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Contaminants characterisation of the Mid-North Sea High Seismic Area

(Strategic Environmental Assessment)

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Executive Summary

1.1. In support of Offshore Energy Strategic Environmental Assessment 3 (OESEA3), an overview of the existing baseline information is required in relation to several topics including 'contaminants'. The area of focus for this current baseline review, namely the 'Mid-North Sea High' is located within the Central/Southern North Sea. For this report data have been referenced by an area defined as: southern boundary - 54°N extending from the coast to the UK median line and northern boundary - formed of a line from Fraserburgh to the intersect with the median line at 56° 30'N. In this report this area is referred to as the 'Mid-North Sea High' and abbreviated to MNSH.

1.2. This report primarily considers the environmental concentrations in sediments and biota of metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs).

1.3. Various assessment criteria are used to provide a reference against which to judge the potential of the contaminant concentrations measured for environmental harm. Many contaminants are associated with the fine particles of marine sediments and aluminosilicates are the main group of minerals generally found in the fine sediment fractions, therefore where this information is available metals were normalised to 5% aluminium concentration and organics to 2.5% organic carbon content of the sediment.

1.4. A consideration is made of the potential chemical inputs from several key marine activities associated with the MNSH area – these are the offshore oil and gas industry and windfarm development, and in coastal areas inputs from dredge disposal and from radioactive sources.

1.5. Chemicals are used in a wide range of processes to produce oil and gas. Some of these chemicals, their components and their reaction products may therefore be present in the discharge of water separated from the oil derived from the exploited formation reservoir. This produced water discharge also contains some residual oil and chemicals derived from the reservoir. To minimise the potential impact of chemicals used and discharged offshore in the UK, the risks from such activities are controlled through the Offshore Chemical Regulations 2002 (as amended). As part of this process, those chemicals that contain components qualifying as particularly hazardous (persistent, bioaccumulative and toxic) are identified as substitutable substances and are scheduled for early phase out of use. Of the total of 14 oil and gas installations and complexes in the MNSH area only one reported discharging 21.5 tonnes of substitutable chemicals in

2012 and four discharged 10 tonnes and the remainder less than 1 tonne. The overall trend is of a significant decrease in such discharges from 2000 to 2012. A more recent initiative focuses on overall toxicity of produced water discharges using a risk based approach but data from this are not yet available.

1.6. Over several years, the UK oil and gas industry has conducted sediment contaminant monitoring for oil and gas installations in the UKCS including seven in the MNSH. These data provide an assessment of selected contaminants that are likely to accumulate and persist in sediments and to potentially affect marine organisms and sediment dwellers. Data are reported for the period from 2005 to 2008 and for 2012. The datasets are quite variable with many measurements below detection and with a variable and sometimes relatively high limit of detection and only the maximum concentration values for selected metals (copper and lead) are at concentrations at which some biological effects are likely. The Total hydrocarbon concentrations are below threshold effects levels for biological effects and that of PAHs are generally between background and likely 10% effect levels.

1.7. Six main areas of offshore windfarm development, including cable corridors, are in offshore areas of the Mid North Sea High Seismic Area (Figure i). Chemical inputs from this industry are likely to be negligible and activities that have the potential for chemical inputs are regulated and managed. Some potential exists for historic sediment contaminants to be disturbed during cable laying and other construction activities and so this is considered as part of each project's Environmental Impact Assessment (EIA). Sediment contaminant data from relevant EIAs were extracted for each development site. As the data are rarely reported as normalised for metals against aluminium or for PAHs against organic carbon, comparison is made here to Cefas Action Levels used by Cefas to assess suitability of dredged sediments for offshore disposal. Overall the mean metals concentrations (chromium, copper, lead) and those of several mean PAH concentrations (naphthalene, phenanthrene and pyrene) are above a level that requires further assessment before re distribution or disposal. Most contaminant concentrations were particularly elevated at Blyth. Historical disposal of dredge material from the River Blyth and from Rivers Tyne and Wear off the northeast coast of England are likely to have contributed to the elevated levels associated with this site. The Dogger cable route also shows some elevated metals concentrations, chromium, and copper. Again this elevation probably relates to historic dredge disposal as the cable route is adjacent to Teeside.

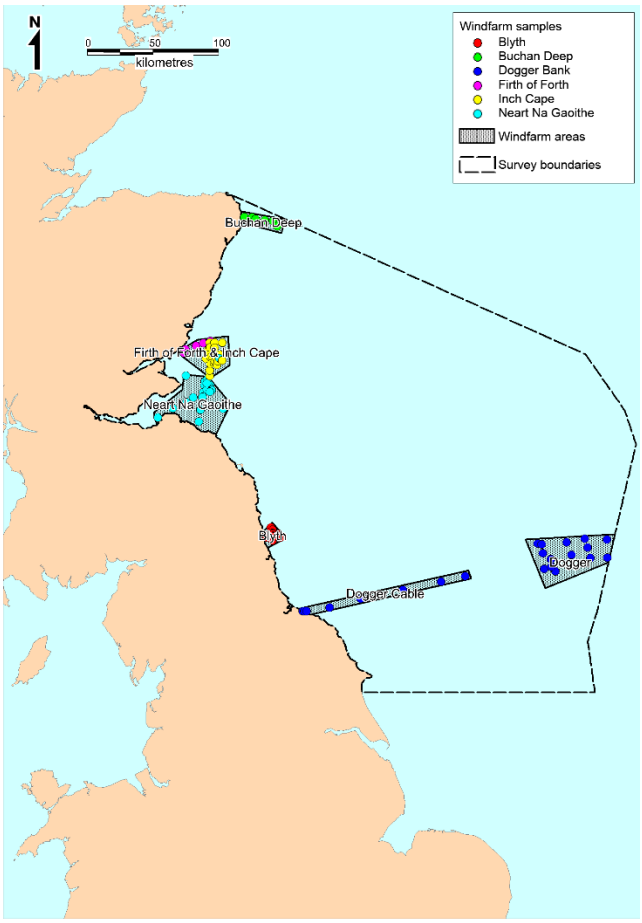

Figure i: Location of offshore windfarm contaminant survey sampling stations

1.8. The disposal of dredge spoil waste at coastal and offshore locations is strictly regulated through the licensing requirements of the Marine and Coastal Access Act 2009 (MCAA). Due to improved environmental regulation the disposal of hazardous substances in dredge spoil has reduced greatly over recent decades. Only essential activity related to the maintenance or development of new ports, marinas and harbours is presently allowed but only material with contaminant levels below a certain threshold (Action Level) can be disposed of at sea. The amount of material disposed to sea is regularly reported to OSPAR and in most cases the impact of such activities is generally confined to the boundaries of the official disposal areas and these tend to be restricted to sites close to the coast. In Scotland within the MNSH area there are 14 open sites routinely used for dredge disposal and shown in five groups on Figure ii. For English waters within the MNSH area, dredge disposal sites are grouped together in in five areas shown in Figure ii.)

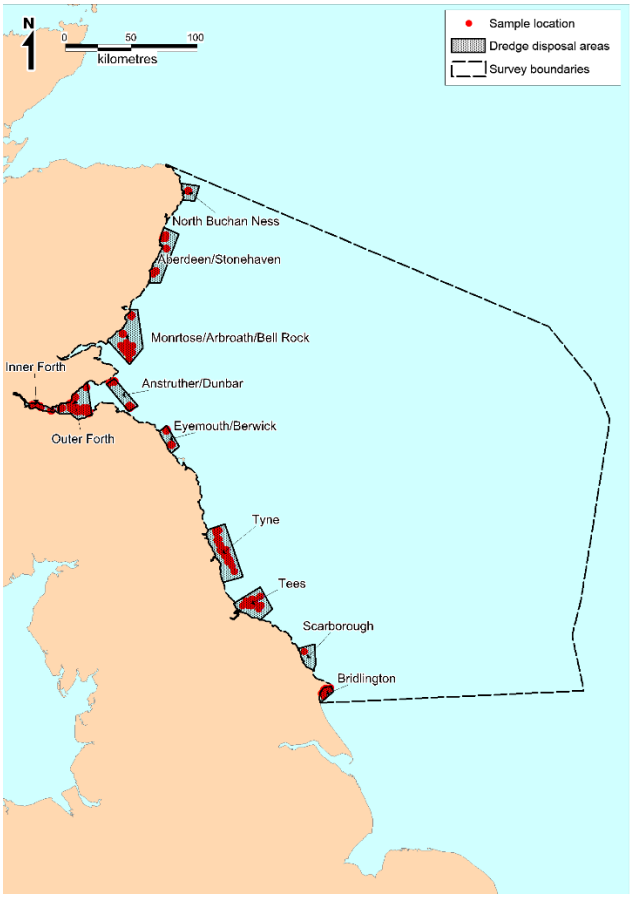

Figure ii: Dredge disposal areas.

1.9. Most data accessible to the public relate to contaminants such as metals, PAHs and PCBs and the two most studied areas are the disposal areas off the Tyne and Tees estuaries. It can be expected that concentrations of contaminants are elevated (in comparison with the surrounding region) directly within the boundaries of a dredge material disposal area. Where assessments have taken place metals and PAHs regularly failed their sediment quality standards within the boundaries of the disposal grounds. Mean concentrations of chromium, lead and zinc exceed Cefas Action Level 1 (a threshold applied for decision making on disposal options) for the Tyne and Tees but values at Scottish sites are either at or below this level. This is illustrated for lead in Figure iii.

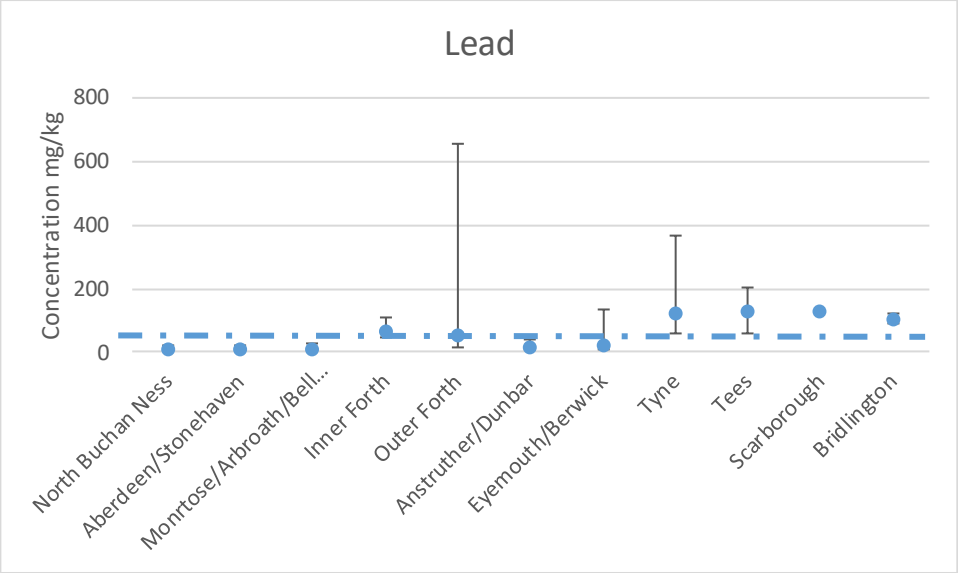

Figure iii: Mean, minimum and maximum concentrations of lead measured in sediment samples from dredge disposal areas between 2005 and 2010 (different periods within this range are covered at each of the sites, data source Marine Scotland and Marine Management Organisation).

For ten polycyclic aromatic hydrocarbons measured in sediments at the dredge disposal sites higher concentrations were also seen in sites off the Tyne and Tees relative to the Scottish sites. The only exception to this general pattern of elevated concentrations was the outer Forth estuary for which several PAHs measured in sediments were at concentrations of a comparable order of magnitude to those of the Tyne and Tees disposal sites e.g. benzo[ghi]perylene]. For chlorinated biphenyls some higher values were also measured for sediments from the outer Forth relative to all other sites. In all cases the most recent data sets were from 2011 so some change may be apparent over the last five years.

In general, the data for all the sites and contaminants measured indicate that concentrations remain temporally stable or show a slight decline.

1.10. Radioactive contamination comes from several sources, some natural and some from industrial activities, from waste materials and from accidents. In 2012, very low concentrations of caesium-137 (up to 0.005 Bq l^{-1}) were found throughout most of the North Sea survey area and these were only slightly above those observed for global fallout levels in surface seawaters (0.0001- 0.0028 Bq l^{-1}).

Figure iv: sites of relevance to radioactivity inputs

1.11. The application and use of radioactivity for a range of purposes has led to other contributions to the natural environment. Various industries and research establishments in the MNSH area have potential to contribute to radioactive inputs to the marine environment – specifically these are industries involved in cleaning equipment contaminated with radioactive scale (Nigg Bay), historical disposal of radioactive material (Dalgety Bay), research establishments (Rosyth) and nuclear power stations (Torness and Hartlepool) (Figure iv).

Stoneyhill Landfill site located in Aberdeenshire has a descaling facility to remove naturally occurring radioactive material (NORM) scale from used oil and gas industry equipment. Leachate from the site is sent to the nearby Nigg sewage treatment works. Water and effluent from both sites are monitored in associated areas e.g. Aberdeen beach and Nigg Bay. All sites were below detection for ^{226}Ra and ^{228}Ra. Other radioactive inputs may occur from a Scotoil facility which cleans oil and gas equipment. Discharges from this source have been monitored in Aberdeen harbour where in 2014 Technetium-99 was detected in seaweed (17 Bq kg^{-1}, fresh), but this was in line with the expected effect from Sellafield discharges (as the releases become diluted or mixed in moving further afield). Gamma-emitting radionuclides were all below or close to the level of detection. In 2014, the dose rate on sediment was 0.092 µGy h^{-1} which was similar to

background. For Dalgety Bay in Fife there was historic contamination by radium-226 since at least 1990. Close monitoring and clean up since that time has resulted in shellfish samples taken between February 2012 and February 2013 showing no evidence of radioactive particles. Radioactivity contributions also occur from research establishments including Rosyth, Fife where the nuclear submarine fleet was decommissioned between 2006 and 2015. To date, more than 99 per cent of the site decommissioning waste arising has been recycled. At Rosyth the total dose from all pathways and sources was less than 0.005 mSv in 2014, which was less than 0.5 per cent of the dose limit. Two nuclear power stations have potential inputs to the area, Torness and Hartlepool. For Torness power station, the results of aquatic monitoring in 2014 show very low concentrations of activation products in environmental samples, many below detection. An americium-241 concentration was elevated in a *Nephrops* sample (from Dunbar Bay) and technetium-99 concentrations in marine samples (indicator of farfield disposal from Sellafield) were like those in 2013 with low levels in crabs and lobsters collected from Torness and *Fucus vesiculosus* from Thornton Lochs. Hartlepool power station has regulated discharges to Hartlepool Bay (with a minor component to the Tees). Discharges of tritium and sulphur-35 decreased in 2014, in comparison to those in 2013. In 2014, the reported polonium-210 concentration in winkles from South Gare was 18 Bq kg^{-1} and enhanced above the value expected due to natural sources.

1.12. The Clean Seas Environment Monitoring Programme (CSEMP) is the main means by which the UKs national and international commitments (e.g. OSPAR and Marine Strategy Framework Directive, MSFD) to monitor marine sediments and biota in coastal and offshore marine waters are met. Quality controlled data relating to the levels of chemical contamination (metals, PAHs and PCBs) in both sediment and biota is held within the UK Marine Environment Monitoring and Assessment National database (MERMAN).

1.13. Sediments act as a sink for many contaminants including metals, PCBs and PAHs. Broad spatial assessment of the data for most metal/Al ratios show low ratios in this region of the North Sea with higher ratios restricted to several sites of concern in industrialized estuaries such as the Inner Forth, Tees and Tyne which may lead to toxicological impacts. There is no overall significant trend in the contamination status of metals, but if metal inputs from rivers, sewage and industry continue to decrease, further significant downward trends would be expected in future assessments. The concentration of metals in sediments collected from offshore locations are, in general, not considered to

pose a toxicological threat to marine species. A broad spatial assessment of the data for the levels of PCBs in sediments in the MNSH shows that most sites contained samples with low levels of PCB contamination. It should be noted that while the congener CB118 regularly exceeded sediment quality guidelines this is consistent with other areas around the UK. The Environmental Assessment Criteria (EAC) is lowest for CB118 (0.6 µg/kg dw), a mono-*ortho* CB and the most toxic of the ICES7 CBs. EACs were also exceeded for CB28, CB52 and CB101 at a limited number of other locations. Again, many sites with high levels of contamination were restricted to the industrialized estuaries (Inner Forth, Tyne and Tees). Major UK assessments have taken place in recent years and these demonstrate that CB concentrations appear to be relatively stable. The worldwide ban on the use of PCBs has resulted in a decrease in contaminant loading (e.g. riverine inputs and atmospheric transport) over time. However, the slow degradation of CBs means this could take some time to be reflected in actual measured concentrations in sediments and will require continued monitoring. A similar finding was observed for PAH contamination, where hotspots (multiple samples exceeding sediment quality guidelines) were restricted to the historically industrialized estuaries, such as the Tyne and Tees on the north-east coast where there is a high degree of legacy contamination. The PAH data presented below indicates that any toxicological threat is restricted to these heavily contaminated estuarine locations and coastal or offshore locations remain uncontaminated and pose little or no risk to marine organisms.

1.14. The CSEMP programme has collected data of a variety of fish species for the assessment of both metal and PCB contamination. Samples relating to this region are restricted to material from dab (*Limanda limanda*) and plaice (*Pleuronectes platessa*). Regulatory drivers for the measurement of metals in biota includes OSPAR Co-ordinated environmental monitoring programme (CEMP) which requires Hg to be measured in fish flesh, and Cd and Pb to be measured in fish liver. In summary, concentrations of Hg in fish flesh are elevated in some industrial estuaries, although these do not pose any risks to human health. Concentrations of Cd and Pb in fish liver are again elevated in industrialized estuaries and in a few other coastal areas, but are unlikely to pose a risk to human health. Data for other metals (e.g. Zn, Cu and Cr) are sporadic, with varying numbers of sites sampled for each metal. However, there are no BACs or EC limit values available for these metals and therefore it is difficult to assess these data objectively in terms of their significance. The limited amount of data reported for metals other than

Cd, Hg and Pb is probably due to the lack of a regulatory driver, and has contributed to the lack of suitable assessment criteria against which to compare the data. The available PCB contaminant data in fish suggest that contamination has reduced in several areas. And like the sediment data where EACs ($EAC_{passive}$) were exceeded it generally was restricted to data on levels of CB118, a mono-*ortho* CB and the most toxic of the ICES7 CBs.

1.15. In overall summary the MNSH area has several coastal locations where metals, PCBs and PAHs are elevated above background levels in sediments and in some cases at levels of concern for biological effects but these are predominantly associated to areas of current or historic dredge disposal. As there are fewer developments in this region there are few data for offshore sediment contaminant concentrations associated with the oil and gas industry within the MNSH area but those available indicate contaminant concentrations are below levels that are of concern.

1.16. Inputs of radioactivity to the MNSH area occur via the atmosphere and from the nuclear industry including power stations (Hartlepool and Torness), nuclear research establishments, processing of radioactive material (NORM) scale from used oil and gas infrastructure and from historic waste disposal. However, overall the inputs of radioactivity to the area are very limited and levels of different activation products with a few exceptions are frequently at or below limits of detection.

1.17. In terms of inputs into the region it is known that atmospheric and riverine inputs have been reduced significantly in recent years. However, in some of the historically industrialized estuaries, such as the Tyne and Tees on the north-east coast, there can be high levels of legacy contamination.

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1 Introduction

1.1 Background to the project

In support of current Offshore Energy Strategic Environmental Assessment 3 (OESEA3), an overview of the existing baseline information with respect to contamination was commissioned. A detailed, desk based review is provided here of the overall contaminant status of the 'Mid North Sea High', an area of relevance to the 29th Licensing Round for which a technical report is required to inform the baseline assessment.

This assessment considers the major inputs of contaminants to this area, which include those from a range of current and historic marine activities i.e. from the oil and gas industry, offshore windfarm development, dredged material disposal and nuclear establishments and power stations. In terms of nuclear industry and related inputs, the report discusses radioactivity resulting from natural and anthropogenic sources, although these are not significant for installations and operations in this area. Finally, the report evaluates the environmental concentrations of chemicals against background levels and provides spatial and temporal assessments where possible.

2 Assessment of Near Field data around Offshore Energy Installations

2.1 Introduction

This section covers various sources of chemical and radioactive contaminants that may be introduced to the MNSH marine environment because of the construction and operation of offshore energy installations. For offshore oil and gas development the industry has been established for at least 50 years and there are many operational activities that include chemical use and potential discharges of chemicals e.g. contaminants present in produced formation water and chemicals used in oil separation as well as the release of contaminants during the drilling process. For the offshore wind industry, a much more recent development, contaminant release from seabed sediment disturbance during construction is one main initial consideration and during the laying of associated cables. Chemical use for windfarms is more limited and mainly concerns the use of some biocide and lubricant chemicals in small quantities. The following sections consider potential chemical inputs from both industries.

2.2 Development of the Oil and Gas Industry

Hydrocarbons have been produced from the North Sea for over 50 years. On the UK continental shelf there are 326 offshore fields in production, 170 oil, 123 gas and 33 condensate production. These fields produce between 700, 000 to just over one million barrels per day of oil, 35 – 88 million m^3 per day of gas and from just over 3,000 to nearly 8,000 barrels per day of condensate (based on data from Oil and Gas Authority, 2016). The extraction of these reserves requires the use of chemicals, both during the exploration phase, primarily related to the use of complex drilling fluids, and during the subsequent production phase, where chemicals are required to assist gas, condensate, oil and water separation, to protect equipment from corrosion and to ensure safety.

Chemicals used offshore may consist of a single substance such as calcium chloride used in brine solutions for the completion and workover of wells, or a drilling fluid consisting of many different component chemicals. All chemicals used offshore go through a hazard and risk assessment before they are given permission for use and potential release. During their use offshore, chemicals or their reaction products may be released to the environment in drilling operations or subsequently from associated drill cuttings at the surface of a well and discharged in produced water.

Potential contaminants from drilling operations

From the early 1970s through to 2000 oil based mud (OBM) was formulated with diesel oil. However, the high aromatic content (25% by weight) resulted in health and safety concerns with handling and toxicity in the marine environment. The use of diesel-oil based drilling fluids was prohibited by OSPAR from 1 January 1987 and the discharge of untreated cuttings contaminated with oil-based drilling fluids ceased following PARCOM Decision 92/2 on the use of oil-based muds.

In 1998 United Kingdom Offshore Operators Association (UKOOA) took forward an initiative to develop a strategy for dealing with oil contaminated cuttings piles that had accumulated under some installations in the North Sea. In early 2001 the discharge of any cuttings contaminated with oil was not permitted (OSPAR Decision 2000/3), this included discharge of cuttings contaminated with oil based fluids (OBF) (includes OBM and synthetic based muds, SBM) greater than 1% by weight on dry cuttings. After this other legislation reinforced the position with respect to any discharge of cuttings with associated oil i.e. the Offshore Chemical Regulations 2002 require a chemical permit for the use and discharge of chemicals including drilling muds. A permit is also required for discharge or reinjection of cuttings containing hydrocarbons from the reservoir (Oil Pollution Prevention and Control Regulations 2005).

The risk of environmental contamination or effects from cuttings piles was assessed under OSPAR Recommendation 2006/5. Work completed in 2009, indicated that appropriate management of cuttings piles on a case by case basis at the time of decommissioning of the installation would be sufficient to mitigate wider field effects. Factors such as the age of the wells influence the contamination associated with drilling operations (i.e. what type of drilling fluids have been used), and the rate of cuttings discharge and depth and hydrodynamics of the location, influence the extent to which materials might be dispersed. There were 1,071 wells drilled in the MNSH (Figure 2:1), 320 of which were completed between 2000 and the present – 62 were appraisal wells, 180 were development wells and 78 were exploration wells. Of these 320 wells 138 have been abandoned, 80 were completed, 31 were suspended and information isn't available for 71 of the wells.

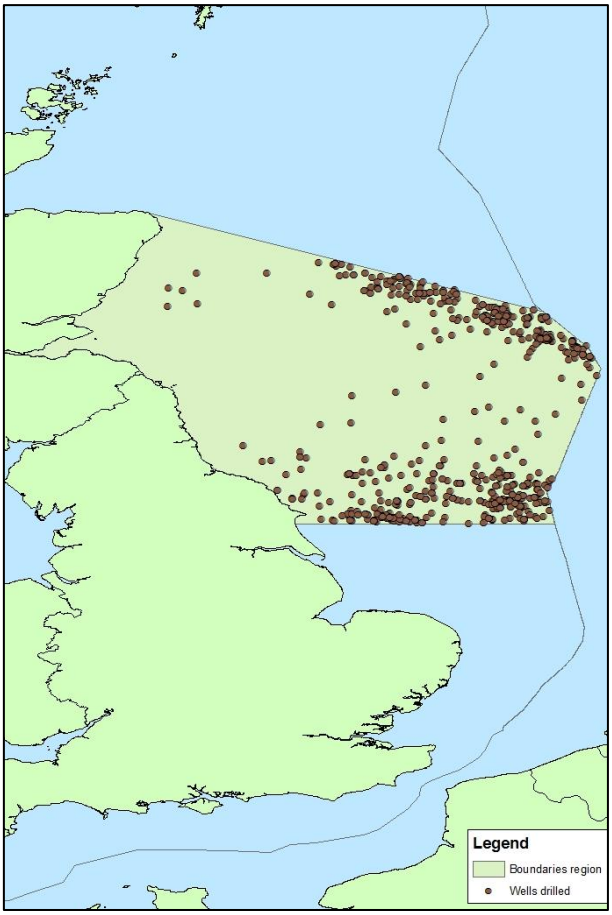

Figure 2:1 Map showing location of wells drilled between 2000 and 2015 within the SEA area

2.2.1.1 Drilling Chemicals

During the early period of North Sea development, all wells were drilled with water-based muds (WBM) using the experience of US companies operating in the Gulf of Mexico. WBMs are formulated

either with fresh water, seawater or with a brine (e.g. potassium chloride which inhibits reactive clays). The salinity ranged from 0 to approximately 900 kg/m^3, depending on the salt type and desired density of the mud (OLF, 1998). The environmental impact of drilling with WBMs was found to be very small. Later, diesel oil began to be added to water-muds to combat problems encountered when drilling through strata containing shales, claystones and salts which softened, swelled or dissolved on contact with WBMs and which lead to the drill string sticking or ultimately to the collapse of the well. In the North Sea increasing frequency of drilling at greater depths (i.e. during the late 1970s) lead to an increased requirement for directional drilling, which in turn required the greater lubrication and temperature tolerance provided by oil-based muds (or OBMs). Low cost diesel oil-based muds were commonly employed and this continued until the prohibition of their use in 1987. During this period (1980s to early 1990s) drilling operations were a significant source of oil being discharged to the sea. An estimated 158,000 tonnes of hydrocarbons associated with cuttings were discharged to the North Sea between 1983 -1997 with annual values of between 14,000 -20,000 during the 1980s diminishing to around 3,000 tonnes per year in the late 1990s (DTI, 1996). Following the ban on use of diesel oil, lower toxicity oil based muds such as those using dearomatised kerosenes came into greater use. From this time however there was a greater focus on the reduction of the oil content of cuttings prior to discharge.

During drilling operations cuttings and associated drilling chemical residues are discharged at the location of the well and where currents are weaker may build up to form a cuttings pile. Due to the mostly shallower depth in which seabed sediments become resuspended and dispersed during storms (Breuer et al., 2008) such piles are not a typical feature of sites located in the MNSH area. However, contamination associated with cuttings may nevertheless be dispersed into the area around a drill site leading to localised elevation of some contaminant levels.

The types and amounts of chemical additives included in the mud formulation vary per the physical characteristics of the mud required. Drill cuttings with associated drilling muds may therefore contain a range of contaminants, e.g. certain heavy metals which may present an environmental risk if they are present at elevated concentrations and in a toxic state. Barite may be contaminated with variable amounts of heavy metals depending on the source of the mineral, and since it is used in large quantities in muds, it is the main source of heavy metals contamination in cuttings piles. The major chemical functions and types of additives used in the various drilling muds are illustrated in Table 2.1.

In addition to those chemicals listed in Table 2.1, biocides and corrosion inhibitors are also added to formulated drilling muds. It should however be noted that for many applications, mud mixes may consist of relatively few chemicals and often these are classified by OSPAR as Presenting Little Or No

Risk (PLONOR). In general, studies on drill cuttings from oil and gas platforms have concluded that OBMs have impacted on the marine environment. Studies indicate that biological changes can be detected in benthic communities up to 5 km from some drilling sites (Gray *et al*., 1990). However, the effects are most noticeable in a zone that generally extends to a maximum of between 200-2,000 m from the drilling site and has been described as a transition zone in terms of benthic community structure and within which hydrocarbon levels are 10 -700 times background concentrations (Davies *et al*., 1984).

Table 2.1 Major chemical functions and types of additives used in drilling muds

Chemical Function Group	**Function**	**Composition**
Weighting materials	Increase weight of mud, which maintains well pressure. Major component of mud system.	Most commonly barite, which may contain traces of heavy metals.
Viscosifiers	Build viscosity through complex interactions with the emulsions.	Bentonite clay in the majority of most water-based muds. Organic polymers derived from cellulose and natural biopolymers also used.
Fluid loss control agents	Serve to reduce the loss of fluid from mud into drilled formation.	Bentonite clay, lignite and polymers: carboxymethyl cellulose (CMC), polyanionic cellulose (PAC) and modified starch.
Emulsifiers	*Stabilise oil-in-water emulsions.*	Fatty acids (and derivatives), rosin acid (and derivatives) prepared from sodium soaps from the paper industry and fatty imidazoline derivatives. Secondary emulsifiers include amines, amides, sulfonic acids, lignosulfonates, alcohols and related co-polymers.
Brines	Concentrated inorganic salt solutions balance the interactions of drilling fluid with clay and soluble salts.	For WBMs: KCl, NaCl. For completion fluids NaCl, CaCl2, ZnCl2, CaBr2 and ZnBr2. For OBM/SBMs, CaCl2, (NaCl). Typical use concentrations are 20% CaCl2 brine,added by 20-40% to the mud.
Alkaline chemicals	Control pH, reducing corrosion and also activating some emulsifiers.	Lime (Ca (OH)2) is with OBM/SBM. Caustic soda, and other inorganic compounds including NaOH, KOH, *Ca(OH)2, K2CO3 in WBMs.*
Lost circulation materials	*Block pores and fractures.*	Crushed nut shell, shredded vegetable fibre, mica flakes, calcium carbonate, shredded cellophane: concentrations used varies widely.
Shale control additives	Prevent fluid loss in dry reactive shales and prevent the swelling of shale and possibility of stuck pipes	Most commonly KCl, also polyglycols and polyglycerols, polyacrylamides (with high molecular weight), aluminium sulfate, inorganic silicates, sulfonated asphalts and synthetic cationic polyamines.
Lubricants and detergents	Enhance the rate of penetration of drill string	Most common lubricants are modified natural esters, fatty acids or glycol esters. Most popular detergent used is *ethoxylated alcohols.*

Production Chemicals

Production treating chemicals are used on oil and gas platforms for several functions including prevention of corrosion and scale formation, to aid the free flow of oil or gas and to separate oil from formation water. To meet the functional demands of the offshore environment a wide range of chemicals are required. The main chemical functions are described in Table 2. and Table ***2.*** respectively.

Table 2.4 Major chemical functions used in Well Stimulation and Workover Procedures

Product Function	**Function Description**
Stimulation and Workover Chemicals	Stimulation and workover treatments are performed to improve the productivity or injectivity of wells, although careful attention to cleanliness during completion and injection can reduce the need for such work.
Acids	Used to open up lumen at the bottom of wells in limestone reservoirs. A mixture of hydrochloric and hydrofluoric acids, known as 'mud acid' can dissolve sand and also clays, which may have entered the formation from drilling mud. Organic acids such as acetic, formic and citric acids may also be used to prevent chloride corrosion of tubulars. Citric acid or EDTA can be used to remove scale deposits.
Hydraulic fracturing	Requires large volumes of fluid containing proppants and other additives to be pumped under high pressure into the formation. The most common proppants are graded sands and alumina which has a greater crushing strength. These materials may be coated with phenolic or epoxy resins, which harden at elevated temperatures in the formation and lock the proppant into place. Oil soluble resins can be added to increase the fracture lengths attainable with given pumping capacity.
Brines	Range in density from concentrated sodium chloride through calcium chloride to bromides of which zinc bromide is the heaviest. Caesium formate is increasingly used as a safer alternative to zinc bromide.
Viscosifiers	Typical viscosifiers: celluloses, guar gum and starches or sugars although synthetic polymers may be needed in high temperature wells.

Table 2.5 Major chemical functions and types of additives used in Oil and Gas Production

Product Function	Function Description
Corrosion Inhibitor	Corrosive gases in produced water (oxygen, hydrogen sulphide, carbon dioxide) and seawater itself, can cause corrosion in pipework and tubulars. Products generally comprise complex mixtures: amides, amines, amine salts, imadazolines, quaternary ammonium salts.
Scale Inhibitor	Scaling can occur within pores of the formation itself as reservoir pressures reduce and within well tubulars. Scale inhibitors inhibit crystal growth. Most are based on phosphonates, phosphate esters or acrylic acid copolymers.
Emulsion Breaker	Water is dispersed in oil or as wells age, a reverse emulsion is produced, with oil suspended in water. Most installations use demulsifiers to accelerate separation. These include: oxalkylated resins (alkylphenol/formaldehyde reaction products), polyglycol esters, alkyl aryl sulphonates.
Reverse emulsion Breaker	Oil left in produced water following primary separation is removed to <40 ppm, using positively charged polyamines or polyamine quaternary compounds added to cause the negatively charged oil droplets to aggregate.
Antifoam chemicals	Hydrocarbon foaming causes significant problems in oil and water separators. Polyglycol esters or silicones can reduce these.
Paraffin treatment and dewaxing chemicals	Solid hydrocarbon waxes build up in tubing, vessels and flowlines. Deposition may be inhibited by vinyl polymers, sulphonate salts or mixtures of alkyl and aryl polyethers; also by pushing scrapers or pigs through flowlines and pipelines often in combination with low-cut aromatic solvents.
Water treatment chemicals	Seawater is used to maintain pressure by displacing oil through the reservoir. Suspended solids and micro-organisms must be removed before injection. It is also used to cool process vessels and in fire fighting systems.
Biocides	Sodium hypochlorite prevents biological growth in the seawater intake and injection systems. Typically 0.2 to 0.5 ppm hypochlorite is discharged. Organic biocides are also added to prevent growth of sulphate-reducing bacteria which cause damage to the pumps and tubing and H2S within pressure piping. Typical biocides include quaternary amine salts, amine acetates, formaldehyde and gluteraldehyde.
Flocculants and coagulants	Suspended solids are removed with mechanical strainers, while smaller particles are removed by chemicals. Coagulants, similar to cationic polymers are used for reverse emulsion breaking. Flocculants are generally high molecular weight polymers, although aluminium or iron chlorides and sulphates are also used.
Hydrate inhibition	Hydrates are ice-like solids, which can form above 0°C in gas wells and pipelines. Freeze-ups can be prevented by the addition of methanol or monoethylene glycol. Treatment may be required when extra wells are started from cold and also before shutdowns. Subsea completions usually require continuous treatment.
Gas dehydration	Monoethanol glycol or triethanol glycol are used to adsorb water from the gas. Glycols, whether for hydrate inhibition or dehydration, are recycled. Where produced water is very saline, re-distillation is impossible and large quantities can be discharged.
Gas Sweetening	Acid gases (H2S and CO2) are of a corrosive nature and toxic to humans. Biocides are often added to produced fluids to prevent sulphide corrosion within pipework and vessels.

Most production chemicals are made up of many individual chemical components although there may be common chemical groups for products with similar functions. The Offshore Chemicals Database (Cefas, April 2016) currently lists over 4,323 products that have full, temporary, or provisional classification for use in oil and gas production and completion and workover operations on the UK continental shelf. There are on average three chemical components per product, although the number of chemical components ranges between 1-16. Although a potentially wide range of products may be used for a variety of functions offshore, in practice, chemicals utilised at offshore installations during any given year may be relatively few. Of those products used, not all will be subject to discharge and will either be used within closed circulation systems or, due to their physicochemical characteristics, will partition to the process stream.

To minimise the potential impact of chemicals used and potentially discharged offshore in the UK, the risks from such activities are controlled through the Offshore Chemical Regulations 2002 (as amended) which are based upon internationally-agreed principles set out in OSPAR Decision, 2000/2 (as amended by OSPAR Decision, 2005/1) on a harmonised mandatory control system for the use and reduction of the discharge of offshore chemicals (HMCS). The regulations are administered and enforced by the Department of Energy and Climate Change (DECC) and require operators to perform an environmental risk assessment of the use and discharge of chemicals as part of a permit application process.

To obtain a permit, the operator must select only chemicals that have been registered and their hazards assessed by Cefas, acting on behalf of Department for Business Energy and Industrial Strategy (BEIS). One of the key components in the registration process is pre-screening, and it is at this stage that substances that are candidates for substitution, i.e. substitutable substances (SSs), are identified. The pre-screening is conducted per OSPAR Recommendation 2010/4, which examines chemicals based upon the persistence, bioaccumulation potential and toxicity (PBT) of their component substances. Those chemicals that contain components qualifying as particularly hazardous are identified as substitutable substances and are flagged in the lists of registered substances with a substitution warning.

2.2.1.2 Quantifying Production chemical discharge

There are a total of 14 installations that are found within the area defined for this report and these are shown in Figure 2:2 with some additional detail provided for them in Table 2.2. Figure 2:2 shows the same installations within the area assessed for this report and in relation to the area defined as the Mid North Sea High.

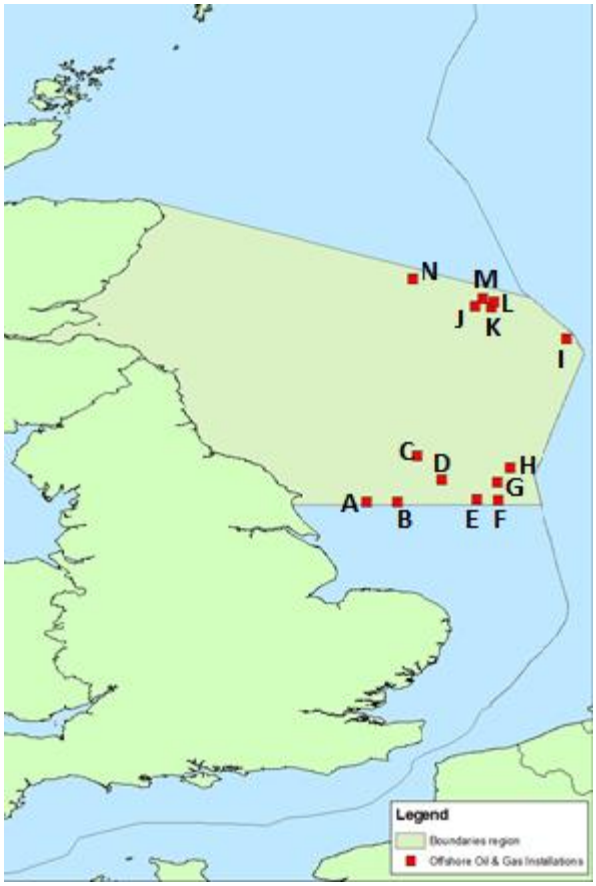

Figure 2:2: Map showing location of oil and gas producing installations present in the assessment area

Table 2.2: Names of installations in the Mid North Sea High area as defined for this report, types of production and production start-up date

Installation name	Letter identification on Map (Figure 2:2)	Type of production	Production start-up
Cleeton	A	Gas	1988
Ravenspurn North	B	Gas	1990
Kilmar	C	Gas	2006
Trent	D	Gas	1996
Schooner A	E	Gas	1996
Ketch A platform	F	Gas	1999
Murdoch	G	Gas	1993
Tyne	H	Gas	1996
Fife FPSO – Uisge Gorm	I	Oil and Gas	1995-2008
Auk A platform	J	Oil and Gas	1975
Janice A FPU	K	Oil and Gas	1999
Clyde	L	Oil and Gas	1987
Fulmar A	M	Oil and Gas	1982
Curlew FPSO	N	Oil and Gas	1997

Substances with hazardous properties considered to represent an unacceptable risk to the marine environment are identified for substitution in support of OSPAR Recommendation, 2006/3. The use and discharge of these so called substitutable substances at North Sea installations has been decreasing and gas only producing installations use and discharge very low amounts of substitutable chemicals (La Vedrine *et al*., 2015). In 2012, only two of the gas producing installations in the southern part of the map (Figure 2:2, letters A-H) discharged substitutable substances and the amounts were less than 1 tonne (696 kg and 227 kg). The Oil and Gas producing Fife FPSO (I) has been decommissioned and so there was no use or discharge of substitutable chemicals from 2012. The five other oil and gas producing installations in the Northern part of the area were active in 2012; four of these discharged less than 10 tonnes of substitutable substances within the year and Fulmar (M) discharged 21.5 tonnes.

In addition to the identification and phase out of substitutable substances in 2012, OSPAR Recommendation 2012/5 for a risk-based approach to the management of produced water discharges from offshore installations was adopted. The UK use a substance level and whole effluent toxicity approach for the RBA assessments, that commenced in 2014, with approximately 20 installations undertaking an assessment each year through to 2018. The UK has requested that operators undertake the full assessment process, including dispersion modelling, to be able to determine a baseline for all installations with a produced water discharge. Data from this programme has yet to be made public.

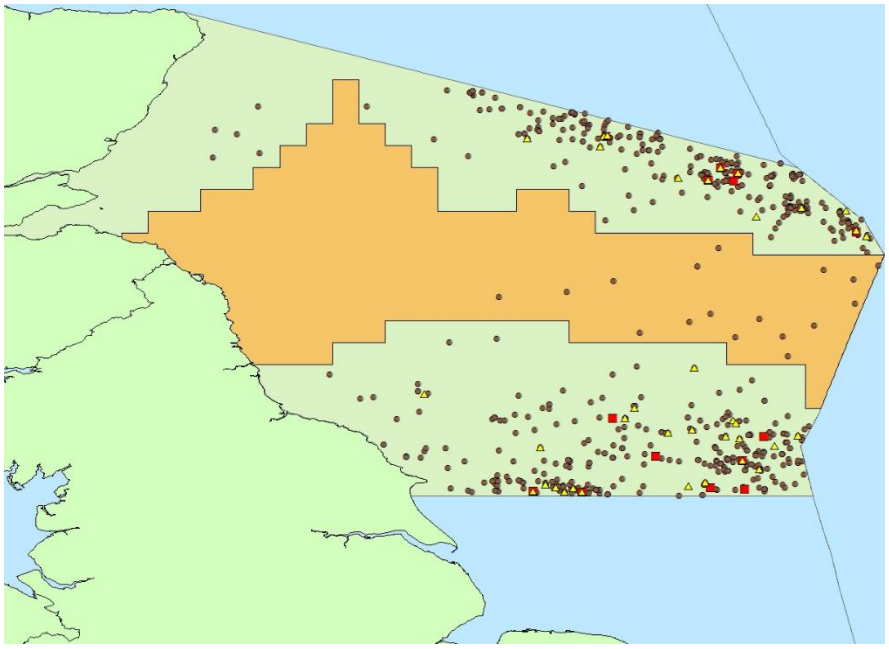

Figure 2:3: Map showing location of oil and gas producing installations and wells drilled in the assessment area and relative to the area defined as the North Sea High Seismic Area (shaded brown)

In addition to monitoring the use and discharge of chemicals intentionally added to produced water the risk based approach also takes account of a range of naturally present chemicals in the produced water that are derived from the drilled formation.

Sediment monitoring data associated to the Offshore Oil and Gas Industry

Offshore environmental impact surveys have been carried out by oil and gas operators in the North Sea since 1975, initially as part of corporate environmental management programmes and latterly as a regulatory requirement. Routine monitoring of the area around installations to confirm impact hypotheses of the seabed and check the general health of the marine environment is now endorsed in UK Regulations notably under the Offshore Chemicals Regulations 2002.

Monitoring surveys have traditionally been carried out along one or more transects at increasing distance (500; 800; 1,200; 2,500 and 5,000 metres) from various offshore installations and following the prevailing current direction. Sediment samples were taken at relevant stations. Also included are samples from reference stations located at 8 to 10 kilometres from the installations. Samples were analysed for hydrocarbons and metals content and to investigate the seabed biological communities. This approach to monitoring is designed to measure gradients of environmental effects near a given platform. Between 1975 and 1998, it is estimated that some 520 seabed surveys were carried out across the UKCS. However, a lack of consistency and standardisation in the way these surveys were conducted has led to difficulty in establishing long-term environmental effects.

To that purpose, Oil & Gas UK (UKOOA at the time) funded a project with the aim of collating and reviewing all seabed monitoring data collected by the UK oil and gas industry from 1975 to 1998.

Data from the UKbenthos sediment contaminants database are collated here and are shown below for 2005 onwards for locations relevant to the area of interest to this report. All analyses were undertaken using the whole sediment rather than a fraction of particle size range. Metals samples were not normalised for aluminium content as this was not determined, but PAHs were normalised for an organic carbon content of 2.5%. Summary statistics for metals and PAHs were produced for each of the prospects/wells around which samples were taken, and are presented in Table 2.3 andThe PAH concentrations reported in **Error! Not a valid bookmark self-reference.** are low by comparison to those for which an assessment criterion is set under OSPAR (naphthalene and phenanthrene), being at background levels or between background and ERL (i.e. 10% effects level). The other PAH analyses for 4, 5 and 6 ring compounds recorded do not have a direct match to PAH criteria as now set. However, the values for four ring compounds (molecular weight 202) are at background levels as defined for chrysene/triphenylene and four ring compounds (mw 228) compared to the benz[a]anthracene criterion are between background and the ERL. For the five ring compounds values are at background levels as defined for individual PAH assessment criteria for

Benzo[a]pyrene and are also at background for six ring compounds relative to the individual assessment criteria for Benzo[ghi]perylene.

Table 2.4. The sampling locations are shown in Figure 2:4. The results for three prospect/well survey areas in close proximity to one another are summarised together (Cygnus, Cygnus Macadam and Humphrey).

As the sediment metals data is not normalised to the aluminium content no direct comparison to ERL/ERM threshold effect values can be made. The datasets are also quite variable with many measurements below detection and with a variable and often very high apparent limit of detection of 1 mg/kg. For this dataset therefore the high below detection limit values are excluded and only positive values above detection are used to derive statistics for each site. Data on the toxicity of sediments and levels of lead and copper around another installation, North West Hutton that is not in the MNSH area, were reported by Grant and Briggs, 2002, and these indicate that the lead levels reported in Table 2.3 are unlikely to result in short term toxicity (i.e. based on tests run over a 10-day exposure period). However, the maximum copper concentrations sampled at Bonneville and the Cygnus complex are at a level at which some biological effects would be likely. The highest cadmium concentrations for the Cygnus complex are also in the ERM range but the data are not normalised so this comparison is only indicative.

Table 2.3: Summary statistics for metals in sediment by prospect/well (mg/kg) showing mean, minimum, maximum based on all values above detection with number of values <detection excluded

Metal	Sample pospect/wells	Year sampled	Measured positive	Mean	Min.	Max.	<Values (No)
	Airidh	2008	0	<0.25	<0.25	<0.25	<0.25 (10)
	Bonneville	2012	4	0.22	0.2	0.3	<0.1 (5)
	Cygnus/Cygnus Macadam/Humphrey	2005-2008	10	0.57	0.2	0.57	<1 (17)
Cadmium	Emerald	2005	0	<0.1	<0.1	<0.1	<0.1(12)
	Airidh	2008	10	4.91	3.70	7.80	
	Bonneville	2012	9	20.79	16.70	24.50	
	Cygnus/Cygnus Macadam/Humphrey	2005-2008	27	24.06	7.00	47.00	
Chromium	Emerald	2005	12	3.33	3.00	4.00	
	Airidh	2008	1	-	<2	2.40	<2(9)
	Bonneville	2012	9	9.48	5.10	14.30	
	Cygnus/Cygnus Macadam/Humphrey	2005-2008	27	7.84	2.50	14.00	
Copper	Emerald	2005	1	-	<1	1.00	<1(11)
	Airidh	2008	10	5.11	4.00	8.50	
	Bonneville	2012	9	9.99	8.10	13.90	
	Cygnus/Cygnus Macadam/Humphrey	2005-2008	27	8.86	6.80	15.00	
Lead	Emerald	2005	2	3.5	3	4	<3(10)

	Airidh	2008	0	-	<0.12	-	<0.12(10)
	Bonneville	2012	9	0.01	0.01	0.03	
	Cygnus/Cygnus Macadam/Humphrey	2005-2008	3	-	<0.01	0.02	<0.01(24)
Mercury	Emerald	2005	0	<0.01	<0.01	<0.01	<0.01(12)
	Airidh	2008	10	7.38	5.20	12.80	
	Bonneville	2012	9	13.96	7.30	28.00	
	Cygnus/Cygnus Macadam/Humphrey	2005-2008	27	22.59	11.20	45.80	
Zinc	Emerald	2005	12	5.75	5.00	7.00	

Data Source UKBenthos database http://oilandgasuk.co.uk/knowledgecentre/uk_benthos_database.cfm

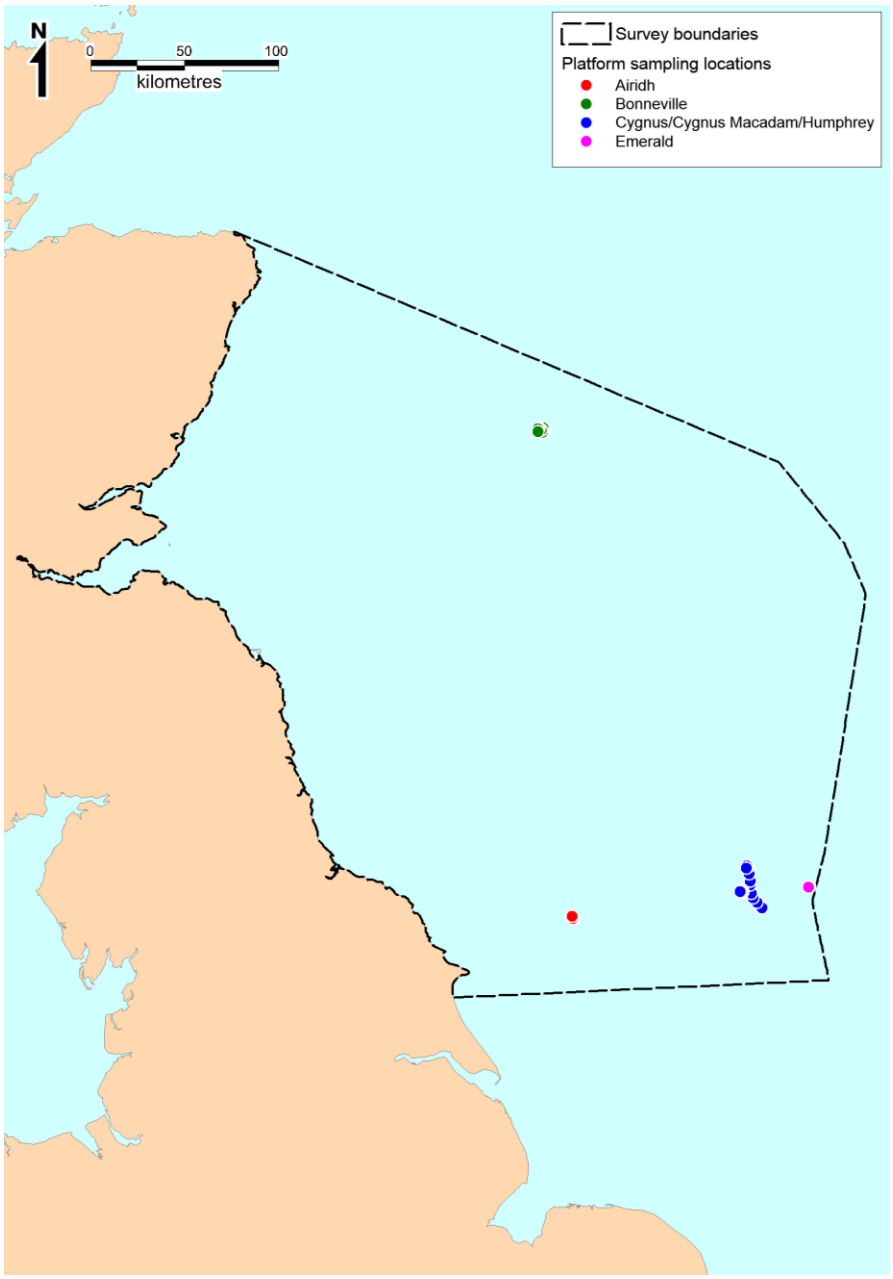

Figure 2:4: Sediment sampling locations for prospect Well sites associated to Oil and Gas developments in the MNSH area

The PAH concentrations reported in **Error! Not a valid bookmark self-reference.** are low by comparison to those for which an assessment criterion is set under OSPAR (naphthalene and phenanthrene), being at background levels or between background and ERL (i.e. 10% effects level). The other PAH analyses for 4, 5 and 6 ring compounds recorded do not have a direct match to PAH criteria as now set. However, the values for four ring compounds (molecular weight 202) are at background levels as defined for chrysene/triphenylene and four ring compounds (mw 228) compared to the benz[a]anthracene criterion are between background and the ERL. For the five ring compounds values are at background levels as defined for individual PAH assessment criteria for

Benzo[a]pyrene and are also at background for six ring compounds relative to the individual assessment criteria for Benzo[ghi]perylene.

Table 2.4: Summary statistics for PAHs in sediment (µg/kg) normalised for an organic carbon content of 2.5% showing mean, minimum, maximum based on all values above detection with number of values <detection excluded

PAHs	Platform	Year sampled	Measured Positive	Mean	Min.	Max.	<Values (No)
Naphthalenes (mw 128)	Airidh	2008	10	0.12	0.02	0.44	
	Bonneville	2012	6	0.02	0.004	0.05	<0.5(3)
	Cygnus/Cygnus Macadam/Humphrey	2005-2008	6	0.04	0.00	0.11	<1(21)
	Emerald	2005	1	-	0.03	-	<1(11)
Phenanthrenes (mw 178)	Airidh	2008	10	0.05	0.01	0.17	
	Bonneville	2012	8	0.03	0.01	0.06	<1(1)
	Cygnus/Cygnus Macadam/Humphrey	2005-2008	5	0.05	0.01	0.11	<1(22)
	Emerald	2005	2	0.029	0.025	0.033	<1(10)
Diabenzothiophenes (mw 184)	Airidh	2008	4	0.013	0.004	0.025	6
	Bonneville	2012	1	-	0.0036	-	9
	Cygnus/Cygnus Macadam/Humphrey	2005-2008	1	-	0.02	-	<1(26)
	Emerald	2005	0	-	<1	-	<1(12)
Four ring compounds (mw 202)	Airidh	2008	10	0.05	0.01	0.19	
	Bonneville	2012	8	0.05	0.02	0.08	<1(1)
	Cygnus/Cygnus Macadam/Humphrey	2005-2008	6	0.05	0.01	0.11	<1(21)
	Emerald	2005	8	0.05	0.02	0.09	<1(4)
Four ring compounds (mw 228)	Airidh	2008	10	0.05	0.01	0.20	
	Bonneville	2012	8	0.03	0.01	0.06	<1(1)
	Cygnus/Cygnus Macadam/Humphrey	2005-2008	3	0.04	0.0096	0.07	<1(24)
	Emerald	2005	0	-	-	-	<1(12)
Five ring compounds (mw 252)	Airidh	2008	10	0.08	0.02	0.32	
	Bonneville	2012	9	0.17	0.08	0.29	
	Cygnus/Cygnus Macadam/Humphrey	2005-2008	5	0.05	0.01	0.11	<1(22)
	Emerald	2005	2	0.02	0.02	0.03	<1(10)
Six ring compounds (mw 276)	Airidh	2008	10	0.05	0.01	0.18	
	Bonneville	2012	9	0.19	0.08	0.33	
	Cygnus/Cygnus Macadam/Humphrey	2005-2008	6	0.03	0.01	0.08	<1(21)
	Emerald	2005	0	-	-	-	<1(12)
Total hydrocarbons (GC)	Airidh	2008	10	9.49	3.33	21.43	
Total hydrocarbons (GC)	Bonneville	2012	9	26.97	11.67	43.75	
Total hydrocarbons (GC)	Cygnus/Cygnus Macadam/Humphrey	2005-2008	27	7410.38	63.75	33643.14	
Total hydrocarbons (GC)	Emerald	2005	11	1403.22	400.00	2733.33	<20(1)

For total hydrocarbons the most elevated levels were measured at the Cygnus/Cygnus Macadam/Humphrey complex. A value of 50 mg THC/kg in sediments was the (lower) limit for a biological effect as defined by UKOOA 2002. The maximum values reported for each of the four sites are below the UKOOA THC threshold with Emerald sediments an order of magnitude below and those from Airidh and Bonneville three orders of magnitude below.

2.3 Offshore Wind Farm Development

Six main areas of offshore windfarm development including cable corridors are in offshore areas of the Mid North Sea High Seismic Area (Figure 2:5). Forewind is a consortium comprising four leading international energy companies – RWE, SSE, Statkraft and Statoil. The Dogger Bank Teesside project now consists of two wind farms, each with a generating capacity of up to 1.2 gigawatts (GW), which connect into the national grid just south of the Tees Estuary.

Blyth demonstration project - The proposed scheme could potentially comprise a maximum of 15 wind turbines, to be constructed across three arrays, with a maximum number of five turbines in each array. Each turbine array will be positioned at a different water depth and distance from the coast and will be connected to the shore by a single subsea export cable (i.e. maximum of three export cables). The first five turbines are to be installed in summer 2017.

Three sites planned for development in Scottish waters are currently in dispute with a legal challenge from RSPB. The planned developments are Neart Na Gaoithe, the outer Firth of Forth and Inch Cape:

Neart Na Gaoithe Mainstream Renewable Power Ltd plan to develop an offshore wind farm in the Firth of Forth, 15.5 km directly east of Fife Ness to comprise between 64 and 125 turbines and have a capacity of 450 megawatts (MW).

Seagreen Wind Energy Limited, a joint venture partnership between SSE and Fluor, was awarded by The Crown Estate the exclusive development rights for the Firth of Forth Zone of the UK's Round 3 offshore wind farm development programme. The Zone is located approximated 25 km east of Fife and covers an area of 2,852 km^2 in the outer Firth of Forth.

Inch Cape Offshore Limited (ICOL) plan to develop a wind farm, in the North Sea around 15 km off the Angus coastline, which will cover an area of approximately 150 km^2 and will consist of up to 110 turbines.

Statoil Wind Limited (SWL) has been awarded an agreement for deployment of floating wind turbine generator units in an area known as the Buchan Deep which is an area of deep water (95 to 120 m) located approximately 25 km off the coast of Peterhead, north east Scotland just outside the 12 nm territorial water limit.

Potential contaminants from Offshore Wind Farm development

The principal areas of concern regarding chemical emissions associated with the development of offshore windfarms are potential releases from contaminated sediment during construction and lubricants and anti -corrosion chemicals used for the turbines and associated structure. Potential for disturbance of contaminated sediments and subsequent chemical release is usually assessed as part of the environmental assessment. Data in the following section considers sediment contaminant survey data for the MNSH area. The corrosion protection of the external underwater substructure is usually a combination of cathodic protection and coating. The external structure above the waterline (upper part of substructure and turbine tower) is usually coated. Internal ballast tank(s) may be coated or uncoated. Corrosion inhibitors (such as biocides) may also be used for protection against micro-biological corrosion in the ballast compartment(s).

The Wind Turbine Generator (WTG) Unit includes small quantities of liquids in the auxiliary systems for the following functions:

- Blade pitch (dependent on supplier);
- Cooling systems (possibly containing glycol);
- Lubrication;
- Transformer cooling oil (biodegradable) if oil cooled transformer is selected; and
- SF6 gas4, if gas insulated switchgear are selected.

Lubricants and liquids (including hydrocarbons) associated with the temporary generators will also be present at those times when the generators are installed on the WTG Units. Replacement of consumable liquids (e.g. fuel) associated with these temporary generators will be undertaken by supply vessel.

Chemical release from offshore windfarms is likely to be negligible but in any case, for all uses chemicals must be selected from the List of Notified Chemicals approved for use by the offshore oil and gas industry under the Offshore Chemicals Regulations 2002(a) unless otherwise agreed in writing by the Marine Management Organisation (MMO). The same applies to any coatings or treatments. The storage, handling, transport and use of fuels, lubricants, chemicals, and other substances must also be undertaken to prevent releases into the marine environment, including the use of bunding to contain the total volume of all reservoirs and containers should spillage occur.

Where foundation drilling works are proposed, if any system other than water-based mud is proposed the MMO's written approval in relation to the proposed disposal of any chemicals or contaminated materials must be obtained before the drilling commences, which may also require a marine licence. The undertaker shall ensure that any debris arising from the construction of the authorised scheme or temporary works placed below MHWS are removed on completion of the authorised scheme.

Data associated with Offshore Wind Farm development

The results of contaminant measurements (metals, PAHs and PCBs) taken in sediment samples at offshore windfarm sites (Figure 2:5) from 2005 onwards were obtained from relevant environmental assessments and appendices.

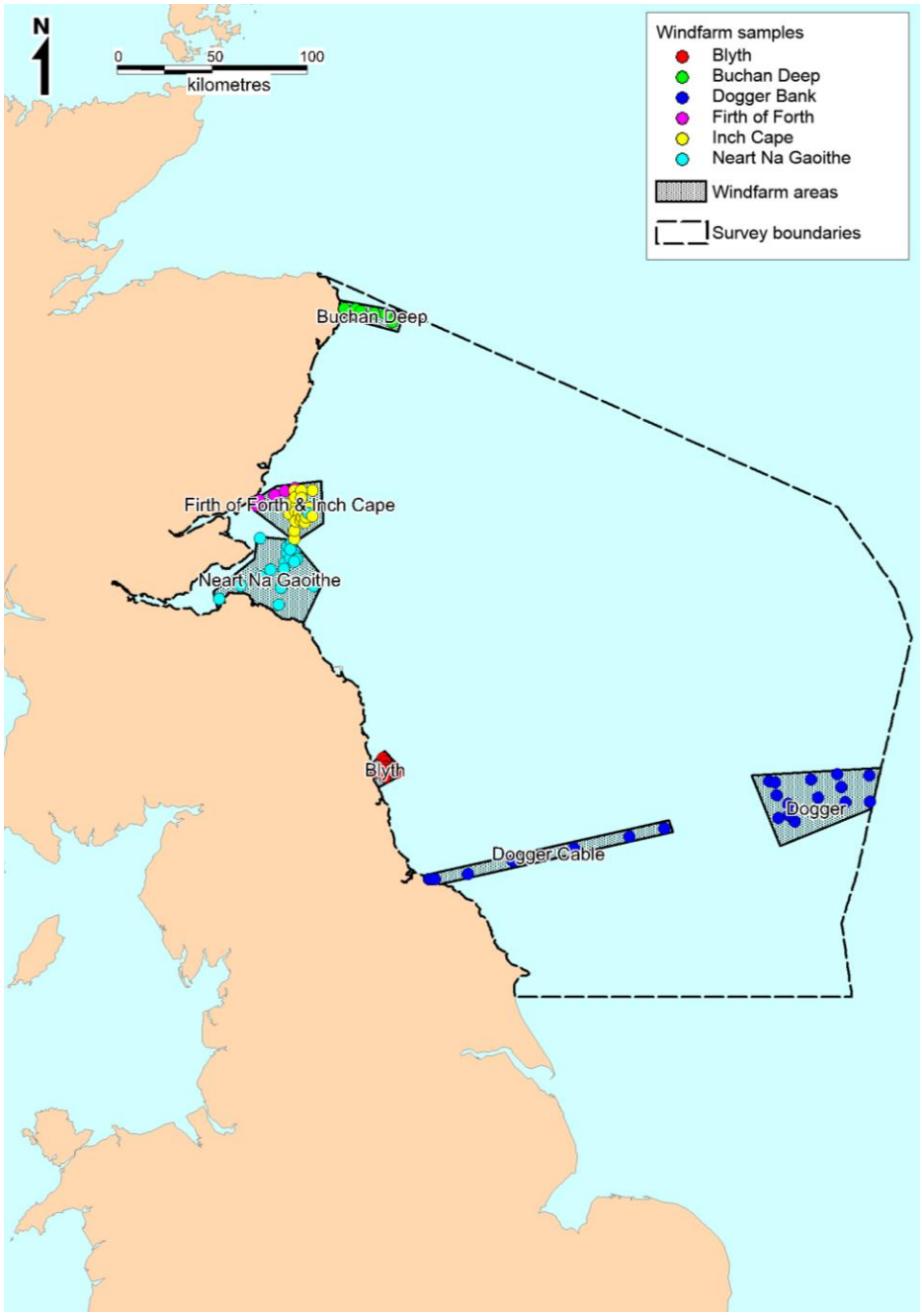

Figure 2:5 :Location of offshore windfarm contaminant survey sampling stations

Summary statistics for the contaminants of interest were produced for each of the development sites within which samples were taken, and are presented in Table 2.5 to Table 2.7. As the data are rarely reported as normalised for metals against aluminium or for PAHs against organic carbon comparison is made here to Cefas Action levels used to assess suitability of dredged sediments for

offshore disposal. In Table 2.5 data above action level 1 is shown in bold and above action level 2 is bold and underlined and for PAHs where a total PAH value exceeding 1 mg/kg only has an Action level 1 defined individual PAH values that exceed this are shown in bold.

Table 2.5: Summary statistics for metals in sediments at offshore windfarm sites (mg/kg). Levels above Cefas Action Level 1 shown in bold and above 2 are bold and underlined

Metal	Windfarm area	Year sampled	No.	Mean	Min.	Max.
Cadmium	Blyth	2010	21	0.18	0.10	**0.53**
	Dogger	2011-12	14	0.02	0.02	0.07
	Dogger Cable	2011-12	8	0.11	0.05	0.17
	Firth of Forth & Inch Cape	2009-12	48	0.11	0.01	**0.60**
	Neart Na Gaoithe	2009	19	**0.92**	**0.50**	1.80
Chromium	Blyth	2010	21	**146.10**	**98.60**	**355.00**
	Buchan Deep	2013	7	13.27	0.00	24.20
	Dogger	2011-12	14	23.30	10.00	**112.00**
	Dogger Cable	2011-12	8	**196.50**	**66.00**	**387.00**
	Firth of Forth & Inch Cape	2009-12	48	**122.60**	9.50	**1110.00**
	Neart Na Gaoithe	2009	19	37.73	11.70	**149.00**
Copper	Blyth	2010	21	**134.40**	30.50	**346.00**
	Buchan Deep	2013	7	11.40	7.20	15.10
	Dogger	2011-12	14	15.10	2.60	**160.00**
	Dogger Cable	2011-12	8	**102.90**	**55.90**	**196.00**
	Firth of Forth & Inch Cape	2009-12	48	18.90	1.07	**91.50**
	Neart Na Gaoithe	2009	19	19.24	5.80	**90.90**
Lead	Blyth	2010	21	**64.40**	36.70	**115.00**
	Buchan Deep	2013	7	10.84	8.90	12.40
	Dogger	2011-12	14	8.07	6.38	12.60
	Dogger Cable	2011-12	8	47.05	14.90	**104.00**
	Firth of Forth & Inch Cape	2009-12	48	20.58	4.24	**49.50**
	Neart Na Gaoithe	2009	19	44.80	10.80	**297.20**
Mercury	Blyth	2010	21	0.14	0.02	**0.87**
	Buchan Deep	2013	7	0.00	0.00	0.00
	Dogger	2011-12	14	0.00	0.00	0.00
	Dogger Cable	2011-12	8	0.02	0.00	0.05
	Firth of Forth & Inch Cape	2009-12	70	0.02	0.00	0.07
	Neart Na Gaoithe	2009	19	0.02	0.01	0.05
Zinc	Blyth	2010	21	123.27	79.30	**245.00**
	Dogger	2011-12	13	12.25	0.00	46.30
	Dogger Cable	2011-12	8	82.50	31.00	118.00
	Firth of Forth & Inch Cape	2009-12	48	42.38	14.60	92.50
	Neart Na Gaoithe	2009	19	42.14	15.50	**162.30**

Table 2.6: Summary statistics for PAHs in sediments at offshore windfarm sites (µg/kg) Levels above Cefas Action Level 1 shown in bold and above 2 are bold and underlined

PAH	Windfarm area	Year sampled	No.	Mean	Min.	Max.
Anthracene	Blyth	2010	21	63.00	7.10	**299.00**
	Buchan Deep	2013	7	0.29	0.00	2.00
	Dogger	2011-12	14	1.00	1.00	1.00
	Firth of Forth & Inch Cape	2012	20	1.14	1.00	2.81
Benzo[a]anthracene	Blyth	2010	21	86.80	15.00	331.00
	Buchan Deep	2013	7	1.36	0.00	6.50
	Dogger	2011-12	14	1.00	1.00	1.00
	Firth of Forth & Inch Cape	2012	20	3.08	1.00	7.16
Benzo[a]pyrene	Blyth	2010	21	79.40	12.00	**310.00**
	Buchan Deep	2013	7	2.20	0.00	7.30
	Dogger	2011-12	14	1.00	1.00	1.00
	Firth of Forth & Inch Cape	2012	20	2.56	1.00	5.61
Benzo[ghi]perylene	Blyth	2010	21	69.40	5.00	**241.00**
	Firth of Forth & Inch Cape	2012	20	5.00	5.00	5.00
Chrysene	Blyth	2010	21	79.30	12.50	**340.00**
	Buchan Deep	2013	7	1.61	0.00	6.10
	Dogger	2011-12	14	4.25	1.50	5.00
	Firth of Forth & Inch Cape	2012	20	3.96	1.50	9.74
Dibenzo[a,h]anthracene	Buchan Deep	2013	7	0.33	0.00	1.20
	Dogger	2011-12	14	2.50	2.50	2.50
Fluorene	Blyth	2010	21	44.50	5.00	**208.00**
	Buchan Deep	2013	7	0.00	0.00	0.00
	Dogger	2011-12	14	5.00	5.00	5.00
	Firth of Forth & Inch Cape	2012	20	5.00	5.00	5.00
Indeno[123cd]pyrene	Blyth	2010	21	46.95	5.00	**153.00**
	Firth of Forth & Inch Cape	2012	20	5.00	5.00	5.00
Napthalene	Blyth	2010	21	**154.60**	15.00	**507.00**
	Buchan Deep	2013	7	0.00	0.00	0.00
	Dogger	2011-12	14	24.08	15.00	69.60
	Firth of Forth & Inch Cape	2012	20	15.00	15.00	15.00
Phenanthrene	Blyth	2010	21	**214.20**	30.30	**921.00**
	Buchan Deep	2013	7	0.97	0.00	3.30
	Dogger	2011-12	14	6.68	5.00	16.70
	Firth of Forth & Inch Cape	2012	20	6.63	5.00	22.00
Pyrene	Blyth	2010	21	**127.20**	20.40	**497.00**
	Buchan Deep	2013	7	2.14	0.00	8.80
	Dogger	2011-12	14	1.95	1.50	5.28
	Firth of Forth & Inch Cape	2012	20	4.65	1.50	9.86

All analyses were undertaken using the whole sediment rather than a fraction of a particle size range. Metals samples were not normalised for aluminium content as this was rarely determined, nor were PAH or PCB results normalised for an organic carbon content of 2.5%. This precluded direct comparison of the results against the various assessment criteria, such as those used for the Clean Safe Seas Monitoring Programme in Section 5). Comparisons are made against Cefas Action Levels.

The results for two surveys near one another are summarised together (Firth of Forth and Inch Cape). There were also two locations sampled within the Firth of Forth and Inch Cape area which were undertaken as part of the Neart Na Gaoithe survey, but given their location they were included with Firth of Forth and Inch Cape.

Overall the metals concentrations and those of several of the PAHs measured were particularly elevated at Blyth. Historical disposal of dredge material from the Blyth and from Tyne and Wear off the northeast coast of England are likely to have contributed to the elevated levels associated with this site. The Dogger cable route also shows some elevated metals concentrations chromium and copper. Again this elevation probably relates to historic dredge disposal.

Table 2.7: Summary statistics for PCBs in sediments at offshore windfarm sites (µg/kg)

PCB	Windfarm area	Year sampled	No.	Mean	Min.	Max.
CB28	Blyth	2010	21	0.31	0.05	5.52
	Firth of Forth & Inch Cape	2011-12	25	0.34	0.05	1.50
CB52	Blyth	2010	21	0.15	0.05	1.84
	Firth of Forth & Inch Cape	2011-12	25	0.34	0.05	1.50
CB101	Blyth	2010	21	0.28	0.05	3.68
	Firth of Forth & Inch Cape	2011-12	25	0.34	0.05	1.50
CB118	Blyth	2010	21	0.19	0.05	2.88
	Firth of Forth & Inch Cape	2011-12	25	0.34	0.05	1.50
CB138	Blyth	2010	21	0.49	0.05	7.88
	Firth of Forth & Inch Cape	2011-12	25	0.34	0.05	1.50
CB153	Blyth	2010	21	0.60	0.05	**9.84**
	Firth of Forth & Inch Cape	2011-12	25	0.34	0.05	1.50
CB180	Blyth	2010	21	0.14	0.05	1.57
	Firth of Forth & Inch Cape	2011-12	25	0.34	0.05	1.50

3 Dredge Disposal contaminant inputs to the region

3.1 Contaminant inputs associated with direct discharges and riverine inputs

Background

Disposal of waste at sea is strictly regulated through the licensing requirements of the Marine and Coastal Access Act 2009 (MCAA). The MCAA provides the principal statutory means by which the UK complies with EU law, such as the Water Framework Directive (WFD, 2000/60/EC), the Habitats and Species Directive (92/43/EEC), the Wild Birds Directive (79/409/EEC) and international obligations such as under the OSPAR Convention and the London Protocol, in relation to disposals at sea (Bolam et al., 2014). Due to this regulation disposal to sea of hazardous substances has greatly reduced over recent times and since the 1980s disposal at sea of radioactive wastes (stopped in 1982), industrial wastes (stopped in 1992), colliery mine-stone (stopped in 1995) and sewage sludge (stopped in 1998) has been progressively phased out and prohibited. Only essential activity related to the maintenance or development of new ports, marinas and harbours is presently allowed.

In England, the MMO regulates and is responsible for licensing activities in the marine area around England including the disposal of dredged material at sea (in Scotland this role is undertaken by Marine Scotland). These regulators assess the suitability of dredged material for disposal at sea in line with the OSPAR Guidelines for the management of dredged material (OSPAR, 2014). These guidelines provide generic guidance on determining the conditions under which dredged material may (or may not) be deposited at sea and involve the consideration of alternative uses, disposal sites and the suitability of the dredged material for disposal to sea including the presence and levels of contaminants in the dredged material, along with assessed impacts on any sites of conservation value near disposal. The selection of disposal sites at sea will also be based on several criteria including their location in relation to amenities and other uses of the sea in the area, economic and operational feasibility, and physical, chemical, and biological characteristics. The aim is to minimise seabed disposal and seek alternative, beneficial use by conducting a Best Practicable Environmental Option (BPEO) assessment and considering practicable alternative options before granting a licence. Dredged material may be re-used for land reclamation or beach nourishment where it is uncontaminated and physically suitable (Bolam *et al*., 2006).

In Scotland there are 66 open sites routinely used for disposal. A further 50 disposal sites are either closed (not having been used for at least 10 years) or disused (not having been used for at least five years). In England there are approximately 155 open sites designated for dredged material disposal,

though not all are used in any one year. Across the UK in general most these are located on the coast of the mainland, generally close to where the material is excavated (e.g. a major port or estuary entrance), though some may also be positioned within estuaries (e.g., Humber) or on intertidal mudflats as part of beneficial use schemes (Bolam et al., 2006).

Before dredging operations can begin licences must be obtained (e.g. from MMO) and the material assessed for contaminants before a decision is made in relation to permissions to allow disposal at sea. Dredged material with contaminant levels below a certain threshold (action level) can be disposed of at sea (OSPAR, 2015).

Tonnages deposited are recorded and reported to OSPAR (OSPAR, 2015). Scottish data shows that during 2009 a total of 2,901,499 tonnes was dredged and deposited and this value has remained relatively constant over time. In England approximately 40 million tonnes (Mt wet weight) are annually disposed to coastal sites around England, although this can vary from 28 to 57 Mt (wet weight) (data for the period between 1986 and 2010). In total, individual quantities licensed may range from a few hundred to several million tonnes, and nature may vary from soft silts to boulders or even crushed rock per origin, although the majority consists of finer material (Bolam *et al*., 2006). Most disposal occurs in the sea areas adjacent to the highest densities of human population and industry. Impact is generally confined to the boundaries of the official disposal areas and these tend to be restricted to sites close to the coast.

Contaminants data from dredge disposal areas

The results of contaminant measurements (metals, PAHs and PCBs) taken in sediment samples from dredge disposal sites within the survey area from 2005 onwards were sourced from Marine Scotland and Cefas. These were not normalised for aluminium or total organic carbon as neither of these measurements were available for a significant number of samples. Summary statistics for the contaminants of interest were produced (Table ***3.1*** to Table ***3.4***) for each of the geographic areas shown inFigure 3:1. Some of these include more than one dredge disposal ground where they either overlap or are near.

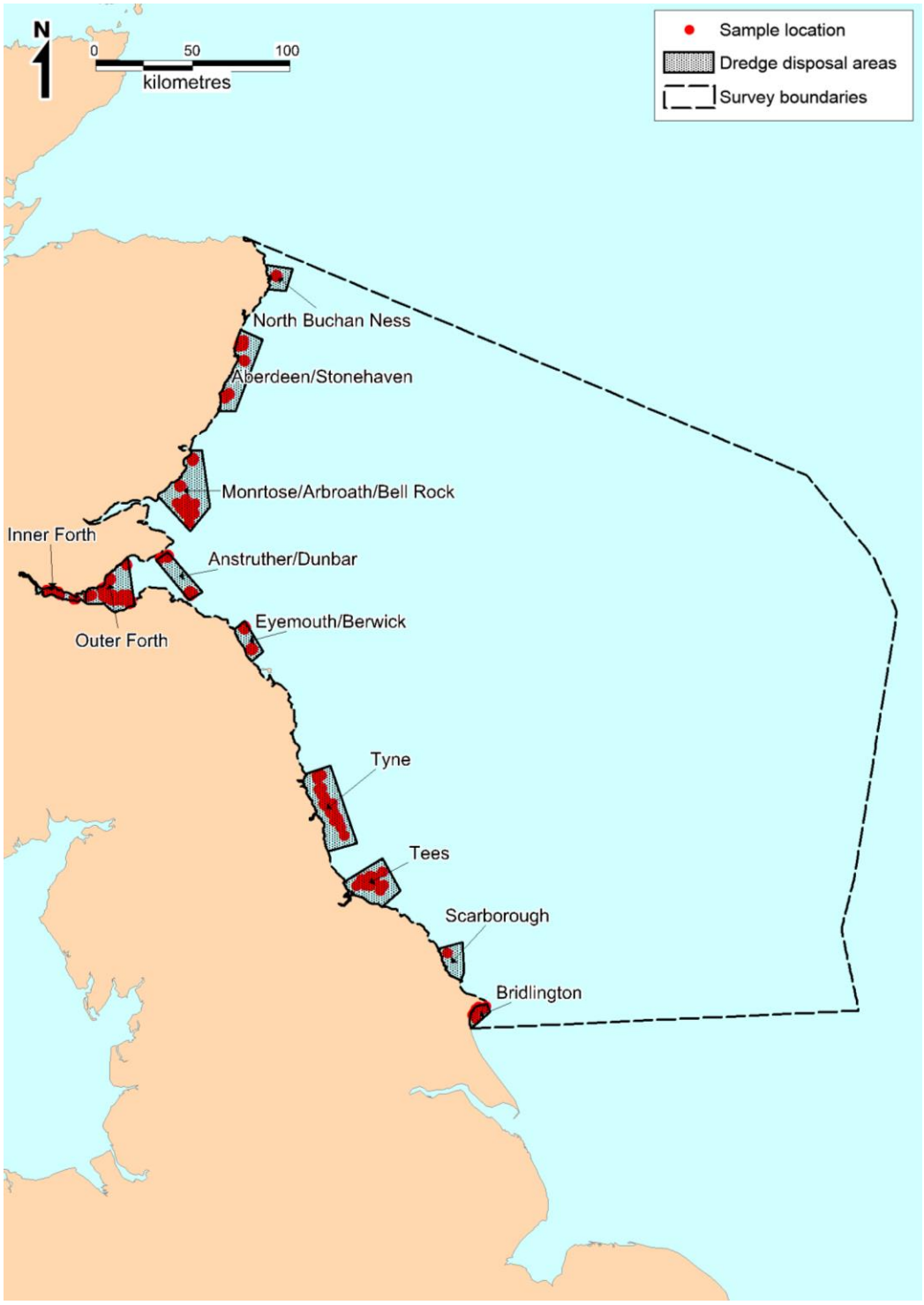

Figure 3:1: Dredge disposal areas.

Table 3.1: Summary statistics for cadmium, chromium, copper in sediment by dredge disposal areas (mg/kg)

Metal	Area	Fraction	First sample	Last sample	No.	Mean	Min.	Max.
Cadmium	Aberdeen/Stonehaven	Whole	2006	2011	41	0.07	0.02	0.09
	Anstruther/Dunbar	Whole	2008	2011	26	0.06	0.02	0.26
	Eyemouth/Berwick	Whole	2011	2011	25	0.04	0.02	0.08
	Inner Forth	Whole	2011	2011	11	0.15	0.10	0.37
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	30	0.06	0.02	0.09
	North Buchan Ness	Whole	2011	2011	5	0.03	0.02	0.04
	Outer Forth	Whole	2007	2011	66	0.11	0.03	0.64
	Scarborough	<63um	2008	2008	1	0.23	0.23	0.23
	Tees	<63um	2006	2013	26	0.46	0.00	1.10
	Tyne	<63um	2005	2011	31	0.32	0.00	1.20
Chromium	Aberdeen/Stonehaven	Whole	2006	2011	41	15.67	5.32	29.50
	Anstruther/Dunbar	Whole	2008	2011	26	20.93	11.16	33.00
	Bridlington	<63um	2009	2009	4	110.00	96.00	143.00
	Eyemouth/Berwick	Whole	2011	2011	25	14.84	10.13	20.06
	Inner Forth	Whole	2011	2011	11	50.87	35.59	59.19
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	30	15.24	7.88	31.80
	North Buchan Ness	Whole	2011	2011	5	5.53	4.53	7.07
	Outer Forth	Whole	2007	2011	66	40.55	10.21	88.30
	Tees	<63um	2006	2011	25	126.32	74.00	202.00
	Tyne	<63um	2005	2013	25	113.20	80.00	156.00
Copper	Aberdeen/Stonehaven	Whole	2006	2011	41	3.82	2.02	9.42
	Anstruther/Dunbar	Whole	2008	2011	26	7.30	2.08	39.48
	Eyemouth/Berwick	Whole	2011	2011	25	5.99	2.86	30.24
	Inner Forth	Whole	2011	2011	11	30.61	17.33	96.52
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	30	4.36	1.45	17.70
	North Buchan Ness	Whole	2011	2011	5	4.34	2.06	5.87
	Outer Forth	Whole	2007	2011	66	20.09	2.95	65.70
	Scarborough	<63um	2008	2008	1	54.00	54.00	54.00
	Tees	<63um	2006	2013	29	47.69	27.00	77.00
	Tyne	<63um	2005	2013	31	42.51	27.00	81.00

Table 3.2: Summary statistics for lead, mercury and zinc in sediment by dredge disposal areas (mg/kg)

Metal	Area	Fraction	First sample	Last sample	No.	Mean	Min.	Max.
Lead	Aberdeen/Stonehaven	Whole	2006	2011	41	7.94	3.46	18.60
	Anstruther/Dunbar	Whole	2008	2011	26	17.92	6.45	42.75
	Bridlington	<63um	2009	2009	2	106.00	93.00	119.00
	Eyemouth/Berwick	Whole	2011	2011	25	20.97	11.20	132.12
	Inner Forth	Whole	2011	2011	11	63.21	46.70	106.68
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	30	9.24	3.74	27.70
	North Buchan Ness	Whole	2011	2011	5	7.97	4.30	21.23
	Outer Forth	Whole	2007	2011	66	53.98	12.69	655.37
	Scarborough	<63um	2008	2008	1	129.00	129.00	129.00
	Tees	<63um	2006	2011	26	127.04	60.00	206.00
	Tyne	<63um	2005	2010	29	121.40	62.00	366.00
Mercury	Aberdeen/Stonehaven	Whole	2006	2011	41	0.04	0.02	0.08
	Anstruther/Dunbar	Whole	2008	2011	26	0.11	0.02	0.41
	Bridlington	<63um	2009	2009	1	0.29	0.29	0.29
	Eyemouth/Berwick	Whole	2011	2011	25	0.06	0.06	0.08
	Inner Forth	Whole	2011	2011	11	0.76	0.53	0.96
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	30	0.05	0.02	0.07
	North Buchan Ness	Whole	2011	2011	5	0.06	0.06	0.06
	Outer Forth	Whole	2007	2011	66	0.44	0.06	1.33
	Scarborough	<63um	2008	2008	1	0.28	0.28	0.28
	Tees	<63um	2006	2009	28	0.32	0.00	0.71
	Tyne	<63um	2005	2011	26	0.35	0.15	1.60
Zinc	Aberdeen/Stonehaven	Whole	2006	2011	41	25.66	13.59	47.60
	Anstruther/Dunbar	Whole	2008	2011	26	37.68	17.78	100.11
	Bridlington	<63um	2009	2009	1	164.00	164.00	164.00
	Eyemouth/Berwick	Whole	2011	2011	25	30.93	21.57	62.30
	Inner Forth	Whole	2011	2011	11	158.10	81.50	653.00
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	30	26.84	14.99	79.80
	North Buchan Ness	Whole	2011	2011	5	16.73	12.56	26.83
	Outer Forth	Whole	2007	2011	66	82.62	26.78	243.00
	Tees	<63um	2006	2013	28	160.69	99.00	256.00
	Tyne	<63um	2005	2013	32	169.70	100.00	517.40

Table 3.3: Summary statistics for PAHs, anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[ghi]perylene and chrysene, fluorene, Indeno[123-cd]pyrene, napthalene, phenanthrene and pyrene in sediment by dredge disposal areas (mg/kg)

PAH	Area	Fraction	First sample	Last sample	No.	Mean	Min.	Max.
Anthracene	Aberdeen/Stonehaven	Whole	2006	2011	29	63.6	0.0	673.4
	Anstruther/Dunbar	Whole	2011	2011	6	3.4	1.3	9.3
	Eyemouth/Berwick	Whole	2011	2011	9	3.4	0.4	11.1
	Inner Forth	Whole	2011	2011	5	59.3	38.7	98.6
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	7	1.7	0.3	3.4
	Outer Forth	Whole	2007	2011	27	47.3	7.5	255.0
	Tees	Whole	2006	2010	12	141.9	9.7	359.6
	Tyne	Whole	2006	2010	8	130.8	22.0	192.0
Benzo[a]anthracene	Aberdeen/Stonehaven	Whole	2006	2011	29	90.6	0.4	884.2
	Anstruther/Dunbar	Whole	2011	2011	6	7.8	4.7	14.9
	Eyemouth/Berwick	Whole	2011	2011	9	12.1	1.0	43.3
	Inner Forth	Whole	2011	2011	5	108.1	64.5	211.2
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	7	5.4	1.1	12.8
	Outer Forth	Whole	2007	2011	27	86.0	16.4	440.5
	Tees	Whole	2006	2010	12	259.1	35.0	869.0
	Tyne	Whole	2006	2010	8	260.2	47.0	595.0
Benzo[a]pyrene	Aberdeen/Stonehaven	Whole	2006	2011	29	81.6	0.5	814.3
	Anstruther/Dunbar	Whole	2011	2011	6	10.9	5.5	18.3
	Bridlington	Whole	2009	2009	1	148.2	148.2	148.2
	Eyemouth/Berwick	Whole	2011	2011	9	13.0	1.8	42.4
	Inner Forth	Whole	2011	2011	5	126.9	77.7	249.0
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	7	7.2	1.5	16.1
	Outer Forth	Whole	2007	2011	27	88.3	18.7	243.5
	Tees	Whole	2006	2010	11	263.2	67.0	943.0
	Tyne	Whole	2006	2010	7	250.4	53.0	543.9
Benzo[ghi]perylene	Aberdeen/Stonehaven	Whole	2006	2011	29	62.0	0.7	603.6
	Anstruther/Dunbar	Whole	2011	2011	6	14.7	9.1	18.5
	Bridlington	Whole	2009	2009	1	129.9	129.9	129.9
	Eyemouth/Berwick	Whole	2011	2011	9	15.6	2.6	38.3
	Inner Forth	Whole	2011	2011	5	108.8	64.1	190.9
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	7	8.2	2.1	16.0
	Outer Forth	Whole	2007	2011	27	81.8	23.0	196.9
	Tees	Whole	2006	2009	10	103.2	53.0	165.4
	Tyne	Whole	2006	2010	12	171.6	42.7	396.0
Chrysene	Aberdeen/Stonehaven	Whole	2006	2011	29	91.5	0.5	879.3
	Anstruther/Dunbar	Whole	2011	2011	6	10.8	6.6	19.1
	Bridlington	Whole	2009	2009	1	110.1	110.1	110.1
	Eyemouth/Berwick	Whole	2011	2011	9	13.7	1.8	43.0
	Inner Forth	Whole	2011	2011	5	121.3	69.8	225.2
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	7	6.7	1.6	13.7
	Outer Forth	Whole	2007	2011	27	95.5	20.6	423.2

PAH	Area	Fraction	First sample	Last sample	No.	Mean	Min.	Max.
	Tees	Whole	2006	2010	13	239.4	21.0	981.0
	Tyne	Whole	2006	2010	8	146.9	1.0	291.3
Fluorene	Aberdeen/Stonehaven	Whole	2006	2011	29	20.2	0.0	317.7
	Anstruther/Dunbar	Whole	2011	2011	6	3.9	0.8	17.3
	Eyemouth/Berwick	Whole	2011	2011	9	2.0	0.2	6.4
	Inner Forth	Whole	2011	2011	5	29.2	18.5	49.6
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	7	0.9	0.2	1.8
	Outer Forth	Whole	2007	2011	27	23.6	3.4	126.7
	Tees	Whole	2006	2006	9	242.0	14.0	1107.0
	Tyne	Whole	2006	2010	7	255.0	64.0	621.8
Indeno[123-cd]pyrene	Aberdeen/Stonehaven	Whole	2006	2011	29	77.8	0.7	754.6
	Anstruther/Dunbar	Whole	2011	2011	6	14.1	7.4	17.8
	Eyemouth/Berwick	Whole	2011	2011	9	17.9	2.2	48.8
	Inner Forth	Whole	2011	2011	5	100.1	61.1	189.4
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	7	9.7	2.4	20.8
	Outer Forth	Whole	2007	2011	27	79.4	18.2	243.8
	Tees	Whole	2006	2010	12	124.4	21.0	549.6
	Tyne	Whole	2006	2010	6	211.7	40.0	666.9
Napthalene	Aberdeen/Stonehaven	Whole	2006	2011	29	42.1	0.2	652.2
	Anstruther/Dunbar	Whole	2011	2011	6	4.4	2.2	8.8
	Eyemouth/Berwick	Whole	2011	2011	9	5.6	0.6	14.0
	Inner Forth	Whole	2011	2011	5	85.0	46.2	154.2
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	7	2.0	0.7	4.9
	Outer Forth	Whole	2007	2011	27	88.5	11.9	301.8
	Tees	Whole	2006	2007	11	1226.0	275.0	6354.0
	Tyne	Whole	2006	2010	8	338.6	125.0	852.0
Phenanthrene	Aberdeen/Stonehaven	Whole	2006	2011	29	154.1	0.6	2062.8
	Anstruther/Dunbar	Whole	2011	2011	6	16.4	5.7	52.4
	Eyemouth/Berwick	Whole	2011	2011	9	18.1	3.1	42.6
	Inner Forth	Whole	2011	2011	5	151.2	95.0	273.3
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	7	7.9	1.8	20.6
	Outer Forth	Whole	2007	2011	27	140.0	26.9	840.3
	Tees	Whole	2006	2010	15	1879.0	369.0	6427.0
	Tyne	Whole	2006	2010	9	1062.0	18.0	3207.0
Pyrene	Aberdeen/Stonehaven	Whole	2006	2011	29	159.5	0.7	1808.3
	Anstruther/Dunbar	Whole	2011	2011	6	17.7	9.2	36.5
	Bridlington	Whole	2009	2009	1	867.0	867.0	867.0
	Eyemouth/Berwick	Whole	2011	2011	9	22.5	2.7	66.2
	Inner Forth	Whole	2011	2011	5	217.9	133.8	375.0
	Montrose/Arbroath/Bell Rock	Whole	2007	2011	7	10.5	2.2	21.2
	Outer Forth	Whole	2007	2011	27	168.0	35.6	800.9
	Tees	Whole	2006	2010	13	610.0	120.0	1550.0
	Tyne	Whole	2006	2010	6	302.0	49.0	846.0

Table 3.4: Summary statistics for CBs in sediment by dredge disposal areas (µg/kg)

CB#	Area	Fraction	First sample	Last sample	No.	Mean	Min.	Max.
CB28	Aberdeen/Stonehaven	Whole	2011	2011	3	0.07	0.00	0.10
	Anstruther/Dunbar	Whole	2011	2011	6	0.14	0.00	0.38
	Eyemouth/Berwick	Whole	2011	2011	4	0.08	0.00	0.10
	Inner Forth	Whole	2011	2011	6	0.64	0.54	0.77
	Montrose/Arbroath/Bell Rock	Whole	2011	2011	4	0.00	0.00	0.00
	Outer Forth	Whole	2007	2011	28	0.74	0.09	2.40
	Tees	Whole	2006	2011	12	0.08	0.00	0.27
	Tyne	Whole	2006	2013	13	0.17	0.00	0.47
CB52	Aberdeen/Stonehaven	Whole	2011	2011	3	0.07	0.00	0.10
	Anstruther/Dunbar	Whole	2011	2011	6	0.13	0.00	0.68
	Bridlington	Whole	2009	2009	2	0.00	0.00	0.00
	Eyemouth/Berwick	Whole	2011	2011	4	0.00	0.00	0.00
	Inner Forth	Whole	2011	2011	6	0.64	0.41	1.10
	Montrose/Arbroath/Bell Rock	Whole	2011	2011	4	0.03	0.00	0.10
	Outer Forth	Whole	2007	2011	28	1.90	0.00	33.09
	Tees	Whole	2006	2011	14	0.07	0.00	0.54
	Tyne	Whole	2006	2011	9	0.31	0.00	1.40
CB101	Aberdeen/Stonehaven	Whole	2011	2011	3	0.07	0.00	0.10
	Anstruther/Dunbar	Whole	2011	2011	6	0.16	0.00	0.64
	Eyemouth/Berwick	Whole	2011	2011	4	0.08	0.00	0.10
	Inner Forth	Whole	2011	2011	6	0.58	0.44	0.80
	Montrose/Arbroath/Bell Rock	Whole	2011	2011	4	0.17	0.10	0.33
	Outer Forth	Whole	2007	2011	28	3.38	0.00	66.52
	Tees	Whole	2006	2010	14	0.11	0.00	0.69
	Tyne	Whole	2006	2011	10	0.18	0.00	0.65
CB118	Aberdeen/Stonehaven	Whole	2011	2011	3	0.06	0.00	0.09
	Anstruther/Dunbar	Whole	2011	2011	6	0.25	0.10	0.83
	Bridlington	Whole	2009	2009	2	0.00	0.00	0.00
	Eyemouth/Berwick	Whole	2011	2011	4	0.08	0.00	0.11
	Inner Forth	Whole	2011	2011	6	0.59	0.48	0.68
	Montrose/Arbroath/Bell Rock	Whole	2011	2011	4	0.12	0.10	0.17
	Outer Forth	Whole	2007	2011	28	2.87	0.00	58.14
	Tees	Whole	2006	2011	14	0.05	0.00	0.25
	Tyne	Whole	2006	2013	10	0.50	0.00	2.80
CB138	Aberdeen/Stonehaven	Whole	2011	2011	3	0.05	0.00	0.07
	Anstruther/Dunbar	Whole	2011	2011	6	0.21	0.04	0.75
	Eyemouth/Berwick	Whole	2011	2011	4	0.10	0.10	0.11
	Inner Forth	Whole	2011	2011	6	0.71	0.59	0.86
	Montrose/Arbroath/Bell Rock	Whole	2011	2011	4	0.26	0.08	0.63
	Outer Forth	Whole	2007	2011	28	3.47	0.00	59.98
	Tees	Whole	2006	2011	14	0.14	0.00	0.48
	Tyne	Whole	2006	2013	9	0.29	0.00	0.80

CB#	Area	Fraction	First	Last	No.	Mean	Min.	Max.

			sample	**sample**				
CB153	Aberdeen/Stonehaven	Whole	2011	2011	3	0.06	0.00	0.12
	Anstruther/Dunbar	Whole	2011	2011	6	0.22	0.04	0.71
	Eyemouth/Berwick	Whole	2011	2011	4	0.11	0.09	0.14
	Inner Forth	Whole	2011	2011	6	0.89	0.74	1.17
	Montrose/Arbroath/Bell Rock	Whole	2011	2011	4	0.31	0.11	0.75
	Outer Forth	Whole	2007	2011	28	3.28	0.09	46.44
	Tees	Whole	2006	2011	13	0.08	0.00	0.43
	Tyne	Whole	2006	2013	10	0.70	0.00	3.40
CB180	Aberdeen/Stonehaven	Whole	2011	2011	3	0.00	0.00	0.00
	Anstruther/Dunbar	Whole	2011	2011	6	0.09	0.02	0.23
	Bridlington	Whole	2009	2009	2	0.00	0.00	0.00
	Eyemouth/Berwick	Whole	2011	2011	4	0.07	0.05	0.10
	Inner Forth	Whole	2011	2011	6	0.78	0.57	1.46
	Montrose/Arbroath/Bell Rock	Whole	2011	2011	4	0.15	0.02	0.40
	Outer Forth	Whole	2007	2011	28	2.16	0.00	18.45
	Tees	Whole	2006	2011	9	0.00	0.00	0.00
	Tyne	Whole	2006	2011	10	0.29	0.00	1.70

Results reported as ND adjusted to 0.
Results reported as below detection limits adjusted to 0.1

Assessment of contaminants in disposal grounds

Two of the most studied areas (thus allowing temporal assessments) are disposal areas located off the Tyne and Tees. Monitoring of both the Tyne and Tees dredge material disposal sites have been conducted for several consecutive years. It can be expected that concentrations of contaminants are elevated (in comparison with the surrounding region) directly within the boundaries of a dredge material disposal area but dispersal of material from the site will also contribute to some elevation of contaminants beyond the immediate disposal area (Bolam *et al*., 2014). In general, monitoring surveys indicate that concentrations of contaminants (e.g. metals, PCBs, PAHs etc) remain temporally stable or show a slight decline (Webster *et al*., 2010 and Bolam *et al*., 2014). Dredge disposal monitoring reports produced for the Tyne and Tees have attempted to characterise the ecological risk posed by the level of contaminants within the disposal sites (Bolam *et al.,* 2012 and 2014). These assessments for PAHs were based on modified Effects Range Low/Effects Range Medium (ERL/ERM, Long *et al*., 1995; Long and MacDonald 1998). The ERL/ERM methodology is also applied to metals. To simplify assessment of large numbers of PAHs separate ERL/ERM derived SQGs are set for "Low molecular weight (LMW) PAHs" and "High molecular weight (HMW) PAHs" (Gorham-Test, 1999). In this context, LMW PAH which include the 2- and 3-ring PAH compounds e.g. naphthalene are primarily oil-derived compounds; HMW PAH which are the 4- and 5-ring PAH compounds e.g. fluoranthene are primarily combustion-derived compounds. Although a wider suite of PAHs is determined routinely for both licensing and monitoring purposes, these can be considered

as toxicity markers for the PAHs. In a recent survey all samples collected from the Tyne disposal sites exceeded the ERL for LMW PAHs (522 µg kg^{-1}) while a few locations exceeded the ERM for HMW PAHs (9,600 µg kg^{-1}) (Bolam *et al*., 2015). Concentrations of chlorobiphenyls (CBs) at all stations per the OSPAR guidelines, were at levels indicating 'good' environmental status for all ICES 7 CBs and 'good' status overall. Enrichment relative to regional baseline concentrations was observed for several metals, (especially for Hg, Cd and Zn), although the highest enrichment was generally observed within the disposal site boundaries (Bolam *et al*., 2012 and 2014). Similar findings were also observed from samples on the Tees disposal grounds where levels of PAHs regularly breached the ERL for LMW PAHs within the boundaries of the disposal grounds. Other contaminants such as tributyltin were also reported for both regions, but were generally found to be low or below limits of detection. Samples analysed from the dredge disposal sites in Scotland generally had lower levels of contaminants than those found at the Tyne and Tees disposal grounds. Higher concentrations were reported at locations in the inner Firth of Forth, which was thought to be partly related to additional contributions from industrial operations within the Forth's catchment area. At other locations, PCBs and PAHs were generally below concentrations thought to pose toxicological effects to exposed biota (Hayes *et al.,* 2005).

4 Radioactivity in the environment

4.1 Background

Over sixty radionuclides can be found in the environment, and they can be placed in three general categories:

1. Primordial – from before the creation of the Earth

2. Cosmogenic - formed because of cosmic ray interactions

3. Human produced - enhanced or formed due to human actions (minor amounts compared to natural).

Primordial radionuclides left over from when the world and the universe were created are typically long lived, with half-lives often about hundreds of millions of years. Consequently, Uranium-238 (^{238}U) and Thorium-232 (^{232}TH) and their daughter products are present in both the water column and seabed sediments. Cosmogenic radionuclides such as tritium (^{3}H) and carbon-14 (^{14}C) are continuously produced in the upper atmosphere because of cosmic ray induced spallation and particle interactions. They can have long half-lives, but the majority have shorter half-lives than the primordial nuclides. They are transported into seawater via the hydrologic cycle. The application and use of radioactivity for a range of purposes has led to other contributions to the natural environment. Radioactive inputs to the air or discharged to water may subsequently by taken up by living organisms and so become part of the food chain. To ensure dose levels remain at levels that do not represent a significant risk to human health, extensive monitoring programmes are conducted by Cefas on behalf of the UK Environment Agencies and the Food Standards Agency. Monitoring focuses on a range of matrices (seawater, sediment and biota) for analysis from the marine environment and are reported below in the context of sites that are potential sources of radioactivity in the MNSH area. The data presented here include a subset of those reported in annual Radioactivity in Food and the Environment Report (RIFE 20, 2014).

Seawater surveys

A programme of surveillance into the distribution of key radionuclides is maintained using research vessels and other means of sampling. The seawater surveys reported here also support international studies concerned with the quality status of coastal seas (e.g. OSPAR, 2010) and progress towards the UK's commitments for radioactive substance objectives for 2020. Measurement of radioactivity in seawater also underpins assessments of the variation in exposure at coastal sites around the UK.

Annual marine surveys generally focus on the Bristol Channel, western English Channel and every two years the Irish and North Sea.

Sediment surveys

Marine sediments are a sink for a range of contaminants including radioactive elements and therefore can provide a useful indicator of trends in the environment.

Biota surveys

Large numbers of environmental samples are collected and analysed as part of monitoring and surveillance programmes managed by the Environment Agency (EA), Food Standards Agency (FSA), Northern Ireland Environment Agency and the Scottish Environment Protection Agency (SEPA); these data are collated and jointly published in the RIFE report series (Environment Agency *et al*., 2013).

4.2 Survey locations

Landfill and non-nuclear

4.2.1.1 Stoneyhill landfill

During 2014 SEPA continued its programme of monitoring at the Stoneyhill Landfill Site in Aberdeenshire which is authorised to dispose of conditioned Naturally occurring radioactive material (NORM) waste. NORM is found within oil and gas reserves and can precipitate onto oil and gas industry equipment creating an insoluble scale (NORM scale). Stoneyhill Landfill facility descales oil and gas industry equipment and the solid scale removed from the equipment is then grouted into drums and can be consigned to Stoneyhill Landfill site.

SEPA monitor landfill leachate, groundwater and surface water on a quarterly basis and analysing for radium-226 and radium-228. For 2014 all locations monitored radium-226 and radium-228 were below method detection limits (Table 4.1). As leachates from the site are also processed at Nigg Sewage Treatment Works (STW) samples from this site and seawater from the surrounding area are also analysed and in 2014 all results were below method detection limits.

Table 4.1: Concentration radionuclides water and effluents near Nigg sewage treatment works 2014.

Sample Location	Number samples	$^{226}Ra^{a}$	$^{228}Ra^{b}$
Aberdeen Beach (Seawater)	4	<0.10	<0.25
Cove Bay (Seawater)	4	<0.11	<0.21
Gregg Ness (Seawater)	4	<0.08	<0.18
Greyhope Bay (Seawater)	4	<0.09	<0.20
Nigg Bay (Seawater)	4	<0.08	<0.18

Nigg Bay Sewage Treatment (Final effluent)	4	<0.08	<0.18

a: ^{226}Ra activity based on ^{214}Pb activity; b: ^{228}Ra activity based on ^{228}Ac activity.

Source document:RIFE 20

https://www.gov.uk/government/publications/radioactivity-in-food-and-the-environment-2014-rife-20

4.2.1.2 Aberdeen

Scotoil operates a cleaning facility for equipment from the oil and gas industry contaminated with enhanced concentrations of radionuclides of natural origin. They are authorised to discharge liquid effluent to sea with the primary discharge being radium-226 and radium-228, with lead-210 and polonium-210 in smaller quantities. The authorisation includes conditions requiring Scotoil to undertake environmental monitoring.

Seaweed (*Fucus vesiculosus*) from Aberdeen Harbour was monitored in 2014. Technetium-99 was detected in seaweed (17 Bq kg^{-1}, fresh), in line with the expected effect from Sellafield discharges (as the releases become diluted or mixed in moving further afield). Gamma-emitting radionuclides were all below or close to the LoD. In 2014, the dose rate on sediment was 0.092 µGy h^{-1} and similar to background. The dose rate was lower than the results in earlier years when discharges were higher.

4.2.1.3 Dalgety Bay, Fife

Radioactive items containing radium-226 and associated daughter products have been detected at Dalgety Bay in Fife since at least 1990. The contamination is associated with historical disposals of waste from past military operations at the Royal Naval Air Station (RNAS) Donibristle, which closed in 1959 and upon which large areas of the town of Dalgety Bay have been built.

In June 1990, environmental monitoring showed elevated radiation levels in the Dalgety Bay area. Following the increased number of particle finds and the discovery of the high activity particles in 2011, additional public protection measures were established and these were maintained during 2014 and into 2015. The Scottish Environment Protection Agency (SEPA) undertook a programme of shellfish monitoring between February 2012 and February 2013 samples collected were analysed for the presence of radium-226 and all were found to be less than the level of detection.

Research Establishments

The site at Rosyth, Fife is operated by Babcock Marine, a division of Babcock International Group plc, who are responsible for the management of radioactive waste that was generated when the site supported the nuclear submarine fleet. Site decommissioning started in April 2006 and has mainly been completed, except for some small areas of the site where facilities continue to be required to

manage radioactive wastes. To date, more than 99 per cent of the waste arising because of site decommissioning has been recycled.

The *total dose* from all pathways and sources was less than 0.005 mSv in 2014, which was less than 0.5 per cent of the dose limit. In 2014, authorised gaseous discharges from Rosyth were reported as nil. Liquid wastes are discharged via pipeline to the Firth of Forth. In all cases the activities in the liquid discharged were below authorised limits. Discharges of tritium from Rosyth decreased in 2014, due to a reduction in the numbers of samples of nuclear submarine primary coolant that were disposed of following analysis in the Rosyth Radiochemistry Laboratory. SEPA's routine monitoring programme included analysis of shellfish, environmental indicator materials and measurements of gamma dose rates in intertidal areas. Results are shown in Table 4.2. The radioactivity levels detected were at similar low levels to 2013 and in most part due to the combined effects of Sellafield, weapon testing and Chernobyl. Gamma dose rates were difficult to distinguish from natural background. The most recent habits survey was undertaken in 2010 (Rumney *et al.*, 2013).

Table 4.2: Mean radioactivity concentration (fresh)[a], Bq kg^{-1} in marine organisms and environment samples near Rosyth 2014.

Material	Location	No Samples	Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{125}Sb	^{131}I	^{134}Cs	^{137}Cs
Mackerel	Firth of Forth	1				<0.10	<0.24		<0.10	0.15
Winkles	St Davids Bay	1				<0.10	<0.27		<0.11	0.19
Sediment	East Dockyard	1				<0.10	<0.13		<0.10	<0.10
Sediment	East Dockyard	1				<0.10	<0.20		<0.10	2.2
Sediment	Port Edgar	1				<0.10	<0.29		<0.15	8.2
Sediment	West Dockyard	1				<0.10	<0.14		<0.10	1.1
Sediment	East Ness pier	1				<0.10	<0.18		<0.10	5.8
Sediment	Blackness Castle	1				<0.10	<0.27		<0.12	5.7
Sediment	Charlestown Pier	1				<0.10	<0.14		<0.10	0.60
Seawater	East of Dockyard	2		<1.0		<0.10	<0.18		<0.10	<0.10

a: Except for sediment where dry concentrations apply, and for water where units are Bq l^{-1}

Source document:RIFE 20

https://www.gov.uk/government/publications/radioactivity-in-food-and-the-environment-2014-rife-20

Nuclear Power Stations

This section considers the effects of discharges from nuclear power stations during 2005 - 2014. There is a total of 19 nuclear power stations at 14 locations in the UK, of which two are in areas that have a potential influence on the area of interest in this SEA (Hartlepool and Torness). In England it is the Environment Agency and in Scotland SEPA that regulate gaseous and liquid discharges from each of the power stations.

4.2.1.4 Hartlepool

Hartlepool Power Station is situated on the mouth of the Tees estuary, on the north east coast of England, and is powered by twin Advanced Gas-cooled Reactors (AGRs). It is estimated that its power generation will continue until at least 2019.

Regulated discharges of radioactive liquid effluent are made to Hartlepool Bay with a minor component being discharged directly to the River Tees. Discharges of tritium and sulphur-35 decreased in 2014, in comparison to those in 2013. Results of the aquatic monitoring programme conducted in 2014 are shown in Table 4.3 to Table 4.5. Small enhancements of carbon-14 concentrations, above expected background, were observed in seafood samples. Enhancements are most likely to be due to carbon-14 discharges from a nearby non-nuclear site since carbon-14 discharges from the power station are low. Technetium-99 analysis in seaweed is used as an indication of the far-field effects of disposals to sea from Sellafield.

Table 4.3: Mean radioactivity concentration (fresh)[a], Bq kg^{-1} in marine organisms sampled near Hartlepool nuclear power stations, 2014.

Material	Location	No. Samples	Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{99}Tc	^{131}I	^{137}Cs	^{210}Pb
Plaice	Pipeline	1	<25	<25	24	<0.06		*	0.15	
Crabs	Pipeline	1	<25	<25	34	<0.06		*	<0.06	
Winkles	South Gare	2	<26	<25		<0.05		<0.52	0.18	1.8
Seaweed	Pilot Station	2[E]				<0.98	4.2	11	<0.69	
Sediment	Old Town Basin	2[E]				<0.45			2.1	
Sediment	Seaton Carew	2[E]				<0.29			<0.22	
Sediment	Paddy's Hole	2[E]				<0.40			1.8	
Sediment	North Gare	2[E]				<0.25			<0.20	
Sediment	Greatham Creek	2[E]				<0.45			3.0	
Sea coal	Old Town Basin	2[E]				<0.39			<0.73	
Sea coal	Carr House Sands	2[E]				<0.61			<0.53	
Seawater	North Gare	2[E]		<3.1		<0.28			<0.23	

*Not detected by the method used; a except for water where units are Bq l^{-1}, and for sediment and sea coal where dry concentrations apply: E Measurements labelled 'E' are made on behalf of the Environment Agency, all other measurements made on behalf of Food Standards Agency

Source document:RIFE 20

https://www.gov.uk/government/publications/radioactivity-in-food-and-the-environment-2014-rife-20

Table 4.4: Mean radioactivity concentration (fresh)a, Bq kg^{-1} in marine organisms sampled near Hartlepool nuclear power stations, 2014.

Material	Location	No. Samples	^{210}Po	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Plaice	Pipeline	1				<0.05				
Crabs	Pipeline	1				<0.15				
Winkles	South Gare	2	18	0.0061	0.041	<0.022	*	*		
Seaweed	Pilot Station	2^{E}				<0.66				
Sediment	Old Town Basin	2^{E}				<0.52				
Sediment	Seaton Carew	2^{E}				<0.32				
Sediment	Paddy's Hole	2^{E}				<0.63				
Sediment	North Gare	2^{E}				<0.34				
Sediment	Greatham Creek	2^{E}				<0.82				
Sea coal	Old Town Basin	2^{E}				<0.54				
Sea coal	Carr House Sands	2^{E}				<0.61				
Seawater	North Gare	2^{E}				<0.28			<4.0	17

*Not detected by the method used; a except for water where units are Bq l^{-1}, and for sediment and sea coal where dry concentrations apply: E Measurements labelled 'E' are made on behalf of the Environment Agency, all other measurements made on behalf of Food Standards Agency.
Source document:RIFE 20

https://www.gov.uk/government/publications/radioactivity-in-food-and-the-environment-2014-rife-20

Concentrations in seaweed were low and much less than the peak observed in 1998. They are less than 1 per cent of the equivalent concentrations near Sellafield. Iodine-131 was again positively detected in seaweed samples collected around the mouth of the River Tees Estuary in 2014. The detected values, as in previous years, are believed to originate from the therapeutic use of this radionuclide in a local hospital. Detectable concentrations of radiocaesium and transuranics were mainly due to disposals from Sellafield and to weapon test fallout. However, caesium-137 concentrations in sediment have remained low over the last 7 years (Table 4.3 to Table 4.5 show data for 2014). Overall, gamma dose rates in 2014 were generally like those in 2013.

In 2014, the reported polonium-210 concentration in winkles from South Gare was 18 Bq kg^{-1} and enhanced above the value expected due to natural sources. These samples (collected inside the Tees Estuary entrance) consisted of a mixture including some winkles collected from the estuary entrance near Paddy's Hole. The polonium-210 concentration is consistent with previously reported values in winkles from Paddy's Hole, obtained from sampling and analysis undertaken between 2004 and 2006. The enhanced levels of polonium-210 were believed to be due to a combination of waste slag from local iron and steel industries, used in sea defences, and/or the build-up of naturally occurring gamma-emitting radionuclides in sediments at this location as the result of degradation of the sea defence materials over time.

Table 4.5: Monitoring of radiation dose rates near Hartlepool nuclear power station

Location	Ground Type	No. Samples	µGy h^{-1}
Fish sands	Sand	1	0.068
Fish sands	Sand and stones	1	0.072
Old Town Basin	Sand	1	0.077
Old Town Basin	Sand and coal	1	0.070
Carr House	Sand	1	0.068
Carr House	Sand and coal	1	0.065
Seaton Carew	Sand	1	0.064
Seaton Carew	Pebbles and sand	1	0.061
Seaton Sands	Sand	2	0.061
North Gare	Sand	2	0.064
Paddy's Hole	Pebbles and slag	1	0.17
Paddy's Hole	Pebbles and stones	1	0.16
Greatham Creek Bird hide	Mud and rock	1	0.091

Source document:RIFE 20

https://www.gov.uk/government/publications/radioactivity-in-food-and-the-environment-2014-rife-20

4.2.1.5 Torness

Torness Power Station is located near Dunbar on the east coast of Scotland. This station, which is powered by two AGRs, began operation at the end of 1987 and it is currently scheduled to cease generation in 2023.

In December 2013, EDF Energy applied to SEPA to vary the authorisation for Torness to allow radioactive waste to be disposed of by transfer to any waste permitted person, both within the UK and overseas, and to be able to accept radioactive waste from other EDF Energy stations for the purposes of bulking up low volume wastes before final disposal.

EDF Energy is continuing with its programme to reduce carbon deposition within the reactor and has continued to inject carbonyl sulphide (COS) into both reactors during 2014. This process was started in 2011 and after the initial expected increase in sulphur-35 levels discharged to the local environment, via the liquid and gaseous routes, the levels have stabilised. In 2014, the sulphur-35 discharged to the local environment was like that discharged in 2013 and remained within the authorised limits. The most recent habits survey was undertaken in 2011 (Clyne *et al.*, 2013).

Discharges of tritium decreased by a small amount, in comparison to those releases in 2013. Samples of seawater and *F.vesiculosus*, as useful environmental indicators, were collected in addition to seafood. Measurements were also made of gamma dose rates over intertidal areas, supported by analyses of sediment, and beta dose rates on fishing gear.

The results of the aquatic monitoring in 2014 are shown in Table 4.6 and Table 4.7 Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield discharges and to weapon testing and Chernobyl fallout. In 2014, an americium-241 concentration was elevated in a *nephrops* sample (from Dunbar Bay). As in recent years, a few very low concentrations of activation products were detected in environmental indicator samples. These were likely to have originated from the station. Technetium-99 concentrations in marine samples were like those in 2013. Caesium-137 concentrations in sediment have remained low over the last decade. Beta radiation from fishermen's pots are reported as less than values. Gamma dose rates over intertidal areas were generally indistinguishable from natural background and were like those measured in recent years.

Table 4.6: Mean radioactivity concentration (fresh)a, Bq kg-1 in marine organisms and environment sampled in the vicinity of Torness nuclear power stations, 2014.

Material	Location	No. Samples	^{54}Mn	^{60}Co	^{65}Zn	^{99}Tc	^{110m}Ag	^{137}Cs
Cod	White Sands	2	<0.11	<0.10	<0.21		<0.13	0.24
Crabs	Torness	1	<0.10	<0.10	<0.14	0.40	<0.10	<0.10
Lobsters	Torness	1	<0.10	<0.10	<0.23	3.3	<0.10	<0.10
Nephrops	Dunbar	2	<0.10	<0.10	<0.21		<0.10	0.13
Winkles	Pipeline	2	<0.16	<0.17	<0.28		<0.79	<0.10
Fucus vesiculosus	Pipeline	2	<0.44	<0.48	<0.16		<0.06	<0.10
Fucus vesiculosus	Thornton Lochs	2	<0.17	<0.18	<0.18	7.6	<0.10	<0.10
Fucus vesiculosus	White Sands	2	<0.10	<0.10	<0.18		<0.10	<0.10
Fucus vesiculosus	Pease Bay	2	<0.10	<0.10	<0.15		<0.10	<0.10
Fucus vesiculosus	Coldingham Bay	2	<0.10	<0.10	<0.22		<0.10	<0.10
Sediment	Dunbar	1	<0.10	<0.10	<0.22		<0.11	1.4
Sediment	Barns Ness	1	<0.10	<0.10	<0.14		<0.10	0.84
Sediment	Thornton Loch	1	<0.10	<0.10	<0.15		<0.10	0.80
Sediment	Heckies Hole	1	<0.10	<0.10	<0.22		<0.10	1.2
Sediment	Belhaven Bay	1	<0.10	<0.10	<0.27		<0.11	2.0
Sediment	Coldingham Bay	1	<0.10	<0.10	<0.16		<0.10	0.89
Sediment	Pease Bay	1	<0.10	<0.10	<0.25		<0.10	0.95
Sediment	Pipeline	2	<0.10	<0.10	<0.17		<0.10	<0.10

Source document:RIFE 20

https://www.gov.uk/government/publications/radioactivity-in-food-and-the-environment-2014-rife-20

Table 4.7: Mean radioactivity concentration (fresh)a, Bq kg^{-1} in marine organisms sampled in the vicinity of Torness nuclear power stations, 2014.

Material	Location	No. Samples	^{155}Eu	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Am	Gross alpha	Gross beta
Cod	White Sands	2	<0.25			<0.13		
Crabs	Torness	1	<0.12			<0.10		
Lobsters	Torness	1	<0.20			<0.12		
Nephrops	Dunbar	2	<0.21	<0.12	0.15	0.53		
Winkles	Pipeline	2	<0.18			<0.10	1.9	67
Fucus vesiculosus	Pipeline	2	<0.14			<0.11		
Fucus vesiculosus	Thornton Lochs	2	<0.16			<0.11		
Fucus vesiculosus	White Sands	2	<0.15			<0.10		
Fucus vesiculosus	Pease Bay	2	<0.13			<0.10		
Fucus vesiculosus	Coldingham Bay	2	<0.13			<0.11		
Sediment	Dunbar	1	0.44			<0.25		
Sediment	Barns Ness	1	<0.13			<0.22		
Sediment	Thornton Loch	1	0.34			<0.21		
Sediment	Heckies Hole	1	<0.31			<0.28		
Sediment	Belhaven Bay	1	1.0			<0.29		
Sediment	Coldingham Bay	1	<0.59			<0.27		
Sediment	Pease Bay	1	<0.31			<0.29		
Seawater	Pipeline	2	<0.18			<0.11		

Source document:RIFE 20

https://www.gov.uk/government/publications/radioactivity-in-food-and-the-environment-2014-rife-20

5 Clean Seas Environmental Monitoring Programme survey data

5.1 Background

The Clean Seas Environment Monitoring Programme (CSEMP) is one means by which the UKs national and international commitments to monitor marine sediments and biota in coastal and offshore marine waters are met (Nicolaus et al., 2015). The main policy drivers for the programme include the CEMP and Joint Assessment and Monitoring Programme (JAMP) of the OSPAR convention and the European Union (EU) MSFD; (European Commission, 2008).

For this study the assessments were made using quality controlled data currently held within the UK Marine Environment Monitoring and Assessment National database (MERMAN) (www.bodc.ac.uk/projects/uk/merman/). Raw data for contaminants (metals, PAHs and PCBs) in biota and sediment were queried from MERMAN in December 2015 by the British Oceanographic Data Centre (BODC) and sent to Cefas. These were manipulated and presented as described in the following sections.

Quality control of data used in CSEMP

To ensure quality control and assurance, certified reference materials are routinely analysed within batch to monitor day-to-day method performance of laboratories submitting data to CSEMP. The results obtained for these samples were assessed against performance criteria which allowed the acceptance or rejection of the batch data to be decided. In addition to the in-house Analytical Quality Control (AQC), laboratories participated in external laboratory proficiency schemes, including QUASIMEME (Quality Assurance of Information for Marine Environmental Monitoring in Europe). In addition, the analyses of the trace metals and PCBs are accredited by the United Kingdom Accreditation Service (UKAS). More information on quality assurance can be found in the CSEMP Green book (Cefas, 2012) and associated appendices.

Assessment approaches

One of the benefits of using internationally established assessment criteria, is the ability to easily summarise the assessment in a visual and meaningful way. One approach used recently in both the UK and OSPAR is the development of a three-colour “traffic light” system based on the specified assessment criteria (Charting Progress 2, 2010; QSR, 2010). Where data allow the approach taken in

this report for the wider area monitoring data mirrors that of recent UK wide assessments undertaken for marine contaminant data and follows the approach undertaken as part of the OSPAR Co-ordinated Environmental Monitoring Programme (CEMP) (OSPAR, 2008).

Metals in sediment

Marine sediments can act as a sink or source of metals in the environment depending on historical inputs and changes in the sediment regime within a defined area (e.g. storm or dredging disturbance). Many metals present in the environment are essential for normal biological activity; however, some are known to induce toxicological effects when present at high concentrations. The risk metals pose to marine organisms is related to the species ecology (such as feeding mechanisms), the bioavailability of the metal (phase of sediment within which the metal is associated) and the physiological ability of the organisms to regulate body burdens.

The data reviewed in this report was based on surficial sediments as they integrate the contamination status of the environment over a period of months. Higher concentrations of metals are usually found in fine-grained sediments because of the greater surface area to volume ratio that is available for interaction. Therefore, when comparing the enrichment of metals in sediments over a large study area, such as in this report, it is essential to compensate for these 'grain size' effects. The assessments conducted under CSEMP use Aluminium (Al) as a reference element to 'normalise' for grain size differences because it is a conservative element unaffected by anthropogenic discharges and activities (Charting Progress 2). This approach has been previously used throughout the UK to identify spatial trends in trace metal contamination (Charting Progress 2; Lyons *et al*., 2015; Nicolaus *et al.,* 2015). Two different particle size fractions were tested (<63 μm and <2000 μm) and these are presented separately again due to grain size effects. Where a result was reported as a less than value, it was assigned a nominal value of half the limit of quantification.

To investigate temporal differences, sample results were presented separately for the periods 2005-09 and 2010-14. The survey area was divided into 0.5 degree by 0.5 degree rectangles (79 rectangles or part rectangles) and enclosed estuaries. Summary statistics were calculated for all samples by rectangle (which were set at a size that gave the best overall presentation of spatial differences within the MNSH area) or estuary for spatial assessments of metal concentrations to be made.

Metal/Al ratios are compared to the BACs to identify if concentrations are 'close to background' and also against the Effects Range- Low (ERL) concentrations and Effects Range- Median (ERM)

concentrations to identify if toxicological effects on marine organisms are 'negligible' or 'likely', respectively (Table 5.1 and Appendix **Error! Reference source not found.** to **Error! Reference source not found.**; Table 5.1 to **Error! Reference source not found.**). The tables of summary statistics present the range of years within which the samples were taken, the arithmetic mean result, the minimum and maximum result, and the percentage of samples exceeding the assessment concentrations. The thematic maps present colour coded symbols based on the mean result in relation to the assessment levels within each of the geographic divisions sampled.

Table 5.1: Assessment criteria used for metals in sediment

Metal	Less than the Background Assessment Concentration (BAC)	From the BAC to the Effects Range Low (ERL)	From the ERL to the Effects Range Median (ERM)	>= to the ERM
Cadmium	<310 µg/kg	>= 310 µg/kg to 1,200 µg/kg	>= 1,200 µg/kg to 9,600 µg/kg	>= 9,600 µg/kg
Chromium	Not stated	<81 mg/kg	>= 81 mg/kg to 370 mg/kg	>= 370 mg/kg
Copper	Not stated	<34 mg/kg	>= 34 mg/kg to 270 mg/kg	>= 270 mg/kg
Mercury	<70 µg/kg	>= 70 µg/kg to 150 µg/kg	>= 150 µg/kg to 710 µg/kg	>= 710 µg/kg
Lead	<38 mg/kg	>= 38 mg/kg to 47 mg/kg	>= 47 mg/kg to 220 mg/kg	>= 220 mg/kg
Zinc	Not stated	<150 mg/kg	>= 150 mg/kg to 410 mg/kg	>= 410 mg/kg

Overview CSEMP metals sediment data

Broad spatial assessment of the data for most metal/Al ratios show low ratios in this region of the North Sea with higher ratios restricted to several sites of concern in industrialized estuaries such as the Inner Forth, Tees and Tyne which may lead to toxicological impacts. There is no overall significant trend in the contamination status of metals, but if metal inputs from rivers, sewage and industry continue to decrease further significant downward trends would be expected in future assessments (Charting progress 2, 2010). Offshore samples are not considered to pose a toxicological threat to marine species.

Cadmium

In 2005-09 mean cadmium concentrations in samples within only one offshore rectangle (G5) were within the ERL-ERM range and all other samples collected were below the ERL. In 2010-2014 mean cadmium concentrations from one inshore site (C6) were within the ERL-ERM range. Of interest was that samples from rectangle C6 in 2005-2009 were below the ERL. All other sample locations were

below the ERL in 2010-2014. However, in this latter sample period sample sites were predominantly from the Southern part of the MNSH and rectangle C6 from which the ERL exceedance was recorded in 2005-09 was not included. The data would suggest that in offshore sediments toxicological effects are highly unlikely as many sites had concentrations below the ERL or are close to background. As can be seen from Appendix **Error! Reference source not found.** to **Error! Reference source not found.** and Appendix Figures 1.1 to 1.4 the number of samples breaching the ERL was far greater in the estuaries bordering the sector under investigation with Cd/AL ratios in 2005-2009 exceeding the ERL for the Tees, Tyne and Wear and in 2010-2014 for the Tees. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal data set was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Chromium

In 2005-09 mean chromium concentrations most of sediment samples exceeded the ERL (i.e. 28 of 30 rectangles. In 2010-2014 mean sediment chromium concentrations exceeded the ERL in 23 of 30 rectangles (Appendix Figures 1.5 – 1.8 and Appendix Tables 1.7 -1.10). These data suggest that toxicological effects may occur in sensitive species in these locations. Use of the MERMAN data assessment tool (http://www.bodc.ac.uk/projects/uk/merman/) to investigate sediment concentration trends for chromium indicated that only in the Tees (Seal sands) and allocation close to the Durham coast was there an upward trend.

Copper

The CSEMP data analysed between 2005 and 2009 revealed that a number of offshore and estuarine sectoral boxes (19/38) contained samples where the mean Cu/Al ratios were > ERL but below the ERM (Appendix **Error! Reference source not found.** to **Error! Reference source not found.**;Appendix **Error! Reference source not found.** to 1.114). The remaining sites were below the ERL and not thought to pose any toxicological risk. The analysis of 2010-2014 found less offshore sites recording a mean Cu/AL ratio above the ERL (6/30). However, sediment samples collected from the Tyne, Wear and Tees still exceeded the ERL. Data would suggest that such Cu/Al ratios at these locations regularly exceeding the ERL may lead to toxicological effects in sensitive species. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal data set was available (http://www.bodc.ac.uk/projects/uk/merman/). The only observable upwards trends for Cu/Al ratios were found in the Tees (seal sands) and a location close to the Durham coast (Off Seaham).

Mercury

The CSEMP data analysed between 2005 and 2009 revealed that a number of offshore and estuarine sectorial boxes (18/37) contained samples where the mean Hg/Al ratios in the sectorial boxes were > ERL but below the ERM (Appendix **Error! Reference source not found.** to **Error! Reference source not found.**; Appendix **Error! Reference source not found.** to **Error! Reference source not found.**). In 12 sectorial boxes the mean recoded Hg/Al ratios could be considered close to background. A similar pattern was observed for CSEMP data collected from 2010-2014, where 11/30 sectorial boxes recorded mean Hg/Al ratios close to background. Samples collected from the Tees estuary recorded mean Hg/Al ratios that exceeded the ERM in both 2005-2009 and 2010-2014 datasets. Data suggest that such Hg/Al ratios at these locations are likely to lead to toxicological effects. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal data set was available (http://www.bodc.ac.uk/projects/uk/merman/). The only observable upwards trends for Hg/Al ratios were found in the Wear (Sandy Point), while decreasing trends were observed at sites located in the Forth Estuary.

Lead: The CSEMP data analysed between 2005 and 2009 revealed that many offshore and estuarine sectorial boxes (30/38) contained samples where the mean Pb/Al ratios in the sectorial boxes were > ERL. Of these 5 sectorial boxes contained samples with the mean Pb/Al ratio > than the ERM (Appendix **Error! Reference source not found.** to **Error! Reference source not found.**; Appendix Table 1.19 to **Error! Reference source not found.**). A similar pattern was observed for CSEMP data collected from 2010-2014 with 21/30 sectorial boxes containing mean Pb/Al ratios above the ERL. In one case this also exceeded the ERM. Data suggest that such Pb/Al ratios may lead to toxicological effects in sensitive species at these locations. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Zinc

The CSEMP data analysed between 2005 and 2009 revealed that many offshore and estuarine sectorial boxes (18/38) contained samples where the mean Zn/Al ratios in the sectorial boxes were > ERL. Of these 2 sectorial boxes contained samples with the mean Zn/Al ratio > than the ERM (Appendix **Error! Reference source not found.** to **Error! Reference source not found.**; Appendix **Error! Reference source not found.** to **Error! Reference source not found.**). The sites exceeding the ERM threshold were confined to estuarine locations in the Tees and Tyne. A similar pattern was observed for CSEMP data collected from 2010-2014 with 8/20 sectorial boxes containing mean Zn/Al

ratios above the ERL. No mean values of Zn/Al ratios exceeded the ERM. Data suggest that such Zn/Al ratios at locations exceeding the ERM may lead to toxicological effects in sensitive species. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

PCBs

Polychlorinated bipheyl contamination started in the 1940s, peaked in the 1970s, and declined afterwards, due to prohibition of use in many countries. Nevertheless, concentrations of PCBs are still very high in many regions due to their hydrophobic nature and low solubility in water; properties which initially contributed to their widespread use. PCB content is compared to the Background Assessment Concentration (BAC) to identify if concentrations are 'close to background' and against Environmental Assessment Criteria (EAC). BACs have been established for the ICES7 CBs in sediment. Concentrations are expressed in µg/kg dry weight (dw), normalised to 2.5% total organic carbon (Appendix **Error! Reference source not found.** to **Error! Reference source not found.** and Appendix **Error! Reference source not found.** to **Error! Reference source not found.**). In general, the assessment of the majority sites and samples examined were < BAC or < EAC and therefore not thought to pose any significant toxicological risk. The EAC is lowest for CB118 (0.6 µg/kg dw), a mono-*ortho* CB and the most toxic of the ICES7 CBs. Therefore, it is not surprising that several sites regularly failed the EAC for this CB. EACs were also exceeded for CB 28 (E6), CB 52 (D5 and E6) and CB 101 (D5 and E6) on a limited number of occasions. The broad spatial assessment of the data for most CB data in this region of the North Sea shows that most sites contained sediment that had low levels of CB contamination. Wide spread failures of CB118 were observed, though this is consistent with other areas around the UK (Nicolaus et al., 2015). The EAC is lowest for CB118 (0.6 µg/kg dw), a mono-*ortho* CB and the most toxic of the ICES7 CBs. EACs were also exceeded for CB28, CB 52 and CB101 at a limited number of other locations. Again most sites with high levels of contamination were restricted to the industrialized estuaries (Inner Forth, Tyne and Tees). Major UK assessments have taken place in recent years and these demonstrate that CB concentrations appear to be relatively stable (Nicolaus *et al.,* 2015). The ban on the use of PCBs has resulted in a decrease in contaminant loading (e.g. riverine inputs and atmospheric transport) over time (Charting Progress 2, 2010). However, the slow degradation of CBs means this could take some

time to be reflected in actual measured concentrations in sediments and will require continued monitoring.

PAHs

Polycyclic aromatic hydrocarbons: PAHs bind to sediments due to their hydrophobicity and, in such matrices, they can persist for decades due to their low level of degradation in anaerobic environments. PAHs normally reach the marine environment because of fossil fuel combustion, waste incineration and oil spills, posing a threat to benthic organisms due to their acutely toxic, mutagenic, and carcinogenic properties (Nicolaus *et al*., 2015). In summary the data presented mirrors that presented in Defra's charting progress 2 report (Charting Progress 2, 2010). In terms of inputs into the region it is known that atmospheric inputs have been reduced significantly in recent years. However, in some of the historically industrialized estuaries, such as the Tyne and Tees on the north-east coast, there can be high levels of legacy contamination (Lyons *et al*., 2004; Nicolaus *et al*., 2015). As PAHs are persistent (particularly in low oxygen conditions, as found in organic-rich muddy estuarine sediments) these levels of contamination are reducing slowly and therefore there is a risk of re-mobilisation following flooding events, dredging activities or storms. The data shown in Appendix Figures 1.53 to 1.91 and Appendix Tables 1.57 to 1.94 indicate that any toxicological threat is restricted to these heavily contaminated estuarine locations and coastal or offshore locations remain uncontaminated and pose little or no risk to marine organisms.

Metals in biota: A variety of biota species were sampled and tested for metal content. Of the species sampled, only dab (*L.limanda*) and plaice (*P.platessa*) were sampled away from the nearshore region. Results for these species only are presented as they are of most relevance to the assessment. The range of metals measured included the six for which summary data were presented previously in Section 5. The reference values against which the results were compared are shown in Appendix Table 1.93, and these reference values were used as previously to produce thematic maps. For some metals there were no reference levels, so for these the symbol size on the maps were directly scaled against the mean result.

Regulatory drivers for the measurement of metals in biota includes OSPAR CEMP which require Hg to be measured in fish flesh, and Cd and Pb to be measured in fish liver (OSPAR, 2008). In summary, concentrations of Hg (Appendix Figures 1.98-1.99 and Tables 1.102-1.103) in fish flesh are elevated

in some industrial estuaries, although these do not pose any risks to human health. Concentrations of Cd (Appendix Figures 1.92-1.93 and Tables 1.96-1.97) and Pb (Appendix Figures 1.100-1.101 and Tables 1.104-1.105) in fish liver are again elevated in industrialized estuaries and in a few other coastal areas, but are unlikely to pose a risk to human health. Data for other metals (e.g. Zn - Appendix Figures 1.102-1.103 and Tables 1.106-1.107; Cu- Appendix Figures 1.96-1.97, Tables 1.100-1.101; and Cr- Figures 1.94-1.95 Tables 1.98-1.99) are sporadic, with varying numbers of sites sampled for each metal. However, there are no BACs or EC limit values available for these metals and therefore it is difficult to assess these data objectively in terms of their significance. The limited amount of data reported for metals other than Cd, Hg and Pb is probably due to the lack of a regulatory driver, and has contributed to the lack of suitable assessment criteria against which to compare the data (Charting Progress 2, 2010; Nicolaus *et al*., 2015).

PCBs in biota

In terms of inputs into the region it is known that atmospheric and riverine inputs have been reduced significantly in recent years. However, in some of the historically industrialized estuaries, such as the Tyne and Tees on the north-east coast, there can be high levels of legacy contamination. Overall it can be seen that PCB concentrations in fish has reduced in many areas and for CB138 (Appendix Figures 1.112-1.113 and Tables 1.117-1.118), CB153 (Appendix Figures 1.114-1.115 and Tables 1.119-1.120) and CB180 (Appendix Figures 1.116-1.117 and Tables 1.121-1.122) a significant downward trend was detected for Tees Bay, Amble (both N.E English coast) and off the Scottish East coast (Montrose Bank). No trend was seen for CB28 (Appendix Figures 1.104-1.105 and Tables 1.109-1.110), CB52 (Appendix Figures 1.106-1.107 and Tables 1.111-1.112) and CB101 (Appendix Figures 1.108-1.109 and Tables 1.113-1.114). Where the $EAC_{passive}$ was breached it tended to be restricted to data on levels of CB118 (Appendix Figures 1.110-1.111 and Tables 1.115-1.116), a mono-*ortho* CB and the most toxic of the ICES7.

6 Conclusions

The main routes through which hazardous substances can enter the marine environment are through the aquatic pathway via waterborne discharges and losses, and via the atmospheric pathway through emissions which fall out of the atmosphere and into the sea. The Mid-North Sea High Seismic Area as defined for this report includes inputs from more industrialised areas via estuaries e.g. the Forth, Tay, Tweed, Blyth, Tyne and Tees as well as well as via dredge disposal, from the offshore wind industry from cable laying and potential disturbance of historically contaminated sediment and from the drilling of wells and produced water discharges from the offshore oil and gas industry. Inputs of radioactivity to the MNSH area occur via the atmosphere and from the nuclear industry including power stations (Hartlepool and Torness), nuclear research establishments, processing of radioactive material (NORM) scale from used oil and gas industry and from historic waste disposal i.e. elevated levels of radium-226 in Dalgety Bay in the 1990s. However overall the inputs of radioactivity to the area are very limited and levels of different activation products with a few exceptions are frequently at or below limits of detection.

The offshore oil and gas development within the MNSH area is limited to relatively few existing installations although there have been many wells drilled along the southern and northern margins of the defined area. Data for sediment contamination levels associated with oil and gas activity in the MNSH area for metals Total hydrocarbon concentrations and concentrations for PAHs with a few exceptions (i.e. cadmium and copper for two sites) generally indicate relatively low concentrations are present.

Other than riverine discharges the main input of contaminants to coastal areas within the MNSH area are from dredge disposal generally in areas adjacent to relevant dredged estuaries where the concentration of various contaminants are elevated above background. Many of the Scottish disposal sites on the East coast are now not used and this is reflected in the generally lower concentrations of contaminants measured at these locations relative to sites such as the Tyne and Tees. For the wind industry, elevated levels of sediment contaminants are generally present where development sites (e.g. cable routes) overlap with dredge disposal areas. Therefore, as the general trend of contamination associated with dredge disposal sites generally increased further south in the MNSH area so too sediment contaminants showed higher elevation for areas off the Tees along the planned location of the Dogger Bank cable corridor.

Marine sediments can act as a sink or source of a range of contaminants in the environment depending on historical inputs and changes in the sediment regime within a defined area. The risk that metals and other contaminants pose to marine organisms is related to the species ecology (such as feeding mechanisms), the bioavailability of the contaminant (phase of sediment within which it is associated) and the physiological ability of the organisms to regulate body burdens.

For metals there is no overall significant trend in the contamination status, but if metal inputs from rivers, sewage and industry continue to decrease further significant downward trends would be expected in future assessments (Charting progress 2, 2010). Offshore samples are not considered to pose a toxicological threat to marine species. In general, the Tees, Tyne and Wear showed exceedance or ERL values for several metals in samples from 2005 – 2009 and from 2010 – 2014. Most notably observable upwards trends for Cr/Al and Cu/Al ratios were found in the Tees (seal sands) and a location close to the Durham coast (Off Seaham). Mercury was also elevated in the Tees Estuary with samples collected having a mean Hg/Al ratio that exceeded the ERM in both 2005-2009 and 2010-2014 datasets.

Despite bans on use in many countries PCBs are still very high in many regions due to association to sediments but mainly in industrialized estuaries (Inner Forth, Tyne and Tees). Major UK assessments have taken place in recent years and these demonstrate that CB concentrations appear to be relatively stable. The ban on the use of PCBs has resulted in a decrease in contaminant loading (e.g. riverine inputs and atmospheric transport) over time although sediments in industrialised estuaries e.g. inner Forth, Tyne Tees show some of the more elevated concentrations. The slow degradation of CBs means it could take some time for the effects of the ban to be reflected in actual measured concentrations in sediments and will require continued monitoring. For PAHs in summary the data presented mirrors that presented in Defra's Charting Progress 2 report. In terms of inputs into the region it is known that atmospheric inputs have been reduced significantly in recent years. However, in some of the historically industrialized estuaries, such as the Tyne and Tees on the north-east coast, there can be high levels of legacy contamination.

Contaminant levels in biota mirror those for sediment contamination e.g. concentrations of Cd and Pb in fish liver are elevated in industrialized estuaries and in a few other coastal areas, although they are unlikely to pose a risk to human health. Data for other metals (e.g. Zn, Cu and Cr) is more limited and therefore difficult to assess particularly as there are no BACs or EC limit values available for these metals. A variety of biota species were sampled and tested for PCB content. Of the species

sampled, only dab (*L.limanda*) and plaice (*P.platessa*) were sampled away from the nearshore region. In summary the data presented mirrors previously reported (Charting Progress 2, 2010) with a significant downward trend for many PCBs.

In overall summary the MNSH area has several coastal locations where metals, PCBs and PAHs are elevated above background levels in the sediments and in some cases at levels of concern for biological effects but these are predominantly associated with areas of current or historic dredge disposal. Limited data for offshore sediment contaminant concentrations associated with the oil and gas industry indicate relatively fewer samples for which contaminant concentrations reach levels that could be of concern. In terms of inputs into the region it is known that atmospheric and riverine inputs have been reduced significantly in recent years. However, in some of the historically industrialized estuaries, such as the Tyne and Tees on the north-east coast, there can be high levels of legacy contamination.

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8 Annexes

8.1 Data references for report

Table 8.1 Summary of data sources and links for oil and gas and wind energy for this report for North Sea High Seismic area defined for this report as southern boundary - 54°N extending from the coast to the UK median line and northern boundary - formed of a line from Fraserburgh to the intersect with the median line at 56° 30'N.

Activity	Data description	Data Source and link
Oil and Gas	There is data from 61 surveys within the area and 875 survey stations. However, there is only data from 8 surveys and 69 survey stations from 2005 to 2015, this increases to 13 surveys and 151 survey stations from 2000 to 2015. Data retrieved include installation name, location, Depth, sediment characteristics, sediment concentration data for six metals and seven groupings of data related to PAHs	UKbenthos database of Offshore environmental impact surveys that have been carried out by oil and gas operators in the North Sea since 1975. The data was originally sourced from http://oilandgasuk.co.uk/knowledgecentre/uk_benthos_database.cfm but this site became inactive from Ocotober 2016 and data are now available from: http://www.bgs.ac.uk/services/NGDC/citedData/catalogue/f9c724ab-006b-4256-8553-928f23736ab2.html A number of shapefiles and KML files can be found on the gov.uk website – https://www.ogauthority.co.uk/data-centre/interactive-maps-and-tools/
Wind Farms	Buchan Deep – Section 3.5 Environmental survey report Hywind Offshore Windfarm August to September 2013 Inch Cape Volume 2B Appendix 12D, January 2013 Neart Na Gaoithe Benthic ecology characterisation Report Chapter 14, 2010 Blyth Offshore Demonstration Project, ES Volume 3 Appendix 6.4 The physical Environment Appendix D Dogger Bank Teeside A and B Environmental Statement Chapter 10 Water and Sediment Quality	https://www.statoil.com/content/dam/statoil/documents/impact-assessment/Hywind/Statoil-Environmental%20survey%20report.pdf https://www.statoil.com/content/dam/statoil/documents/impact-assessment/Hywind/Statoil-Environmental%20Statement%20April%202015.pdf http:// www.inchcapewind.com%2Ffiles%2FEnvironmental_Statement_Structure%2FChapter12%2FAppendix12B.pdf&usg=AFQjCNHwwRuIMNzX3j0WAknQyqDoW0bW7A http://www.neartnagaoithe.com/environmental-statement1.asp http://edf-er.com/OurProjects/Proposed/BlythOffshore/ProjectDocuments.aspx http://www.forewind.co.uk/uploads/files/TeessideAB/Application_Documents/6.Environmental_Statement/6.10_ES_Chapter_10_Marine_Water_and_Sediment_Quality.pdf

Table 8.2 Summary of data sources and links for dredging, nuclear industry and related and wider area monitoring for this report for North Sea High Seismic area defined for this report as southern boundary - 54°N extending from the coast to the UK median line and northern boundary - formed of a line from Fraserburgh to the intersect with the median line at 56° 30'N.

Activity	Data description	Data Source and link
Dredging	East coast Scotland dredge disposal sites active over the period 2005 to the present (Covering East Scotland coast and Forth sites). The sediment contaminants include metals, PAHs, and Polychlorinated biphenyls A request Cefas Chemistry Team for dredge disposal data from 2005 to 2015 covering East coast disposal sites for England for all sediment contaminants to include, metals, PCBs and PAHs	Data Request from Marine Scotland MS.MarineLicensing@gov.scot https://www.gov.uk/government/organisations/centre-for-environment-fisheries-and-aquaculture-science
Nuclear industry and related	Data for sites of relevance to the survey area sourced from RIFE20	https://www.gov.uk/government/publications/radioactivity-in-food-and-the-environment-2014-rife-20
Wider Area Monitoring	Data request made to BODC for extraction of datasets covering period 2005 to 2015 based on a shapefile for the North Sea HIgh Seismic Area and covering all contaminants in sediment, water and biota	merman@bodc.ac.uk]

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Appendix to Contaminants characterisation of the Mid-North Sea High Seismic Area

(Strategic Environmental Assessment)

Authors: Alastair Cook, Max La Vedrine, Brett Lyons, Rachel Parks, Fiona Vogt, Dave Sheahan

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Appendix to Contaminants characterisation of the Mid-North Sea High Seismic Area

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Appendix 1: Clean Seas Environmental Monitoring Programme survey data, Tables and Maps

1.1 Data Sources and approach

The contaminant data included in this report is derived from several sources. Data characterising chemical use for different marine activities is derived from various reports and scientific papers and these are cited where used. The principal source of contaminant data for the Offshore Oil and Gas industry was the UKbenthos sediment database derived from a project funded by Oil & Gas UK (UKOOA at the time) and which collates seabed monitoring data collected by the UK oil and gas industry from 1975 to 1998 (This dataset was subsequently incorporated into the site operated by the British Geological Survey, www.bgs.ac.uk). Dredge disposal data for English waters was provided by the Cefas analytical team, from data used in support of licensing advice. The Marine Licensing Team of Marine Scotland Dredge provided the data for Scottish waters. Offshore windfarm data is derived from supporting survey data provided in publicly available Environmental Impact assessment reports for individual developments. The radioactivity data reported comes from relevant Radioactivity in Food and the Environment (RIFE) reports by the Food Standards Agency. The main source for contaminant monitoring sites is derived from searches run on the MERMAN database.

All data searches used as a point of reference an area defined as: southern boundary - 54°N extending from the coast to the UK median line and northern boundary - formed of a line from Fraserburgh to the intersect with the median line at 56° 30'N. More detail on data requests and relevant links are provided in Appendix Table 8.1 and 8.2. For this report this area is referred to as 'Mid-North Sea High' and abbreviated to MNSH although it is recognised that the area defined by this title may be smaller than that covered in this review.

Each section provides background on the potential inputs from relevant marine activities and considers associated contaminants data which are presented as a series of tables with summary statistics for metals and selected organic chemicals. This report considers only sediment and biota data as substances that accumulate in these media represent the greatest potential longer term risk to the marine environment and are accordingly the focus of marine water quality status assessment under the Marine Strategy Framework Directive.

1.2 Relevant contaminants to the region and assessment approaches applied

1.2.1 Metals

Metals are naturally present in coastal waters and are mostly derived from the underlying geology of the region under investigation. Additional anthropogenic inputs of metals into the marine environment derive mainly from industrial discharges and sewage effluents. While many metals are essential for normal biological activity they are also of concern because they can induce toxicological effects when present at high concentrations. Dissolved metals present in seawater can readily bioaccumulate in marine organisms and sediments may also act as a source or sink of metal contamination. The exposure of the organism to trace metals is related to its ecology (such as feeding mechanisms) and the phase of sediment with which the trace metal is associated.

1.2.2 Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous, persistent organic contaminants arising as products of incomplete combustion, from both domestic and industrial sources, and are components of crude oil and refined oil products. PAHs derived from petroleum based sources show a higher proportion of the low molecular weight (LMW) PAHs (including alkylated PAHs) and those from combustion a greater proportion of the high molecular weight (HMW) (4- to 6-ring) parent PAHs. This class of contaminant are of concern as the LMW PAHs cause tainting of fish and shellfish and can be acutely toxic, while some of the HMW PAHs can be activated to cancer-causing (genotoxic) breakdown derivatives following ingestion and metabolism in fish, marine mammals and human consumers of seafood. The degree of carcinogenicity is closely related to the structure of the PAH compounds and the metabolic capability of the exposed organism. It has been reported that atmospheric inputs of PAHs have significantly reduced in recent years (Charting Progress 2, 2010). However, in some historically industrialized estuaries, such as the Tyne and Tees estuaries of north-east England, or the Thames and Medway in the south-east, there can be high levels of contamination (Lyons *et al*., 2004; Nicolaus *et al*., 2015).

1.2.3 Polychlorinated biphenyls

Polychlorinated biphenyls (PCBs) are a group of 209 manufactured industrial chemical compounds which were mainly used in electrical equipment until their manufacture was banned in Europe in the mid-1980s because of environmental and biological concerns about their toxicity and accumulation (PARCOM 1992). PCBs are chemically inert and stable when heated. The chemical inertness and heat

stability properties that make PCBs desirable for industry also protect them from destruction when the products in which they are used are discarded. These same properties also enable PCB residues to persist in the environment for long periods of time and translocate to regions of the globe far removed from any obvious point sources of pollution. PCBs have been associated with toxic effects in birds and marine mammals, such as reduction in eggshell thickness, endocrine disruption, which impairs reproduction and development, and immunotoxicity, which increases susceptibility to infectious diseases and cancers. A sub-group of PCBs is 'dioxin-like', meaning they are highly toxic and persistent environmental pollutants. Due to their persistence, potential to bio-accumulate and toxicity they have been included on the OSPAR List of Chemicals for Priority Action and have been regulated by the Stockholm Convention of Persistent Organic Pollutants (POPs). Between 1998 and 2005 there were large reductions in releases and regulations on their production came into force and remaining stocks were phased out. However, despite European-wide action, use of PCBs in other parts of the world is still ongoing and releases continue through diffuse emissions to air and water. Remaining sources include electrical and hydraulic equipment containing PCBs, waste disposal, redistribution of historically contaminated marine sediments and by-products of thermal and chemical industrial processes. Seven PCB compounds were recommended for monitoring by the European Union Community Bureau of Reference (EUR-Lex - 52001DC0593 – EN). These were selected as indicators of wider PCB contamination due to their relatively high concentrations and toxic effects. These are known as the ICES7 CBs and include the congeners CB28, CB52, CB101, CB118, CB138, CB153 and CB180.

1.2.4 Polybrominated diphenyl ethers

Polybrominated diphenyl ethers (PBDEs) are a group of widely used brominated flame retardants (BFRs), although they are now banned in EU countries. Commercial PBDE mixtures are classified per the degree of bromination. The penta-mix contains mainly tetra-and penta-BDEs, the octa-mix mainly hexa- to hepta-BDEs and the deca-mix containing mainly deca-BDE. The penta-BDE product is mainly used in furniture and upholstery, the octa-PBDE product in plastics and the deca-PBDE product in textiles (Webster et al., 2010). There is a limited amount of chronic and acute toxicity data for BFRs. The lower brominated BDEs are more toxic and more likely to bioaccumulate, while deca-BDE is the least toxic, mainly due to its large molecular weight, which reduces its tendency to bioaccumulate through the food chain (Law *et al*., 2006). However, there are concerns that deca-BDE may break down to the more harmful tetra- and penta-congeners in the marine environment (Charting Progress 2, 2010). To date there is little information available on the health effects of BDEs in exposed marine animals, although studies using rodents have shown that BDEs are endocrine disruptors, affect thyroid

hormone functions and can impair the developing central nervous system and brain (Darnerud *et al*., 2001; Zhou *et al*., 2002).

In 2001, the European Commission issued a proposal to ban the penta- technical mixture and this was passed into law in August 2004. This restricted the use of the penta- and the octa- technical mixtures to a limit of 0.1% by mass for all products placed on the European market. Further restrictions on the marketing of electrical and electronic equipment containing PBDEs, became effective on 1 July 2006. PBDEs can be released to the environment during their production and while manufacturing other products, as well as during disposal of products containing these chemicals. In addition, PBDEs may continue to leak out of treated material. In the UK the manufacturing plants (based in County Durham in the northeast of England) ceased production in 1996.

1.2.5 Assessment approaches for sediments

To enable assessments of monitoring data for hazardous substances in marine sediments and biota, there is a need to have relevant assessment tools. In recent years a large amount of effort has been focused on developing Background Assessment Criteria (BACs) and Environmental Assessment Criteria (EACs) for contaminants in sediment and biota (OSPAR, 2008; Roose, 2012). OSPAR has developed Background Concentrations (BCs), which is the concentration of a contaminant at a 'pristine' or 'remote' site based on contemporary or historical data, which observed concentrations are said to be 'near background' if the mean concentration is statistically significantly below the corresponding BAC (OSPAR, 2008; QSR, 2010). Priority substance EACs are defined as a concentration of chemical contamination in the environment below which it is unlikely that unexpected or unacceptable biological effects will occur in exposed marine species. EACs and other appropriate assessment criteria (e.g. US EPA adopted Effects Range Low (ERLs), Long *et al*., 1995) have been developed to act as pivot points when assessing safe limits of contaminant concentrations in sediment and biota and therefore can be considered analogous to the Environmental Quality Standards (EQS) applied to water under the Water Framework Directive (WFD).

The more recent wider area monitoring data for sediment contaminants have sufficient associated information on the nature of the sediments to allow an assessment of the likely effects which might occur in the environment because of the contaminant concentrations observed. So primarily for the data described in section 5, the measured environmental concentration for each contaminant and site was calculated. These were then compared to derived assessment criteria. For the PCB congeners, EACs derived by OSPAR were used (OSPAR, 2009). In the absence of EACs for metals and PAHs, Effects Range Low (ERL) and Effects Range Medium (ERM) values were used in their assessments. The ERL and ERM represent sediment quality guidelines (SQGs) derived from a large database of sediment

toxicity and benthic community information (Long *et al.,* 1998). The ERL and ERM represent, the 10th and 50th percentiles of the effects dataset. In broad terms, the ERL indicates a concentration above which effects are possible and the ERM a concentration above which effects are likely to occur.

Because sediment contaminant bioavailability heavily influences their potential to cause harm, any sediment properties that influence this must be considered in their assessment. Sediment organic carbon content is primarily responsible for the adsorption of neutral organic chemicals such as PCBs and PAHs and can reduce the potential uptake of associated contaminants. For this reason, OSPAR (OSPAR, 2008; QSR, 2010) and the US EPA (Long *et al*., 1995) normalise PCB, PAH and PBDE concentrations to a 2.5% organic carbon content. As sediment particle size decreases, the surface area of the unit mass of sediment increases. Increasing the surface area number of negatively charged sites for adsorption, and therefore cations that can be carried on the sediment. Sediment metal concentrations are usually normalised to sediment aluminium concentration as this is predominantly associated to the presence of finer clay particles.

Therefore prior to assessments against SQGs, concentrations of metals were normalised to 5% aluminium concentration and organics to 2.5% organic carbon content. All samples for which a less than value was reported were assigned a nominal value of half the limit of quantification. Where data permit some of the same comparisons are made against available SQGs.

There are no statutory thresholds to assess the quality of marine sediment in the UK. However, there are upper threshold limits of sediment which are acceptable for disposal to sea. These contaminant disposal limits are regulated in England by the Marine Management Organisation under the Marine and Coastal Access Act 2009. The aim of these limits is to prevent accumulation of high levels of contamination in offshore sediments and to avoid direct toxic effects on marine flora and fauna.

Levels of contamination in dredged sediment are assessed against Cefas Action Levels to help reduce any impacts (OSPAR, 2010):

- In general, contaminant levels in dredged material below Cefas Action Level 1 are of no concern and are unlikely to influence the licensing decision.
- Between Cefas Action Level 1 and Cefas Action Level 2 limits - Dredged material with contaminant levels between Cefas Action Levels 1 and 2 requires further consideration and testing (where appropriate) before a decision can be made.
- Above Cefas Action Level 2 limit - Dredged material with contaminant levels above Cefas Action Level 2 is generally considered unsuitable for sea disposal.

Cefas Action Levels are used as part of a 'weight of evidence' approach to assessing dredged material and its suitability for disposal to sea. The Cefas Action Level limits for contaminants are shown in Table

0.1; these were set in 1994. The MMO commissioned a high level review of current Action Level guidance applied by the MMO to the licensing of the disposal of dredged material to sea (MMO, 2015a). The report recommended that the UK approach to action levels would benefit from a further, more detailed review of the action levels and guidance to establish whether they are fit for purpose given current policy and regulatory requirements. However, there are no current studies or reviews into the existing Action Levels and guidance.

Table 0.1 Cefas Action Levels in sediments (MMO, 2015b)

Contaminant or compound	Action Level 1 (mg/kg dry weight (ppm))	Action Level 2 (mg/kg dry weight (ppm))
Arsenic	20	100
Mercury	0.3	3
Cadmium	0.4	5
Chromium	40	400
Copper	40	400
Nickel	20	200
Lead	50	500
Zinc	130	800
Organotins (TBT, DBT, MBT)	0.1	1
PCBs – sum of ICES 7	0.01	None
PCBs – sum of 25 congeners	0.02	0.2
PAHs	0.1	None
DDT	*0.001	
Dieldrin	*0.005	

To investigate temporal differences, sample results were presented separately for the periods 2005-09 and 2010-14. The survey area was divided into 0.5 degree by 0.5 degree rectangles (79 rectangles or part rectangles) and enclosed estuaries. Summary statistics were calculated for all samples by rectangle (which were set at a size that gave the best overall presentation of spatial differences within the MNSH area) or estuary for spatial assessments of metal concentrations to be made.

Metal/Al ratios are compared to the BACs to identify if concentrations are 'close to background' and also against the Effects Range- Low (ERL) concentrations and Effects Range- Median (ERM) concentrations to identify if toxicological effects on marine organisms are 'negligible' or 'likely'(Table 1.2). The tables of summary statistics present the range of years within which the samples were taken, the arithmetic mean result, the minimum and maximum result, and the percentage of samples exceeding the assessment concentrations. The thematic maps present colour coded symbols based on the mean result in relation to the assessment levels within each of the geographic divisions sampled. Data for cadmium concentrations in sediments are shown in Figure 0:1 to Figure 0:4; Table 0. to Table 0..

Table 0.2: Assessment criteria used for metals in sediment

Metal	Less than the Background Assessment Concentration (BAC)	From the BAC to the Effects Range Low (ERL)	From the ERL to the Effects Range Median (ERM)	>= to the ERM
Cadmium	<310 µg/kg	>= 310 µg/kg to 1,200 µg/kg	>= 1,200 µg/kg to 9,600 µg/kg	>= 9,600 µg/kg
Chromium	Not stated	<81 mg/kg	>= 81 mg/kg to 370 mg/kg	>= 370 mg/kg
Copper	Not stated	<34 mg/kg	>= 34 mg/kg to 270 mg/kg	>= 270 mg/kg
Mercury	<70 µg/kg	>= 70 µg/kg to 150 µg/kg	>= 150 µg/kg to 710 µg/kg	>= 710 µg/kg
Lead	<38 mg/kg	>= 38 mg/kg to 47 mg/kg	>= 47 mg/kg to 220 mg/kg	>= 220 mg/kg
Zinc	Not stated	<150 mg/kg	>= 150 mg/kg to 410 mg/kg	>= 410 mg/kg

Cadmium

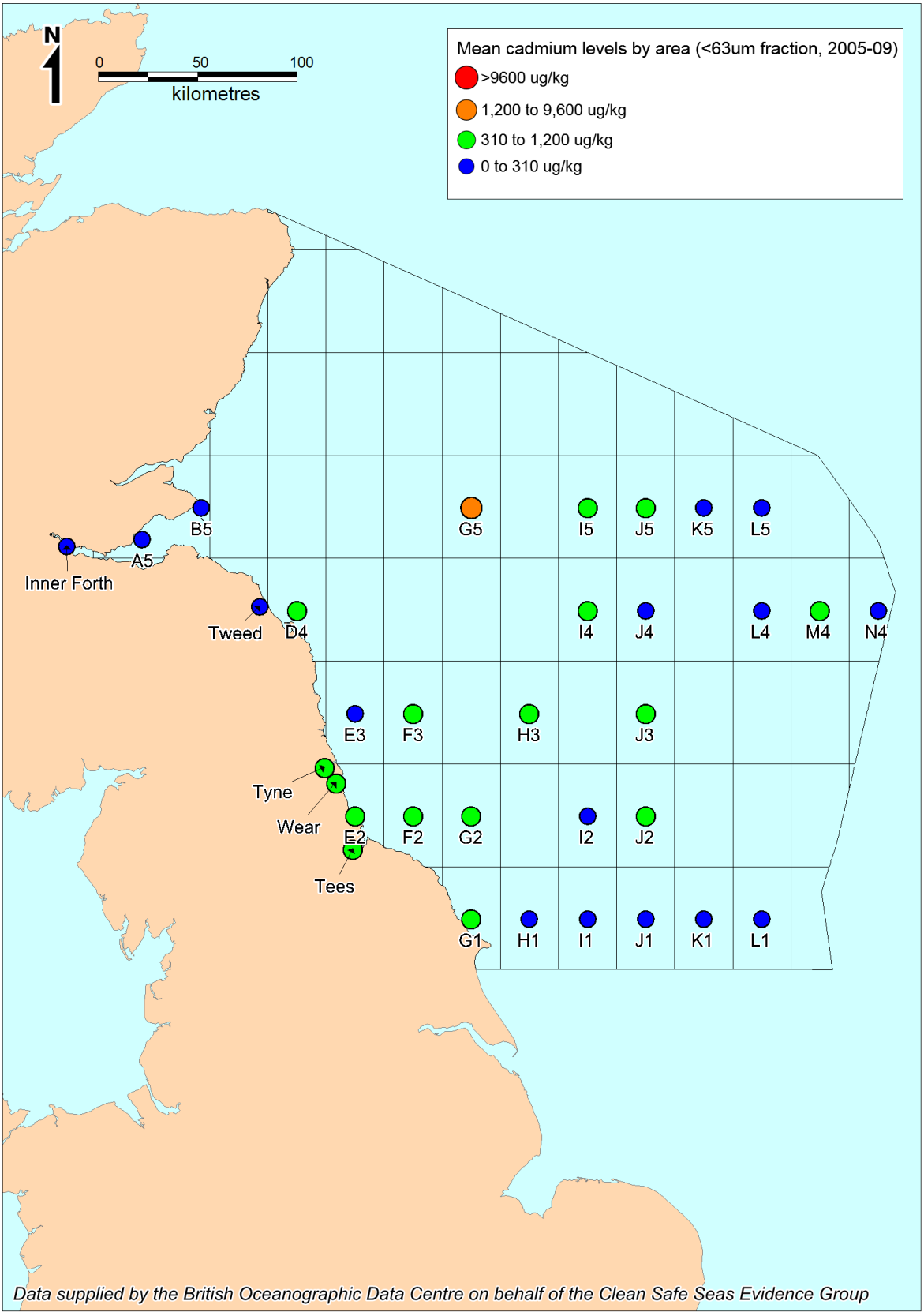

Figure 0:1: Map of mean cadmium concentrations by area (< 63 µm fraction, 2005-09)

Table 0.3: Summary of cadmium concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Cadmium sample results (ug/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2006	2009	7	133.2	72.7	280.3	0%	0%	0%
B5	2005	2009	16	172.2	52.4	289.5	0%	0%	0%
D4	2005	2008	17	598.6	272.5	1397.3	76%	6%	0%
E2	2005	2008	32	330.2	150.8	777.4	50%	0%	0%
E3	2005	2009	29	204.9	57.8	1113.1	24%	0%	0%
F2	2008	2008	1	751.1	751.1	751.1	100%	0%	0%
F3	2008	2008	3	500.0	143.0	692.0	67%	0%	0%
G1	2008	2008	1	484.6	484.6	484.6	100%	0%	0%
G2	2008	2008	1	481.8	481.8	481.8	100%	0%	0%
G5	2008	2008	1	1619.5	1619.5	1619.5	100%	100%	0%
H1	2006	2006	2	75.4	74.4	76.4	0%	0%	0%
H3	2008	2008	1	460.2	460.2	460.2	100%	0%	0%
I1	2008	2008	1	144.1	144.1	144.1	0%	0%	0%
I2	2006	2008	2	110.1	66.1	154.0	0%	0%	0%
I4	2008	2008	2	558.1	512.4	603.7	100%	0%	0%
I5	2008	2008	1	1149.7	1149.7	1149.7	100%	0%	0%
J1	2006	2006	1	239.8	239.8	239.8	0%	0%	0%
J2	2005	2009	22	481.0	36.0	3185.0	36%	9%	0%
J3	2006	2008	2	523.0	340.0	706.0	100%	0%	0%
J4	2008	2008	1	301.3	301.3	301.3	0%	0%	0%
J5	2008	2008	1	599.3	599.3	599.3	100%	0%	0%
K1	2005	2009	21	244.1	42.1	720.1	29%	0%	0%
K5	2008	2008	4	236.0	225.7	255.7	0%	0%	0%
L1	2006	2006	4	202.0	69.0	583.0	25%	0%	0%
L4	2008	2008	1	184.7	184.7	184.7	0%	0%	0%
L5	2008	2008	1	102.5	102.5	102.5	0%	0%	0%
M4	2006	2006	1	400.3	400.3	400.3	100%	0%	0%
N4	2008	2008	1	136.3	136.3	136.3	0%	0%	0%
Tees	2005	2009	35	1173.6	328.7	2639.5	100%	51%	0%
Tweed	2005	2008	15	290.5	200.5	424.0	33%	0%	0%
Tyne	2005	2009	35	1166.0	285.0	3156.0	83%	43%	0%
Wear	2005	2009	35	804.6	227.5	1970.4	77%	29%	0%
Inner Forth	2005	2009	20	181.7	91.4	282.4	0%	0%	0%

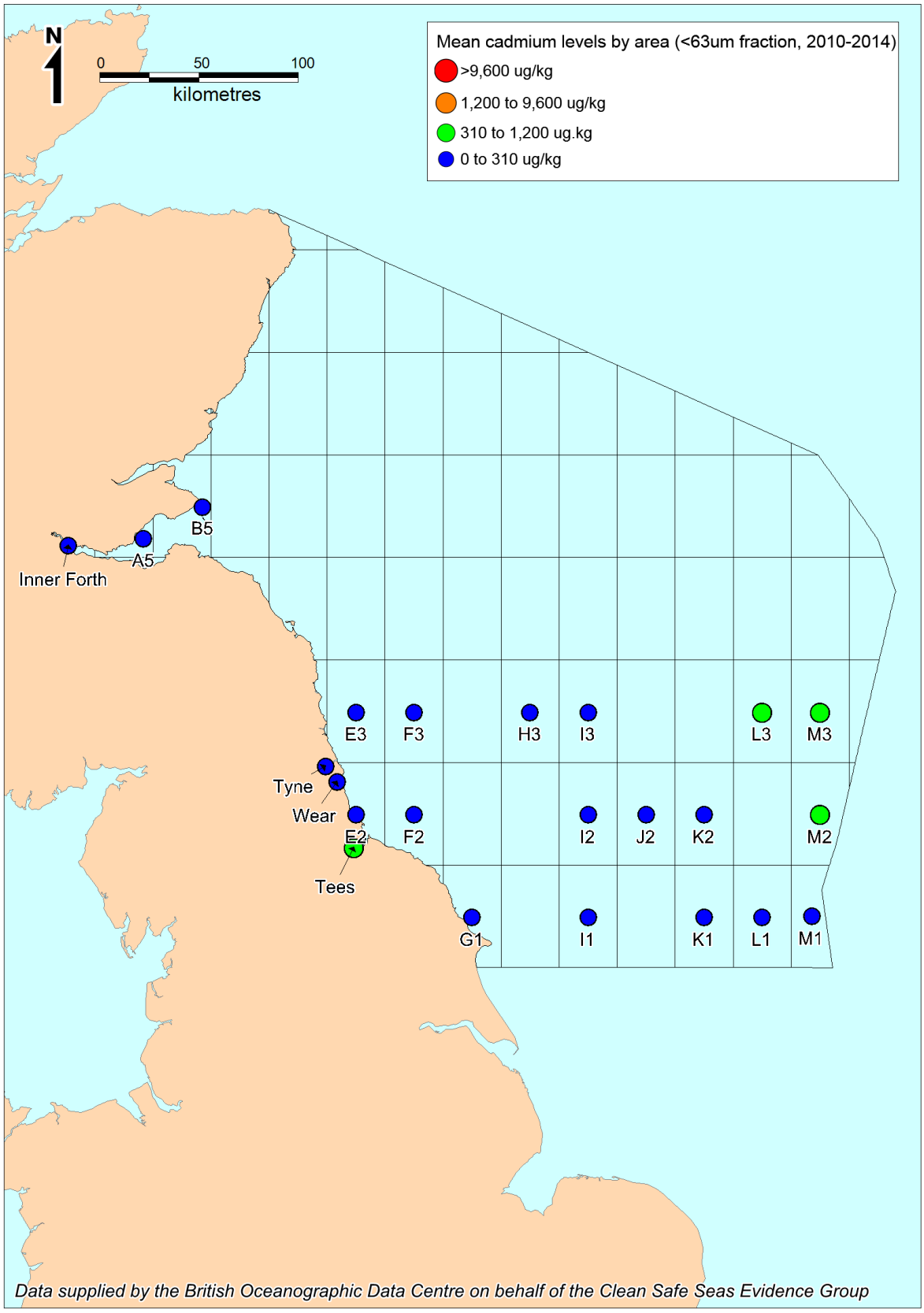

Figure 0:2: Map of mean cadmium concentrations by area (< 63 µm fraction, 2010-14)

Table 0.4: Summary of cadmium concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Cadmium sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2010	2014	19	109.0	12.4	310.3	5%	0%	0%
B5	2010	2014	15	84.6	10.1	181.8	0%	0%	0%
E2	2011	2011	4	294.1	91.0	410.7	75%	0%	0%
E3	2010	2013	19	212.6	64.8	1028.4	5%	0%	0%
F2	2010	2013	4	298.0	142.0	652.0	25%	0%	0%
F3	2011	2013	5	96.8	63.5	135.1	0%	0%	0%
G1	2011	2011	1	257.9	257.9	257.9	0%	0%	0%
H3	2011	2013	2	109.9	84.4	135.4	0%	0%	0%
I1	2011	2011	1	188.5	188.5	188.5	0%	0%	0%
I2	2013	2013	1	121.5	121.5	121.5	0%	0%	0%
I3	2013	2013	2	92.1	82.5	101.7	0%	0%	0%
J2	2010	2013	7	291.4	70.9	489.9	57%	0%	0%
K1	2010	2013	7	191.4	80.3	335.4	14%	0%	0%
K2	2011	2011	3	205.4	196.6	216.5	0%	0%	0%
L1	2011	2013	6	274.5	115.3	555.6	33%	0%	0%
L3	2011	2011	1	576.4	576.4	576.4	100%	0%	0%
M1	2011	2013	3	130.5	111.3	156.1	0%	0%	0%
M2	2011	2011	1	331.7	331.7	331.7	100%	0%	0%
M3	2011	2011	1	459.2	459.2	459.2	100%	0%	0%
Tees	2010	2013	10	1016.0	569.0	1784.0	100%	20%	0%
Tyne	2010	2010	5	287.7	249.6	331.1	40%	0%	0%
Wear	2010	2010	5	294.5	246.1	353.8	40%	0%	0%
Inner Forth	2010	2014	16	126.3	68.1	214.4	0%	0%	0%

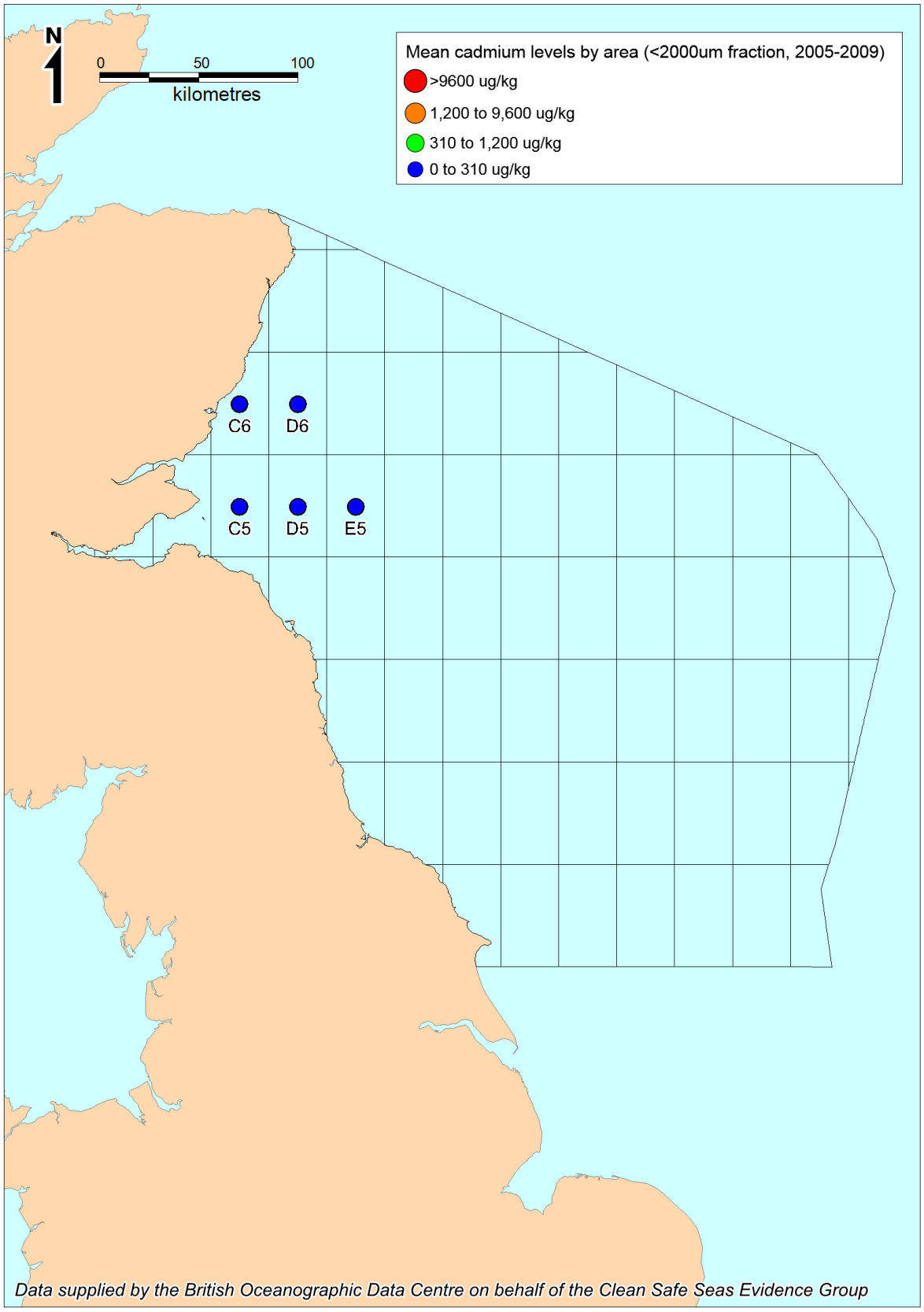

Figure 0:3: Map of mean cadmium concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.5: Summary of cadmium concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Cadmium sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
C5	2006	2006	1	34.0	34.0	34.0	0%	0%	0%
C6	2006	2009	19	53.4	34.4	149.2	0%	0%	0%
D5	2006	2009	9	80.2	42.4	98.3	0%	0%	0%
D6	2008	2008	1	69.2	69.2	69.2	0%	0%	0%
E5	2005	2005	5	83.1	78.1	93.1	0%	0%	0%

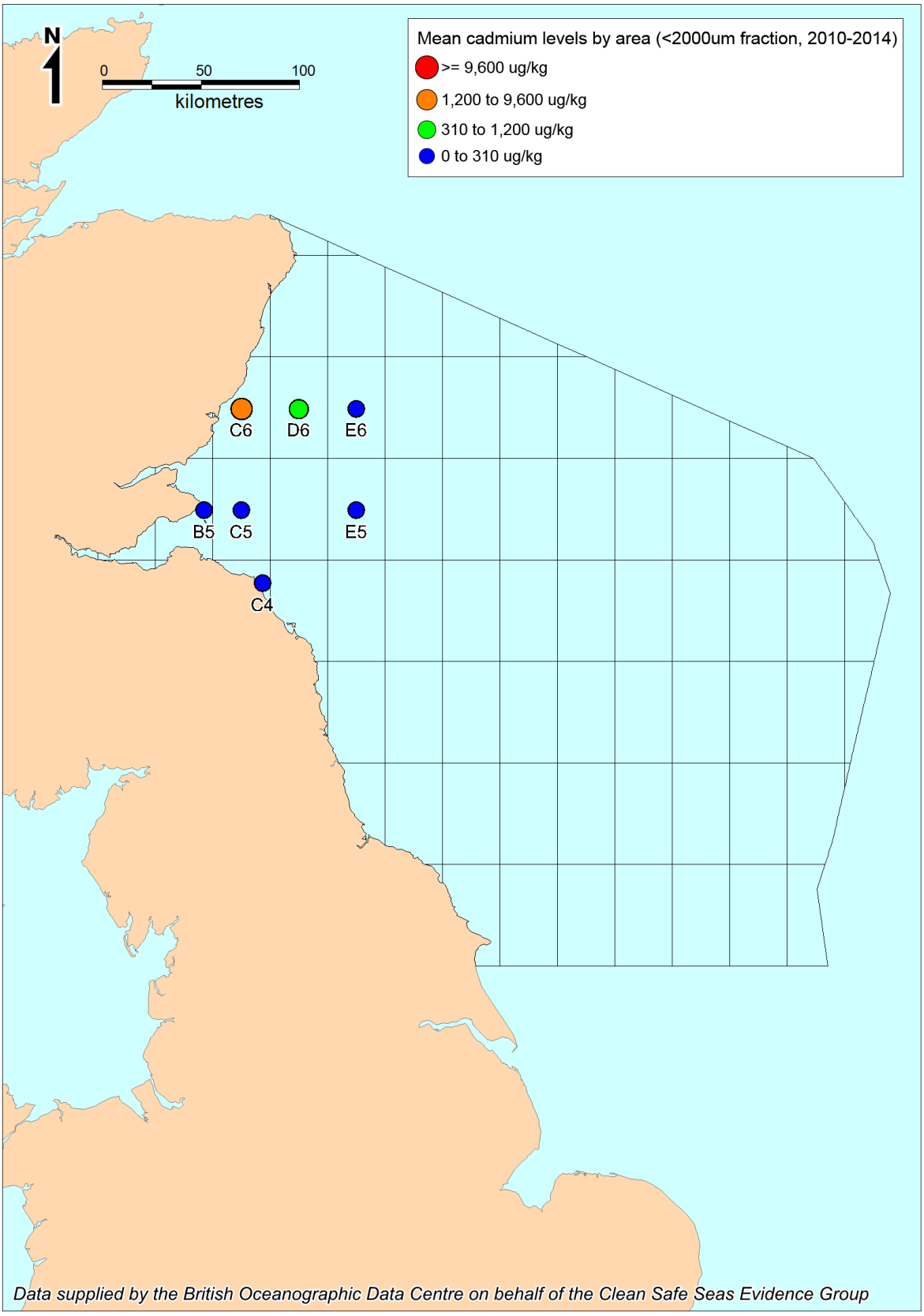

Figure 0:4: Map of mean cadmium concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.6: Summary of cadmium concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Cadmium sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
B5	2012	2014	15	104.6	33.7	156.6	0%	0%	0%
C4	2014	2014	1	171.4	171.4	171.4	0%	0%	0%
C5	2010	2014	3	105.4	33.7	149.7	0%	0%	0%
C6	2010	2014	28	1209.0	35.0	25806.0	18%	7%	4%
D6	2011	2013	2	543.0	57.0	1028.0	50%	0%	0%
E5	2010	2012	2	80.5	77.4	83.7	0%	0%	0%
E6	2014	2014	1	53.9	53.9	53.9	0%	0%	0%

Summary Cadmium sediment

The CSEMP data analysed between 2005-2009 revealed that only one sector (G5) in the offshore area contained samples where the mean Cd/Al ratios results from that sector were > ERL (Figure 0:1 and Figure 0:3). A similar pattern was observed for CSEMP data collected from 2010-2014. Again only one sector (C6) contain mean Cd/Al ratios that exceeded the ERL (Figure 0:2 and Figure 0:4). The data would suggest that in offshore sediments toxicological effects are highly unlikely as many sites had concentrations below the ERL or are close to background. As can be seen from Table 0. to Table 0. the number of samples breaching the ERL was far greater in the estuaries bordering the sector under investigation with Cd/AL ratios in the Tees (2005-2009 = 51%; 2010-2014 = 20%), Tyne (2005-2009 = 43%; 2010-2014 = 0%) and Wear (2005-2009 = 29%; 2010-2014 = 0%) exceeding the ERL. At a localised level these are potentially of concern and the risk these pose has previously been addressed (Charting Progress 2; Nicolaus *et al*., 2015). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal data set was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Chromium

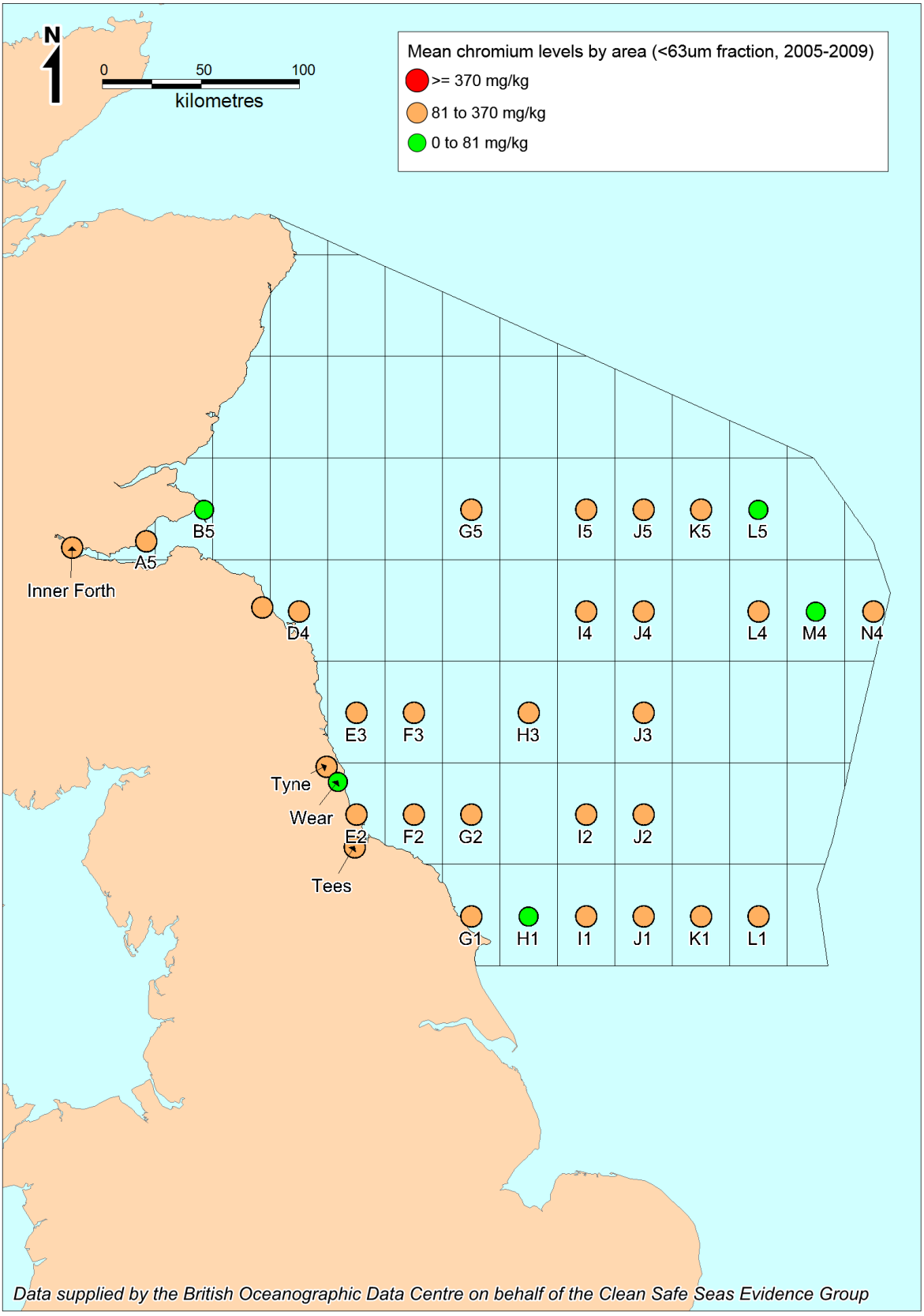

Figure 0:5: Map of mean chromium concentrations by area (< 63 µm fraction, 2005-09)

Table 0.7: Summary of chromium concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Chromium sample results (mg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
A5	2006	2009	7	84.5	71.1	96.3	57%	0%
B5	2005	2009	16	80.5	64.9	103.5	44%	0%
D4	2005	2008	22	187.0	67.1	680.0	95%	9%
E2	2005	2008	42	104.4	62.6	262.5	43%	0%
E3	2005	2009	29	111.0	46.9	315.9	48%	0%
F2	2008	2008	1	200.3	200.3	200.3	100%	0%
F3	2008	2008	3	161.5	136.1	191.9	100%	0%
G1	2008	2008	1	140.4	140.4	140.4	100%	0%
G2	2008	2008	1	155.5	155.5	155.5	100%	0%
G5	2008	2008	1	296.3	296.3	296.3	100%	0%
H1	2006	2006	2	71.7	67.9	75.4	0%	0%
H3	2008	2008	1	186.8	186.8	186.8	100%	0%
I1	2008	2008	1	145.9	145.9	145.9	100%	0%
I2	2006	2008	2	136.8	62.0	211.5	50%	0%
I4	2008	2008	2	207.6	147.6	267.7	100%	0%
I5	2008	2008	1	185.1	185.1	185.1	100%	0%
J1	2006	2006	1	111.1	111.1	111.1	100%	0%
J2	2005	2009	22	114.8	53.3	305.8	68%	0%
J3	2006	2008	2	107.3	73.9	140.7	50%	0%
J4	2008	2008	1	139.4	139.4	139.4	100%	0%
J5	2008	2008	1	239.7	239.7	239.7	100%	0%
K1	2005	2009	21	113.9	56.2	179.7	67%	0%
K5	2008	2008	4	226.9	213.0	249.7	100%	0%
L1	2006	2006	4	90.7	70.3	129.9	50%	0%
L4	2008	2008	1	209.3	209.3	209.3	100%	0%
L5	2008	2008	1	76.1	76.1	76.1	0%	0%
M4	2006	2006	1	72.3	72.3	72.3	0%	0%
N4	2008	2008	1	114.5	114.5	114.5	100%	0%
Tees	2005	2009	45	227.6	64.8	610.8	98%	22%
Tweed	2005	2008	20	134.2	89.6	232.0	100%	0%
Tyne	2005	2009	45	97.3	56.7	240.1	33%	0%
Wear	2005	2009	45	79.3	57.3	154.5	44%	0%
Inner Forth	2005	2009	25	106.5	67.4	266.3	68%	0%

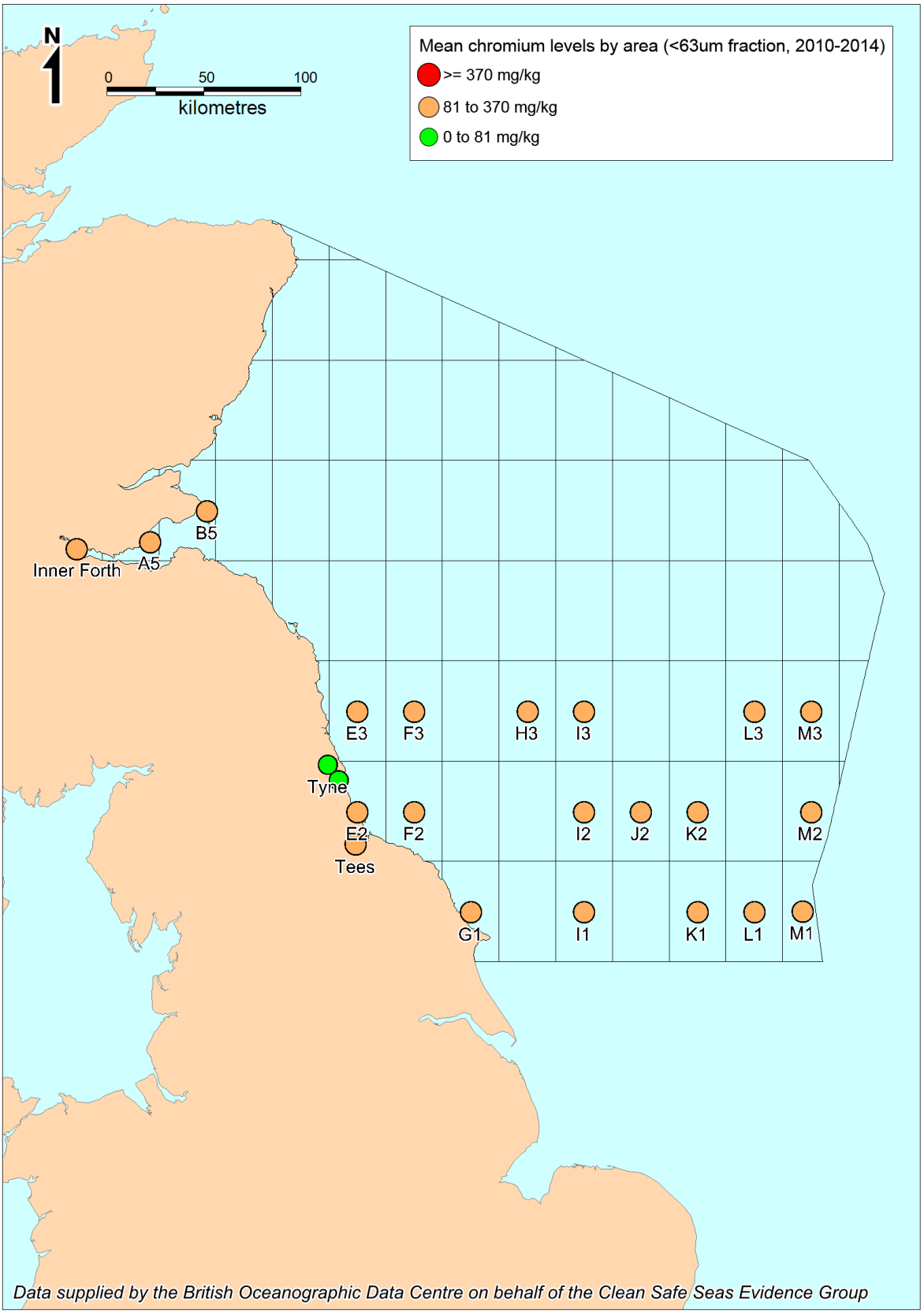

Figure 0:6: Map of mean chromium concentrations by area (< 63 µm fraction, 2010-14)

Table 0.8: Summary of chromium concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Chromium sample results (mg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
A5	2010	2014	19	96.9	11.2	311.4	79%	0%
B5	2010	2014	15	92.0	71.1	192.7	73%	0%
E2	2011	2011	4	151.6	106.0	220.0	100%	0%
E3	2010	2013	19	101.9	73.1	183.2	68%	0%
F2	2010	2013	4	107.8	93.5	114.0	100%	0%
F3	2011	2013	5	111.2	77.2	150.9	80%	0%
G1	2011	2011	1	94.2	94.2	94.2	100%	0%
H3	2011	2013	2	125.1	95.0	155.2	100%	0%
I1	2011	2011	1	107.1	107.1	107.1	100%	0%
I2	2013	2013	1	156.7	156.7	156.7	100%	0%
I3	2013	2013	2	117.1	107.0	127.2	100%	0%
J2	2010	2013	7	95.3	59.5	149.5	43%	0%
K1	2010	2013	7	90.3	55.5	139.4	71%	0%
K2	2011	2011	3	125.3	116.1	137.8	100%	0%
L1	2011	2013	6	140.7	78.9	202.8	83%	0%
L3	2011	2011	1	185.9	185.9	185.9	100%	0%
M1	2011	2013	3	127.0	108.9	143.3	100%	0%
M2	2011	2011	1	159.7	159.7	159.7	100%	0%
M3	2011	2011	1	131.4	131.4	131.4	100%	0%
Tees	2010	2013	10	190.3	129.2	411.3	100%	10%
Tyne	2010	2010	5	66.6	62.6	70.8	0%	0%
Wear	2010	2010	5	59.8	53.0	63.7	0%	0%
Inner Forth	2010	2014	16	101.5	74.9	122.0	94%	0%

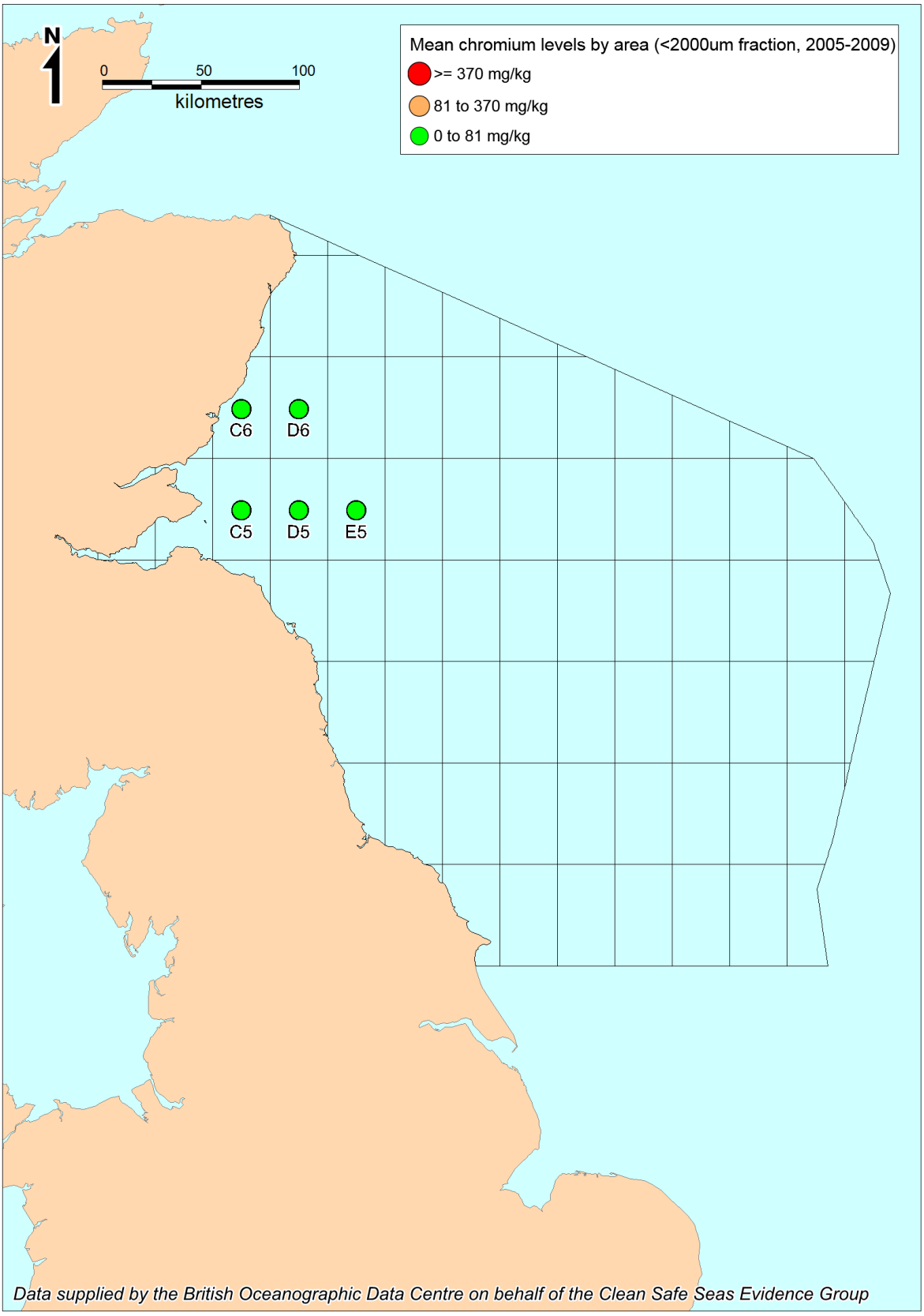

Figure 0:7: Map of mean chromium concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.9: Summary of chromium concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Chromium sample results (mg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
C5	2006	2006	1	25.2	25.2	25.2	0%	0%
C6	2006	2009	19	45.8	29.6	67.4	0%	0%
D5	2006	2009	9	47.5	39.4	53.9	0%	0%
D6	2008	2008	1	50.6	50.6	50.6	0%	0%
E5	2005	2005	5	45.0	39.4	50.0	0%	0%

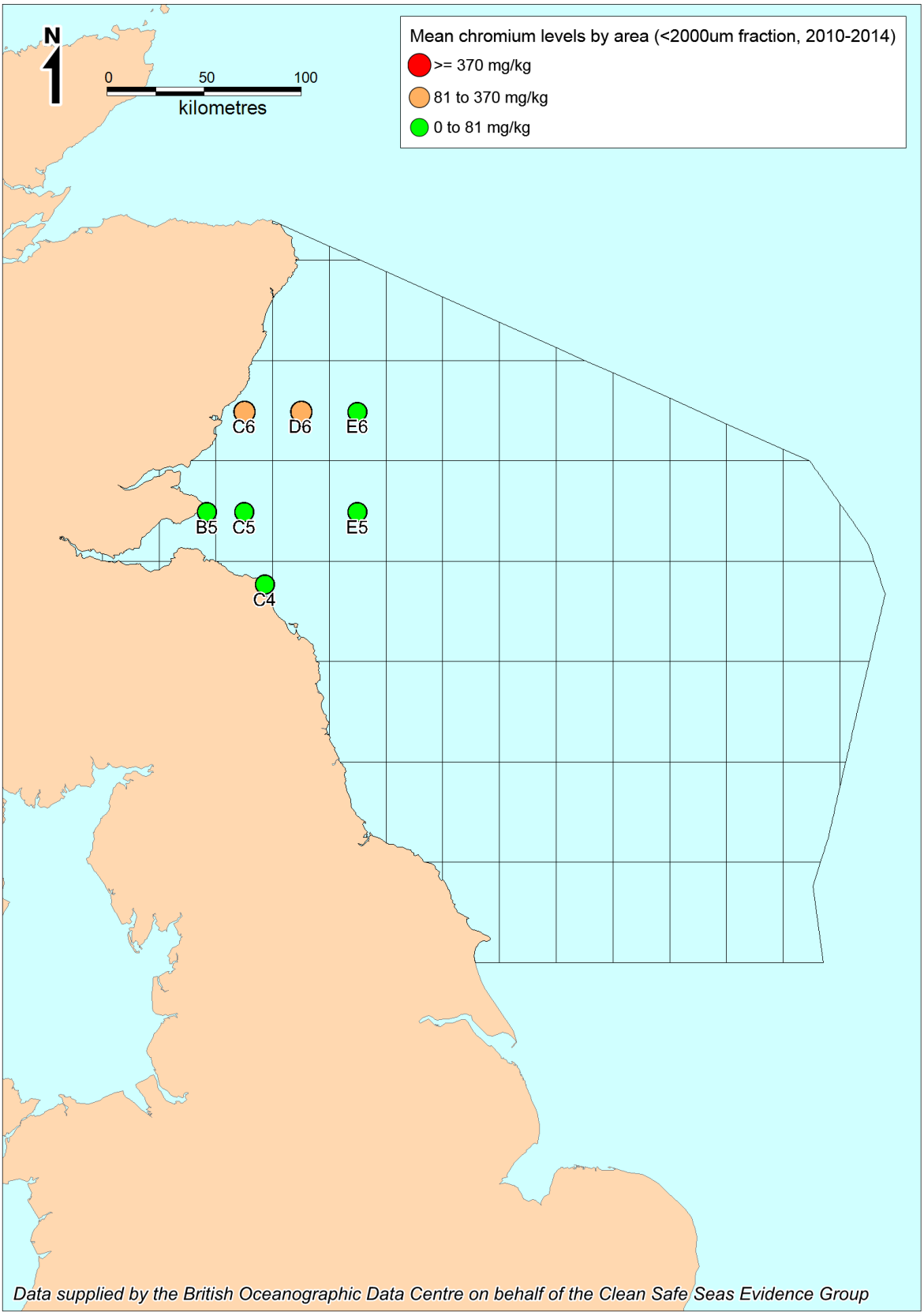

Figure 0:8: Map of mean chromium concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.10: Summary of chromium concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Chromium sample results (mg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
B5	2012	2014	15	57.5	38.8	97.3	7%	0%
C4	2014	2014	1	53.1	53.1	53.1	0%	0%
C5	2010	2014	3	53.6	45.0	65.3	0%	0%
C6	2010	2014	28	94.4	29.0	697.6	18%	4%
D6	2011	2013	2	84.5	44.8	124.1	50%	0%
E5	2010	2012	2	51.8	48.6	55.0	0%	0%
E6	2014	2014	1	43.2	43.2	43.2	0%	0%

Summary Chromium sediment

The CSEMP data analysed between 2005 and 2009 revealed that the majority of offshore and estuarine sectorial boxes (28/30), contained samples where the mean Cr/Al ratios were > ERL but below the ERM (Figure 0:5 to Figure 0:8; Table 0. **Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.** to **Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.** Table 0.). A similar pattern was observed for CSEMP data collected from 2010-2014, with 23/30 sectorial boxes containing samples with a mean Cr/Al ratio >ERL <ERM. Data would suggest that such Cr/Al ratios may lead to toxicological effects in sensitive species at these locations. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal data set was available (http://www.bodc.ac.uk/projects/uk/merman/). The only observable upwards trends for Cr/Al ratios were found in the Tees (seal sands) and a location close to the Durham coast (Off Seaham).

Copper

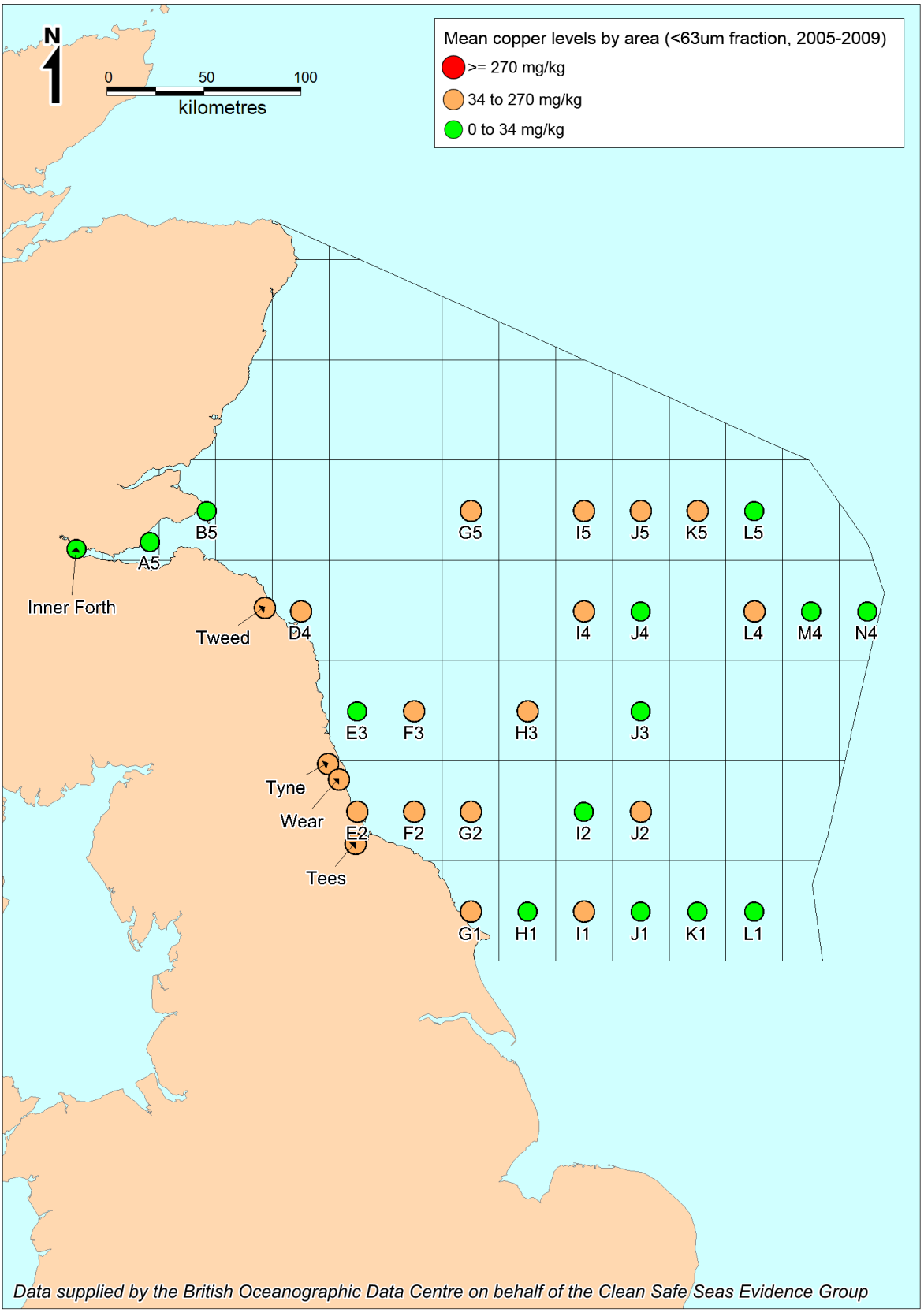

Figure 0:9: Map of mean copper concentrations by area (< 63 µm fraction, 2005-09)

Table 0.2: Summary of copper concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Copper sample results (mg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
A5	2006	2009	7	20.8	17.3	25.6	0%	0%
B5	2005	2009	16	17.2	10.8	24.6	0%	0%
D4	2005	2008	22	44.7	26.4	94.7	59%	0%
E2	2005	2008	42	65.1	31.0	180.6	93%	0%
E3	2005	2009	29	22.2	10.1	69.2	10%	0%
F2	2008	2008	1	52.2	52.2	52.2	100%	0%
F3	2008	2008	3	36.5	28.6	45.5	67%	0%
G1	2008	2008	1	55.1	55.1	55.1	100%	0%
G2	2008	2008	1	52.6	52.6	52.6	100%	0%
G5	2008	2008	1	71.1	71.1	71.1	100%	0%
H1	2006	2006	2	22.1	22.0	22.3	0%	0%
H3	2008	2008	1	40.6	40.6	40.6	100%	0%
I1	2008	2008	1	39.6	39.6	39.6	100%	0%
I2	2006	2008	2	25.3	15.7	34.9	50%	0%
I4	2008	2008	2	53.9	36.9	70.9	100%	0%
I5	2008	2008	1	39.3	39.3	39.3	100%	0%
J1	2006	2006	1	25.2	25.2	25.2	0%	0%
J2	2005	2009	22	46.9	13.1	116.5	50%	0%
J3	2006	2008	2	23.0	21.3	24.7	0%	0%
J4	2008	2008	1	28.2	28.2	28.2	0%	0%
J5	2008	2008	1	52.9	52.9	52.9	100%	0%
K1	2005	2009	21	21.8	12.2	35.7	14%	0%
K5	2008	2008	4	47.4	42.1	56.2	100%	0%
L1	2006	2006	4	20.6	13.9	38.4	25%	0%
L4	2008	2008	1	34.5	34.5	34.5	100%	0%
L5	2008	2008	1	27.8	27.8	27.8	0%	0%
M4	2006	2006	1	18.6	18.6	18.6	0%	0%
N4	2008	2008	1	25.5	25.5	25.5	0%	0%
Tees	2005	2009	45	144.0	53.2	474.1	100%	13%
Tweed	2005	2008	20	40.9	28.7	63.5	65%	0%
Tyne	2005	2009	45	81.1	30.9	277.7	89%	2%
Wear	2005	2009	45	51.2	27.4	95.8	89%	0%
Inner Forth	2005	2009	25	33.0	16.8	66.1	24%	0%

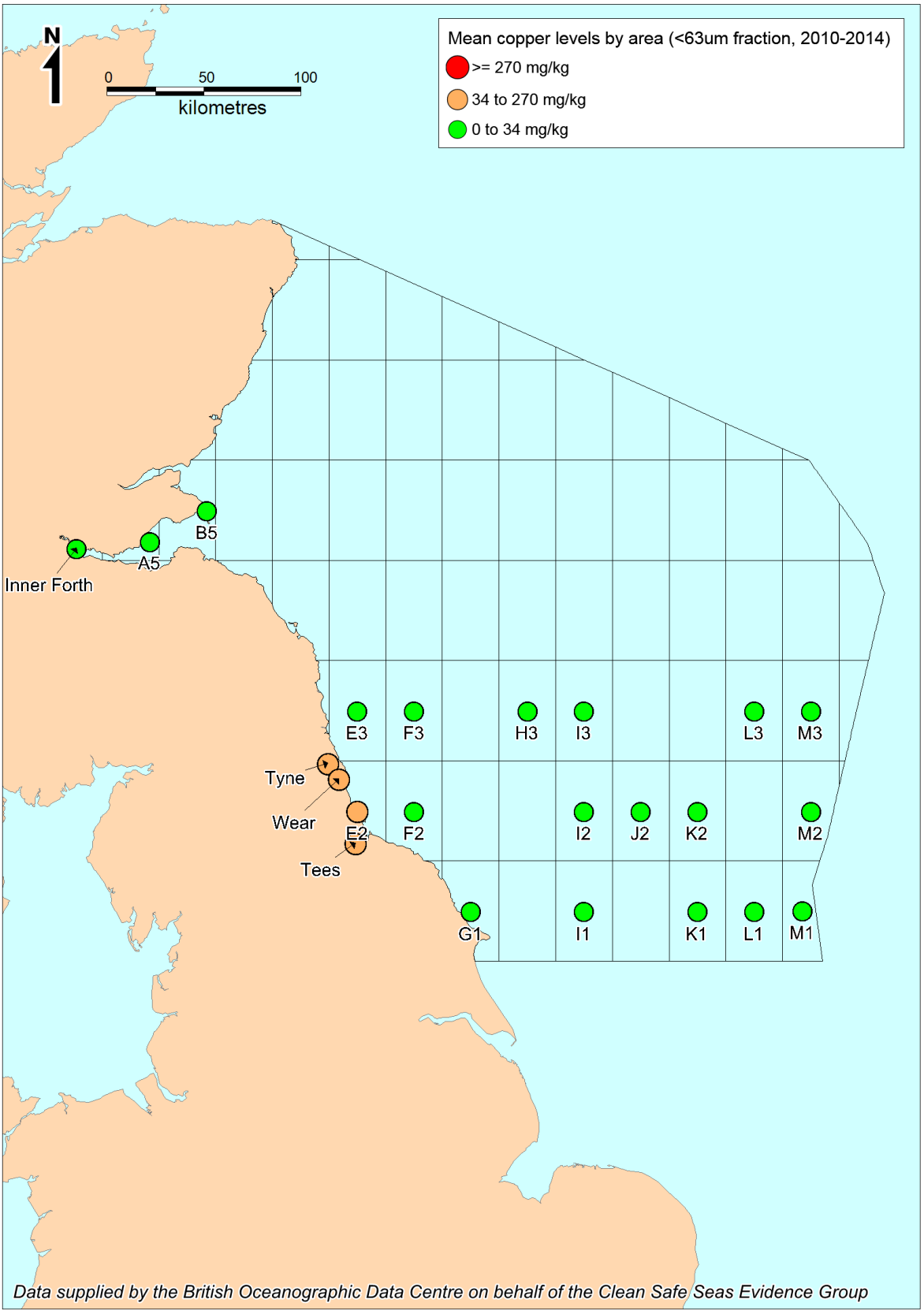

Figure 0:10: Map of mean copper concentrations by area (< 63 µm fraction, 2010-14)

Table 0.12: Summary of copper concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Copper sample results (mg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
A5	2010	2014	19	26.0	3.8	75.2	11%	0%
B5	2010	2014	15	17.6	8.6	44.3	7%	0%
E2	2011	2011	4	43.3	24.3	53.2	75%	0%
E3	2010	2013	19	22.4	13.9	53.6	11%	0%
F2	2010	2013	4	25.5	21.7	28.2	0%	0%
F3	2011	2013	5	18.1	13.8	21.5	0%	0%
G1	2011	2011	1	21.8	21.8	21.8	0%	0%
H3	2011	2013	2	18.8	16.6	21.0	0%	0%
I1	2011	2011	1	18.8	18.8	18.8	0%	0%
I2	2013	2013	1	23.5	23.5	23.5	0%	0%
I3	2013	2013	2	17.2	13.5	20.9	0%	0%
J2	2010	2013	7	24.6	16.8	36.1	14%	0%
K1	2010	2013	7	15.6	11.5	18.3	0%	0%
K2	2011	2011	3	23.9	20.6	29.5	0%	0%
L1	2011	2013	6	21.9	10.4	28.0	0%	0%
L3	2011	2011	1	30.3	30.3	30.3	0%	0%
M1	2011	2013	3	20.5	17.9	23.9	0%	0%
M2	2011	2011	1	30.7	30.7	30.7	0%	0%
M3	2011	2011	1	21.7	21.7	21.7	0%	0%
Tees	2010	2013	10	130.5	79.5	419.8	100%	10%
Tyne	2010	2010	5	50.5	38.0	66.9	100%	0%
Wear	2010	2010	5	48.6	45.1	57.8	100%	0%
Inner Forth	2010	2014	16	32.9	19.6	50.9	56%	0%

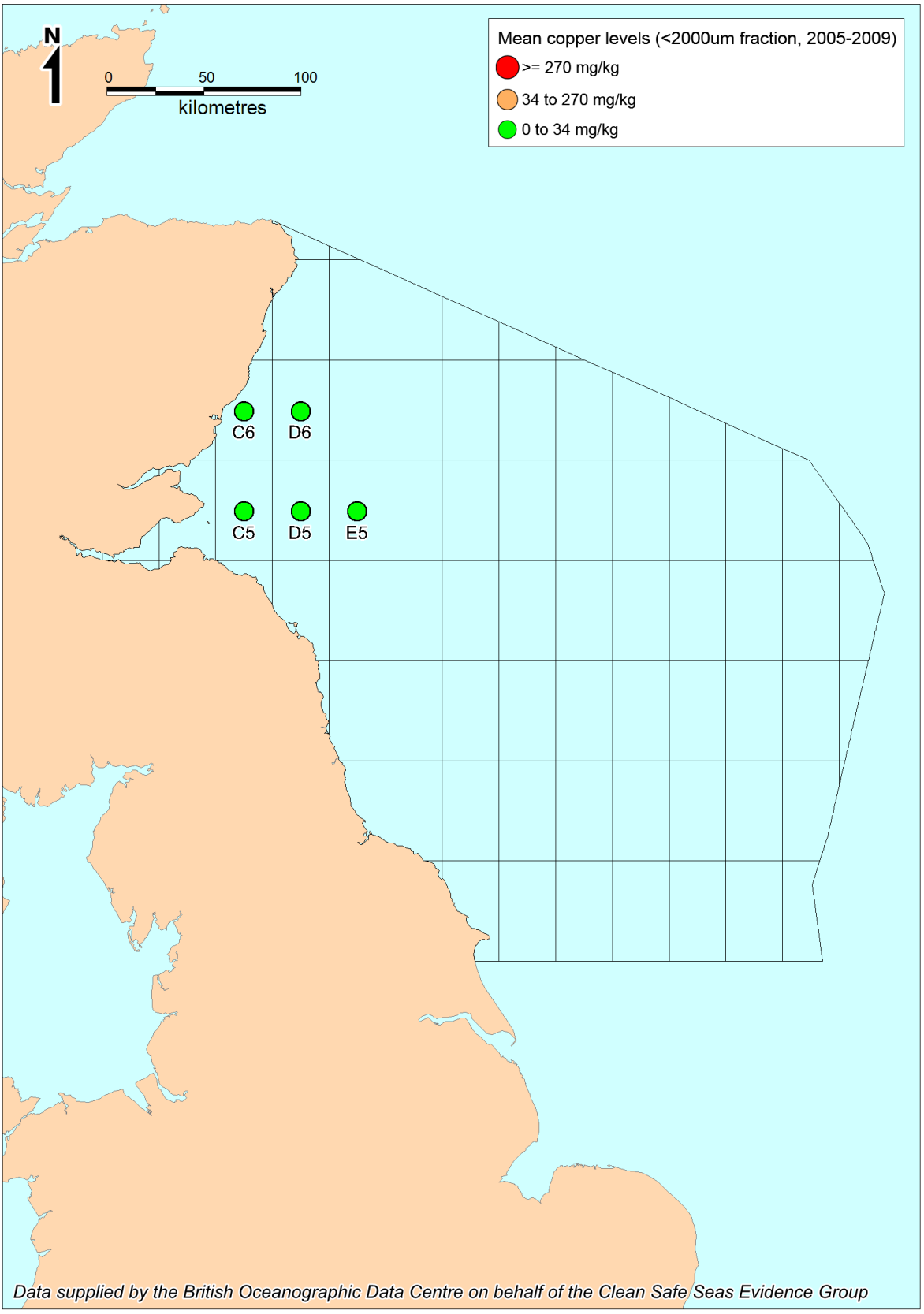

Figure 0:11: Map of mean copper concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.3: Summary of copper concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Copper sample results (mg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
C5	2006	2006	1	3.7	3.7	3.7	0%	0%
C6	2006	2009	19	6.5	4.3	9.9	0%	0%
D5	2006	2009	9	5.1	3.9	6.4	0%	0%
D6	2008	2008	1	6.3	6.3	6.3	0%	0%
E5	2005	2005	5	6.3	4.9	8.9	0%	0%

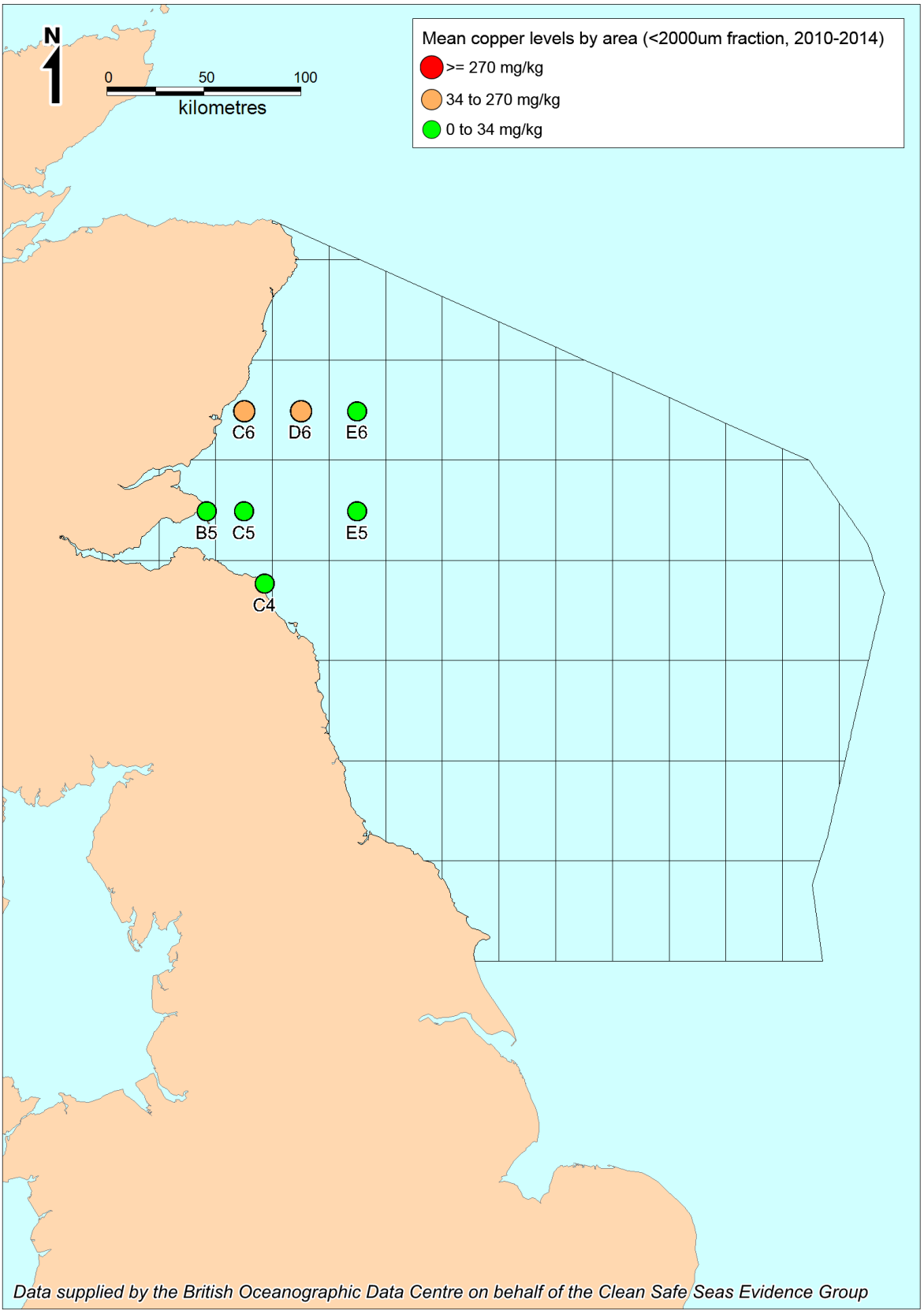

Figure 0:12: Map of mean copper concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.4: Summary of copper concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Copper sample results (mg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
B5	2012	2014	15	5.1	3.8	10.1	0%	0%
C4	2014	2014	1	7.2	7.2	7.2	0%	0%
C5	2010	2014	3	7.9	7.4	8.7	0%	0%
C6	2010	2014	28	49.1	5.7	677.4	18%	4%
D6	2011	2013	2	51.4	5.0	97.8	50%	0%
E5	2010	2012	2	5.4	5.2	5.6	0%	0%
E6	2014	2014	1	4.5	4.5	4.5	0%	0%

Summary copper sediment

The CSEMP data analysed between 2005 and 2009 revealed that a number of offshore and estuarine sectoral boxes (19/38) contained samples where the mean Cu/Al ratios were > ERL but below the ERM (Figure 0:9 to Figure 0:12;Table 0.2 to Table 0.4). The remaining sites were below the ERL and not thought to pose any toxicological risk. The analysis of 2010-2014 found less offshore sites recording a mean Cu/AL ratio above the ERL (6/30). However, sediment samples collected from the Tyne, Wear and Tees still exceeded the ERL. Data would suggest that such Cu/Al ratios at these locations regularly exceeding the ERL may lead to toxicological effects in sensitive species. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal data set was available (http://www.bodc.ac.uk/projects/uk/merman/). The only observable upwards trends for Cu/Al ratios were found in the Tees (seal sands) and a location close to the Durham coast (Off Seaham).

Mercury

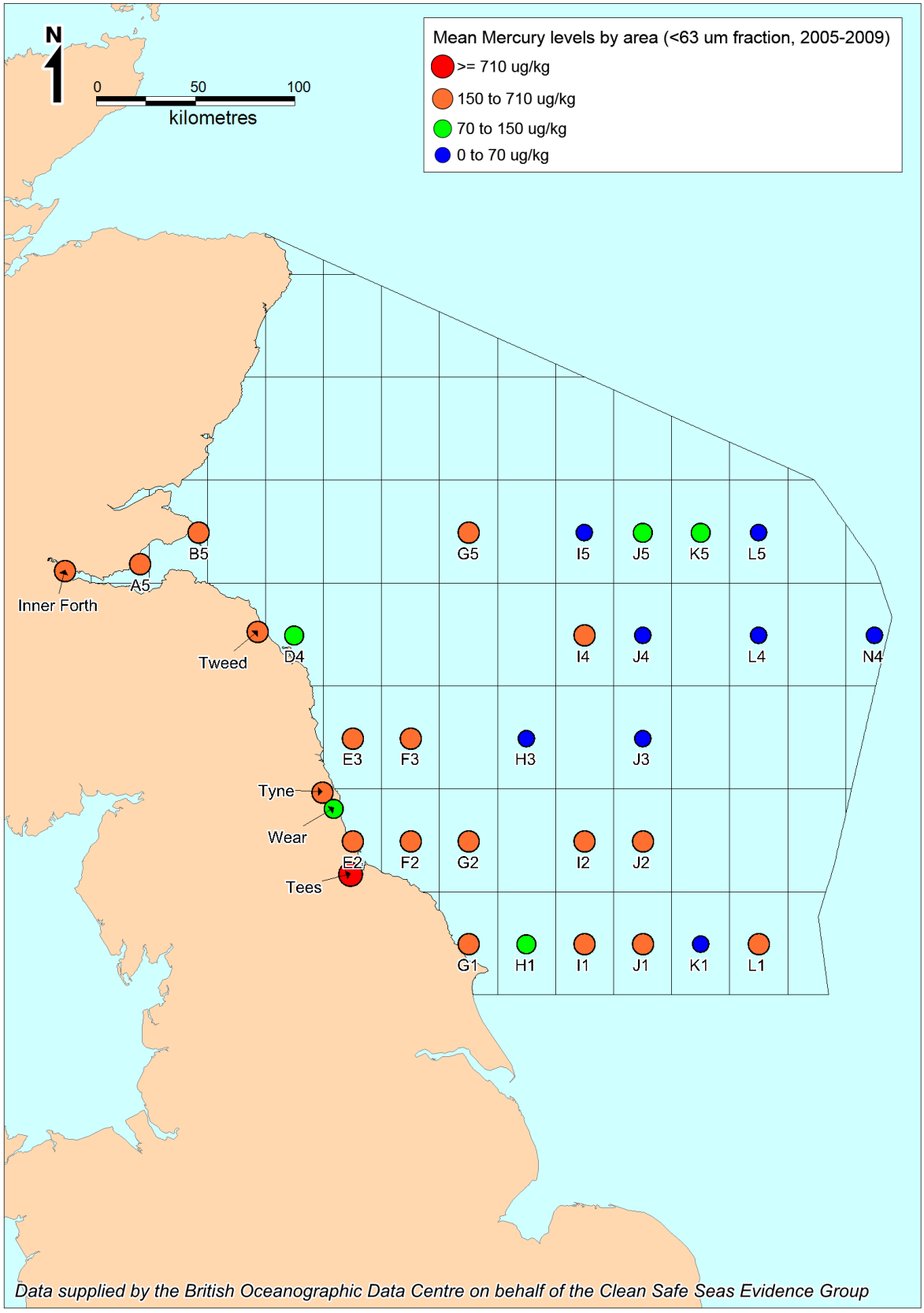

Figure 0:13: Map of mean mercury concentrations by area (< 63 µm fraction, 2005-09)

Table 0.5: Summary of mercury concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Mercury sample results (ug/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2006	2009	7	410.6	292.0	526.8	100%	100%	0%
B5	2005	2009	16	276.7	155.2	815.4	100%	100%	6%
D4	2005	2008	22	104.6	26.5	540.9	36%	23%	0%
E2	2005	2008	42	346.3	117.4	1207.6	100%	83%	14%
E3	2005	2009	28	152.0	21.8	419.9	64%	43%	0%
F2	2008	2008	1	187.8	187.8	187.8	100%	100%	0%
F3	2008	2008	3	244.2	161.1	375.8	100%	100%	0%
G1	2008	2008	1	351.0	351.0	351.0	100%	100%	0%
G2	2008	2008	1	350.4	350.4	350.4	100%	100%	0%
G5	2008	2008	1	237.0	237.0	237.0	100%	100%	0%
H1	2006	2006	2	140.7	95.5	186.0	100%	50%	0%
H3	2008	2008	1	67.7	67.7	67.7	0%	0%	0%
I1	2008	2008	1	342.2	342.2	342.2	100%	100%	0%
I2	2006	2008	2	216.0	83.0	349.0	100%	50%	0%
I4	2008	2008	2	173.9	164.0	183.7	100%	100%	0%
I5	2008	2008	1	56.1	56.1	56.1	0%	0%	0%
J1	2006	2006	1	201.9	201.9	201.9	100%	100%	0%
J2	2005	2009	20	157.0	23.8	657.7	50%	25%	0%
J3	2006	2008	2	63.3	49.3	77.3	50%	0%	0%
J4	2008	2008	1	47.1	47.1	47.1	0%	0%	0%
J5	2008	2008	1	88.1	88.1	88.1	100%	0%	0%
K1	2005	2009	21	66.1	7.6	686.3	10%	5%	0%
K5	2008	2008	4	74.9	61.7	82.6	75%	0%	0%
L1	2006	2006	4	169.0	49.0	517.0	25%	25%	0%
L4	2008	2008	1	49.2	49.2	49.2	0%	0%	0%
L5	2008	2008	1	36.6	36.6	36.6	0%	0%	0%
N4	2008	2008	1	45.4	45.4	45.4	0%	0%	0%
Tees	2005	2009	45	1943.0	476.0	7651.0	100%	100%	89%
Tweed	2005	2008	20	213.7	27.1	1901.2	55%	25%	10%
Tyne	2005	2009	45	338.7	106.8	1319.3	100%	71%	13%
Wear	2005	2009	45	144.8	49.1	446.0	98%	31%	0%
Inner Forth	2005	2009	25	618.5	44.7	1507.0	92%	84%	32%

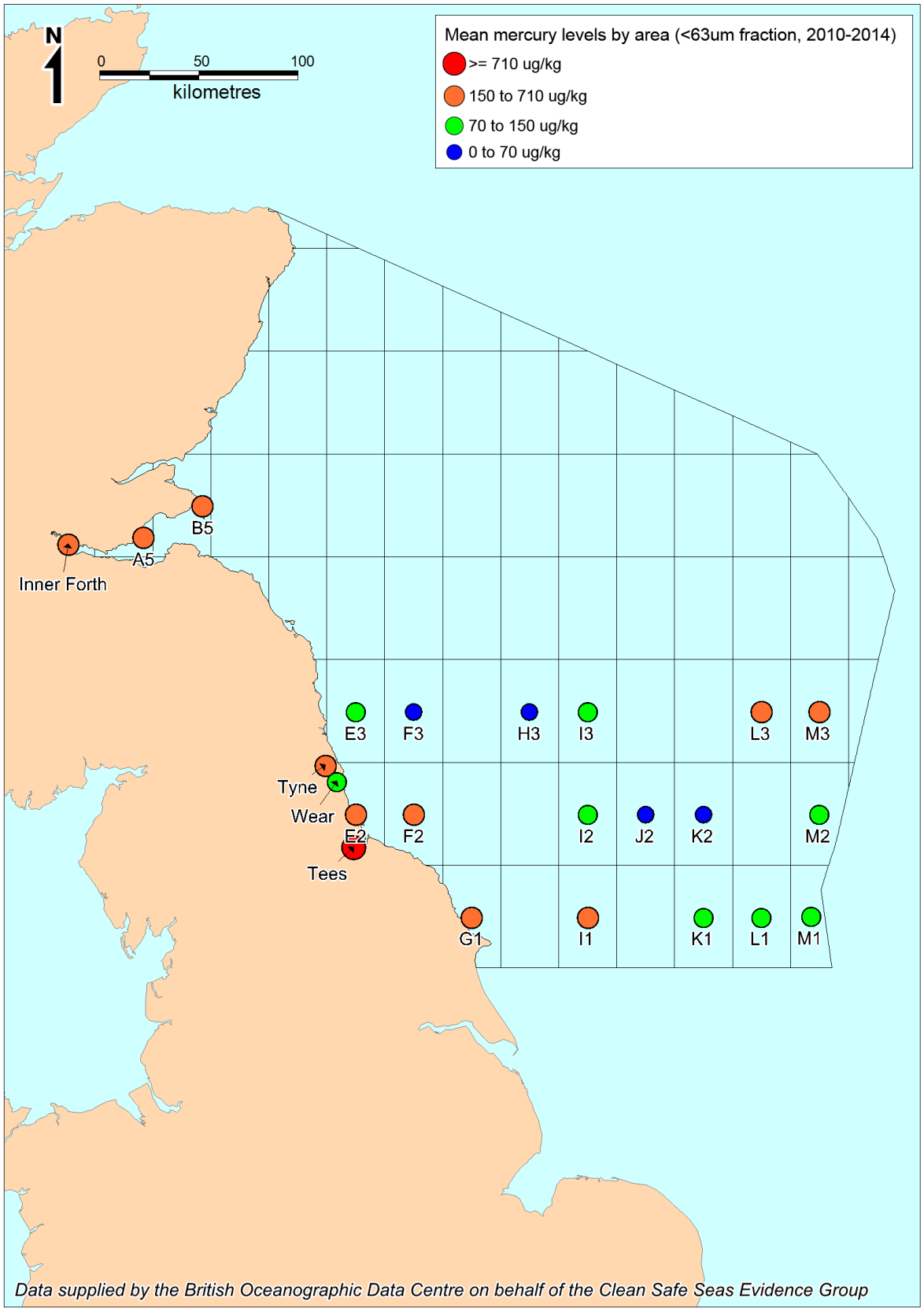

Figure 0:14: Map of mean mercury concentrations by area (< 63 µm fraction, 2010-14)

Table 0.6: Summary of mercury concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Mercury sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2010	2014	19	391.7	62.2	1069.0	95%	95%	5%
B5	2010	2014	15	185.5	111.1	454.5	100%	60%	0%
E2	2011	2011	4	217.1	107.0	293.4	100%	75%	0%
E3	2010	2013	19	129.6	39.2	382.9	58%	32%	0%
F2	2010	2013	4	263.7	178.1	370.4	100%	100%	0%
F3	2011	2013	5	58.2	38.2	81.2	20%	0%	0%
G1	2011	2011	1	208.3	208.3	208.3	100%	100%	0%
H3	2011	2013	2	66.1	50.7	81.4	50%	0%	0%
I1	2011	2011	1	168.7	168.7	168.7	100%	100%	0%
I2	2013	2013	1	73.0	73.0	73.0	100%	0%	0%
I3	2013	2013	2	121.5	49.7	193.2	50%	50%	0%
J2	2010	2013	7	66.1	33.0	129.7	43%	0%	0%
K1	2010	2013	7	78.0	4.6	163.8	43%	14%	0%
K2	2011	2011	3	55.5	46.8	66.0	0%	0%	0%
L1	2011	2013	6	85.1	31.7	171.4	50%	17%	0%
L3	2011	2011	1	172.9	172.9	172.9	100%	100%	0%
M1	2011	2013	3	78.3	66.8	94.0	67%	0%	0%
M2	2011	2011	1	71.9	71.9	71.9	100%	0%	0%
M3	2011	2011	1	153.1	153.1	153.1	100%	100%	0%
Tees	2010	2013	10	1003.0	242.0	5277.0	100%	100%	20%
Tyne	2010	2010	5	201.5	140.9	263.4	100%	80%	0%
Wear	2010	2010	5	137.8	118.4	155.0	100%	20%	0%
Inner Forth	2010	2014	16	602.3	263.2	1354.8	100%	100%	38%

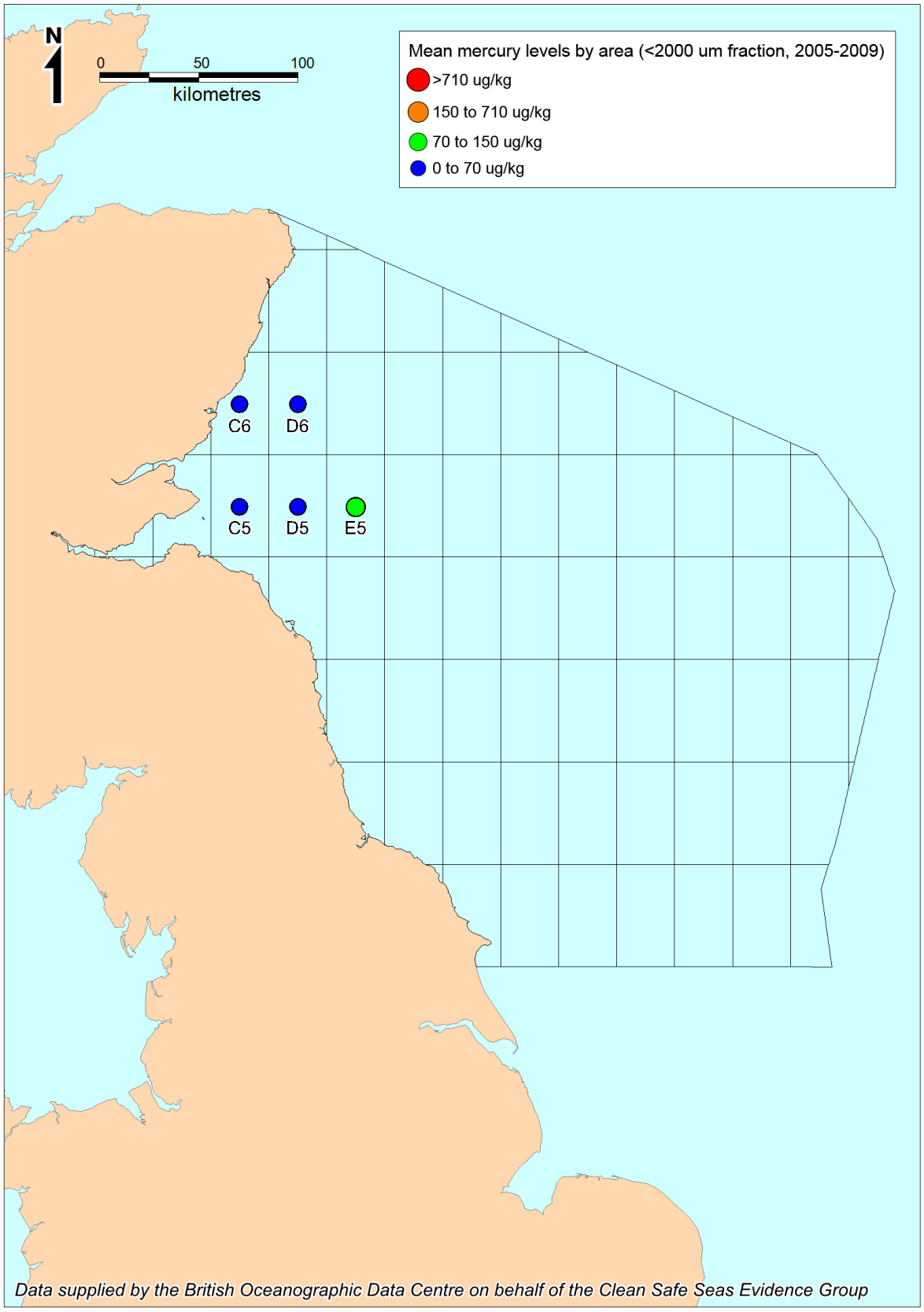

Figure 0:15: Map of mean mercury concentrations by area (<2000 µm fraction, 2005-09)

Table 0.7: Summary of mercury concentrations by area (<2000 µm fraction, 2005-09)

Box	Year		Mercury sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
C5	2006	2006	1	17.8	17.8	17.8	0%	0%	0%
C6	2006	2009	19	27.5	15.1	53.9	0%	0%	0%
D5	2006	2009	9	20.6	8.5	36.8	0%	0%	0%
D6	2008	2008	1	16.6	16.6	16.6	0%	0%	0%
E5	2005	2005	5	81.8	34.7	111.6	80%	0%	0%

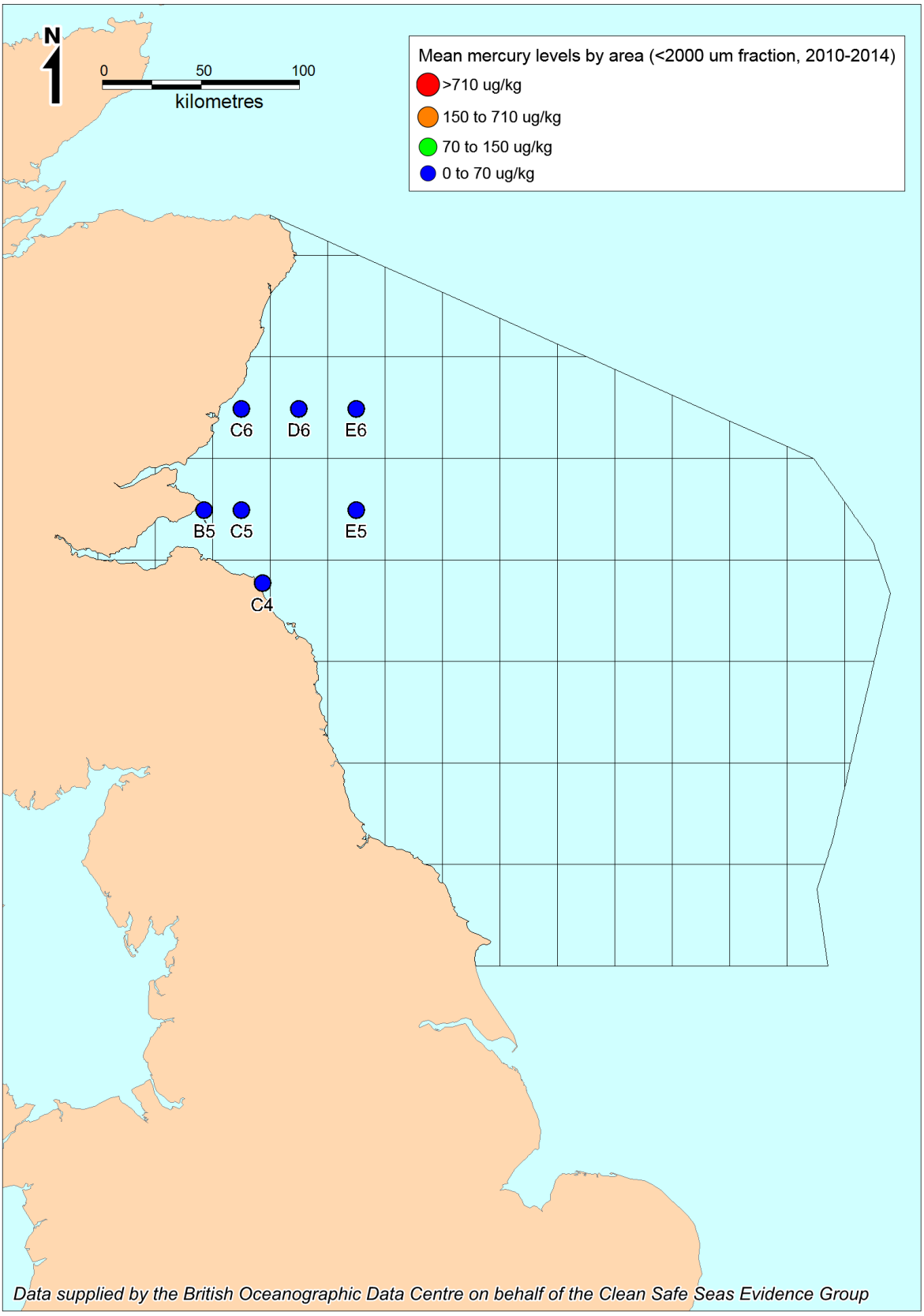

Figure 0:16: Map of mean mercury concentrations by area (<2000 µm fraction, 2010-14)

Table 0.8: Summary of mercury concentrations by area (<2000 µm fraction, 2010-14)

Box	Year		Mercury sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
B5	2012	2014	15	20.3	8.1	117.7	7%	0%	0%
C4	2014	2014	1	48.3	48.3	48.3	0%	0%	0%
C5	2010	2014	3	39.9	16.4	56.2	0%	0%	0%
C6	2010	2014	27	21.5	6.3	55.1	0%	0%	0%
D6	2011	2013	2	8.9	4.0	13.8	0%	0%	0%
E5	2010	2012	2	13.5	8.4	18.6	0%	0%	0%
E6	2014	2014	1	12.9	12.9	12.9	0%	0%	0%

Summary Mercury sediment

The CSEMP data analysed between 2005 and 2009 revealed that a number of offshore and estuarine sectorial boxes (18/37) contained samples where the mean Hg/Al ratios in the sectorial boxes were > ERL but below the ERM (Figure 0:13 to Figure 0:16;Table 0.5 to Table 0.8). In 12 sectorial boxes the mean recoded Hg/Al ratios could be considered close to background. A similar pattern was observed for CSEMP data collected from 2010-2014, where 11/30 sectorial boxes recorded mean Hg/Al ratios close to background. Samples collected from the Tees estuary recorded mean Hg/Al ratios that exceeded the ERM in both 2005-2009 and 2010-2014 datasets. Data suggest that such Hg/Al ratios at these locations are likely to lead to toxicological effects. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal data set was available (http://www.bodc.ac.uk/projects/uk/merman/). The only observable upwards trends for Hg/Al ratios were found in the Wear (Sandy Point), while decreasing trends were observed at sites located in the Forth Estuary.

Lead

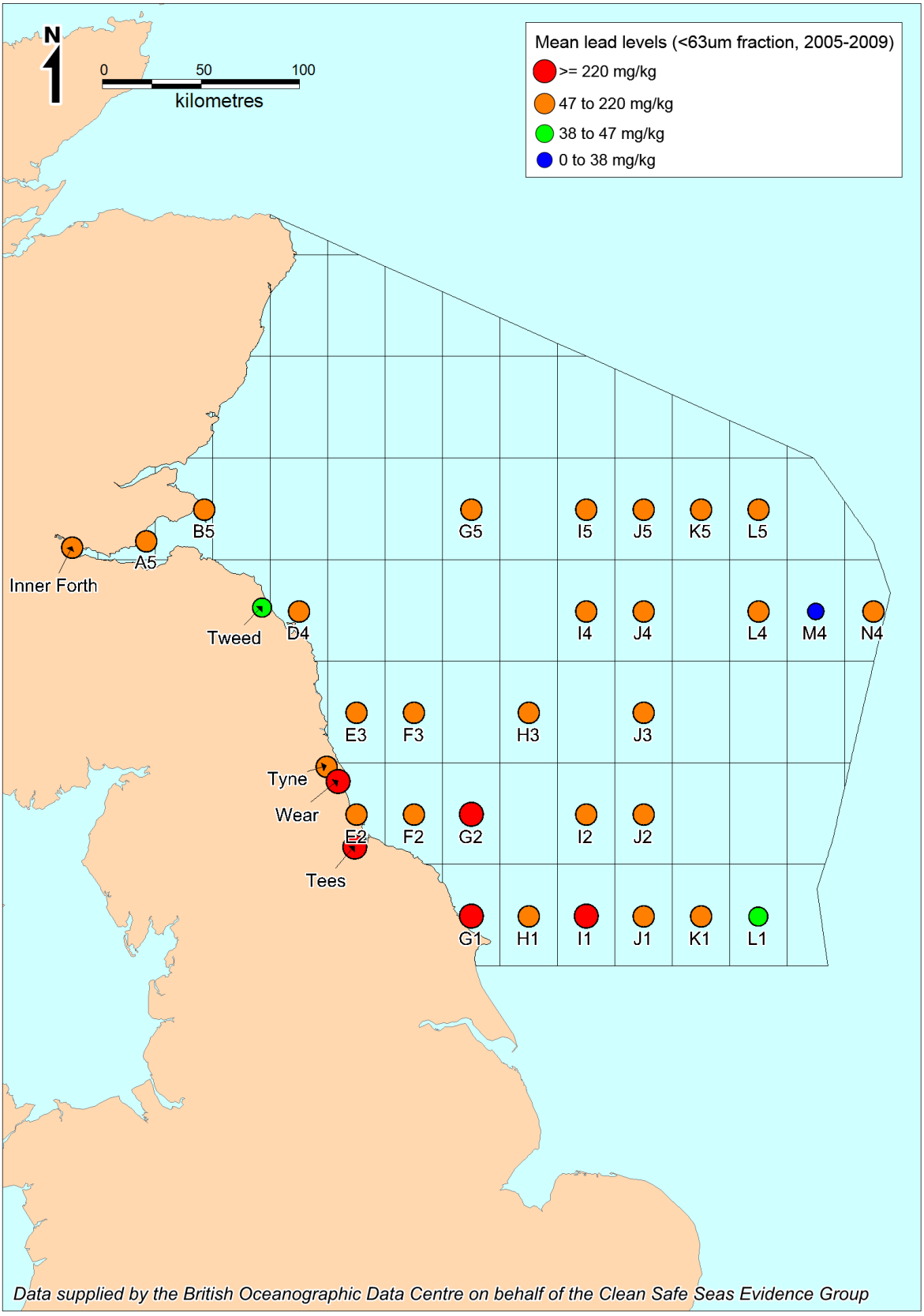

Figure 0:17: Map of mean lead concentrations by area (< 63 µm fraction, 2005-09)

Table 0.9: Summary of lead concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Lead sample results (mg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2006	2009	7	48.7	42.2	55.9	100%	57%	0%
B5	2005	2009	16	60.2	35.3	339.1	69%	13%	6%
D4	2005	2008	22	59.2	24.6	229.9	36%	36%	5%
E2	2005	2008	42	113.4	53.5	313.1	100%	100%	12%
E3	2005	2009	29	76.1	19.3	204.6	97%	69%	0%
F2	2008	2008	1	204.5	204.5	204.5	100%	100%	0%
F3	2008	2008	3	120.0	102.0	144.4	100%	100%	0%
G1	2008	2008	1	235.6	235.6	235.6	100%	100%	100%
G2	2008	2008	1	286.9	286.9	286.9	100%	100%	100%
G5	2008	2008	1	197.5	197.5	197.5	100%	100%	0%
H1	2006	2006	2	83.0	80.0	85.9	100%	100%	0%
H3	2008	2008	1	138.1	138.1	138.1	100%	100%	0%
I1	2008	2008	1	239.6	239.6	239.6	100%	100%	100%
I2	2006	2008	2	89.1	52.9	125.3	100%	100%	0%
I4	2008	2008	2	206.6	202.1	211.1	100%	100%	0%
I5	2008	2008	1	120.6	120.6	120.6	100%	100%	0%
J1	2006	2006	1	80.8	80.8	80.8	100%	100%	0%
J2	2005	2009	22	67.6	20.8	163.5	73%	68%	0%
J3	2006	2008	2	72.0	57.5	86.6	100%	100%	0%
J4	2008	2008	1	122.4	122.4	122.4	100%	100%	0%
J5	2008	2008	1	193.9	193.9	193.9	100%	100%	0%
K1	2005	2009	21	47.3	23.2	78.0	62%	48%	0%
K5	2008	2008	4	166.8	159.5	172.6	100%	100%	0%
L1	2006	2006	4	38.4	30.1	55.7	25%	25%	0%
L4	2008	2008	1	145.3	145.3	145.3	100%	100%	0%
L5	2008	2008	1	98.1	98.1	98.1	100%	100%	0%
M4	2006	2006	1	37.1	37.1	37.1	0%	0%	0%
N4	2008	2008	1	107.3	107.3	107.3	100%	100%	0%
Tees	2005	2009	45	451.3	61.5	1163.9	100%	100%	78%
Tweed	2005	2008	20	43.2	28.0	86.8	30%	25%	0%
Tyne	2005	2009	45	216.1	56.6	762.0	100%	100%	42%
Wear	2005	2009	45	285.0	58.6	801.7	100%	100%	47%
Inner Forth	2005	2009	25	52.0	20.4	77.7	88%	60%	0%

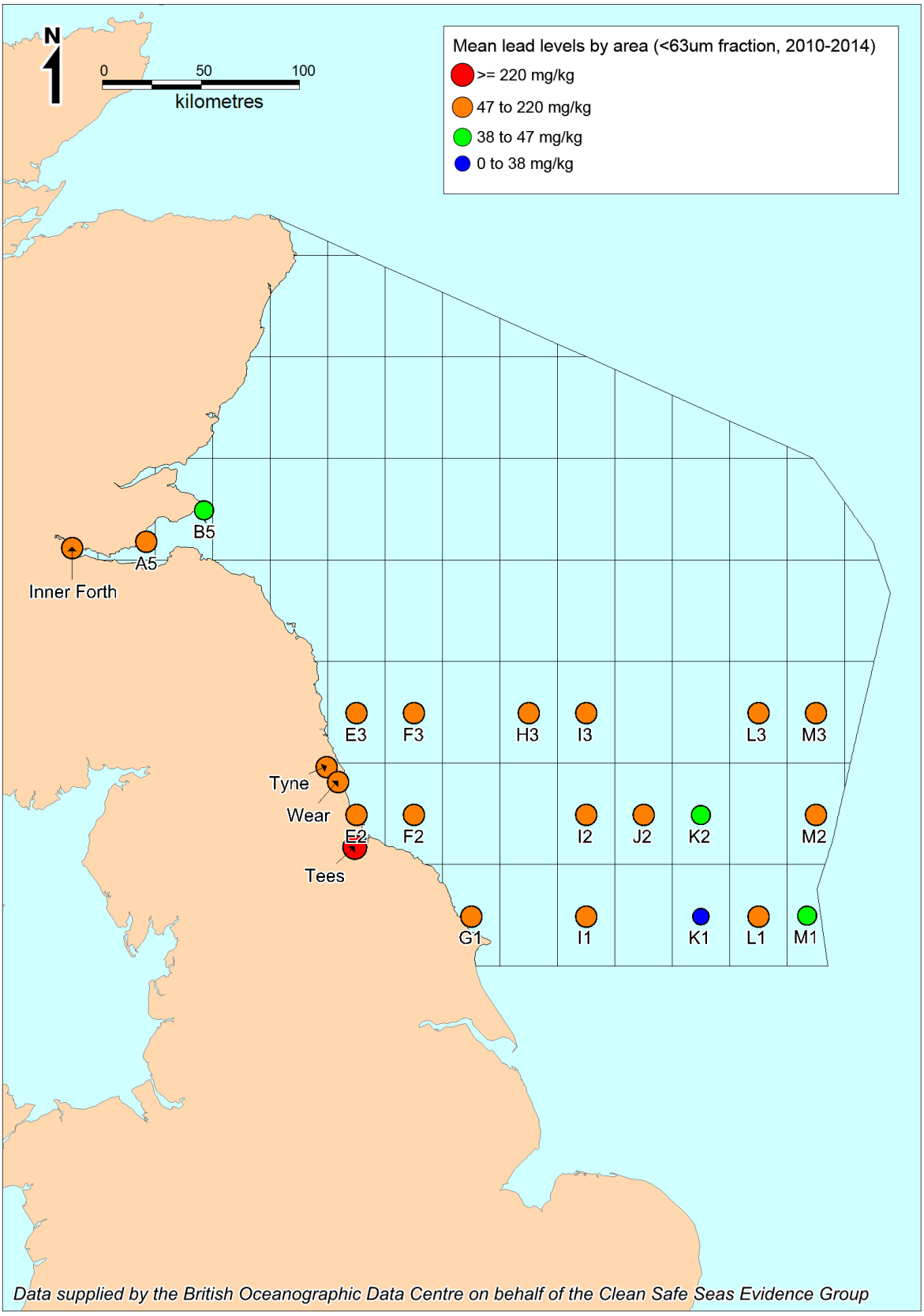

Figure 0:18: Map of mean lead concentrations by area (< 63 µm fraction, 2010-14)

Table 0.20: Summary of lead concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Lead sample results (mg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2010	2014	19	68.6	7.4	190.9	84%	58%	0%
B5	2010	2014	15	42.7	30.1	105.2	60%	13%	0%
E2	2011	2011	4	123.3	70.0	158.0	100%	100%	0%
E3	2010	2013	19	71.2	34.8	218.1	89%	84%	0%
F2	2010	2013	4	118.8	102.9	152.5	100%	100%	0%
F3	2011	2013	5	62.8	36.7	81.8	80%	80%	0%
G1	2011	2011	1	74.4	74.4	74.4	100%	100%	0%
H3	2011	2013	2	72.8	49.8	95.8	100%	100%	0%
I1	2011	2011	1	164.7	164.7	164.7	100%	100%	0%
I2	2013	2013	1	102.7	102.7	102.7	100%	100%	0%
I3	2013	2013	2	74.6	58.2	91.1	100%	100%	0%
J2	2010	2013	7	55.0	31.3	87.5	71%	43%	0%
K1	2010	2013	7	35.9	24.2	55.5	29%	14%	0%
K2	2011	2011	3	43.3	39.5	47.2	100%	33%	0%
L1	2011	2013	6	55.4	26.5	86.3	83%	50%	0%
L3	2011	2011	1	77.8	77.8	77.8	100%	100%	0%
M1	2011	2013	3	41.9	35.4	47.1	67%	33%	0%
M2	2011	2011	1	57.7	57.7	57.7	100%	100%	0%
M3	2011	2011	1	58.7	58.7	58.7	100%	100%	0%
Tees	2010	2013	10	359.0	172.5	874.0	100%	100%	80%
Tyne	2010	2010	5	66.5	60.7	74.8	100%	100%	0%
Wear	2010	2010	5	123.8	106.3	149.8	100%	100%	0%
Inner Forth	2010	2014	16	58.3	36.2	93.3	88%	63%	0%

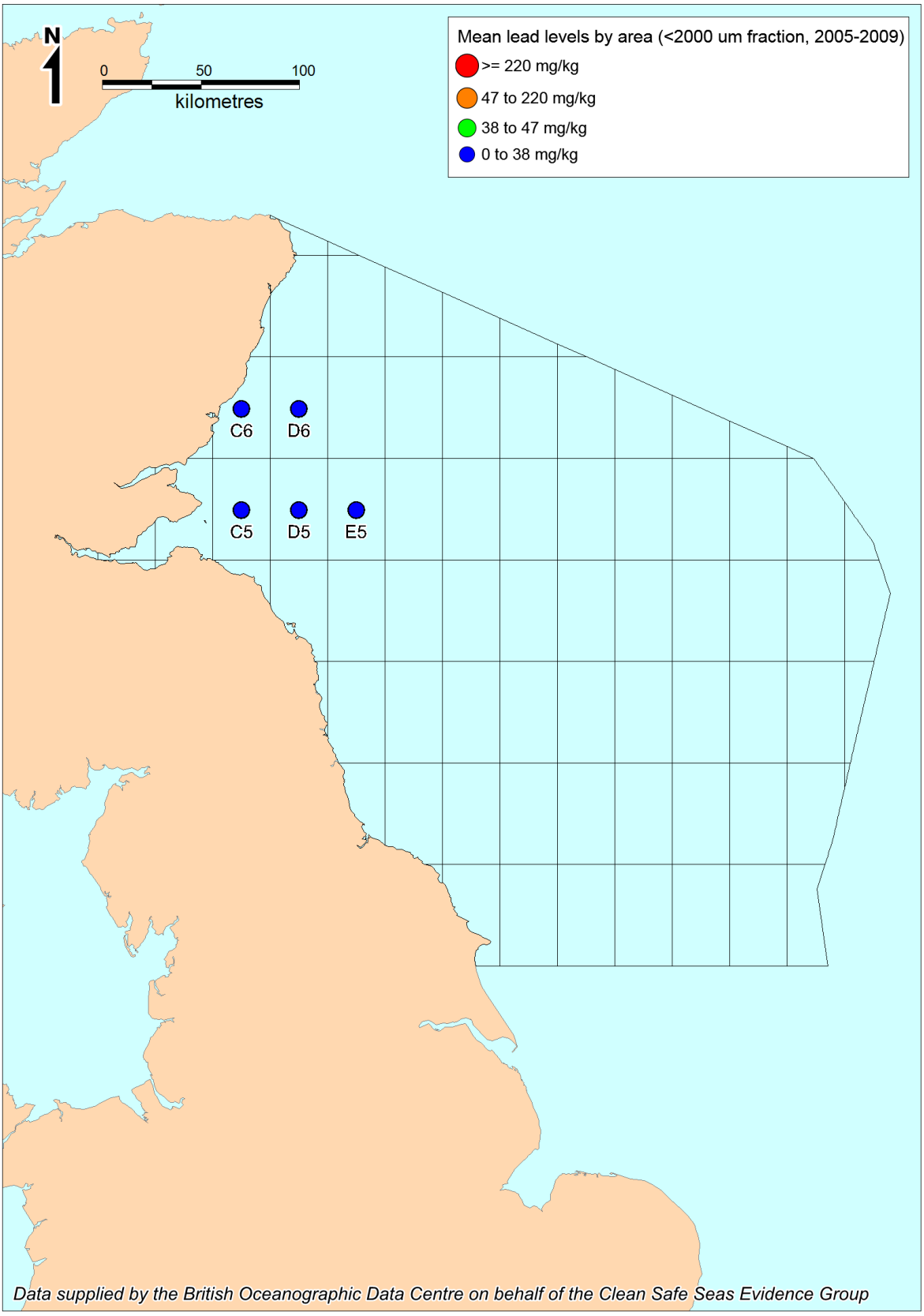

Figure 0:19: Map of mean lead concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.10: Summary of lead concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Lead sample results (mg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
C5	2006	2006	1	15.6	15.6	15.6	0%	0%	0%
C6	2006	2009	19	21.4	15.2	26.6	0%	0%	0%
D5	2006	2009	9	31.1	24.8	38.5	11%	0%	0%
D6	2008	2008	1	25.5	25.5	25.5	0%	0%	0%
E5	2005	2005	5	32.1	30.6	34.3	0%	0%	0%

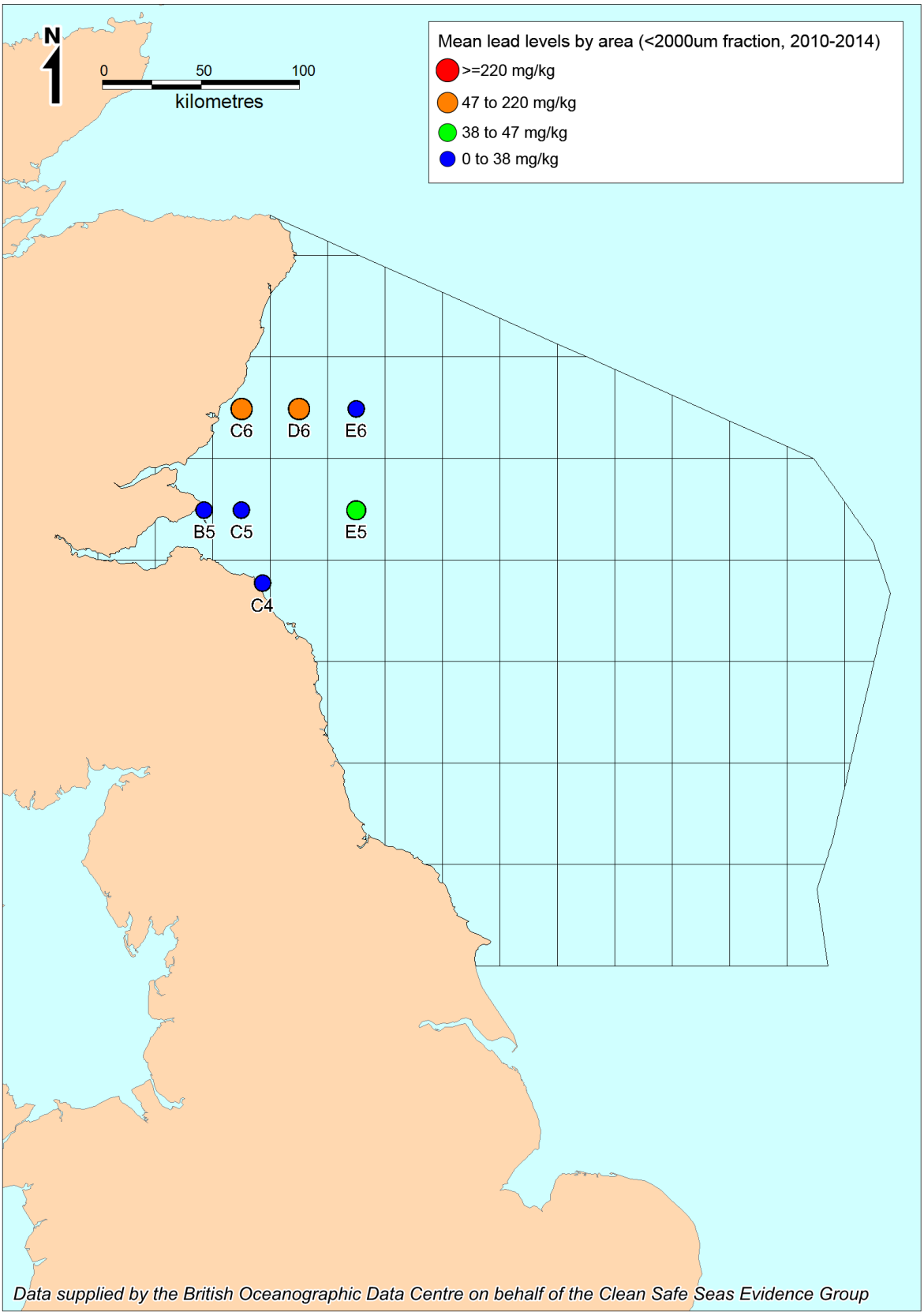

Figure 0:20: Map of mean lead concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.11: Summary of lead concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Lead sample results (mg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
B5	2012	2014	15	18.9	13.8	31.9	0%	0%	0%
C4	2014	2014	1	26.0	26.0	26.0	0%	0%	0%
C5	2010	2014	3	23.9	21.3	25.3	0%	0%	0%
C6	2010	2014	28	61.3	14.9	754.0	18%	18%	4%
D6	2011	2013	2	50.4	27.9	72.9	50%	50%	0%
E5	2010	2012	2	39.3	32.1	46.4	50%	0%	0%
E6	2014	2014	1	24.8	24.8	24.8	0%	0%	0%

Summary Lead sediment

The CSEMP data analysed between 2005 and 2009 revealed that a number of offshore and estuarine sectorial boxes (30/38) contained samples where the mean Pb/Al ratios in the sectorial boxes were > ERL. Of these 5 sectorial boxes contained samples with the mean Pb/Al ratio > than the ERM (Figure 0:17 to Figure 0:20;Table 0.9 to Table 0.11). A similar pattern was observed for CSEMP data collected from 2010-2014 with 21/30 sectorial boxes containing mean Pb/Al ratios above the ERL. In one case this also exceeded the ERM. Data suggest that such Pb/Al ratios may lead to toxicological effects in sensitive species at these locations. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Zinc

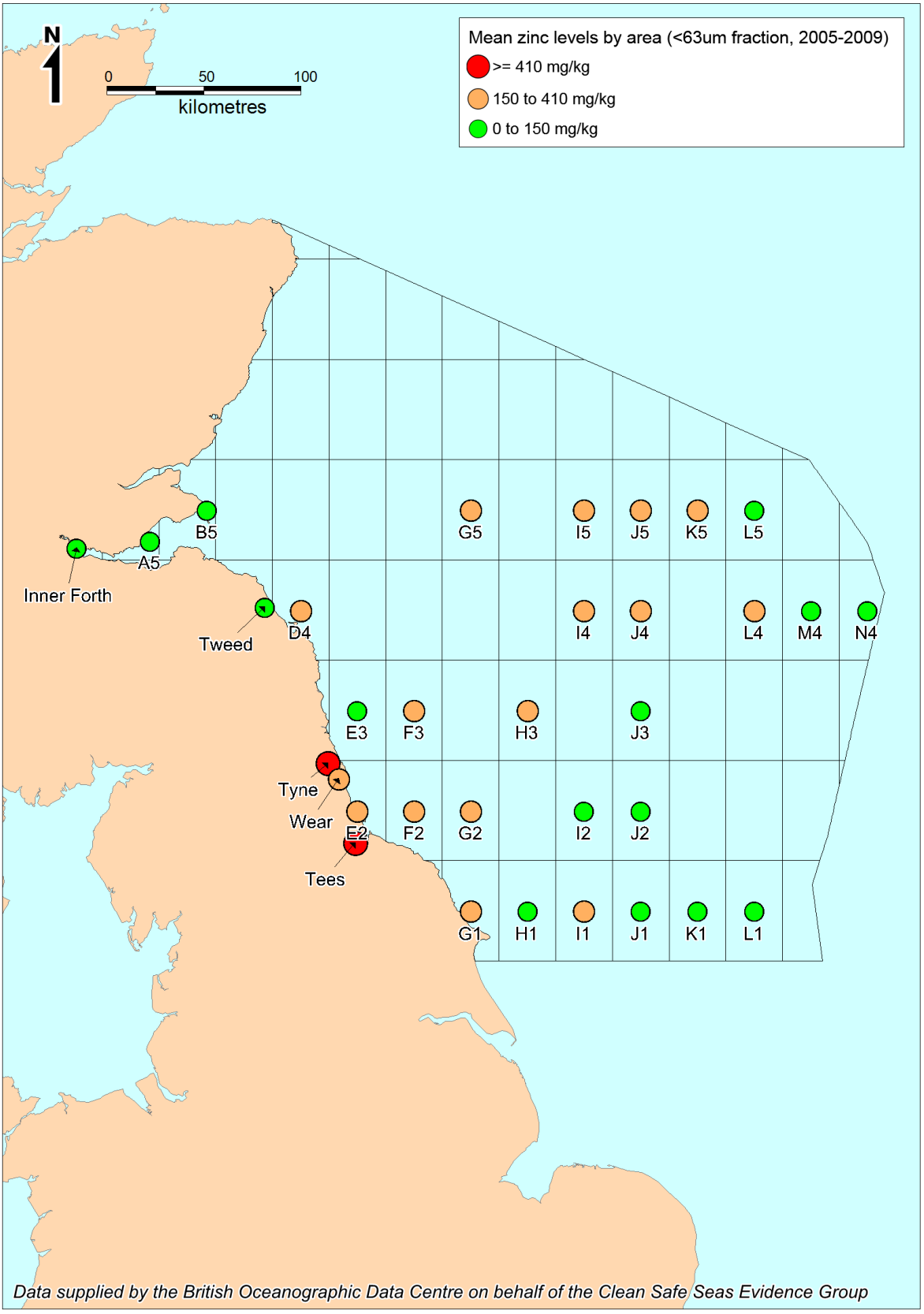

Figure 0:21: Map of mean zinc concentrations by area (< 63 µm fraction, 2005-09)

Table 0.12: Summary of zinc concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Zinc sample results (mg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
A5	2006	2009	7	95.5	78.2	116.6	0%	0%
B5	2005	2009	16	82.8	66.8	102.6	0%	0%
D4	2005	2008	22	153.1	61.0	459.7	32%	5%
E2	2005	2008	42	198.9	92.9	647.3	33%	12%
E3	2005	2009	29	114.2	51.1	343.0	17%	0%
F2	2008	2008	1	269.2	269.2	269.2	100%	0%
F3	2008	2008	3	197.1	148.6	237.4	67%	0%
G1	2008	2008	1	254.0	254.0	254.0	100%	0%
G2	2008	2008	1	297.9	297.9	297.9	100%	0%
G5	2008	2008	1	383.2	383.2	383.2	100%	0%
H1	2006	2006	2	113.1	109.8	116.5	0%	0%
H3	2008	2008	1	238.2	238.2	238.2	100%	0%
I1	2008	2008	1	201.7	201.7	201.7	100%	0%
I2	2006	2008	2	134.2	91.7	176.6	50%	0%
I4	2008	2008	2	277.4	221.4	333.3	100%	0%
I5	2008	2008	1	210.3	210.3	210.3	100%	0%
J1	2006	2006	1	140.1	140.1	140.1	0%	0%
J2	2005	2009	22	137.3	59.1	386.4	32%	0%
J3	2006	2008	2	117.7	85.4	150.0	0%	0%
J4	2008	2008	1	158.2	158.2	158.2	100%	0%
J5	2008	2008	1	299.7	299.7	299.7	100%	0%
K1	2005	2009	20	108.1	50.0	211.5	20%	0%
K5	2008	2008	4	251.1	240.7	265.3	100%	0%
L1	2006	2006	4	96.7	72.0	148.4	0%	0%
L4	2008	2008	1	194.5	194.5	194.5	100%	0%
L5	2008	2008	1	123.0	123.0	123.0	0%	0%
M4	2006	2006	1	85.9	85.9	85.9	0%	0%
N4	2008	2008	1	149.1	149.1	149.1	0%	0%
Tees	2005	2009	45	507.3	127.0	1203.0	98%	44%
Tweed	2005	2008	20	137.0	87.7	285.0	25%	0%
Tyne	2005	2009	45	462.6	105.1	1936.7	78%	49%
Wear	2005	2009	45	291.0	101.8	843.2	84%	18%
Inner Forth	2005	2009	20	108.3	76.9	171.0	10%	0%

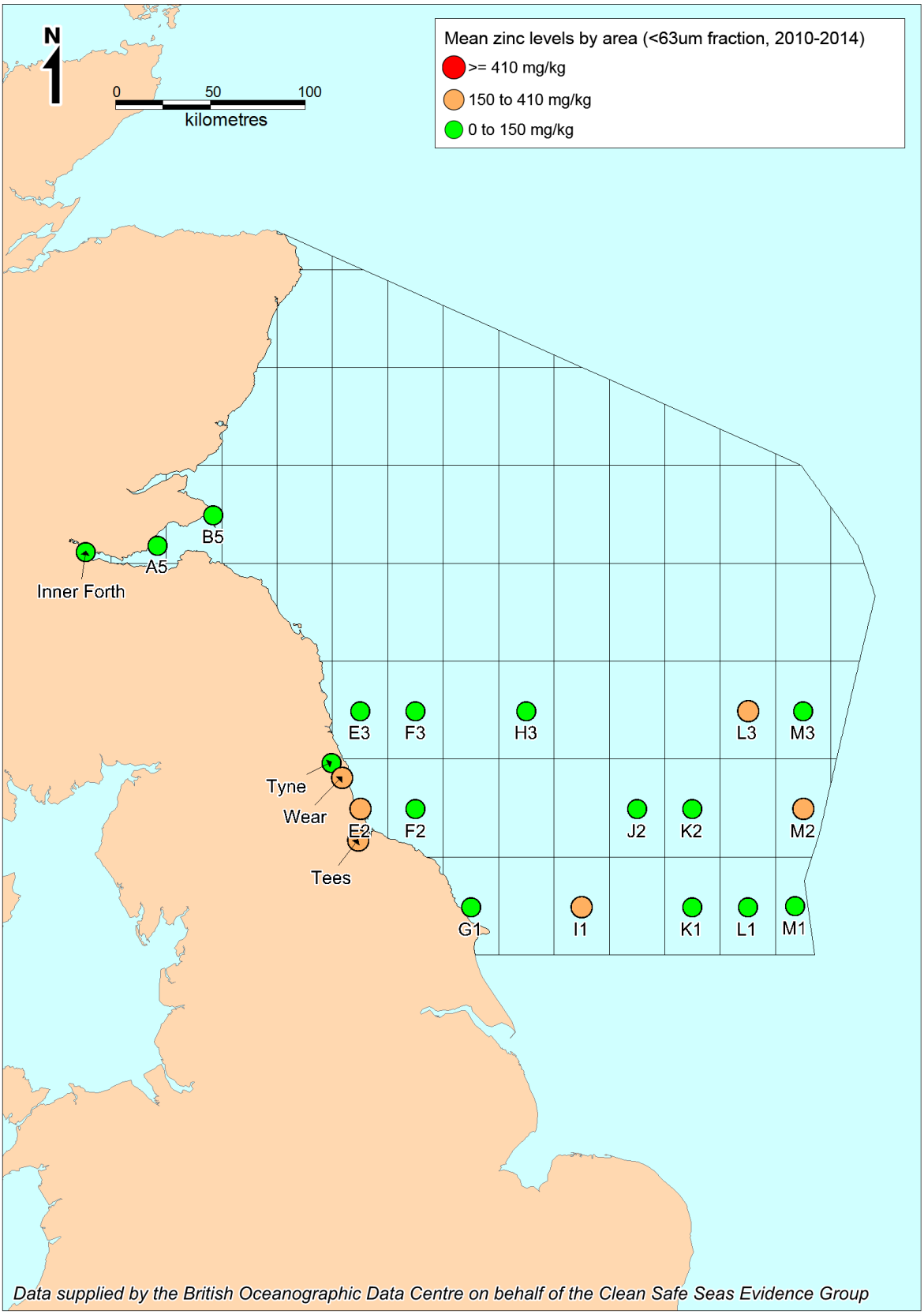

Figure 0:22: Map of mean zinc concentrations by area (< 63 µm fraction, 2010-14)

Table 0.13: Summary of zinc concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Zinc sample results (mg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
A5	2010	2014	19	124.6	15.7	338.3	16%	0%
B5	2010	2014	15	88.9	66.3	198.9	7%	0%
E2	2011	2011	4	182.7	117.7	228.4	75%	0%
E3	2010	2011	14	101.5	75.9	173.7	14%	0%
F2	2010	2011	2	132.6	124.8	140.5	0%	0%
F3	2011	2011	2	94.4	78.0	110.9	0%	0%
G1	2011	2011	1	101.2	101.2	101.2	0%	0%
H3	2011	2011	1	94.1	94.1	94.1	0%	0%
I1	2011	2011	1	155.8	155.8	155.8	100%	0%
J2	2010	2011	6	117.2	78.7	164.9	13%	0%
K1	2010	2011	6	77.8	55.5	93.5	17%	0%
K2	2011	2011	3	113.9	106.1	128.9	0%	0%
L1	2011	2011	3	98.3	60.8	131.7	0%	0%
L3	2011	2011	1	172.9	172.9	172.9	0%	0%
M1	2011	2011	2	122.8	110.2	135.4	100%	0%
M2	2011	2011	1	163.4	163.4	163.4	0%	0%
M3	2011	2011	1	122.5	122.5	122.5	100%	0%
Tees	2010	2013	10	404.7	303.5	745.2	0%	0%
Tyne	2010	2010	5	135.8	125.0	150.5	100%	30%
Wear	2010	2010	5	150.1	137.7	172.2	20%	0%
Inner Forth	2010	2014	16	125.4	84.5	169.1	40%	0%

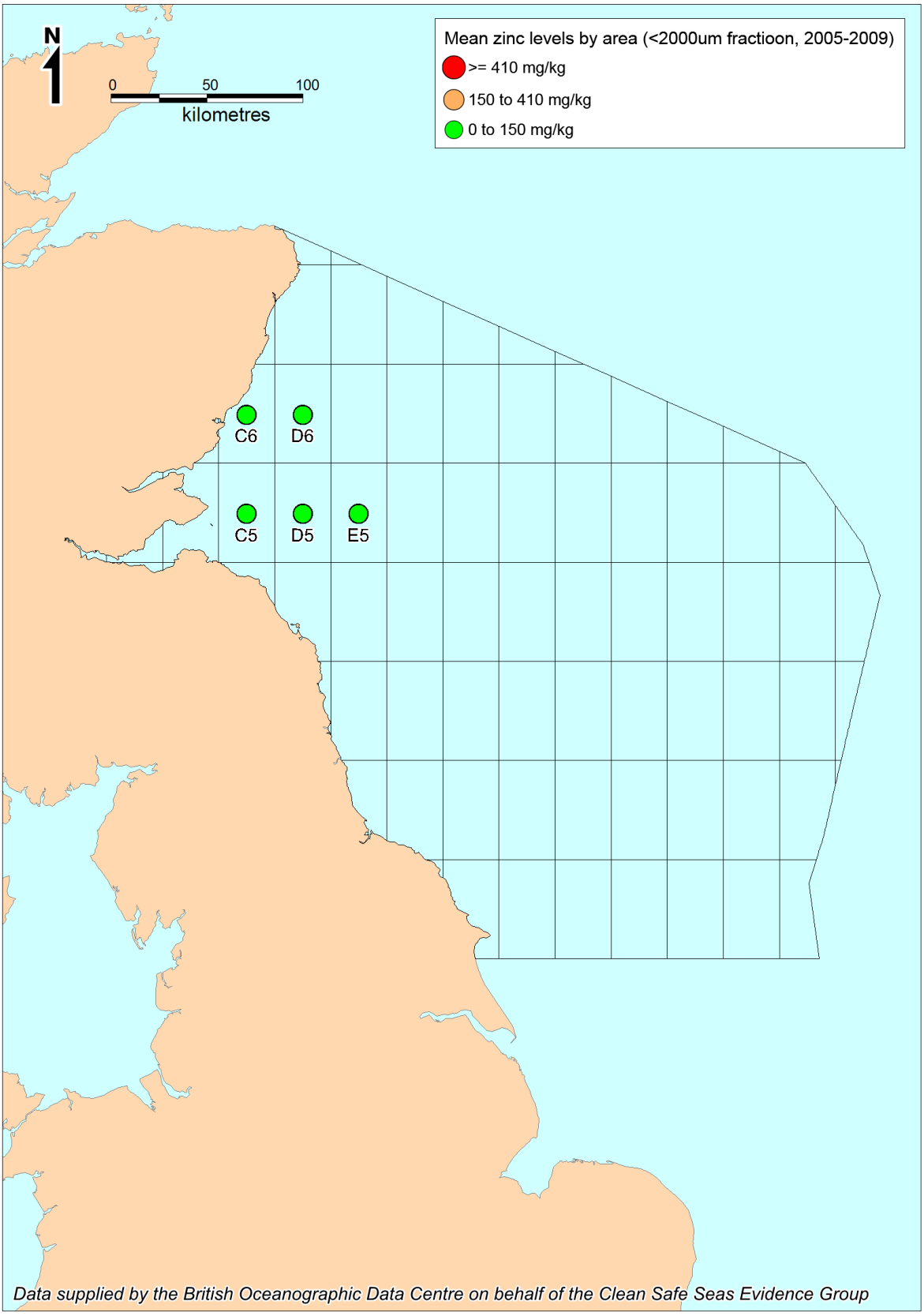

Figure 0:23: Map of mean zinc concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.14: Summary of zinc concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Zinc sample results (mg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
C5	2006	2006	1	28.1	28.1	28.1	0%	0%
C6	2006	2009	19	46.7	31.7	62.6	0%	0%
D5	2006	2009	9	34.8	29.1	45.8	0%	0%
D6	2008	2008	1	32.6	32.6	32.6	0%	0%
E5	2005	2005	5	29.2	27.9	30.8	0%	0%

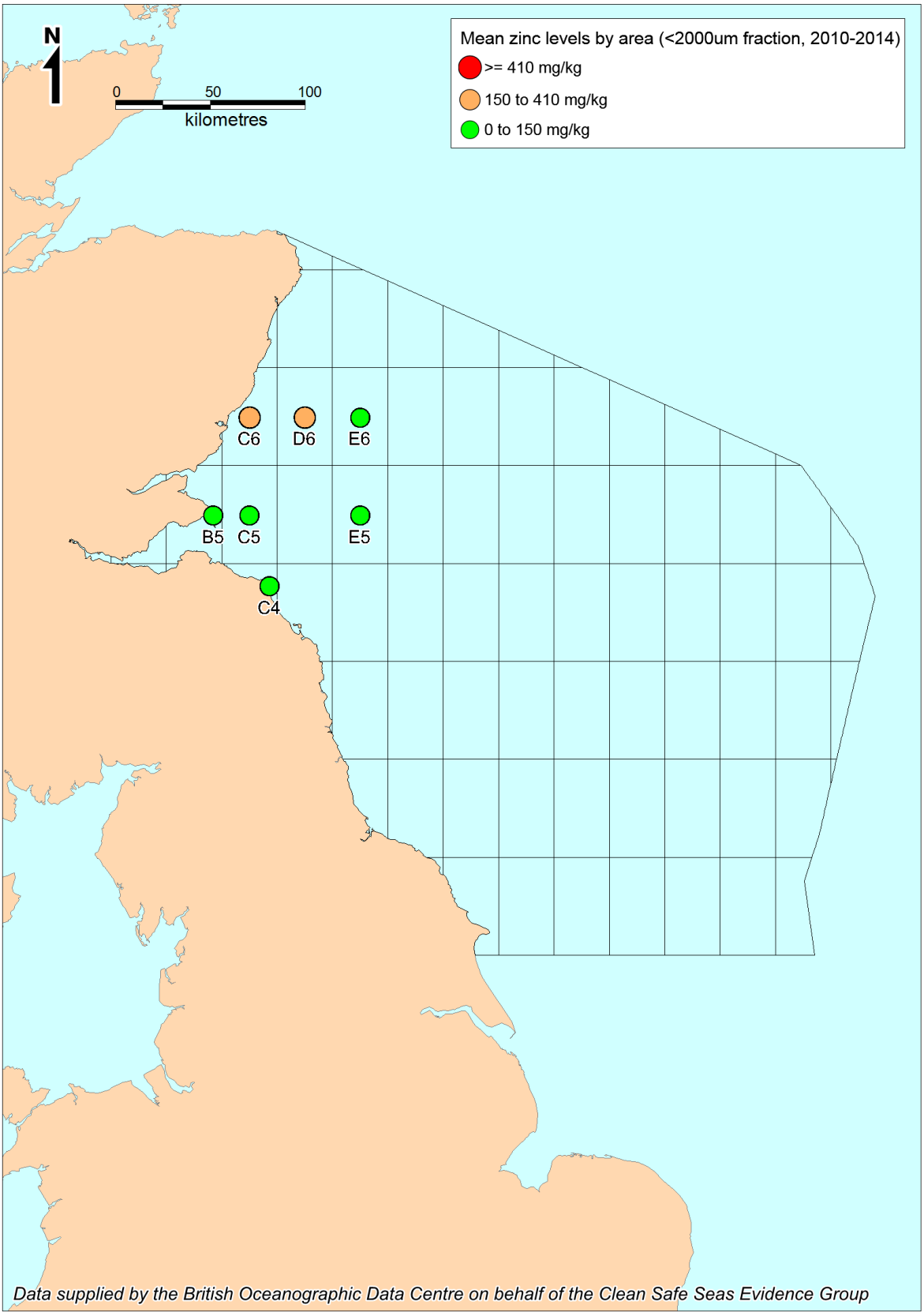

Figure 0:24: Map of mean zinc concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.15: Summary of zinc concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Zinc sample results (mg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
B5	2012	2014	15	46.3	34.0	138.0	0%	0%
C4	2014	2014	1	44.5	44.5	44.5	0%	0%
C5	2010	2014	3	46.6	42.3	51.6	0%	0%
C6	2010	2014	27	189.2	38.6	1588.7	19%	11%
D6	2011	2013	2	316.0	31.0	600.0	50%	50%
E5	2010	2012	2	36.8	35.4	38.3	0%	0%
E6	2014	2014	1	24.1	24.1	24.1	0%	0%

Summary Zinc sediment

The CSEMP data analysed between 2005 and 2009 revealed that a number of offshore and estuarine sectorial boxes (18/38) contained samples where the mean Zn/Al ratios in the sectorial boxes were > ERL. Of these 2 sectorial boxes contained samples with the mean Zn/Al ratio > than the ERM (Figure 0:21 to Figure 0:24; Table 0.12 to Table 0.15). The sites exceeding the ERM threshold were confined to estuarine locations in the Tees and Tyne. A similar pattern was observed for CSEMP data collected from 2010-2014 with 8/20 sectorial boxes containing mean Zn/Al ratios above the ERL. No mean values of Zn/Al ratios exceeded the ERM. Data suggest that such Zn/Al ratios at locations exceeding the ERM may lead to toxicological effects in sensitive species. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

1.2.6 Polychlorinated biphenyls in sediments

PCB contamination started in the 1940s, peaked in the 1970s and declined afterwards, due to prohibition of use in many countries. Nevertheless, concentrations of PCBs are still very high in many regions due to their hydrophobic nature and low solubility in water; properties which initially contributed to their widespread use. PCBs may leach from residues within old electrical transformers and other dielectric fluids present in landfill, and once in the environment, can absorb to particulate matter and accumulate in sediments (Nicolaus *et al.,* 2015). As such sediments commonly form the final sink for PCBs, presenting a secondary form of contamination with bioavailability being increased through re-suspension after storms or dredging activities.

Two different particle size fractions were tested (<63 um and <2,000um) and these are presented separately due to grain size effects. Where a result was reported as a less than value, it was assigned a nominal value of half the limit of quantification. To investigate temporal differences sample results were presented separately for the periods 2005-09 and 2010-14. The survey area was divided into 0.5 degree by 0.5 degree rectangles and enclosed estuaries. Summary statistics were calculated for all samples by rectangle or estuary to make spatial assessments of PCB concentrations. Although results were available for many chlorinated biphenyls, results are only presented for the 'ICES 7' (CB28, CB52, CB101, CB118, CB153, CB138 and CB180) which are commonly used for assessment purposes.

The data reviewed for PCBs were assessed using the 'traffic light' system based on the assessment criteria adopted by OSPAR for use in the 2008 Coordinated Environmental Monitoring Programme (CEMP) assessment (OSPAR, 2008). PCB content are compared to the Background Assessment Concentration (BAC) to identify if concentrations are 'close to background' and against Environmental Assessment Criteria (EAC). BACs have been established for the ICES7 CBs in sediment. Concentrations are expressed in µg/kg dry weight (dw), normalised to 2.5% total organic carbon. The tables of summary statistics present the range of years within which the samples were taken, the arithmetic mean result, the minimum and maximum result, and the percentage of samples exceeding the assessment concentrations. Thematic maps were produced with colour coded symbols based on the mean result in relation to the assessment levels for each geographic division.

In general, the assessment of the majority sites and samples examined were < BAC or < EAC and therefore not thought to pose any significant toxicological risk. The EAC is lowest for CB118 (0.6 µg/kg dw), a mono-*ortho* CB and the most toxic of the ICES7 CBs. Therefore, it is not surprising that a number of sites regularly failed the EAC for this CB (Figure 0:25 to Figure 0:28 and Table 0. to Table 0.18). EACs were also exceeded for CB 28 (E6), CB 52 (D5 and E6) and CB 101 (D5 and E6) on a limited number of occasions.

Table 0.16: Assessment criteria used for chlorinated biphenyls

CB #	Less than the Background Assessment Concentration (BAC)	From the BAC to the Environmental Assessment Criteria (EAC)	>= to the EAC
2,4,4'-trichlorobiphenyl (CB28)	< 0.22 µg/kg	>= 0.22 µg/kg to 1.7 µg/kg	>= 1.7 µg/kg
2,2',5,5'-tetrachlorobiphenyl (CB52)	< 0.12 µg/kg	>= 0.12 µg/kg to 2.7 µg/kg	>= 2.7 µg/kg
2,2',4,5,5'-pentachlorobiphenyl (CB101)	< 0.14 µg/kg	>= 0.14 µg/kg to 3.0 µg/kg	>= 3.0 µg/kg
2,3',4,4',5-pentachlorobiphenyl (CB118)	< 0.17 µg/kg	>= 0.17 µg/kg to 0.6 µg/kg	>= 0.6 µg/kg
2,2',3,4,4',5'-hexachlorobiphenyl (CB138)	< 0.15 µg/kg	>= 0.15 µg/kg to 7.9 µg/kg	>= 7.9 µg/kg
2,2',4,4',5,5'-hexachlorobiphenyl (CB153)	< 0.19 µg/kg	>= 0.19 µg/kg to 40 µg/kg	>= 40 µg/kg
2,2',3,4,4',5,5'-heptachlorobiphenyl (CB180)	< 0.1 µg/kg	>= 0.1 µg/kg to 12 µg/kg	>= 12 µg/kg

1.2.7 Overview CSEMP CB sediment data

The broad spatial assessment of the data for most CB data in this region of the North Sea shows that most sites contained sediment that had low levels of CB contamination. Wide spread failures of CB118 were observed, though this is consistent with other areas around the UK (Nicolaus et al., 2015). The EAC is lowest for CB118 (0.6 µg/kg dw), a mono-*ortho* CB and the most toxic of the ICES7 CBs. EACs were also exceeded for CB28, CB 52 and CB101 at a limited number of other locations. Again most sites with high levels of contamination were restricted to the industrialized estuaries (Inner Forth, Tyne and Tees). Major UK assessments have taken place in recent years and these demonstrate that CB concentrations appear to be relatively stable (Nicolaus *et al.,* 2015). The ban on the use of PCBs has resulted in a decrease in contaminant loading (e.g. riverine inputs and atmospheric transport) over time (Charting Progress 2, 2010). However, the slow degradation of CBs means this could take some time to be reflected in actual measured concentrations in sediments and will require continued monitoring.

CB28

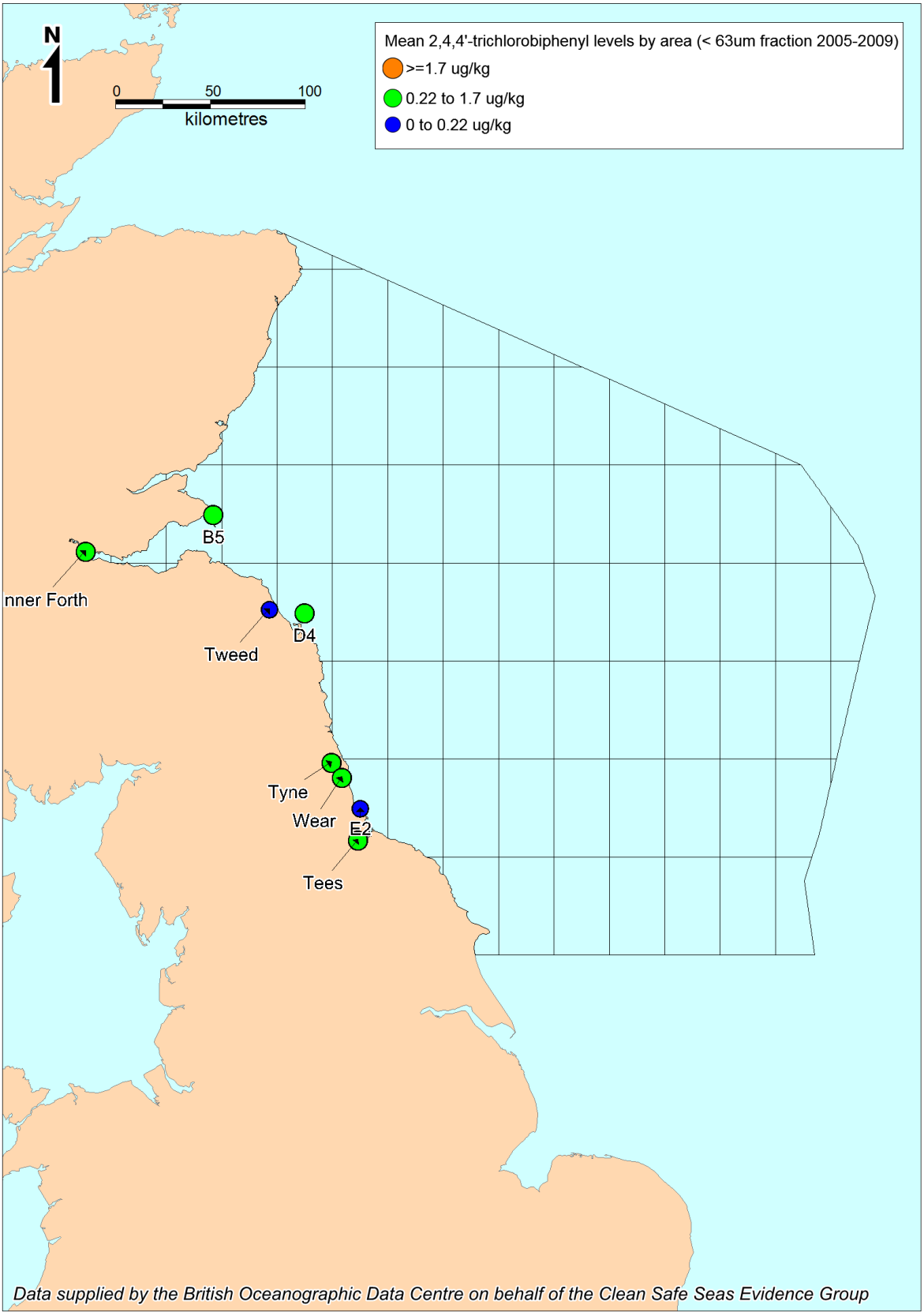

Figure 0:25: Map of mean 2,4,4'-trichlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Table 0.28: Summary of 2,4,4'-trichlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		2,4,4'-trichlorobiphenyl (CB28) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
B5	2005	2005	5	1.2	0.7	3.0	100%	20%
D4	2006	2008	14	0.2	0.1	0.6	36%	0%
E2	2006	2008	30	0.1	0.0	0.9	10%	0%
Inner Forth	2005	2005	5	0.6	0.5	0.7	100%	0%
Tees	2006	2009	35	0.7	0.0	2.3	77%	9%
Tweed	2006	2008	14	0.1	0.1	0.2	14%	0%
Tyne	2006	2009	35	0.4	0.0	2.1	60%	3%
Wear	2006	2009	35	0.3	0.0	2.9	29%	3%

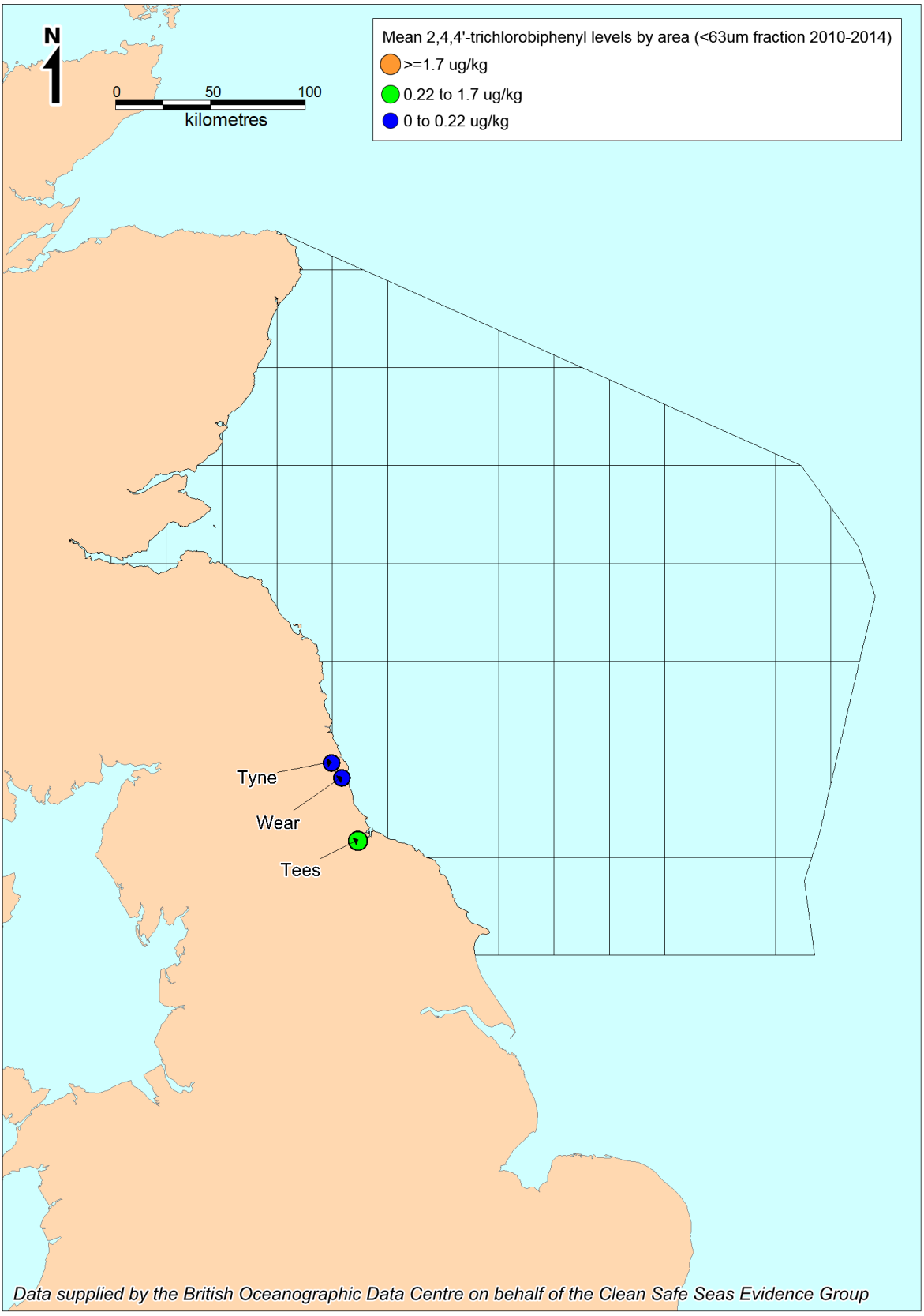

Figure 0:26: Map of mean 2,4,4'-trichlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Table 0.17: Summary of 2,4,4'-trichlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		2,4,4'-trichlorobiphenyl (CB28) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
Tees	2010	2013	10	1.6	0.3	12.0	100%	10%
Tyne	2010	2010	5	0.1	0.1	0.2	0%	0%
Wear	2010	2010	5	0.1	0.1	0.2	0%	0%

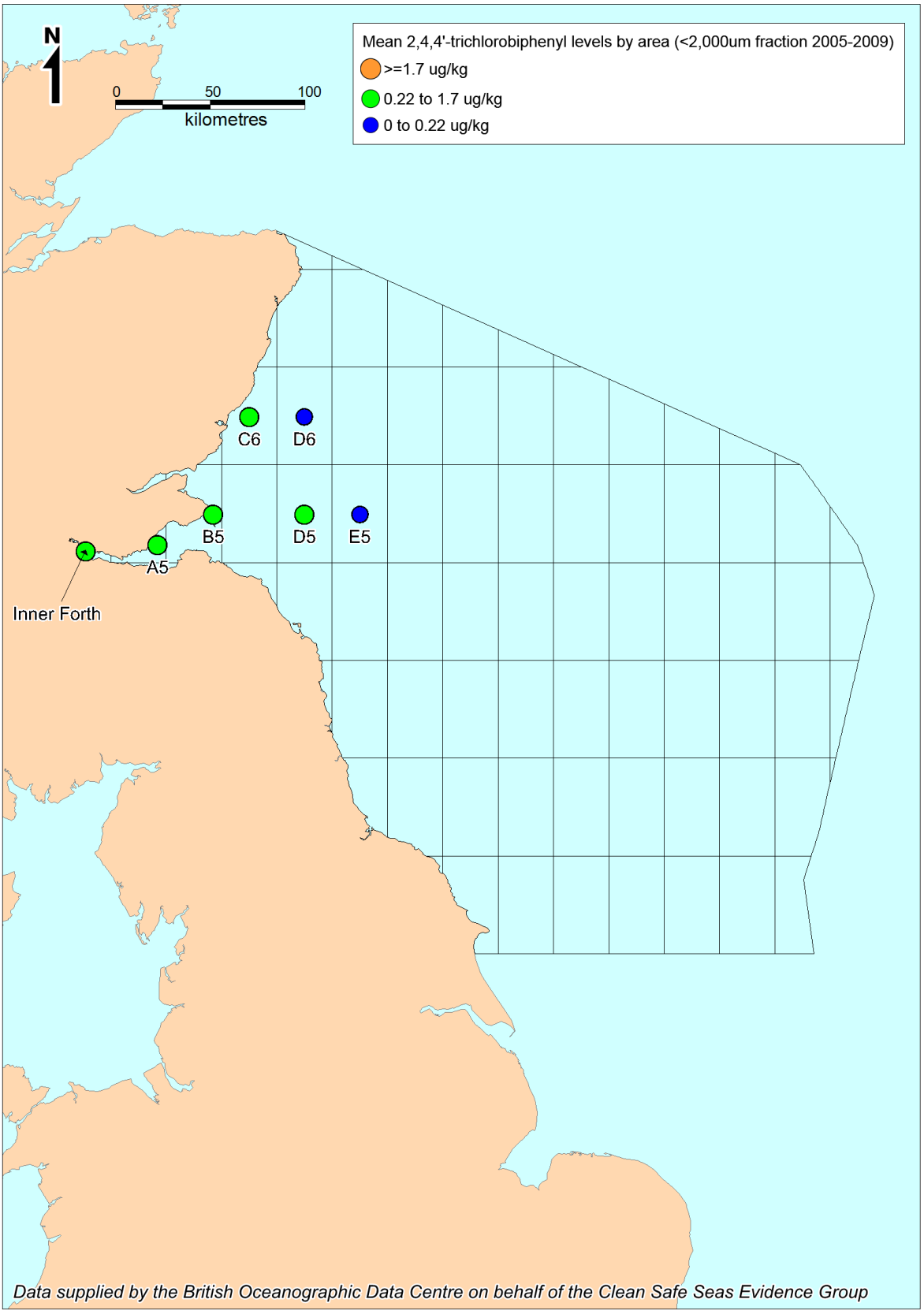

Figure 0:27: Map of mean 2,4,4'-trichlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.30: Summary of 2,4,4'-trichlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		2,4,4'-trichlorobiphenyl (CB28) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2005	2009	6	0.9	0.5	1.1	100%	0%
B5	2005	2009	11	0.3	0.0	0.8	64%	0%
C6	2006	2009	12	0.3	0.2	0.9	92%	0%
D5	2006	2009	9	1.1	0.2	2.8	100%	33%
D6	2008	2008	1	0.1	0.1	0.1	0%	0%
E5	2005	2005	5	0.2	0.1	0.2	0%	0%
Inner Forth	2005	2009	6	1.4	0.9	2.6	100%	33%

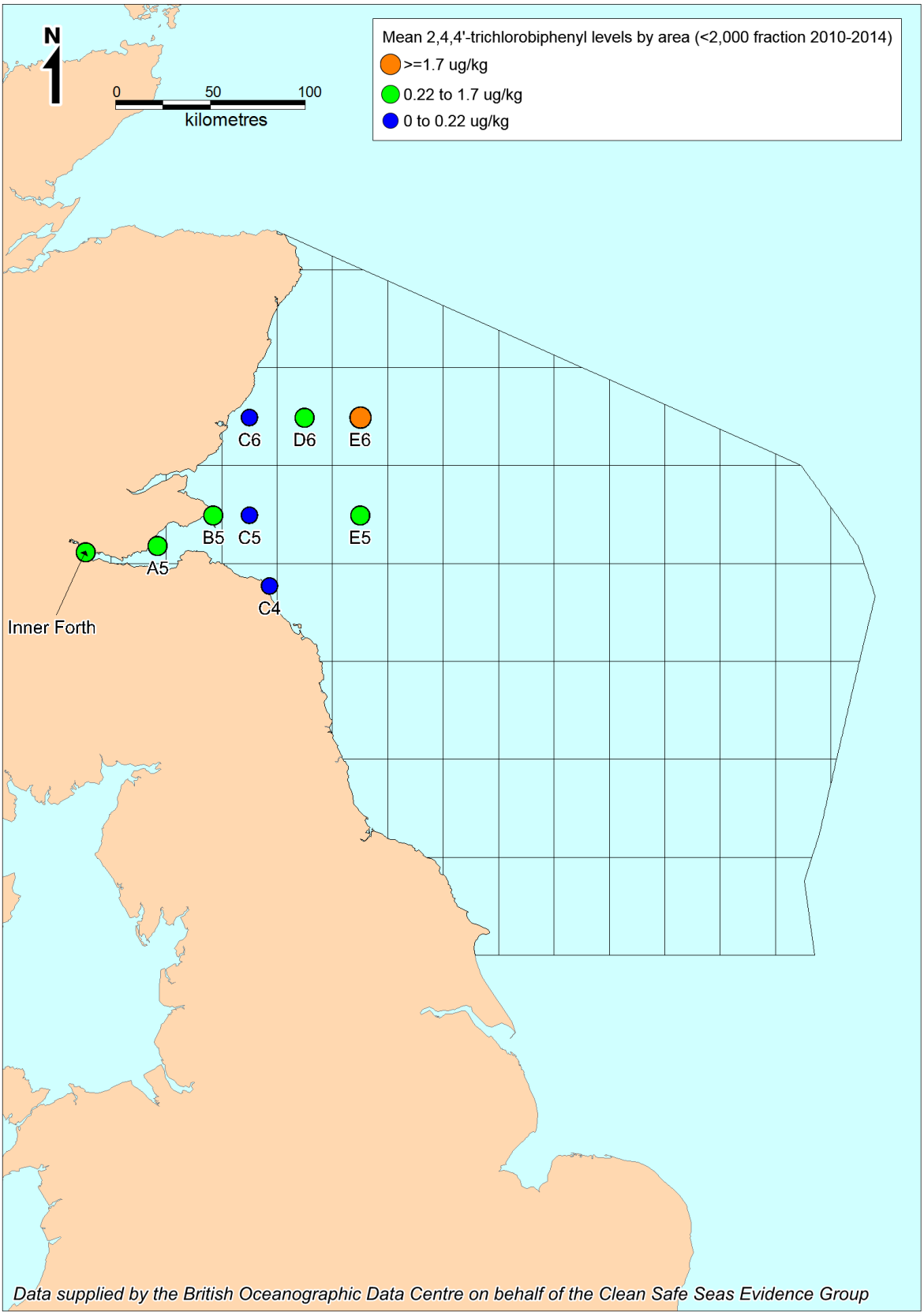

Figure 0:28: Map of mean 2,4,4'-trichlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.18: Summary of 2,4,4'-trichlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		2,4,4'-trichlorobiphenyl (CB28) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2010	2014	19	0.8	0.1	1.1	95%	0%
B5	2010	2014	28	0.6	0.1	2.6	96%	4%
C4	2014	2014	1	0.1	0.1	0.1	0%	0%
C5	2014	2014	2	0.1	0.1	0.2	0%	0%
C6	2010	2014	20	0.1	0.1	0.4	15%	0%
D6	2011	2013	2	0.2	0.2	0.2	50%	0%
E5	2010	2012	2	0.4	0.3	0.6	100%	0%
E6	2014	2014	1	2.0	2.0	2.0	100%	100%
Inner Forth	2010	2014	23	0.8	0.4	2.0	100%	4%

Summary CB28 sediment

The CSEMP data analysed for all years revealed that the vast majority of sites analysed for CB 28 were either below the BAC or between the BAC and EAC. Only one sectorial box (E6) sampled during the period 2010-2014 exceeded the EAC (1.7µg/kg) (Figure 0:25 to Figure 0:28;Table 0. to Table 0.18). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

CB52

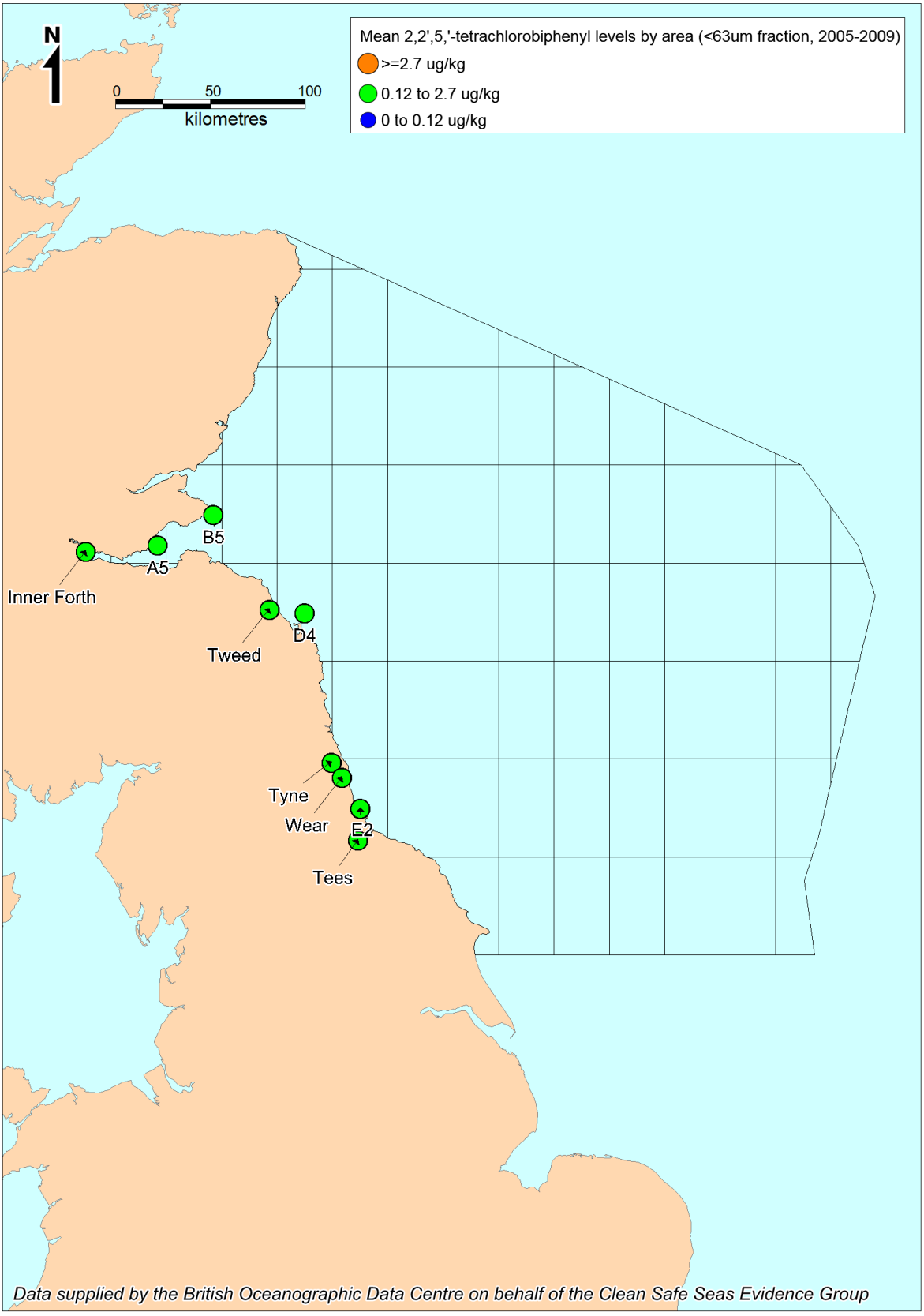

Figure 0:29: Map of mean 2,2',5,5'-tetrachlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Table 0.19: Summary of 2,2',5,5'-tetrachlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		2,2',5,5'-tetrachlorobiphenyl (CB52) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2006	2006	1	0.6	0.6	0.6	100%	0%
B5	2005	2006	6	0.5	0.3	1.4	100%	0%
D4	2006	2008	14	0.4	0.1	1.9	64%	0%
E2	2006	2008	30	0.9	0.2	5.4	100%	3%
Inner Forth	2005	2006	10	0.4	0.2	1.0	100%	0%
Tees	2006	2009	35	1.0	0.0	2.6	86%	0%
Tweed	2006	2008	14	0.1	0.1	0.3	71%	0%
Tyne	2006	2009	35	0.7	0.0	3.0	86%	3%
Wear	2006	2009	35	0.9	0.1	6.3	97%	6%

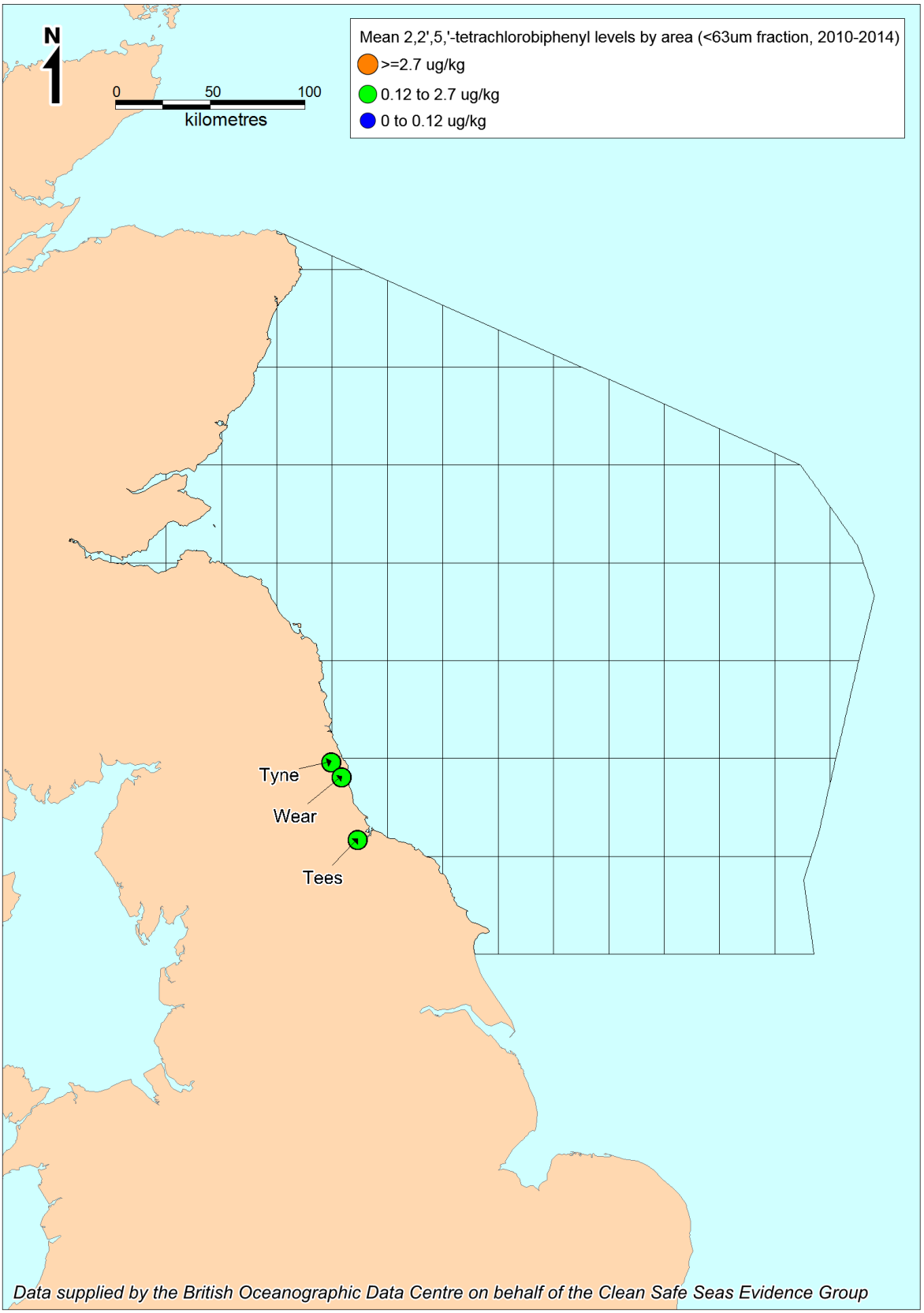

Figure 0:30: Map of mean 2,2',5,5'-tetrachlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Table 0.20: Summary of 2,2',5,5'-tetrachlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		2,2',5,5'-tetrachlorobiphenyl (C52) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
Tees	2010	2013	10	2.1	0.2	17.9	100%	10%
Tyne	2010	2010	5	0.2	0.1	0.3	80%	0%
Wear	2010	2010	5	0.2	0.1	0.3	60%	0%

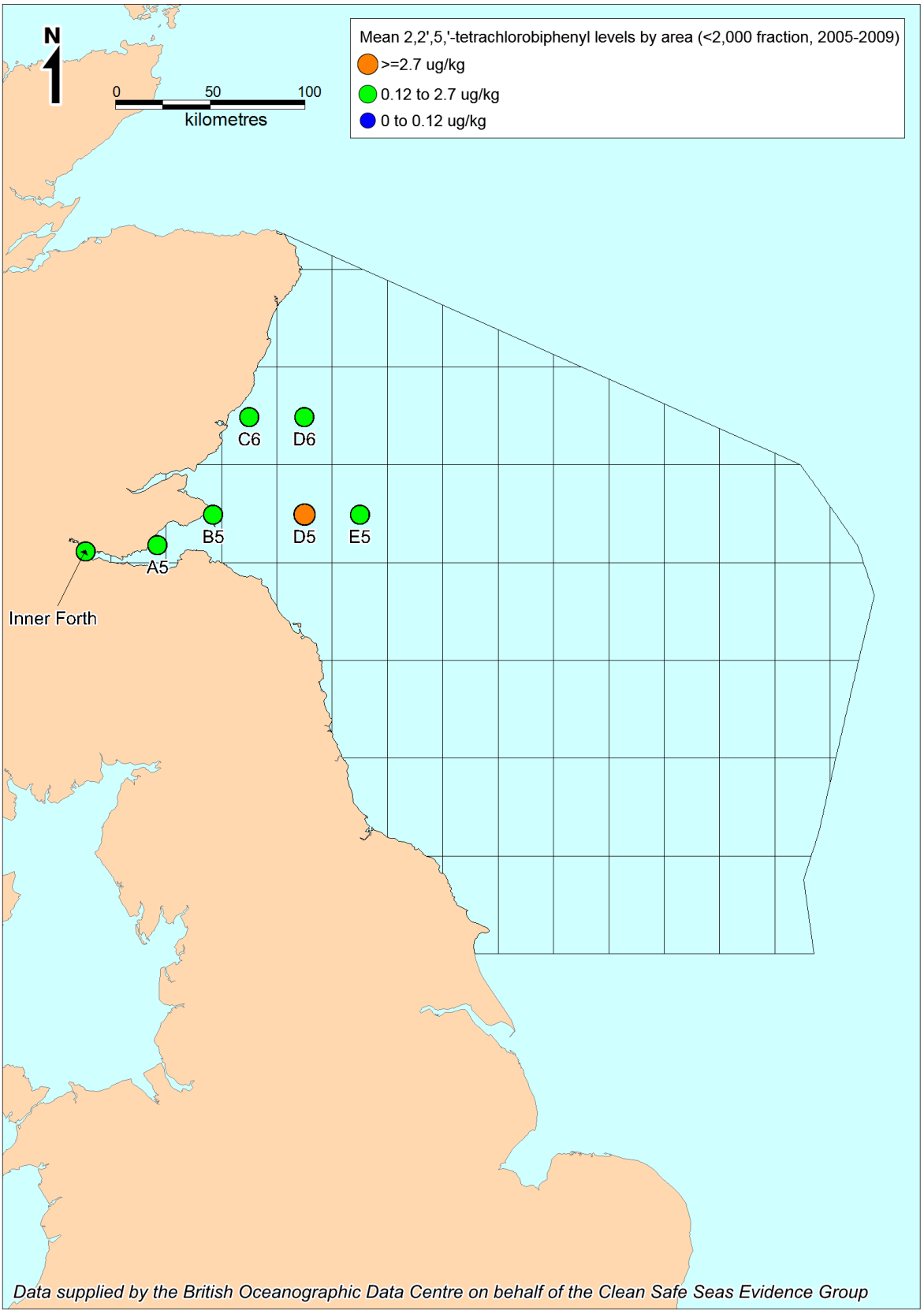

Figure 0:31: Map of mean 2,2',5,5'-tetrachlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.34: Summary of 2,2',5,5'-tetrachlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		2,2',5,5'-tetrachlorobiphenyl (CB52) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2005	2009	4	0.4	0.3	0.5	100%	0%
B5	2005	2009	8	0.3	0.1	0.9	88%	0%
C6	2006	2009	12	0.7	0.1	1.8	92%	0%
D5	2006	2009	9	3.5	0.4	18.5	100%	22%
D6	2008	2008	1	1.1	1.1	1.1	100%	0%
E5	2005	2005	5	0.4	0.1	0.6	80%	0%
Inner Forth	2005	2009	6	1.3	0.4	4.2	100%	17%

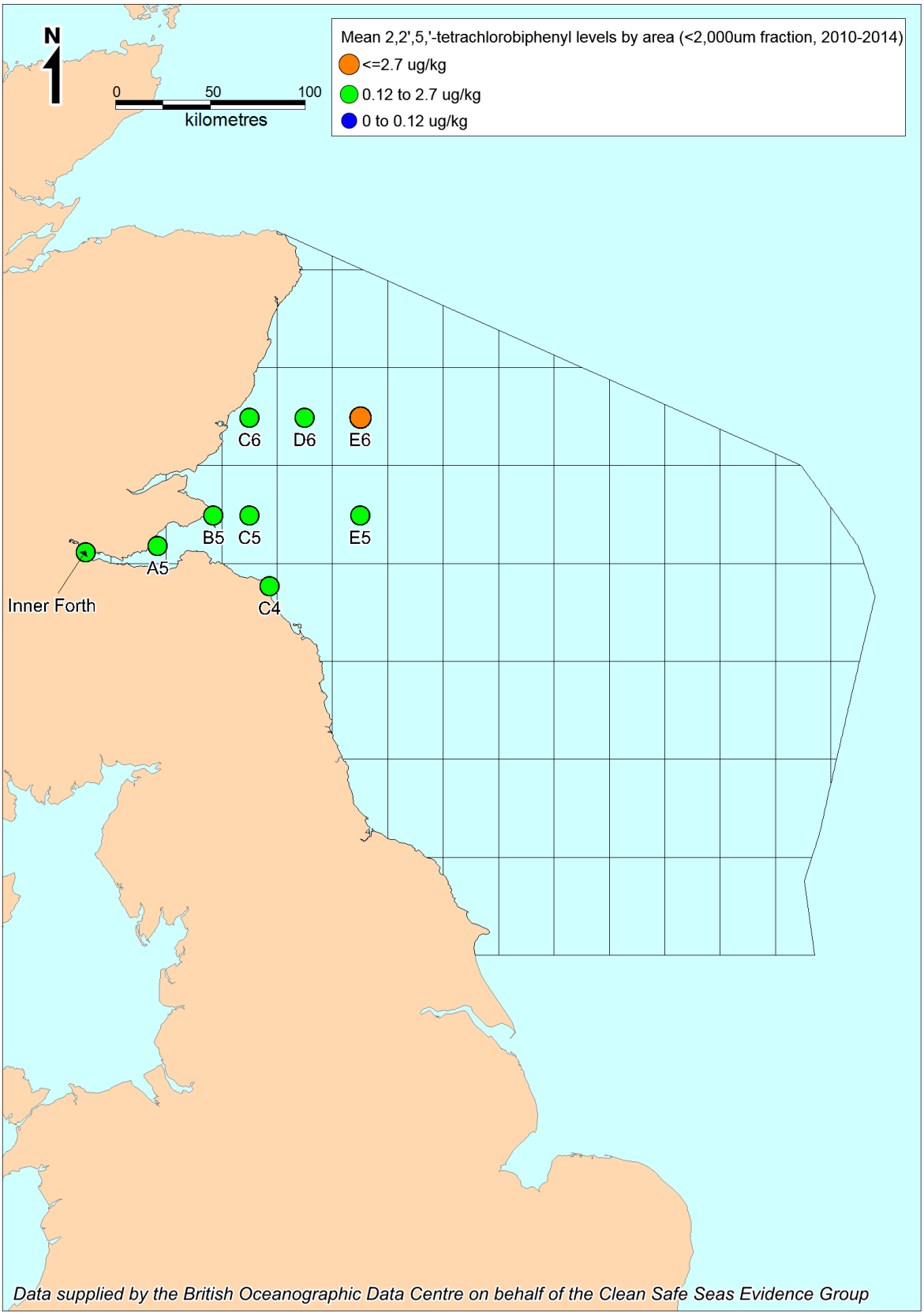

Figure 0:32: Map of mean 2,2’,5,5’-tetrachlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.21: Summary of 2,2',5,5'-tetrachlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		2,2',5,5'-tetrachlorobiphenyl (CB52) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2010	2014	19	0.3	0.0	0.5	84%	0%
B5	2010	2014	28	0.9	0.1	4.5	100%	4%
C4	2014	2014	1	0.3	0.3	0.3	100%	0%
C5	2014	2014	2	0.2	0.1	0.3	50%	0%
C6	2010	2014	20	0.5	0.2	1.3	100%	0%
D6	2011	2013	2	0.8	0.7	0.8	100%	0%
E5	2010	2012	2	1.4	0.9	2.0	100%	0%
E6	2014	2014	1	6.6	6.6	6.6	100%	100%
Inner Forth	2010	2014	23	0.5	0.2	3.4	100%	4%

Summary CB52 sediment

The CSEMP data analysed for all years revealed that the vast majority of sites analysed for CB 52 were either below the BAC or between the BAC and EAC. Only two sectorial boxes D5 (2005-2009) and E6 (2010-2014) exceeded the EAC (2.7µg/kg) (Figure 0:29 to Figure 0:32;Table 0.19 to Table 0.21). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

CB101

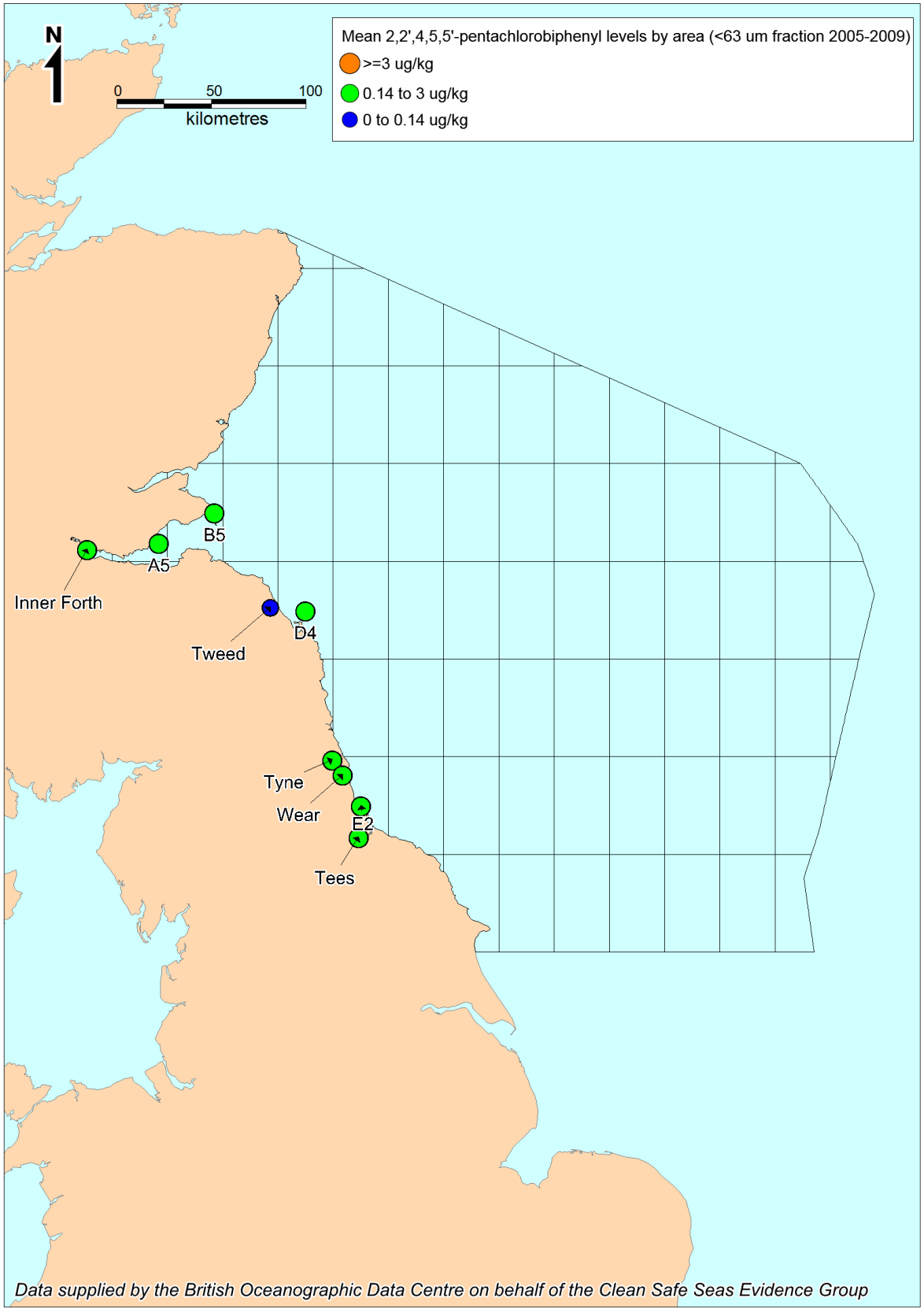

Figure 0:33: Map of mean 2,2’,4,5,5’-pentachlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Table 0.22: Summary of 2,2',4,5,5'-pentachlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		2,2',4,5,5'-pentachlorobiphenyl (CB101) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2006	2006	1	1.2	1.2	1.2	100%	0%
B5	2005	2006	6	0.9	0.4	2.0	100%	0%
D4	2006	2008	14	0.2	0.1	0.6	64%	0%
E2	2006	2008	30	0.3	0.1	1.2	83%	0%
Inner Forth	2005	2006	10	0.9	0.3	1.8	100%	0%
Tees	2006	2009	35	0.9	0.0	3.3	86%	6%
Tweed	2006	2008	14	0.1	0.1	0.2	29%	0%
Tyne	2006	2009	35	0.9	0.0	2.6	94%	0%
Wear	2006	2009	35	0.7	0.1	6.0	94%	6%

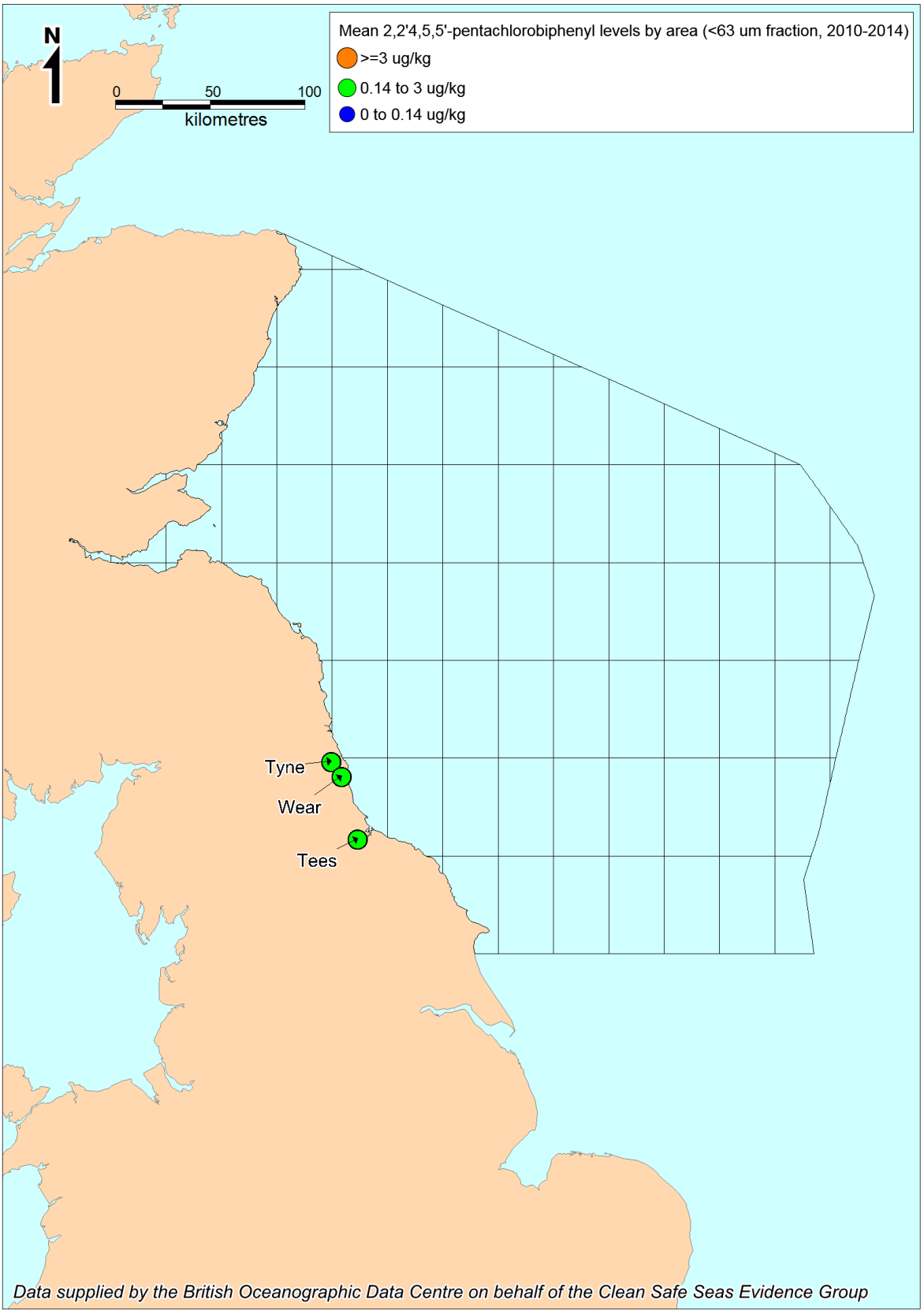

Figure 0:34: Map of mean 2,2',4,5,5'-pentachlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Table 0.23: Summary of 2,2',4,5,5'-pentachlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		2,2',4,5,5'-pentachlorobiphenyl (CB101) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
Tees	2010	2013	10	1.4	0.4	9.3	100%	10%
Tyne	2010	2010	5	0.4	0.4	0.5	100%	0%
Wear	2010	2010	5	0.3	0.2	0.4	100%	0%

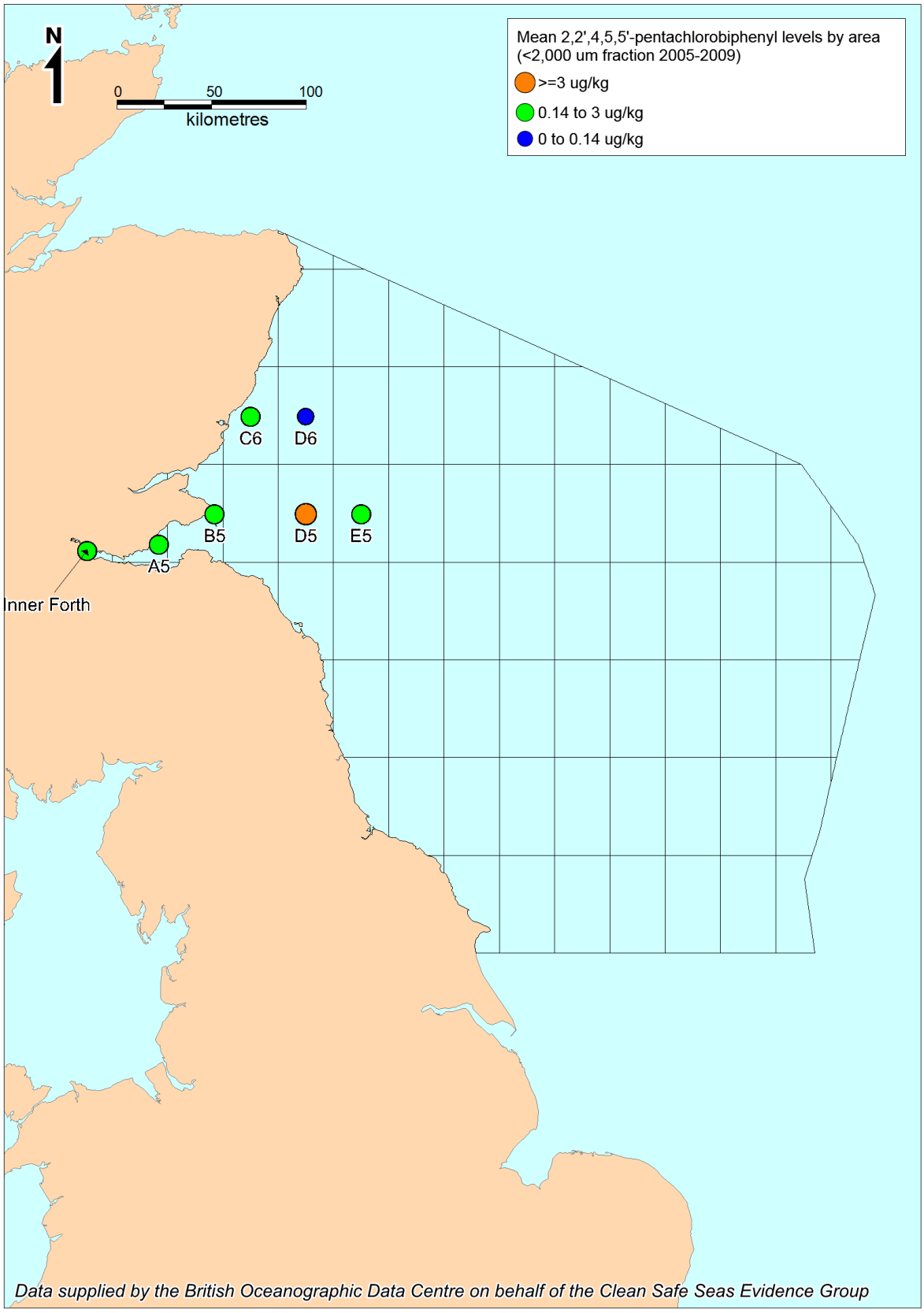

Figure 0:35: Map of mean 2,2',4,5,5'-pentachlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.24: Summary of 2,2',4,5,5'-pentachlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		2,2',4,5,5'-pentachlorobiphenyl (CB101) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2005	2009	8	0.6	0.5	0.8	100%	0%
B5	2005	2009	14	0.4	0.1	1.1	79%	0%
C6	2006	2009	12	0.6	0.1	1.0	92%	0%
D5	2006	2009	9	3.4	0.4	18.3	100%	11%
D6	2008	2008	1	0.1	0.1	0.1	0%	0%
E5	2005	2005	5	0.2	0.1	0.4	80%	0%
Inner Forth	2005	2009	11	1.2	0.1	6.4	91%	9%

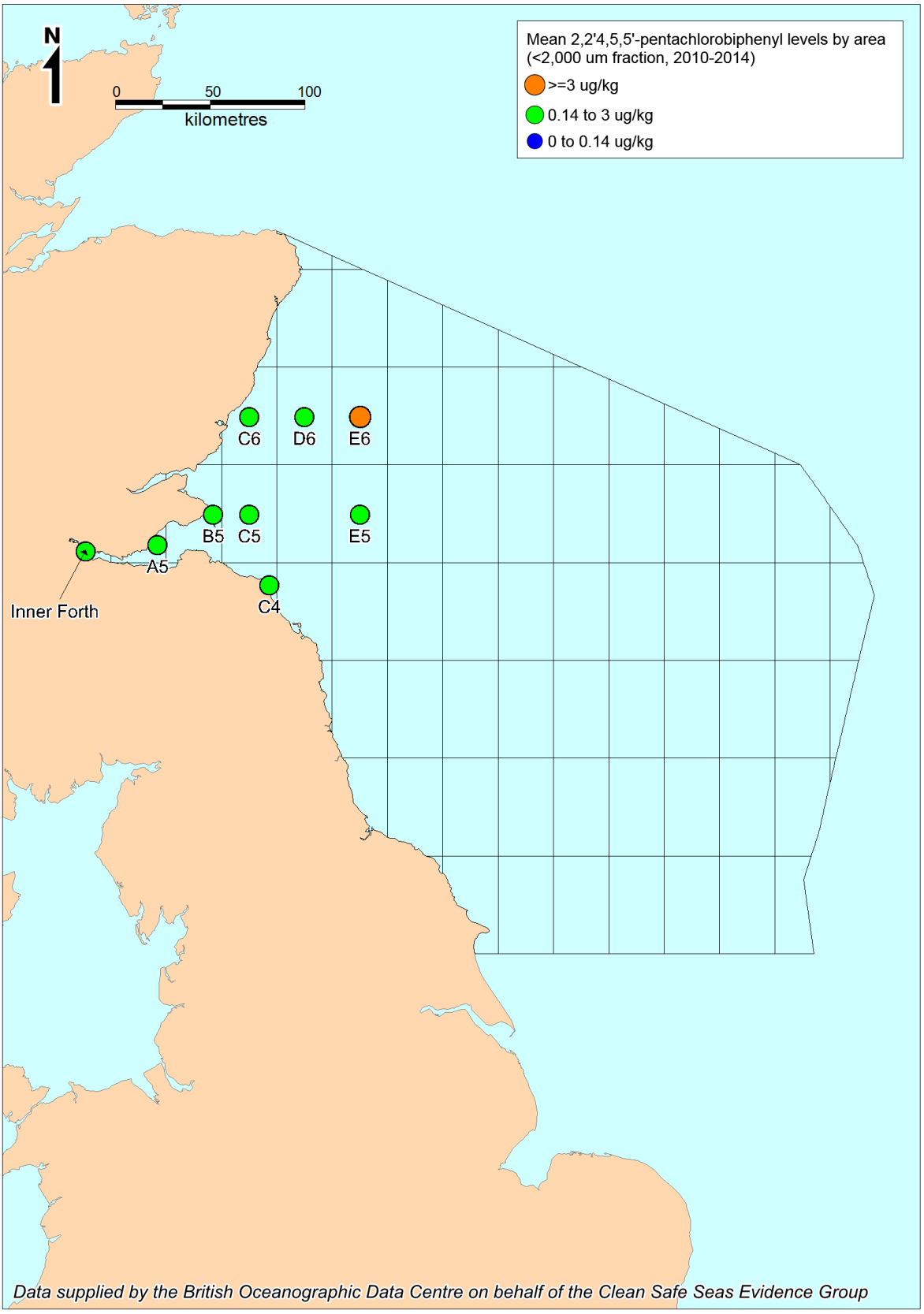

Figure 0:36: Map of mean 2,2',4,5,5'-pentachlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.25: Summary of 2,2',4,5,5'-pentachlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		2,2',4,5,5'-pentachlorobiphenyl (CB101) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2010	2014	19	0.6	0.2	0.8	100%	0%
B5	2010	2014	28	0.8	0.1	3.2	96%	4%
C4	2014	2014	1	0.2	0.2	0.2	100%	0%
C5	2014	2014	2	0.1	0.1	0.2	50%	0%
C6	2010	2014	20	0.3	0.2	0.9	100%	0%
D6	2011	2013	2	0.5	0.5	0.6	100%	0%
E5	2010	2012	2	1.0	0.6	1.4	100%	0%
E6	2014	2014	1	4.6	4.6	4.6	100%	100%
Inner Forth	2010	2014	23	0.9	0.3	5.3	100%	4%

Summary CB101 sediment

The CSEMP data analysed for all years revealed that the vast majority of sites analysed for CB 101 were either below the BAC or between the BAC and EAC. Only two sectorial boxes D5 (2005-2009) and E6 (2010-2014) exceeded the EAC (3.0 µg/kg) (Figure 0:33 to Figure 0:36;Table 0.22 to Table 0.25). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

CB 118

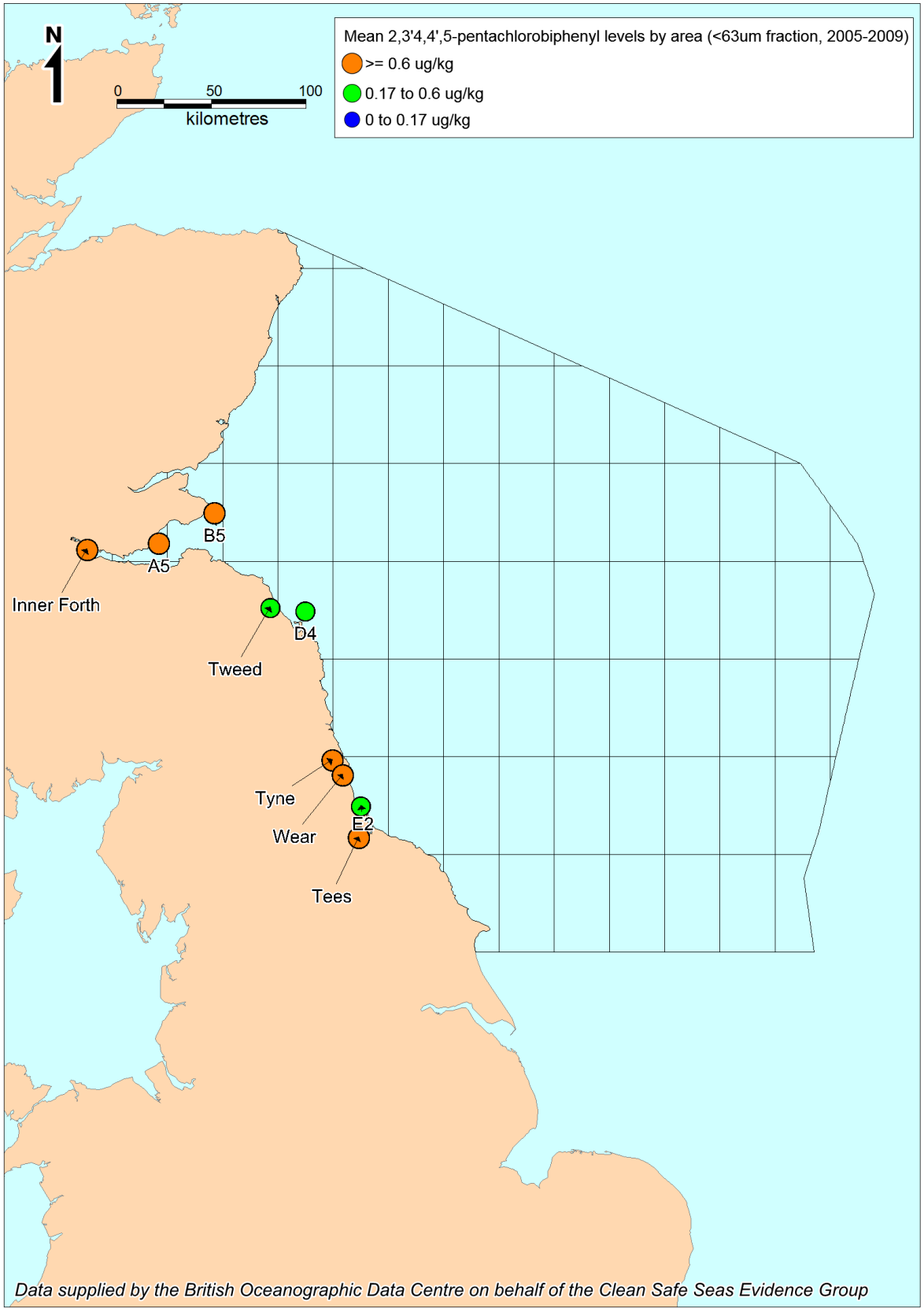

Figure 0:37: Map of mean 2,3',4,4',5-pentachlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Table 0.40: Summary of 2,3',4,4',5-pentachlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		2,3',4,4',5-pentachlorobiphenyl (CB118) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2006	2006	1	0.9	0.9	0.9	100%	100%
B5	2005	2006	6	0.9	0.5	2.3	100%	33%
D4	2006	2008	14	0.2	0.1	0.6	50%	14%
E2	2006	2008	30	0.3	0.1	1.7	70%	7%
Inner Forth	2005	2006	10	0.8	0.4	1.6	100%	60%
Tees	2006	2009	35	0.7	0.0	3.9	86%	46%
Tweed	2006	2008	14	0.2	0.1	0.4	43%	0%
Tyne	2006	2009	35	0.8	0.0	2.2	89%	60%
Wear	2006	2009	35	0.6	0.0	6.8	71%	20%

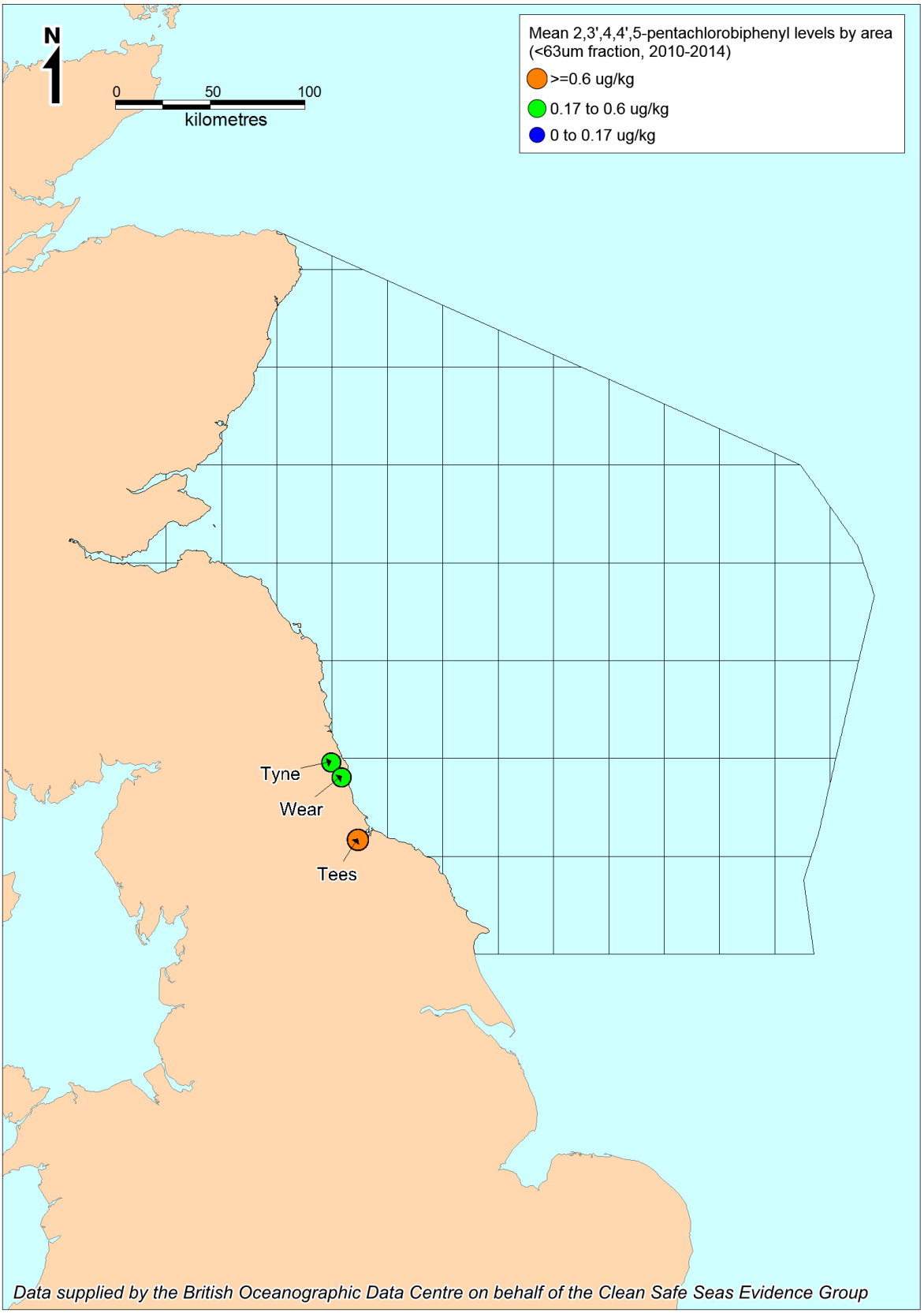

Figure 0:38: Map of mean 2,3',4,4',5-pentachlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Table 0.26: Summary of 2,3',4,4',5-pentachlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		2,3',4,4',5-pentachlorobiphenyl (CB118) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
Tees	2010	2013	10	1.1	0.4	6.5	100%	30%
Tyne	2010	2010	5	0.4	0.2	0.4	100%	0%
Wear	2010	2010	5	0.2	0.1	0.3	60%	0%

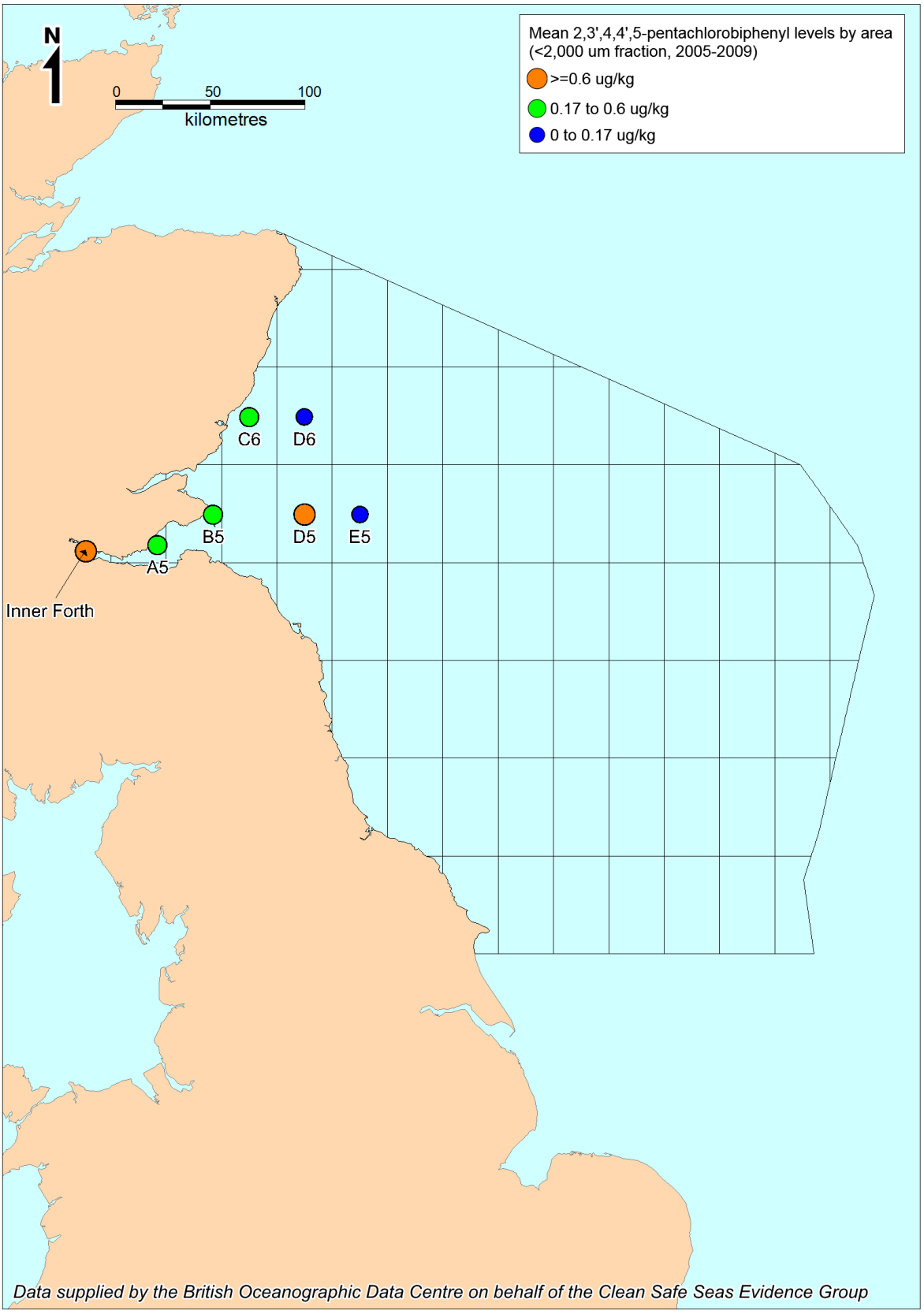

Figure 0:39: Map of mean 2,3',4,4',5-pentachlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.27: Summary of 2,3',4,4',5-pentachlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		2,3',4,4',5-pentachlorobiphenyl (CB118) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2005	2009	8	0.6	0.3	0.7	100%	50%
B5	2005	2009	14	0.3	0.1	0.6	71%	0%
C6	2006	2009	12	0.3	0.1	0.8	92%	8%
D5	2006	2009	9	1.2	0.4	2.8	100%	56%
D6	2008	2008	1	0.1	0.1	0.1	0%	0%
E5	2005	2005	5	0.2	0.1	0.2	60%	0%
Inner Forth	2005	2009	11	0.9	0.1	3.0	91%	64%

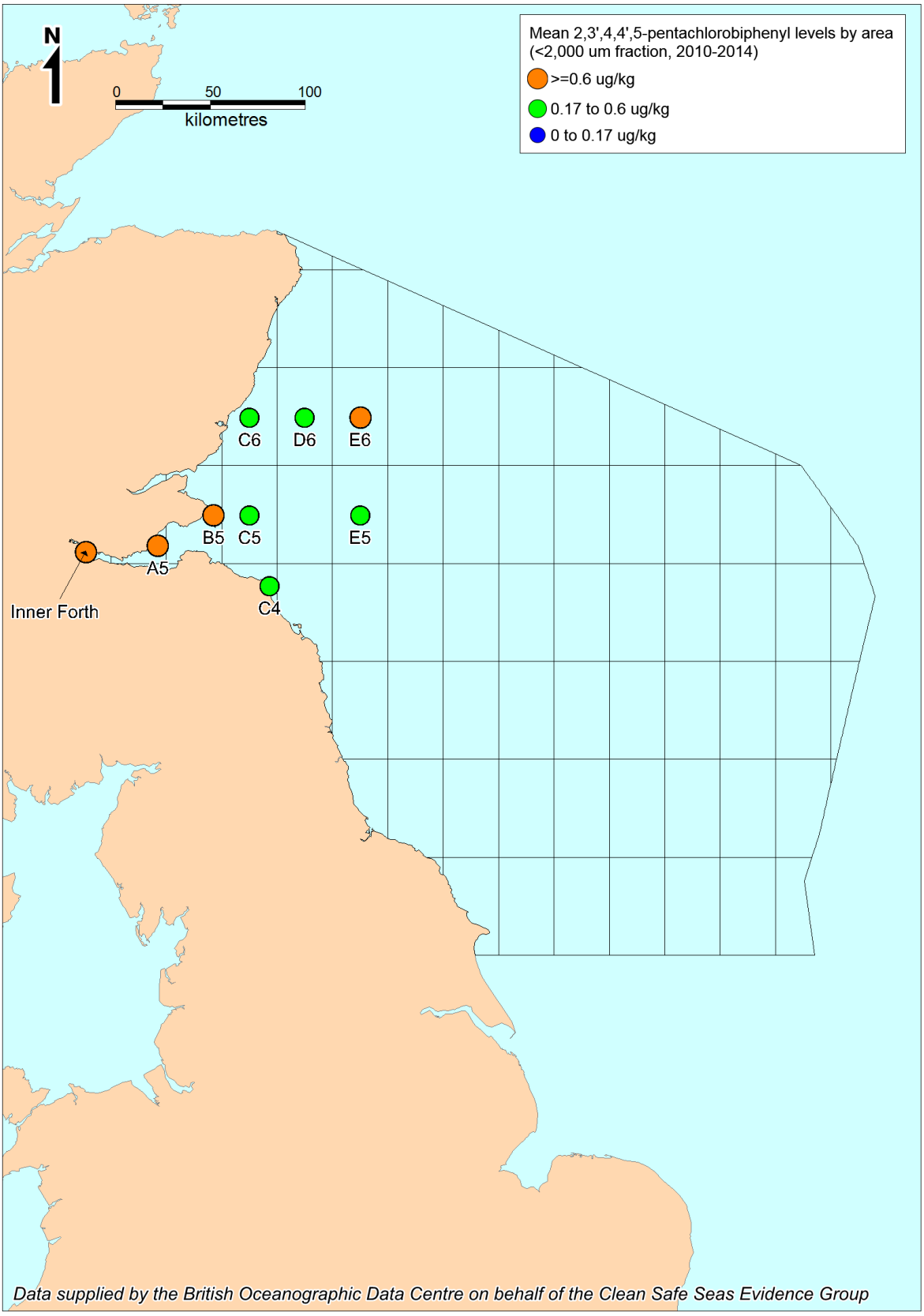

Figure 0:40: Map of mean 2,3',4,4',5-pentachlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.28: Summary of 2,3',4,4',5-pentachlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		2,3',4,4',5-pentachlorobiphenyl (CB118) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2010	2014	19	0.6	0.2	0.9	100%	63%
B5	2010	2014	28	0.6	0.2	2.1	100%	36%
C4	2014	2014	1	0.3	0.3	0.3	100%	0%
C5	2014	2014	2	0.2	0.2	0.2	100%	0%
C6	2010	2014	20	0.2	0.1	0.5	55%	0%
D6	2011	2013	2	0.3	0.3	0.3	100%	0%
E5	2010	2012	2	0.6	0.3	0.8	100%	50%
E6	2014	2014	1	2.6	2.6	2.6	100%	100%
Inner Forth	2010	2014	23	0.8	0.3	4.5	100%	61%

Summary CB118 sediment

The CSEMP data analysed for all years revealed that a proportion of the sites analysed for CB 118 exceeded the EAC (0.6 µg/kg). These sites included the locations within known industrial estuaries (Tees, Tyne, Wear and Forth) along with offshore sectorial boxes (A5, B5, D5 and E6) (Figure 0:37 to Figure 0:40; Table 0. to Table 0.28). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

CB138

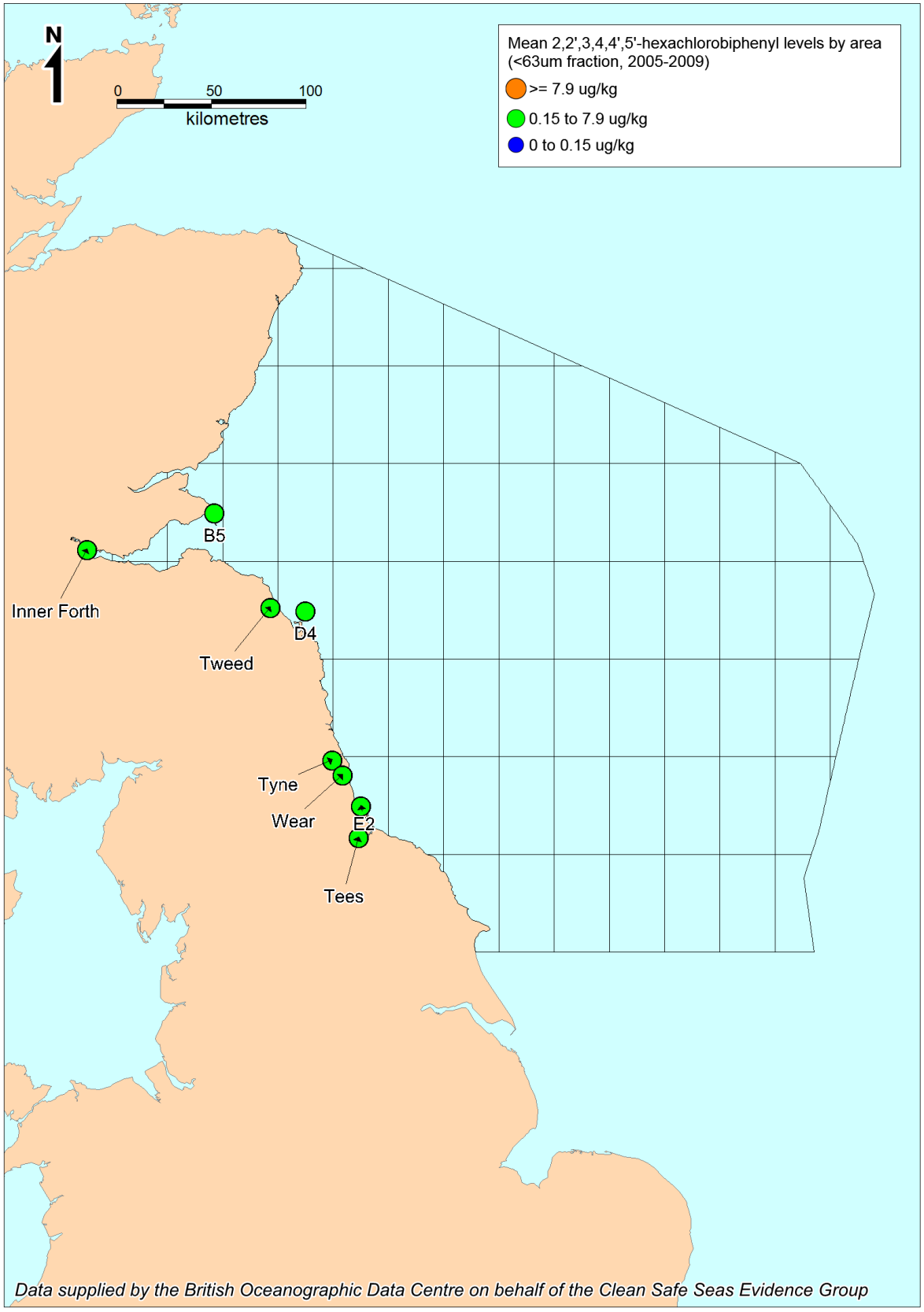

Figure 0:41: Map of mean 2,2',3,4,4',5'-hexachlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Table 0.29: Summary of 2,2',3,4,4',5'-hexachlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		2,2',3,4,4',5'-hexachlorobiphenyl (CB138) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
B5	2005	2005	5	1.0	0.5	2.6	100%	0%
D4	2006	2008	14	0.2	0.1	0.6	50%	0%
E2	2006	2008	30	0.4	0.0	5.2	67%	0%
Inner Forth	2005	2005	5	0.6	0.5	0.9	100%	0%
Tees	2006	2009	35	0.7	0.0	4.1	83%	0%
Tweed	2006	2008	14	0.2	0.1	0.3	36%	0%
Tyne	2006	2009	35	0.8	0.0	2.5	89%	0%
Wear	2006	2009	35	0.6	0.0	4.6	80%	0%

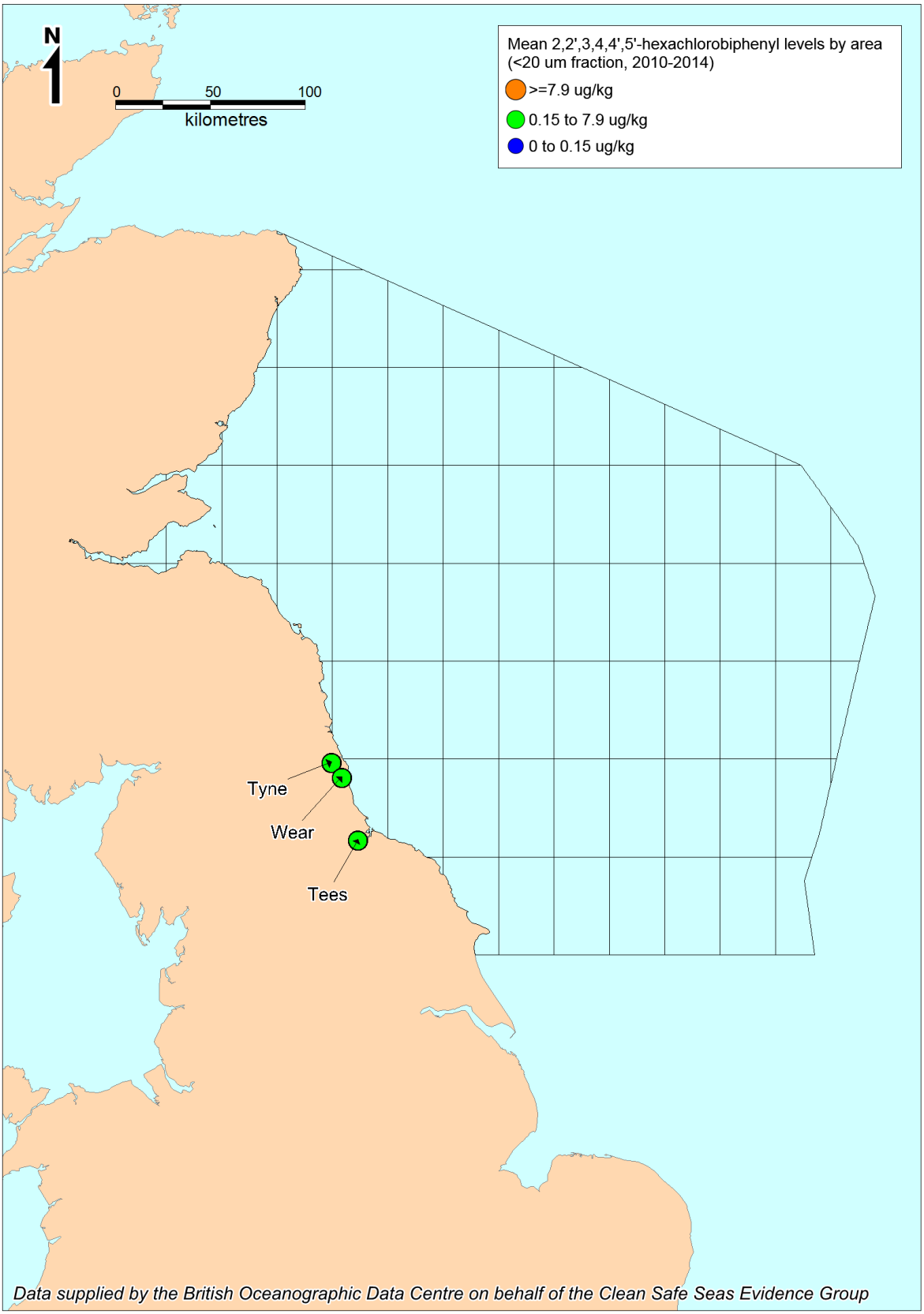

Figure 0:42: Map of mean 2,2',3,4,4',5'-hexachlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Table 0.45 Summary of 2,2',3,4,4',5'-hexachlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		2,2',3,4,4',5'-hexachlorobiphenyl (CB138) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
Tees	2010	2013	10	1.2	0.2	7.5	100%	0%
Tyne	2010	2010	5	0.3	0.3	0.4	100%	0%
Wear	2010	2010	5	0.2	0.1	0.3	60%	0%

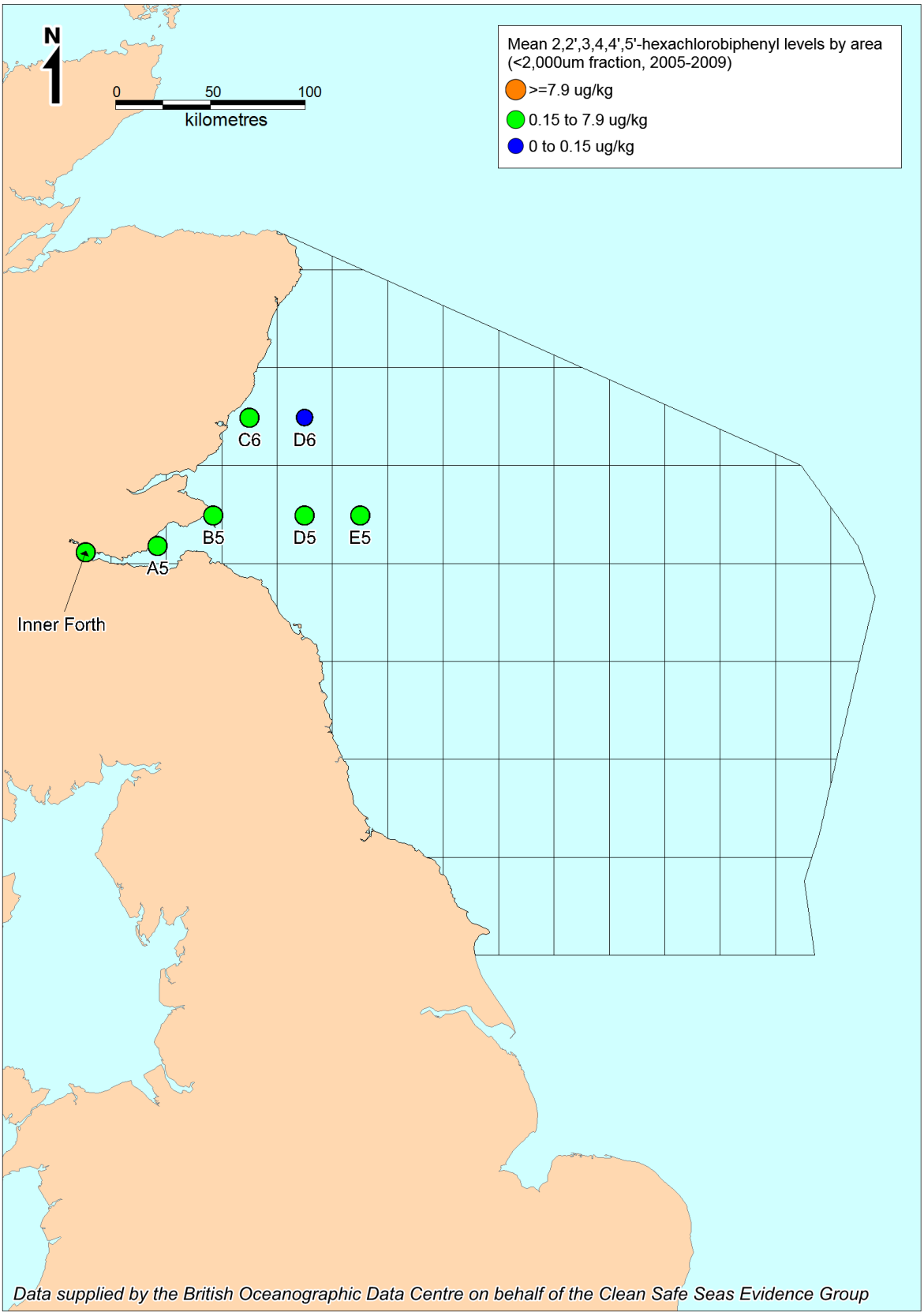

Figure 0:43: Map of mean 2,2',3,4,4',5'-hexachlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.30: Summary of 2,2',3,4,4',5'-hexachlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		2,2',3,4,4',5'-hexachlorobiphenyl (CB138) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2005	2009	8	0.8	0.4	1.0	100%	0%
B5	2005	2009	14	0.4	0.1	0.7	93%	0%
C6	2006	2009	12	0.3	0.1	0.5	83%	0%
D5	2006	2009	9	1.1	0.2	2.8	100%	0%
D6	2008	2008	1	0.1	0.1	0.1	0%	0%
E5	2005	2005	5	0.2	0.1	0.2	60%	0%
Inner Forth	2005	2009	11	1.1	0.3	2.8	100%	0%

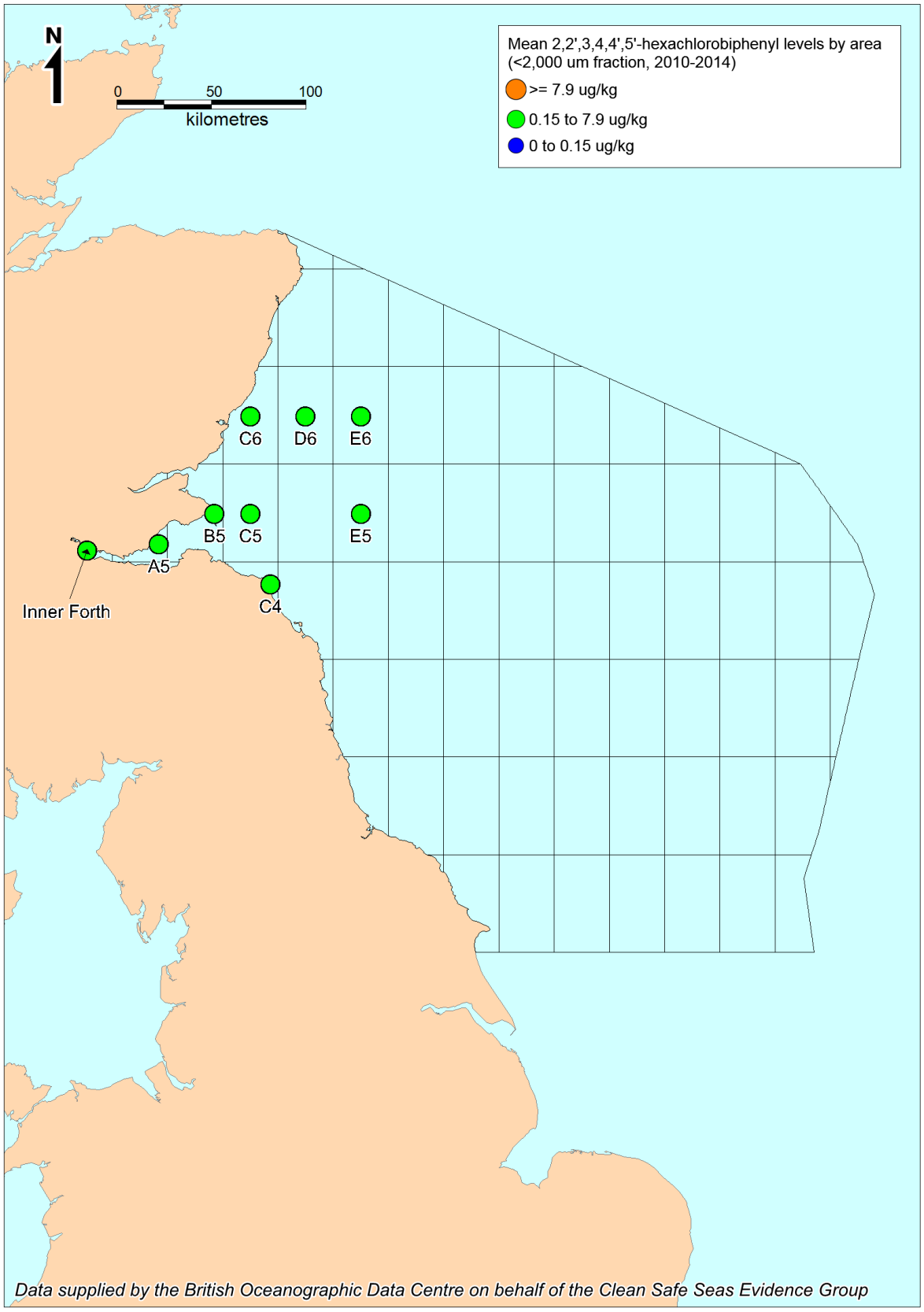

Figure 0:44: Map of mean 2,2',3,4,4',5'-hexachlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.31: Summary of 2,2',3,4,4',5'-hexachlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		2,2',3,4,4',5'-hexachlorobiphenyl (CB138) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2010	2014	19	0.7	0.3	1.1	100%	0%
B5	2010	2014	28	0.6	0.2	2.6	100%	0%
C4	2014	2014	1	0.7	0.7	0.7	100%	0%
C5	2014	2014	2	0.3	0.2	0.4	100%	0%
C6	2010	2014	20	0.2	0.1	0.4	45%	0%
D6	2011	2013	2	0.2	0.1	0.2	50%	0%
E5	2010	2012	2	0.5	0.4	0.7	100%	0%
E6	2014	2014	1	1.3	1.3	1.3	100%	0%
Inner Forth	2010	2014	23	1.0	0.3	3.9	100%	0%

Summary CB138 sediment

The CSEMP data analysed for all years revealed that all the sites analysed for CB 138 were either below the BAC or between the BAC and EAC (Figure 0:41 to Figure 0:44;Table 0.29 to Table 0.31). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

CB153

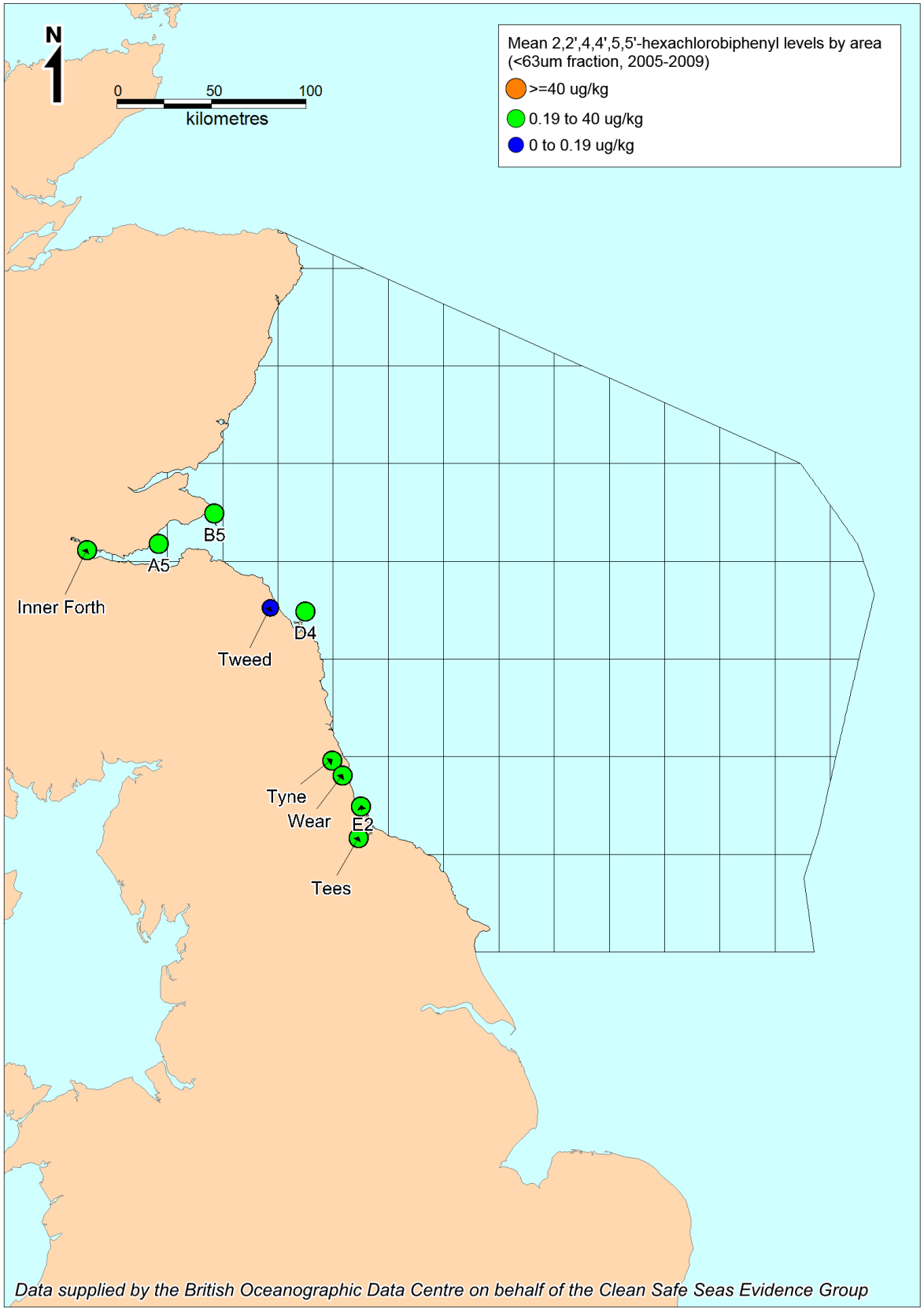

Figure 0:45: Map of mean 2,2',4,4',5,5'-hexachlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Table 0.32: Summary of 2,2',4,4',5,5'-hexachlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		2,2',4,4',5,5'-hexachlorobiphenyl (CB153) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2006	2006	1	1.3	1.3	1.3	100%	0%
B5	2005	2006	6	1.0	0.6	2.5	100%	0%
D4	2006	2008	14	0.2	0.1	0.6	43%	0%
E2	2006	2008	30	0.4	0.1	2.4	70%	0%
Inner Forth	2005	2006	10	1.2	0.5	2.4	100%	0%
Tees	2006	2009	35	1.2	0.0	4.8	86%	0%
Tweed	2006	2008	14	0.2	0.1	0.3	29%	0%
Tyne	2006	2009	35	0.9	0.0	2.9	94%	0%
Wear	2006	2009	35	0.6	0.0	5.0	77%	0%

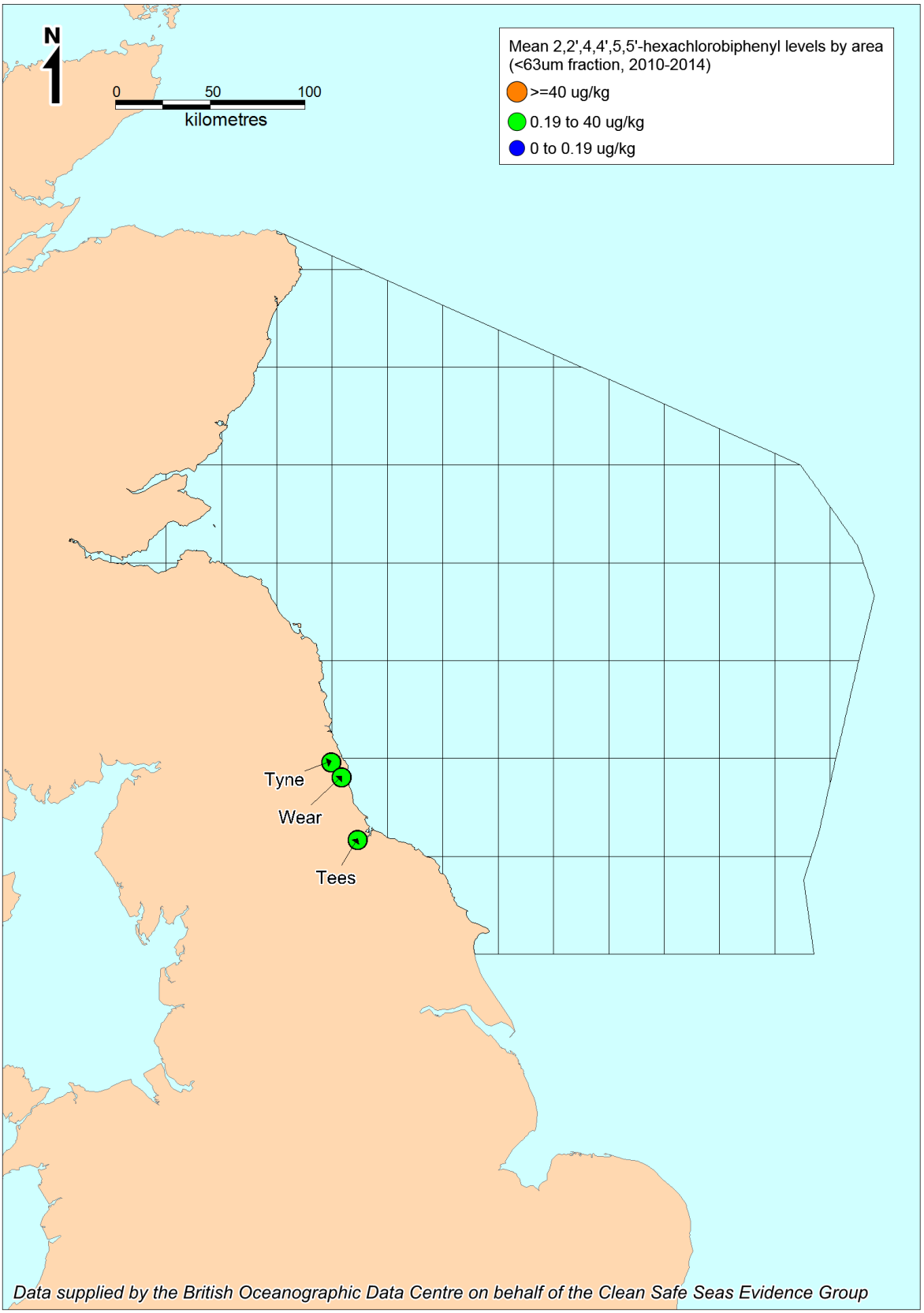

Figure 0:46: Map of mean 2,2',4,4',5,5'-hexachlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Table 0.33: Summary of 2,2',4,4',5,5'-hexachlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		2,2',4,4',5,5'-hexachlorobiphenyl (CB153) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
Tees	2010	2013	10	3.4	0.6	24.0	100%	0%
Tyne	2010	2010	5	0.4	0.3	0.5	100%	0%
Wear	2010	2010	5	0.3	0.2	0.4	80%	0%

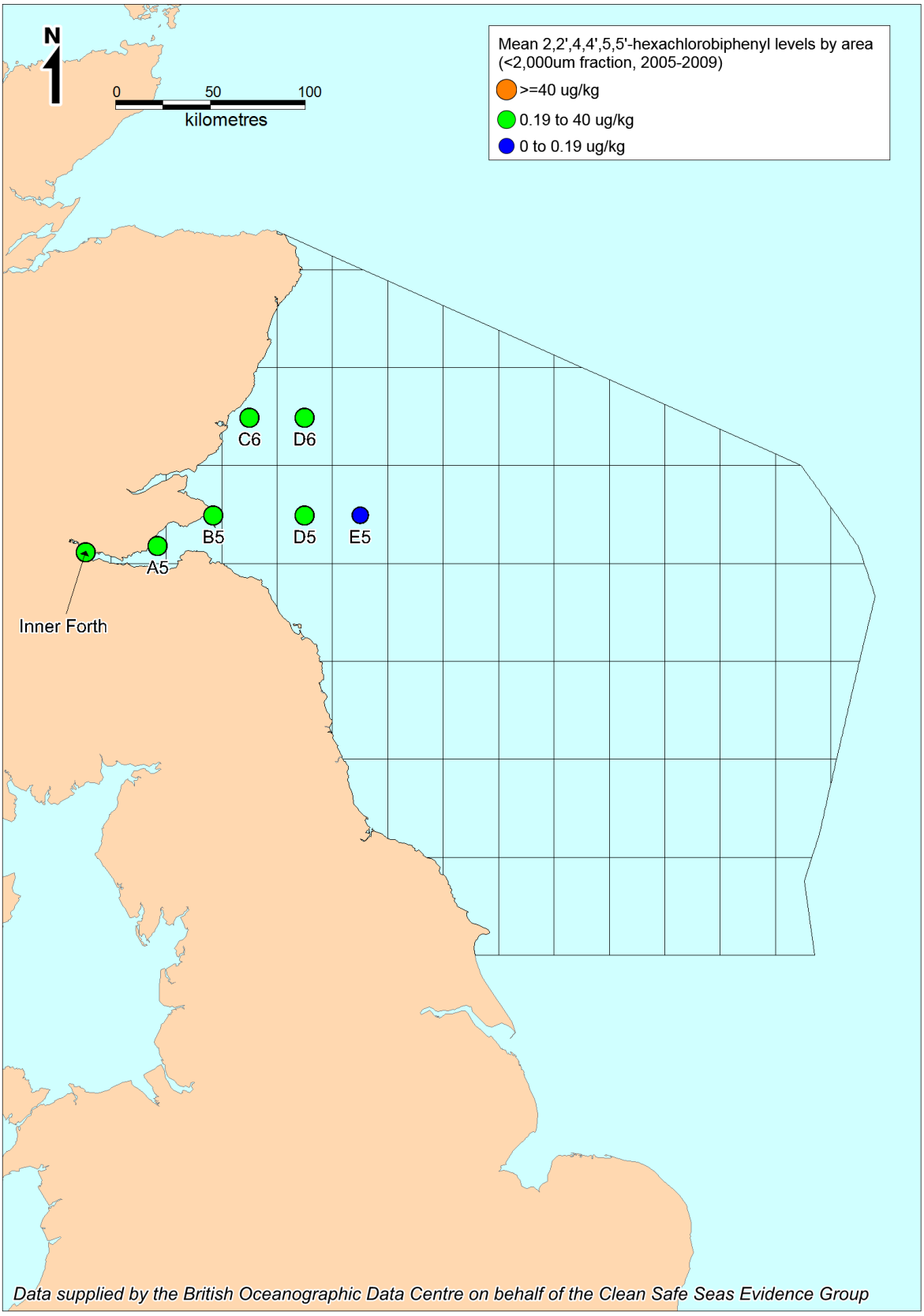

Figure 0:47: Map of mean 2,2',4,4',5,5'-hexachlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.50: Summary of 2,2',4,4',5,5'-hexachlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		2,2',4,4',5,5'-hexachlorobiphenyl (CB153) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2005	2009	8	0.8	0.5	1.0	100%	0%
B5	2005	2009	14	0.4	0.1	0.7	93%	0%
C6	2006	2009	12	0.4	0.1	0.7	92%	0%
D5	2006	2009	9	1.1	0.2	2.8	100%	0%
D6	2008	2008	1	0.4	0.4	0.4	100%	0%
E5	2005	2005	5	0.2	0.1	0.2	40%	0%
Inner Forth	2005	2009	11	1.1	0.3	2.6	100%	0%

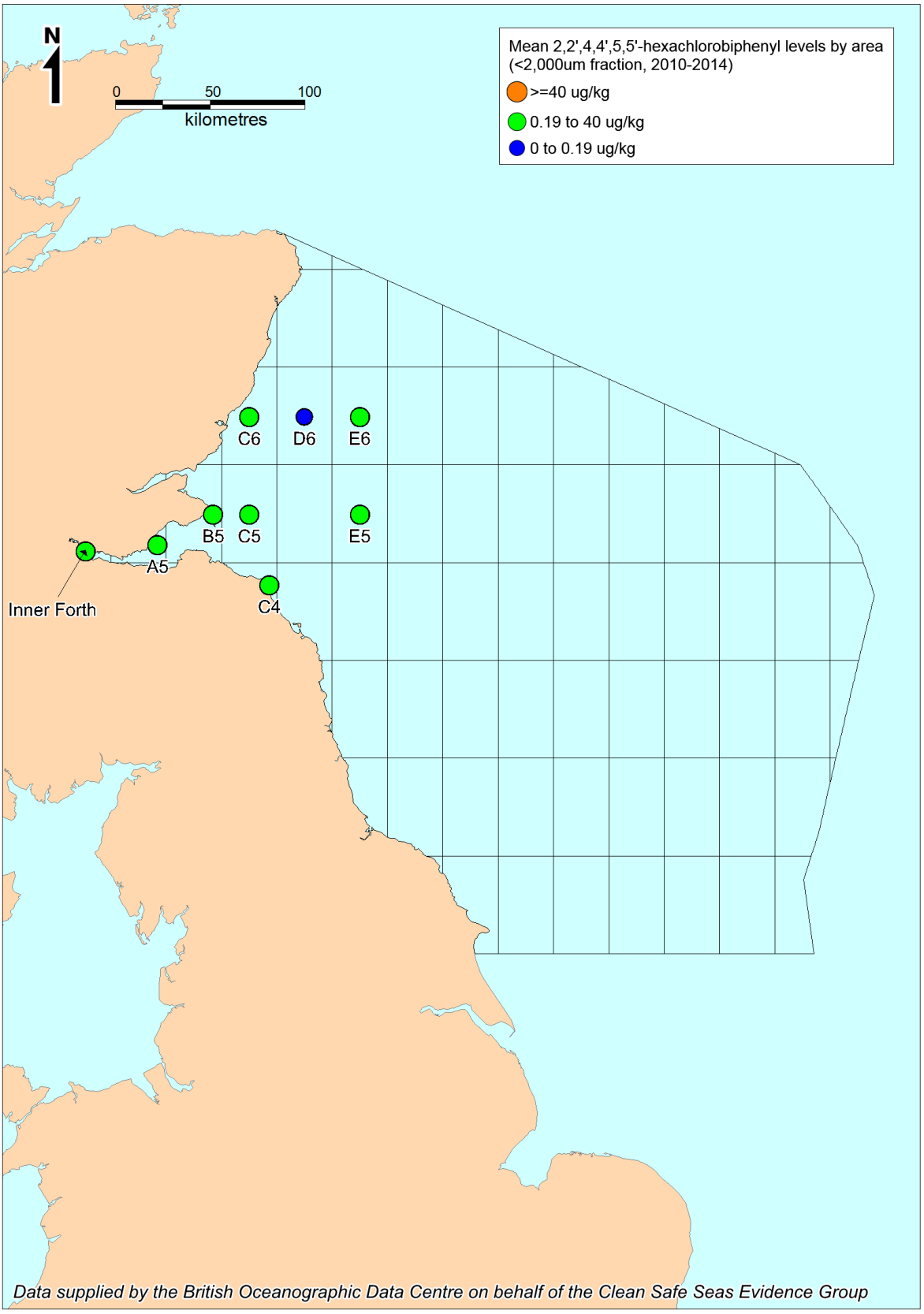

Figure 0:48: Map of mean 2,2',4,4',5,5'-hexachlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.34: Summary of 2,2',4,4',5,5'-hexachlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		2,2',4,4',5,5'-hexachlorobiphenyl (CB153) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2010	2014	19	0.8	0.3	1.1	100%	0%
B5	2010	2014	28	0.7	0.2	3.5	100%	0%
C4	2014	2014	1	0.6	0.6	0.6	100%	0%
C5	2014	2014	2	0.3	0.2	0.4	100%	0%
C6	2010	2014	20	0.3	0.1	0.8	45%	0%
D6	2011	2013	2	0.2	0.1	0.2	0%	0%
E5	2010	2012	2	0.6	0.4	0.9	100%	0%
E6	2014	2014	1	1.3	1.3	1.3	100%	0%
Inner Forth	2010	2014	23	1.0	0.5	3.4	100%	0%

Summary CB153 sediment

The CSEMP data analysed for all years revealed that all the sites analysed for CB 153 were either below the BAC or between the BAC and EAC (Figure 0:45 to Figure 0:48; Table 0.32 to Table 0.34). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

CB180

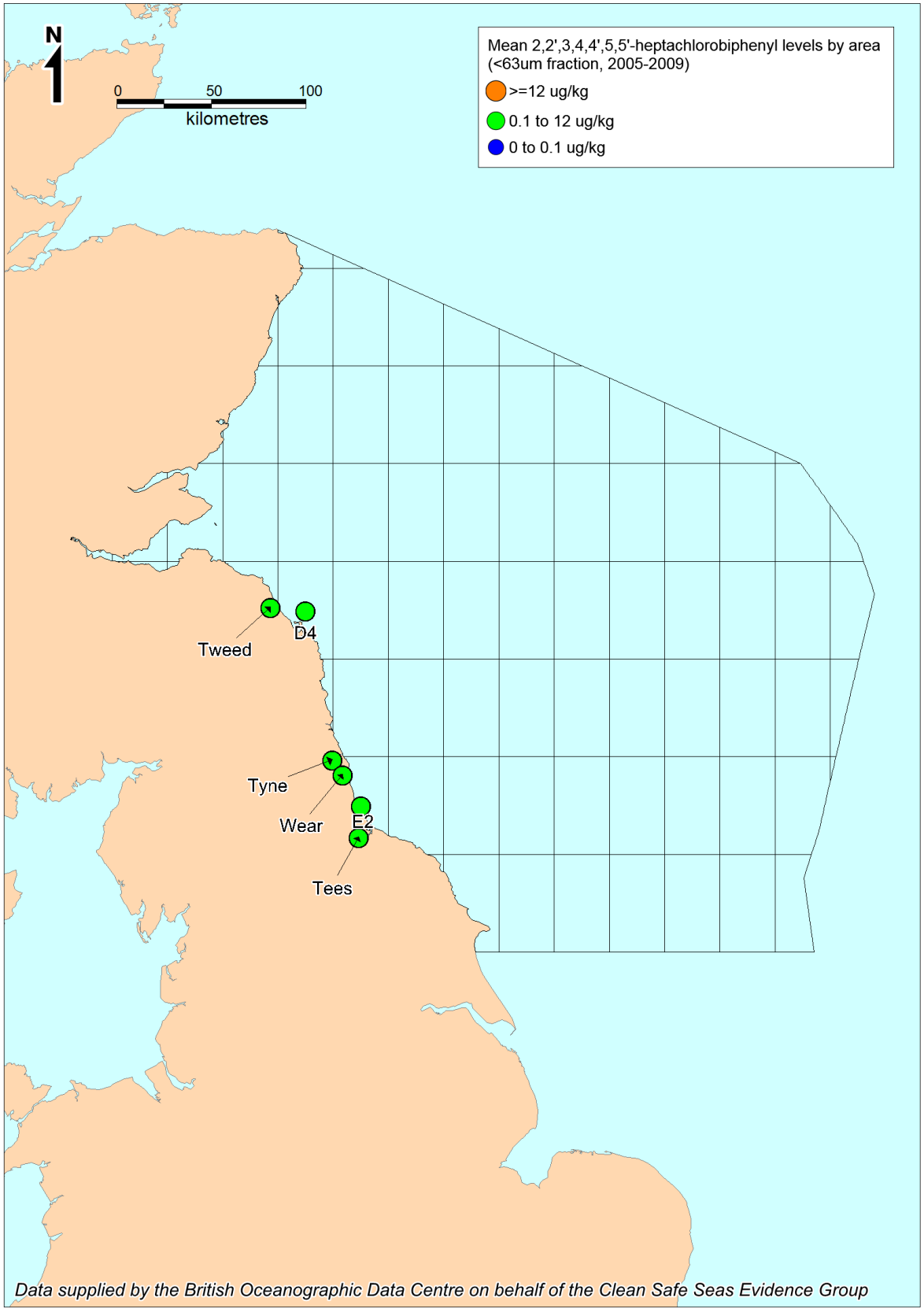

Figure 0:49: Map of mean 2,2',3,4,4',5,5'-heptachlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Table 0.35: Summary of 2,2',3,4,4',5,5'-heptachlorobiphenyl concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		2,2',3,4,4',5,5'-heptachlorobiphenyl (CB180) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
D4	2006	2008	14	0.6	0.1	4.9	79%	0%
E2	2006	2008	30	0.3	0.0	4.3	67%	0%
Tees	2006	2009	35	1.0	0.0	3.4	80%	0%
Tweed	2006	2008	14	0.1	0.1	0.2	71%	0%
Tyne	2006	2009	35	0.5	0.0	2.0	77%	0%
Wear	2006	2009	35	0.3	0.0	1.9	60%	0%

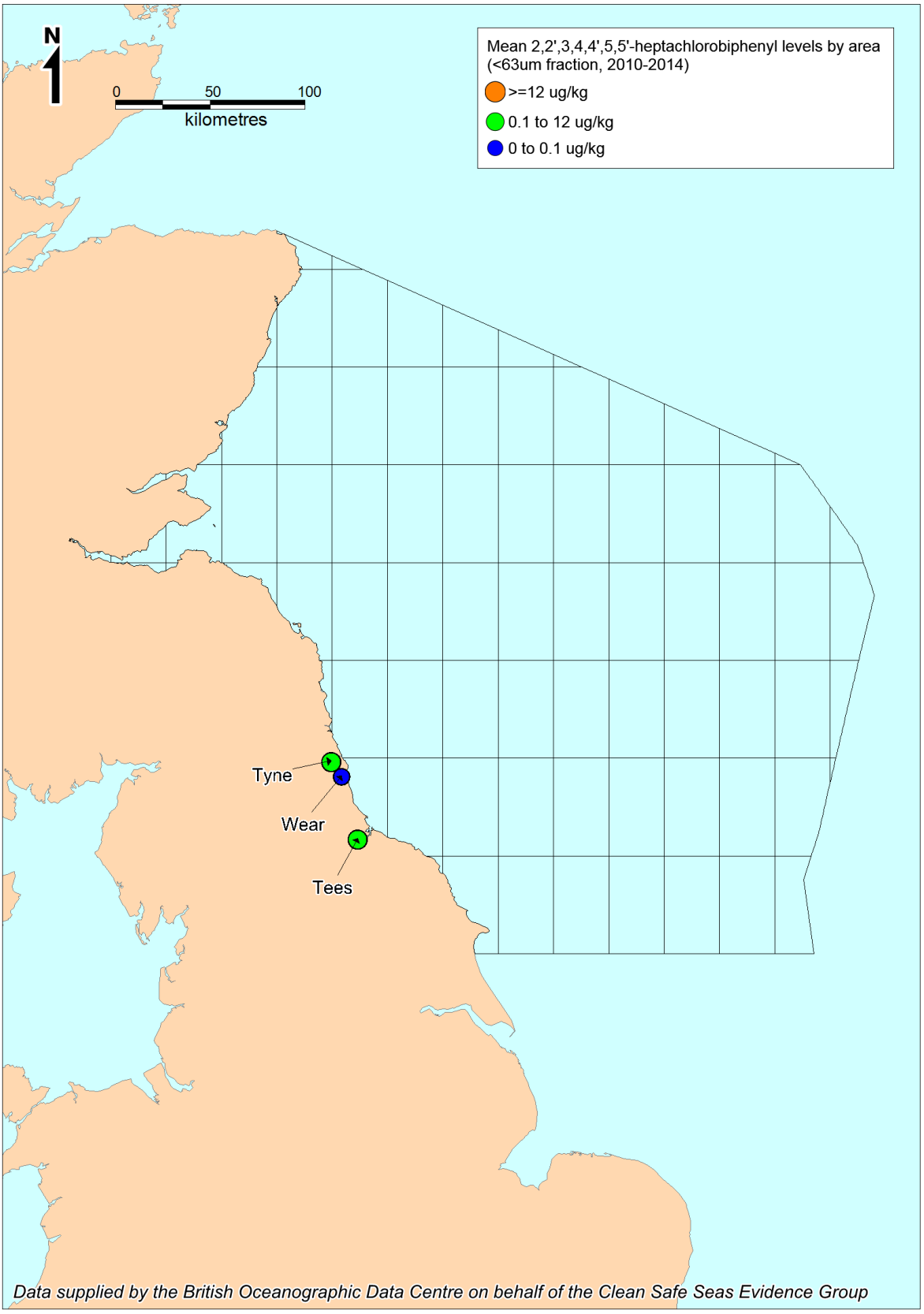

Figure 0:50: Map of mean 2,2',3,4,4',5,5'-heptachlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Table 0.36: Summary of 2,2',3,4,4',5,5'-heptachlorobiphenyl concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		2,2',3,4,4',5,5'-heptachlorobiphenyl (CB180) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
Tees	2010	2013	10	3.9	0.5	27.5	100%	10%
Tyne	2010	2010	5	0.1	0.1	0.1	40%	0%
Wear	2010	2010	5	0.1	0.0	0.1	20%	0%

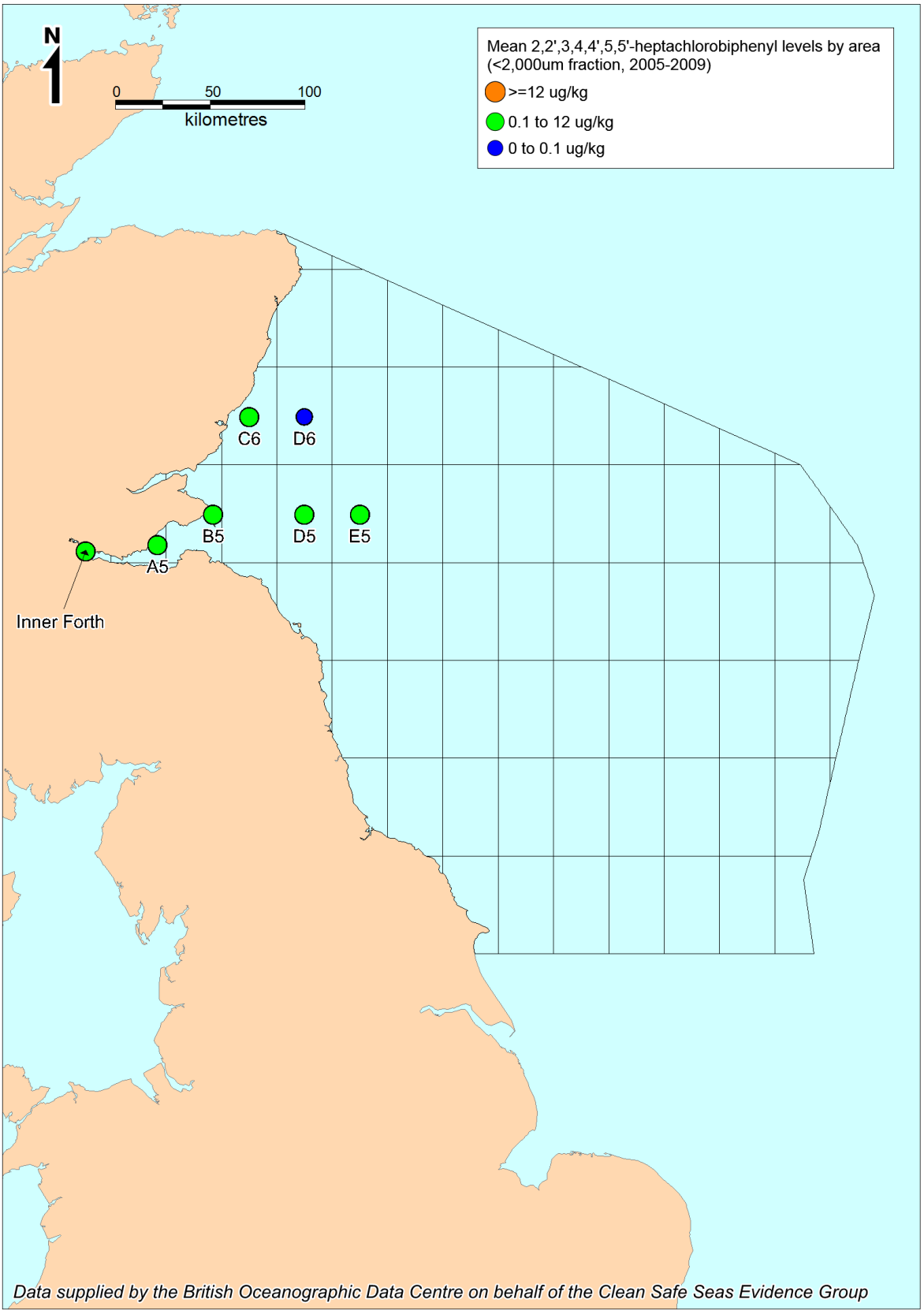

Figure 0:51: Map of mean 2,2’,3,4,4’,5,5’-heptachlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.37: Summary of 2,2',3,4,4',5,5'-heptachlorobiphenyl concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		2,2',3,4,4',5,5'-heptachlorobiphenyl (CB180) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2005	2009	8	0.6	0.4	0.9	100%	0%
B5	2005	2009	14	0.3	0.0	0.5	93%	0%
C6	2006	2009	12	0.1	0.1	0.3	33%	0%
D5	2006	2009	9	1.1	0.2	2.8	100%	0%
D6	2008	2008	1	0.1	0.1	0.1	0%	0%
E5	2005	2005	5	0.2	0.1	0.2	80%	0%
Inner Forth	2005	2009	11	0.8	0.2	1.9	100%	0%

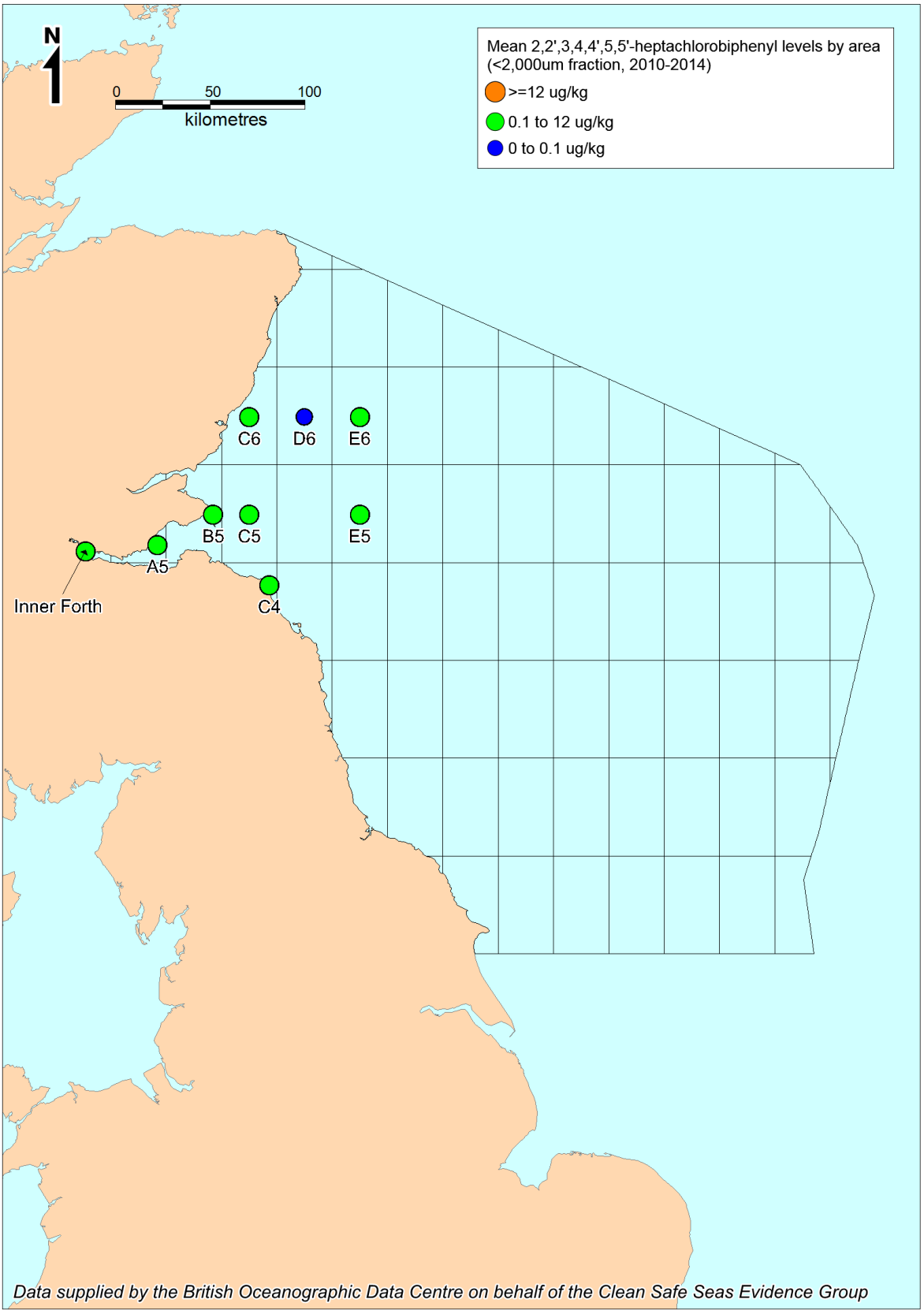

Figure 0:52: Map of mean 2,2’,3,4,4’,5,5’-heptachlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.38: Summary of 2,2',3,4,4',5,5'-heptachlorobiphenyl concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		2,2',3,4,4',5,5'-heptachlorobiphenyl (CB180) sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EAC
A5	2010	2014	19	0.7	0.3	1.1	100%	0%
B5	2010	2014	28	0.6	0.1	5.2	89%	0%
C4	2014	2014	1	0.3	0.3	0.3	100%	0%
C5	2014	2014	2	0.1	0.1	0.1	50%	0%
C6	2010	2014	20	0.1	0.0	0.3	35%	0%
D6	2011	2013	2	0.1	0.1	0.1	0%	0%
E5	2010	2012	2	0.3	0.2	0.3	100%	0%
E6	2014	2014	1	0.7	0.7	0.7	100%	0%
Inner Forth	2010	2014	23	0.8	0.3	2.9	100%	0%

Summary CB180 sediment

The CSEMP data analysed for all years revealed that all the sites analysed for CB 180 were either below the BAC or between the BAC and EAC (Figure 0:49 to Figure 0:52;Table 0.35 to Table 0.38). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

1.2.8 Polycyclic aromatic hydrocarbons in sediment

PAHs bind to sediments due to their hydrophobicity and, in such matrices, they can persist for decades due to their low level of degradation in anaerobic environments. PAHs normally reach the marine environment because of fossil fuel combustion, waste incineration and oil spills, posing a threat to benthic organisms due to their acutely toxic, mutagenic and carcinogenic properties (Nicolaus *et al*., 2015).

Two different particle size fractions were tested (<63 um and <2000um) and these are presented separately due to grain size effects. Where a result was reported as a less than value, it was assigned a nominal value of half the limit of quantification. To investigate temporal differences sample results were presented separately for the periods 2005-09 and 2010-14. The survey area was divided into 0.5 degree by 0.5 degree rectangles and enclosed estuaries. Summary statistics were calculated for all samples by rectangle or estuary for spatial assessments of PAH concentrations to be made. Although results were available for a larger range of PAHs, data were only presented for those listed in **Table *0.39***. These are most commonly used for assessment purposes and have defined assessment criteria.

Table 0.39: Assessment criteria used for PAHs

PAHs	Less than the Background Assessment Concentration (BAC)	From the BAC to the Effects Range Low (ERL)	From the ERL to the Effects Range Median (ERM)	>= to the ERM
Anthracene	<5 µg/kg	>= 5 µg/kg to 85 µg/kg	>= 85 µg/kg to 1,100 µg/kg	>= 1,100 µg/kg
Benz[a]anthracene	<16 µg/kg	>= 16 µg/kg to 261 µg/kg	>= 261 µg/kg to 1,600 µg/kg	>= 1,600 µg/kg
Benzo[a]pyrene	<30 µg/kg	>= 30 µg/kg to 430 µg/kg	>= 430 µg/kg to 1,600 µg/kg	>= 1,600 µg/kg
Benzo[ghi]perylene	<80 µg/kg	>=80 µg/kg to 85 µg/kg	>= 85 µg/kg	Not stated
Chrysene (+ triphenylene)	<20 µg/kg	>= 20 µg/kg to 384 µg/kg	>= 384 µg/kg to 2,800 µg/kg	>= 2,800 µg/kg
Fluorene	Not stated	< 19 µg/kg	>= 19 µg/kg to 540 µg/kg	>= 540 µg/kg
Indeno[123-cd]pyrene	<103 µg/kg	>=103 µg/kg to 240 µg/kg	>= 240 µg/kg	Not stated
Naphthalene	<8 µg/kg	>= 8 µg/kg to 160 µg/kg	>= 160 µg/kg to 2,100 µg/kg	>= 2,100 µg/kg
Phenanthrene	<32 µg/kg	>= 32 µg/kg to 240 µg/kg	>= 240 µg/kg to 1,500 µg/kg	>= 1,500 µg/kg
Pyrene	<29 µg/kg	>= 29 µg/kg to 665 µg/kg	>= 665 µg/kg to 2,600 µg/kg	>= 2,600 µg/kg

PAH content are compared to the Background Assessment Concentration (BAC) to identify if concentrations are 'close to background' and against Environmental Assessment Criteria (EAC). The tables of summary statistics present the range of years within which the samples were taken, the arithmetic mean result, the minimum and maximum result, and the percentage of samples exceeding the assessment concentrations. Thematic maps were produced with colour coded symbols based on the mean result in relation to the assessment levels for each geographic division.

1.2.9 Overview CSEMP PAH sediment data

In summary the data presented mirrors that presented in Defra's charting progress 2 report (Charting Progress 2, 2010). In terms of inputs into the region it is known that atmospheric inputs have been reduced significantly in recent years. However, in some of the historically industrialized estuaries, such as the Tyne and Tees on the north-east coast, there can be high levels of legacy contamination (Lyons *et al*., 2014; Nicolaus *et al*., 2015). As PAHs are persistent (particularly in low oxygen conditions, as found in organic-rich muddy estuarine sediments) these levels of contamination are reducing slowly and therefore there is a risk of re-mobilisation following flooding events, dredging activities or storms. The data presented below indicate that any toxicological threat is restricted to these heavily contaminated estuarine locations and coastal or offshore locations remain uncontaminated and pose little or no risk to marine organisms.

Anthracene

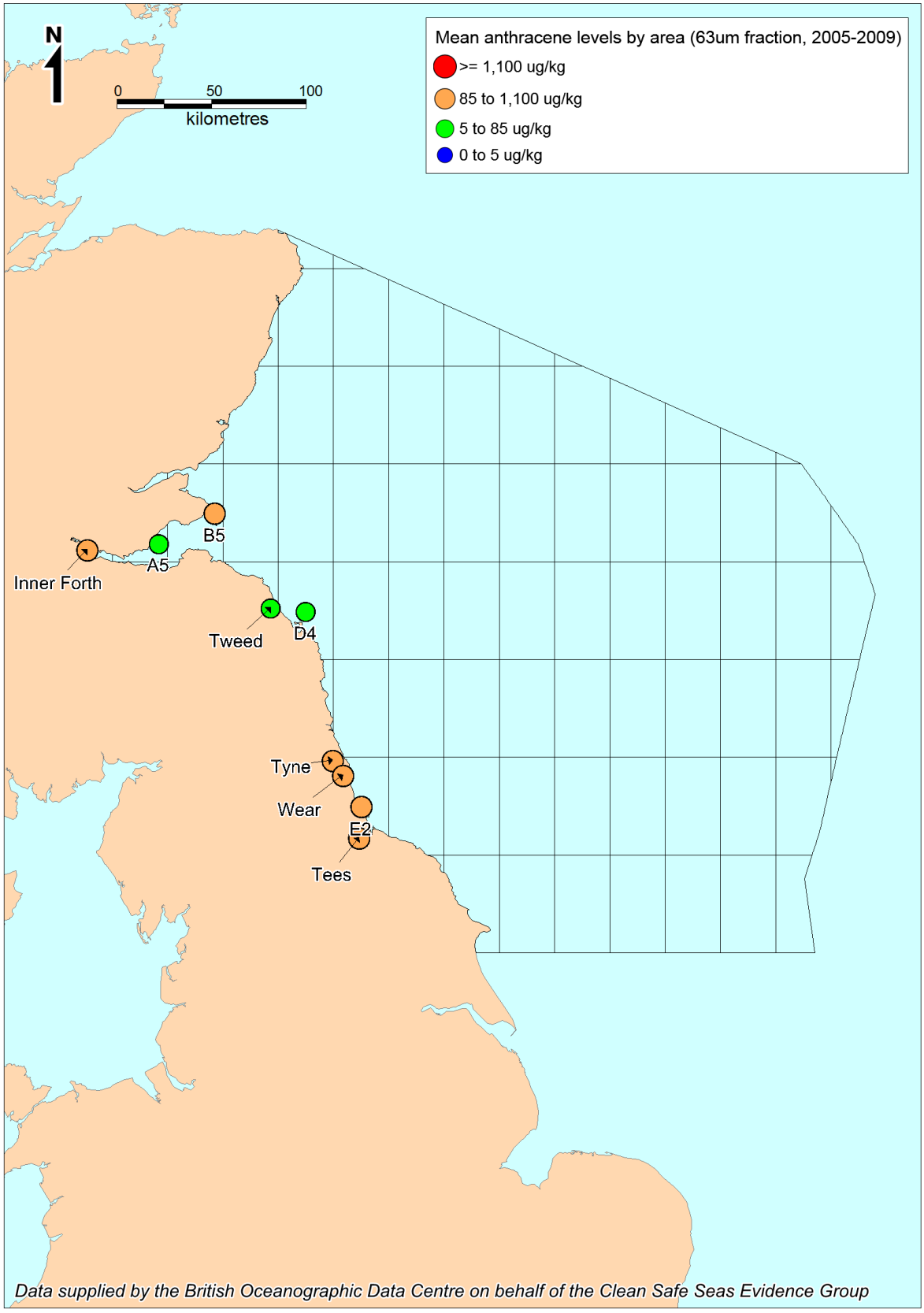

Figure 0:53: Map of mean anthracene concentrations by area (< 63 µm fraction, 2005-09)

Table 0.40: Summary of anthracene concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Anthracene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2006	2006	1	51.1	51.1	51.1	100%	0%	0%
B5	2005	2006	6	158.2	88.2	399.7	100%	100%	0%
D4	2006	2008	15	83.0	27.8	237.5	100%	40%	0%
E2	2006	2008	30	102.4	23.9	336.9	100%	60%	0%
Inner Forth	2005	2006	10	121.3	38.6	289.6	100%	40%	0%
Tees	2006	2009	35	311.2	113.9	1010.5	100%	100%	0%
Tweed	2006	2008	14	42.3	14.0	64.7	100%	0%	0%
Tyne	2006	2009	35	195.8	84.9	535.5	100%	97%	0%
Wear	2006	2009	35	297.7	60.4	2037.5	100%	97%	6%

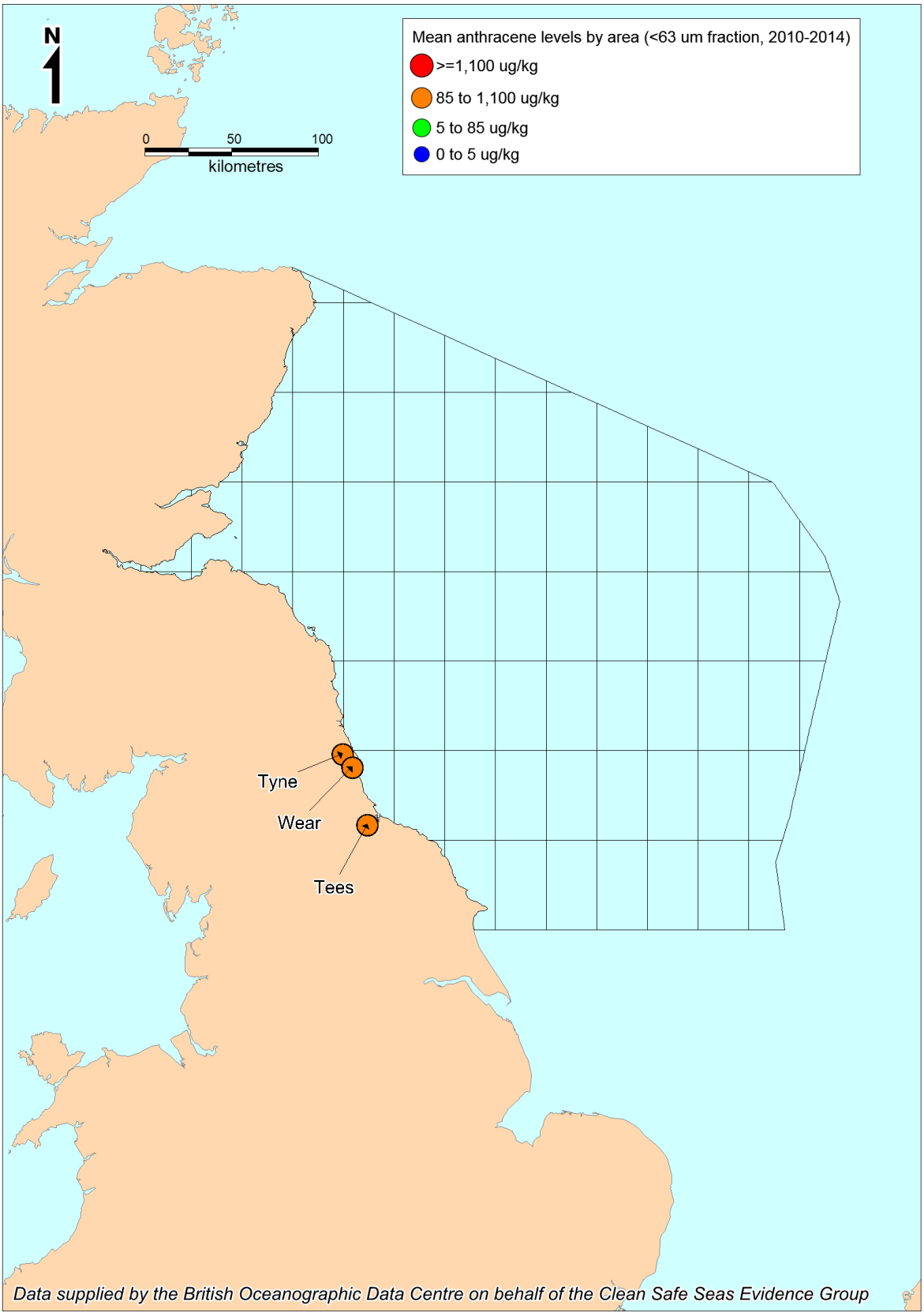

Figure 0:54: Map of mean anthracene concentrations by area (< 63 µm fraction, 2010-14)

Table 0.41: Summary of anthracene concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Anthracene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
Tees	2010	2013	10	336.8	146.8	1142.7	100%	100%	10%
Tyne	2010	2010	5	163.65	148.75	181.18	100%	100%	0%
Wear	2010	2010	5	156.7	122.5	188.9	100%	100%	0%

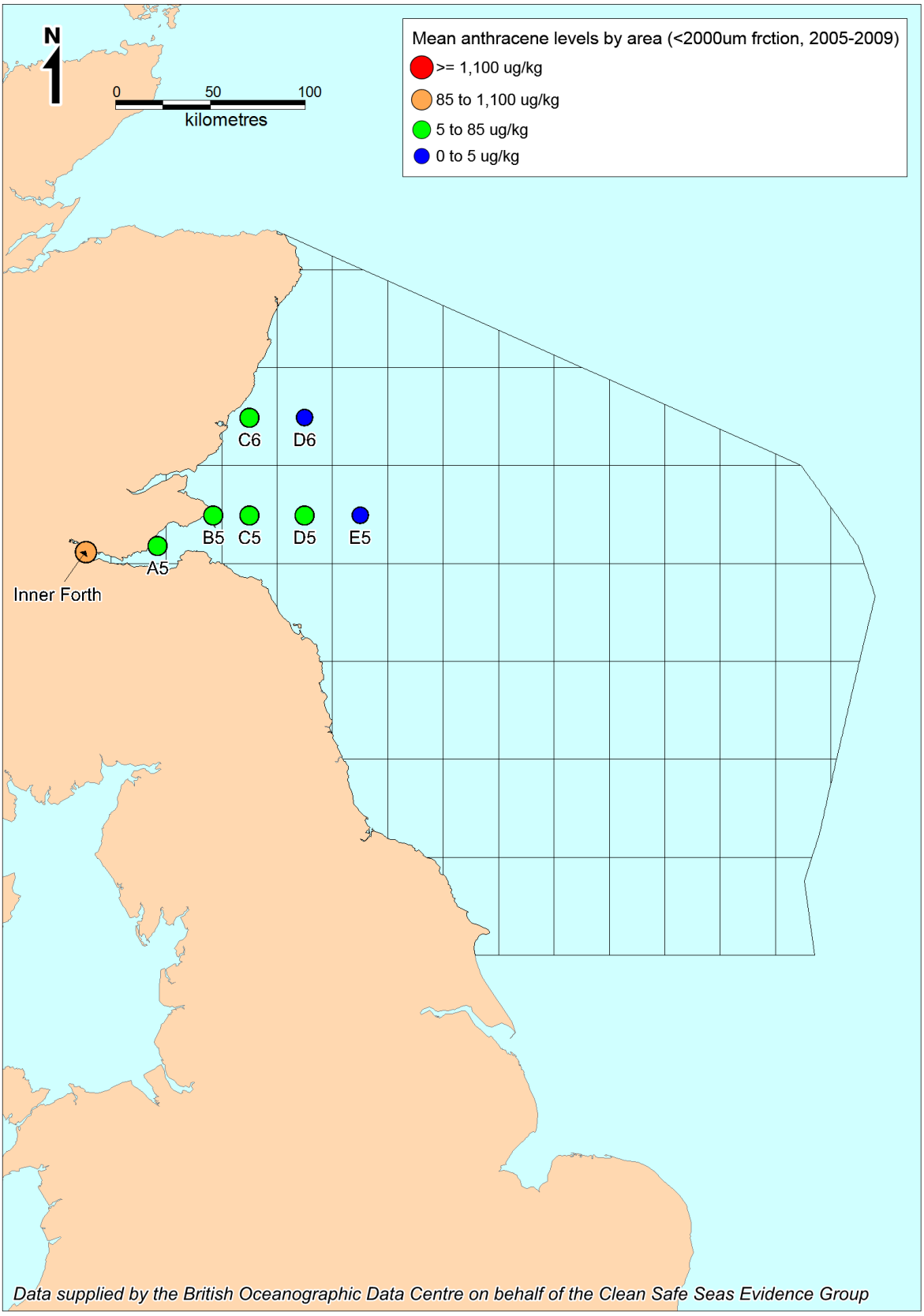

Figure 0:55: Map of mean anthracene concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.42: Summary of anthracene concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Anthracene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2005	2009	8	32.9	7.3	60.4	100%	0%	0%
B5	2005	2009	14	9.6	0.3	24.7	43%	0%	0%
C5	2006	2006	1	43.4	43.4	43.4	100%	0%	0%
C6	2006	2009	19	14.1	2.4	71.4	68%	0%	0%
D5	2006	2009	9	8.0	0.2	16.7	56%	0%	0%
D6	2008	2008	1	0.3	0.3	0.3	0%	0%	0%
E5	2005	2005	5	1.4	1.3	1.5	0%	0%	0%
Inner Forth	2005	2009	13	116.6	21.7	216.3	100%	69%	0%

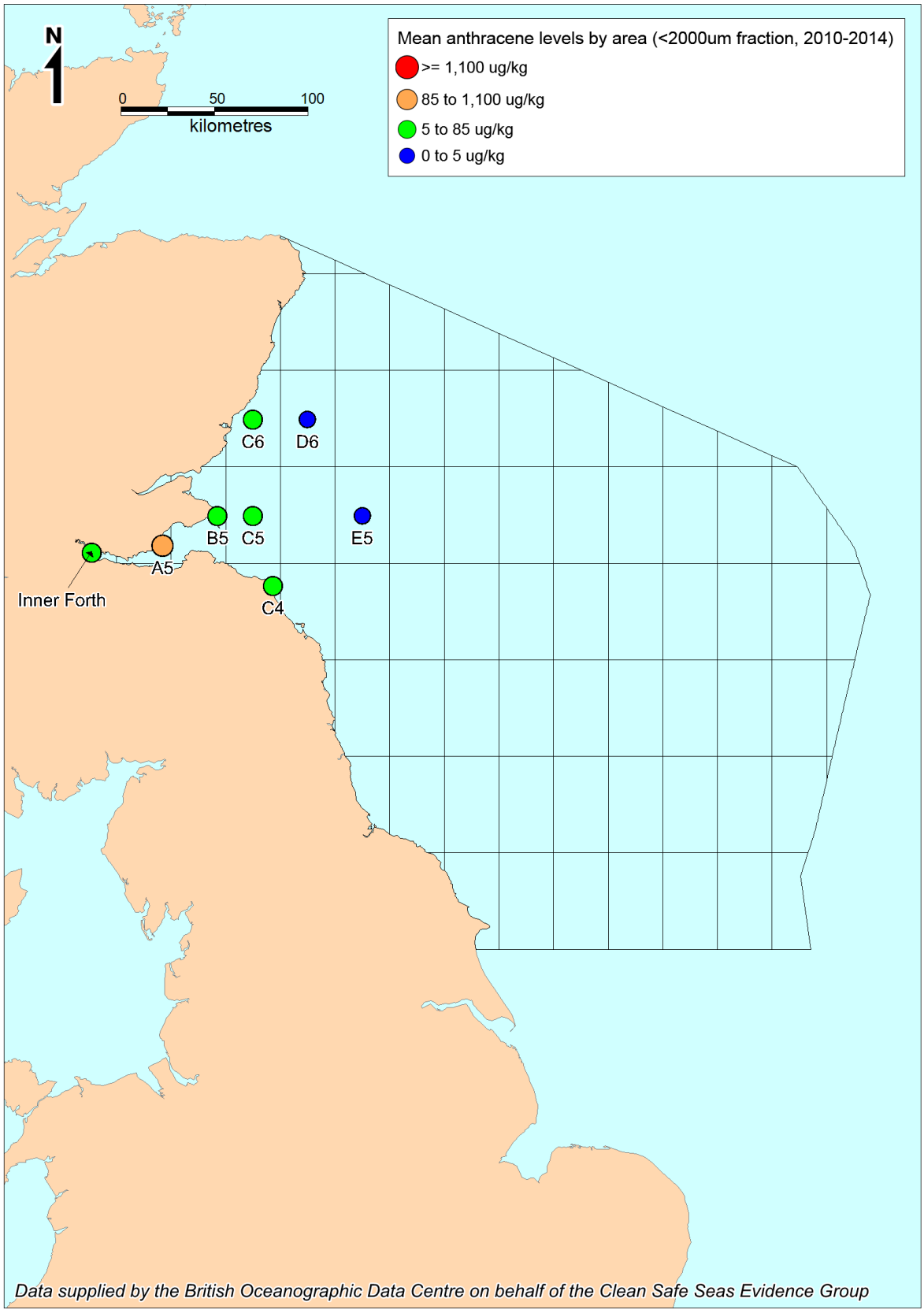

Figure 0:56: Map of mean anthracene concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.60: Summary of anthracene concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Anthracene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2010	2014	19	90.3	57.6	259.8	100%	42%	0%
B5	2010	2014	33	27.9	0.4	78.8	76%	0%	0%
C4	2014	2014	1	17.5	17.5	17.5	100%	0%	0%
C5	2010	2014	3	7.3	5.9	9.7	100%	0%	0%
C6	2010	2013	24	11.4	2.2	43.7	71%	0%	0%
D6	2011	2013	2	0.3	0.3	0.3	0%	0%	0%
E5	2010	2012	2	0.4	0.3	0.4	0%	0%	0%
Inner Forth	2010	2014	26	66.2	14.1	108.7	100%	23%	0%

Summary Anthracene sediment

The CSEMP data analysed revealed that 7/17 and 4/11 sectorial boxes exceeded the ERL for anthracene between 2005-2009 (Figure 1.53 and 1.55 and Table 1.57 and 1.59) and 2010-2014 (Figure 1.54 and 1.56 and Table 1.58 and 1.60). Many of these exceedances occurred in the industrialised estuaries (Tyne, Tees Forth and Wear). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Benz[a]anthracene

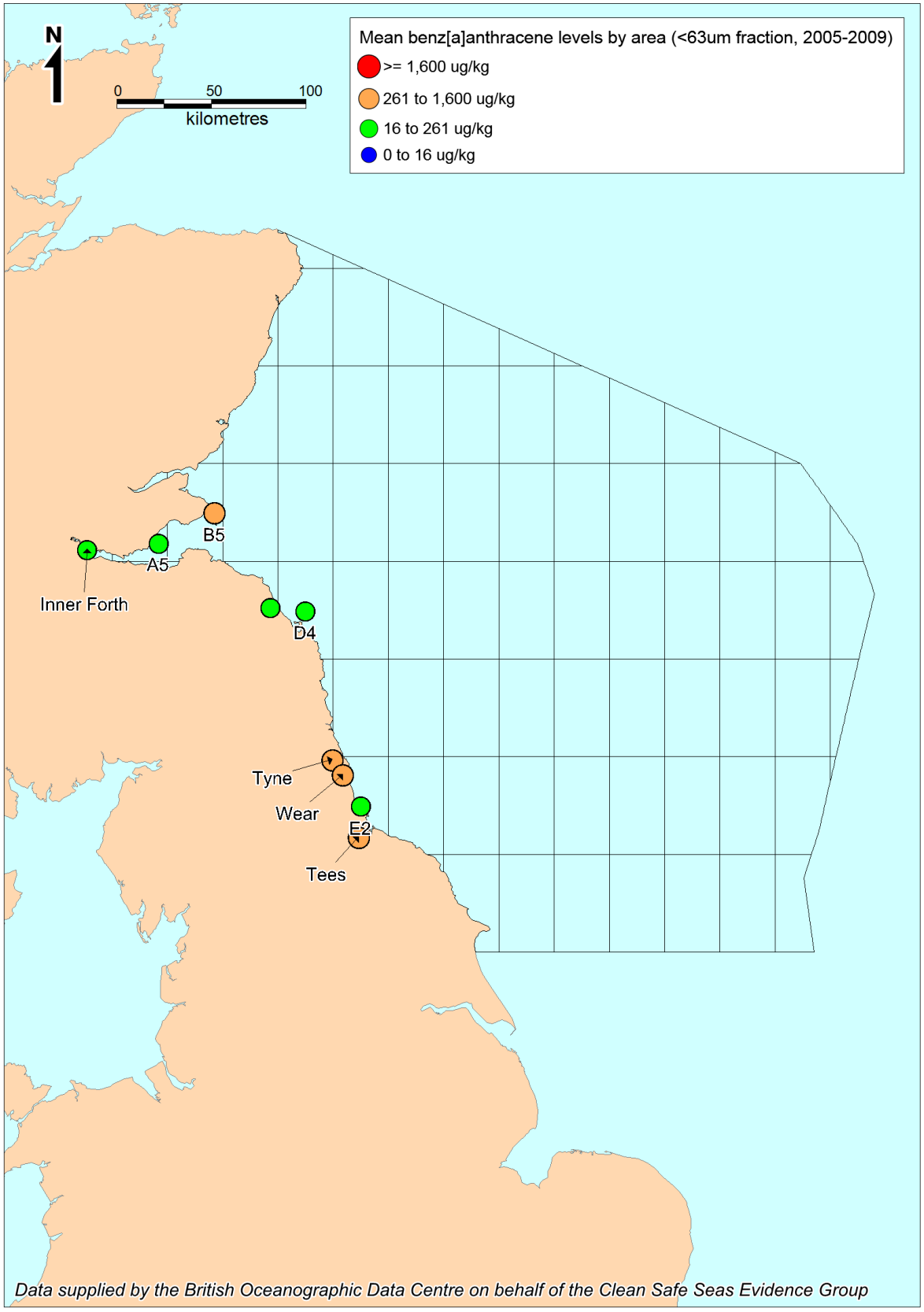

Figure 0:57: Map of mean benz[a]anthracene concentrations by area (< 63 µm fraction, 2005-09)

Table 0.43: Summary of benz[a]anthracene concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Benz[a]anthracene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2006	2006	1	152.6	152.6	152.6	100%	0%	0%
B5	2005	2006	6	367.0	193.0	992.0	100%	50%	0%
D4	2006	2008	15	216.9	95.9	602.5	100%	20%	0%
E2	2006	2008	30	173.4	36.3	505.3	100%	20%	0%
Inner Forth	2005	2006	10	179.3	64.9	300.0	100%	30%	0%
Tees	2006	2009	35	576.8	197.9	1542.0	100%	97%	0%
Tweed	2006	2008	14	155.8	91.7	246.6	100%	0%	0%
Tyne	2006	2009	35	352.6	150.6	837.3	100%	69%	0%
Wear	2006	2009	35	654.0	130.0	5350.0	100%	74%	6%

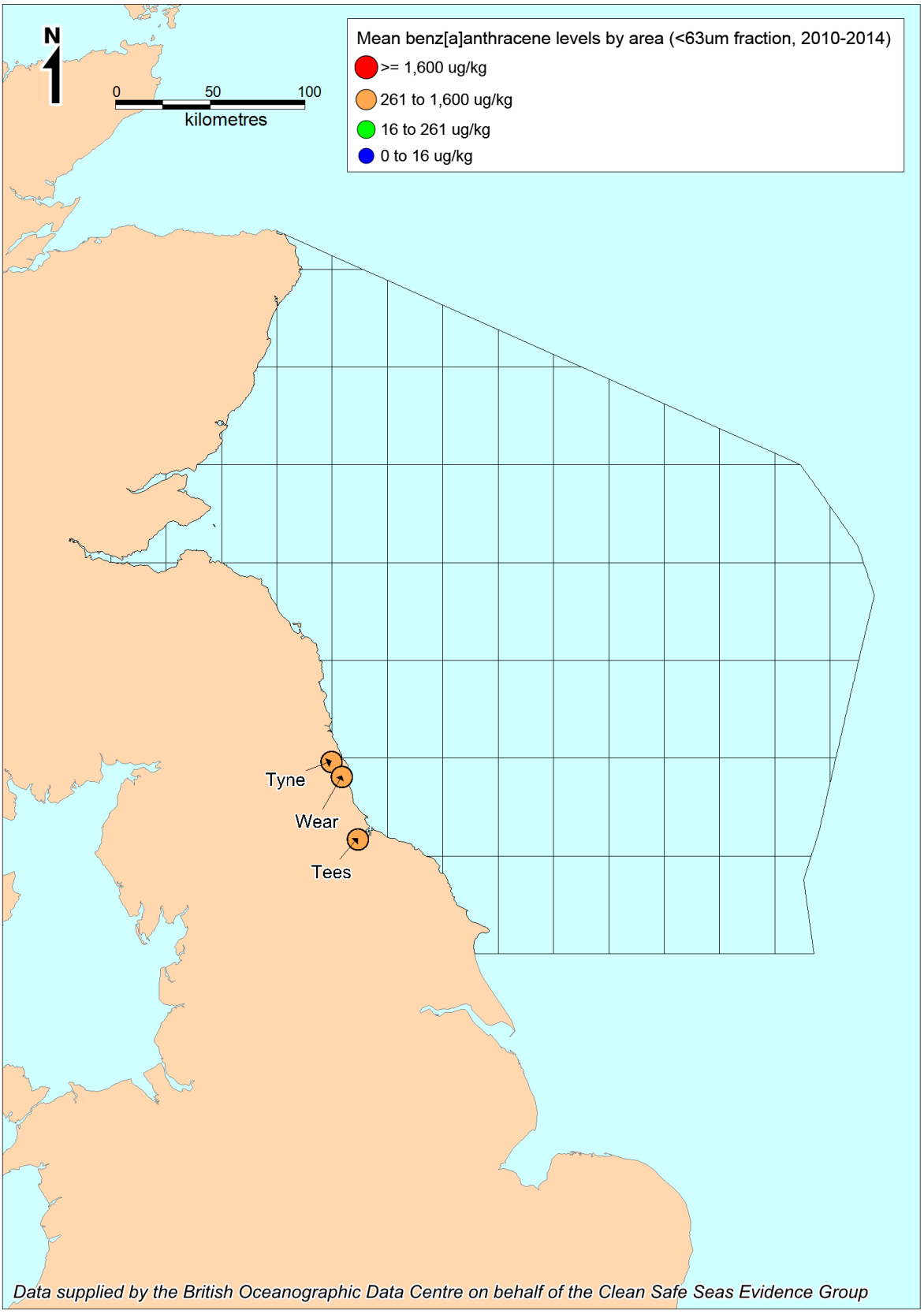

Figure 0:58: Map of mean benz[a]anthracene concentrations by area (< 63 µm fraction, 2010-14)

Table 0.44: Summary of benz[a]anthracene concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Benz[a]anthracene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
Tees	2010	2013	10	602.9	434.9	910.7	100%	100%	0%
Tyne	2010	2010	5	296.3	255.8	341.4	100%	80%	0%
Wear	2010	2010	5	334.1	273	394.7	100%	100%	0%

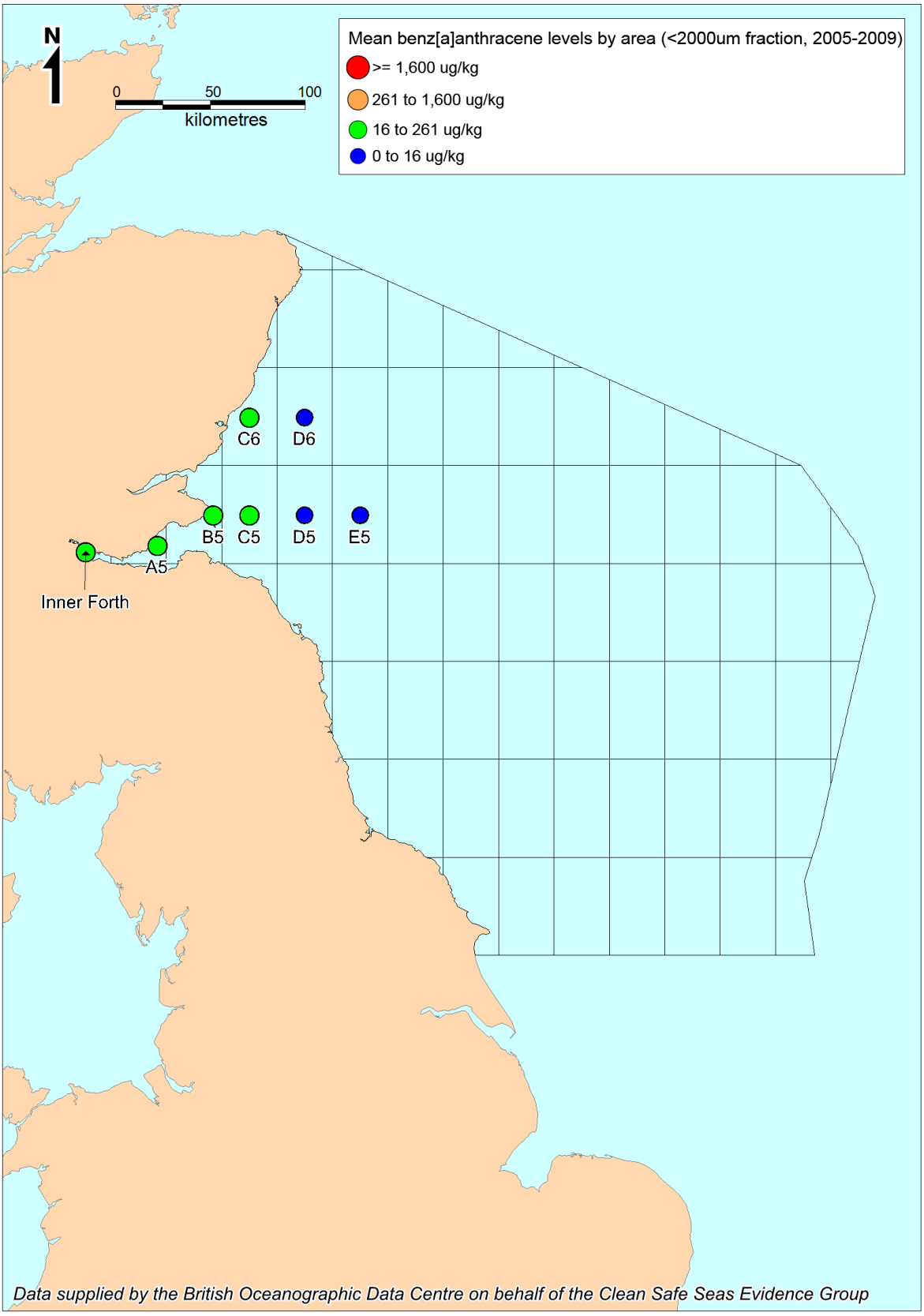

Figure 0:59: Map of mean benz[a]anthracene concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.45: Summary of benz[a]anthracene concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Benz[a]anthracene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2005	2009	12	108.4	15.6	240.6	92%	0%	0%
B5	2005	2009	20	54.9	1.1	183.8	60%	0%	0%
C5	2006	2006	1	78.0	78.0	78.0	100%	0%	0%
C6	2006	2009	19	42.5	7.1	133.3	79%	0%	0%
D5	2006	2009	9	14.5	1.7	33.3	44%	0%	0%
D6	2008	2008	1	0.9	0.9	0.9	0%	0%	0%
E5	2005	2005	5	2.8	1.5	3.8	0%	0%	0%
Inner Forth	2005	2009	18	161.2	23.4	341.3	100%	17%	0%

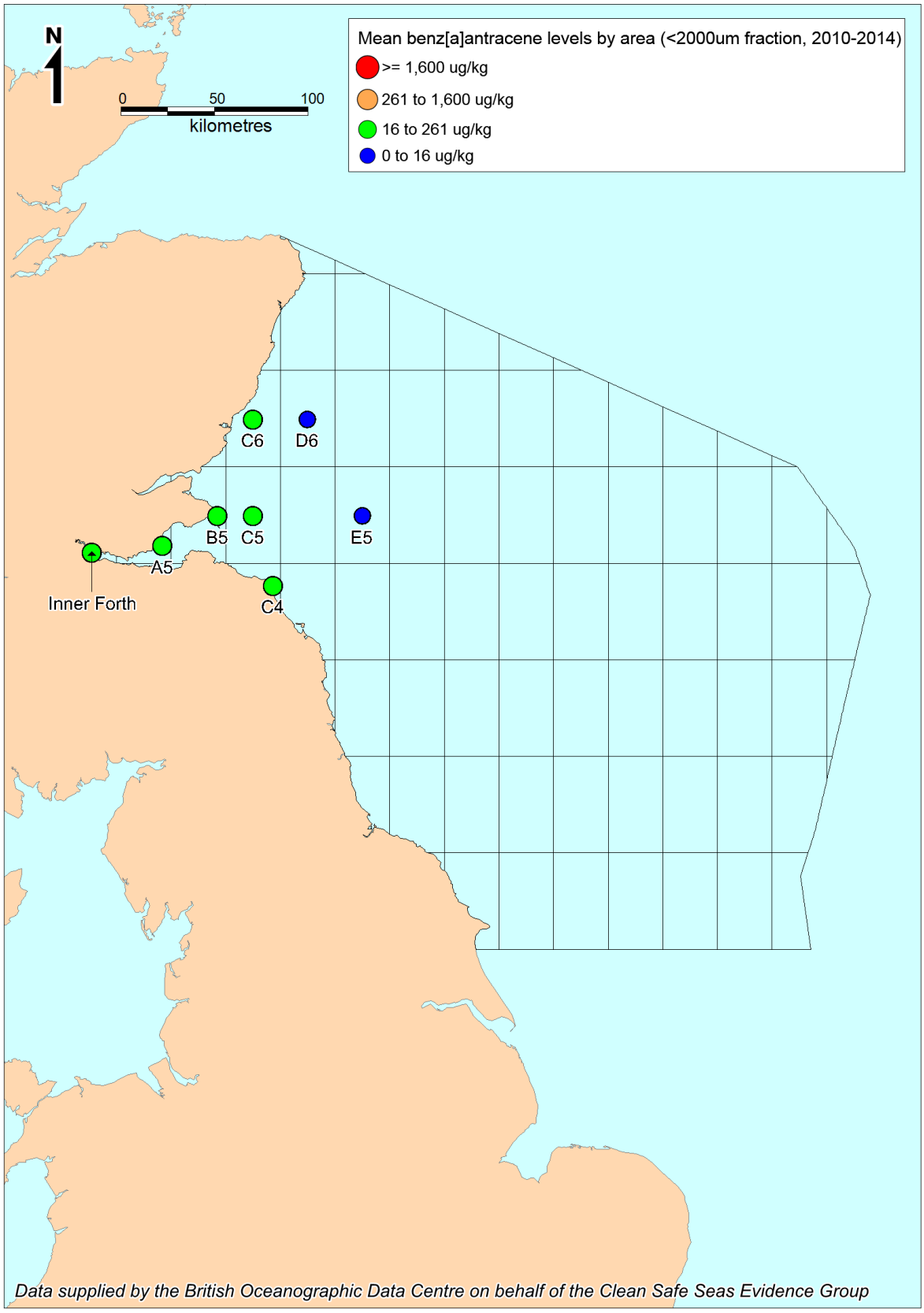

Figure 0:60: Map of mean benz[a]anthracene concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.46: Summary of benz[a]anthracene concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Benz[a]anthracene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2010	2010	2	131.3	112.8	149.9	100%	0%	0%
B5	2010	2014	21	41.6	1.4	166.8	57%	0%	0%
C4	2014	2014	1	44.9	44.9	44.9	100%	0%	0%
C5	2010	2014	3	19.4	15.9	25.8	67%	0%	0%
C6	2010	2013	24	40.0	10.4	140.8	71%	0%	0%
D6	2011	2013	2	2.7	2.7	2.8	0%	0%	0%
E5	2010	2012	2	2.4	1.4	3.5	0%	0%	0%
Inner Forth	2010	2012	10	79.3	34.7	144.6	100%	0%	0%

Summary Benz[a]anthracene sediment

The CSEMP data analysed revealed that 4/17 and 3/11 sectorial boxes exceeded the ERL for benz[a]anthracene between 2005-2009 (Figure 1.57 and 1.59 and Table 1.61 and 1.63 and 2010-2014 (Figure 1.58 and 1.60 and Table 1.62 and 1.64). Many these exceedances occurred in the industrialised estuaries (Tyne, Tees and Wear). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Benzo[a]pyrene

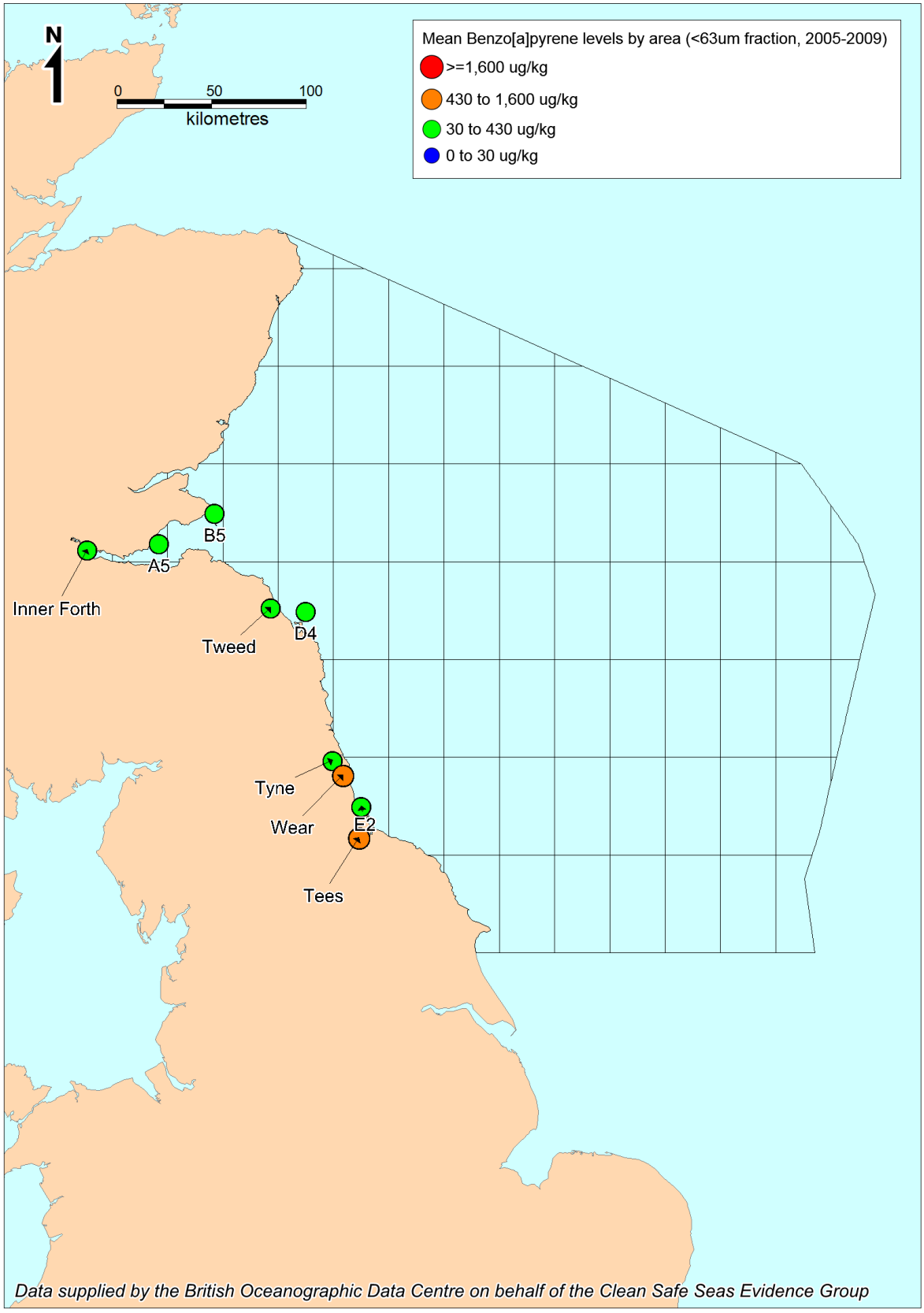

Figure 0:61: Map of mean benzo[a]pyrene concentrations by area (< 63 µm fraction, 2005-09)

Table 0.47: Summary of benzo[a]pyrene concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Benzo[a]pyrene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2006	2006	1	117.4	117.4	117.4	100%	0%	0%
B5	2005	2006	6	422.0	255.0	1049.0	100%	17%	0%
D4	2006	2008	15	218.9	102.2	606.3	100%	13%	0%
E2	2006	2008	30	151.4	32.3	439.8	100%	3%	0%
Inner Forth	2005	2006	10	193.9	39.0	357.1	100%	0%	0%
Tees	2006	2009	35	566.8	209.4	1469.8	100%	71%	0%
Tweed	2006	2008	14	161.1	85.9	232.5	100%	0%	0%
Tyne	2006	2009	35	334.5	145.2	797.5	100%	20%	0%
Wear	2006	2009	35	594.0	127.0	4838.0	100%	40%	6%

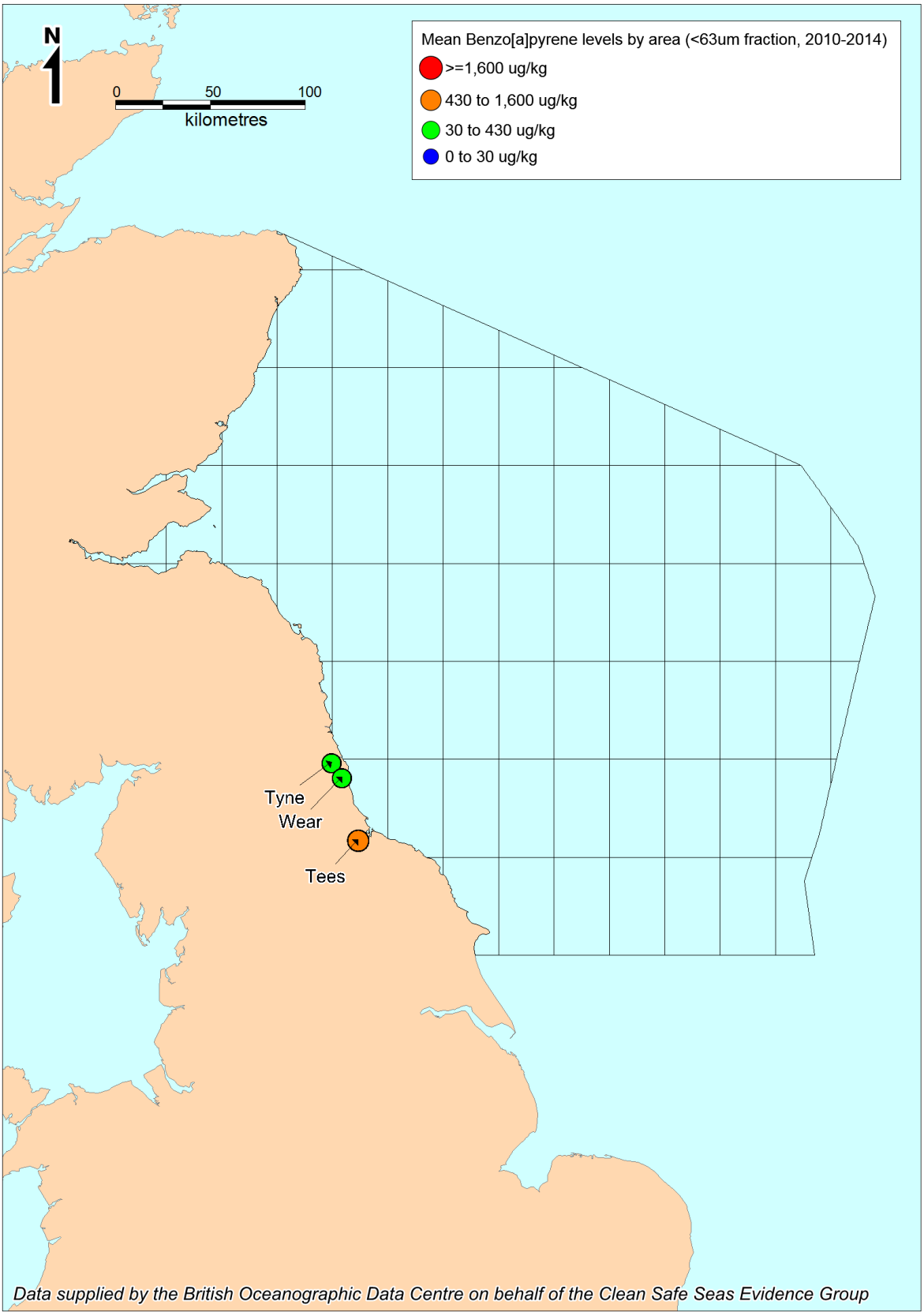

Figure 0:62: Map of mean benzo[a]pyrene concentrations by area (< 63 µm fraction, 2010-14)

Table 0.48: Summary of benzo[a]pyrene concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Benzo[a]pyrene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
Tees	2010	2013	10	628.9	488.7	850.1	100%	100%	0%
Tyne	2010	2010	5	295.4	258.6	334.4	100%	0%	0%
Wear	2010	2010	5	338.5	275.4	410.6	100%	0%	0%

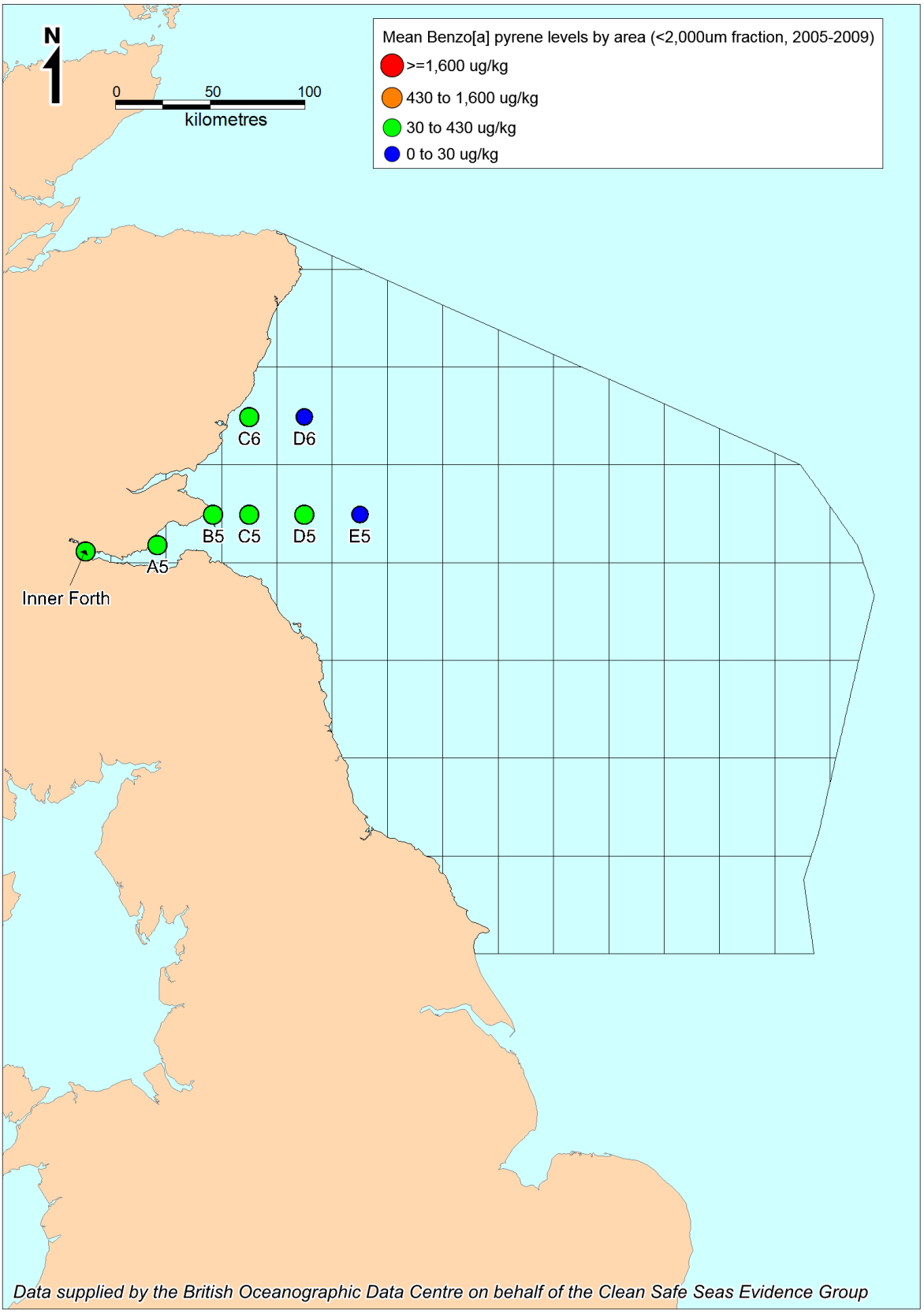

Figure 0:63: Map of mean benzo[a]pyrene concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.49: Summary of benzo[a]pyrene concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Benzo[a]pyrene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2005	2009	12	115.9	18.5	300.0	92%	0%	0%
B5	2005	2009	20	61.6	1.3	212.4	60%	0%	0%
C5	2006	2006	1	65.0	65.0	65.0	100%	0%	0%
C6	2006	2009	19	58.1	14.6	175.0	68%	0%	0%
D5	2006	2009	9	36.3	1.7	100.0	56%	0%	0%
D6	2008	2008	1	2.6	2.6	2.6	0%	0%	0%
E5	2005	2005	5	4.2	1.3	5.8	0%	0%	0%
Inner Forth	2005	2009	18	175.1	43.8	532.7	100%	6%	0%

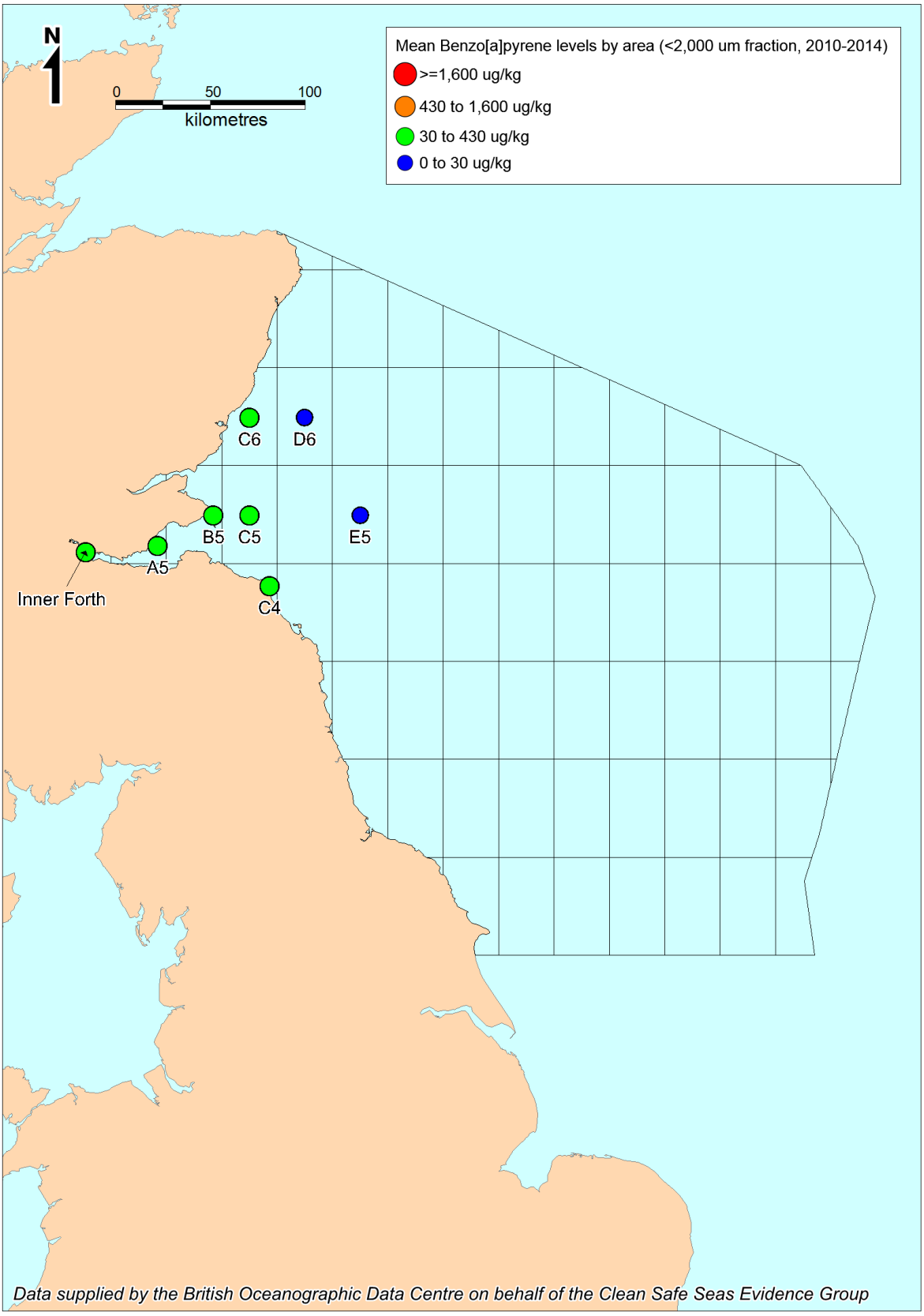

Figure 0:64: Map of mean benzo[a]pyrene concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.50: Summary of benzo[a]pyrene concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Benzo[a]pyrene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2010	2010	2	186.3	171.6	201.0	1%	0%	0%
B5	2010	2014	21	64.0	7.7	214.9	1%	0%	0%
C4	2014	2014	1	96.2	96.2	96.2	1%	0%	0%
C5	2010	2014	3	36.3	33.3	38.6	1%	0%	0%
C6	2010	2013	24	52.1	16.4	172.4	1%	0%	0%
D6	2011	2013	2	3.5	2.7	4.2	0%	0%	0%
E5	2010	2012	2	5.5	5.2	5.8	0%	0%	0%
Inner Forth	2010	2012	10	78.0	44.2	154.1	1%	0%	0%

Summary Benzo[a]pyrene sediment

The CSEMP data analysed show that 2/17 and 1/11 sectorial boxes exceeded the ERL for benzo[a]pyrene between 2005-2009 (Figure 1.61 and 1.63 and Table 1.65 and 1.67) and for 2010-2014 (Figure 1.62 and 1.64 and Table 1.66 and 1.68). Many of these exceedances occurred in the industrialised estuaries (Tyne, Tees and Wear). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Benzo[ghi]perylene

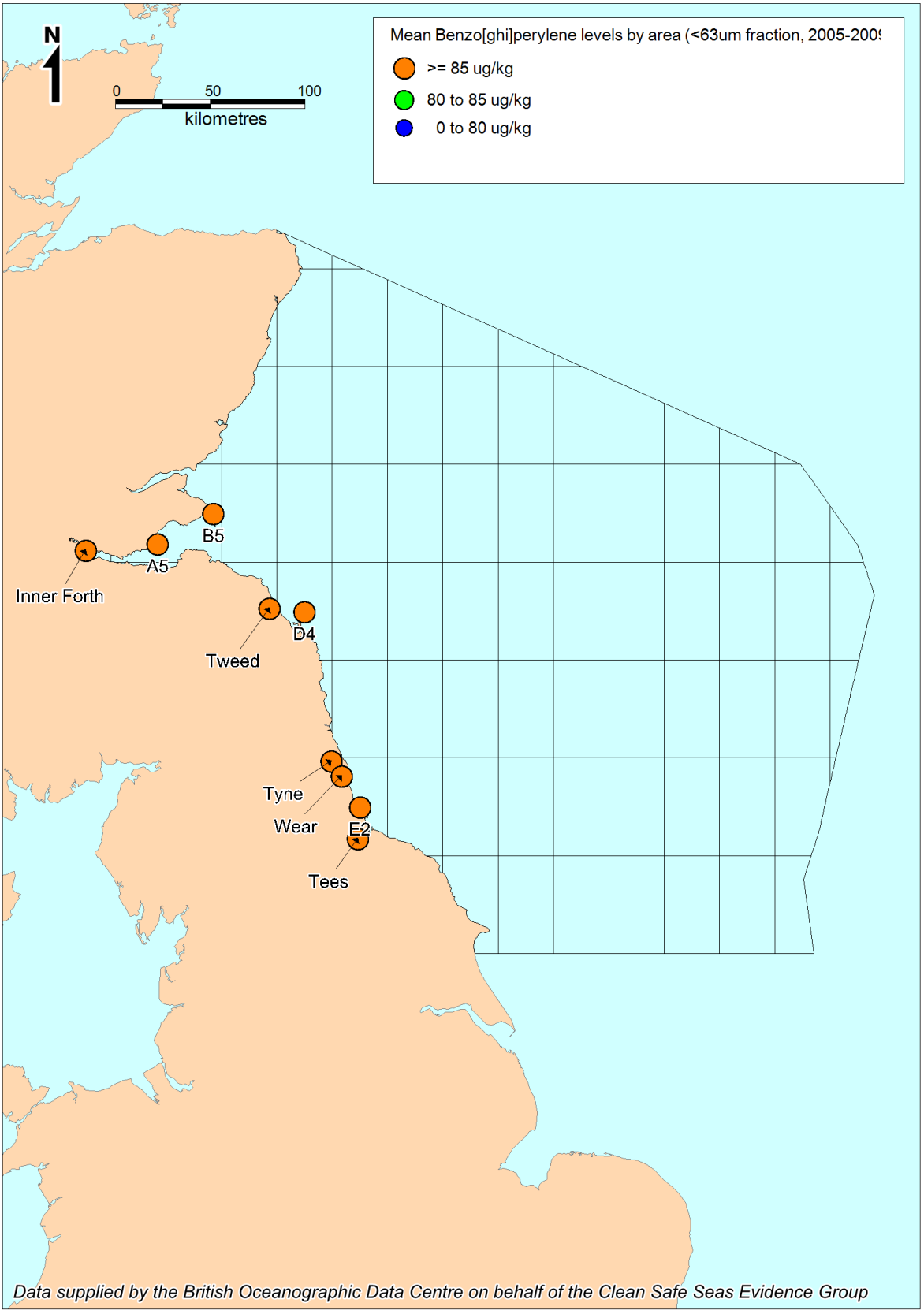

Figure 0:65: Map of mean Benzo[ghi]perylene concentrations by area (< 63 µm fraction, 2005-09)

Table 0.51: Summary of Benzo[ghi]perylene concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Benzo[ghi]perylene sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL
A5	2006	2006	1	164.3	164.3	164.3	100%	100%
B5	2005	2006	6	631.0	296.0	1843.0	100%	100%
D4	2006	2008	15	189.3	83.0	500.0	100%	93%
E2	2006	2008	30	137.6	30.7	322.2	77%	73%
Inner Forth	2005	2006	10	247.9	103.9	296.8	100%	100%
Tees	2006	2009	35	422.3	159.9	951.4	100%	100%
Tweed	2006	2008	14	139.0	88.4	196.1	100%	100%
Tyne	2006	2009	35	301.2	148.2	898.7	100%	100%
Wear	2006	2009	35	462.0	130.0	3613.0	100%	100%

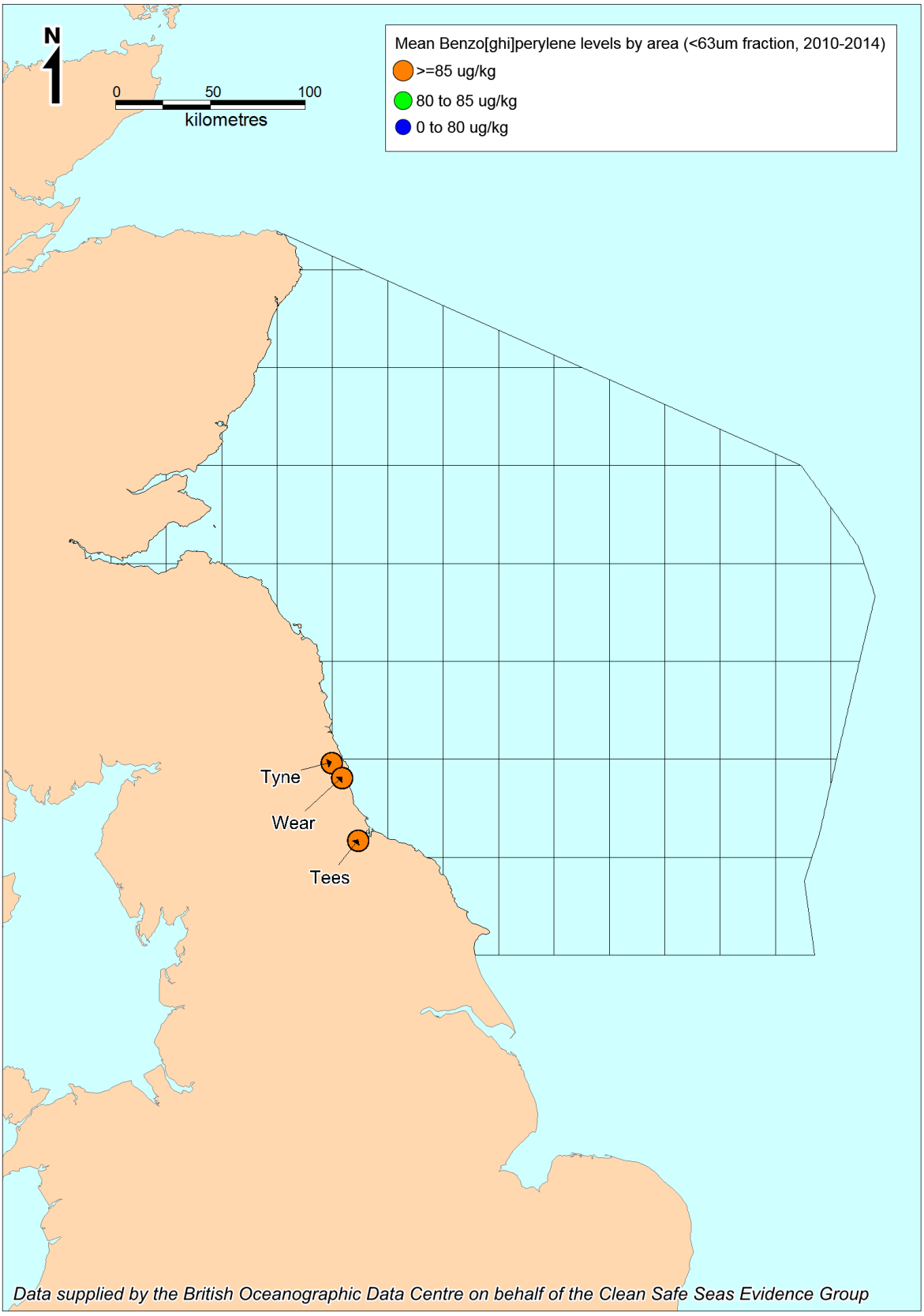

Figure 0:66: Map of mean Benzo[ghi]perylene concentrations by area (< 63 µm fraction, 2010-14)

Table 0.70: Summary of Benzo[ghi]perylene concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Benzo[ghi]perylene sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL
Tees	2010	2013	10	366.2	292.3	459.3	100%	100%
Tyne	2010	2010	5	233.5	206.3	254.3	100%	100%
Wear	2010	2010	5	234.4	186.4	279.7	100%	100%

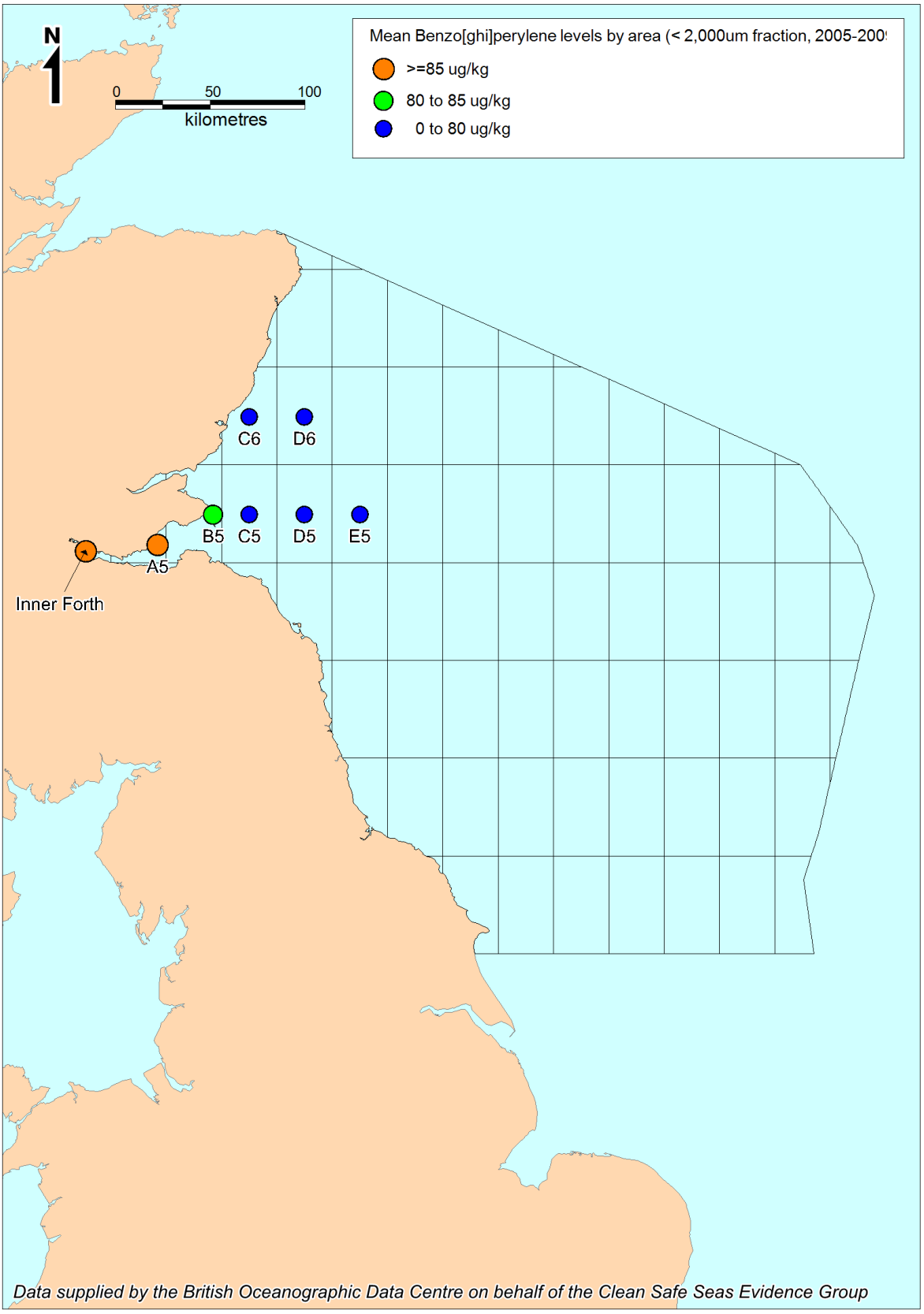

Figure 0:67: Map of mean Benzo[ghi]perylene concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.52: Summary of Benzo[ghi]perylene concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Benzo[ghi]perylene sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL
A5	2005	2009	12	124.8	19.0	265.1	50%	50%
B5	2005	2009	20	81.0	3.0	227.8	40%	40%
C5	2006	2006	1	59.2	59.2	59.2	0%	0%
C6	2006	2009	19	79.3	21.7	362.5	21%	16%
D5	2006	2009	9	79.2	8.3	183.3	56%	56%
D6	2008	2008	1	11.8	11.8	11.8	0%	0%
E5	2005	2005	5	17.9	16.7	21.2	0%	0%
Inner Forth	2005	2009	18	198.2	33.6	567.8	89%	78%

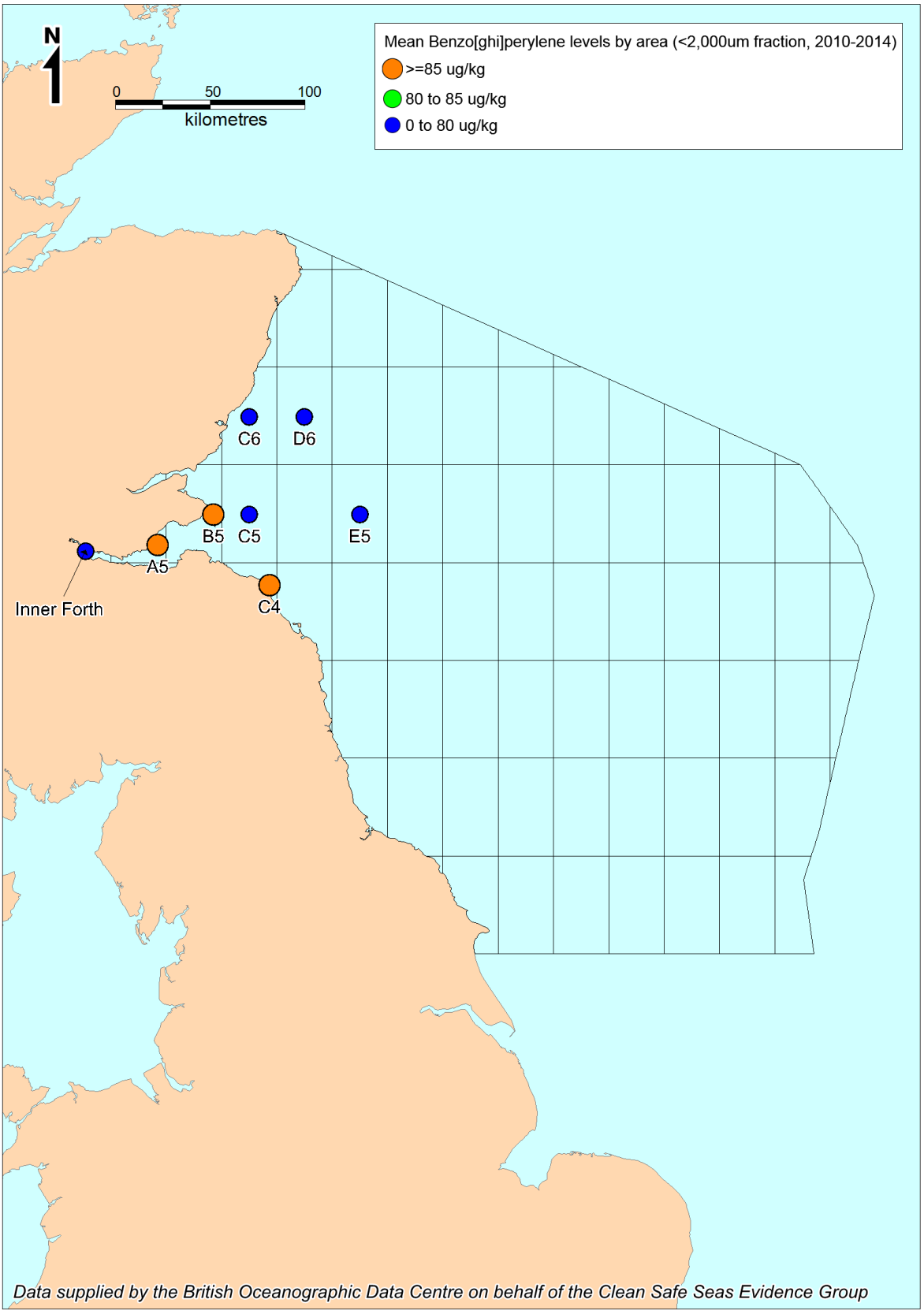

Figure 0:68: Map of mean Benzo[ghi]perylene concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.53: Summary of Benzo[ghi]perylene concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Benzo[ghi]perylene sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL
A5	2010	2010	2	181.2	156.5	205.9	100%	100%
B5	2010	2014	21	99.9	17.3	306.8	52%	48%
C4	2014	2014	1	158.2	158.2	158.2	100%	100%
C5	2010	2014	3	49.4	39.5	61.7	0%	0%
C6	2010	2013	24	58.2	29.2	137.5	21%	17%
D6	2011	2013	2	17.2	12.5	21.9	0%	0%
E5	2010	2012	2	19.1	17.3	20.8	0%	0%
Inner Forth	2010	2012	10	76.6	41.1	115.1	40%	40%

Summary Benzo[ghi]perylene sediment

The CSEMP data analysed revealed that 11/17 and 6/11 sectorial boxes exceeded the ERL for benzo[ghi]perylene between 2005-2009 (Figure 1.65 and 1.67 and Table 1.69 and 1.71) and 2010-2014 (Figure 1.66 and 1.68 and Table 1.70 and 1.72). Many of these exceedances occurred in the industrialised estuaries (Tyne, Tees, Forth and Wear), though coastal locations in the Forth (e.g. A5 and B5) also exceeded the EAC. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Chrysene (& triphenylene)

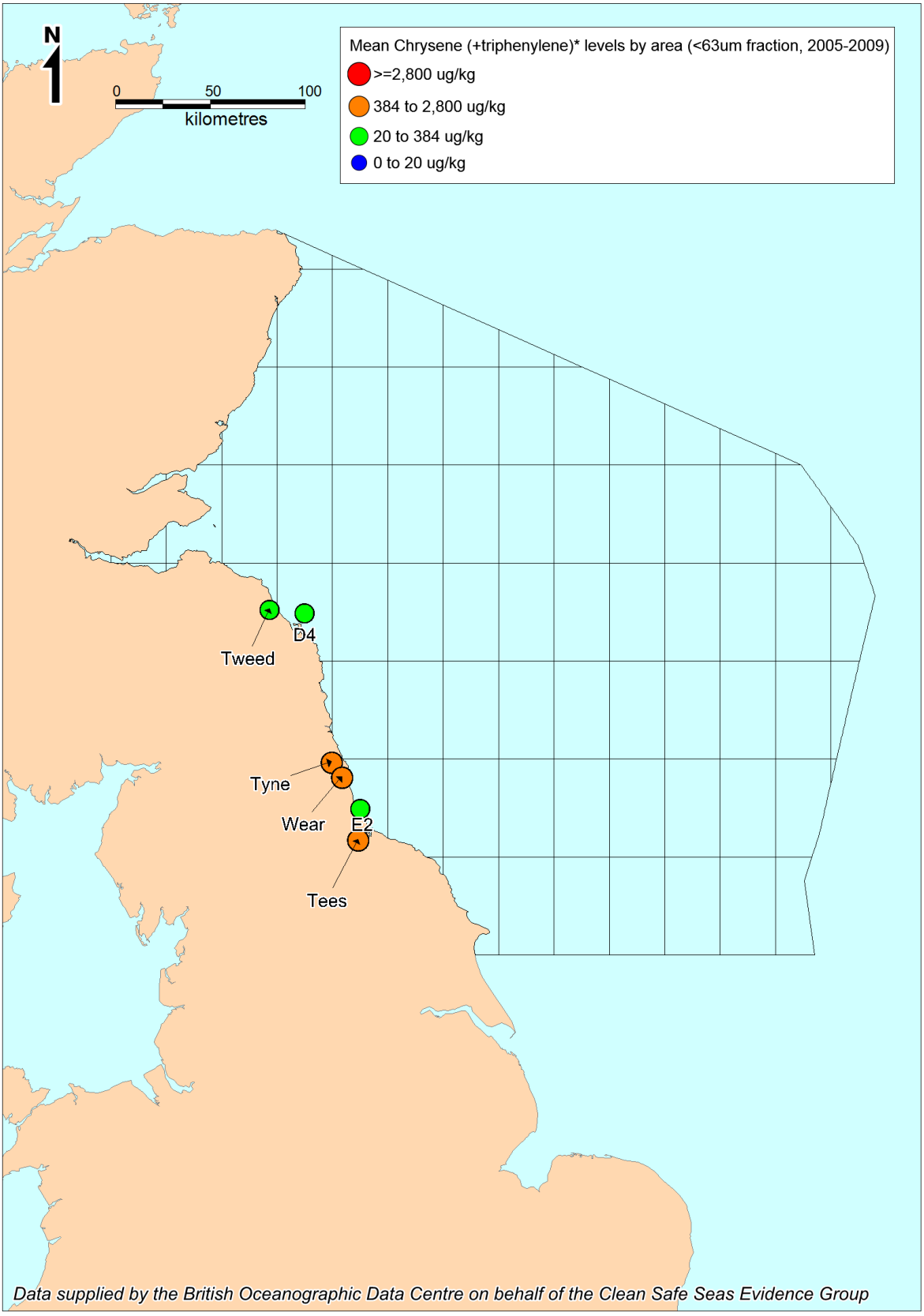

Figure 0:69: Map of mean Chrysene (+ triphenylene) concentrations by area (< 63 µm fraction, 2005-09*)*

Table 0.73: Summary of Chrysene (+ triphenylene) concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Chrysene (+ triphenylene) sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
D4	2006	2007	10	271.8	108.6	602.5	100%	20%	0%
E2	2006	2007	20	184.7	45.1	581.6	100%	5%	0%
Tees	2006	2007	20	656.8	233.9	1679.8	100%	70%	0%
Tweed	2006	2007	10	187.0	109.0	291.2	100%	0%	0%
Tyne	2006	2007	20	434.0	188.0	1019.0	100%	55%	0%
Wear	2006	2007	20	1075.0	165.0	6513.0	100%	85%	10%

None of the samples taken from 2010 to 2014 included analyses of Chrysene (+ triphenylene) undertaken on the <63 µm fraction.

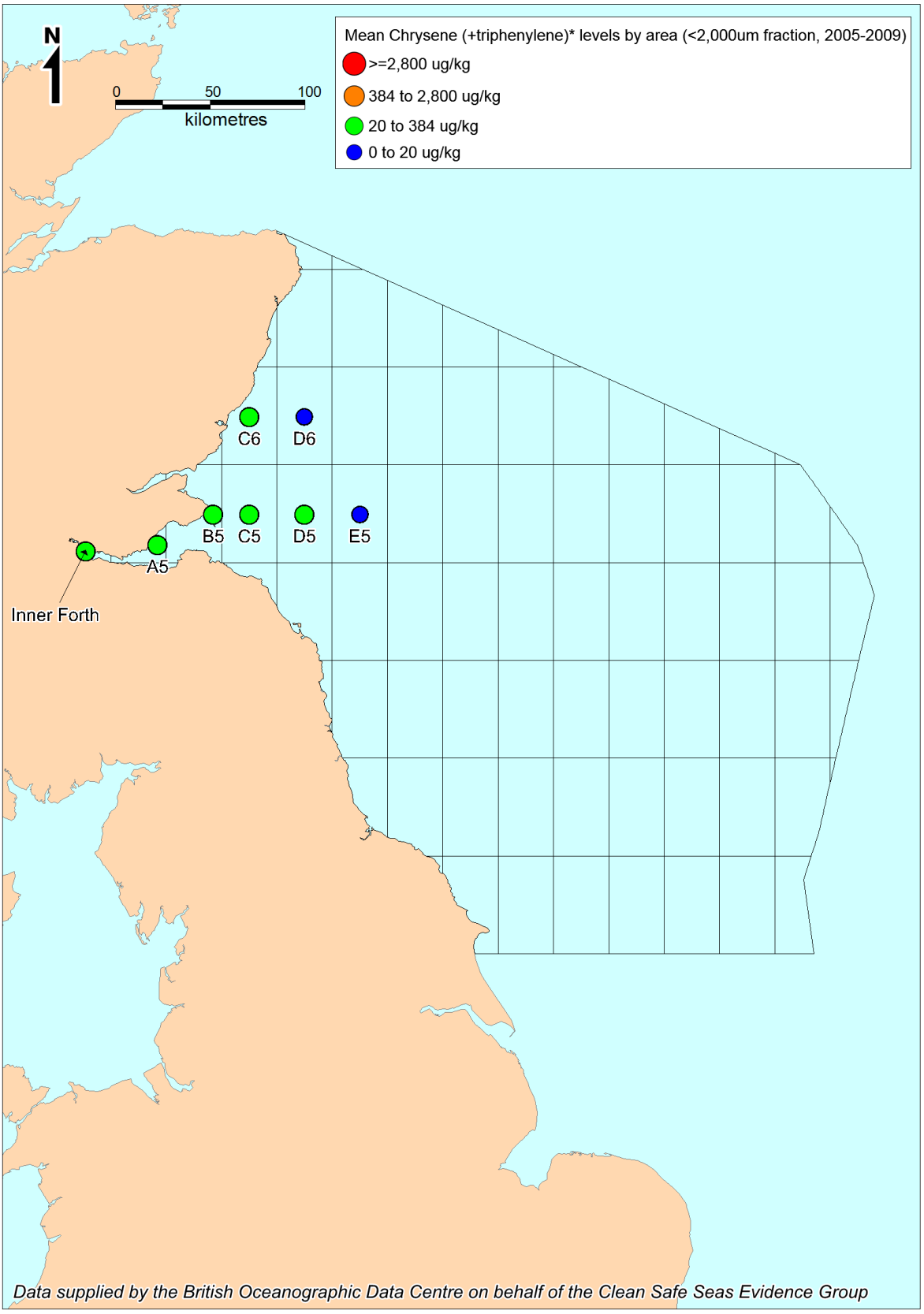

Figure 0:70: Map of mean Chrysene (+ triphenylene) concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.54: Summary of Chrysene (+ triphenylene) concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Chrysene (+ triphenylene) sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2005	2009	8	63.9	21.6	92.5	100%	0%	0%
B5	2005	2009	14	31.0	1.4	82.6	50%	0%	0%
C5	2006	2006	1	101.2	101.2	101.2	100%	0%	0%
C6	2006	2009	19	58.7	11.9	187.5	89%	0%	0%
D5	2006	2009	9	32.6	3.3	83.3	56%	0%	0%
D6	2008	2008	1	3.9	3.9	3.9	0%	0%	0%
E5	2005	2005	5	7.7	6.3	9.6	0%	0%	0%
Inner Forth	2005	2009	13	166.3	35.1	298.8	100%	0%	0%

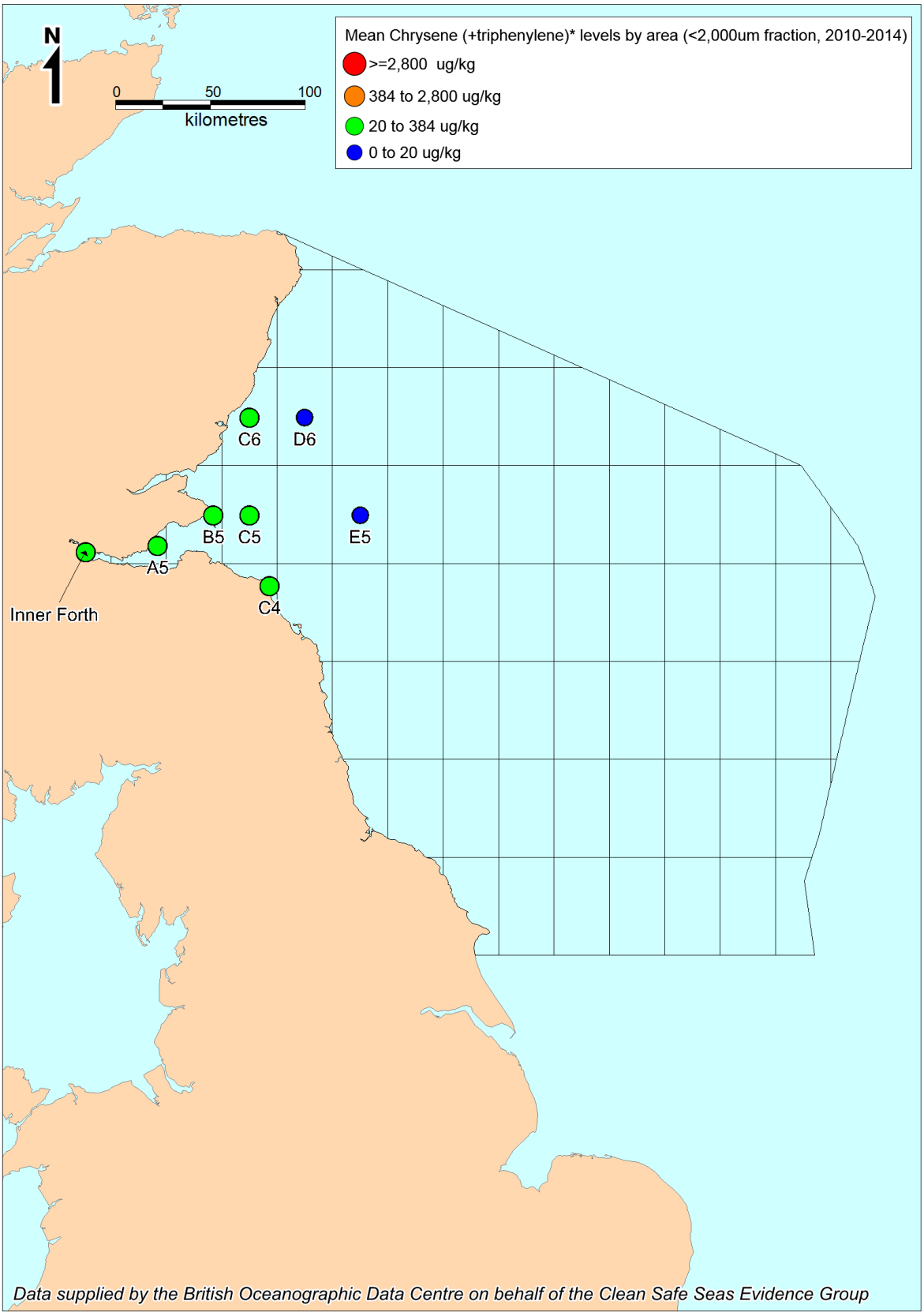

Figure 0:71: Map of mean Chrysene (+ triphenylene) concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.55: Summary of Chrysene (+ triphenylene) concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Chrysene (+ triphenylene) sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2012	2014	13	195.1	102.9	282.2	100%	0%	0%
B5	2011	2014	27	69.6	5.8	204.9	67%	0%	0%
C4	2014	2014	1	62.0	62.0	62.0	100%	0%	0%
C5	2010	2014	3	26.1	21.4	33.9	100%	0%	0%
C6	2010	2013	24	46.7	14.7	154.0	79%	0%	0%
D6	2011	2013	2	5.7	5.6	5.8	0%	0%	0%
E5	2010	2012	2	6.4	5.8	6.9	0%	0%	0%
Inner Forth	2011	2014	14	159.8	42.1	351.0	100%	0%	0%

Summary Chrysene (+ triphenylene) sediment

The CSEMP data analysed revealed that 3/14 and 0/8 sectorial boxes exceeded the ERL for Chrysene (+ triphenylene) between 2005-2009 (Figure 1.69 and 1.70 and Table 1.73 and 1.74). For 2010-2014 no data could be retrieved for <63 µm faction but data for <2000 µm faction are shown in Figure 1.79 and Table 1.75). Many of these exceedances occurred in the industrialised estuaries (Tyne, Tees and Wear). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Fluorene

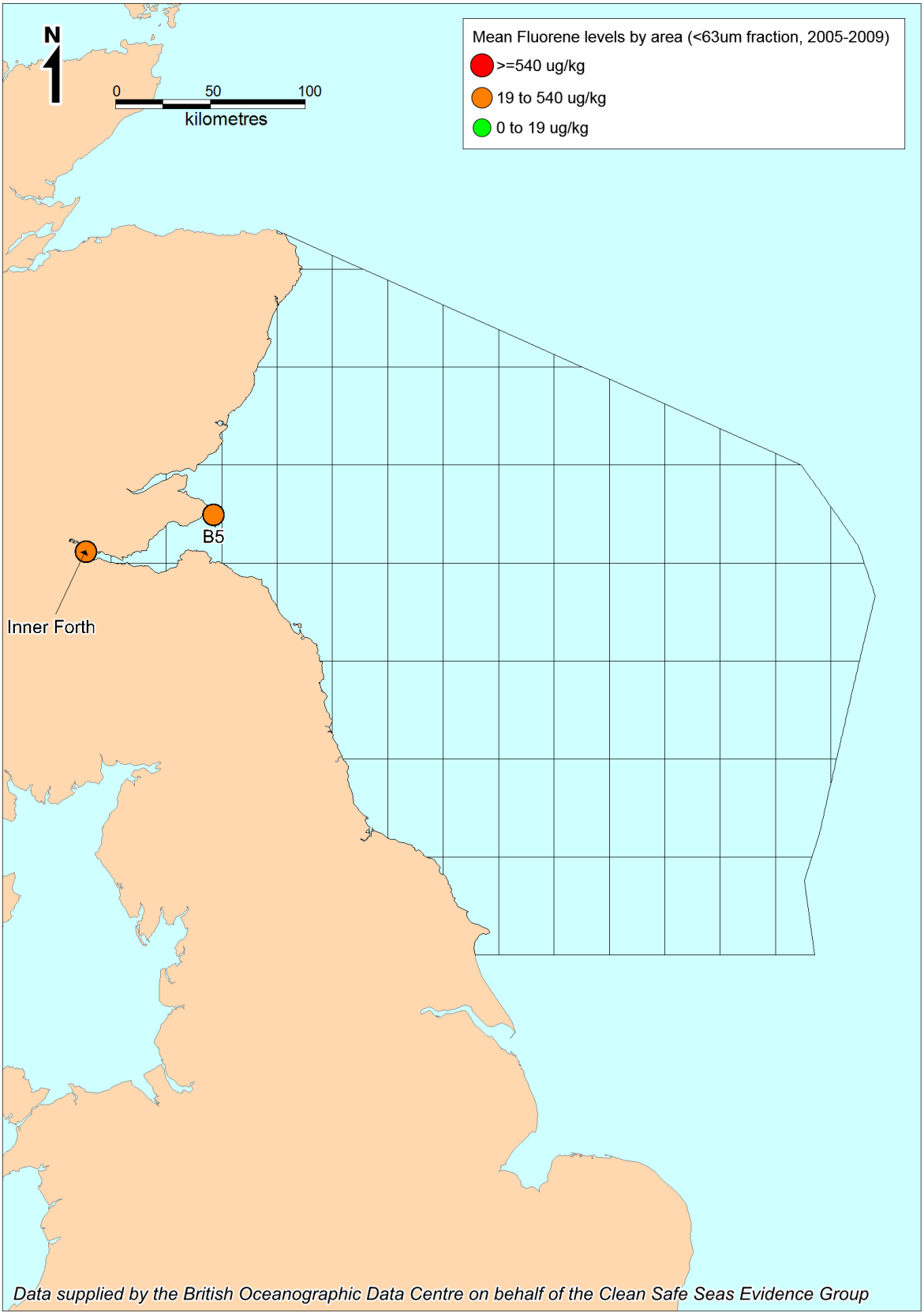

Figure 0:72: Map of mean Fluorene concentrations by area (< 63 µm fraction, 2005-09)

Table 0.56: Summary of Fluorene concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Fluorene sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
B5	2005	2005	5	64.9	36.6	156.4	100%	0%
Inner Forth	2005	2005	5	21.2	16.7	23.7	80%	0%

None of the samples taken from 2010 to 2014 included analyses of Fluorene undertaken on the <63 µm fraction.

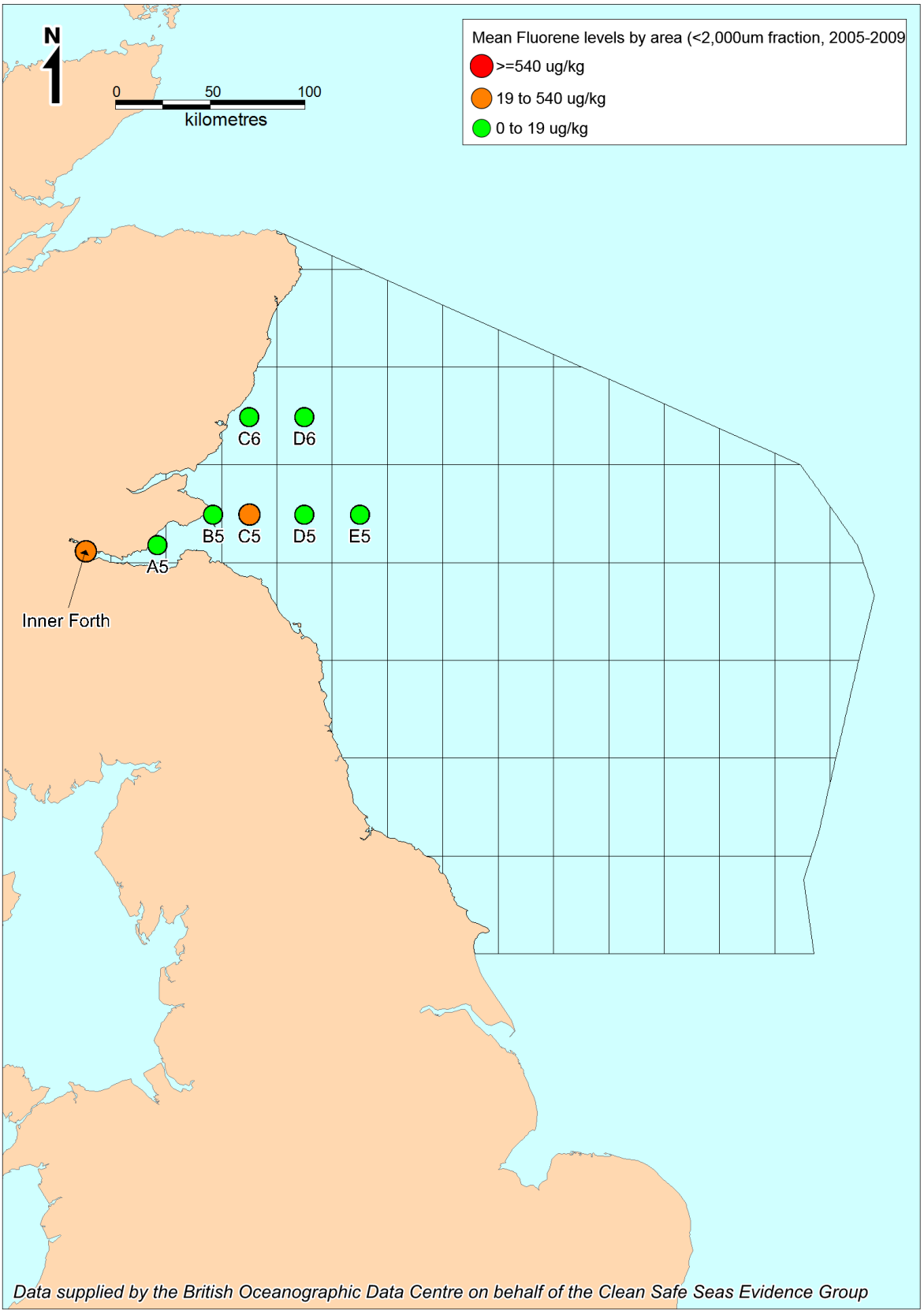

Figure 0:73: Map of mean Fluorene concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.57: Summary of Fluorene concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Fluorene sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
A5	2005	2007	6	13.0	4.2	19.7	0%	0%
B5	2005	2009	11	3.6	0.1	11.2	0%	0%
C5	2006	2006	1	21.7	21.7	21.7	1%	0%
C6	2006	2009	19	7.2	1.2	36.9	0%	0%
D5	2006	2009	9	8.0	0.2	16.7	0%	0%
D6	2008	2008	1	0.3	0.3	0.3	0%	0%
E5	2005	2005	5	1.4	1.3	1.5	0%	0%
Inner Forth	2005	2007	3	26.8	9.2	48.4	1%	0%

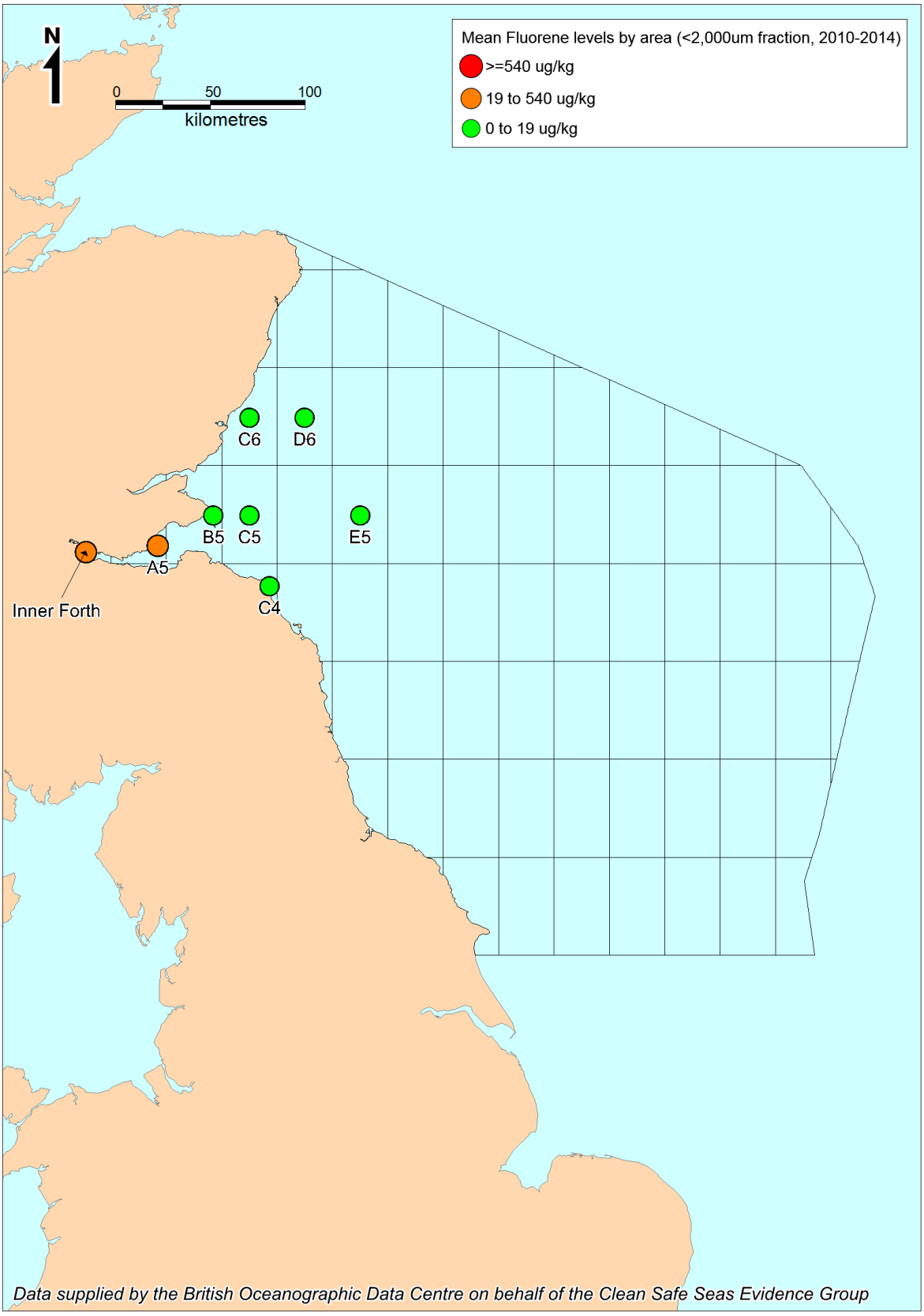

Figure 0:74: Map of mean Fluorene concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.58: Summary of Fluorene concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Fluorene sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= ERL	% >= ERM
A5	2011	2014	17	39.2	20.6	53.5	100%	0%
B5	2011	2014	30	12.1	0.4	31.7	23%	0%
C4	2014	2014	1	12.8	12.8	12.8	0%	0%
C5	2010	2014	3	4.3	3.5	4.8	0%	0%
C6	2010	2013	24	4.9	1.5	17.9	0%	0%
D6	2011	2013	2	0.4	0.3	0.5	0%	0%
E5	2010	2012	2	0.4	0.3	0.4	0%	0%
Inner Forth	2011	2014	22	36.1	10.1	76.1	86%	0%

Summary fluorene sediment

The CSEMP data analysed revealed that 4/10 and 2/8 sectorial boxes exceeded the ERL for fluorene between 2005-2009 and 2010-2014. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Indeno[123-cd]pyrene

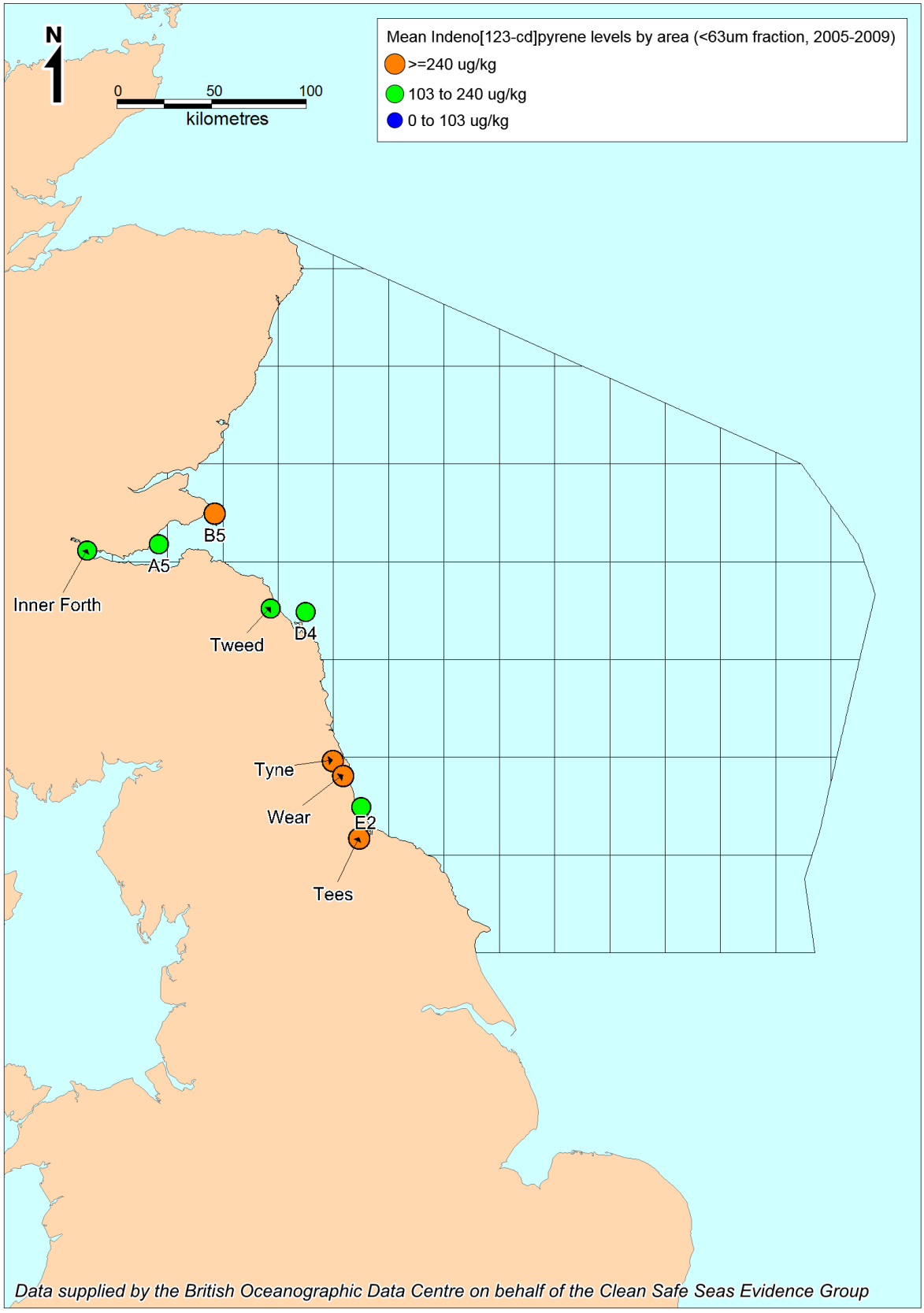

Figure 0:75: Map of mean Indeno[123-cd]pyrene concentrations by area (< 63 µm fraction, 2005-09*)*

Table 0.59: Summary of Indeno[123-cd]pyrene concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Indeno[123-cd]pyrene sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL
A5	2006	2006	1	140.9	140.9	140.9	100%	0%
B5	2005	2006	5	654.0	351.0	1653.0	100%	100%
D4	2006	2008	15	159.6	50.7	490.0	47%	13%
E2	2006	2008	30	111.8	21.5	307.5	63%	3%
Inner Forth	2005	2006	10	233.6	42.2	444.0	90%	60%
Tees	2006	2009	35	484.7	222.4	1102.4	100%	97%
Tweed	2006	2008	14	133.4	66.5	212.6	71%	0%

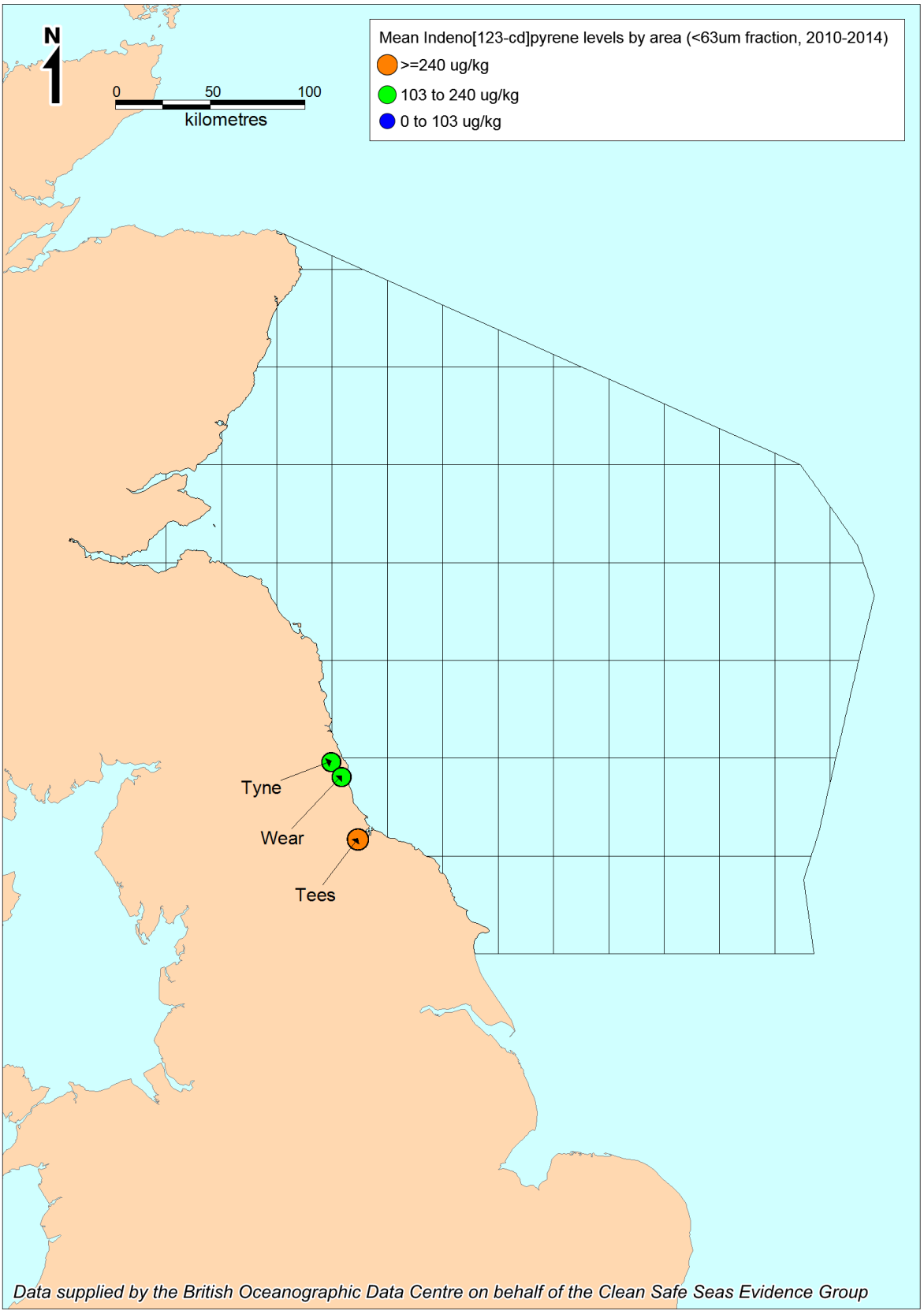

Figure 0:76: Map of mean Indeno[123-cd]pyrene concentrations by area (< 63 µm fraction, 2010-14)

Table 0.80: Summary of Indeno[123-cd]pyrene concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Indeno[123-cd]pyrene sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL
Tees	2010	2013	10	301.8	203.7	402.1	100%	60%
Tyne	2010	2010	5	177.7	143.5	201.1	100%	0%
Wear	2010	2010	5	193.2	150.9	237.0	100%	0%

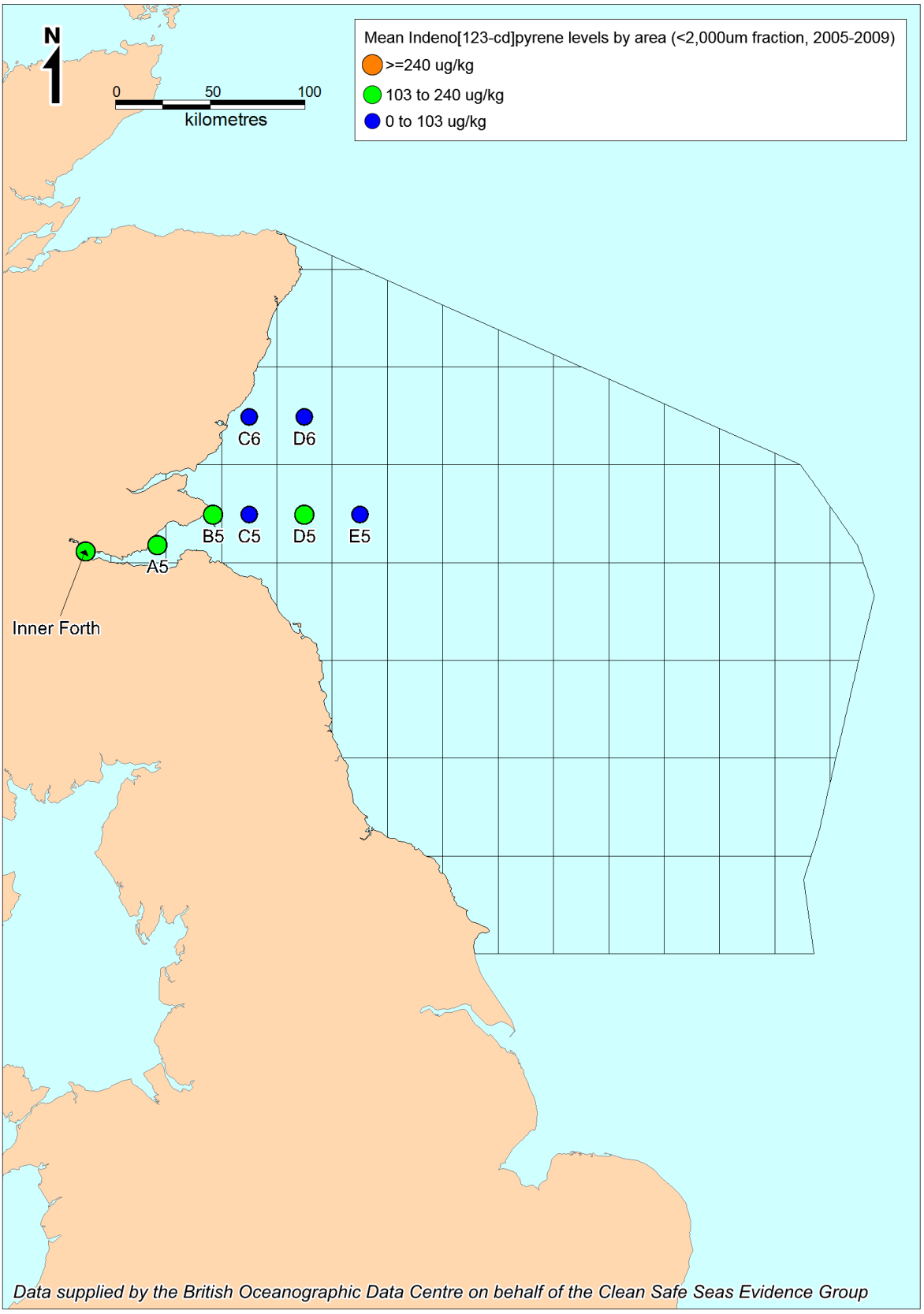

Figure 0:77: Map of mean Indeno[123-cd]pyrene concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.60: Summary of Indeno[123-cd]pyrene concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Indeno[123-cd]pyrene sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL
A5	2005	2009	12	145.5	16.8	423.1	50%	17%
B5	2005	2009	20	115.5	2.7	632.8	40%	10%
C5	2006	2006	1	70.8	70.8	70.8	0%	0%
C6	2006	2009	19	88.3	1.2	437.5	21%	5%
D5	2006	2009	9	103.3	10.0	233.3	56%	0%
D6	2008	2008	1	14.5	14.5	14.5	0%	0%
E5	2005	2005	5	19.9	18.8	23.1	0%	0%
Inner Forth	2005	2009	18	160.2	29.4	497.7	61%	11%

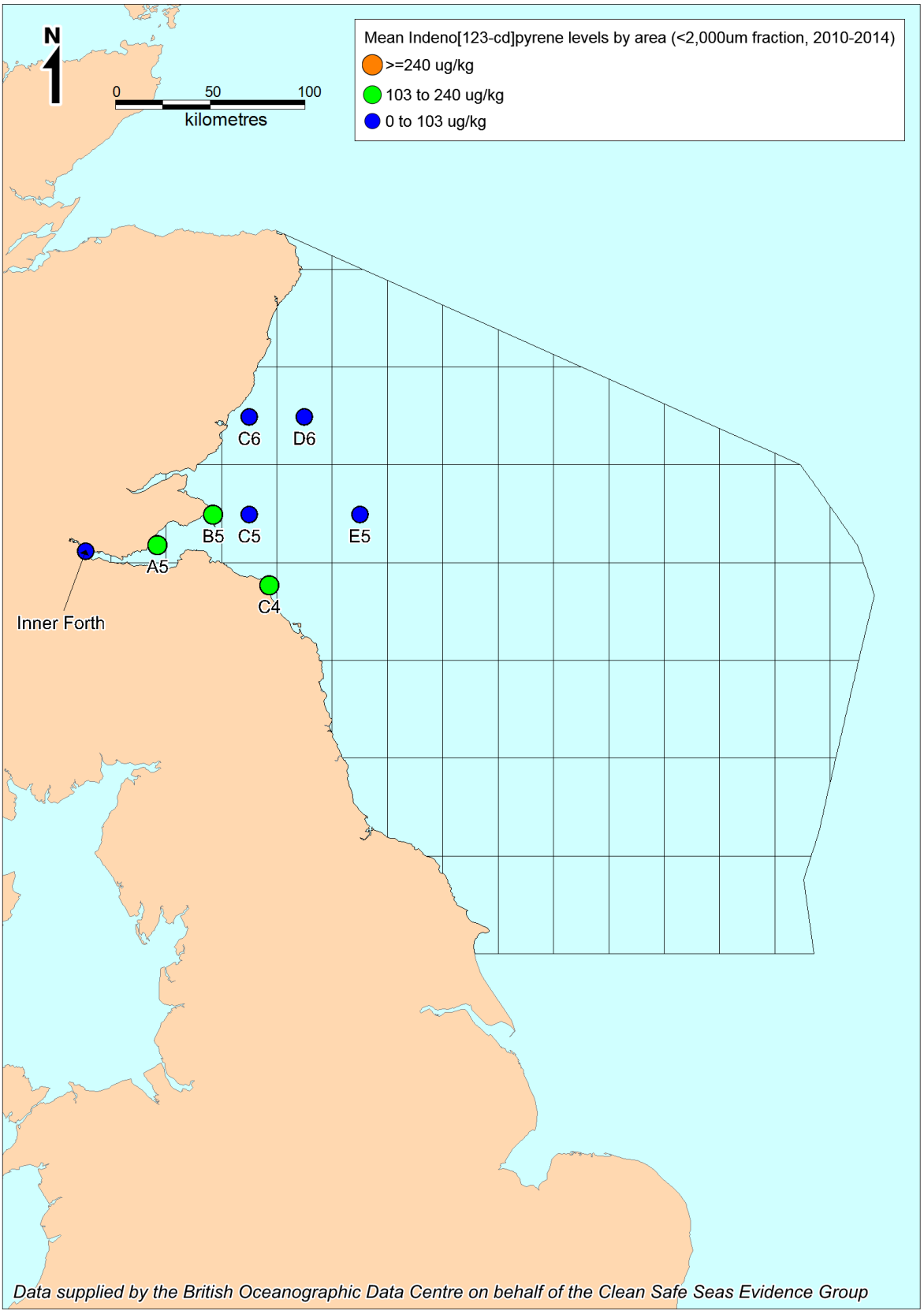

Figure 0:78: Map of mean Indeno[123-cd]pyrene concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.61: Summary of Indeno[123-cd]pyrene concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Indeno[123-cd]pyrene sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL
A5	2010	2010	2	188.4	166.1	210.8	100%	0%
B5	2010	2014	21	107.5	19.2	325.8	43%	10%
C4	2014	2014	1	193.7	193.7	193.7	100%	0%
C5	2010	2014	3	60.2	46.0	74.5	0%	0%
C6	2010	2013	24	65.9	33.3	141.6	13%	0%
D6	2011	2013	2	21.6	16.7	26.6	0%	0%
E5	2010	2012	2	23.7	23.1	24.3	0%	0%
Inner Forth	2010	2012	10	72.9	38.9	106.7	20%	0%

Summary Indeno[123-cd]pyrene sediment

The CSEMP data analysed revealed that 4/17 and 1/11 sectorial boxes exceeded the ERL for Indeno[123-cd]pyrene between 2005-2009 (Figures 1.72 and 1.73 and Tables 1.76 and 1.77). For 2010-2014 no data could be retrieved for the <63 µm faction but data for the <2000 µm faction are shown in Figure 1.74 and Table 1.78. Many of these exceedances were restricted to heavily polluted estuaries such as the Tees, Tyne and Wear. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Napthalene

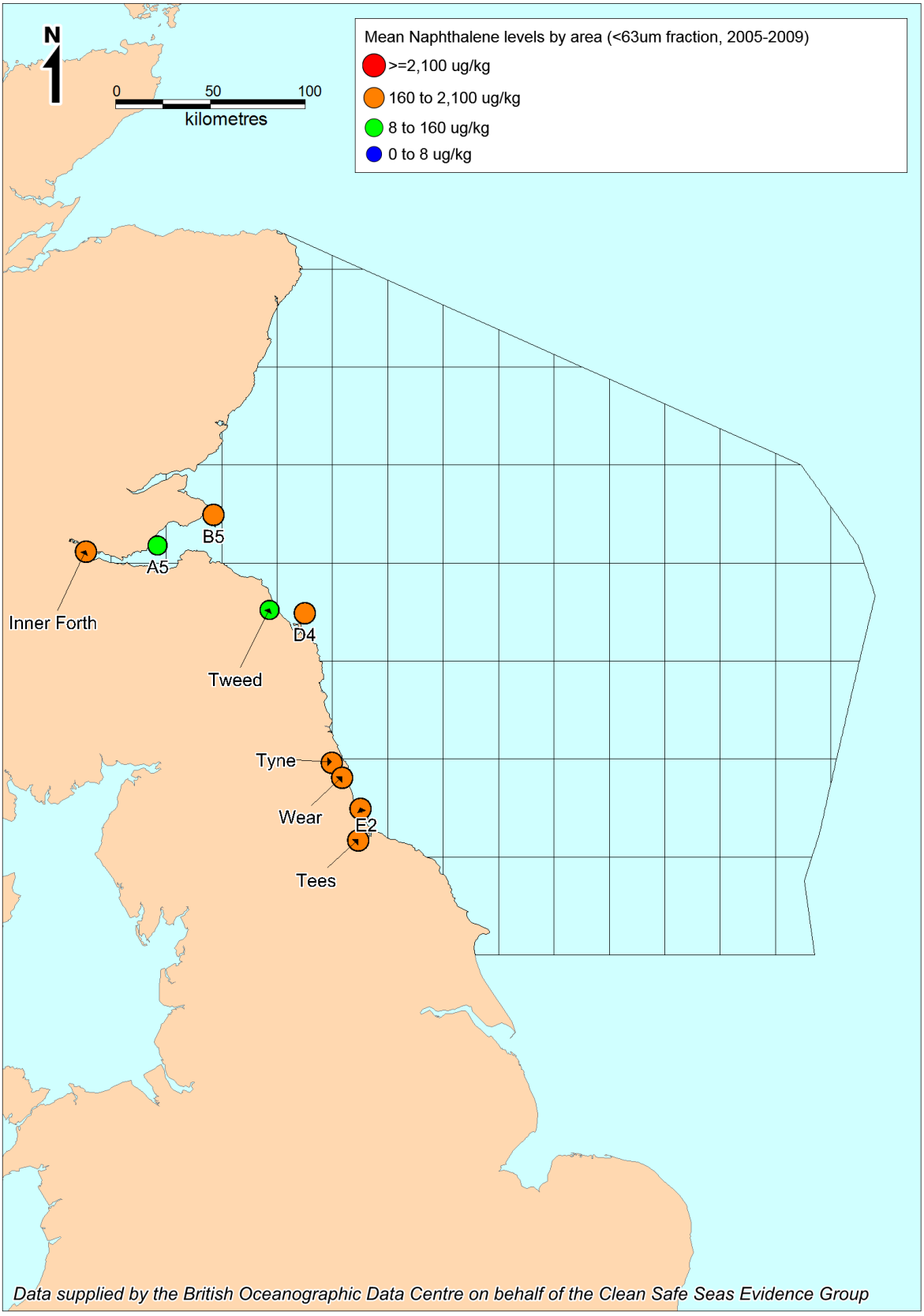

Figure 0:79: Map of mean naphthalene concentrations by area (< 63 µm fraction, 2005-09*)*

Table 0.62: Summary of naphthalene concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Naphthalene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2006	2006	1	82.2	82.2	82.2	100%	0%	0%
B5	2005	2006	6	196.1	97.6	459.3	100%	33%	0%
D4	2006	2008	15	191.4	14.7	466.2	100%	47%	0%
E2	2006	2008	30	825.0	163.0	2594.0	100%	100%	3%
Inner Forth	2006	2006	5	195.1	116.9	318.5	100%	80%	0%
Tees	2006	2009	35	1120.0	357.0	4645.0	100%	100%	9%
Tweed	2006	2008	14	88.7	14.0	183.4	100%	14%	0%
Tyne	2006	2009	35	452.3	181.3	1090.0	100%	100%	0%
Wear	2006	2009	35	854.0	254.0	5125.0	100%	100%	6%

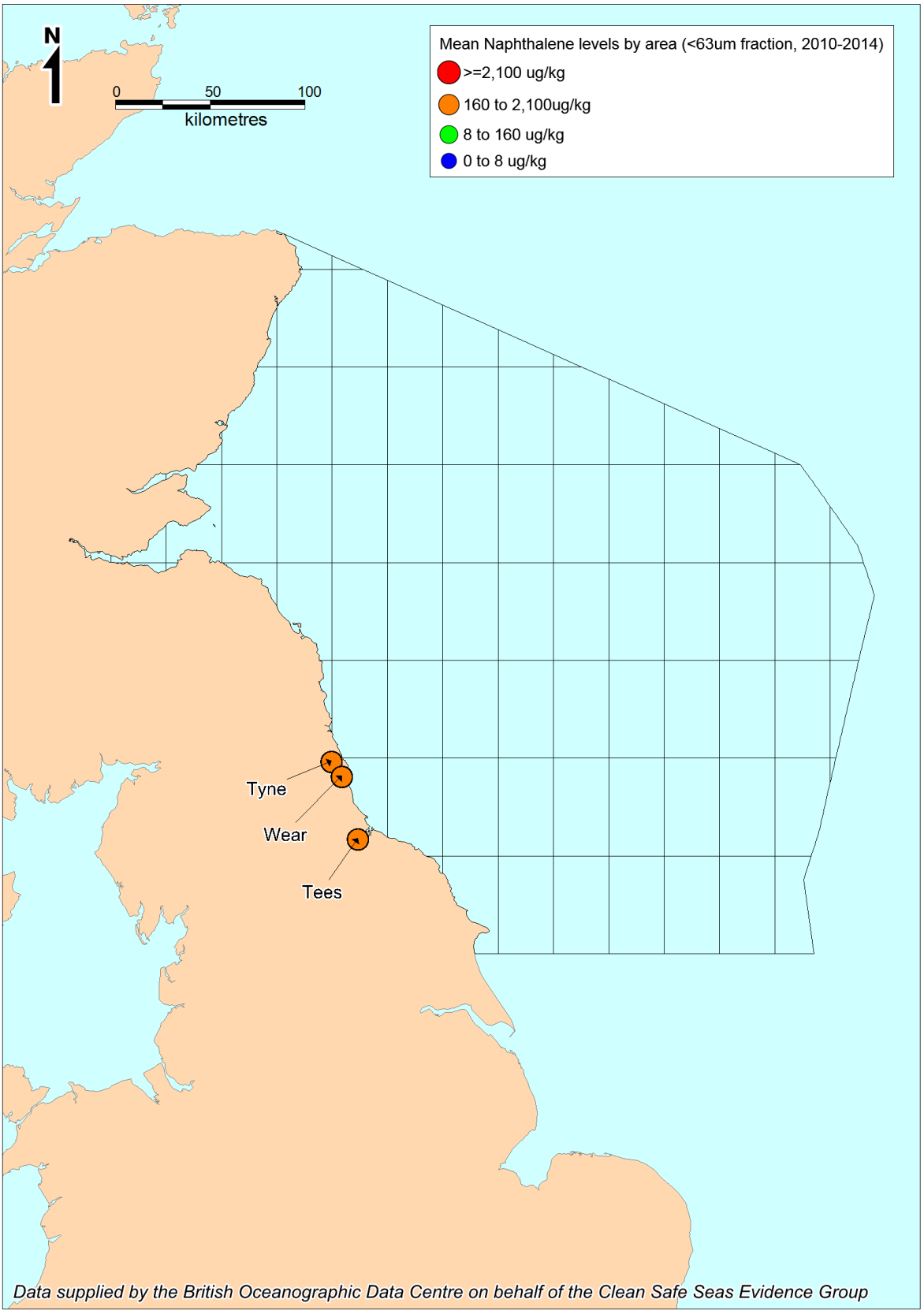

Figure 0:80: Map of mean naphthalene concentrations by area (< 63 µm fraction, 2010-14)

Table 0.63: Summary of naphthalene concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Naphthalene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
Tees	2010	2013	10	759.0	420.0	1489.0	100%	100%	0%
Tyne	2010	2010	5	467.6	394.4	517.7	100%	100%	0%
Wear	2010	2010	5	524.4	429.2	660.8	100%	100%	0%

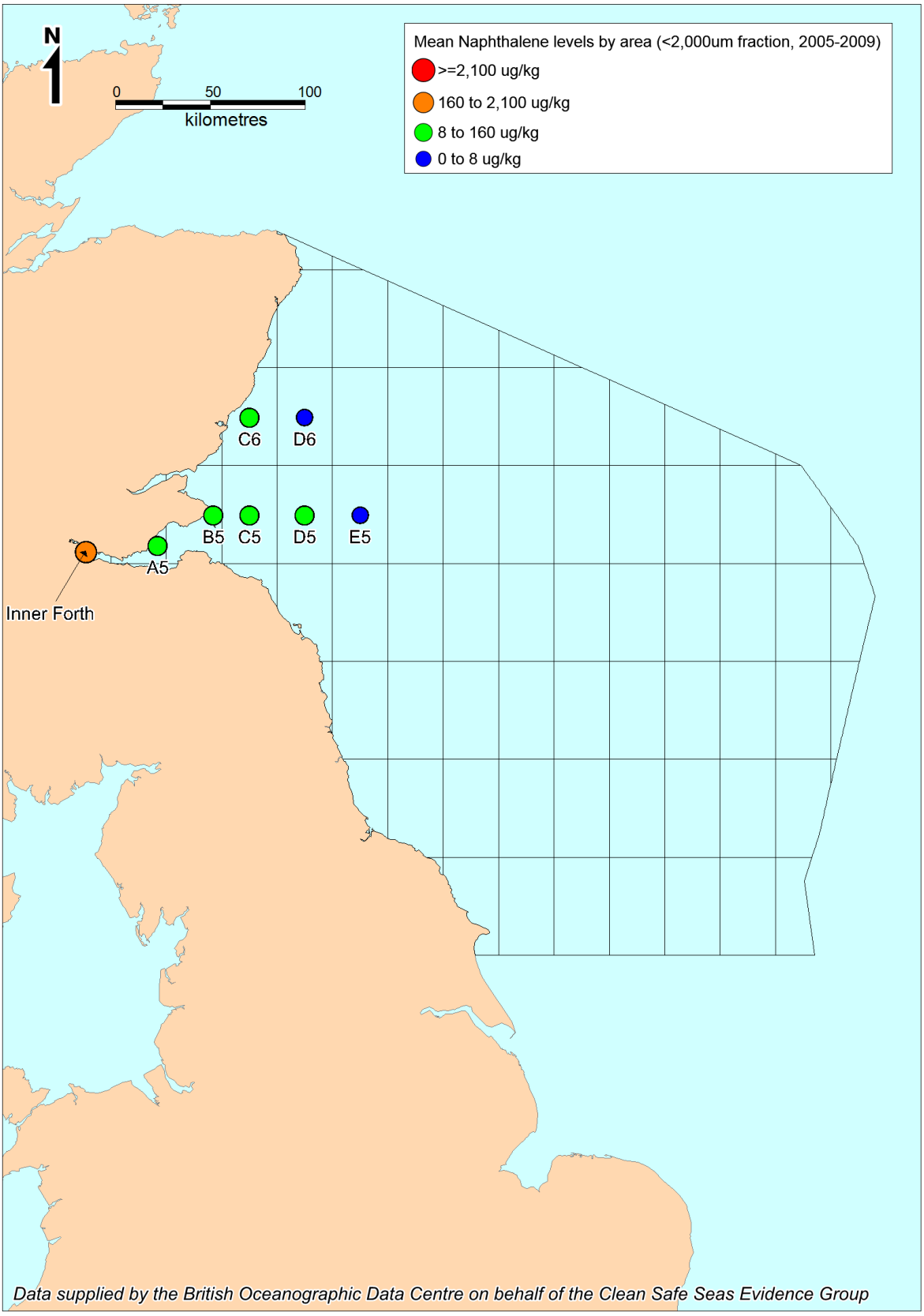

Figure 0:81: Map of mean naphthalene concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.64: Summary of naphthalene concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Naphthalene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2005	2009	8	43.2	9.6	67.8	100%	0%	0%
B5	2005	2009	14	12.8	0.5	50.7	36%	0%	0%
C5	2006	2006	1	20.2	20.2	20.2	100%	0%	0%
C6	2006	2009	19	15.1	3.6	62.5	74%	0%	0%
D5	2006	2009	9	16.8	0.6	37.5	56%	0%	0%
D6	2008	2008	1	0.9	0.9	0.9	0%	0%	0%
E5	2005	2005	5	2.8	1.3	5.8	0%	0%	0%
Inner Forth	2005	2009	13	172.0	42.9	515.0	100%	39%	0%

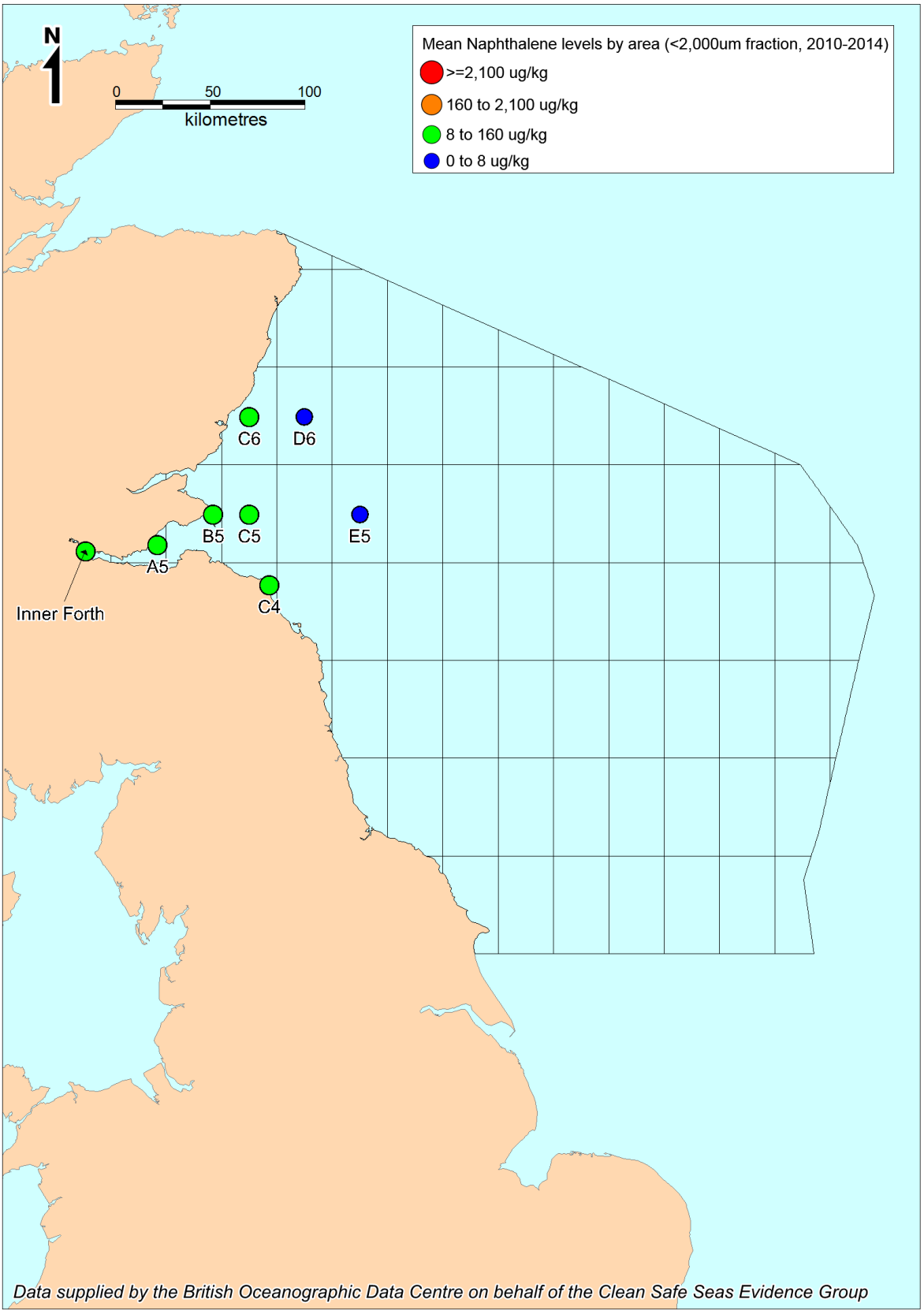

Figure 0:82: Map of mean naphthalene concentrations by area (<2,000 µm fraction, 2010-14)

Table 0:83: Summary of naphthalene concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Naphthalene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2010	2014	19	103.0	61.2	178.3	100%	5%	0%
B5	2010	2014	33	40.9	0.4	117.9	73%	0%	0%
C4	2014	2014	1	45.6	45.6	45.6	100%	0%	0%
C5	2010	2014	3	11.2	8.1	15.9	100%	0%	0%
C6	2010	2013	24	9.1	2.5	48.5	42%	0%	0%
D6	2011	2013	2	0.9	0.8	1.0	0%	0%	0%
E5	2010	2012	2	3.5	1.2	5.8	0%	0%	0%
Inner Forth	2010	2014	26	86.7	9.8	158.3	100%	0%	0%

Summary naphthalene sediment

The CSEMP data analysed revealed that 8/17 and 3/11 sectorial boxes exceeded the ERL for naphthalene between 2005-2009 (Figures 1.79 and 1.81 and Table 1.83 and 1.85) and 2010-2014 (Figures 1.80 and 1.82 and Tables 1.84 and 1.86). Many of these exceedances were restricted to heavily polluted estuaries such as the Forth, Tees, Tyne and Wear. Several other coastal locations also (e.g. sectorial boxes D4 and B5) also contained samples that breached the ERL. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). A significant downward trend was observed for samples reported from sectorial box C6. Samples for this area were already below the ERL and data indicated that values were now approaching the BAC for naphthalene.

Phenanthrene

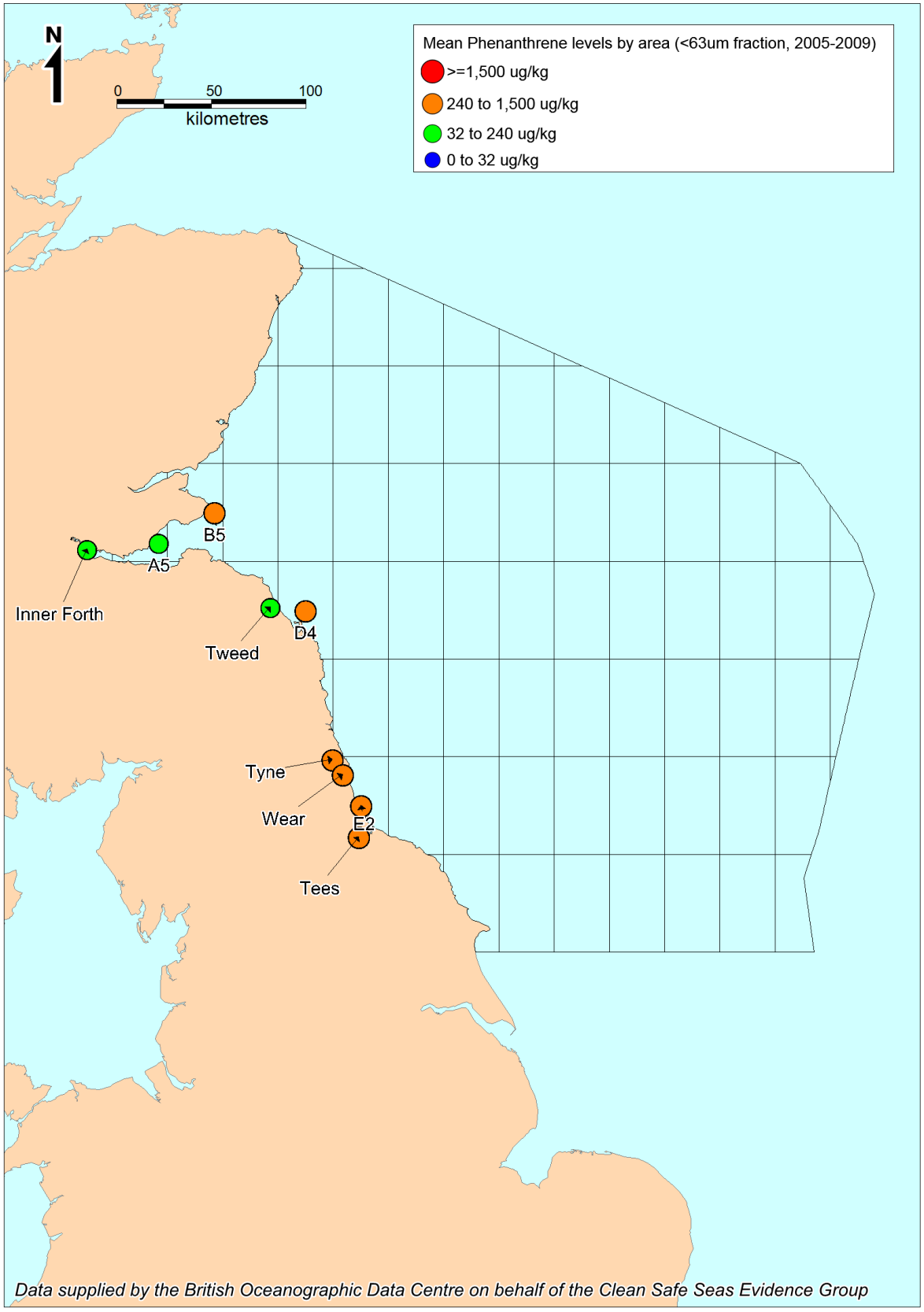

Figure 0:84: Map of mean phenanthrene concentrations by area (< 63 µm fraction, 2005-09)

Table 0.65: Summary of phenanthrene concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Phenanthrene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2006	2006	1	123.2	123.2	123.2	100%	0%	0%
B5	2005	2006	6	336.0	169.0	871.0	100%	50%	0%
D4	2006	2008	15	351.4	133.4	1073.8	100%	53%	0%
E2	2006	2008	30	630.4	136.5	2018.7	100%	90%	3%
Inner Forth	2005	2006	10	183.5	83.5	347.5	100%	20%	0%
Tees	2006	2009	35	994.4	409.5	2454.1	100%	100%	11%
Tweed	2006	2008	14	191.9	118.8	368.6	100%	21%	0%
Tyne	2006	2009	35	711.7	386.7	2094.9	100%	100%	3%
Wear	2006	2009	35	1352.0	297.0	10325.0	100%	100%	17%

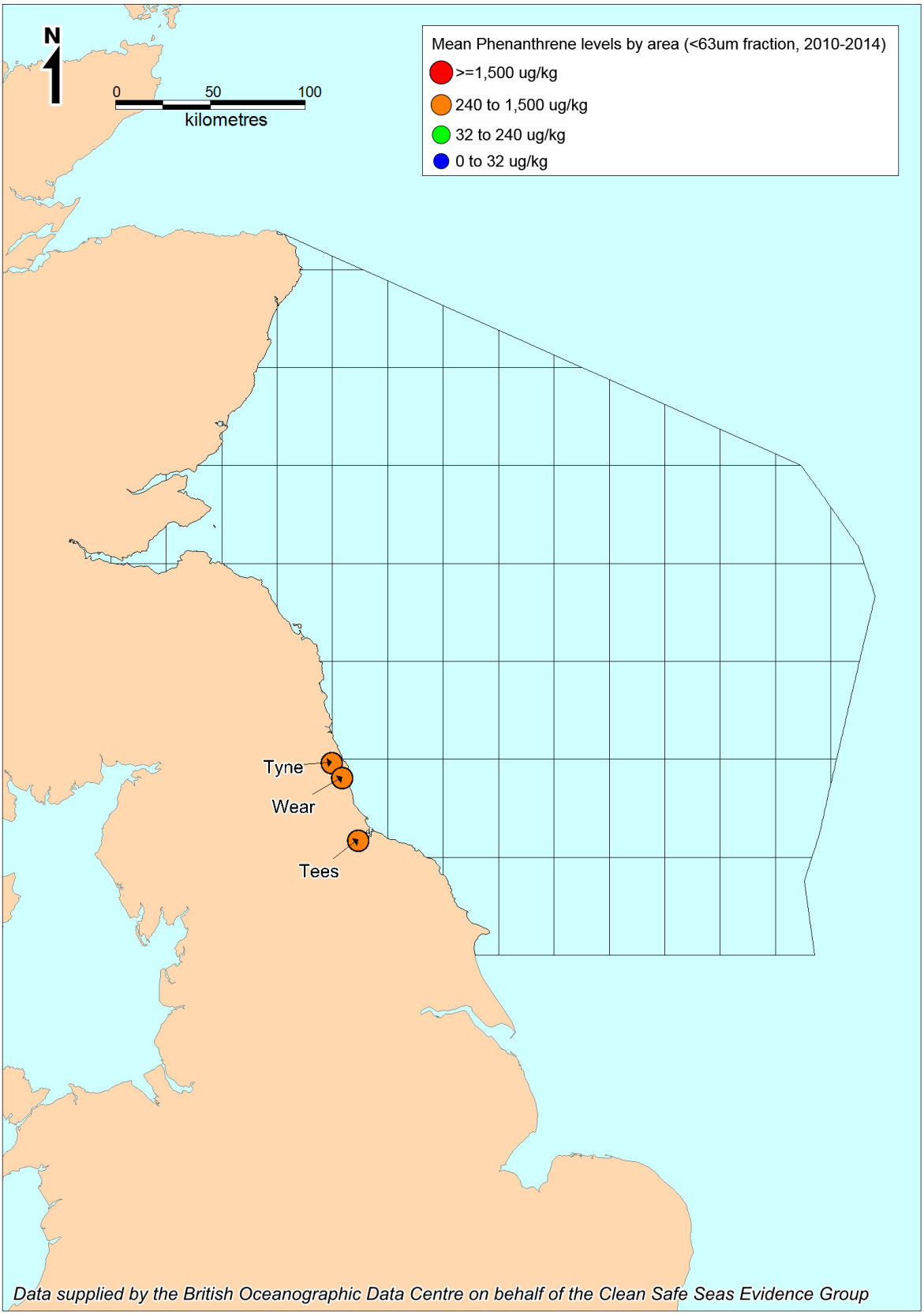

Figure 0:85: Map of mean phenanthrene concentrations by area (< 63 µm fraction, 2010-14)

Table 0.66: Summary of phenanthrene concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Phenanthrene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
Tees	2010	2013	10	1153.0	616.0	3284.0	100%	100%	20%
Tyne	2010	2010	5	667.2	604.6	727.2	100%	100%	0%
Wear	2010	2010	5	692.7	554.2	798.5	100%	100%	0%

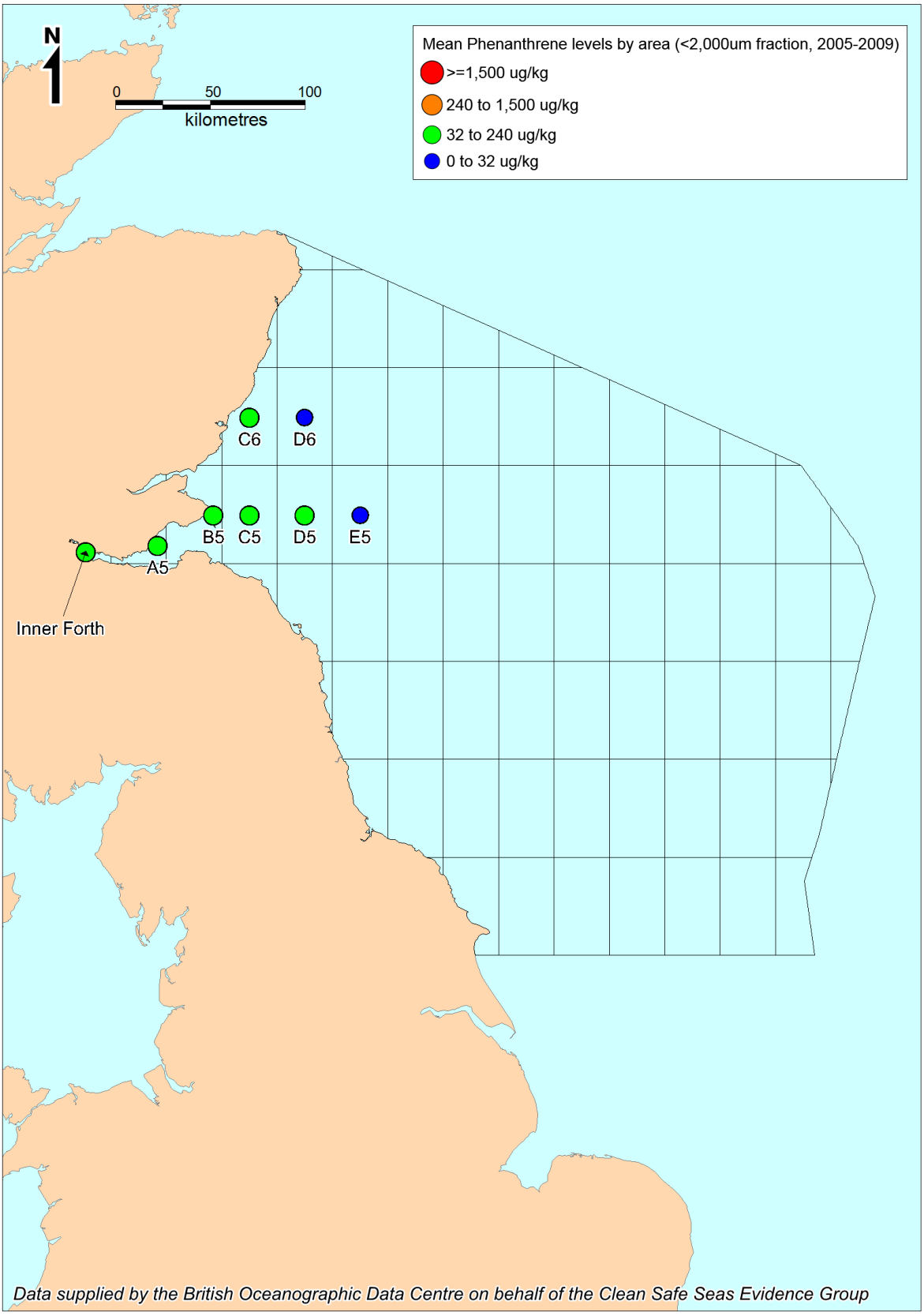

Figure 0:86: Map of mean phenanthrene concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.67: Summary of phenanthrene concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Phenanthrene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2005	2009	12	121.4	22.5	281.4	92%	8%	0%
B5	2005	2009	20	62.5	1.4	193.3	55%	0%	0%
C5	2006	2006	1	146.0	146.0	146.0	100%	0%	0%
C6	2006	2009	19	65.5	10.7	315.5	47%	5%	0%
D5	2006	2009	9	41.1	2.5	112.5	44%	0%	0%
D6	2008	2008	1	5.3	5.3	5.3	0%	0%	0%
E5	2005	2005	5	5.8	3.9	8.9	0%	0%	0%
Inner Forth	2005	2009	18	221.7	41.8	721.3	100%	44%	0%

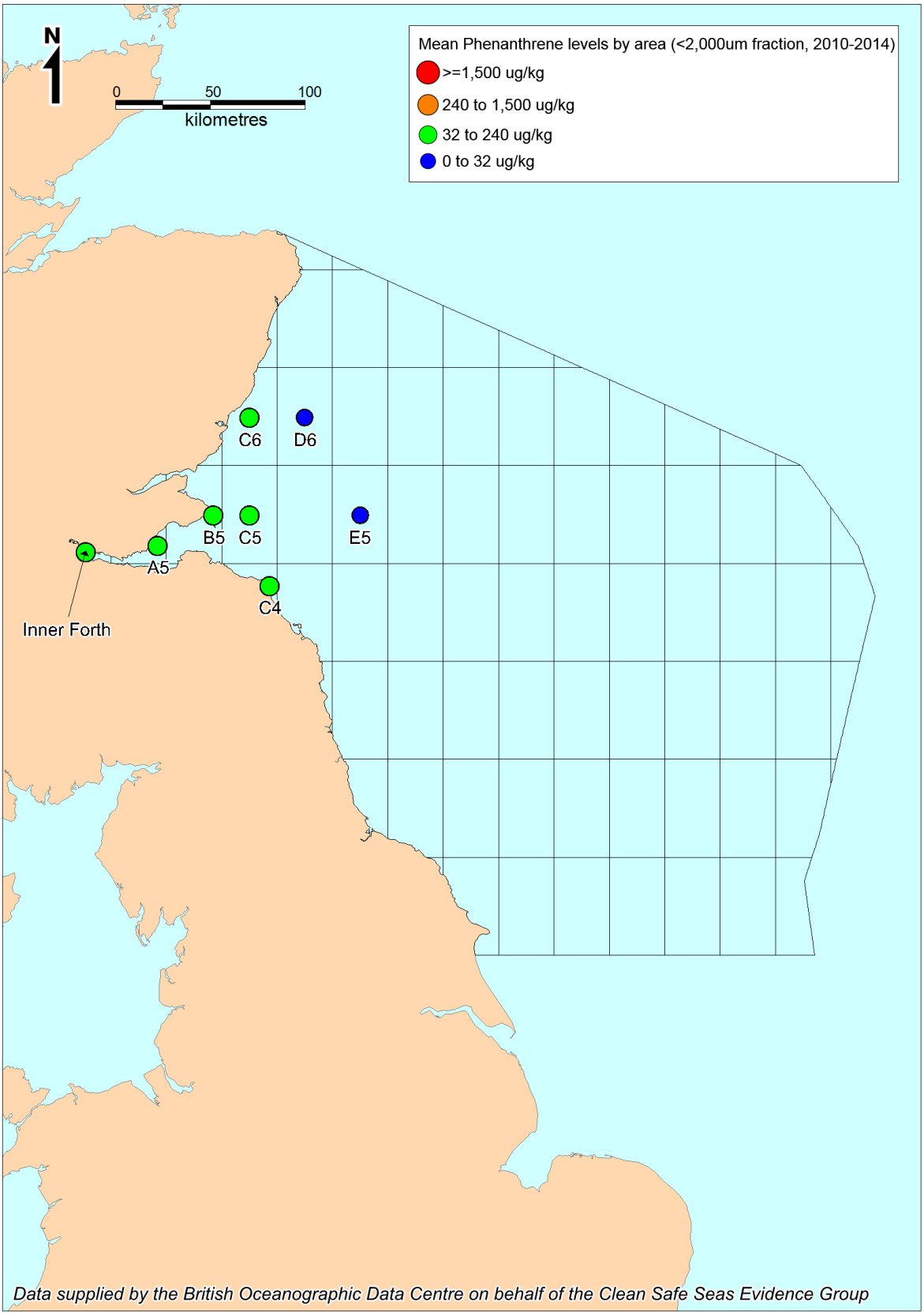

Figure 0:87: Map of mean phenanthrene concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.90: Summary of phenanthrene concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Phenanthrene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2010	2014	19	172.2	99.7	277.4	100%	5%	0%
B5	2010	2014	33	77.2	2.9	276.0	67%	3%	0%
C4	2014	2014	1	108.9	108.9	108.9	100%	0%	0%
C5	2010	2014	3	37.3	33.1	40.2	100%	0%	0%
C6	2010	2013	24	45.8	11.3	169.1	50%	0%	0%
D6	2011	2013	2	5.2	4.9	5.6	0%	0%	0%
E5	2010	2012	2	5.5	5.2	5.8	0%	0%	0%
Inner Forth	2010	2014	26	140.6	5.4	448.9	96%	8%	0%

Sediment phenanthrene sediment

The CSEMP data analysed revealed that 6/17 and 3/11 sectorial boxes exceeded the ERL for phenanthrene between 2005-2009 (Figures 1.84 and 1.86 and Tables 1.87 and 1.89) and 2010-2014 (Figures 1.85 and 1.87 and Tables 1.88 and 1.90). Many of these exceedances were restricted to heavily polluted estuaries such as the Forth, Tees, Tyne and Wear. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Pyrene

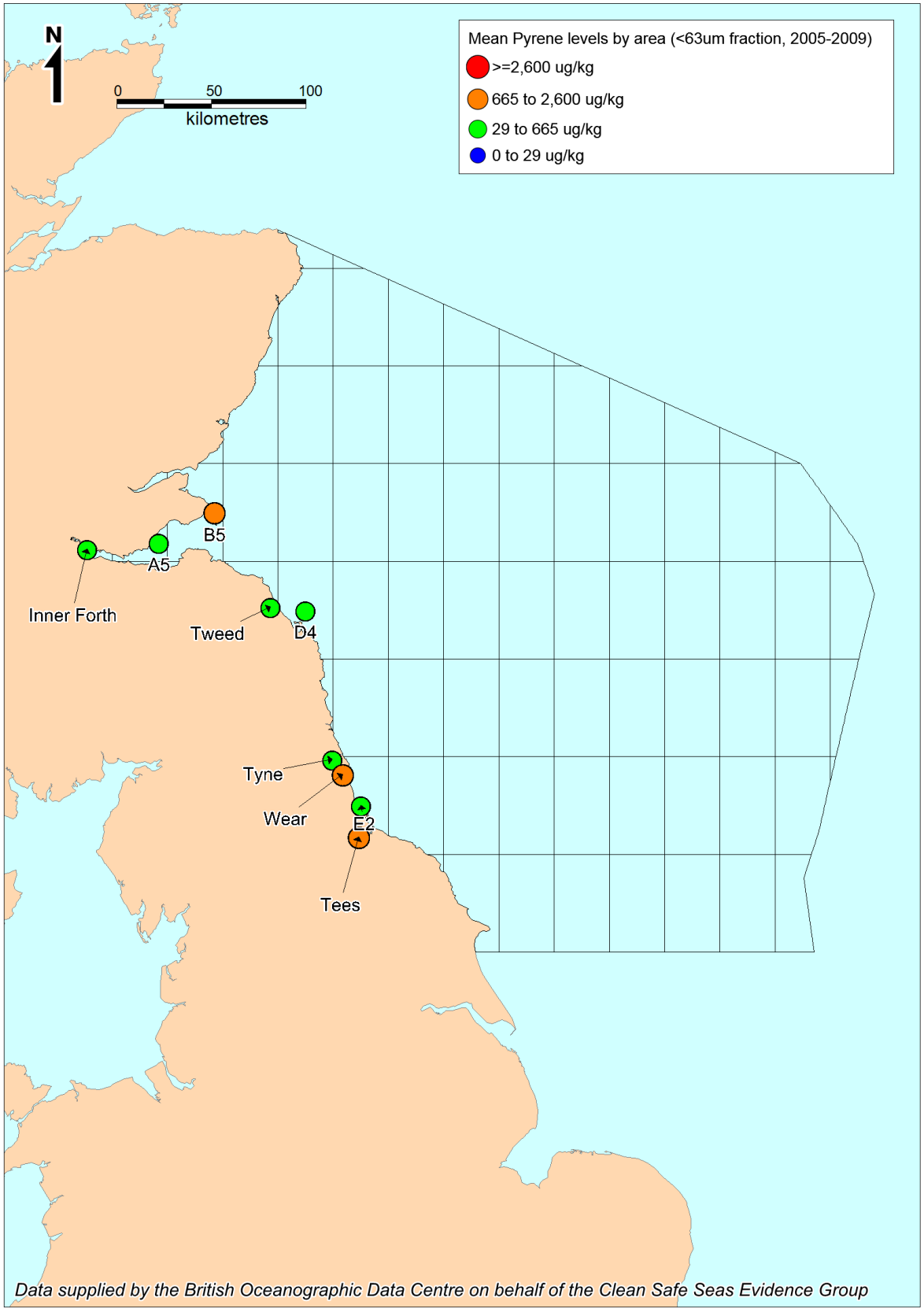

Figure 0:88: Map of mean pyrene concentrations by area (< 63 µm fraction, 2005-09)

Table 0.91: Summary of pyrene concentrations by area (< 63 µm fraction, 2005-09)

Box	Year		Pyrene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2006	2006	1	246.5	246.5	246.5	100%	0%	0%
B5	2005	2006	6	914.0	491.0	2587.0	100%	33%	0%
D4	2006	2008	15	375.0	160.4	1103.8	100%	13%	0%
E2	2006	2008	30	261.9	63.5	858.3	100%	3%	0%
Inner Forth	2005	2006	10	467.7	276.0	705.6	100%	10%	0%
Tees	2006	2009	35	1071.1	369.6	2992.1	100%	86%	3%
Tweed	2006	2008	14	255.2	148.0	427.8	100%	0%	0%
Tyne	2006	2009	35	552.7	253.6	1294.5	100%	20%	0%
Wear	2006	2009	35	989.0	204.0	8300.0	100%	43%	6%

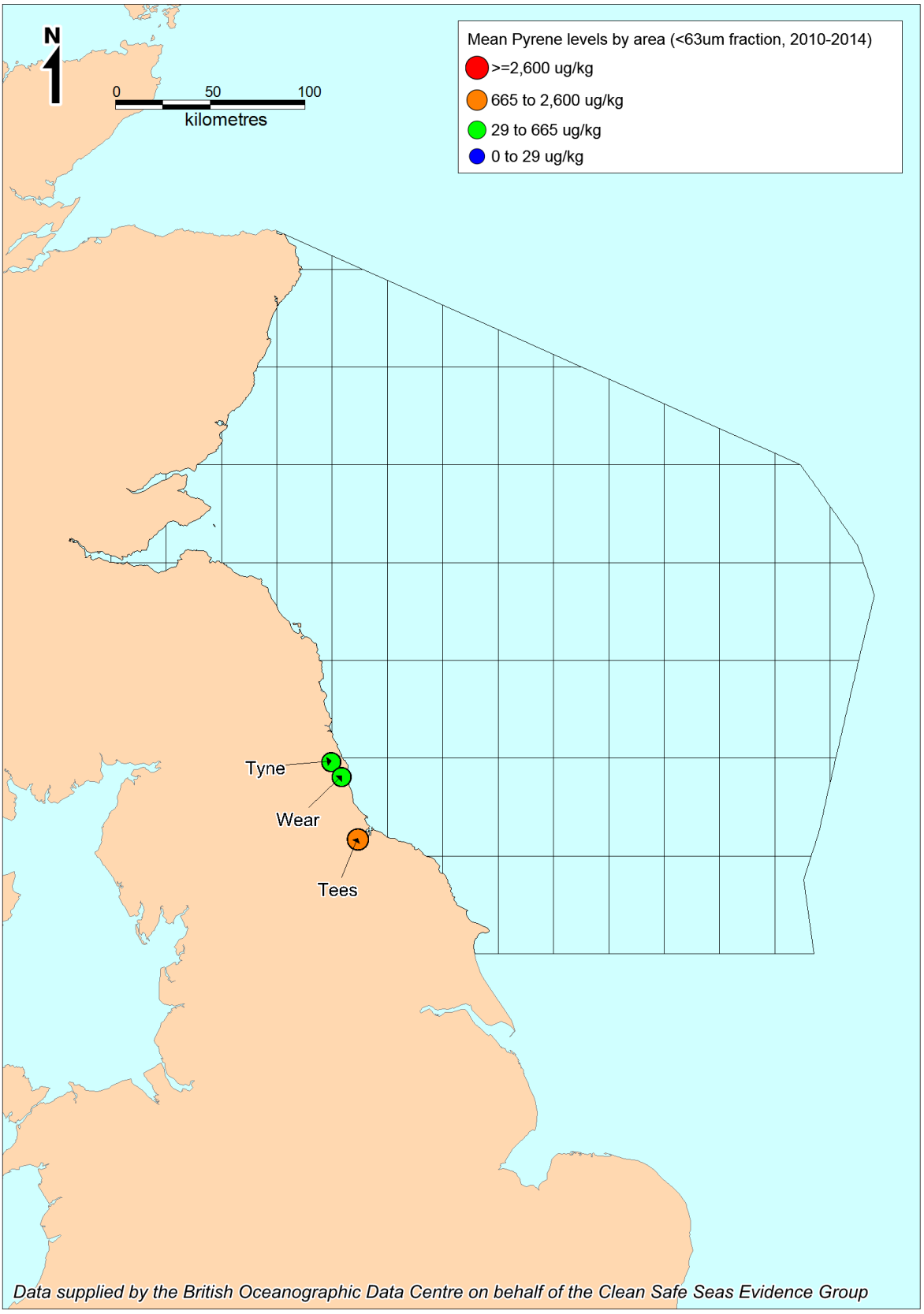

Figure 0:89: Map of mean pyrene concentrations by area (< 63 µm fraction, 2010-14)

Table 0.68: Summary of pyrene concentrations by area (< 63 µm fraction, 2010-14)

Box	Year		Pyrene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
Tees	2010	2013	10	972.0	726.0	1979.0	100%	100%	0%
Tyne	2010	2010	5	433.1	378.1	495.2	100%	0%	0%
Wear	2010	2010	5	480.1	399.2	565.0	100%	0%	0%

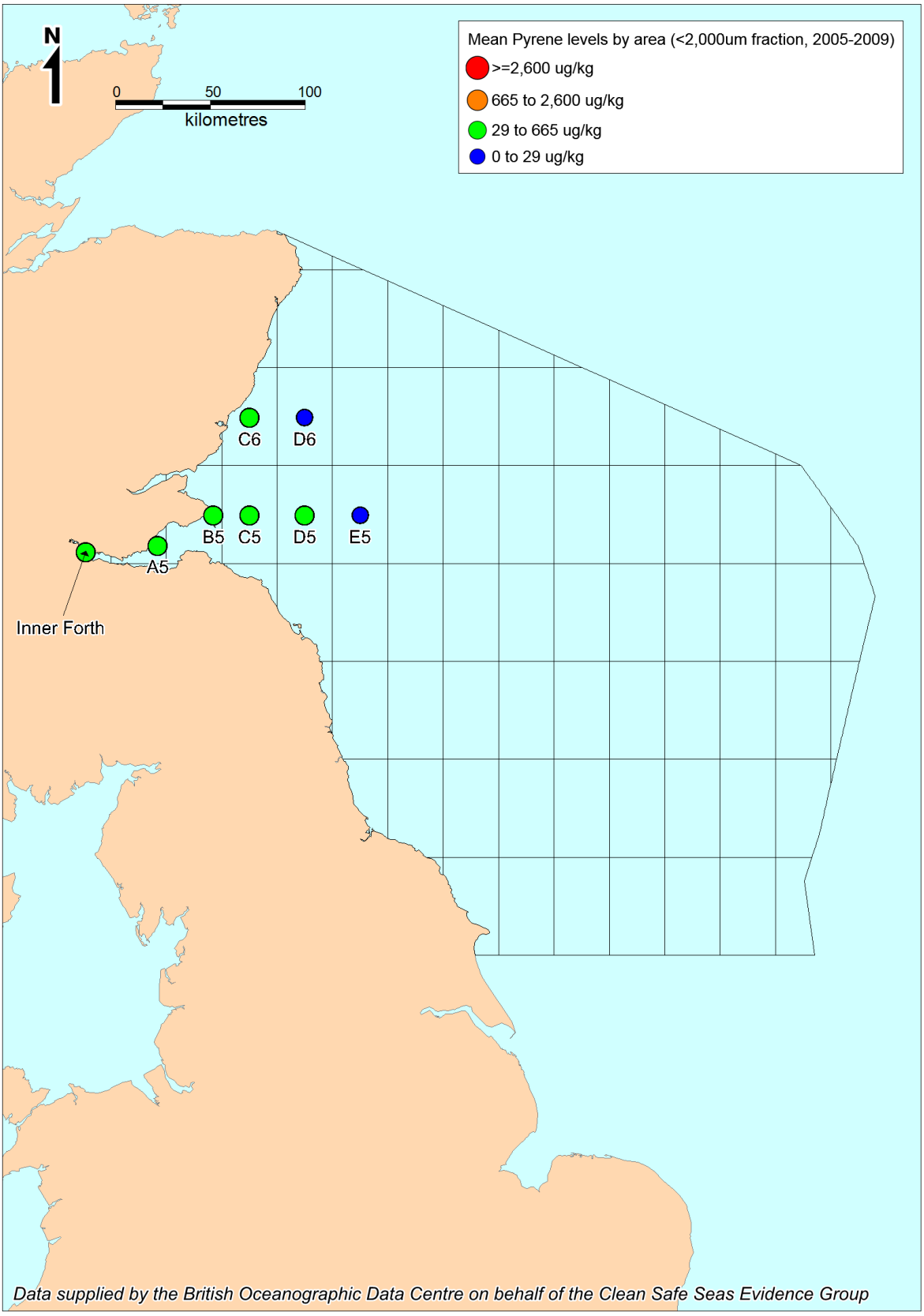

Figure 0:90: Map of mean pyrene concentrations by area (<2,000 µm fraction, 2005-09)

Table 0.69: Summary of pyrene concentrations by area (<2,000 µm fraction, 2005-09)

Box	Year		Pyrene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2005	2009	12	218.6	32.0	478.3	100%	0%	0%
B5	2005	2009	20	101.7	1.9	335.1	70%	0%	0%
C5	2006	2006	1	119.9	119.9	119.9	100%	0%	0%
C6	2006	2009	19	89.2	15.5	329.8	89%	0%	0%
D5	2006	2009	9	36.9	2.5	100.0	56%	0%	0%
D6	2008	2008	1	2.6	2.6	2.6	0%	0%	0%
E5	2005	2005	5	5.4	4.2	7.1	0%	0%	0%
Inner Forth	2005	2009	18	359.8	74.0	870.0	100%	11%	0%

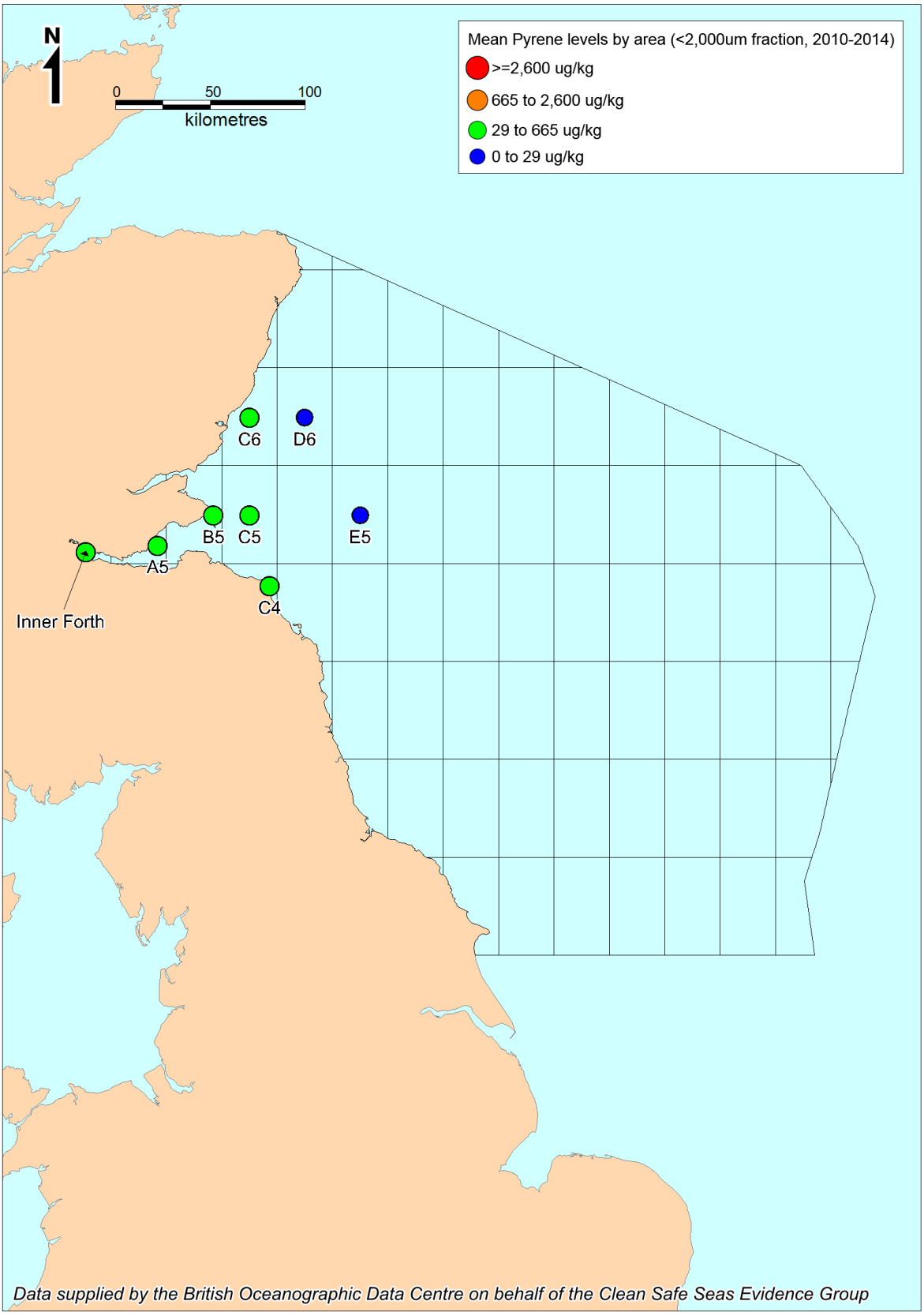

Figure 0:91: Map of mean pyrene concentrations by area (<2,000 µm fraction, 2010-14)

Table 0.70: Summary of pyrene concentrations by area (<2,000 µm fraction, 2010-14)

Box	Year		Pyrene sample results (µg/kg)						
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ERL	% >= ERM
A5	2010	2014	19	285.9	177.6	478.1	100%	0%	0%
B5	2010	2014	33	132.8	5.8	364.0	76%	0%	0%
C4	2014	2014	1	100.0	100.0	100.0	100%	0%	0%
C5	2010	2014	3	42.2	36.7	52.4	100%	0%	0%
C6	2010	2013	24	71.8	18.2	329.6	83%	0%	0%
D6	2011	2013	2	4.3	4.2	4.5	0%	0%	0%
E5	2010	2012	2	4.5	3.8	5.2	0%	0%	0%
Inner Forth	2010	2014	26	224.7	49.2	429.0	100%	0%	0%

Summary Pyrene sediment

The CSEMP data analysed revealed that 3/17 and 1/11 sectorial boxes exceeded the ERL for pyrene between 2005-2009 (Figures 1.88 and 1.90 and Tables 1.91 and 1.93) and 2010-2014 (Figures 1.89 and 1.91 Tables 1.92 and 1.94). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

1.2.10 Metals in biota

A variety of biota species were sampled and tested for metal content. Of the species sampled, only dab (*Limanda limanda*) and plaice (*Pleuronectes platessa*) were sampled away from the nearshore region. Results for these species only are presented as they are of most relevance to the assessment. The reference values against which the results were compared are shown in Table 1.95, and these reference values were used as previously to produce thematic maps. For some metals there were no reference levels, so for these the symbol size on the maps were directly scaled against the mean result.

Table 0.71: Assessment criteria used for metals in biota

Metal	Tissue	Less than the Background Assessment Concentration(BAC)	From the BAC to the European Commission Limit (EC Limit)	From the EC Limit
Cadmium	Liver	<26 µg/kg	>=26 µg/kg	>= 1000 µg/kg
Chromium	Liver	Not specified	Not specified	Not specified
Copper	Liver	Not specified	Not specified	Not specified
Mercury	Flesh (muscle)	<35 µg/kg	>= 35 µg/kg to 500 µg/kg	>= 500 µg/kg
Lead	Liver	<26 µg/kg	>= 26 µg/kg	>= 1500 µg/kg
Zinc	Liver	Not specified	Not specified	Not specified

1.2.11 Overview CSEMP metals biota data

Regulatory drivers for the measurement of metals in biota includes OSPAR CEMP which require Hg to be measured in fish flesh, and Cd and Pb to be measured in fish liver (OSPAR, 2008). In summary, concentrations of Hg in fish flesh are elevated in some industrial estuaries, although these do not pose any risks to human health. Concentrations of Cd and Pb in fish liver are again elevated in industrialized estuaries and in a few other coastal areas, but are unlikely to pose a risk to human health. Data for other metals (e.g. Zn, Cu and Cr) are sporadic, with varying numbers of sites sampled for each metal. However, there are no BACs or EC limit values available for these metals and therefore it is difficult to assess these data objectively in terms of their significance. The limited amount of data reported for metals other than Cd, Hg and Pb is probably due to the lack of a regulatory driver, and has contributed to the lack of suitable assessment criteria against which to compare the data (Charting Progress 2, 2010; Nicolaus *et al*., 2015).

Cadmium

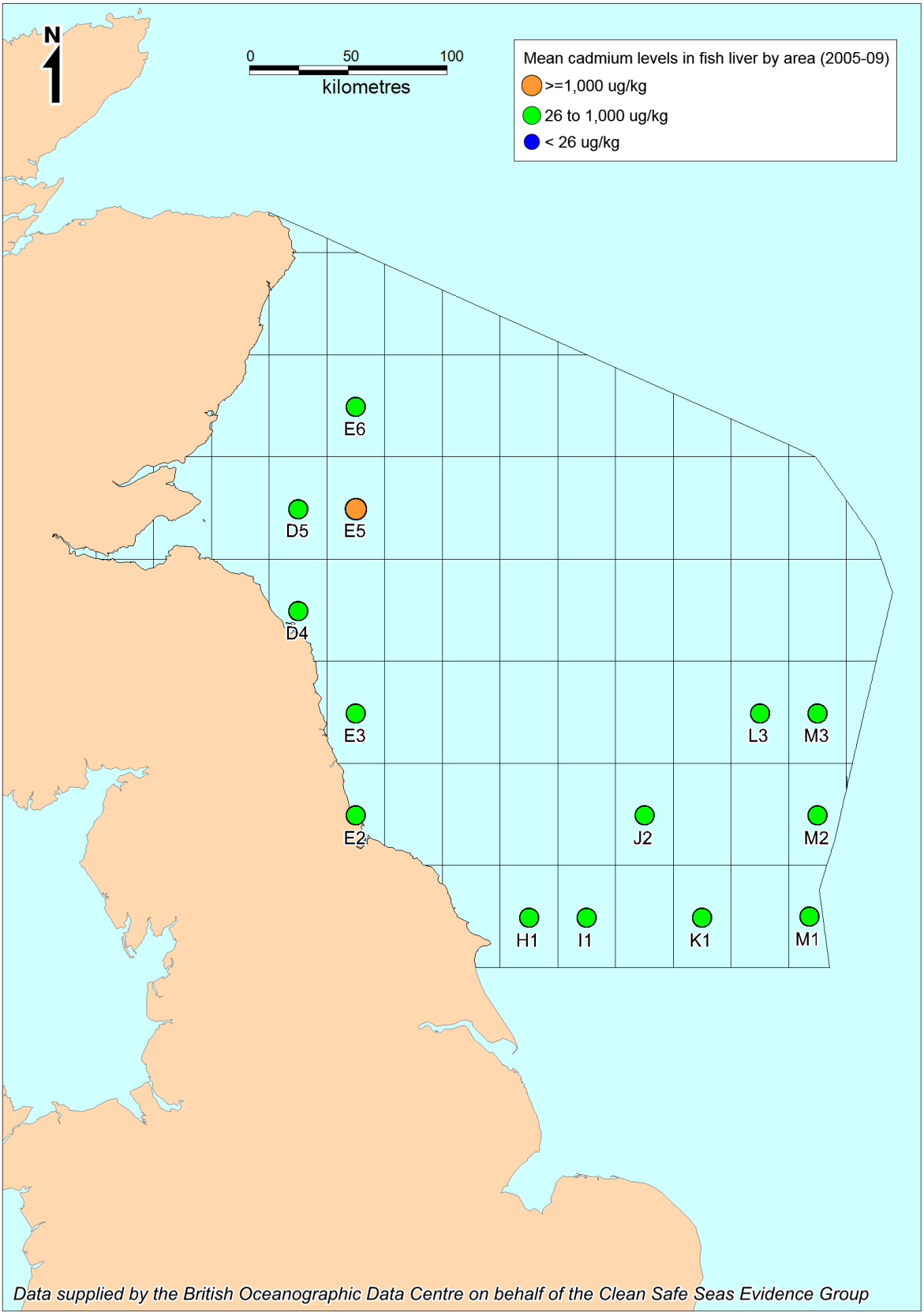

Figure 0:92: Map of mean cadmium concentrations by area (2005-09)

Table 0.72: Summary of cadmium concentrations by area (2005-09)

Box	Year		Cadmium sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >=EC limit
D4	2005	2005	2	777	109	1444	50%	50%
D5	2005	2007	8	247.3	108	430	100%	0%
E2	2005	2009	30	127.5	11.6	450	90%	0%
E3	2005	2009	30	272	100	1200	97%	3%
E5	2008	2009	10	1168	348	1838	50%	50%
E6	2006	2006	5	697	391	1250	80%	20%
H1	2005	2009	10	315	170	970	100%	0%
I1	2006	2008	14	307.1	210	560	100%	0%
J2	2005	2009	20	439.5	140	980	100%	0%
K1	2005	2009	20	311	100	1800	95%	5%
L3	2005	2009	20	394.5	210	790	100%	0%
M1	2005	2009	10	311	200	480	100%	0%
M2	2006	2008	10	347	160	500	100%	0%
M3	2005	2009	20	344.5	180	560	100%	0%

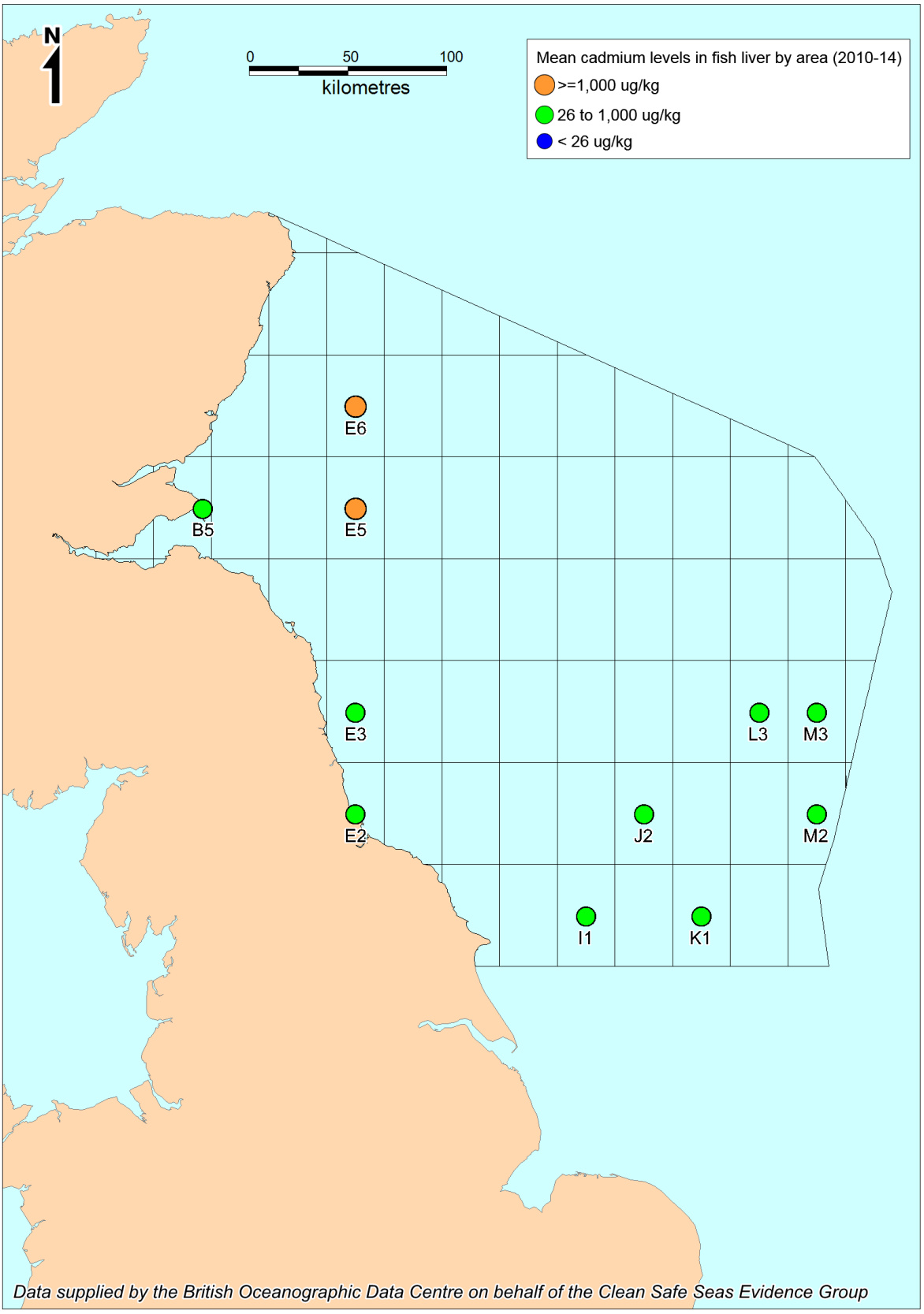

Figure 0:93: Map of mean cadmium concentrations by area (2010-14)

Table 0.73: Summary of cadmium concentrations by area (2010-14)

Box	Year		Cadmium sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >=EC limit
B5	2013	2014	7	351	140	996	100%	0%
E2	2011	2011	5	90	40	140	100%	0%
E3	2011	2011	10	211	110	430	100%	0%
E5	2011	2011	5	3130	1370	5200	0%	100%
E6	2010	2014	23	2415	217	11900	26%	74%
I1	2011	2011	5	494	270	1100	80%	20%
J2	2011	2011	5	706	280	2200	80%	20%
K1	2011	2011	5	304	200	450	100%	0%
L3	2011	2011	5	454	70	1000	80%	20%
M2	2011	2011	5	242	170	390	100%	0%

Summary Cadmium biota

Cadmium concentrations in fish liver were compared to the OSPAR BAC of 26 µg/kg ww and to the EU limit value of 1000 µg/kg ww for fish muscle and bivalves as foodstuffs, set to protect human health. Levels at most sites in this region were above the BAC but below the EC limit value. However sectorial boxes E5 (2005-2009, Figure 1.92 and Table 1.96 and 2010-2014, Figure 1.93 and Table 1.97) and E6 (2010 – 2014, Figure 1.93 and Table 1.97) contained sampled that regularly breeched the EU limit. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). A significant upward trend was observed in samples collected from Tees Bay, however the levels detected were still well below the EU limit.

Chromium

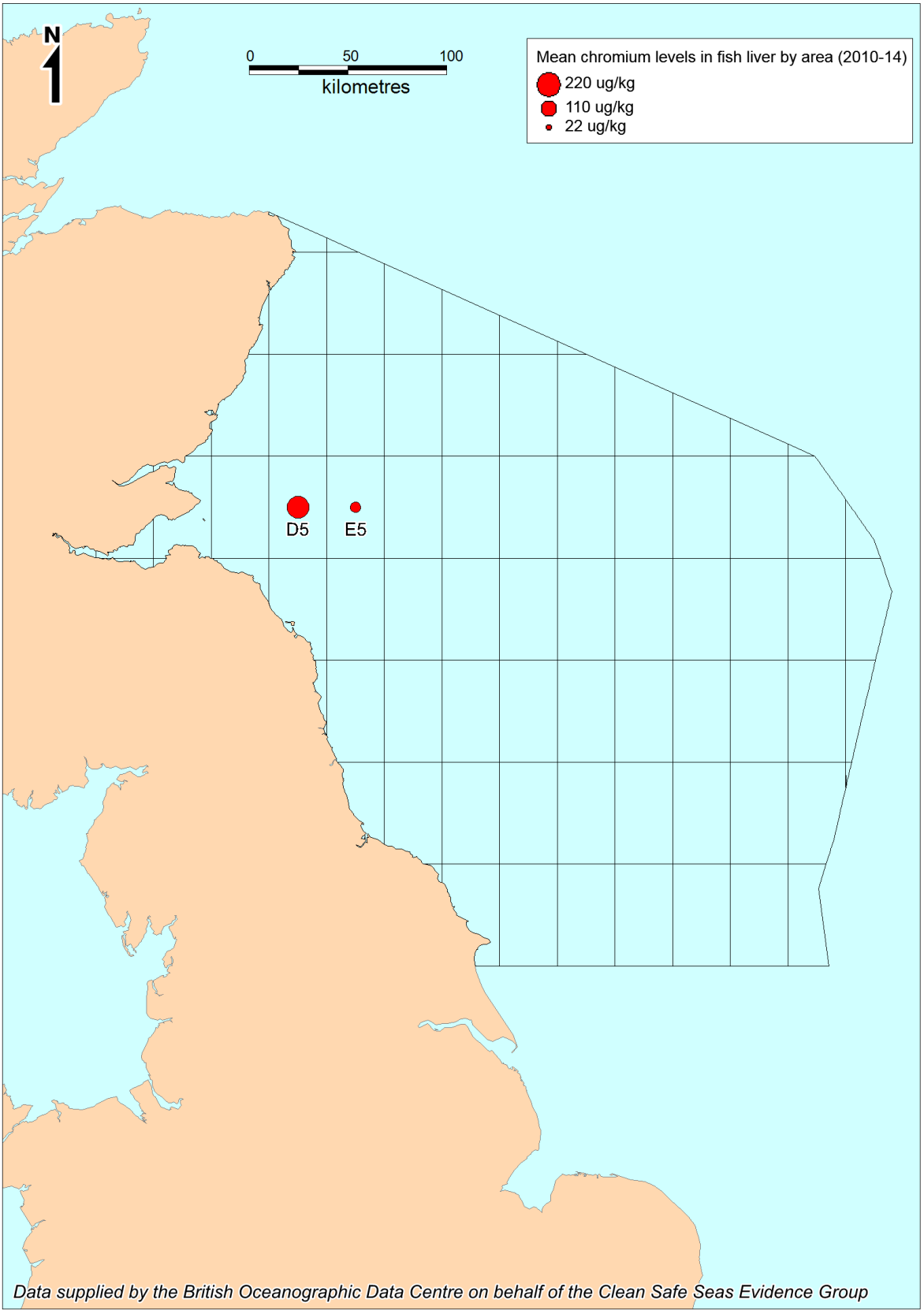

Figure 0:94: Map of mean chromium concentrations by area (2005-09)

Table 0.74: Summary of chromium concentrations by area (2005-09)

Box	Year		Chromium sample results (ug/kg)			
	From	To	No.	Mean	Minimum	Maximum
D5	2007	2007	5	208.0	208.0	208.0
E5	2008	2009	10	55.9	19.5	74.0

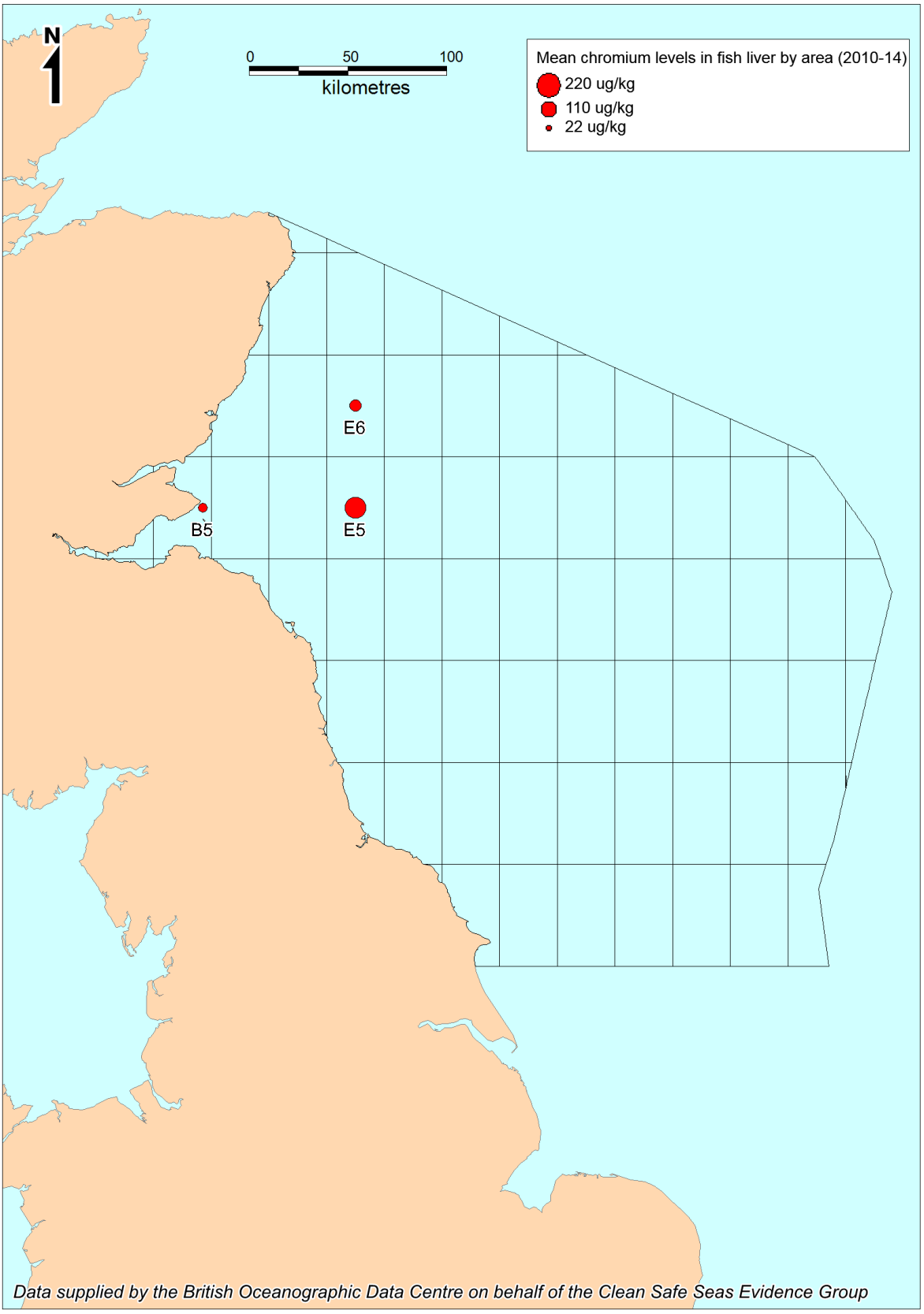

Figure 0:95: Map of mean chromium concentrations by area (2010-14)

Table 0.75: Summary of chromium concentrations by area (2010-14)

Box	Year		Chromium sample results (ug/kg)			
	From	To	No.	Mean	Minimum	Maximum
B5	2013	2014	7	36.94	15.3	74.4
E5	2011	2011	5	185.4	118	275
E6	2010	2014	23	61	15.3	347

Summary Chromium biota

There are no BACs or EC limit values available for chromium (2005-09, Figure 1.94 and Table 1.98 and Figure 1.95 and Table 1.99) so the data are shown as symbol sizes on the maps scaled against the mean result. Therefore, it is difficult to assess these data objectively in terms of their toxicological significance. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Copper

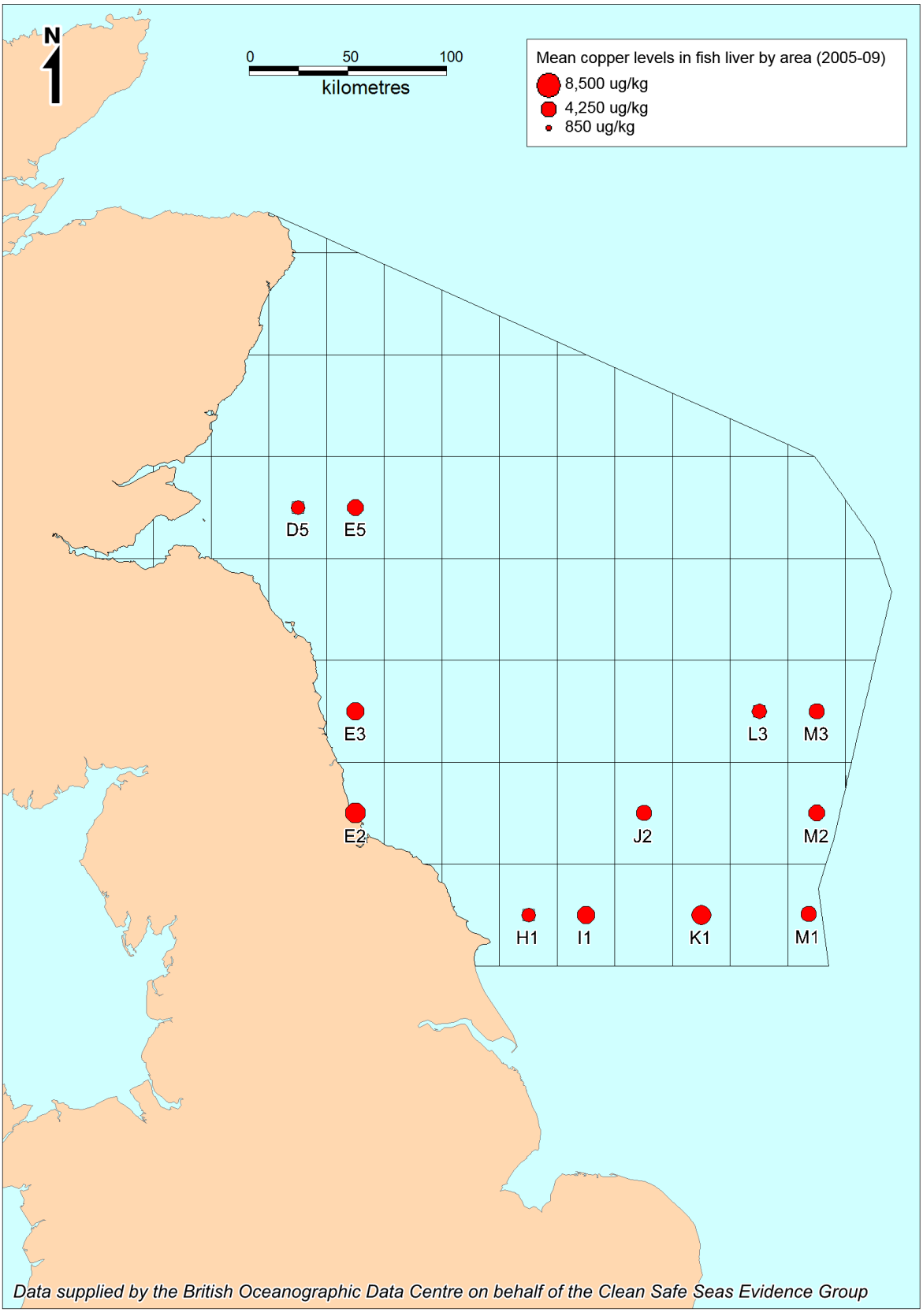

Figure 0:96: Map of mean copper concentrations by area (2005-09)

Table 0.100: Summary of copper concentrations by area (2005-09)

Box	Year		Copper sample results (ug/kg)			
	From	To	No.	Mean	Minimum	Maximum
D5	2007	2007	5	3296	2210	4660
E2	2006	2009	15	6727	3600	10000
E3	2006	2009	25	5288	2800	10000
E5	2009	2009	3	4812	3017	5862
H1	2009	2009	5	3360	2300	5200
I1	2006	2008	14	5093	2600	9000
J2	2006	2009	15	4327	2500	7800
K1	2006	2009	15	6320	2900	12000
L3	2006	2009	15	3613	2000	5300
M1	2009	2009	5	4140	3400	5100
M2	2006	2008	10	4690	3200	7200
M3	2006	2009	15	4387	2100	7300

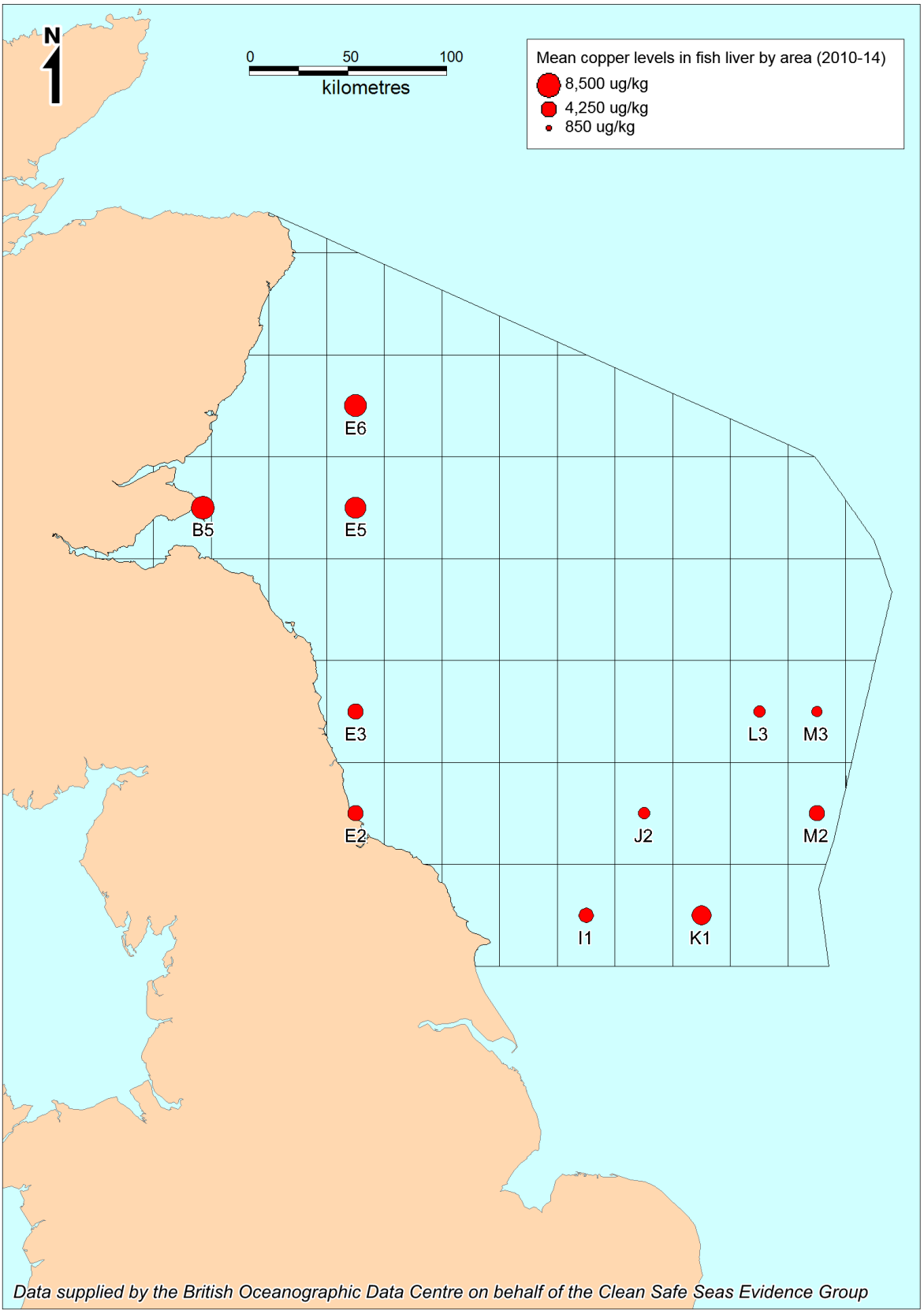

Figure 0:97: Map of mean copper concentrations by area (2010-14)

Table 0.101: Summary of copper concentrations by area (2010-14)

Box	Year		Copper sample results (ug/kg)			
	From	To	No.	Mean	Minimum	Maximum
B5	2013	2014	8	8420	4200	11500
E2	2011	2011	5	4100	2300	5700
E3	2011	2011	10	4380	2600	9200
E5	2011	2011	5	7164	4820	9850
E6	2010	2014	23	7636	3180	22000
I1	2011	2011	5	3660	2100	7800
J2	2011	2011	5	2520	1800	3200
K1	2011	2011	5	6040	3400	9200
L3	2011	2011	5	2448	340	4400
M2	2011	2011	5	3980	3400	4500
M3	2011	2011	5	2000	1600	2400

Summary Copper biota

There are no BACs or EC limit values available for copper, so the data shown for these are displayed as symbol sizes on the maps scaled against the mean result (2005-09, Figure 1.96 and Table 1.100 and 2010-14, Figure 1.97 and Table 1.101). Therefore, it is difficult to assess these data objectively in terms of their toxicological significance. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Mercury

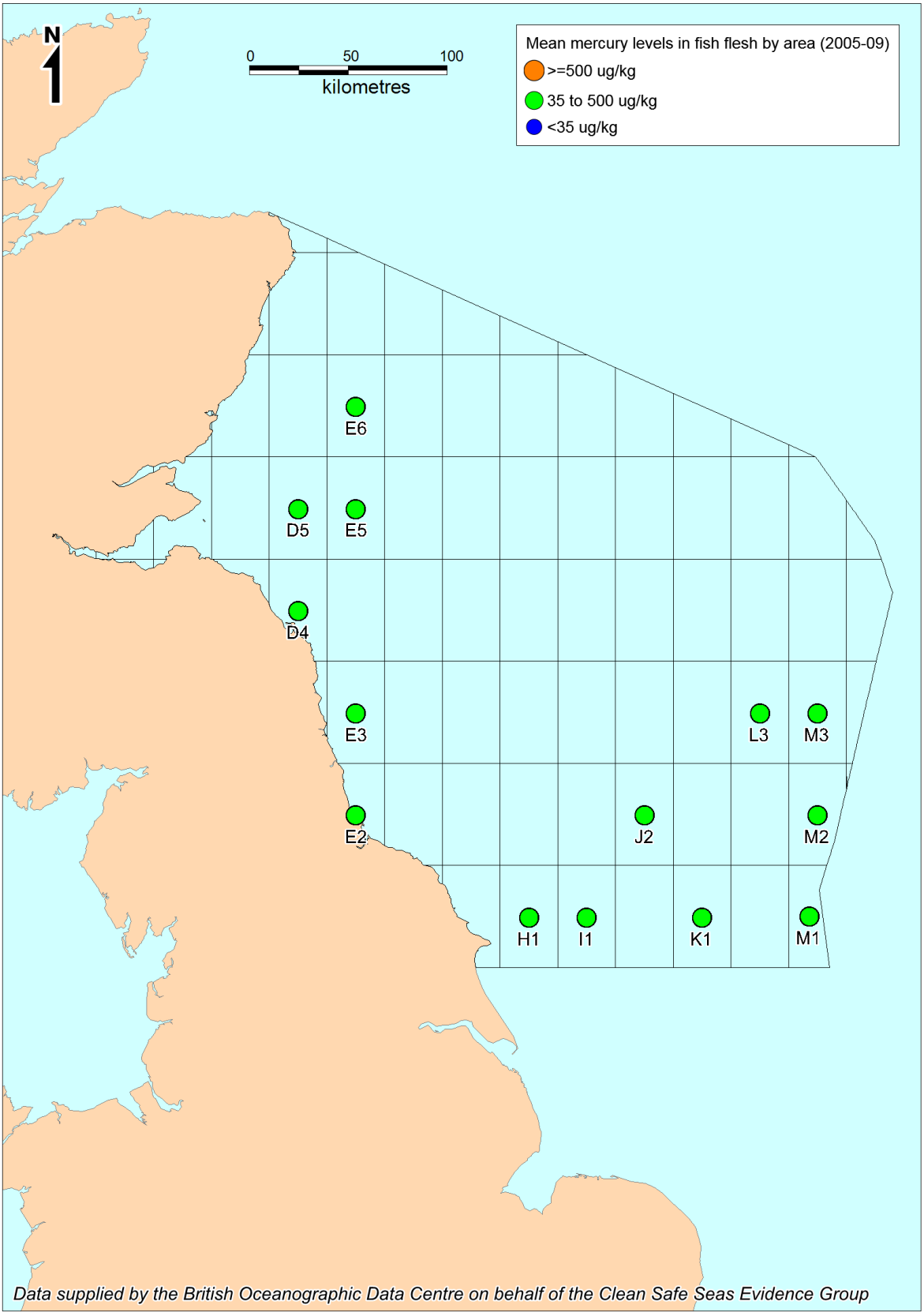

Figure 0:98: Map of mean mercury concentrations by area (2005-09)

Table 0.76: Summary of mercury concentrations by area (2005-09)

Box	Year		Mercury sample results (ug/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ECL
D4	2005	2005	2	101.8	35.0	168.6	100%	0%
D5	2005	2007	8	70.4	46.0	109.0	100%	0%
E2	2005	2009	35	50.2	20.0	210.0	57%	0%
E3	2005	2009	30	105.7	30.0	380.0	97%	0%
E5	2008	2009	10	111.6	88.8	134.8	100%	0%
E6	2006	2006	5	77.6	65.0	95.0	100%	0%
H1	2005	2009	10	176.0	60.0	310.0	100%	0%
I1	2006	2008	14	120.7	60.0	250.0	100%	0%
J2	2005	2009	20	90.5	30.0	210.0	90%	0%
K1	2005	2009	20	125.5	50.0	280.0	100%	0%
L3	2005	2009	20	82.5	20.0	170.0	85%	0%
M1	2005	2009	10	76.0	50.0	100.0	100%	0%
M2	2006	2008	10	124.0	30.0	250.0	90%	0%
M3	2005	2009	20	62.5	10.0	100.0	90%	0%

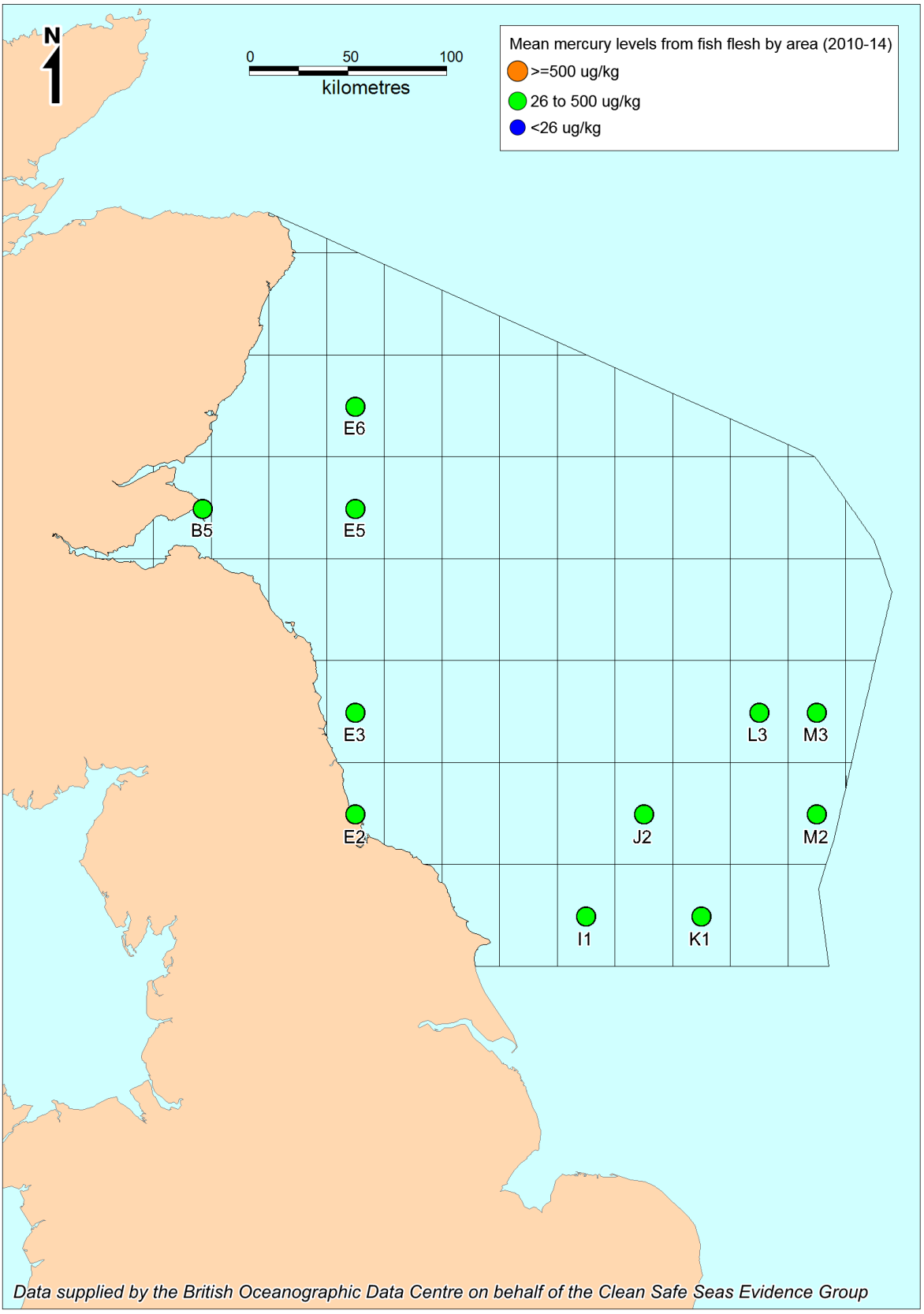

Figure 0:99: Map of mean mercury concentrations by area (2010-14)

Table 0.77: Summary of mercury concentrations by area (2010-14)

Box	Year		Mercury sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= ECL
B5	2013	2014	8	155.13	115	186	100%	0%
E2	2011	2011	5	50	40	60	100%	0%
E3	2011	2011	10	65	40	90	100%	0%
E5	2011	2011	5	139.6	115	178	100%	0%
E6	2010	2014	24	127.53	78.7	195	100%	0%
I1	2011	2011	5	150	120	170	100%	0%
J2	2011	2011	5	68	60	80	100%	0%
K1	2011	2011	5	96	80	110	100%	0%
L3	2011	2011	5	78	70	90	100%	0%
M2	2011	2011	5	60	50	70	100%	0%
M3	2011	2011	5	74	50	100	100%	0%

Summary Mercury biota

Mercury concentrations in fish flesh were compared to the OSPAR BAC of 35 µg/kg ww and to the EU limit value of 500 µg/kg ww for fish muscle and bivalves as foodstuffs, set to protect human health. Levels at most sites in this region were above the BAC but below the EC limit value (2005-09, Figure 1.98 and Table 1.102 and 2010-14, Figure 1.99 and Table 1.103). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Lead

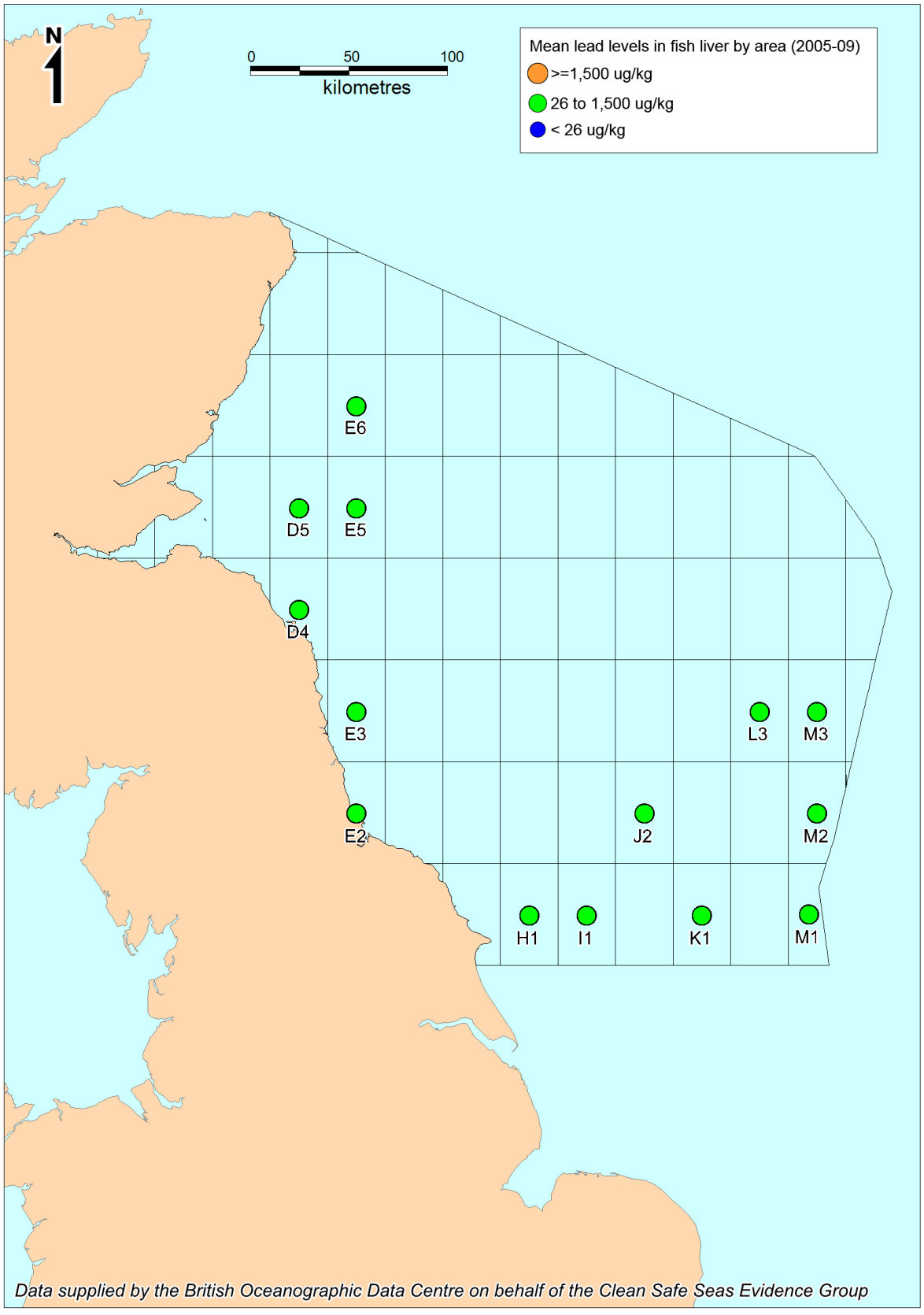

Figure 0:100: Map of mean lead concentrations by area (2005-09)

Table 0.78: Summary of lead concentrations by area (2005-09)

Box	Year		Lead sample results (ug/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EC limit
D4	2005	2005	2	30.0	17.5	42.5	50%	0%
D5	2005	2007	8	740.0	97.0	1850.0	87%	13%
E2	2005	2009	25	436.4	164.0	780.0	100%	0%
E3	2005	2009	30	139.3	40.0	300.0	100%	0%
E5	2008	2009	10	137.9	56.0	442.0	100%	0%
E6	2006	2006	5	58.2	46.0	71.0	100%	0%
H1	2005	2009	10	122.0	70.0	180.0	100%	0%
I1	2006	2008	14	124.3	70.0	230.0	100%	0%
J2	2005	2009	20	112.5	10.0	810.0	75%	0%
K1	2005	2009	20	1012.0	100.0	3200.0	75%	25%
L3	2005	2009	20	41.0	10.0	100.0	55%	0%
M1	2005	2009	10	53.0	30.0	130.0	100%	0%
M2	2006	2008	10	52.0	10.0	100.0	70%	0%
M3	2005	2009	20	45.0	10.0	100.0	75%	0%

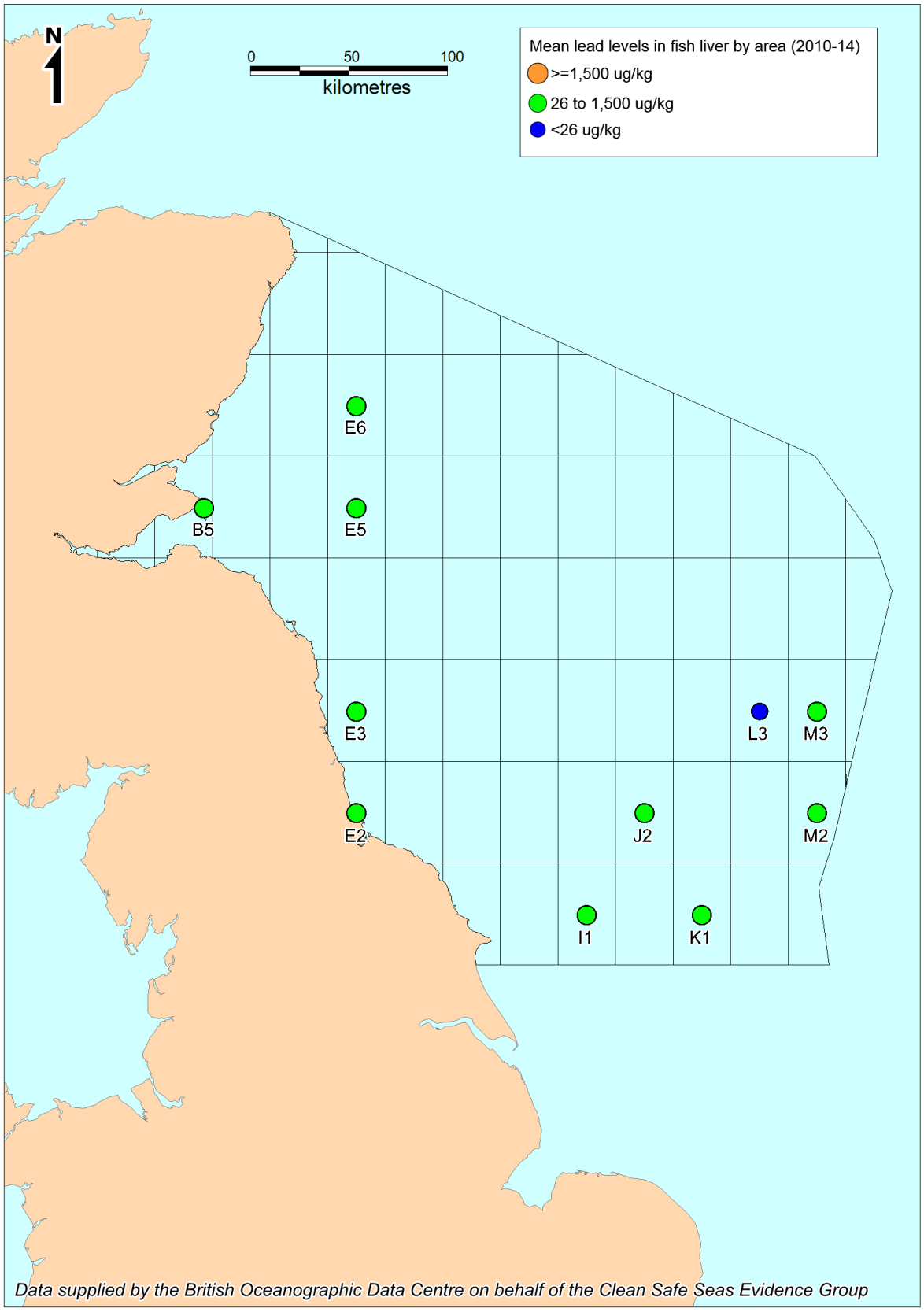

Figure 0:101: Map of mean lead concentrations by area (2010-14)

Table 0.79: Summary of lead concentrations by area (2010-14)

Box	Year		Lead sample results (µg/kg)					
	From	To	No.	Mean	Minimum	Maximum	% >= BAC	% >= EC limit
B5	2013	2014	8	165.5	87.9	285.0	100%	0%
E2	2011	2011	5	282.0	90.0	610.0	100%	0%
E3	2011	2011	10	116.0	70.0	270.0	100%	0%
E5	2011	2011	5	64.2	36.3	130.0	100%	0%
E6	2010	2014	23	87.2	25.0	158.0	96%	0%
I1	2011	2011	5	132.0	90.0	260.0	100%	0%
J2	2011	2011	5	80.0	70.0	90.0	100%	0%
K1	2011	2011	5	820.0	200.0	2000.0	80%	20%
L3	2011	2011	5	23.0	5.0	40.0	40%	0%
M2	2011	2011	5	50.0	30.0	70.0	100%	0%
M3	2011	2011	5	38.0	30.0	50.0	100%	0%

Summary Lead biota

Lead concentrations in fish liver were compared to the OSPAR BAC of 26 µg/kg ww and to the EU limit value of 1500 µg/kg ww for fish muscle and bivalves as foodstuffs, set to protect human health. Levels at most sites in this region were above the BAC but below the EC limit value (2005-09, Figure 1.100 and Table 1.104 and 2010-14, Figure 1.101 and Table 1.105). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

Zinc

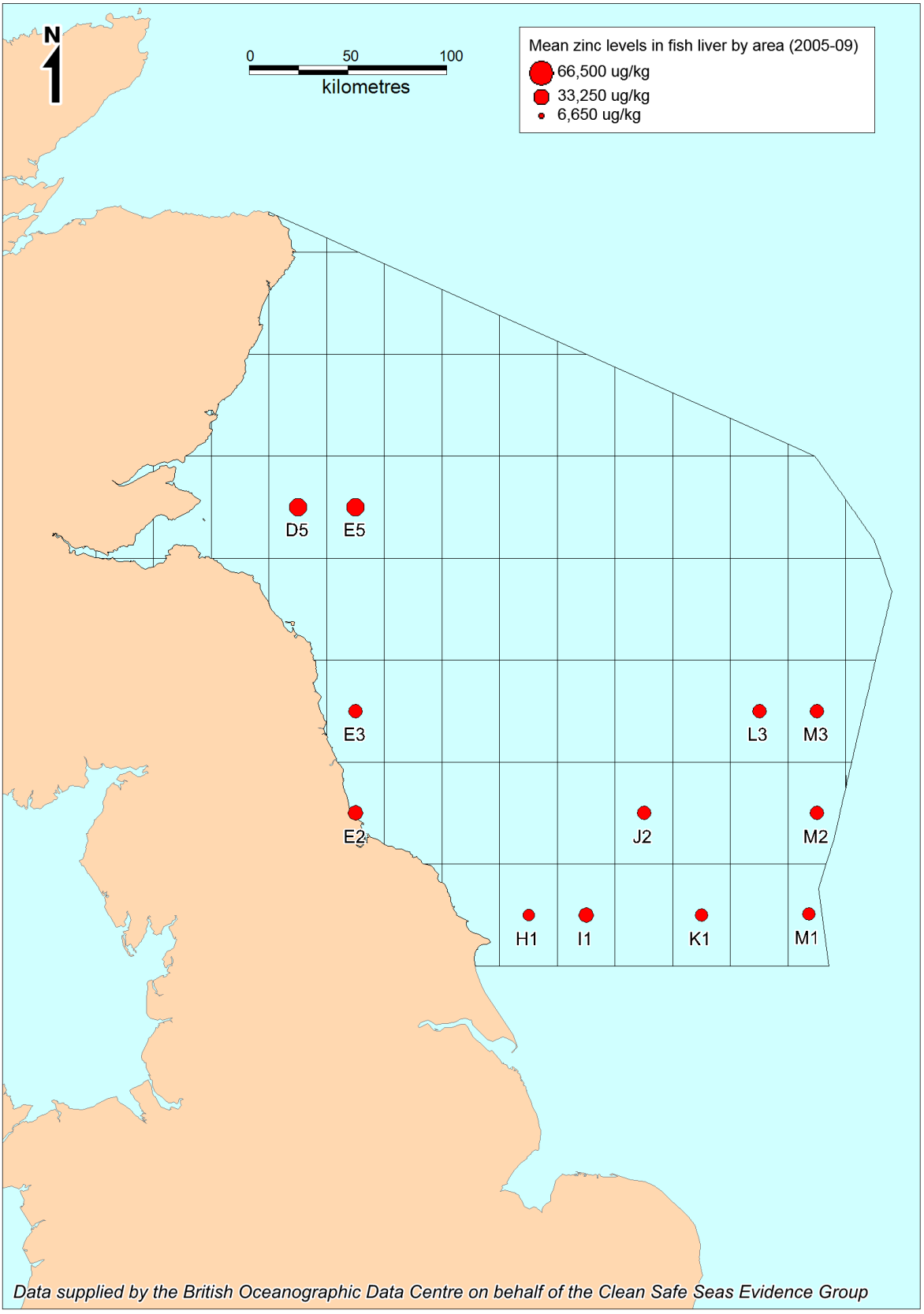

Figure 0:102: Map of mean zinc concentrations by area (2005-09)

Table 0.80: Summary of zinc concentrations by area (2005-09)

Box	Year		Zinc sample results (µg/kg)			
	From	To	No.	Mean	Minimum	Maximum
D5	2007	2007	5	40720	31100	48300
E2	2006	2009	15	28133	21000	36000
E3	2006	2009	25	27160	19000	36000
E5	2009	2009	5	40783	26376	68656
H1	2009	2009	5	20000	17000	23000
I1	2006	2008	14	30071	25000	36000
J2	2006	2009	15	26267	20000	36000
K1	2006	2009	15	23867	18000	37000
L3	2006	2009	15	26000	20000	35000
M1	2009	2009	5	24200	19000	29000
M2	2006	2008	10	27300	24000	34000
M3	2006	2009	15	26533	20000	36000

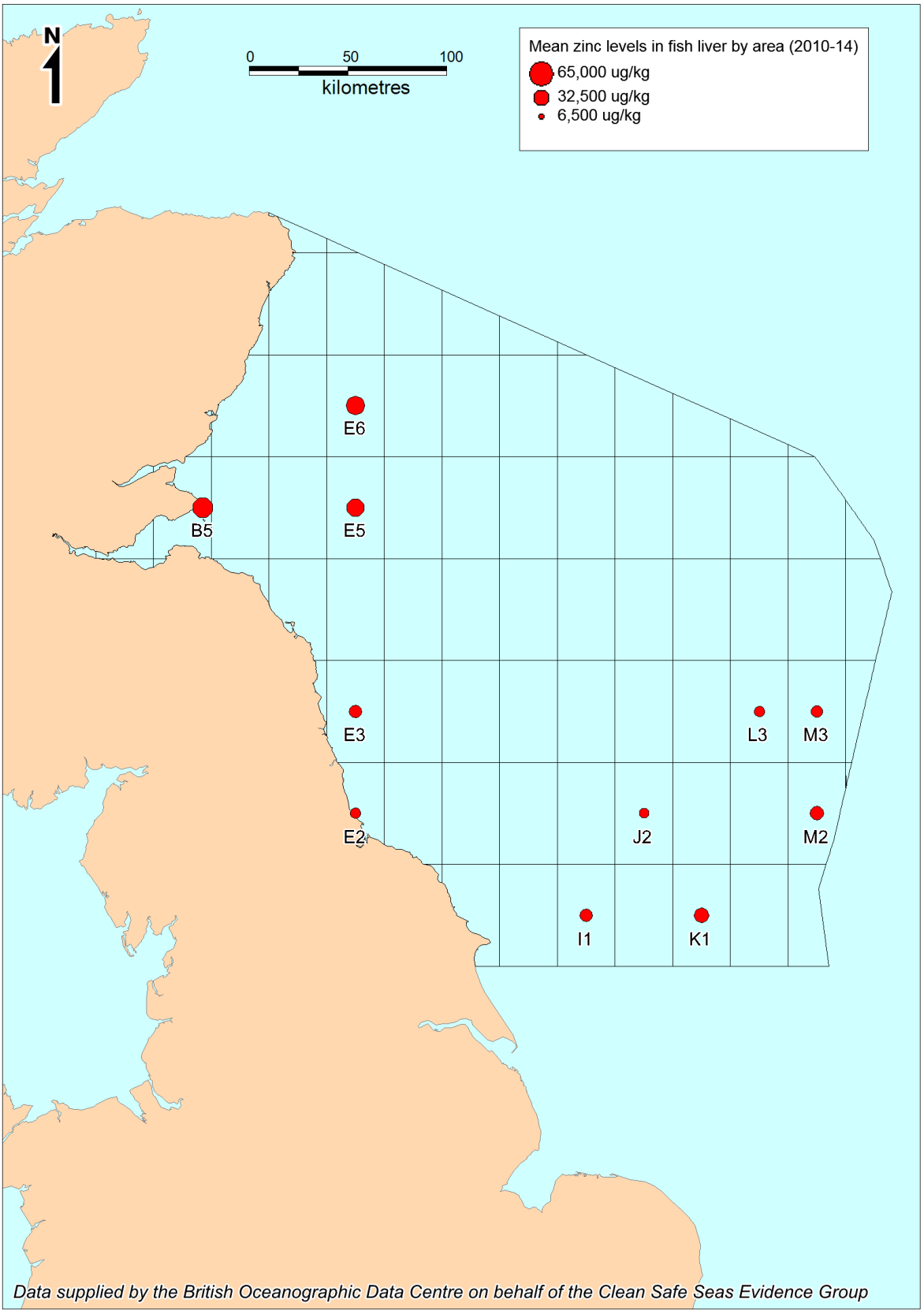

Figure 0:103: Map of mean zinc concentrations by area (2010-14)

Table 0.81: Summary of zinc concentrations by area (2010-14)

Box	Year		Zinc sample results (µg/kg)			
	From	To	No.	Mean	Minimum	Maximum
B5	2013	2014	8	50438	28000	66500
E2	2011	2011	5	16560	8500	22000
E3	2011	2011	10	22400	16000	34000
E5	2011	2011	5	37840	35100	41800
E6	2010	2014	23	43808	24400	66400
I1	2011	2011	5	23400	21000	29000
J2	2011	2011	5	14600	14000	16000
K1	2011	2011	5	27400	23000	34000
L3	2011	2011	4	16750	15000	18000
M2	2011	2011	5	24800	23000	27000
M3	2011	2011	5	20600	19000	22000

Summary Zinc biota

There are no BACs or EC limit values available for zinc, so the data are shown for these as symbol sizes on the maps scaled against the mean result (2005-09, Figure 1.102 and Table 1.106 and 2010-14, Figure 1.103, Table 1.107). Therefore, it is difficult to assess these data objectively in terms of their toxicological significance. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

1.2.12 Poly chlorinated biphenyls in biota

A variety of biota species were sampled and tested for PCB content. Of the species sampled, only dab (*Limanda limanda*) and plaice (*Pleuronectes platessa*) were sampled away from the nearshore region. Results for these species only are presented as they are of most relevance to the assessment. The range of PCBs measured included the seven for which summary data were presented previously in Section 5. Data was normalised to a liver lipid content throughout. The reference values against which the results were compared are shown in Table 1.108, and these reference values were used as previously to produce thematic maps.

Table 0.82 Assessment criteria used for PCBs in biota

PCB	Less than the Environmental Assessment Concentration (EAC)	Above the EAC
2,4,4'-trichlorobiphenyl (CB28)	< 64 µg/kg	>= 64 µg/kg
2,2',5,5'-tetrachlorobiphenyl (CB52)	< 108 µg/kg	>= 108 µg/kg
2,2',4,5,5'-pentachlorobiphenyl (CB101)	< 120 µg/kg	>= 120 µg/kg
2,3',4,4',5-pentachlorobiphenyl (CB118)	< 24 µg/kg	>= 24 µg/kg
2,2',3,4,4',5'-hexachlorobiphenyl (CB138)	< 316 µg/kg	>= 316µg/kg
2,2',4,4',5,5'-hexachlorobiphenyl (CB153)	< 1,600 µg/kg	>= 1,600 µg/kg
2,2',3,4,4',5,5'-heptachlorobiphenyl (CB180)	< 480 µg/kg	>= 480 µg/kg

1.2.13 Overview CSEMP CB biota data

In summary the data presented mirrors previously reported (Charting Progress 2, 2010). In terms of inputs into the region it is known that atmospheric and riverine inputs have been reduced significantly in recent years. However, in some of the historically industrialized estuaries, such as the Tyne and Tees on the north-east coast, there can be high levels of legacy contamination. Overall it can be seen that PCB concentrations in fish has reduced in several areas. Were the $EAC_{passive}$ was breached it tended to be restricted to data on levels of CB118, a mono-*ortho* CB and the most toxic of the ICES7 CBs.

CB28

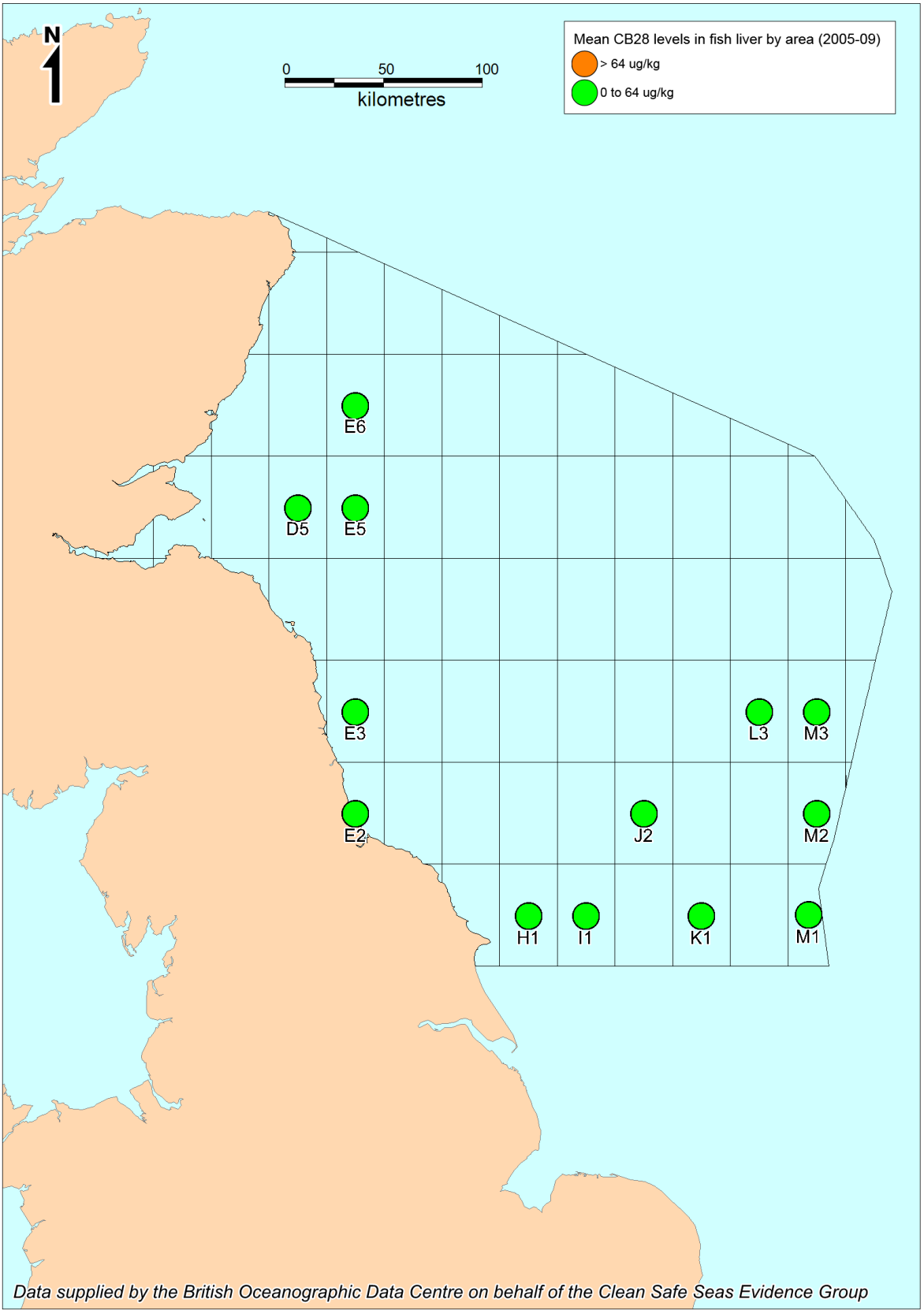

Figure 0:104: Map of mean 2,4,4'-trichlorobiphenylconcentrations by area (2005-09)

Table 0.83: Summary of 2,4,4'-trichlorobiphenylconcentrations by area (2005-09)

Box	Year		2,4,4'-trichlorobiphenyl sample results (ug/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
D5	2005	2007	7	4.0	2.0	6.2	0%
E2	2005	2009	26	3.3	0.7	6.6	0%
E3	2005	2009	15	3.9	1.1	7.4	0%
E5	2008	2009	10	8.6	1.0	21.0	0%
E6	2006	2006	5	1.8	1.1	2.6	0%
H1	2005	2009	10	4.7	0.5	8.7	0%
I1	2008	2008	5	8.6	5.6	10.2	0%
J2	2005	2009	15	41.9	3.6	315.7	13%
K1	2005	2008	10	4.1	2.0	9.2	0%
L3	2005	2009	15	4.6	2.8	7.5	0%
M1	2005	2009	10	5.2	2.5	8.8	0%
M2	2008	2008	5	3.7	2.7	5.1	0%
M3	2005	2009	15	7.1	2.2	19.7	0%

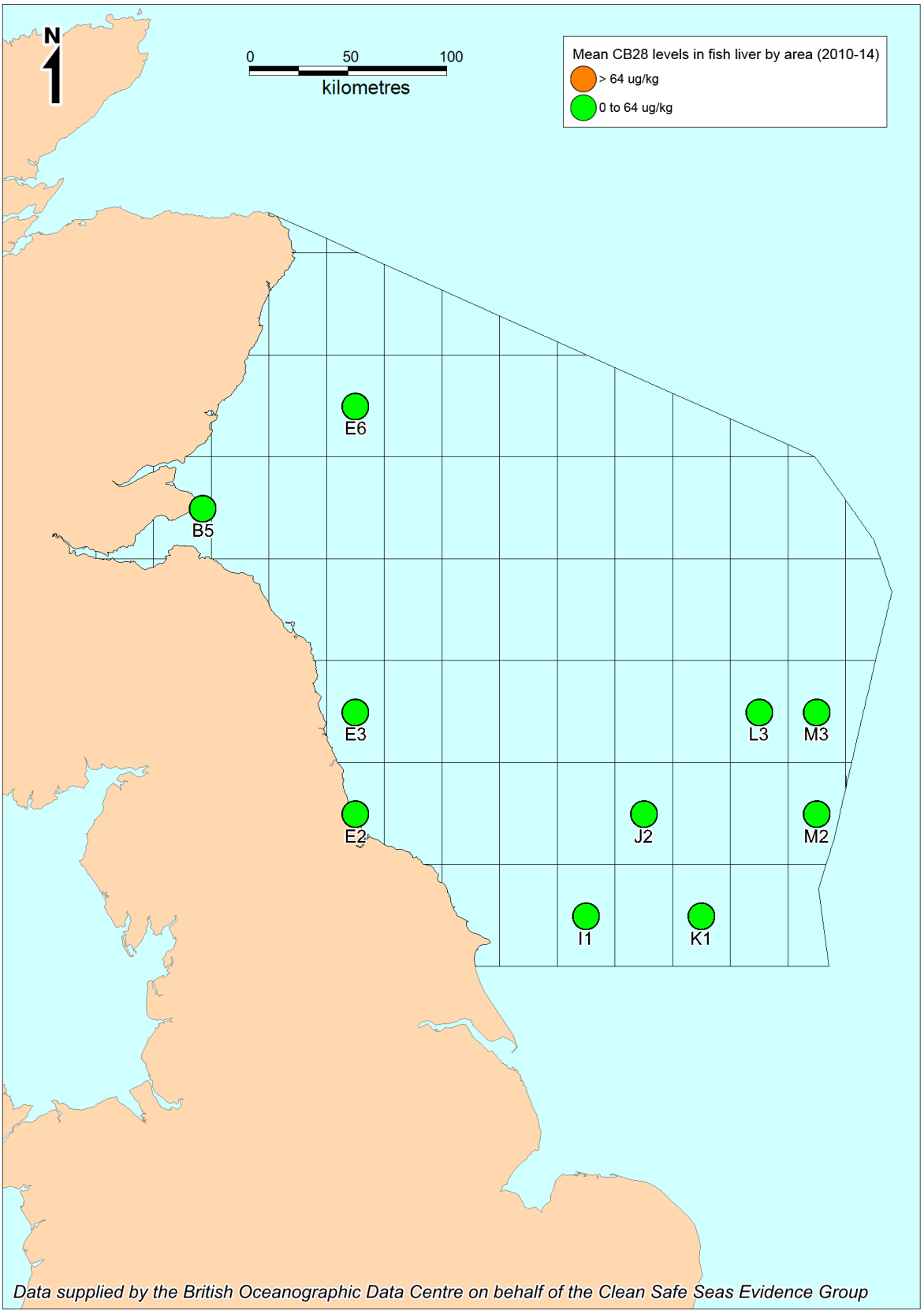

Figure 0:105: Map of mean 2,4,4'-trichlorobiphenylconcentrations by area (2010-14)

Table 0.10: Summary of 2,4,4'-trichlorobiphenylconcentrations by area (2010-14)

Box	Year		2,4,4'-trichlorobiphenyl sample results (µg/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
B5	2013	2014	8	5.2	3.5	10.0	0%
E2	2010	2011	10	2.3	1.1	3.1	0%
E3	2011	2011	10	1.3	1.0	2.5	0%
E6	2010	2014	25	2.3	0.3	7.7	0%
I1	2011	2011	5	3.3	1.1	4.1	0%
J2	2010	2011	10	4.3	2.8	6.9	0%
K1	2010	2011	10	2.0	1.0	4.4	0%
L3	2010	2011	10	3.3	2.3	4.0	0%
M2	2010	2011	10	2.6	1.1	3.6	0%
M3	2010	2011	10	4.0	2.5	6.1	0%

Summary CB28 biota data

The CSEMP data analysed revealed that all sectorial boxes were below the EAC for CB28 (2005-09, Figure 1.104 and Table 1.109 and 2010-14, Figure 1.105 and Table 1.10). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

CB52

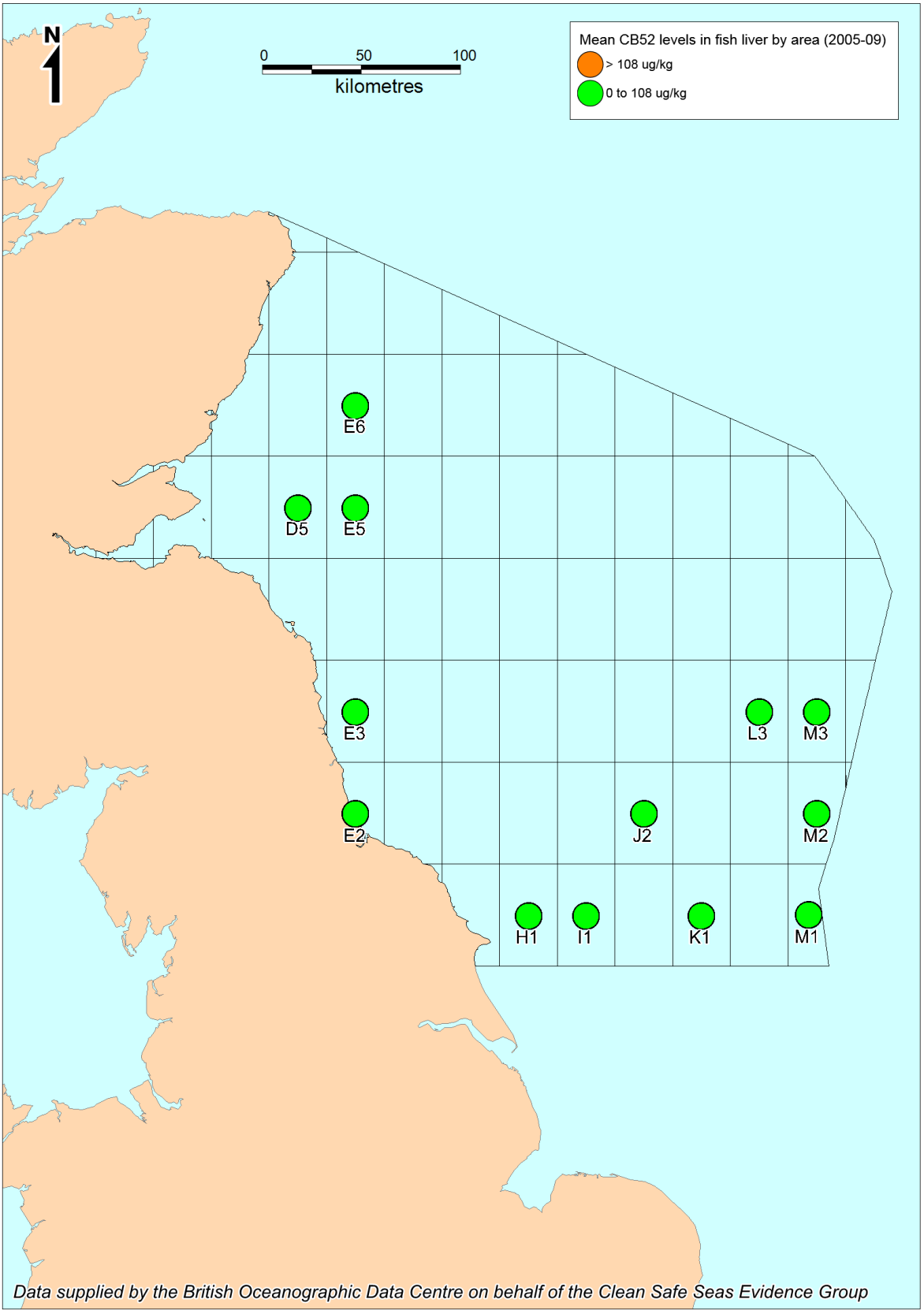

Figure 0:106: Map of mean 2,2',5,5'-tetrachlorobiphenyl concentrations by area (2005-09)

Table 0.84: Summary of 2,2',5,5'-tetrachlorobiphenyl concentrations by area (2005-09)

Box	Year		2,2',5,5'-tetrachlorobiphenyl sample results (ug/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
D5	2005	2007	7	23.1	4.3	54.5	0%
E2	2005	2009	26	3.5	0.8	6.6	0%
E3	2005	2009	15	4.0	1.1	7.8	0%
E5	2008	2009	10	20.8	1.0	44.6	0%
E6	2006	2006	5	12.2	6.0	17.3	0%
H1	2005	2009	10	5.3	1.8	15.4	0%
I1	2008	2008	5	15.2	10.1	20.5	0%
J2	2005	2009	15	67.9	5.1	339.0	20%
K1	2005	2008	10	7.2	2.0	37.0	0%
L3	2005	2009	15	6.2	2.8	15.8	0%
M1	2005	2009	10	4.3	2.2	6.0	0%
M2	2008	2008	5	7.3	5.5	10.2	0%
M3	2005	2009	15	12.5	2.2	61.2	0%

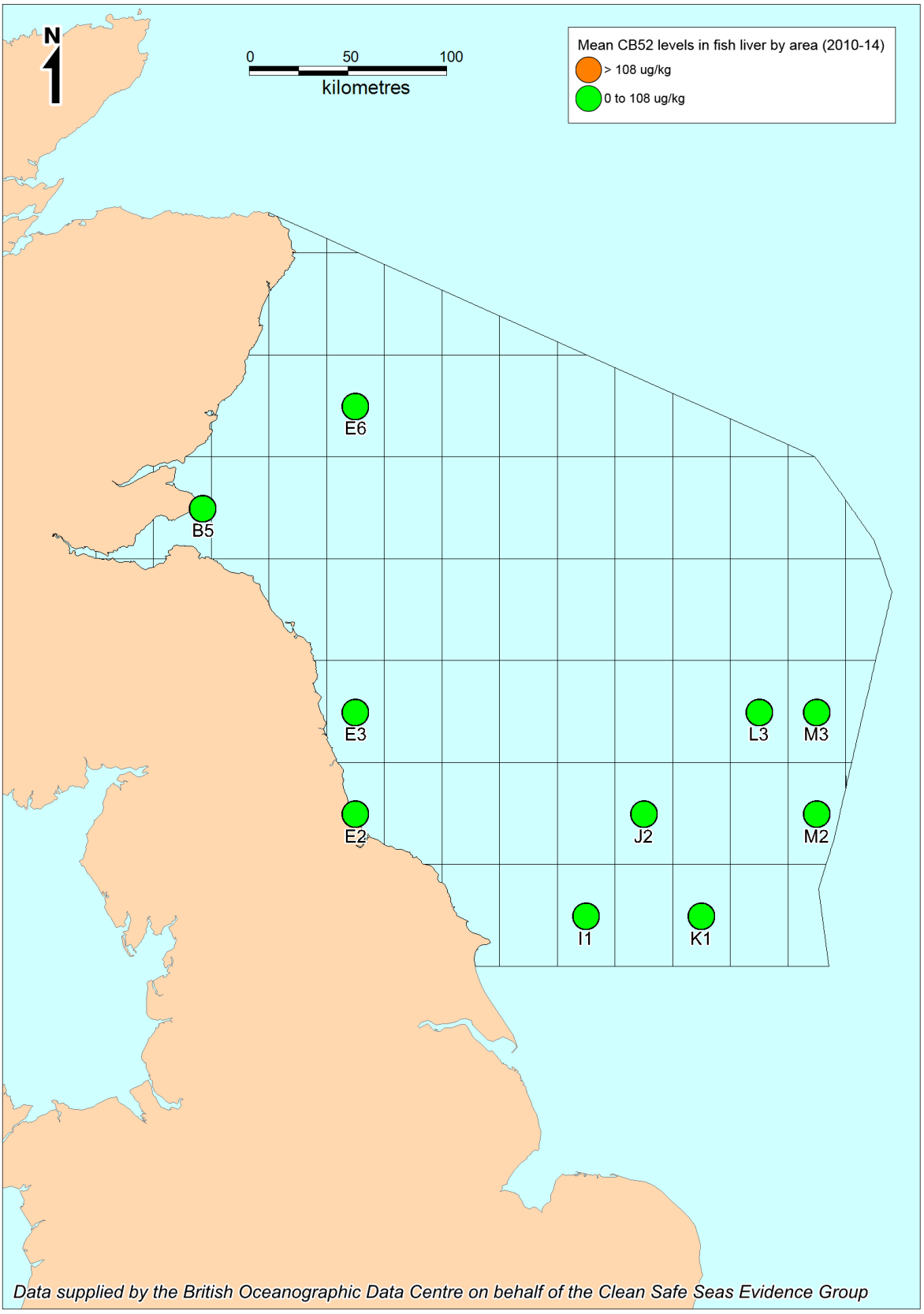

Figure 0:107: Map of mean 2,2',5,5'-tetrachlorobiphenylconcentrations by area (2010-14)

Table 0.112: Summary of 2,2',5,5'-tetrachlorobiphenylconcentrations by area (2010-14)

Box	Year		2,2',5,5'-tetrachlorobiphenyl sample results (µg/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
B5	2013	2014	8	5.2	0.8	22.0	0%
E2	2010	2011	10	3.8	2.4	7.2	0%
E3	2011	2011	10	1.2	1.0	2.6	0%
E6	2010	2014	25	6.3	0.3	44.2	0%
I1	2011	2011	5	14.0	5.2	17.9	0%
J2	2010	2011	10	10.2	6.1	13.8	0%
K1	2010	2011	10	3.4	1.0	9.2	0%
L3	2010	2011	10	8.5	4.4	13.3	0%
M2	2010	2011	10	6.7	4.8	9.2	0%
M3	2010	2011	10	9.5	3.2	13.3	0%

Summary CB52 biota data

The CSEMP data analysed revealed that all sectorial boxes were below the EAC for CB 52 (2005-09, Figure 1.106 and Table 1.111 and 2010-14, Figure 1.107 and Table 1.12). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

CB101

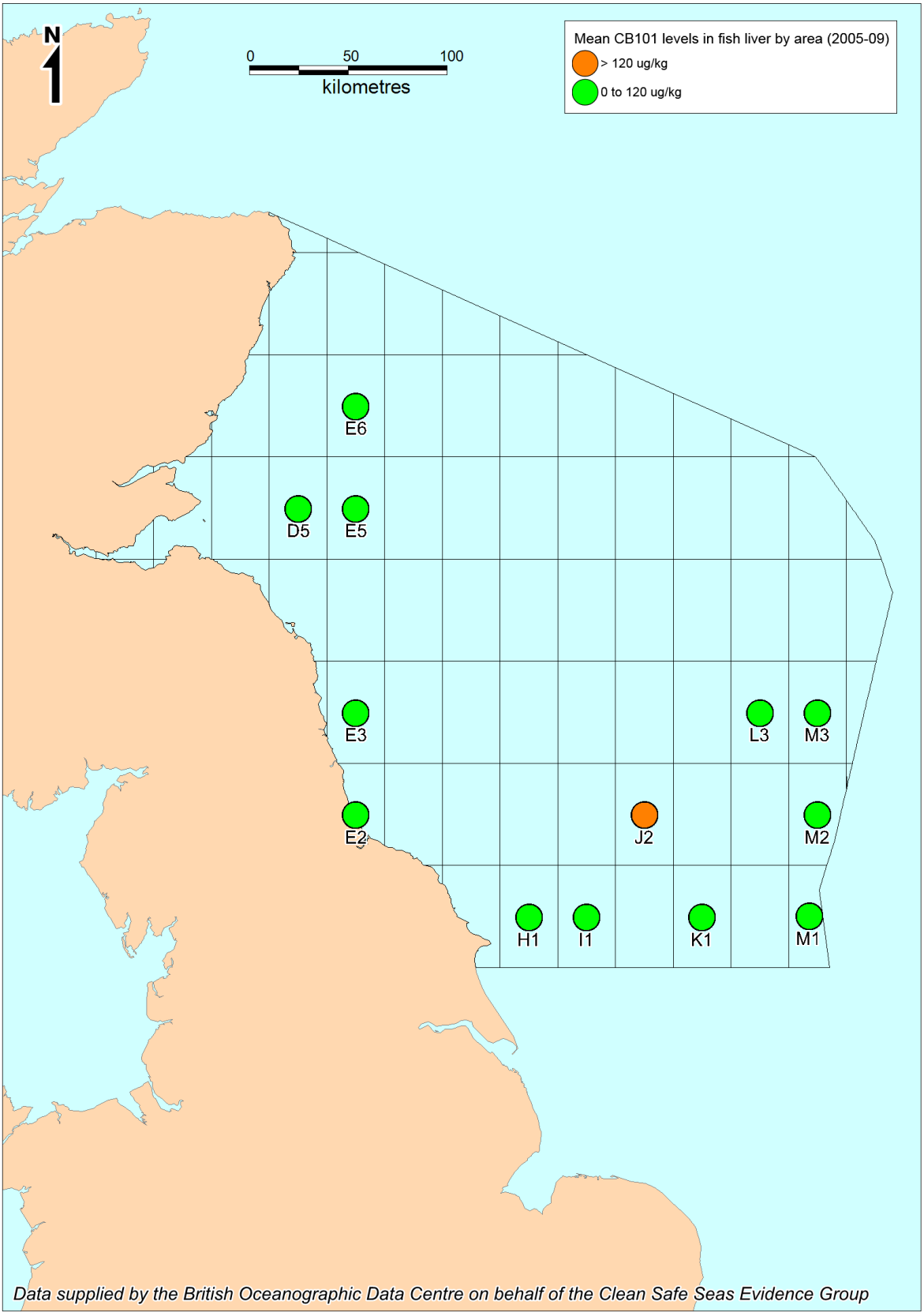

Figure 0:108: Map of mean 2,2',4,5,5'-pentachlorobiphenyl concentrations by area (2005-09)

Table 0.85: Summary of 2,2',4,5,5'-pentachlorobiphenyl concentrations by area (2005-09)

Box	Year		2,2',4,5,5'-pentachlorobiphenyl sample results (ug/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
D5	2005	2007	7	19.4	4.3	42.1	0%
E2	2005	2009	26	10.1	2.7	79.7	0%
E3	2005	2009	15	7.6	3.0	26.3	0%
E5	2008	2009	10	40.4	11.9	86.9	0%
E6	2006	2006	5	13.9	8.4	22.2	0%
H1	2005	2009	10	26.9	4.1	70.3	0%
I1	2008	2008	5	51.3	43.9	61.5	0%
J2	2005	2009	15	163.9	5.1	1219.2	20%
K1	2005	2008	10	28.3	2.0	92.4	0%
L3	2005	2009	14	16.2	5.0	39.4	0%
M1	2005	2009	10	9.9	5.0	17.6	0%
M2	2008	2008	5	29.3	16.5	50.9	0%
M3	2005	2009	15	26.5	5.1	81.5	0%

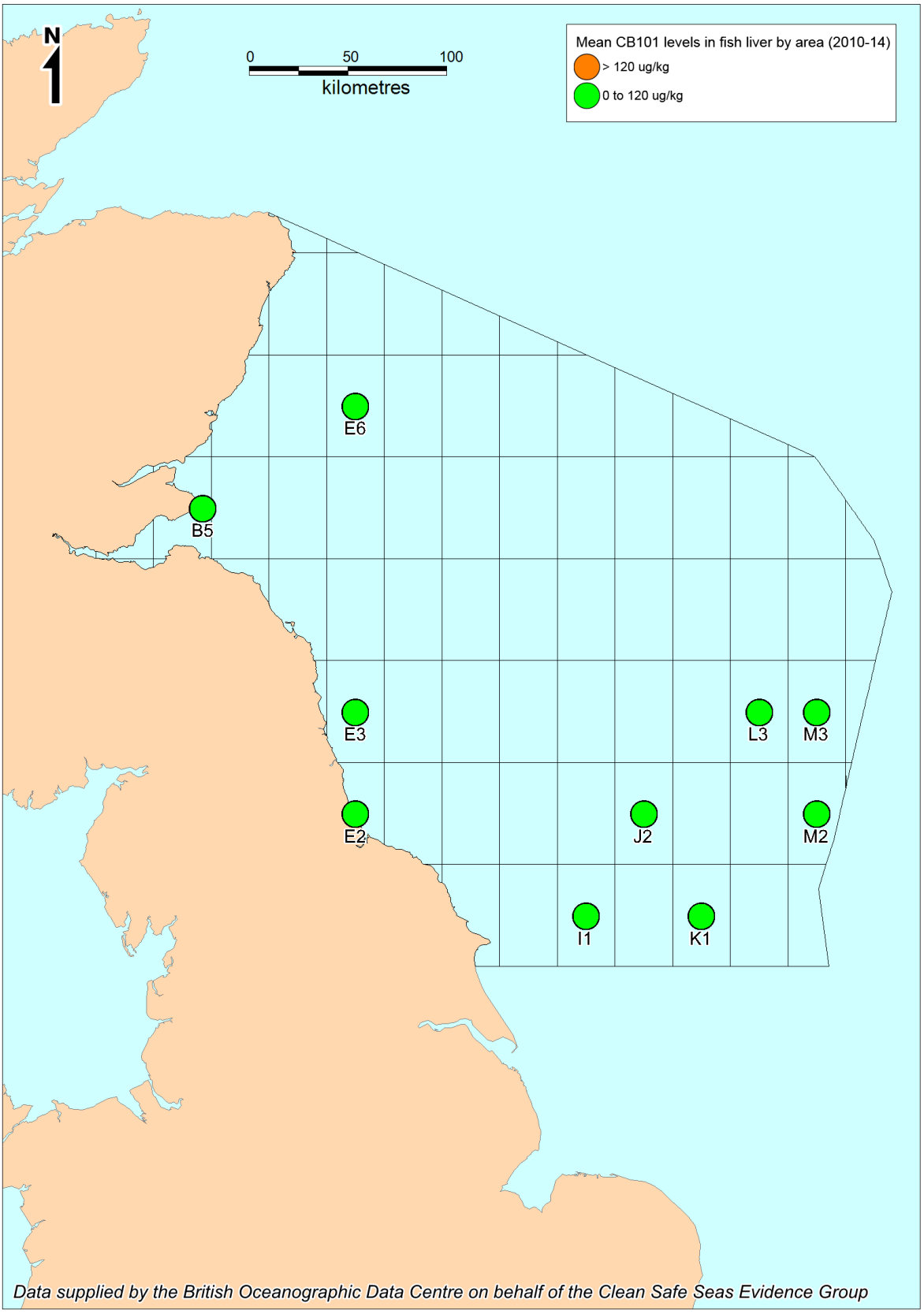

Figure 0:109: Map of mean 2,2',4,5,5'-pentachlorobiphenyl concentrations by area (2010-14)

Table 0.86: Summary of 2,2',4,5,5'-pentachlorobiphenyl concentrations by area (2010-14)

Box	Year		2,2',4,5,5'-pentachlorobiphenyl sample results (µg/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
B5	2013	2014	8	22.1	8.6	63.8	0%
E2	2010	2011	10	14.8	1.3	35.9	0%
E3	2011	2011	10	7.3	5.3	10.2	0%
E6	2010	2014	25	14.4	0.5	73.2	0%
I1	2011	2011	5	46.4	18.8	57.6	0%
J2	2010	2011	10	34.1	21.9	43.1	0%
K1	2010	2011	10	15.3	6.6	36.7	0%
L3	2010	2011	10	24.3	14.5	41.1	0%
M2	2010	2011	10	19.3	13.4	28.3	0%
M3	2010	2011	10	31.8	21.9	48.3	0%

Summary CB101 biota data

The CSEMP data analysed revealed that all sectorial boxes bar one (J2, 2005-2009) were below the EAC for CB101 (2005-09, Figure 1.108 and Table 1.113 and 2010-14, Figure 1.109 and Table 1.14). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

CB118

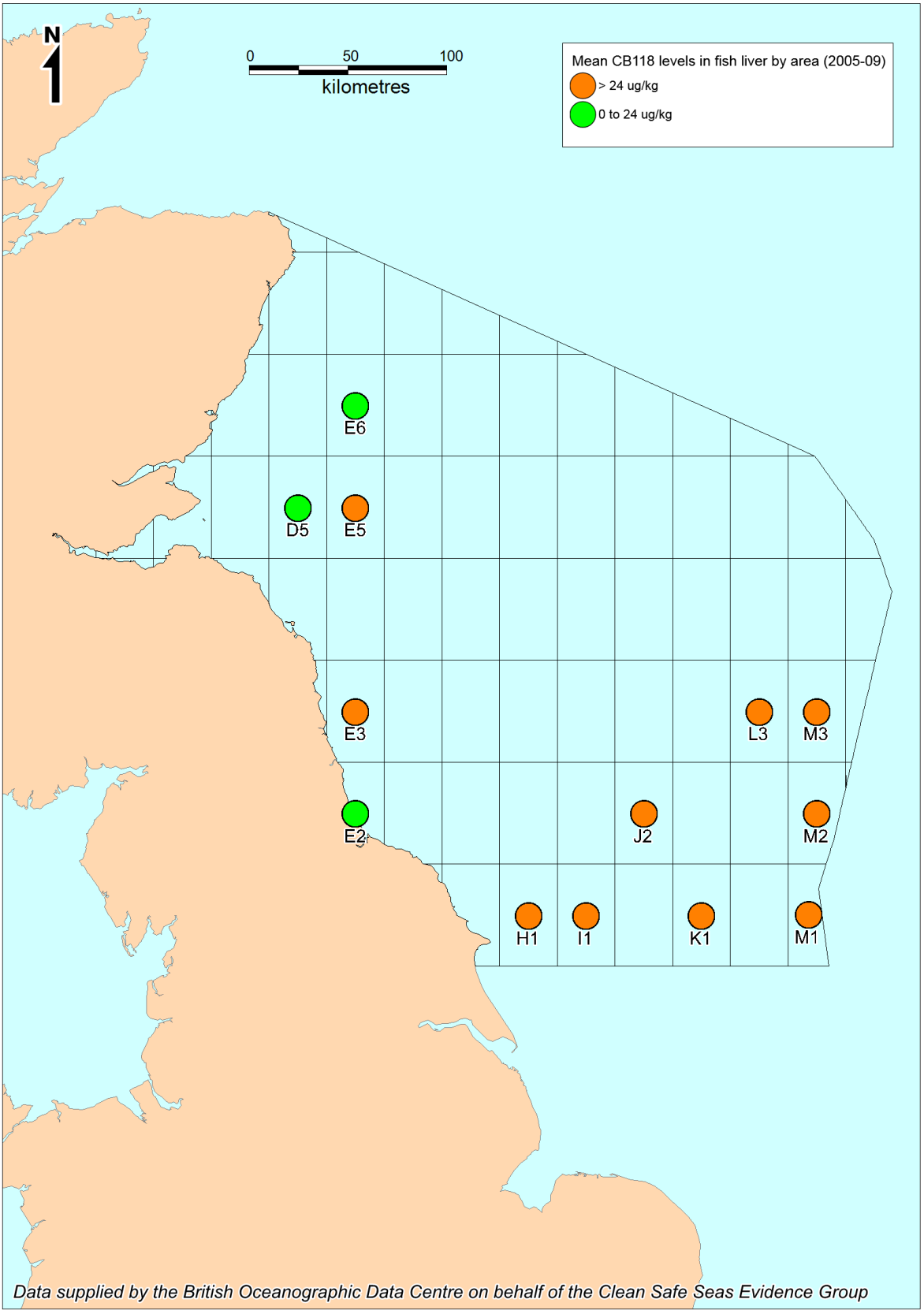

Figure 0:110: Map of mean 2,3',4,4',5-pentachlorobiphenyl concentrations by area (2005-09)

Table 0.87: Summary of 2,3',4,4',5-pentachlorobiphenyl concentrations by area (2005-09)

Box	Year		2,3',4,4',5-pentachlorobiphenyl sample results (ug/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
D5	2005	2007	7	19.2	4.6	36.3	29%
E2	2005	2009	26	17.8	2.7	66.4	23%
E3	2005	2009	15	29.7	16.5	40.6	67%
E5	2008	2009	10	55.2	9.3	139.1	80%
E6	2006	2006	5	15.3	10.9	20.7	0%
H1	2005	2009	10	43.1	3.7	86.6	90%
I1	2008	2008	5	76.8	67.0	92.2	100%
J2	2005	2009	15	167.0	16.3	952.6	93%
K1	2005	2008	10	52.1	27.7	103.1	100%
L3	2005	2009	14	38.1	12.5	78.9	71%
M1	2005	2009	10	39.2	22.6	73.7	90%
M2	2008	2008	5	39.2	22.0	61.1	80%
M3	2005	2009	15	44.9	23.0	142.7	93%

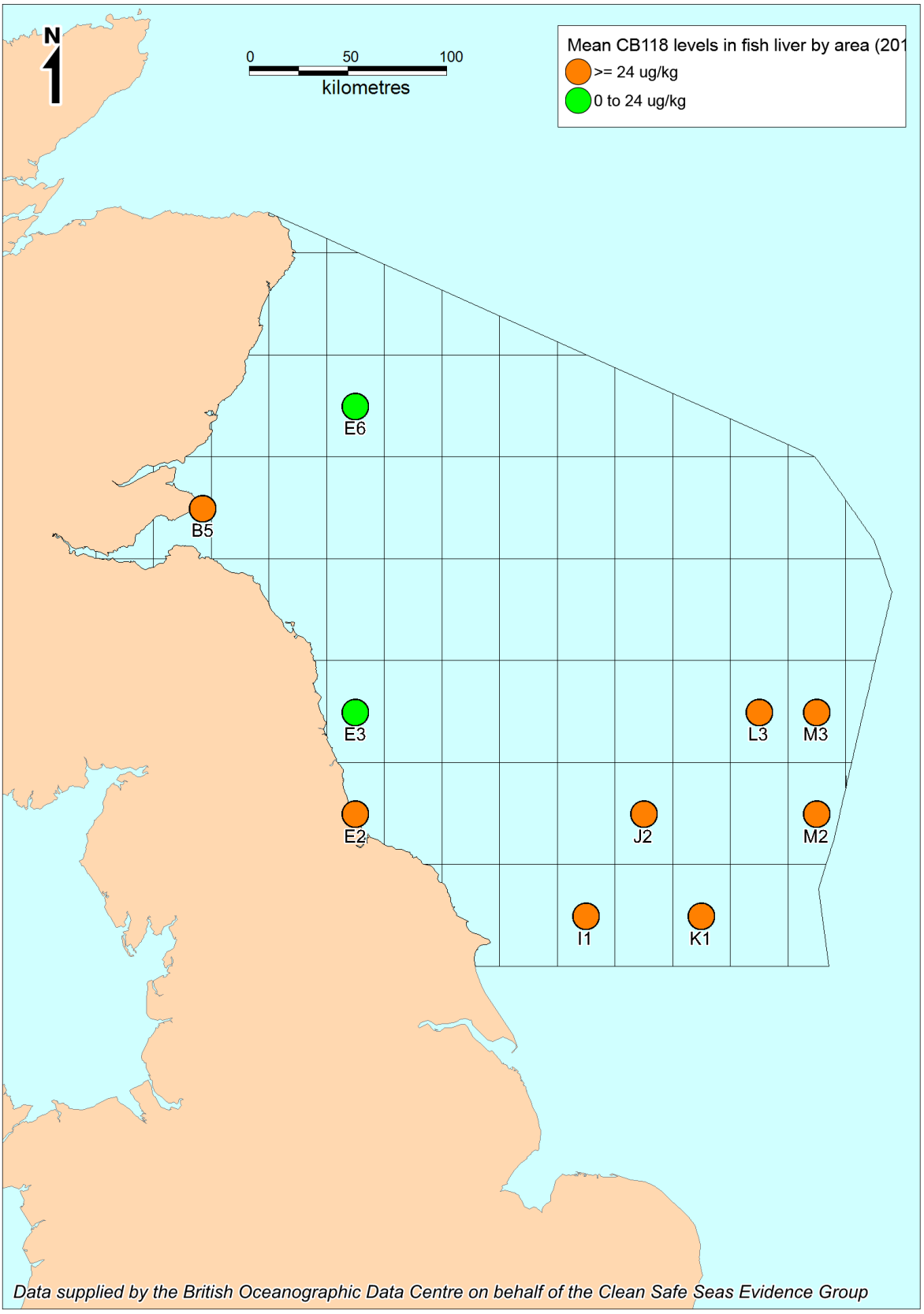

Figure 0:111: Map of mean 2,3',4,4',5-pentachlorobiphenyl concentrations by area (2010-14)

Table 0.88: Summary of 2,3',4,4',5-pentachlorobiphenyl concentrations by area (2010-14)

Box	Year		2,3',4,4',5-pentachlorobiphenyl sample results (µg/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
B5	2013	2014	8	43.6	25.9	88.2	100%
E2	2010	2011	10	32.1	20.4	59.9	90%
E3	2011	2011	10	21.9	15.9	28.2	30%
E6	2010	2014	25	18.5	0.7	72.3	28%
I1	2011	2011	5	72.1	32.4	88.7	100%
J2	2010	2011	10	42.1	24.2	55.4	100%
K1	2010	2011	10	32.3	20.3	77.9	80%
L3	2010	2011	10	32.0	17.5	56.8	80%
M2	2010	2011	10	26.6	17.2	38.9	60%
M3	2010	2011	10	48.1	24.2	89.0	100%

Summary CB118 biota data

The CSEMP data analysed revealed that 10/13 and 8/10 sectorial boxes exceeded the EACpassive for CB118 between 2005-2009 and 2010-2014 (2005-09, Figure 1.110 and Table 1.115 and 2010-14, Figure 1.111, and Table 1.116). The EACpassive is lowest for CB118 (24 µg/kg lw), a mono-*ortho* CB and the most toxic of the ICES7 CBs. Therefore, it is not surprising that a high proportion of sites gave concentrations for CB118 above the EACpassive. The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). No significant trends were detected.

CB138

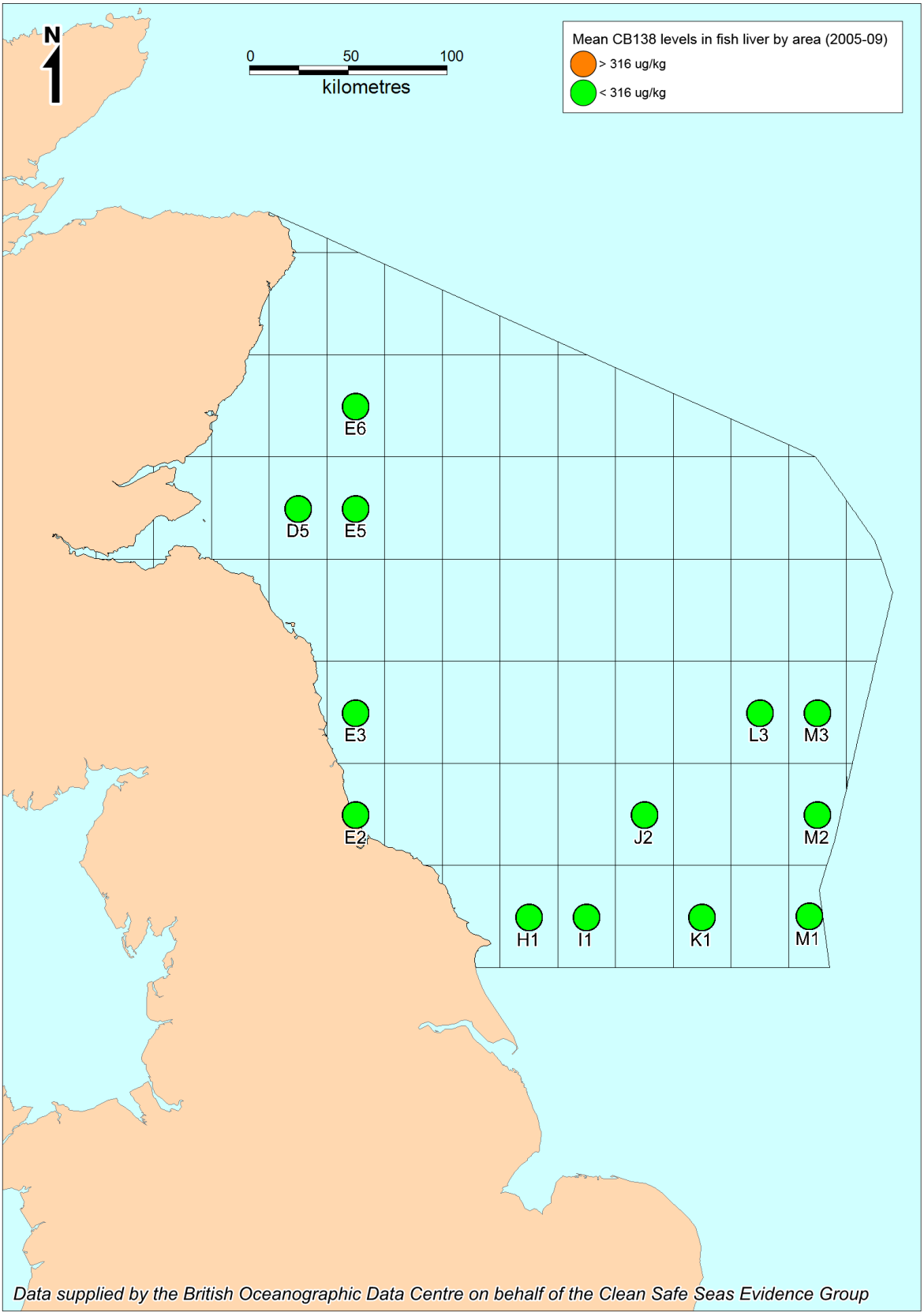

Figure 0:112: Map of mean 2,2',3,4,4',5'-hexachlorobiphenyl concentrations by area (2005-09)

Table 0.89: Summary of 2,2',3,4,4',5'-hexachlorobiphenyl concentrations by area (2005-09)

Box	Year		2,2',3,4,4',5'-hexachlorobiphenyl sample results (ug/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
D5	2005	2007	7	33.4	12.2	83.3	0%
E2	2005	2009	21	53.3	5.4	239.1	0%
E3	2005	2009	15	66.8	33.0	92.5	0%
E5	2008	2009	10	121.8	31.7	306.4	0%
E6	2006	2006	5	24.9	18.2	37.5	0%
H1	2005	2009	10	103.9	9.0	221.4	0%
I1	2008	2008	5	201.7	151.5	239.9	0%
J2	2005	2009	15	195.6	56.3	831.8	20%
K1	2005	2008	10	113.1	47.5	261.1	0%
L3	2005	2009	15	82.9	28.2	191.8	0%
M1	2005	2009	10	83.3	43.9	187.0	0%
M2	2008	2008	5	84.5	43.9	152.7	0%
M3	2005	2009	15	87.0	39.1	285.3	0%

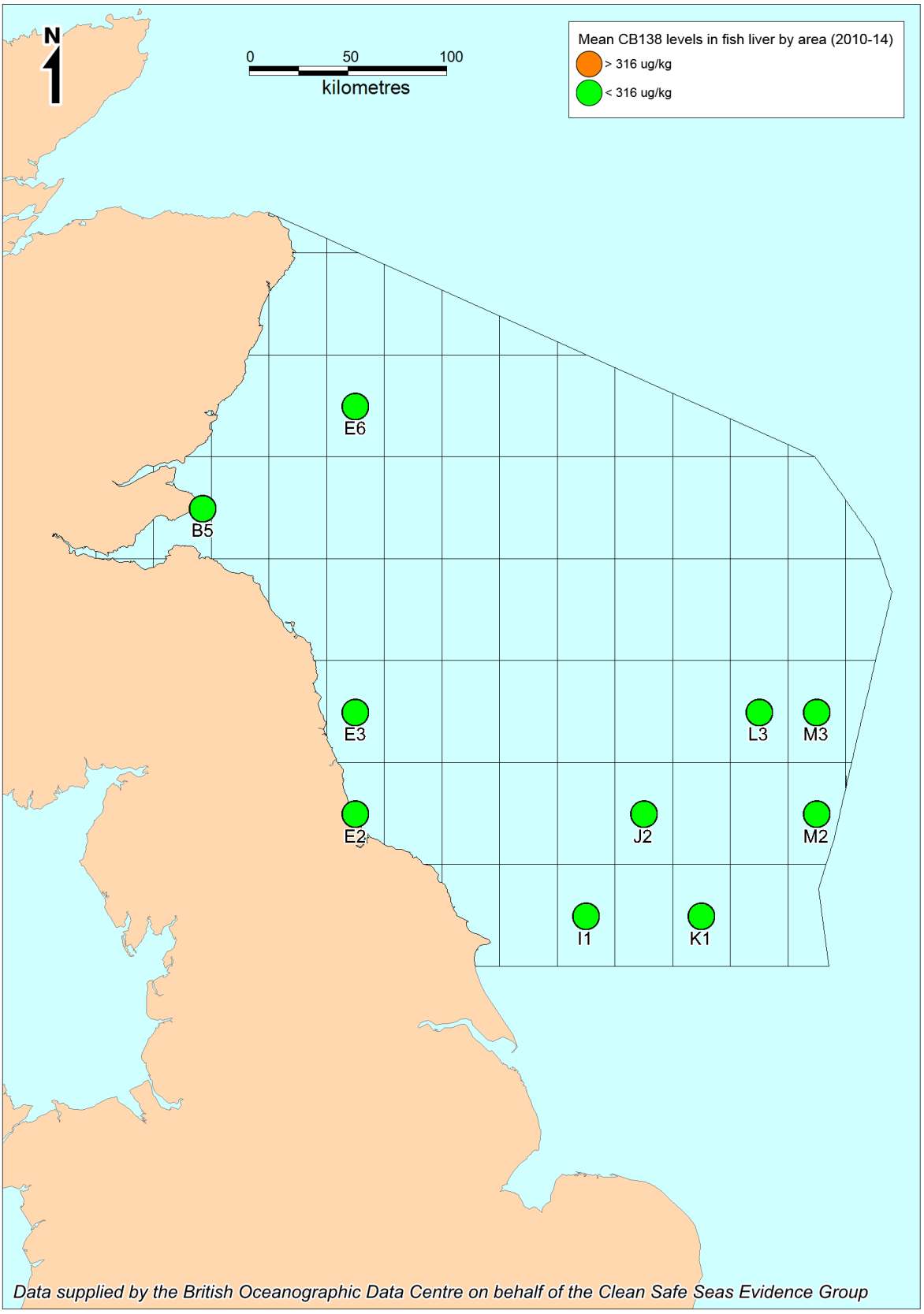

Figure 0:113: Map of mean 2,2',3,4,4',5'-hexachlorobiphenyl concentrations by area (2010-14)

Table 0.90: Summary of 2,2',3,4,4',5'-hexachlorobiphenyl concentrations by area (2010-14)

Box	Year		2,2',3,4,4',5'-hexachlorobiphenyl sample results (µg/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
B5	2013	2014	8	92.9	49.4	202.2	0%
E2	2010	2011	10	60.3	36.3	143.7	0%
E3	2011	2011	10	43.2	29.1	56.3	0%
E6	2010	2014	25	36.0	1.9	116.9	0%
I1	2011	2011	5	174.2	73.8	214.3	0%
J2	2010	2011	10	95.7	53.0	169.2	0%
K1	2010	2011	10	66.0	38.5	148.9	0%
L3	2010	2011	10	69.9	30.5	125.6	0%
M2	2010	2011	10	48.2	27.3	80.1	0%
M3	2010	2011	10	102.0	36.9	179.9	0%

Summary CB138 biota data

The CSEMP data analysed revealed that all sectorial boxes were below the EAC for CB138 (2005-09, Figure 1.112 and Table 1.117 and 2010-14, Figure 1.113 and Table 1.118). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). Significant downward trends were detected in Tees Bay, Amble (both N.E English coast) and off the Scottish East coast (Montrose Bank).

CB153

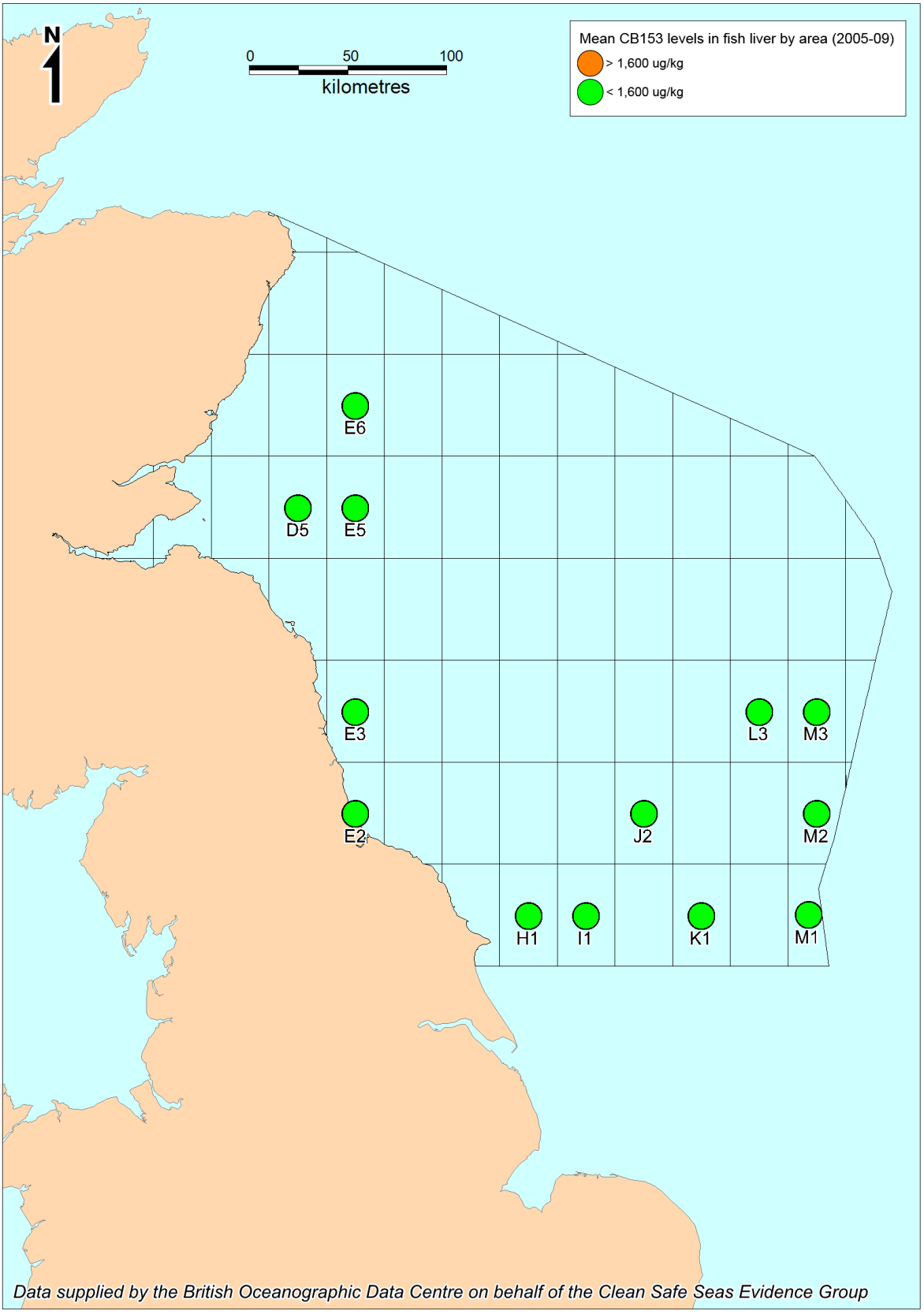

Figure 0:114: Map of mean 2,2',4,4',5,5'-hexachlorobiphenyl concentrations by area (2005-09)

Table 0.91: Summary of 2,2',4,4',5,5'-hexachlorobiphenyl concentrations by area (2005-09)

Box	Year		2,2',4,4',5,5'-hexachlorobiphenyl sample results (ug/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
D5	2005	2007	7	45.6	16.0	116.2	0%
E2	2005	2009	26	76.0	2.7	398.5	0%
E3	2005	2009	15	98.7	52.1	150.9	0%
E5	2008	2009	10	173.9	42.4	445.8	0%
E6	2006	2006	5	30.7	19.6	45.5	0%
H1	2005	2009	10	151.4	12.7	336.9	0%
I1	2008	2008	5	300.7	202.0	412.9	0%
J2	2005	2009	15	508.0	29.0	2617.0	13%
K1	2005	2008	10	174.5	67.4	384.8	0%
L3	2005	2009	15	102.3	34.5	244.4	0%
M1	2005	2009	10	98.1	53.9	274.9	0%
M2	2008	2008	5	106.5	54.9	183.3	0%
M3	2005	2009	15	96.4	48.9	265.0	0%

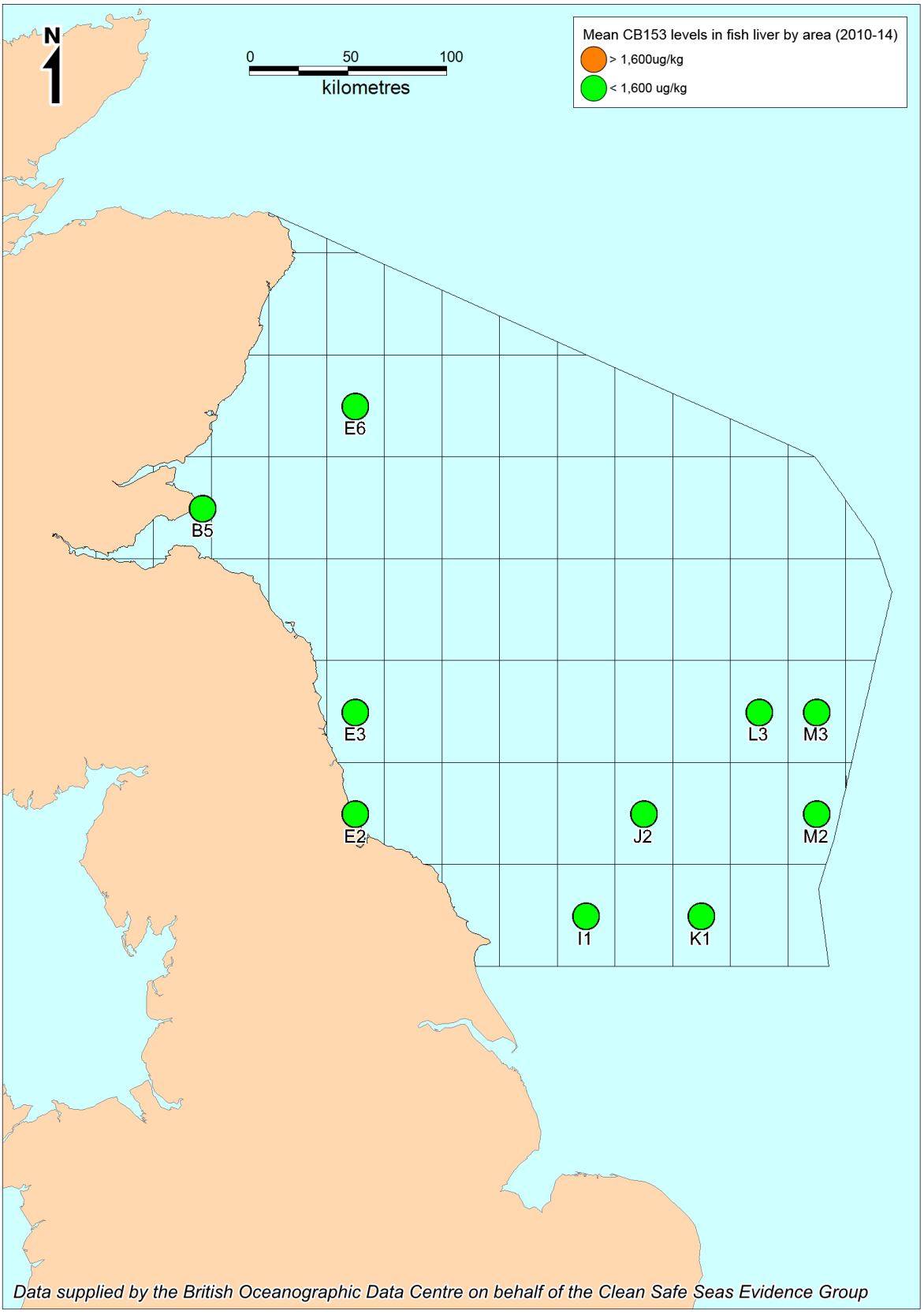

Figure 0:115: Map of mean 2,2',4,4',5,5'-hexachlorobiphenyl concentrations by area (2010-14)

Table 0.92: Summary of 2,2',4,4',5,5'-hexachlorobiphenyl concentrations by area (2010-14)

Box	Year		2,2',4,4',5,5'-hexachlorobiphenyl sample results (µg/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
B5	2013	2014	8	169.2	91.9	392.1	0%
E2	2010	2011	10	104.9	64.6	227.6	0%
E3	2011	2011	10	69.5	45.5	96.5	0%
E6	2010	2014	25	65.1	3.0	230.1	0%
I1	2011	2011	5	259.3	113.0	317.7	0%
J2	2010	2011	10	124.3	63.3	261.5	0%
K1	2010	2011	10	106.5	67.6	240.5	0%
L3	2010	2011	10	89.9	35.1	191.8	0%
M2	2010	2011	10	63.1	32.4	108.4	0%
M3	2010	2011	10	136.4	41.5	227.2	0%

Summary CB153 biota data

The CSEMP data analysed revealed that all sectorial boxes were below the EAC for CB153 (2005-09, Figure 1.114 and Table 1.119 and 2010-14, Figure 1.115 and Table 1.120). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). Significant Downward trends were detected in Tees Bay, Amble (both N.E English coast) and off the Scottish East coast (Montrose Bank).

CB180

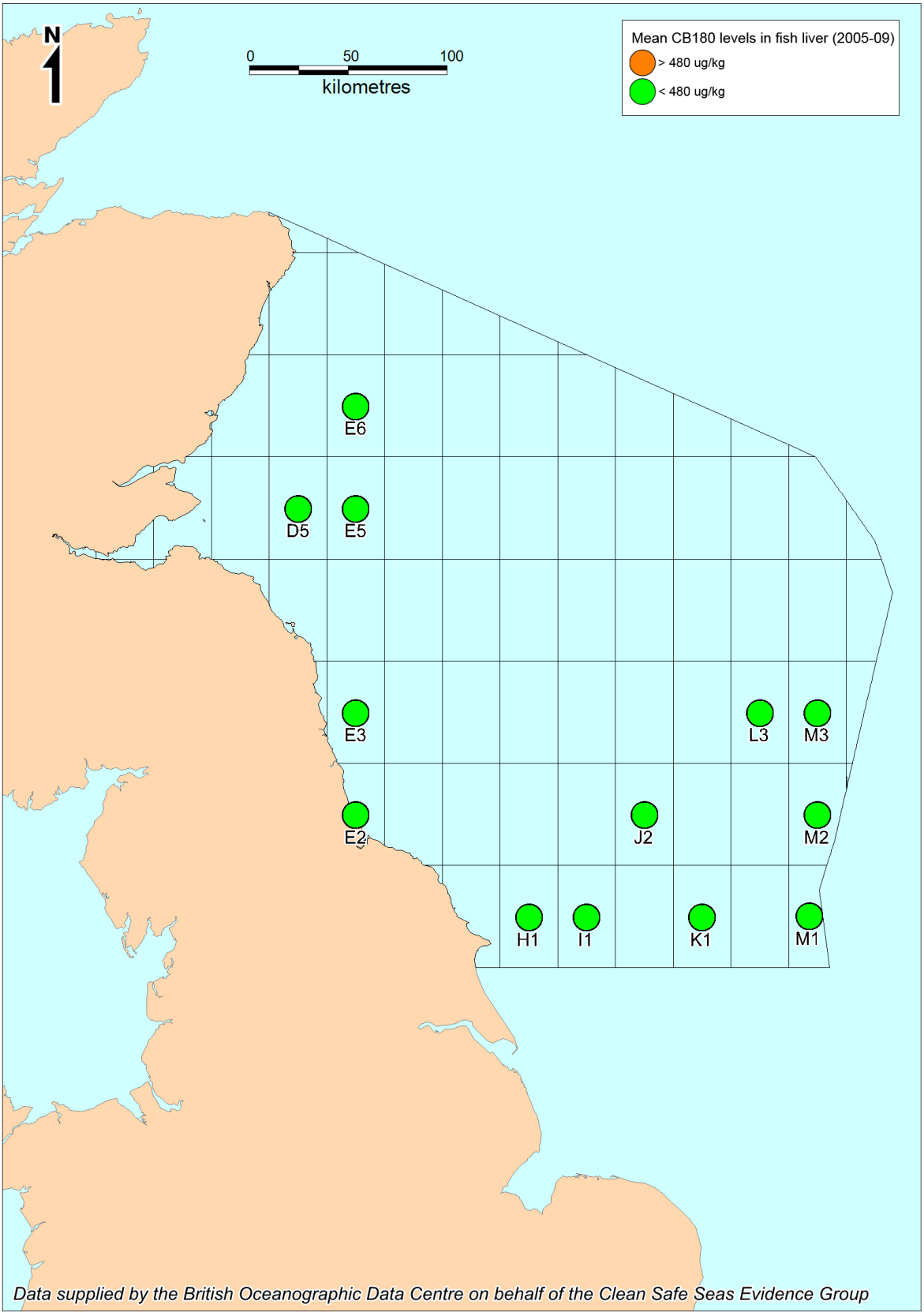

Figure 0:116: Map of mean 2,2',3,4,4',5,5'-heptachlorobiphenyl concentrations by area (2005-09)

Table 0.93: Summary of 2,2',3,4,4',5,5'-heptachlorobiphenyl concentrations by area (2005-09)

Box	Year		2,2',3,4,4',5,5'-heptachlorobiphenyl sample results (ug/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
D5	2005	2007	7	11.6	2.9	27.6	0%
E2	2005	2009	26	34.5	2.7	172.7	0%
E3	2005	2009	15	29.5	15.8	44.5	0%
E5	2008	2009	10	42.2	9.0	121.1	0%
E6	2006	2006	5	8.0	4.6	14.5	0%
H1	2005	2009	10	36.9	3.0	78.0	0%
I1	2008	2008	5	81.4	50.5	111.6	0%
J2	2005	2009	15	432.0	11.0	3384.0	13%
K1	2005	2008	10	41.9	25.5	75.6	0%
L3	2005	2009	15	21.5	5.2	55.2	0%
M1	2005	2009	10	22.4	5.1	41.8	0%
M2	2008	2008	5	13.5	2.8	30.6	0%
M3	2005	2009	15	13.3	5.1	40.8	0%

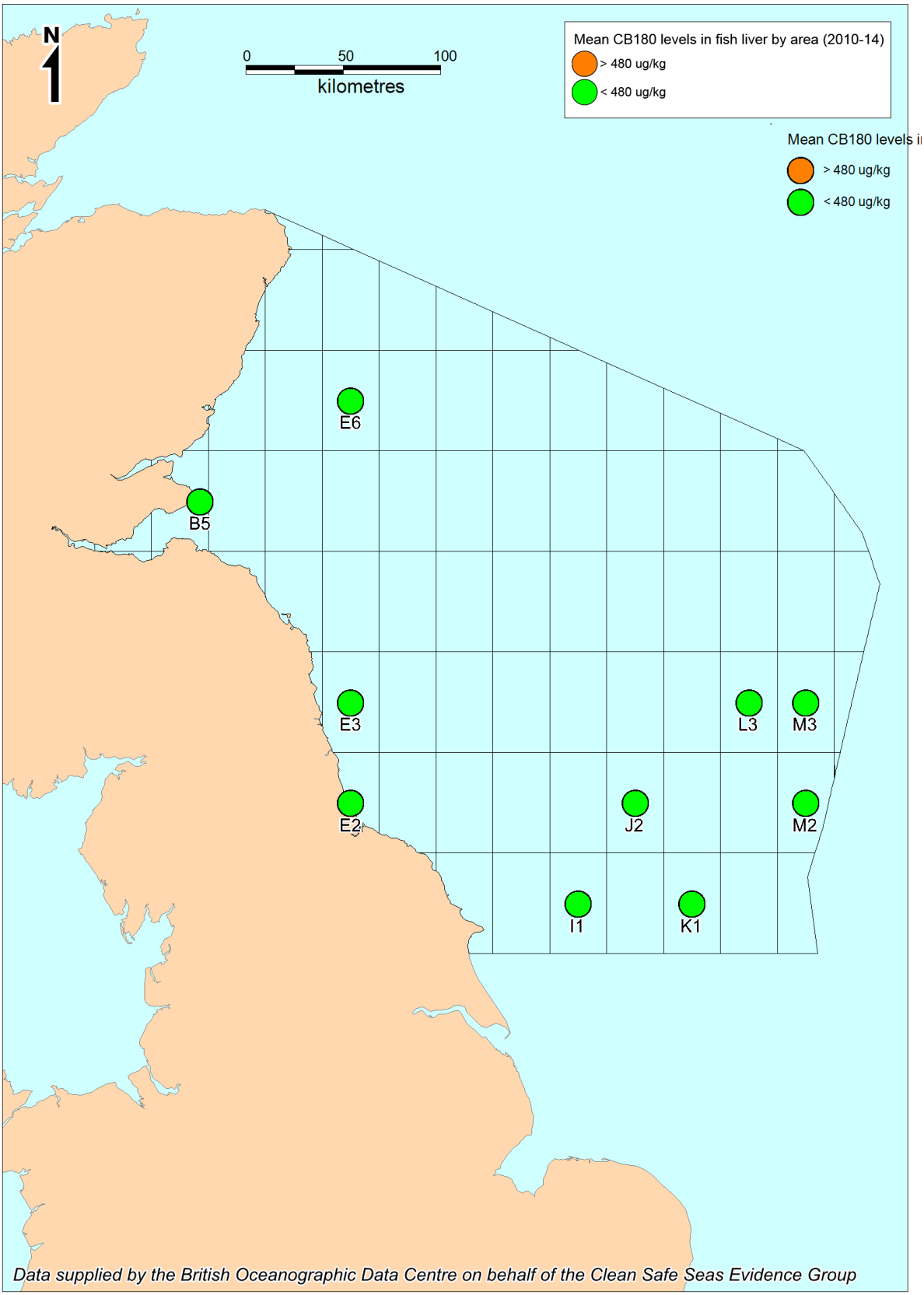

Figure 0:117: Map of mean 2,2',3,4,4',5,5'-heptachlorobiphenyl concentrations by area (2010-14)

Table 0.94: Summary of 2,2',3,4,4',5,5'-heptachlorobiphenyl concentrations by area (2010-14)

Box	Year		2,2',3,4,4',5,5'-heptachlorobiphenyl sample results (µg/kg)				
	From	To	No.	Mean	Minimum	Maximum	% >= EAC
B5	2013	2014	8	80.4	40.7	202.0	0%
E2	2010	2011	10	42.4	25.4	76.7	0%
E3	2011	2011	10	18.5	12.7	24.1	0%
E6	2010	2014	25	14.9	0.9	73.2	0%
I1	2011	2011	5	50.9	24.1	73.9	0%
J2	2010	2011	10	17.1	5.4	44.6	0%
K1	2010	2011	10	22.8	13.9	49.2	0%
L3	2010	2011	10	11.6	4.3	29.1	0%
M2	2010	2011	10	8.3	3.2	13.8	0%
M3	2010	2011	10	19.9	6.8	43.6	0%

Summary CB180 biota data

The CSEMP data analysed revealed that all sectorial boxes were below the EAC for CB180 (2005-09, Figure 1.116 and Table 1.121 and 2010-14, Figure 1.117 and Table 1.122). The MERMAN data assessment tool was used to investigate the presence of significant upwards or downwards trends at those sites where a sufficient temporal dataset was available (http://www.bodc.ac.uk/projects/uk/merman/). Significant downward trends were detected in Tees Bay and Amble (both N.E English coast).

Appendix 2 Report Data Sources

2.1 Data references for report

Table 2.1 Summary of data sources and links for oil and gas and wind energy for this report for North Sea High Seismic area defined for this report as southern boundary - 54°N extending from the coast to the UK median line and northern boundary - formed of a line from Fraserburgh to the intersect with the median line at 56° 30'N.

Activity	Data description	Data Source and link
Oil and Gas	There is data from 61 surveys within the area and 875 survey stations. However, there is only data from 8 surveys and 69 survey stations from 2005 to 2015, this increases to 13 surveys and 151 survey stations from 2000 to 2015. Data retrieved include installation name, location, Depth, sediment characteristics, sediment concentration data for six metals and seven groupings of data related to PAHs	UKbenthos database of Offshore environmental impact surveys that have been carried out by oil and gas operators in the North Sea since 1975. The data was originally sourced from http://oilandgasuk.co.uk/knowledgecentre/uk_benthos_database.cfm but this site became inactive from Ocotober 2016 and data are now available from: http://www.bgs.ac.uk/services/NGDC/citedData/catalogue/f9c724ab-006b-4256-8553-928f23736ab2.html A number of shapefiles and KML files can be found on the gov.uk website – https://www.ogauthority.co.uk/data-centre/interactive-maps-and-tools/
Wind Farms	Buchan Deep – Section 3.5 Environmental survey report Hywind Offshore Windfarm August to September 2013 Inch Cape Volume 2B Appendix 12D, January 2013 Neart Na Gaoithe Benthic ecology characterisation Report Chapter 14, 2010 Blyth Offshore Demonstration Project, ES Volume 3 Appendix 6.4 The physical Environment Appendix D Dogger Bank Teeside A and B Environmental Statement Chapter 10 Water and Sediment Quality	https://www.statoil.com/content/dam/statoil/documents/impact-assessment/Hywind/Statoil-Environmental%20survey%20report.pdf https://www.statoil.com/content/dam/statoil/documents/impact-assessment/Hywind/Statoil-Environmental%20Statement%20April%202015.pdf http:// www.inchcapewind.com%2Ffiles%2FEnvironmental_Statement_Structure%2FChapter12%2FAppendix12B.pdf&usg=AFQjCNHwwRuIMNzX3j0WAknQyqDoW0bW7A http://www.neartnagaoithe.com/environmental-statement1.asp http://edf-er.com/OurProjects/Proposed/BlythOffshore/ProjectDocuments.aspx http://www.forewind.co.uk/uploads/files/TeessideAB/Application_Documents/6.Environmental_Statement/6.10_ES_Chapter_10_Marine_Water_and_Sediment_Quality.pdf

Table 2.2 Summary of data sources and links for dredging, nuclear industry and related and wider area monitoring for this report for North Sea High Seismic area defined for this report as southern boundary - 54°N extending from the coast to the UK median line and northern boundary - formed of a line from Fraserburgh to the intersect with the median line at 56° 30'N.

Activity	Data description	Data Source and link
Dredging	East coast Scotland dredge disposal sites active over the period 2005 to the present (Covering East Scotland coast and Forth sites). The sediment contaminants include metals, PAHs, and Polychlorinated biphenyls A request Cefas Chemistry Team for dredge disposal data from 2005 to 2015 covering East coast disposal sites for England for all sediment contaminants to include, metals, PCBs and PAHs	Data Request from Marine Scotland MS.MarineLicensing@gov.scot https://www.gov.uk/government/organisations/centre-for-environment-fisheries-and-aquaculture-science
Nuclear industry and related	Data for sites of relevance to the survey area sourced from RIFE20	https://www.gov.uk/government/publications/radioactivity-in-food-and-the-environment-2014-rife-20
Wider Area Monitoring	Data request made to BODC for extraction of datasets covering period 2005 to 2015 based on a shapefile for the North Sea ~~high~~ HIgh Seismic Area and covering all contaminants in sediment, water and biota	merman@bodc.ac.uk]

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