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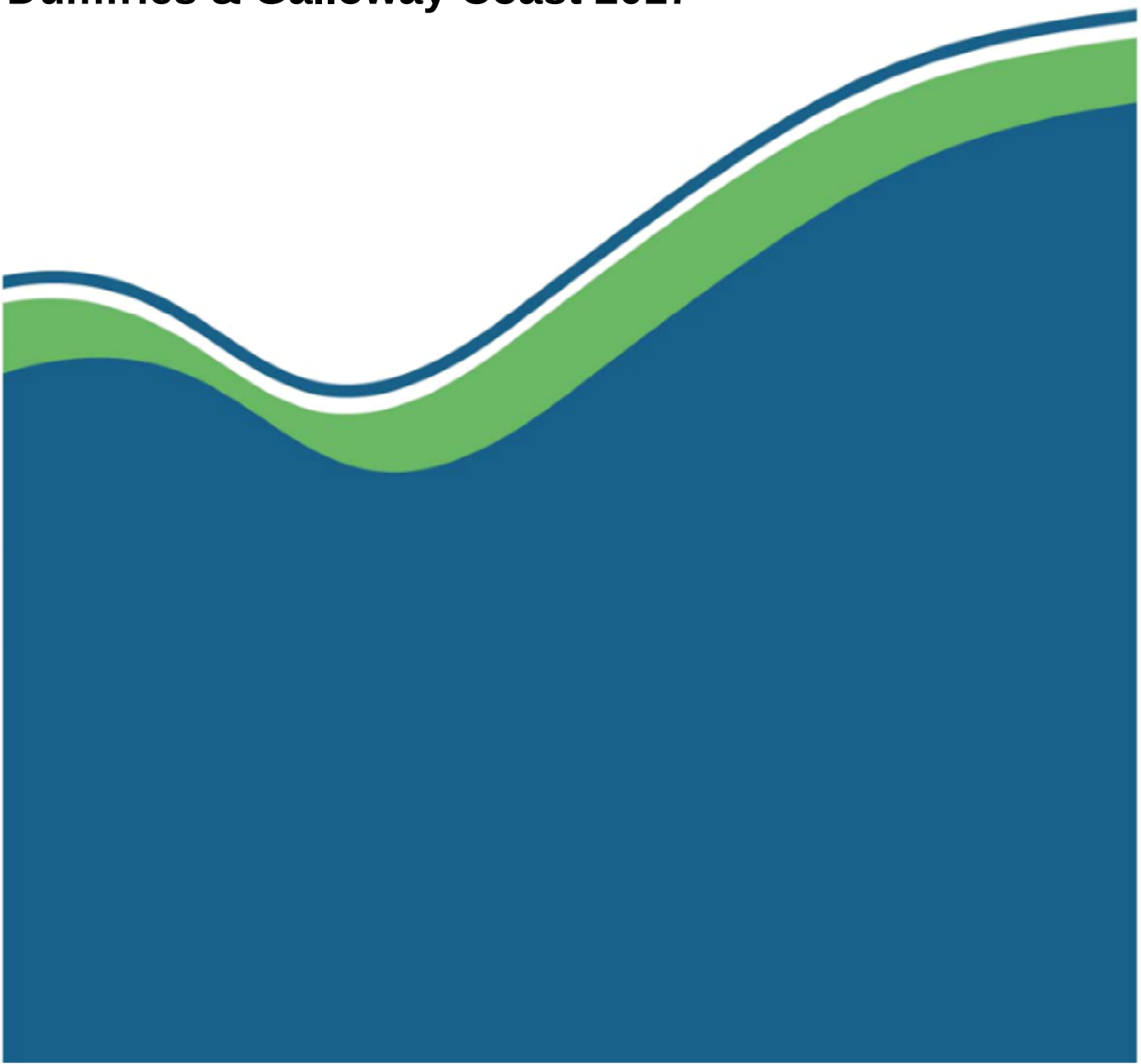
Scottish Environment Protection Agency
Buidheann Dion Àrainneachd na h-Alba

Radiological Habits Survey:

Dumfries & Galloway Coast 2017



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Dumfries & Galloway Coast 2017

Authors and Contributors:

P. Smith, I. Dale, A. Tyler, D. Copplestone, A. Varley, S. Bradley, P Bartie, M. Clarke and M. Blake

External Reviewer:

A. Elliot

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List of Abbreviations and Definitions

AGRs	Advanced Gas-Cooled Reactors
BSS	Basic Safety Standards
CEFAS	Centre for Environment, Fisheries and Aquaculture
DCC	Dose Conversion Coefficient
DORIS	Dispersion of Radionuclides into the Sea
ERL	Environmental Radioactivity Laboratory, University of Stirling
GPS	Global Positioning System
GRANIS	Gamma Radiation above Nuclides in Soil
HSE	Health and Safety Executive
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units and Measurements
ILB	In-shore lifeboat
ILW	Intermediate Level Waste
LOD	Limit of Detection
MOD	Ministry of Defence
MoGSS	Mobile Gamma Spectrometry System
NDA	Nuclear Decommissioning Authority
NDAWG	National Dose Assessment Working Group
ONR	Office of Nuclear Regulation
PC-CREAM	Consequences of Releases to the Environment: Assessment. Methodology
RESUS	The Re-Suspension Model
RIB	Rigid Inflatable Boats
RIFE	Radioactivity in Food and the Environment
RSPB	Royal Society for the Protection of Birds
RNLI	Royal National Lifeboat Institute
RSA	Radioactive Substances Act 1993
SEPA	Scottish Environment Protection Agency
SSSI	Site of Special Scientific Interest
UKAS	United Kingdom Accreditation Service

Units

Bq	Becquerel	k	kilo (thousand, E^{3})
Gy	gray	m	milli (one thousandth, E^{-3})
[H'(0.07)]	Directional dose equivalent at 0.07 mm depth	µ	micro (one millionth, E^{-6})
Sv	Sievert	ha	hectare
eV	electron-volt	m	metre
t	ton	cm	centimetre
g	gram	y	year
l	litre	d	day
%	percentage	per	$^{-1}$
T	Tera (E^{12})	K_d	sediment distribution coefficient
M	Mega (one million, E^{6})		

Summary

This report presents the results of the 2017 radiological habits survey to determine the habits and consumption patterns of people living; working and/or undertaking recreational activities along the northern coast of the Solway Firth that may be subjected to long-range effects of permitted radioactive liquid discharges into the Irish Sea primarily from the Sellafield Nuclear site in Cumbria.

The aquatic and intertidal coastal survey targeted approximately 140 km of coastline extending from the Isle of Whithorn in the west to Glencaple in the east.

During the survey, a number of potential exposure pathways were investigated through various methods including face-to-face surveys; focus groups and direct observations.

Interviews with members of the public were carried out over a period of 14 days (Phase 1 survey) and were conducted between March 6th – 12th and July 1st – 7th, 2017 at coastal sites. A total of 387 individuals were surveyed and their results are presented and discussed. Those high-rate individuals are identified using established methods comprising a 'cut-off' to define the high-rate group and 97.5th percentiles for dose assessment analysis. Nine face-to-face surveys were followed up in November 2017 (Phase 2 survey) as a means of validation and are discussed within the report.

The aquatic survey area

Adults consumed the following aquatic foods sourced from within the survey area: crustaceans, fish; molluscs; wildfowl; game birds; and salt marsh grazed lambs. The mean consumption rates for adult high-rate groups for each of these food groups were:

- 53.4 kg y^{-1} for fish (cod; mackerel; plaice and salmon);
- 72.6 kg y^{-1} for crustaceans (brown crab; common lobster and langoustines (prawns));
- 27.6 kg $^{-1}$ for molluscs (mussels and scallops);
- 41.5 kg y^{-1} for Wildfowl (greylag goose; mallard; pink-footed goose; teal and widgeon); and
- 10 kg y^{-1} for saltmarsh grazed animals (lamb).

Children consumed the following aquatic foods sourced from within the survey area: crustaceans; fish; and molluscs. The mean consumption rates for the high-rate group for each of these food groups were:

- 4.00 kg y^{-1} for fish (bass; Dover sole; flounder and salmon);
- 0.50 kg y^{-1} for crustaceans(common lobster); and
- 2.10 kg y^{-1} for molluscs (cockles; mussels and razor clams).

Infants consumed the following aquatic foods sourced from within the survey area: crustaceans and fish. The mean consumption rates for the high-rate group for each of these food groups were:

- 2.64 kg y^{-1} for fish (bass; flounder; mackerel and pollock); and
- 0.24 kg y^{-1} for crustaceans (brown crab and common lobster).

A total of seven adults reported using seaweed as fertiliser. It was reported that seaweed was also used to clean ropes following activities.

The mean occupancy rates for the adult high-rate group within the aquatic survey area were:

- 1 539 h y^{-1} for intertidal activities;
- 1 762 h y^{-1} for activities in water;
- 1 720 h $y^{-}$for activities on water;
- 637 h y^{-1} for handling sediment; and
- 1 632 h y^{-1} for handling equipment.

Dose assessment

The highest retrospective dose for all exposure pathways was 5.5E-2 mSv y^{-1} and was the same for both the Phase 11and 2surveys.

A significant portion of the direct radiation survey area was surveyed by car-borne gamma spectrometry.

Comparisons with previous surveys

The results of the 2017 Dumfries & Galloway Coastal Habits Survey were compared with the previous habits survey carried out in 2012.

The mean consumption rate for the adult high-rate group increased in the 2017 survey for: crustacean; fish; molluscs; and wildfowl consumption. The mean consumption for the adult high-rate group for wildfowl and lamb consumption increased in the 2017 survey.

The mean of the adult high-rate group for in water activities increased significantly in the 2017 survey compared to the previous survey. On water activities for the adult high-rate group decreased compared to 2012. Handling equipment and sediment increased in the 2017 survey compared to the previous survey. The mean occupancy times for the adult high-rate group for handling equipment and sediment increased in 2017.

The mean of the children high-rate group for in water activities increased significantly 2017 compared to the 2012 survey. On water occupancy for the children high-rate group were very similar. Handling sediment was found to have increased significantly in the 2017 survey compared to the previous survey. The 2012 survey did not identify any children whose activities involved handling equipment, whereas the 2017 survey identified children who did.

No comparison could be made for any infant in water or on water activities or handling equipment or sediment between the 2012 and 2017 surveys.

Suggestions for changes to the monitoring programme

It is considered that SEPA's current monitoring programme provides adequate coverage. However, based on the findings of this habits survey, the following suggestions are presented for consideration:

- The discontinuation of the annual sampling of limpets at Kirkcudbright given that no consumption was identified in this and the previous habits survey;
- The replacement of limpet sampling with the sampling of whelks at Kirkcudbright and off Garlieston Harbour, Wigtown Bay as they have been identified as being harvested commercially; and

- The sampling of lamb annually at Creetown Merse given that several farms were identified who graze sheep on saltmarshes with two retail outlets known to sell the saltmarsh lamb.

1. Introduction

1.1 Regulatory Context

Radionuclides from permitted discharges of liquid radioactive waste into the Irish Sea primarily from the Sellafield Nuclear site in Cumbria have been recorded at locations around the Irish Sea including along the Dumfries and Galloway coastline. These radionuclides are transported to the coastline in a liquid phase and in particulate form largely associated with sediment transport. It is recognised that doses from external exposure along the coastline and the consumption of locally sourced foods, which relate either directly or indirectly (e.g. use of seaweed as a soil conditioner) with the coastal environment, may be higher as a result of contemporary and historical discharges being concentrated through natural processes leading to environments with elevated concentrations of anthropogenic radioactivity (Dale *et al.,* 2008; Tyler *et al*., 2013; Tyler *et al*., 2010; Tyler, 1999; Hunt 1998; McDonald *et al*., 1990).

Discharges from Sellafield are regulated by the Environment Agency and authorisations are granted under the Environmental Permitting (England and Wales) Regulations 2010, which set limits on the activities of specified radionuclides that are released from the site.

This survey, conducted along the Dumfries and Galloway coastline in Scotland, considers the effects of permitted liquid discharges from the Sellafield nuclear site in Cumbria as a result of releases into the Irish Sea. Any potential effect of these wastes are monitored in the Solway Firth, which has its northern coastline in Scotland and southern coastline in England.

SEPA's role in this case is directed at its general duty to protect the public from radiation exposure. In support of this objective, SEPA undertakes routine monitoring of the environment and reports the results through the Radioactivity in Food and the Environment (RIFE) series.

1.2 Definition of the Representative Person

The optimal approach for assessing doses to the public is through a combination of site-specific habit data and an environmental monitoring programme to determine ambient dose rates and concentrations in foodstuffs. In addition to the various interactions an individual may have with exposure pathways, the actual doses received are also dependent upon age, size and metabolism. Thus, the standard approach is to identify and consider these sources of variability in appropriate groups. The concept of the *representative person* was introduced by the International Commission on Radiological Protection, (ICRP), (2006) and recommended to replace the previously used concept of the *critical group* in 2007 (ICRP, 2007). The *representative person* is the individual that represents the more highly exposed members of the public and is typically defined by a cut-off, for example the top 97.5 % of the dose distribution within one or more routes of exposure. Within this concept, if the dose received by the *representative person(s)* can be demonstrated to be within the accepted dose limits and constraints, then the general public are considered to be protected.

1.3 Dose Limits and Constraints

The system of dose limitation recommended by ICRP (2007), and subsequently by the Radioactive Substances Basic Safety Standards (BSS), requires that dose equivalents received by individuals shall not exceed the limits set out in Article 13 of Council Directive 96/29/Euratom (CEC, 1996). The *retrospective* maximum permissible dose limits are set out as 1 mSv y^{-1}.

The *retrospective* maximum permissible dose limits are set out as 1 mSv y^{-1}. For *prospective* assessments, the maximum permissible doses or constraints used by SEPA are:

(i) 0.3 mSv y^{-1} for any single source of radioactivity; and

(ii) 0.5 mSv y^{1} for a single site from which radioactive discharges are made.

It is also accepted by the UK Government that it should be possible to operate existing nuclear facilities without exceeding the 0.3 mSv y^{-1} constraint (Hunt *et al.,* 1982; Leonard *et al.,* 1982). It is therefore incumbent upon SEPA to ensure that these dose

limits/constraints are not exceeded for all authorised discharges of ionising radiation to the environment.

1.4 Habits Survey Aim

The aim of the habits survey is to collect site-specific data to allow a bespoke assessment to be made that identifies the representative individual(s). The identification of the representative person is a result of combining known information on the consumption of local marine and marine-derived terrestrial foods and occupancy times with data from SEPA's routine environmental monitoring programme. The survey aims to collect data on the consumption rates of locally sourced foods that might be impacted by the marine and intertidal environments, and occupancy times along the coastline to identify the doses to the representative person(s). The survey also aims to identify any habits which the routine monitoring programme does not currently cover adequately and may recommend the adoption of new monitoring due to new or changing habits or the removal of monitoring that is no longer required. The survey does this by:

(i) Collecting data on a range of habits/activities by the general public in the marine, intertidal or near shore terrestrial environment that might lead to exposure to radioactivity from any licensed liquid discharges from Sellafield;
(ii) Collecting information on consumption of marine or food caught or produced (including wild and free foods and any novel pathway) that may be related directly or indirectly (e.g. use of seaweed or salt marsh grazed animals) to the Solway, and determine an annual rate of consumption for each individual surveyed and household members of all ages; and
(iii) Quantifying the amounts of radioactivity and subsequent doses to individual members of the general public as a result of the discharges or operations of the nuclear site.

This report presents the findings for the 2017 habits survey of the Dumfries and Galloway coast. The previous habits survey fieldwork was undertaken during the period 22nd July to the 5th August 2012 (Garrod *et al*., 2012).

2 The Survey

2.1 Introduction

This chapter describes the site principles used to define the survey area along with characteristics that define the area and the potential routes of radioactivity or radiation exposure from Sellafield to the public.

2.2 Defining the Survey Area

2.2.1 The Fate of Radioactivity in the Coastal Area of Dumfries and Galloway

The fate of radionuclides released from the Sellafield (Windscale) site has been the focus of much research. Early investigations utilised ^{137}Cs in particular as a tracer for water and sediment transport in the Irish Sea and West Coast of Scotland (Baxter *et al*., 1979; McKinley *et al*. 1981 a, b; McKay and Baxter 1985; McKay *et al*., 1986). McDonald *et al*., (1990) demonstrated the importance of sediment transfer mechanisms of radionuclides, including ^{241}Am and ^{241}Pu, to intertidal and saltmarsh sediments. Further investigations by McKenzie *et al*., (1994) suggested that about 90% of the ^{137}Cs discharged along with Pu^{5+} remained in solution and migrated out of the Irish Sea. The remaining ^{137}Cs; Pu^{4+} and ^{241}Am was incorporated into fine sediments, detailed further by McKenzie *et al*., (1999). McKenzie and Scott (1993) also highlight that although radionuclide discharges from Sellafield have decreased by two orders of magnitude, the legacy of the longer-lived radionuclides discharged to the environment has resulted in only one order of magnitude reduction in dose rates to critical groups.

Shallow coastal environments, saltmarshes and intertidal environments represent important arenas, which promote the deposition of sediment bound radionuclides and therefore represent important routes of exposure. Allan and Pye (1992) describe the factors that control the dynamics of these environmental systems, which can exhibit continual natural intra- and inter- annual change in depositional/erosional cycles (erosion and accretion of fine intertidal sediments, erosion and growth of salt marshes).

Harvey and Allan (1998) provide a good description of the Solway Saltmarshes, which represent the largest single expanse of saltmarshes in the UK (*ca.* 200 ha). Detailed mapping of sedimentation rates across these environments by Tyler (1999) show how they vary greatly and systematically within saltmarshes, depending on proximity to the channel edge and creek with surface roughness (vegetation) and local microtopography (levees and terraces). This largely controls grain size distribution and sedimentation rate resulting in a complex balance between higher clay content (higher ^{137}Cs and ^{241}Am activity concentrations) but lower sedimentation rates (<0.1 cm y^{-1}) towards the back of the salt marsh, to greater sand content (lower radionuclide activity concentrations) and higher sedimentation rates (>1 cm y^{-1}) towards the intertidal edge of the saltmarsh. The balance between clay content and sedimentation rate tends to result in higher total activity deposition towards the centre of the saltmarshes (Tyler, 1999). The legacy of the ^{137}Cs peak discharges from Sellafield in 1970s remains the dominant anthropogenic contributor to external exposure (Tyler, 1999). However, increasing burial by more recent lower activity sediments and radioactive decay is progressively reducing the external measured doses. The exact dose varies, however, as temporal and spatial heterogeneity is expected over intertidal surfaces depending on whether there is ongoing erosion (to a potentially pre-Sellafield level) or accretion (bearing well mixed Sellafield radionuclides).

^{99}Tc discharges peaked in the mid-1990s. The biogeochemical behavior of ^{99}Tc is largely controlled by its oxidation state (Leonard and McCubbin, 2004), with low adsorption to oxic sediments and higher adsorption to reducing anoxic sediments. There is a significant desorption potential when sediments are mixed in oxic environments, resulting in generally low radionuclide concentrations in sediment, particularly those found in the Solway. Leonard and McCubbin (2004) also indicated from experimental work, that the primary uptake mechanism of ^{99}Tc by marine biota is probably directly from surrounding seawater. Importantly, the bioaccumulation factor for ^{99}Tc can be very high in some marine species, including up to and greater than 1 000 for Crustacea (2 000 for Norwegian Lobster) and consequently understanding the consumption rates of different marine seafood species may be important.

Tidal current data for the Solway from the UK Hydrographic Office (1992) and Yr (2013) were reviewed. Both these sources show accelerating currents during the flood

tide between the area immediately south of the Wigtown peninsula (Figure 2.1) and north of the Isle of Man funneling and accelerating the tide into the inner Solway, supported by currents moving up from the south along the Cumbrian coastline. This is likely to have the effect of moving contaminated sediment off the Cumbrian coastline into the inner Solway. As the tide turns, the currents flow to the west and to the south with the result of potentially dispersing sediment around the Irish Sea. However, the overall result is for the inner Solway to be a net recipient of Sellafield-contaminated sediment. Of the remaining Solway coastline, little current flow appears to enter significantly into the northern reaches of Luce Bay. This is confirmed by a number of reports where samples have been collected offshore showing that the bed sediments to the west of Wigtown peninsular reflect higher energy currents with >80% gravel content phasing towards 80% sand content towards Glen Luce, whilst Wigtown and Kirkcudbright has >15% mud (Leonard *et al*., 2008).

The data suggest that sediment entering Luce Bay are dominated by material derived from the west coast of Scotland with limited mixing with radionuclide contaminated sediments from Sellafield. Published data from airborne gamma ray survey results (Sanderson *et al*., 1992, 2004) confirms that the intertidal and saltmarsh environments of the inner Solway east of Wigtown have enhanced ^{137}Cs signatures compared to adjacent terrestrial areas. Sampling and ground based in-situ investigations onshore and offshore have also confirmed broad systematic associations between ^{137}Cs with Pu and ^{241}Am and with the finer sediment fractions (Mackenzie *et al*., 1999; Tyler, 1999).

McCubbin *et al*. (2006) show that the ^{99}Tc activity concentrations associated with the muddier sediments in the Scottish coast are higher (20 Bq kg^{-1}) in the inner Solway than towards the south west of Wigtown (0.3 Bq kg^{-1}) and North Channel (0.1 Bq kg^{-1}). These lower activity concentrations reflect the higher energy environment and coarser bed sediments of this western sector of the Solway. Furthermore, ^{99}Tc activity concentrations in water have also tended to be lower in areas to the west of the Wigtown peninsula (Leonard and McCubbin, 2004). RIFE (2016) also reported very low levels of ^{99}Tc in seaweed off the Wigtown peninsula and below 0.14 Bq kg^{-1} in plaice (Kirkcudbright).

In 2009, 60 wind turbines were installed in Scottish Territorial Waters off the coast of Dumfries in the Solway, making the Robin Rigg windfarm the largest offshore in Scotland. The footings of the turbines are protected to minimize sediment scour (Cassie, 2016).

Based on the available monitoring data and expected current-driven sediment movements, the primary focus for the habits survey should be the coastal environment between Wigtown peninsula and the western side of the Nith Estuary. The area to the east of the Nith Estuary has been surveyed as part of the habits survey in the environs of the Chapelcross nuclear licensed site (Tyler *et al*., 2017) and is therefore not considered further in this report.

The Habits survey will therefore focus on key areas of potential external exposure within the saltmarshes and intertidal areas including: Port Allan; Wigtown Bay, Fleet Bay; Brighouse Bay; Kirkcudbright Bay; Port Mary; Rascarrel Bay; Auchencairn Bay; Needles eye; and Kirkconnell (west side of River Nith).

2.3 The Survey Area

The marine survey area (Figure 2.1) extends from the west of Caerlaverock National Nature Reserve to the Isle of Whithorn representing the locations where current and historic discharges from Sellafield are likely to be found as described in Section 2.2.1. The survey area for the 2017 habits survey is consistent with the previous habits survey (Garrod *et al*., 2013). The survey area is defined by a series of larger bays interspersed with rocky headlands and small bays. The heads of the larger bay areas are characterised by mudflats and salt marshes of varying size whilst the smaller bays are predominantly sandy. Between Southerness and Sandyhills the coastline differs consisting of large areas of sandy beaches. Descriptions for each site visited and surveyed are provided in Appendix A.

2.4 Land Cover Data

The intertidal and salt marsh (highlighted) environments are also shown in Figure 2.1. The area represented by saltmarshes within the survey area is 1 306 ha. Land cover data for the survey area and further inland are presented in Figure 2.2.

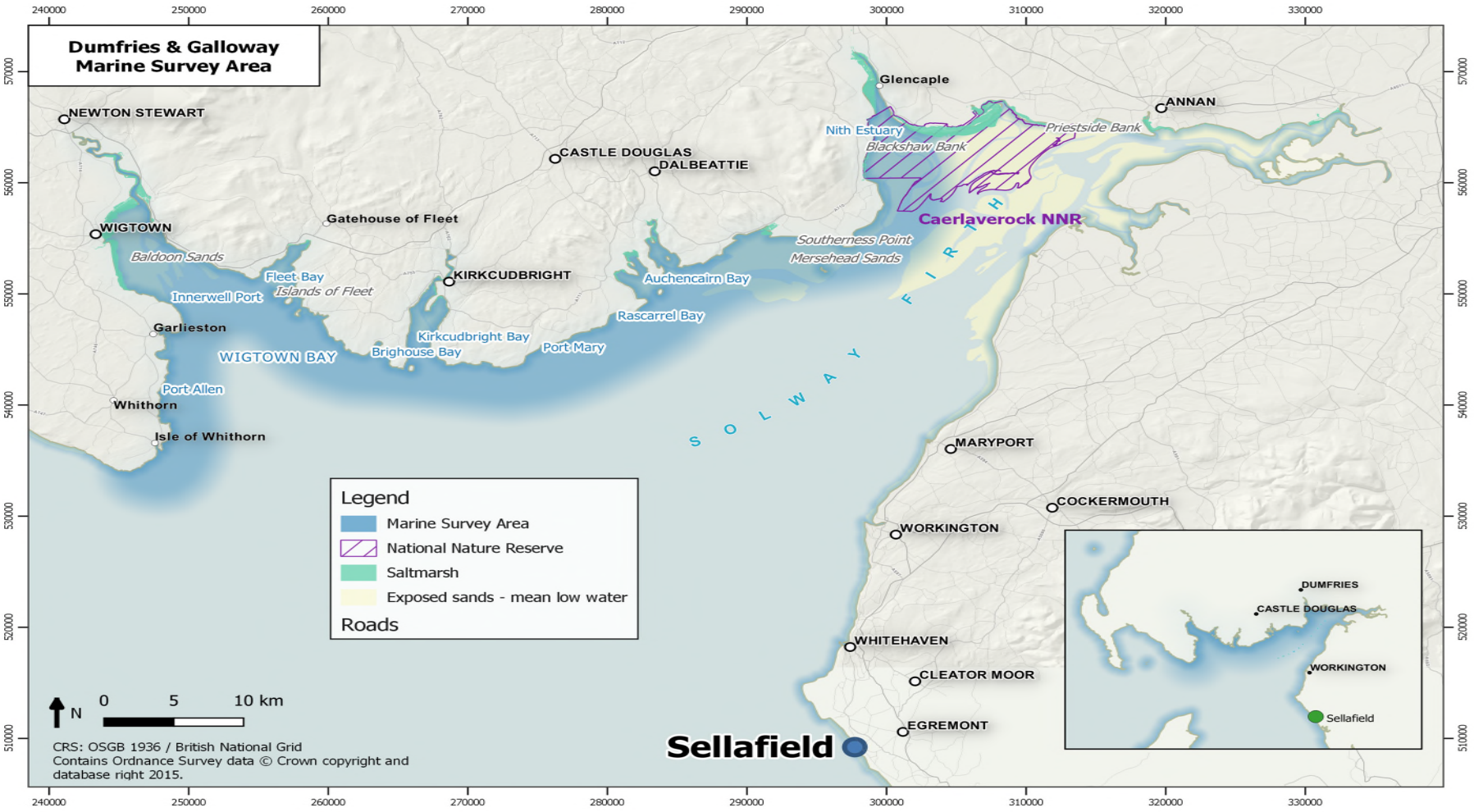

Figure 2.1. Coastal survey area extending from the Isle of Whithorn to Glencaple.

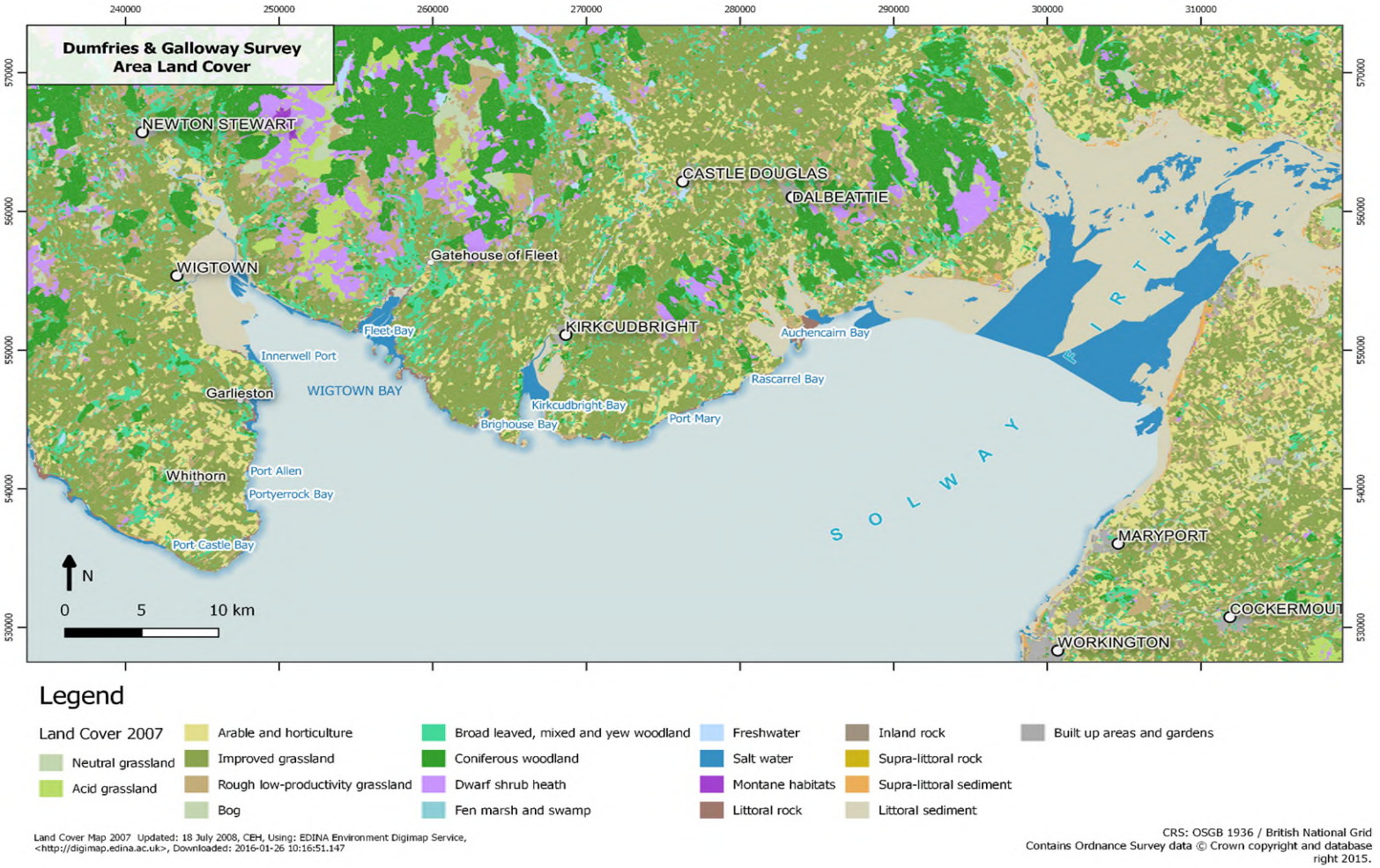

Figure 2.2 Land cover of coastal survey and inland areas

2.5 Soil Data

Soil data for the surrounding inland area of the coastal survey area are presented in Figure 2.3. Along coastal margins, the dominant soil type is brown earth with smaller localised areas of humic gleys.

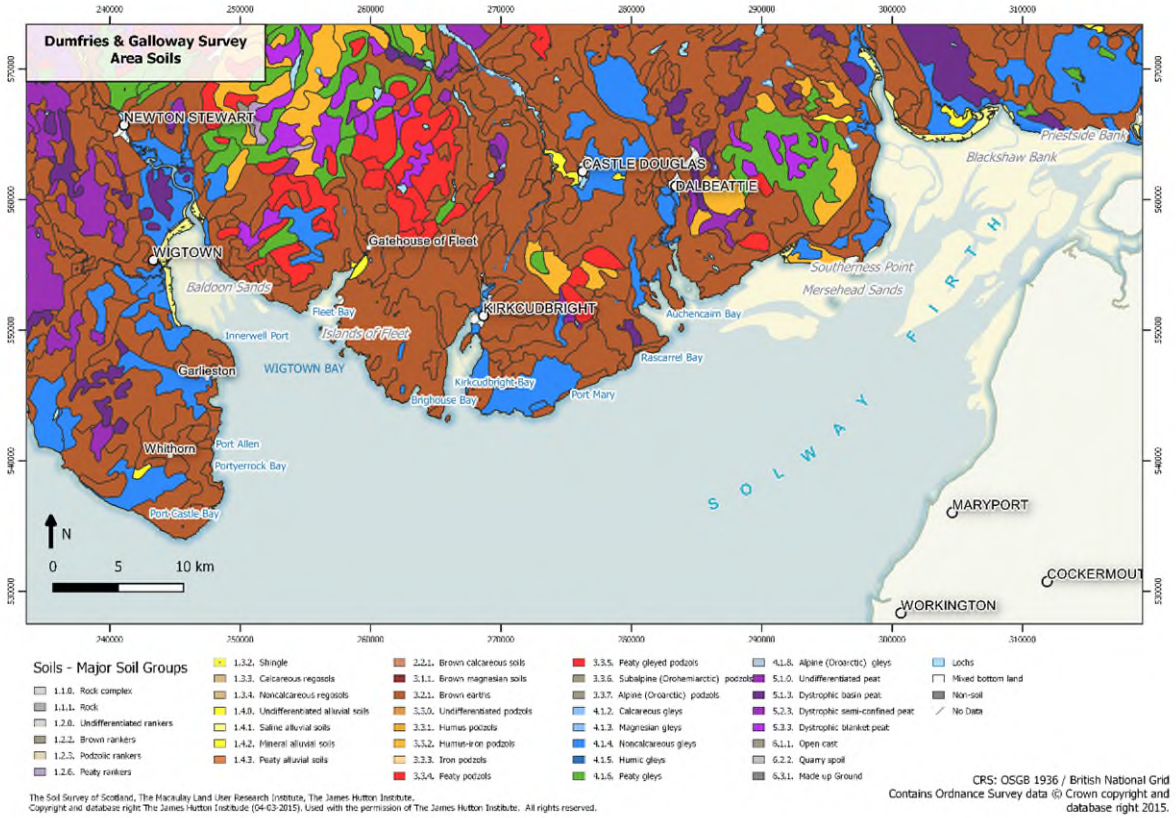

Figure 2.3 Soil map of coastal and inland areas

2.6 Topographic Wetness Index

Catchment hydrology can be important in the redistribution of radionuclides. For example, organic soils can allow radionuclides (e.g. ^{137}Cs from fallout) to be transported in solution as well as in particulate form. When these hydrological flow paths cross from organic to mineral rich soils, the radionuclides can become bound to clays and oxides within the soil matrices. In extreme conditions, these areas have been shown to result in elevated concentrations of radioactivity (Tyler and Heal, 2000). Building on the soil and 50 m resolution digital elevation model for Scotland using the

OS Terrain 50 product (https://www.ordnancesurvey.co.uk/business-and-government/products/terrain-50.html). The topographic wetness Index (TWI) for the survey area and further inland are presented in Figure 2.4. The lighter area indicates low flow, water flowing away, whilst areas of increasing blueness represent wetter areas. This provides more detail of hydrological flow paths than would otherwise be possible from standard maps and highlights areas where radionuclides from atmospheric fallout might accumulate.

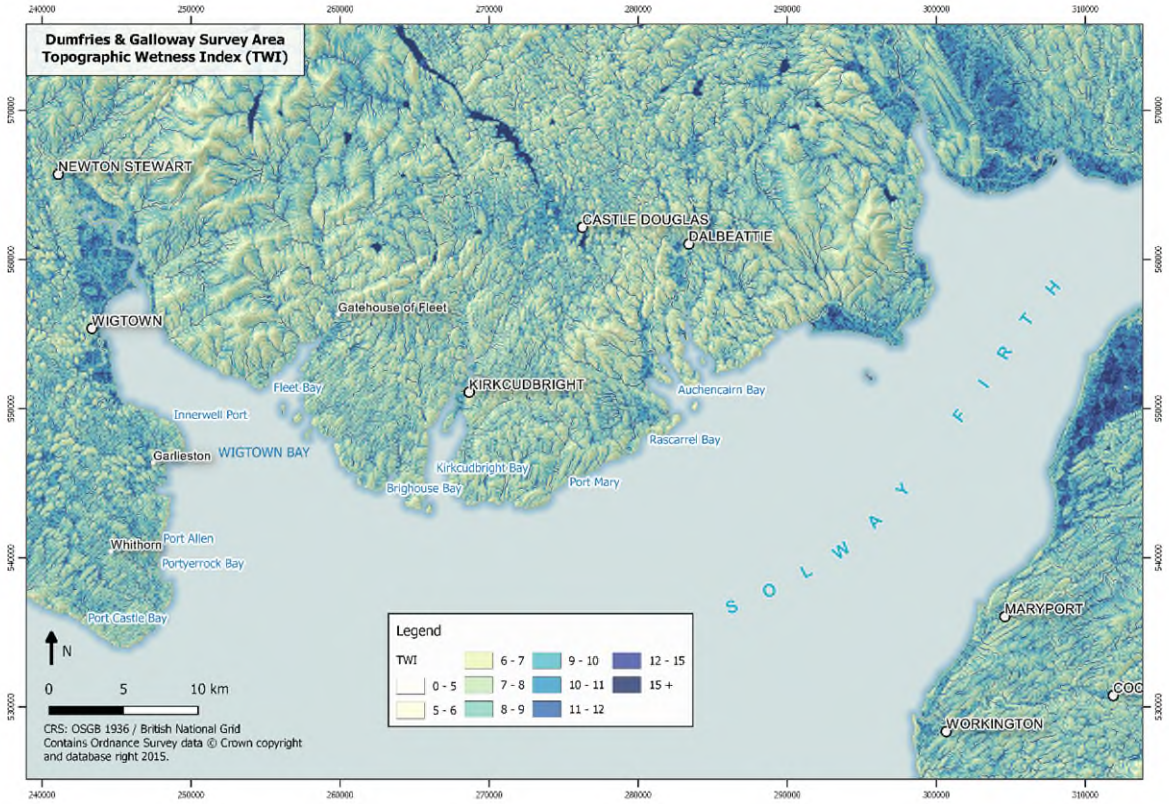

Figure 2.4 The Topographic Wetness Index in the Solway Firth area (Ordnance Survey Great Britain, 2018).

3 Methods

3.1 Introduction

To provide consistency and traceability to previous habit surveys, the methods employed and described in this chapter are largely based on the approach outlined in Leonard *et al.* (1982), Green *et al.* (2001) and National Dose Assessment Working Group (NDAWG) (2013). The previous habit surveys provided a useful frame of reference for undertaking this survey of the Dumfries and Galloway site. Chapter 2 described the desktop study undertaken to characterise and define the Habits Survey area, including:

(i) A brief overview of Sellafield site activities; and
(ii) A review of the distribution of Sellafield radionuclides.

The 2017 Habits Survey of Dumfries and Galloway covers marine and intertidal activities and primarily seafood consumption. This survey utilised the following methods:

(i) a mobile radiometric survey to characterise the heterogeneity of radiation in the environment of the Dumfries and Galloway Coast that may be related to discharges from Sellafield;
(ii) Global Positioning System GPS tracking on a limited number of volunteers to better understand the time spent by individuals as they interact with the marine environment; and
(iii) information meetings, during and after, the face-to-face surveys to validate the data and findings.

The fieldwork component of the survey (Phase 1) in two stages and conducted outwith the school holiday between March 6th – 12th (outwith the school holiday period) and July 1st – 7th (during the school holiday period). Additionally, information was gathered from informal meetings with groups and information collated from the past reports, web searches and local people. Four members of staff from the University of Stirling conducted the face-to-face interviews, observations and gamma dose rate measurements.

To support SEPA's role, this report, provides an assessment of public habits along the northern coastline of the Solway Firth and to assist with future environmental monitoring programmes. The Habits survey, along with other factors such as modelling, can also confirm if the current programme is fit for purpose.

3.2 Radiometric Surveys

The mobile radiometric surveys comprised a car-borne gamma spectrometry survey, *in-situ* gamma dosimetry and beta skin dosimetry. The car-borne survey methodology is described in Appendix A2.

3.2.1 *In-situ* Dosimetry

The Environmental Radioactivity Laboratory (ERL) has ISO 17025:2005 accredited procedures for the deployment and recording of gamma dose rate in air, using ISO 17025:2005 accredited (UKAS) calibrations for two Thermo-Radeye instruments. Measurements were undertaken at all locations where occupancy or location was likely to lead to higher exposure to radioactivity. These included areas that may have elevated radionuclide concentrations where fine sediment is known to accumulate (e.g. salt marshes and mudflats). The effective dose from terrestrial gamma radiation was calculated and reported in μSv h^{-1}. Further details of the *in-situ* methodology can be found in Appendix A3.

3.2.2 *Beta* Dosimetry

A ruggedized *Thermo BP19RD /Electra* instrument was deployed to assess the Beta dosimetry of skin dose [H'(0.07)]. The BP19RD provided a wide area monitor instrument (100 cm^2) and was used to monitor items that were potentially exposed to the higher radioactivity concentrations. Further details of the Beta skin dosimetry methodology can be found in Appendix A4.

3.3 GPS Tracking

Members of the public and targeted groups completing face-to-face surveys were approached to wear a GPS tracker unit for validation of their activities, of which three

individuals agreed to wear a tracker. Further details of the system deployed are described in Appendix A5.

3.4 Conduct of the Survey

The pre-survey preparations involved a range of investigations including SEPA being contacted to discuss the requirements for the Dumfries and Galloway survey. Past surveys, reports and maps for this site were investigated giving substantial and vital information. A directory of key groups, bodies and organisations involved in activities in the area was compiled from web searches and from contacting people within the local area with relevant knowledge pertaining to the survey. The directory proved an invaluable resource throughout the survey period both for contacting groups. By doing so, the directory was used and for use as a checklist against which responses and non-responses from potentially important groups regarding activity, occupancy, exposure and local food consumption could be recorded. The directory development required extensive web searches, follow-up telephone calls and use of earlier contacts across organisations and businesses. For future surveys, the directory will provide a useful starting point and a means of monitoring any changes in group/business or other activity in the area. A proposed programme for the fieldwork was then established.

3.5 Meetings and Informal Contacts

In the 2017 survey, a range of data was gathered by a variety of approaches. This included holding focus groups with relevant parties and individuals as well as a ‘standard’ face-to-face interview schedule. The multi-methods approach provided a means to ‘triangulate’ (verify) the data gathered through the different approaches: for example to check occupancy and activity data against the ‘snapshot’ observations recorded over a limited number of days in one season acquired from the individual face-to-face interviews. The information provided also facilitated some snowballing of the survey because the individual meetings provided additional contacts to follow-up. These groups were approached prior to, during and after the face-to-face interviews by telephone and email.

3.6 Data Conversion & Analyses

During the face-to-face interviews, data on marine and marine derived terrestrial food consumption were recorded in units provided by respondents (e.g. pounds, grams, and ounces) and later converted into kilograms per year. In some cases, individuals were unable to estimate food consumption in kilograms per year and these data were converted into consumption rates using conversion weights. Data from the paper copies of each survey were transferred to a purpose developed database prior to analyses. Raw data can be found in Appendix A6 and A7.

3.7 Data Rounding and Grouping

All data collected from the face-to-face surveys were reported to at least three significant figures.

Table 3.1 Food groups used in the Habits Survey

Food Group	Example of Foods Within Group
Eggs	duck eggs; goose eggs; hen eggs.
Wild/free foods	blackberry; garlic; nettle; raspberry; rowanberry; sloe; strawberry.
Honey	honey.
Fish	bass; cod; Dover sole; kipper (herring); mackerel; pollock; thornback-ray; flounder; plaice; tope; salmon; sea trout; trout (freshwater).
Crustaceans	brown crab; common lobster; shrimps; prawns (langoustines).
Molluscs	Mussels; razor clams; scallops; winkles; cockles; whelks; oysters.
Wildfowl	Mallard; grey-lag & pink-footed goose; teal; widgeon.
Saltmarsh grazed cattle meat	beef.
Saltmarsh grazed sheep meat	lamb.

The Food items were placed into groups with similar attributes (Table 3.1). These groups are similar to those used in previous survey reports. Individuals were given the option to add any additional food items in the 'Other' food category.

The time individuals spent carrying out activities was calculated by multiplying frequency (occasions per year) and duration (hours) considering seasonality where appropriate. Individuals accounted for any holidays and working hours within their survey replies. In addition, individuals who carried out aquatic activities that could result in the inadvertent ingestion of water, e.g. outdoor swimming/sailing, were identified to account for this pathway. The age groupings used in this report are based on International Commission of Radiological Protection (ICRP) recommendations and are listed below in Table 3.2.

Table 3.2 ICRP age groups used in the dose assessment

Age Group	Age Range
Group 1 - Infant	0-5 year old
Group 2 - Child	6-15 year old
Group 3 - Adult	16 year old and over

3.8 Qualitative and Quantitative Observations

Whilst undertaking the face-to-face surveys, observational data were acquired on obvious changes to each location such as new buildings, along with information on site usage and numbers of individuals undertaking specific habits. Observations were acquired over a specified time period, e.g. 20 minutes, and onshore and offshore (including intertidal) activities were noted. The number of individuals, their gender and their approximate age group undertaking each activity were also noted or estimated where large numbers were observed, e.g. beach activities. Some individuals were approached where possible and subsequent face-to-face surveys were conducted. Contact with individuals during face-to-face interviews frequently allowed the accuracy of observations to be checked and sometimes to be expanded. For example, dog-walkers might also engage in beachcombing and sailing at other times. Along with

noting the weather conditions at the time of survey, this approach provided a basis for making a comparison with habits at different times and within and outwith the period of the local school holidays.

3.9 Dose Assessment Tool

The Habits Dose Assessment Spreadsheet Tool collated the data from the face-to-face surveys for Dumfries and Galloway and then used the consumption rates and habits data to calculate the retrospective dose to each interviewed member of the public, covering the total exposure from all pathways. It should be noted that consumption of locally sourced marine food has been included in the retrospective dose assessment (i.e. food from outwith the survey area was not included within the assessment) and foods sourced from animals known to graze on coastal salt marsh areas. Dose assessment was carried out following the guidance in NDAWG and ICRP for the *Representative Person*.

The tool analysed three general exposure pathways:

(i) *Internal aquatic*, which includes consumption of fish; crustaceans; molluscs and inadvertent ingestion of seawater. A proxy for inadvertent drinking of water was calculated by multiplying the time spent on aquatic activities by the known average of water ingested in such activities as described in Leonard *et al.* (2015) and Stone *et al.* (2008);

(ii) *Internal marine influenced terrestrial foods,* includes salt marsh grazed animals; and

(iii) *External aquatic,* which estimates the dose from external exposure through aquatic activities e.g. from radionuclides present in the aquatic environment (in water and sediments in saltmarshes or intertidal areas).

The representative person was calculated independently for the total consumption and habits first and then by each exposure pathway. To identify the representative person, the 97.5th percentile rate cut off method was applied (Chapter 1). The representative person was calculated separately for external marine and intertidal exposure, internal marine and any intertidal internal consumption related exposure. The combined calculated total integrated all routes of exposure to find the most exposed by all routes.

The representative pathway for each exposure pathway is described separately in Chapter 8.

4. Aquatic Radiation Pathways

4.1. Introduction

The survey locations were established following a desktop review of the survey area and presented in Chapter 2 to allow effective comparison with the previous Dumfries & Galloway Habits Survey undertaken in 2012 (Garrod *et al*., 2012). The survey locations were revisited throughout two survey periods, the first outwith the school holiday period (16th to 22nd May) and the second during the school holiday period (11th to 15th August) of 2016.

The sites were visited throughout the survey periods and observations of offshore and onshore activities were undertaken at each site. The survey schedule was designed to ensure that each site was visited at different times of the day, which reflected the activities occurring at each site along the coastline of the Solway Firth. Focus groups with local activity groups were arranged, as part of the survey.

4.2. Aquatic Survey Area Descriptions

The survey area included approximately 140 km of coastline included intertidal areas and waters along the northern shore of the Solway Firth between the Isle of Whithorn in the west and Glencaple in the East (Figure 2.1). Kirkconnell merse is the last survey point, opposite Glencaple, and therefore provides continuity with the Chapelcross Habits Survey (Tyler *et al*., 2017). The Admiralty charts show fast flowing tides in the main channel beyond the bay areas. Overall, the coastline is dominated by a series of rocky peninsulas, which may or may not be accessible, interspersed with four large sandy bays: Wigtown-; Fleet-; Kirkcudbright-; and Auchencairn- Bays, and a series of much smaller bays. At low tide these larger bays expose large tracks of sand and mud. The eastern end of the survey area is bounded by the western side of the Caerlaverock National Nature Reserve (NNR), which extends across to the opposite side of the Nith estuary between Carse Bay and Airds merse. Across the survey area, six main rivers enter the Solway Firth. From west to east these are the Rivers Bladnoch; Cree; Water of Fleet; Dee; Urr Water; and Nith.

Site descriptions and observations can be found in Appendix A1.

4.3 Commercial Seafood Operations

Commercial sea fishing operations and associated food processing operate within the survey area. Commercial fishing is mainly, but not exclusively, for shellfish and is centred at Kirkcudbright, which is the main port in the UK for scallop landings. Landings take place also at Isle of Whithorn and Garlieston harbours. Most of the larger boats fish offshore in deeper water outside the survey area with smaller boats closer to shore within the survey area. A total of 3 477 tonnes of shellfish were landed during 2016 at Kirkcudbright. Of which, 3 395 tonnes were scallops; 5 tonnes of lobster, 63.3 tonnes of whelks and 13 tonnes of other shellfish which includes winkles. A total of 1.34 tonnes of fish were landed during the same period which included cod, plaice and skate. Contact was made with commercial fishing organisations and individuals. The following information was obtained:

(i) Isle of Whithorn: It is reported that five commercial fishing boats are based at the harbour, fishing for either lobster or crabs with scallops in winter. In summer occasional landings of queen scallops are recorded but are caught outside the survey area. Contact with one static-line fisherman indicated fishing every two days outside the survey area. A local inn sources crabs and lobster from this harbor.

(ii) Garlieston: A total of five boats also work out of the harbour, it is reported that with one fishing for lobster and the rest for whelks. Observations outwith the holiday survey period shows that an individual fishes for whelks up to four or five times per week, depending upon the weather, in Wigton Bay with an average catch of approximately 360kg. The whelks are sold to a processor in Fleetwood who shell, cook and freeze them before exporting to South Korea.

(iii) Kirkcudbright: It is reported that 13 commercial boats, greater than 10 m in length, work out of the Kirkcudbright with scallops their main catch, but not exclusively. The harbour is dredged on a regular basis, the last time being September 2016. A shellfish wholesaler with a processing plant in Kirkcudbright owns five boats working out of Kirkcudbright with crew numbers of between five and eight per boat, catching both queen and king scallops. Contact with the company reported that most scallops are caught outside the

survey area. However, they do catch some queen scallop off the Isle of Whithorn for one or two months in summer but could not provide any quantities caught. A small proportion are sold locally at a local fishmonger. It is reported this processor sends a lorry load of scallops daily to Glasgow for processing. Other scallops landed at the port are sent to Oban, South Shields and Fleetwood.

Table 4.1 Fish and shellfish landed at Kirkcudbright by a local fisherman and where products go to market

Product	Quantity	Sells To:	Market
Prawns	15 - 200 kg d^{-1}	Local wholesaler	France & Spain
Brill	20 - 30 kg d^{-1}	Local smokehouse	
Skate	250 kg m^{-1}		Small quantity to local Smokehouse
Plaice	30 kg d^{-1}		
Whelks	up to 1 t $2d^{-1}$	Local wholesaler	South Korea

It is reported that an inshore fisherman based in Kirkcudbright fishes up to 4.8 km offshore in the following areas: Wigtown Bay; off Ross Island and around Hestan Island all year round and sells both locally and further afield. Examples of the fish caught and quantities landed by the said fisherman are displayed in Table 4.1.

(i) Wigtown Bay: the local smokehouse also obtains fish from the bay from April to October with an individual fishing for four to five hours each week and they sell the catch in the smokehouse: Grey mullet: 500 kg per year; flounder, 200 kg per year; thornback ray, 300 kg per year. He also buys lobster and crabs from a local fisherman. It is reported that winkle-picking takes place in the bay over winter and are sold to a shellfish processor in Kirkcudbright and onward sale abroad;

(ii) Kippford: A creel boat was observed lying on the upper beach area near the slipway in Kippford. However, it is reported that the boat owner no longer fishes; and

(iii) Kirkandrews Bay: It has been established that two small fishing boats work out of the bay. It is reported that one fishes commercially for razor clams employing two scuba divers, who between them, collect approximately 800 kg of razor clams. They fish in Fleet-; Kirkcudbright-; and Wigtown-Bays all year round in shallow waters with a sandy seabed. The razor clams are sold to a local shellfish wholesaler who exports them live to Hong Kong. It is reported that the other boat-owner is also a commercial fisherman who operates part –time and fishes for lobster, for approximately 6 months of the year between May and October. Approximately 24 creels are set off the coast between Kirkandrews Bay and Barlocco Island and between 100 kg and 200 kg y^{-1} of lobster are caught and are sold to a seafood processor/wholesaler in Ayr who export them to France, Spain and Italy.

The banning of commercial cockle-picking, except by hand-raking in the area, is widely known and has been reported by several sources. It is reported that the hand raking industry supports approximately 30 local people. It has also been reported by various sources that illegal electro-fishing occurs in the area, mainly in Luce Bay but a few do so off the Isles of Fleet. Here, divers using small boats collect razor clams and sell them abroad due to the high price they command. It is reported that the cockles are sent to South Korea. In April 2017 the Scottish Government announced a consultation on whether electro-fishing for razor clams should be permitted. As such, any information pertaining to this illegal activity is not included in this report.

4.4 Chandlery and Boat Salvaging

A chandlery shop and boat repair business is located in Kippford with several boats seen in various states of repair in the boat yard behind the shop. It is reported that the owner helps to salvage one or two boats each year who have gotten into trouble on the mud banks in the area. It is also reported the owner also helps to clear propellers of caught lines, ropes and debris in Fleet-; Kirkcudbright-; and Wigtown-Bays.

4.5 Food Processors

Several shellfish processors are based in Kirkcudbright, along with two smokehouses and were contacted as part of the survey. Investigations indicate that only a small proportion of shellfish landed are sold locally with most sold abroad. Details are as follow:

(i) Shellfish processor #1: reported they source shellfish from local fishermen and sell them to France & Spain. Quantities reported were: Winkles, approximately three tonnes per week (all year) & two tonnes cockles per week (winter only). The company also stated they used to farm mussels and lobsters for the market but have not done so for the past five or six years. They also provide Public Health England with the following shellfish for testing such as for *E-coli*, which are sent to Glasgow: Winkles (3 kg); Mussels (3 kg); Cockles (3 kg); 10 -12 crabs and 10-12 lobsters twice a year;

(ii) Shellfish processor #2: reported processing both king and queen scallops, most of which are caught in deeper waters of the Irish Sea, with only a small proportion of queen scallops caught in Wigtown Bay during the summer. Most are sold abroad but they do supply small quantities to smokehouse based within the survey area. They also sell crushed shells as a by-product of processing for landscaping;

(iii) Smokehouse #1: The owner catches some of the fish and shellfish in Wigtown Bay during part of the year, some of which are smoked and are sold through the shop. They also supply several local hotels and restaurants

(iv) Smokehouse #2: Has a retail outlet selling smoked fish products. The company website notes that salmon is caught in the Cree estuary using the traditional 'net and cobble' method. The fish is smoked and sold through the business. However, no further information on how often they fished, quantity caught and sold was provided.

4.6 Local Food Retailers

Fish and shellfish products are the main food stuffs sourced locally that are promoted in local shops and restaurants. Two hotels in Kirkcudbright source some of their ingredients locally.

(i) Kirkcudbright Hotel #1: Report having local haddock on their menu, which is supplied by a local fishmonger: However, contact with the fishmonger indicates the haddock is landed elsewhere usually at Peterhead;

(ii) Kirkcudbright Hotel #2: Report they have locally landed scallops on their menu, which are sourced from Kirkcudbright. Contact with the hotel reports they source the following fish and shellfish from one of the smokehouses, based in within the survey area, when in season: lobsters; crabs; skate wing; sea- and stone- bass; and occasionally salmon.

(iii) Smokehouse #1: Also sells fish, to other local hotels and restaurants caught by the owner;

(iv) Inn: Located in the Isle of Whithorn, advertise they source their seafood locally from boats using the harbour. Seafood on the menu includes lobster; crab; sole Scallops (both king & queen); flatfish and monkfish. It is reported that lobster and crab are provided by a fisherman working out of the harbour, whilst other products on the menu are provided by differing boats who land their catch at the harbour;

(v) A fishmonger based in Kirkcudbright reports selling locally landed prawns (average 28 kg per week May to September); lobster (average 10 per week from May to September); crabs (average 10 per week from May to September); mackerel (up to 100 per week in summer); queen scallops (average 40 kg per week in summer) and king scallops (average 40 kg per week during the winter season- 1st November to the end of April). The location of where the fish and shellfish were caught was not known;

(vi) Butcher #1: For the past three years, a local butcher in the area has sourced and marketed saltmarsh lamb from a farmer who grazes animals on Creetown merse. The lamb is available from the end of July through to the end of September and he sells between 80 and 120 per season; and

(vii) Butcher #2: It is reported that another farm, based near Creetown, grazes sheep and lambs on Creetown merse and supplies another butcher in the local area with approximately 20 lambs per year grazed on saltmarsh.

4.7 Saltmarsh Grazing

Contact, via telephone, with over 25 farms was attempted to enquire if they graze livestock on the coastline in the survey area. Of the 13 farms who were contacted, eight reported grazing some of their sheep or cattle on the shoreline. The animals tended to graze on saltmarsh areas with at least one farm identified from each of the following bays; Wigtown, Kirkcudbright, and Auchencairn plus RSPB Mersehead reserve and the Nith estuary valley. Grazing was reported to take place over the spring and/or summer months. The following information was obtained:

(i) Wigtown Bay: Investigations identified four farms who reported grazing some livestock on part of the Wigtown Bay reserve. One farmer reported grazing 20 – 30 beef cattle on Creetown merse over the summer plus up to 450 ewes and lambs all year round. It was confirmed that five adults from the farm consume two or three lambs per year between them. The farm also supplies a local butcher in the area with lamb. A second farmer also reports grazing animals on Creetown merse with up to 120 ewes and 200 lambs for approximately nine months of the year from spring up to autumn. Lambs are usually sold through Castle Douglas auction. The farm also supplies a local butcher with saltmarsh lamb;

(ii) On the Wigtown side of the Bay, two dairy farms report grazing non-productive cattle on poor grazing quality saltmarsh areas (approximately 60-70 animals from one farm & approximately 10 animals the other). The RSPB also graze animals on the reserve at Crook of Baldoon as part of the management of the site (Section 4.14) with two farms usually grazing livestock on the reserve. One of the farmers reported grazing 59 cattle between May and October on the reserve this year. The farm doesn't consume or sell any beef locally. The other farmer reports to grazing 53 cattle on the reserve in 2017. No further information this farming activity could be obtained;

(iii) Kirkcudbright Bay: A dairy farm reported that they grazed a maximum of 30 cattle of their total herd on poor quality saltmarsh during the summer. These animals are non-milk producing heifers. They also cut approximately three hectares (ha) of improved grass from a coastal area subjected to sea spray for silage, producing approximately 100 t y^{-1} of silage for animal feed from two cuts. The farmer spends a maximum of one h d^{-1} checking animals or cutting grass during the summer;

(iv) Auchencairn Bay: Two farms reported grazing animals on saltmarsh. One farm reported grazing both cattle (approximately 20) between April and September and sheep (approximately 190) most of the year except when lambing in March and April. The other is an organic dairy farm who only graze approximately 10 non-productive animals on coastal saltmarsh. They supply a central Scotland based dairy processor with organic milk. Contact with the farmer reported that 80 litres of milk per month are consumed on the farm, between four people, but from animals that are not grazed on the salt marsh. It is reported that three farms graze some of their animals on the RSPB Mersehead reserve during the summer as part of the management of the site for wildlife (Section 4.14); and

(v) Nith Estuary: One farmer reported grazing shorthorn cattle (dual dairy and beef cattle) on Carse Bay saltmarsh near Carsethorn. They turn out a maximum of 20 animals between May and the end of September, usually to help cure lameness. Milk is sent to Stranraer for cheese making whilst 20 beef cattle were sold through Dumfries mart in the past year.

4.8 Net Fishing

In general, there has been a marked decline in net fishing activity across the survey area due to recently introduced conservation measures. Stake net posts were observed across the survey area in the intertidal zone including Wigtown-; Fleet-; and Auchencairn-Bays. However, no nets were seen to be set within or outwith the school holiday period. Some net posts were seen also at Innerwell Fisheries. It is reported that the owner of the fishing rights in the bay does not set the nets as fish no longer entered the bay.

Contact with the Galloway Fisheries Trust found that no net fishing takes place on the Rivers Cree; Fleet and Dee. However, there is a catch and release policy in place for rod anglers whereby fish must be returned to the river. It is reported that net fishing on the River Bladnoch had not taken place for a number of years. However, it is reported that a net fisherman will set nets on the River Urr this year. A local Smoke house report catching fish in the River Cree estuary by the net and cobble method.

Net fishing on the River Nith still takes place and during 2016 a total of 163 salmon and 348 trout were caught by haaf netters. However, information supplied by the River Nith District Salmon Board stated that the fish had to be released. For 2017, changes to conservation measures by the Scottish government have been made. As a result, two salmon per season per licence can now be taken by haaf netting provided each carcass is tagged. For 2017, 36 licences have been issued with the net season between 25th February and 9th September. When surveyed, two people reported having obtained salmon from a net fisherman on the river in recent years. No further information was forthcoming.

4.9 RNLI & Coastguard

The Maritime and Coastguard Agency (MCA) are responsible for coordinating maritime rescues around the coastline of the UK. There are two RNLI in-shore lifeboats plus an independent lifeboat stationed within the survey area. Details are as follows:

(i) MCA Coastguard: Within the Solway Firth, there are four MCA coastguard rescue teams, three of which are located within the survey area: Portling Bay; Kirkcudbright & Isle of Whithorn. All three are designated as water and cliff rescue teams. There are 12 people per team with each team called out on average 30 times per year. They train four times a month for approximately eight hours, of which up to two hours may be spent training in the water and six on the water;

(ii) Kirkcudbright RNLI: The station is approximately five kilometers from the town centre and located on the eastern side of Manxman's Lake but have a training base in the town. There are 13 members on the team with four crew required

to launch the in-shore rescue boat. They cover the in-shore waters from Burrow Head/Luce Bay to Sandyhills. They conduct exercises once a fortnight for up to a total of 8 hours per month, which involves spending <10% of the time in the water. On average they are called out to 12 rescues per year. Training can take place anywhere in the survey area. RNLI Workington and Ramsay, on the Isle of Man, both have all-weather boats for responding to incidents further out to sea in the area;

(iii) Kippford RNLI: The team covers the in-shore waters from Kippford eastwards to Southerness. Crew members vary between 12 and 14 with one station manager and three deputy launch authority members. The D-class in-shore rescue boat has a crew of three. The team trains four times each month all year round with each exercise lasting between one and 2 hours on the water and no more than 15 minutes in the water if a man overboard training occurs. The exercises are usually within 2 miles of the lifeboat station. According to the lifeboat station manager there were 6 rescue call outs during 2016; and

(iv) Nith Inshore Rescue Boat: Is an independent lifeboat based at Glencaple manned by volunteers. There are a total of 18 members on the team with the inshore boat manned by a crew of five. They are also a mud rescue team. They train once a month for approximately four hours on mud rescue techniques with an average of four mud rescues per year. According to their website the number of call out varies from year to year. In 2014, they were called out 22 times, 13 times in 2015 and 12 times in 2016.

4.10 Wildfowling

Wildfowling takes place in Wigtown Bay with the season between 1st September and 20th February. There are two wildfowling clubs in the survey area, both in based in Wigtown Bay. Members shoot on Wigtown Bay merse area and Creetown merse with evidence provided that one member was identified as shooting from a punt in the Cree estuary, whereby shooting is only allowed within 100 m of the shoreline. Information provided by members indicated that many live outwith the Solway Firth and travel from as far south as Yeovil. Contact with both clubs indicate the following wildfowl were shot and consumed by club members and their families: mallard; teal; widgeon; pintail

duck, pink-footed-and grey lag-goose. Several members were contacted and completed a Habits survey via telephone.

4.11 Non-Commercial Sea Angling & Shell-Fishing

The SW Scotland coastline is a popular area for sea angling with many fishing marks identified on fishing websites. Newton Stewart Angling Club reported members only fish on rivers and lochs in the area.

A local angling shop provided some information on fishing activities across the survey area:

(i) Summertime is the main fishing period with many anglers travelling from outside the area. A few locals fish in autumn and winter;
(ii) People fish from the beach for pollock, bass; dogfish; and flatfish;
(iii) People fish from rocks in shallow waters mainly for bass; and for pollock;
(iv) People fish from rocks in deeper water for coley; wrasse; and tope; and
(v) Other fish reported to have been caught includes mackerel, grey mullet, plaice and flounder.

Attempts to contact more sea anglers has proved difficult. A message for participants to complete a survey via telephone was published on the SW Scotland sea anglers' Facebook group page without success. Monitoring of the Facebook group indicates the majority of sea angling takes place in Luce Bay and Mull of Galloway.

A total of 15 individuals surveyed reported they fished offshore with a further 21 who reported fishing from the shore. However, no sea angling activities were observed across the survey area outwith the school holiday survey. During the school holiday survey, four adults and one child were observed sea angling at Isle Head, Isle of Whithorn. At Sandgreen, one person was observed bait digging with a view to fishing whilst two people were observed bait digging in Garlieston Bay. 20 sea anglers were observed taking part in a fishing competition at Abbey Burn Foot. At Kirkandrews Bay, one person reported sea angling from a boat during the summer. The face-to-face surveys noted that people fished for bass; cod; Dover sole; flounder; mackerel; plaice; grey mullet; and pollock. There is a fishing charter business based in the Wigtown Bay which also specialises in diving and wildlife tours.

Non-commercial shellfish harvesting has been reported across the survey area including mussels, cockles, razor clams, shrimps & scallops. They are reported to be collected from the Isle of Whithorn, Cairn head, Innerwell Point, Fleet Bay, Portling Bay, Isles of Fleet, Carrick Bay and Rockcliffe. Shellfish activity has been reported by the following groups of people wildfowlers, sea anglers, divers, retired commercial fishermen and members of the wider public. Table 4.2 lists where such activities occur:

Table 4.2 Locations associated with non-commercial fishing activities

Bait-Digging:
Brighouse Bay; Carrick Bay; Garlieston; Isle of Whithorn; Kirkcudbright Bay; Port O' Warren Bay; and Sandgreen.
Fishing:
Abbey Burn Foot; Auchencairn Bay; Balcary Bay; Balcary Point; Brighouse Bay; Carrick Bay; Creetown merse; Dundrennan; Fleet Bay; Garlieston; Gypsy Point; Hestan Island; Innerwell Fishery; Isle of Whithorn; Isle of Whithorn harbour; Kirkcudbright; Kirkcudbright Bay; Nun Mill Bay; Portling Bay; Rockcliffe; Sandgreen; Torr Point; Torrs Point; Wigtown; and Wigtown Bay.
Collecting Shellfish*:
Brighouse Bay; Carrick Bay; Mossyard Bay; Portling Bay; Rockcliffe; Ringdoo Point; Barlocco Island; Isle of Whithorn; and Wigtown Bay.

* Cockles, mussels, razor clams and winkles.

4.12 Wild Foraging and Seaweed

Wild food foraging has been identified at certain intertidal locations within the survey area. Areas identified includes Carrick Bay, Cardonness, Barlocco Island and Garlieston Bay. One wild forager reported collecting and consuming samphire, sea aster, sea grass, sea radish, sea kale, sea plantain, scurvy grass and seaweed from the intertidal zone. The forager also collects wild foods from above the high-water mark including rock samphire, sea buckthorn, Scots lovage and wild thyme.

A total of five people reported collecting seaweed in the past year from beach areas for fertiliser on their vegetables and fruit. The amounts of seaweed collected by individuals are detailed as follows:

(i) One individual collected approximately 50 kg from Kirkandrews Bay for fertiliser to put on vegetable plots and garden;
(ii) One individual collected approximately 100 kg from Wigtown Bay to fertilise their fruit bushes;
(iii) Two people collect approximately 20 kg from Abbey Burn Foot to fertiliser their vegetable plots. They reported collecting the seaweed fresh and rinse the salt off with fresh water prior to application. They also reported consuming cabbage; kale; lettuce; and garlic grass which has been fertilised with the seaweed this year; and
(iv) Another person collected approximately 500 kg of bladderwrack seaweed which was washed up on the beach at Kirkandrews Bay. The seaweed is either applied fresh over winter or composted first on the vegetable patch in garden or in greenhouse with two adults and one child consuming the vegetables.

During the survey, a member of the Nith Inshore Rescue Team reported that the team use seaweed to clean ropes when conducting mud rescues or training. Seaweed is used close to the activity concerned and could be anywhere from Glencaple to the Isle of Whithorn.

4.13 Aquatic Sports and Activity Clubs

The coastal area is popular with a range of water-based activities with several interest sports clubs with bases in the survey area. Three sailing; one canoe and one dive club in the survey area plus a sea cadet troupe were contacted:

(i) The Isle of Whithorn Sailing Club: Has approximately 100 members with many living outwith the area. They meet in a clubhouse on the harbour side and have regular sailing meets during the summer months. Members sail off the isle and other areas of Wigtown Bay as well as further afield. Some members also canoe and swim outdoors in the area. Boats are stored on a hard-standing area on the beach area behind the harbour;
(ii) Kirkcudbright Bay Sailing Club: Has a clubhouse and slipway on the River Dee close to the harbour. The club has approximately 62 adult members. Not all members sail. A similar number of children also sail with the club but do not have their own membership. Members sail in Fleet, Kirkcudbright & Wigtown

Bays on a regular basis between spring and autumn with some members cruising on the west coast of Scotland. The club runs a series of 12 races on the river between April and October. Boat-maintenance takes place either on the pontoons or club yard. It is reported that some members also participate in sea kayaking and open water swimming in the bay;

(iii) Solway Yacht Club: Based in Kippford with a clubhouse and hard standing area for boat storage. Contact with the membership secretary reported the club currently has 210 adult and 65 junior members. Their main area for sailing includes the tidal reaches of the Urr Water and out as far as Hestan Island. Members occasionally venture across to the south side of the Solway Firth and further west to Stranraer;

(iv) Sea Cadets Stewartry: Has approximately 24 cadet members, aged between 10 and 18 years old. The cadets are based next to the Kirkcudbright sailing clubhouse where they have their own storage compound and slipway for boat launches. The cadets undertake three activities on the same day, during fortnightly meetings: sailing, powerboating and canoeing on the tidal reaches of the River Dee. They usual spend approximately four hours doing so between the 1st March and 31st October. Boats, equipment and clothing, including wetsuits, are rinsed in the compound after each meeting on the water;

(v) Kirkcudbright Canoe Club: Has approximately 30 members, with four or five child members. The club meets on a weekly basis for canoeing and/or kayaking with sea-based activities accounting for a third of club meets. Contact with the club indicated canoes in three main coastal locations: Carrick Bay; Brighouse Bay & the Dhoon (Nun Mill Bay); and

(vi) Newton Stewart Dive Club: Has approximately 30 members with most club members live outwith the area, only visiting at weekends from spring through to autumn. The dive club moors its Rigid Inflatable Boat (RIB) in the harbour. Divers in the area reported collecting crustaceans and molluscs off Cairn Head and local wrecks for personal consumption.

4.14 Wildlife and Ranger Activities

The coastline of Dumfries & Galloway is a major attraction for ornithologists and wildlife watchers across the survey area. The RSPB; Scottish Wildlife Trust (SWT) and Wildfowl & Wetlands Trust (WWT) have coastal reserves within the survey area. Activities at the WWT Caerlaverock NNR were explored as part of the 2015/2016 Chapelcross Habits survey. Other organisations arrange coastal walks and bird ringing trips. Details are as follows:

(i) RSPB-Crook of Baldoon: Covers a large area of the Baldoon merse close to Wigtown. The merse is a mixture of established saltmarsh inland and a more open expanse of mudflats on the seaward edge. The site has a car park and a new hide but no other facilities. The warden reports visiting the site on a daily basis and also leads up to two public walks per month throughout the year. It is reported that animals are grazed on the reserve during the summer as part of the management. It was noted in the last Habits survey that rangers from Dumfries & Galloway Council also led walks during the summer onto the merse. Since then, the Council has reduced the number of their countryside rangers to one and it is unclear if any council organised walks still occur on the reserve;

(ii) RSPB-Mersehead: Located towards the eastern end of the survey area, consists of sand dunes, saltmarsh and farmland. It is popular with ornithologists and visitors. In early 2017, the RSPB extended the reserve by buying an extra 118 ha of land to manage it for Natterjack toads. The reserve has a small visitor information centre and attracts many bird watchers and nature lovers throughout the year. The land is also farmed as part of the management of the site, with cattle grazing reported on the saltmarsh during the summer months. The reserve has five full-time staff, including a farm manager, one part-time staff and three long-term (three months) volunteers. A single, short-term volunteer is rotated every two-weeks. There are also nine local volunteers. A full-time education officer is also employed at the reserve who goes into local schools and also organises up to 40 school trips per year around the reserve, generally during the spring and early summertime. The average class size is 30 but groups may be up to 60. The volunteers also lead weekly walks around

the reserve during the summer for visitors. It is possible to walk from the reserve along the sands to Southerness Point at low tide;

(iii) North Solway Bird-Ringing Group: Have approximately 30 active and 15 non-active members. Many do not live in the Solway Firth area. The main bird-ringing period for the group is between March and September with a close season between November and February which coincides with the wildfowling season. They have two, onshore ringing sites at Caerlaverock NNR and the mouth of the River Nith. Offshore, they visit three islands in the survey area once a year by boat: Hestan Island, off Auchencairn Bay is accessed from Balcary Bay; Little Ross Island is accessed from Kirkcudbright and Murray Island is accessed from Gatehouse of Fleet. Between six and 12 people are reported to visit the islands each trip;

(iv) National Trust for Scotland (NTS): Organise public walks onto the shoreline within the survey area outwith May and June which is the spring breeding time. In July and August, walks are arranged to visit Rough Island, a bird sanctuary in Auchencairn Bay, from Rockcliffe which is accessed via a beach causeway. They are also involved with Wild Oceans, a marine conservation charity, and organised a beach clean-up day which took place in June 2017; and

(v) Wildlife Tours: A sea safari company is based at a harbour in Wigtown Bay. They specialise in diving; sea fishing and wildlife-watching trips using their own boat in Wigtown Bay and also into Luce Bay. The boat is licenced to carry six passengers and one crew member. Activities occur from spring to autumn, with daily trips run during the summer lasting up to eight hours.

4.15 Holiday Parks

SW Scotland is a major holiday destination with many caravan-based holiday parks located on the coastline. In the survey area, four were contacted for information on residency times and facilities for visitors who stay at the sites:

(i) Caravan Park #1, Fleet Bay: Provides over 300 pitches for static caravans as well as providing for visiting caravans and tents. The site is open all year for owners of caravans who are allowed to stay on site for 50 weeks of the year. Contact with the holiday-park indicated that some people stay for a number of

months each year or are regular visitors throughout the year. For those hiring caravans, the site is open from March to September. Access to the beach area is through the holiday park either via a footpath or a slipway;

(ii) Caravan Park #2, Fleet Bay: The site has over 200 static caravans and is open between March and October and it is reported that most caravans are privately owned with some residents living on site for some of the season. The park promotes the use of the beach for aquatic and coastal activities such as sailing; windsurfing; and sea swimming;

(iii) Caravan Park #3, Brighouse Bay: The site is open all year and consists of both static caravans and chalets plus spaces for touring caravans and tents. Caravans and chalets can be hired although some are owned. It is reported some owners staying on a regular basis throughout the year; and

(iv) Caravan Park #4, Sandyhills: The site is relatively small and is open between April and October and it is reported that the caravans are either privately owned or available for hire. There are spaces for touring caravans and tents. It is located with easy access onto a beach.

4.16 Phase 1 Survey Results: Internal Exposure

4.16.1 Introduction

A total of 387 face-to-face surveys were completed during the two fieldwork periods in 2017. Following each phase of fieldwork, data from the face-to-face surveys were entered into a database by each respective surveyor.

4.16.2 Adult Consumption Rates

Table 4.3 presents a summary of the consumption rates for aquatic food types including; fish, crustaceans, molluscs and wildfowl. The table represent mean values for both the whole dataset and the high-rate group as well as the 97.5th percentile rates. The generic mean and generic 97.5th percentile rates based on National Habit Data is also included (Smith and Jones, 2003).

The national data values are used to compare the high-rate mean and high-rate maximum consumers within the habits survey. During the Dumfries & Galloway Habits survey it became apparent that the national data does not consider any extreme habits of consumption. For example, there may be regional or local differences in habits which may result in very different rates of consumption for fish; crustacean and molluscs which is vastly greater than the national mean and may represent an important local pathway. It may be necessary to consider that the national data cannot capture local or regional variations in habits, which may have local significance within habits-based assessment.

Adults consumed a range of fish caught within the survey area. These included: bass (16 individuals); brill (one individual); cod (9 individuals); Dover sole (five individuals); flounder (eight individuals); grey mullet (seven individuals); mackerel (32 individuals); plaice (11 individuals); pollock (nine individuals); and salmon (four individuals). It should be noted that some adults consumed more than one fish type. The observed maximum consumption by an individual (quantity x frequency) of fish was 53. 4 kg y^{-1} which included: cod; mackerel; plaice; and salmon. The fish was landed at the isle of Whithorn harbour.

Table 4.3 Summary of adult consumption rates of foods from the aquatic survey area

Food Group	Number of observations in full data set	Number of observations in high-rate group	Observed maximum for high-rate group (kg y^{-1})	Observed minimum for high-rate group (kg y^{-1})	Observed mean for high-rate group (kg y^{-1})	Observed 97.5th percentile for high-rate group (kg y^{-1})	Observed mean for full data set (kg y^{-1})	Observed 97.5th percentile for full data set (kg y^{-1})	National Data mean (kg y^{-1})	National data 97.5th percentile (kg y^{-1})
Fish	50	1	53.4	53.4	53.4	53.4	7.17	29.9	15.0	40.0
Crustaceans	17	2	72.8	64.0	68.4	72.6	13.1	69.3	4.00	10.0
Molluscs	23	1	27.6	27.6	27.6	27.6	4.03	19.0	4.00	10.0
Wildfowl	12	1	41.5	41.5	41.5	41.5	10.9	37.7	ND	ND
Salt marsh lamb	6	5	10.0	10.0	10.0	10.0	9.83	10.0	ND	ND
Game birds*	1	1	1.00	1.00	1.00	1.00	1.00	1.00	ND	ND

ND - No data

* Pheasant shot on the saltmarsh

Crustaceans were consumed by 17 individuals which included: brown crab (11 individuals); common lobster (15 individuals); prawns (one individual); and shrimps (two individuals). The observed maximum consumption rate was by a commercial fisherman, consuming 72.8 kg y^{-1} consisting of: prawns (52 kg y^{-1}); brown crabs (13

kg y^{-1}); and, common lobster (7.8 kg y^{-1}). It should be noted that some adults consumed more than one crustacean type.

A total of 23 individuals reported consuming at least one type of mollusc with the observed maximum consumption by an individual of 27.6 kg y^{-1} consisting of mussels (12 kg y^{-1}) and scallops (15.6 kg y^{-1}) collected from Cairnhead near Isle of Whithorn by a sub-aqua diving instructor. It should be noted that some adults consumed more than one mollusc type.

12 individuals consumed some type of wildfowl from the survey area, with Wigtown Bay the most common area for wildfowling reported. The observed maximum consumption rate for wildfowl by any one individual was 41.5 kg y^{-1} a local wildfowler. Wildfowl consumed by this individual included: mallard (6 kg y^{-1}); pink-footed goose (27 kg y^{-1}); greylag goose (3 kg y^{-1}); teal (3.5 kg y^{-1}); and widgeon (2 kg y^{-1}). One individual consumed one kg y^{-1} of pheasant which was shot on Carse Bay merse. A family of four adults consumed 10 kg y^{-1} of salt marsh grazed lamb each from their own farm near Creetown with another individual consuming 9 kg y^{-1} of such lamb sourced locally. No individuals were identified as eating salt marsh grazed beef cattle.

4.16.2 Children and Infant Consumption Rates

Table 4.4 presents a summary of the children's and infant's consumption rates of aquatic foods from across the survey area. Quantities of aquatic foods consumed were lower in both age groups than for adults.

A total of five children reported fish consumption with two from the same family consuming the highest quantity of 4kg y^{-1} of: bass (2 kg y^{-1}); salmon (1.5 kg y^{-1}); flounder (0.25 kg y^{-1}); and Dover sole (0.25 kg y^{-1}).

Only four children consumed crustaceans, with the highest consumption rate being 0.5 kg y^{-1} of common lobster caught by a family member who fishes commercially. Other crustaceans consumed by children included: shrimps (0.3 kg y^{-1}) and brown crab (0.09 kg y^{-1}). Molluscs consumed by children included: cockles (highest 0.3 kg y^{-1}); mussels (1.5 kg y^{-1}) and razor clams (0.3 kg y^{-1}) with highest overall consumption by an individual child being 2.10 kg y^{-1} whose family report consuming aquatic foods

on a regular basis. Neither survey identified any children consuming any wildfowl, salt marsh grazed lamb and beef or game birds.

Table 4. 4 Summary of children consumption rates of foods from the aquatic survey area.

Food Group	Number of observations in full data set	Number of observations in high-rate group	Observed maximum for high-rate group (kg y^{-1})	Observed minimum for high-rate group (kg y^{-1})	Observed mean for high-rate group (kg y^{-1})	Observed 97.5th percentile for high-rate group (kg y^{-1})	Observed mean for full data set (kg y^{-1})	Observed 97.5th percentile for full data set (kg y^{-1})
Children (6 - 15 years old)								
Fish	5	2	4.00	4.00	4.00	4.00	2.34	4.00
Crustaceans	4	1	0.50	0.50	0.50	0.50	0.50	0.49
Molluscs	2	1	2.10	2.10	2.10	2.10	1.40	2.07
Infants (0 - 5 years old)								
Fish	3	1	2.64	2.64	2.64	2.64	1.44	2.58
Crustaceans	1	1	0.24	0.24	0.24	0.24	0.24	0.24

A total of three infants were identified as consuming some fish with highest consumption by an individual being 2.64 kg y^{-1} which included bass; flounder; mackerel; and pollock caught at either Innerwell fishery or Isle of Whithorn by their father. The other two infants only consumed mackerel. One infant consumed

crustaceans (0.24 kg y^{-1}) consisting of brown crab and common lobster caught by their father at Sandgreen. No other aquatic food types were reported to be consumed by infants.

4. 17 Phase 1 Survey Results: External Exposure

4.17.1 External Exposure

The face-to-face interviews revealed that individuals take part in a range of aquatic and intertidal activities within the survey area. Occupancy rates for adults in intertidal; aquatic (in water aquatic (on water); handling rates of equipment; and handling rates of sediment can be found in Table 4.5.

Table 4.5 Summary of adult occupancy for intertidal, aquatic, handling of equipment and handling of sediment.

Activity	Number of observations in full data set	Number of observations in high-rate group	Observed maximum in high-rate group (h y^{-1})	Observed minimum in high-rate group (h y^{-1})	Observed mean in high-rate group (h y^{-1})	Observed 97.5th percentile in high-rate group (h y^{-1})	Observed mean in full data set (h y^{-1})	Observed 97.5th percentile in full data set (h y^{-1})
Intertidal	247	7	2 054	1 257	1 539	2 007	138	1 238
Aquatic (In water)	47	1	1 762	1 762	1 762	1 762	73.6	849
Aquatic (On water)	70	4	2 099	1 556	1 720	2 066	258	1 589
Handling equipment	71	5	1776	1 540	1 632	1 771	191	1 602
Handling sediment	121	4	650	624	637	650	48.5	650

A total of 247 adult individuals reported undertaking Intertidal activities across the whole of the survey area. Intertidal activities for adults included: bait digging (nine individuals); BBQ/sitting/picnicking (16 individuals); beachcombing (22 individuals); bird/nature watching (23 individuals); bird ringing (three individuals); boat maintenance (nine individuals); boat salvaging (one individual); collecting cockles (four individuals); collecting mussels (four individuals); collecting razor clams (four individuals); collecting seaweed (three individuals); collecting winkles (two individuals); crabbing (six individuals); dog walking (71 individuals); drainage ditching (one individual); farming (11 individuals); fishing (20 individuals); fixing moorings (five individuals); flying a kite (two individuals); horse riding (three individuals); jogging (one individual); metal detecting (one individual); mud rescue & training (one individual); paddling (11 individuals); painting (one individual); photography (one individual); playing (59 individuals); playing boules (four individuals); research/education (seven individuals); rock climbing (one individual); rock pooling (15 individuals); sunbathing (nine individuals); volunteering (three individuals); wild food foraging (one individual); walking (83 individuals); and wildfowling (six individuals). The highest intertidal occupancy rate for anyone individual was 2054 h y^{-1} who spent time beachcombing (Auchencairn Bay and Southerness), bird/nature watching, dog walking; and volunteering (RSPB Mersehead).

A total of 47 individual adults reported a range of in water aquatic which included: boat maintenance (two individuals); body boarding (four individuals); outdoor swimming (35 individuals); RNLI rescue duties (one individual); safety boat duties (one individual); snorkeling (one individual); sub aqua diving (seven individuals) and training and rescue duties (two individuals). The highest in water activity occupancy for an adult individual is (1 762 h y^{-1}) and included sub-aqua diving (1 760 h y^{-1}) and boat-maintenance (2 h y^{-1}) which occurred in Fleet; Wigtown; and Kirkcudbright Bays. Some individuals participated in more than one activity.

A total of 70 individual adults reported doing at least one on water activity which included: sea angling from a boat (15 individuals); being on a dive boat (five individuals); boat maintenance (15 individuals); canoeing (13 individuals); commercial fishing/creeling (five individuals); dingy sailing (two individuals); kayaking (nine

individuals); kite surfing (one individual); non-commercial fishing/creeling (one individual); power boating (nine individuals); RNLI rescue duties (two individuals); safety boat duties (four individuals); sailing (27 individuals); sport fishing (two individuals); training and rescue activities (three individuals); water skiing (two individuals); wildfowling from a boat (two individuals); wildlife tours on a boat (one individual); wind surfing (one individual); and working on a boat (three individuals). The highest occupancy for on-water activity was 2 099 h y^{-1} by an individual who ran wildlife, fishing, and sub-aqua diving tours from the Isle of Whithorn. Some individuals participated in more than one activity.

A total of 71 individual adults reported handling some form of equipment. The highest number of hours recorded for handling equipment by an individual was 1 776 h y^{-1} by a fisherman. A total of 121 individual adults were reported to undertake various activities that involved coming into contact with or handling sediment. The highest number of hours for handling sediment was 650 h y^{-1} by two adults who beachcombed in Brighouse Bay. Mud rescue training & actual rescues and metal detecting were two new activities identified in this survey.

The occupancy data for intertidal activities were used for estimating the external gamma dose rate. Selected relevant intertidal activity occupancy data were also used to derive the handling sediment category which was then used for estimating the beta skin dose rate.

Occupancy rates for children and infants in intertidal, aquatic (in-water), aquatic (on-water), handling rates of equipment and sediment are summarised in Table 4.6. A total of 59 children undertook at least one activity in the intertidal area. The highest intertidal occupancy by a child was 136 h y^{-1} and is associated with playing (48 h y^{-1}), crabbing (10 h y^{-1}) and dog walking (78 h y^{-1}).

Table 4.6 Summary of children's and infants' occupancy for intertidal, aquatic and handling of equipment and handling of sediment.

Activity	Number of observations in full data set	Number of observations in high-rate group	Observed maximum of high-rate group (h y^{-1})	Observed minimum of high-rate group (h y^{-1})	Observed mean of high-rate group (h y^{-1})	Observed 97.5th percentile of high-rate group (h y^{-1})	Observed mean of full data set (h y^{-1})	Observed 97.5th percentile of full data set (h y^{-1})
Children (6 - 15 years old)								
Intertidal	59	5	136	94.5	103	132	27.4	96.0
Aquatic (In-water)	10	1	48.0	48.0	48.0	48.0	7.49	40.1
Aquatic (On-water)	6	2	142	134	138	142	65.9	141
Handling equipment	3	1	24.8	24.8	24.8	24.8	8.41	23.5
Handling sediment	55	4	96.0	58.0	85.8	95.9	19.8	94.5
Infants (0 - 5 years old)								
Intertidal	32	1	208	136	160	204	37.4	152
Aquatic (In-water)	5	3	4.00	3.00	3.33	3.95	2.50	3.90
Handling sediment	29	5	96.0	58.0	73.2	95.4	25.4	91.8

Intertidal activities reported for children included: BBQ/sitting/picnicking (four individuals); beachcombing (three individuals); collecting shells (four individuals); crabbing (six individuals); dog walking (five individuals); fishing (one individual); flying a kite (four individuals); helping at a lifeboat station (one individual); playing boules (one individual); paddling (12 individuals); playing (39 individuals); rock pooling (15 individuals); sun bathing (three individuals); and walking on the beach (13 individuals). Helping at a lifeboat station and playing boules by children were new activities identified in this survey. Some children participated in more than one activity.

Thirty-two infants were surveyed who undertook at least one activity in the intertidal zone. Intertidal activities for infants included: BBQ/sitting/picnicking (two individuals); beachcombing (two individuals); crabbing (four individuals); dog walking (two individuals); flying a kite (one individual); horse riding (one individual); paddling (nine individuals); playing (26 individuals); playing boules (one individual); rock pooling (three individuals); and walking on the beach (six individuals). The highest intertidal occupancy by an infant was 208 h y^{-1} horse riding at Rockcliffe. Some infants participated in more than one activity.

The highest occupancy in the water for a child was 48 h y^{-1} helping with rescues and associated training at Glencaple. In water activities by children included: body boarding (one individual); outdoor swimming (nine individuals); and rescue training & rescues (one individual). The highest on water activity reported by a child was 142 h y^{-1}; and included: kayaking (8 h y^{-1}); being on a power boat (30 h y^{-1}) and sailing (104 h y^{-1}). On-water activities reported by other children included: kayaking (three individuals); power boating (two individuals); rescue training and rescues (one individual); sailing (three individuals); and stand-up paddle boarding (one individual).

A total of five infants reported in-water activities with the highest occupancy of 4 hy^{-1} swimming in the sea at Rigg Bay. The other activity reported was body boarding by a single individual infant. No infant was identified participating in any activities on the water.

The highest level for handling equipment for children was 24.8 hy^{-1} associated with fishing gear. Other activities involving handling equipment by children included: boats and boating equipment (two individuals) and clothes and overalls (two individuals).

A total of 55 children were identified who undertook activities which involved handling sediment. The highest occupancy rate handling sediment by a child was 96 h yr^{-1} whilst playing on the beach at Southerness and Sandyhills Bay. Other activities involving handling sediment included: paddling; playing; beachcombing; crabbing; collecting shells; rock-pooling; BBQ; picnicking; or sitting on the beach.

A total of 29 infants were identified as undertaking activities that involved handling sediment. The highest occupancy by an infant handling sediment was 96 h y^{-1} with the individual playing on the beach at Southerness and Sandyhills Bay. No infants were identified from the surveys who undertook any activities that involved handling equipment.

Gamma dose rate measurements over different substrates within the survey area can be found in Chapter 5.

4.18 GPS Tracking

Validation of face-to-face survey data was attempted using GPS tracker data. Only three participants, who completed a face-to-face-survey, volunteered to have their movements tracked for the study for a minimum of 6 days and then collected. Trackers were deployed and results determined that, in general, individuals over-estimated time spent undertaking some activities. The tracker for one individual was not worn for the full six-day duration therefore the survey team were unable to validate their data.

5 Direct Radiation Exposure

5.1 Introduction

A gamma-ray spectrometry survey was undertaken to estimate the dose received by the general public along the Solway Firth coastline in Dumfries and Galloway. The survey only covered the coastline and as a result, very few terrestrial roads or public areas were covered as they were not the focus of the survey. Approximately 180 miles of coastal roads were covered and over 20 predetermined intertidal areas were monitored on foot to determine dose contributions on beaches. Coverage of the survey area by the MoGGS systems is displayed in Figure 5.1.

Noteworthy, Dumfries and Galloway was known to have high deposition of Chernobyl derived ^{137}Cs in 1986, although most of which is found in the hills outside of the coastal area. It was assumed that contributions in intertidal areas, particularly saltmarshes, were almost exclusively from Sellafield. Another significant contribution to dose is likely to be received from the local geology as this area is known to have a large igneous intrusion centered on Kippford.

MoGSS data were used to help target follow up *in-situ* terrestrial air-kerma measurements, which were undertaken at all face-to-face survey locations, access point to intertidal area or at any location where an apparent anomaly was observed. Beta dosimetry was undertaken over intertidal environments to estimate the skin dose associated with the anthropogenic radioactivity in the environment. Measurements were conducted in intertidal areas spanning from Luce Bay to Kirkconnell merse RSPB reserve.

5.2 Survey Area

To measure such an extensive area, a Mobile Gamma-ray Spectrometry System (MoGSS) was utilised to measure the differential dose estimations for the natural radioelements (^{40}K and the ^{238}U and ^{232}Th series) alongside estimates for anthropogenic ^{137}Cs. All major beaches along with the coastal road network were survey. Two systems operating MoGSS were deployed in order to cover the area in

sufficient spatial detail: a backpack system and car-borne system (Figure 5.1). Details of the operating systems can be found in Appendix A2.

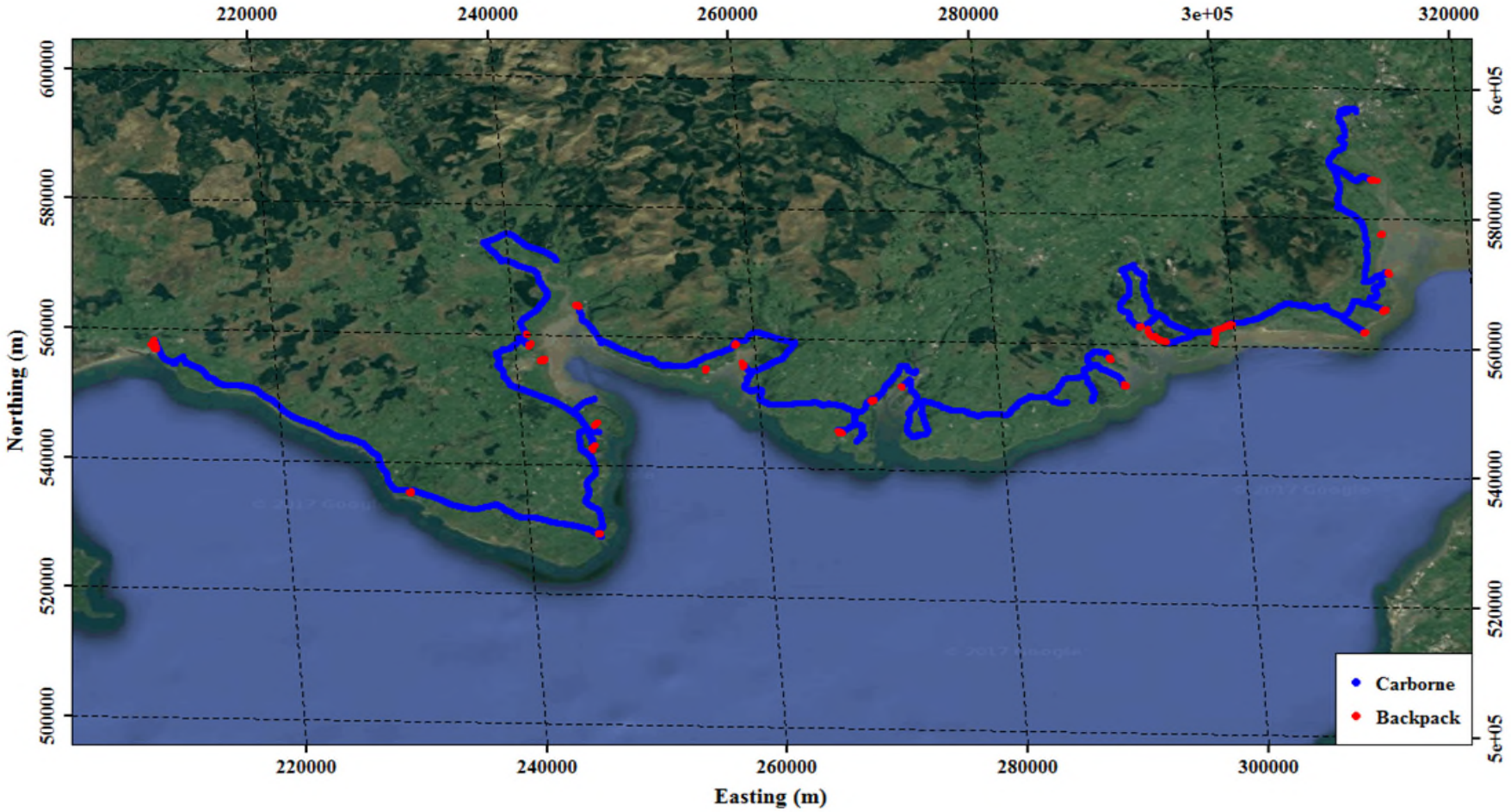

Figure 5.1 MoGSS coverage of Dumfries and Galloway survey area. Red points demonstrate the area covered using the backpack system and blue points represent roads covered by the car-borne system

5.3 MoGGS Survey Results

In total, over 12 hours of data were captured encompassing 46 256 spectral measurements. (29 606 – road survey; 15 650– backpack). Dose contribution can mostly be attributed to the natural contributions, however noticeable contributions from Cs-137 (<30 nGy h^{-1}) can be observed. Most of these were derived from backpack results taken over intertidal areas in particular the saltmarshes at Kirkconnell, Kirkcudbright and Wigtown (Figure 5.2).

Dumfries and Galloway is known to have a very distinct distribution of radioactivity due the local geology and significant inputs of ^{137}Cs from Chernobyl (mainly on elevated areas) and intertidal regions around Sellafield (Sanderson *et al*., 2004).

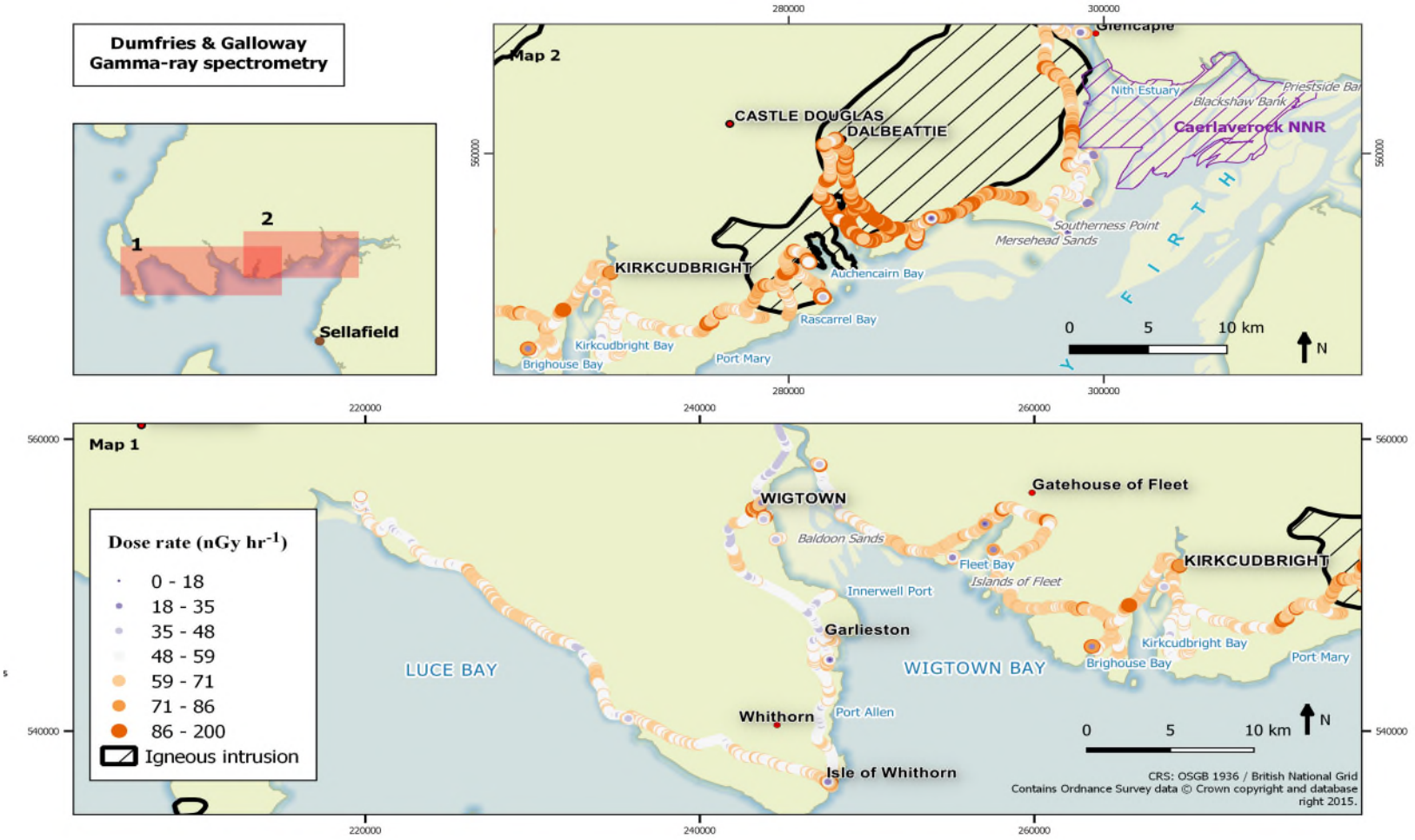

Figure 5.2 Total dose rate across the survey area

5.4 *In-Situ* Gamma Dosimetry

A total of 37 in-situ air-kerma (dose rate in air) measurements were collected at both terrestrial and intertidal sites during the survey (Figure 5.3). A UKAS accredited procedure was followed to estimate the terrestrial gamma dose rate. Since the vast majority of dose contribution was thought to be from the natural radionuclides a ^{226}Ra calibration was used to estimate dose rate for all air-kerma measurements given that ^{226}Ra occurs naturally in the environment and emits a number of gamma-rays spanning the entire environmentally relevant spectrum.

A summary of the dose rate measurements made across the site for terrestrial areas can be found in Table 5.1. The highest dose rate is found at Port ‘o’ Warren Bay, which is located near the igneous intrusion and was a pebble beach with large rocky outcrop surrounded by high cliffs.

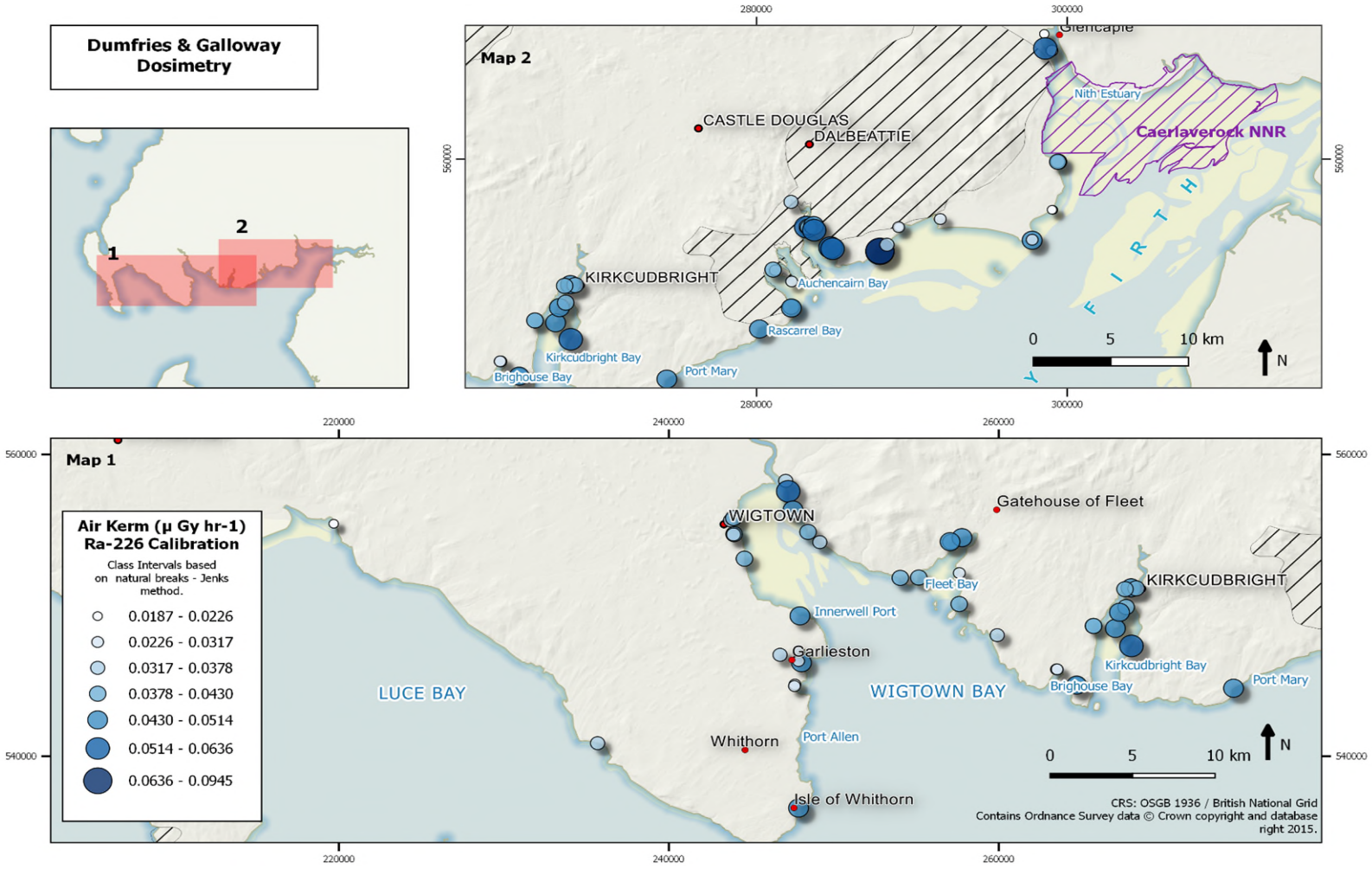

Figure 5.3 Summary of the gamma dose rate measurements across Dumfries and Galloway.

Table 5.1 Summary of gamma dose rate measurements collected across Dumfries and Galloway.

Site	Surface	Eastings	Northings	Dose (μGy hr^{-1})	2σ Uncertainty (μGy hr^{-1})
Abbey Burn Foot	Pebbles	274224	544507	0.0479	0.0044
Acherlanie	Pebbles	254026	551818	0.0387	0.0041
Balcary Beach	Mud	282218	549595	0.0412	0.0042
Balcary House	Sand	282242	549510	0.0505	0.0045
Brighouse bay	Sand	263489	545758	0.0296	0.0038
Brighouse Bay	Sand	263537	545757	0.0312	0.0039
Burnfoot	Saltmarsh	299016	567620	0.0264	0.0037
Carsethorn	Mud	299430	559809	0.0397	0.0041
Carsethorn	Sand	299384	559813	0.0371	0.004
Carsluith	Saltmarsh	247585	550792	0.0366	0.004
Carsluith	Shingle	249149	554185	0.0368	0.004
Gartshore park	Saltmarsh	267646	551072	0.0414	0.0042
Castle Cary	Rocks	247234	557553	0.0598	0.0049
Craigibhoch	Sand	257764	554486	0.0514	0.0045
Creetown saltmarsh	Saltmarsh	247080	558248	0.0376	0.0041
Crook of Baldoon	Saltmarsh	244580	553088	0.0414	0.0042
Dhoon Bay	Sand & stones	265742	548632	0.0424	0.0042
Garlieston	Concrete	248034	546197	0.0471	0.0044
Garlieston	Sand	247860	546305	0.0305	0.0038
Garlieston beach	Sand	247860	546907	0.0303	0.0038
Glen Isle	Concrete	283198	555207	0.0636	0.005
Glen Isle	Saltmarsh	283312	555205	0.0409	0.0042
Innerwell Fishery	Rocks	247942	549301	0.049	0.0045
Kippford	Rocks	283712	554987	0.0579	0.0048
Kippford harbour	Saltmarsh	283674	555314	0.0479	0.0044
Kirkandrews	Pebbles	259901	548023	0.0349	0.004
Kirkconnell	Saltmarsh	298521	568799	0.0226	0.0036
Kirkconnell merse	Saltmarsh	298583	567775	0.0536	0.0046
Kirkcudbright Marina	Concrete	268014	551159	0.048	0.0044
Kirkcudbright Marina	Grass	268322	551126	0.0416	0.0042
Kirkmabreck quarry	Rocks	247522	556314	0.0497	0.0045
Knockbrex	Pebbles	257597	550084	0.043	0.0042
Luce Bay	Sand	219687	555404	0.0187	0.0035
Manxman’s lake	Pebbles	268036	547309	0.0525	0.0046
Mersehead	Saltmarsh	291826	555773	0.0293	0.0038

Table 5.1 Summary of gamma dose rate measurements collected across Dumfries and Galloway (continued).

Site	Surface	Eastings	Northings	Dose (µGy hr^{-1})	2σ Uncertainty (µGy hr^{-1})
Monreith	Sand	235679	540867	0.0333	0.0039
Mossyard	Sand	255144	551839	0.0429	0.0042
Nun Mill bay	Sand	265731	548634	0.0393	0.0041
Old Torr	Saltmarsh	281210	552168	0.0298	0.0038
Old Torr farm	Saltmarsh	281065	552213	0.0405	0.0042
Palnackie	Grass	282218	556980	0.0378	0.0041
Port 'o' Warren Bay	Rocks	287938	553502	0.0898	0.0061
Portling Bay	Sand	288394	553966	0.0344	0.004
Powillimount	Sand	299076	556415	0.0212	0.0036
Powillimount	Sand & stones	299019	556422	0.0195	0.0035
Rascarrel Bay	Saltmarsh	280181	548033	0.0459	0.0043
Rigg Bay	Sand	247625	544701	0.029	0.0038
Rockcliffe	Sand	284890	553681	0.0561	0.0047
Rockcliffe	Sand & stones	284762	553767	0.0562	0.0047
Ross Bay	Mud	264725	544755	0.0389	0.0041
Ross Bay	Saltmarsh	264714	544714	0.0463	0.0044
Sanderness	Sand	297740	554316	0.031	0.0038
Sandgreen	Sand	257604	552137	0.0264	0.0037
Sandyhills	Sand	289147	555203	0.0276	0.0037
Skyreburn Bay	Mud	257042	554216	0.0462	0.0044
Skyreburn Bay	Sand	257083	554200	0.0405	0.0042
Southerness	Sand & stones	297738	554277	0.0478	0.0044
St Mary’s Isle	Saltmarsh	267713	549887	0.0417	0.0042
St Mary's Isle	Saltmarsh	267310	549539	0.0468	0.0044
St Mary's Isle	Stones	267062	548471	0.0498	0.0045
Torr Point	Rocks	282261	551378	0.0279	0.0037
Whithorn Harbour	Concrete	247860	536570	0.0472	0.0044
Wigtown Harbour	Grass	243938	554712	0.0374	0.0041
Wigtown merse	Saltmarsh	243740	555628	0.0359	0.004
Wigtown Saltmarsh	Saltmarsh	243925	555766	0.0386	0.0041
			Mean	**0.0409**	**0.0012**

5.5 *In-Situ* Beta Dosimetry

Beta dosimetry of skin dose [H*(0.07)] was measured over intertidal areas (stones, mud, sand and seaweed). A total of 56 measurements were made, approximately 60 % of all measurement were below the 0.2 µSv h^{-1} per cm^{-2} detection limit and thus are not summarized in Table 5.2. A total of 22 readings were found to be above this detection limit, beta doses and locations of these measurements are summarised in Table 5.2. Notice that included high dose rates are mostly associated with either mud, sand or saltmarsh. Doses are plotted in Figure 5.4.

Table 5.2 Estimated beta dose rates for Dumfries & Galloway coastal survey area

Site	Surface	Eastings	Northings	Dose (µGy hr^{-1})	2σ Uncertainty (µGy hr^{-1})
Auchenlarie Beach	Pebbles	254027	551809	0.36	0.07
Balcary Bay	Sand	282234	549612	0.2	0.08
Brighouse Bay	Sand	263547	545755	0.335	0.07
Burns Foot	Pebbles	248442	554879	0.329	0.06
Carsethorn Beach	Sand	299420	559791	0.625	0.06
Carsluith Castle	Pebbles	249153	554178	0.25	0.06
Castle Cary campsite	Mud	247230	557552	0.316	0.07
Castle Cary campsite	Rocks	247245	557548	0.513	0.08
Dhoon Bay	Sand	265737	548589	0.205	0.06
Innerwell Fishery	Seaweed	247942	549301	0.409	0.08
Kippford harbour	Mud	283650	555314	0.6	0.09
Kirkconnell merse	Saltmarsh	298599	567768	0.309	0.06
Kirkcudbright Marina	Mud	268002	551130	0.2	0.09
Kirkmabreck	Mud	247515	556296	0.273	0.07
Manxman's Lake	Pebbles	268034	547300	0.213	0.08
Mersehead RSPB	Saltmarsh	291816	555772	0.204	0.07
Mossyard Beach	Sand	255137	551815	0.46	0.07
Rockcliffe	Sand	284888	553673	0.219	0.08
Ross Bay	Mud	264753	544717	0.224	0.07
Southerness	Sand	297774	554328	0.494	0.06
Whithorn Harbour	Rocks	247800	536500	0.35	0.08
Wigtown Harbour	Mud	243934	554660	0.35	0.08

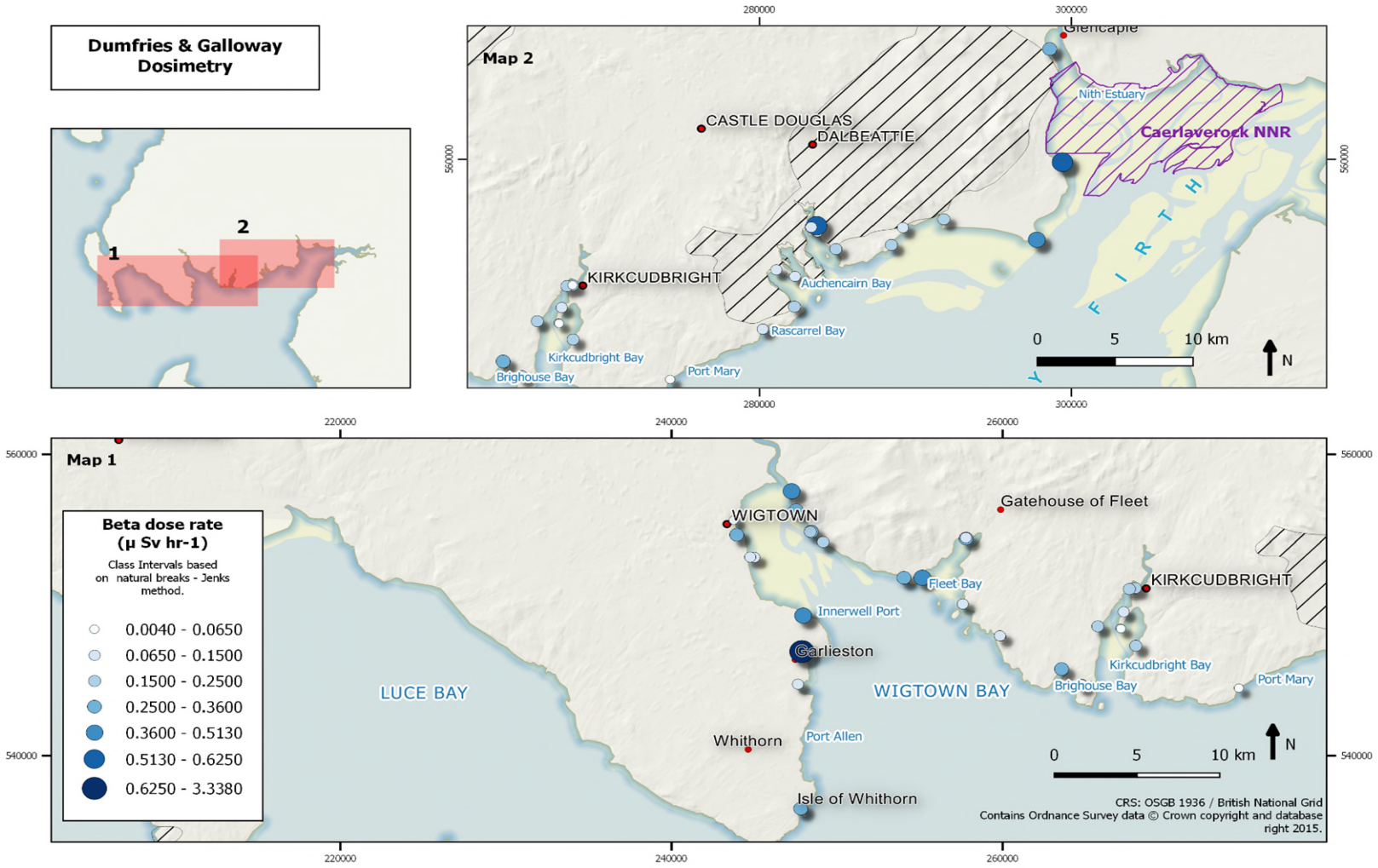

Figure 5.4 Summary of the beta dose rate measurements across Dumfries and Galloway

5.6 Occupancy Rates

5.6.1 Occupancy Data for Survey Area

The Phase 1 interviews revealed that individuals take part in a range aquatic and intertidal activities within the survey area (Table 5.3). For in-water activities, the most popular activity was outdoor swimming (44 individuals) with the highest occupancy spending 26 h y^{-1} at Garlieston. For on-water activities, sailing was the most popular pastime (44 individuals) with the highest occupancy of 702 h y^{-1} sailing either off Garlieston or Isle of Whithorn. For Intertidal activities, playing on the beach proved the most popular (134 individuals) with the highest occupancy being 104 h y^{-1} at Mersehead.

Table 5.3. Summary of the activities and total number of individuals that take part in the activities. The location of the maximum occupancy is also given.

Activity Type	Activity	Number Individuals	Maximum Occupancy (h y^{-1})	Location(s) of Maximum Occupancy
Aquatic	Sub-aqua diving	7	1 760	Fleet/Kirkcudbright/Wigtown Bay
Aquatic	Outdoor swimming	44	26.0	Garlieston
Aquatic	Snorkelling	1	6.50	Carrick Bay
Aquatic	Boat-maintenance	2	2.25	Fleet/Kirkcudbright/Wigtown Bay
Aquatic	Bodyboarding	5	1.00	Sandyhills Bay
Aquatic	Training & rescue	3	48.0	Glencaple
Aquatic	RNLI rescue duties	1	0.50	Kirkcudbright/Wigtown Bays
Aquatic	Safety boat duties	1	0.30	Kirkcudbright Bay
Aquatic	Com. fish/creeling	5	1 664	Wigtown Bay; Ross Island
Aquatic	Non-com fish/creeling	1	1 560	Wigtown Bay
Aquatic	Wildlife tours	1	1 460	Wigtown Bay area
Aquatic	Working on a boat	3	1 392	Fleet/Kirkcudbright/Wigtown Bay
Aquatic	Sailing	36	702	Garlieston; Isle of Whithorn
Aquatic	Sports fishing	2	548	Isle of Whithorn
Aquatic	Being on a dive boat	7	468	Wigtown Bay
Aquatic	Angling - Sea	15	365	Kirkcudbright Bay
Aquatic	Boat-maintenance	15	156	Kirkcudbright marina
Aquatic	Canoeing	16	117	Isle of Whithorn
Aquatic	Power-boating	11	117	Brighouse/Kirkandrews Bays

Table 5.3. Summary of the activities and total number of individuals that take part in the activities. The location of the maximum occupancy is also given (continued).

Activity Type	Activity	Number Individuals	Maximum Occupancy	Location(s) of Maximum Occupancy
Aquatic	Kayaking	13	104	Garlieston
Aquatic	Safety boat duties	7	96.0	Kirkcudbright Bay
Aquatic	Stand-up paddle boarding	1	6.50	Carrick Bay
Aquatic	Training & rescue	4	72.0	Glencaple
Aquatic	RNLI rescue duties	2	72.0	Kirkcudbright/Wigtown Bays
Aquatic	Wildfowling from boat	2	36.0	River Cree estuary
Aquatic	Water-skiing	2	20.0	Brighouse/Kirkcudbright Bays
Aquatic	kitesurfing	1	12.0	Cardonness
Aquatic	Windsurfing	1	12.0	Cardonness
Aquatic	Dinghy Sailing	2	4.00	Rockcliffe
Intertidal	Dog-walking	79	1 460	Rockcliffe
Intertidal	Walking	38	1 040	Rockcliffe
Intertidal	Fishing	84	1 095	Abbey Burn Foot/Isle of Whithorn/Wigtown
Intertidal	Volunteering	3	702	RSPB Mersehead
Intertidal	Beachcombing	27	650	Brighouse Bay
Intertidal	Bird/Nature watching	23	624	RSPB Mersehead
Intertidal	Farming	11	365	Wigtown merse
Intertidal	Research/education	7	312	RSPB Mersehead
Intertidal	Wildfowling	6	312	Maidland merse
Intertidal	Horse-riding	4	208	Rockcliffe
Intertidal	Wild Food Foraging	1	156	Across all survey area
Intertidal	Collect winkles	2	130	Wigtown Bay
Intertidal	Playing	124	104	RSPB Mersehead
Intertidal	Boat-maintenance	9	91.3	Isle of Whithorn Harbour
Intertidal	Mud rescue & training	1	56.0	Across all survey area
Intertidal	Bait-digging	9	52.0	Carrick Bay
Intertidal	BBQ/Picnicking/sitting	22	45.0	Rockcliffe
Intertidal	Painting	1	42.0	Brighouse Bay; Carrick Bay
Intertidal	Sunbathing	12	40.0	Sandyhills Bay; Southerness
Intertidal	Crabbing	16	24.0	Kippford
Intertidal	Rock-pooling	33	24.0	Fleet Bay
Intertidal	photography	1	23.0	Brighouse Bay, Carrick Bay
Intertidal	Jogging	1	18.0	Carrick Bay, Isle Mouth
Intertidal	Collect seaweed	3	12.0	Barlocco Island
Intertidal	Collect shells	4	13.0	Carrick Bay
Intertidal	Collect mussels	4	10.0	Carrick Bay, Rockcliffe
Intertidal	Rock-climbing	1	10.0	Fox Craig

Table 5.3. Summary of the activities and total number of individuals that take part in the activities. The location of the maximum occupancy is also given (continued).

Activity Type	Activity	Total No. Individuals	Maximum Occupancy	Location(s) of Maximum Occupancy
Intertidal	Bird-ringing	3	9.00	Hestan/Little Ross/Murray's Isles
Intertidal	Fixing moorings	5	8.00	Isle of Whithorn Harbour
Intertidal	Collect cockles	4	5.00	Portling Bay
Intertidal	Metal-detecting	1	5.00	Southerness
Intertidal	Paddling	34	18.0	Sandyhills Bay
Intertidal	Playing boules	6	4.50	Nun Mill /Sandyhills Bays/Southerness
Intertidal	Boat-salvaging	1	4.00	Kippford, Palnackie harbour
Intertidal	Collect razor clams	4	4.00	Wigtown Bay
Intertidal	Drainage-ditching	1	1.00	Carse Bay merse
Intertidal	Flying a kite	7	1.00	Southerness

6. Phase 2 Survey Results

6.1 Introduction

The aim of the Phase 2 surveys was to validate the Phase 1 face-to-face surveys, identify any major changes to internal/external exposure paths and to identify any new pathways within a select group of participants. These groups were determined according to the total dose received as calculated from the dose assessment tool and based on a percentage of the highest dose rate with the highest value being 100%. (Table 6.1). Dose assessment is based upon all pathways (intertidal, aquatic and marine-derived consumption).

Through discussion with SEPA it was determined that Phase 2 surveys for nine individuals (three from the high exposure group, three from the medium exposure group and three from the low exposure group) should be established.

Table 6.1 Survey comparison of aquatic food types

Dose Rate Group	Unique ID
High	A
High	B
High	C
Total in high group:*	**4**
Medium	D
Medium	E
Medium	F
Medium	
Total in medium group:*	**8**
Low	G
Low	H
Low	I
Total in low group:*	**260**

*Number of surveys from Phase 1 within corresponding dose rate banding

These groups were determined according to the total dose received as calculated from the dose assessment tool and based on a percentage of the highest dose. Sampling individuals in the Phase 2 surveys was restricted by some people not wishing to be

contacted again (when asked during the face-to-face surveys), incorrect follow-up details, or individuals not responding to approaches made by the survey team.

6.2 Phase 2 Internal Exposure

6.2.1 Internal Aquatic

Only one individual reported a change in their aquatic food consumption. The consumption of pheasant was a new food type reported in Phase 2 with individual C reported consuming 9 kg y^{-1} of the game birds not previously reported. This is included in the report due to the birds being shot by the individual on a saltmarsh. This consumption figure was verified in a follow-up contact with the individual.

6.3 Phase 2 External Exposure

6.3.1 Aquatic/Intertidal Activities

Several changes were reported in the Phase 2 surveys regarding external exposure pathways (Table 6.2). Individual B initially reported sub-aqua diving for an average of 6 h y^{-1} in Phase 1, but none in Phase 2.

Table 6.2 Survey comparison of aquatic & intertidal activity occupancies

			OCCUPANCY CHANGES:	
Unique ID & Dose Rate	**Category**	**Activity**	**Phase 1**	**Phase 2**
HIGH GROUP			**(h y^{-1})**	**(h y^{-1})**
B	In-water	Sub-aqua diving	6	0
C	Handling equipment	Boat maintenance	0	24
C	On-water	Boat maintenance	52	20
LOW GROUP				
H	On-water	Canoeing	9	9

In Phase 1, individual C reported carrying out boat maintenance on water for approximately 52 h y^{-1}. In the Phase 2 survey this had fallen to 20 h y^{-1}. Individual C also reported spending 24 h y^{-1} maintaining a boat out of the water in Phase 2 but not

in Phase 1. Individual H reported canoeing on six occasions in Phase 1 for 9 h y^{-1}. In Phase 2 Individual H also reported canoeing for 9 h y^{-1} on only three occasions.

6.3.2 Handling Equipment or Sediment

No changes to handling sediment occupancies were reported by any individual the in Phase 2 survey. An adjustment to the number of hours spent handling equipment by individual C was reported in the Phase 2 survey. In Phase 1, individual C reported handling equipment totally 100 h y^{-1} (sea fishing, 48 h y^{-1}) and (boat maintenance, 52 h y^{-1}). In Phase 2, the occupancy for sea angling had not changed but the number of hours conducting boat maintenance had fallen slightly (44 h y^{-1}).

7 Comparisons with Previous Survey

7.1 Introduction

The results for the 2017 face-to-face survey have been reported in Section 4.16 and can be compared with results from the previous Habits survey, undertaken in in 2012 by the Centre for Environment Fisheries and Aquaculture Science (CEFAS). The 2017 aquatic and intertidal survey area is consistent with the 2012 survey.

7.2 Internal Exposure Comparison

7.2.1 Adult Consumption Rates

Table 7.1 presents the comparison consumption rates for aquatic foods for the adult high dose rate group in the face-to-face surveys. In the 2017 survey, there were significant increases in consumption of fish; crustaceans; molluscs and wildfowl compared to 2012.

In the 2017 survey the main species of fish consumed in the high dose group were, in order: salmon (43.8%); cod (22.5%); plaice (22.5%) and mackerel (11.2%). Whereas in the 2012 survey the main fish consumed were, in order: cod (34%); bass (18%); mackerel (14%); plaice (10%); grey mullet (10%) and pollock (7%) plus smaller quantities of whiting; salmon; plaice; flounder; thornback ray; dab and smooth hound. It is noted that the high dose rate group consisted of one individual compared to 41 in 2012. Mean consumption in the high-rate group in 2017 were increased in fish, crustaceans, molluscs and wildfowl than in 2012.

Species of wildfowl that were consumed in both surveys were: mallard; pink-footed and greylag-goose; teal; widgeon; greylag- and pin-tail duck with pink-footed goose been consumed in highest quantities in both surveys. The highest consumption of wildfowl identified in the 2017 survey was by a local wildfowler in Wigtown Bay. Quantities of salt marsh grazed lamb consumed were comparable in both surveys. No saltmarsh grazed beef was identified in the 2017 survey.

Table 7.1 Comparison between the 2012 and 2017 surveys for adult consumption rates of aquatic foods.

	2012			2017		
Food group	**Number of observations in high-rate group**	**Observed maximum for high-rate group (kg y^{-1})**	**Observed mean for high rate group (kg y^{-1})**	**Number of observations in high-rate group**	**Observed maximum for high-rate group (kg y^{-1})**	**Observed mean for high rate group (kg y^{-1})**
Adult age group (16 + years old)						
Fish	41	30.8	18.1	1	53.4	53.4
Crustaceans	9	27.5	14.5	2	72.8	68.4
Molluscs	1	19.2	19.2	1	27.6	27.6
Wild Fowl	2	31.7	30.9	1	41.5	41.5
Salt marsh lamb	4	9.90	9.90	5	10.0	10.0
Salt marsh beef	4	35.5	35.5	-	-	-
Game birds	-	-	-	1	1.00	1.00

* Pheasant shot on saltmarsh

7.2.2 Children and Infants Consumption Rates

A comparison between 2012 and 2017 children and infant's consumption rates of aquatic foods in the face-to-face interviews is presented in Table 7.2. The 2012 survey reported higher consumption rates of fish and crustaceans compared to 2017. Molluscs were consumed however in 2017 but not in 2012.

The 2012 survey also identified more children consuming fish than in 2017. A wider range of fish species were also consumed in the 2012 survey: bass; cod; dab; flounder;

grey mullet; mackerel; plaice; pollock; salmon; smooth hound; thornback ray and whiting.

Table 7.2 Comparison between the 2012 and 2017 surveys for children and infant's consumption rates of aquatic foods.

	2012			2017		
Food Group	**Number of observations in high-rate group**	**Observed maximum for high rate group (kg y^{-1})**	**Observed mean for high rate group (kg y^{-1})**	**Number of observations in high-rate group**	**Observed maximum for high rate group (kg y^{-1})**	**Observed mean for high rate group (kg y^{-1})**
Children age group (6 - 15 years old)						
Fish	6	21.5	11.5	2	4.00	4.00
Crustaceans	2	1.50	1.50	1	0.50	0.50
Molluscs	-	-	-	1	2.10	2.10
Infant age group (0 - 5 years old)						
Fish	1	2.60	2.60	1	2.64	2.64
Crustaceans	-	-	-	1	0.24	0.24

By comparison, the 2017 survey reported children consuming: bass; Dover sole; flounder; mackerel; pollock and salmon. Lower quantities of crustaceans were also noted in 2017 survey compared to 2012. The mean of the higher consumption group in 2017 was 0.50 kg y^{-1} compared to 1.5 kg y^{-1} in 2012. Brown crab (Sandgreen); common lobster (Sandgreen) and shrimps (Kirkcudbright Bay) were consumed by children in 2017 with brown crab; common lobster and *Nephrops* consumed in 2012 caught in Wigtown Bay.

No children were identified who consumed molluscs in the 2012 survey. In 2017 two children were reported as consuming 2.10 kg y^{-1} molluscs which included cockles; mussels and razor clams caught in Kirkcudbright Bay. Neither survey identified any children who consumed wildfowl.

Both surveys identified infants who consumed some fish with comparable quantities consumed in 2012 and 2017 (2.60 kg y^{-1} and 2.64 kg y^{-1}respectively). In 2012, one individual infant consumed: bass; cod; dab; mackerel and whiting whilst in the 2017 survey, one individual infant consumed: bass; flounder; mackerel and pollock. No other aquatic food types were reported to be consumed by infants in the 2012 survey. The 2017 survey reports one infant consuming small quantities of crustaceans which were brown crab and common lobster (0.24 kg y^{-1}) caught off Sandgreen. No wildfowl was consumed by any infants in either survey.

7.3 External Exposure

The 2017 survey, external exposure was divided into the same five distinct groups as in the previous report: intertidal activities; aquatic in water activities; aquatic on water activities; the handling of equipment and the handling of sediment.

7.3.1 Adult Intertidal Activities

External exposure was divided into five groups: intertidal activities; aquatic in water activities; aquatic on water activities; handling of equipment; and handling of sediment. In 2017 the highest total intertidal occupancy for adults was determined as 2 054 h y^{-1} (on saltmarsh, sand and stones substrate and rock).

The highest occupancy on sand in 2017 was 730 h y^{-1} (two individuals) which was comparable with 743 h y^{-1} in 2012. The highest occupancy on sand and stones in 2017 was 1 460 h y^{-1} which an increase from 648 h y^{-1} in 2012. The highest occupancy on stones in 2017 was 117 h y^{-1}. Stone substrate was not identified in 2012. The highest occupancy on saltmarsh in 2017 was 1 107 h y^{-1} which was an increase from 530 h y^{-1} in 2012. The highest occupancy on mud in 2017 was 375 h y^{-1} which was a slight decrease from 565 h y^{-1} in 2012. The highest occupancy on rock in 2017 was 1 040 h y^{-1} which was an increase from 860 h y^{-1} in 2012.

7.3.2 Children and Infants Intertidal Activities

As with the adult intertidal/aquatic occupancy, external exposure was divided into five groups: intertidal activities; aquatic in-water activities; aquatic on-water activities; handling of equipment; and handling of sediment. In 2017 the highest total intertidal occupancy for children and infants was determined.

In 2017 the highest occupancy on mud substrate was 26 h y^{-1} with no mud occupancy in 2012. In 2017 the highest occupancy on rock substrate was 103 h y^{-1} which decreased from 184 h y^{-1} in 2012. In 2017 the highest occupancy on sand substrate was 126h y^{-1} which decreased from 190 h y^{-1} in 2012. In 2017 the highest occupancy for sand and stones substrate and stone substrate was 96 h y^{-1} and 10 h y^{-1} with no occupancy on these substrates in 2012. No occupancy was identified in 2017 on mud and sand substrate, mud and stones substrate and saltmarsh substrate but these substrates were all identified in 2012 (78 h y^{-1}, 6 h y^{-1} and 24 h y^{-1} respectively).

In 2017 the highest infant occupancy on sand was 126 h y^{-1} which decreased from 156 h y^{-1}. In 2017 the highest infant occupancy on mud substrate (208 h y^{-1}), rock substrate (12 h y^{-1}), saltmarsh substrate (12 h y^{-1}), sand and stones substrate (96 h y^{-1}) and stone substrate (90 h y^{-1}) was identified, but this was not identified in 2012.

7.3.3 Adult Aquatic Activities

Comparison between the 2012 and 2017 surveys for aquatic activities for all age groups are summarised in Table 7.3.

The 2017 means of the adult high-rate group for occupancy times in water were significantly greater than in 2012. These increases are most likely due to the targeting of groups of people who participate in aquatic sports such as sailing; kayak and diving clubs in the area. As a result of the targeting, the 2017 survey provides more representation of these activities across the survey area. In 2017 on water occupancy times were lower than that of the 2012 survey within the adult age group.

Table 7.3 Comparison between the 2012 and 2017 surveys for occupancy rates for aquatic activities for all age groups.

	2012			2017		
Activity	**Number of observations in high-rate group**	**Observed maximum for high-rate group ($h\ y^{-1}$)**	**Observed mean in high-rate group ($h\ y^{-1}$)**	**Number of observations in high-rate group**	**Observed maximum in high-rate group ($h\ y^{-1}$)**	**Observed mean in high-rate group ($h\ y^{-1}$)**
Adults (16+ years old)						
Aquatic (In-water)	3	105	105	1	1 762	1 762
Aquatic (On-water)	3	2 100	1 883	4	2 099	1 720
Children age group (6 - 15 years old)						
Aquatic (In-water)	4	40.0	26.5	1	48.0	48.0
Aquatic (On-water)	12	140	140	2	142	138
Infant age group (0 - 5 years old)						
Aquatic (In-water)	-	-	-	3	4.00	3.33
Aquatic (On-water)	1	40.0	40.0	-	-	-

7.3.4 Children and Infants Aquatic Activities

Comparison between the 2012 and 2017 surveys for aquatic activities by children and infants are summarised in Table 7.3.

In 2017, there was a significant increase in the mean occupancy times for children in the high-rate group for in water activities compared to 2012. However, the mean occupancy of the high-rate group for children for on water activities were very similar in both surveys. In 2017 the mean occupancy for in water activities was 3.33 h y^{-1} with no occupancy identified in 2012. Occupancy however on water was identified in 2012 (40 h y^{-1}) but was not identified in 2017.

7.4 Handling Equipment and Sediment

The 2017 mean occupancy rates for all age groups handling equipment and sediment are compared to the 2012 survey (Table 7.4)

For handling equipment, the mean occupancy of the adult high-rate group was higher in 2017 than in 2012 (1 632 h y^{-1} and 1 180 h y^{-1} respectively). These increases may be accounted due to the targeting of specific groups, such as sailors, resulting in a higher number of people surveyed in 2017 whose activities involves handling some form of equipment and or sediment. In 2017, the mean occupancy for handling sediment was increased from 2012 (1 040 h y^{-1} and 879 h y^{-1} respectively).

In 2017 the mean occupancy of the child high-rate group for handling equipment was 24.8 h y^{-1} compared to none being identified in 2012. In 2017 the mean occupancy of the child high-rate group for handling sediment was significantly increased compared to 2012.

In 2017 mean occupancy for the high-rate group for handling sediment was 73.2 h y^{-1} compared to none being identified in 2012. No handling equipment was identified in both the 2012 and 2017 surveys.

Table 7.4 Comparison between the 2012 and 2017 surveys for occupancy rates for handling equipment and sediment for all age groups.

	2012			2017		
Activity	**Number of observations in high-rate group**	**Observed maximum for high-rate group ($h\ y^{-1}$)**	**Observed mean for high-rate group ($h\ y^{-1}$)**	**Number of observations in high-rate group**	**Observed maximum for high-rate group ($h\ y^{-1}$)**	**Observed mean for high-rate group ($h\ y^{-1}$)**
Adults (16+ years old)						
Handling equipment	7	1 750	1 180	5	1 776	1 632
Handling sediment	15	1 503	879	1	1 040	1 040
Children age group (6 - 15 years old)						
Handling equipment	-	-	-	1	24.8	24.8
Handling sediment	2	21.0	20.0	4	96.0	85.8
Infant age group (0 - 5 years old)						
Handling sediment	-	-	-	5	96.0	73.2

8 Dose Assessment

8.1 Phase 1 Aquatic Radiation Pathways

8.1.1 Internal Exposure

The retrospective dose arising from internal exposure (via food sources from the aquatic environment) was used to determine the representative person from this pathway. The retrospective dose to the most exposed person from this exposure pathway is 5.5E-2 mSv y^{-1}. The dose to the (hypothetical) representative person (97.5%) is 5.3E-2 mSv y^{-1}. In the case of the most exposed person the dose arises from the consumption of locally obtained fish (30 kg y^{-1}) and crustaceans (52 kg y^{-1}).

8.1.2 External Exposure

The retrospective dose arising from external exposure (via people's habit activities in and on the aquatic environment) was used to determine the representative person from this pathway. The retrospective dose to the most exposed person from this exposure pathway is 4.5E-3 mSv y^{-1}. The dose to the (hypothetical) representative person (97.5%) is 4.4E-3 mSv y^{-1}. In the case of the most exposed person the dose arises from the handling of fishing gear (54 h y^{-1}), undertaking activities in water (1 762 h y^{-1}) and on water (464 h y^{-1}).

8.2 Phase 1 Terrestrial Radiation Pathways

8.2.1 Internal Exposure

The retrospective dose arising from internal exposure (via food sources from the terrestrial environment) was used to determine the representative person from this pathway. The retrospective dose to the most exposed person from this exposure pathway is 2.7E-3 mSv y^{-1}. The dose to the (hypothetical) representative person (97.5%) is 2.6E-3 mSv y^{-1}. In the case of the most exposed person the dose arises from the consumption of wild fowl (41.5 kg y^{-1}).

8.2.2 External exposure

The retrospective dose arising from external exposure (via people's habit activities in the terrestrial environment) was used to determine the representative person from this pathway. The retrospective dose to the most exposed person from this exposure pathway is 8.7E-4 mSv y^{-1}. The dose to the (hypothetical) representative person (97.5%) is 8.5E-4 mSv y^{-1}. The most exposed person's external terrestrial dose was derived from handling sediment (624 h y^{-1}), and walking over intertidal areas (rock, saltmarsh and sand/stones) (312, 1 040 and 702 h y^{-1} respectively).

8.2.3 Overall Combined Radiation Exposure

The retrospective dose arising from all exposure pathways (e.g. via people's habit activities in and on the aquatic, intertidal or terrestrial environments and the consumption of all foodstuffs derived locally from the aquatic or terrestrial environments) has been used to determine the representative person. The dose rate to the most exposed person from all exposure pathways is 5.5E-2 mSv y^{-1}. The retrospective dose to the representative person (97.5%) is 5.3E-2 mSv. In the case of the most exposed person, the dose was derived from consumption of locally obtained fish (30 kg y^{-1}) and crustaceans (52 kg y^{-1}) and undertaking activities that involved handling sediment (130 h y^{-1}) and spending time on water (130 h y^{-1}). These doses are all very small in comparison with the 1 mSv public dose limit. Table 8.1 contains some summarised dose information based on the average doses to different people based on age profile.

Table 8.1 Average dose estimates (mSv y^{-1}) to stylised people averaged by age (Phase 1 survey).

Age Category	Dose (mSv y^{-1})
Infant	2.10E-05
Child	9.00E-06
Adult	1.20E-03
All Age Groups	**1.20E-03**

8.3 Phase 2 Aquatic Radiation Pathways

8.3.1 Introduction

The Phase 2 surveys were undertaken in the winter of 2017 and were re-analysed to determine the dose from each radiation exposure pathway using the same approach and data groups as for the original survey to allow comparisons to be drawn between the two survey periods. The results are described below.

8.3.2 Internal Exposure

The retrospective dose arising from internal exposure (via food sources from the aquatic environment) was used to determine the representative person from this pathway. The retrospective dose to the most exposed person from this exposure pathway is 5.5E-2 mSv y^{-1}. The dose to the (hypothetical) representative person (97.5%) is 5.3E-2 mSv y^{-1}. In the case of the most exposed person, the dose arises from the consumption of locally obtained fish (30 kg y^{-1}) and Crustaceans (52 kg y^{-1}).

8.3.3 External Exposure

The retrospective dose arising from external exposure (via people's habit activities in and on the aquatic environment) was used to determine the representative person from this pathway. The retrospective dose to the most exposed person from this exposure pathway is 4.0E-3 mSv y^{-1}. The dose to the (hypothetical) representative person (97.5%) is 3.9E-3 mSv y^{-1}. In the case of the most exposed person, the dose arises from the handling of sediment and spending time doing activities on the water (1 562 and 1 555 h y^{-1} respectively).

8.4 Phase 2 Terrestrial Radiation Pathways

8.4.1 Internal Exposure

The retrospective dose arising from internal exposure (via food sources from the terrestrial environment) was used to determine the representative person from this pathway. The retrospective dose to the most exposed person from this exposure pathway is 8.0E-3 mSv y^{-1}. The dose to the (hypothetical) representative person

(97.5%) is 7.8E-3 mSv y^{-1}. In the case of the most exposed person the dose arises from the consumption of wild fowl (14 kg y^{-1}) and pheasant (9kg y^{-1}).

8.4.2 External Exposure

The retrospective dose arising from external exposure (via people's habit activities in the terrestrial environment) was used to determine the representative person from this pathway. The retrospective dose to the most exposed person from this exposure pathway is 8.7E-4 mSv y^{-1}. The dose to the (hypothetical) representative person (97.5%) is 8.5E-4 mSv y^{-1}. The most exposed person's external terrestrial dose was derived from handling sediment (624 h y^{-1}), and walking over intertidal areas (rock, saltmarsh and sand/stones) (312, 1 040 and 702 h y^{-1} respectively).

8.4.3 Overall Combined Radiation Exposure

The retrospective dose arising from all exposure pathways (e.g. via people's habit activities in and on the aquatic, intertidal or terrestrial environments and the consumption of all foodstuffs derived locally from the aquatic or terrestrial environments) has been used to determine the representative person. Table 8.2 contains some summarised dose information based on the average doses to different people based on age profile. The dose rate to the most exposed person from all exposure pathways is 5.5E-2 mSv y^{-1}. The retrospective dose to the (hypothetical) representative person (97.5%) is 5.3E-2 mSv. In the case of the most exposed person, the dose was derived from consumption of locally obtained fish (30 kg y^{-1}) and Crustaceans (52 kg y^{-1}) and undertaking activities that involved handling sediment (130 h y^{-1}) and spending time on water (130 h y^{-1}).

Table 8.2 Average dose estimates (mSv y^{-1}) to stylised people averaged by age (phase 2 survey).

Age Category	Dose (mSv y^{-1})
Infant	-
Child	-
Adult	3.70E-04
All Age Groups	**3.70E-04**

These doses are all very small in comparison with the 1 mSv public dose limit.

8.5 Dose Comparison

No dose information is provided in the 2012 report. The doses calculated for the different exposure pathways from data in the Phase 1 (during March and July) and Phase 2 (during November) surveys are provided in Table 8.3. For all pathways, and the total from all pathways, the doses for the Phase 1 survey are the same as those for Phase 2 except for the external aquatic exposure pathway, which was slightly higher in the Phase 1 survey. All doses are still well within the 1 mSv public dose limit.

Table 8.3 Comparison of doses calculated from the Phase 1 and Phase 2 survey data

	Phase 1 Survey		Phase 2 Survey	
Pathway	**97.5th Percentile Dose mSv y^{-1}**	**Maximum Dose mSv y^{-1}**	**97.5th Percentile Dose mSv y^{-1}**	**Maximum Dose mSv y^{-1}**
Internal Aquatic	5.30E-02	5.50E-02	5.30E-02	5.50E-02
External Aquatic	4.40E-03	4.50E-03	3.90E-03	4.00E-03
Internal Terrestrial	7.80E-03	8.00E-03	7.80E-03	8.00E-03
External Terrestrial	8.50E-04	8.70E-04	8.50E-04	8.70E-04
All Pathways	**5.30E-02**	**5.50E-02**	**5.30E-02**	**5.50E-02**

9 Recommendations and Suggestions for Monitoring Programme

9.1 Introduction

The Habits Survey presents results for occupancy, activity and food consumption from two main sources of community engagement: (i) face-to-face surveys (n = 387); and (ii) a number of meetings and informal contacts. These data have been supplemented with radiometric surveys including: (i) a car-borne gamma spectrometry survey (n = 29 606) and back-pack (n=15 650) were performed within the survey area; (ii) *in situ* gamma dose rate (n = 37 intertidal), and (iii) Beta skin dose assessments (n = 56).

9.2 Ongoing Monitoring

The RIFE report demonstrates a comprehensive set of monitoring undertaken annually around the Sellafield site encompassing a range of food types and environmental substrates. The gamma dose rates reported by RIFE are generally higher than those reported here because the RIFE data include the cosmic contribution to dose. This habits assessment reports the terrestrial gamma dose rate only. When taking this into account, the results are similar. The RIFE report also samples a range of food types as well as grass and sediment types.

9.3 Conclusions and Recommendations

9.3.1 Conclusions

Of all the pathways identified and considered, the highest retrospective dose for all exposure pathways was 5.5E-2 mSv y^{-1} and was the same for both the phase 1 and 2 surveys. Between the Phase 1 survey and Phase 2 survey the only pathway to change was that for the external aquatic which dropped from 4.5E-3 to 4.0E-3 mSv y^{-1}.

For the Phase 1 survey, the highest dose from internal exposure associated with the terrestrial food pathway was 8.0E-3 mSv y^{-1} arising from the consumption of wild fowl. The highest dose from terrestrial external exposure was from doses received from handling sediment, and walking over intertidal areas (rock, saltmarsh and

sand/stones) (8.7E-4 mSv y^{-1}). The highest dose from internal exposure associated with the aquatic food pathway was 5.5E-2 mSv y^{-1} arising from the consumption of fish and crustaceans. The highest dose from external exposure in the aquatic environment was from doses received by people handling fishing gear and undertaking activities in and on water (4.5E-3 mSv y^{-1}). All doses are still well within the 1 mSv public dose limit.

9.3.2 Consideration for changes to the monitoring programme

It is considered that SEPA's current monitoring programme provides adequate coverage. However, based on the findings of this habits survey, the following suggestions are presented for consideration:

(i) The discontinuation of the annual sampling of limpets at Kirkcudbright given that no consumption was identified in this and the previous habits survey;
(ii) The replacement of limpet sampling with the sampling of whelks at Kirkcudbright and off Garlieston Harbour, Wigtown Bay as they have been identified as being harvested commercially; and
(iii) The sampling of lamb annually at Creetown Merse given that several farms were identified who graze sheep on saltmarshes with two retail outlets known to sell the saltmarsh lamb.

References

Allen, J.R.L., Pye, K. (1992) Coastal saltmarshes: their nature and importance (Article) Saltmarshes pp. 1-18

Baxter, M.S., McKinley, I.G., Mackenzie, A.B., Jack, W. (1979). Windscale radiocaesium in the Clyde sea area. *Marine Pollution Bulletin.* 10(4): 116-120

Cassie, P. Marine licence application for construction project. Version 1.0. Marine (Scotland) Act 2010. 11th August 2016. Application for installation of scour protection systems around four wind turbine generators and one monopole at existing Robin Rigg OWF. https://www2.gov.scot/Resource/0050/00504679.pdf

CEC (1996). Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation. Official Journal of the European Community, 39, 1114.

Dale, P., Robertson, I., Toner, M. (2008). Radioactive Particles in Dose Assessments. Journal of Environmental Radioactivity. 99, pp. 1589-1595

Dumfries & Galloway Council Countryside Range Service. Birdwatching Leaflet. https://www.the-soc.org.uk/files/docs/local-branches/dumfries/birdwatching-in-dumfries-galloway-4th-edition-guide.pdf

Garrod C.J., Clyne, F.J., Ly V.E., Papworth, G.P. (2013). Radiological Habits Survey: Dumfries and Galloway Coast, 2012. *Scottish Environment Protection Agency Report.* 105pp.

Green N, Wilkins B.T., Hammond D.J, Davidson M.F, Richmond S, Brooker S, (2001). Foods found in the wild around nuclear sites: An evaluation of radiological impact. Radiation Protection Dosimetry. 93(1), 67-73.

Green, A.A., Berman, M., Switzer, P., Craig, M.D., 1988. A transformation for ordering multispectral data in terms of image quality with implications for noise removal. Geosci. Remote Sensing, IEEE Trans. 26, 65–74.

Harvey, M.M., Allan, R.L. (1998). The Solway Firth Saltmarshes. *Scottish Geographical Magazine*. 114(1): 42-45

Hunt, G.J. (1998) Transfer across the human gut of environmental plutonium, americium, cobalt, caesium and technetium: Studies with cockles (Cerastoderma edule) from the Irish Sea. *Journal of Radiological Protection*. 18:101-109

ICRP (2006). Assessing Dose of the Representative Person for the Purpose of the Radiation Protection of the Public. ICRP Publication 101a. Ann. ICRP 36 (3).

ICRP (2007). The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2-4).

ICRU, 1994. Gamm-Ray Spectrometry in the Environmental. International Commission on the Radiation Units and Measurements, 7910 Woodmont Avenue Bethesda, Maryland 20814, U.S.A, Maryland 20814, U.S.A

Leonard AFC, Zhang L, Balfour AJ, Garside R, Gaze WH. (2015) Human recreational exposure to antibiotic resistant bacteria in coastal bathing waters. *Environment International*. 82, 92-100.

Leonard, K.S., McCubbin, D., McDonald, P., Service, M., Bonfield, R., Conney, S. (2004). Accumulation of technetium-99 in the Irish Sea? *Science of the Total Environment*. 322(1-3): 255-270.

Leonard DRP, Hunt GJ, Jones PGW, (1982). Investigations of individual radiation exposures from discharges to the aquatic environment: the technique of habit surveys. pp. 512-517 In: 'Proceedings of the Third International Symposium on Radiological Protection - Advances in Theory and Practice', Inverness, 6-11 June 1982, Volume 2. *The Society of Radiological Protection*.

McCubbin, D., Leonard, K.S., McDonald, P., Bonfield, R., Boust, D. (2006). Distribution of Technetium-99 in sub-tidal sediments of the Irish Sea. *Continental Shelf Research.* 26(4): 458-473

McDonald, P, Cook, G. T., Baxter, M. S., & Thompson, J. C. (1990). Radionuclide transfer from Sellafield to south-west Scotland. *Journal of Environmental Radioactivity*, 12, 285-298

McKinley, I.G., Baxter, M.S., Jack, W. (1981a). Tracer applications of radiocaesium in the sea of the Hebrides. *Estuarine, Coastal and Shelf Science.* 13(1): 69-82

McKinley, I.G., Baxter, M.S., Jack, W. (1981b). A simple model of radiocaesium transport from Windscale to the Clyde Sea area. Estuarine, Coastal and Shelf Science. 13(1): 59-67.

McKay, W.A., Baxter, M.S. (1985). Water transport from the North-east Irish Sea to western Scottish coastal waters: Further observations from time-trend matching of Sellafield radiocaesium. *Estuarine, Coastal and Shelf Science.* 21(4): 471-480.

McKay, W.A., Baxter, M.S., Ellett, D.J., Meldrum, D.T. (1986). Radiocaesium and circulation patterns west of Scotland. *Journal of Environmental Radioactivity*. 4(3): 205-232.

Mackenzie, A.B., Scott, R. (1993). Sellafield waste radionuclides in lrish Sea intertidal and salt marsh sediments. *Environmental Geochemistry and Health.* 1993 15(2/3): 173

MacKenzie, A.B., Allan, R.L., Ben Shaban, Y.A., Cook, G.T, Pulford, I.D. (1994). Sediment radionuclide profiles: Implications for mechanisms of Sellafield waste dispersal in the Irish Sea. *Journal of Environmental Radioactivity.* 23(1): 39-64.

MacKenzie A. B., Cook, G. T., & Mc Donald, P. (1999). Radionuclide distribution and particle size associations in Irish Sea surface sediments: implications for actinide dispersion. Journal of Environmental Radioactivity, **44**(2-3): 275—296

NDA (2016). Corporate report. Explained: the new model for managing Sellafield.

NDAWG (2013). Use of Habits Data in Prospective Dose Assessments. NDAWG Guidance Note 7. Available from http://ndawg.org/.

Sanderson D. C. W., Cresswell A. J., Scott, E. M., Lang, J. J. (2004) Demonstrating the European capability for airborne gamma spectrometry: results from the eccomags exercise. Radiat Prot Dosimetry (2004) 109 (1-2): 119-125.

Sanderson D.C.W., Allyson, J.D., Tyler A.N., Ni Riain S., Murphy S. (1993). An Airborne Gamma Ray Survey of Parts of SW Scotland in February 1993. Final Report. Project report. Scottish Universities Research and reactor Centre Glasgow, UK.

Sanderson, D.C.W., Allyson, J.D. and Tyler, A.N. (1992) An Aerial Gamma Ray Survey of Chapelcross and its Surroundings in February 1992. Project Report. Scottish Universities Research and Reactor Centre, Glasgow, UK.

Stone DL, Harding AK, Hope BK, Slaughter-Mason S (2008). Exposure assessment and risk of gastrointestinal illness among surfers. *Journal of Toxicology and Environmental* Health - Part A: Current Issues. 71(24): 1603-1615

Tyler A., Watterson A., Dale I., Smith P., Evans L., Copplestone D., Varley A., Peredo Alverez V., Bradley S., Shaw B., Bartie P., Hunter, P. (2017). Radiological Habits Survey: Chapelcross 2015. *Scottish Environment Protection Agency Report*. 157pp.

Tyler A.N., Scott E.M., Dale P., Elliott A.T., Wilkins B.T., Boddy K., Toole J., Cartwright P. (2010) Reconstructing the abundance of Dounreay hot particles on an adjacent public beach in Northern Scotland. *Science of the Total Environment*, 408 (20), pp. 4495-4503.

Tyler, A.N. Dale, P., Copplestone, D., Bradley, S., Ewen, H., McGuire, C., Scott, E.M. (2013) The radium legacy: contaminated land and the committed effective dose from the ingestion of radium contaminated materials. *Environment International*, 59, 449-455

Tyler A.N. (1999) Monitoring anthropogenic radioactivity in saltmarsh environments through in situ gamma-ray spectrometry. *Journal of Environmental Radioactivity*, 45 (3), pp. 235-252.

www.ukclimbing.com

UK Hydrographic Office (1992): Admiralty Tidal Stream Atlas NP256: Irish Sea and Bristol Channel. Edition 4 (Reprinted 2016)

Varley, A., Tyler, A., Dowdall, M., Bondar, Y., Zabrotski, V., 2017. An in situ method for the high-resolution mapping of 137 Cs and estimation of vertical depth penetration in a highly contaminated environment. *Science of the Total Environment*. 605–606, 957–966.

Yr (2013). Service provided by the Norwegian Meteorological Institute and the Norwegian Broadcasting Corporation. Web site accessed March 2017. https://www.yr.no/kart/#lat=54.39765&lon=-4.87259&zoom=8&laga=straum&proj=3575

Appendices

Appendix A1: Site descriptions and observations

A1.1 Isle of Whithorn to Innerwell

The Isle of Whithorn is a small village situated on a rocky peninsular, based around the harbour (Figure A.1). The lower intertidal substrate is mud, whilst the upper substrate is rocky with small rocks, seaweed, pebbles and shingle. A slipway is located to the left of the harbour with access via a public car park. A children's play area is located on the coastline beyond the car park and is subjected to sea spray.

Figure A.1 Isle of Whithorn harbour (March, 2017)

The harbour is used by both commercial fisherman and leisure craft. Both a sailing and a diving club use a building on the harbour side for equipment storage and function

room. Club sailing boats are stored on a hard-standing area on the beach area behind the harbour opposite the club house. Sailing and kayaking takes place in Wigtown Bay off the harbour and several wrecks provide interest for divers. A charter boat launches from the harbour offering fishing and wildlife trips in Wigtown Bay and also outwith the survey area. The harbour side pub states they have shellfish landed in the harbour on their menu (Section 4.6).

Outwith the school holiday survey, two sailing boats; two large and three smaller commercial boats were observed moored in the harbour, with a further three boats stored in a field behind the car park. Around the harbour, two adults and two children were observed. Offshore, one commercial boat was observed outwith the school holidays. During the holiday survey, two large and two smaller commercial boats were observed in the harbour plus three fishermen. On the quayside, three divers were observed along with six adults and three children walking. Four adults and four children were observed playing and walking on the coastal path at the play area next to the harbour. It is reported that beach clean-up days are organised by the Isle of Whithorn Community Council, every two months with approximately 10 people participating.

Isle Head is a rocky headland next to the Isle of Whithorn harbour. When visited outwith the school holiday period (during Phase 1 survey), no activities were observed. During the school holiday survey, four adults and one child were observed fishing off the rocks.

No spume was observed outwith the school holiday survey. Spume was observed around the rocky headland during the school holiday survey.

Between the Isle of Whithorn and Rigg Bay, access to the shoreline is limited due to rocky cliffs with the exception of Portyerrock Bay which provided easy access to a foreshore consisting of rocky and shingle substrates. Rigg Bay is accessed via a path from Galloway house gardens. The bay consists of large area of sand with areas of pebbles and small rocks. The intertidal substrate is mainly sand with the beach backed with trees. A path follows the coastline round towards Garlieston Bay. Outwith the school holiday survey, evidence of horse riding was found in the bay with four people walking and a dog-walker observed.

No spume was observed outwith or during the school holiday surveys.

Garlieston Bay has a rocky headland on the north side and a working harbour at the south. Around the harbour and town, the lower intertidal substrate is generally sandy with mud towards the low tide zone, whilst the upper zone consists of sand, pebbles, shingle and vegetation. The shoreline is backed by a stone wall around the town and along to the old rope works. The harbour is used by both commercial fishermen (Section 4.3) and leisure craft. Outwith the school holiday survey, one whelk fisherman was observed unloading their catch. A total of five commercial boats were observed in the harbour but no leisure craft were observed on the water. No craft were observed operating offshore. During the school holiday survey, six leisure sailing or motorboats were observed in the harbour area along with three fishing boats and two dinghies. A single adult walker was observed around the harbour and two people working on a sailboat.

Around the harbour the area is hard standing with housing developments and a caravan site, 63 pitches for touring caravans and motorhomes on the coastline close by. At the time of the first survey visit, the site was closed. During the school holiday survey, the campsite was busy with visiting caravans and motorhomes.

No spume was observed outwith or during the school holiday surveys.

Northwards, along the coastline from the town, as far as White Isle, the lower intertidal zone is characterised by sand, stones and mud. The upper intertidal area is sand and pebbles backed with grass up to roadside and a seawall with two areas of marshland vegetation. Beyond the main town, two new houses have been built on the site known as the old rope works. The northern end of the bay is a rocky headland with a coastal path signposted to Innerwell. No activities were observed onshore or offshore at the time of the visit outwith the holidays. During the school holiday survey, three dog-walkers; two walkers; and two bait diggers were observed in the bay.

No spume was observed outwith or during the school holiday surveys.

The shoreline from Garlieston to the small bay at Innerwell is rocky with no easy access to the shore. It was reported locally that wreck diving and fishing offshore is popular along this stretch of coastline.

A1.2 Innerwell to Carsluith

The shore at Innerwell is accessed from a single-track road via a path leading down to the upper intertidal zone consisting of shingle, pebbles and rocks of varying sizes with some covered with seaweed and rocky headlands at either end. The lower zone, exposed at low tide, is sand and mud (Figure A.2). Stake nets post were observed near the bay but no nets. Anecdotal evidence indicates net fishing no longer at Innerwell takes place. No onshore or offshore activities were observed outwith the school holiday survey. During the school holiday survey, two adult cyclists were observed sitting on the beach picnicking and two adult dog-walkers were also seen.

No spume was observed outwith or during the school holiday surveys.

Beyond Innerwell, no access to the shore is possible, due to enclosed farmland, until the RSPB Crook of Baldoon reserve. The reserve forms part of the Wigtown Bay local nature reserve which extends around Bladnoch sands, the River Bladnoch, Wigtown Sands and the Cree estuary. Wildfowling from the shore across the reserve has been reported and on the water from a punt in the Creetown estuary area during the season (Section 4.10).

Figure A.2 Innerwell Bay (July 2017)

The coastal section consists of a large area of established saltmarsh closer to the landward side and mudflats on the seaward side (Figure A.3). There are several well-defined access points to the nature reserve including from the car park at RSPB Crook of Baldoon reserve which is popular with nature watchers (Section 4.14), walkers and dog-walkers. It is reported that two farmers graze cattle during the summer as part of the management of the site with each farmer having 59 and 53 cattle on the reserve between May and October each year. A dog-walker and six walkers were observed when visited outwith the school holiday survey. A farmer was observed on a quad bike tending to his 59 cattle during the school holiday survey. It is possible to walk along the coastline towards the River Bladnoch at Wigtown opposite the harbour, however, no access across the river was possible.

No spume was observed outwith or during the school holiday surveys.

Figure A.3 Section of Wigtown merse with summer grazing cattle as seen from the RSPB Crook of Baldoon reserve (July 2017).

At Wigtown harbour, there is a public car park with footpaths leading onto the wetlands behind the coastline. The area around the harbour has been known to flood on very high tides. The harbour has mooring posts for boats and there are two slipways allowing boats to be launched. Steep mud banks do not allow safe access onto the riverbanks. No boats were observed in the harbour when visited outwith the school holiday survey. However, one dog-walker and two walkers were observed, with six people sitting in their cars by the harbour. During the school holiday survey no activities were observed in the harbour area. During an additional visit, outwith the two main surveys, it was observed that the harbourside area was inundated with seawater due to a high tide.

No spume was observed outwith or during the school holiday surveys.

A short footpath leads from the harbour to a bird hide overlooking Wigtown merse close to the left-hand bank of the River Cree. Access to the saltmarsh beyond the bird hide is restricted due to farmland fencing and drainage channels. Outwith the school holiday survey no activities offshore were observed in this section of the merse. During the school holiday survey visit evidence of drainage improvement was observed on the saltmarsh area, approximately 200 m from the bird hide. No other activities were observed in the area.

No spume was observed outwith or during the school holiday surveys.

Figure A.4 Martyr's Stake and Wigtown merse (March 2017)

Behind the harbour area, a public footpath along the old railway line allows access between the ends of the ponds near the harbour to the Martyr's Stake and the wider saltmarsh with additional access from a public car park near the stake and a boarded footpath (Figure A.4). A single dog-walker was observed on the railway line when

visited outwith the school holiday survey. No activities were observed on the saltmarsh near the Martyr's Stake during the school holiday survey.

Access to the northern section of the reserve, close to the left bank of the River Cree, is restricted due to farmland and drainage channels. No activities were observed offshore in this northern section and no spume reported. Stake net posts were seen but no nets were set during either survey.

Contact via telephone identified three farms that grazed either cattle or sheep on some part of the Wigtown Bay reserve over the summer months with the latter grazing on the Creetown merse area as part of the management of the area (Section 4.7). When visited during the school holiday survey, sheep were observed grazing on the saltmarsh on the right-hand bank of the River Cree. Wildfowling from the shore across the reserve has been reported and on the water from a punt in the Cree estuary area during the season (Section 4.10). Within Wigtown Bay, two wildfowling clubs are active during the season on both Wigtown merse and Creetown merse. When contacted, one member reported wildfowling in the Cree estuary from a narrow, flat bottomed boat (punt) within 100 feet of the shore as required by the permit.

The coastline from the end of the Creetown saltmarsh to Creetown Old Quay is characterised by mudflats on the lower intertidal areas alongside the river channel, which are covered by high tides. The upper intertidal zone is mud, sand, seaweed and stones with large boulders closest to the road acting as sea defences in places. Access down to the shore is limited in places due to dense vegetation cover.

From the Old Quay to the Kirkmabreck Quarry Quay a small area of salt marsh is known to be grazed by sheep. Several footpaths crisscross the Quarry Quay with limited access along both flanks due to steep banks and/or stone walls and large boulders for sea defences. There is no access onto the riverbank at the end of the quay itself due to a high seawall. Ouwith the holiday survey, four dog-walkers were observed on the quay.

No spume was observed outwith or during the school holiday surveys.

The next access onto the shoreline is opposite Galloway Smokehouse at Carsluith, where a footpath leads down to the shore. Net fishing posts were visible on the beach

here but no nets at the time of both survey periods. The intertidal zone consists of mudflats below the low watermark combined with mudflats, sands, pebbles and seaweed on the upper intertidal area backed with vegetation to the A75. No activities onshore or offshore were observed during either survey periods. Access is generally restricted until the small coastal hamlet of Burn's Foot, due to enclosed farmland, walls, fences and thick vegetation.

No spume was observed outwith or during the school holiday surveys.

A side road opposite Carsluith leads down to the hamlet of Burn's Foot where a small bay is enclosed by headlands at both ends (Figure A5) and backed by a short coastal road. Substrates in the lower intertidal zone consist of mudflats, seaweed and stones; the middle section has seaweed covered rocks and saltmarsh vegetation.

Figure A5 Burn's Foot, Carsluith (March 2017)

The upper intertidal zone is shingle, crushed shells and sand with large boulders providing sea defences for the properties. Access to the shoreline is readily available

along the coastal road. A private road extends beyond a bridge over a stream. A number of stake net posts were seen in the area. No activities were observed onshore or offshore during either survey periods.

No spume was observed outwith or during the school holiday surveys.

No further access to the coastline is possible until a rough farm track near Carsluith Castle is reached. The track leads down to a shoreline of sand, rocks, seaweeds and a tide mark of crushed shells. The area is backed by trees and shrubs. No activities were observed onshore or offshore during either survey period.

No spume was observed outwith or during the school holiday surveys.

A1.3 Carsluith to Isle Mouth

No further access onto the intertidal zone was seen until the Mossyard area, where two holiday parks (Section 4.15) are located, separated by a rocky headland known as Ringoo Point. Access to the beach areas is through the holiday parks either via footpaths or a slipway. The coastline is rocky with a couple of sandy bays for holiday makers to use. Access to Mossyard Bay and Ringoo Point can also be made via a side road off the A75 and then a farm track to a public car park behind a sandy bay. No activities in the intertidal zone or offshore were observed outwith the school holiday survey. No spume was observed outwith the school holiday survey. During the school holiday survey there was a noticeable increase in people staying at the caravan sites, however, no activities were observed on the beach at the time of the visit. A single sailboat was seen offshore from Mossyard Bay.

It is reported in the angling press (www.fishpal.com) the area is a good spot for fishing between May and September such as at Ravenshall and Ringoo Points. No activities in the intertidal zone or offshore were observed outwith the holiday.

No spume was observed outwith or during the school holiday surveys.

Fleet Bay is a sandy expanse across much of the bay with mudflats covering the head of the bay from Skyreburn Bay. The outer area of the bay is a popular holiday destination with several large holiday caravan-parks mainly on the left-hand side of the bay offering up to 200 holiday homes. These caravan parks tend to cluster around

smaller sandy bays divided by rocky promontories and stretches of inaccessible rocky coastline. Access to the beaches are predominantly via the caravan sites themselves. Activities reported by people staying at one of the caravan parks include: sailing; canoeing; windsurfing; and kitesurfing. No shore-based activities were observed outwith the school holiday survey. No activities were observed from nearby Skyreburn Bay during the school holiday survey. Posts for net fishing were observed near Cardonness but no nets were seen.

Beyond the caravan parks lies Skyreburn Bay where a roadside cafe, on the southern end of the bay allows easy access onto the coastal area. The coastline is characterised by a grassy area in the upper reaches of the bay leading to sandy beaches with mudflats further out in Fleet Bay. No activities were observed on the shoreline area behind the café outwith the holiday survey. It was reported that people have been observed playing cricket or rounders on the beach behind the café from time to time along with seaweed collecting. During the school holiday survey, one dog-walker was observed on the beach area behind the cafe.

No spume was observed outwith or during the school holiday surveys.

The central area of Skyreburn Bay is bisected by a wide stream with an extensive area of coastal grasses close to the road which gives way to saltmarsh vegetation and then more mudflats. This central area is readily accessed by climbing over the roadside crash barrier. During the school holiday survey, approximately 10 sheep were observed grazing on the saltmarsh area. The surveyors have been unable to establish if they are part of a deliberate grazing policy or if they had escaped from elsewhere.

No spume was observed outwith or during the school holiday surveys.

At the north end of the bay two further roadside lay-bys are ringed with mature trees and enable access to the shoreline area (Figure A6). Here, the upper intertidal zone is sandy with a marked boundary of mud and sand where reeds and saltmarsh grasses grow in the mid-intertidal zone. The lower intertidal zone is mud. Large rocks also prevail in the area. No activities were observed across the northern end of the bay either, onshore or offshore, during either survey periods.

No spume was observed outwith or during the school holiday surveys.

Figure A6 North side of Skyreburn Bay (March 2017)

Access around the head of the bay is restricted due farming activity on both sides of the estuary of the River Fleet, with fields fenced off. The shoreline consists of saltmarsh vegetation and improved grassland up to where the A75 crosses the River Fleet. On the eastern side of the bay, the shoreline is also characterised by a thin saltmarsh extending past Rough Point, behind which there is a thin strip of unimproved grasslands, shrubs and one section of woodland. No farms have been identified that graze animals on the saltmarsh areas. There is no access along the eastern side of fleet Bay until Airds Bay, Sandgreen.

The shoreline at Airds Bay is sandy and is surrounded by a caravan park that promotes the use of the beach for aquatic and coastal activities such as sailing, windsurfing and sea swimming. The park is open between March and October with most caravans privately owned and with some residents living on site for some of the season. Outwith the school holiday survey, one dog-walker was observed.

During the holiday survey the beach area was busy with people. The range of activities and numbers of people observed included: 11 adults walking; four adults and seven children playing; 10 dog-walkers and one bait digger/fisherman. A tractor and driver was also observed on the beach emptying bins from the caravan park. A volleyball net was also set up on the beach. Quad bike tracks were also noted on the beach. Pulled up on the shoreline above the high-water mark were seven rowing dinghies; eight kayaks and two surf boards. Offshore, one motorboat, one SIB (Soft Inflatable Boat) and five sail boats were observed. During one visit, five people were observed sailing and one person on the SIB.

No spume was observed outwith the school holiday survey. Spume was observed during the school holiday survey visit.

From Airds Bay to Isle Mouth the shore is rocky with headlands and sandy bays. Above and behind the shoreline a narrow strip of scrub and unimproved land makes it possible to walk this zone. The area is popular with sea anglers with Carrick Point a well-known fishing mark. Offshore, three small islands: Murray's Isles, Ardwell Isle and Barlocco Isle are known as the Islands of fleet. It is also possible to walk to Ardwell Isle at low tide. Easy access to the coast- and shoreline from Sandygreen to Isle Mouth is possible via a rough track from the west which meets a metalled road from Knockbrex. Several ornithologists reported visiting Barlocco and Murray's isles once a year to ring birds sometime between March and October.

Carrick Bay is a secluded sandy bay with Carrick Point, a rocky promontory extending out to sea (Figure A7). Holiday homes surround the beach area allowing easy access onto the intertidal area. Sea anglers are reported to fish at Carrick Point, however, no fishing activities were observed during either survey.

Figure A7 Carrick Bay (July 2017)

Reported activities at Carrick Bay include beachcombing, walking, paddling, rock pooling, birdwatching and sea swimming. Carrick is also known to attract rock-climbers, mainly in the summer. It has been reported that crushed shells/grit from the beach at Carrick have been used infrequently to feed to chickens to help with egg production. No further information could be obtained by the survey team. At Carrick Bay, 14 adults and six children were observed playing and one dog-walker on the beach outwith the school holiday survey. On the track immediately behind the beach four cyclists were observed outwith the holidays. During the school holiday survey, two adults were observed walking on the beach; one dog-walker; two children and one adult playing on the beach. Offshore, four sailing dinghies were observed.

Spume was observed around the rocky shoreline outwith the school holiday survey. No spume was observed during the holiday survey.

Close by, Isle Mouth is a small bay with rocky headlands. Behind the beach, a grassy area acts as a car park. Grass and scrub slope down to the upper shoreline where the substrate consists of pebbles, shingle and sand with larger rocks interspersed around the bay. The lower intertidal zone is sand which extends out to Ardwall Isle and around to Barlocco Isle. A road sign warned that cattle grazed on the coastline but not during July and August. Efforts to identify the farmer have proved unsuccessful. No onshore or offshore activities observed outwith the holidays. During the school holiday survey, two adults were observed walking on the beach with one adult and two children playing on the beach.

No spume was observed outwith or during the school holiday surveys.

A1.4 Isle Mouth to Kirkcudbright

The next section of coastline as far as Kirkandrews Bay continues to be rocky and can be accessed across fields and open scrubland as far as Castle Haven Bay. A gated farm track from the main road also allows entry to this bay. The coastline at Kirkandrews Bay is gained through a farmer's field from the end of the road in the hamlet with a defined track nearer the shore. The bay is enclosed by rocky headlands with the lower intertidal zone consisting of several large rocky outcrops and sand. Seaweed covered many of the rocks. The upper intertidal zone comprises shingle, sand and crushed shells and bands of dead seaweed.

The shoreline backs onto scrub and grass with agricultural land behind. Outwith the school holiday survey two small boats were observed laid-up in the field close to the shoreline, (Figure A8) one of which was a working boat. The other boat did not look seaworthy. Above the high-water mark two small dinghies were also observed. A decaying boat resides in the intertidal zone to the east of the bay. Outwith the school holiday survey, no activities were observed onshore or offshore. During the school holiday survey, a second commercial fishing boat was observed laid up in the field along with a tractor, used to launch and retrieve the boats.

Figure 4.8 Fishing boats at Kirkandrews Bay (July 2017)

It has been established that one of the boats is used by a commercial razor clam fisherman and the other by a creel fisherman catching lobster (Section 4.3). During the school holiday survey, no activities were observed offshore or on the intertidal zone.

No spume was observed outwith or during the school holiday surveys.

The following five kilometres of coastline to Brighouse Bay is rocky with no obvious access points due to enclosed farmland. Brighouse Bay is an enclosed sandy bay with rocky headlands and rocky strips along the sides of the bay (Figure A9). It is utilised by day-trippers and holidaymakers who rent or own a caravan on the holiday park sited on the western side of the bay. The lower intertidal zone is sand whilst closer to the high tide line the shoreline is more shingle with a stream entering the central area of the bay. Close to the caravan park, public toilets and a car park allow easy access to the central sandy area of the bay whilst another footpath follows the

coastline before turning inland through a wooded area to the caravan park. There is a slipway from the caravan park. Behind the central beach is an area of scrubland, shrubs and unimproved grass. The eastern side of the bay has a slim coastal zone of grasses and scrubland with a couple of houses close to the shoreline. Contact with an equestrian centre near the bay indicated they were not allowed to ride horses on the beach. Outwith the school holiday survey, the bay was relatively quiet with two dog-walkers and four people walking observed. Visits during the school holiday survey observed: one dog-walker; two people camping on the beach; and two adults walking.

No spume was observed outwith or during the school holiday surveys.

Figure A9 Brighouse Bay (July 2017)

From Brighouse Bay the coastline continues to be rocky with scrub dominating behind the high tide mark. There appeared no obvious access to the intertidal zone with the exception of a farm track from Ross Bay to near Fauidbog Bay. The track continues towards the headland at Fox Craig. Another farm track from eastern end of Ross Bay

allows an alternative access point to Fox Craig. According to *UKClimbing*, a climbing website, there are over 100 hundred climbs on the rocks around the headland and is said to be a popular venue for climbers. No climbing activity was observed during either survey. Sea angling from the headland has also been reported. No fishing activity was observed during either survey.

No spume was observed outwith or during the school holiday survey.

Ross Bay forms part of the larger Kirkcudbright Bay with a public road allowing easy access around the hamlet and onto the intertidal zone. The lower intertidal zone is sand and mud whilst the upper area consists of rocks with some covered by saltmarsh grasses (Figure A10). Large boulders have been deposited on the shore in front of the houses to act as sea defences. The head of the bay, beyond the houses, is covered by saltmarsh vegetation with shrub and then farmland behind.

Figure. A10 Ross Bay (July 2017)

A scrap/engineering yard is located on the coastline by the hamlet in Ross Bay. Most of the buildings in the hamlet are holiday-lets known as Ross Bay Retreat. There is a large farm building behind these holiday lets. Several Bird-ringers reported visiting Little Ross Island once a year to ring birds with a boat launched from Ross Bay. On the road behind the beach, two dog-walkers plus two walkers were observed walking outwith the school holiday survey. Beyond Ross Bay Retreat a farm track follows the head of the bay to a small parking area providing access on foot to Fox Craig. Near this parking area, two or three mobile homes/caravans were parked on the coastline when visited during the school holiday survey.

No spume was observed in the bay outwith or during the school holiday surveys.

The next four kilometres of the western side of Kirkcudbright Bay are rocky with woodland behind. No easy access to the shoreline was seen along this stretch, although one person surveyed reported walking on the shoreline at Senwick Bay. Access to this bay is not obvious and may be possible via a farm track from upper Senwick.

Beyond Senwick Bay, the next readily accessible point is approximately 1.5 km further along the coast at Nun Mill Bay which is also known as the Dhoon. The coastline at Nun Mill Bay forms a small sandy bay with a rocky headland which is popular with visitors. Toilets, a car park and grassy picnic area are immediately behind the beach allowing easy access directly onto the shore. A couple of houses are very close to the coastline and one walker was observed outwith the school holiday survey. During the school holiday survey visit, ten adults and seven children were observed playing on the beach along with one dog-walker. A campervan was observed parked on the grassy area behind the beach.

No spume was observed outwith or during the school holiday surveys.

Nearby, a holiday park caters for both visiting caravans and campers as well as having static caravans for hire. It has been reported that nearby in Jock’s Bay, sea angling takes place from rocks at a location known as the Shoulder o’ Craig. No fishing activity was observed during either survey.

Beyond Jock's Bay, access to the shoreline area is restricted for 500 m due to vegetation and a steep bank until a parking bay allows access onto the coastline. The lower intertidal zone comprised mud flats nearer the River Dee channel, then shingle in the upper intertidal zone which is backed by a grassy strip up to the roadside bank. A line of trees also screens the beach from the road in places. At the end of the trees a line of net fishing posts were also observed in the area. No nets were seen to be set during either survey period. No activities onshore or offshore were observed at the time of both surveys.

No spume was observed outwith or during the school holiday surveys.

Beyond the line of trees, access to the intertidal area all the way to Kirkcudbright is restricted by fenced farmland. On the west side of the bay opposite Kirkcudbright marina, a bend in the River Dee is marked by an inaccessible saltmarsh which extends round to the bridge over the A75 which links both sides of Kirkcudbright.

From here, no further access onto the coastline or intertidal zone is possible due to a steep bank and then enclosed fields which extend round a bend in the river at the head of the bay up to where the A75 crosses the River Dee. Between the enclosed fields and the river channel an area of saltmarsh extends and expands around the bend in the River Dee opposite Kirkcudbright marina up to where the A75 crosses the river at Kirkcudbright. Whilst passing this area during the Phase 2 survey, a small herd of cows were observed grazing on the saltmarsh opposite Gartshore Park with further cattle grazing on the saltmarsh.

Kirkcudbright is the main fishing port of the survey area with scallop fishing the principal catch landed there (Section 4.3). A marine engineering company is located nearby on Dee Walk who design and manufacture equipment for scallop fishing. The RNLI have an inshore lifeboat stationed nearby on Manxman's Lake, with a training centre on Dee Walk in the centre of Kirkcudbright from where team members initially meet for a rescue before driving to the lifeboat station. At the quayside three people were observed working on boats, another three repairing another boat, eight walking past, and two working in the harbour office outwith the school holiday survey. During the school holiday survey, the harbour area was busier with holidaymakers and

commercial boats in the harbour. During one visit, scallops from several commercial boats were seen to be loaded onto a trailer prior to be taken to nearby processors.

No spume was observed outwith or during the school holiday surveys.

A1.5 Kirkcudbright to Palnackie

Along the coast from the main harbour area, Kirkcudbright marina has a floating pontoon (Figure A11). Over 20 leisure craft were observed moored on the water, with a further 11 resting on the mud banks outwith the holidays. A single sailor was observed on the pontoons outwith the holidays.

No spume was observed outwith or during the holiday surveys.

There is a slipway for launching boats from Kirkcudbright Bay Sailing Club whose clubhouse and storage yard are located here. Members tend to sail within the bay area with the club holding a series of 12 races between April and October (Section 4.13). It is reported that some members also canoe; row; and swim in Kirkcudbright Bay whilst others also sail in Wigtown Bay and further afield.

Figure A11 Kirkcudbright slipway and marina pontoons (March 2017)

Around the corner from the marina, the coastline forms a bend in the river where Gartshore Park is located. The lower intertidal zone is mud flats with seaweed and pebbles on the upper zone. A stepped bank separates a coastal vegetation strip of unimproved grasses from the pebbled and seaweed area. Ready access to this area is through the park at various places with a footpath leading along the coastline past a sewage works, football ground, on towards a housing estate and a forested area. Evidence of inundation by the sea onto the path area was observed with a seaweed strandline. No activities were observed outwith the holidays. During the school holiday survey, one dog-walker was observed on the path.

No spume was observed during or outwith the school holiday surveys.

From near the football ground, the intertidal zone changes to saltmarsh which stretches over 100 m out into the river channel and south towards St Mary's Isle. Access to the western shoreline of the isle can be made via a metalled road which

leads to several houses. At the slate harbour, the intertidal zone consists of mud flats with pebbles higher up the beach with seaweed and saltmarsh vegetation. A raised bank of pebbles is behind the saltmarsh vegetation. A sign-posted footpath from the metalled road enables walking around the isle with various access points onto a rocky shoreline round to the Point of the isle.

Fig A12 Point of the Isle, St Mary's Isle (March 2017)

The Point is rocky with access onto an area sheltered by a small wooded island (Figure A12). The lower intertidal zone comprises substrates of mudflats in the wider bay, with sand, mud, rocks, seaweed in the mid intertidal zone with saltmarsh vegetation and pebbles across the upper zone. From the Point, a rough track/footpath follows the coastline back towards Kirkcudbright. Outwith the school holidays, one dog-walker was observed.

No spume was observed outwith or during the school holiday surveys.

Manxman's Lake, to the left of St Mary's Isle is a bay consisting of exposed mudflats at low tide. The northern end of the bay is dominated by saltmarsh with no access readily identified until the east side close to where the A711 runs. Seats have been provided along the east side close to the A711 allowing views across to St Mary's Isle. Limited roadside parking and steep banking may restrict access to the saltmarsh area of the intertidal zone, except where a muddy layby enables access to a footpath which leads along the coastline to Mutehill Bridge. No activities were observed onshore or offshore in the bay outwith or during the school holidays.

No spume was observed outwith or during the school holiday surveys.

A metalled road from Mutehill Bridge follows the coastline to a location marked on the map as the Lake. The road allows easy access along this section onto the intertidal zone where mudflats form the lower zone with sand and saltmarsh in the upper zone. A sloping pebble bank protects the road. Where the road turns inland, wooden steps allow access onto the beach area. Outwith the school holiday survey, two dog-walkers were observed on the beach.

No spume was observed outwith or during the school holiday surveys.

From the Lake, the coastline becomes rocky with no access to the shoreline. A rough track leads to the RNLI lifeboat station from which a footpath leads onto Torr Point, a fishing mark. No fishing activity was observed during either the survey period.

The next section of coastline is not readily accessible, being very rocky but also forms part of the MOD Dundrennan. Access to Torr Point at the eastern end of the range was not permitted during live firing exercises. It was reported that a lobster fisherman has pots off the coast near the site. Access to Abbey Burn Foot and Port Mary Bay is possible outwith live firing exercises. Both locations are a small rocky bay covered with rocks and pebbles and fishing is reported here and along the coast. Outwith the school holiday survey, two dog-walkers were observed at Abbey Burn's Foot. During the school holiday survey, approximately 20 fishermen were observed on the beach in a fishing competition plus four dog-walkers.

No spume was observed outwith or during the school holiday surveys.

No access is possible until Rascarrel Bay which is only accessed on foot by the general public due to a new barrier preventing parking any closer to the shoreline. The barrier may allow access to a collection of four or five houses at the far end of the bay. The nearest public parking is now 300 – 400 m back up the road. The lower intertidal zone at Rascarrel Bay is rocky with an uneven surface of saltmarsh vegetation incised with narrow channels in the upper zone. Beyond the bay the coastline continues to be rocky with no access onto the shoreline. No activities were observed during both survey periods.

No spume was observed outwith or during the school holiday surveys.

Balcary Point marks the western edge of Auchencairn Bay. This is approached from Balcary Bay via a track or coastal footpath from the tower. Sea angling is known to take place from the point.

Hestan Island sits off the end of Auchencairn Bay, approximately 1.25 km from the Point. Bird-ringers reported visiting the island once a year following the spring breeding season (May and June) to ring the chicks.

Figure A13 Balcary Bay (March 2017)

Balcary Bay is a sheltered bay, with holidaymakers visiting or staying in the hotel or self-catering accommodation (Figure A13). The beach is accessed from a public car park near the buildings with one path leading to the beach and another sign posted for Rascarrel Bay. The lower intertidal zone is sandy with a rocky outcrop near the tower. The mid zone is described as having small stones and larger pebbles. The upper zone is shingle and sandy with the odd larger rock, behind which large boulders and a stone wall act as sea defences. Net fishing posts were observed in the bay but no nets. Outwith the school holiday survey, two walkers and a dog-walker were observed. During the school holiday survey, one adult was observed walking on the beach.

No spume was observed outwith or during the school holiday surveys.

No more access was possible along this side of Auchencairn Bay until the end of a wooded coastline near a few houses beyond the trees or if walking along the road and

a public car park. Access onto the shoreline is then restricted by walls, hedges and reed beds until the village of Auchecairn.

From Auchencairn village a footpath, not marked on the map, starting in the public park area of the village, directs walkers onto the saltmarsh area at the head of the Auchencairn Bay. A bird hide has been constructed for the public to use. The lower intertidal zone is sand and mudflats with saltmarsh and reed bed in the upper zone. The footpath passes through the reed bed with boarded sections laid where the ground is too wet. No activities were observed outwith or during the school holidays.

No spume was observed outwith or during the holiday surveys.

The path continues along the edge of the shoreline and meets a track coming from the north at Old Torr farm. A couple of cars were parked by the roadside next to the farmhouse. A sign-posted footpath leads from the end of the track through farmland towards Torr Point and the smaller Red Haven Bay. The former is a small rocky bay, separating the larger Auchencairn Bay with the smaller Orchardton Bay. Torr Point is characterised by sand exposed at low tide and rockier closer to shore where the bedrock is covered with seaweed below- and lichen above-the high tide mark. The upper intertidal zone is interspersed with areas of sand, mud, smaller rocks and pebbles. Saltmarsh vegetation also grows in the upper intertidal zone up to the tree line. Contact with a farmer indicated that cattle are grazed on the saltmarsh of Craigrow Bay which is inaccessible to the general public. No activities were observed outwith or during the school holidays.

No spume was observed outwith or during the school holiday surveys.

Orchardton Bay has an established saltmarsh at the head of the bay with a sandy substrate further out. A burn enters on the right-hand side. Access to the coastline around Almorness is via a road from Orchcardton village and then a rough track and footpaths to Almorness Point. No activities were observed outwith or during the school holidays.

No spume was observed outwith or during the school holiday surveys.

A1.6 Palnackie to Southerness Point

Palnackie is a quiet village on the estuary of the Urr Water with a small harbour. The river channel is defined by steep muddy banks with no safe access possible. At the time of the first visit, one large unserviceable and two smaller operational boats were resting on the mud in the harbour. It was reported that one of the operating boats is used for research purposes and the other only on a part-time basis. The Palnackie Port Group are a local activist group formed two years ago to get the harbour used more often by having it dredged, so allowing pleasure craft to berth there. To date the harbour has not been dredged.

The next access to the coastline is via the road from Palnackie to South Glen, a peninsula separating Auchencairn Bay from Rough Firth. A hard-standing area for cars can be used by the public at the south end of Glen Isle. A private track leads from the hard-standing area south to the end of the peninsula where there is a community of approximately 14 holiday homes with most located at the southern end. A footpath leads onto the rocky shoreline close to the holiday homes, beyond which, extensive mudflats extend across the bay in both directions. No activities were observed when visited during the school holiday survey. On the western side of Glen Isle no public access is possible onto the salt marsh due to fenced farmland.

No spume was observed outwith or during the school holiday surveys.

On the eastern side, a saltmarsh extends towards Kippford near a bend on the Urr Water. The saltmarsh is incised with deep muddy channels flooded at high tide. Evidence of public access was seen with faint footpaths. The main river channel consists of steep muddy banks and is navigable up to at least the harbour at Palnackie. No more access to the coastline was possible until Kippford. No activities were observed outwith the holidays. A single walker was observed on the saltmarsh area with one sailboat and one dinghy on the mud banks when visited during the school holiday survey. No more access to the coastline was possible until Kippford.

No spume was observed outwith or during the school holiday surveys.

To the north of Kippford, a large saltmarsh with open channels can be found along the banks of the Urr Water, with limited access to the shoreline. During the holiday survey,

approximately 50 sheep were observed grazing on this saltmarsh. However, contact with several farmers in the area indicated that they did not graze the saltmarsh.

Figure A14 Slipway and pontoons at Kippford boat storage from Glen Isle (March 2017)

Kippford is a small coastal settlement and is located where the Urr Water enters the eastern side of Auchencairn Bay. The Solway Yacht Club have a clubhouse near to a stone jetty slipway and floating pontoon with boat storage facilities on the riverside (Figure A14). Further information about club activities can be found in Section 4.13. Outwith the school holiday survey, approximately 20 boats were currently stored on the riverside. On the nearby saltmarsh, five leisure craft, plus one catamaran were also observed. In the boatyard, six people were observed carrying out maintenance on boats. It was reported by a local sailor that boats are lifted out of the water at the end of November as no insurance company would provide cover for any boat if stored on the water over winter due to storms. Boats are then returned to the water from the

beginning of April. During the school holiday survey, the following craft were observed parked on the hard-standing area: 18 sail boats; 11 motorboats; 15 rowing dinghies; and 40 sailing dinghies. On the water, there were 20sailboats; eight motorboats; and two commercial fishing boats. Close by, five sailing boats were seen moored on the saltmarsh area.

A public car park is located next to the boat storage area with access onto the intertidal zone possible from the end of the grassy area which leads to a small area of saltmarsh grass. The lower intertidal zone forms the mudflats along the river with the upper zone being shingle and small stones up to a sea wall.

Further access onto the upper intertidal zone is also possible from a gap in the sea wall onto a small slipway located halfway between the boat storage area and a larger slipway opposite a boat repair business and chandler.

During the school holiday survey, a creel boat was lying on the upper beach area near the slipway (Figure A15). It is reported that the owner of the creel fishing boat no longer operates the boat. No further information could be obtained.

No spume was observed outwith or during the school holiday surveys.

Figure A15 Kippford slipway and creel boat (March 2017)

A RNLI station is also located in the village. A shop also forms part of the lifeboat station to raise funds. In Kippford, two hotels, several guesthouses and an art gallery are also to be found on the main street behind the sea wall. No activities were observed on the intertidal zone outwith the school holiday survey. During the school holiday survey, 12 kayakers were observed on the estuary with four people playing on the intertidal zone.

No spume was observed outwith the school holiday survey. Spume was observed during the school holiday survey.

Rough Island is located in the centre of the bay. There are guided walks to the Island organised by rangers from the National Trust for Scotland outwith the spring breeding season during May and June (Section 4.14). Between 2011 and 2013 the rangers also carried out work to remove the invasive cord grass on Rough Island and on the coastline between Kippford and Rockcliffe and within Rockcliffe Bay itself.

Port Donnel, a rocky headland, marks the coastline at the small village of Rockcliffe. The coastline forms a small bay whereby the lower intertidal zone consists of mud and sand which extends for over one kilometre out to the end of the bay (Figure A16).

Figure A16 Rockcliffe and lower intertidal zone (March 2017)

Closer to shore, rocky outcrops and sand form the substrates, behind which pebbles, sand and crushed shells form the upper intertidal zone. Large rocks form a sloping sea defence with a road behind with a small car park area and public conveniences at the north end of the bay.

Easy access onto the beach is possible along the road. Outwith the school holiday survey, two cockle-pickers were observed on the sands approximately one kilometre out in the bay. On the beach, eight people were also observed walking over sand, mud and rocks near the shore. During the school holiday survey, four people were observed playing on the beach area; five people rock-pooling; two dog-walkers; four

people were walking, six kayakers were launching from the bay with two further people launching a dinghy.

No spume was observed outwith or during the school holiday surveys.

A sign-posted footpath near a car park at the south end of the village leads along the increasingly rocky coastline to the popular viewing point of Castlehill Point, where steep cliffs limit access. The lower intertidal zone is sandy whilst rocks of varying sizes, shingle and sand make up the upper intertidal zone. Robin Rigg offshore windfarm can be seen from the coastline in the area.

From Castlehill Point the coastline continues to be rocky with steep cliffs limiting access onto the intertidal zone. The coastal path continues above the cliffs leading to Port O' Warren Bay. On the beach, the lower intertidal zone forms extensive sands extending out over two kilometres into the Solway Firth in some places and all the way along to Southerness, approximately ten kilometres to the east. Port O' Warren Bay is reached via a road from the village of Portling, where steep cliffs enclose a mainly sandy bay with pebbles and shingles in the upper intertidal area. Above the high tide mark two houses are located, with one person observed working in the garden of one of the houses outwith the school holidays. No activities were observed offshore outwith or during school holiday surveys.

No spume was observed outwith or during the school holiday surveys.

Portling Bay is also reached from Portling village via a slipway onto the beach (Figure A17). Old fishing net posts can be seen on the outer sands, but no nets were set. Closer to the shore, rocks, pebbles and sand for a middle zone with small areas of saltmarsh vegetation and rocks lead up to a wall at the high-water mark. Houses crowd the area behind the seawall. It is known that a coastguard rescue team operates from Portling specialising in water and cliff rescues. No activities were observed outwith the school holidays. During the school holiday survey, two walkers were observed on the beach and one fishing boat was beached on the sand.

No spume was observed outwith or during the school holiday surveys.

Figure A17 Portling Bay (July 2017)

From Portling Bay it is possible to walk on a coastal path above the cliffs but no access down to the shoreline is possible from this path. It is also possible to walk on the sandy shoreline from Portling Bay all the way to Sandyhills passing the popular Needle's Eye cliff archway.

At Sandyhills a public car park with toilets, enable visitors' easy access onto a sandy beach area. Net fishing posts were observed offshore. On the western side of the bay a footbridge crosses Barnhourie Burn allowing access from the main bay and also a caravan park to footpaths leading to the small headland and sandy bays. Saltmarsh vegetation and reeds cover a small corner of the bay near the footbridge. Across most of the bay the upper intertidal zone is a sandy substrate which extends to a small rocky area on the opposite end of the bay at Craigneuk Point. No activities were observed onshore or offshore outwith the holidays. During the school holiday survey, the beach

area and caravan park were busier with 12 people observed playing on the beach; two observed sitting; seven lying on the beach and three dog-walkers.

No spume was observed outwith or during the school holiday surveys.

Southwick Coast Nature Reserve is located along the coast from Sandyhills and is managed by the Scottish Wildlife Trust. It is accessed from the A710 at three designated points. The reserve is a mixture of coastal substrates, with sand and mud at the western side and saltmarsh and estuary on the eastern edge. The reserve is noted for Lot's Wife, an isolated fin of rock and the Needle's Eye, a natural rock arch. It forms the western boundary of the merse sands area and RSPB-Mersehead reserve which owns and manages a large area of the sands (Section 4.14). During the holiday survey, two dog-walkers were seen on the coastal path; two people on the coastal path and saltmarsh area; three people were birdwatching on the saltmarsh and one person was walking on the sandy beach area.

Figure A18 Southerness lighthouse and intertidal zone (March 2017)

Southerness has several large caravan parks, some of which are open all year. A hotel, golf course, public toilets and a car park are nearby. Southerness Point is accessed from a pathway from the village leading directly to the lighthouse around which the beach area is formed of rocky wave cut platforms interspersed with sand in both directions (Figure A18). The Point forms where the coastline turns towards the Nith estuary. Outwith the holiday survey, three dog walkers were observed.

During school holiday survey, there was a noticeable increase in activities in and around the caravan parks and intertidal area. Over 35 people (adults and children) were observed playing on the beach area both on the sandy substrate and on the rocky area around the lighthouse; over 10 people were walking on the beach; and 18 dog-walkers. Over 15 people were observed siting on the beach with three people rock-pooling and one person with a metal detector.

No spume was observed outwith or during the school holiday surveys.

A1.7 Southerness to Glencaple

To the east of Southerness, properties can be found close to the coastline allowing private access to the shore. Public access from the caravan parks can also be found at several locations in Gillfoot Bay through scrub vegetation. The lower intertidal zone is sand with small areas of seaweed. The upper zone is also sandy which is backed by a thin strip of scrub and unimproved grassland. A caravan park is directly behind the scrub. It is possible to walk from Southerness Point to Powillimount where a car parking area has been enlarged and upgraded in recent years. The parking area is accessed via a road inland passing Powillimount Farm. The lower beach area is sand with a wave cut platform up to the upper intertidal mark. No activities onshore or offshore were observed from Powillimount when visited during the school holiday survey.

The next access point onto the coastline is at the hamlet of Carsethorn which has a public car park, toilets and a picnic area as well as a pub. The hamlet signals the start of the estuary proper with mudflats on the lower intertidal zone. Sand and shingle form the upper zone with four groynes leading up to the high tide mark at southern end of the hamlet. Some of the houses back onto the beach area or have gardens

that extend over the road up to the coastline allowing private access to the shore. Public access to the beach area is at various defined places: at the far end of the road; from the public car park and picnic area and just before the road turns inland. A single dog-walker and motor-camper were observed outwith the holidays. During the school holiday survey, three people were observed walking on the beach and one dog-walker.

No spume was observed outwith or during the school holiday surveys.

From Carsethorn onwards, the next access point to the shoreline is at Burnfoot where the mudflats dominate to the intertidal zone. This section of mudflats also forms the western edge of the Wildfowl and Wetlands Trust's (WWT) Caerlaverock NNR up to Airds Point. Contact with the WWT indicated that they do not graze animals as part of the management on this area of the reserve.

Kirkconnell merse forms part of a large saltmarsh on the west bank of the Nith estuary, from Airds Point in the south to where Cargen Pow stream enters the river. Access to the southern end of the merse is from the end of a metalled road at Kirkconnell house where a rough track follows the edge of the saltmarsh through Banks wood to a sewage works. A padlocked gate, halfway down the track prevents any further progress. Access onto the saltmarsh is limited due to a fence. However, a path from a padlocked gate leads onto the merse. Conversation with the area manager of the RSPB reserves noted the merse does not attract a lot of bird-watchers due to these access difficulties. Wildfowling activity has been reported on the saltmarsh. A farmer is reported to graze animals on the southern end of the merse each year during the summer (Section 4.7). Access to the northern end is possible from another farm. No further public access is possible until Glencaple. No activities were observed on Kirkconnell merse when visited during both survey periods.

Appendix A2 The Mobile Gamma Spectrometry System

To measure such an extensive area, a Mobile Gamma-ray Spectrometry System (MoGSS) was utilised to measure the differential dose estimations for the natural radioelements (^{40}K and the ^{238}U and ^{232}Th series) alongside estimates for anthropogenic ^{137}Cs. The ability to separate the contributors is especially important given that any potential contributions from Sellafield ^{137}Cs could potentially be singled

out from the spatially variable background element concentrations. This type of capability is not possible using conventional air-kerma measurements.

Two systems operating MoGSS were deployed in order to cover the area in sufficient spatial detail:

(i) Car-borne: Two large volume sodium iodide detectors were mounted in a box on top of a car, which was driven along all the major roads within the area of interest. The system, owing to the size of detectors, produced high efficiency data, although data could only be collected from roads.
(ii) Back-pack system: To survey areas not accessible by vehicle, and crucially to cover the coastline and measure the dose at relevant access points, two separate backpack systems were used. Areas of saltmarsh and beaches were surveyed using this portable system, (Figure 5.1). Each backpack system comprised of a 71 × 71 mm sodium iodide detector.

All MoGSS units produced a differential energy spectra recorded at 1 second integration times alongside high accuracy (<0.6 m) differential GPS readings.

Conversion of detector count rate (counts s^{-1}) to activity (Bq kq^{-1}) was performed using Monte Carlo calibrations and a conventional window stripping routine derived from concrete calibration pads. Cosmic background was measured on Loch Lomond and stripped from all spectral data. Prior to stripping, the Maximum Noise Fraction algorithm (Green *et al*, 1988) was used on individual instruments to smooth window counts using counts above 400 keV. A spatial Gaussian kernel was then used to further smooth the data. Finally, dose (nGy hr^{-1}) was calculated using ICRU conversion factors (ICRU, 1994)

The Mobile Gamma Spectrometry System (MoGSS) deploys 76 mm x 76 mm and large volume (4 or 8 litre) NaI(Tl) detectors for real time data acquisition gamma ray spectra. One second spectra were acquired whilst driving with the detector mounted in the roof box of the survey vehicle to characterise the heterogeneity in the radiation environment along the Solway Firth coastal zone and further afield to identify exposure pathways that might otherwise be missed through conventional point measurements.

Acquisition rate is limited by road and traffic conditions but aims to achieve better than one measurement per 20 m. MoGSS comprises a real time differential GPS system providing < 0.6 m positional accuracy, controlled by bespoke software through a tablet computer. Spectra were collected with 1 second integration times and data are presented as counts per second (gross counts or counts in the window >350 keV). MoGSS was deployed to identify anomalies in the radiation field to help target follow-up *in-situ* dosimetry surveys (Section 5.3) and identify the likely source of the radioactive anomaly and spatially extrapolate any anomalous observations identified.

Appendix A3: *In-Situ* Gamma Dose Rate Measurements

The protocol requires the detector to be maintained at 1 m above the surface and counts acquired over a 600 second integration time and the cosmic and intrinsic component to the measurement subtracted. The protocol also requires no persons operating the detector to be within 5 m of the probe during the count. Both instruments are calibrated with ^{226}Ra and ^{137}Cs. Here, gamma dose rates were dominated by the natural background, so all results are reported with the ^{226}Ra calibration and reported as µGy h^{-1}.

For the dose assessment tool, gamma dose rates were converted to Effective Dose (µSv hr^{-1}) using a conversion factor of 0.85, which assumes an individual is standing and exposed to terrestrial derived gamma radiation. This conversion factor is used for most statutory monitoring programmes (Punt *et al*., 2011). All survey measurements are reported as terrestrial gamma dose measurements and have had the cosmic and intrinsic component subtracted.

Appendix A4: Beta Skin Dosimetry Measurements

The instrument was calibrated under UKAS accreditation against strontium-90 (^{90}Sr) and yttrium-90 (^{90}Y); chlorine-36 (^{36}Cl) and carbon-14 (^{14}C) (and put inside a file poly-pocket to protect the system from the weather). A 12 mm Perspex shield was used to shield out any beta emissions and so enable the gamma contribution to the instrument to be established. All measurements were made with a 20 second integration time and in duplicate, with and without the 12 mm Perspex shield, enabling the net beta contribution to skin dose rate to be estimated (effective dose, or ambient dose

equivalent) and reported in μSv h^{-1}. The system is estimated to have a detection limit of around 0.2 μSv h^{-1}.

Appendix A5: GPS Tracker Device

To ensure consistency in data a wearable GPS tracking device was considered the most suitable device for the Dumfries & Galloway Habits Survey.

The devices used were iGOTU GT600 trackers (Figure A19), which have a capacity to record 262 000 waypoints, at user defined intervals. The battery life varies depending on the sampling rate, which was set to record once every 6 seconds, giving 30 hours of use on a single charge.

Figure A19 iGOTU GPS tracker

This battery life could be extended by enabling motion detection, whereby the device sleeps until an on-board accelerometer detects motion and then enables the GPS tracking (which has a bigger battery cost). However initial tests showed that the device would not wake from its sleep mode if used on certain modes of transport, such as trains, where the motion was not severe enough to be detected. For this reason, the motion detection was disabled so that the tracker logged continuously.

The devices require specialist software to download the trajectory data, and all units were password protected to maintain data security and privacy. The participants were informed that the tracker worked best when positioned on their wrist, or on a bag/belt strap, where they had a clear line of sight to the sky. The participants were asked to take the device with them whenever they left their home and instructions were given regarding use and recharging of the device.

With the 6 second sample rate, the device was able to store the last 16 days of position data on board. Participants were asked to stop charging the unit on the last day of use before collection, to ensure it would run out of power and stop logging position data.

Appendix A6 Raw Data

Table A6.1 Phase 1 Adult Crustacean Consumption

Unique ID	Food type	Consumption Rate (kg y^{-1})
54	Brown crab	0.09
89	Brown crab	0.09
90	Brown crab	0.09
92	Brown crab	0.09
101	Brown crab	0.75
14	Brown crab	0.90
15	Brown crab	0.90
252	Brown crab	6.00
233	Brown crab	13.0
56	Brown crab	26.0
251	Brown crab	52.0
54	Common lobster	0.15
89	Common lobster	0.15
90	Common lobster	0.15
92	Common lobster	0.15
101	Common lobster	0.50

Unique ID	Food type	Consumption Rate (kg y^{-1})
146	Common lobster	0.50
222	Common lobster	0.50
223	Common lobster	0.50
289	Common lobster	4.00
14	Common lobster	6.00
15	Common lobster	6.00
252	Common lobster	6.00
233	Common lobster	7.80
251	Common lobster	12.0
56	Common lobster	26.0
233	Prawns (langoustines)	52.0
4	Shrimps	0.30
13	Shrimps	0.30

Table A6.2 Phase 1 Adult Fish Consumption Rate

Unique ID	Food type	Consumption Rate (kg y^{-1})
2	Bass	5.00
3	Bass	1.50
4	Bass	3.00
13	Bass	3.00
46	Bass	2.00
56	Bass	15.0

Unique ID	Food type	Consumption Rate (kg y^{-1})
58	Bass	0.75
59	Bass	0.75
69	Bass	1.00
75	Bass	0.75
76	Bass	0.75
146	Bass	4.00
257	Bass	6.00
275	Bass	1.50
284	Bass	6.00
289	Bass	2.00
233	Brill	10.4
2	Cod	5.00
33	Cod	12.0
69	Cod	1.00
217	Cod	1.00
218	Cod	1.00
244	Cod	3.96
252	Cod	6.00
284	Cod	1.00
289	Cod	15.0
2	Dover sole	2.00
4	Dover sole	0.50

Unique ID	Food type	Consumption Rate (kg y^{-1})
13	Dover sole	0.50
252	Dover sole	14.4
289	Dover sole	3.00
4	Flounder	0.50
13	Flounder	0.50
58	Flounder	0.63
59	Flounder	0.63
101	Flounder	0.75
246	Flounder	1.00
249	Flounder	2.00
265	Flounder	1.00
46	Grey Mullet	3.00
56	Grey Mullet	15.0
75	Grey Mullet	0.75
76	Grey Mullet	0.75
101	Grey Mullet	0.75
246	Grey Mullet	1.50
265	Grey Mullet	1.50
2	Mackerel	5.00
14	Mackerel	0.45
15	Mackerel	0.90
33	Mackerel	6.00

Unique ID	Food type	Consumption Rate (kg y^{-1})
46	Mackerel	0.50
51	Mackerel	2.65
54	Mackerel	3.00
58	Mackerel	0.63
59	Mackerel	0.63
63	Mackerel	2.50
67	Mackerel	4.00
89	Mackerel	3.00
90	Mackerel	3.00
92	Mackerel	3.00
101	Mackerel	0.50
159	Mackerel	0.17
175	Mackerel	20.0
179	Mackerel	0.174
180	Mackerel	0.17
181	Mackerel	0.17
209	Mackerel	2.50
240	Mackerel	3.00
241	Mackerel	2.00
246	Mackerel	2.00
252	Mackerel	9.00
256	Mackerel	10.0

Unique ID	Food type	Consumption Rate (kg y^{-1})
265	Mackerel	2.00
268	Mackerel	20.0
279	Mackerel	3.00
282	Mackerel	2.00
284	Mackerel	3.00
289	Mackerel	1.00
14	Plaice	1.50
15	Plaice	1.50
33	Plaice	12.0
46	Plaice	1.00
69	Plaice	1.00
75	Plaice	0.70
76	Plaice	0.70
101	Plaice	1.50
175	Plaice	1.50
252	Plaice	0.20
268	Plaice	1.50
58	Pollock	0.63
59	Pollock	0.63
175	Pollock	5.00
222	Pollock	4.00
223	Pollock	4.00

Unique ID	Food type	Consumption Rate (kg y^{-1})
246	Pollock	2.00
265	Pollock	2.00
268	Pollock	5.00
279	Pollock	3.00
4	Salmon	2.00
13	Salmon	2.00
26	Salmon	6.00
33	Salmon	23.4

Table A6.3 Phase 1 Adult Molluscs Consumption Rate

Unique ID	Food type	Consumption Rate (kg y^{-1})
4	Cockles	0.30
13	Cockles	0.30
101	Cockles	0.08
101	Cockles	0.08
146	Cockles	10.0
175	Cockles	0.80
241	Cockles	0.10
268	Cockles	0.80
282	Cockles	0.10
4	Mussels	0.30
13	Mussels	0.30

Unique ID	Food type	Consumption Rate (kg y^{-1})
33	Mussels	5.90
101	Mussels	0.08
101	Mussels	0.08
175	Mussels	0.50
241	Mussels	2.00
251	Mussels	12.0
268	Mussels	0.50
282	Mussels	2.00
4	Razor clams	0.30
13	Razor clams	0.30
75	Razor clams	0.35
75	Razor clams	0.35
76	Razor clams	0.35
76	Razor clams	0.35
146	Razor clams	0.75
253	Razor clams	4.00
33	Scallops	5.90
51	Scallops	0.60
146	Scallops	0.30
233	Scallops	6.00
236	Scallops	0.60
239	Scallops	0.25

Unique ID	Food type	Consumption Rate (kg y^{-1})
244	Scallops	3.60
249	Scallops	0.20
251	Scallops	15.6
252	Scallops	0.40
264	Scallops	0.30
285	Scallops	12.0
289	Scallops	4.00

Table A6.4 Phase 1 Adult Wildfowl and Game Bird Consumption Rate

Unique ID	Food type	Consumption Rate (kg y^{-1})
175	Greylag goose	3.00
224	Greylag goose	3.00
268	Mallard	6.00
2	Mallard	6.00
285	Mallard	1.00
252	Mallard	2.00
175	Mallard	6.00
246	Pin tail duck	3.00
28	Pink-Footed Goose	1.00
39	Pink-Footed Goose	1.00
175	Pink-Footed Goose	27.0
224	Pink-Footed Goose	20.0

Unique ID	Food type	Consumption Rate (kg y^{-1})
282	Pink-Footed Goose	4.00
241	Pink-Footed Goose	4.00
157	Pheasant	1.00
2	Teal	3.00
28	Teal	0.10
39	Teal	0.10
224	Teal	3.00
282	Teal	4.00
175	Teal	3.50
241	Teal	4.00
175	Widgeon	2.00
241	Widgeon	5.00
91	Widgeon	6.00
282	Widgeon	5.00
28	Widgeon	0.10
2	Widgeon	5.00
252	Widgeon	0.10
224	Widgeon	1.50
246	Widgeon	1.00
39	Widgeon	0.10

Table A6.5 Phase 1 Adult Saltmarsh Lamb Consumption Rate

Unique ID	Meat	Consumption Rate (kg y^{-1})
183	Lamb	10.0
227	Lamb	10.0
228	Lamb	10.0
229	Lamb	10.0
230	Lamb	10.0
283	Lamb	9.00

Table A6.6 Phase 1 Children Crustacean Consumption Rate

Unique ID	Food type	Consumption Rate (kg y^{-1})
302	Brown crab	0.09
302	Common lobster	0.145
346	Common lobster	0.50
294	Shrimps	0.30
295	Shrimps	0.30

Table A6.7 Phase 1 Children Fish Consumption Rate

Unique ID	Food type	Consumption Rate (kg y^{-1})
294	Bass	2.00
295	Bass	2.00
294	Dover sole	0.25
295	Dover sole	0.25

Unique ID	Food type	Consumption Rate (kg y^{-1})
294	Flounder	0.25
295	Flounder	0.25
302	Mackerel	1.50
334	Mackerel	0.17
346	Pollock	2.00
294	Salmon	1.50
295	Salmon	1.50

Table A6.8 Phase 1 Children Molluscs Consumption Rate

Unique ID	Food type	Consumption Rate (kg y^{-1})
295	Cockles	0.20
294	Cockles	0.30
295	Mussels	0.20
294	Mussels	1.50
295	Razor clams	0.30
294	Razor clams	0.30

Table A6.9 Phase 1 Infant Crustacean Consumption Rate

Unique ID	Food type	Consumption Rate (kg y^{-1})
363	Brown crab	0.09
363	Common lobster	0.145

Table A6.10 Phase 1 Infant Fish Consumption Rate

Unique ID	Food type	Consumption Rate (kg y^{-1})
358	Bass	0.75
358	Flounder	0.63
378	Mackerel	0.17
363	Mackerel	1.50
358	Mackerel	0.63
358	Pollock	0.63

Table A6.11 Phase 1 Adult In-Water Activities

Unique ID	Aquatic Activity	h y^{-1}
219	Boat maintenance	0.75
220	Boat maintenance	0.75
219	Boat maintenance	0.75
220	Boat maintenance	0.75
219	Boat maintenance	0.75
220	Boat maintenance	0.75
159	Body boarding	1.00
179	Body boarding	1.00
180	Body boarding	1.00
181	Body boarding	1.00
44	Outdoor swimming	0.25
235	Outdoor swimming	0.25

Unique ID	Aquatic Activity	h y^{-1}
269	Outdoor swimming	0.25
11	Outdoor swimming	1.00
64	Outdoor swimming	0.50
76	Outdoor swimming	0.36
213	Outdoor swimming	0.50
266	Outdoor swimming	10.0
257	Outdoor swimming	3.00
262	Outdoor swimming	6.50
16	Outdoor swimming	26.0
74	Outdoor swimming	1.50
256	Outdoor swimming	3.00
25	Outdoor swimming	0.25
80	Outdoor swimming	0.25
98	Outdoor swimming	0.25
135	Outdoor swimming	1.19
148	Outdoor swimming	1.19
12	Outdoor swimming	3.00
76	Outdoor swimming	0.36
159	Outdoor swimming	0.50
179	Outdoor swimming	0.50
180	Outdoor swimming	0.50
181	Outdoor swimming	0.50

Unique ID	Aquatic Activity	h y^{-1}
239	Outdoor swimming	0.12
263	Outdoor swimming	1.50
278	Outdoor swimming	1.00
278	Outdoor swimming	1.00
203	Outdoor swimming	0.50
164	Outdoor swimming	4.00
167	Outdoor swimming	4.00
80	Outdoor swimming	0.25
64	Outdoor swimming	0.50
213	Outdoor swimming	0.50
96	Outdoor swimming	0.10
129	Outdoor swimming	0.10
130	Outdoor swimming	0.10
131	Outdoor swimming	0.10
132	Outdoor swimming	0.10
134	Outdoor swimming	0.10
159	Outdoor swimming	0.50
179	Outdoor swimming	0.50
180	Outdoor swimming	0.50
181	Outdoor swimming	0.50
262	Outdoor swimming	6.50
279	Rescue Training & Rescue Duties	1.00

Unique ID	Aquatic Activity	h y^{-1}
285	Rescue Training & Rescue Duties	0.3
289	RNLI Rescue duties	0.25
289	RNLI Rescue duties	0.25
284	Safety boat duties	0.30
223	Snorkelling	6.50
33	Sub-aqua diving	3.00
219	Sub-aqua diving	96.0
220	Sub-aqua diving	96.0
250	Sub-aqua diving	390
252	Sub-aqua diving	52.0
219	Sub-aqua diving	832
220	Sub-aqua diving	416
33	Sub-aqua diving	3.00
219	Sub-aqua diving	832
220	Sub-aqua diving	416
251	Sub-aqua diving	117
255	Sub-aqua diving	104

Table A6.12 Phase 1 Adult On-Water Activities

Unique ID	Aquatic Activity	h y^{-1}
257	Angling - Sea	1.50
54	Angling - Sea	60.0

Unique ID	Aquatic Activity	h y^{-1}
256	Angling - Sea	78.0
279	Angling - Sea	72.0
255	Angling - Sea	156
91	Angling - Sea	12.0
275	Angling - Sea	104
275	Angling - Sea	104
275	Angling - Sea	104
257	Angling - Sea	1.50
284	Angling - Sea	365
223	Angling - Sea	24.0
223	Angling - Sea	24.0
2	Angling - Sea	24.0
2	Angling - Sea	24.0
175	Angling - Sea	36.0
14	Angling - Sea	18.0
82	Angling - Sea	96.0
289	Angling - Sea	156
246	Angling - Sea	30.0
251	Being on a dive boat	468
250	Being on a dive boat	78.0
255	Being on a dive boat	104
219	Being on a dive boat	208

Unique ID	Aquatic Activity	h y^{-1}
219	Being on a dive boat	48.0
219	Being on a dive boat	208
220	Being on a dive boat	208
220	Being on a dive boat	208
220	Being on a dive boat	48.0
251	Boat maintenance	6.00
257	Boat maintenance	3.00
255	Boat maintenance	26.0
262	Boat maintenance	12.0
258	Boat maintenance	9.00
250	Boat maintenance	12.0
2	Boat maintenance	52.0
264	Boat maintenance	12.0
277	Boat maintenance	4.00
279	Boat maintenance	12.00
289	Boat maintenance	156
252	Boat maintenance	91.3
256	Boat maintenance	3.00
11	Boat maintenance	7.00
266	Boat maintenance	20.0
9	Canoeing	18.0
93	Canoeing	9.00

Unique ID	Aquatic Activity	h y^{-1}
42	Canoeing	9.00
5	Canoeing	12.0
244	Canoeing	117
5	Canoeing	12.0
257	Canoeing	3.00
5	Canoeing	12.0
12	Canoeing	78.0
289	Canoeing	18.0
254	Canoeing	6.00
254	Canoeing	78.0
253	Canoeing	78.0
239	Canoeing	24.0
275	Canoeing	30.0
12	Canoeing	78.0
253	Canoeing	6.00
275	Canoeing	30.0
33	Canoeing	78.0
14	Commercial fishing/creeling	260
14	Commercial fishing/creeling	1278
233	Commercial fishing/creeling	1040
56	Commercial fishing/creeling	130
223	Commercial fishing/creeling	52.0

Unique ID	Aquatic Activity	h y^{-1}
223	Commercial fishing/creeling	52.0
233	Commercial fishing/creeling	624
171	Creel fishing/handling creels (not commercial)	1560
142	Dinghy Sailing	4.00
137	Dinghy Sailing	400
191	Kayaking	36.0
9	Kayaking	60.0
64	Kayaking	14.0
87	Kayaking	3.00
87	Kayaking	3.00
98	Kayaking	0.50
213	Kayaking	14.0
211	Kayaking	9.00
211	Kayaking	9.00
193	Kayaking	36.0
98	Kayaking	0.50
16	Kayaking	6.00
16	Kayaking	6.0
16	Kayaking	104
193	kite surfing	12.0
73	Power boating	0.50

Unique ID	Aquatic Activity	h y^{-1}
101	Power boating	0.75
103	Power boating	30.0
2	Power boating	24.0
2	Power boating	24.0
246	Power boating	48.0
73	Power boating	0.50
73	Power boating	0.50
101	Power boating	0.75
193	Power boating	58.5
231	Power boating	58.5
231	Power boating	58.5
194	Power boating	58.5
54	Power boating	90.0
201	Power boating	10.0
201	Power boating	10.0
101	Power boating	0.75
13	Rescue Training & Rescue duties	72.0
285	Rescue Training & Rescue duties	24.0
284	Rescue Training & Rescue duties	24.0
289	RNLI Rescue duties	36.0
2	RNLI Rescue duties	12.0
289	RNLI Rescue duties	36.0

Unique ID	Aquatic Activity	h y^{-1}
2	RNLI Rescue duties	12.0
254	Safety boat duties	39.0
264	Safety boat duties	3.00
103	Safety boat duties	12.0
279	Safety boat duties	96.0
254	Safety boat duties	39.0
91	Sailing	30.0
277	Sailing	18.0
239	Sailing	208
253	Sailing	6.00
253	Sailing	78.0
240	Sailing	182
280	Sailing	130
254	Sailing	39.0
256	Sailing	58.5
256	Sailing	58.5
240	Sailing	520
254	Sailing	39.0
104	Sailing	26.0
191	Sailing	18.0
289	Sailing	78.0
193	Sailing	18.0

Unique ID	Aquatic Activity	h y^{-1}
232	Sailing	36.0
215	Sailing	351
54	Sailing	90.0
280	Sailing	130
191	Sailing	18.0
11	Sailing	30.0
223	Sailing	45.0
223	Sailing	18.0
222	Sailing	45.0
222	Sailing	18.0
261	Sailing	12.0
261	Sailing	12.0
215	Sailing	234
236	Sailing	468
289	Sailing	78.0
266	Sailing	45.0
266	Sailing	45.0
11	Sailing	60.0
232	Sailing	36.0
262	Sailing	78.0
259	Sailing	104
258	Sailing	54.0

Unique ID	Aquatic Activity	h y^{-1}
263	Sailing	39.0
257	Sailing	19.5
257	Sailing	19.5
264	Sailing	30.0
193	Sailing	18.0
252	Sports fishing	548
69	Sports fishing	480
69	Sports fishing	48.0
202	Water skiing	10.0
201	Water skiing	10.0
202	Water skiing	10.0
201	Water skiing	10.0
246	Wildfowling from boat	24.0
175	Wildfowling from boat	36.0
252	Wildlife tours	548
252	Wildlife tours	365
252	Wildlife tours	547.5
193	Wind surfing	12.0
264	Working on a boat	20.0
217	Working on a boat	624
217	Working on a boat	144
257	Working on a boat	6.0

Unique ID	Aquatic Activity	h y^{-1}
217	Working on a boat	624

Table A6.13 Phase 1 Adult Intertidal Activities

Unique ID	Intertidal Activity	h y^{-1}
67	Bait digging	36.0
275	Bait digging	26.0
275	Bait digging	26.0
46	Bait digging	19.5
284	Bait digging	13.0
289	Bait digging	12.0
255	Bait digging	9.0
51	Bait digging	4.00
58	Bait digging	3.25
252	Bait digging	3.00
123	BBQ/Picnicking/Sitting	45.0
124	BBQ/Picnicking/Sitting	45.0
151	BBQ/Picnicking/Sitting	4.00
153	BBQ/Picnicking/Sitting	4.00
29	BBQ/Picnicking/Sitting	2.00
49	BBQ/Picnicking/Sitting	2.00
111	BBQ/Picnicking/Sitting	2.00
133	BBQ/Picnicking/Sitting	2.00

Unique ID	Intertidal Activity	h y^{-1}
149	BBQ/Picnicking/Sitting	2.00
150	BBQ/Picnicking/Sitting	2.00
159	BBQ/Picnicking/Sitting	2.00
159	BBQ/Picnicking/Sitting	2.00
179	BBQ/Picnicking/Sitting	2.00
179	BBQ/Picnicking/Sitting	2.00
180	BBQ/Picnicking/Sitting	2.00
180	BBQ/Picnicking/Sitting	2.00
181	BBQ/Picnicking/Sitting	2.00
181	BBQ/Picnicking/Sitting	2.00
187	BBQ/Picnicking/Sitting	2.00
212	BBQ/Picnicking/Sitting	2.00
208	Beachcombing	650
216	Beachcombing	650
30	Beachcombing	312
30	Beachcombing	312
34	Beachcombing	312
34	Beachcombing	312
238	Beachcombing	52.0
271	Beachcombing	52.0
74	Beachcombing	42.0
275	Beachcombing	26.0

Unique ID	Intertidal Activity	h y^{-1}
254	Beachcombing	24.0
256	Beachcombing	24.0
251	Beachcombing	12.0
257	Beachcombing	12.0
11	Beachcombing	8.00
266	Beachcombing	4.00
243	Beachcombing	3.00
266	Beachcombing	3.00
266	Beachcombing	3.00
126	Beachcombing	2.00
126	Beachcombing	2.00
126	Beachcombing	2.00
127	Beachcombing	2.00
127	Beachcombing	2.00
127	Beachcombing	2.00
174	Beachcombing	2.00
174	Beachcombing	2.00
249	Beachcombing	2.00
249	Beachcombing	2.00
100	Beachcombing	1.00
184	Beachcombing	1.00
206	Beachcombing	0.25

Unique ID	Intertidal Activity	h y^{-1}
101	Bird ringing	7.00
73	Bird ringing	3.00
73	Bird ringing	3.00
73	Bird ringing	3.00
212	Bird ringing	2.00
238	Bird/Nature watching	624
270	Bird/Nature watching	365
20	Bird/Nature watching	312
243	Bird/Nature watching	309
21	Bird/Nature watching	234
272	Bird/Nature watching	234
175	Bird/Nature watching	183
30	Bird/Nature watching	182
34	Bird/Nature watching	182
248	Bird/Nature watching	78.0
248	Bird/Nature watching	78.0
252	Bird/Nature watching	65.0
252	Bird/Nature watching	52.0
252	Bird/Nature watching	52.0
273	Bird/Nature watching	36.0
273	Bird/Nature watching	36.0
274	Bird/Nature watching	36.0

Unique ID	Intertidal Activity	h y^{-1}
274	Bird/Nature watching	36.0
257	Bird/Nature watching	15.0
257	Bird/Nature watching	15.0
249	Bird/Nature watching	6.00
249	Bird/Nature watching	6.00
249	Bird/Nature watching	6.00
256	Bird/Nature watching	6.00
266	Bird/Nature watching	4.00
266	Bird/Nature watching	3.00
266	Bird/Nature watching	3.00
49	Bird/Nature watching	2.00
139	Bird/Nature watching	1.00
140	Bird/Nature watching	1.00
141	Bird/Nature watching	1.00
47	Bird/Nature watching	0.60
206	Bird/Nature watching	0.60
252	Boat maintenance	91.3
233	Boat maintenance	52.0
254	Boat maintenance	52.0
224	Boat maintenance	24.0
264	Boat maintenance	18.0
259	Boat maintenance	13.0

Unique ID	Intertidal Activity	h y^{-1}
255	Boat maintenance	12.0
11	Boat maintenance	6.00
289	Boat maintenance	3.00
23	Boat salvaging	2.00
23	Boat salvaging	2.00
159	Boules	1.50
159	Boules	1.50
159	Boules	1.50
179	Boules	1.50
179	Boules	1.50
179	Boules	1.50
180	Boules	1.50
180	Boules	1.50
180	Boules	1.50
181	Boules	1.50
181	Boules	1.50
181	Boules	1.50
146	Collecting cockles	5.00
241	Collecting cockles	4.00
282	Collecting cockles	4.00
101	Collecting cockles	1.50
101	Collecting cockles	1.50

Unique ID	Intertidal Activity	h y^{-1}
241	Collecting mussels	10.0
282	Collecting mussels	10.0
255	Collecting mussels	4.00
101	Collecting mussels	1.50
101	Collecting mussels	1.50
253	Collecting razor clams	4.00
252	Collecting razor clams	3.00
76	Collecting razor clams	2.00
76	Collecting razor clams	2.00
255	Collecting razor clams	2.00
76	Collecting seaweed	12.0
262	Collecting seaweed	6.00
239	Collecting seaweed	1.00
15	Collecting winkles	130
255	Collecting winkles	2.00
103	Crabbing	24.0
255	Crabbing	10.0
252	Crabbing	6.00
164	Crabbing	5.00
164	Crabbing	5.00
25	Crabbing	2.00
98	Crabbing	2.00

Unique ID	Intertidal Activity	h y^{-1}
33	Dog walking	1460
208	Dog walking	650
216	Dog walking	650
289	Dog walking	548
30	Dog walking	546
34	Dog walking	546
272	Dog walking	468
161	Dog walking	411
161	Dog walking	411
22	Dog walking	365
22	Dog walking	365
91	Dog walking	365
160	Dog walking	365
203	Dog walking	365
203	Dog walking	365
270	Dog walking	365
164	Dog walking	234
167	Dog walking	234
103	Dog walking	183
165	Dog walking	183
237	Dog walking	183
278	Dog walking	183

Unique ID	Intertidal Activity	h y^{-1}
289	Dog walking	183
43	Dog walking	156
86	Dog walking	156
175	Dog walking	137
85	Dog walking	135
43	Dog walking	104
234	Dog walking	104
245	Dog walking	104
286	Dog walking	94.5
237	Dog walking	91.3
278	Dog walking	91.3
166	Dog walking	78.0
194	Dog walking	78.0
231	Dog walking	78.0
275	Dog walking	78.0
2	Dog walking	72.0
257	Dog walking	60.0
99	Dog walking	56.0
221	Dog walking	56.0
250	Dog walking	52.0
252	Dog walking	52.0
253	Dog walking	52.0

Unique ID	Intertidal Activity	h y^{-1}
253	Dog walking	52.0
277	Dog walking	52.0
279	Dog walking	52.0
279	Dog walking	52.0
50	Dog walking	48.0
50	Dog walking	48.0
50	Dog walking	48.0
214	Dog walking	48.0
214	Dog walking	48.0
214	Dog walking	48.0
2	Dog walking	36.0
109	Dog walking	26.0
109	Dog walking	26.0
255	Dog walking	26.0
135	Dog walking	21.0
144	Dog walking	21.0
114	Dog walking	20.0
223	Dog walking	13.0
264	Dog walking	12.0
172	Dog walking	10.0
238	Dog walking	9.00
41	Dog walking	8.00

Unique ID	Intertidal Activity	h y^{-1}
41	Dog walking	8.00
41	Dog walking	8.00
41	Dog walking	8.00
95	Dog walking	8.00
95	Dog walking	8.00
248	Dog walking	7.92
248	Dog walking	7.92
248	Dog walking	7.92
65	Dog walking	7.00
207	Dog walking	7.00
55	Dog walking	6.00
57	Dog walking	6.00
163	Dog walking	5.00
163	Dog walking	5.00
190	Dog walking	5.00
190	Dog walking	5.00
1	Dog walking	4.00
152	Dog walking	4.00
156	Dog walking	4.00
158	Dog walking	4.00
29	Dog walking	3.50
29	Dog walking	3.50

Unique ID	Intertidal Activity	h y^{-1}
29	Dog walking	3.50
29	Dog walking	3.50
133	Dog walking	3.50
133	Dog walking	3.50
133	Dog walking	3.50
133	Dog walking	3.50
128	Dog walking	2.67
162	Dog walking	2.67
8	Dog walking	2.00
80	Dog walking	2.00
55	Dog walking	1.00
57	Dog walking	1.00
47	Dog walking	0.60
206	Dog walking	0.60
128	Dog walking	0.50
162	Dog walking	0.50
157	Drainage ditching	1.00
170	Farming	365
238	Farming	104
10	Farming	91.3
183	Farming	91.3
226	Farming	91.3

Unique ID	Intertidal Activity	h y^{-1}
283	Farming	82.1
48	Farming	78.0
285	Farming	52.0
276	Farming	22.8
44	Farming	13.7
44	Farming	13.7
157	Farming	6.50
69	Fishing	130
69	Fishing	130
69	Fishing	130
69	Fishing	130
69	Fishing	130
69	Fishing	130
69	Fishing	130
69	Fishing	130
275	Fishing	52.0
275	Fishing	52.0
275	Fishing	52.0
1	Fishing	36.0
255	Fishing	36.0
91	Fishing	30.0
67	Fishing	27.0

Unique ID	Intertidal Activity	h y^{-1}
67	Fishing	27.0
67	Fishing	27.0
67	Fishing	27.0
58	Fishing	26.0
58	Fishing	26.0
63	Fishing	24.0
159	Fishing	24.0
179	Fishing	24.0
180	Fishing	24.0
181	Fishing	24.0
223	Fishing	24.0
284	Fishing	15.0
284	Fishing	15.0
284	Fishing	15.0
146	Fishing	12.0
72	Fishing	8.00
241	Fishing	6.00
51	Fishing	5.00
51	Fishing	5.00
51	Fishing	5.00
241	Fishing	3.00
241	Fishing	3.00

Unique ID	Intertidal Activity	h y^{-1}
289	Fishing	3.00
289	Fishing	3.00
289	Fishing	3.00
249	Fishing	2.00
255	Fixing moorings	8.00
251	Fixing moorings	4.00
12	Fixing moorings	2.00
264	Fixing moorings	2.00
289	Fixing moorings	1.00
138	Flying a kite	0.17
143	Flying a kite	0.17
242	Horse riding	208
224	Horse riding	40.0
24	Horse riding	2.00
87	Jogging	9.00
87	Jogging	9.00
156	Metal detecting	5.00
13	Mud rescue	8.00
13	Mud rescue training	48.0
257	Paddling	18.0
138	Paddling	12.0
143	Paddling	12.0

Unique ID	Intertidal Activity	h y^{-1}
284	Paddling	6.50
284	Paddling	6.50
168	Paddling	5.00
169	Paddling	5.00
266	Paddling	2.00
114	Paddling	1.00
172	Paddling	1.00
25	Paddling	0.50
98	Paddling	0.50
235	Painting	21.0
235	Painting	21.0
269	photography	21.0
269	photography	21.0
238	Playing	104
54	Playing	64.0
74	Playing	48.0
94	Playing	48.0
94	Playing	48.0
164	Playing	48.0
167	Playing	48.0
257	Playing	36.0
111	Playing	30.0

Unique ID	Intertidal Activity	h y^{-1}
185	Playing	30.0
187	Playing	30.0
83	Playing	28.0
293	Playing	28.0
148	Playing	21.0
42	Playing	20.0
62	Playing	20.0
93	Playing	20.0
107	Playing	20.0
108	Playing	20.0
210	Playing	20.0
96	Playing	18.0
129	Playing	18.0
130	Playing	18.0
131	Playing	18.0
132	Playing	18.0
134	Playing	18.0
168	Playing	15.0
169	Playing	15.0
223	Playing	13.0
96	Playing	12.0
102	Playing	12.0

Unique ID	Intertidal Activity	h y^{-1}
129	Playing	12.0
130	Playing	12.0
131	Playing	12.0
132	Playing	12.0
134	Playing	12.0
159	Playing	12.0
159	Playing	12.0
159	Playing	12.0
179	Playing	12.0
179	Playing	12.0
179	Playing	12.0
180	Playing	12.0
180	Playing	12.0
180	Playing	12.0
181	Playing	12.0
181	Playing	12.0
181	Playing	12.0
182	Playing	12.0
250	Playing	12.0
284	Playing	6.50
284	Playing	6.50
84	Playing	6.00

Unique ID	Intertidal Activity	h y^{-1}
287	Playing	6.00
288	Playing	6.00
149	Playing	4.00
150	Playing	4.00
35	Playing	3.00
40	Playing	3.00
81	Playing	3.00
290	Playing	3.00
291	Playing	3.00
292	Playing	3.00
112	Playing	2.50
112	Playing	2.50
112	Playing	2.50
195	Playing	2.50
195	Playing	2.50
195	Playing	2.50
196	Playing	2.50
196	Playing	2.50
196	Playing	2.50
197	Playing	2.50
197	Playing	2.50
197	Playing	2.50

Unique ID	Intertidal Activity	h y^{-1}
198	Playing	2.50
198	Playing	2.50
198	Playing	2.50
199	Playing	2.50
199	Playing	2.50
199	Playing	2.50
100	Playing	2.00
110	Playing	2.00
184	Playing	2.00
188	Playing	2.00
60	Playing	0.33
61	Playing	0.33
238	Research/education	312
243	Research/education	155
20	Research/education	52.0
21	Research/education	13.0
270	Research/education	12.0
76	Research/education	9.00
76	Research/education	9.00
76	Research/education	9.00
76	Research/education	9.00
76	Research/education	9.00

Unique ID	Intertidal Activity	h y^{-1}
76	Research/education	9.00
767	Research/education	3.00
6	Research/education	3.00
249	Research/education	3.00
249	Research/education	3.00
257	Rock pooling	24.0
37	Rock pooling	21.0
223	Rock pooling	13.0
138	Rock pooling	12.0
143	Rock pooling	12.0
84	Rock pooling	6.00
256	Rock pooling	6.00
287	Rock pooling	6.00
288	Rock pooling	6.00
83	Rock pooling	4.00
154	Rock pooling	4.00
155	Rock pooling	4.00
293	Rock pooling	4.00
243	Rock pooling	3.00
266	Rock pooling	2.00
5	Rock climbing	10.0
115	Sunbathing	20.0

Unique ID	Intertidal Activity	h y^{-1}
115	Sunbathing	20.0
116	Sunbathing	20.0
116	Sunbathing	20.0
117	Sunbathing	20.0
117	Sunbathing	20.0
118	Sunbathing	20.0
118	Sunbathing	20.0
119	Sunbathing	20.0
119	Sunbathing	20.0
121	Sunbathing	20.0
122	Sunbathing	20.0
64	Sunbathing	12.0
213	Sunbathing	12.0
30	Volunteering	702
34	Volunteering	390
43	Volunteering	390
45	Walking	548
45	Walking	548
46	Walking	548
46	Walking	548
43	Walking	468
43	Walking	468

Unique ID	Intertidal Activity	h y^{-1}
262	Walking	365
270	Walking	365
285	Walking	312
194	Walking	156
231	Walking	156
239	Walking	156
103	Walking	104
256	Walking	104
24	Walking	78.0
24	Walking	78.0
24	Walking	78.0
77	Walking	52.0
238	Walking	52.0
247	Walking	52.0
271	Walking	52.0
281	Walking	52.0
208	Walking	36.0
216	Walking	36.0
225	Walking	26.0
225	Walking	26.0
247	Walking	26.0
247	Walking	26.0

Unique ID	Intertidal Activity	h y^{-1}
281	Walking	26.0
281	Walking	26.0
248	Walking	24.0
145	Walking	21.0
147	Walking	21.0
36	Walking	20.0
38	Walking	20.0
62	Walking	20.0
210	Walking	20.0
70	Walking	18.0
70	Walking	18.0
70	Walking	18.0
71	Walking	18.0
71	Walking	18.0
71	Walking	18.0
235	Walking	14.0
235	Walking	14.0
235	Walking	14.0
269	Walking	14.0
269	Walking	14.0
269	Walking	14.0
26	Walking	12.0

Unique ID	Intertidal Activity	h y^{-1}
26	Walking	12.0
27	Walking	12.0
27	Walking	12.0
104	Walking	12.0
64	Walking	10.0
213	Walking	10.0
273	Walking	10.0
273	Walking	10.0
273	Walking	10.0
273	Walking	10.0
274	Walking	10.0
274	Walking	10.0
274	Walking	10.0
274	Walking	10.0
64	Walking	9.00
64	Walking	9.00
213	Walking	9.00
213	Walking	9.00
186	Walking	8.00
192	Walking	8.00
200	Walking	8.00
248	Walking	7.92

Unique ID	Intertidal Activity	h y^{-1}
25	Walking	7.50
98	Walking	7.50
284	Walking	6.50
284	Walking	6.50
81	Walking	5.00
81	Walking	5.00
97	Walking	5.00
186	Walking	5.00
186	Walking	5.00
186	Walking	5.00
192	Walking	5.00
192	Walking	5.00
192	Walking	5.00
200	Walking	5.00
200	Walking	5.00
200	Walking	5.00
204	Walking	5.00
267	Walking	5.00
290	Walking	5.00
290	Walking	5.00
291	Walking	5.00
291	Walking	5.00

Unique ID	Intertidal Activity	h y^{-1}
292	Walking	5.00
292	Walking	5.00
11	Walking	4.50
11	Walking	4.50
11	Walking	4.50
136	Walking	4.50
21	Walking	4.00
21	Walking	4.00
52	Walking	4.00
53	Walking	4.00
113	Walking	4.00
113	Walking	4.00
113	Walking	4.00
113	Walking	4.00
173	Walking	4.00
173	Walking	4.00
173	Walking	4.00
173	Walking	4.00
176	Walking	4.00
176	Walking	4.00
176	Walking	4.00
176	Walking	4.00

Unique ID	Intertidal Activity	h y^{-1}
177	Walking	4.00
177	Walking	4.00
177	Walking	4.00
177	Walking	4.00
178	Walking	4.00
178	Walking	4.00
178	Walking	4.00
178	Walking	4.00
243	Walking	4.00
266	Walking	4.00
276	Walking	4.00
266	Walking	3.00
266	Walking	3.00
66	Walking	2.50
104	Walking	2.00
120	Walking	2.00
125	Walking	2.00
125	Walking	2.00
125	Walking	2.00
152	Walking	2.00
152	Walking	2.00
174	Walking	2.00

Unique ID	Intertidal Activity	h y^{-1}
174	Walking	2.00
174	Walking	2.00
174	Walking	2.00
249	Walking	2.00
249	Walking	2.00
7	Walking	1.50
7	Walking	1.50
137	Walking	1.50
142	Walking	1.50
205	Walking	1.50
205	Walking	1.50
31	Walking	1.00
31	Walking	1.00
31	Walking	1.00
31	Walking	1.00
31	Walking	1.00
31	Walking	1.00
32	Walking	1.00
32	Walking	1.00
32	Walking	1.00
32	Walking	1.00
32	Walking	1.00

Unique ID	Intertidal Activity	h y^{-1}
32	Walking	1.00
36	Walking	1.00
38	Walking	1.00
78	Walking	1.00
79	Walking	1.00
100	Walking	1.00
105	Walking	1.00
106	Walking	1.00
137	Walking	1.00
137	Walking	1.00
137	Walking	1.00
137	Walking	1.00
184	Walking	1.00
68	Walking	0.50
76	Wild Food Foraging	156
175	Wildfowling	208
175	Wildfowling	104
91	Wildfowling	36.0
246	Wildfowling	18.0
2	Wildfowling	12.0
252	Wildfowling	6.00
28	Wildfowling	2.60

Unique ID	Intertidal Activity	h y^{-1}
28	Wildfowling	2.60
28	Wildfowling	2.60

Table A6.14 Phase 1 Children In-Water Activities

Unique ID	Aquatic Activity	h y^{-1}
334	Body boarding	1.00
331	Outdoor swimming	0.25
330	Outdoor swimming	0.25
329	Outdoor swimming	0.25
334	Outdoor swimming	0.50
334	Outdoor swimming	0.50
332	Outdoor swimming	4.00
317	Outdoor swimming	3.00
316	Outdoor swimming	3.00
321	Outdoor swimming	1.19
346	Outdoor swimming	13.0
294	Rescue Training & Rescue Duties	48.0

Table A6.15 Phase 1 Children On-Water Activities

Unique ID	Aquatic Activity	h y^{-1}
330	Kayaking	0.50
330	Kayaking	0.50

Unique ID	Aquatic Activity	h y^{-1}
329	Kayaking	0.50
329	Kayaking	0.50
303	Kayaking	8.00
304	Power boating	30.0
304	Power boating	30.0
294	Rescue Training & Rescue duties	48.0
346	Sailing	18.0
346	Sailing	45.0
304	Sailing	104
303	Sailing	104
346	Stand-up paddle boarding	6.50

Table A6.16 Phase 1 Children Intertidal Activities

Unique ID	Intertidal Activity	h y^{-1}
334	BBQ/Picnicking/Sitting	2.00
334	BBQ/Picnicking/Sitting	2.00
339	BBQ/Picnicking/Sitting	2.00
340	BBQ/Picnicking/Sitting	2.00
341	BBQ/Picnicking/Sitting	2.00
303	Beachcombing	26.0
304	Beachcombing	26.0
338	Beachcombing	1.00

Unique ID	Intertidal Activity	h y^{-1}
334	Boules	1.50
334	Boules	1.50
334	Boules	1.50
308	Collecting Shells	0.30
309	Collecting Shells	0.30
310	Collecting Shells	0.30
346	Collecting Shells	13.0
303	Crabbing	24.0
304	Crabbing	24.0
329	Crabbing	2.00
330	Crabbing	2.00
331	Crabbing	2.00
332	Crabbing	5.00
332	Crabbing	5.00
297	Dog walking	8.00
297	Dog walking	8.00
297	Dog walking	8.00
297	Dog walking	8.00
298	Dog walking	8.00
298	Dog walking	8.00
298	Dog walking	8.00
298	Dog walking	8.00

Unique ID	Intertidal Activity	h y^{-1}
303	Dog walking	26.0
304	Dog walking	26.0
332	Dog walking	78.0
334	Fishing	24.0
320	Flying a kite	0.17
326	Flying a kite	1.00
327	Flying a kite	1.00
328	Flying a kite	1.00
295	Helping out at lifeboat station	96.0
296	Paddling	2.00
311	Paddling	0.80
312	Paddling	0.80
313	Paddling	0.80
316	Paddling	9.00
317	Paddling	9.00
320	Paddling	12.0
322	Paddling	1.00
329	Paddling	0.50
330	Paddling	0.50
331	Paddling	0.50
333	Paddling	5.00
296	Playing	1.00

Unique ID	Intertidal Activity	h y^{-1}
299	Playing	48.0
299	Playing	48.0
300	Playing	0.33
305	Playing	20.0
306	Playing	20.0
307	Playing	20.0
316	Playing	6.00
317	Playing	6.00
321	Playing	21.0
322	Playing	3.00
323	Playing	4.00
324	Playing	4.00
325	Playing	4.00
329	Playing	3.00
330	Playing	3.00
331	Playing	3.00
332	Playing	48.0
333	Playing	15.0
334	Playing	12.0
334	Playing	12.0
334	Playing	12.0
335	Playing	12.0

Unique ID	Intertidal Activity	h y^{-1}
336	Playing	12.0
337	Playing	12.0
338	Playing	2.00
339	Playing	30.0
340	Playing	30.0
341	Playing	30.0
342	Playing	2.00
343	Playing	2.00
344	Playing	20.0
345	Playing	20.0
346	Playing	13.0
347	Playing	94.5
348	Playing	94.5
349	Playing	6.00
350	Playing	6.00
351	Playing	3.00
352	Playing	3.00
353	Playing	3.00
354	Playing	28.0
308	Rock pooling	0.20
309	Rock pooling	0.20
310	Rock pooling	0.20

Unique ID	Intertidal Activity	h y^{-1}
314	Rock pooling	21.0
315	Rock pooling	21.0
318	Rock pooling	21.0
319	Rock pooling	21.0
320	Rock pooling	12.0
326	Rock pooling	3.00
327	Rock pooling	3.00
328	Rock pooling	3.00
346	Rock pooling	13.0
349	Rock pooling	6.00
350	Rock pooling	6.00
354	Rock pooling	4.00
311	Sunbathing	20.0
312	Sunbathing	20.0
313	Sunbathing	20.0
301	Walking	52.0
308	Walking	1.50
309	Walking	1.50
310	Walking	1.50
329	Walking	7.50
330	Walking	7.50
331	Walking	7.50

Unique ID	Intertidal Activity	h y^{-1}
338	Walking	1.00
344	Walking	20.0
345	Walking	20.0
351	Walking	5.00
351	Walking	5.00
352	Walking	5.00
352	Walking	5.00
353	Walking	5.00
353	Walking	5.00

Table A6.17 Phase 1 Infant In-Water Activities

Unique ID	Aquatic Activity	h y^{-1}
378	Body boarding	1.00
375	Outdoor swimming	4.00
369	Outdoor swimming	3.00
368	Outdoor swimming	3.00
362	Outdoor swimming	1.50

Table A6.18 Phase 1 Infant Intertidal Activities

Unique ID	Intertidal Activity	h y-1
378	BBQ/Picnicking/Sitting	2.00
378	BBQ/Picnicking/Sitting	2.00

Unique ID	Intertidal Activity	h y-1
381	BBQ/Picnicking/Sitting	2.00
362	Beachcombing	42.0
380	Beachcombing	1.00
378	Boules	1.50
378	Boules	1.50
378	Boules	1.50
373	Crabbing	2.00
374	Crabbing	2.00
375	Crabbing	5.00
375	Crabbing	5.00
376	Crabbing	5.00
376	Crabbing	5.00
375	Dog walking	78.0
376	Dog walking	78.0
370	Flying a kite	0.17
386	Horse riding	208
355	Paddling	0.60
356	Paddling	2.00
368	Paddling	9.00
368	Paddling	9.00
369	Paddling	9.00
369	Paddling	9.00

Unique ID	Intertidal Activity	h y-1
370	Paddling	12.0
371	Paddling	1.00
373	Paddling	0.50
374	Paddling	0.50
377	Paddling	5.00
356	Playing	1.00
357	Playing	48.0
357	Playing	48.0
359	Playing	0.33
360	Playing	0.33
362	Playing	48.0
363	Playing	64.0
365	Playing	20.0
365	Playing	20.0
366	Playing	20.0
366	Playing	20.0
367	Playing	20.0
368	Playing	6.00
368	Playing	6.00
369	Playing	6.00
369	Playing	6.00
371	Playing	3.00

Unique ID	Intertidal Activity	h y-1
371	Playing	3.00
374	Playing	3.00
375	Playing	48.0
376	Playing	48.0
377	Playing	15.0
378	Playing	12.0
378	Playing	12.0
378	Playing	12.0
379	Playing	12.0
380	Playing	2.00
381	Playing	30.0
382	Playing	2.00
383	Playing	2.00
384	Playing	2.50
384	Playing	2.50
384	Playing	2.50
385	Playing	2.50
385	Playing	2.50
385	Playing	2.50
387	Playing	28.0
370	Rock pooling	12.0
372	Rock pooling	4.00

Unique ID	Intertidal Activity	h y-1
998	Rock pooling	4.00
355	Walking	12.0
355	Walking	12.0
361	Walking	52.0
364	Walking	5.00
373	Walking	7.50
374	Walking	7.50
380	Walking	1.00

Table A6.19 Phase 1 Adult Handling Sediment Activities

Unique ID	Intertidal Activities	h y^{-1}
51	Bait digging	4.00
255	Bait digging	9.00
58	Bait digging	3.25
289	Bait digging	12.0
67	Bait digging	36.0
46	Bait digging	19.5
252	Bait digging	3.00
284	Bait digging	13.0
275	Bait digging	52.0
180	BBQ/Picnicking/Sitting	4.00
49	BBQ/Picnicking/Sitting	2.00

Unique ID	Intertidal Activities	h y^{-1}
187	BBQ/Picnicking/Sitting	2.00
181	BBQ/Picnicking/Sitting	4.00
212	BBQ/Picnicking/Sitting	2.00
179	BBQ/Picnicking/Sitting	4.00
150	BBQ/Picnicking/Sitting	2.00
111	BBQ/Picnicking/Sitting	2.00
159	BBQ/Picnicking/Sitting	4.00
153	BBQ/Picnicking/Sitting	4.00
151	BBQ/Picnicking/Sitting	4.00
29	BBQ/Picnicking/Sitting	2.00
133	BBQ/Picnicking/Sitting	2.00
123	BBQ/Picnicking/Sitting	45.0
149	BBQ/Picnicking/Sitting	2.00
124	BBQ/Picnicking/Sitting	45.0
251	Beachcombing	12.0
127	Beachcombing	6.00
126	Beachcombing	6.00
249	Beachcombing	4.00
243	Beachcombing	3.00
238	Beachcombing	52.0
100	Beachcombing	1.
216	Beachcombing	650

Unique ID	Intertidal Activities	h y^{-1}
174	Beachcombing	4.00
208	Beachcombing	650
206	Beachcombing	0.25
184	Beachcombing	1.00
74	Beachcombing	42.0
275	Beachcombing	26.0
256	Beachcombing	24.0
266	Beachcombing	10.0
34	Beachcombing	624
257	Beachcombing	12.0
271	Beachcombing	52.0
30	Beachcombing	624
254	Beachcombing	24.0
11	Beachcombing	8.00
23	Boat salvaging	4.00
159	Boules	4.50
181	Boules	4.50
179	Boules	4.50
180	Boules	4.50
101	Collecting cockles	3.00
146	Collecting cockles	5.00
282	Collecting cockles	4.00

Unique ID	Intertidal Activities	h y^{-1}
241	Collecting cockles	4.00
282	Collecting mussels	10.0
255	Collecting mussels	4.00
241	Collecting mussels	10.0
101	Collecting mussels	3.00
252	Collecting razor clams	3.00
255	Collecting razor clams	2.00
253	Collecting razor clams	4.00
76	Collecting razor clams	4.00
262	Collecting seaweed	6.00
239	Collecting seaweed	1.00
76	Collecting seaweed	12.0
255	Collecting winkles	2.00
15	Collecting winkles	130
255	Crabbing	10.0
164	Crabbing	10.0
98	Crabbing	2.00
103	Crabbing	24.0
25	Crabbing	2.00
252	Crabbing	6.00
156	Metal detecting	5.00
13	Mud rescue	8.00

Unique ID	Intertidal Activities	h y^{-1}
13	Mud rescue training	48.0
169	Paddling	5.00
114	Paddling	1.00
25	Paddling	0.50
143	Paddling	12.0
138	Paddling	12.0
284	Paddling	13.0
266	Paddling	2.00
257	Paddling	18.0
98	Paddling	0.50
172	Paddling	1.00
168	Paddling	5.00
61	Playing	0.33
35	Playing	3.00
130	Playing	30.0
131	Playing	30.0
129	Playing	30.0
42	Playing	20.0
40	Playing	3.00
81	Playing	3.00
83	Playing	28.0
84	Playing	6.00

Unique ID	Intertidal Activities	h y^{-1}
54	Playing	64.0
96	Playing	30.0
94	Playing	96.0
108	Playing	20.0
107	Playing	20.0
112	Playing	7.50
100	Playing	2.00
62	Playing	20.0
74	Playing	48.0
111	Playing	30.0
102	Playing	12.0
60	Playing	0.33
110	Playing	2.00
93	Playing	20.0
250	Playing	12.0.
188	Playing	2.00
195	Playing	7.50
196	Playing	7.50
197	Playing	7.50
132	Playing	30.0
199	Playing	7.50
167	Playing	48.0

Unique ID	Intertidal Activities	h y^{-1}
210	Playing	20.0
187	Playing	30.0
238	Playing	104
198	Playing	7.50
257	Playing	36.0
284	Playing	13.0
287	Playing	6.00
288	Playing	6.00
290	Playing	3.00
291	Playing	3.00
292	Playing	3.00
293	Playing	28.0
223	Playing	13.0
179	Playing	36.0
164	Playing	48.0
150	Playing	4.00
168	Playing	15.0
149	Playing	4.00
185	Playing	30.0
169	Playing	15.0
159	Playing	36.0
180	Playing	36.0

Unique ID	Intertidal Activities	h y^{-1}
148	Playing	21.0
134	Playing	30.0
181	Playing	36.0
182	Playing	12.0
184	Playing	2.00
20	Research/education	52.0
270	Research/education	12.0
76	Research/education	60.0
249	Research/education	6.00
21	Research/education	13.0
243	Research/education	155
238	Research/education	312
266	Rock pooling	2.00
84	Rock pooling	6.00
288	Rock pooling	6.00
283	Rock pooling	4.00
287	Rock pooling	6.00
143	Rock pooling	12.0
138	Rock pooling	12.0
83	Rock pooling	4.00
223	Rock pooling	13.0
154	Rock pooling	4.00

Unique ID	Intertidal Activities	h y^{-1}
37	Rock pooling	21.0
257	Rock pooling	24.0
155	Rock pooling	4.00
256	Rock pooling	6.00
243	Rock pooling	3.00
91	Wildfowling	36.0
175	Wildfowling	312
252	Wildfowling	6.00
2	Wildfowling	12.0
246	Wildfowling	18.0
28	Wildfowling	7.80

Table A6.20 Phase 1 Adult Handling Equipment Activities

Unique ID	Aquatic Activities	h y^{-1}
289	Angling - Sea	156
284	Angling - Sea	365
279	Angling - Sea	72.0
275	Angling - Sea	312
257	Angling - Sea	3.00
256	Angling - Sea	78.0
255	Angling - Sea	156
246	Angling - Sea	30.0

Unique ID	Aquatic Activities	h y^{-1}
223	Angling - Sea	48.0
175	Angling - Sea	36.0
91	Angling - Sea	12.0
82	Angling - Sea	96.0
54	Angling - Sea	60.0
14	Angling - Sea	18.0
2	Angling - Sea	48.0
289	Boat maintenance	159
279	Boat maintenance	12.0
277	Boat maintenance	4.00
266	Boat maintenance	20.0
264	Boat maintenance	30.0
262	Boat maintenance	12.0
259	Boat maintenance	13.0
258	Boat maintenance	9.00
257	Boat maintenance	3.00
256	Boat maintenance	3.00
255	Boat maintenance	38.0
254	Boat maintenance	52.0
252	Boat maintenance	183
251	Boat maintenance	6.00
250	Boat maintenance	12.0

Unique ID	Aquatic Activities	h y^{-1}
233	Boat maintenance	52.0
224	Boat maintenance	24.0
220	Boat maintenance	2.25
219	Boat maintenance	2.25
11	Boat maintenance	13.0
2	Boat maintenance	52.0
289	Boats and boating equipment	104
279	Boats and boating equipment	8.00
275	Boats and boating equipment	0.50
264	Boats and boating equipment	40.0
259	Boats and boating equipment	52.0
257	Boats and boating equipment	26.0
252	Boats and boating equipment	50.0
251	Boats and boating equipment	104
246	Boats and boating equipment	1.00
239	Boats and boating equipment	7.80
236	Boats and boating equipment	100
223	Boats and boating equipment	3.00
217	Boats and boating equipment	96.0
215	Boats and boating equipment	117
211	Boats and boating equipment	0.50
191	Boats and boating equipment	10.0

Unique ID	Aquatic Activities	h y^{-1}
142	Boats and boating equipment	0.17
137	Boats and boating equipment	0.17
98	Boats and boating equipment	0.12
93	Boats and boating equipment	0.50
91	Boats and boating equipment	9.00
82	Boats and boating equipment	5.00
54	Boats and boating equipment	30.0
16	Boats and boating equipment	15.6
11	Boats and boating equipment	6.00
9	Boats and boating equipment	7.25
5	Boats and boating equipment	2.00
281	Clothes and overalls	6.24
280	Clothes and overalls	1.56
279	Clothes and overalls	6.00
259	Clothes and overalls	2.00
258	Clothes and overalls	0.12
257	Clothes and overalls	1.50
253	Clothes and overalls	4.68
247	Clothes and overalls	6.24
246	Clothes and overalls	0.50
240	Clothes and overalls	1.56
239	Clothes and overalls	6.50

Unique ID	Aquatic Activities	h y^{-1}
236	Clothes and overalls	4.00
233	Clothes and overalls	6.24
225	Clothes and overalls	6.24
223	Clothes and overalls	0.50
215	Clothes and overalls	39.0
211	Clothes and overalls	0.50
104	Clothes and overalls	0.17
103	Clothes and overalls	0.50
98	Clothes and overalls	0.12
91	Clothes and overalls	1.50
73	Clothes and overalls	0.25
67	Clothes and overalls	0.25
56	Clothes and overalls	0.30
46	Clothes and overalls	6.24
16	Clothes and overalls	15.6
15	Clothes and overalls	1.56
14	Clothes and overalls	6.24
12	Clothes and overalls	4.50
9	Clothes and overalls	0.75
5	Clothes and overalls	2.00
233	Commercial fishing/creeling	1664
223	Commercial fishing/creeling	104

Unique ID	Aquatic Activities	h y^{-1}
56	Commercial fishing/creeling	130
14	Commercial fishing/creeling	1537.5
171	Creel fishing/handling creels (not commercial)	1560
142	Dinghy Sailing	4.00
137	Dinghy Sailing	4.00
251	Diving gear	730
250	Diving gear	19.5
220	Diving gear	52.0
219	Diving gear	52.0
217	Diving gear	52.0
289	Fishing	9.00
284	Fishing	45.0
275	Fishing	156
255	Fishing	36.0
249	Fishing	2.00
241	Fishing	12.0
223	Fishing	24.0
181	Fishing	24.0
180	Fishing	24.0
179	Fishing	24.0
159	Fishing	24.0
146	Fishing	12.0

Unique ID	Aquatic Activities	h y^{-1}
91	Fishing	30.0
82	Fishing	36.0
72	Fishing	8.00
69	Fishing	1040
67	Fishing	108
63	Fishing	24.0
58	Fishing	52.0
51	Fishing	15.0
289	Fishing gear	39.0
284	Fishing gear	1.56
275	Fishing gear	6.00
246	Fishing gear	0.25
241	Fishing gear	1.00
181	Fishing gear	0.75
180	Fishing gear	0.75
179	Fishing gear	0.75
159	Fishing gear	0.75
91	Fishing gear	0.25
69	Fishing gear	208
67	Fishing gear	3.00
63	Fishing gear	0.75
51	Fishing gear	0.75

Unique ID	Aquatic Activities	h y^{-1}
46	Fishing gear	6.24
289	Fixing moorings	1.00
264	Fixing moorings	2.00
255	Fixing moorings	8.00
251	Fixing moorings	4.00
12	Fixing moorings	2.00
252	Sports fishing	548
69	Sports fishing	528
193	Wind surfing	12.0
264	Working on a boat	20.0
257	Working on a boat	6.00
217	Working on a boat	1392

Table A6.21 Phase 1 Children Handling Sediment Activities

Unique ID	Intertidal Activities	h y^{-1}
340	BBQ/Picnicking/Sitting	2.00
334	BBQ/Picnicking/Sitting	4.00
339	BBQ/Picnicking/Sitting	2.00
341	BBQ/Picnicking/Sitting	2.00
338	Beachcombing	1.00
303	Beachcombing	26.0
304	Beachcombing	26.0

Unique ID	Intertidal Activities	h y^{-1}
334	Boules	4.50
308	Collecting Shells	0.30
309	Collecting Shells	0.30
310	Collecting Shells	0.30
346	Collecting Shells	13.0
331	Crabbing	2.00
330	Crabbing	2.00
332	Crabbing	10.0
329	Crabbing	2.00
304	Crabbing	24.0
303	Crabbing	24.0
331	Paddling	0.50
333	Paddling	5.00
330	Paddling	0.50
329	Paddling	0.50
296	Paddling	2.00
320	Paddling	12.0
317	Paddling	9.00
316	Paddling	9.00
313	Paddling	0.80
312	Paddling	0.80
311	Paddling	0.80

Unique ID	Intertidal Activities	h y^{-1}
322	Paddling	1.00
314	Playing	6.00
350	Playing	6.00
344	Playing	20.0
321	Playing	21.0
353	Playing	3.00
345	Playing	20.0
334	Playing	36.0
352	Playing	3.00
323	Playing	4.00
346	Playing	13.0
324	Playing	4.00
351	Playing	3.00
305	Playing	20.0
306	Playing	20.0
347	Playing	94.5
348	Playing	94.5
349	Playing	6.00
307	Playing	20.0
329	Playing	3.00
330	Playing	3.00
335	Playing	12.0

Unique ID	Intertidal Activities	h y^{-1}
333	Playing	15.0
336	Playing	12.0
332	Playing	48.0
337	Playing	12.0
331	Playing	3.00
322	Playing	3.00
339	Playing	30.0
317	Playing	6.00
340	Playing	30.0
296	Playing	1.00
341	Playing	30.0
342	Playing	2.00
343	Playing	2.00
299	Playing	96.0
300	Playing	0.33
354	Playing	28.0
325	Playing	4.00
338	Playing	2.00
350	Rock pooling	6.00
308	Rock pooling	0.20
309	Rock pooling	0.20
349	Rock pooling	6.00

Unique ID	Intertidal Activities	h y^{-1}
310	Rock pooling	0.20
314	Rock pooling	21.0
315	Rock pooling	21.0
346	Rock pooling	13.0
319	Rock pooling	21.0
320	Rock pooling	12.0
326	Rock pooling	3.00
327	Rock pooling	3.00
328	Rock pooling	3.00
354	Rock pooling	4.00
318	Rock pooling	21.0

Table A6.22 Phase 1 Children Handling Equipment Activities

Unique ID	Intertidal Activities	h y^{-1}
340	BBQ/Picnicking/Sitting	2.00
334	BBQ/Picnicking/Sitting	4.00
339	BBQ/Picnicking/Sitting	2.00
341	BBQ/Picnicking/Sitting	2.00
338	Beachcombing	1.00
303	Beachcombing	26.0
304	Beachcombing	26.0
334	Boules	4.50

Unique ID	Intertidal Activities	h y^{-1}
308	Collecting Shells	0.30
309	Collecting Shells	0.30
310	Collecting Shells	0.30
346	Collecting Shells	13.0
331	Crabbing	2.00
330	Crabbing	2.00
332	Crabbing	10.0
329	Crabbing	2.00
304	Crabbing	24.0
303	Crabbing	24.0
331	Paddling	0.50
333	Paddling	5.00
330	Paddling	0.50
329	Paddling	0.50
296	Paddling	2.00
320	Paddling	12.0
317	Paddling	9.00
316	Paddling	9.00
313	Paddling	0.80
312	Paddling	0.80
311	Paddling	0.80
322	Paddling	1.00

Unique ID	Intertidal Activities	h y^{-1}
316	Playing	6.00
350	Playing	6.00
344	Playing	20.0
321	Playing	21.0
353	Playing	3.00
345	Playing	20.0
334	Playing	36.0
352	Playing	3.00
323	Playing	4.00
346	Playing	13.0
324	Playing	4.00
351	Playing	3.00
305	Playing	20.0
306	Playing	20.0
347	Playing	94.5
348	Playing	94.5
349	Playing	6.00
307	Playing	20.0
329	Playing	3.00
330	Playing	3.00
335	Playing	12.0
333	Playing	15.0

Unique ID	Intertidal Activities	h y^{-1}
336	Playing	12.0
332	Playing	48.0
337	Playing	12.0
331	Playing	3.00
322	Playing	3.00
339	Playing	30.0
317	Playing	6.00
340	Playing	30.0
296	Playing	1.00
341	Playing	30.0
342	Playing	2.00
343	Playing	2.00
299	Playing	96.0
300	Playing	0.33
354	Playing	28.0
325	Playing	4.00
338	Playing	2.00
350	Rock pooling	6.00
308	Rock pooling	0.20
309	Rock pooling	0.20
349	Rock pooling	6.00
310	Rock pooling	0.20

Unique ID	Intertidal Activities	h y^{-1}
314	Rock pooling	21.0
315	Rock pooling	21.0
346	Rock pooling	13.0
319	Rock pooling	21.0
320	Rock pooling	12.0
326	Rock pooling	3.00
327	Rock pooling	3.00
328	Rock pooling	3.00
354	Rock pooling	4.00
318	Rock pooling	21.0

Table A6.23 Phase 1 Infant Handling Sediment Activities

Unique ID	Intertidal Activities	h y^{-1}
381	BBQ/Picnicking/Sitting	2.00
378	BBQ/Picnicking/Sitting	4.00
380	Beachcombing	1.00
362	Beachcombing	42.0
378	Boules	4.50
374	Crabbing	2.00
376	Crabbing	10.0
375	Crabbing	10.0
373	Crabbing	2.00

Unique ID	Intertidal Activities	h y^{-1}
368	Paddling	18.0
369	Paddling	18.0
370	Paddling	12.0
371	Paddling	1.00
355	Paddling	0.60
373	Paddling	0.50
373	Paddling	2.00
374	Paddling	0.50
377	Paddling	5.00
369	Playing	12.0
387	Playing	28.0
356	Playing	1.00
357	Playing	96.0
359	Playing	0.33
360	Playing	0.33
385	Playing	7.50
362	Playing	48.0
363	Playing	64.0
365	Playing	40.0
366	Playing	40.0
367	Playing	20.0
384	Playing	7.50

Unique ID	Intertidal Activities	h y^{-1}
373	Playing	3.00
383	Playing	2.00
376	Playing	48.0
382	Playing	2.00
381	Playing	30.0
371	Playing	3.00
380	Playing	2.00
379	Playing	12.0
378	Playing	36.0
377	Playing	15.0
374	Playing	3.00
375	Playing	48.0
368	Playing	12.0
370	Rock pooling	12.0
372	Rock pooling	4.00
387	Rock pooling	4.00

Appendix A7 Phase 2 Survey Data

Table A7.1 Phase 2 Adult Crustacean Consumption

Unique ID	Food type	Consumption Rate (kg y^{-1})
1000	Brown crab	26.0
1000	Common lobster	26.0

Unique ID	Food type	Consumption Rate (kg y^{-1})
1005	Common lobster	6.00
1005	Brown crab	0.90
1003	Common lobster	0.50
1004	Shrimps	0.30

Table A7.2 Phase 2 Adult Fish Consumption

Unique ID	Food type	Consumption Rate (kg y^{-1})
1000	Bass	15.0
1002	Bass	5.00
1003	Bass	4.00
1004	Bass	3.00
1001	Cod	12.0
1002	Cod	5.00
1002	Dover sole	2.00
1004	Dover sole	0.50
1001	Mackerel	6.0
1002	Mackerel	5.0
1005	Mackerel	0.45
1001	Salmon	23.4
1004	Salmon	2.00
1001	Plaice	12.0
1005	Plaice	1.50

Unique ID	Food type	Consumption Rate (kg y^{-1})
1004	Flounder	0.50
1000	Grey Mullet	15.0

Table A7.3 Phase 2 Adult Molluscs Consumption

Unique ID	Food type	Consumption Rate (kg y^{-1})
1004	Cockles	0.30
1003	Cockles	10.00
1004	Mussels	0.30
1001	Mussels	5.90
1004	Razor clams	0.30
1003	Razor clams	0.75
1001	Scallops	5.90
1003	Scallops	0.30

Table A7.4 Phase 2 Adult Wildfowl Consumption

Unique ID	Food type	Consumption Rate (kg y^{-1})
1002	Mallard	6.00
1002	Teal	3.50
1002	Teal	3.00
1002	Widgeon	5.00

Table A7.5 Phase 2 Adult Terrestrial Food Consumption

Unique ID	Food type	Consumption Rate (kg y^{-1})
1002	Pheasant	9.00

Table A7.6 Phase 2 Adult On-Water Activities

Unique ID	Aquatic Activity	Hours per year
1002	Angling - Sea	24.0
1002	Angling - Sea	24.0
1005	Angling - Sea	18.0
1002	Boat maintenance	20.0
1001	Canoeing	78.0
1007	Canoeing	9.00
1005	Commercial fishing/creeling	1 278
1005	Commercial fishing/creeling	260
1000	Commercial fishing/creeling	130
1002	Power boating	24.0
1002	Power boating	24.0
1004	Rescue Training & Rescue duties	72.0
1002	RNLI Rescue duties	12.0
1002	RNLI Rescue duties	12.0

Table A7.7 Phase 2 Adult Intertidal Activities

Unique ID	Intertidal Activity	Total Hours (h y^{-1})
1006	Beachcombing	312
1006	Beachcombing	312
1006	Bird/Nature watching	182

Unique ID	Intertidal Activity	Total Hours (h y^{-1})
1002	Boat maintenance	24.0
1003	Collecting cockles	5.00
1001	Dog walking	1460
1006	Dog walking	546
1008	Dog walking	156
1008	Dog walking	104
1002	Dog walking	72.0
1002	Dog walking	36.0
1003	Fishing	12.0
1004	Mud rescue	8.00
1004	Mud rescue training	48.0
1007	Playing	20.0
1006	Volunteering	702
1008	Volunteering	390
1008	Walking	468
1008	Walking	468
1002	Wildfowling	12.0

Table A7.8 Phase 2 Adult Handling Sediment Activities

Unique ID	Intertidal Activities	Total Hours (h y^{-1})
1006	Beachcombing	624
1003	Collecting cockles	5.00

Unique ID	Intertidal Activities	Total Hours (h y^{-1})
1004	Mud rescue	8.00
1004	Mud rescue training	48.0
1007	Playing	20.0
1002	Wildfowling	12.0

Table A7.9 Phase 2 Adult Handling Equipment Activities

Unique ID	Aquatic Activities	Total Hours (h y^{-1})
1005	Angling - Sea	18.0
1002	Angling - Sea	48.0
1002	Boat maintenance	44.0
1000	Clothes and overalls	0.30
1005	Clothes and overalls	6.24
1000	Commercial fishing/creeling	130
1005	Commercial fishing/creeling	1538
1003	Fishing	12.0