aquaculture

Licensed sites	25 licensed sites in Belfast Lough although not all are currently in production
Total aquaculture area (km2)	7.5 km2
Species	Mussels

3.1 Physical data

For management purposes the Lough can be divided into boxes defined according to homogenous physical conditions. For this purpose morphology, currents and vertical stratification are evaluated. Morphology is analysed through bathymetry data. Vertical stratification assessment is done by comparing surface and bottom density, calculated using salinity and temperature data gathered by AFBI.

3.2 Other Management Units. Water bodies defined for Water Framework Directive (WFD) implementation

The management options that will be implemented for the WFD (Directive 2000/60/EC of the European Parliament and of the Council) rely on the division of water bodies which are in essence “functional” units based on hydrological and morphological characteristics. As these water bodies will be the basis for the regulation of inputs to these systems, it is strongly recommended that these water body boundaries should be taken into account when considering management options.

3.3 Aquaculture sites

The definition of the model boxes aggregate the aquaculture areas in the system. These areas were included in the GIS and information on the commercial and biological status of the cultivated species is analysed for the purpose of potential spatial aggregation.

Physical data

The Belfast Lough morphology was analysed through a bathymetric reclassification (Figure 6). Based on bathymetry data and on the patterns of current flows, the aggregated grid for ECOWIN is shown in Figure 6 (in red), with 19 boxes split at mid depth (a total of 38 boxes were defined for the system). This grid was created from the black (DELFT 3D) grid layout shown in the same figure. An analysis of density data collected from a regular grid of sampling stations (Figure 7a) shows that vertical stratification in the water column is insignificant (Figure 7b) using the criteria of Simpson (1990) . In winter when freshwater inputs from the rivers are highest, negative values are generally observed due to the fresh less dense water floating on the surface of the more saline water beneath. In the summer positive values are often recorded which is probably due to the complex mixing between water bodies of different salinities. However the difference between the density of the surface and bottom water is small suggesting a well mixed water column for most of the stations. From this perspective, the box division into vertical layers would probably be unnecessary.

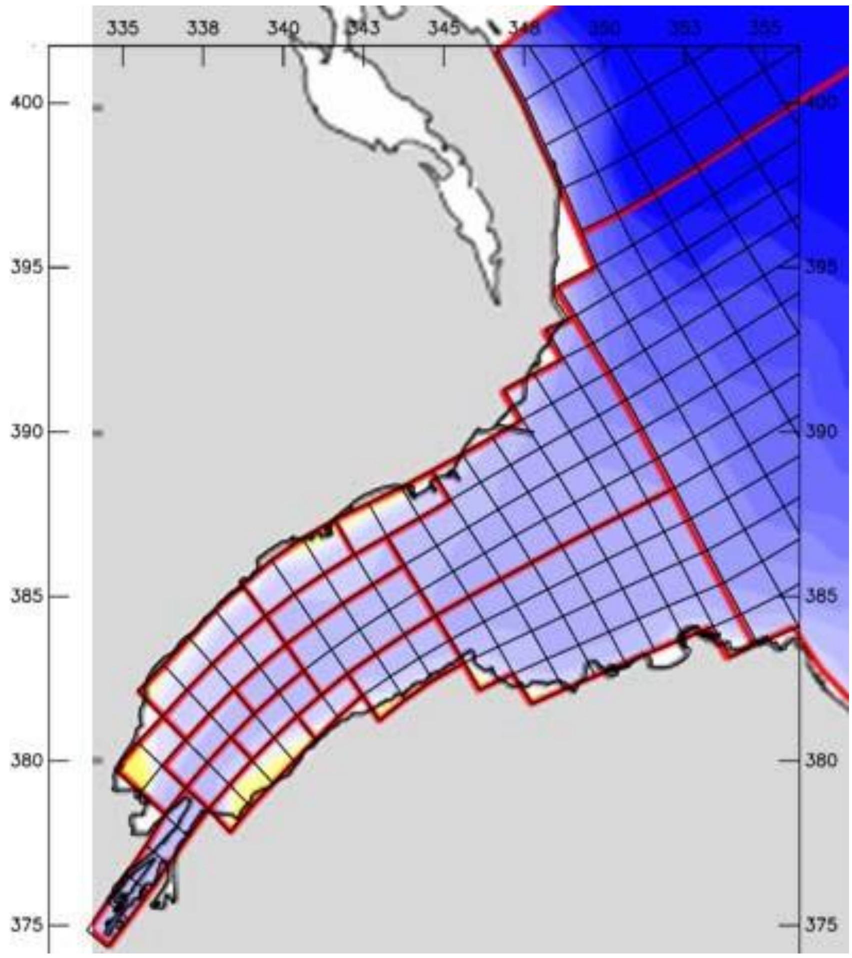
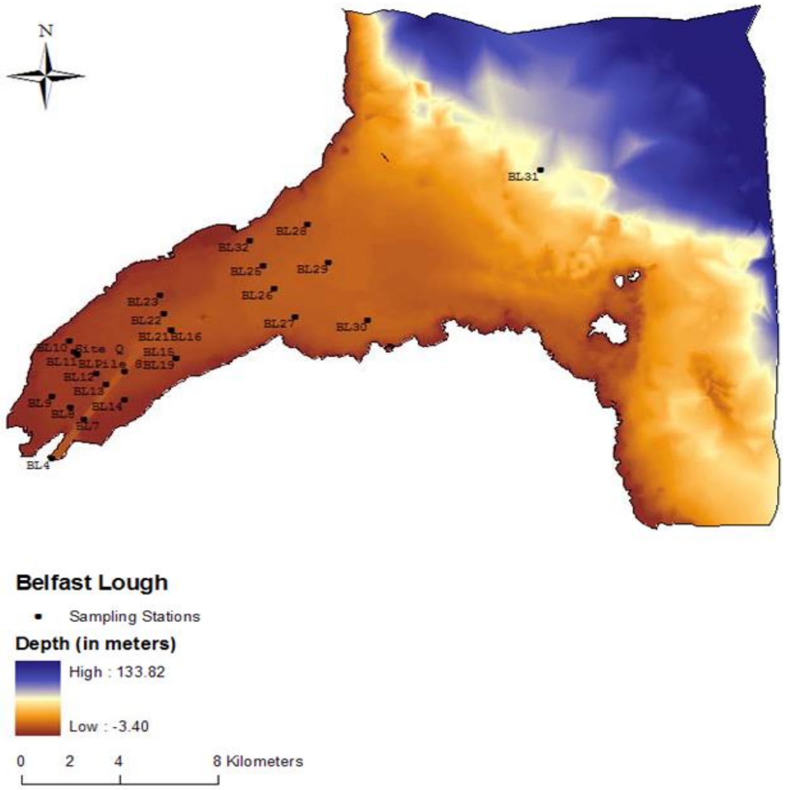


Figure 6: Suggestion for box limits in Belfast Lough based on bathymetry and current data (in red), based on the black grid layout (ocean boxes only partially shown)



a)

Season	Station	Date	Density (kg l^{-1}) Surface (S)	Bottom (B)	Difference (B - S)
Winter	#7	10/01/1996	1024.00	1024.78	0.79
	#10	10/01/1996	1023.08	1025.47	2.39
	#14	07/12/1995	1024.58	1024.72	0.14
	#16	20/03/1996	1026.29	1026.66	0.37
	#21	07/12/1995	1025.26	1025.73	0.48
Spring	#5	23/05/1995	1025.42	1026.24	0.81
	#9	28/03/1995	1025.92	1025.96	0.04
	#12	19/06/1996	1025.08	1026.01	0.93
	#17	02/04/1996	1026.76	1026.80	0.04
	#19	02/04/1996	1026.04	1026.73	0.69
	#22	21/03/1995	1026.19	1026.25	0.06
Summer	#1	31/08/1995	1023.71	1024.92	1.21
	#4	12/09/1995	1023.31	1024.62	1.31
	#6	16/08/1995	1023.77	1025.07	1.29
	#9	28/09/1995	1025.21	1025.21	0.00
	#21	01/08/1995	1024.44	1025.39	0.95
Autumn	#8	11/10/1995	1024.44	1024.53	0.09
	#11	22/09/1995	1024.70	1024.70	0.00
	#13	26/10/1995	1024.61	1024.36	-0.26
	#15	26/10/1995	1024.29	1024.87	0.58
	#18	28/09/1995	1025.19	1025.33	0.14
	#20	26/10/1995	1025.20	1025.22	0.02

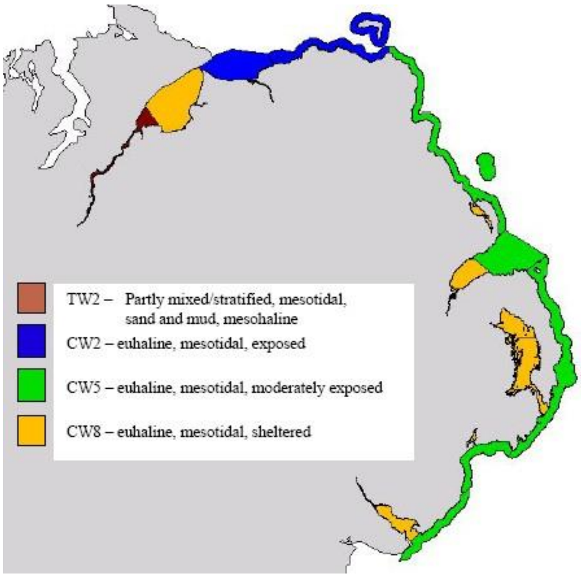
b)

Figure 7: a) Sampling stations in Belfast Lough used to establish salinity profiles b) Density differences.

WFD water bodies

For management, water bodies are divided into transitional (essentially estuarine) and coastal types. Further divisions are based on hydrological and morphlogical characterisitics. The water bodies defined for Northern Ireland are shown in 8 a) and b).

a)



b)

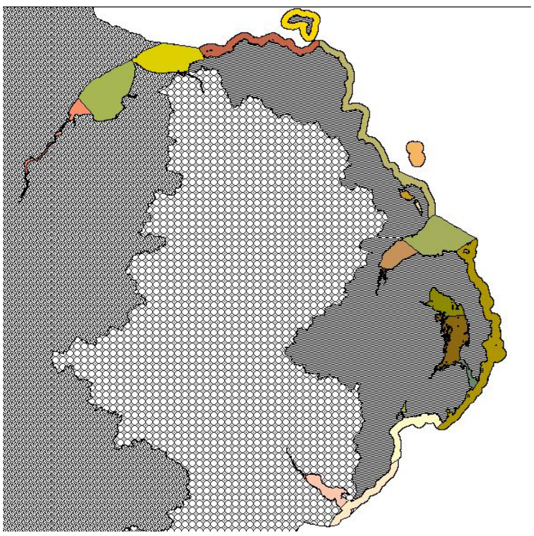
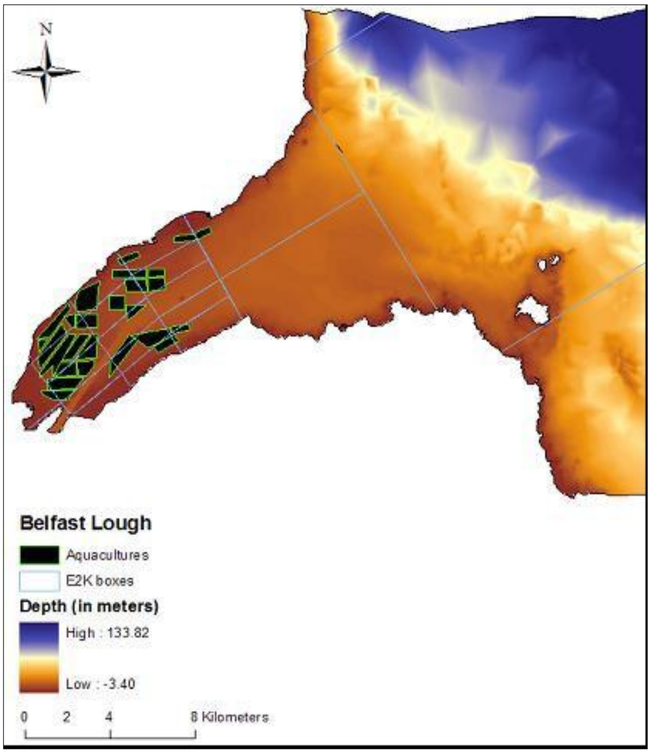


Figure 8: WFD a) typology and b) water bodies for transitional and coastal systems in Northern Ireland

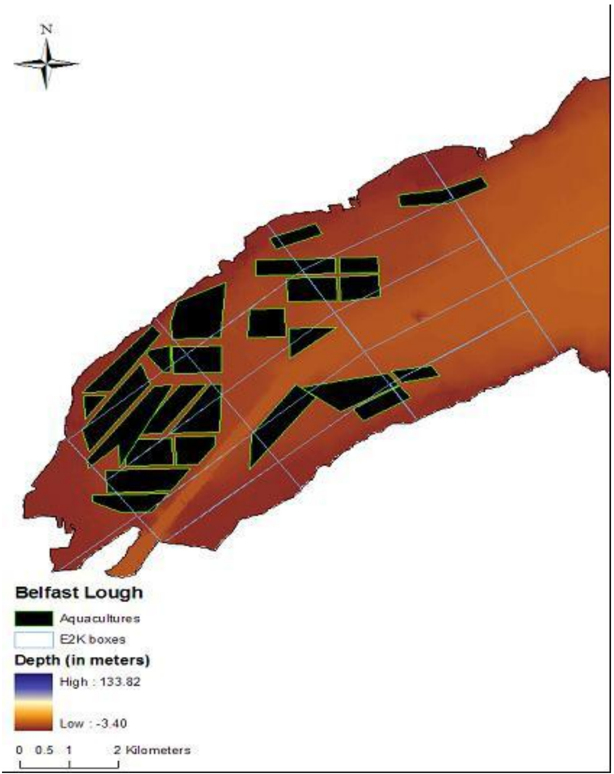
Two types of transitional water bodies are identified for Northern Ireland: Group 2 (TW2), strongly mesotidal estuaries that are generally partly mixed or stratified, mesohaline or polyhaline; and Group 6 (TW6), brackish lagoons.

Each transitional system from the TW2 type is considered to be an individual water body. The Northern Ireland systems included in the TW6 type have a very small individual area so they are not included in this analysis. Adjustments were then made to the box proposals, in order to better fit the aquaculture sites inside the boxes and the WFD water body division (Figure 9a).

The aquaculture areas in Belfast Lough are presented in Figure 9 together with the final hydrographic boxes.Although this design does not totally confine aquaculture limits within boxes (Figure 9b), this compromise was necessary to conduct the hydrodynamic model setup. The difference between the layout and the WFD division into water bodies is not considered to be relevant.



A



B

Figure 9: a) Aquaculture locations in Belfast Lough overlapped with the final E2K box proposal; b) Detail of box limits at the centre of the Lough.

This hydrodynamic modelling of the Lough using the Delft 3D and Ecowin models as part of the SMILE programme indicated that the Lough has a water residence time of 10 to 20 days (Figure 10). The inner Lough where the bulk of the shellfish beds are located has the longest residence time. Residences are generally longer in summer as freshwater forcing is reduced, however it is evident that the inner Lough has a residence time in the order of 20 days. This study was based on a simulation using a conservative tracer.

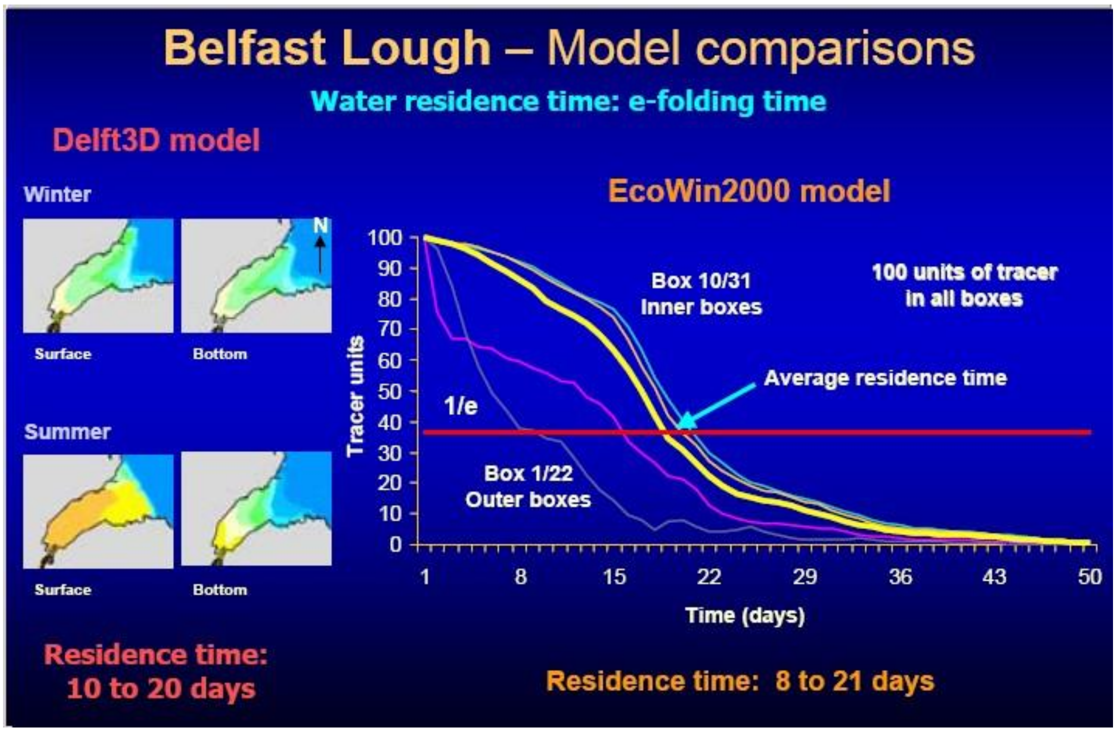


Figure 10: Water Residence Time in Belfast Lough

4. Inputs and Contaminant Status

Sewage effluent is discharged from a number of sewage treatment works situated around the Lough (Figure 11). Riverine inputs to the Lough are dominated by the River Lagan although there are number of smaller streams and rivers along the North and South shores of the Loughs (Figure 12 and 13).

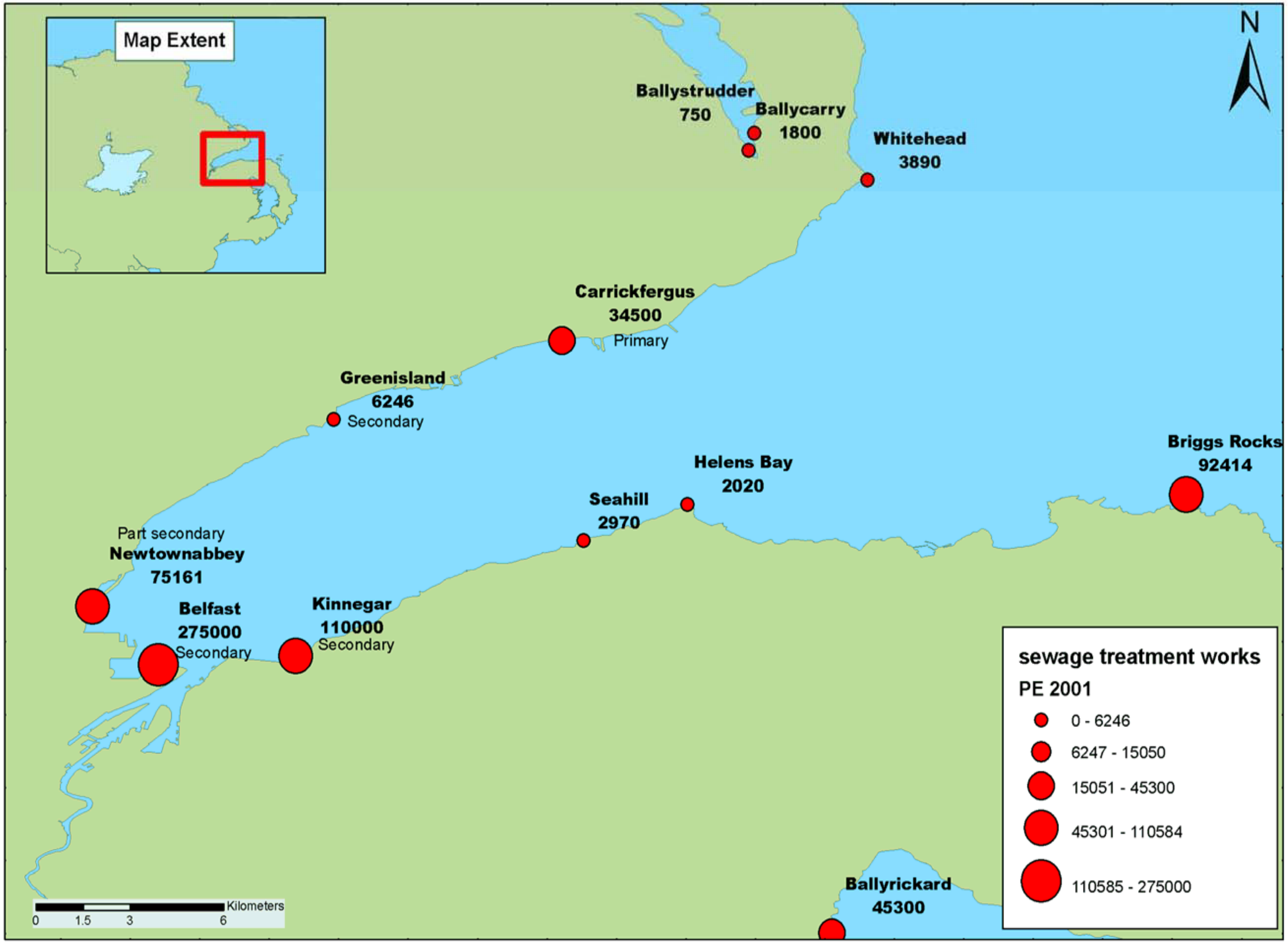


Figure 11: Principle Sewage Discharges shown as Population Equivalents (PE)

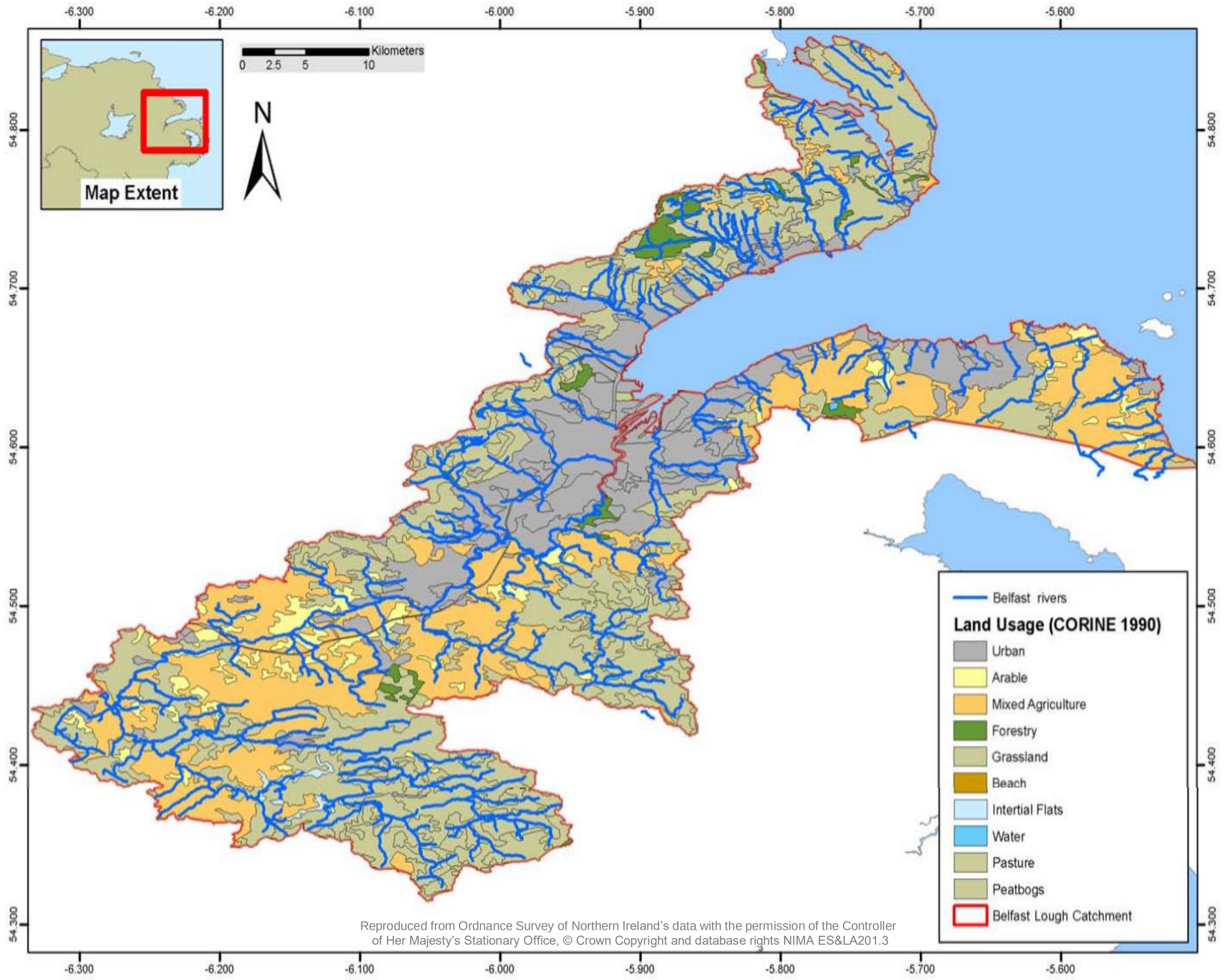


Figure 12: Riverine Inputs

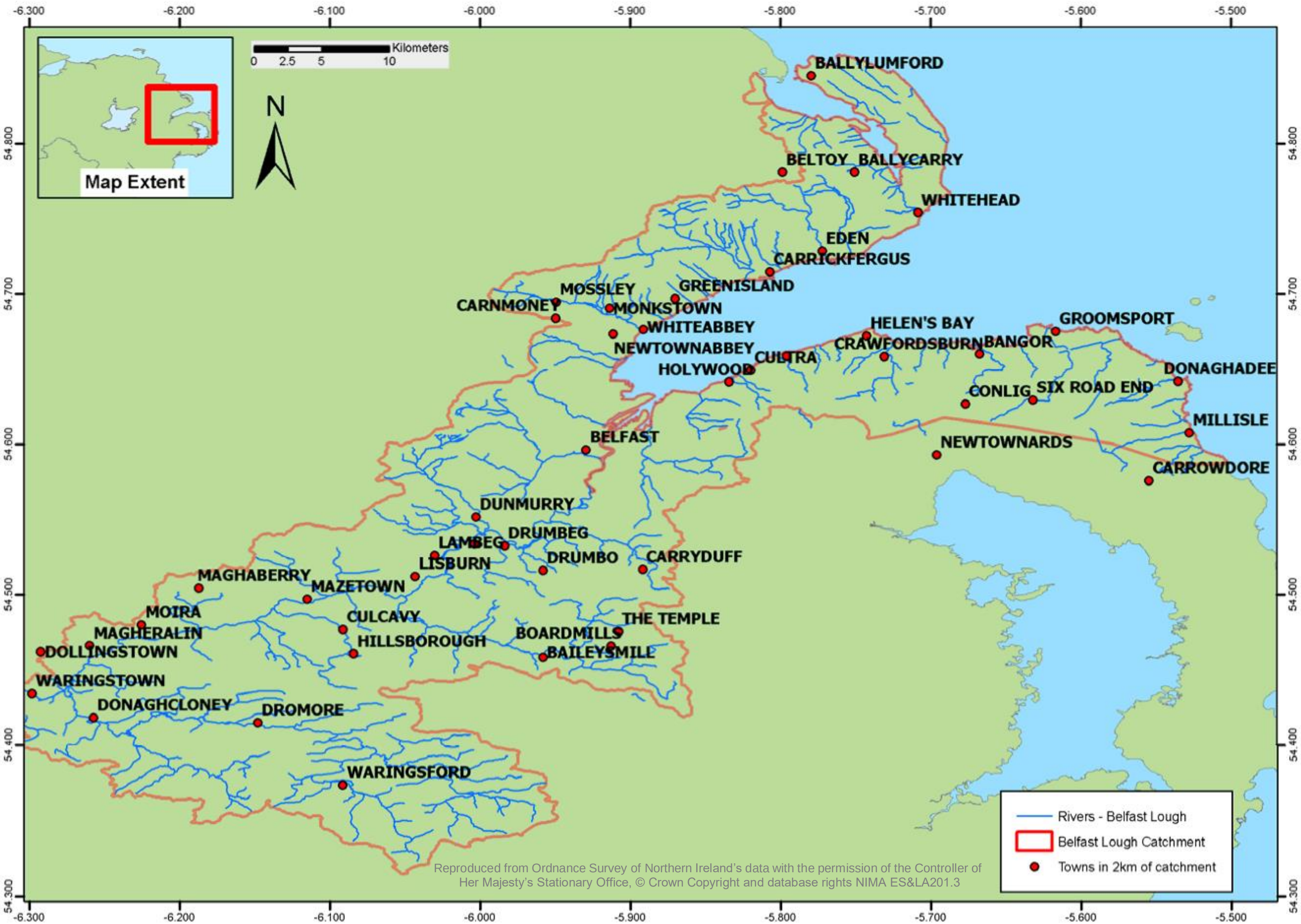


Figure 13: Rivers and Towns within Belfast Catchment

Recreationally, the Lough is of particular importance to yachtsmen. There are moorings off Holywood, Newtownabbey, Whitenhead and Ballyholme while there are marinas at Carrickfergus and Bangor (Figure 14).

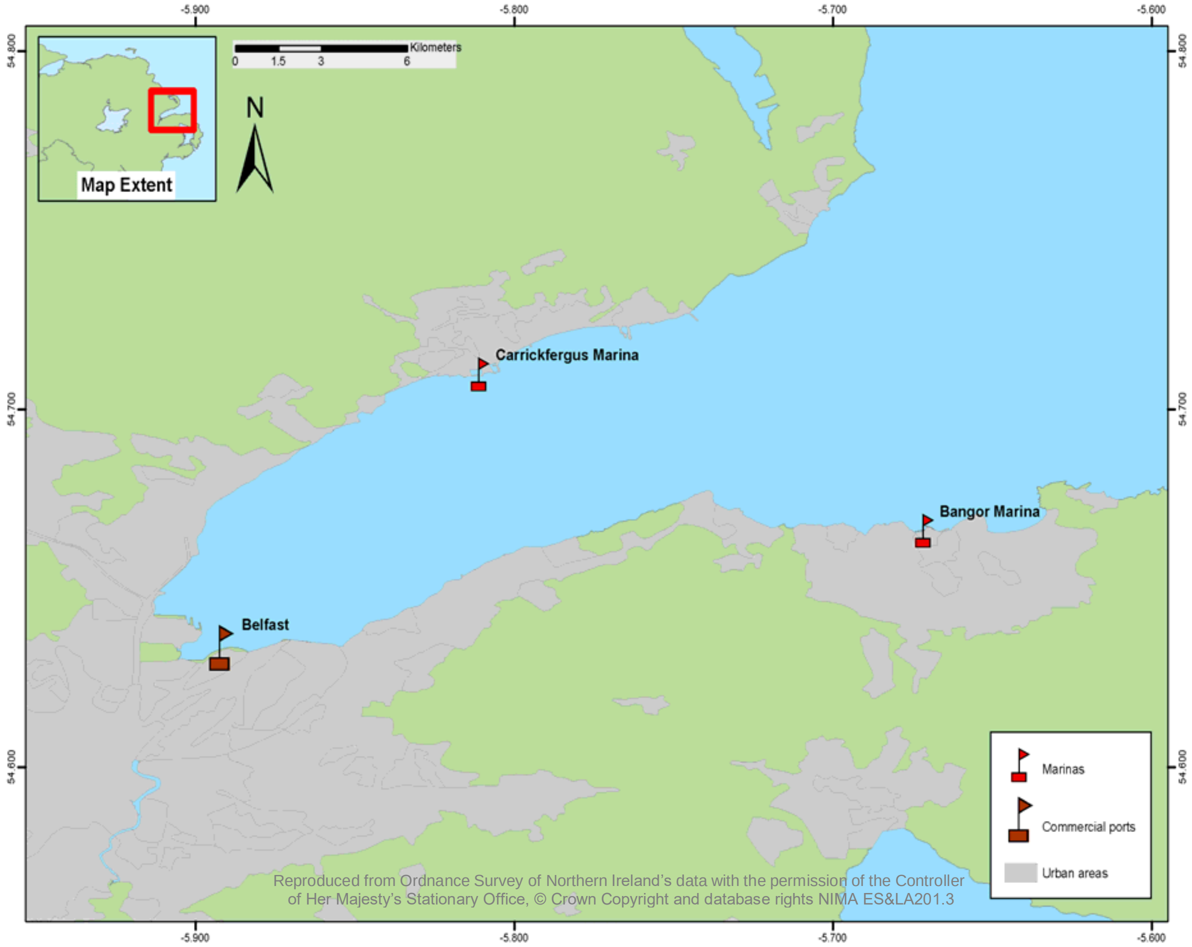


Figure 14: Marinas and harbour developments in Belfast Lough

Although the Lough was extensively studied in the mid Nineteenth Century by the Belfast Dredging Committee and highly regarded for its range of specimens (Kinahen 1857) by the early 1900's it was regarded as severely impacted by organic pollution, to the extent that the then common activity of shellfish harvesting was banned.

5. Conservations and Habitats

At low water extensive areas of mud flats are exposed which are of international importance for over-wintering birds particularly the Redshank (*Itringa totanus)* and the Turnstone *(Arenaria interpres).* This inner region has been classified as an Area of Special Scientific Interest (ASSI). There are also two bird sanctuaries situated on the southern harbour shore just outside the tank farm (figure15). Although no figures are available, run off from these sanctuaries during periods when birds are aggregating this may add to the bacterial load in the system.

The Belfast Harbour complex itself, is built entirely upon reclaimed land, owned by the Crown Estate Commissioners and held in trust by the Belfast Harbour Commissioners (BHC); reclamation work is still under way. The main shipping lane, the Victoria Channel, is dredged out to the Northern limit of the port to a minimum depth of 9.1m. Maintenance dredging is conducted, at present, every five years

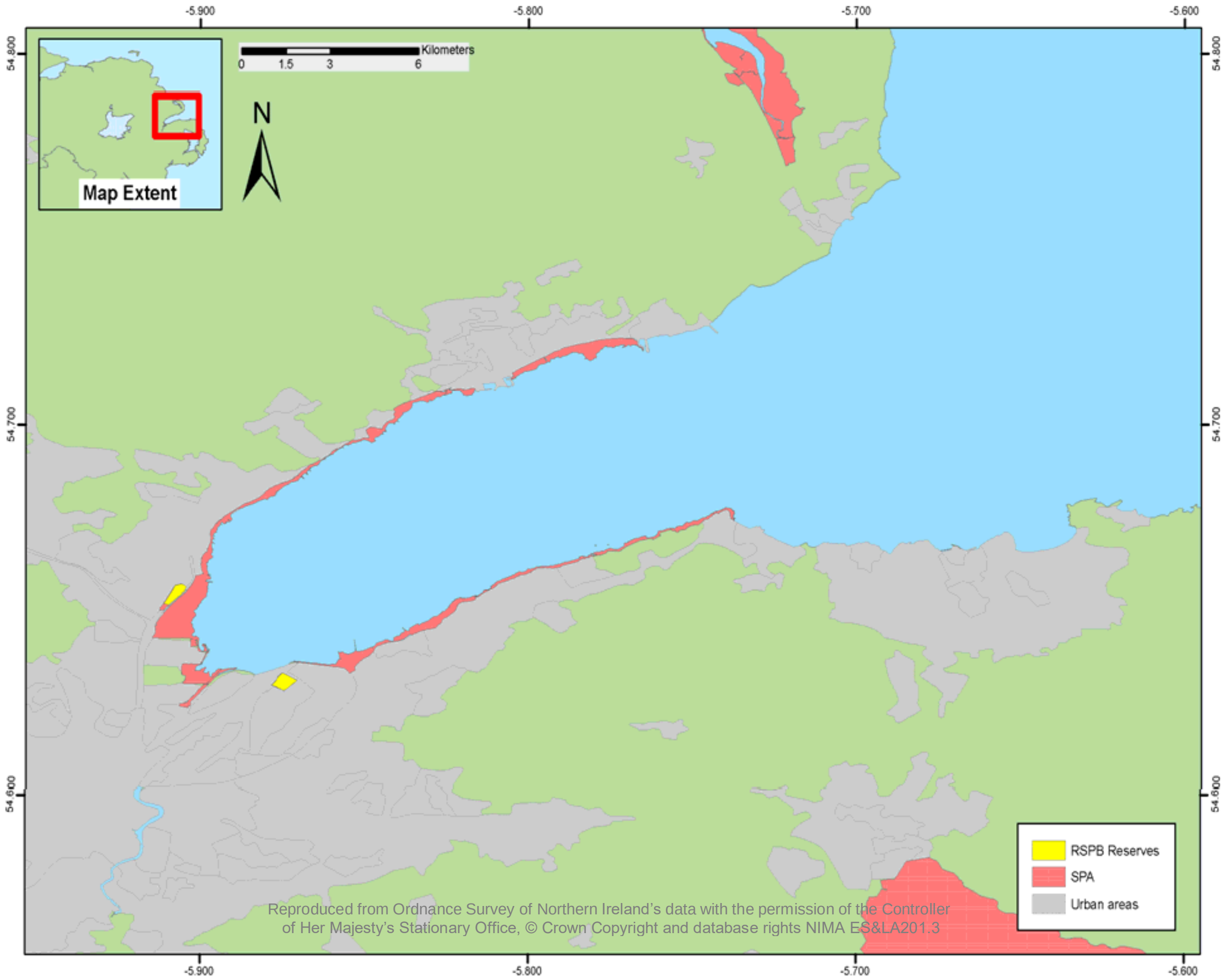


Figure 15: Bird Sanctuaries and SPA

6. Aquaculture

Although in the nineteenth century Belfast Lough supported a thriving shellfish industry this declined rapidly in the early 20th century largely due to public health concerns (Robinson and Stafford 1904). The industry has redeveloped in the last 20 years using bottom culture of the common mussel *Mytilus edulis*. Currently about 25 sites are licensed although at present only 13 are operational (Figure 16). This industry is reliant on a supply of wild seed to stock the beds which are then managed as plots. Dredging operations can occur throughout the year to manage predators, thin and relay stock. Harvesting is principally in the winter months. More detail can be found in Moore and Service (2001).

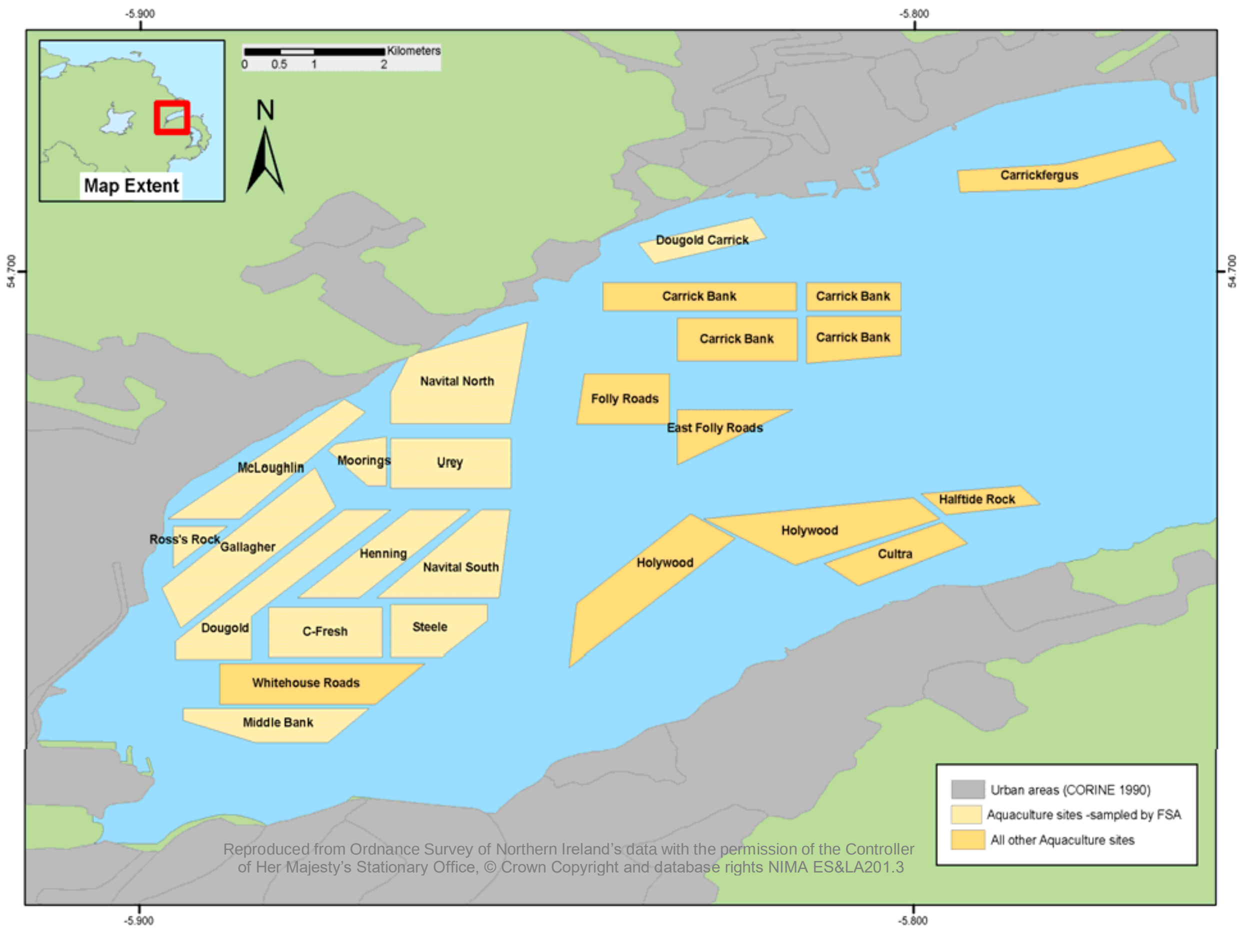


Figure 16: Aquaculture Sites

7. Shellfish Hygiene

In accordance with EC Regulation 854/2004, the Food Standards Agency NI (FSANI), as Competent Authority, is responsible for classifying shellfish harvesting areas according to the degree of *E-coli* contamination detected in samples of shellfish flesh.

Regulation (EC) 854/2004 outlines the requirements for Competent Authorities to put in place Official Controls to protect public health. FSANI is responsible for carrying out an Official Control monitoring programme in classified shellfish production areas in Northern Ireland.

Flesh samples from classified harvesting areas are periodically monitored to check the microbiological quality of the shellfish – *E-coli* is used as an indicator of faecal contamination. Harvesting areas are also monitored for the presence of toxin producing phytoplankton in shellfish waters, specifically *Alexandrium* spp. and marine biotoxins (DSP, PSP and ASP) in shellfish flesh.

In accordance with EU legislation, a sanitary survey must be carried out on classified shellfish areas in order to evaluate potential sources of contamination and establish microbiological sampling points which are representative of the Lough.

Currently 13 aquaculture sites are classified in Belfast Lough as these are the only sites in production. This number will vary between years depending on activity. The sites correspond to licenced sites.

8. The Shoreline Survey

The survey was conducted over 3 days; 16-18th January 2008. A total of 17.3 Kilometres of shoreline was covered, encompassing all accessible areas of Inner Belfast Lough.

The proceeding days had had long periods of sustained rainfall and it was concluded that most discharges would be running during the period of the survey.

Almost all running outfalls were sampled. Exceptions being where no discharge was present, or where an outlet was clearly for drainage from a path above and so on. If an outlet was discovered the following procedures were carried out:

A GPS position for each sample was logged using a Garmin GPS 60. A site description was made along with notes of any wildlife, shore litter, type of discharge and type of discharged material (table 2). A photograph was then taken (using an Olympus E-500 Digital SLR camera and a Samsung L760). Lastly a sample of water was collected from the outlet, stored in a sterile 200ml sample bottle (with long handle to prevent possible sample contamination) and labelled.

In the laboratory water samples were logged into the AFBI Food Microbiology Lab (UKAS accredited) for coliform analysis. Samples were vacuum filtered and filters were incubated overnight at 37^{0}C, suspects isolated and confirmatory tests performed using Tryptone water. Total coliform count per 100ml was determined as was faecal coliform count per 100ml.

On 4th March 2008 mussel samples were collected for microbiological analysis. Mussels were collected from 4 sites within the inner lough around FSA sampled mussel beds. The mussels sampled were chosen to represent the beds adjacent to the shore, outer/mid lough area and southern bed. A total of 20 mussels were collected at each site and a random subsample of 3 were masticated, incubated for 24 hours in liquid media, plated and incubated for another

24hours on violet red bile and MacConkey agar. Coliforms per gram and Faecal coliforms per gram were determined.

The GPS positions were imported to GIS and all attributes were added to compile a GIS project detailing all of the information collected from the survey and a visual display of all results from the water sample analyses (figures 17-23).

Table 2 Site Descriptions

Id	St	Northing	Westing	type of discharge	shore_animals	shore_litter
1	1	54.635280	5.865580	Small underground stream.	None.	Shopping trolley.
2	2	54.635130	5.864400	Stormwater culvert	None.	None.
3	3	54.634790	5.861420	Stormwater culvert	Few birds. Gulls, Oystercatchers and Curlews.	Six industrial tyres and plastic wrapping.
4	4	54.634530	5.859990	Stormwater culvert	Few birds. Gulls, Oystercatchers and Curlews.	None.
5	5a	54.634170	5.855000	Stream / River	Few birds. Gulls, Oystercatchers and Curlews.	Tyre, sanitary towels, plastic bottles, plastic bags, one shoe and other domestic waste.
	5b	54.632940	5.853800	Stream / River	Few birds. Gulls, Oystercatchers and Curlews.	Tyres, gas cylinder, copious numbers of sanitary towels and more domestic type waste.
6	6	54.644410	5.832850	Stormwater culvert	None.	None.
7	7	54.645970	5.828650	Stream / River	Few birds. Gulls, Oystercatchers and grey crows.	Sanitary waste deposition.
8	8	54.646640	5.827610	Stormwater pipe	None.	Tyre on beach.
9	9	54.646880	5.827700	Outfall pipe of questionable use	None.	None.
10	10	54.647220	5.827480	Outfall pipe of questionable use	None.	None.
11	11	54.648700	5.824950	Stream / River	Four dogs.	None.
12	12	54.652420	5.818140	Small outfall pipe of questionable use.	Two dogs.	None.
13	13	54.654467	5.906500	Stormwater pipe	None.	None.
14	14	54.652833	5.808667	Stormwater pipe	Grey Crows	None.
15	15	54.653667	5.806833	Stormwater pipe behind rocks.	None.	None.
16	16	54.655500	5.802333	Stream / River	None.	None.
17	17	54.656667	5.790333	Stormwater pipe	None.	Toilet roll and other sanitry depositions evident at appature of pipe on shore.
18	18	54.656167	5.771500	Stream / River	None.	None.
19	BLN 01	54.645600	5.914200	main sewage outlet	mud flat birds	sanitary towels
20	BLN 02	54.642390	5.915140	stream outlet	no wildlife	sanitary towels
21	BLN 03	54.649070	5.910420	sewage outlet pipe	few birds	sanitary towels
22	BLN 04	54.650650	5.910420	large pipe	/	sanitary towels

id	St	Northing	Westing	type of discharge	shore_animals	shore_litter
23	BLN 05	54.654490	5.905840	3 large pipes	mussels plentiful	None noted
24	BLN 06	54.655060	5.905210	3 large pipes	mussels plentiful	None noted
25	BLN 07	54.657740	5.903060	Pipe	mussels plentiful	None noted
26	BLN 08	54.659210	5.902260	small outlet pipe	birds, gulls	None noted
27	BLN 09	54.660340	5.900500	Pipe	wildlife present - birds	None noted
28	BLN 10	54.663920	5.900850	small river - outflow pipes going into it	/	None noted
29	BLN 11	54.665190	5.899940	Pipe	lots of birds- different species. Dogs	None noted
30	BLN 12	54.665510	5.899560	small pipe	/	None noted
31	BLN 13	54.672940	5.896400	Pipe	some mussels, no birds. Dogs	sanitary towels
32	BLN 14	54.673960	5.895530	pipe and stream	some mussels, no birds. Dogs	sanitary towels, leaves!
33	BLN 15	54.677620	5.889700	Pipe	mussels	None noted
34	BLN 16	54.677930	5.888430	Pipe	some mussels, some birds	None noted
35	BLN 17	54.680020	5.884070	River	mussels	None noted
36	BLN 18	54.683190	5.879000	River	mussels, seaweeds	None noted
37	BLN 19	54.684620	5.875290	Pipe	/	None noted
38	BLN 20	54.685630	5.872500	River	/	None noted
39	BLN 21	54.687480	5.870250	Pipe	mussels, lots of birds - oyster catchers and cormarants	None noted
40	BLN 22	54.699310	5.849110	River	/	None noted
41	BLN 23	54.698430	5.850450	River	/	None noted
42	BLN 24	Redacted	Redacted	spillage over wall of WWTW	/	sanitary towel, rubbish

Table 2 continued

Results

From table two it is clear that a number of sites were showing evidence of contamination from sanitary waste (Photographs 1-4). All of the water samples returned positive results for total coliforms and faecal coliforms. Total coliform count ranged from 70 – 560,000 coliforms/100ml, faecal coliform count ranged from 7 – 9,700 coliforms/100ml and *E. coli* (cfu) per 100ml from 5 to 7500 (table 3). All sites correspond to table two.

Photographs

Site 5

Site 7

BLN24 Overflowing sewage treatment works

BLN3

Table 3: Coliform and Faecal Coliform

ID	Northing	Westing	Total Coliform Count/100ml	Faecal Coliform Count/100ml	Equivalent E-Coli/100ml
1	54.6353	-5.8656	70	7	5
2	54.6351	-5.8644	79	11	8
3	54.6348	-5.8614	1080	120	92
4	54.6345	-5.8600	24000	2500	1925
5	54.6342	-5.8550	1320	97	75
6	54.6329	-5.8538	3200	1300	1001
7	54.6444	-5.8329	13000	950	732
8	54.6460	-5.8287	19000	1700	1309
9	54.6466	-5.8276	360	47	36
10	54.6469	-5.8277	500	60	46
11	54.6472	-5.8275	24000	2500	1925
12	54.6487	-5.8250	5000	175	135
13	54.6524	-5.8181	750	54	42
14	54.6545	-5.9065	270000	8300	6391
15	54.6528	-5.8087	120	69	53
16	54.6537	-5.8068	860	89	69
17	54.6555	-5.8023	68000	1000	770
18	54.6567	-5.7903	17500	4000	3080
19	54.6562	-5.7715	8600	1900	1463
20	54.6456	-5.9142	49000	2800	2156
21	54.6424	-5.9151	560000	6100	4697
22	54.6491	-5.9104	340	90	69
23	54.6507	-5.9104	2900	990	762
24	54.6545	-5.9058	47000	590	454
25	54.6551	-5.9052	8400	2200	1694
26	54.6577	-5.9031	6900	1800	1386
27	54.6592	-5.9023	900	300	231
28	54.6603	-5.9005	1800	600	462
29	54.6639	-5.9009	1470	870	670
30	54.6652	-5.8999	1200	900	693
31	54.6655	-5.8996	560	49	38
32	54.6729	-5.8964	6900	2100	1617
33	54.6740	-5.8955	16400	6300	4851
34	54.6776	-5.8897	30000	5900	4543
35	54.6779	-5.8884	30000	8300	6391
36	54.6800	-5.8841	14000	5000	3850
37	54.6832	-5.8790	13500	4800	3696
38	54.6846	-5.8753	1100	480	370
39	54.6856	-5.8725	1500	990	762
40	54.6875	-5.8703	720	95	73
41	54.6993	-5.8491	1400	770	593
42	54.6984	-5.8505	8500	2200	1694
43	54.7026	-5.8423	30000	9700	7469

Table 3: Analysis on water samples collected from Survey

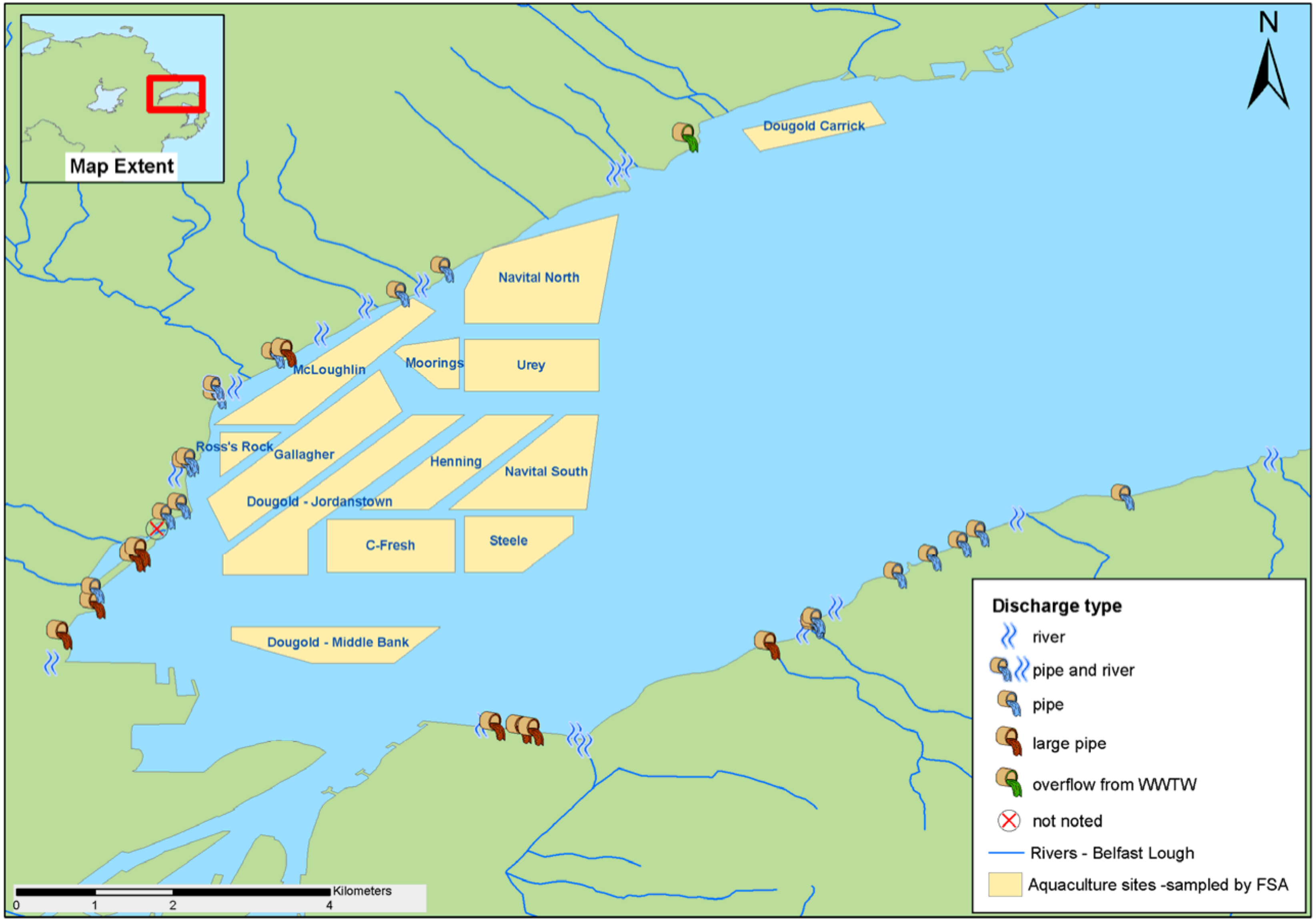


Figure 17: Observed discharges in to Belfast Lough

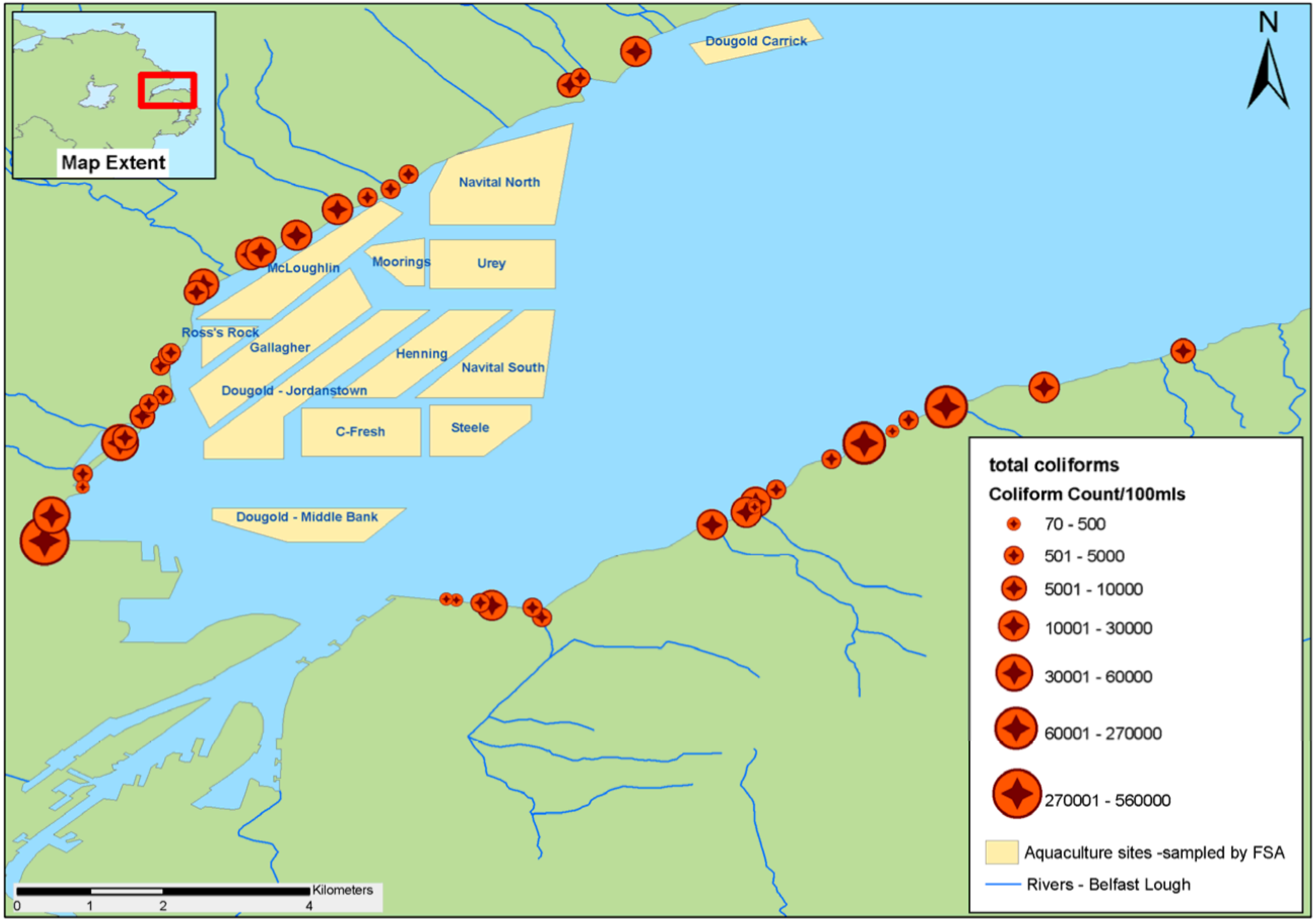


Figure 18 : Total Coliform counts from water sample analysis

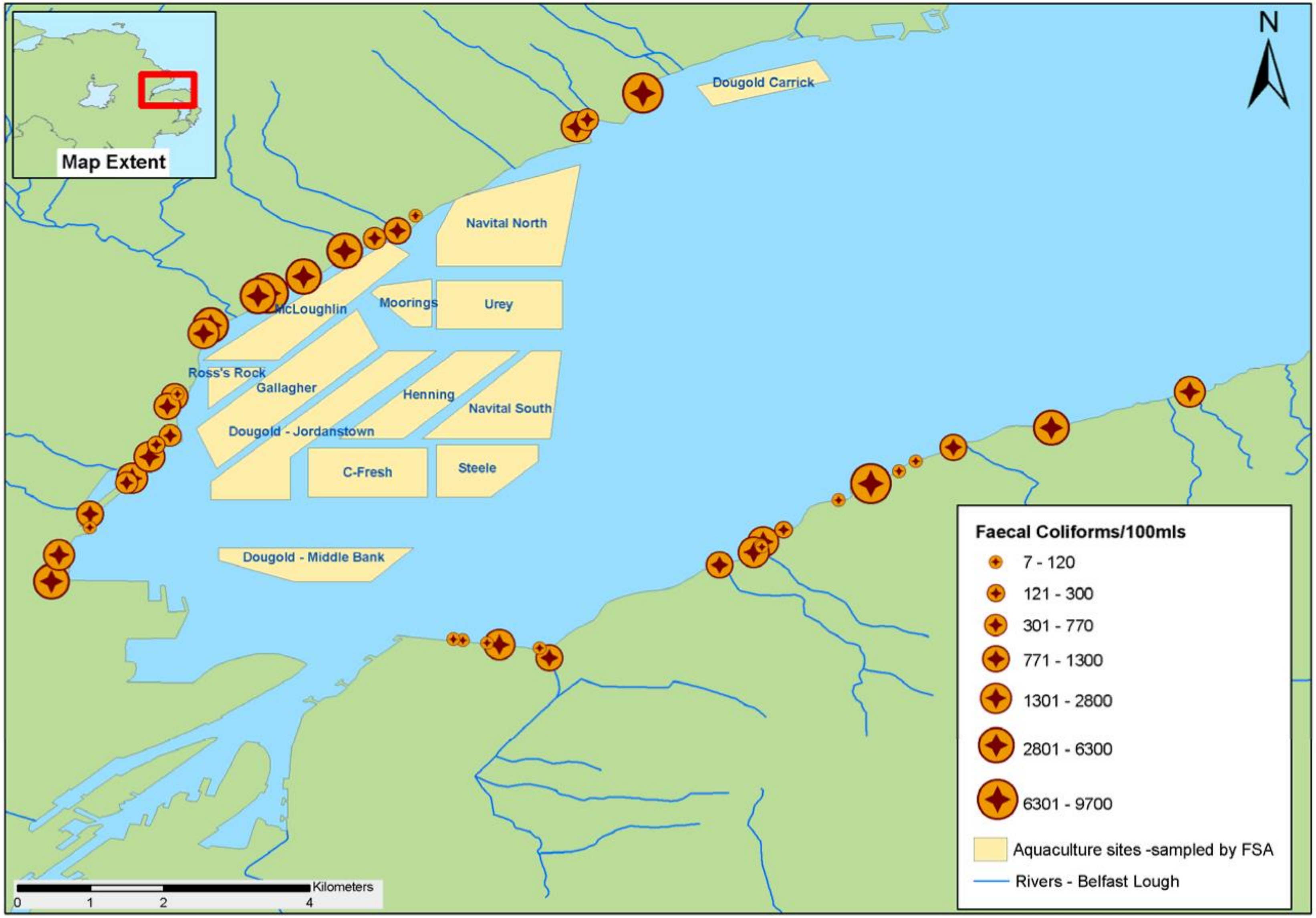


Figure 19: Faecal Coliform counts from water sample analysis

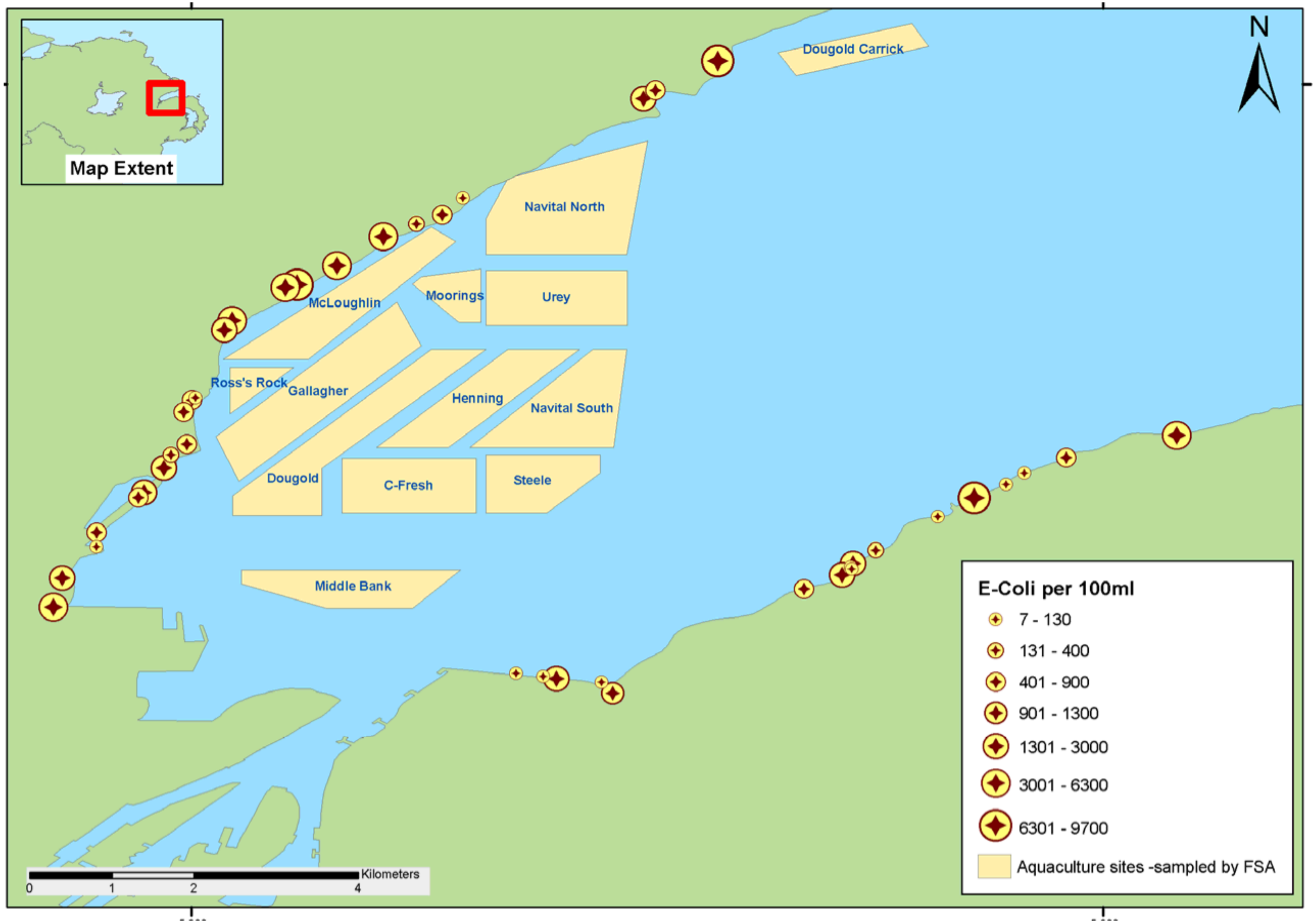


Figure 20 : Showing E-Coli equivalents at each site

All of the mussel samples returned positive results for coliforms but only one site returned a positive for faecal coliforms. (Table 4)

Table 4: Coliform and Faecal Coliform analysis on Mussel samples from Survey

Id	Site	Northing	Westing	Coliforms/g	E coli/g	cfu/100g	Faecal coliforms/g
1	Urey	54.6773	-5.8671	50	38.5	0.385	Not Detected
2	Carlingford Lough/ McLoughlin	54.6701	-5.8898	60	46.2	0.462	Not Detected
3	Whitehouse Roads/ Dougold	54.6490	-5.8876	200	154.0	1.540	1
4	Dougold	54.6545	-5.8937	70	53.9	0.539	Not Detected

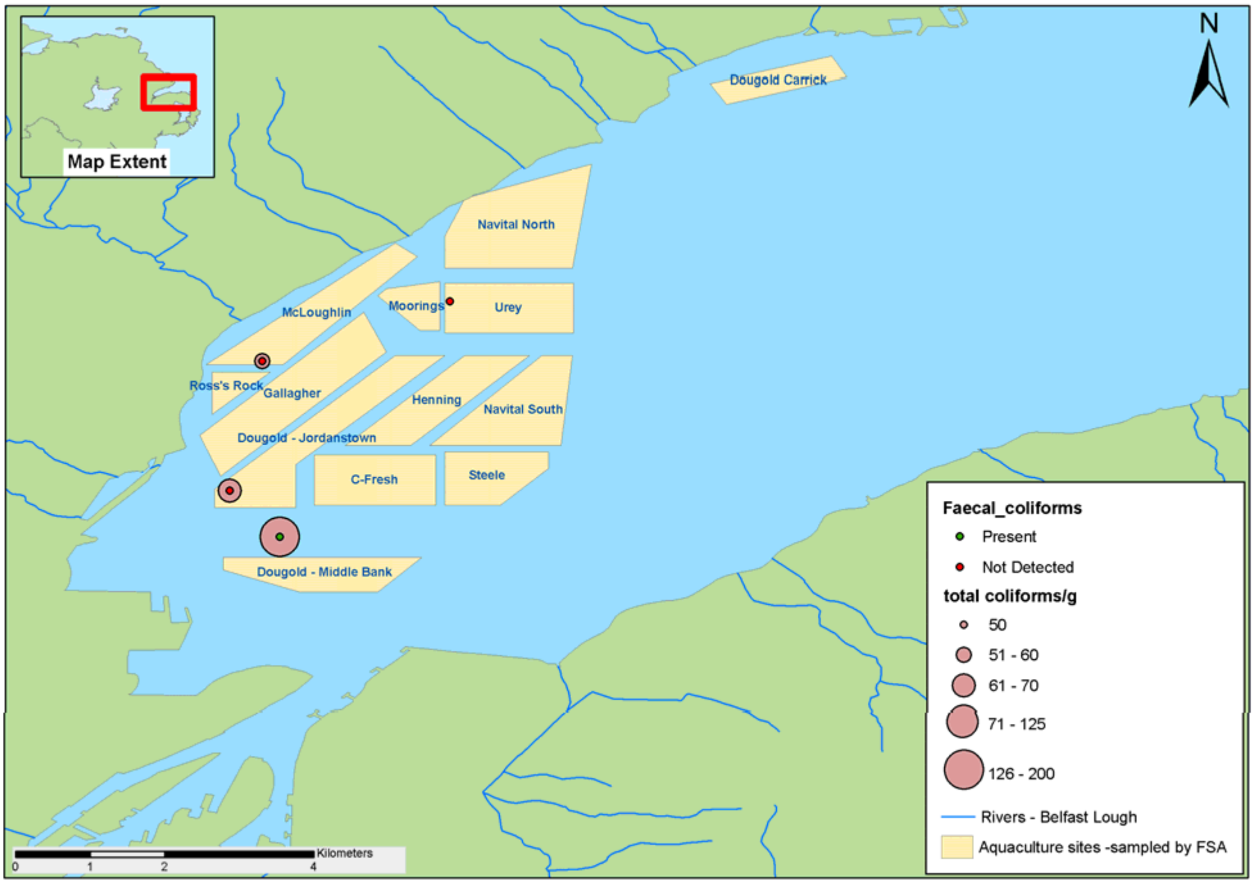


Figure 21: Concentrations of Coliforms in Mussels

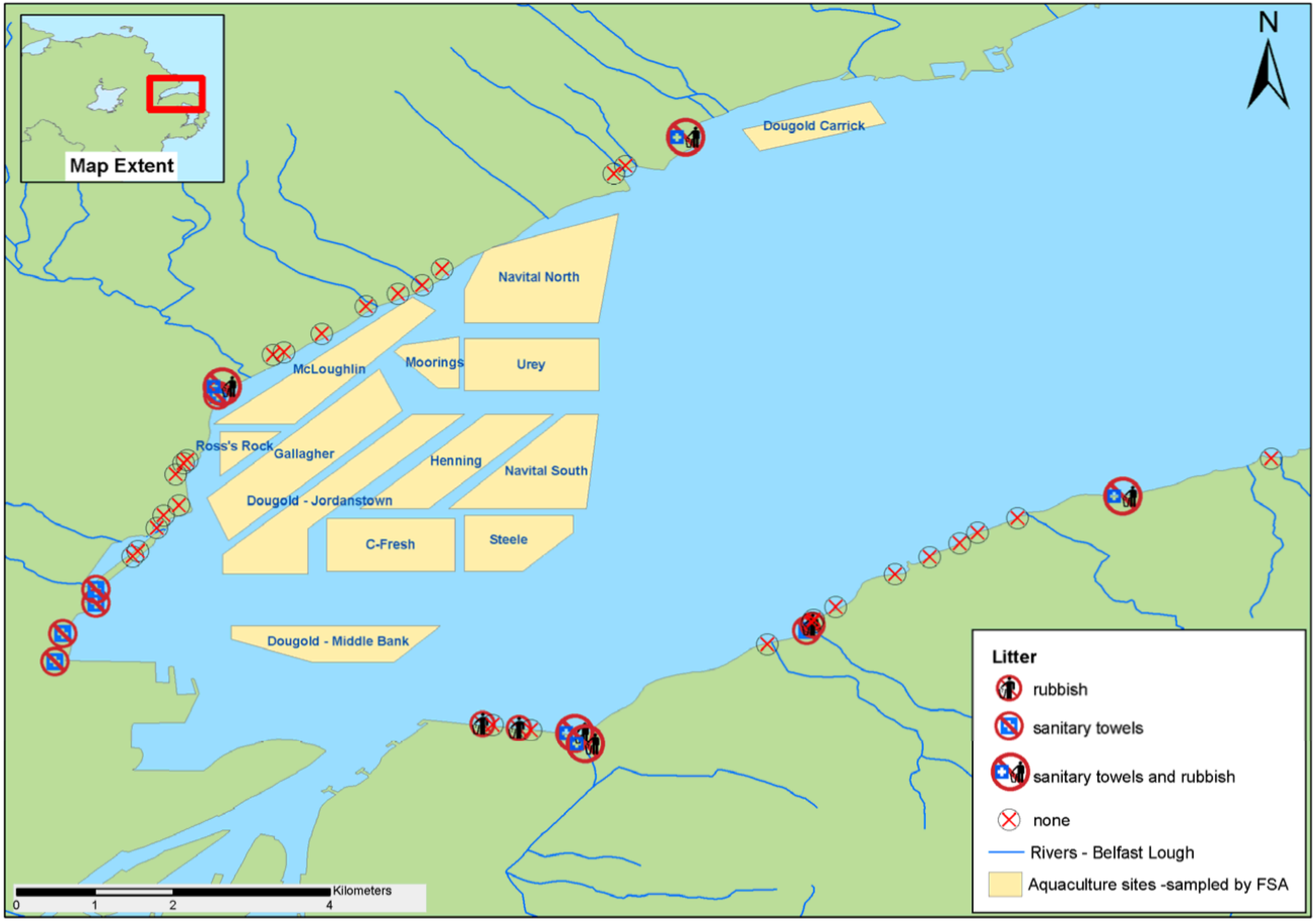


Figure 22: Litter (see also table one)

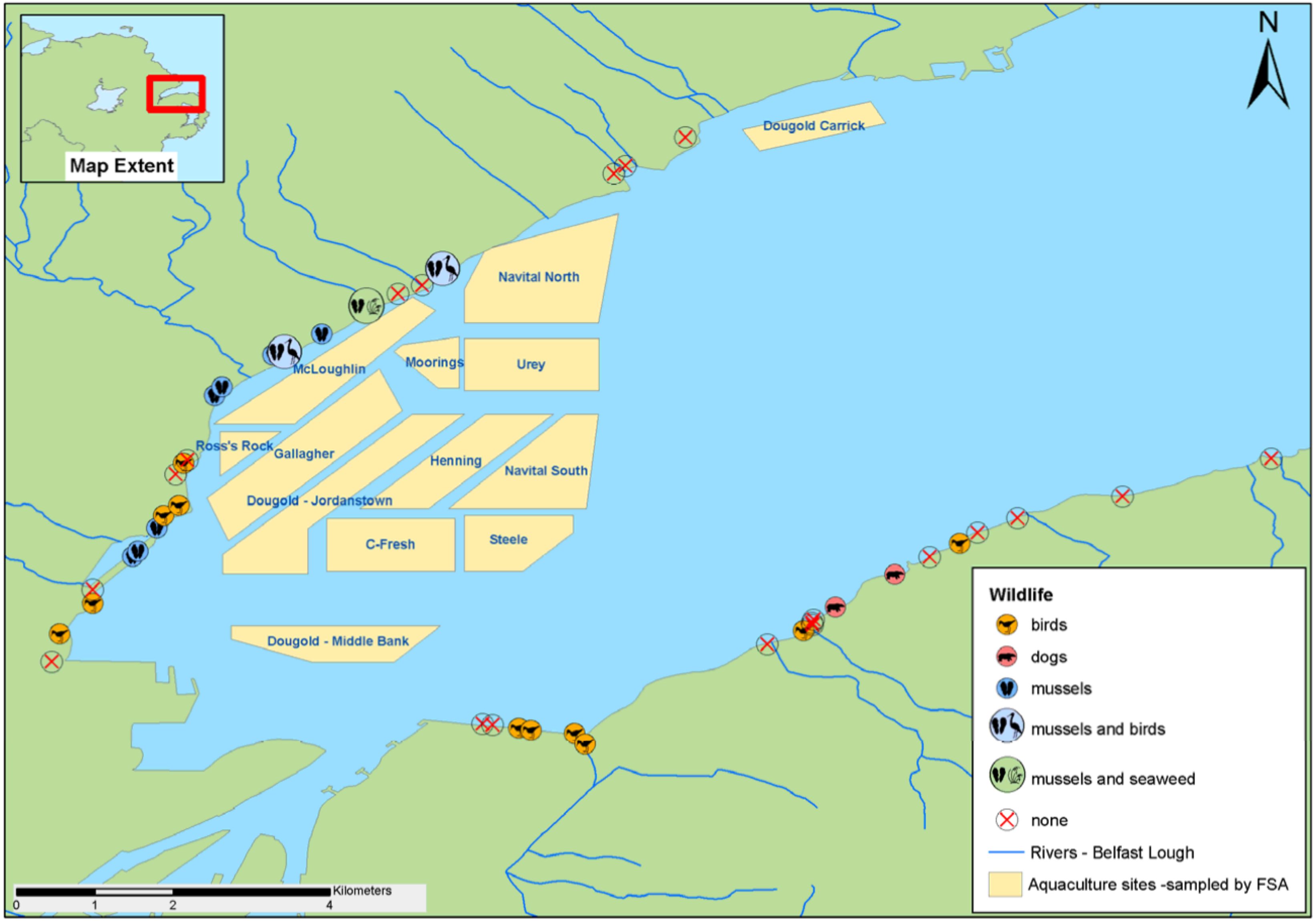


Figure 23: Wildlife (see also table one)

9. Discussion

A number of discharges to the Lough were observed which are not shown on available maps or charts. The policy of surveying immediately after wet weather meant that most discharges were in flow. Most showed levels of faecal contamination and were clearly contributing to shoreline litter. Despite this levels of faecal contamination in the shellfish beds are low. However, sewage derived litter was widespread and abundant (Figure 22) and it is evident that the current sewerage system is not coping well in wet weather. There is little evidence of widespread shoreline contamination from wild or domestic animals although significant bird aggregations may occur in the intertidal particularly on the South Western quarter of the lough. The potential for wet weather events to influence classification of beds must be considered. Rainfall is gauged at several points around the catchment (Figure 24). While seasonal patterns are evident (figures 25 and 26) a number of short term events can be also be detected which are a factor in interpreting any survey results. It should also be noted that while, as might be expected, winter months generally generate the highest rainfall, July and August frequently generate high rainfall as well.

Rainfall should be logged alongside sample data. Future work should include an analysis of the relationship between rainfall events and bacteria levels in shellfish in order to fully develop a risk assessment model.

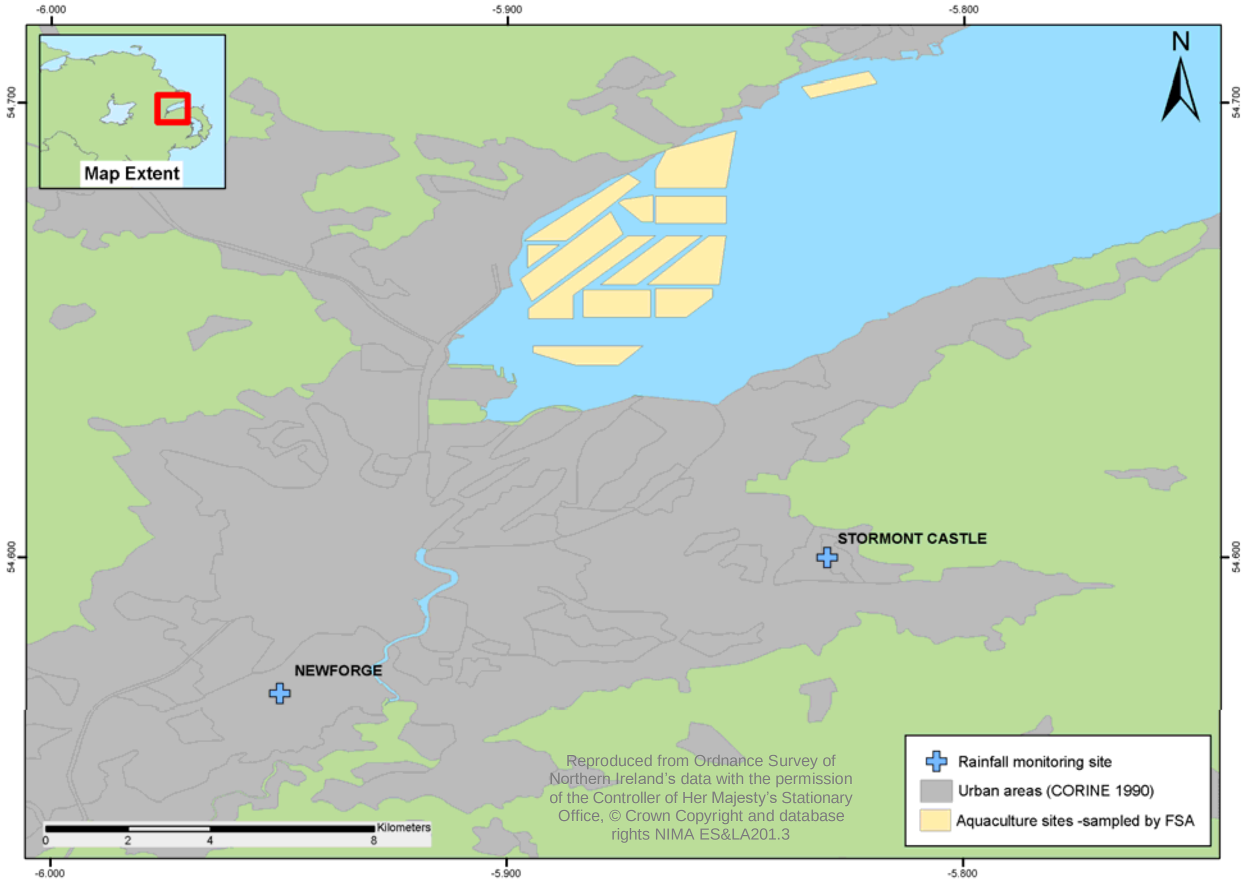


Figure 24: Rainfall gauges near Belfast Lough

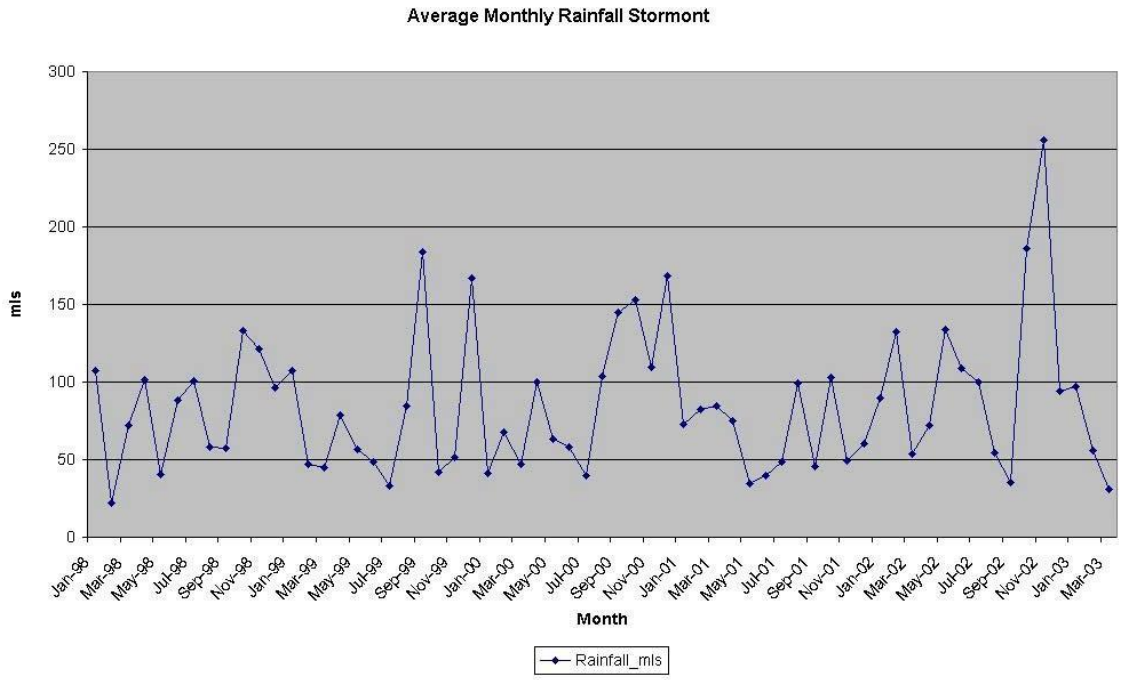


Figure 25: Monthly rainfall for Stormont weather station; five year trend

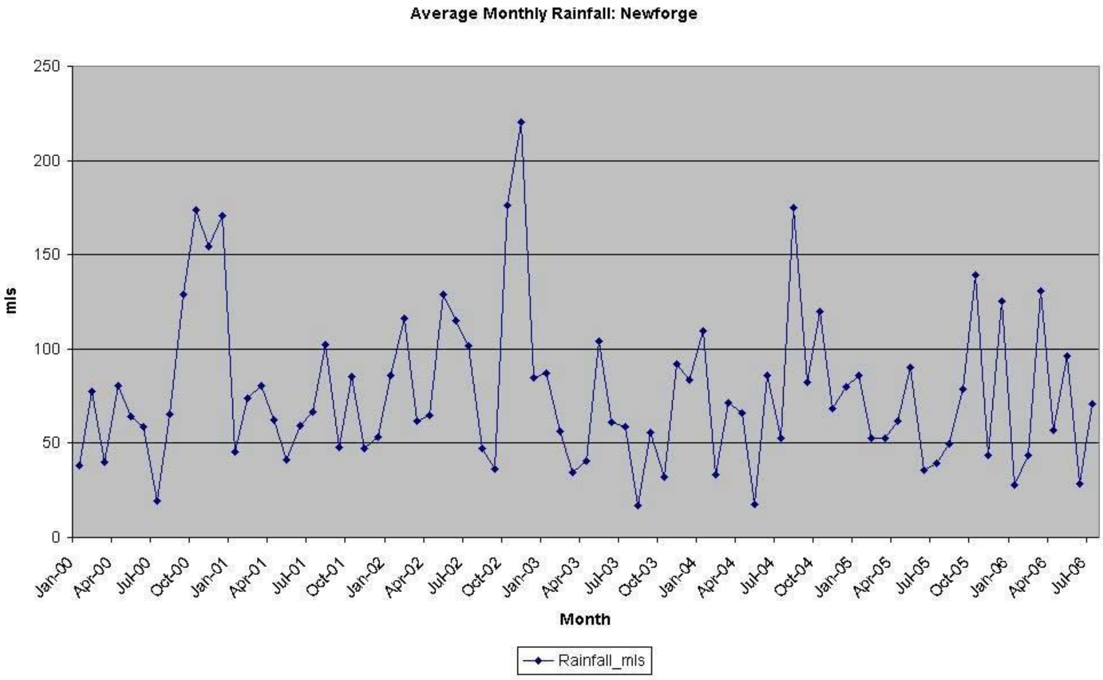


Figure 26: Monthly rainfall for Newforge weather station; five year trend

Modelling work discussed under section 3 proposed the use of distinct boxes to manage shellfish culture. These are shown again in Figure 27 numbered according to their model unit (bottom layer)

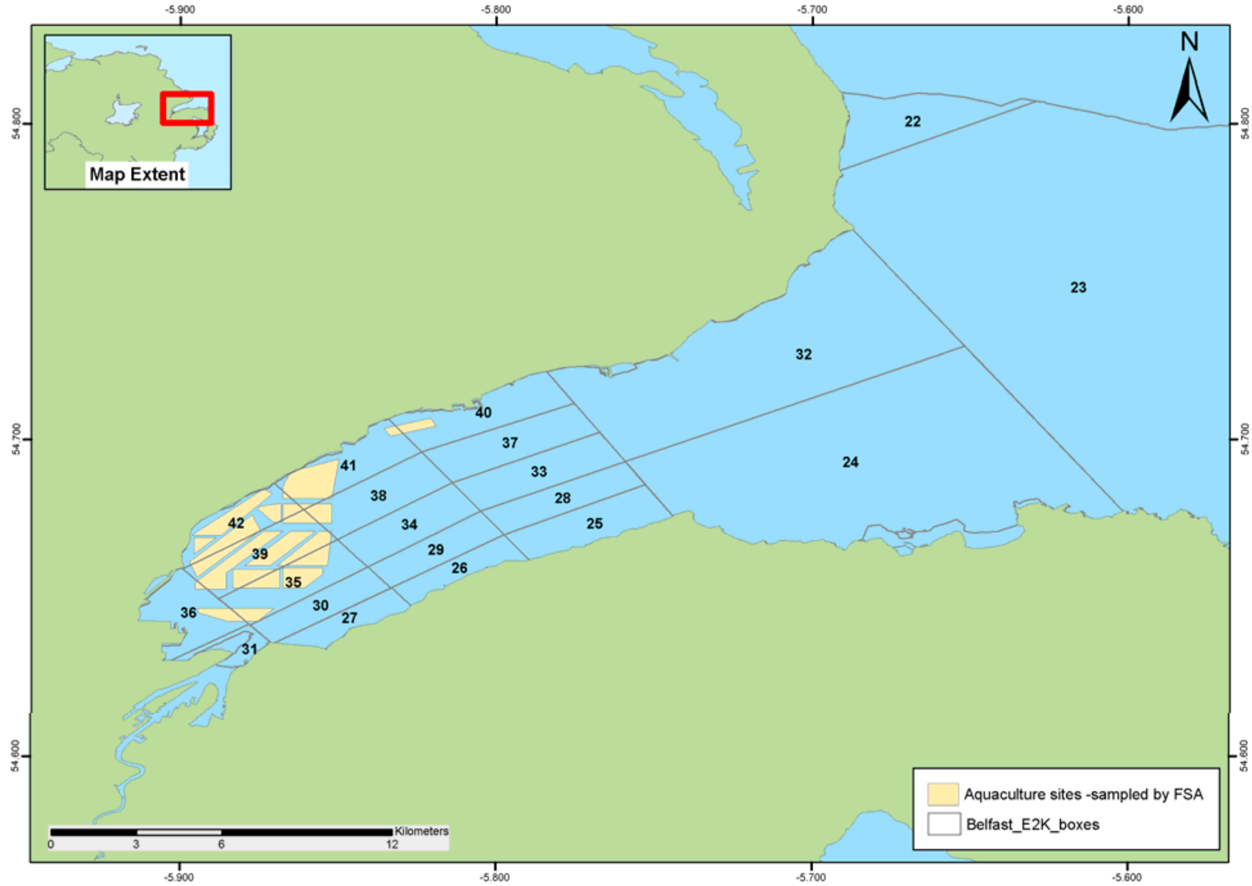


Figure 27 Model Boxes

As discussed above the model boxes are split into two layers at their mid depth to form a surface and bottom box. For the purposes of this study the bottom boxes were chosen as they will represent the conditions prevailing in the locality of the shellfish beds. Examination of residence times for the boxes using a simulated conservative tracer suggest that boxes 42, 39 and 35 have similar properties and samples taken from them will be representative of the inner lough, while boxes 38 and 40 and similarly representative of the outer beds.

10.Recommendation

Taking the above into account it is considered that microbiological sampling of shellfish flesh sampling can be rationalised to the following five sites. (Figure 28): Samples to be collected within 50m of the designated co-ordinates.

Station	Latitude(N)	Longitude(W)
Rosses Rock	54.6669	5.8934
Dougold Jordonstown	54.6625	5.8819
Dougold Middle Bank	54.6446	5.8809
Urey	54.6765	5.8593
Dougold Carrick	54.7038	5.8274

Sampling to be within a radius of 50m of point

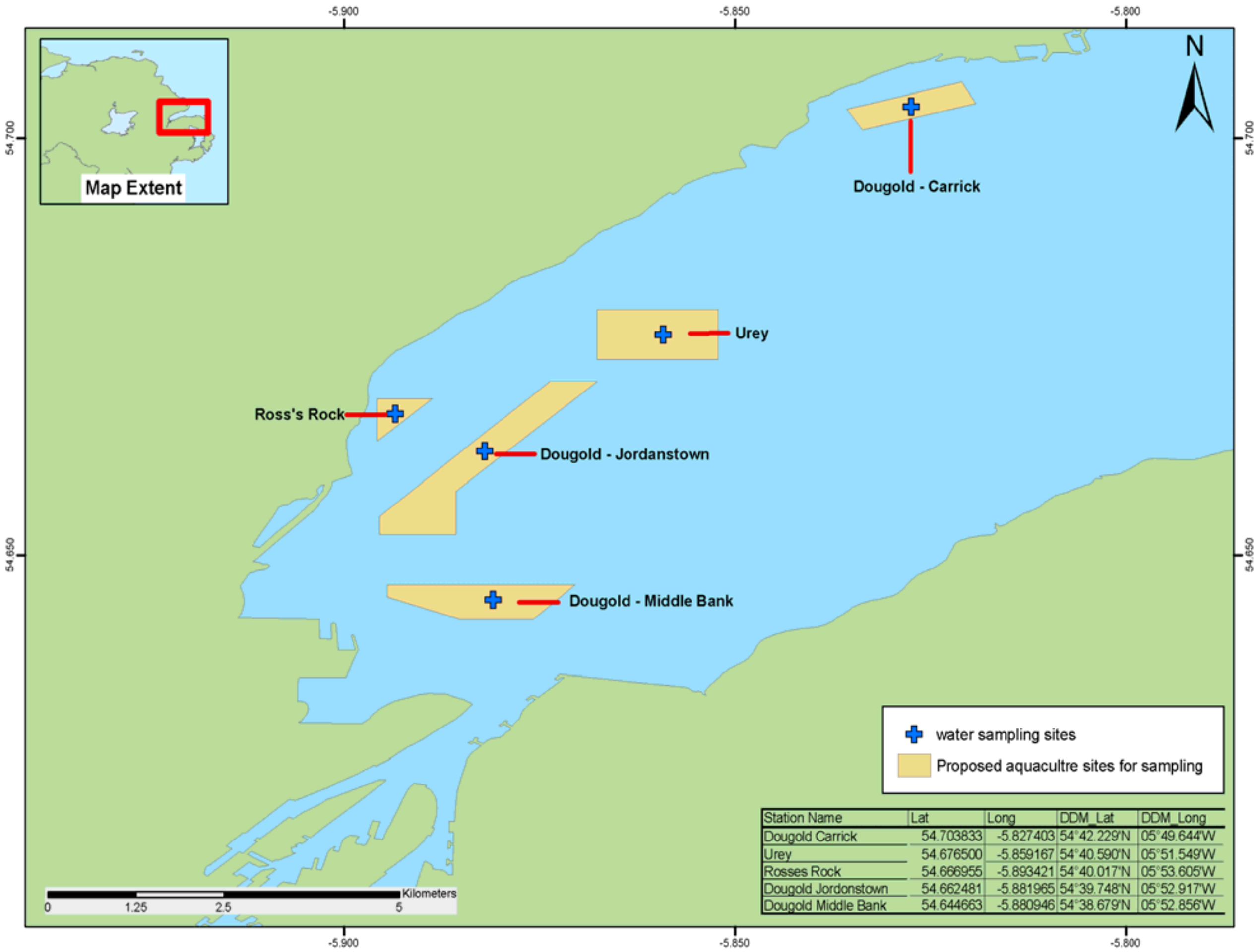


Figure 28: Proposed aquaculture sites for sampling (including midpoint positions of each bed)

The Rosses Rock site has been chosen due its proximity to a number of dischages and it is considerd that this station will be important in determining the linkages between rainfall and classification. The remaining four have been selected to provide adequate coverage and number of samples to provide further statistical assessment of the data.

Sampling frequency should be maintained at fortnightly subject to the outcome of further studies into the impact of high rainfall events. A lower sampling frequency would not allow the risk assessment to be developed. However, in the longer term if the relationship with rainfall, dicharge rate and classification is established a more targetted sampling regime may well be able to be implemented. By integration with other environmental monitoring programmes undertaken by AFBI it may be possible to determine linkages between inputs, climate and classificaion of the beds.

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Glossary

Area of Special Scientific Interest	
Bivalve mollusc	Any marine or freshwater mollusc of the class *Pelecypoda* (formerly *Bivalvia* or *Lamellibranchia*), having a laterally compressed body, a shell consisting of hinged valves, and gills for respiration. The group includes clams, cockles, oysters and mussels.
Classification of shellfish harvesting areas	A system for grading harvesting areas based on levels of bacterial indicator organisms (*E. coli*).
Chlorophyll 'a'	Chlorophyll's are the principle photsynthetic pigments in phytoplankton of which chlorophyll 'a' is the most common. Therefpre the concentration of chlorophyll'a' may be used as an indicator of phytoplankton biomass.
Coliform	Gram negative, facultative anaerobic rod-shaped bacteria which ferment lactose to produce acid and gas at 37ºC. Members of this group normally inhabit the intestine of warm-blooded animals but may also be found in the environment (e.g. on the plant material and soil).
Discharge	Flow of effluent into the environment.
***Escherichia coli* (*E. coli*)**	A species of bacterium that is a member of the faecal coliform group (see below). It is more specifically associated with the intestines of warm-blooded animals and birds than other members of the faecal coliform group. The enterohemorrhagic strain of this bacterium O157:H7 is the cause of infections in humans
Euhaline	A reference to waters containing between 30 and 40 parts per thousand of dissolved salts; that is, in most cases, normal sea water.
Eutrophication	The enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorous, causing an accelerated growth of algae and higher plant life to produce an undesirable disturbance to the balance of organisms in the water and to the quality of the water concerned (EEC, 1991a)
Faecal Coliform	Coliforms (see above) which can produce their characteristic reactions (e.g. production of acid from lactose) at 44 ºC as well as 37 ºC. Usually, but not exclusively, associated with the intestines of warm-blooded animals and birds.

Halocline	The sharp vertical gradient of salinity in stratefied waters.
Hydrodynamic models	In this context a numerical model that approximates the detail of real fluid flow i.e. velocities and water levels as functions of time and space. Output from these models can be used together with a representation of the diffusive process in the water column (Particle Transport Models) to represent the fate and dispersion of bacteria.
Mesohaline	Moderately brackish water with a salinity range of 5-18 ppt.
Mesotidal	Coastal ocean or waterway with a moderate mean tidal range, eg, between 2 and 4 metres.
Salinity	A measure of salt in seawater measured in practical salinity units (p.s.u) which is a dimensionless number.
Sampling plan	A formal record of the intended sampling to be undertaken in a harvesting area with respect to species(s), position of sampling point(s) and frequency of sampling. The components of the sampling plan are identified following the sanitary survey.
Sanitary Survey	An evaluation of the sources of faecal contamination in or near a harvesting area together with an assessment of the potential impact of these source on the microbial status of the harvesting area.
Sewage	Sewage can be defined as liquid, of whatever quality that is or has been in a sewer. It consists of waterborne waste from domestic, trade and industrial sources together with rainfall from subsoil and surface water.
Sewage Treatment Works (STW)	Facility for treating the wastewater from predominantly domestic and trade premises.
Shoreline survey	A physical survey of the shoreline and area adjacent to the shore to confirm the presence of potentially contaminating sources identified through a desk-based study and to identify additional potential sources of contamination.
Stratified	Water bodies that have a sharp vertical interface, above and below which is water of different physical and/or chemical properties.
Waste Water	Any waste water – also see sewage.

List of Abbreviations

AFBI	Agri Food Biosciences Institute
ASP	Amnesic Shellfish Poison
ASSI	Area of Special Scientific Interest
BHC	Belfast Harbour Commissioners
Cfu	Colony forming units
DSP	Diarrhetic Shellfish Poison
E. coli	*Escherichia coli*
FSANI	Food Standards Agency NI
GPS	Global Positioning Systems
GIS	Geographical Information System
km	Kilometres
m	Metres
ml	Mililitres
PAH	Polycyclic Aromatic Hydrocarbons
PE	Population Equivalents
PSP	Paralytic Shellfish Poison
psu	Practical salinity units
RMPs	Representative Monitoring Points
TW2	Transitional Water Bodies Group 2
TW6	Transitional Water Bodies Group 6
UKAS	United Kingdom Accreditation Service
WFD	Water Framework Directive
WWTW	Waste water treatment works

APPENDICES

Appendix A

Classification history for shellfish beds in Belfast Lough

Bed Name	Species	2002/ 2003	2003/ 2004	2004/ 2005	2005/ 2006	2006/ 2007	2007/ 2008
C Fresh	Mussels	NC	B prov	B prov	B	B	B
Dougold	Mussels	B	B	B prov	B	B	B
Dougold Carrick	Musels	NC	B prov	B	B	B	B
Gallagher	Mussels	B	B	B prov	B	B	B
Henning	Mussels	NC	B prov	B prov	B	B	B
McLoughlin	Mussels	NC	NC	B prov	B prov	B	B
Middle Bank	Cockles	NC	NC	B prov	B prov	B prov	B
The Moorings	Mussels	NC	B prov	B prov	B	B	B
Ross' Rock	Mussels	NC	NC	B prov	B prov	B	B
Steele	Mussels	NC	B prov	B prov	B prov	B	B
Urey	Mussels	NC	B prov	B	B	B	B
Navital North	Mussels	NC	NC	NC	NC	NC	B prov
Navital South	Mussels	NC	NC	NC	NC	NC	B prov

prov – Provisional
NC - Not classified

Appendix B

Sampling Plan

Number and Location of RMPs and Frequency of Sampling

Map ref	Bed name	Location		Species	Harvesting method	Sampling frequency
		Latitude	**Longtitude**			
1	Dougold Middlebank	54.6446	-5.8809	Cockles	Suction Dredging	Fortnightly
2	Dougold	54.6625	-5.8819	Mussels	Dredging	Fortnightly
3	Ross's Rock	54.6669	-5.8934	Mussels	Dredging	Fortnightly
4	Urey	54.6765	-5.8593	Mussels	Dredging	Fortnightly
5	Dougold Carrick	54.7038	-5.8274	Mussels	Dredging	Fortnightly

Note

Tolerance around sampling point 5m