Institution: Robert Gordon University

Unit of Assessment: UOA 15 General Engineering

Title of case study: Environmental Monitoring/ Sampling in the Marine Environment

1. Summary of the impact (indicative maximum 100 words)

This impact study deals with the development and implementation of an internationally recognised, statistically-based sampling regime for marine sediment hydrocarbon contamination. Its Economic and Environmental impacts include a reduction in sampling and analysis costs to operators while maintaining a statistically robust monitoring procedure to protect and enhance the environment (including valuable fisheries) and support oil and gas exploration/production. This regime was initially adopted by the UK Government in the UK Marine Monitoring and Assessment Strategy in 2009. These statistical-based sampling protocols have subsequently passed into wider environmental policy and the Random Stratified Statistical Sampling Regime represents the accepted standard for marine monitoring in the £22 billion oil exploration and production industry in the UK Continental Shelf. This regime has now been taken-up internationally by the other 14 countries bordering/discharging to the North East Atlantic through the OSPAR Convention for the Protection of the Marine Environment of the North East Atlantic.

2. Underpinning research (indicative maximum 500 words)

Based on knowledge obtained from research since 1998 a range of novel sampling, measurement and statistical methods have been developed to improve assessment of hydrocarbons and other contaminants in the marine environment. The underpinning research was lead jointly by Pollard at the Robert Gordon University and Moffat at the Marine Scotland Science Marine Laboratory in Aberdeen. Experimental research was carried out at both the Robert Gordon University and Marine Laboratory, and included access to sampling using the Marine Laboratory's coastal and ocean-going research vessels.

Sampling and monitoring of human activities on marine habitats in oil and gas fields is complex. Money, time and very substantial resources are involved in monitoring, in part due to the considerable cost of a ship capable of sampling in such waters and in proximity to oil and gas installations. This underpinning research developed measuring methods, certified reference materials (CRM's) and a robust stratified sampling regime.

a) Development of improved methods of monitoring marine contaminants

PAH Monitoring

The initial research into the development of an HPLC/fluorescence method to provide a better method for monitoring toxic polycyclic aromatic hydrocarbons (PAHs) was carried out in 1998/99. Subsequently (1999-2002) a detailed investigation to assess the significance of the biological effects of these PAHs in the Scottish marine environment was undertaken. This research was partially funded by the then Fisheries Research Services, Marine Laboratory. This provided an improved analytical and assessment methodology to evaluate their effects.

Biomarker Monitoring

Joint research with Marine Scotland Science developed CRMs to enable standardised monitoring of PAH metabolites. Quality assurance and methodology applicable for standardising monitoring through the use of CRMs is a key area in biomarker development. This fed into a 3 year multi-partner EU Standards, Measurements and Testing project (SMT4-CT98-2250). RGU were involved, through the Marine Laboratory, in producing two biliary PAH metabolite CRMs. Biomarker assessments were carried out in the Firth of Forth and the Firth of Clyde, Scotland. The Firth of Forth results demonstrated a clear spatial gradient of PAH uptake and exposure in flounder that was not found in the conventional EROD monitoring method measured in the same fish. This clearly demonstrates a more effective environmental monitoring method (**R1, R2**).

b) Development of an improved sampling strategy

Between 2002-2006 our research designed a robust spatial sampling strategy that would give representative information on hydrocarbon contamination in sediments. This strategy became known as the **Random Stratified Statistical Sampling Regime**. Results from the new Random Stratified Statistical Sampling Regime were compared with those from the conventional grid sampling regime to investigate the effect of oil exploration and production activity in the Fladen Ground in the northern North Sea (**R3**).

The range of measurement methods used to analyse the samples for comparison included Particle Size, Total Organic Carbon, Fluorescence Detection, Gas Chromatography-Mass Spectrometry (for determination of PAHs) and Gas Chromatography-Flame Ionisation Detection (for determination of aliphatic hydrocarbons).

The novel Random Stratified Statistical Sampling design was demonstrated to be cost and time effective, gave much more reliable mean concentrations for all the parameters, and produces data with increased precision (lower variance) compared to the traditional grid sampling design. The increase in precision, or alternatively reductions in variance, time and cost, obtainable through composite random sampling, depends on the quality of the information used to set up the design. **(R4, R5).**

From 2005 to 2008 the research was extended into the development and use of passive samplers to monitor bioavailability of organic contaminants in sediments and risk management **(R6).**

Researchers

Pat Pollard: Lecturer, Reader, Professor (1990-)

Colin Moffat: Honorary Professor at the Robert Gordon University (2005-). Also Head of Science, Marine Scotland (previously Fisheries Research Services Marine Laboratory, Aberdeen)

Linda Lawton: Lecturer, Reader, Professor (1995-)

Kyari Yates: Research Student (2004-8), James Hutton Institute North (2008-10), Lecturer (2010-)

Abdulwaheed Ahmed: Research Student (2002- 2005)

3. References to the research (indicative maximum of six references)

Key references are marked *

R1 D. M. Richardson, I. M. Davies, **C. F. Moffat**, **P**. **Pollard** and R. M. Stagg, "Biliary PAH metabolites and EROD activity on flounder from a contaminated estuarine environment." *Journal of Environmental Monitoring*, 2001, 3, 610-615. DOI: 10.1039/B106353G

R2 D. M. Richardson, M. Gubbins, I. M. Davies, **C. F. Moffat** and **P**. **Pollard**, "Effects of Feeding Status on Biliary PAH metabolite and Biliverdin concentrations in plaice", *Environmental Toxicology and Pharmacology*, 2004, 17, 79-85. DOI: 10.1016/j.etap.2004.03.003

***R3 A. Ahmed**, L. Webster, **P. Pollard**, I. M. Davies, M. Russell, P. Walsham, G. Packer and **C. Moffat,** "The distribution and composition of hydrocarbons in sediments from the Fladen ground, North Sea, an area of oil production" *Journal of Environmental Monitoring,* 2006, 8, 307-316. **DOI:** 10.1039/B512616A

R4 C. F. Moffat, L. Webster, **P. Pollard**, **A. Ahmed**, M. Russell and I. M. Davies "Sampling Sediments in the Marine Environment". In: F. Ruggeri, R. S. Kenett and F. W. Faltin, Editors. *The Encyclopedia of Statistics in Quality and Reliability*. J Wiley & Sons, Chichester, UK, 2007, 1756-1761.

***R5 A. Ahmed**, L. Webster, **P. Pollard**, I. M. Davies and **C. F**. **Moffat,** "Description and evaluation of a sampling system for monitoring of hydrocarbons in sediments" *Journal of Environmental Monitoring,* 2007, 9, 730-739. DOI: 10.1039/B701474K

R6 K. Yates, I. M. Davies, L. Webster, **P. Pollard, L**. **Lawton** and **C. F. Moffat,** "Passive sampling: Partition coefficients for a silicone rubber reference phase". *Journal of Environmental Monitoring,* 2007, 9, 1116 – 1121. DOI: 10.1039/B706716J

4. Details of the impact (indicative maximum 750 words)

The UK continental shelf hosts significant on-going exploration and production of oil and gas. The UK and Scottish Governments are responsible for assessing the environmental impact of human activities and, where appropriate, the introduction of relevant regulation. As such, there is a need to undertake monitoring of marine sediments, both to assess possible impacts, and to determine if the regulation is delivering what it is intended to do.

A key aspect to any monitoring programme is survey design. Ultimately, this is a process which takes account of the main causes of random, between year variation, as this is fundamental to improving the power of trend monitoring programmes. There is also the desire to reduce costs by analysing as few samples as possible whilst maintaining the required discriminatory power. Ultimately, Governments and Industry together have a responsibility for monitoring and assessing the impact of anthropogenic activities; this must be done in as efficient a way as possible, coupled with a common methodology to permit comparability of data. This was a central objective of the process to provide a more robust statistically-based sampling regime for sediments, to inform Government and Industry.

The Scottish Government's national monitoring programme for marine sediments is now based entirely around the **Random Stratified Statistical Sampling Regime**. There has been a period of overlap between the former (fixed sampling) protocol and the introduction of this new regime. However this is now well established and being used in assessments (**IR1** pages 44-47). As part of the UK Marine Monitoring & Assessment Strategy (UKMMAS), the Marine Laboratory has promoted the sampling scheme through the UK Clean and Safe Seas Evidence Group and the data has been used in UK assessments (**IR2** pages 65–66).

Such methodology has proved very successful, and the UK offshore Oil & Gas industry now routinely uses the **Random Stratified Statistical Sampling Regime**. It is the adopted regime that monitors the £22 billion Oil & Gas Industry in the North Sea**.** Not only has this provided a robust methodology, but it has also ensured that the Department of Energy and Climate Change regulators have a high confidence in the assessments. The studies, which have been conducted, have shown clearly that the regulation that was introduced was appropriate, and there is a high confidence in the assessment, including following specific incidents (**IR3, IR4, IR5**).

The UK, as a Contracting Party to OSPAR, has promoted the methodology at relevant Working Groups, in both OSPAR and the International Council for the Exploration of the Sea (ICES). This includes the ICES Marine Chemistry Working Group and the OSPAR Working Group on Monitoring in the Marine Environment. This has resulted in data from the **Random Stratified Statistical Sampling Regime** being incorporated into international assessments (**IR6** page 44). Key to assessments at a regional scale (such as the North Sea) is a common methodology across the various countries. The UK has taken a strong lead both in the determination of assessment criteria and sampling methodologies which are part of the OSPAR Coordinated Environmental Monitoring Programme (CEMP) which is the international basis on which many North Sea countries base their monitoring. This lead has leant heavily on the science of the sampling as detailed above and the use of passive samplers, which are now being considered as one of the key ways forward in environmental sampling.

In recent times the EU have introduced new legislation pertaining to the marine ecosystems. The Marine Strategy Framework Directive (EU Directive 2008/56/EC; MSFD) and the associated Decision of 1 September 2010 (2010/477/EU) detail the descriptors of good environmental status and the required criteria and indicators. For hazardous substances, the descriptor is "*Concentrations of contaminants are at levels not giving rise to pollution effects*." While the common indicators (across Member States bordering a Region e.g. North Sea) link concentration with effect.

Marine Scotland has just published a report (**IR7**) outlining the proposed new sampling programme to meet the requirements of the MSFD Monitoring, to be implemented from July 2014. The **Random Stratified Statistical Sampling Regime** of the sediments is integral to the monitoring programme.

Basically, there is a critical need to correctly assess the human impact on the environment. ICES

and OSPAR both play a fundamental role in providing direction and ensuring a common methodology across marine regions. By presenting robust data, backed up with peer-reviewed publications, UK representation at both OSPAR and ICES, on occasions led from Marine Scotland Science, is based on a strong and robust evidence base of which this is a fundamental and important part [**IR8**]. The outcomes are monitoring programmes that deliver in a sound and robust way, ensuring that the UK is compliant and also using common techniques and assessment criteria.

Environmental impact has been achieved for a range of different beneficiaries both in the UK and internationally providing cleaner seas which has improved marine sustainability particularly the fish stocks and marine animals. Cleaner beaches and seas encourage increased leisure activities which improve lifestyles and consequently health.

Economic impact has been achieved in the Fisheries industry as cleaner seas provide increasing and healthier fish stocks. Also the earlier indication of problems in an area instigates timely corrective action which can reduce costs to the Oil & Gas and others industries.

5. Sources to corroborate the impact (indicative maximum of 10 references)

IR1 J. M Baxter, I. L. Boyd, M. Cox, A. E. Donald, S. J. Malcolm, H. Miles, B. Miller, and C.F. Moffat**,** (Editors). "*Scotland's Marine Atlas: Information for the National Marine Plan"*, Edinburgh, UK, 2011, 191 pages.

IR2 "*Charting Progress 2-The state of UK Seas 2010 Department for Environment Food and Rural Affairs on behalf of the UK Marine Monitoring and Assessment Strategy Community"*, Crown Copyright, 2010, 166 pages.

IR3 L. Webster, M. Russell, P. Walsham, L. A. Phillips, I. Hussy, G. Packer, E. J. Dalgarno, and C. F. Moffat, "An Assessment of persistent organic pollutants in Scottish coastal and offshore marine environments". *Journal of Environmental. Monitoring,* 13, 2011, 1288 - 1307.

IR4 L. Webster, I. Hussy, A. Craig, M. Russell, G. Packer, E. J. Dalgarno, D. C. Moore, and C. F. Moffat, "Determination and environmental assessment of hydrocarbons in water, fish and sediment following oil spill at the Gannet Oil Field". *Scottish Marine and Freshwater Science,* 2(12), 2011, 1-26.

IR5 L. Webster, M. Russell, I. Hussy, G. Packer, E. J. Dalgarno, D. C. Moore, and C.F. Moffat, "Environmental Assessment of Elgin Gas Field Incident – Report 2 Water and Sediment". *Marine Scotland Science Report,* 2012, 1-18.

IR6 *"OSPAR. 2010 Quality Status Report*". OSPAR Commission, London, 2010, 176 pages.

IR7 L. Webster, C. D. Robinson, M. Russell, and C. F. Moffat**, "**Measurement of contaminants and their effects in environmental samples - Proposal for the revision of the sampling programme". *Scottish Marine and Freshwater Science*, 4, 2013, 1-43.

IR8 Marine Scotland Policy Officer, Scottish Government. Letter confirming use of the random stratified sampling regime by OSPAR and ICES.