SALMON MORTALITIES AT INVER BAY AND MCSWYNE'S BAY FINFISH FARMS, COUNTY DONEGAL, IRELAND, DURING 2003

February 2004

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CHAPTER 1. INTRODUCTION

1.1 Summary

This report details the investigations into a major mortality of farmed salmon at Inver Bay and McSwyne's Bay, Co. Donegal in July 2003. Previous reports were provided on 29th July 2003 and on 11th August 2003.

The information is based upon analysis and research by MI scientists, a review of environmental data, survey reports by external consultants, inputs from veterinary practitioners who visited the site, reports from DCMNR staff in Killybegs, and site visits made by DCMNR / MI inspectors.

Following a review meeting of the principal investigators on the 9th October, 2003, MI proceeded to carry out further scientific investigations. DCMNR also commissioned Kirk McClure Morton Consulting Engineers (KMM) to carry out a parallel investigation of the mortalities at Inver Bay and McSwynes Bay salmon farms. MI provided support as required to the KMM study, the report for which was furnished to DCMNR and MI on 11 February 2004. (KMM, 2004)

MI wishes to acknowledge the high level of co-operation and assistance that it received from the owners and staff of Creevin Fish Farm Ltd, Eany Fish Products Ltd and Ocean Farms Ltd. It also wishes to acknowledge the assistance of veterinary practitioners, DCMNR staff and others in the course of this investigation.

1.2 Background

Salmon farming has been carried out in this area of south Donegal for over twenty years. There are currently three companies licensed to farm salmon in the area - Ocean Farm, Creevin Salmon Farm and Eany Fish Products (see Figure 1.1. for locations and numbers of licensed sites). Approximately 13% of the total Irish production of farmed salmon is produced in this area. In Inver Bay, each company owns two sites, a smolt-rearing site and a grower-rearing site. One company (Eany Fish Products) also produces sea-reared rainbow trout. Only one company, Ocean Farm, operates in McSwynes Bay. This company is licensed to operate both a smolt site and a grower site at this location.

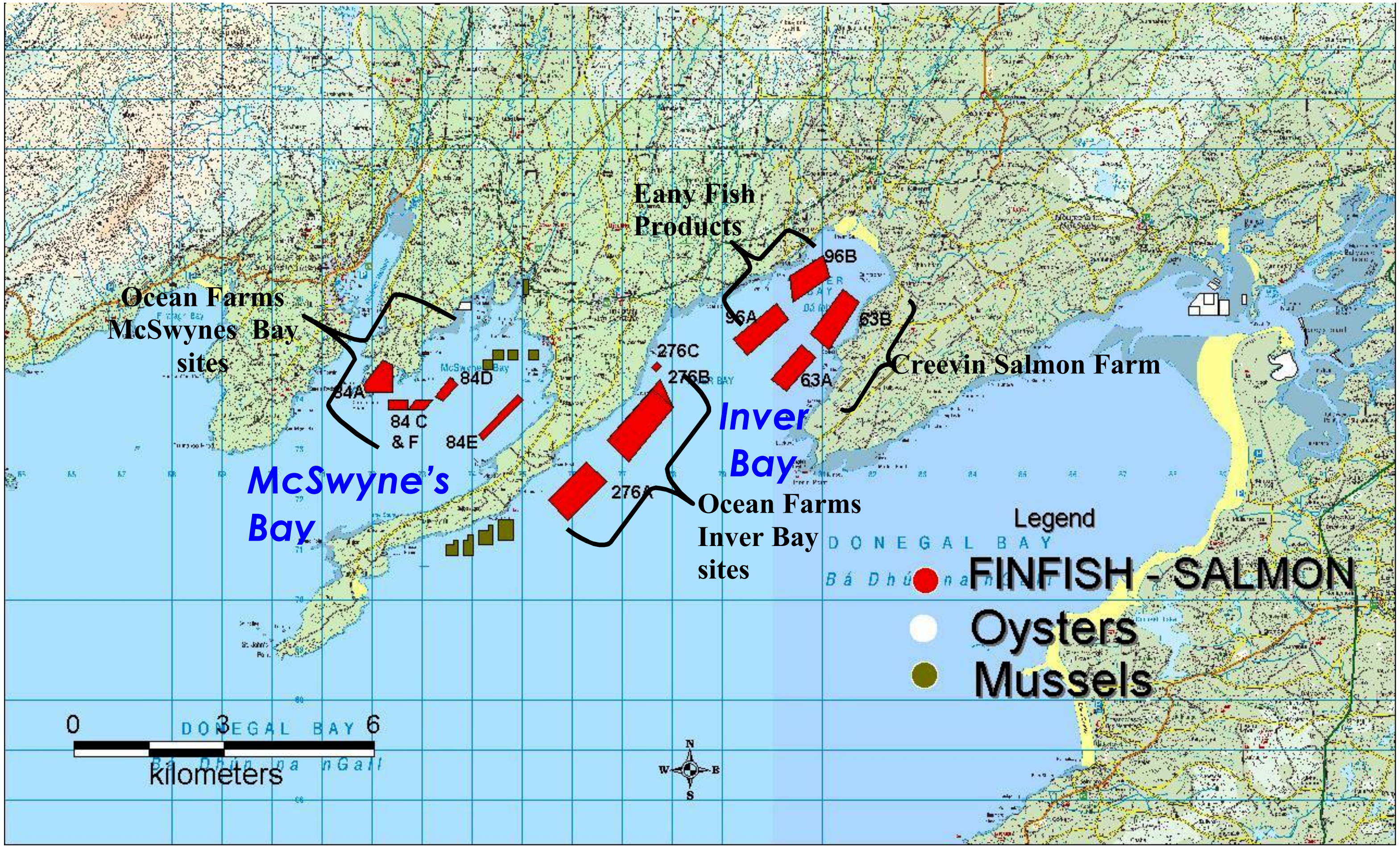


Figure 1.1 Locations of licensed aquaculture sites in Inver Bay and McSwynes Bay, Co. Donegal. (Copyright Ordnance Survey Ireland.)

1.3 Summary mortalities by farm

A rise in mortality rates was reported to MI in early July 2003. The rate of mortality increased dramatically during the month of July, and continued on into August and September. Approximately 1,000,000 fish had died by September and all three companies had placed Inver staff on protective notice.

1.3.1 Ocean Farm

Prior to this episode, Ocean Farm had a standing stock in Inver Bay of 483,019 smolts, of which 453,019 (94%) were lost. Also in Inver Bay Ocean Farm had a standing stock of 323,172 growers, of which 236,011 (73%) were lost between June and 4th November 2003.

Prior to this episode, Ocean Farm had a standing stock of 665,545 smolts in McSwynes Bay, of which 149,890 (23%) were lost and 479,982 growers, of which 115,195 (24%) were lost. (These figures were provided to the Marine Institute by Ocean Farm on 5th November, 2003.)

1.3.2 Creevin Salmon Farm

In March of 2003, Creevin Salmon Farm introduced 233,000 smolts. As of September 11th, 218,000 (94%) of these fish were lost.

There were approximately 180,000 growers on site at 1st January, 2003. Harvesting commenced on the 24th March, 2003 and a total of 116,960 fish were harvested. Approximately 15,000 growers remained on site on 11th September, equating to mortality of 76% of the grower fish since the event began. (These figures were provided to the Marine Institute / DCMNR during a site visit on 11th September 2003.)

1.3.3 Eany Fish Products

Smolts were introduced to this site at various stages during February, March and April 2003. In total, 262,000 smolts were stocked. As of 11th September, 232,000 (86%) had died.

Although 138,000 growers and 15,000 2001 S0s were on site on 1st January , harvesting commenced on 13th January 2003, and there were only 31,000 growers on-site when the mortality problems commenced. Of these 22,000 (71%) died. There were 60,000 rainbow trout also on site when the problem occurred. These fish remain unaffected.

Table 1.1 Standing stock prior to mortality event, and losses incurred at each fish farm.

	Standing stock prior to mortality event	*% loss incurred*	*Standing stock prior to mortality event*	*% loss incurred*
Farm	***Smolts***		***Growers***	
Ocean Farm - Inver	483,019	94%$	323,172$	73%$
Ocean Farm McSwynes	665,545	23%$	479,982$	24%$
Eany Fish Products	262,000	86%*	31,000	71%*
Creevin Fish Farm	233,000	94%*	180,000	76%*

* *% loss incurred as of 11/09/2003*

$ *% loss incurred as of 04/11/2003*

1.4 Pattern of mortality development

MI investigated the pattern of development of the mortalities in the Donegal Bay sites by means of a series of site visits by technical personnel. In September 2003, formal interviews with the owners of the farms were also conducted by DCMNR and MI staff. Based on interpretation of farm data supplied, the progression of this incident can be outlined as follows.

1.4.1 Eany Fish Products

- A sharp decrease in appetite was observed on 7/8th July 2003
- Mortality started on 11th July (Week 28), with a peak of 35,000 fish dying on 15th July (Week 29)

1.4.2 Creevin Fish Farm

- A sharp decrease in appetite was observed during the week commencing July 7th (Week 28)
- Mortality commenced on 14th July (Week 29), with a peak on 21st July (Week 30)

1.4.3 Ocean Farm – Inver (see Figure 1.2)

- Fish started to go off their feed on 25th June.
- Mortality started in Week 26 in the growers and peaked in Week 29 (14th July). Mortalities in Weeks 26 & 27 were of the order of 5,000 fish in each week, increasing to approximately 23,000 fish on Week 28.
- Mortality started on (Week 27) 30th June in the smolts and peaked in Week 34 (week commencing 18th August)

1.4.4 Ocean Farm – McSwynes

- Mortality started on 30th June (Week 27) in the smolts and peaked in Week 36 (week commencing 1st September) (Figure 1.2)
- Mortality started on 30th June (Week 27) in the growers and peaked in Week 32 (week commencing 4th August) (Figure 1.2)

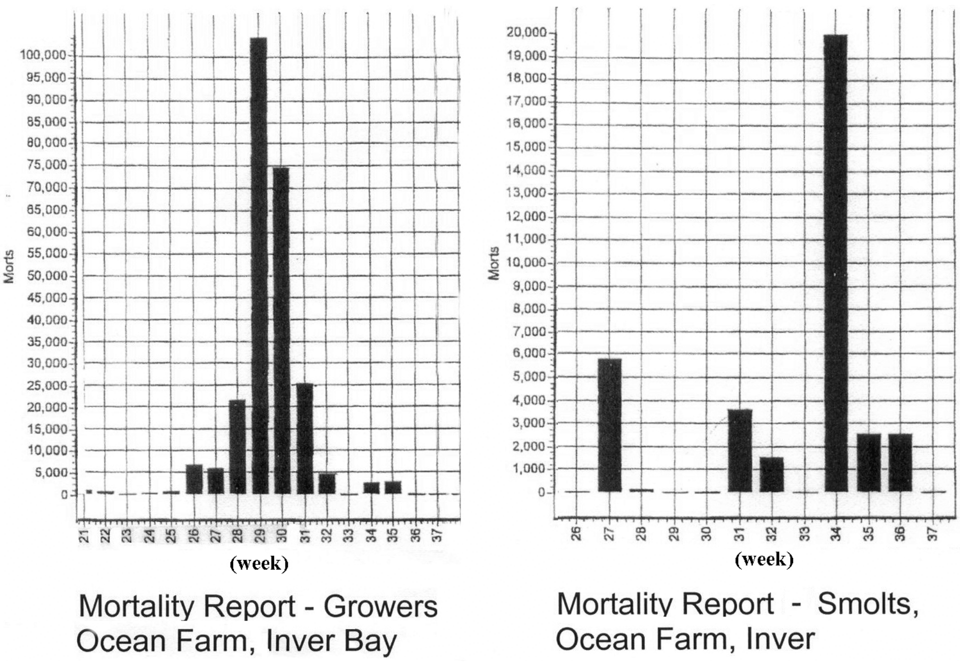


Figure 1.2 Record of mortalities at Ocean Farm Inver Bay sites (supplied by Ocean Farm).

In Inver Bay, the peak of mortality appears to have occurred during weeks 29 / 30 (14th –21st July). The exception to this was the Ocean Farm smolts which peaked in week 34 (week commencing 18th August).

In McSwynes Bay, mortalities started at approximately the same time as Inver Bay i.e. 30th June (week 27), but the peak of mortality was reached later. This pattern was also observed with the Ocean Farm's smolt site in Inver Bay.

The mortality pattern on each affected site was described as typical of a toxic or pollution incident, where the mortality curve was exponential in nature and where 50% accumulated mortalities were reached over a very short period of time (McLoughlin, *pers. comm.*).

1.5 Phases of Initial MI investigation

09 Jul 2003	Increase in morts reported by Ocean Farm to MI
10 July 2003	Written report received by MI from Ocean Farm, re: "fish going off their feed since 25th June" at Ocean Farm. Reports of inappetence also from Creevin and Eany.
15 July 2003	MI meeting to discuss reports from Inver Bay and to arrange for site visits by technical staff. Liaison with DCMNR and producers.
16 July 2003	Survey in Inver Bay by MI staff. Vertical profiling carried out for DO and temperature. Samples collected for plankton, water chemistry and fish health. Visual inspection of the seabed carried out at two sites (see Chapters 3, 4, 5 & 6). Visit by Veterinary Practitioner to Inver Bay farms showed fish to be suffering from severe gill damage (See Fig 1.3 below)

Figure 1.3 Gill tissue of moribund salmon from Inver showing loss of gill epithelial tissue and exposure of branchial cartilage (Photograph Copyright H. Rodger).

Following analysis of fish samples taken on 16th July, at all three farm sites in Inver Bay, the involvement of a bacterial or viral fish pathogen in the mortality observed was ruled out by MI and relevant veterinary practitioners (See Chapter 3 for details of work carried out by Fish Health Unit, and appendix 1 for details of analysis).

Meetings were held between MI, DCMNR and the relevant producers in Donegal (on 29th July and 6th August, in addition to MI meetings with officials at DCMNR, Dublin on 25th July and 16th August) at which the fish health results were presented. A number of other possible explanations for the mortality event were explored. Based on these discussions and on the conclusions of the initial fish health study, MI investigation was broadened to include the following hypotheses for the mortality event.

1.6 Alternative scenarios

Having excluded disease as a cause of the mortality, MI went on to consider various possibilities as potential causes of the event, including the following:

- Primary fish pathogen
- Farm practices
- A spill or discharge of a toxic chemical.
- Potential contamination associated with sediments from Killybegs dredge spoil dumpsite.
- Sediment disturbance from fishing activity in Inver Bay resulting in the release of toxic gas(es) from the benthic environment.
- Other physico-chemical water quality factors
- Misuse or accident with chemical (veterinary) treatment
- Biotoxin associated with a Harmful Algal Bloom (HAB)
- Jellyfish or siphonophore event

CHAPTER 2. ENVIRONMENTAL CONDITIONS AT INVER BAY AND McSWYNES BAY

2.1 Summary

The purpose of this Chapter is to provide a summary of the environmental conditions and oceanography within Donegal bay. It is based on the results of work carried out as part of this study, prior research work carried out by the Marine Institute and from other published sources. It provides an environmental context for the mortality events in summer 2003.

2.2 Currents

The circulation pattern for Donegal Bay was reviewed due to its importance in understanding the interactions between the marine environment and salmon farming operations. In particular, a review of currents is essential in considering the various scenarios that were proposed by local interests to explain the mortality events in summer 2003.

Two current meters were deployed in Inver Bay, covering a neap – spring tidal cycle, during the period 21st August – 4th September 2003. Measurements of current speed and direction were made at 20-minute intervals throughout the deployment period. The locations of the deployments are shown in the following figure 2.1.

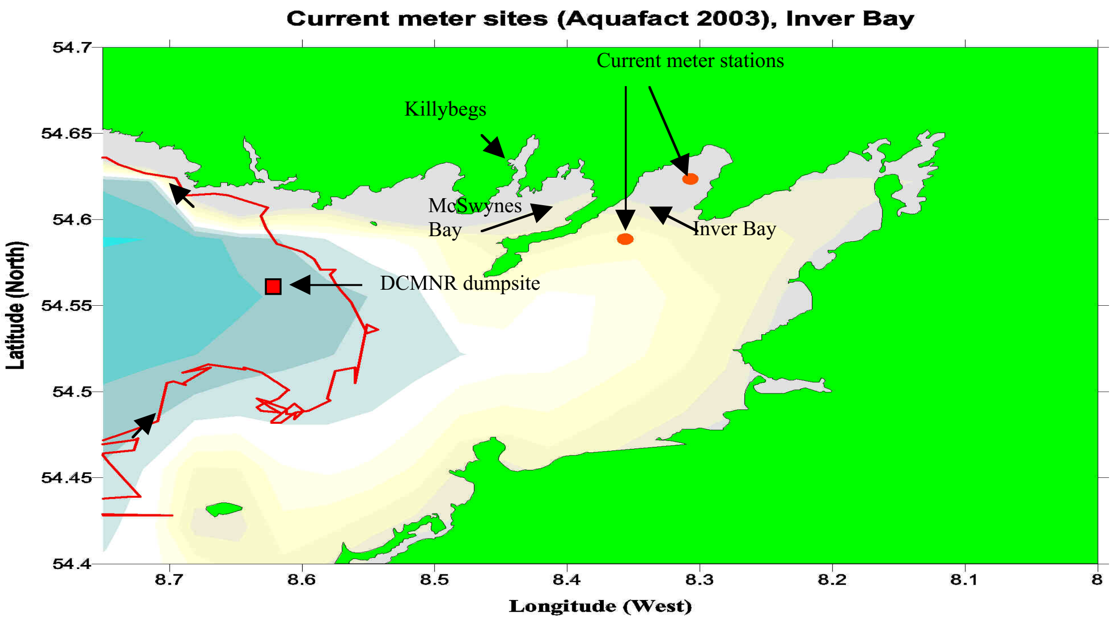


Figure 2.1. Location of current meters deployed in Inver Bay in August 2003. (The red line shows the path of the satellite drifter referred to in Section 2.1.2; arrows show the current flow in a counter clockwise direction.)

2.1.1 Inner site – Inver Bay

At the inner Inver Bay site the measured currents were at the lower end of the range for salmon farming sites in Irish waters, with a mean current speed for the period of deployment of 3.9 cm s^{-1}. Ninety five percent of the current speeds were recorded at < 10 cm s^{-1} (Figure 2.2).

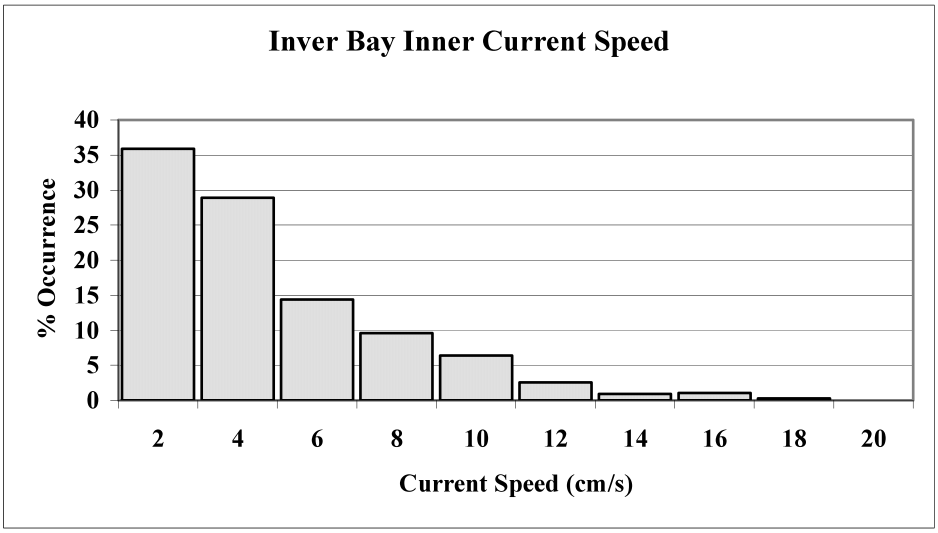


Figure 2.2. Current speed measured at the inner site in Inver Bay 21st August to 4th September 2003

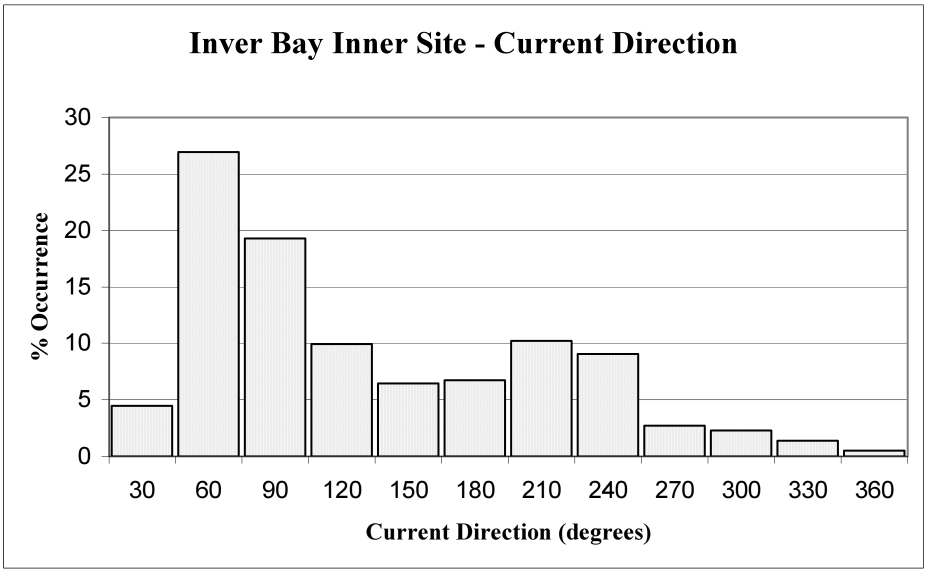


Figure 2.3 Current direction measured at the inner site in Inver Bay Bay 21st August to 4th September 2003

Figure 2.3 shows that for the duration of the deployment the current directions were variable with a major mode between 30^o and 90^o and a minor mode between 180^o and 240$^{o.}$ This indicates that the flow of the current is generally along the main axis of the bay, in a northeast – south-westerly direction.

A progressive vector plot of currents for the inner site is shown in Figure 2.4 below. The 24-hour residual flows were in the range 1 –2 km day^{-1}, which is equivalent to a residual flow of only 1 - 2 cm s^{-1}.

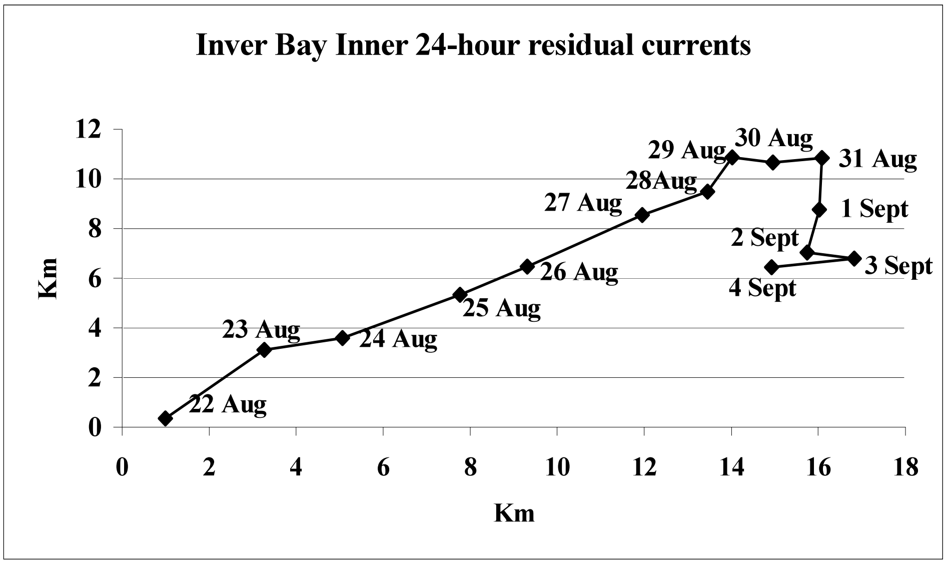


Figure 2.4 Progressive vector plot showing the 24-hour residual flows measured at the inner site in Inver Bay during the period 22nd August – 4th September 2003.

2.1.2 Outer Site – Inver Bay

At the outer site, measured current speeds were also weak, with an average speed of 6.4 cm s^{-1} and 90% < 12 cm s^{-1} during the period of the deployment (Figure 2.5)

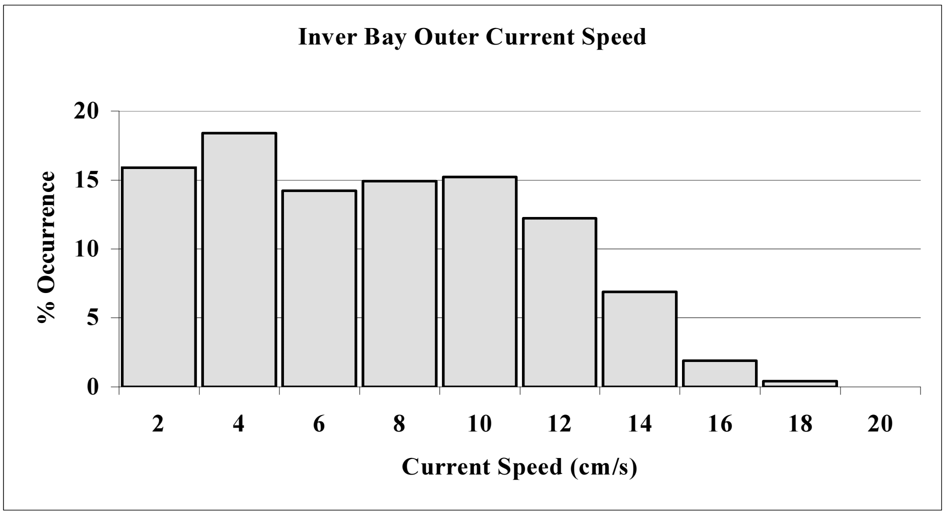


Figure 2.5 Current speeds measured at the outer site in Inver Bay 21 August – 4 September 2003

The current direction measured (Figure 2.6) was bimodal with modes between 30° and 90° and 240° – 300° reflecting the current direction on the ebbing and flooding tides flowing along the main axis of the bay.

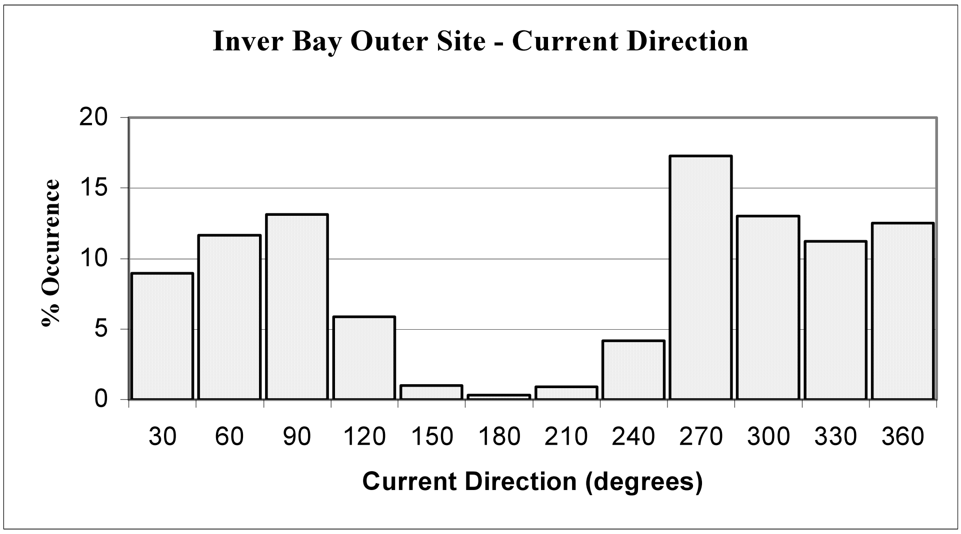


Figure 2.6 Current direction measured at the outer site in Inver Bay 21st August – 4th September 2003

A progressive vector plot of currents for the outer site is shown in Figure 2.7 below. The 24-hour residual flows were weak, typically in the range 1 –2 km day^{-1}, which is equivalent to a residual flow of only 1 - 2 cm s^{-1}, similar to the flows recorded at the inner site.

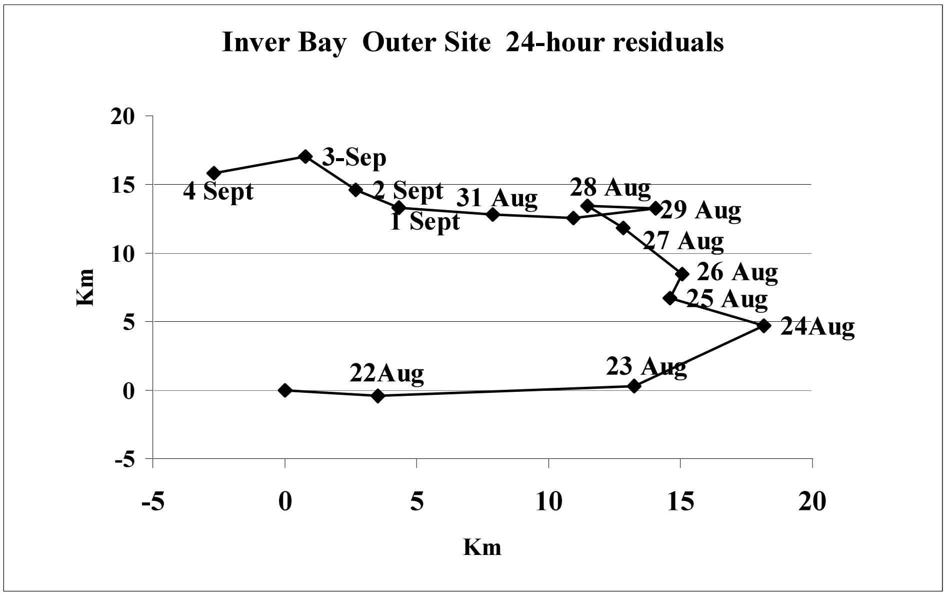


Figure 2.7 Progressive vector plot showing the 24-hour residual flows measured at the outer site in Inver Bay during the period 22nd August – 4th September 2003.

The data recorded from the two current meters deployed in Inver Bay show that currents in the bay are weak. These measurements agree with previous measurements made in the area. In a review of benthic conditions and oceanography at Irish salmon farms it is stated "weak current speeds also occur in semi-enclosed bays such as McSwynes Bay and Inver Bay, where tidal flushing is weak" (<10 cm s^{-1}) (AquaFact, 2002). The weak residual flows recorded are supported by those predicted by the hydrodynamic model run by Kirk McClure Morton Consultants Engineers in 2003 (KMM, 2004).

2.2.1 Historical data on currents in Inver Bay

A report was prepared for the Ocean Farm site in Inver Bay by Kirk Mc Clure Morton consultants. A two-dimensional depth integrated model (finite difference grid) was used to compute tidal velocities, water elevation (or tidal elevation) and discharges (between each model element). The horizontal model grid was 90 metres in Inver Bay. Average tidal currents at spring tide at the site were computed at 8 to 9 cm s^{-1} (relatively weak), with flow in the direction of the main axis of the bay. The model was validated with measurements of currents and water elevation in the model domain.

2.2.2 Observed shelf current flow patterns west of Ireland

In 2001, several satellite-tracked drifters were deployed on the shelf west of Ireland by NUIG. One particular drifter provides an insight into circulation patterns in Donegal Bay. Drifter 21576 was deployed on 28th July 2001 and was tracked continuously until August 17th when it reached landfall to the north of Rathlin O'Beirne Island. The track of the drifter is shown in Figure 2.8 below.

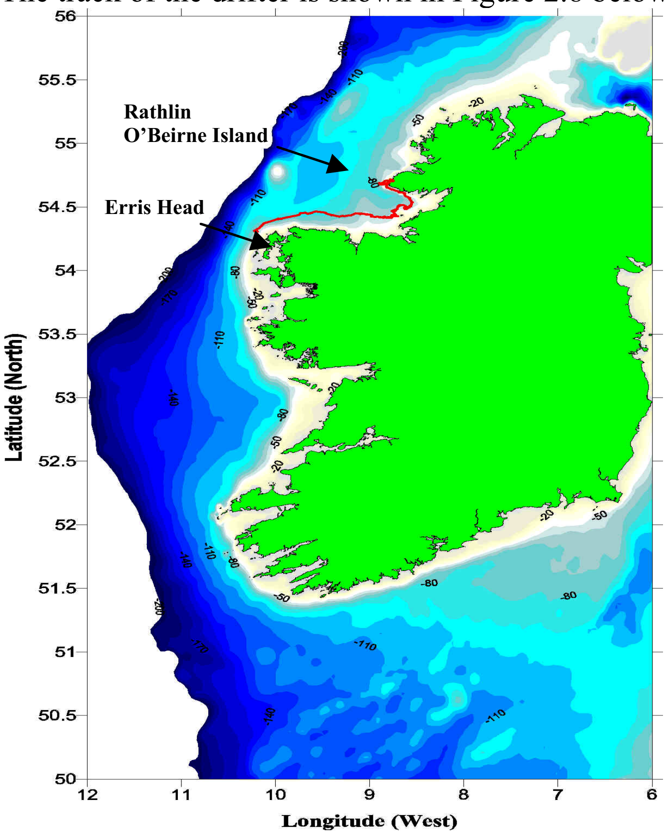


Figure 2.8 Track of satellite drifter (red line) 21576 during summer 2001 showing anti-clockwise circulation in Donegal Bay. (Drifter track in red, commences near Erris Head)

From the initial deployment position west of Erris Head, the drifter proceeded around Erris and headed eastward into Donegal Bay. Southwest of Killybegs the drifter turned in a north-easterly direction before finally moving to the northwest and rounding Rathlin O'Beirne around August 15th. The drifter track is consistent with our understanding of the Irish Coastal Current, a density driven current evident in late spring and summer that extends from the Celtic Sea in the south to at least Malin Head in the north. This satellite drifter study shows that the main non-tidal circulation is anti-clockwise in the Donegal Bay area and supports the output of the hydrodynamic model of the bay (Kirk McClure Morton, 2004).

2.3 Water column structure

The structure of the water column for Donegal Bay was reviewed due to its potential significance in the interactions between the biological, chemical and physical aspects of the marine environment and salmon farming operations. The key factors in terms of water column structure are temperature and salinity. In particular, a review of the water column structure and temperature / salinity variations is essential in considering the various scenarios that were proposed to explain the mortality events in summer 2003.

A comprehensive oceanographic section was completed in Donegal Bay in July 2001 on MI's research vessel, ***Celtic Voyager***. High-resolution measurements of conductivity (salinity), temperature and pressure were made at approximately 500 metre intervals, using a Scanfish profiler along the ships track shown in Figure 2.9

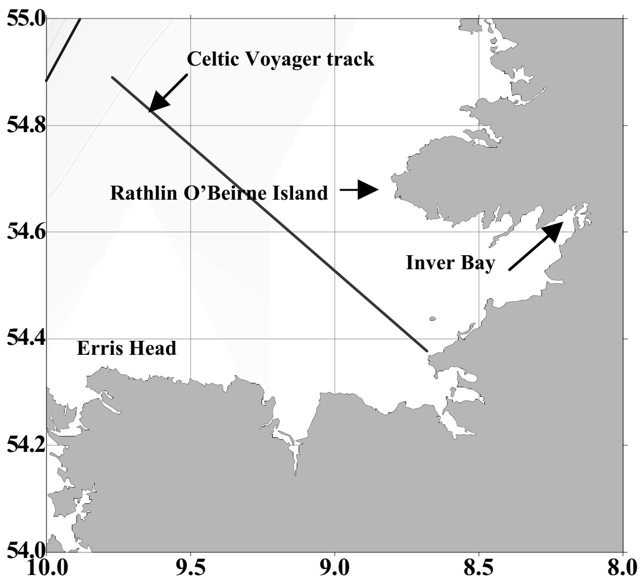


Figure 2.9 Location of Oceanographic section in Donegal Bay, July 2001

2.3.1 Temperature:

The water column was thermally stratified with differences between surface and bottom water of up to 5° C at sampling stations at the western end of the section. Differences between surface and bottom water temperature nearer to Mullaghmore, on the eastern end of the section, were ca. 3° C. The temperature and salinity data recorded along the section are shown in Figure 2.10

2.3.2 Salinity

Salinity values were consistent with those expected in a coastal embayment and ranged from 34.5 to 35 psu. Offshore of this, oceanic water (≥ 35.3) was encountered. On the basis of the 2001 data, it is reasonable to infer that water in and around Inver Bay is unlikely to exceed salinity of 35 psu.

Data from a CTD cast in Inver Bay on July 29th 2002 as part of an R.V. Celtic Voyager research cruise supports the 2001 data. These data are shown in Figure 2.11 below. Temperature ranged from 16.3°C at the surface to 14.7° C at 15 metres. The 1.6 ° C surface to bottom difference in temperature (rather than 3°C in 2001) is likely to be explained by the shallower water column. Salinity varied from 32 at the surface to 33.7 at 15 metres.

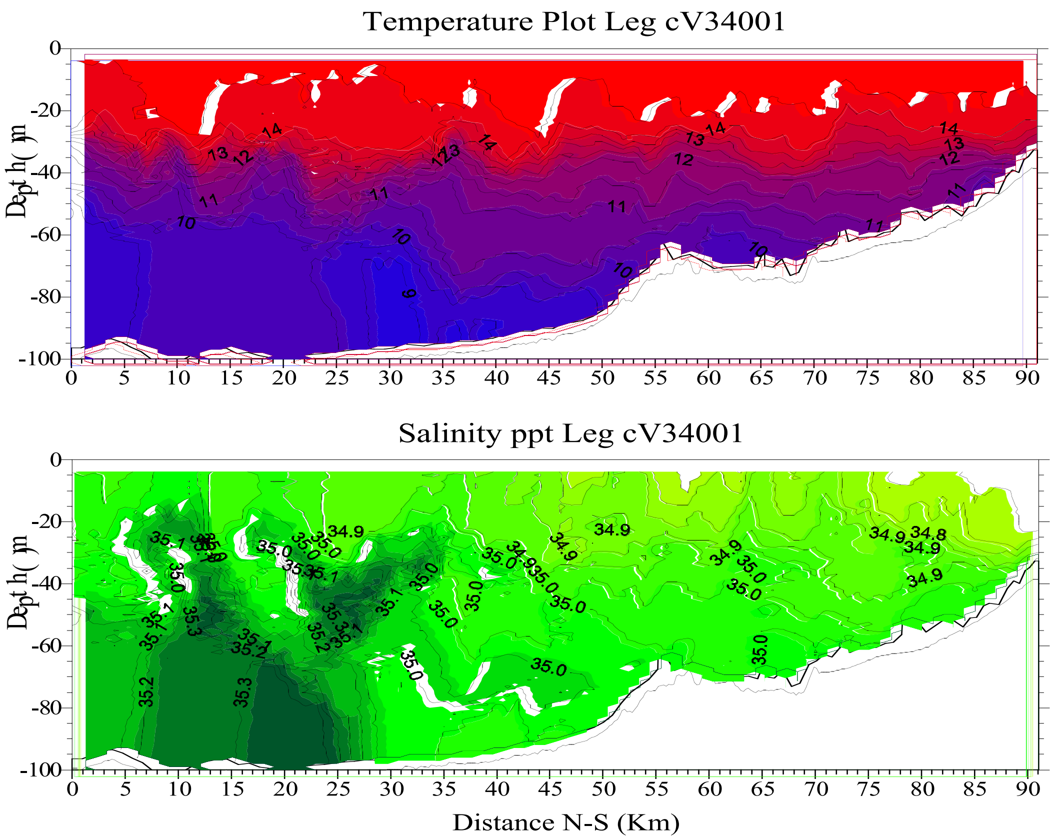


Figure 2.10. Oceanographic data from Donegal Bay showing temperature (upper) and salinity (lower) along the track shown in Figure 2.9

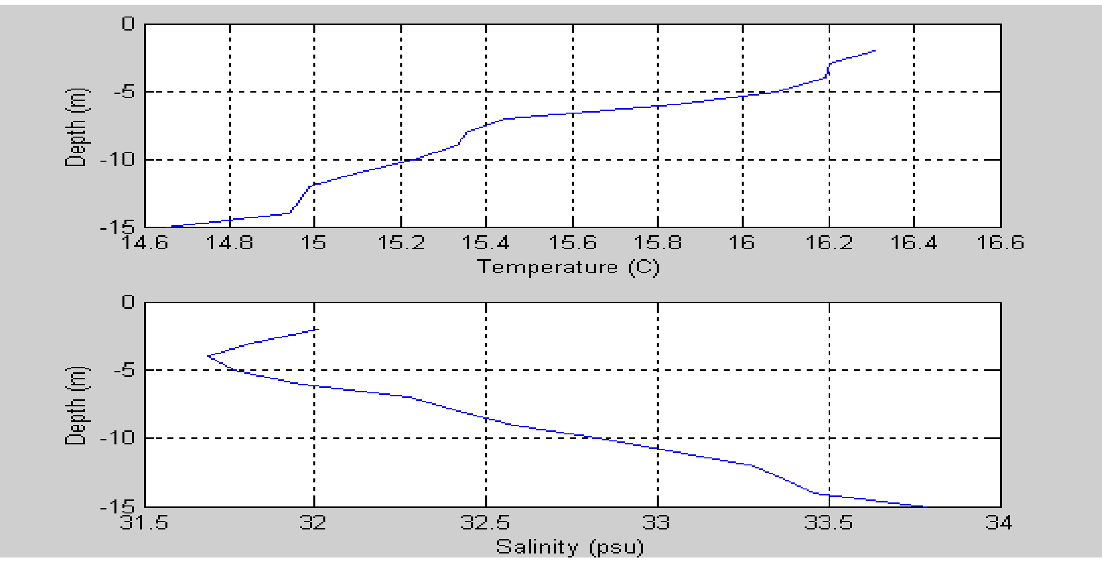


Figure 2.11 Single CTD profile taken in Inver Bay, July 29th 2002 showing temperature (upper panel) and salinity (lower panel).

2.4 Wind data

An analysis of wind data from the Marine Institute's M4 Data buoy, located at 54° 40'N 09°04'W (southwest of Burtonport) off Donegal was carried out to establish what, if any, significant wind events occurred during 2003 that may have affected circulation patterns and sediment transport in the study area. Data for wind direction and speed from the M4 buoy are shown below in Figure 2.12 and 2.13.

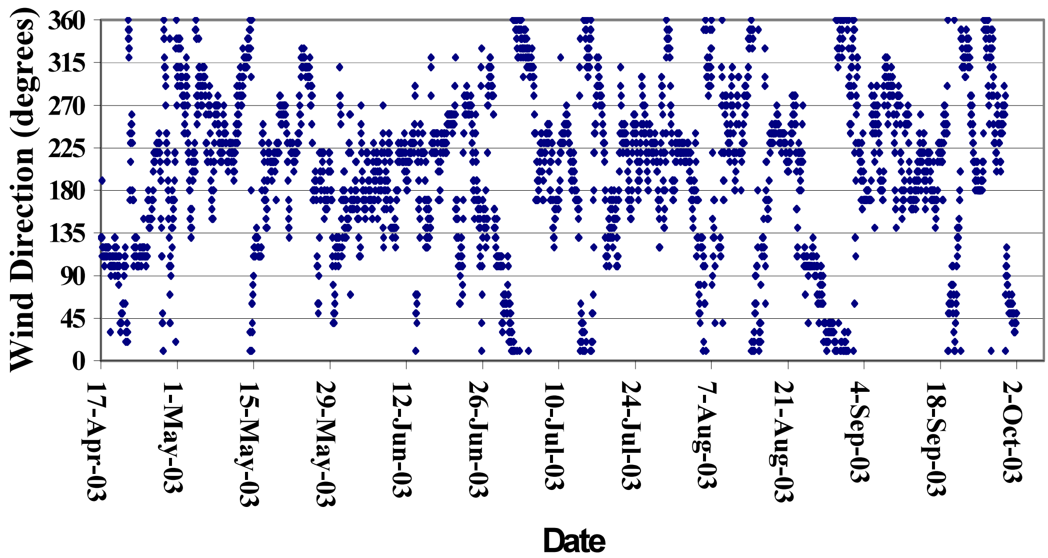


Figure 2.12 Wind Direction measured at the M4 Data Buoy, 17th April – 1st October 2003

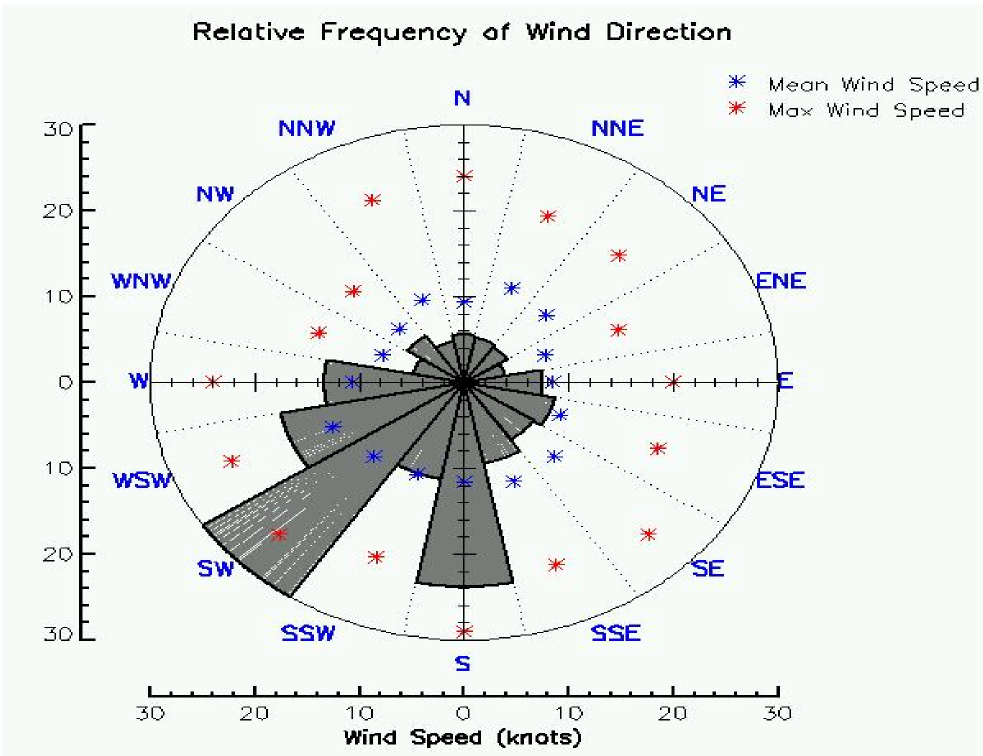


Figure 2.13 Rose plot showing relative frequency of occurrence of wind from different directions recorded at the M4 Data Buoy from June to August 2003.

During the recording period the winds were variable in direction but were predominantly from a southwesterly direction (180° – 270°). In early July there was pronounced shift in wind direction with northerly winds prevailing from 1st – 5th July and a similar shift in wind direction recorded in early September. The change in wind direction recorded in early July was associated with a sharp decrease in water temperature in both Inver and McSwynes Bays but a similar decrease in water temperature was not recorded in early September (see Section 2.5 below)

Wind speeds (Figure 2.14) were variable throughout the recording period, with an average speed of 12.4 Knots (Force 4) and 99% of recorded speeds < 30 Knots (Force 7). Wind speeds of up to 40 Knots (Force 8) were recorded in early May. There were no significant storm events (wind speeds >40 Knots) during the recording period

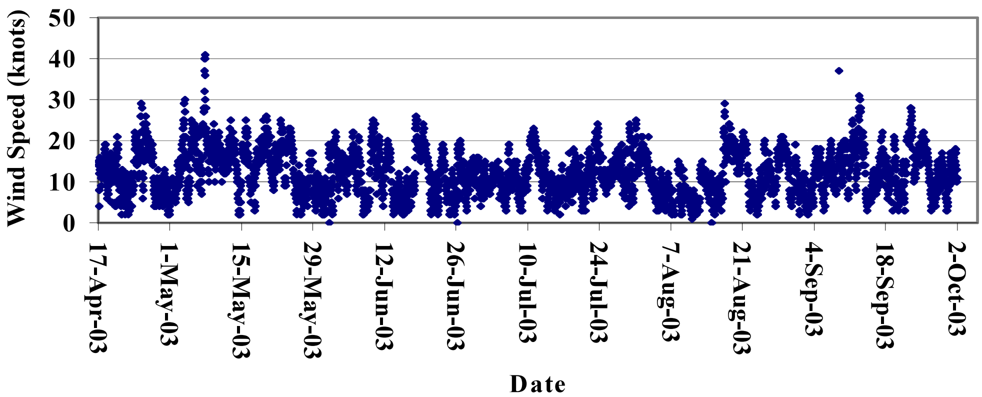
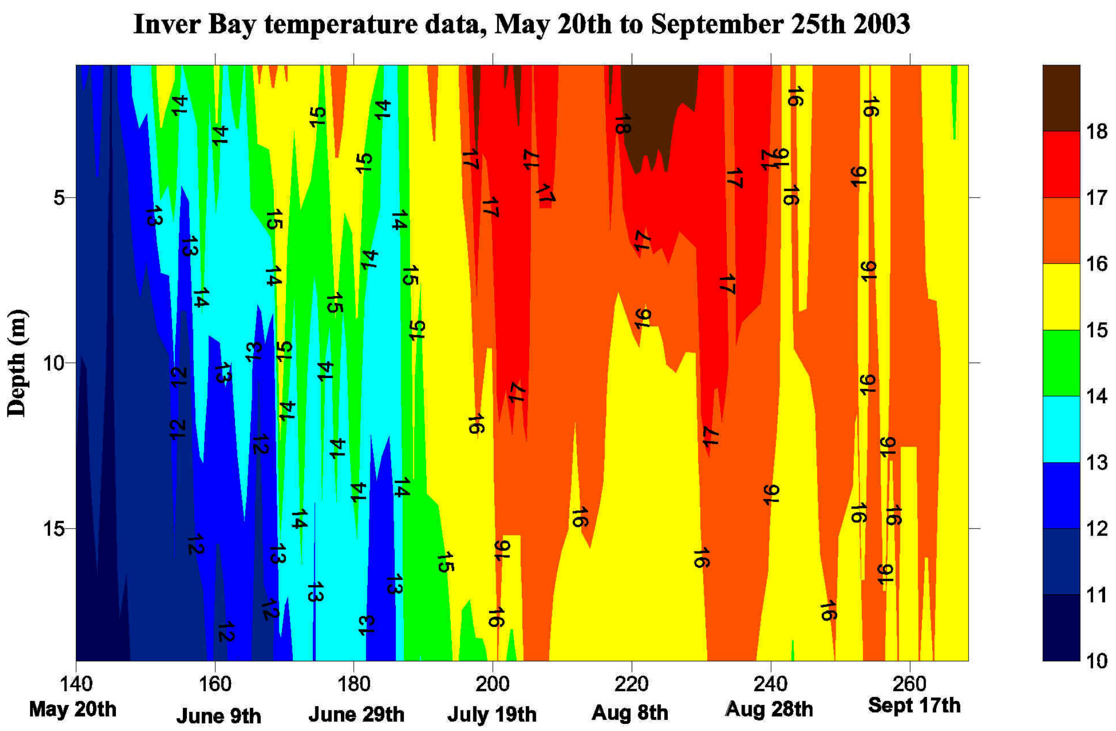


Figure 2.14 Wind speed measured at M4 Data Buoy, 17th April – 1st October 2003

2.5 Temperatures recorded in Inver and McSwynes Bay during 2003

TidBit temperature loggers have been installed by MI in over 20 aquaculture bays, including Inver Bay and McSwynes Bay in the recent years. The temperature time series for Inver Bay from May 20th to September 25th 2003 is based on temperature loggers that were deployed at the 1m, 10m and 19m depth while that from McSwynes Bay is based on loggers deployed at 1m, 10m, 20m and 28m. The data from these loggers are shown in Figure 2.15 and 2.16.

In late May and early June surface water temperatures were typically 13 -14°C but increased steadily throughout the summer reaching a maximum of approximately 19 °C in early August. Throughout July and August the temperature in the upper 10m of the water column generally exceeded 17 °C but water temperature at 19m was generally < 16 °C. There was a sharp decrease in water temperature recorded in the first week in July when temperatures decreased from >15 °C to <14 °C at the surface and water temperatures of <13 °C were recorded at 19m. These data indicate an intrusion of water, originating from offshore, into the area at this time. The timing of this event coincided with a change in wind direction from southwesterly to northerly. The event was of short duration, lasting approximately 5 days. Thermal stratification of the water column was evident during the summer, particularly during August.



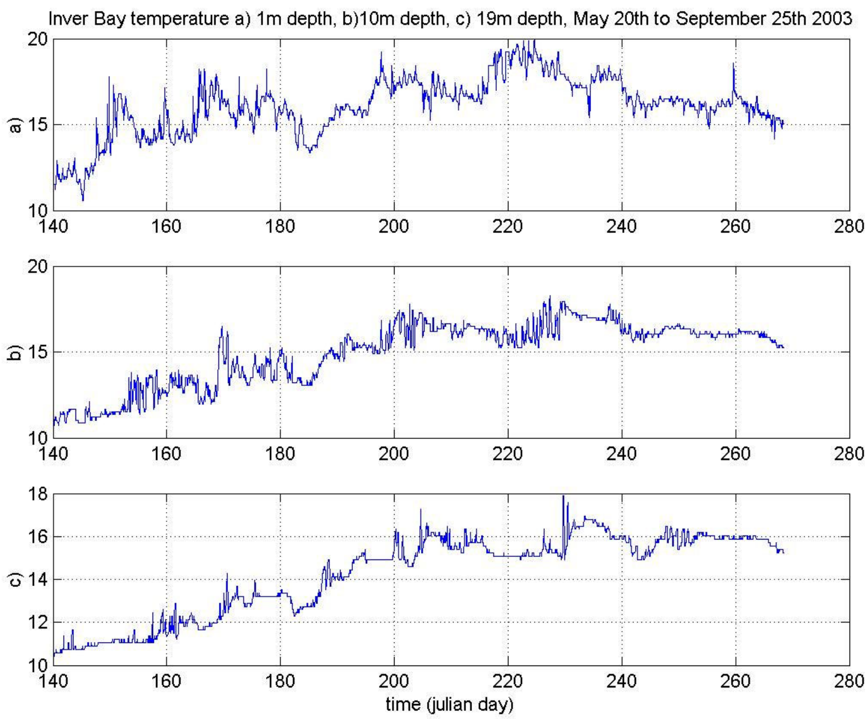


Figure 2.15 Temperature data from Inver Bay, May 20 to September 25 2003.

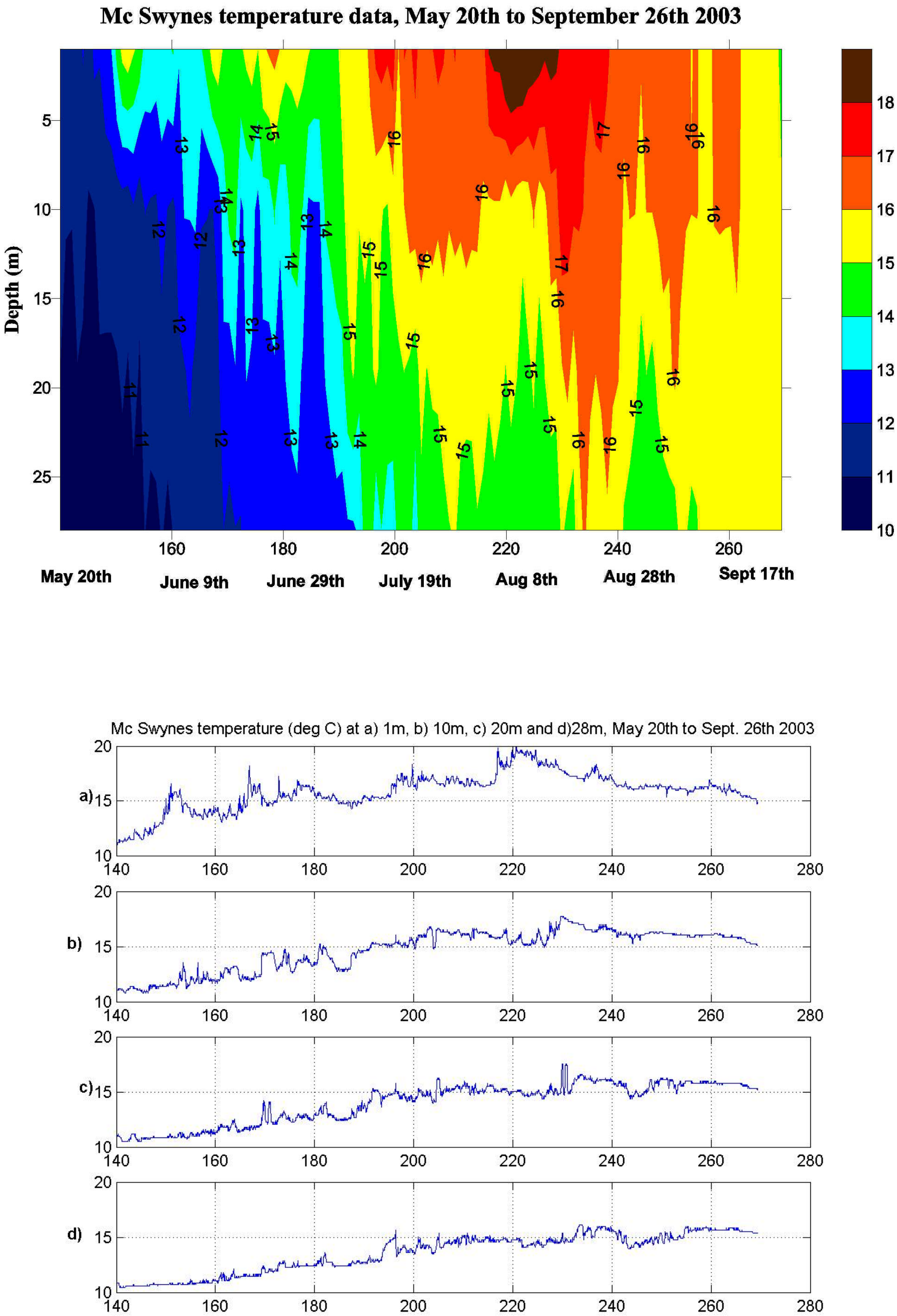


Figure 2.16 Temperature data from McSwynes Bay, May 20th – Sept. 25th, 2003.

The temperature data recorded in McSwynes Bay was generally similar to that measured in Inver Bay. The highest temperatures were recorded during August when surface temperature exceeded 19^{o}C. Temperatures in the upper 10m of the water column were > 16 ^{o}C from mid July through to early September and thermal stratification of the water column was also evident during this period. There was a decrease in temperature recorded in early July, coincident with that noted in Inver Bay, but the decrease in temperature was generally confined to water below 10m in depth and less pronounced at the surface.

While no long-term seawater temperature data are available from sites in Donegal Bay a useful data set is available from the Met Eireann station at Malin Head. Comparison of the monthly average sea surface data at Malin Head in 2002 and 2003 with the long-term 30-year (1961 –1990) average are shown in Figure 2.17 below.

These data show that sea surface temperatures in 2003 exceeded the 30 year average each month and in particular during July and August when the temperature was 1.1 – 1.4 ^{o}C above the average. Similarly, sea surface temperature data recorded at the M1 data buoy, located to the west of the Aran Island, shows that the monthly average temperature in July, August and September 2003 were the highest recorded since the buoy was deployed in February 2001(Figure 2.18). It is reasonable therefore, to assume that the temperatures recorded in Inver Bay and McSwynes Bay during 2003 were also above average.

The optimum temperature range for the culture of Atlantic salmon is 14 - 16 ^{0}C. Salmon exposed to temperatures > 16 ^{0}C, particularly for prolonged periods, may suffer physiological stress making them more susceptible to disease and environmental insult (Kling and Opitz, 2000). Additionally the reduction in oxygen content of the water with increasing temperature can also lead to stress. As the temperatures recorded in the upper 10m of the water column in both Inver Bay and McSwynes Bay during July and August 2003 were typically > 17 ^{0}C it is clear that environmental conditions were sub-optimal for the farmed stock and are likely to have contributed to mortalities observed.

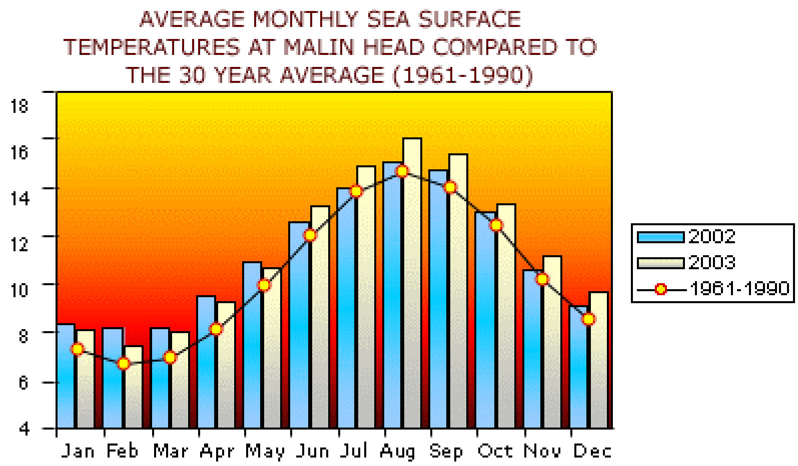


Figure 2.17 Average monthly sea surface temperatures at Malin Head compared to the 30 year average (Data from Met Eireann)

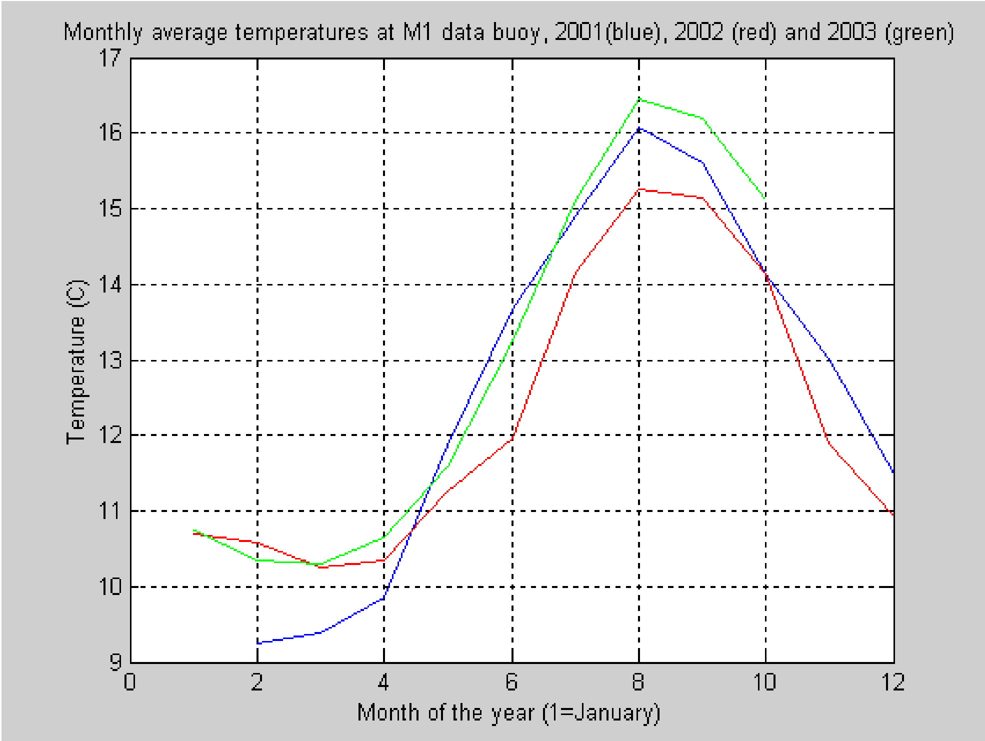


Figure 2.18 Monthly average temperature sea-surface temperature data recorded at MI's data buoy (53^0 07.6'N, 11^0 12'W), February 2001 – October 2003.

2.6 References

Kirk McClure Morton 2004. Investigations of salmon mortalities at Inver Bay and McSwynes Bay fish farms.

Kling, L.J. and Opitz, H. M. 2000. The Farming of Atlantic Salmon in the State of Maine. University of Maine website (http://www.umaine.edu/mainesci/Archives/MarineSciences/salmon-farming.htm)

CHAPTER 3 FISH HEALTH AND FARM MANAGEMENT, 2003

3.1 Data sources and approach

All available veterinary and histopathology reports (in excess of thirty, from six different authors) were obtained for the affected sites from the relevant investigators. Supplementary data was collected by Dr. Marian McLoughlin, Aquaculture Veterinary Consultant, on behalf of the Marine Institute. An inspection of sites was also carried out by personnel from DCMNR and the Marine Institute in order to collect mortality data, details on fish treatments and relevant management data.

Results of all analysis carried out by MI Fish Health Unit (FHU) can be seen in Appendix 1.

3.2 Site visits and Veterinary investigations

* *17-23/06/2003 (Ocean Farm report 1 & 2, Eany 1 and Creevin 1)*

All 3 farms were inspected and 30 smolts per site were sampled by Marine Institute personnel for virology and bacteriology, under Directive 91/67/EEC. No viruses or significant bacteria were isolated from these samples. No significant lesions were found on histopathology.

* *17 & 26/06/2003 (Ocean Farm report No 3, 4 and 5)*

A drop in dissolved oxygen was recorded by staff on the Ocean Farm Inver site, with a 10-metre reading of 4.7mg l-1. Samples were sent by Ocean Farm, to Dr Francis Scullion, Aquaculture Veterinary Consultant, on 26/6/03, which indicated sub-acute to chronic Pancreas Disease (PD). No gill pathology was recorded. Samples of 3 growers ex cage 6 indicated mild to moderate focal gill hyperplasia.

A further 3 growers from cage 3 were sampled by Ocean Farm staff on 06/07/03 and read by Dr. Scullion. These slides revealed mild-moderate focal gill hyperplasia, but not enough to cause death. This suggests that a gill irritant may have been in the water at this stage.

* *09/07/2003 (Ocean Farm report No 5 & 6)*

A site visit was undertaken by Dermot Sparrow (Ocean Farm Company vet) on 09/07/03. Two nets that had just come off the Inver smolt site were observed (Figure 9) and described as being coated with black sludge. Two samples of this (raw and washed sludge) were taken by the farm for analyses. The raw sludge had a very strong odour of hydrogen sulphide (H2S). Samples were examined microscopically. Dr Scullion reported mixed motile bacteria with much organic and inorganic matter in both samples. A strong odour of H_2S was also noted from the sludge by Ocean Farm personnel. One of these samples was delivered to MI for analysis. A sudden increase in mortalities was reported to MI by Ocean Farm Biologist, Ger Meade.

Figure 3.1: Smolt net from Ocean Farm Inver Site at 5pm on 09/07/2003 taken and certified by Dermot Sparrow

* *10/07/2003*

Water samples taken by Ocean Farm from various locations in the vicinity of cage 15 at a depth of 15metres, were reported to show hydrogen sulphide levels up to 13.85mg l^{-1} (analysis carried out by Mercury Analytical). The samples had not been fixed immediately, possibly indicating that higher levels of H_2S may have been present at the time of sampling.

* *10/07/2003 (Creevin Report no 2 & Eany Report no 2)*

Night time 12 hour oxygen, temperature and salinity monitoring was undertaken by Ocean Farm. This indicated that oxygen levels outside the cage at a depth of 15m ranged from 3.8 to 4.4 mg l^{-1} with an average of 4.2 mg l^{-1} throughout the period, while inside and outside the cage at 1m and 10 m the oxygen level was within normal range during the same period. This indicates low oxygen in the surrounding deeper water overnight.

Creevin Salmon Farm requested that a site visit be undertaken by Vet-Aqua International [VA], due to concerns about inappetence and increasing mortalities. Clinical examination and histological sampling indicated gross branchitis (inflammation of the gills) in all smolt cages and in Cage 2 growers. Fish from all cages showed acute gill pathology (lifting and oedema of secondary lamellar epithelium) and focal hyperplasia (thickening of the lamellae due to an increase in epithelial cells) was severe in some fish. Occasional algal remnants were noted trapped in the gills.

Fish from smolt cages 4 & 5 at Eany Fish Products were examined by Mary Gallagher, Aquaculture Consultant. Gross gill necrosis, damage to the gill rakers and buccal cavity lesions were observed. No parasites or amoeba were detected on gill squashes but small numbers of green algae were seen. Histological examination revealed mainly severe gill hyperplasia and necrosis in 8/8 fish. 25-50% of the primary gill lamellae were affected, seriously interfering with the respiratory and excretory function of the gill. No other significant lesions were detected.

* *15/07/2003 (Ocean Farm Report no 7)*
Histological samples from Ocean Farm Inver grower cage 4 (4 fish) were sampled and examined by Dr Francis Scullion. Some chronic Pancreas Disease (PD) lesions and mild to moderate gill hyperplasia with haemorrhage and some bacterial invasion were noted (growers had suffered PD in October-November 2002). Focal liver necrosis and focal thinning of skin epithelium were also noted.

* *15/07/2003 (Eany report no 3)*
Twenty two smolts from various cages at the Eany site were subjected to gross examination by Mary Gallagher, Aquaculture Consultant. Consistent damage to the gills and gill rakers especially at the angle of the gill cartilage was reported, including inflammation, reddening haemorrhage and necrosis. Histological examination Histological examination, carried out by Dr. Marian McLoughlin, revealed gill epithelial lifting, hyperplasia, haemorrhage and necrosis to varying degrees in the 4 fish sampled.

* *16/07/03 (Ocean Farm report no 9, Creevin no 3 & Eany no 4)*
All three Inver sites were visited by VA on behalf of the Marine Institute. Findings were reported (3/286-88A) to the Institute on 23/07/03. High numbers of moribund fish on the Ocean farm grower site were noted. Mild gross and histological lesions were reported in the Ocean farm smolts, while severe gross and histological gill damage were reported in the Ocean farm growers. Focal thinning of the skin epithelium was also reported in one grower. Secondary bacterial infection was also noted. The photograph below shows loss of the distal primary lamellae (Figure 3.2).

Vet-Aqua International reported moribund smolts at Eany Farm, with many suffering erosion and tissue damage to the gill lamellae and rakers, and buccal cavity (similar to that observed by Mary Gallagher). Histological examination of smolts from cage 1, 2, 3, 5 & 8 revealed moderate to focally severe gill hyperplasia, and necrosis with bacterial clumps was observed. Some acute gill damage with epithelial lifting and necrosis was also present. Occasional algal remnants were seen as well as a few necrotic hepatocytes. The cage of rainbow trout on this farm were examined and found to be feeding normally with no gross gill lesions.
High mortalities were reported in all Creevin smolt and growers. Moribund smolts had necrotic tissue at the junction of the gill rakers and haemorrhages. (Figure 3.3) Moderate to focally severe gill hyperplasia and necrosis with some areas of focal liver necrosis was observed.

Examination of the Creevin growers in Cage 2 revealed the fish to be very lethargic and all examined had severe gill damage with erosion of the epithelia down to the gill cartilage. Histological examination revealed severe gill damage and necrosis especially at the distal tips of the primary lamellae. Bacterial mats were noted on the gill surface.

Vet-Aqua's examination confirmed severe gill damage, which was indicative of exposure to an acute water-borne irritant. Possible causes of the gill damage were cited to be:
a. A harmful algal bloom
b. Jellyfish or siphonophore swarms
c. Release of irritant chemical or material from sediment or seabed
d. Discharge of irritant from point source.

Figure 3.2. Gill tissue of moribund salmon from Inver showing loss of gill epithelial tissue and exposure of branchial cartilage (Photograph Copyright H. Rodger).

Figure 3.3 Post smolt showing inflammation and necrosis at the junction of the gill rakers (Photograph Copyright H. Rodger).

* *16/07/2003 (Ocean Farm report no 10)*
Fish Vet Group (FVG) and MOSS Veterinary completed a site visit to Ocean Farm Inver site, at the request of the company.

Examination of smolts by FVG revealed the fish to be high in the water column, but no significant numbers of moribund fish were reported. A number of fish were examined from smolt cage 9, revealing that the "gills were slightly patchy and had a bluish appearance close to the gill arches". Tissue samples were taken from 4 fish and water samples were taken from surface and 10 m zones for sulphide determination and algal identification.

Examination of the Grower site revealed large numbers of dead fish. Cage 3 was closely examined and revealed many lethargic fish. Several moribund fish were culled and examined, "all had severe, patchy sloughing of gill epithelium exposing primary filament cartilage. Remaining gill epithelium appeared dull grey/blue particularly close to the gills". Tissue samples were taken from 4 fish and water samples were taken from surface and 15 m zones for sulphide determination and algal identification. In addition preserved tissue taken from moribund fish by Ocean farm staff on 14/15/07/03 were collected for histological examination.

Results of further analysis found:

- Water samples taken at the time of the visit as detailed above were negative for sulphide (limit of detection 0.2ppm)
- Algal analysis of water samples revealed no significant algal numbers. However, some inorganic dark opaque particles were seen in the surface sample from the grower site
- Histological evaluation of the various tissue samples from grower fish revealed severe gill and liver changes consistent with a severe water borne insult. Milder changes were seen in the smolts.
- One grower fish appeared to have an infection with *Exophiala* in the kidney. This is likely to be an incidental finding not particularly relevant to the current problem
- The pathology seen in the affected growers resembles that seen previously by FVG, following experimental exposure of fish to toxic levels of hydrogen sulphide

Based on previous experimental work carried out by FVG, it was felt that "the pathology seen in the affected grower fish is consistent with that which might be expected following exposure to toxic levels of hydrogen sulphide. There is no clear evidence for recent toxic algal blooms or other possible causes of severe gill pathology". Moribund fish on the Ocean farm grower site were culled over subsequent days on recommendation of all veterinary advisors.

* *22/07/03 (Ocean Farm report no12)*
Eighteen smolts from cages 6, 7, 9 & 11 were sampled by Ocean Farm staff at their McSwynes Bay site and histology was read by Dr Francis Scullion. Mild focal hyperplasia and telangiectasis in the gills of the majority of smolts were reported. Also reported were mild liver pathology, occasional kidney pathology and mild pancreas disease.

* *25/07/2003 (Creevin report no 4)*
A site visit was completed at Creevin Salmon Farm by Dr. Marian McLoughlin on the 25th July 2003, (3 weeks after the first clinical signs were detected) and both smolts and growers were found to be inappetent, lethargic with many growers swimming around the surface. Feeding response was very poor.

Gross and histological examination of the surviving smolts revealed continued inappetence, mild focal hyperplasia (thickening) of the gills with organised thrombi within damaged lamellae. Similar lesions were found in all four gill arches taken from left gill compartment. Mouth haemorrhages and inflammation were noted in 2/12 fish. (Figure 3.4) Hypertrophy, vacuolation and focal necrosis of cells were seen in a number of pseudobranches (which are very sensitive to pollutants) from cage 11 smolts. In 4/8 there was diffuse vacuolation of hepatocytes.

A single fish displayed multi-focal single hepatic cell necrosis, while 2/8 exhibited focal congestion of hepatic sinusoids. The latter liver lesions are non-specific in nature but have been recorded to be associated with xenobiotic contaminants in the liver. Mild focal myocardial inflammation was noted in 3/8 hearts but this was not thought to be clinically significant.

Gross and histological examination of four Cage 2 growers revealed severe and diffuse hyperplasia of the secondary lamellae from the mid to the distal region of the majority of primary lamellae (Figures 3.5, 3.6 and 3.7). Limited spongiosis (oedema within gill epithelium) of the distal primary lamellae was also noted. Numerous organised thrombi were observed in the secondary lamellae. Multi-focal hepatic necrosis was seen in one out of four fish sampled. No other pathological lesions were detected.

This examination confirmed the most significant lesions to be severe gill damage in the growers with less severe gill lesions in the smolts. It was concluded that given the mortality pattern and consistent nature of the gill lesions (recorded by the fish pathologists who visited this site), it is highly likely that the site was exposed to a water-borne insult at the end of June.

The surviving fish were considered to be very susceptible to stress and secondary bacterial infections.

Figure 3.4: Mouth lesions in Creevin Cage 11 smolts
(Creevin Salmon Farm 25/07/03 Copyright M. McLoughlin)

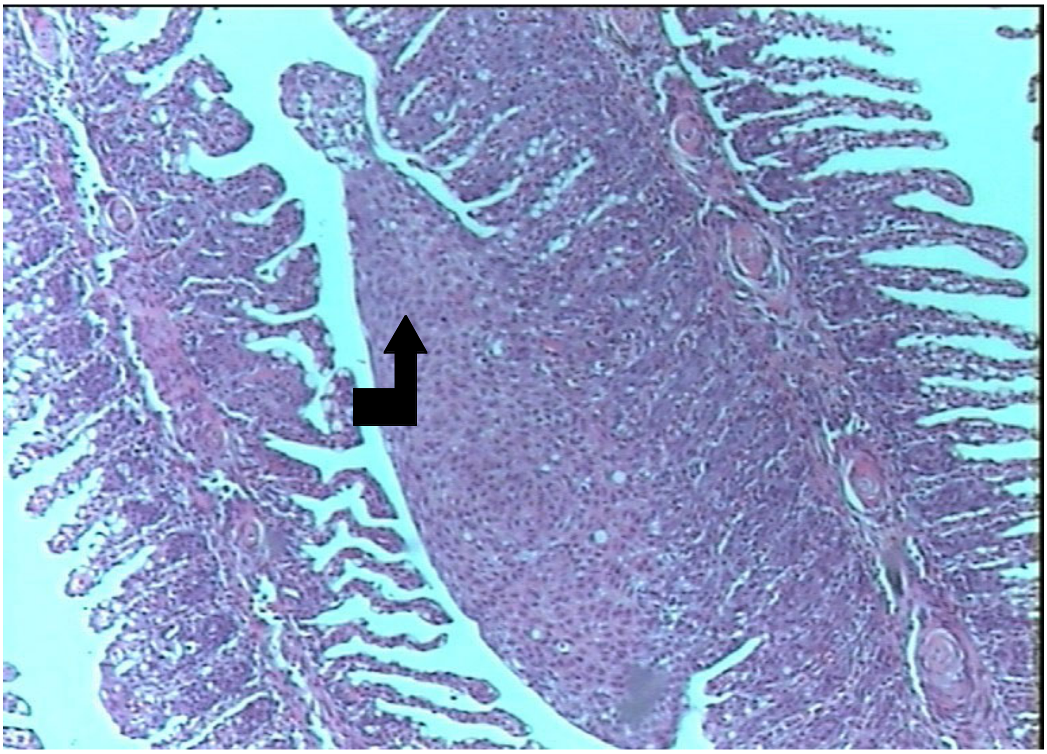


Figure 3.5 Typical focal hyperplasia of the gills noted in Creevin smolts. (Creevin Salmon Farm 25/07/03 Copyright M. McLoughlin)

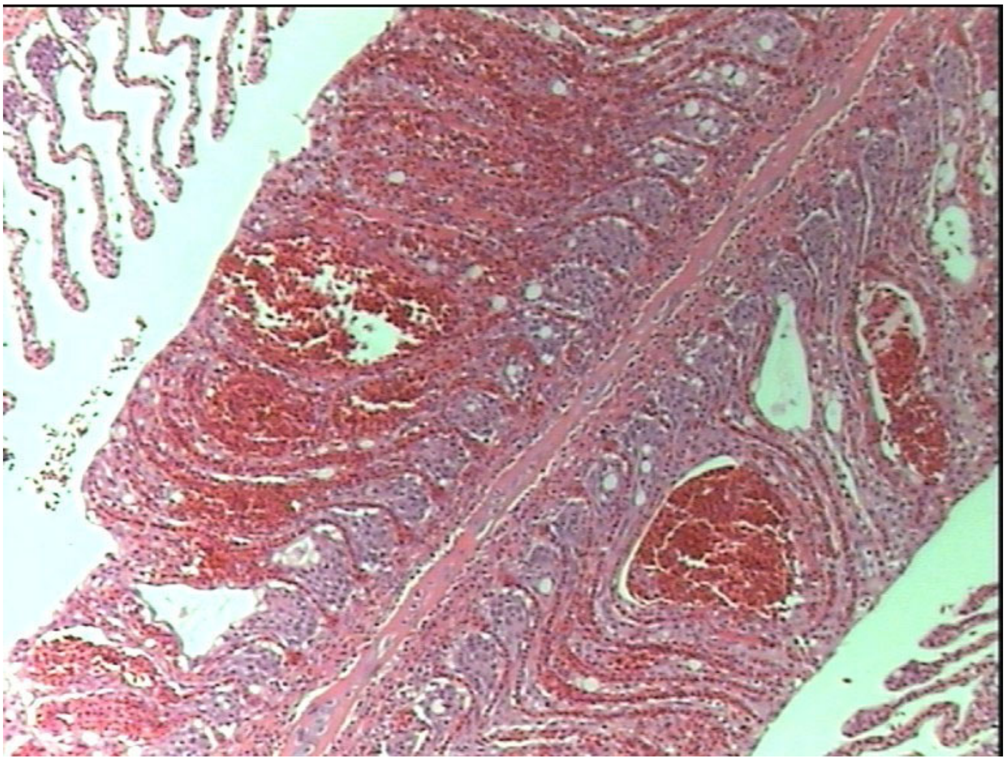


Figure 3.6 Severe gill inflammation and necrosis in grower from Cage 2 (Creevin Salmon Farm 25/07/03 Copyright M. McLoughlin)

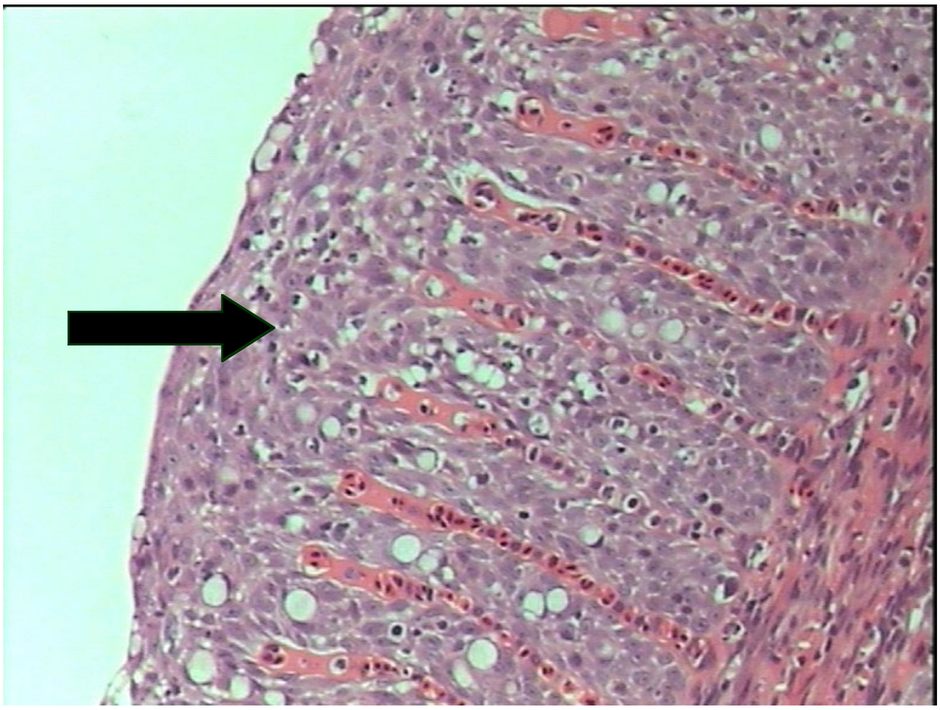


Figure 3.7 Severe hyperplasia (accumulation of epithelial cells between secondary lamellae (→) and progressing over the surface of the primary lamellae) Creevin grower Cage 2 (Creevin Salmon Farm 25/07/03 Copyright M. McLoughlin)

**01/08/2003 (2558, 2559, 2560/03 & 3/324A)*
Ocean Farm 11, Eany 5 & Creevin 5

Further samples were taken at Creevin, Eany and Ocean Farm by the MI on 1/08/03 for microbiological and histological examination. Clinical observations during these site visits included very lethargic smolts in all three smolt sites with very dark gills and grossly evident gill lesions i.e. necrosis, haemorrhages and ragged in appearance. The Eany smolts were considered to be the most severely affected.

No evidence of Infectious Pancreatic Necrosis (IPN),Viral Haemorrhagic Septicaemia (VHS), Infectious Haematopoietic Necrosis (IHN), Infectious Salmon Anaemia (ISA) viruses, or significant bacterial pathogens was detected at this time on any of the sites tested.

Histological examination revealed severe gill pathology in 2/6 fish sampled on the Ocean Farm Inver bay smolt site. Algal remnants were noted in the gill lesions. Liver lesions were also noted.

Diffuse lamellar oedema and focal hyperplasia was noted in Creevin smolts. Organic material was also seen in association with the thickened tissue. Focal hepatic changes were noted in 2/4 fish examined.

All fish samples from Eany smolts exhibited severe secondary lamellar hyperplasia and fusion, and in 3/7 there was septic necrosis. Organic material was seen in association with damaged gill tissues. Liver lesions were seen in most fish.

**05/08/03 (Eany Report No 6)*

Gross examination of moribund smolts was carried out by Mary Gallagher, on behalf of the company. Six smolts and six randomly collected growers were sampled from Eany sites.

Examination revealed mild to moderate gross and histological damage in all 6 smolts. Lesions were still apparent on the mouth and gill rakers. Necrotic lesions on the gill lamellae were noted particularly on the dorsal region of the gill above the gill arch angle. On reading the slides, Dr. Marian McLoughlin noted histological lesions which included varying degrees of epithelial lifting, hyperplasia and hypertrophy. Non-specific liver lesions were also noted.

Gross and histological examination of the growers revealed varying degrees of gill hyperplasia and mild to severe necrosis. Multi-focal liver necrosis was noted in one fish.

**08/08/03 (Ocean Farm Report No 13)*

Twenty one Inver Bay smolts from cages 7, 8, 9 & 11 were sampled by Ocean Farm staff. Histology was read by Dr Francis Scullion. Gills and liver lesions were similar, but less severe than those previously described in Inver Bay growers. Chronic inflammation of the rakers and underlying connective tissue was also recorded. This is consistent with gross findings on all farms. Some regeneration of the gills was reported. Evidence of active pancreas disease was also reported

**09/08/03 (Ocean farm Report No 14)*

Four smolts from cages 4 & 6 in McSwynes Bay were sampled by Ocean Farm staff. Histology was read by Dr Francis Scullion. Severe liver necrosis and degeneration in all 4 fish were observed. Acute to more chronic life threatening gill lesions were also observed, including haemorrhages, necrosis, hypertrophy and hyperplasia of the tips of the primary lamellae. In addition, acute changes in the gill rakers (epithelial detachment) and early evidence of more chronic inflammation of the rakers in one fish were also observed.

**12/08/03 (Creevin Report No 6)*

Four moribund smolts, and three smolts from a feeding population in cage 7 at Creevin Salmon Farm were sampled and examined by Mary Gallagher, on behalf of the company. Histological examination revealed mild acute to chronic gill lesions consistent with ongoing and persistent gill irritation. There is also some evidence of liver damage and in one fish there were unusual casts (collection of cellular and non-cellular material) in the renal tubules.

**13/08/03 (Eany Report No 7)*

Photographs and histological samples were taken from a selection of smolts and healthy rainbow trout at Eany Fish Products, by Dr. Marian McLoughlin. This examination confirmed continuing inappetence and ongoing gill damage in the smolts.

A striking feature of the gross gill lesions was the consistent involvement of the gill rakers, and occasionally buccal lesions suggesting a severe oral insult. Many of the gills were showing necrotic lesions especially at the tips of the primary lamellae and, more commonly, in the dorsal part of the gill arch (see Figure 3.8). Small haemorrhagic nodules were observed on the pseudobranch in two fish. The majority of the fish were not feeding.

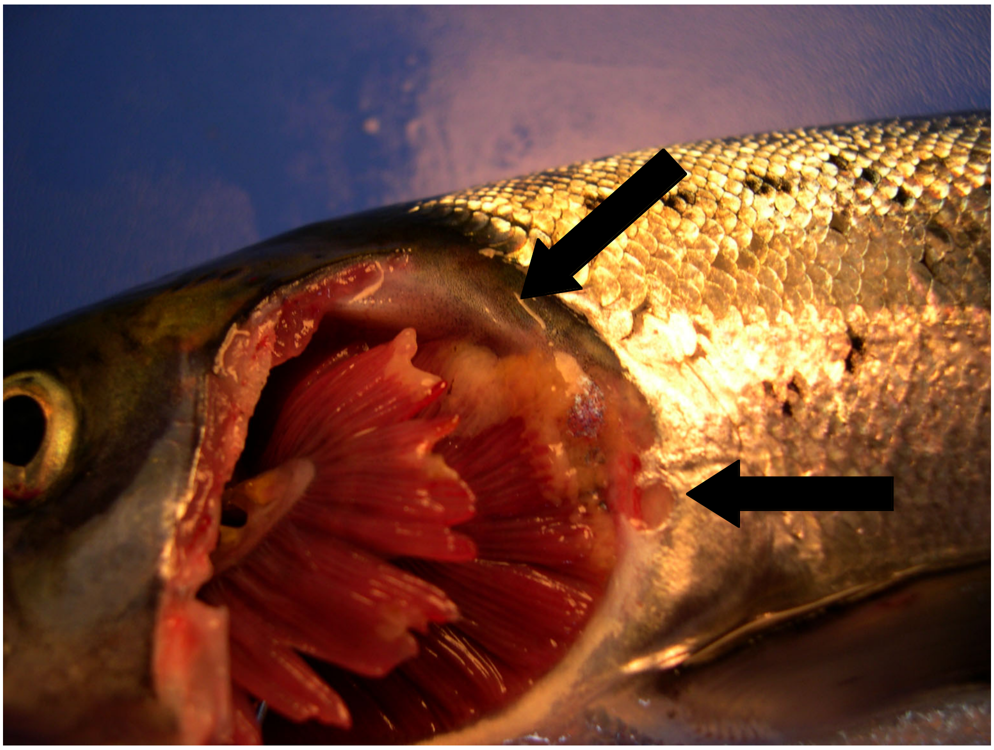


Figure 3.8 Necrosis of the tips of the primary lamellae typical of the gill lesions plus erosion of the edge of gill chamber (arrows) seen on Eany smolts 13/08/03 (Copyright M McLoughlin)

Mild to moderate gill damage, with recent haemorrhages and severe focal hyperplasia were exhibited by many fish. *Epitheliocystis* organisms were found on a few gills, and in this case were not associated with gill damage. Focal liver necrosis and pyknosis (shrinkage of nuclei) was noted in a minority of fish, the significance of which is unclear. No other disease processes were seen. The trout remained apparently unaffected and were keen to feed but were being restricted due to the high water temperatures. No significant gill pathology was noted in the trout.

**20/08/03 (Ocean Farm report no 15)*

A site visit to Ocean Farm McSwynes Bay sites was carried out Dr. Hamish Rodger, on behalf of the Marine Institute. Growers in Cage 6 (the outermost cage) were reported to have obvious gill damage. Fixed samples of gill tissue had obvious erosion or necrosis of the primary lamellae, similar in appearance to the gross pathology observed in the grower stock in Inver Bay.

<u>Inner smolt site (2003 S1s) - Cage 7</u>

Clinical appearance: Some lethargic fish were obvious around the edge of the cage and these were culled and post-mortemed. Feeding response was reasonable in the remainder of the population; however, it was reported to be significantly reduced.

Histology: Three surface fish were sampled, all with gill patch necrosis (see Figure 3.9) and no feed in their intestines, 1/3 had a flank lesion. Gill pathology in all three fish was the most significant finding and consisted of severe hyperplasia and secondary lamellar fusion with some necrotic epithelium, epithelial blebbing, lacunae and in 2/3 fish mats of *Flexibacter*-type filamentous bacteria on the damaged gill tissue. Melanomacrophages appeared active in the gills and although there were some algal remnants in some areas, there were also large hypertrophied cells in the gills with either melanin granules or some other particulate material present. A low level of *epithieliocystis* was also present.

Other less significant, probably secondary, findings included focal liver necrosis, shrunken pancreatic acinar cells and depleted red pulp in the spleen. A microsporidean xenoma was also present in the muscle section of one fish.

<u>Inner smolt site (2003 S1s) - Cage 8</u>

Clinical appearance: some lethargic fish were obvious around the edge of the cage and these were culled and post-mortemed. Feeding response was reported by farm personnel, to be significantly reduced. Histology: Two surface fish were sampled, both with gill patch necrosis and no feed in their intestines. Histopathology of the gills was as in cage 7, although in the gills of one fish high levels of *Trichodina* and some *telangiectasis* were also present.

<u>Outer grower site (2002 S1s) - Cage 5</u>

Clinical appearance: Lethargic fish near the water surface were obvious in this cage and five of these were post mortemed. All were in moderate to good condition but gills in all five fish had large eroded or thickened areas obvious (see Figure 3.8). Internally no abnormalities were observed.

Histopathology: Three fish were sampled for histology and all presented with similar findings; severe gill hyperplasia and fusion of the secondary lamellae, focal haemorrhage and necrosis of the epithelium and significant *eosinophilic* granular cell response in 2/3 fish in the primary lamellae. Mats of filamentous bacteria were present on the damaged tissue in 1/3 fish. Other organs sampled had no significant findings.

Interpretation of findings of 20/08/03 visit (by Dr. Hamish Rodger, on behalf of the Marine Institute): The most significant finding in the post smolts and the grower fish is the gill pathology which indicates exposure to a water-borne irritant.

There is evidence for secondary opportunistic bacterial infection in the gills of both stocks. The gill pathology is very similar to that seen in the stocks in Inver Bay and the most severely affected fish appear to be the outermost cages.

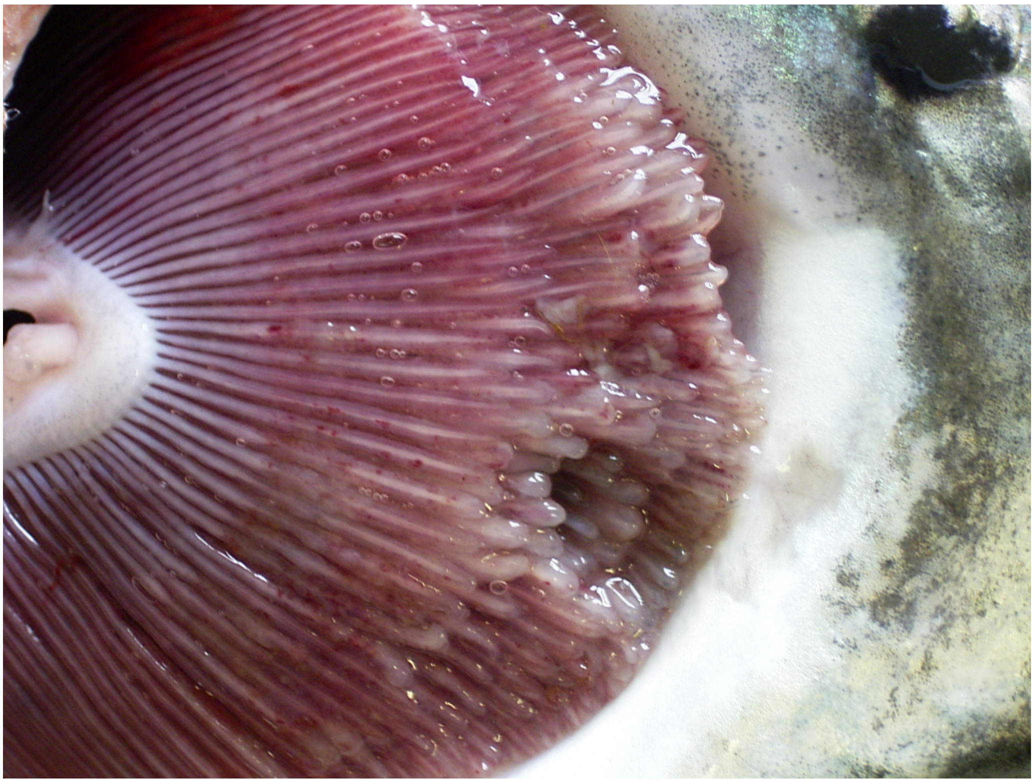


Figure 3.9 Gills of grower salmon from MacSwynes Bay with thickened and eroded gill lamellae plus focal haemorrhage (Copyright H. Rodger).

Review of histological slides

A review of histological slides from all 3 farms up to the end of July was completed by Dr. Marian McLoughlin, on behalf of MI. This review has confirmed the descriptions reported by the various fish pathologists originally involved in the case. It also confirms that histological lesions commenced in week 27 (week beginning June 30) in the majority of sites with evidence of acute gill damage, progressing rapidly to severe hyperplasia. There was some evidence of early gill pathology in the Ocean Farm growers at the end of June. An emerging consistent finding in all veterinary reports in addition to the gill lesions, is the presence of acute and chronic liver lesions of varying severity. This may suggest a common aetiology (cause). Gross and histological gill damage of variable severity persisted on all Inver Bay sites throughout August and into September.

3.3 Farm management

Farm management practices have been reviewed on all sites, both through on-site visits and through the examination of farm records. Whilst the practices observed are generally acceptable, and not thought to have caused the events described above, the infrequency with which dead fish were removed from some sites is a cause for concern and may have contributed to some of the environmental conditions described during the early days of the mortality event.

3.4 Feed

Fish feed from four different companies (see table below) was used in the bay prior to this event and would tend to rule out the involvement of nutritional factors since the problem was widespread across all sites and since two of the feeds are produced outside of Ireland, they would therefore have different sources of ingredients, which would make an association with feed even more unlikely.

Farm	Smolts	Growers
Ocean Farm	Biomar	Trouw & Biomar
Creevin	Aller-Aqua	Aller-Aqua
Eany	Aller-Aqua	Hoey

3.5 Cage analysis

The pattern of mortality in relation to the date of net change has been analysed. A possibly significant pattern is that the fish held in dirtier nets were unaffected in the case of the rainbow trout, and less affected in the case of the Creevin grower salmon (Cage 1). In the case of Eany, peak mortalities were observed in the cages with the nets which had been changed most recently, that is cages 1,2,4,and 8.

Cage 8 (Eany) was more severely affected than any other cage on the site, displaying 100% mortality within 5 days of the start of the event. This cage was moored slightly north of the main line and contained the smallest fish on the site.

A similar pattern was observed at Creevin Cage 7, which was the cleanest net on site and which encountered 50% mortality by 15 July, indicating a very acute and severe event.

Nets at Eany Fish Products have not been treated with anti-foulant since summer 2000 (W. Ward, *pers. comm.*). Ocean Farms nets in Inver Bay were also untreated in summer 2003. There were only two antifouled nets in use in MacSwynes Bay. Both of these were treated using Hyperlast, and were used on a trial basis (G. Mead, *pers. comm.*). Hyperlast is an insoluble polyurethane coating.

Based on the above information, it is extremely unlikely that net anti-foulants contributed negatively towards the mortality event.

3.6 Sea lice (Counts & treatments)

As part of the National Sea Lice Monitoring Programme, the sites in Inver and McSwynes Bays were inspected in the months prior to the mortality event in Inver Bay. Results of inspections can be seen in Appendix 2.

All sites were inspected in December/January again in February, twice in March, April and May and again in June. In addition to the inspection of a standard and random cage to assess lice levels at each site, a farm inspection report was completed. This included information on treatments carried out. From these inspection reports and other correspondence with the farms regarding treatments carried out under advice there is a good record of the treatment pattern within the bay in the months preceding the mortality event. Two products were used to treat fish for lice infestations - Excis and SLICE. The first is a topical or bath treatment and the second is an in-feed treatment. There were no reports of treatment related mortalities in the months prior to the major mortality event in July 2003.

Treatment trigger levels (according to DCMNR Aquaculture Protocols, 2000) during the spring period are set in the range 0.3 – 0.5 egg bearing (ovigerous) females per fish. During the spring period water temperatures are rising and the rate of development of sea lice, which is very slow or almost static at low winter water temperatures, increases. Strategic control of ovigerous lice numbers during this period is a key to controlling lice levels on fish later in the season. Low lice levels during the spring period, when wild smolts are migrating, also ensures there is minimal potential for any adverse interaction with wild fisheries. Outside of the critical spring period a level of 2.0 egg bearing lice per fish acts as a trigger for treatments.

Lice levels on smolts in both Inver Bay and McSwynes Bay in the months preceding the mortality were below the treatment trigger levels, and substantially lower than a level that could cause stress or damage to the fish. The trigger levels are set below the levels at which stress or damage will be caused to fish. The levels of lice which can be tolerated by salmon vary widely both with the size of the fish and the water temperature. The trigger levels in spring are less than one twentieth of the levels known to potentially adversely affect smolts. Larger fish can tolerate a much higher loading. Wild salmon, sampled offshore, returning to the rivers routinely have mean lice levels in excess of ten adult females without apparent ill effects.

Lice levels on growers in Inver Bay and McSwynes Bay exceeded trigger levels on a number of occasions in the spring of 2003. In the majority of cases the levels reached were not high enough to have caused any damage to the fish, except in late May and June 2003, when lice levels on growers in Creevin were at levels that would be expected to cause increased stress to the fish. However, the levels recorded would not be expected to give rise to increased mortalities in fish of this size.

There is no evidence to suggest that either lice infestation levels or treatment toxicity is to blame for the mortality problems recorded in July 2003 and subsequently.

3.7 Discussion

Consistent clinical signs, gross and histological lesions were observed by the different fish health professionals across all affected sites. Significant gill pathology was not noted on any site prior to this incident although early gill lesions were noted in Ocean Farm growers at the end of June. All veterinary reports indicate the cause of the observed lesions to be an acute water-borne irritant. It appears, from the chronology of events i.e. inappetence, followed by the observation of gross and histological lesions and mortality, that this water borne irritant is most likely to have appeared in Inver Bay during weeks 26-27.

Initially, the Ocean Farm smolt site, the most westerly site in Inver Bay, seemed to be least affected, which suggested that the main concentration of the water borne irritant was present from the Ocean Farm grower site, to the inner part of the bay. This is borne out by plots showing the progression of mortalities in Inver Bay. However, from mid-July onwards, gill lesions, lethargy and mortalities occurred in Ocean Farm smolts.

The pattern was slightly different in McSwynes Bay in that mortalities started at the same time as those in Inver Bay, but took longer to escalate.

Although there is evidence to suggest that both the Ocean Farm smolts and growers on the Inver site had Pancreas Disease there is no evidence to suggest that the presence of a fish pathogen was responsible for the mortalities. The lesions observed on those fish with Pancreas Disease were described as "not life threatening".

A possibly significant observation was the fact that Eany's rainbow trout were unaffected by this waterborne insult and this may be due to the fact that they were held in what would be considered a "dirty" net and may therefore have been protected from the irritant. Another grower net at the Creevin inner site was also considered "dirty" and these salmon also appeared to be less affected during July. Eany has reported that the fish in the cleanest nets were the most severely affected. These observations have been confirmed by interrogation of the mortality data. In both Eany and Creevin, the cages with the cleanest nets had the most acute and severe mortalities. This would suggest that the dirty nets protected the fish and might indicate a particulate rather than a dissolved irritant.

The liver pathology observed at the Ocean Farm site showed some similarities with experimental H_2S toxicity, but the gill lesions were not consistent with H_2S as being the sole cause of this event.

A similar event occurred at approximately the same time, in both Inver and McSwynes Bays. The onset of significant mortalities occurred later in McSwynes and although very serious for Ocean Farm, the incident in general, was less severe than that observed in Inver Bay.

Fish feed from four different companies was being fed prior to this event. This would tend to rule out any feed involvement.

Farm management practices were generally acceptable but the length of time taken to remove mortalities from certain sites was excessive and could have contributed to the unusual environmental conditions described during the early days of this mortality event.

Lice levels on smolts in both Inver Bay and McSwynes Bay in the months preceding the mortality were below the treatment trigger levels and substantially lower than a level that could cause stress or damage to the fish.

Lice levels on growers in Inver Bay and McSwynes Bay exceeded trigger levels on a number of occasions in the spring of 2003. In the majority of cases the numbers present were not considered high enough to have caused any damage to the fish.

In late May and June 2003, lice levels on growers in Creevin Salmon farm were at levels that would be expected to cause increased stress to the fish. The levels recorded would not be expected to give rise to increased mortalities in fish of this size. In any event, damage by lice usually occurs on the skin surface, and not on the gill. It is thus highly unlikely that this mortality incident has been caused by or perpetuated by sea lice.

3.8 References

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CHAPTER 4 BENTHIC CONDITIONS IN INVER BAY & McSWYNE'S BAY, Co. DONEGAL.

4.1 Introduction

This chapter consists of a review of benthic conditions found in Inver Bay and McSwynes Bay during routine monitoring surveys from 1997 onwards, and summarises additional surveys that have taken place since July 2003. The reports for each farm are presented as a summary of monitoring reports or on the basis of bay-wide sampling or monitoring for discrete events in the Bay. The purpose of this chapter is to determine if historical and prevailing conditions on the seabed in Inver and McSwynes Bay have influenced the mortalities at the fish-farm sites.

4.2 Benthic Surveys

4.2.1 Ocean Farm – Inver Bay

Surveys were carried out at the Ocean Farms Inver sites in January 1997 (Aquafact, 1998), October 2001 (Aquafact, 2001) and September 2002 (Aquafact 2002). The reports consisted of photographic records allied with a commentary on the conditions and biota observed. At all of the sites, undercage seabed was impacted with extensive bacterial mats (*Beggiatoa* sp.). Seabed enrichment was evident up to 20m from the edge of the cage array.

4.2.2 Creevin Salmon Farm – Inver Bay

Surveys of seabed conditions were carried out at Creevin Salmon Farms in January 1997 (Aquafact, 1998), January 2001 (Aquafact, 2001b), and September 2002 (Aquafact, 2002b). The smolt site typically had very little impact beneath the cages with no impact realised at the cage edge and beyond. The grower site had hypoxic conditions with extensive bacterial mats directly under the cages. Conditions returned to ambient at 20m beyond the cage edge, in all surveys. The conditions, for the most part, have remained consistent at the Creevin Farm sites since the first survey.

4.2.3 Eany Fish Products - Inver Bay

Surveys were carried out at Eany Fish Products in January 1997 (Aquafact, 1998), January 2001 (Aquafact, 2001a), and September 2002 (Aquafact, 2002a). The undercage seabed at the smolt site was mildly impacted with little or no impact beyond the cage edge. This was consistently observed in all surveys reviewed. At the grower site, the impact of food pellets and faecal matter resulted in bacterial mats and hypoxic conditions beneath the cages. Conditions returned to ambient at 20m beyond the cage edge.

4.2.4 Ocean Farms - McSwynes Bay

Surveys were carried at 3 sites McSwynes Bay in September 2002 (Aquafact, 2002c) with a follow-up survey in June 2003 (Aquafact, 2003e). The seabed was heavily impacted at all sites. The extent of this impact varied at each location with the grower site having very heavy impact out to 20m beyond the cage edge. Two sites (grower and harvest) were considered to have unacceptable conditions according to DCMNR protocols. The follow up survey of the grower site indicated that conditions had improved at this site and was considered within the allowable limits.

4.2.5 Overall Studies of Inver Bay

SPI Survey and EIS 1998

As part of an EIS in support of an application to increase salmon production in Inver Bay, benthic surveys were carried out using underwater photography and Sediment Profiling Imaging (SPI) system (Aquafact, 1998). Sediment Profile Imaging takes *in-situ* photographs of vertical sections of the seabed sediments. This can provide information on the physical, chemical and biological status of the seabed, and can determine the quality or "health status" of the seabed. It can also show any recent disturbance or changes in seabed conditions.

The SPI survey was carried out in January 1997. In total, 62 stations were sampled including sites beneath the cages, sites in the vicinity of the cages and sites remote from fish farming in the main body of the bay.

The results of the SPI survey revealed that fine sands dominate throughout the bay with small areas of coarser material closer to both shorelines. The Apparent Redox Potential Discontinuity (ARPD) layer was assessed visually at several random locations during the dive. The APRD is a surrogate measure of the depth of oxygen penetration into the seabed. ARPD measurements ranged from 0.0 – 9.7 cm, with values increasing away from the cages. The impact of the cages was very localised. The faunal status ranged from healthy, well developed communities to an azoic area found beneath one set of cages. The organism-sediment index (OSI) at 75% of the sites sampled was greater than 5. This indicates a healthy benthos.

4.3 Surveys related to the mortality event at Ocean Farms Inver Cage 10 site, June 2002

Between 5-7th June 2002, there was a large mortality event at cage 10 at the Ocean Farms Inver site (site 276B, see map at Figure 1.1). Following removal of many of the fish from the seafloor, it was estimated that between 6,000-8,000 were left on the seabed (Aquafact, 2002d). The fish had been on the seabed for more than 2 months and were in an advanced state of decay. It was recommended that the material be left undisturbed on the seafloor and that a monitoring program be implemented to assess the seabed recovery. MI and DCMNR accepted this recommendation. In September, October and November 2002 reports were submitted to the DCMNR and MI on behalf of Ocean Farms (Aquafact 2002e,f,g). Decomposition of fish continued and greatly impacted upon the sediment with considerable anoxia evident at the site in September 2002. By October the seabed had extensive layers of bacteria *Beggiatoa* sp. Carcasses were still evident on the seafloor in October 2002 but none were photographed in November 2002.

Further reports were submitted in January and March 2003 as surveys were carried out on a bi-monthly basis (Aquafact 2003 a,b). In January 2003, the seabed demonstrated a considerable degree of recovery with numerous benthic organisms present (*Marthasterias glacialis*, *Asterias rubens* and *Capitella* sp, *Malacocerus* sp – very dense beds indicative of high organic loading.) By March 2003 the coverage of worm species on the seabed had greatly increased thus indicating the potential for great oxygenation. The degree of *Beggiatoa* cover was greatly decreased in percentage cover and intensity. Further surveys in May and June 2003 showed little evidence of the incident (Aquafact 2003c, d).

4.3.1 MI Dive survey – Part l, July 16th, 2003

On July 16, 2003, a dive was carried out by MI personnel at the Cage 10 site. The purpose of the dive was twofold:

1. To confirm the findings of the most recent survey of the site (June 2003) and,
2. To assess whether the seabed had been disturbed, in light of claims by Ocean Farm personnel that trawlers had been fishing adjacent to the Ocean Farms, Inver cages.

A visual inspection of the seabed was carried out along the dive track, which consisted of a circular search of the seabed beneath the cage location and moved out to the surrounding seabed.

Bottom sediments at this site were consistent with surrounding sediments, with significant numbers of prawn burrows, and numerous fish and crustaceans species at the sediment surface. There was no evidence of organic enrichment such as fish carcasses from previous incidents. In addition, there was no evidence of any fishing activity through the area surveyed.

The ARPD layer was assessed visually at several random locations during the dive and was found to be not less than 3 cm at any of the locations. There was no evidence of outgassing.

It was concluded from the dive that benthic conditions at the site were good and there was no evidence of any disturbance through the site. This site is considered to have almost fully recovered from the disturbance in 2002.

4.3.2 MI Dive survey – Part 2, July 16th, 2003

A dive was carried out by MI personnel adjacent to the Ocean Farm grower cages, during the mortality event.

The purpose of the dive was to visually inspect the seafloor for evidence of dredging and to sample water near the surface of the sediment. The dive was carried out at the location of the line of grower cages inside the Ocean Farms Licence area 276B. A point to the SE of the second to last northerly cage in this array was taken as the entry point and A transect was dived in a south-easterly direction away from the cages for approx. 150m, and then SW for approximately 50m.

The seabed appeared normal, with many mounds created by the bioturbatory activity of *Nephrops sp*. and other crustaceans e.g. *Callianassa sp.* The ARPD layer (assessed visually) was in the region of 6 – 7 cm. Both the visual inspection and the ARPD readings indicated healthy and well-oxygenated sediment. There was no evidence of dredging activity along the track of the dive. It should be noted that the dive covered a very small portion of the licence area and may not represent conditions in the vicinity of all the cages**.**

It was concluded that the seabed in the vicinity of the grower cages appeared undisturbed with no re-suspension of material or deposition of material from elsewhere (i.e. black silty material as reported on the Ocean Farm nets).

4.3.3 Review of Inver Bay ROV survey 16th July, 2003

A video of sea floor conditions taken on behalf of the operators in Inver Bay by Halia Oceanographic was forwarded to MI for review (Halia Oceanographic Consulting Services, 2003). The survey comprised video clips of 15 locations within Inver Bay and encompassed images from the three farms. The aim of this survey was to estimate if there was disturbance on the seabed. The first 11 images were taken around the Ocean Farms licence areas.

Two clips, from an area midway between licence areas 276B and 96A, showed signs of disturbance with flattened seabed, no obvious burrows and shell debris on the surface. All other video clips (including at the site of cage 10 where the mortality event occurred in 2002) showed a healthy seabed with heavy bioturbation and no evidence of anoxia. The Eany fish licence area was also filmed, and showed typical seabed conditions beneath fish farm cages (faecal matter and hypoxic sediments), but with epifauna present (live mussels and starfish).

At Eany Grower site, dead fish were evident at the bottom of a net, which was sitting on the seabed (video Section No. 19).

Footage from Creevin Salmon farms showed impacted seabed beneath the cages, with little impact evident a short distance (from 25m) away from the cages.

4.3.4 SPI Survey 2003

The Marine Institute commissioned a survey of seabed conditions in Inver and McSwynes Bays during August 2003 (Aquafact 2003f). Photographs of the sediment surface were also taken. The objectives of the survey in Inver Bay were to determine if:

- there was a reservoir of noxious gases in anoxic sediments in the Bay by measuring REDOX depths at various locations in the Bay.
- there was evidence of seabed disturbance as a consequence of fishing activity in the Bay.
- there was evidence of recent deposition of sediment in the Bay as a consequence of suspension and subsequent deposition of material on the seabed.

<u>Results –SPI Survey Inver Bay</u>

Ninety stations were sampled in Inver Bay. Stations in Inver Bay showed a predominance of fine to very-fine sands in the topmost layer of sediments, with patches of coarser sediments on the west side of the bay. Healthy living maerl, indicative of good water quality, was also observed at a number of stations.

Outside of the immediate influence of fish cages, sediments were healthy and aerated with no evidence of large areas comprising anoxic sediments. In the vicinity of fish cages, the environment showed varying degrees of habitat disturbance attributable to organic enrichment - an allowable impact of aquaculture activity.

Only three of the 90 stations sampled during the survey showed evidence of recent physical disturbance. The condition of the seabed was consistent with a mature habitat that has remained undisturbed for more than 2 years (T. Pearson, SEAS Ltd. *pers. comm.*). The sediments appeared to be well sorted with no evidence of recent deposition of fine material in the bay. The description of the seabed in this survey was for the most part consistent with that of the previous SPI survey in Inver Bay carried out in 1997.

<u>Results – SPI Survey McSwynes Bay</u>

Ten stations were sampled in McSwynes Bay. All stations sampled in McSwynes Bay showed a mature healthy habitat and biological community status, with healthy well aerated sediments. There is no evidence from the SPI survey to suggest any recent physical disturbance or deposition of sediments in McSwynes Bay.

4.4 Discussion

The majority of the surveys carried out in Inver Bay since 1997 showed predictable impacts on the seabed underneath the fish farm cage structures. The level of impact varied considerably, based on the time of year the survey was conducted and upon the biomass of fish held in the cages. Based on the levels of allowable impacts outlined in the DCMNR Benthic Protocols (2001), all monitoring surveys in Inver Bay in 2001 & 2002 indicated that conditions observed in Inver Bay were within the allowable levels of impact.

The results of the 2003 SPI survey in Inver Bay indicated that seabed conditions in the bay had changed little since the first SPI survey was carried out in 1997. There was no evidence to suggest that there was;

1. a large reservoir of anoxic sediments in the Bay,
2. large scale disturbance of sediments in the bay and,
3. recent deposition of sediment in the bay.

In McSwynes Bay, the SPI survey indicated that benthic conditions were good within the bay. The monitoring of the aquaculture sites in 2002 indicated that all three sites were very heavily impacted. Two sites (grower and harvest sites) fell outside the "acceptable" level of impact, defined by DCMNR protocol (2001). A follow-up survey at the grower site in June 2003 indicated that conditions at that site had improved considerably.

4.5 References

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Aquafact 2002a. Environmental surveys of Eany Fish Products Ltd aquaculture sites in Inver Bay Co. Donegal, September 2002. 23pp.

Aquafact 2002b. Environmental surveys of Creevin Salmon Farm aquaculture sites in Inver Bay Co. Donegal, September 2002. 21pp

Aquafact 2002c. Environmental surveys of the Ocean Farm Ltd aquaculture sites in McSwynes Bay Co. Donegal, September 2002. 30pp

Aquafact 2002d, e, f, g. Environmental survey of underneath cage conditions Inver Bay, Co. Donegal. d-August 2002, e-September 2002, f–October 2002 and g-November 2002.

Aquafact 2003a, b, c and d. Environmental survey of underneath cage conditions Inver Bay, Co. Donegal. a-January 2003, b–March 2003 and c-May 2003 and d-June 2003

Aquafact 2003e. Environmental Survey of an Ocean Farm Ltd. Salmon production site in McSwynes Bay Co. Donegal. June 2003. 22pp.

Aquafact 2003f. Sediment Profile Imagery (SPI) – Survey of Inver Bay, McSwynes Bay and Killybegs Disposal Site 12-14 August 2003. 32pp + 5 Appendices.

Halia Oceanographic Consulting Services. 2003. ROV Survey Report. Inver Bay, July 15, 16 2003. 7pp.

CHAPTER 5 ASSESSMENT OF CHEMISTRY AND RESIDUES TEST RESULTS

5.1. Background & approach:

After the initial investigation eliminated disease as the primary cause of the fish kill, the MI investigation was broadened to include detailed chemical analysis of fish, water and sediment samples from the affected sites.

The possibility that a chemical agent was responsible for the fish mortalities was considered from a number of viewpoints. A broad range of chemical testing was initiated to see if residues of any substances that could possibly be implicated could be detected. The difficulties of such testing are that there is no one approach for detecting the 'universe' of chemicals, and the difficulty of distinguishing likely candidate substances from test results. Chemical testing alone cannot provide a basis to rule out all possible chemicals agents. However, testing can be devised to maximise the chance of detecting a causative agent.

The strategy taken in this regard was:

- Consideration and desk review of potential scenarios and information, whereby chemical agents could have given rise to fish toxicity. This included investigation into potential leads and concerns expressed by various interests.
- Arising from these scenarios - testing for residues of specific candidate substances (where possible).
- Implementation of broad range screening tests where possible to try and narrow down potential causative agents (e.g. toxicity testing).
- Testing of a variety of samples and matrices.

The following possibilities were considered specifically from a 'chemistry' perspective.

1) Large release of toxic gas(es) from the benthic environment.
2) Other physico-chemical water quality factors
3) A spill or discharge of a toxic chemical.
4) Potential contamination associated with sediments from Killybegs dredge spoil dumpsite.
5) Toxic biomolecule associated with a Harmful Algal Bloom
6) Misuse or accident with chemical (veterinary) treatment

Several organisations were informally consulted for assistance/information, including FRS Marine Laboratory, Aberdeen; CEFAS, Burnham-on-Crouch; Western Isles Sea Foods, Isle of Lewis; SEPA, Glasgow; MoreNets, Galway; Aquatic Services Unit, UCC and Ecotoxicology Unit, Athlone Institute of Technology. Samples were collected from Inver Bay by MI staff. Further samples were supplied by fish farms themselves and by Veterinary Practitioners.

5.2 Sampling and analysis

A broad ranging test regime was implemented. Sampling of biota and sediment was included as well as water to give the best chance of detecting residues of substances that might indicate a chemical contamination incident. Unidentified samples supplied by fish farms, as well as those taken by MI staff were also included for analysis. Details of samples are given in tables 5.3.1 to 5.3.4. Analysis was carried out at MI laboratories and at contracted laboratories.

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Table 5.3.1 Summary of sampling, analyses and results for water samples from Inver Bay and McSwynes Bay, summer 2003.

Sample Description ***Water Samples***	**Collected by /Received from**	**Date Collected/ Received**	**Analysis**	**Analysis carried out by**	**Outcome**
9 Seawater Samples from Inver Bay	MI	16/7/03	• All samples were sub-sampled and tested for **sulphide**. • 5 water samples were screened for **organic substances** by GCMS. • 3 sub-samples sent for **toxicity testing**	CAL, Dun Laoghaire MI, Abbotstown Enterprise Ireland, Shannon	All samples < LOD (0.1 mg l^{-1}) See appendix 4 for results. Nothing of note identified [Note 1] See appendix 7. Results of toxicity tests demonstrated no toxicity to *Tisbe battagliai* (copepod, Crustacean), *Skeletonema costatum* (alga), and *Vibrio fischeri* (bacterium). See appendix 17.
Seawater Samples	Ocean Farms	31/7/03 collected	• Samples sent for **sulphide** testing	CAL, Dun Laoghaire	All samples <0.1 mg l^{-1} (LOD) See appendix 4
Seawater Samples	MI	1/8/03	• Samples sent for **sulphide** testing	CAL, Dun Laoghaire	All samples <0.1 mg l^{-1} (LOD) See appendix 4
Water samples 5 sites in Mc Swynes Bay, and control sites.	MI	19 / 22 Aug 2003	• Samples sent for **sulphide** testing • Ammonia	CAL, Dun Laoghaire MI Galway	All samples < LOD (0.1 mg l^{-1}) See appendix 4 for results. All samples < 1 _mol l^{-1}. See appendix 7

Note 1: See section 5.3.2 on screening for organic compounds by GCMS

Table 5.3.2 Summary of sampling, analyses and results for tissue samples from Inver Bay and Mc Swynes Bay, summer 2003.

Sample Description ***Tissue Samples***	**Collected by /Received from**	**Date Collected/ Received**	**Analysis**	**Analysis carried out by**	**Outcome**
Fish Tissue: 4 X Mixed tissue, consisting of spleen, kidney and gill tissue (Eany)	Vet Aqua on behalf of MI	24/7/03	• Solvent extract screened for organic substances by GCMS	MI, Abbotstown	Nothing of note identified [Note 1] See appendix 8
Mussels collected from cages	MI	30/7/03 (rec'd)	• Selected Samples for screening for metals (SEPA – using ICPMS, MI – Hg using CVAFS)	MI, Abbotstown	Metals results indicate levels of cadmium, lead and mercury to be similar to background levels for mussels in Irish waters See Appendix 5
Mussels collected from Ocean Farm Smolts Cage	MI	1/8/03	• Marine biotoxin screening of selected samples	MI, Galway	Amnesic Shellfish Poisoning (ASP) and Azaspiracid (AZA) < LoD.

Table 5.3.2 (continued) Summary of sampling, analyses and results for tissue samples from Inver Bay and Mc Swynes Bay, summer 2003.

Sample Description ***Tissue Samples (continued)***	**Collected by /Received from**	**Date Collected/ Received**	**Analysis**	**Analysis carried out by**	**Outcome**
Salmon Smolts –	Creevin Salmon Farm	25/07/03	• Selected samples screened for organic substances by GCMS & Hg using CVAFS) (MI) • Selected samples analysed for veterinary residues(MI) • Selected Samples screened for metals (– using ICPMS, MI – • Further smolt and grower tissue received on 18th September analysed for a range of metals	MI, Abbotstown MI, Abbotstown SEPA , Glasgow MI, Abbotstown	Nothing of note detected [Note 1] See appendix 8 Results showed no veterinary residues at levels of concern. (see appendix 16) Metals results showed levels of no concern. See Appendix 5 Levels of metals at LOD or LOQ for majority of metals. See Appendix 6.
Fish samples	MI / DCMNR / Ocean Farm / Eany Fish	22 /08/ 2003	• Analyses for range of organic compounds. • Veterinary residues	MI, Abbotstown National Food Centre, Castleknock, Dublin CCFRA Technology Limited, Gloucestershire, UK	Screening did not indicate elevated levels. See appendix 8 for results. No residues detected (see appendix 16 for results)

Note 1: See section 5.3.2 on screening for organic compounds by GCMS

Table 5.3.3 Summary of sampling, analyses and results of sediment samples from Inver Bay, Mc Swynes Bay and Donegal Bay, summer 2003.

Sample Description ***Sediment Samples***	**Collected by /Received from**	**Date Collected/ Received**	**Analysis**	**Analysis carried out by**	**Outcome**
Grab samples taken from - DCMNR dumpsite - cages Inver Bay - inner & outer Inver Bay - control Donegal Bay west of dumpsite	DCMNR / MI	13/14 Aug 2003	• Samples sieved, ashed • Samples structurally analysed by scanning electron microscopy (SEM) and X-ray diffraction (XRD)	Ashing and sieving at MI, Abbotstown SEM / XRD at Centre for Microscopy Analysis, TCD	Organic matter/ organic carbon and granulometry results showed nothing unusual. See appendices 9 -12 Results of SEM / XRD show similar geology for all post-ash samples, with exception of sample from nets (Ocean Farm sample) that was composed of shell fragments. See appendix 13
Grab samples taken in Inver Bay	DCMNR / MI	22 Aug 2003	• Samples analysed for granulometry, organic carbon (OC) and loss on ignition (LOI).	Granulometry and LOI at MI, Abbotstown. OC at Alcontrol Laboratories, Dublin	Organic matter/ organic carbon and granulometry results showed nothing unusual. See appendices 9 -12
Sediment samples from McSwynes and Inver Bay.	MI	03 Oct 2003	• Pore waters analysed for toxicity by Microtox test	Enterprise Ireland, Shannon.	Results showed no toxicity in interstitial waters to *Vibrio fischeri* (ie, if anything were bioavailable in pore water, light inhibition would have been detected) See appendix 17.

Table 5.3.4 Summary of sampling, analyses and results for unidentified substances from Inver Bay, Mc Swynes Bay and Donegal Bay, summer 2003.

Sample Description ***Unidentified Samples***	**Collected by /Received from**	**Date Collected/ Received**	**Analysis**	**Analysis carried out by**	**Outcome**
1 unknown material stored in formalin in a plastic container	Vet Aqua	24/7/03	• GCMS analysis of an extract was carried out by the Marine Institute • Sample sent for fatty acid profiling	MI, Abbotstown Teagasc Laboratory Moorpark	Nothing of note identified. Primarily fatty acids and esters. [Note 1] See appendix 8 Fatty acid profile indicates material may have been feed mix.
Unknown material from fish cage in Inver Bay Feed sample (growers) Feed sample (smolts)	MI / DCMNR	22 Aug 2003 01 Aug 2003	• Samples analysed for fatty acid profile.	Reading Scientific Services Limited, Reading, UK	Results indicate that substance was of similar fatty acid composition as grower feed. See appendix 15
Silt sample from nets & black water sample rec'd from Ocean Farm	Moss Veterinary	25/7/03	• Solvent extract screened for organic substances by GCMS	MI, Abbotstown	Nothing of note identified [Note 1] See appendix 8
2 X sediment samples. 1 from fish cage net (Ocean Farm) 1 x residue remaining after the net was put through net washing apparatus.	Ocean Farm	13/14 Aug 2003	• Samples filtered and ashed. Remaining particulates sent for structurally analysis by scanning electron microscopy (SEM) and X-ray diffraction (XRD)	Ashing and sieving at MI, Abbotstown SEM / XRD at Centre for Microscopy Analysis, TCD	Results of ashing show "silt" taken from "black water" to be 100% organic matter. Remainder of ashed sample from nets was composed entirely of mussel shell. See Appendix 5
Sample of black deposit taken from Ocean Farm diver's regulator	MI	11 Sept 2003	• Sample analysed by FTIR and SEM.	Centre for Microscopy Analysis, TCD	Found to be mix of salt, calcium stearate and fungal hyphae. See appendix 14.

Note 1: See section 5.3.2 on screening for organic compounds by GCMS

5.3 Discussion - assessment of chemical testing:

The previous tables 5.3.1 to 5.3.4 summarise the sampling and analyses of water, tissue, sediment and unidentified substances. Full results can be found in appendices 4 to 17.

5.3.1 Hydrogen sulphide & ammonia

Water samples collected at locations in Inver on 16th July, 31st July, 1st August and 19th – 22nd August 2003 were sub-sampled and tested for sulphide using the Lange methods at CAL Laboratories, Dun Laoghaire.

All analyses, carried out at CAL laboratories, indicated that sulphide was not present above the detection limit of 0.1 mg l^{-1} in any of the samples.

Samples taken by MI in McSwynes Bay from 19th – 22nd August were analysed for ammonia at MI Galway laboratories. Levels were found to be low (all < 1 _mol l^{-1}) and typical of that time of year.

5.3.2 Screening for organic compounds by Gas Chromatography Mass Spectrometry (GC-MS) and Gas Chromatography-Electron Capture Detection (GC-ECD)

Gas chromatography (GC) provides a mechanism for the separation of organic mixtures into individual compounds. Mass spectrometry provides spectra based on the molecular structure of the substance. Mass spectra can be computer matched against commercially available mass spectral libraries to assist in the identification of substances. The application of coupled GC-MS provides a powerful technique for separation and identification of unknown substances at relatively low concentrations. However, the application of this technique is limited to volatile and semi volatile, non-polar, thermally stable organic substances. Other substances (e.g. inorganic compounds, polar substances) will not be amenable to and thus are not detectable by this technique.

GCMS gives no information on the potential hazards associated with substances identified in environmental samples, many of which may be analytical artefacts or of natural origin. Experienced assessment is required to determine which substances may be of significance. Qualitative screening was carried out to see if any substance(s) could be identified that would suggest a potential causative agent for these mortalities.

Electron capture detection provides a selective tool with a particularly sensitive response to halogenated substances. Many priority pollutants, for example, organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs -flame retardants), are examples of this group of chemicals, and are often toxic, persistent and liable to bioaccumulate. GC-ECD semi-quantitative analysis was employed to screen for a response for selected substance groups that would be regarded as above the normal range in fish tissue, when compared to routine monitoring results for these substances in fish tissue.

<u>MI Organics analysis:</u>

GC-MS: Available water sub-samples (*circa* 200mls) were extracted with dichloromethane. Sediment and tissue were soxhlet extracted with dichloromethane. Extracts were passed through anhydrous sodium sulphate, concentrated and analysed directly, and/or passed through an alumina column prior to injection on GCMS. The MS was operated in positive electron ionisation mode and scanned from 50-350 amu. Mass spectra were computer matched with the NIST library (*circa* 65000 compounds)

For water, sediment and tissue samples, substances detected were tentatively identified and appeared to be primarily of natural origin or typical laboratory artefacts. On expert review of this list, no substances that would suggest an obvious causative or contributing agent to the fish kill was identified (see appendix 8).

GC-ECD: Further tissue samples were screened using Gas Chromatography – Electron Capture Detection (GC-ECD) for a range of organohalogenated compounds including polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs) and polybrominated diphenyl ethers (PBDEs). The objective was to detect if any of these compound groups fell above the normal range. Samples were extracted using the Smedes method and cleaned–up on an activated alumina column prior to concentration and injection on the GC-ECD. Other wild fish samples (a herring and a cod sample) were analysed concurrently for comparative purposes.

Semi-quantitative screening for persistent organic pollutant (PCB, OCP and PBDE) did not indicate levels of these substances to be elevated (see appendix 8) when compared against MI routine monitoring data for fish (wild and farmed), and data from literature (Green, 2003).

5.3.3 Trace metals

Two smolt tissue samples and 3 mussel tissue samples were freeze-dried and despatched to the Scottish Environmental Protection Agency (SEPA) for Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) testing for trace metals. This provided results for a broad range of metals. Mercury analysis was carried out by MI using Cold Vapour Atomic Fluorescence spectroscopy. Further metal analysis was carried out by MI on salmon smolts received on 18th September. Levels of metals were below the Limit of Detection or Limit of Quantification for the majority of metals. For metals routinely monitored in Irish fish landings, levels were generally within the ranges measured in fish sampled at Irish fishing ports. (MI port sampling and shellfish reports, 1999 - 2002). See appendices 5 and 6 for analyses results.

5.3.4 Veterinary residues

As discussed in chapter 3, farmed salmon may be treated, under prescription, with antibiotics and sea lice treatments. Certain therapeutants are licensed for use on salmon in Ireland. The following antibiotics can be used: oxytetracycline, sarafloxacin and amoxicillin, while authorised sea lice treatments are emamectin benzoate, teflubenzuron and cypermethrin.

Selected samples of salmon smolts and mussel tissue from the Inver Bay area, July 2003 underwent residue testing at MI, Abbotstown laboratory. Two samples were screened for antimicrobials using the four-plate test. This test specifically reports for tetracyclines, nitrofurans, quinolones and sulphonamides, but high levels of other antimicrobials would also show zones of inhibition on the plates. Results for both samples tested were negative.

Testing was also carried out for lice treatments, both authorised and unauthorised (eg. emamectin benzoate, ivermectin, bifenthrin, cyfluthrin, cyhalothrin, cypermethrin, deltamethrin, fenvalerate, fenpropathrin, permethrin, albendezol sulphone, oxfendazole, cambendazole, mebendazole, thiabendazole, abamectin, doramectin, moxidectin, eprinomectin, emamectin).

Results of testing of Inver and McSwynes Bay fish showed no veterinary residues at levels of concern (see appendix 16). Levels of veterinary residues found in the samples analysed here would be reported as negative in the context of the Irish Residues Monitoring Programme, which is in accordance with EU Directive (96/23/EC), i.e. less than an Maximum Residue Limits (MRL) set for authorised substances, or less than an action limit for an unauthorised substance.

MRLs are set only for authorised medicines in Regulation EC/2377/90. Action limits are based on limits of quantification.

5.3.5 Sediment characterisation

Sediment samples were taken from the DCMNR dump-site (See Chapter 8), from Inver Bay, from McSwynes Bay and from reference sites in Donegal Bay. Samples were also provided by Ocean Farm. One of these was a water sample containing a heavy suspended sediment load, sampled on 10th July by Ocean Farm staff, (referred to as "*black wate*" by locals in the Inver area). The other sample, also sampled by Ocean Farm staff, was taken from the bund around the net washer, and was from the sediment that was heavily fouling the nets at that time.

Samples were analysed for organic matter, total organic carbon and granulometry. The dumpsite and reference samples had low organic matter (<4%), while samples near fish cages had concentrations up to 14%. Total organic carbon at dumpsite and outer Inver Bay site were very low (<1%). The highest value found was 3.05%, near cages in McSwynes Bay, which would be expected in such environment. The material filtered from the sample of "black" water comprised 100% organic matter. The material taken from the nets contained 57% organic matter, with the remaining material visually classed as blue shell fragments. (See appendices 9 – 12 for results).

The un-ashed portion of the above samples (sediments less organic matter) were structurally examined by scanning electron microscopy (SEM) and x-ray diffraction (XRD) to characterise the suspended sediment observed on nets/cages in Inver Bay, and to determine if there was any comparability with sediments from the dumpsite. Scanning electron microscopy examines the morphological structure of the specimen in three dimensions. XRD can identify the elemental composition of a sample through diffraction of characteristic x-ray into an energy spectrum. Apart from the samples provided by Ocean Farm, all others were of similar geological origin (see appendix 13 for results)

The microscopy and the x-ray diffraction indicated that the remaining material of the sample taken from the net washer at Ocean Farm consisted almost entirely of calcite, thus confirming initials thoughts that it was entirely made up of shell.

5.3.6 Unidentified Materials

(a) An unidentified white material that was observed and sampled in Inver Bay was solvent extracted. GCMS analysis was carried out and nothing of concern was identified in the sample, the results of which indicated the presence of alkanes, fatty acids and long chain esters (appendix 8). Subsequent fatty acid profiling suggested that the substance might be of feed origin.

Further samples of this substance were analysed and compared to feed samples. The fatty acid profile of the unidentified substance corresponded well (>95% similarity) with the growers feed; the fatty acid composition of both smolt and grower feed, as well as the unidentified sample, were composed entirely of fish oil (see appendix 15 for analysis results).

(b) Black material found in a fish farm diver's regulator, that had not been used since 11th July, was subjected to SEM / Fourier Transform Infra-red (FTIR) and X-ray analysis. FTIR identifies a sample's chemical make-up through the interaction (absorption, intensity and frequency) of infra-red radiation with the sample. Results of the analysis showed the black regions to be due to the presence of fungal hyphae, while significant amounts of material matched reasonably closely to calcium stearate. Calcium stearate is used as a mould release agent, and is likely to have been present since the manufacture of the regulator. Salt was also identified as a component, likely present from seawater (see appendix 14 for results).

5.3.7 Marine toxins

Selected mussel samples from Inver Bay were screened for marine biotoxins. This involved LCMSMS analysis for a standard suite of marine toxins encountered in Irish waters.

Amnesic Shellfish Poisoning (ASP) and Azaspiracid (AZA) were both found to be below limits of detection. Dinophysistoxins were present at levels significant for human consumption of these mussels, but these toxins have not been reported to cause fish kills directly. See appendix 18 for results.

5.3.8 Toxicity Testing

Three water samples collected on the 16th July were sent to Enterprise Ireland, Shannon for a limited range of aquatic toxicity testing. Results showed no toxicity to *Tisbe battagliai* (copepod, crustacean), *Skeletonema costatum* (alga), and *Vibrio fischeri* (bacterium).

In addition, 8 sediment samples collected 3rd October were sent for Microtox testing of sediment interstitial waters. None of the samples elicited a toxic response of any significance to *Vibrio fischeri* (bacterium). See appendix 17.

5.4 Conclusions

An assessment of the results of a broad range of chemical testing did not identify any substance that suggests a potential causative agent that may have contributed to the mortalities in Inver / McSwynes Bay.

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CHAPTER 6 INVESTIGATION OF THE PRESENCE OF HARMFUL PHYTOPLANKTON IN DONEGAL BAY

6.1 Introduction

Phytoplankton blooms are naturally occurring phenomena and simply refer to the proliferation of algal populations in coastal waters. Harmful algal blooms (HABs) are commonly referred to when naturally occurring harmful or toxic phytoplankton species are present in marine or brackish waters. These are usually visible to the naked eye through water discolouration, hence the term, "red tides". Some HAB species can produce toxins that, even when present at low cell concentrations, can contaminate seafood through the filter feeding of bivalve molluscs (Hallegraeff, 2002, Andersen, 1996). Other HAB species can, at high cell densities (100,000s of cells per litre) cause stress to farmed fish by clogging the gills, through gill damage by physical mechanisms or by production of ichthyotoxins (Hallegraeff, 2002). Harmful algae are microscopic plants and while they produce oxygen during daylight through photosynthesis, they respire at night and blooms of these organisms can therefore lead to anoxic conditions and finfish mortalities. Indiscriminate kills of marine organisms can also arise from anoxia caused by bacterial decomposition of a collapsed bloom. Some species, such as *Phaeocystis* spp., produce large amounts of foam or mucilage, which accumulate along beaches (Moestrup & Thomsen, 1995).

A number of HAB species, potentially harmful to finfish, occur naturally in Irish waters and include, *Karenia mikimotoi* (*Gyrodinium aureolum*), *Heterosigma akashiwo* (referred to as "flagellate X" in the past), *Noctilluca scintillans* and *Prorocentrum balticum*. The presence of any of these organisms would generate concern among the Irish finfish industry. Periodical blooms of these organisms occur off the Irish coast and the effects on the aquaculture industry depend on the intensity and length of time these blooms persist.

Karenia mikimotoi was first recorded off the coast of Ireland in the late 1970's when blooms of this organism led to large mortalities of rainbow trout off the south west coast (Doyle *et al*., 1984). Indiscriminate kills of other marine life were also reported (e.g. marine macro-invertebrates and epibenthic fish) off the southwest coast during blooms of *K. mikimotoi* (Ottway *et al*., 1979). This dinoflagellate usually appears in the plankton in May and/or June and if thermally stratified waters and relatively calm weather conditions exist, population increases can be observed in July and August.

Heterosigma akashiwo was the causative organism for finfish kills (trout and salmon) off the west coast of Ireland in the mid to late 1980's (Doyle *et. al*., 1984, McMahon & Silke, 1998). This raphidophyte is euryhaline and eurythermal (i.e. can tolerate a wide range of salinities and temperatures), and blooms of this organism are often associated with low salinity (Symda, 1998, Anderson *et al*., 2001). In Ireland, it generally blooms in autumn (but was observed in high densities in June, 1989) and is always associated with large freshwater influx (G. O'Donoghue, *pers. comm*.).

Prorocentrum balticum, a cosmopolitan dinoflagellate common to both brackish and marine waters, has also been associated with reduced feeding and mortalities in caged fish in Ireland. It is suspected to produce toxins but the nature of the toxicity is unknown. In 1997, fish kills associated with this HAB species were reported along the west and northwest coasts of Ireland (Cusack and Raine, 1997). Caged fish in the vicinity of the bloom exhibited abnormal behaviour (starvation), and in many cases died. The presence of *P. balticum* so late in the year was thought to be the result of high sea surface temperatures that persisted through to October, that year (Cusack and Raine, 1997).

In September, 2003, a *P.* cf. *balticum* bloom was recorded in Lough Swilly (Cusack *et al*., 2003). Although high mortalities of caged fish in the area were not experienced, some fish were reported to be stressed and off their food (C. McManus, *pers. comm*). In October 2003, *P.* cf. *balticum* was also recorded in the brackish waters of Lough Furnace in Clew Bay (west coast). No fish were being cultured in the cages in the vicinity of the bloom at this time (Cusack *et al*., 2003).

Noctiluca scintillans, a hetertrophic dinoflagellate, frequently blooms off the Irish coast, e.g. Irish Sea in the summer months, (Cusack *et al*., 2002). This organism has been implicated in fish kills in other parts of the world and can cause irritation to cultivated fish by mechanical clogging of the gills (Anderson *et al*., 2001). When the bloom subsides and the cells begin to breakdown, ammonium is released which can cause additional stress to the fish (Hallegraeff, 2002).

The raphidophyte, genus *Phaeocystis* is common component of the phytoplankton in Irish waters during early summer. This organism can irritate the gills of fishes, although there have been no reports of fish kills to date. The current Marine Institute Phytoplankton Monitoring Programme focuses for the main part on the identification of all potentially toxic phytoplankton and problematic species.

The Marine Institute (MI) therefore investigated the possibility that a phytoplankton event may have been the cause of the fish mortalities in Inver Bay.

6.2 Materials and Methods:

Integrated water samples were collected using a 15 m length "Lund tube" at Ocean Farm, Inver Bay on the 24th June, 26th June, 30th June, 9th July and 16th July for phytoplankton analysis by staff at MI, Galway (see figure 6.1). Additional samples were also collected at a depth of 15 metres at this location at hourly intervals from 10:30 to 19:30 on the 11th July. On the 16th July, water samples were collected by MI staff using vertical plankton net hauls (20um mesh, 0.3 m net mouth diameter) to a depth of 14 m, and by divers at discrete depths. Further sampling was carried out throughout the survey area by MI staff on 31st July, 1st August and 13th August. This included the collection of integrated (15m) and discrete water samples (0m). Figure 6.1 presents the locations of stations sampled in Inver Bay.

After collection the water samples were preserved in Lugol's iodine. On arrival to the MI Phytoplankton laboratory the samples were allowed to settle overnight (>12 hrs) in 25 mL sedimentation chambers before analysis was carried out. Phytoplankton cell numbers were counted using a modified version of Utermöhl's method (Hasle, 1978). This was carried out under phase contrast light microscopy (LM) using a Olympus IMT-2, a Olympus 1X50 or a Nikon TMS inverted LM (Light microscope). Net samples were also examined under an inverted LM and the relative percentage abundance of phytoplankton species present was determined by counting all identifiable phytoplankton species in a drop of sample placed on a glass slide.

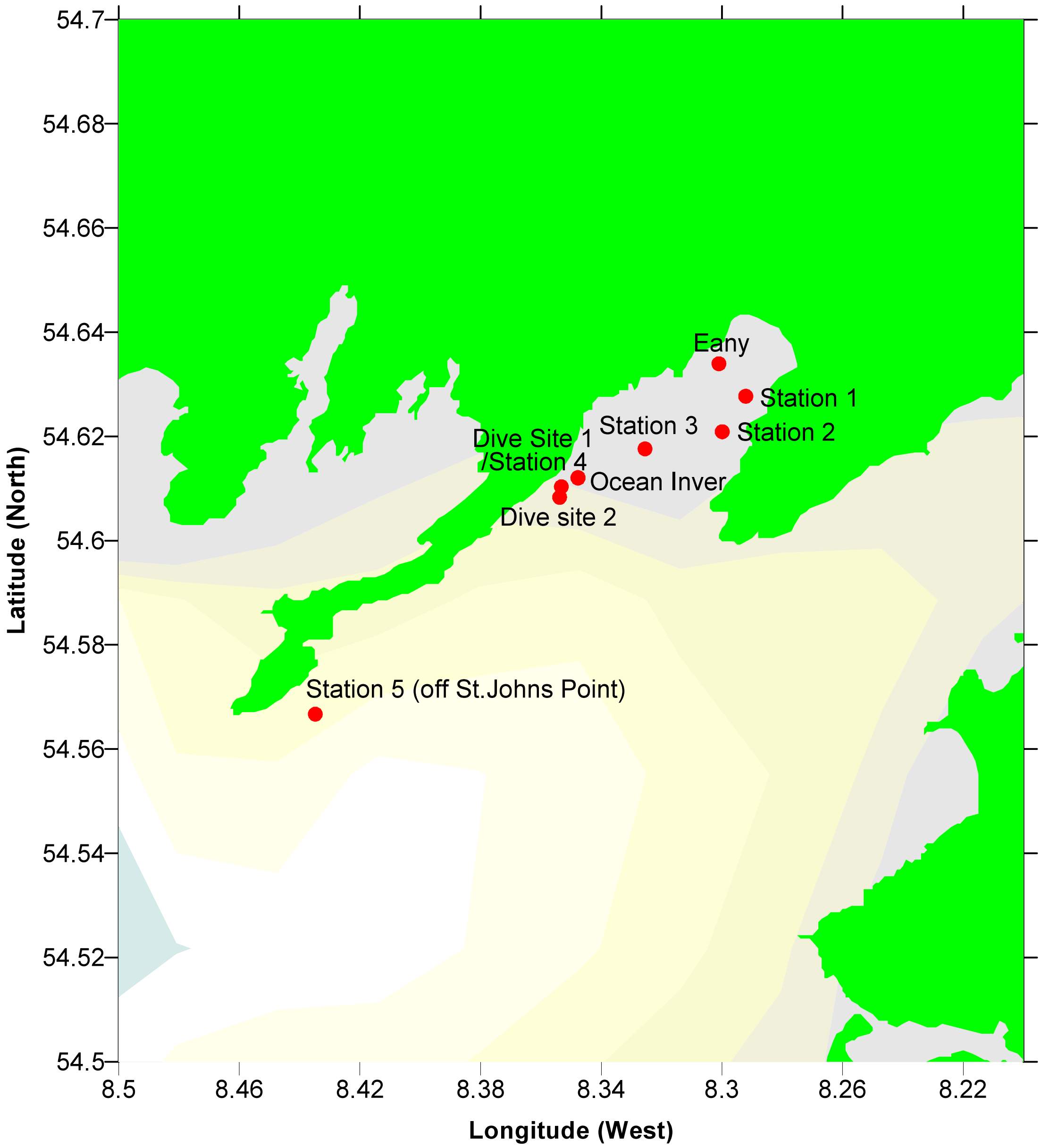


Figure 6.1. Location of stations sampled for phytoplankton in Inver Bay, 16th July, 2003.

6.3 Results

In general, diatoms were widely distributed throughout the sample area. The summer diatom, *Leptocylindrus danicus* was the predominant phytoplankton species in the discrete samples collected at Ocean Farm, Inver Bay over the course of the investigation. Highest recorded cell concentrations of this organism was 250,000 cells.L^{-1}.

Net samples examined from the 16th July showed that this diatom was the most relatively abundant organism at the inshore stations (1 and 2) making up >45% of the phytoplankton assemblage. Although this diatom was observed in both inshore and offshore waters, a species succession was evident from the sites situated at the inner part of the bay to further offshore. At Station 3, the net samples were predominated by the diatom *Thalassionema nitzschioides* (~ 40 % of the sample) and further offshore at stations 4-5 the diatom *Proboscia alata* made up ~ 65% of the net sample examined.

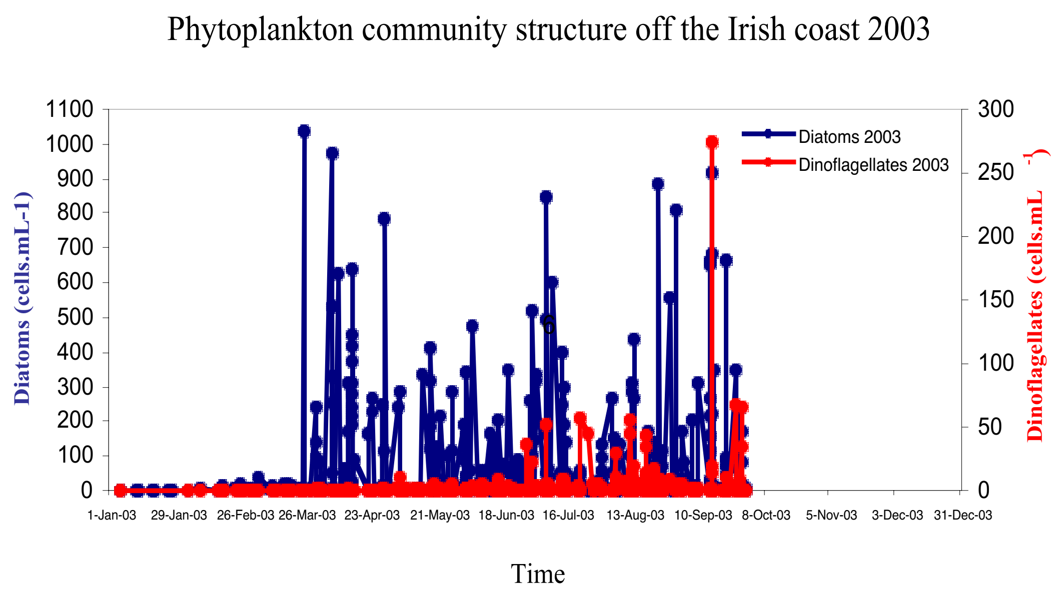
It is worth noting that *Amphidoma caudata,* a dinoflagellate associated with thermally well stratified water (McDermott, 2002) was evident in samples collected at the end of July beginning of August when thermal stratification of the water column was well established in the area (see Chapter 2).

Discrete water samples collected at the surface and at depth just above the sediment on the 16th July did not show any evidence of a surface or collapsed phytoplankton bloom. In addition to this there were no visual reports of discoloured water in the vicinity of Ocean farm.

The additional samples taken at the end of July/beginning of August showed that a healthy population of diatoms, with background levels of summer dinoflagellates, was present in Inver Bay (Figure 6.2).

Low cell concentrations (80 cells.L^{-1}) of *K. mikimotoi* were recorded in samples from the Ocean Inver site in March, and in samples from McSwynes Bay on 19th May (40 cells.L^{-1}) and 17th June (80 cells.L^{-1}) (Figure 6.3). Low cell concentrations (40-80 cells.L^{-1}) were also recorded in samples collected in Inver Bay on 16th July and 13th August and in McSwynes Bay on 22nd August (120 cells.L^{-1}). Cell concentrations of *K. mikimotoi* recorded in samples from sites off the Donegal coast were much lower then those recorded from other sites around the Irish coast in 2003 (Figures 6.3 & 6.4).

Note: Phytoplankton cell concentrations recorded in all samples (discrete depths, integrated and net samples) collected in Inver Bay from the 24th June to 1st August, 2003 are presented in Appendix 20. Phytoplankton data used to generate the figures below can be obtained on request from the Marine Institute.



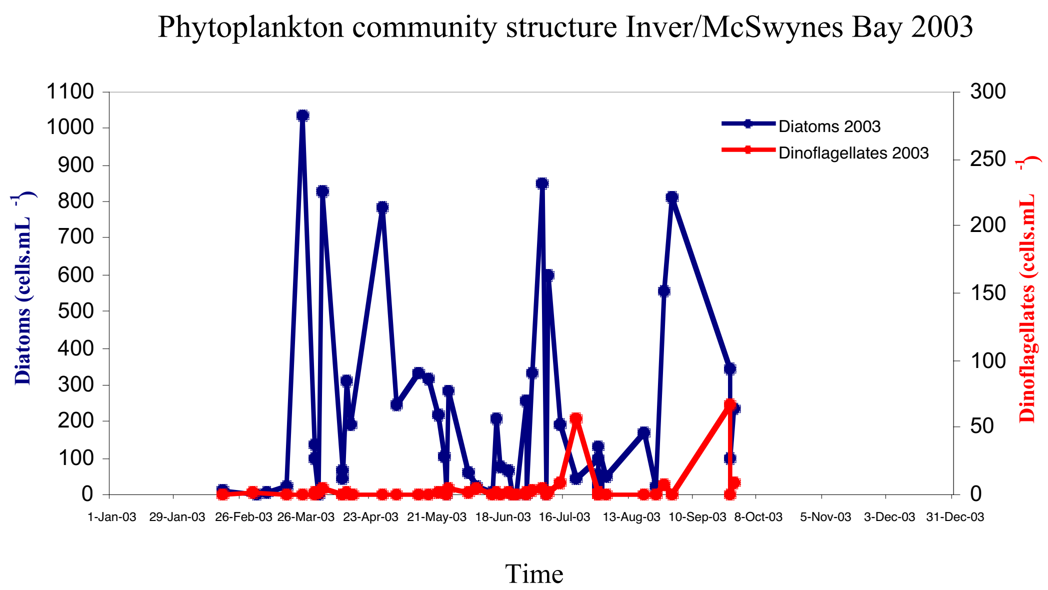


Figure 6.2. The above graphs show the comparison between the phytoplankton structure (total dinoflagellate and total diatom) both nationally and in the Inver/Mc Swynes area. The similarity can be seen in the diatom numbers that increase in spring and persist through the summer. Dinoflagellates are present at lower levels and increase towards the middle of summer. The cell counts are similar between both graphs and overall it would appear that diatom and dinoflagellate communities in Inver/McSwynes are typical, in both succession and intensity, of the national picture.

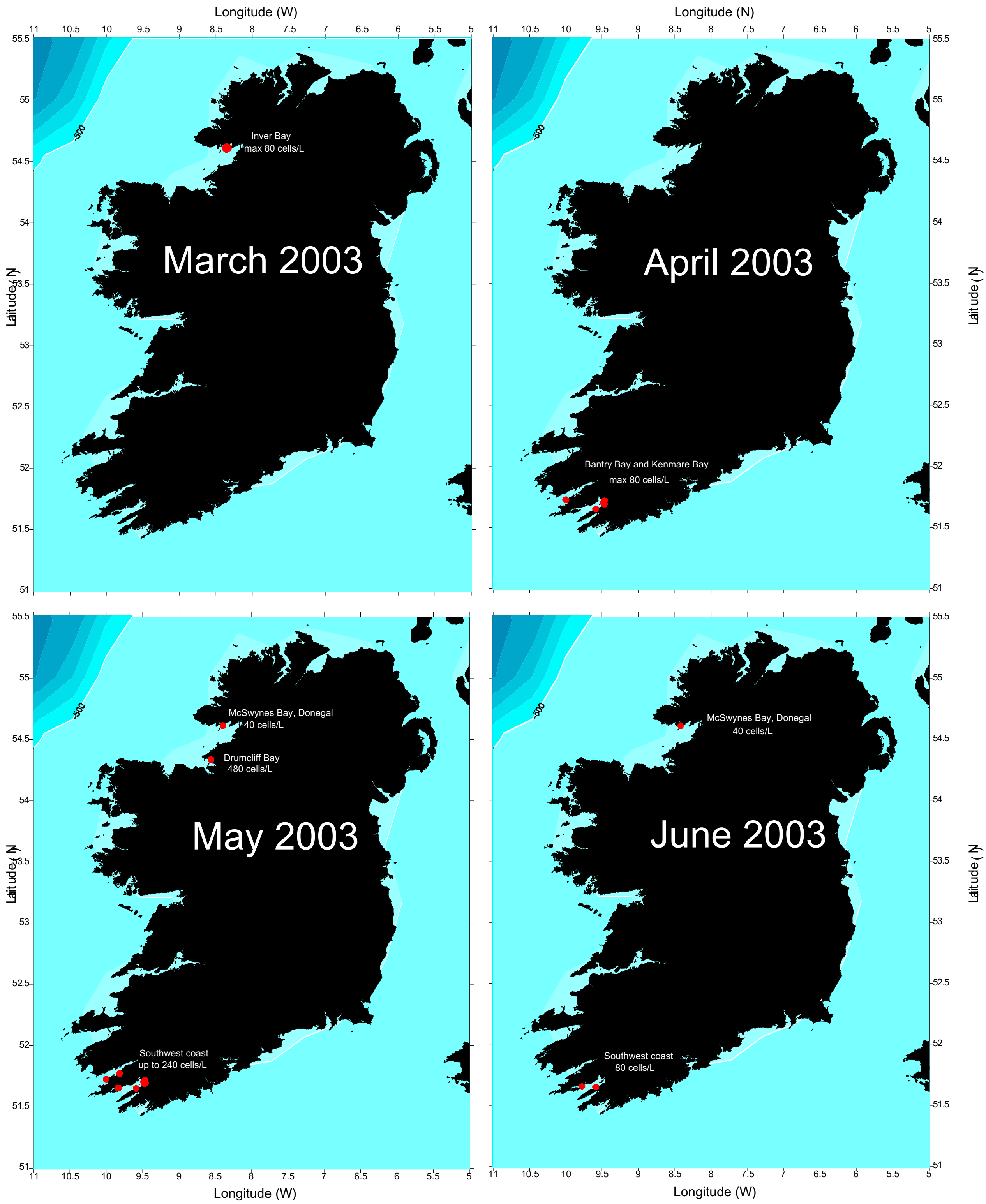


Figure 6.3. The maps plotted above show the distribution of the problematic dinoflagellate, *Karenia mikimotoi* off the Irish coast, from March-June 2003.

Figure 6.4. The maps plotted above show the distribution of the problematic dinoflagellate, *Karenia mikimotoi* off the Irish coast, between July-September 2003.

6.4 Discussion:

Water samples examined by MI from Inver Bay from 24th June to 1st August, 2003 showed a mixed population of diatoms and dinoflagellates, typical of midsummer phytoplankton populations in Irish coastal waters (see Figure 6.2). The water samples showed no evidence of a harmful algal bloom.

In support of this, a survey carried out by the Environmental Protection Agency in an adjacent bay (McSwynes Bay, Co. Donegal) on 10th July showed a phytoplankton assemblage similar to that recorded at Inver Bay (S. O'Boyle, EPA, *pers. comm*..).

Phytoplankton monitoring in the last week in June and the first week in July 2003 did not reveal any significant numbers of potentially toxic algae in Inver Bay. While algae were seen microscopically in gill squashes (M. Gallagher pers. Comm.), and algal remnants were only reported in a small number of histological samples (Vet Aqua International personal communication) the amount of phytoplankton cells noted did not appear to be in sufficient numbers to have caused this severe mortality event (M. McLoughlin *pers. comm*.).

Potentially harmful phytoplankton species that have been implicated in fish kills in Irish waters in the past include *Karenia mikimotoi*, *Heterosigma* akashiwo, Prorocentrum *balticum* and *Noctiluca scintillans* (Ottway *et al.* 1979, Cusack and Raine, 1997). Although *Karenia mikimotoi* was observed in Inver Bay and McSwynes Bay in 2003, levels recorded by MI (< 100 cells.L^{-1}) would not be considered harmful to fish.

Mortalities associated with a bloom of *Karenia mikimotoi* were observed in the Orkney Islands, Scotland in summer 2003. The cell counts at the surface were in the order of 18 million cells.L^{-1} with clear water discolouration observed (ref Eileen Bresnan FRS Lab Aberdeen). Symptoms displayed by fish in stress as a result of the *K. mikimotoi* bloom in Scotland, summer 2003, are quoted as follows: "*The salmon weren't feeding, staying low down in the cage below the algae. Some were jumping more that usual. Ill effects on the fish were: pale gills, hemorrhaging on the outer edges of the gills, gills full of mucous. There was a higher frequency of smaller fish killed. Those that died had nothing in their stomachs"* (H. Irvine cited in E. Bresnan (FRS) Pers. Comm., 10th October 2003).

Samples were taken by MI using a Lund Tube. This method offers the advantage of sampling the top 15 metres of the water column, giving an integrated sample of the photic zone where most phytoplankton are present. The sampling method would however underestimate cell counts of a thin dense layer should it be present. If, for instance a metre deep subsurface layer of *Karenia* was present at 1 million cells.L^{-1} in this layer, it would be observed in the integrated sample at approx. 66 thousand cells.L^{-1}. Even a 10 cm thick layer of 1 million cells.L^{-1} would appear in the integrated sample at a level of several thousand cells.L^{-1}. No such levels were recorded in the samples presented to the Marine Institute between June/July or from the Inver/Mc Swynes area in 2003.

While the samples taken through the month of June and July did not contain appreciable levels of harmful species, it must be stated that it is impossible to rule out the possibility of a missed event between sample dates. While this is feasible, it would be unusual to have such a catastrophic event at the cages without (a) dramatically discoloured surface water, and (b) shore invertebrate mortality reports

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CHAPTER 7. INVESTIGATION OF THE PRESENCE OF SIPHONOPHORES (JELLYFISH) IN DONEGAL BAY.

7.1 Introduction

There have been several references to jellyfish swarms causing mortalities to caged finfish in recent years in the summer months. Jellyfish and siphonophore species that have been associated with fish kills in recent years include *Solmaris corona*, *Apolemia uvaria* and *Muggiaea atlantica* among others (International Foundation of the Conservation of Natural Resources - Fisheries Committee Webpage Posted 9/6/01, Marine Institute, 1998, BMLSS (British Marine Life Study Society) Webpage Posted 7/8/2002, Båmstedt *et al*. 1998).

In 2002, the British Marine Life Study Society (BMLSS*)* reported "An invasion of tiny (12-15 mm) jellyfish has killed about 900,000 salmon at two fish farms in Loch Erisort on the Isle of Lewis in the Outer Hebrides. The offending deadly organism travelling like large 15 metre deep clouds through the sea have been identified as the narcomedusan, *Solmaris corona*."

The *IFCNR-Fisheries Committee* referring to salmon mortalities in The Shetlands and the Scottish Highlands in 2001, stated "The latest theory from Scotland is that the fish killed during the initial wave of algae blooms (approximately 300,000 from three different farms) actually died from reactions to jellyfish stings. Tests on the dead fish appear to confirm that scenario. According to Dr. Alan Brown of Highland Fish Farmers, a tiny larval jellyfish stung the fish triggering massive histamine reactions that caused the deaths."

Similarly, in 2002, mortalities of >100,000 farmed salmon in Norway were associated with the presence of the siphonophore, *Muggiaea atlantica*. Typical concentrations of this animal recorded at the time was in the order of 2 individuals.L^{-1} or 2 000 individuals.m^{-3} (J. H. Fosså, pers. Comm..). Vertical distribution of *M. atlantica* at salmon cage sites at the time showed that this animal could be found at higher concentrations in thin layers, at depths between 5-12 m, above where the salmon were swimming (20 m). At these depths (5 to 12 m) highest densities of *M. atlantica* recorded were in the order of 5,000 individuals.m^{-3} (Fosså *et al*., 2003).

Details on the pathology observed at the time are quoted as follows:
"In the late summer and early autumn of 2002, sudden acute losses were recorded in fish farms on the Western coast of Norway. The National Veterinary Institute, Bergen received large numbers of samples from affected fish farms. Water temperatures had been unusually high for several weeks with measurements up to 20ºC at 20 m depth at several locations. In this period, large numbers of the siphonophore, *M. atlantica* were observed in water samples by the Institute of Marine research. (see Figure7.1 below).

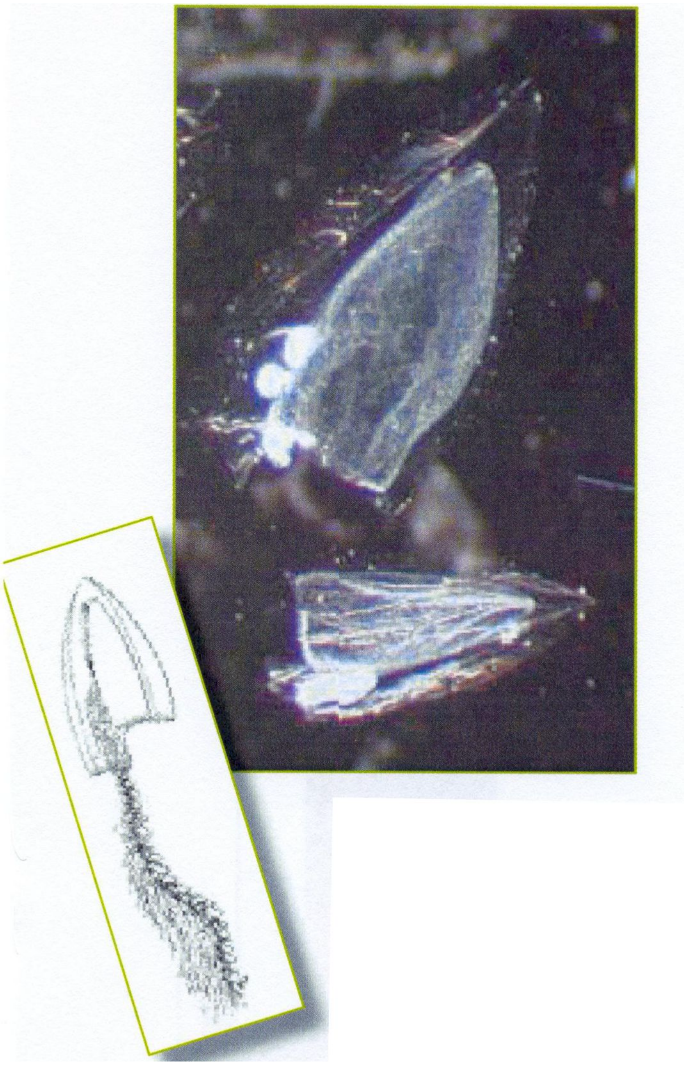

Figure 7.1 An example of *Muggiaea atlantica*, found south of Bergen, Norway in summer 2002. (*From Fossa et al, 2003.*)

Muggiaea atlantica is a warm water species and has not been observed in such large numbers in Norwegian waters before. The minute jellyfish (1-2 mm) may cause stinging in swimmers, but has not been reported to cause damage to fish.

Post mortem examination of affected fish revealed haemorrhage and mucosal damage in the buccal and branchial cavities, on the gills and on the medial side of the operculum. Macroscopically, gills appeared swollen with pinpoint haemorrhages and small, white areas. Histopathological examination of organs from affected fish showed acute to subacute gill damage. The respiratory epithelium was usually intact, but extensive haemorrhages were observed in the lamellae, along with large numbers of eosinophilic granule cells (mast cells) in the filaments. Comparable gill histopathological changes have not been observed earlier, and were in several cases associated with observations of *M. atlantica* in water samples from the affected fish farm. This implies a possible connection between the presence of *M. atlantica* and the observed losses and pathology." (Helleberg *et al*., 2003).

7.2 Materials and Methods

Bodies and stomach contents of fish from Inver Bay and McSwynes Bay were examined to investigate the possibility of damage by or ingestion of harmful organisms e.g. jellyfish (in particular *Solmaris corona, Apolemia uvaria* and *Muggiaea atlantica*) or other zooplankton. Samples were taken 31st July and 12th September.

The Marine Institute, reanalysed vertical phytoplankton net haul samples taken in Inver Bay on the 16th July 2003 and in McSwynes Bay on the 22nd August 2003 to investigate if siphonophores were present (see Figure 7.1 for station positions). It should be noted that the sampling methodology was designed for phytoplankton (Chapter 6) and not specifically for zooplankton and that horizontal net tows were not carried out at selected depths beneath the water surface. Discrete samples collected to investigate the phytoplankton community structure could not be reanalysed for siphonophore species (spp.) or jellyfish because of the nature of the sampling methods used.

An aliquot of each net sample (30 mL) was examined under a dissecting LM and the presence/absence and semi-quantitative estimates of Siphonophore/jellyfish spp. were calculated (Table7.2).

The Marine Institute has also carried out sampling and analyses of plankton (zoo- & phyto-) at a number of other salmon farming sites in the southwest of Ireland in autumn 2003. These sampling events were coincident with observed salmon mortalities showing similar gill pathology to that seen in Donegal Bay (MI, in prep.). The Marine Institute is in the process of carrying out a national review of salmon mortalities at finfish farms, at the request of the DCMNR.

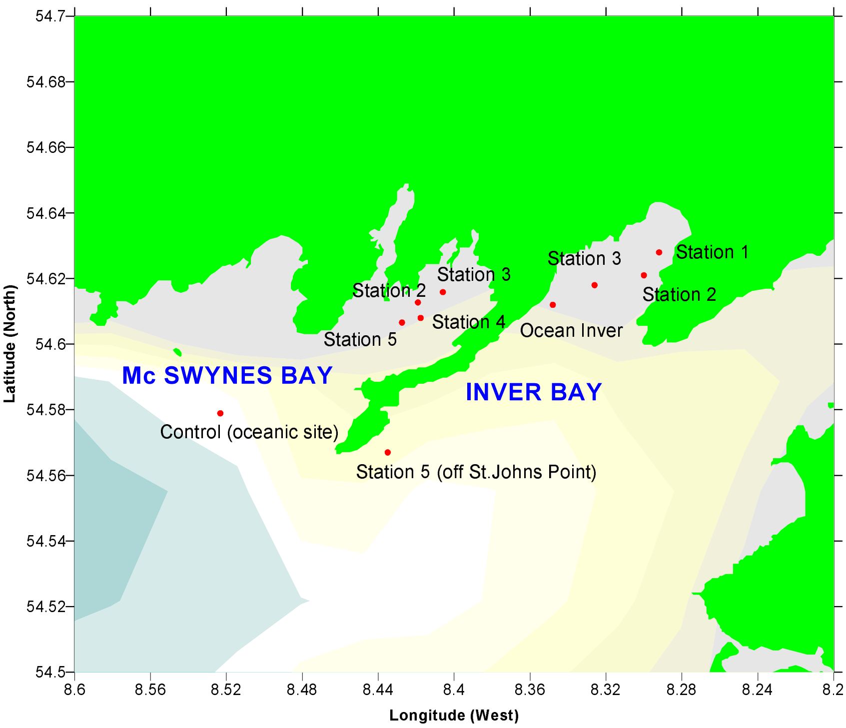

Figure 7.1. Location of stations sampled for phytoplankton (re-examined for the presence of jellyfish/siphonophores) in Inver Bay, 16th July, and M^{c}Swynes Bay, 22nd August, 2003.

7.3 Results

No external damage was observed on any of the fish samples examined. Gut analysis of fish sampled late July showed empty stomachs and little faecal matter in the intestines. Fish samples in September displayed stomachs full of oily feed pellets with no plankton or jellyfish. No physical evidence of jellyfish was found on the gills of either batch of samples (McCormack, *pers. comm.*).

Jellyfish species noted in the samples included *Sarsia* sp., and *Obelia.* The siphonophore, *Muggiaea* spp. were the most abundant siphonophore in the samples examined from Inver Bay and McSwynes Bay. Semi-quantitative counts of *Muggiaea* spp.are presented in Table 7.1.

Table 7.1. Semi-quantitative counts of the siphonophore, genus, *Muggiaea* (tentatively identified as *M. atlantica*) from samples collected using phytoplankton nets off the northwest coast in July and August 2003 (analysis carried out by B. O'Connor, Aqua-Fact). See Figure 7.1 for station positions.

NW coast
Mesh size: 20 micrometer
Net mouth diameter: 0.3 m
VPH depth: 14 m
Sample fixed in Lugols Iodine

Bay	Date	ref. no.	Station	individuals.m^{-3}	individuals.L^{-1}
Inver	16-Jul-03	Phy0330004	Station 1	42	0.04
Inver	16-Jul-03	Phy0330005	Station 2	0	0.00
Inver	16-Jul-03	Phy0330007	Ocean Inver	8	0.01
Inver	16-Jul-03	Phy0330009	Station 5	34	0.03
Inver	16-Jul-03	Phy0330010	Station 3	34	0.03
McSwynes	22-Aug-03	Phy0335025	Station 3	42	0.04
McSwynes	22-Aug-03	Phy0335027	Station 2	0	0.00
McSwynes	22-Aug-03	Phy0335029	Station 4	8	0.01
McSwynes	22-Aug-03	Phy0335031	Station 5	152	0.15
McSwynes	22-Aug-03	Phy0335033	Control	160	0.16

7.4 Discussion

Retrospective analysis of phytoplankton samples indicated the presence of *Sarsia* sp., *Obelia,* and the siphonophore, *Muggiaea* spp.. *Muggiaea* were the most abundant siphonophore found. No information can be found on the contribution of *Sarsia* or *Obelia* to fish kills. *Muggiaea* spp., however, have been associated with fish kills in recent years.

The genus, *Muggiaea* is well documented off the Irish coast (West and Jeal, 1970; Boyd *et al.* 1973; O'Connor, 1973). It has been recorded throughout the year in Galway Bay with highest numbers (ca. 200 *Muggiaea*.m^{-3}) recorded in November (O'Connor, 1973). Similar densities for siphonopores (mixture of *Muggiaea, Lensia* and *Agalma)* were recorded in September 2000 off Keeraun Point, Galway Bay (Aqua-Fact, 2000). Kirkpatrick and Pugh (1984) record *Muggiaea* as being common in coastal European waters. (See 2003 report by O'Connor.)

In Inver Bay, during July and August 2003 numbers of *Muggiaea* species ranged between 0-160 individuals.m^{-3} (please note that these are estimated concentrations). It should be noted that the plankton sampling in Inver Bay at the time of the mortalities was not carried out with zooplankton in mind, instead the target organisms were phytoplankton. Thus, the use of a 20 um mesh net is likely to have greatly underestimated zooplankton numbers owing to the reduction in flow-through caused by clogged mesh. It is also possible that the method used to collect the phytoplankton samples may have damaged delicate siphonophore spp. if they were present. In Irish waters, normal densities of siphonophores from the genus *Muggiaea* would be in the order of 150 individuals.m^{-3}. Exceptional densities of these animals would, however, be in the range of ca. 1,000 individuals.m^{-3} (B. O'Connor, Aqua-Fact, *pers. comm.*).

Finfish mortalities attributed to this siphonophore (at ca. 2,000 individuals.m^{-3}) were recorded in Norway in 2002 (J. H. Fosså, *pers. comm.*). The gross pathology and buccal erosions observed in south Donegal showed similar pathological findings to those reported off the southwest coast of Norway in 2002, however, some of the insult to the fishes gills such as the stripped gill epithelium and exposure of primary lamellae cartilage in discrete patches was unique to fish samples examined in Donegal Bay (see Chapter 3, Helleberg *et al*. 2003, H. Rodgers *pers. comm.*).

Although the siphonophore, *Muggiaea atlantica*, was associated with the Norwegian incident, where > 1,000 tonnes of salmon mortalities were recorded, this was not confirmed conclusively (Helleberg *et al*., 2003). Fish cages with dirty nets in Norway at the time of the mortalities were least affected (Fosså *et al*., 2003). This trend is similar to that observed in Inver Bay.

Although jellyfish were not noted at the time of the fish mortalities in Inver Bay, reports of stings and skin irritations were noted (M. Cronin, *pers. comm.*). During the bloom of *M. atlantica* in southern Norway in 2002, people and fish were stung and the affected salmon exhibited a similar behaviour to when these fish are exposed to the larger siphonophore called *Apolemia uvaria* (Fosså *et al*., 2003).

7.5 References

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CHAPTER 8 REVIEW OF KILLYBEGS HARBOUR DREDGE AND DISPOSAL OPERATIONS 2002

8.1 Introduction

This part of the report focuses upon:

(a) the assessment of sediments from the Killybegs Harbour Development which were to be dredged and disposed of at a designated site south of Teelin (see figure 8.1 below)

(b) the monitoring reports presented for the spoil site in Donegal Bay and

(c) the SPI survey carried out in Inver and McSwynes Bays and at the spoil site in August 2003.

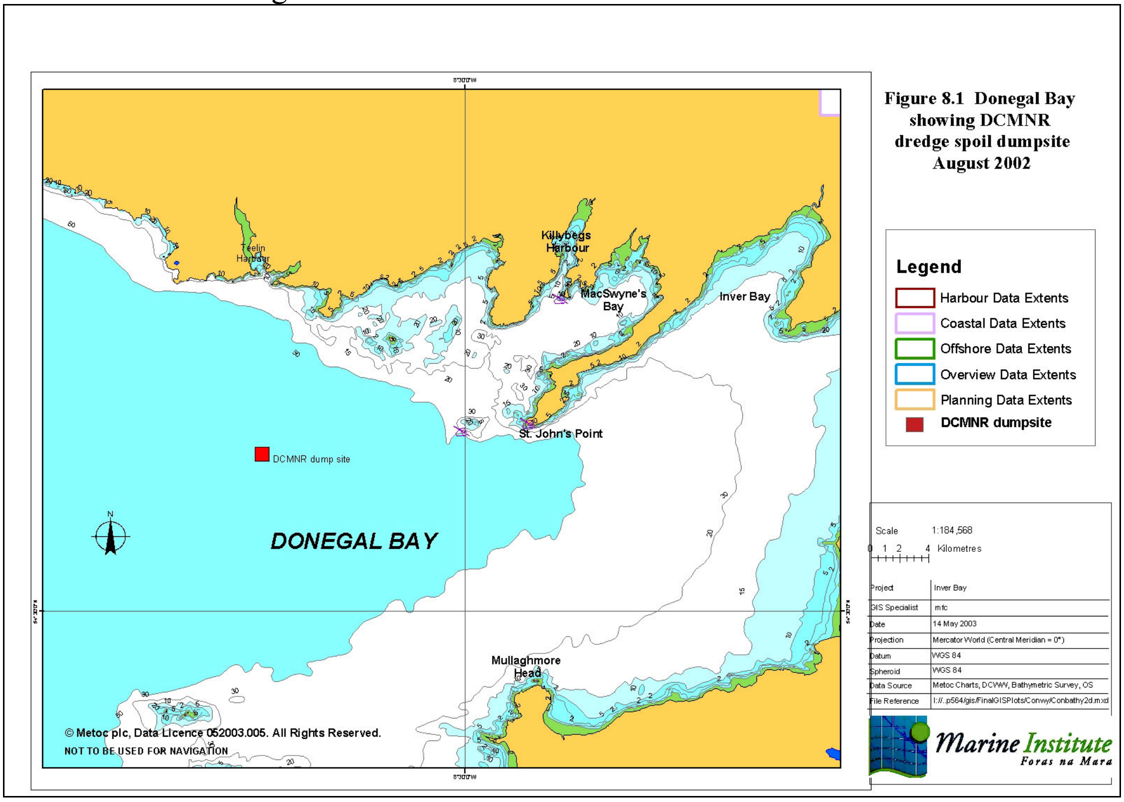

Figure 8.1 Map of Donegal Bay showing location of DCMNR dumpsite south of Teelin.

Applications for Dumping at Sea permits for dredge spoil, are subject to rigorous evaluation before a permit is granted. All applications for Dumping at Sea permits are processed by DCMNR in consultation with the Minister for the Environment, Heritage and Local Government, and with the Minister for Enterprise, Trade and Employment, and any other body that the Minister considers appropriate. The Minister for Communications, Marine and Natural Resources may decide to grant or refuse to grant a permit.

The decision takes account of the recommendations of the Marine Licence Vetting Committee (MLVC) - a multi-disciplinary committee composed of representatives of the DCMNR, MI, Central Fisheries Board and Marine Survey Office. The MLVC has expertise in fisheries, biology, chemistry, oceanography, navigation and engineering disciplines and assesses all permit applications prior to making a recommendation to the Minister.

The assessment of applications to dump at sea is carried out under the strict criteria laid down under the OSPAR Convention as set out in the First Schedule to the Dumping at Sea Act, 1996. Briefly, those criteria are:

- the availability, or otherwise, of suitable land-based alternative disposal options or there being other possible beneficial uses of the material (e.g. land reclamation, beach nourishment, etc.)
- the characteristics and composition of the material to be dumped
- the characteristics of the dumping site and method of disposal
- potential interference with other legitimate uses of the area including fisheries, aquaculture, areas of special scientific importance, areas of wildlife importance, recreation, navigation and shipping both from the dumping and dredging aspects of the proposed project
- proper certification of the disposal vessel and crew; and
- potential impact on the marine ecosystem

All of the above were taken into account in the Environmental Impact Assessment of the development.

8.2 Chronology of the Killybegs Harbour dredging and disposal operations

January 2000	*- Initial sediment sampling for dredging of Killybegs Harbour carried out under advice of MI Senior Chemist.*
April 2000	*- Additional sediment sampling to further examine elevated values found.*
July 2000	*- Supplementary grab and borehole samples taken to delineate problem area.*
June 2001	*– Baseline Benthic survey carried out in vicinity of dumpsite.*
May 2002	*– Baseline water quality sampling.*
July 18- August 2, 2002	*– Dredging and disposal operations carried out*
July 18- August 2, 2002	*– Water quality monitoring during operations*
August 21-22, 2002	*– 1st Benthic sampling post-dumping*
October 2002	*– Report of 1st Benthic survey submitted to Department of Communications Marine and Natural Resources (DCMNR)*
December 12-13, 2002	*– 2nd Benthic sampling carried out.*
April 2003	*– 2nd Benthic Report Submitted*
August 2003	– SPI Survey of Inver Bay, McSwynes Bay and Spoil Site - Monitoring Results and Overview submitted by Kirk-McLure-Morton (KMM) to DCMNR and forwarded to MI - *3rd Benthic sampling carried out*
September 2003	*- 3rd Benthic Report Submitted*

8.3 Dumpsite selection

A dredge spoil dumpsite was chosen by DCMNR following consultation with the Killybegs Fishermen's Organisation (KFO) and local aquaculture groups, including those operating in Inver and McSwynes Bays. Three sites were originally suggested by the KFO. Each was investigated for potential impacts on the marine environment and on fish farms in the Donegal Bay area.

The site south of Teelin was eventually selected on the grounds that:

- it was reported as an area not usually fished owing to hard ground (fast) on the western side
- it was located within an area of low hydrodynamic activity.

It was, therefore, unlikely to be disturbed by fishing activity, and extremely unlikely to be resuspended by current or wave action.

A multi-beam bathymetric survey of the area was carried out by the Geological Survey of Ireland (GSI) and Marine Institute as part of the National Seabed Survey in October 2002. The acquired data showed the site to be reasonably flat ground, with depths between 66.5m and 68.5m CD.

The following (Figure 8.2) shows the backscatter plot of the dumpsite. This gives an indication of the hardness of the seabed. The harder a substrate the greater the reflectivity. The site can be seen to be fairly uniform in substrate.

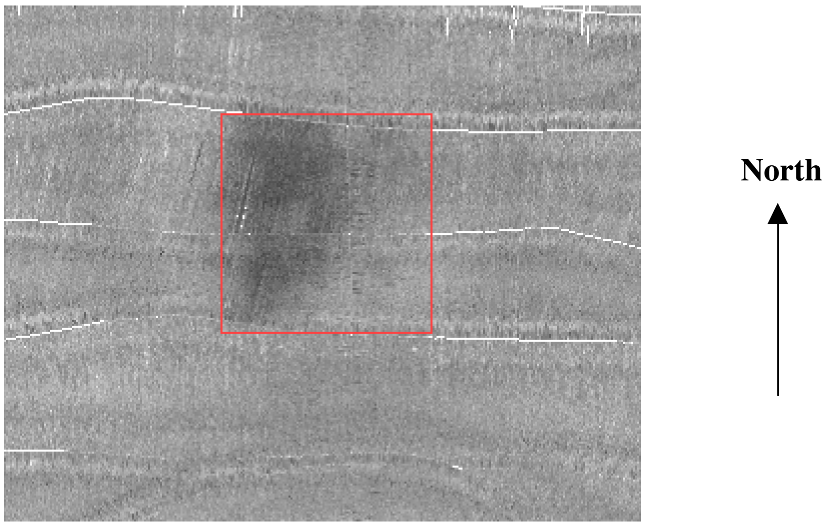

Figure 8.2 Plot of back-scatter for DCMNR dumpsite in Donegal Bay, October 2002 (courtesy of MI/GSI). The red rectangle indicates the outline of dumpsite.

Grab samples taken at the dumpsite confirmed it to be predominantly sand. The area of darker shading seen on the western part of the dumpsite signifies harder ground than the surrounding lighter coloured areas. While this may be rock, the uniformity of the depths indicates that it is more likely to be gravel or hard sand.

8.4 Assessment of Killybegs Dredge Material

In total, 333,000 m^3 of material was required to be dredged from Killybegs Harbour in order to facilitate the building of a new quay. It was agreed that the vast majority (230,000 m^{-3}) of dredged sediments (composed of sands, gravels and boulder clays) could be incorporated into the building of the new quay, but the remaining 103,000m^3 of silt would require a Dumping at Sea Permit as silt lacks engineering properties.

Initial sediment sampling took place in January 2000 at 18 surface sites, under instruction from MI. Analyses, carried out by a UKAS accredited laboratory, included granulometry, heavy metals, organotins, organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs). Results of the analyses indicated areas of organotin and heavy metal contamination, especially in the vicinity of the synchrolift. Although the presence of OCPS and PCBs would generally be anticipated in sediments from more developed harbours, concentrations were below limits of detection (LoD) for these analyses.

Additional sampling at the above stations took place in April 2000, but at greater depth. These samples were analysed for the same determinands as the previous samples. Again elevated concentrations of heavy metals and organotins were detected in areas, and concentrations of OCPs and PCBs were below limits of detection.

Further surface grab sampling and borehole drilling was carried out in July 2000 in an attempt to further delineate the problem areas. These samples were analysed for heavy metals and organotins but not for OCPs or PCBs, the previous analyses having indicated no organic contamination.

Sediment chemistry was assessed by MI against provisional Irish action levels, in use at the time for assessing suitability of dredge spoil for disposal at sea. These provisional levels are comparable with action levels for many other European countries, eg Norway, Netherlands and UK. Based on the cut-off levels in these guidelines, few samples would have exhibited contaminant concentrations where disposal at sea would be prohibited.

A total of 126 samples were analysed. The following table summarises the sediment chemistry for those samples exceeding the provisional Irish action levels.

Table 8.1 Summary of sediment chemistry for those samples exceeding Provisional Irish Action levels, in use at time of chemistry assessment (Data from Kirk McClure Morton, 2000)

Parameter	**Cut-off for sea disposal (Prov. action level 3) mg kg^{-1}**	**Values exceeding cut-off mg kg^{-1}**	**Depth & origin of samples exceeding cut-off**
Arsenic	80	0	
Cadmium	3	0	
Chromium	300	308	1m at Station 2, beside synchrolift
Copper	100	183, 248	0.5m & 1m at Station 2, beside synchrolift
		106	Surface at Station 4 on Rough Point
Nickel	200	0	
Lead	400	0	
Mercury	0.5	0.52	0.5m at station 8 near channel
Zinc	700	0	
Tributyltin	0.5	0.71	0.5m at station 1, beside synchrolift
		1.5 & 5.1	0.5m & 1m at station 2, beside synchrolift
		0.95	Grab sample 23, beside synchrolift
Dibutyltin	0.5	1.2	1m at station 2, beside synchrolift

Except in the case of sample GS23, concentrations of lithium, aluminium or organic carbon are not available to normalise the results for any of the above samples. In the case of GS23, the organic carbon was low but TBT was the elevated result, which can be present as paint flakes, thus the organic carbon may be less important.

Tributyltin (TBT) is an aggressive biocide that has been used in anti-fouling ship paints since the 1970s. It adsorbs and partitions to particulate matter, with subsequent sedimentation resulting in significant accumulation of TBT in sediments. Under aerobic conditions, tributyltin takes one to three months to degrade. However, in anaerobic sediments, this compound can persist for more than two years.

Copper was the other analyte found to be appreciably elevated. Copper is also a biocide used in paints and anti-foulants (including on nets in aquaculture), and is considered to be a less destructive alternative to TBT in the marine environment. It accumulates in sediments due to its affinity to organic / particulate matter in the water column, resulting in deposition.

Correspondence between MI Senior Chemist and DCMNR (dated 04/02/2001) detailed the area allowed to be dredged as being south of Smooth Point. Sediments from the area north of Smooth Point were considered unsuitable for sea disposal owing to contamination, especially of TBT and copper. Based on the above chemical data the MLVC recommended that the dredging and disposal at sea of sediments from around the synchrolift should be prohibited and this area was excluded in the dumping at sea permit issued by the Minister. This area remains undredged. Sediments in the remainder of the proposed dredging area were considered to be suitable for sea disposal.

Prior to the commencement of dredging and dumping of spoil, the fish farmers in Inver Bay and McSwynes Bay were consulted and an agreed monitoring programme, to be overseen by DCMNR, was put in place.

8.5 Review of Water Quality Monitoring

A water quality monitoring programme was devised by DCMNR, in co-operation with the fish farms, to monitor any potential adverse effects of the dumpsite on aquaculture in Donegal Bay. Transects of sample sites were drawn up to allow any increase in turbidity or decrease in dissolved oxygen to be detected in McSwynes Bay or in Inver Bay. Monitoring in the vicinity of the dredging operation was also included.

Water samples were taken during May and June 2002 to provide background values for dissolved oxygen (DO) and turbidity. Further samples were taken during and subsequent to the dredging and dumping operations. A total of 23 stations were monitored, with varying regularity, from May to September 2002. Dissolved oxygen levels prior to and during the dredging and dumping operations appeared, for the most part, to be stable. Generally, the concentration of DO was in the range 8 – 10 mg l^{-1}, which is typical for coastal water with similar temperature and salinity characteristics. On no occasion did the DO level fall below 6 mg l^{-1} at the mouth of McSwynes Bay, which was the agreed trigger level for temporary suspension of dredging and dumping operations.

Prior to the dredging operation, turbidity appeared relatively low throughout the area, except at a station close to the shore inside Killybegs harbour, which may be susceptible to high turbidity levels. During dredging and disposal the levels of turbidity peaked at a number of locations. These locations were in the immediate area of the dredging activity. After dredging and disposal was complete, turbidity reverted to background levels at most sampling stations. On no occasion did the level of suspended solids in the water column exceed 50 mg l^{-1} at the mouth of McSwynes Bay, which was the agreed trigger level for temporary suspension of dredging and dumping operations.

These results confirm that the dredging and dumping operation had no significant impact on dissolved oxygen and suspended sediments in Inver Bay and McSwynes Bay.

8.6 Review of benthic conditions

8.6.1 Review of Baseline Benthic Survey

The survey was carried out in June 2001 and covered 15 sample sites within the proposed disposal area and one site to the North West of the spoil site that would act as a control for future monitoring (Aquatic Services Unit, 2001). The survey described a relatively rich benthic community typical of fine sand communities.

8.6.2 Review of first Benthic sampling post-dumping

The first post-dumping benthic survey was carried out on 21st –22nd August, 2002 (Wood Environmental Management Ltd., 2002). Inconsistencies in the sampling procedures within this post-dump survey make it incomparable with baseline and later surveys.

8.6.3 Review of 2nd Benthic sampling post-dumping

The second post-dumping benthic survey was carried out on December 12th –13th, 2002 (Wood Environmental Management Ltd., 2003a). By this time, the granulometry had reverted to baseline levels, with the exception of the centre of the spoil site station.

8.6.4 Review of 3rd Benthic sampling post-dumping

The third post-dumping survey was carried out on August 6th, 2003 (Wood Environmental Management Ltd., 2003b). The conclusion from this survey was that the granulometry in the vicinity of the spoil site had reverted to pre-dumping conditions for the most part. It was noted at station 16 that the <63um fraction had decreased from 81.1 % to 4.44% and the fraction >0.15mm had increased from 7.7% to 70.25%. This discrepancy was explained by the large degree of heterogeneity observed in the samples taken from this site. Only one sample was taken for granulometric analysis whereas five were taken for faunal analysis. The subsequent MDS analysis of the faunal replicates indicates a large difference in faunal constituents among the replicates from this site alone. This would support the conclusion that the site is very patchy and may explain the difference between the granulometry results observed between survey II and III.

In summary, the overall pattern of faunal constituents and granulometry at the sampling locations since the disposal of the dredge spoil are as expected. There was an accumulation of fine sedimentary material in the centre of the spoil site with reduced faunal assemblages. Over time a gradual coarsening of material was observed presumably as a consequence of bioturbation by deposit feeding or burrowing species.

8.6.5 Review of SPI Study Findings

The Marine Institute commissioned a Sediment Profile Imagery survey of seabed conditions in the area used for the disposal of dredge spoil from Killybegs Harbour in August, 2002 (Aquafact, 2003). Photographs of the sediment surface were also taken. The objective of the survey was to assess the overall benthic condition of the spoil site and determine if there was evidence of migration of spoil material from the site.

A total of 31 stations were sampled in the vicinity of the spoil site. The majority of stations on, and in the vicinity of, the dredge spoil disposal site were shown to have a predominance of fine to medium sands in the topmost layer of sediments. Patches of coarse sand were also recorded. Some physical disturbance was evident at two of the stations situated to the northwest of the disposal site, but the level and extent of the disturbance appeared quite limited.

The results of the survey indicate significant deposition of material at the site with the presence of loose fine sediments. The pattern of results fits a typical dredge spoil disposal site settlement pattern.

The results of the survey indicate significant deposition of material at the site, with the presence of loose finer sediments. The sedimentary profile observed was what might be expected a spoil site location, i.e., centre of spoil site dominated by loose material (hence greater SPI penetration) with more stable compact material sampling away from the centre (as witnessed by reducing SPI penetration depths).

8.7 Discussion

Extensive sampling and analyses of dredge material was carried out prior to the dredging and dumping operation and established the existence of an area of contaminated sediments in the vicinity of the synchrolift. The MLVC recommended that the dredging of contaminated sediments from this area be prohibited. This area was excluded in the Dumping at Sea Permit issued by the Minister. Remaining sediments in the proposed dredging area were considered suitable for sea disposal

The area around the synchrolift was excluded from dredging operations. Evidence of this may be taken from extensive sampling of sediments at the dumpsite, at the fish farms and at many sites in between, carried out in September 2003 by Marenco, on behalf of Kirk McClure Morton. These samples were analysed by the Environment Agency Laboratory, Wales. Results showed no elevated levels for metals or TBT in any of the samples, in the context of the Provisional Irish action levels (Kirk McClure Morton, 2004).

The water quality monitoring programme carried out by DCMNR indicated no adverse effect from the dredging and dumping operation. Suspended solids trigger levels were not exceeded nor were any decreases in oxygen levels detected after cessation of operations.

The findings of the benthic studies indicate that certain parts of the deposited material had been reworked into the sediment through feeding and burrowing activities of sediment dwelling organisms. Reworking of the sediments at the centre of the site was also apparent.

The bathymetric data, together with the SPI data from this study, indicate that the most significant deposits of dredge spoil were found within a radius of approximately 500m from the centre of the disposal site. This is typical of spoil sites with similar hydrographic conditions. This suggests that the dredge spoil had remained where it had been dumped more than a year previously.

There is no evidence that the dredging / dumping operation impacted on the salmon farms in Inver Bay and McSwynes Bay.

8.7 References

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Kirk McClure Morton 2001. Killybegs Harbour Development – Environmental Impact Statement.

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Wood Environmental Management Ltd. 2003b. Benthic monitoring of the dredge spoil disposal site, Donegal Bay: Sampling Program III – September 2003. 23pp

CHAPTER 9 DISCUSSION

9.1 Introduction

This section initially looks at the mechanisms associated with the proposed scenarios considered to have been possible causes for the mortality event in Inver Bay and McSwynes Bay. The latter section summarises the evidence available for each of the various scenarios considered, and gives an overall assessment of each case.

9.1.1 Fish pathogen

Following analyses of fish samples, as detailed in chapter 3 above, the involvement of a primary bacterial or viral fish pathogen in the initial mortality event was ruled out by MI and all relevant veterinary practitioners. Secondary bacterial and parasitic infections (*Flexibacter sp* and *Trichodina sp)* were subsequently noted in fish whose gills were already compromised by the initial insult.

9.1.2 Sediment disturbance at Inver Bay (resulting in release of hydrogen sulphide or other noxious gases)

Intensification of organic matter in sediments in the vicinity of fish farms (from feed, faeces and fish tissue) can lead to an increase in oxygen demand and microbial activity. This can deplete the oxygen in the water overlying the sediment. There may also be a reduction of the oxygen in the sediment. This can be measured by the redox potential, which is the relative balance between oxidation and reduction in the sediments. Large decreases in oxygen concentration can result in sulphate reduction, which may result in the release of bubbles containing hydrogen sulphide from the sediment (outgassing). These bubbles are not stable and are depleted in oxic seawater via oxidation. Loss processes include reactions with dissolved oxygen, hydrogen peroxide, iron oxides and iodates, as well as by biologically mediated processes and photochemical oxidation (Radford-Knoery and Cutter, 1994, cited in Shooter, 1999), ultimately to form sulphates or insoluble metal sulphides.

Dissolved hydrogen sulphide exists in seawater as HS^- and H_2S, (primarily the former). It is oxidised to sulphate in oxic seawaters, which presumably, may depress the oxygen concentrations in these waters.

Bacterial decomposition of organic compounds under anaerobic processes in bottom sediments can lead to the production of harmful gases. The most prevalent of these are methane (CH_4) and hydrogen sulphide (H_2S). H_2S is normally oxidized back to sulphate at the sediment – seawater interface, except in the rare situation where the overlying seawater is depleted of oxygen. In the event that the over lying seawater was depleted of oxygen, it would be expected that the sulphate present in the seawater would be reduced to sulphide. At the time of the fish kill in Inver Bay, there were reports from Ocean Farm staff of a strong odour of hydrogen sulphide.

H_2S was initially cited as being the causative agent for the fish-kill. Veterinary reports indicated gill damage in mortalities and morbid fish from Inver Bay to be consistent with H_2S exposure (McLoughlin, 2003). Available literature regarding the effects of hydrogen sulphide on farmed fish indicates gill necrosis (Kiemer *et al*, 1995). Analysis of water samples contracted by Ocean Farm pointed to the presence of sulphide in the water. The result for one sample (14 ppm) was well in excess of the level at which toxic effects on salmon have been reported (Kiemer et al., 1995). The source of the elevated hydrogen sulphide has not been established, but could have been the sediment, the fish mortalities themselves, or it could have been due to a sampling or analytical error.

A recent review of aquaculture impacts for DFO, Canada (EVS Environment Consultants, 2000), considered H_2S and concluded that generally 'H_2S toxicity in water [*sic* with respect to aquaculture] does not constitute a significant problem and is only likely to occur under certain extreme conditions, such as where sediment is extremely polluted, where hydrographic conditions permit vertical currents or in shallow waters' (Black *et al*, 1996; Brooks, 1996 (Brooks cited in DFO, 2000), Lumb, 1989.) However, this largely considers H_2S generated from organic matter derived from aquaculture.

Black *et al*. (1996) found that even with year round stratification, H_2S would have to accumulate in the water overlying the sediment for a considerable period in order to cause harm to the caged fish. Samuelson *et al* (1988, cited in Black *et al,* 1996), found that all hydrogen sulphide entrained in hydrogen bubbles from agitated anoxic sediments had dissolved from the bubbles within 9m of the bottom sediments. This figure might be expected to be less for undisturbed sediments.

9.1.3 Farm Management - treatments, waste

Farm management practices have been reviewed on all sites, both through on-site visits and through the examination of farm records. Whilst the practices observed are generally acceptable, and not thought to have caused the events described above, the frequency with which dead fish were removed from some sites is a cause for concern and may have contributed to some of the environmental conditions described during the early days of the mortality event.

Fish feeds from four different companies were used in the bay prior to this event and would tend to rule out the involvement of nutritional factors since the problem was widespread across all sites and since two of the feeds are produced outside of Ireland, they would therefore have different sources of ingredients, which would make an association with feed even more unlikely.

The pattern of mortality in relation to the date of net change has been analysed. A possibly significant pattern is that the fish held in dirtier nets were unaffected in the case of the rainbow trout, and less affected in the case of the Creevin grower salmon (Cage 1). In the case of Eany, peak mortalities were observed in the cages with the nets that had been changed most recently, that is cages 1,2,4,and 8.

A similar pattern was observed at Creevin Cage 7, which was the cleanest net on site and which encountered 50% mortality by 15th July, indicating a very acute and severe event.

There is no evidence to suggest that either lice infestation levels or treatment toxicity is to blame for the mortality problems recorded in July 2003 and subsequently. Inspections carried out at sites in Inver Bay and McSwynes Bay as part of the National Sea Lice Monitoring Programme, indicate that there were no treatment related mortalities in the months prior to the major mortality event in July 2003. Two products were used to treat fish for lice infestations; Excis and SLICE.
Lice levels on smolts in both Inver Bay and McSwynes Bay in the months preceding the mortality were below the treatment trigger levels and substantially lower than a level that could cause stress or damage to the fish.

Lice levels on growers in Inver Bay and McSwynes Bay exceeded trigger levels on a number of occasions in the spring of 2003. In the majority of cases the levels reached were not high enough to have caused any damage to the fish. However, in late May and June 2003, lice levels on growers in Creevin Salmon farm were at levels that would be expected to cause increased stress to the fish. The levels recorded would not be expected to give rise to increased mortalities in fish of this size.

9.1.4 Biological event
Water samples examined by MI from Inver Bay from 24th June to 1st August, 2003 showed a mixed population of diatoms and dinoflagellates, typical of midsummer phytoplankton populations in Irish coastal waters (see figure 6.2). The water samples showed no evidence of a harmful algal bloom.

Natural biotoxins from phytoplankton and jellyfish are known to have been responsible for fish kills both in this country and elsewhere. Samples of mussels taken from one of the cages in inner Inver Bay were analysed for such toxins. The algal toxins detected, while sufficient to cause concern over human consumption, have not been reported as toxic to fish.

9.1.5 Pollution incident
No pollution incidents or unlicensed discharges were reported at or before the time of the fish kill incident.

A review was carried out by DCMNR Engineering Division in Ballyshannon of all discharges to Donegal Bay. Information was provided by Donegal County Council. Most discharges are to the sewers. None of these would be considered likely to be a cause of the fish kill.

The possible addition of corrosive chemicals such as acids or bases to the fish cages was considered. However, the quantities required to alter the pH significantly would be vast, due to the buffering capacity of seawater. For this reason, this scenario was deemed an unlikely occurrence.

9.1.6 Environmental stressors
Chief among environmental stressors likely to have been involved in an incident of this type are temperature and oxygen. Salmon are very susceptible to changes in these

parameters, with maximum health performance occurring within an optimum range for both.

The optimal temperature for the culture of Atlantic salmon is approximately 14-16^{0}C. Additionally, the reduction in dissolved oxygen with increasing temperature can also lead to stress. As the temperatures recorded in both Inver Bay and McSwynes Bay during July and August 2003 were typically > 17 ^{0}C it is clear that environmental conditions were sub-optimal for the farmed stock and is likely to have contributed to mortalities observed. However, such environmental conditions on their own were not sufficient to cause the severe gill lesions observed in both Inver and McSywnes Bays.

Oxygen depletion has been the reported cause of many fish kills worldwide (DFO, 2000). Causes of the depletion would include pollution events involving substances with high biochemical and chemical oxygen demand such as slurry, milk or sewage. Possible spillages of any of these substances would most likely have been to a river (possibly the Eany) and no such incidents were reported, nor were any wild fish kills noted for the river (North West Fisheries Board, *pers. comm*.).

Diurnal depression of oxygen levels can be caused by high numbers of phytoplankton respiring at night, when photosynthesis has ceased. Ocean Farm noted reduced dissolved oxygen levels at depth early in July, but these would not be sufficient to allow H_2S production. The most likely source of a significant oxygen-depleting event at a fish farm would be the decomposition of an algal bloom or decomposition of dead fish.

However, as stated above, oxygen depletion alone is not consistent with the pathology reported, but could be seen as a contributing factor to the overall mortality event.

9.2 Overall assessment and discussion

The following overall assessment considers the information from the desk review and chemical testing carried out, specifically from the perspective of the scenarios used in formulating the testing plan.

9.2.1 Primary fish pathogen

- Bacteriological testing, using standard isolation techniques, did not result in the isolation of any significant bacterial pathogens.
- Virological screening using BF2, EPC and SHK1 cell lines, did not result in the isolation of IPN, VHS, IHN or ISA viruses.
- Extensive histopathological screening did not indicate the involvement of any primary bacterial or viral pathogens, which might warrant further, more specific investigation.
- Secondary bacterial and parasitic infection of damaged gill tissue was diagnosed some time after the initial insult occurred. These infections are likely to have contributed to the severity and protracted nature of the event.

Conclusion: There is no evidence to suggest that the initial mortality event was caused by infection with a primary fish pathogen.

9.2.2 Farm practices

- Feeds from four different manufacturers were in use in Inver Bay and McSwynes Bay at the time of this event, thus making an association highly unlikely.
- Although infrequent removal of mortalities may have contributed to environmental conditions described during the early days of the event in Inver Bay, it is not thought to have caused or contributed appreciably to the event.
- Cage analysis showed that fish held in dirtier nets were less affected than those held in recently changed nets. This suggests that the cause may have been particulate in nature.
- At least two of the farms were using nets which had not been anti-fouled, thus ruling this out as a possible cause of the mortality event.
- Lice levels on growers in Inver Bay and McSwynes Bay exceeded trigger levels on a number of occasions in the spring of 2003. In the majority of cases however, the levels reached were not high enough to have caused any damage to the fish, except in May / June 2003, when lice levels on growers in Creevin were at levels that would be expected to cause increased stress to the fish. However, the recorded levels alone would not be expected to give rise to increased mortalities in fish of this size.

Conclusion: There is no evidence to suggest that farm practices, including housekeeping, net treatment, lice infestation or treatment toxicity are to blame for the mortality problems recorded in July 2003 and thereafter.

9.2.3 A spill or discharge of a toxic chemical

- There were no reported spills or information suggesting that a spill or discharge from a land based source or a marine source had occurred.
- Testing for specific substances (e.g. environmental contaminants such as trace metals) and broad screen testing using GC-MS did not show any residues of substances at levels that would be of concern.
- A range of toxicity testing did not show a response for samples tested.
- Analysis indicated that unknown white material sampled was of similar composition to fish feed.

Conclusion: There is no evidence for a discharge of a chemical pollutant, and testing did not identify any residual substances or toxicity that could be associated with a significant pollution event.

9.2.4 Potential contamination associated with sediments from Killybegs dredge spoil dumpsite

- Although there were some areas of sediment in Killybegs Harbour with elevated TBT and marginally elevated metal levels, the bulk of the sediment from Killybegs harbour was suitable for disposal at sea.
- The gill pathology and high numbers of mortalities were not consistent with the adverse effects that might be expected even with heavily contaminated dredge spoil.
- Sediments from the area identified as having elevated contaminant levels were not dredged.
- Dredging and dumping ceased in August 2002 and no adverse effects were reported.
- Other habitats and biological communities, such as the benthic community in Inver Bay appeared healthy and did not show evidence of exposure to contaminants at a toxic level.
- Both measured and modelled data indicate that currents in Inver Bay are weak (< 10 cm s^{-1}) and insufficient to transport sediment particles over long distances.
- The general circulation pattern in Donegal Bay is anti-clockwise, which would transport material seaward of the disposal site.
- The temperature data have clearly shown that the water column thermally stratifies during the summer. This indicates that tidal and wind induced currents are insufficient to fully mix the water column, thus showing that there was insufficient energy in the system to resuspend sediments.
- There were no significant storm events recorded during the period April – October 2003 which could have been responsible for resuspension of sediments from depths of 70m.
- MI testing for environmental contaminant residues in biota in Inver bay did not indicate any substances present at levels of concern.
- The results of the SPI survey showed that there was little evidence of recent disturbance of the seabed at the disposal site and no evidence of recent settlement of sediments at the farm sites in Inver Bay and McSwynes Bay.
- It was suggested that the 'black water' and 'suspended sediment' reported as fouling nets in Inver bay were associated with dredge sediment mobilised from the dumpsite. Chemical analysis of samples of the suspended matter

(submitted to MI by Ocean Farm) revealed them not to be sediment, but 100% organic matter, or organic matter with mussel shell.

- Sources of organic matter in the vicinity of the fish cages in Inver Bay are likely to be directly from the cages themselves in the form of faeces, left-over food, dead fish and biota die-back e.g. the hydroid *Tubularia indivisia* is known to foul nets. On dying, these organisms create a black mulch, which eventually breaks down (J. Costello, *pers comm*.).

Conclusion: There is no evidence that the disposal of dredge spoil from Killybegs at the dumpsite in Donegal Bay is implicated in this fish kill. Considering the suitability of the dredge spoil for sea disposal, the mechanisms for adverse effects of contaminated sediments on marine biota, information on local hydrodynamics, and results of testing carried out, the likelihood of sediment from the Killybegs dredge disposal site being responsible for the fish kills is extremely remote.

9.2.5 Large release of toxic gas(es) from the benthic environment

- Scientific literature suggests that the pathology observed could be consistent with H_2S exposure. H_2S was specifically considered because of its toxicity (as compared with methane).
- A possible mechanism suggested for release of H_2S gas from anaerobic sediments was disturbance through prawn fishing. The SPI survey however, did not show evidence of recent physical disturbance and indicated a very healthy benthos with a relatively deep redox layer in sediment in Inver and McSwynes Bay. The shallowest redox depths were recorded in the vicinity of the farm sites. There was no evidence of gas build up in the sediments and thus no large reservoir of anoxic sediments in which H_2S could accumulate.
- Healthy living maerl, indicative of good water quality was observed at a number of stations in Inver Bay.
- All MI testing indicated levels of H_2S to be below the levels of detection.
- Ocean Farm also carried out H_2S measurements. One high level was detected (14ppm). The origin is not clear, but it is possible that decomposing fish following the mortality could have contributed to this value.

Conclusion: given the scale of the fish kill, the generally healthy, undisturbed state of the benthos, and the lack of any evidence of a reservoir of anoxic sediments, there is no evidence to suggest that H_2S generation from anaerobic sediments was the primary cause of the fish kill. It is possible that H_2S generation from decaying fish could have exacerbated the situation, but there is no clear evidence to support this.

In addition, while there were reports of vessels fishing close to the salmon farms in Inver Bay, the lack of a reservoir of anoxic sediments and the weak currents in the bay which are insufficient to transport sediments over long distances, indicate that sediment disturbance by fishing activity was not the primary cause of the mortalities observed.

9.2.6 Other physico-chemical water quality factors

- While recognising that measurements may have been taken after the initial event, water quality measurements did not reveal any obvious indications of a problem.
- There is no evidence for an algal bloom or a large spill of an organic substance that could have led to oxygen depletion.
- The gill pathology is not consistent with oxygen deficiencies.
- Salmon are sensitive to environmental stress. Water temperatures in Donegal bay were higher than normal (for that area) during the summer of 2003. While unlikely to be the primary cause of mortalities, environmental stress due to high water temperatures may have exacerbated the event.

9.2.7 Misuse or accident with chemical (veterinary) treatment

- Testing of mussels and salmon from Inver Bay for residues of veterinary treatments did not reveal any of the determinands to be present at levels of concern. Specifically the main sea lice treatments and antibiotic residues were tested for, but were not detected at significant concentrations.
- The main sea lice treatments (Emamectin, Ivermectin, Cypermethrin, Diflubenzuron and Teflubenzuron) while toxic to organisms such as crustacea, are not especially toxic to fish.
- Information provided by the fish farmers to DCMNR and MI, did not suggest farm management practice or any issue with respect to use of chemicals onsite that could lead to a fish kill.

Conclusion: There is no evidence that misuse or an accident in application of a veterinary treatment or another chemical at the farm level is implicated in this fish kill.

9.2.8 Biotoxin associated with a harmful algal bloom

- Biotoxins associated with harmful algal blooms can be particularly potent toxicants.
- LC-MS-MS testing indicated that the biotoxins associated with Irish waters were not present at levels of concern from a fish toxicology perspective from the samples analysed.
- Whilst algal remains were seen microscopically in certain gill squashes and algal remnants were reported in a small number of histological samples, there is no evidence that they were present in sufficient numbers to have caused this severe mortality event.
- There was no report of a phytoplankton bloom.

Conclusion: There is no evidence that any of phytoplankton toxins routinely monitored in Ireland contributed to the fish kill.

9.2.9 Jellyfish or siphonophore event

- Norwegian veterinary consultants have confirmed that the gross pathology and buccal erosions observed in south Donegal were similar to the pathological findings reported after a fish kill of >1,000 tonnes of salmon off SW coast of Norway, in the summer 2002 (Dr. Freddy Jensen *pers. comm.*).
- It was reported by Dr. Jensen that fish in cages with dirty nets were least affected, which coincides with the progression of mortality in Inver Bay.

- A water sample taken south of Killybegs by DCMNR staff on 12th July was reported to have contained high densities of very small jellyfish, 1 – 2 mm in size (Gavin Poole, DCMNR, *pers. comm*.). These were tentatively identified as *Solmaris corona.*
- Although jellyfish were not noted at the time of the fish mortalities in Inver Bay, reports of stings and skin irritations were noted in August (Séamus Hopkins, DCMNR, *pers. comm*.).
- Photographs of histopathology slides from Donegal Bay have been sent to the Norwegian Veterinary Institute for comparative purposes. The conclusion has been drawn that the histopathology observed in Donegal Bay was "*within the range observed in Norway, but was not typical".*
- Figure 2.13 shows the predominance of onshore west and south-westerly winds during the months of June, July and August. This may have resulted in the transport of organisms including jellyfish from offshore into the affected bays.

  Conclusion: There is little clear evidence that a jellyfish/siphonophore swarm was the cause of these mortalities. However, given the pathology and the nature of such events it is quite likely that a jellyfish/siphonophore swarm provided the initial insult to the fish, without being observed and without leaving a clear trace to be detected in subsequent investigation.

9.3 References

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CHAPTER 10 – CONCLUSIONS

- There is no evidence to suggest that the initial mortality event was caused by a fish pathogen.
- Secondary bacterial and parasitic infections caused by *Flexibacter sp* and *Trichodina* were observed at a later stage in the event, once gill tissue had been compromised by the initial insult.
- The liver pathology observed at the Ocean Farm site showed some similarities with experimental H_2S toxicity, but the gill lesions were not consistent with H_2S as being the sole cause of this event.
- Farm management practices were generally acceptable but the length of time taken to remove mortalities from certain sites was unduly excessive and could have contributed to the unusual environmental conditions described during the early days of this mortality event.
- There is no evidence to suggest that misuse of, or an accident with, a chemical (e.g. veterinary treatment) on one of the farms, was responsible for the fish kill.
- Given the healthy state of the benthos in Inver Bay and McSwynes Bay, release of H_2S gas from the sediments in sufficient quantities to be a primary cause of the fish kill seems very unlikely. It is possible that gas release from fish decomposition following the initial mortalities could have exacerbated the situation, but there is no evidence of this.
- A broad range of chemical testing did not indicate any substance or pollutant, especially in relation to the scenarios considered, that would suggest a causative agent for the fish kill.
- There is no evidence to show that a chemical pollution event occurred, and testing did not identify any residual substances or toxicity that could be associated with a significant pollution event.
- Assessment of Killybegs dredge spoil showed the material was suitable for sea disposal. Chemical analyses of sediments and fish samples from both effected bays, indicates that the likelihood of mobilised sediments from the Killybegs dredge spoil disposal site being the cause of the fish kill is extremely remote.
- There is no evidence that the disposal of sediments from Killybegs Harbour at the Donegal Bay dumpsite was implicated in this fish kill. Considering the review of the Killybegs sediments disposed of at sea, the mechanisms for adverse effects of contaminated sediments on marine biota, results of testing carried out and a review of the hydrography in Donegal Bay, the likelihood of contaminated sediment from the Killybegs dredge sediment disposal site being implicated in this fish kill seem extremely remote.

- Both measured and modelled data indicate that currents in Inver Bay are weak (< 10 cm s^{-1}) and insufficient to transport sediment particles over long distances. The general circulation pattern in Donegal Bay is anti-clockwise, which would transport material seaward of the disposal site.
- The water quality monitoring programme (agreed by DCMNR and fish farms) did not detect any adverse effects of the dumpsite on aquaculture in Donegal Bay. Water samples taken during and after the dredging and dumping operations demonstrated that no depletion of dissolved oxygen occurred, and that levels of turbidity at the mouth of McSwynes Bay did not exceed the trigger level.
- While not directly responsible for the fish kill, environmental stress (including water temperatures above those considered optimal for farmed salmon) coupled with secondary bacterial colonisation of the gills and parasitic infection, could have exacerbated and prolonged the mortality event.
- Although it cannot be proven that jellyfish/siphonophores caused the mortality observed in Inver / McSwynes bays in 2003, it is possible that some form of siphonophore swarm may have caused an initial insult to the fish in Donegal Bay. This initial insult, coupled with high water temperatures, low oxygen levels and secondary bacterial colonisation of the gills, could have been enough to give rise to the losses observed.

In summary, many events have been ruled out as the cause of the fish mortality event experienced in Donegal Bay in 2003. These include infection with a primary fish pathogen, poor farm management, harmful algal bloom, pollution incident, sediment disturbance or damage caused by the dumping of dredge spoil material.

When the mortality incident is reviewed in detail, it appears most likely that the initial insult may have been caused by a biological event such as a siphonophore bloom, that may have occurred in both Inver and McSwynes Bays, and which probably coincided with an intrusion of offshore water, such as occurred in early July.

The initial insult occurred when water temperatures were very high in relation to the optimal temperature for the cultivation of salmonids. Subsequent to the initial event, secondary bacterial and parasitic infections were noted. These infections would have added considerably to the stress of fish, which were already severely debilitated.

It is proposed that the cause of the protracted and extensive mortalities recorded in Donegal Bay was multi-factorial in nature, where the net cumulative result was much greater than it would have been should the initial event have occurred at lower water temperatures or in the absence of secondary infection of the gill tissue.

CHAPTER 11: APPENDICES

Appendix 1 Results of fish health analysis

Date sample rec'd at FHU	Ref No.	Farm / Site	Sample Type	Sampled By	FHU Laboratory Results			
					Post Mortem	Virology	Bacteriology	Histology
18/06/03	2522	Creevin	EU	MI	Nothing abnormal noted	Negative IPN, IHN & VHSV	Negative	No indication of disease
18/06/03	2523	Eany	EU	MI	Nothing abnormal noted	Negative IPN, IHN & VHSV	1/30 *Vibrio sp.*	No indication of disease
19/06/03	2524	Ocean Farm / Mc Swynes Bay	EU	MI	Failed Smolts, Increased mortalities	Negative IPN, IHN & VHSV	1/30 *A. hydrophila & Vibrio sp* (SWA) *1/30 Vibrio fluvalis* (Blood agar + Salt)	Kidney pathology consistent with failed smolts. Skin pathology possibly due to physical damage
24/06/03	2529	Ocean Farm / Inver Site	EU	MI	Fish not feeding, some failed smolts, yellow casts present	Negative IPN, IHN & VHSV	1/30 kidney swabs yielded *Vibrio sp* on blood agar plus salt	No evidence of significant disease process
14/07/03	2544	Ocean Farms	Diagnostic	Vet Aqua on behalf of MI	See report outlined in main text (Section 3.2)	N/A	N/A	See Report outlined in main text (Section 3.2)
17/07/03	2549	Ocean Farms	Diagnostic	Vet Aqua on behalf of MI		N/A	N/A	
17/07/03	2550	Eany	Diagnostic	VetAqua on behalf of MI		N/A	N/A	
17/07/03	2551	Creevin	Diagnostic	VetAqua on behalf of MI		N/A	N/A	
24/07/03	2553 *	Eany Creevin Inver Growers Inver Smolt Site	Diagnostic	VetAqua on behalf of MI	See report outlined in main text (Section 3.2)	Negative IPN, IHN & VHSV	N/A	See report outlined in main text (Section 3.2)
08/02/03	2558	Ocean Farms Inver Bay	Diagnostic	MI	Fish not feeding, yellow casts present, gills ragged at ends, swimming high in water	Negative IPN, IHN VHS & ISAV	Negative	

08/02/03	2559	Creevin	Diagnostic	MI	Fish not feeding, yellow casts present, gills ragged at ends	Negative IPN, IHN VHS & ISAV	Negative
08/02/03	2560	Eany	Diagnostic	MI		Negative IPN, IHN VHS & ISAV	*Vibrio nereis* from 4/20 kidney swabs. Not considered to be a fish pathogen
21/08/03	2575 & 2576	Ocean Farm / Mc Swynes Bay	Diagnostic	MI / VetAqua	Smolts: Gills ragged, interlamellar haemorrhages, some necrotic tips, not feeding & swimming at edge of cages Growers: necrotic gills, swimming high in water, not feeding	Negative IPN, IHN VHS & ISAV	*Vibrio sp* from gill and lesion swabs. No significant organisms from kidney swabs

*samples taken at the same time as samples 2549 - 2551

Appendix 2: Sea Lice Data 2003

OCEAN FARM LTD.	Date	Lepeophtheirus salmonis		Caligus elongatus	
		F + eggs	Total	F + eggs	Total
Inver Bay					
Atlantic salmon, 2002	12/12/02	1.64	5.78	0.03	0.16
	19/2/03	0.59	1.9	0	0.02
	4/3/03	0.95	2.07	0	0.03
	21/3/03	0.87	1.63	0	0
	2/4/03	0.54	1.38	0	0.05
	16/4/03	0.24	0.72	0.02	0.03
	15/5/03	0.99	10.52	0.06	0.15
	27/5/03	1.1	5.69	0.04	0.11
	25/6/03	1.31	3.45	0.02	0.09
	9/7/03	0.77	1.45	0.04	0.21
	August	Not sampled due to fish health problems			
Atlantic salmon, 2003	25/6/03	0	0.12	0.08	0.15
	9/7/03	0	0.09	0.01	0.04
	August	Not sampled due to fish health problems			
McSwynes					
Atlantic salmon, 2001	11/12/02	1.92	11.79	0.04	0.15
			Harvested		
Atlantic salmon, 2002	20/2/03	2.93	15.1	0.09	0.14
	6/3/03	3.58	12.54	0.02	0.05
	21/3/03	1.11	1.79	0	0
	3/4/03	0.48	1.15	0	0
	15/4/03	0.3	1.17	0	0
	15/5/03	1.06	8.18	0.06	0.27
	28/5/03	2.69	11.42	0.24	0.32
	18/6/03	2.83	5.87	0.05	0.14
	10/7/03	1.63	3.37	0.02	0.05
	August	Not sampled due to fish health problems			
Atlantic salmon, 2003	10/7/03	0.17	1.33	0.02	0.04
	August	Not sampled due to fish health problems			
Castlemurry					
Atlantic salmon, 2002	11/12/02	0.57	7.15	0.03	0.15
	Fish transferred to Carntullagh Point				

CREEVIN SALMON FARM LTD.					
	Date	Lepeophtheirus salmonis		Caligus elongatus	
		F + eggs	Total	F + eggs	Total
Inver Bay					
Atlantic salmon, 2002	12/12/02	0.17	0.97	0.03	0.14
S1/2	19/2/03	0.84	12.74	0.19	0.52
	4/3/03	2.27	22.87	0.47	1
	20/3/03	0.79	1.9	0	0
	2/4/03	6.81	10.81	0.04	0.11
	8/5/03	1.4	8.2	0.4	0.8
	27/5/03	1.84	31.19	0.39	0.74
	17/6/03	13.52	33.59	1.1	1.9
	10/7/03	2.27	4.07	0	0
	August	Harvested			
Atlantic salmon, 2002	12/12/02	0.27	1.27	0.03	0.15
	19/2/03	1.5	22.37	0.73	1.53
	4/3/03	2.53	21.7	0.33	0.83
	20/3/03	1.63	3.7	0	0.07
	2/4/03	1	2.16	0.03	0.13
	15/4/03	1.6	12.77	0.1	0.44
	8/5/03	0.9	15.43	0.37	0.47
	27/5/03	5.21	40.68	0.71	0.93
	17/6/03	5.27	20.8	0.13	0.23
	20/8/03	2.27	5.4	0.07	0.07
Atlantic salmon, 2003	10/7/03	0	0.03	0	0.01
	20/8/03	0.54	3.73	0	0

EANY FISH PRODUCTS LTD.					
Inver Bay	Date	Lepeophtheirus salmonis		Caligus elongatus	
		F + eggs	Total	F + eggs	Total
Atlantic salmon, 2002	Harvested				
S 1/2					
Atlantic salmon, 2001	12/12/02	0.33	1.43	0.02	0.06
	19/2/03	0.54	18.32	0.23	0.67
	4/3/03	0.67	2.03	0	0.04
	20/3/03	1.43	3.57	0	0
	2/4/03	0.41	2.97	0.05	0.35
	16/4/03	0.53	2.37	0	0.1
	8/5/03	0.33	1.8	0.03	0.13
	27/5/03	0.62	34.14	1.03	1.9
	17/6/03	2.07	3.16	0.03	0.1
	10/7/03	0.61	7.52	0.29	0.9
	August	Not sampled due to fish health problems			
Atlantic salmon, 2003	10/7/03	0.02	0.3	0	0
	20/8/03	0.18	4.72	0	0
Rainbow trout, 2002	19/2/03	0	5.33	0.22	0.56
	4/3/03	0.03	0.1	0.03	0.17
	20/3/03	0.13	0.87	0.1	0.1
	2/4/03	0.1	1.17	0	0.03
	16/4/03	0	1.4	0	0.03
	8/5/03	0.03	4.5	0.33	0.5
	27/5/03	0.13	10.87	0.17	0.47
	17/6/03	0.1	0.77	0.03	0.13
	10/7/03	0.52	4	0.16	0.42
	20/8/03	4	13.6	0.3	0.43

Appendix 3: Results of fish gut analysis

From: Edward McCormack
Sent: 07 October 2003 15:59
Subject: Re: Fish stomach contents

I examined the fish and externally there were no indications of damage by jellyfish - no welts or inflamed areas. They were moderately infested with sea lice (at least nine or ten per fish, generally concentrated around the fins, eyes and anus) and exhibited the usual sea lice-associated damage – grey and white lesions and missing scales.

On dissection all of the fish were found with full stomachs, which consisted entirely of the oily food pellets. There was no indication of any other food item (including jellyfish or other members of the plankton).

So, there was no evidence of ingested jellyfish (*Solmaris corona* or otherwise) and no visible external welts from jellyfish stings but that doesn't mean that the jellyfish weren't there. So it’s been inconclusive.

From: Edward McCormack
Sent: 20 October 2003 20:22
Subject: RE: Fish stomach contents

Just finished off the fish there now. Once again, as I mentioned on Friday, there was no evidence of jellyfish – either externally or in the gut contents. All of the fish were devoid of sea lice and showed no external damage. The stomachs of all the fish were empty and the lower intestinal tracts were virtually without faecal matter.

In comparison to the last batch of fish I looked at (whose stomachs were all full of oily food pellets) this would suggest that they hadn't been feeding prior to death. So still inconclusive. It might be helpful after any future fish kills to take plankton samples from around the site (as I’d mentioned before) and also to take some healthy fish from the same site for comparison.

From: Edward McCormack
Sent: 22 October 2003 17:53
Subject: guillemot

Finished the guillemot dissection, and I'm afraid you've heard it all before. There was nothing significant left in the crop or intestinal tract. No identifiable food remains. The crop was empty. Digested food was found in the intestines but they were too far-gone to say what was ingested. The odd tiny feather or bit of algae was all that I saw on microscopic examination of contents.

No evidence that I could tell of any oil/tar ball/hydrocarbon ingestion either. So once again you seem to have the same story from me.

From: Edward McCormack
Sent: 28 October 2003 17:19
Subject: examination of gills

Finished examining the gills of the smolt heads I'd kept from the first batch of salmon. I've found no jellyfish, no detached tentacles or nematocysts and no apparent major damage to the gills (some are slightly tattered but not anything that you wouldn't expect from normal wear and tear. Have you identified the jellyfish that were taken in the plankton samples? Was
Solmaris found? If it turns out that the jellyfish found are species that have been known to cause death of salmon by stinging (species such as *Apolemia uvaria* and *Solmaris corona*), then I'd say its fairly probable that they are your culprits. Often the minute tentacles break off outside of the salmon cage and float in. If the stinging tentacle passes through the gills and out the operculum it can sting the fish on the gills causing suffocation. Stings on the outside of the fish cause lesions but don't usually directly kill the fish (they may lead to secondary infection).

Appendix 4: Results of sulphide analysis on water samples (carried out by CAL laboratories on water samples from Inver Bay.)

(Limit of Detection < 0.1mg/l)

Laboratory Number	**Sample details**	Sulphide content (mg l^{-1})
31093	1. Dive Site 1 16/07/03 Surface	< 0.1
31094	2. Station 1 16/07/03 Surface (2M)	< 0.1
31095	3. Station 2 16/07/03 (3M)	< 0.1
31096	4. Station 3 16/07/03 Surface	< 0.1
31097	1. Station 4 16/07/03 15M (3M off Bottom)	< 0.1
31098	6. Station 5 16/07/03 Surface (2M)	< 0.1
31099	7. Station 5 16/07/03 Bottom ~14M	< 0.1
31100	8. Station 6 16/07/03 Surface	< 0.1
31101	9. Station 7 16/07/03 Surface	< 0.1

Laboratory Number	**Sample details**	Sulphide content (mg l^{-1})
31324	MSC/03/022 – McSwynes Bay Station 3 – 01/08/03	< 0.1
31325	MSC/03/023 – McSwynes Bay Station 2 – 01/08/03	< 0.1
31326	MSC/03/024 – McSwynes Bay Station 4 – 01/08/03	< 0.1
31327	MSC/03/025 – McSwynes Bay Station 5 – 01/08/03	< 0.1
31328	MSC/03/026 – McSwynes Bay Station Control – 01/08/03	< 0.1
31329	MSC/03/027 – McSwynes Bay Station 1 – 01/08/03	< 0.1
31330	MSC/03/028 – Inver Bay Ocean Farm cages – 01/08/03	< 0.1

Laboratory Number	Sample details	Sulphide content (mg l^{-1})
31140	Env/03/079 – 19-22/08/03	< 0.1
31141	Env/03/080 – 19-22/08/03	< 0.1
31142	Env/03/081 – 19-22/08/03	< 0.1
31143	Env/03/082 – 19-22/08/03	< 0.1
31144	Env/03/083 – 19-22/08/03	< 0.1
31145	Env/03/084 – 19-22/08/03	< 0.1
31146	Env/03/085 – 19-22/08/03	< 0.1
31147	Env/03/086 – 19-22/08/03	< 0.1
31148	Env/03/087 – 19-22/08/03	< 0.1
31149	Env/03/088 – 19-22/08/03	< 0.1
31150	Env/03/089 – 19-22/08/03	< 0.1
31151	Env/03/090 – 19-22/08/03	< 0.1
31152	Env/03/091 – 19-22/08/03	< 0.1
31153	Env/03/092 – 19-22/08/03	< 0.1
31154	Env/03/093 – 19-22/08/03	< 0.1
31155	Env/03/094 – 19-22/08/03	< 0.1
31156	Env/03/095 – 19-22/08/03	< 0.1
31157	Env/03/096 – 19-22/08/03	< 0.1
31158	Env/03/097 – 19-22/08/03	< 0.1
31159	Env/03/098 – 19-22/08/03	< 0.1

Appendix 5: Result of metals analysis ($\mu g g^{-1}$ wet wt) (carried out on smolt tissue and mussel samples from Inver and Mc Swynes Bay)

Sample No.	Sample Info	Hg	Cd	Cr	Cu	Pb	Ni	Zn	Al	As
ENV03/070/Me/I	Salmon smolt	0.04	<0.02	<0.18	0.90	<0.02	0.03	4.33	<0.24	0.82
ENV03/071/Me/I	Salmon smolt	0.04	<0.02	<0.17	1.18	<0.02	0.76	5.23	<0.23	0.83
ENV03/072/Me/I	*M edulis* Sample taken from freezer on site	nd	0.17	1.45	4.92	0.06	0.99	22.51	34.14	1.91
ENV03/073/Me/I	*M edulis* Taken from cage at approx 3m	nd	0.37	<0.20	6.10	0.04	0.41	20.89	21.81	2.99
ENV03/074/Me/I	*M edulis* Taken from bottom approx 12m	<0.03	0.43	<0.17	4.63	0.15	0.58	24.27	97.71	3.19

Note:
Mercury Analysis carried out on wet tissue by MI using CV-AFS
Remaining metal analysis carried out on freeze-dried tissue by SEPA using ICP-MS

Appendix 6: Result of metals analysis (µgg^{-1} wet wt)
(carried out on smolt and grower tissue from Inver and Mc Swynes Bays)

Metal concentration
(µgg^{-1} wet wt)

Sample No.	Sample Info	Species	**Pb**	**Cu**	**Cd**	**Cr**	**Zn**
MSC/03/055	Ocean Farm – Mc Swynes	Salmon Growers	<0.06	<0.44	nd	nd	2.23
MSC/03/056	Ocean Farm – Mc Swynes	Salmon Smolts	<0.06	<0.44	nd	nd	4.80
MSC/03/057	Eany – Inver Bay	Salmon Smolts	nd	<0.44	nd	nd	3.81

Appendix 7: Results of ammonia analysis (of water samples taken in the vicinity of fish farm cages in McSwynes Bay, August 2003)

Sample	**Ammonia umol l^{-1}**
	(mean value +/- difference of 2 measurements)
Control	<0.100
Stn1	0.541+/- 1.550
Stn2	0.298+/- 0.188
Stn3	0.149+/- 0.325
Stn4	0.210+/- 0.028
Stn5	0.244+/- 0.047

Results based on analysis based of duplicate samples

Appendix 8: Results of GC-MS screening and water and tissue results of GC-ECD of tissue

1) Qualitative screening for organic contaminants using GCMS

Indicative substances/ substance groups tentatively identified in water & tissue sample analysis: (note many substances tentatively identified are analytical artefacts, identified in system blanks)

Water Samples: Phthalates, siloxanes, triphenyl phosphate, alkanes

Tissue (ENV 2003 63-66): phthalates, alkanes, fatty acids, steroidal compounds (gill), various organic substances (poor identification – probably of biogenic origin), siloxanes

Unknown material (ENV 2003/067): alkanes (series), isoprenoids, fatty acids and long chain esters, siloxanes

Suspended Sediment (ENV2003/068 & 69): siloxanes (analytical artifact -column bleed)

2) Results of organics analysis of tissue samples from Inver (MSC–03-057) and McSwynes Bay (MSC-03-55 &56), September 2003.

Indicative concentration of indicator compounds in various samples (μg kg^{-1}) wet weight.

Sample	CB 153	BDE 47	CHB 26
msc-03-055 liver	0.47	0.08	0.23
msc-03-056 liver	0.48	0.07	0.13
msc-03-057 liver	2.26	0.21	0.34
msc-03-055 muscle	0.55	0.08	0.26
msc-03-056 muscle	0.11	nd	0.03
msc-03-057 muscle	0.60	0.06	0.13
env-02-092 Herring	0.88	0.16	0.30
env-02-043 Cod	0.20	0.05	0.04

Appendix 9: Results of granulometry for sediment samples (carried out by MI on sediments from DCMNR Dump Site, Inver and Mc Swynes Bay)

Sample No.	Sampling Site	< 2.00mm (%)	< 1.00mm (%)	< 500µm (%)	< 150µm (%)	< 63µm (%)
MSC/03/001	Stn 1 near cages McSwynes	92.9	76.3	56.5	36.8	27.7
MSC/03/002	Stn 3 McSwynes	99.8	99.4	99.1	89.3	45.4
MSC/03/016	Eany Cages - Grab 1	99.4	99.2	98.9	96.1	41.5
MSC/03/017	Central Inver Bay - Grab 2	100	100	99.9	97.5	39.2
MSC/03/018	Ocean Farm Cages - Grab 3	100	99.9	99.7	99.2	49.5
MSC/03/019	Outer Inver Bay - Grab 4	100	100	89.9	88.7	22.7
ENV/03/105	DCMNR Dump Site, Killybegs	99.5	98.7	97.7	92.1	40.3
ENV/03/106	DCMNR Dump Site, Killybegs	100	99.6	99.4	98.1	34.6
ENV/03/107	Half way between spoil site and dump site (off St. John's Point)	53.7	14.3	7.6	6.1	5.4

Appendix 10: Results of organic matter analysis on sediment samples (ashing carried out by MI on sediment samples collected from DCMNR Dumpsite and Inver Bay 13/08/03)

Sample No.	Sample Information	% Organic matter
ENV/03/105	DCMNR Dump Site, Killybegs	3.66
ENV/03/106	DCMNR Dump Site, Killybegs	2.60
ENV/03/108	Ocean Farm grower site – Inver Bay	10.6
ENV/03/109	Inner Inver Bay Sediment	6.33
ENV/03/110	Outer Inver Bay Sediment	5.16
ENV/03/111	Sediment + Water sampled from beside Port Pier Inver Bay	24.0
MSC/03/014	"Sediment"/Water "Black Water"	100
MSC/03/015	"Sediment" from nets at Ocean Farm	57.5

Appendix 11: Results of organic matter and carbonate analysis on sediment samples (Loss on Ignition carried out by MI carried out on sediment samples from DCMNR Dump Site, Inver and Mc Swynes Bay)

Step 1 3hrs @500ºC (Determines Loss on Ignition)
Step 2 4hrs @925ºC (Determination of Carbonate %)

Sample No.	Sample Information	LOI %	Carbonate %
ENV/03/105	DCMNR Dump Site, Killybegs	2.89	13.57
ENV/03/106	DCMNR Dump Site, Killybegs	2.51	14.29
MSC/03/001	Stn 1 near cages McSwynes	14.06	16.59
MSC/03/002	Stn 3 McSwynes	9.08	12.62
MSC/03/016	Eany Cages - Grab 1	12.55	8.22
MSC/03/017	Central Inver Bay - Grab 2	8.01	9.77
MSC/03/018	Ocean Farm Cages - Grab 3	6.79	14.14
MSC/03/019	Outer Inver Bay - Grab 4	6.54	15.77

Appendix 12: Results of Total Organic Carbon analysis from sediment samples

Sediment samples (<63µm fraction) from DCMNR Dump Site, Inver and Mc Swynes Bay. Analysis by "Alcontrol" laboratories

Sample No.	Sampling Site	TOC (%)
MSC/03/001	Stn 1 near cages McSwynes	3.05
MSC/03/002	Stn 3 McSwynes	2.17
MSC/03/016	Eany Cages - Grab 1	2.07
MSC/03/017	Central Inver Bay - Grab 2	2.07
MSC/03/018	Ocean Farm Cages - Grab 3	1.53
MSC/03/019	Outer Inver Bay - Grab 4	0.89
ENV/03/105	DCMNR Dump Site, Killybegs	0.87
ENV/03/106	DCMNR Dump Site, Killybegs	0.47

Appendix 13: Results of Scanning Electron Microscopy (SEM) and X Ray Diffraction (XRD) from sediment samples and "silt" sample

(carried out by Centre for Microscopy and Analysis (CMA), Trinity College Dublin, on sediment samples collected from DCMNR Dumpsite and Inver Bay 13/08/03)

SAMPLE ID: Sea Sediment Samples. Your Ref: ENV/03/105, ENV/03/106, ENV/03/108, ENV/03/109, ENV/03/110, ENV/03/111 & MSC/03/015.
REFERENCE NUMBER: S2931
ANALYST: Colin Reid

Introduction

7 Sea Sediment Samples (Our ref: 7183-7189), (Your Ref: ENV/03/105, ENV/03/106, ENV/03/108, ENV/03/109, ENV/03/110, ENV/03/111 & MSC/03/015) were supplied by Marine Institute on the 27th August, 2003. Analysis of the seven samples using XRD analysis and SEM/X-Ray analysis was requested.

Technical Details

SAMPLE PREPARATION: The samples were analysed as received.
ELECTRON MICROSCOPE: Hitachi S-3500N VPSEM
ACCELERATING VOLTAGE: 20 KV
ANALYSIS TYPE: Energy Dispersive X-ray Analysis
X-RAY ANALYSER: PGT IMIX-PTS
ANALYSIS TYPE: X-ray Diffraction
INSTRUMENT: Philips PW1010/1050
X-RAY TUBE: Copper
OTHER CONDITIONS: 40KV and 20mA with a graphite crystal monochromator.

Results

Sample 7183 – ENV/03/105 Photos 30135-38 Analysis1-5 XRD Spectrum appended.
Sample 7184 – ENV/03/106 Photos 30139-42 Analysis6-10 XRD Spectrum appended
Sample 7185 – ENV/03/108 Photos 30143-46 Analysis11-15 XRD Spectrum appended
Sample 7186 – ENV/03/109 Photos 30147-50 Analysis16-20 XRD Spectrum appended
Sample 7187 – ENV/03/110 Photos 30151-54 Analysis17-25 XRD Spectrum appended
Sample 7188 – ENV/03/111 Photos 30155-58 Analysis26-30 XRD Spectrum appended
Sample 7189 – MSC/03/015 Photos 30159-62 Analysis31-35 XRD Spectrum appended

Discussion and Conclusions

Five areas were analysed in each sample and the results quantified. Samples 7183-7188 were found to be similar in composition. This was confirmed by the XRD analysis which identified the presence of the same minerals [Quartz, Feldspar (Albite), Calcite and Mica (Muscovite)] in each of these samples. Samples 7184-7188 also contained some Chlorite. Sample 7189 visually appeared to be mainly shell fragments and was found to consist almost entirely of Calcite.

Appendix 14: Results of Scanning Electron Microscopy (SEM) and Fourier Transformation Infra-red
(carried out by Centre for Microscopy and Analysis (CMA), Trinity College Dublin, of diver's regulator by SEM and FTIR.)

SAMPLE ID: Diver's Regulator. Your Ref: FM deposits.
REFERENCE NUMBER: S3002
ANALYST: Colin Reid

Introduction
A Diver's Regulator (Our ref: 7383), (Your Ref: FM deposits) was supplied by the Marine Institute on the 26th September, 2003. Analysis of the deposits was requested.

Technical Details
SAMPLE PREPARATION: The samples were analysed as received.
ELECTRON MICROSCOPE: Hitachi S-3500N VPSEM
ACCELERATING VOLTAGE: 20 KV
ANALYSIS TYPE: Energy Dispersive X-ray Analysis
X-RAY ANALYSER: PGT IMIX-PTS
ANALYSIS TYPE: FT-IR
INSTRUMENT: Perkin Elmer Spectrum One uATR

Results
Sample 7383 – Diver's Regulator FM. Photos 30399-30401 Analysis36-39 FT-IR Spectra appended.

Discussion and Conclusions
Sample 7383 – Diver's Regulator FM. The deposit was analysed initially by FT-IR. Spectra were collected which library matched closely to Calcium Stearate. X-Ray analysis of the FM showed that salts were present. The elements found included Sodium, Chlorine, Carbon, Oxygen, Magnesium, Calcium, Aluminium, Silicon, Phosphorous, Sulphur & Potassium. Examination of the deposit morphology identified the presence of Fungal hyphae.

In conclusion the black regions appear to be due to the presence of fungal hyphae. There are deposits of salts, as expected, but there were also significant amounts of material that matched reasonably closely to Calcium Stearate.

Appendix 15: Analysis of unknown material found in cages in Inver Bay, and of smolt and grower feed samples.

CERTIFICATE OF ANALYSIS

Report No: P3-3410
Company: Marine Institute — Your Ref:MI-03-960
Address: Galway Technology Park — Received: 30.09.03
Parkmore Galway — Page No: 1 of 2

Fatty Acid Analysis of Feed Samples and Unidentified Substance

Results	**Fatty Acid Profile (expressed as % of total fatty acids)**		
Your Code:	Sample A	Sample B	Sample C
	Smolt Feed 01-08-03	Grower Feed 01-08-03	Unidentified Substance
Our Code:	P3-3410-1	P3-3410-2	P3-3410-3
C14:0	6.2	5.4	4.8
C14:1	0.3	0.1	0.3
C15:0	0.6	0.3	0.4
C16:0	18.9	12.8	15.7
C16:1	6.7	5.8	5.7
C17:0 (iso)	0.2	0.3	0.4
C17:0	0.4	0.3	0.4
C18:0 (iso)	0.7	0.4	0.4
C18:0	4.7	3.5	4.0
C18:1 (trans)	0.3	0.5	1.5
C18:1	13.9	13.0	20.6
C18:2	3.0	2.0	3.1
C18:3(n-6)	0.2	0.1	0.0
C18:3(n-3)	0.8	0.5	0.8
C20:0	0.4	0.2	0.3
C20:1 (n-9 + 11)	6.0	18.4	14.2
C20:2 (n-6)	0.3	0.2	0.5
C20:3 (n-6)	0.1	0.0	0.1
C20:4 (n-6) (Arachidonic)	1.1	0.3	0.3
C20:5 (n-3) (EPA)	12.7	5.6	2.4
C22:0	0.3	0.1	0.1
C22:1 (n-9, 11 + 13)	4.5	22.7	16.0
C22:4 (n-6)	0.6	0.3	0.2
C22:5 (n-6)	0.5	0.2	0.2
C22:5 (n-3)	1.8	0.7	1.7
C22:6 (n-3) (DHA)	12.2	5.2	4.4
C24:0	0.3	0.0	0.1
C24:1	0.8	1.0	1.3
Unidentified	1.7	0.0	0.0

Signatories: — Date: 27th October 2003
R G Griffiths (Technical Manager-Lipids)

These results relate only to the sample(s) tested and do not guarantee the bulk of the material to be of equal quality.RSSL staff were not responsible for the taking of samples. RSSL cannot be held liable in respect of the use to which the information is put

CERTIFICATE OF ANALYSIS

Report No:	P3-3410		
Company:	Marine Institute	Your Ref:	MI-03-960
Address:	Galway Technology Park Parkmore Galway	Received:	30.09.03
		Page No:	2 of 2

Fatty Acid Analysis of Feed Samples and Unidentified Substance

The fatty acid profiles of the two feed samples correspond to that of fish oils. The fatty acid profiles differ in their composition and are likely to be oils from different fish species. The fatty acid profiles would suggest the oil present in the feed samples is mainly composed of fish oil and any other oil, if present, would have to be at levels less than approximately 5 %.

The fatty acid profile of the oil extracted from the unidentified substance also corresponds to that of a fish oil. The fatty acid profile of the unidentified substance more closely resembles the fatty acid profile from the grower feed (sample B), however there may also be some oil present from the smolt feed (sample A).

Since the unidentified substance and the feed samples all contain oil mainly of fish origin, it is not possible to tell if the unidentified substance is derived from the feed samples or fish origin. However, the fatty acid profile of the unidentified substance does resemble that of the grower feed with a smaller amount of the smolt feed.

Signatories: Date: 27th October 2003

R G Griffiths (Technical Manager-Lipids)

These results relate only to the sample(s) tested and do not guarantee the bulk of the material to be of equal quality.

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Appendix 16: Results of veterinary residue testing on tissue samples (fish tissue samples taken from fish from Eany Fish Products and Ocean Farms, Inver Bay, 5th – 8th September, 2003)

(i) Pyrethroid residues: Analysis by CCFRA Technology Limited, Gloucestershire, UK

Sample description	Residues / analytes	LOD (mg kg^{-1})	Samples analysed for:	MRL (mg kg^{-1})
MSC / 03 / 055 Blended fish	None detected	0.050	Bifenthrin Cyfluthrin	none 0.01*
MSC / 03 / 056 Blended fish	None detected	0.050	Cyhalothrin, Cypermethrin	0.05* 0.05
MSC / 03 / 057 Blended fish	None detected	0.050	Deltamethrin Fenvalerate Fenpropathrin Permethrin	0.01 0.025* none 0.05*

(ii) Benzimidazole residues: Analysis by National Food Centre, Castleknock, Dublin

Sample description	Residues / analytes	Samples tested for: LOD in brackets (mg kg^{-1})	MRL (mg kg^{-1})
MSC / 03 / 055 Blended fish	None detected	Albendezole Sulphone (0.1), Oxfendazole (0.1)	0.1* 0.01*
MSC / 03 / 056 Blended fish	None detected	Cambendazole (0.1) Mebendazole(0.1)	 0.06*
MSC / 03 / 057 Blended fish	None detected	Thiabendazole(0.05)	0.1*

(iii) Avermectin residues: Analysis by National Food Centre, Castleknock, Dublin.

Sample description	Residues / analytes	LOD (mg kg^{-1})	Samples tested for:	MRL (mg kg^{-1})
MSC / 03 / 055 Blended fish	None detected	0.002	Abamectin Doramectin	0.02* 0.01*
MSC / 03 / 056 Blended fish	None detected	0.002	Moxidectin Eprinomectin	0.05* 0.03*
MSC / 03 / 057 Blended fish	None detected	0.002	Emamectin benzoate Ivermectin	0.1 0.1*

(iv) Residue testing

Sample description	Residues / analytes	Samples tested for: (LOD (mg kg^{-1}) in brackets)	MRL (mg kg^{-1})
ENV 2003 070	None detected	Teflubenzuron (0.083) & Diflubenzuron (0.124) not detected in 070 and 071.& Cypermethrin (0.01)- < LoD in all samples	0.5 1.0*$ 0.05
ENV 2003 071	None detected		
ENV 2003 072	None detected		
ENV 2003 074	None detected		

* Figures listed are limits of action, available for unauthorised substances. MRLs are set only for authorised substances.

$ Diflubenzuron is not licensed for use in Ireland. It does, however, have a provisional MRL set for use in Scotland.

& Insufficient sample available for to test samples ENV 2003 072 and ENV 2003 074

Appendix 17: Results of Microtox testing of water and pore samples (water and interstitial water samples)
(carried out by Enterprise Ireland Shannon Laboratory)

1) Microtox results for waters samples taken 16th July 2003.

Sample location	% Light inhibition	Number of toxicity units (tu)
Station 3 Inver Bay (ENV03/100/ORI)	1.6% at 100% vol/vol after 30 mins.	<1
Station 5 Inver Bay (ENV03/99/ORI)	0.0%	<1
Station 6 Inver Bay (ENV03/101/ORI)	0.0%	<1

2) Microtox results for interstitial waters from sediments sampled 3rd October 2003.

Sample location	% Light inhibition	Number of toxicity units (tu)
Inner Inver	0%	<1
Mid Inver	0%	<1
Outer Inver Nr growers	0%	<1
Outer Inver Nr growers	0%	<1
Smolt cages	0%	<1
Inner McSwynes	0%	<1
McSwynes, between growers and smolt cages	0%	<1
Outer McSwynes, sth of grower	0%	<1

Appendix 18: Results of analysis of mussel tissue for biotoxins.

HABs code	Chemistry log-in code	Location reference	Sample date	Receipt date at GTP	OA[1] equiv. (μgg^{-1})	AZP[2] equiv. (μgg^{-1})	ASP[3] equiv. (μgg^{-1})
BTX0335091	ENV03-073	Cage 2 (1), 3 m depth	30-Jul-03	12-Aug-03	0.33	<0.01	<1.00
BTX0335092	ENV03-073	Cage 2 (2), 3 m depth	30-Jul-03	12-Aug-03	0.24	<0.01	<1.00
BTX0335093	n/a	Smolt	01-Aug-03	12-Aug-03	0.13	<0.01	<1.00
BTX0335094	ENV03-072	Creevin cage 2	10-Jul-03	12-Aug-03	0.18	<0.01	<1.00

1 = the legal threshold for OA equivalents in mussels intended for human consumption is 0.16 µg/g
2 = the legal threshold for AZA equivalents in mussels intended for human consumption is 0.16 µg/g
3 = the legal threshold for ASP equivalents in mussels intended for human consumption is 20 µg/g

1,2,3 = none of these compounds have been reported to be causing fish kills directly

Appendix 19: Phytoplankton data recorded from discrete depths collected in Inver Bay from the 24th June to 1st August, 2003 and vertical phytoplankton net hauls collected in Inver Bay on the 16th July, 2003.

Inver Bay, Ocean Inver (54.61034N, 8.35322W), 15m integrated sample (Lund tube)				
Total count not carried out.				
Identifiable phytoplankton coverage of plate: Low to Medium				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
24-Jun-03	PHY0326056	Leptocylindrus danicus		PREDOMINANT
24-Jun-03	PHY0326056	Pseudo-nitzschia seriata group	160	ASP toxin producer (shellfish)
24-Jun-03	PHY0326056	Thalassiosira rotula/gravida	present	
24-Jun-03	PHY0326056	Proboscia alata	present	
DINOFLAGELLATES				
24-Jun-03	PHY0326056	Dinophysis acuminata	80	DSP toxin producer (shellfish)
24-Jun-03	PHY0326056	Ceratium horridum	80	
24-Jun-03	PHY0326056	Protoperidinium oblongum	40	
24-Jun-03	PHY0326056	Protoperidinium mite	40	
24-Jun-03	PHY0326056	Dinophysis rotundata	40	DSP toxin producer (shellfish)
24-Jun-03	PHY0326056	Dinophysis acuta	40	DSP toxin producer (shellfish)
24-Jun-03	PHY0326056	Ceratium furca	40	

Inver Bay, Ocean Inver (54.61034N, 8.35322W), 15m integrated sample (Lund tube)				
Total count not carried out.				
Identifiable phytoplankton coverage of plate: Medium				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
26-Jun-03	PHY0326055	Leptocylindrus danicus		Predominant organism
26-Jun-03	PHY0326055	Pseudo-nitzschia seriata group	640	ASP toxin producer (shellfish)
26-Jun-03	PHY0326055	Proboscia alata	present	
26-Jun-03	PHY0326055	Thalassiosira rotula/gravida	present	
26-Jun-03	PHY0326055	Leptocylindrus minimus	present	
26-Jun-03	PHY0326055	Thalassionema nitzschioides	present	
26-Jun-03	PHY0326055	Chaetoceros sp. (Hyalochaete group)	present	
26-Jun-03	PHY0326055	Proboscia alata	present	
DINOFLAGELLATES				
26-Jun-03	PHY0326055	Prorocentrum micans	80	

Inver Bay, Ocean Inver (54.61034N, 8.35322W), 15m integrated sample (Lund tube)				
Total count not carried out.				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
30-Jun-03	PHY0327027	Leptocylindrus danicus		Predominant organism
30-Jun-03	PHY0327027	Proboscia alata	present	
30-Jun-03	PHY0327027	Leptocylindrus minimus	present	
30-Jun-03	PHY0327027	Pseudo-nitzschia seriata	280	ASP toxin producer (shellfish)
DINOFLAGELLATES				
30-Jun-03	PHY0327027	Scrippsiella sp.	present	
30-Jun-03	PHY0327027	Dinophysis acuta	40	DSP toxin producer (shellfish)
30-Jun-03	PHY0327027	Dinophysis acuminata	120	DSP toxin producer (shellfish)
OTHER				
30-Jun-03	PHY0327027	Cilliates	present	

Inver Bay, Ocean Inver (54.61034N, 8.35322W), 15m integrated sample (Lund tube)				
Total count not carried out.				
Identifiable phytoplankton coverage of plate: High				
Debris coverage of plate: Medium				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
9-Jul-03	PHY0329001	Leptocylindrus danicus	250000	PREDOMINANT
9-Jul-03	PHY0329001	Pseudo-nitzschia delicatissima group	1200	ASP toxin producer (shellfish)
9-Jul-03	PHY0329001	Pseudo-nitzschia seriata group	320	ASP toxin producer (shellfish)
9-Jul-03	PHY0329001	Chaetoceros danicus	200	Harmful to finfish when present in high cell densities
9-Jul-03	PHY0329001	Chaetoceros sp. (Hyalochaete group)	present	
9-Jul-03	PHY0329001	Thalassiosira sp.	present	
9-Jul-03	PHY0329001	Rhizosolenia setigera	present	
9-Jul-03	PHY0329001	Proboscia alata	present	
9-Jul-03	PHY0329001	Guinardia deliculata	present	
9-Jul-03	PHY0329001	Cylidrotheca closterium	present	
DINOFLAGELLATES				
9-Jul-03	PHY0329001	Prorocentrum micans	200	
9-Jul-03	PHY0329001	Alexandrium sp.	80	PSP toxin producer (shellfish)
9-Jul-03	PHY0329001	Protoperidinium pellucidum	40	
9-Jul-03	PHY0329001	Dinophysis acuminata	40	DSP toxin producer (shellfish)
9-Jul-03	PHY0329001	Armoured dinoflagellate sp.	present	
9-Jul-03	PHY0329001	Diplopsalis lenticula	present	

Dive site 1 (54.612N, 8.3477W), Bottom sample (20 m)					
Identifiable phytoplankton coverage of plate: Low					
Debris coverage of plate: Medium					
Sample date		MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS	16-Jul-03	PHY0330003	Leptocylindrus danicus	81750	Predominant organism
	16-Jul-03	PHY0330003	Chaetoceros curvisetus/C. debilis	10500	
	16-Jul-03	PHY0330003	Proboscia alata	3000	
	16-Jul-03	PHY0330003	Thalassiosira rotula/gravida	1500	
	16-Jul-03	PHY0330003	Cylindrotheca closterium/Nitzschia longissima	750	
	16-Jul-03	PHY0330003	Leptocylindrus mediterraneus	750	
	16-Jul-03	PHY0330003	Chaetoceros sp. (Hyalochate group)	440	
	16-Jul-03	PHY0330003	Pseudo-nitzschia delicatissima group	280	ASP toxin producer (shellfish)
	16-Jul-03	PHY0330003	Leptocylindrus minimus	160	
	16-Jul-03	PHY0330003	Skeletonema costatum	160	
	16-Jul-03	PHY0330003	Unidentified Thalassiosira sp.	160	
	16-Jul-03	PHY0330003	Guinardia flaccida	120	
	16-Jul-03	PHY0330001	Pseudo-nitzschia seriata group	120	ASP toxin producer (shellfish)
	16-Jul-03	PHY0330003	Guinardia delicatula	80	
	16-Jul-03	PHY0330003	Navicula sp.	40	
DINOFLAGELLATES					
	16-Jul-03	PHY0330003	Gymnodinium sp.	750	
	16-Jul-03	PHY0330003	Scrippsiella sp.	750	
	16-Jul-03	PHY0330003	Prorocentrum micans	80	
OTHER	16-Jul-03	PHY0330003	Euglena/Eutriptiella spp.	750	
	16-Jul-03	PHY0330003	Microflagellates	750	
	16-Jul-03	PHY0330003	Amobea	750	
	16-Jul-03	PHY0330003	Mesodinium rubrum	80	

Dive site 2 (54.6083N, 8.3538W), Bottom sample (21.6 m)					
Identifiable phytoplankton coverage of plate: Low					
Debris coverage of plate: High					
Sample date		MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS	16-Jul-03	PHY0330008	Leptocylindrus danicus	44640	Predominant organism
	16-Jul-03	PHY0330008	Chaetoceros sp. (Hyalochate group)	2720	
	16-Jul-03	PHY0330008	Guinardia delicatula	320	
	16-Jul-03	PHY0330008	Leptocylindrus minimus	1760	
	16-Jul-03	PHY0330008	Paralia sulcata	1600	
	16-Jul-03	PHY0330008	Proboscia alata	1760	
	16-Jul-03	PHY0330008	Skeletonema costatum	640	
	16-Jul-03	PHY0330008	Thalassionema nitzschioides	320	
	16-Jul-03	PHY0330008	Unidentified pennate diatom	160	

Station 3 (54.6176N, 8.3255W): 15 m				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: High				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
16-Jul-03	PHY0330010	Leptocylindrus danicus	37500	Predominant organism
16-Jul-03	PHY0330010	Chaetoceros socialis	5250	
16-Jul-03	PHY0330010	Proboscia alata	2250	
16-Jul-03	PHY0330010	Cylindrotheca closterium/Nitzschia longissima	1560	
16-Jul-03	PHY0330010	Guinardia delicatula	480	
16-Jul-03	PHY0330010	Unidentified Thalassiosira sp.	120	
16-Jul-03	PHY0330010	Navicula sp.	40	
16-Jul-03	PHY0330010	Pleurosigma/Gyrosigma sp.	40	
DINOFLAGELLATES				
16-Jul-03	PHY0330010	Diplopsalis lenticula	160	
16-Jul-03	PHY0330010	Oblea rotunda	80	
16-Jul-03	PHY0330010	Naked dinoflagellate	80	
16-Jul-03	PHY0330010	Protoperidinium achromaticum	40	
16-Jul-03	PHY0330010	Scrippsiella sp.	40	
16-Jul-03	PHY0330010	Unidentified armoured dinoflagellate	40	
OTHER				
16-Jul-03	PHY0330010	Cilliates	120	
16-Jul-03	PHY0330010	Amobea	40	

Station 5 (54.5667N, 8.4348W): Surface (2 m)				
Identifiable phytoplankton coverage of plate: Medium				
Debris coverage of plate: Medium				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
16-Jul-03	PHY0330001	Leptocylindrus danicus	93606	Predominant organism
16-Jul-03	PHY0330001	Proboscia alata	7020	
16-Jul-03	PHY0330001	Ceratulina pelagica	3900	
16-Jul-03	PHY0330001	Guinardia delicatula	3120	
16-Jul-03	PHY0330001	Thalassionema nitzschioides	2340	
16-Jul-03	PHY0330001	Chaetoceros sp. (Hyalochate group)	1560	
16-Jul-03	PHY0330001	Pseudo-nitzschia seriata group	880	ASP toxin producer (shellfish)
16-Jul-03	PHY0330001	Guinardia flaccida	80	
DINOFLAGELLATES				
16-Jul-03	PHY0330001	Gymnodinium sp.	3900	
16-Jul-03	PHY0330001	Prorocentrum micans	780	
16-Jul-03	PHY0330001	Diplopsalis bomba	780	
16-Jul-03	PHY0330001	Oxytoxum caudatum	780	
16-Jul-03	PHY0330001	Scrippsiella sp.	780	
16-Jul-03	PHY0330001	Naked dinoflagellate	780	
16-Jul-03	PHY0330001	Alexandrium sp.	160	PSP toxin producer (shellfish)

16-Jul-03	PHY0330001	Protoperidinium leonis	80	
16-Jul-03	PHY0330001	Diplopsalis lenticula	80	
16-Jul-03	PHY0330001	Karenia mikimotoi	40	Harmful to finfish when present in high cell densities
16-Jul-03	PHY0330001	Ceratium tripos	40	
16-Jul-03	PHY0330001	Spiny dinoflagellate cyst	40	
OTHER				
16-Jul-03	PHY0330001	Microflagellates	53820	
16-Jul-03	PHY0330001	Euglena/Eutriptiella spp.	2340	
16-Jul-03	PHY0330001	Cilliates	2340	
16-Jul-03	PHY0330001	Amobea	1560	

Station 5 (54.5667N, 8.4348W): Bottom (~14 metres), above the sediment				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: High				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
16-Jul-03	PHY0330002	Leptocylindrus danicus	25500	Predominant organism
16-Jul-03	PHY0330002	Proboscia alata	750	
16-Jul-03	PHY0330002	Pseudo-nitzschia seriata group	440	ASP toxin producer (shellfish)
16-Jul-03	PHY0330002	Thalassionema nitzschioides	320	
16-Jul-03	PHY0330002	Paralia sulcata	280	
16-Jul-03	PHY0330002	Pleurosigma/Gyrosigma sp.	280	
16-Jul-03	PHY0330002	Chaetoceros sp. (Hyalochate group)	160	
16-Jul-03	PHY0330002	Ceratulina pelagica	120	
16-Jul-03	PHY0330002	Unidentified Thalassiosira sp.	40	
DINOFLAGELLATES				
16-Jul-03	PHY0330002	Protoperidinium brevipes	80	
16-Jul-03	PHY0330002	Diplopsalis lenticula	80	
16-Jul-03	PHY0330002	Protoperidinium mite	40	
16-Jul-03	PHY0330002	Protoperidinium bipes	40	
16-Jul-03	PHY0330002	Gymnodinium sp.	40	
16-Jul-03	PHY0330002	Gonyaulax scrippsae	40	
16-Jul-03	PHY0330002	Naked dinoflagellate	40	
OTHER				
16-Jul-03	PHY0330002	Cilliates	750	

Control 1: 500m out the Bay from BS7 (outermost cage), 15m integrated sample (Lund tube)				
Note: Latitude or Longitude co-ordinate values were not provided				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
31-Jul-03	PHY0332001	Proboscia alata	30000	Predominant organism
31-Jul-03	PHY0332001	Chaetoceros sp. (Hyalochate group)	20250	
31-Jul-03	PHY0332001	Leptocylindrus danicus	12750	
31-Jul-03	PHY0332001	Thalassionema nitzschoides	8250	
31-Jul-03	PHY0332001	Chaetoceros didymus	6000	
31-Jul-03	PHY0332001	Asterionellopsis glacialis	6000	
31-Jul-03	PHY0332001	Thalassiosira sp	3750	
31-Jul-03	PHY0332001	Pseudo-nitzschia delicatissma group	2480	ASP toxin producer (shellfish)
31-Jul-03	PHY0332001	Dactyliosolen fragilissimus	1500	
31-Jul-03	PHY0332001	Rhizosolenia setigera	1500	
31-Jul-03	PHY0332001	Cerataulina pelagica	1500	
31-Jul-03	PHY0332001	Pseudo-nitzschia seriata group	1200	ASP toxin producer (shellfish)
31-Jul-03	PHY0332001	Cylidrotheca closterium	750	
31-Jul-03	PHY0332001	Pennate Diatom sp.	750	
31-Jul-03	PHY0332001	Ditylum brightwellii	40	
31-Jul-03	PHY0332001	Pleurosigma / Gyrosigma sp	40	
DINOFLAGELLATES				
31-Jul-03	PHY0332001	Amphidoma caudata	800	
31-Jul-03	PHY0332001	Scrippsiella sp	320	
31-Jul-03	PHY0332001	Alexandrium sp.	160	PSP toxin producer (shellfish)
31-Jul-03	PHY0332001	Dinophysis acuta	40	DSP toxin producer (shellfish)
31-Jul-03	PHY0332001	Prorocentrum micans	40	

Control 2: 50 m out the Bay from BS7 (outermost cage), 15m integrated sample (Lund tube)				
Note: Latitude or Longitude co-ordinate values were not provided				
Total count not carried out.				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
31-Jul-03	PHY0332002	Thalassionema nitzschoides		Predominant organism
31-Jul-03	PHY0332002	Proboscia alata		Predominant organism
31-Jul-03	PHY0332002	Pseudo-nitzschia delicatissma group	12320	ASP toxin producer (shellfish)
31-Jul-03	PHY0332002	Pseudo-nitzschia seriata group	3440	ASP toxin producer (shellfish)
31-Jul-03	PHY0332002	Chaetoceros sp. (Hyalochate group)	present	
31-Jul-03	PHY0332002	Cylidrotheca closterium	present	
31-Jul-03	PHY0332002	Ditylum brightwellii	present	
31-Jul-03	PHY0332002	Leptocylindrus danicus	present	
31-Jul-03	PHY0332002	Rhizosolenia setigera	present	

31-Jul-03	PHY0332002	Thalassiosira sp	present	
DINOFLAGELLATES				
31-Jul-03	PHY0332002	Alexandrium sp.	280	PSP toxin producer (shellfish)
31-Jul-03	PHY0332002	Prorocentrum micans	120	
31-Jul-03	PHY0332002	Protoperidinium oblongum	40	
31-Jul-03	PHY0332002	Protoperidinium brevipes	40	
31-Jul-03	PHY0332002	Dinophysis acuminata	40	DSP toxin producer (shellfish)
31-Jul-03	PHY0332002	Scrippsiella sp	present	
31-Jul-03	PHY0332002	Amphidoma caudata	present	
31-Jul-03	PHY0332002	Heterocapsa triquetra	present	

Control 3: 100m towards joes cages from BS12 innermost smolt cage, 15m integrated sample (Lund tube)				
Note: Latitude or Longitude co-ordinate values were not provided				
Total count not carried out.				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
31-Jul-03	PHY0332003	Leptocylindrus danicus		Predominant organism
31-Jul-03	PHY0332003	Pseudo-nitzschia delicatissma group	20080	ASP toxin producer (shellfish)
31-Jul-03	PHY0332003	Pseudo-nitzschia seriata group	2880	ASP toxin producer (shellfish)
31-Jul-03	PHY0332003	Dactyliosolen fragilissimus	present	
31-Jul-03	PHY0332003	Cylidrotheca closterium	present	
31-Jul-03	PHY0332003	Thalassionema nitzschoides	present	
31-Jul-03	PHY0332003	Cerataulina pelagica	present	
31-Jul-03	PHY0332003	Chaetoceros didymus	present	
31-Jul-03	PHY0332003	Chaetoceros decipiens	present	
31-Jul-03	PHY0332003	Chaetoceros (Hyalochaete) sp	present	
31-Jul-03	PHY0332003	Proboscia alata	present	
DINOFLAGELLATES				
31-Jul-03	PHY0332003	Alexandrium sp.	720	PSP toxin producer (shellfish)
31-Jul-03	PHY0332003	Prorocentrum micans	320	
31-Jul-03	PHY0332003	Dinophysis acuminata	80	DSP toxin producer (shellfish)
31-Jul-03	PHY0332003	Protoperidinium leonis	40	
31-Jul-03	PHY0332003	Scrippsiella sp	present	
31-Jul-03	PHY0332003	Ceratium lineatum	present	
31-Jul-03	PHY0332003	Gyrodinium fusiforme	present	
OTHER				
31-Jul-03	PHY0332003	Dictyocha speculum	present	

Control 4: inside Bay close to Willies smolt cages, 15m integrated sample (Lund tube)				
Note: Latitude or Longitude co-ordinate values were not provided				
Total count not carried out.				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
31-Jul-03	PHY0332004	Proboscia alata		Predominant organism
31-Jul-03	PHY0332004	Pseudo-nitzschia delicatissma group	21750	ASP toxin producer (shellfish)
31-Jul-03	PHY0332004	Pseudo-nitzschia seriata group	11250	ASP toxin producer (shellfish)
31-Jul-03	PHY0332004	Cerataulina pelagica	present	
31-Jul-03	PHY0332004	Dactyliosolen fragilissimus	present	
31-Jul-03	PHY0332004	Rhizosolenia setigera	present	
31-Jul-03	PHY0332004	Chaetoceros didymus	present	
31-Jul-03	PHY0332004	Cylidrotheca closterium	present	
31-Jul-03	PHY0332004	Leptocylindrus danicus	present	
31-Jul-03	PHY0332004	Chaetoceros (Hyalochaete) sp	present	
31-Jul-03	PHY0332004	Thalassionema nitzschoides	present	
31-Jul-03	PHY0332004	Thalassiosira sp	present	
31-Jul-03	PHY0332004	Chaetoceros decipiens	present	
DINOFLAGELLATES				
31-Jul-03	PHY0332004	Alexandrium sp.	240	PSP toxin producer (shellfish)
31-Jul-03	PHY0332004	Prorocentrum micans	200	
31-Jul-03	PHY0332004	Dinophysis acuminata	40	DSP toxin producer (shellfish)
31-Jul-03	PHY0332004	Scrippsiella sp	present	
31-Jul-03	PHY0332004	Ceratium lineatum	present	
31-Jul-03	PHY0332004	Ceratium tripos	present	
31-Jul-03	PHY0332004	Gyrodinium fusiforme	present	
31-Jul-03	PHY0332004	Amphidoma caudata	present	
OTHER				
31-Jul-03	PHY0332004	Mesodinium rubrum	present	

Control 5: 100m off Joe Roses cages towards the centre of the Bay, 15m integrated sample (Lund tube)				
Note: Latitude or Longitude co-ordinate values were not provided				
Total count not carried out.				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
31-Jul-03	PHY0332005	Proboscia alata		Predominant organism
31-Jul-03	PHY0332005	Chaetoceros sp. (Hyalochate group)		Predominant organism
31-Jul-03	PHY0332005	Pseudo-nitzschia delicatissma group	45750	ASP toxin producer (shellfish)
31-Jul-03	PHY0332005	Pseudo-nitzschia seriata group	9750	ASP toxin producer (shellfish)
31-Jul-03	PHY0332005	Leptocylindrus danicus	present	
31-Jul-03	PHY0332005	Dactyliosolen fragilissimus	present	

31-Jul-03	PHY0332005	Cylidrotheca closterium	present	
31-Jul-03	PHY0332005	Thalassiosira sp	present	
31-Jul-03	PHY0332005	Chaetoceros didymus	present	
31-Jul-03	PHY0332005	Rhizosolenia setigera	present	
31-Jul-03	PHY0332005	Cerataulina pelagica	present	
31-Jul-03	PHY0332005	Thalassionema nitzschoides	present	
DINOFLAGELLATES				
31-Jul-03	PHY0332005	Alexandrium sp.	480	PSP toxin producer (shellfish)
31-Jul-03	PHY0332005	Dinophysis acuminata	80	DSP toxin producer (shellfish)
31-Jul-03	PHY0332005	Protoperidinium brevipes	80	
31-Jul-03	PHY0332005	Prorocentrum micans	80	
31-Jul-03	PHY0332005	Protoperidinium oblongum	40	
31-Jul-03	PHY0332005	Protoperidinium leonis	40	
31-Jul-03	PHY0332005	Diplopsalis lenticula	present	
31-Jul-03	PHY0332005	Gonyaulax sp	present	
31-Jul-03	PHY0332005	Gyrodinium sp	present	
31-Jul-03	PHY0332005	Gymnodinium sp	present	
31-Jul-03	PHY0332005	Amphidinium sp.	present	
31-Jul-03	PHY0332005	Ceratium macroceros	present	
31-Jul-03	PHY0332005	Scrippsiella sp	present	

Cage number BS 7 (outside this cage), 15m integrated sample (Lund tube)				
Note: Latitude or Longitude co-ordinate values were not provided				
Total count not carried out.				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
31-Jul-03	PHY0332006	Chaetoceros sp. (Hyalochate group)		Predominant organism
31-Jul-03	PHY0332006	Leptocylindrus danicus		Predominant organism
31-Jul-03	PHY0332006	Proboscia alata		Predominant organism
31-Jul-03	PHY0332006	Pseudo-nitzschia delicatissma group	25500	ASP toxin producer (shellfish)
31-Jul-03	PHY0332006	Pseudo-nitzschia seriata group	1500	ASP toxin producer (shellfish)
31-Jul-03	PHY0332006	Chaetoceros danicus	40	Harmful to finfish when present in high cell densities
31-Jul-03	PHY0332006	Thalassiosira sp	present	
31-Jul-03	PHY0332006	Pennate Diatom sp.	present	
31-Jul-03	PHY0332006	Cylidrotheca closterium	present	
31-Jul-03	PHY0332006	Cerataulina pelagica	present	
31-Jul-03	PHY0332006	Chaetoceros didymus	present	
31-Jul-03	PHY0332006	Dactyliosolen fragilissimus	present	
31-Jul-03	PHY0332006	Thalassionema nitzschoides	present	
31-Jul-03	PHY0332006	Rhizosolenia setigera	present	
DINOFLAGELLATES				
31-Jul-03	PHY0332006	Alexandrium sp.	1080	PSP toxin producer (shellfish)
31-Jul-03	PHY0332006	Prorocentrum micans	520	

31-Jul-03	PHY0332006	Dinophysis tripos	40	DSP toxin producer (shellfish)
31-Jul-03	PHY0332006	Dinophysis acuminata	40	DSP toxin producer (shellfish)
31-Jul-03	PHY0332006	Protoperidinium steinii	40	
31-Jul-03	PHY0332006	Ceratium lineatum	present	
31-Jul-03	PHY0332006	Ceratium tripos	present	
31-Jul-03	PHY0332006	Scrippsiella sp	present	

Cage number BS 12 (outside this cage), 15m integrated sample (Lund tube)				
Note: Latitude or Longitude co-ordinate values were not provided				
Total count not carried out.				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
31-Jul-03	PHY0332007	Proboscia alata		Predominant organism
31-Jul-03	PHY0332007	Leptocylindrus danicus		Predominant organism
31-Jul-03	PHY0332007	Pseudo-nitzschia delicatissma group	12000	ASP toxin producer (shellfish)
31-Jul-03	PHY0332007	Pseudo-nitzschia seriata group	6000	ASP toxin producer (shellfish)
31-Jul-03	PHY0332007	Chaetoceros sp. (Hyalochate group)	present	
31-Jul-03	PHY0332007	Cylidrotheca closterium	present	
31-Jul-03	PHY0332007	Chaetoceros didymus	present	
31-Jul-03	PHY0332007	Licmophora sp	present	
31-Jul-03	PHY0332007	Dactyliosolen fragilissimus	present	
31-Jul-03	PHY0332007	Cerataulina pelagica	present	
31-Jul-03	PHY0332007	Thalassiosira sp	present	
31-Jul-03	PHY0332007	Rhizosolenia setigera	present	
31-Jul-03	PHY0332007	Thalassionema nitzschoides	present	
DINOFLAGELLATES				
31-Jul-03	PHY0332007	Alexandrium sp.	360	PSP toxin producer (shellfish)
31-Jul-03	PHY0332007	Prorocentrum micans	120	
31-Jul-03	PHY0332007	Dinophysis acuminata	80	DSP toxin producer (shellfish)
31-Jul-03	PHY0332007	Protoperidinium leonis	40	
31-Jul-03	PHY0332007	Gonyaulax sp	present	
31-Jul-03	PHY0332007	Scrippsiella sp	present	

Cage number BS 15 (outside this cage), 15m integrated sample (Lund tube)				
Note: Latitude or Longitude co-ordinate values were not provided				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
31-Jul-03	PHY0332008	Chaetoceros sp. (Hyalochate group)	46500	Predominant organism
31-Jul-03	PHY0332008	Proboscia alata	24750	
31-Jul-03	PHY0332008	Leptocylindrus danicus	23250	
31-Jul-03	PHY0332008	Chaetoceros decipiens	9750	
31-Jul-03	PHY0332008	Thalassionema nitzschoides	7500	
31-Jul-03	PHY0332008	Pseudo-nitzschia delicatissma group	4560	ASP toxin producer (shellfish)
31-Jul-03	PHY0332008	Pseudo-nitzschia seriata group	3920	ASP toxin producer (shellfish)
31-Jul-03	PHY0332008	Cerataulina pelagica	3000	
31-Jul-03	PHY0332008	Leptocylindrus minimus	3000	
31-Jul-03	PHY0332008	Dactyliosolen fragilissimus	1500	
31-Jul-03	PHY0332008	Cylindrotheca closterium/Nittzschia longissima	1500	
31-Jul-03	PHY0332008	Rhizosolenia setigera	750	
31-Jul-03	PHY0332008	Pennate Diatom sp.	750	
31-Jul-03	PHY0332008	Asterionellopsis formosa	600	
31-Jul-03	PHY0332008	Thalassiosira sp	400	
31-Jul-03	PHY0332008	Asterionellopsis glacialis	240	
31-Jul-03	PHY0332008	Chaetoceros didymus	120	
31-Jul-03	PHY0332008	Pleurosigma / Gyrosigma sp	40	
31-Jul-03	PHY0332008	Chaetoceros danicus	40	Harmful to finfish when present in high cell densities
31-Jul-03	PHY0332008	Navicula sp	40	
DINOFLAGELLATES				
31-Jul-03	PHY0332008	Prorocentrum micans	320	
31-Jul-03	PHY0332008	Scrippsiella sp	320	
31-Jul-03	PHY0332008	Ceratium macroceros	160	
31-Jul-03	PHY0332008	Alexandrium sp.	80	PSP toxin producer (shellfish)
31-Jul-03	PHY0332008	Gonyaulax sp	80	
31-Jul-03	PHY0332008	Protoperidinium steinii	40	
31-Jul-03	PHY0332008	Dinophysis acuta	40	DSP toxin producer (shellfish)
31-Jul-03	PHY0332008	Diplopsalis lenticula	40	
31-Jul-03	PHY0332008	Protoperidinium brevipes	40	
31-Jul-03	PHY0332008	Gyrodinium sp	40	
OTHER				
31-Jul-03	PHY0332008	Euglena/Eutreptiella sp	160	
31-Jul-03	PHY0332008	Mesodinium rubrum	80	
31-Jul-03	PHY0332008	Dictyocha speculum	40	

Station 1 (54.62 N, 8.3018W), surface sample				
Total count not carried out.				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
1-Aug-03	PHY0332009	Proboscia alata		Predominant organism
1-Aug-03	PHY0332009	Pseudo-nitzschia delicatissma group	56250	ASP toxin producer (shellfish)
1-Aug-03	PHY0332009	Pseudo-nitzschia seriata group	12750	ASP toxin producer (shellfish)
1-Aug-03	PHY0332009	Prorocentrum micans	560	
1-Aug-03	PHY0332009	Chaetoceros decipiens	present	
1-Aug-03	PHY0332009	Cylidrotheca closterium	present	
1-Aug-03	PHY0332009	Rhizosolenia setigera	present	
1-Aug-03	PHY0332009	Cerataulina pelagica	present	
1-Aug-03	PHY0332009	Thalassiosira sp	present	
1-Aug-03	PHY0332009	Chaetoceros (Hyalochaete) sp	present	
1-Aug-03	PHY0332009	Asterionellopsis formosa	present	
1-Aug-03	PHY0332009	Leptocylindrus danicus	present	
1-Aug-03	PHY0332009	Thalassionema nitzschoides	present	
DINOFLAGELLATES				
1-Aug-03	PHY0332009	Alexandrium sp.	440	PSP toxin producer (shellfish)
1-Aug-03	PHY0332009	Dinophysis acuminata	120	DSP toxin producer (shellfish)
1-Aug-03	PHY0332009	Minuscula bipes	40	
1-Aug-03	PHY0332009	Protoperidinium leonis	40	
1-Aug-03	PHY0332009	Dinoflagellate cysts (spiny)	present	
1-Aug-03	PHY0332009	Ceratium macroceros	present	
1-Aug-03	PHY0332009	Ceratium tripos	present	
1-Aug-03	PHY0332009	Scrippsiella sp	present	
1-Aug-03	PHY0332009	Ceratium lineatum	present	

Station 4 (54.623N, 8.321W), surface sample				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
1-Aug-03	PHY0332010	Leptocylindrus danicus	36750	Predominant organism
1-Aug-03	PHY0332010	Chaetoceros socialis	24750	
1-Aug-03	PHY0332010	Proboscia alata	23250	
1-Aug-03	PHY0332010	Thalassionema nitzschoides	21000	
1-Aug-03	PHY0332010	Pseudo-nitzschia delicatissma group	8720	ASP toxin producer (shellfish)
1-Aug-03	PHY0332010	Cerataulina pelagica	3750	
1-Aug-03	PHY0332010	Dactyliosolen fragilissimus	3750	
1-Aug-03	PHY0332010	Leptocylindrus minimus	2250	
1-Aug-03	PHY0332010	Thalassiosira sp	1000	
1-Aug-03	PHY0332010	Rhizosolenia setigera	750	
1-Aug-03	PHY0332010	Cylidrotheca closterium	750	
1-Aug-03	PHY0332010	Pennate Diatom sp.	750	

1-Aug-03	PHY0332010	Pseudo-nitzschia seriata group	640	ASP toxin producer (shellfish)
1-Aug-03	PHY0332010	Chaetoceros didymus	240	
1-Aug-03	PHY0332010	Asterionellopsis formosa	160	
1-Aug-03	PHY0332010	Chaetoceros decipiens	120	
1-Aug-03	PHY0332010	Licmophora sp	40	
1-Aug-03	PHY0332010	Pleurosigma / Gyrosigma sp	40	
DINOFLAGELLATES				
1-Aug-03	PHY0332010	Scrippsiella sp	750	
1-Aug-03	PHY0332010	Alexandrium sp.	400	PSP toxin producer (shellfish)
1-Aug-03	PHY0332010	Prorocentrum micans	40	
1-Aug-03	PHY0332010	Gonyaulax sp	40	
1-Aug-03	PHY0332010	Oblea rotundata	40	
1-Aug-03	PHY0332010	Amphidoma caudata	40	
OTHER				
1-Aug-03	PHY0332010	Cilliate sp	40	

Station 7 (54.589 N, 8.382W), surface sample				
Total count not carried out.				
Identifiable phytoplankton coverage of plate: Low				
Debris coverage of plate: Low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
1-Aug-03	PHY0332011	Leptocylindrus danicus		Predominant organism
1-Aug-03	PHY0332011	Pseudo-nitzschia delicatissma group	82500	ASP toxin producer (shellfish)
1-Aug-03	PHY0332011	Pseudo-nitzschia seriata group	12000	ASP toxin producer (shellfish)
1-Aug-03	PHY0332011	Proboscia alata	present	
1-Aug-03	PHY0332011	Leptocylindrus minimus	present	
1-Aug-03	PHY0332011	Chaetoceros sp. (Hyalochate group)	present	
1-Aug-03	PHY0332011	Dactyliosolen fragilissimus	present	
1-Aug-03	PHY0332011	Thalassiosira sp	present	
1-Aug-03	PHY0332011	Thalassionema nitzschoides	present	
1-Aug-03	PHY0332011	Rhizosolenia setigera	present	
1-Aug-03	PHY0332011	Cerataulina pelagica	present	
1-Aug-03	PHY0332011	Ditylum brightwellii	present	
1-Aug-03	PHY0332011	Cylidrotheca closterium	present	
DINOFLAGELLATES				
1-Aug-03	PHY0332011	Alexandrium sp.	3200	PSP toxin producer (shellfish)
1-Aug-03	PHY0332011	Prorocentrum micans	360	
1-Aug-03	PHY0332011	Dinophysis acuminata	240	DSP toxin producer (shellfish)
1-Aug-03	PHY0332011	Protoperidinium steinii	80	
1-Aug-03	PHY0332011	Protoperidinium oblongum	80	
1-Aug-03	PHY0332011	Ceratium lineatum	present	
1-Aug-03	PHY0332011	Gonyaulax sp	present	
1-Aug-03	PHY0332011	Gymnodinium sp	present	
1-Aug-03	PHY0332011	Diplopsalis lenticula	present	
1-Aug-03	PHY0332011	Scrippsiella sp	present	

Near DCMNR dumpsite (54.55755 N, 8.6265666W), 15m integrated sample (Lund tube)				
Total count not carried out.				
Identifiable phytoplankton coverage of plate: low				
Debris coverage of plate: low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
13-Aug-03	PHY0333065	Chaetocereos sp.	present	Predominant organism
13-Aug-03	PHY0333065	Pseudo-nitzschia seriata group	120	ASP toxin producer (shellfish)
13-Aug-03	PHY0333065	Pseudo-nitzschia delicatissma group	120	ASP toxin producer (shellfish)
13-Aug-03	PHY0333065	Rhizosolenia setigera	120	
13-Aug-03	PHY0333065	Striatella unipunctata	80	
13-Aug-03	PHY0333065	Ditylum brightwellii	40	
DINOFLAGELLATES				
13-Aug-03	PHY0333065	Heterocapsa sp.	160	
13-Aug-03	PHY0333065	Scrippsiella sp.	80	

Inver Bay (54.6338166N, 8.29585W), 15m integrated sample (Lund tube)				
Identifiable phytoplankton coverage of plate: low				
Debris coverage of plate: low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
13-Aug-03	PHY0333066	Chaetoceros sp.	103500	Predominant organism
13-Aug-03	PHY0333066	Chaetoceros socialis	63000	
13-Aug-03	PHY0333066	Pseudo-nitzschia delicatissma group	40500	ASP toxin producer (shellfish)
13-Aug-03	PHY0333066	Pseudo-nitzschia seriata group	39000	ASP toxin producer (shellfish)
13-Aug-03	PHY0333066	Thalassionema nitzschoides	12750	
13-Aug-03	PHY0333066	Leptocylindrus danicus	9000	
13-Aug-03	PHY0333066	Chaetoceros didymus	5250	
13-Aug-03	PHY0333066	Chaetoceros decipiens	3750	
13-Aug-03	PHY0333066	Cylindrotheca closterium	3750	
13-Aug-03	PHY0333066	Rhizosolenia setigera	2250	
13-Aug-03	PHY0333066	Dactyliossen fragilissimus	1500	
13-Aug-03	PHY0333066	Ceratulina pelagica	1280	
13-Aug-03	PHY0333066	Rhizosolenia alata	750	
13-Aug-03	PHY0333066	Rhizosolenia shrubsolei	750	
DINOFLAGELLATES				
13-Aug-03	PHY0333066	Scrippsiella sp.	13500	
13-Aug-03	PHY0333066	Prorocentrum micans	160	
13-Aug-03	PHY0333066	Karenia mikimotoi	80	Harmful to finfish when present in high cell densities
13-Aug-03	PHY0333066	Ceratium macroceros	80	
13-Aug-03	PHY0333066	Diniphysis acuta	40	DSP toxin producer (shellfish)
13-Aug-03	PHY0333066	Diplopsalis lenticula	40	
13-Aug-03	PHY0333066	Gymnodinium sp.	40	
13-Aug-03	PHY0333066	Protoperidinium sp.	40	
OTHER				
13-Aug-03	PHY0333066	Dinobryon pellucidum	5250	

Inver Bay (54.5811N, 8.3991166W), 15m integrated sample (Lund tube)				
Identifiable phytoplankton coverage of plate: low				
Debris coverage of plate: low				
Sample date	MI sample ref. no.	Phytoplankton species name	cells/L	Additional information
DIATOMS				
13-Aug-03	PHY0333067	Chaetoceros sp.	5640	Predominant organism
13-Aug-03	PHY0333067	Pseudo-nitzschia seriata group	2840	ASP toxin producer (shellfish)
13-Aug-03	PHY0333067	Pseudo-nitzschia delicatissma group	1440	ASP toxin producer (shellfish)
13-Aug-03	PHY0333067	Skeletonema costatum	540	
13-Aug-03	PHY0333067	Rhizosolenia setigera	440	
13-Aug-03	PHY0333067	Rhizosolenia alata	400	
13-Aug-03	PHY0333067	Chaetoceros danicus	320	
13-Aug-03	PHY0333067	Cylindrotheca closterium	200	
13-Aug-03	PHY0333067	Ditylum brightwellii	160	
13-Aug-03	PHY0333067	Thalassionema nitzschoides	160	
13-Aug-03	PHY0333067	Pleurosigma sp.	80	
13-Aug-03	PHY0333067	Stephanopyxis turris	80	
13-Aug-03	PHY0333067	Rhizosolenia hebetata	40	
13-Aug-03	PHY0333067	Chaetoceros tricoceros	40	
DINOFLAGELLATES				
13-Aug-03	PHY0333067	Scrippsiella sp.	200	
13-Aug-03	PHY0333067	Heterocapsa sp.	120	
13-Aug-03	PHY0333067	Heterocapsa niei	120	
OTHER				
13-Aug-03	PHY0333067	Ciliates sp.	40	

Table 11.1 Relative percentage abundance of phytoplankton species present in vertical net phytoplankton hauls taken in Inver Bay on the 16th July, 2003.

	relative % abundance					
VERTICAL PLANKTON HAULS	VPH 1	VPH 2	VPH 3	VPH 4	VPH 5	Dive siite 1
SPECIES LIST wirh Basionyms and Synonyms	Station 1	Station 2	Station 3	Station 4	Station 5	Dive siite 1
Leptocylindrus danicus	58.02	44.09	18.85	12.38	32.55	40.32
Proboscia alata (Rhizosolenia alata, Rhizosolenia indica)	17.52	27.19	38.67	61.87	64.66	57.60
Thalassionema nitzschioides (Thalassiothrix nitzschioides, Synedra nitzschioides)	6.78	21.74	39.60	20.29	0.00	0.89
Diplopsalis lenticula	2.60	0.53	0.56	0.18	0.00	0.15
Chaetoceros (Hyalochaete) sp.	2.40	1.57	0.00	0.09	0.63	0.42
Scrippsiella sp.	2.26	0.14	0.09	0.69	0.20	0.06
Oblea rotunda (Peridinopsis rotunda)	2.06	0.53	0.23	0.34	0.70	0.00
Prorocentrum micans	2.06	0.22	0.05	0.11	0.05	0.00
Dinophysis acuminata	1.64	0.53	0.05	0.00	0.08	0.03
Chaetoceros didymus	1.64	0.17	0.14	2.40	0.00	0.00
Unidentified armoured dinoflagellate	0.68	0.06	0.05	0.00	0.05	0.00
Cylindrotheca closterium (Nitzschia closterium, Ceratoneis closterium)	0.34	2.53	0.05	0.00	0.00	0.00
Guinardia flaccida	0.34	0.00	0.19	0.07	0.10	0.03
Pseudo-nitzschia seriata complex (Nitzschia seriata)	0.34	0.34	0.70	0.11	0.03	0.00
Cerataulina pelagica (Ceratulina bergonii, Ceratulus bergonii)	0.21	0.06	0.00	0.34	0.00	0.00
Chaetoceros danicus	0.21	0.03	0.05	0.00	0.00	0.00
Unidentified naked dinoflagellate	0.21	0.03	0.00	0.00	0.08	0.00
Thalassiosira rotula/Thalassiosira gravida	0.15	0.00	0.09	0.07	0.00	0.12
Ceratium macroceros (Peridinium macroceros)	0.13	0.06	0.05	0.11	0.33	0.18
Pseudo-nitzschia delicatissima complex (Nitzschia delicatissima)	0.08	0.00	0.00	0.00	0.03	0.09
Ceratium tripos	0.06	0.03	0.00	0.04	0.00	0.03
Minuscula bipes (Glenodinium bipes, Peridinium minusculum, Protoperidinium bipes)	0.06	0.00	0.00	0.00	0.00	0.00
Alexandrium minutum (Alexandrium ibericum, Pyrodinium minutum)	0.02	0.00	0.00	0.02	0.00	0.00
Ceratium furca (Peridinium furca)	0.02	0.06	0.05	0.02	0.05	0.00
Ceratium fusus (Peridinium fusus)	0.02	0.00	0.00	0.09	0.00	0.03
Ceratium horridum (Ceratium tripos var. horridum)	0.02	0.00	0.00	0.00	0.03	0.00
Dinophysis acuta	0.02	0.03	0.05	0.04	0.05	0.00
Gonyaulax spinifera (Peridinium spiniferum)	0.02	0.00	0.00	0.00	0.00	0.00
Guinardia delicatula (Rhizosolenia delicatula)	0.02	0.03	0.00	0.00	0.05	0.00
Protoperidinium leonis (Peridinium leonis)	0.02	0.00	0.05	0.02	0.00	0.03
Protoperidinium oblongum (Peridinium oblongum, Peridinium divergens var. oblongum)	0.02	0.00	0.00	0.00	0.00	0.00
Protoperidinium sp.	0.02	0.00	0.00	0.00	0.00	0.00
Protoperidinium steinii (Peridinium steinii, Peridinium michaelis)	0.02	0.00	0.05	0.00	0.03	0.00
Corethron criophilum	0.02	0.00	0.00	0.00	0.00	0.00

Alexandrium sp.	0.00	0.00	0.05	0.00	0.00	0.00
Ceratium lineatum (Peridinium lineatum)	0.00	0.00	0.00	0.04	0.05	0.00
Dinophysis sp.	0.00	0.00	0.00	0.00	0.03	0.00
Leptocylindrus minimus	0.00	0.00	0.00	0.00	0.10	0.00
Licmophora sp.	0.00	0.00	0.00	0.34	0.03	0.00
Oblea sp./Diplopsalis sp.	0.00	0.00	0.00	0.00	0.00	0.00
Paralia sulcata (Melosira sulcata, Gaillonella sulcata)	0.00	0.00	0.28	0.00	0.00	0.00
Protoperidinium brevipes (Peridinium brevipes)	0.00	0.00	0.00	0.00	0.00	0.00
Protoperidinium pellucidum (Peridinium pellucidum)	0.00	0.00	0.00	0.00	0.03	0.00
Rhizosolenia imbricata (Rhizosolenia shrubsolei, Rhizosolenia imbricata var. shrubsolei)	0.00	0.03	0.05	0.04	0.00	0.00
Rhizosolenia setigera	0.00	0.00	0.05	0.34	0.00	0.00
Tintinnids	0.00	0.00	0.00	0.00	0.05	0.03
Dinophysis tripos		0.00	0.00	0.00	0.05	0.00