TRACE METAL CONCENTRATIONS IN SHELLFISH FROM IRISH WATERS, 2003.

September 2006

B. BOYLE, L. TYRRELL, B. MCHUGH, E. JOYCE, J. COSTELLO, D. GLYNN AND E. MCGOVERN[1].

Marine Institute
Marine Environment and Food Safety Services
Rinville, Oranmore, Co. Galway

[1]Author to whom correspondence should be addressed.

Marine Environment and Health Series, No. 25, 2006

ABSTRACT

In accordance with the monitoring requirements of Council Directive 79/923/EEC, on the quality required of shellfish waters, and Council Directive 91/492/EEC, laying down the health conditions for the production and placing on the market of live bivalve molluscs, water samples from major shellfish growing areas were tested for physicochemical parameters and shellfish were tested for trace metal levels. In 2003, a total of 30 samples were analysed for trace metals. All mercury concentrations measured were below or close to the limit of quantification, 0.03 mg kg^{-1} wet weight, which is well within the European maximum level of 0.50 mg kg^{-1} wet weight for mercury in bivalve molluscs. Levels of lead were typically low, with a mean of 0.26 mg kg^{-1} wet weight and maxima of 1.04 mg kg^{-1} wet weight, also below the respective European maximum level of 1.50 mg kg^{-1} wet weight. In addition, levels of cadmium were all below the European maximum level of 1 mg kg^{-1} wet weight, though the level of cadmium determined at Castlegregory in Tralee Bay was 0.97 mg kg^{-1}, close to the European limit. Castlegregory has not been included in the sampling programme since 1994, but will be included in future monitoring.

There are no internationally agreed standards or guidelines available for the remaining trace metals in shellfish. A compilation by the OSPAR Commission of standard and guidance values applied by member states of OSPAR indicated the Spanish standard for copper in shellfish of 20 mg kg^{-1} wet weight to be the strictest available. This excludes oysters for which a higher standard of 60 mg kg^{-1} wet weight has been set, as oysters accumulate copper to higher levels. All copper results were within these Spanish standards. The results obtained provide evidence of the clean, unpolluted nature of Irish shellfish and shellfish producing waters.

As in previous years, the water quality from shellfish growing areas was good and conformed to the requirements of the Directive. Petroleum hydrocarbons were not visible in any of the shellfish waters or as deposits on the shellfish. This survey confirms previous studies (Glynn *et al.,* 2004, 2003a, 2003b; McGovern *et al.,* 2001; Bloxham *et al.,* 1998; Smyth *et al.,* 1997 and Nixon *et al.,* 1995, 1994, and 1991), which show that contamination from trace metals is low in Irish shellfish aquaculture.

TABLE OF CONTENTS

INTRODUCTION

The determination of trace metal concentrations in shellfish from Irish waters is carried out by the Marine Institute in part fulfillment of the monitoring requirements of various EU legislation, including:

- EU Council Directive 79/923/EEC on the quality required of shellfish growing waters, as implemented in Ireland by Statutory Instrument (SI) No. 200 of 1994.
- EU Directive 91/492/EEC laying down the health conditions for the production and placing on the market of live bivalve molluscs.
- Directive 2001/22/EC laying down the sampling methods and the methods of analysis for the official control of the levels of lead, cadmium, mercury and 3-MPCD in foodstuffs.

This information also contributes to the Joint Assessment and Monitoring Programme (JAMP) of the 1992 OSPAR Convention for the Protection of the Marine Environment of the North East Atlantic.

Trace metals exist naturally in the environment and many including chromium, cobalt, copper, iron, manganese, molybdenum, vanadium, strontium and zinc are essential elements for living organisms. However, some trace metals such as mercury, lead and cadmium are not required for metabolic activity and can be toxic at quite low concentrations.

Although mercury, lead and cadmium occur naturally in the earth's crust, they can also be introduced into the aquatic environment from anthropogenic activities such as mining, industry and agriculture. Once in the aquatic environment these metals can be bioaccumulated in fish tissues. Due to physiological differences, certain species will concentrate these metals more readily than others (Clark *et al*., 2001).

Council Directive 79/923/EEC requires that Member States designate shellfish growing areas. Directive 79/923/EEC was transposed into Irish legislation through SI No. 200 of 1994 and this also sets out designated shellfish waters in Ireland.

Sampling during 1993 and 1994 was carried out bi-annually for selected sites. The results of these surveys (Nixon *et al*., 1994, 1995) showed that the quality of designated shellfish growing waters in Ireland was appreciably higher than required by the guidelines of the Directive, and therefore the frequency of monitoring was reduced to an annual basis in 1995, as permitted under the Directive. Previous results were published by Glynn *et al.,* 2003a, 2003b; McGovern *et al.,* 2001; Bloxham *et al.,* 1998; Smyth *et al.,* 1997 and Nixon *et al.,* 1995, 1994 and 1991. This report presents the results of 30 shellfish samples; 9 pacific oysters *(C. gigas)*, 4 native oysters *(O. edulis)* and 17 blue mussels *(M. edulis)*, from 27 sites in 2003 including a number of areas not formally designated.

Analyses of mercury, cadmium, chromium, copper, lead, nickel, silver and zinc were carried out on shellfish from all of the sites. 2003 was the second year that nickel and silver were included in the suite of determinants.

With the exception of mercury, cadmium and lead (Commission Regulation 466/2001/EC as amended by Regulation 221/2002/EC) there are currently no applicable European standards for trace metals in fishery products. Therefore, in the absence of EU standards for other contaminants in shellfish, monitoring results have been compared to strictest guidance or standard values available in other OSPAR Convention contracting countries.

Other reports on residue and contaminants monitoring in farmed and wild finfish, as well as other food safety and environmental monitoring reports are available on the Marine Institute website (www.marine.ie).

MATERIALS AND METHODS

Sample Collection and Preservation

Samples of shellfish species produced in each of the growing areas were collected; mussels consisted of 50 individuals and oysters of 25 individuals. Shellfish were depurated overnight in seawater collected from the growing area at the time of sampling. The lengths of individual shellfish were recorded prior to the soft tissue being removed from the shells to be washed and drained. The percentage meat and shell weights were calculated and recorded. Soft tissue was pooled and then homogenised prior to being divided into two sub-samples. These samples were stored in pre-weighed, acid washed glass jars in a freezer at less than –20ºC. One sub-sample was freeze-dried for 48 hours and analysed for trace metals (except mercury). The other sub-sample was analysed for mercury. The moisture content was determined by drying approximately 1g of unfrozen tissue overnight at 105ºC to constant weight.

Mercury Analysis

Concentrated nitric acid (4ml) was added to 0.6 - 0.8g of wet tissue, which was then digested in a laboratory microwave oven (CEM Mars5). After cooling, potassium permanganate was added until the purple colour of the solution stabilised. Sufficient hydroxylamine sulphate/sodium chloride solution was added to neutralise the excess potassium permanganate and potassium dichromate was added as a preservative. The solution was diluted to 100mls with deionised water.

Following reduction of the samples with tin (II) chloride, mercury concentrations were determined by Cold Vapour Atomic Fluorescence Spectroscopy (CV-AFS) using a PSA Merlin Analyser.

Trace Metal Analysis (cadmium, chromium, copper, lead, nickel, silver and zinc)

Concentrated nitric acid (4ml) and hydrogen peroxide (4ml) were added to approximately 0.2g freeze-dried tissue, which was then digested in a laboratory microwave oven (CEM Mars5). After cooling, samples were diluted to 50mls with deionised water. Lead, cadmium, chromium, copper, nickel and silver concentrations were determined using Graphite Furnace Atomic Absorption Spectrometry with Zeeman background correction (Varian SpectrAA 220Z). Zinc concentrations were determined using Flame Atomic Absorption Spectroscopy (Varian SpectrAA 20 Plus).

Quality Assurance

A comprehensive analytical quality assurance programme underpins testing. This involves routine testing of quality control samples such as blanks, replicates and reference materials (including certified reference materials, (CRMs)) and participation in the QUASIMEME, (Quality Assurance of Information for Marine Environmental Monitoring) international laboratory proficiency-testing scheme.

Although not certified, QUASIMEME provides materials of suitable matrix and analyte concentrations that have assigned values derived from intercalibrations involving many expert laboratories in this field. Obtaining a Z-score between -2 and +2 is considered satisfactory for environmental monitoring programmes.

Between 3 and 10 analyses were carried out on each RM used in this programme, the results of which are shown in Table 1. The quality assurance results obtained were considered sufficient for the purpose of the monitoring programme.

Table 1: Shellfish 2003 – metal reference materials.

Reference Material	**Assigned Values**	**Measured Value (Mean ± SD)**	**No. of Analyses**	**No. –2<Z<2**
Mussel Tissue CRM 278R				
	mg kg^{-1} wet wt.	***mg kg^{-1} wet wt.***		
Cadmium	0.348	0.34 ± 0.02	10	10
Copper	9.45	8.14 ± 0.32	5	5
Chromium	0.78	0.64 ± 0.07	7	7
Lead	2.00	1.81 ± 0.07	7	7
Mercury	0.196	0.19 ± 0.02	3	3
Zinc	83.1	77.8 ± 7.87	5	5
Oyster Tissue SRM 1566b				
	mg kg^{-1} wet wt.	***mg kg^{-1} wet wt.***		
Cadmium	2.48	2.59 ± 0.10	7	7
Copper	71.6	71.9 ± 0.88	5	5
Lead	0.308	0.36 ± 0.05	6	6
Mercury	0.0371	0.03 ± 0.00	4	4
Nickel	1.04	0.90 ± 0.11	10	10
Silver	0.666	0.66 ± 0.03	9	9
Zinc	1424	1388 ± 186	4	4

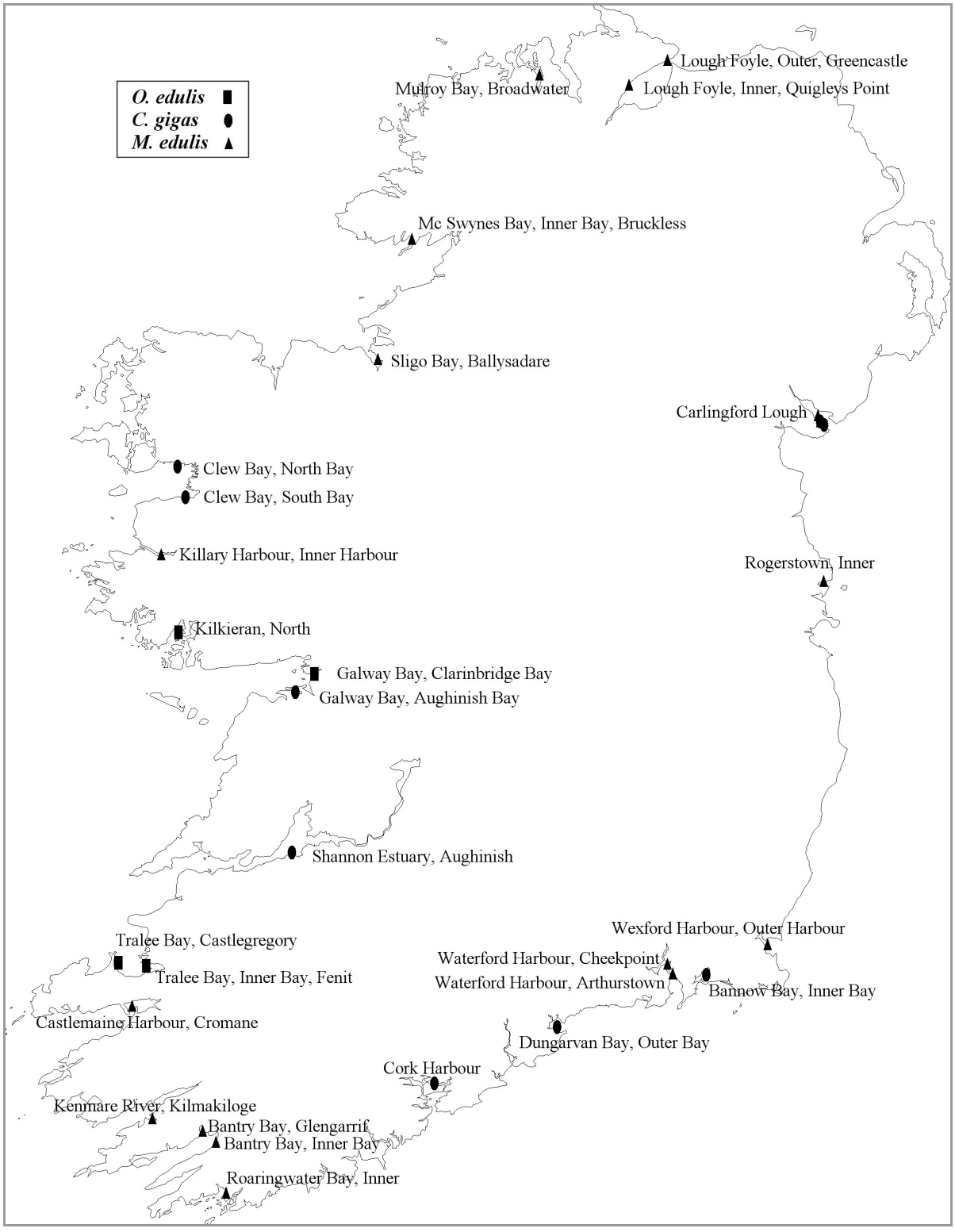

Fig 1. Locations of shellfish growing areas monitored during 2003

RESULTS AND DISCUSSION

Results of the biological measurements and physicochemical monitoring carried out during 2003 are presented in Appendix 1. Salinity and suspended solids data are typical of results from previous monitoring. During sample collection the water surface was examined for the presence of visible petroleum hydrocarbons. No visible hydrocarbon film or deposition was evident at any of the shellfish-growing areas.

Concentrations of mercury and trace metals in the shellfish tissue are presented in Appendix 1. The level of contaminants in shellfish is a good indicator of contaminant levels present in the water column and can provide valuable information on the quality of the shellfish and the waters in which they are grown. As such, Irish shellfish monitoring data has been used for environmental assessments (Boelens *et al.,* 1999; EPA, 2000) as well as food safety assessments of Irish seafood products. Commission Regulation 466/2001/EEC (as amended by Regulation 221/2002/EC) came into effect on 5th April 2002 providing maximum levels for mercury, lead and cadmium in foodstuffs, including bivalve mussels. The maximum levels of 0.5 mg kg^{-1}, 1.0 mg kg^{-1} and 1.5 mg kg^{-1} wet weight for mercury, cadmium and lead respectively in bivalve molluscs are specified in this regulation. As there are no currently applicable European standards for trace metals in shellfish (with the exception of mercury, cadmium and lead) the levels in this study were compared with available standards and guidance values set for human consumption in other jurisdictions, as outlined in Table 2.

Table 2: Maximum levels for trace metals in bivalve molluscs.

Contaminant	Values and Units (wet weight)	Qualifier	Jurisdiction
Cadmium	1.0 mg kg^{-1}	Standard EC1	EC[1]
Copper[2]	20 mg kg^{-1}	Standard EC1	Spain[3]
Lead	1.5 mg kg^{-1}	Standard EC1	EC[1]
Mercury	0.5 mg kg^{-1}	Standard EC1	EC[1]

Notes: 1. Commission Regulation 466/2001/EC as amended by Commission Regulation 221/2002/EC.
2. This value does not apply to oysters for which a higher value of 60 mg kg^{-1} has been set.
3. Source: Synopsis of the strictest guidance and standard values applied by various OSPAR countries for contaminants in shellfish for the assessment of the possible hazards to human health (OSPAR Update 1992), updated to incorporate new European legislation on mercury, cadmium and lead.

Oysters are known to accumulate high levels of zinc with concentrations as high as 11,000 mg kg^{-1} wet weight being found in the digestive glands (Clark *et al.*, 2001). The UK is the only country at present to set down a guideline value of 50 mg kg^{-1} for Zn in food; however this excludes shellfish. Levels in oysters are generally found to be in excess of 100 mg kg^{-1} wet weight, (Anon., 1993).

Chromium, silver and nickel contaminations in shellfish result mainly from human activities. However there are no published guidelines for acceptable concentrations of these contaminants in shellfish. Therefore, results are compared against other areas to assess for any obviously elevated results. Oysters accumulate silver to a higher degree than mussels and this is evident from the results obtained. No specific growing area stands out as having clearly elevated levels of these metals in comparison with other areas. As a larger database of results is obtained, establishment of background levels of these metals in shellfish from Irish coastal waters will enable better assessments in future years.

Assessment of data for individual shellfish growing areas

Data obtained from each of the 27 sampling locations during 2003 monitoring is examined below with respect to human consumption standards and guidance values, and are additionally compared to previously collected monitoring data. All concentrations are in mg kg^{-1} wet weight unless otherwise stated.

Previous years monitoring data are available in Fisheries Research Centre (FRC) Fisheries Leaflets and Marine Institute (MI) Marine Environmental Health Services publications (Glynn *et al*., 2004, 2003a, 2003b; McGovern *et al*., 2001; Bloxham *et al*., 1998; Smyth *et al*., 1997 and Nixon *et al.,* 1995, 1994 and 1991).

Waterford Harbour, Arthurstown

In 2003, *M. edulis* were sampled from Arthurstown, Waterford Harbour. This site was last sampled in 2000. Trace metal concentrations in this study were found to be within standards outlined in Table 2. The concentration of lead (1.04 mg kg^{-1}) was appreciably higher than for other locations. The EC maximum level for lead is 1.5 mg kg^{-1}. In 1999 and 2000 lead concentrations in *M. edulis* for this site were 0.77 mg kg^{-1} and 0.54 mg kg^{-1} respectively. Chromium concentrations were also higher than previous years at 1.12 mg kg^{-1}, compared to 0.75 mg kg^{-1} and 0.86 mg kg^{-1} respectively for 1999 and 2000. Results from this location consistently suggest slightly elevated levels of lead and chromium. Nickel and silver were determined at this location for the first time in 2003 at levels of 0.58 mg kg^{-1} and <0.03 mg kg^{-1} respectively. The concentration for nickel was very similar to that determined for the sample from Waterford Harbour, Cheekpoint, which showed the highest value in 2003. All other trace metal concentrations investigated were consistent with previous years for this location.

Shannon Estuary, Aughinish

C. gigas, were sampled from Aughinish, Shannon Estuary in 2003. Trace metal concentrations in shellfish were all within the tolerance levels given in Table 2. As in previous years, the level of mercury was low at <0.03 mg kg^{-1} wet weight, well below the maximum EC limit of 0.5 mg kg^{-1} indicated in Table 2. Copper concentrations were determined in 2002 at 46.3 mg kg^{-1} and in 1999 at 57.93 mg kg^{-1}, close to the Spanish tolerance of 60 mg kg^{-1} set for oysters. In 2003, the copper concentration for *C. gigas* was found to be 37.1 mg kg^{-1} wet weight.

In 2003 the highest level for silver was measured at this location at 2.63 mg kg^{-1}, although a similar concentration was determined in oysters from Tralee Bay of 2.52 mg kg^{-1}. These were also the locations where the highest values were determined in 2002.

Galway Bay, Aughinish Bay

A sample of *C. gigas* was collected from Aughinish Bay during 2003. All trace metal concentrations investigated were well below human consumption tolerance values as detailed in Table 2. The level of

mercury present in the *C. gigas* sample was <0.03 mg kg^{-1} wet weight, which is more than 10 times lower than the EU maximum limit for mercury in fisheries products.

Sligo Bay, Ballysadare Bay

Ballysadare Bay was introduced as a sampling site in 2003 and sampled in March and September (The March 2003 result was presented with the 2002 data (Glynn, D. *et al.* 2004*)* and only September 2003 data is presented in Appendix 1). Similar values were obtained for both samples and all levels were well within the human health tolerances listed in Table 2.

Bannow Bay, Inner Bay

C. gigas was collected from Bannow Bay in 2003. Mercury was again determined at <0.03 mg kg^{-1} wet weight, well below the EU maximum limit of 0.5 mg kg^{-1} (Table 2). With the exception of 1998, *C. gigas* samples have been collected from this site every year since 1993.

Bantry Bay, Inner Bay

M. edulis were collected from the Inner Bay at Bantry in 2003. Trace metal concentrations in these shellfish were found to be similar to previous years and well within the tolerance levels given in Table 2.

McSwyne's Bay, Inner Bay, Bruckless

M. edulis, were sampled from Bruckless in 2003. Trace metal concentrations in these shellfish were well within the tolerance levels given in Table 2.

Carlingford Lough

Both *M. edulis (2)* and *C. gigas* (2) were sampled from Carlingford Lough 2003. One of the *M. edulis* samples was collected from near Greenore Point where it was dredged from the seabed. Levels of mercury were low at <0.03 mg kg^{-1} wet weight for all four samples as was the case for all samples in 2002. Levels were well within human health tolerance values listed in Table 2 and similar to other locations. Higher concentrations of copper, silver and cadmium in oysters, when compared to mussels, reflect biological differences between the species in regulating trace metals.

Cork Harbour, North & East Passage

C. gigas was collected at Cork Harbour in 2003. Shellfish quality was similar to previous years and conformed to the requirements of the Directive. Levels for trace metals continue to be very low.

Waterford Harbour, Cheekpoint

This location was sampled for the first time in 2003. *M. edulis* were collected and all trace metal levels determined were within the tolerance levels given in Table 2. Mercury was found to be present at <0.03 mg kg^{-1}. The concentration of nickel was 0.60 mg kg^{-1}, which was the highest nickel concentration found

in shellfish in 2003. Lead was determined and found to be 0.55 mg kg^{-1} wet weight. This is lower than the result obtained for the Arthurstown site of Waterford Harbour, 1.04 mg kg^{-1}; also sampled in 2003.

Galway Bay, Clarenbridge

Native oysters (*O. edulis)* were sampled at Clarenbridge in 2003. Trace metal concentrations were all below human consumption tolerance values as compiled by OSPAR (Table 2).

Clew Bay, North Bay

From 1993 to 2002, only *O. edulis (native oysters)* were collected from Clew Bay. However, in 2003, *C. gigas* were collected for the first time. All trace metal concentrations determined were well below the strictest tolerances available and are consistent with results from previous years.

Clew Bay, South Bay

C. gigas were collected from this site for the first time in 2003. Analyses for trace metals reported were well below the strictest guidelines available (Table 2) and most results were similar to those obtained at the northern Clew Bay site in previous years. Chromium was determined at 0.60 mg kg^{-1}. This result is higher than all results determined for chromium at the northern site of Clew Bay, the highest of which was 0.28 mg kg^{-1} wet weight.

Cork Harbour, North & East Passage

C. gigas was collected at Cork Harbour in 2003. Shellfish quality was similar to previous years and conformed to the requirements of the Directive. Levels for trace metals continue to be very low.

Castlemaine Harbour, Cromane

A sample of blue mussels, *M. edulis* was collected from Cromane in 2003. Trace metal concentrations, including mercury continue to be low and within the tolerance levels set out in Table 2.

Dungarvan Bay, Outer Bay

A sample of pacific oyster, *C. gigas*, collected in 2003 was analysed for trace metals. Trace metal concentrations were comparable with previous years and were well below human consumption tolerance values (Table 2). Lead was determined at a level of 0.43 mg kg^{-1}, a concentration slightly higher than previous years.

Bantry Bay, Glengarriff

M. edulis, were sampled from Glengarriff in 2003. All trace metal concentrations determined were below human consumption tolerance values (Table 2).

Mulroy Bay, Broadwater, Cranford

M. edulis were collected at Mulroy Bay. Concentrations were low and similar to previous years monitoring.

Kilkieran, North

A sample of native oysters, *O. edulis*, collected in 2003 was analysed for trace metals. In 2002, *O. edulis* had also been collected. However, prior to 2002, blue mussels, *M. edulis,* were sampled (1993-1996 and 1999-2001). In 2003 the level of mercury was low in oysters at 0.04 mg kg^{-1} wet weight, which was well below the 0.5 mg kg^{-1} wet weight maximum limit (Table 2). Trace metal levels in the shellfish were typical of values expected for oysters and, as for previous years, were well within the strictest tolerance levels available (Table 2).

Killary Harbour, Inner Harbour

M. edulis were collected at Killary Inner and analysed for trace metals in 2003. All trace metal concentrations continue to be very low. Mercury was determined at <0.03 mg kg^{-1}, well within the strictest available tolerance level.

Kenmare River, Kilmakillogue

Mussel samples, *M. edulis*, were collected from Kilmakillogue in 2003. Trace metal levels in the shellfish were low as in previous years and were well within the strictest tolerance levels available (Table 2).

Lough Foyle, Inner Lough, Quigley's Point

A sample of native oysters, *O. edulis*, was sampled from Lough Foyle in 2002. In 2003, a sample of *M. edulis* was collected, as was the case in all years prior (1993 to 2000). The level of mercury was below the limit of quantitation (<0.03 mg kg^{-1} wet weight). Analyses for other trace metals was carried out and results were well within the strictest tolerance levels available (Table 2).

Wexford Harbour, Outer Harbour

M. edulis were collected from Wexford Harbour in 2003 and were analysed for trace metals. The level of mercury in the soft tissues of mussels was again below the limit of quantitation (<0.03 mg kg^{-1} wet weight), well below EU 0.5 mg kg^{-1} maximum limit. Similarly, the lead concentration of 0.37 mg kg^{-1} wet weight was well within the EU maximum limit of 1.5 mg kg^{-1} wet weight. Other trace metal levels were well within the human consumption guidelines and standards (Table 2).

Lough Foyle, Outer Lough, Greencastle

In 2003, mussel samples, *M. edulis* were sampled (dredged) from the seabed near Greencastle. All trace metal concentrations determined were comparable to those determined in 2002 and were well below the maximum levels given in Table 2.

Roaringwater Bay, Inner Bay

A sample of blue mussels *M. edulis*, collected in 2003 was analysed for trace metals. Levels for trace metals remain very low.

Rogerstown Estuary, Inner

M. edulis were collected from this site for the first time in 2003. The cadmium concentration was found to be low at 0.14 mg kg^{-1}. The level of copper determined was 1.81 mg kg^{-1}, well below the strictest tolerance available (Spanish standard value of 20 mg kg^{-1}). Lead was determined at a level of 0.54 mg kg^{-1}, one of the higher concentrations of lead determined in this year. The EC limit set for lead is 1.5 mg kg^{-1}. Mercury was determined to be below the limit of quantitation (<0.03 mg kg^{-1}), over an order of magnitude lower than the maximum limit. Analyses for other trace metals were carried out and results were well below the strictest guidelines available (Table 2). Samples will continue to be collected from this location in future.

Tralee Bay, Castlegregory, Maharees

A sample of *O. edulis* was collected from the Castlegregory site at Tralee Bay in 2003 and analysed for trace metals. Samples were last collected at this location in 1993 (x2) and 1994 (x2), before being sampled again in 2003. In 2003 the level of cadmium determined was 0.97 mg kg^{-1}, comparable with results obtained in 1994 of 0.7 mg kg^{-1} and 0.9 mg kg^{-1}. These concentrations are very close to the EU standard limit of 1.0 mg kg^{-1} and the highest levels recorded to date for cadmium. Copper was present at a concentration of 14.3 mg kg^{-1}, below the Spanish standard limit of 60 mg kg^{-1} set for oysters and consistent with concentrations determined in previous years. The highest recorded concentration for zinc in 2003 was found here at Tralee Bay at 403 mg kg^{-1}, although this is not unusually high for zinc concentrations in oysters. Silver was determined at a concentration of 1.34 mg kg^{-1}, the third highest concentration for silver determined in 2003 after the Shannon Estuary sample and the Inner Tralee Bay sample. Silver accumulates to higher concentrations in oysters than in mussels.

Tralee Bay, Inner Bay, Fenit

A sample of *O. edulis* was collected from Inner Tralee Bay in 2003 and analysed for trace metals. The level of cadmium in the oysters collected was 0.54 mg kg^{-1} wet weight. This concentration is within the EU standard limit of 1.0 mg kg^{-1} and less than the value obtained for the Castlegregory site. As in previous years the mercury concentration measured in the soft tissues of *O. edulis* was very low at <0.03 mg kg^{-1} wet weight when compared with the EU maximum limit of 0.5 mg kg^{-1} wet weight (Table 2). Silver was determined at a concentration of 2.52 mg kg^{-1}, the second highest concentration for silver determined in 2003 after Shannon Estuary, Aughinish. The highest concentrations for silver in 2002 were also recorded at these locations, although it is noted that silver occurs at higher concentrations in oysters compared with mussels. The level of chromium was also low (0.21 mg kg^{-1} wet weight), which conforms to previous monitoring and was considerably lower than the anomalous value observed in the sample collected in 2000 (3.11 mg kg^{-1} wet weight). All other trace metal concentrations were consistent with previous years for this location.

CONCLUSIONS

The water quality monitored in the shellfish growing areas in 2003 was good and conformed to the guidelines of the 1979 Council Directive 79/923/EC. Nickel and silver were included in shellfish monitoring for the first time in 2002 and were again determined in 2003.

Based on the analyses of the 2003 samples, total mercury and trace metal concentrations in shellfish from shellfish growing areas were typically low, which agreed with other studies (Glynn *et al*., 2004, 2003a, 2003b; McGovern *et al*., 2001; Bloxham *et al*., 1998; Smyth *et al.,* 1997 and Nixon *et al.,* 1995, 1994 and 1991). All shellfish samples tested for mercury, cadmium and lead were well within the respective limits of 0.5 mg kg^{-1}, 1.0 mg kg^{-1}, and 1.5 mg kg^{-1} wet weight, as set by European Commission Regulation 466/2001/EC, (as amended by Regulation 221/2002/EC). One *O. edulis* sample collected from Tralee Bay, Castlegregory had a measured value for cadmium of 0.97 mg kg^{-1} wet weight. This is close to the maximum limit set by the EC (1 mg kg^{-1} wet weight).

The analytical results presented in this report are indicative of the unpolluted nature of Irish waters and the high quality of Irish shellfish with respect to environmental contaminants.

REFERENCES

Anon, (1993). Monitoring and Surveillance of Non-Radioactive Contaminants in the Aquatic Environment and Activities Regulating the Disposal of Wastes at Sea, 1991. *Aquatic Environment Monitoring Report No. 36*. Directorate of Fisheries Research, Lowestoft.

Bloxham, M., A. Rowe, E. McGovern, M. Smyth and E. Nixon, (1998). Trace Metal and Chlorinated Hydrocarbon Concentrations in Shellfish and Fin-fish from Irish Waters – 1996. *Fishery Leaflet 179*. Marine Institute, Dublin.

Boelens, R.G.V., D. Maloney, A. Parsons, A. Walsh, (1999). Ireland's Marine and Coastal Areas and Adjacent Seas: an Environmental Assessment. Marine Institute, Dublin.

Clark, R.B., C. Frid and M. Attrill, (2001). Marine Pollution (5th ed.), Clarendon Press, Oxford.

EPA, (2000). Ireland's Environment: a Millennium Report. Stapleton, L., M. Lehane and P. Toner. Environmental Protection Agency, Wexford. ISBN 1-84095-016-1.

Glynn, D., L. Tyrrell, B. McHugh, A. Rowe, E. Monaghan, J. Costello and E. McGovern (2004). Trace Metal and Chlorinated Hydrocarbon Concentrations in Shellfish from Irish Waters, 2002. *Marine Environment and Health Series, No. 16, 2004*.

Glynn, D., L. Tyrrell, B. McHugh, A. Rowe, E. Monaghan, J. Costello and E. McGovern (2003b). Trace Metal and Chlorinated Hydrocarbon Concentrations in Shellfish from Irish Waters, 2001. *Marine Environment and Health Series, No. 10, 2003*.

Glynn, D., L. Tyrrell, B. McHugh, A. Rowe, J. Costello and E. McGovern (2003a). Trace Metal and Chlorinated Hydrocarbon Concentrations in Shellfish from Irish Waters, 2000. *Marine Environment and Health Series, No. 7, 2003*.

McGovern, E., A. Rowe, B. McHugh, J. Costello, M. Bloxham, C. Duffy & E. Nixon (2001). Trace Metal and Chlorinated Hydrocarbon Concentrations in Shellfish from Irish Waters 1997-1999. *Marine Environment and Health Series, No.2, 2001.*

Nixon, E., A. Rowe, M. Smyth, D. McLaughlin and J. Silke, (1995). Monitoring of Shellfish Growing Areas - 1994. *Fishery Leaflet 166*. Department of the Marine, Dublin.

Nixon, E., A. Rowe, M. Smyth, D. McLaughlin and J. Silke, (1994). Monitoring of Shellfish Growing Areas - 1993. *Fishery Leaflet 160*. Department of the Marine, Dublin.

Nixon, E., D. McLaughlin, R.G. Boelens and G. O'Sullivan, (1991). Contaminants in marine biota 1990 monitoring programme. *Fishery Leaflet 151*. Department of the Marine, Dublin.

Smyth, M., A. Rowe, E. McGovern and E. Nixon, (1997). Monitoring of Shellfish Growing Areas - 1995. *Fishery Leaflet 174*. Department of the Marine, Dublin.

APPENDIX 1 - Trace metal concentrations in shellfish from Irish waters 2003

(Page 1 of 3)

Sample Site	Arthurstown, Waterford Harbour	Aughinish, Shannon Estuary	Aughinish, New Quay, Galway Bay	Ballysadare Bay	Bannow Bay	Bantry Bay Inner Bay	Bruckless, McSwyne's Bay, Donegal	Carlingford Lough	Carlingford Lough	Carlingford Lough
M.I. Reference No.	ENV 2003/163	ENV 2003/151	ENV 2003/136	ENV 2003/131	ENV 2003/167	ENV 2003/153	ENV 2003/132	ENV 2003/144	ENV 2003/141	ENV 2003/142
Sampling date	23/10/03	13/10/03	09/09/03	01/09/03	30/10/03	15/10/03	02/09/03	17/09/03	17/09/03	17/09/03
Latitude	54º 14.490'	52º 37.994'	53º 9.149'	54º13.962'	52º 14.217'	51º 41.670'	54º 37.284'	54º 1.834'	54º 1.127'	54º 1.834'
Longitude	6º 57.560'	9º 2.628'	9º 1.461'	8º 34.328'	6º 46.363'	9º 27.600'	8º 23.187'	6º 9.005'	6º 7.654'	6º 9.005'
Species sampled	*M.edulis*	*C. gigas*	*C. gigas*	*M. edulis*	*C. gigas*	*M. edulis*	*M. edulis*	*M. edulis*	*C. gigas*	*C. gigas*
Number individuals	50	25	25	50	25	50	29	50	25	25
Method of cultivation	bed	trestle	trestle	bed	trestle	rope	rope	bed	trestle	trestle
Water Parameters										
Salinity (psu)	NA	NA	34.3	NA	33.7	NA	34.7	33.2	34.2	33.2
Suspended Solids (mg L^{-1})	49.8	54.4	5.60	5.70	12.6	3.20	6.20	30.4	19.6	30.4
Shellfish										
Shell length range (mm)	41.2 – 59.6	79.1 – 111	75.0 – 112	46.4 – 59.2	80.9 – 121	45.0 – 60.0	48.4 – 60.0	46.0 – 59.9	96.8 – 127	88.6 – 127
Shell mean length (mm)	48.8	89.3	92.4	53.2	96.6	54.2	55.0	53.6	113	106
Shell length std dev (mm)	4.27	6.93	9.85	3.37	10.2	3.48	3.16	3.49	8.75	11.6
Meat weight (%)	16.1	9.10	12.8	24.3	23.7	40.2	32.0	23.6	11.4	11.6
Shell weight (%)	83.9	90.9	87.2	75.7	76.3	59.8	68.0	76.4	88.6	88.4
Meat water content (%)	76.2	77.9	75.6	74.2	75.2	75.0	76.5	73.5	76.7	73.4
Metals mg kg^{-1} (ppm) wet wt.										
Cadmium	0.31	0.57	0.25	0.16	0.10	0.19	0.24	0.14	0.29	0.26
Chromium	1.12	<0.19	<0.19	<0.19	nd	<0.19	nd	<0.19	<0.19	<0.19
Copper	2.14	37.1	5.69	1.38	4.66	1.48	1.04	1.45	16.1	20.5
Lead	1.04	0.20	0.12	0.26	0.13	0.12	<0.06	0.57	0.32	0.29
Mercury	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.03	<0.03	<0.03
Nickel	0.58	0.17	0.09	0.16	nd	<0.14	<0.14	0.17	nd	0.36
Silver	<0.03	2.63	0.44	<0.03	0.13	0.04	<0.03	<0.03	1.02	1.18
Zinc	17.0	295	184	19.5	87.9	19.8	22.3	15.0	272	296

Notes: **NA:** **Not Analysed**
nd: **Substances were not detected above the Limit of Detection (LOD) (Appendix 2)**
< value: **value = Limit of Quantitation (LOQ) for the relevant determinand**

(Page 2 of 3): Trace metal concentrations in shellfish from Irish waters 2003

Sample Site	Carlingford Lough, Greenore	Cheekpoint, Waterford Harbour	Clarinbridge, Galway Bay	Clew Bay, South	Clew Bay, North	Cork Harbour	Cromane, Castlemaine Harbour	Dungarvan	Glengarriff, Bantry Bay	Greencastle, Lough Foyle
M.I. Reference No.	ENV 2003/143	ENV 2003/162	ENV 2003/137	ENV 2003/139	ENV 2003/140	ENV 2003/160	ENV 2003/152	ENV 2003/161	ENV 2003/156	ENV 2003/134
Sampling date	17/09/03	22/10/03	09/09/03	11/09/03	11/09/03	21/10/03	14/10/03	22/10/03	15/10/03	02/09/03
Latitude	54º 3.021'	52º 16.338'	53º 12.681'	53º 47.086'	53º 53.006'	51º 53.083'	52º 8.145'	52º 4.008'	51º 43.866'	55º 12.113'
Longitude	6º 9.736'	6º 59.195'	8º 55.308'	9º 37.643'	9º 40.247'	8º 15.732'	9º 55.234'	7º 35.382'	9º 32.019'	6º 59.135'
Species sampled	*M. edulis*	*M. edulis*	*O. edulis*	*C. gigas*	*C. gigas*	*C. gigas*	*M. edulis*	*C. gigas*	*M. edulis*	*M. edulis*
Number individuals	50	50	25	25	25	25	50	25	50	50
Method of cultivation	bed	bed	bed	trestle	trestle	bed	bed	trestle	rope	bed
Water Parameters										
Salinity (psu)	33.9	21.4	31.2	NA	32.3	33.3	32.5	33.7	34.6	NA
Suspended Solids (mg L^{-1})	22.2	NA	3.70	NA	25.6	37.6	3.40	11.8	3.30	NA
Shellfish										
Shell length range (mm)	40.1 – 50.1	31.5 – 50.8	84.4 – 128	113 – 153	80.9 – 116	85.5 – 151	41.3 – 57.1	72.5 – 110	44.4 – 60.0	44.8 – 59.1
Shell mean length (mm)	45.4	38.4	106	132	97.5	128	50.7	89.3	54.4	51.9
Shell length std dev (mm)	2.31	10.9	10.9	11.2	10.3	17.0	3.84	8.54	3.05	3.43
Meat weight (%)	33.3	23.1	19.9	9.06	10.4	12.1	31.8	15.1	44.3	26.6
Shell weight (%)	66.7	76.9	80.1	90.9	89.6	87.98	68.2	84.9	55.7	73.4
Meat water content (%)	75.3	78.3	76.7	78.5	78.9	77.9	73.9	72.9	76.2	73.2
Metals mg kg^{-1} (ppm) wet wt.										
Cadmium	0.10	0.17	0.15	0.45	0.44	0.16	0.13	0.25	0.22	0.06
Chromium	<0.19	0.55	0.37	0.60	<0.19	0.22	0.24	<0.19	<0.19	<0.19
Copper	1.18	2.93	3.83	9.89	12.0	7.37	1.70	10.8	1.27	2.03
Lead	0.34	0.55	0.10	0.09	<0.06	0.29	0.13	0.43	0.16	0.08
Mercury	<0.03	<0.03	<0.03	<0.03	<0.03	0.04	<0.03	<0.03	<0.03	<0.03
Nickel	0.17	0.60	<0.14	0.27	<0.14	nd	0.23	nd	<0.14	<0.14
Silver	<0.03	<0.03	0.17	0.90	0.79	0.30	<0.03	0.55	0.04	nd
Zinc	14.6	16.9	93.5	309	300	202	18.0	167	18.6	15.0

Notes: **NA:** **Not Analysed**
nd: **Substances were not detected above the Limit of Detection (LOD) (Appendix 2)**
< value: **value = Limit of Quantitation (LOQ) for the relevant determinand**

(Page 3 of 3) Trace metal concentrations in shellfish from Irish waters 2003

Sample Site	Kilkieran	Killary Inner	Kilmackillogue, Kenmare River	Mulroy Bay	Quigley's Point, Lough Foyle	Roaring-Water Bay	Rogerstown, Co. Dublin	Tralee Bay, Castlegregory	Tralee Bay, Inner	Wexford Harbour
M.I. Reference No.	ENV 2003/168	ENV 2003/138	ENV 2003/154	ENV 2003/133	ENV 2003/135	ENV 2003/155	ENV 2003/145	ENV 2003/149	ENV 2003/150	ENV 2003/169
Sampling date	07/11/03	10/10/03	15/10/03	02/09/03	02/09/03	16/10/03	16/09/03	14/10/03	14/10/03	12/11/03
Latitude	53º 20.750'	53º 35.974'	51º 46.315'	55º 9.274'	55º 7.260'	51º 31.784'	53º 30.754'	52º 16.508'	52º 15.912'	52º 20.520'
Longitude	9º 40.006'	9º 45.526'	9º 48.539'	7º 41.245'	7º 11.764'	9º 24.277'	6º 7.709'	9º 59.593'	9º 50.483'	6º 27.390'
Species sampled	*O. edulis*	*M. edulis*	*M. edulis*	*M. edulis*	*M. edulis*	*M. edulis*	*M. edulis*	*O. edulis*	*O. edulis*	*M. edulis*
Number individuals	25	50	50	50	50	50	50	21	25	50
Method of cultivation	bed	rope	rope	rope	bed	rope	bed	bed	bed	bed
Water Parameters										
Salinity (psu)	NA	28.0	34.5	34.5	NA	35.0	NA	NA	34.0	26.8
Suspended Solids (mg L^{-1})	1.90	3.80	5.70	4.00	22.7	6.70	13.9	6.10	20.6	15.5
Shellfish										
Shell length range (mm)	65.4 – 87.5	36.7 – 59.4	40.5 – 58.8	41.2 – 54.6	41.1 – 59.6	44.8 – 58.9	42.3 – 55.4	19.8 – 98.4	61.5 – 87.1	46.5 – 59.9
Shell mean length (mm)	74.8	51.6	45.4	46.6	50.0	52.0	49.0	76.1	74.0	53.4
Shell length std dev (mm)	5.85	3.80	3.80	3.04	4.21	3.22	3.09	16.0	6.62	3.21
Meat weight (%)	13.0	46.2	43.2	41.4	15.6	33.8	26.0	8.29	18.9	40.9
Shell weight (%)	87.0	53.8	56.8	58.6	84.4	66.2	74.0	91.7	81.1	59.1
Meat water content (%)	78.0	76.8	77.8	72.9	78.3	76.5	72.4	75.0	74.5	73.1
Metals mg kg^{-1} (ppm) wet wt.										
Cadmium	0.42	0.12	0.11	0.06	0.19	0.11	0.14	0.97	0.54	0.04
Chromium	<0.19	<0.19	<0.19	nd	0.31	<0.19	<0.19	0.23	0.21	<0.19
Copper	4.75	1.51	1.33	1.65	1.33	1.64	1.81	14.3	18.1	1.60
Lead	0.07	<0.06	0.06	nd	0.15	0.13	0.54	0.12	0.11	0.37
Mercury	0.04	<0.03	<0.03	<0.03	<0.03	<0.03	0.04	<0.03	<0.03	<0.03
Nickel	nd	0.14	nd	<0.14	0.35	<0.14	0.25	0.15	<0.14	0.27
Silver	0.75	<0.03	nd	nd	<0.03	nd	0.07	1.34	2.52	nd
Zinc	326	14.0	14.4	13.9	18.5	18.1	18.1	403	373	12.6

Notes: **NA:** **Not Analysed**
nd: **Substances were not detected above the Limit of Detection (LOD) (Appendix 2)**
< value: **value = Limit of Quantitation (LOQ) for the relevant determinand**

APPENDIX 2 - Trace metals – Limits of detection (LOD) (mg kg^{-1} wet weight)

Metal	LOD
Cadmium	0.004
Chromium	0.07
Copper	0.16
Lead	0.02
Mercury	0.01
Nickel	0.06
Silver	0.01
Zinc	1.21

GLOSSARY AND ABBREVIATIONS

Species

M. edulis	*Mytilis edulis*	Blue mussel
O. edulis	*Ostrea edulis*	Native/flat oyster
C. gigas	*Crassostrea gigas*	Pacific oyster

Others

QUASIMEME	Quality assurance of information for marine environmental monitoring
CRM	Certified reference material
LOD	Limit of detection
nd	Not detected
SI	Statutory Instrument
EU	European Union
AA	Atomic absorption (spectroscopy)