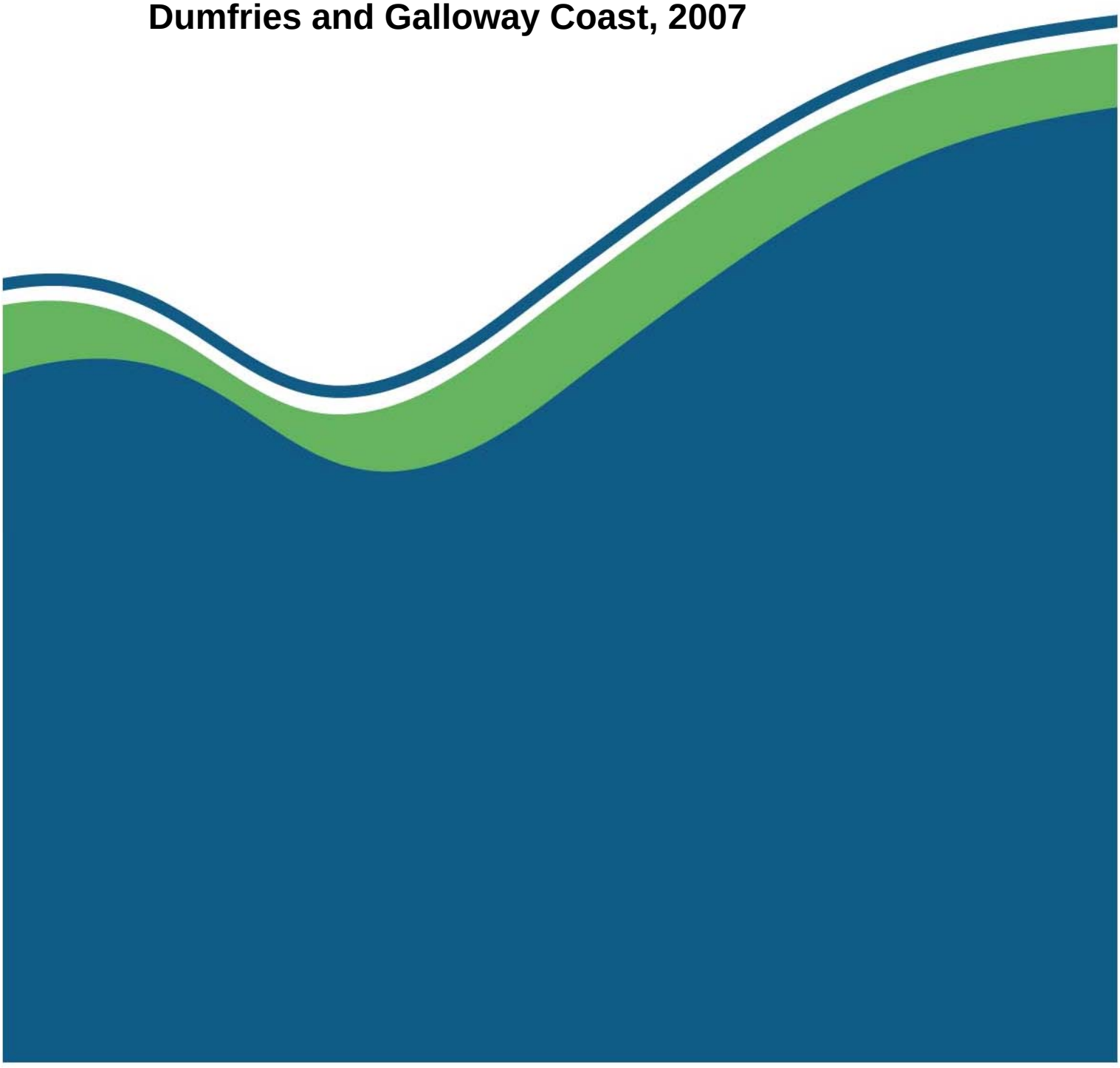
Radiological Habits Survey:

Dumfries and Galloway Coast, 2007



This page has been intentionally left blank

Radiological Habits Survey:
Dumfries and Galloway Coast, 2007

FINAL REPORT

The Centre for Environment, Fisheries & Aquaculture Science
Lowestoft Laboratory
Pakefield Road
Lowestoft
Suffolk
NR33 0HT

F.J. Clyne, C.J. Garrod, J.R. Tipple and T.M. Jeffs

Peer reviewed by G.J. Hunt

Approved for publication by W.C. Camplin

2011

The work described in this report was carried
out under contract to the Scottish Environment Protection Agency
SEPA contract R40067/PUR
Cefas contract C2448

Environment Report RL 08/11

This page has been intentionally left blank

CONTENTS

ANNEXES

SUMMARY

This report presents the results of a survey, conducted in 2007, to investigate the habits of people along the Dumfries and Galloway coast and the waters offshore, in order to determine the potential exposure pathways relating to authorised liquid discharges to the Solway, principally from the Sellafield nuclear site in Cumbria.

The survey area included the Dumfries and Galloway coast from the Caerlaverock National Nature Reserve in the east to the Isle of Whithorn in the west and the waters offshore of this coastline.

Potential exposure pathways investigated during the survey included: the consumption of foods from the survey area including wildfowl and salt marsh grazed livestock; occupancy over intertidal stretches of the coastline; handling of sediment and fishing gear; and the use of seaweed.

Interviews were conducted with members of the public and the data collected for 302 individuals are presented and discussed. High rates of consumption, intertidal occupancy and handling are identified using established methods comprising a 'cut off' to define the critical group, and 97.5 percentiles. The rates so identified can be used in dose assessments.

Aquatic survey area

Mollusc collecting was the dominant commercial fishing activity identified in the survey area, which included scallop dredging for queen scallops and king scallops, hand raking, tractor raking and dredging for cockles, winkle collecting, and creeling for whelks. Haaf netting, stake netting and net-and-cobble fishing for salmon and sea trout were identified as well as gill netting for bass. Creel fishing for lobsters, crabs and *Nephrops* was also noted.

Aquatic foods were consumed from the following food groups: fish, crustaceans, molluscs, wildfowl and salt marsh grazed cattle meat. The adult critical group mean consumption rates for each of these food groups were:

- 51 kg y^{-1} for fish (comprising of cod, mackerel, bass and other species, caught by boat anglers and shore anglers)
- 15 kg y^{-1} for crustaceans (comprising crab, *Nephrops* and lobsters, caught in creels by commercial fishermen)
- 5.7 kg y^{-1} for molluscs (comprising mussels, cockles, king scallops and winkles, collected by shellfish collectors and commercial scallop dredgers)
- 22 kg y^{-1} for wildfowl (comprising geese and ducks shot by wildfowlers)
- 31 kg y^{-1} for salt marsh grazed cattle meat (comprising beef from farms in the survey area)

No consumption of marine plants/algae was identified.

The relative contribution of the component foods within each food group for the adult critical groups were:

- For fish: cod 45%, mackerel 35%, bass 10% and other species 10%
- For crustaceans: crab 55%, *Nephrops 25%* and lobster 20%
- For molluscs: mussels 60%, cockles 25%, king scallops 10% and winkles 5%
- For wildfowl: geese 55% and ducks 45%
- For salt marsh grazed cattle meat: beef 100%

The use of seaweed for livestock feed, fertiliser or soil conditioner was investigated during the survey but was not identified.

Intertidal activities identified for adults or children included angling, stake netting, bait digging, winkle collecting, mussel collecting, cockle collecting (by hand rake and by tractor rake), crab collecting, wildfowling, dog walking, beachcombing, bird watching, working on the shore, coastguard duties, marsh warden duties, fixing moorings, boat maintenance, walking, playing, tending livestock and beach cleaning.

The critical group mean rates for occupancy over intertidal substrates were:

- 780 h y^{-1} over mud (for four stake net fishermen at Balcary Bay and Sandyhills)
- 570 h y^{-1} over mud and sand (for three stake net fishermen at Wigtown Bay and Balcary Bay, one of whom also collected cockles at Southerness, and one bait digger at Sandgreen)
- 670 h y^{-1} over rock (for 10 people whose activities included angling in the Kirkcudbright Bay area, Wigtown Bay, Abbey Burn Foot, Balcary Point and Rascarrel Bay; collecting winkles on the shore between the Isle of Whithorn and Auchencairn Bay, the Kirkcudbright Bay area and at various beaches; and collecting mussels and collecting peeler crabs in the Kirkcudbright Bay area)
- 670 h y^{-1} over salt marsh (for two people wildfowling at Wigtown Bay and the Caerlaverock Nature Reserve and two people conducting marsh warden duties at the Caerlaverock Nature Reserve, one of which was also conducting coastguard duties at the Caerlaverock Nature Reserve)
- 310 h y^{-1} over sand (for one person collecting cockles at Mersehead Sands, three people dog walking at Nun Mill Bay, Carsluith and various beaches, one person working on the shore at Auchencairn Bay, six individuals bird watching at Mersehead RSPB Reserve and two people beachcombing at Fleet Estuary)

Gamma dose rate measurements were taken over substrates in the aquatic survey area where people were spending time.

Fishermen were identified handling fishing gear including creels and nets. Bait diggers, shellfish collectors and wildfowlers were identified handling sediment.

The critical group mean rates for handling were:

- 1300 h y^{-1} for handling fishing gear (for four creel fishermen, three stake net fishermen and one fisherman who was creeling and stake netting)
- 820 h y^{-1} for handling sediment (for seven shellfish collectors, two wildfowlers and one bait digger)

Activities taking place in the survey area in the water around Dumfries and Galloway included jet skiing, kayaking and swimming. Activities on the water in this survey area included commercial fishing (creeling, dredging, haaf netting and gill netting), boat angling, sailing, canoeing, motor cruising, working on the river, hobby fishing (creeling), boat maintenance, paddling, angling, RNLI and coastguard duties. The maximum occupancy rate in water was 160 h y^{-1} for a jet skier in Brighouse Bay. The maximum occupancy rate on water was 2700 h y^{-1} for a commercial creel fisherman around the Isle of Whithorn.

Comparisons with the previous survey

Comparisons were made with a previous habits survey conducted in the same area in 2002. Compared with the 2002 results, the critical group mean consumption rates for fish and wildfowl increased in 2007, whereas the critical group mean consumption rates for crustaceans, molluscs and salt marsh grazed cattle meat decreased. Most notably, the critical group mean consumption rate for molluscs almost halved, (decreasing from 11 kg y^{-1} in 2002 to 5.7 kg y^{-1} in 2007), while the critical group mean consumption rate for wildfowl more than doubled, (increasing from 8.8 kg y^{-1} in 2002 to 21 kg y^{-1} in 2007). The consumption of small quantities of salt marsh grazed lamb was indentified in 2002 but this was not identified in 2007. The intertidal occupancy rates and handling rates of fishing gear and sediment were broadly similar in 2002 and 2007 with the exception of occupancy over rock which had increased from 250 h y^{-1} in 2002 to 670 h y^{-1} in 2007.

Suggestions for changes to the monitoring programme

Based on the findings of this habits survey, it is considered that SEPA's current monitoring programmes provide adequate coverage for the aquatic environment along the Dumfries and Galloway coast. However, a small number of recommendations are provided for consideration to enhance the existing aquatic monitoring programme. An annual sample of cod and mackerel could replace the current samples of plaice and sole due to the higher quantities of cod and mackerel being consumed. An annual sample of beef and a quarterly sample of milk taken from the cattle grazed on salt marsh could be considered.

1. BACKGROUND

1.1 Regulation of radioactive waste discharges

There are generally three main sources of radiation exposure to members of the public from nuclear sites under normal circumstances: discharges of liquid radioactive waste to the aquatic environment, gaseous discharges to the atmosphere and direct radiation from the site. Regulation of waste discharges in Scotland is carried out under the Radioactive Substances Act 1993, (RSA93) (UK Parliament, 1993). Authorisations granted under RSA93 set limits on the quantities and types of radioactivity that are permitted to be released from the site. For discharges in Scotland, the Scottish Environment Protection Agency (SEPA) is the primary regulatory authority under RSA93. Sources of direct radiation from sites are regulated by the Nuclear Installations Inspectorate (NII) of the Health and Safety Executive (HSE).

This survey, conducted along the Dumfries and Galloway coast in Scotland, considered the effects of authorised liquid discharges from the Sellafield nuclear site in Cumbria, which releases wastes into the Irish Sea. The potential effects of these wastes are monitored in the Solway Firth, which has its north coastline in Scotland and its south coastline in England. As Sellafield is in England, the site discharges are regulated by the Environment Agency. SEPA's role in this case is directed at its general duty to protect the public from radiation exposure. In support of this objective, this report provides information to form the basis of assessments of radiation exposures along the Dumfries and Galloway coast and to help direct future environmental monitoring programmes.

The area studied is to the west of the area likely to be affected by discharges from the Chapelcross nuclear site, which is the subject of separate studies.

1.2 The critical group concept

Radiological protection of the public is based on the concept of a critical group. The critical group is defined as those people who, because of where they live and their habits, receive the highest radiation dose from a nuclear site and its discharges. It is the assessed radiation dose to the critical group that is compared to relevant limits and constraints. If the dose to the critical group is acceptable, it follows that the lower doses received by other members of the public will be below any limits and constraints, and overall protection of the public is provided. This report provides information to assist SEPA in determining critical groups for the Dumfries and Galloway coast.

1.3 Dose limits and constraints

Assessed radiation doses to critical groups are compared to nationally and internationally recommended dose limits and constraints.

The Radioactive Substances (Basic Safety Standards) (Scotland) Direction 2000 (Scottish Executive, 2000) directs SEPA to ensure that the sum of doses of ionising radiation to the public does not exceed the limits set out in Article 13 of Council Directive 96/29/Euratom (CEC, 1996) and that doses should be as low as reasonably achievable (ALARA), economic and social factors being taken into account. In connection with the latter, SEPA is directed to have regard to the following maximum doses which may result from a defined source, for use at the planning stage in radiation protection:

a) 0.3 millisieverts per year from any source from which radioactive discharges are first made on, or after 13 May 2000: or
b) 0.5 millisieverts per year from the discharges from any single site.

Additionally, the Government accepts that, in general it should be possible to operate existing facilities within the 0.3 mSv per year constraint. The International Commission on Radiological Protection (ICRP).recommends a dose limit of 1 mSv per year to members of the public from all anthropogenic sources.

As the Sellafield Nuclear Licensed Site operates in England, the appropriate regulatory authority is the Environment Agency, who operate following equivalent criteria and consult SEPA on site issues where appropriate.

2. THE SURVEY

2.1 Survey aims

The Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook the survey in 2007 on behalf of SEPA (Cefas contract C2448 and SEPA contract R40067/PUR). The aim of the survey was to review the habits of the public along the Dumfries and Galloway coast relating to liquid discharges to the Solway, principally from the Sellafield nuclear site in Cumbria.

Investigations were carried out to ascertain the following:

- The consumption of foods from the aquatic environment (including wildfowl and livestock grazed on salt marsh)
- Activities and occupancy over intertidal areas
- The handling of fishing gear and sediment
- Activities and occupancy in and on water (relating to the inhalation of re-suspended radioactivity in sea spray and the inadvertent ingestion of contaminated seawater)
- Intertidal land use in the area
- Any new or unusual exposure pathways
- The use of any natural resources from the aquatic environment (e.g. sand/gravel extraction, use of seaweed as a fertiliser)

The habits data are used in combination with monitoring data to determine the critical group(s) and identify critical exposure pathways to the local population. The previous aquatic habits survey along the Dumfries and Galloway coast conducted by Cefas was in 2002 (Sherlock *et al*., 2003). The data from the 2002 survey are currently being used in dose assessments for the Dumfries and Galloway coast.

2.2 Survey area

The survey area covered the Dumfries and Galloway coast from the Caerlaverock National Nature Reserve in the east to the Isle of Whithorn in the west and the waters offshore (Figure 1). This area was chosen to include the locations where the far-field effects of current and historic discharges from Sellafield were likely to be most pronounced.

Figure 1. The aquatic survey area.

Key to numbered locations in Figure 1

1	Glencaple	18	Nun Mill Bay
2	Carsethorn	19	Milton Sands
3	Mersehead	20	Ross Bay
4	Sandyhills Bay	21	Fox Craig
5	Castlehill Point	22	Brighouse Bay
6	Kippford	23	Kirkandrews
7	Urr Water	24	Ardwall Isle
8	South Glen	25	Isle Mouth
9	Almorness Point	26	Carrick Bay
10	Orchardton Bay	27	Sandgreen
11	Balcary Bay	28	Water of Fleet
12	Port Mary	29	Ringdoo Point
13	Abbey Burn Foot	30	Carsluith
14	Torrs Point	31	River Bladnoch
15	Manxman’s Lake	32	Innerwell
16	St Mary’s Isle	33	Cruggleton Bay
17	River Dee	34	Cairn Head

2.3 Conduct of the survey

The fieldwork component of the survey was carried out during the period 23rd July to 6th August 2007 by three members of staff from the Cefas Laboratory at Lowestoft, according to techniques as described by Leonard *et al.* (1982).

During the survey, people with a local knowledge of the survey area were contacted for information on any aspects relevant to the exposure pathways. These included the Solway Shellfish Management Association (SSMA), commercial fishermen, angling clubs, marsh wardens, farmers and wildfowlers.

Interviews were used to establish individual's consumption rates and occupancy rates relevant to exposure pathways and to obtain any general information. Emphasis was placed on interviewing those individuals who were likely to be in the most exposed groups. These included stake netters, haaf netters, creel fishermen, shellfish collectors, anglers, bait diggers, wildfowlers and marsh wardens.

Gamma dose rate measurements were taken over intertidal substrates in the survey area using a Mini 6-81 instrument and a compensated Geiger-Muller tube.

3 METHODS FOR DATA ANALYSIS

3.1 Data recording and presentation

Data collected during the fieldwork were recorded in logbooks. On return to the laboratory, the data were examined and any notably high rates were double-checked, where possible, by way of a follow-up phone call. In rare cases where follow-up phone calls were not possible (e.g. interviewees who wished to remain anonymous), the data were accepted at face value. The raw data were entered into a purpose-built database where each individual for whom information was obtained was given a unique identifier (the observation number) to assist in maintaining data quality.

The results of the individuals' consumption, intertidal occupancy and handling rates collected during the survey were grouped and presented in tables with the critical group members indicated in bold. The consumption rates, intertidal occupancy rates and handling rates for all groups are presented in Annexes 1 and 2 for adults and children respectively, with the critical group members indicated in bold.

3.2 Data conversion

During the interviews, people could not always provide consumption rates in kilograms per year for food. In these circumstances, interviewees were asked to provide the information in a different format such as the number of units, e.g. the number of crabs or lobsters. These data were converted to consumption rates, in kilograms per year, using edible fraction data researched by Cefas.

3.3 Rounding and grouping of data

The consumption and occupancy data in the text of this report are rounded to two significant figures, except for values less than 1.0, which are rounded to one decimal place. This method of presentation reflects the authors' judgement on the accuracy of the methods used. In the tables and annexes, the consumption rate data are usually presented to one decimal place. Occasionally, this rounding process causes the computed values (row totals, mean rates and 97.5 percentiles), which are based on un-rounded data, to appear slightly erroneous. Consumption rates less than 0.05 kg y^{-1} are presented to two decimal places in order to avoid the value of 0.0 kg y^{-1}. External exposure data are quoted as integer numbers of hours per year.

For internal exposure, the consumption data are structured into food groups with similar attributes. For example, all mollusc species are grouped as 'molluscs'. Examples of typical aquatic food groups are shown in Table 1.

Table 1 Typical food groups used in aquatic habits surveys

Food group	Typical foods within the food groups
Sea fish	Bass, brill, cod, common ling, dab, Dover sole, flounder, gurnard, haddock, hake, herring, lemon sole, mackerel, monkfish, mullet, plaice, pollack, witch saithe, salmon, sea trout, squid[a], cuttlefish[a], rays, turbot, whitebait, whiting
Crustaceans	Brown crab, spider crab, crawfish, lobster, *Nephrops,* squat lobster, prawn, shrimp
Molluscs	Cockles, limpets, mussels, oysters, scallops, razor shells, whelks, winkles

[a] Although squid and cuttlefish are molluscs, radiologically they are more akin to fish

For external exposure over intertidal sediments, occupancies over the same substrate, such as sand, are grouped together.

Data are structured into age groups because different dose coefficients (i.e. the factors which convert intakes of radioactivity into dose) can apply to different ages. The age groups and their relevant age ranges are based on the recommendations in ICRP 72 (ICRP, 1996), and are listed below:

Age group	Age range in group
3-month-old	Under 1-year-old
1-year-old	1-year-old
5-year-old	2-year-old to 6-year-old
10-year-old	7-year-old to 11-year-old
15-year-old	12-year-old to 16-year-old
Adult	17-year-old and over

3.4 Data analysis

The habits data have been analysed to indicate high rates of consumption, occupancy and handling, prior to a formal assessment being undertaken. Two approaches have been used:

Firstly, the 'cut-off' method described by Hunt *et al.* (1982) was used. With the cut-off method, the appropriate high rate was calculated by taking the arithmetic mean of the maximum observed rate and all observed rates within a factor of three of the maximum value (termed the lower threshold value). In this report, the term 'critical group' is used to represent the individuals derived by the cut-off method. The critical group mean was calculated for each food group, intertidal substrate and handling pathway identified in the survey. In certain cases, using the cut-off method can result in a single person in the critical group. In these cases, expert judgement was used to decide whether the critical group should remain as one individual or whether others should be included. If it was appropriate to include others, the second highest rate was divided by three and all observations above this were included in the critical group.

Secondly, 97.5 percentile rates were calculated using the Excel mathematical function for calculating percentiles. The use of percentiles accords with precedents used in risk assessment of the safety of food consumption.

Mean and 97.5 percentile rates based on national statistics have been derived by the Ministry of Agriculture, Fisheries and Food (MAFF) (now part of Defra) and the Food Standards Agency (Byrom *et al.,* 1995 and FSA, 2002), and these are referred to as generic rates in this report. The generic rates are used as a baseline for comparison with the observed rates.

For the direct radiation pathway, mean occupancy rates and 97.5 percentile rates have not been calculated. Such an analysis is of limited value without a detailed knowledge of the spatial extent of dose rates due to direct radiation.

3.5 Child ratios for use in dose assessments

For ingestion pathways, critical group mean rates for children have been calculated from the survey data. However, because few child observations were identified, the rates should be viewed with caution. For assessment purposes, an alternative approach may be taken which involves scaling the mean rates for the adult critical groups by ratios. These ratios are given in Table 2 and have been calculated using generic 97.5 percentile consumption rates. Note that the age ranges within the 1-year-old and 10-year-old age groups in Table 2 do not correspond exactly with the age ranges within these age groups used throughout the rest of this report.

Table 2 Ratios for determining consumption and occupancy rates for children

Food group	Ratio child/adult	
	1-year-old	10-year-old
Fish[a]	0.050	0.200
Crustaceans[a]	0.050	0.250
Molluscs[a]	0.050	0.250
External exposure	0.030	0.500

Notes

[a] Ratios were derived from Smith and Jones, (2003) which presented data for infants and children.

4 AQUATIC RADIATION PATHWAYS

4.1 Aquatic survey area

The aquatic survey area, shown in Figure 1, covered the Dumfries and Galloway coast from the Caerlaverock National Nature Reserve in the east to the Isle of Whithorn in the west and waters offshore of this coastline.

The survey area included approximately 140 km of coastline along the north shore of the Solway Firth. The coastline was dominated by a series of mostly inaccessible rocky peninsulas, interspersed with large sandy bays. At low tide, Mersehead Sands, Auchencairn Bay, Kirkcudbright Bay, Fleet Bay and Wigtown Bay, had vast areas of exposed sand and mud. Fast flowing tides limited activities at certain locations along the coast. Six main rivers flowed into this stretch of the Solway Firth. From east to west these were the River Nith, Urr Water, River Dee, Water of Fleet, River Cree and River Bladnoch.

Caerlaverock National Nature Reserve to Southerness Point

The Caerlaverock National Nature Reserve was situated on the eastern side of the Nith Estuary. It was the largest wetland reserve in Britain, comprising 8000 hectares of mudflats and salt marsh, and was jointly managed by Scottish Natural Heritage (SNH) and the Wildfowl and Wetlands Trust (WWT). The reserve was popular with birdwatchers and tourists, and had a large car park for visitors. Wildfowling was permitted within the reserve and areas of salt marsh were rented to local farmers for grazing cattle.

The River Nith flowed through Dumfries in the north and entered the Solway Firth to the west of Caerlaverock. On the upper stretches of the river near Dumfries, fly-fishing for salmon and sea trout was popular. On the lower stretches of the river there were large areas of salt marsh and grass, particularly on the west bank, and at low tide, large areas of mud were exposed. Access to the river was possible on the lower stretch from the eastern shore, although since this area was very muddy, it was only used by haaf netters. There was evidence of a decline in the haaf netting fishery; eight licences had been issued for this stretch of the river in 2007 compared with 40 in 2002. At Glencaple, there was an unmanned inshore lifeboat station, several boats were moored in the river and people were angling from the quay.

Public access along the west bank of the River Nith was difficult due to a limited number of roads leading to the shore. Access was possible at Carsethorn, which was located to the south of the Nith Estuary. The upper shore at Carsethorn was sand and stones, and there were large sand banks exposed on the lower shore at low water. Only one angler was observed at this location and two

small boats were drawn up on the beach. Signs warning of strong currents were clearly visible on the beach.

To the south of Carsethorn was Southerness Point, which was a rocky promontory that extended out into the Solway Firth and divided the beach into two; Gillfoot Bay to the east and Mersehead Sands to the west. There was a large caravan park close to the shore at Southerness Point that attracted numerous visitors. Activities observed in this area were walking, shellfish collecting and bait digging.

Southerness Point to Palnackie

Mersehead Sands was an extensive area of tidal flats stretching approximately ten kilometres west of Southerness Point and three kilometres offshore. The mud and sand flats were exposed at low tide and were the main location for commercial cockle collection within the survey area.

The Mersehead Nature Reserve, owned by the Royal Society for the Protection of Birds (RSPB), covered several kilometres of shore within Mersehead Sands. The reserve attracted approximately 20,000 day-visitors per year who could access the sandy beach and salt marsh areas. The reserve was extremely popular with bird watchers. On the salt marsh areas, a limited amount of wildfowling took place in the winter months and cattle grazing took place in the summer months.

To the west of Mersehead was Sandyhills Bay. The bay was the largest sandy beach within the survey area and was backed by sand dunes. Parking facilities and a caravan site were close to the beach, and the area was popular amongst families. Activities observed during the survey included dog walking, angling, metal detecting and sunbathing.

Pedestrian access to Castlehill Point, the southeastern point of the Urr Estuary, was possible from Sandyhills Bay via a footpath following the rocky coastline. At low tide, the Urr Estuary was predominantly an area of mud and salt marsh. Vehicular access to the eastern shore of the estuary was limited to two locations; Rockcliffe and Kippford. Rockcliffe was a large rocky bay with a small area of sand on the upper shore and mud and sand on the lower shore. A few people were observed on the rocky area during the survey. The village of Kippford was the main sailing centre in the survey area; facilities included a yacht club, a large compound for sailboats and dinghies, pontoons and a slipway. Sailboats and small motorboats were moored in the river. On several occasions during the survey, the river was busy with people sailing dinghies.

To the north of Kippford was Palnackie; here the Urr Water was tidal with steep sided muddy banks. Sheep and cattle were observed grazing on the grass bank at the waters edge. The grass bank was not subject to regular tidal inundation, although it was vulnerable to occasional flooding. The small stonewalled harbour was the nominal homeport for two fishing boats, however they were generally fishing outside the survey area and seldom visited Palnackie.

Palnackie to Kirkcudbright

South of Palnackie on the western banks of Urr Water at South Glen, vehicular access to the water was possible and there was space to park cars on a verge. Each year South Glen hosted The World Flounder Trampling Championship. This unique event involved competitors wading out across the mud flats with the aim of catching flounders by using only their bare feet to detect the fish. Historically three haaf net licences have been issued for use on the river between Palnackie and South Glen, however these were not in operation in 2007.

Further south were Orchardton and Auchencairn Bays. These sheltered areas of sand, mud and salt marsh lay between rocky outcrops. Sheep were observed grazing on the salt marsh on the west shore of Orchardton Bay but public access was not identified. A narrow road extended down the western side of Auchencairn Bay, where there was limited parking in a small lay-by. The upper shore of the bay was rocky, and there were cockles in the large expanse of mud and sand below. Although not observed at the time of the survey, anglers were reported to walk out over the beach and fish the rising tide. Two adults were observed swimming during high tide.

Balcary Bay was located at the southern end of Auchencairn Bay, where there was road access and a car park. A hotel and some holiday cottages were situated close to the beach. The upper shore was rocky with boulders, whilst the mid shore was sandy with stones; the wide expanse of mud and sand on the lower shore was scattered with old mussel beds. Two fixed engine stake nets were operated in the bay and a lobster boat was moored off the beach. Bait digging for lugworm and ragworm was reported to occur. The beach was popular with families and approximately 50 people were observed using the beach on some days during the survey; beach activities included walking, sunbathing, playing, paddling and rock pooling. One adult was seen swimming at high tide. To the south of Balcary Bay was the rocky headland of Balcary Point. The point could be accessed via a footpath from the car park and was a popular winter angling location.

To the west of Balcary Point, towards Torrs Point in Kirkcudbright Bay, the coastline was rocky. Along this stretch Rascarrel Bay and Abbey Burn Foot were the only places with road access to the shore. The Dundrennan military range spanned the coastline from Port Mary in the east to Torrs Point in the west. The road to Abbey Burn Foot passed through the range and was closed when firing was in progress. Other tracks passing through the firing range to the coast were closed to the public at all times. However, at the time of the survey, local angling clubs were negotiating with the MoD regarding the future use of the paths. Several angling venues along this stretch of coast were noted, the most popular locations being close to the road access points. Winkle collecting was also reported to occur in several places.

The rocky coast continued over one kilometre northwards from Torrs Point to the lifeboat station on the east side of Kirkcudbright Bay. Angling was popular around the lifeboat station; public access was possible only by foot as the track was closed to vehicles.

Northeast of Kirkcudbright Bay was Manxman's Lake, the upper shore comprised rocks and stones above a muddy lower shore. Lugworm was dug from the mud and peeler crabs were collected from among the stones and these were used as bait by anglers. Planning permission had been granted for a mussel farm and some plots had been staked out in the mud to the south of St Mary's Isle. However, the project had encountered problems and at the time of the survey the development was on hold. There was a bank of wild mussels in the centre of the Dee Estuary at the foot of St Mary's Isle.

The town of Kirkcudbright was situated on the east bank of the River Dee. It was the main fishing harbour in the survey area and at the time of the survey it was home to seven commercial fishing boats and a number of hobby fishermen. During the winter months the number of commercial vessels increased significantly with followers of the king scallop fishery. Two shellfish wholesale companies were based in Kirkcudbright, one specialised in scallops, the other in winkles and cockles. Kirkcudbright marina had floating pontoon berths for 50 pleasure craft and river moorings for 40 more boats. Most of the moorings dried out at low tide and the vessels rested on the mud. Boat angling and sailing clubs were present. A small motor cruiser offered boat trips down the estuary. Anglers were observed fishing from the harbour wall and from salt marsh on the east bank of the River Dee.

Kirkcudbright to Kirkandrews

Just south of Kirkcudbright, on the west bank of the Dee Estuary, cattle were observed grazing on a narrow strip of tide-washed land. The coastline along the western side of the estuary to Nun Mill Bay was rocky with a muddy lower shore. At high tide, anglers wearing chest waders were observed wading out over the mud to spin for bass. There were rocky outcrops on the upper shore of the bay, coarse sand along the mid shore and muddy sand along the lower shore; the muddy sand stretched into the estuary to form Milton Sands. A large car park and a caravan and camping site were sited close to Nun Mill Bay. The bay was a popular recreational area with families and up to 150 people were observed there on sunny days. Activities included sunbathing, picnicking, playing, rock pooling, crabbing and swimming.

There was no road access to the western shore of Kirkcudbright Bay between Nun Mill Bay and Ross Bay. Angling was reported to occur along this stretch but it was not particularly popular owing to the long walks required to reach the fishing locations. The shore at Ross Bay could be accessed by road and limited parking was available on the verge. This small bay, with an upper shore of rocks and stones, and a lower shore of mud and sand, was too muddy for beach activities although bait digging

for lugworm and razor shells was reported to occur. To the south, footpaths across farmland provided access to angling locations around the rocky headland of Fox Craig.

Brighouse Bay was approximately two kilometres further west along the rocky coast from Fox Craig. There was road access to the small sheltered bay, and a car park and a large caravan and camping site were situated close by. The upper shore of rocks and stones gave way to an expanse of sand at low tide. The area was very popular with holidaymakers and during the survey approximately 100 people were observed on the beach on warm sunny days. The campsite had a private slipway from which jet skis and sailing dinghies were launched.

Northwest of Brighouse Bay the coastline remained rocky for a further five kilometres up to Kirkandrews. Along this stretch access to the coast was difficult but a few anglers made the long walks across farmland in order to reach the various angling locations. At the hamlet of Kirkandrews, a narrow road passed closer to the coast and a few visitors walked down to the small sandy coves exposed below the rocks at low tide.

Kirkandrews to Carsluith

West of Kirkandrews, the coastline was rocky with several small sandy bays. Isle Mouth and Carrick Bay were two popular areas for tourists because of easy road access. The beach at Isle Mouth was sand and stones and at low tide it was possible to walk across the sand and mud to Ardwall Isle. The rocky shores of the island were popular with anglers and winkle collectors. A track led from Isle Mouth to Carrick Bay where many holiday homes were located. The sandy beach at Carrick Bay was popular with tourists and activities including water sports, swimming, kayaking and boogie boarding were observed. Dinghies were pulled up on the beach and a few small sailboats were moored in the bay.

Sandgreen was the next coastal access point to the west of Carrick Bay. There was a large caravan site, which was open from March to October, and a private beach. The beach was sandy on the upper shore, mud and sand on the lower shore and was backed by rocks at either end. Beach activities included sailing, swimming, angling, windsurfing and kayaking. No commercial shellfish collection was identified, but people from the caravan site were collecting cockles and mussels for their own consumption.

There was no access to the shore between Sandgreen and Gatehouse of Fleet. Fleet Water flowed from the north through Gatehouse of Fleet into Fleet Bay. On the western shore of Fleet Bay, there were several caravan parks and access to the shore was only possible through these parks. The beaches near the head of the bay were sand, mud and stones. Activities in this area included walking, swimming, non-commercial cockle collecting, sailing and water sports. Towards the mouth of the bay and west of Ringdoo Point the shore was rocky with small sandy coves; the rocky areas were

interspersed with mud, sand and stones. Activities in these areas included angling from the rocks, dog walking, sunbathing, boat angling and jet skiing.

To the west of Ringdoo Point, the shore at Carsluith was mud, sand and stones. No one was observed on this beach during the survey, but it was reported that dog walkers visited the area. Two stake nets were in operation at Carsluith.

Carsluith to Innerwell

The Wigtown Bay Local Nature Reserve is the largest Local Nature Reserve in Britain and covers a large part of Wigtown Bay between Carsluith and Innerwell, including the Cree Estuary and the Bladnoch Estuary. The reserve included vast mudflats and areas of salt marsh, and wildfowling was popular at various locations.

The shore between Carsluith and Creetown was mud, sand and stones, interspersed with rocks and salt marsh. Creetown was located at the head of Wigtown Bay; here the shore was salt marsh with sand and stones on the upper foreshore and mud on the lower foreshore. Two stake nets were in operation on the muddy shore. North of Creetown, farmers grazed their livestock on salt marsh along the banks of the River Cree to Newton Stewart. Net-and-cobble fishing (a form of seine netting) was identified on the River Cree and gill netting was identified in the Cree Estuary.

Several farmers grazed their livestock on the salt marsh along the western shore of Wigtown Bay. Apart from private farm tracks, access to the salt marsh was only possible at Wigtown where the footpaths that led out onto the salt marsh were predominantly boardwalks raised above tidal level. The Dumfries and Galloway Council Ranger Service from the Wigtown Bay Local Nature Reserve provided guided walks out onto the mudflats and salt marsh.

South of Wigtown, the substrate changed at Innerwell from salt marsh and mud to rock, stones and sand. There was a small bay with rocks at either end of the beach, stones on the upper shore and mud and sand exposed at low tide. The beach was deserted on the occasions that the survey team visited Innerwell and only one person who was interviewed at another location was angling from the rocks at Innerwell. It was reported that mussels and winkles collected from the shore were being consumed, but this was not identified during the survey. Two stake nets were located here but they were not in operation.

Innerwell to the Isle of Whithorn

The shore between Innerwell and Garlieston was predominantly rocky. At Garlieston, the upper shore of the bay was rock, sand, stone and salt marsh, and the lower shore was a large expanse of sand and mud. There was good access and parking, and a campsite for touring caravans. Many tourists staying at the campsite and locals undertook activities in the bay, including walking, dog walking, bait

digging, angling and kayaking. Garlieston Harbour had three full-time registered creel fishing boats. Angling boats and sailing yachts were also moored in the harbour. South of Garlieston, Cruggleton Bay was a sandy bay that was popular with anglers and dog walkers.

Between Cruggleton Bay and the Isle of Whithorn, the coastline was predominantly rocky. Access to the coast was limited to tracks through farms, but despite this, it was reported that there were many popular angling spots on the rocks along this stretch of coast. The rocky headland of Cairn Head was reported to be particularly popular with anglers.

At the southernmost part of the survey area, Isle of Whithorn was a small village located on a rocky peninsular. The boats based in the Isle of Whithorn Harbour included creel fishing boats, sailing yachts and angling boats. A sailing club and coastguard station were also based in the harbour. Angling was popular with local and visiting anglers, both at the harbour and on the rocks around the peninsula, the latter of which was the favoured location for angling competitions. At low tide, the exposed mud and sand of the harbour was popular with bait diggers.

4.2 Commercial fisheries

There was a diverse range of commercial fisheries in the survey area. The main harbours used by the commercial fishermen were Kirkcudbright, Garlieston and Isle of Whithorn.

Commercial fishing in the rivers and estuaries in the survey area was popular, with four main methods employed. Haaf netting was undertaken on the River Nith; stake netting in Balcary Bay and the Cree Estuary; net-and-cobble fishing in the River Cree; and gill netting in the Cree Estuary. The target species were salmon (*Salmo salar*) and sea trout (*Salmo trutta)*, with the exception of gill netting where the target species was bass. A by-catch of flounder (*Platichthys flesus*), grey mullet (*Chelon labrosus*) and bass (*Dicentrarchus labrax*) was also noted.

Crustacean fisheries were pursued using creels. One creel fisherman was based in Balcary Bay, three in Kirkcudbright, three in Garlieston and two at the Isle of Whithorn. The main target species were lobsters (*Homarus gammarus*), crabs (*Cancer pagurus*) and *Nephrops* (*Nephrops norvegicus*).

Mollusc collecting was the dominant commercial fishing activity in the area. Two scallop dredgers were based in Kirkcudbright and fished for queen scallops (*Chlamys opercularis*) in the summer. Another 11 scallop boats joined them during the winter king scallop (*Pecten maximus*) season. Cockles (*Cerastoderma edule*) were collected by hand raking, tractor raking and dredging, mainly in the Southerness/Mersehead Sands area. Two cockle dredgers were based in Kirkcudbright. The cockle fishery reopened in November 2007 after a closure of four years, which allowed stocks to recover. Fishing was limited to a 500 tonne quota for the 2007/8 season. Winkles (*Littorina littorea*) were collected commercially by hand from rocky areas along the survey area, such as Carrick Bay

and Rascarrel Bay. Six local winkle collectors were identified and winkle collecting gangs from outside the area also visited this coast. One fisherman from Garlieston used creels to fish for whelks (*Buccinum undatum*).

4.3 Seafood wholesalers and retailers

Three shellfish wholesalers were identified in the survey area and they bought the majority of the king scallops, queen scallops, cockles and winkles caught or landed within the survey area; most of this was exported to Europe, particularly France. All of the whelks were exported to the Far East after processing in Ireland. Two smokehouses were identified selling local produce (salmon, sea trout, bass, grey mullet and lobsters). Local fishmongers were visited and a proportion of their produce was sourced locally; mainly lobster, salmon and queen scallops. The remainder of the catches were sold to individuals on an *ad hoc* basis or consumed by the fishermen and their families.

4.4 Angling and hobby fishing

Sea angling from the shore occurred at many places along the rocky stretches of coast but was most prevalent where road access was easiest. Angling also took place to a lesser extent from sand beaches and tide washed riverbanks. Boat angling was carried out on a small scale and one charter boat operated out of Kippford Harbour. Several of the anglers interviewed dug their own bait.

In this report, the term 'hobby fishing' is used to describe recreational fishing on a small scale with creels. It is usually carried out from boats that do not have commercial fishing licences, and therefore, it is illegal to offer the catch for sale. Several hobby fishermen were noted to set creels for lobsters and crabs for their households' consumption.

4.5 Wildfowling

Wildfowling occurred in the survey area at Caerlaverock and Wigtown Bay. It was undertaken both by members of wildfowling clubs and by individuals not belonging to clubs. Wildfowling was allowed within the Caerlaverock National Nature Reserve and permits were issued by Scottish Natural Heritage. Two wildfowling clubs were identified whose members shot in the Wigtown Bay area, including Innerwell and Carsenstock. Seasonal and weekly permits to shoot on the Wigtown Bay Local Nature Reserve were issued by Dumfries and Galloway Council. The main duck species being shot were mallard (*Anas platyrhynchus*), teal (*Anas* crecca), wigeon (*Anas penelope*) and pintail (*Anas acuta*). The main goose species being shot were pink-footed (*Anser brachyrhynchus*) and greylag (*Anser anser*).

Geese are known to arrive in the Solway during mid to late September and leave the area in March or April. They generally feed on salt marsh grass for 2-4 weeks at the beginning and/or at the end of their stay, and feed inland on pasture and cereal for the remainder of the time. Pink-footed goose, the main species shot by wildfowlers in the Solway, typically feed inland for most of the time and feed on salt marsh during the last month of their stay. The geese roost on the mudflats at night and wildfowlers shoot the geese as they fly to and from the feeding grounds.

4.6 Livestock grazed on salt marsh

Four farmers were interviewed whose farms were located near the River Cree and who grazed their sheep and/or cattle on salt marsh in the survey area. One of these farms produced milk, beef and lamb, one produced beef and lamb, one produced beef; and one produced milk. One of these farmers kept beef for their household's consumption. No consumption of milk and lamb was identified.

4.7 The use of seaweed for livestock feed or fertiliser

The use of seaweed for human consumption, livestock feed, fertiliser or soil conditioner was investigated during the survey but was not identified.

4.8 Internal exposure

Adult's consumption rates

The consumption of fish, crustaceans, molluscs and salt marsh grazed cattle meat from the aquatic survey area were identified. The main consumers were commercial fishermen, hobby fishermen, shellfish collectors, anglers, wildfowlers, farmers and families of these people. No consumption of marine plants/algae, or milk or lamb from livestock grazed on salt marsh was identified.

Adults' consumption rates of fish are presented in Table 3. The main species of fish consumed by adults in the critical group were cod (*Gadus morhua*) and mackerel (*Scomber scombrus*), with smaller amounts of bass (*Dicentrarchus labrax*), pollack (*Pollachius pollachius*), whiting (*Merlangius merlangus*), plaice (*Pleuronectes platessa*) and flounder (*Platichthys flesus*). A critical group of eight individuals was identified with a maximum consumption rate of 68 kg y^{-1} and a mean rate of 51 kg y^{-1}. The observed 97.5 percentile rate based on 70 observations was 68 kg y^{-1}. These rates compare with the adult generic mean and 97.5 percentile consumption rates for fish of 15 kg y^{-1} and 40 kg y^{-1}, respectively. The percentage breakdown of fish species consumed by the critical group, rounded to the nearest 5%, consisted of, cod 45%, mackerel 35%, bass 10% and other species 10%.

Table 3 Adults' consumption rates of fish (kg y^{-1})

Observation number	Bass	Cod	Dover sole	Flounder	Grey mullet	Lemon sole	Mackerel	Mixed fish	Monkfish	Plaice	Pollack	Salmon	Sea trout	Turbot	Whiting	Total
70-73		**33.8**					**33.8**									**67.6**
141	**10.7**	**15.0**		**3.1**						**3.0**					**11.6**	**43.3**
153							**13.8**			**3.0**	**14.1**					**30.9**
90-91	**12.8**	**18.0**														**30.8**
84-85		1.8					13.8									15.6
253-254		4.0					2.3				9.3					15.5
219	4.3				4.3							4.3				12.9
36-39								11.8								11.8
74-75		11.8														11.8
226		6.3				3.0				2.1						11.4
234	0.9	1.0					1.8				6.2					10.0
220	2.6				2.6							2.6				7.8
227-228		1.5		0.8							4.7					7.0
231-233							2.6				4.3					6.9
207-210	0.2	2.6					0.9				3.1					6.9
289-290							1.7					4.9				6.6
82-83	6.4															6.4
260-261		5.3		0.7												6.0
264		5.3		0.7												6.0
221	1.7				1.7							1.7				5.1
286-287													4.7			4.7
168-169	4.3															4.3
97-100		3.4														3.4
212-213	0.9			0.8											1.1	2.9
49-55			0.9						0.9					0.9		2.7
123-124	0.5	1.6								0.5						2.6
242-243	0.5			0.2								1.8				2.4
101-104		1.8														1.8
156-158							0.9					0.7				1.6
237							0.2				1.2					1.4
267-268							0.6									0.6

Notes

Emboldened observations are the critical group consumers

Adults' consumption rates of crustaceans are presented in Table 4. The species consumed were crab (*Cancer pagurus*), *Nephrops* (*Nephrops norvegicus*) and lobster (*Homarus gammarus*). A critical group of 11 individuals was identified with a maximum consumption rate of 29 kg y^{-1} and a mean rate of 15 kg y^{-1}. The observed 97.5 percentile rate based on 21 observations was 23 kg y^{-1}. These rates compare with the adult generic mean and 97.5 percentile consumption rates for crustaceans of 3.5 kg y^{-1} and 10 kg y^{-1} respectively. The percentage breakdown of crustacean species consumed by the critical group, rounded to the nearest 5%, consisted of crab 55%, *Nephrops* 25% and lobster 20%.

Table 4 Adults' consumption rates of crustaceans (kg y^{-1})

Observation number	Crab	Lobster	*Nephrops*	Total
274	**0.5**	**0.1**	**28.5**	**29.1**
134-135	**10.7**	**5.6**		**16.3**
70-71	**10.7**	**4.1**		**14.8**
275	**0.3**	**0.1**	**14.3**	**14.6**
74-75	**10.7**	**3.1**		**13.8**
219	**4.3**	**4.3**	**2.5**	**11.1**
72-73	**10.7**			**10.7**
220	2.6	2.6	2.6	7.8
27-28		7.5		7.5
221	1.7	1.7	1.7	5.2
161-162	3.6	1.3		4.9
156-158		1.7		1.7
260		0.9		0.9

Notes
Emboldened observations are the critical group consumers

Adults' consumption rates of molluscs are presented in Table 5. The main species of molluscs consumed by adults in the critical group were mussels (*Mytilus edulis*), cockles (*Cerastoderma edule*) and king scallops (*Pecten maximus*), and a small amount of winkles (*Littorina littorea*). A critical group of six individuals was identified with a maximum consumption rate of 8.8 kg y^{-1} and a mean rate of 5.7 kg y^{-1}. The observed 97.5 percentile rate based on 26 observations was 7.4 kg y^{-1}. These rates compare with the adult generic mean and 97.5 percentile consumption rates for molluscs of 3.5 kg y^{-1} and 10 kg y^{-1} respectively. The percentage breakdown of mollusc species consumed by the critical group, rounded to the nearest 5%, consisted of mussels 60%, cockles 25%, king scallops 10% and winkles 5%.

Table 5 Adults' consumption rates of molluscs (kg y^{-1})

Observation number	Cockles	King scallops	Mussels	Queen scallops	Winkles	Total
134	**4.4**		**4.4**			**8.8**
260	**4.0**		**1.9**		**0.6**	**6.5**
70-73		**1.0**	**3.7**			**4.7**
273					2.0	2.0
285	1.4					1.4
125					1.1	1.1
156-157			0.5	0.4		0.9
249-251	0.6		0.2			0.8
84-85			0.7			0.7
158				0.4		0.4
242-243	0.1					0.1
49-55				0.1		0.1

Notes
Emboldened observations are the critical group consumers

Adults' consumption rates of wildfowl are presented in Table 6. The main groups consumed were geese (unspecified species) and ducks which were shot within Wigtown Bay and the Caerlaverock National Nature Reserve. The ducks included mallard (*Anas platyrhynchus*), teal (*Anas* crecca), wigeon (*Anas penelope*), pintail (*Anas acuta*) and unspecified species. A critical group of three individuals was identified with a maximum consumption rate of 35 kg y^{-1} and a mean rate of 22 kg y^{-1}. The observed 97.5 percentile rate based on 16 observations was 28 kg y^{-1}. There are no generic consumption data for wildfowl for comparison. The percentage breakdown of wildfowl consumed by the critical group, rounded to the nearest 5%, consisted of geese 55% and ducks 45%.

Table 6 Adults' consumption rates of wildfowl (kg y^{-1})

Observation number	Duck (unspecified species)	Mallard	Pintail	Teal	Wigeon	Goose (unspecified species)	Total
278		**3.6**	**2.8**	**1.3**	**2.8**	**24.8**	**35.4**
7	**9.1**					**5.4**	**14.5**
12	**9.1**					**5.4**	**14.5**
70-73				1.3	5.6		6.9
279		0.4	0.3	0.1	2.8	2.8	6.4
258-259		1.0			1.5	3.3	5.8
289-290		0.7		0.2		4.4	5.3
267-268		1.0				3.3	4.3
217-218						2.2	2.2

Notes
Emboldened observations are the critical group consumers

Adults' consumption rates of salt marsh grazed cattle meat are presented in Table 7. A critical group of five individuals was identified with an equivalent maximum consumption rate of 31 kg y^{-1}, therefore a mean of 31 kg y^{-1}. The observed 97.5 percentile rate based on five observations was 31 kg y^{-1}. No generic data are available for salt marsh grazed cattle meat.

Table 7 Adults' consumption rates of salt marsh grazed cattle meat (kg y^{-1})

Observation number	Salt marsh grazed beef
296	**31.0**
297	**31.0**
298	**31.0**
299	**31.0**
300	**31.0**

Notes
Emboldened observations are the critical group consumers

A summary of adults' consumption rates of foods from the aquatic survey area is presented in Table 8.

Table 8 Summary of adults' aquatic consumption rates (kg y^{-1})

Food group	Number of observations	Number of consumers in the critical group	Observed maximum critical group consumption rate	Observed minimum critical group consumption rate	Observed critical group mean consumption rate	Observed 97.5 percentile consumption rate	Generic mean consumption rate	Generic 97.5 percentile consumption rate
Fish	70	8	67.6	30.8	50.8	67.6	15.0	40.0
Crustaceans	21	11	29.1	10.7	15.1	22.7	3.5	10.0
Molluscs	26	6	8.8	4.7	5.7	7.4	3.5	10.0
Wildfowl	16	3	35.4	14.5	21.5	27.5	ND	ND
Salt marsh grazed cattle meat	5	5	31.0	31.0	31.0	31.0	ND	ND

Notes
ND = Not determined

Children's consumption rates

Children's consumption rates for aquatic foods were obtained for the 15-year-old, 10-year-old and 5-year-old age groups. No children in the 10-year-old and 5-year-old age groups were consuming crustaceans, molluscs or wildfowl. No children in the 5-year-old age group were consuming salt marsh grazed beef. No children in the 1-year-old and 3-month-old age groups were noted to be consuming foods from the survey area. No children were identified that consumed salt marsh grazed lamb or marine plants/algae. The age groups and their relevant age ranges are listed in Section 3.3.

Fish

Children's consumption rates of fish are presented in Table 9.

For the 15-year-old age group, a critical group of four individuals was identified with a maximum consumption rate of 15 kg y^{-1} and a mean rate of 11 kg y^{-1}. The observed 97.5 percentile rate based on six observations was 15 kg y^{-1}. These rates compare with the generic mean and 97.5 percentile consumption rates for fish of 6.5 kg y^{-1} and 20 kg y^{-1}, respectively.

For the 10-year-old age group, one individual was identified with a consumption rate of 12 kg y^{-1}. The observed 97.5 percentile rate based on five observations was 11 kg y^{-1}. These rates compare with the generic mean and 97.5 percentile consumption rates for fish of 6.0 kg y^{-1} and 20 kg y^{-1} respectively.

For the 5-year-old age group, one individual was identified with a consumption rate of 0.3 kg y^{-1}, which is taken as the critical group rate. The observed 97.5 percentile rate is not applicable for one observation. No generic data have been derived for this age group.

Table 9 Children's consumption rates of fish (kg y^{-1})

Observation number	Age	Bass	Cod	Flounder	Mackerel	Mixed fish	Plaice	Pollack	Salmon	Total
15-year-old age group										
154	**14**				**6.9**		**1.5**	**7.0**		**15.4**
155	**12**				**6.9**		**1.5**	**7.0**		**15.4**
262	**13**		**5.3**	**0.7**						**6.0**
263	**14**		**5.3**	**0.7**						**6.0**
239	12				0.2			1.2		1.4
159	14								0.7	0.7
10-year-old age group										
40	**8**					**11.8**				**11.8**
238	10				0.2			1.2		1.4
244	9	0.2		0.1					0.9	1.2
245	9	0.2		0.1					0.9	1.2
246	7	0.2		0.1					0.9	1.2
5-year-old age group										
265	**2**		**0.3**	**0.03**						**0.3**

Notes
Emboldened observations are the critical group consumers

Crustaceans

Children's consumption rates of crustaceans are presented in Table 10.

For the 15-year-old age group, a critical group of two individuals was identified with consumption rates of 7.3 kg y^{-1}. The observed 97.5 percentile rate based on three observations was 7.3 kg y^{-1}. These rates compare with the generic mean and 97.5 percentile consumption rates for crustaceans of 2.5 kg y^{-1} and 6.0 kg y^{-1}, respectively.

Table 10 Children's consumption rates of crustaceans (kg y^{-1})

Observation number	Age	Crab	Lobster	*Nephrops*	Total
15-year-old age group					
276	**14**	**0.1**	**0.1**	**7.1**	**7.3**
277	**12**	**0.1**	**0.1**	**7.1**	**7.3**
262	13		0.9		0.9

Notes
Emboldened observations are the critical group consumers

Molluscs

Children's consumption rates of molluscs are presented in Table 11.

For the 15-year-old age group, a critical group of one individual was identified with a consumption rate of 6.5 kg y^{-1}. The observed 97.5 percentile rate based on two observations was 6.3 kg y^{-1}. These rates compare with the generic mean and 97.5 percentile consumption rates for molluscs of 2.5 kg y^{-1} and 6.0 kg y^{-1}, respectively.

Table 11 Children's consumption rates of molluscs (kg y^{-1})

Observation number	Age	Cockle	Mussel	Queen scallop	Winkle	Total
15-year-old age group						
262	**13**	**4.0**	**1.9**		**0.6**	**6.5**
159	14			0.4		0.4

Notes
Emboldened observation is the critical group consumer

Wildfowl

Children's consumption rates of wildfowl are presented in Table 12.

For the 15-year-old age group, a critical group of three individuals was identified with a consumption rate of 15 kg y^{-1}. The observed 97.5 percentile rate based on three observations was 15 kg y^{-1}. No generic data have been derived for this age group.

Table 12 Children's consumption rates of wildfowl (kg y^{-1})

Observation number	Age	Duck (unspecified species)	Goose (unspecified species)	Total
15-year-old age group				
9	**14**	**9.1**	**5.4**	**14.5**
10	**12**	**9.1**	**5.4**	**14.5**
11	**12**	**9.1**	**5.4**	**14.5**

Notes
Emboldened observations are the critical group consumers

Salt marsh grazed cattle meat

Children's consumption rates of salt marsh grazed cattle meat are presented in Table 13. No generic consumption rates have been derived for salt marsh grazed cattle meat.

For the 15-year-old age group, a critical group of one individual was identified with a consumption rate of 15 kg y^{-1}. The observed 97.5 percentile rate is not applicable for one observation.

For the 10-year-old age group, a critical group of one individual was identified with a consumption rate of 7.5 kg y^{-1}. The observed 97.5 percentile rate is not applicable for one observation.

Table 13 Children's consumption rates of salt marsh grazed cattle meat (kg y^{-1})

Observation number	Age	Salt marsh grazed beef
15-year-old age group		
301	**12**	**15.0**
10-year-old age group		
302	**8**	**7.5**

Notes

Emboldened observations are the critical group consumers

A summary of the children's consumption rates of foods from the aquatic survey area is presented in Table 14.

Table 14 Summary of children's aquatic consumption rates (kg y^{-1})

Food group	Number of observations	Number of consumers in the critical group	Observed maximum critical group consumption rate	Observed minimum critical group consumption rate	Observed mean critical group consumption rate	Observed 97.5 percentile consumption rate	Generic mean consumption rate	Generic 97.5 percentile consumption rate
15-year-old age group								
Fish	6	4	15.4	6.0	10.7	15.4	6.5	20.0
Crustaceans	3	2	7.3	7.3	7.3	7.3	2.5	6.0
Molluscs	2	1	6.5	6.5	6.5	6.3	2.5	6.0
Wildfowl	3	3	14.5	14.5	14.5	14.5	ND	ND
Salt marsh grazed cattle meat	1	1	15.0	15.0	15.0	NA	ND	ND
10-year-old age group								
Fish	5	1	11.8	11.8	11.8	10.8	6.0	20.0
Crustaceans	NC	NC	NC	NC	NC	NC	2.5	7.0
Molluscs	NC	NC	NC	NC	NC	NC	2.5	7.0
Wildfowl	NC	NC	NC	NC	NC	NC	ND	ND
Salt marsh grazed cattle meat	1	1	7.5	7.5	7.5	NA	ND	ND
5-year-old age group								
Fish	1	1	0.3	0.3	0.3	NA	ND	ND
Crustaceans	NC	NC	NC	NC	NC	NC	ND	ND
Molluscs	NC	NC	NC	NC	NC	NC	ND	ND
Wildfowl	NC	NC	NC	NC	NC	NC	ND	ND
Salt marsh grazed cattle meat	NC	NC	NC	NC	NC	NC	ND	ND

Notes

ND = not determined
NC = not consumed
NA = not applicable

4.9 External exposure

Intertidal occupancy

External exposure from artificial radiation to members of the public who frequent intertidal areas depends on the occupancy rate and dose rate after subtraction of an appropriate value for natural background radiation. Dose rates over mud and salt marsh can be higher than those over coarser substrates due to fine grain size and ability to adsorb more radioactivity. Consequently, occupancy rates over these substrates are considered to be radiologically more important than similar rates over other substrates. Estimates of natural backgrounds used by Cefas for assessing doses to individuals (EA, EHS, FSA and SEPA, 2007) are 0.05 µGy h^{-1} for sandy substrates, 0.07 µGy h^{-1} for mud and salt marsh and 0.06 µGy h^{-1} for all other substrates.

The predominant intertidal substrate in the survey area where activities were observed taking place were mud; mud and sand; rock; salt marsh; and sand.

Table 15 shows the intertidal occupancy rates, grouped by substrate. Intertidal activities observed during the survey included angling, stake netting, bait digging, winkle collecting, mussel collecting, cockle collecting (by hand rake and by tractor rake), crab collecting, wildfowling, dog walking, beach combing, bird watching, working on the shore, coastguard duties, marsh warden duties, fixing moorings, boat maintenance, walking, playing, tending livestock and beach cleaning.

The maximum occupancy rate recorded over mud was 1100 h y^{-1} for two stake net fishermen. Two other stake net fishermen had occupancy rates within a factor of three of this and formed the critical group of four individuals over mud with a mean rate of 780 h y^{-1}.

The maximum occupancy rate recorded over mud and sand was 1000 h y^{-1} for one stake net fisherman. Two other stake net fishermen, one of whom also collected cockles, and one bait digger, had occupancy rates within a factor of three of this and formed the critical group of four individuals over mud and sand with a mean rate 570 h y^{-1}.

The maximum occupancy rate recorded over rock was 960 h y^{-1} for one individual collecting winkles. Nine other individuals participating in the collection of winkles, mussels and crabs and angling had occupancy rates within a factor of three of this and formed the critical group of ten individuals over rock with a mean rate of 670 h y^{-1}.

The maximum occupancy rate recorded over salt marsh was 860 h y^{-1} for one marsh warden who also participated in coastguard duties. One other marsh warden and two wildfowlers had occupancy rates within a factor of three of this and formed the critical group of four individuals over salt marsh with a mean rate of 670 h y^{-1}.

The maximum occupancy rate recorded over sand was 610 h y^{-1} for an individual collecting cockles using a tractor. Twelve other individuals participating in dog walking, bird watching, beach combing and working on the shore had occupancy rates within a factor of three of this and formed the critical group of 13 individuals over sand with a mean rate of 310 h y^{-1}.

Table 15 Intertidal occupancy rates (h y^{-1})

Observation number	Location[a]	Activity[a]	Mud	Mud and sand	Rock	Salt marsh	Sand
86-87	**Balcary Bay**	**Stake netting/**Bait digging	**1120**	180			
36,41	**Sandyhills**	**Stake netting**	**430**				
156160	Kirkcudbright Marina	Fixing moorings	230				
134	Kirkcudbright Marina	Boat maintenance	130				
42-43	Sandyhills	Stake netting	80				
136	Kirkcudbright Marina	Boat maintenance	3				
215	**Wigtown Bay**	**Stake netting**		**1035**			
216	**Wigtown Bay**	**Stake netting**		**540**			
152	**Balcary Bay and Southerness**	**Stake netting and collecting cockles**		**355**			
	Auchencairn Bay	**Working on the shore**					**312**
153	**Sandgreen**	**Bait digging**		**350**			
	Kirkcudbright lifeboat station and Wigtown Bay	**Angling**			**500**		
	Various beaches	**Dog walking**					**500**
129-133	Southerness	Collecting cockles		300			
	Isle of Whithorn to Auchencairn Bay	**Collecting winkles**			**750**		
242	Cardoness	Walking, stake netting, collecting cockles		170			
260	St Mary's Isle and Southerness	Bait digging and collecting cockles		156			
	Kirkcudbright Bay area and various beaches	**Collecting mussels and winkles, angling**			**543**		
	Various beaches	Angling					165
283-284	Garlieston	Dog walking		112			
270-272	Sandgreen and Carrick	Playing		110			
243-246	Cardoness	Walking		104			
235-236	Garlieston	Walking		100			
269	Sandgreen and Carrick	Playing		84			
207-208	Isle of Whithorn Harbour/Isle of Whithorn	Bait digging/Angling		50	50		
240-241	Garlieston	Walking		50			
141	Various beaches	Bait digging		45			
	Kirkcudbright lifeboat station and various beaches	**Collecting peeler crabs and angling**			**453**		
255-257	Garlieston	Dog walking		42			

Observation number	Location[a]	Activity[a]	Mud	Mud and sand	Rock	Salt marsh	Sand
267	Wigtown Bay**/Carsluith**	Angling/Wildfowling**/Dog walking**		32		54	**365**
147-151	Various beaches	Bait digging/Angling		24	100		
262	Southerness/Kirkcudbright Bay	Collecting cockles/Collecting winkles and mussels		24	48		
280-282	Garlieston/Isle of Whithorn	Bait digging/Angling		20	55		
249	Sandgreen	Collecting cockles/Collecting mussels		14	7		
74	Ross Bay	Bait digging		9			
	Kirkcudbright lifeboat station and various beaches	Collecting crabs and angling			45		
	Various beaches	Walking					88
194-197	Ross Bay/Brighouse Bay and Nun Mill Bay	Walking/Playing		8			42
212	Garlieston/Innerwell and Shaddock Point	Bait digging/Angling		6	70		
101-103	Balcary Bay/Rascarrel Bay	Bait digging/Angling		6	24		
84-85	Kirkcudbright Bay area/Torrs Point and Kirkcudbright lifeboat station	Bait digging/collecting mussels and angling		6	20		
97-100	Southerness Point/Rascarrel Bay	Bait digging/Angling		3	42		
273	**Various beaches**	**Collecting winkles**			**960**		
90	**Abbey Burn Foot, Balcary Point and Rascarrel Bay**	**Angling**			**480**		
154-155	Kirkcudbright lifeboat station and Wigtown Bay	Angling			250		
91-93	Abbey Burn Foot, Balcary Point and Rascarrel Bay	Playing			240		
82	Kirkcudbright lifeboat station/East bank of River Dee	Angling			225	225	
123	Balcary Point	Angling			210		
278	Isle of Whithorn**/Wigtown Bay**	Angling**/Wildfowling**			160	**480**	
231-233	Cairn Head	Angling			140		
227-228	Isle of Whithorn	Angling			96		
94-96	Rascarrel Bay	Collecting crabs			90		
70	Carrick Point/Nun Mill Bay	Collecting mussels/Dog walking			75		150
125127	Abbey Burn Foot	Angling			60		
126128	Abbey Burn Foot	Playing			60		
229-230	Isle of Whithorn	Angling			36		
237-239	Garlieston	Angling			30		
88-89	Abbey Burn Foot	Angling			24		
7	**Caerlaverock Nature Reserve**	**Marsh warden and coastguard duties**				**857**	
8	**Caerlaverock Nature Reserve**	**Marsh warden**				**821**	
289	**Caerlaverock Nature Reserve**	**Wildfowling**				**500**	
6	Caerlaverock National Nature Reserve	Tending livestock				260	
4-5	Caerlaverock National Nature Reserve	Tending livestock				150	
14	Caerlaverock National Nature Reserve	Tending livestock and walking				146	

Observation number	Location[a]	Activity[a]	Mud	Mud and sand	Rock	Salt marsh	Sand
291-292	West bank of River Cree	Tending livestock				104	
293	Creetown	Tending livestock				104	
294-295	Creetown	Tending livestock				104	
296-297	West bank of River Cree	Tending livestock				104	
13	Caerlaverock National Nature Reserve	Tending livestock				75	
258	Wigtown Bay	Wildfowling				72	
217	Wigtown Bay	Wildfowling				60	
252	Wigtown Bay	Marsh warden				43	
15-16	Caerlaverock National Nature Reserve	Walking				26	
266	River Cree	Tending livestock				26	
1-3	Caerlaverock National Nature Reserve	Marsh warden				10	
48	**Mersehead Sands**	**Collecting cockles**					**608**
225	**Nun Mill Bay**	**Dog walking**					**308**
30-35	**Mersehead RSPB Reserve**	**Bird watching**					**240**
174-175	**Fleet Estuary**	**Beach combing**					**225**
247-248	Sandgreen	Beach cleaning					200
71	Nun Mill Bay	Dog walking					150
190-193	Brighouse Bay	Playing					140
222	Nun Mill Bay	Walking					140
75	Various beaches	Walking					88
29	Mersehead RSPB Reserve	Bird watching					80
202-206	Carrick, Isle Mouth and Sandgreen	Playing					65
186-189	Brighouse Bay	Playing					48
115-116	Balcary and Nun Mill Bay	Playing					45
117-120	Balcary and Nun Mill Bay	Playing					30
105-114	Balcary, Sandy Hills and Southerness	Playing					24
182-185	Brighouse Bay	Playing					24
223-224	Nun Mill Bay	Playing					20
198-201	Isle Mouth	Playing					18
121-122	Balcary Bay	Walking					15
176-177	Brighouse Bay and Rockcliffe	Walking					12
170-171	Nun Mill Bay	Playing					10
172-173	Nun Mill Bay	Playing					6
178-181	Brighouse Bay	Playing					6

Notes

Emboldened observations are the critical group members.

[a]The forward slash (/), separates the locations of, and activities taking place on, the separate substrates for that individual.

Gamma dose rate measurements were taken at selected locations, shown in Table 16, to supplement those of SEPA's scheduled monitoring programme. The data in Table 16 (where comparison can be made) are consistent with those reported by SEPA in RIFE 12 (EA, EHS, FSA and SEPA, 2007).

Table 16 Gamma dose measurements over intertidal substrates (µGy h^{-1})

Location	National Grid Reference	Substrate	Gamma dose rate at 1 metre (µGy h^{-1})
River Nith haaf netting location	NX 993 677	Mud and sand	0.102
River Nith haaf netting location	NX 995 677	Salt marsh	0.094
Carsethorn	NX 993 600	Mud	0.086
Sandyhills	NX 895 550	Mud	0.091
Sandyhills	NX 892 550	Salt marsh	0.096
Stake net position at Sandy Hills	NX 893 546	Mud and sand	0.080
Urr Water haaf netting location	NX 832 554	Mud	0.109
Auchencairn Bay angling location	NX 820 505	Mud and sand	0.075
Balcary Point angling location	NX 829 492	Rock	0.122
Balcary Bay	NX 823 497	Mud	0.094
Balcary Bay	NX 822 495	Stones	0.104
Balcary Fishery stake net position	NX 822 500	Mud	0.084
Rascarrel Bay angling location	NX 803 479	Stones	0.127
Abbey Burn Foot angling location	NX 743 444	Rock	0.069
Kirkcudbright Bay lifeboat station	NX 675 464	Stones	0.085
Manxman's Lake	NX 680 476	Mud	0.084
Kirkcudbright Marina	NX 680 512	Mud	0.076
East bank of River Dee	NX 686 514	Salt marsh	0.088
West bank of River Dee	NX 668 497	Mud	0.083
Nun Mill Bay	NX 660 485	Sand	0.077
Ross Bay	NX 653 446	Mud and sand	0.072
Ross Bay	NX 652 444	Mud	0.082
Brighouse Bay	NX 635 455	Sand	0.062
South of Ardwall Isle	NX 581 489	Sand	0.062
Isle Mouth	NX 575 500	Mud and sand	0.067
Isle Mouth	NX 575 500	Sand	0.062
Isle Mouth	NX 575 500	Sand and stones	0.076
Sandgreen	NX 575 524	Mud and sand	0.069
Carsluith	NX 486 543	Mud and sand	0.099
Creetown stake net location	NX 471 576	Mud	0.085
Garlieston	NX 481 468	Mud and sand	0.069
Garlieston	NX 479 463	Mud and sand	0.065

Handling

Handling commercial fishing gear, or handling sediment while undertaking activities such as bait digging or mollusc collecting, can potentially give rise to skin exposure from beta radiation. This needs consideration even though the annual dose limit for skin is a factor of 50 times higher than that for effective dose. There is also a contribution to effective dose due to skin exposure (ICRP, 1991).

The handling rates for fishing gear and sediment are presented in Table 17. For handling fishing gear, the maximum rate was 2200 h y^{-1} and the critical group mean was 1300 h y^{-1} for eight fishermen. For handling sediment, the maximum rate was 1100 h y^{-1} and the critical group mean was 820 h y^{-1} for 10 individuals who were collecting cockles and winkles, bait digging and wildfowling.

Handling of angling equipment was not considered to be a significant pathway. Therefore, as in previous surveys, data for this pathway were not collected.

Table 17 Handling rates of fishing gear and sediment (h y^{-1})

Observation number	Location[a]	Activity[a]	Fishing gear	Sediment
274	**Garlieston to Isle of Whithorn**	**Creeling**	**2228**	
214	**Off the Isle of Whithorn**	**Creeling**	**1650**	
70	**Kirkcudbright Bay area**	**Creeling**	**1500**	
	Carrick Point	Collecting mussels		75
86-87	**Balcary Bay**	**Stake netting/**Bait digging	**1120**	180
152	**Balcary Bay, Torrs Point to Auchencairn Bay**	**Creeling and stake netting**	**1050**	
	Southerness	Collecting cockles		250
215	**Wigtown Bay**	**Stake netting**	**1035**	
	Wigtown Bay	Setting up stake nets		40
74	**Kirkcudbright Bay**	**Creeling**	**770**	
	Kirkcudbright lifeboat station and Ross Bay	Collecting crabs and bait digging		18
76-81	Solway Firth	Dredging for cockles	600	
216	Wigtown Bay	Stake netting	540	
36	Sandyhills and River Nith/Sandyhills	Stake netting/Setting up nets	530	80
41	Sandyhills	Stake netting/Setting up nets	350	80
226	Isle of Whithorn	Creeling	336	
49-69	Off the Isle of Whithorn	Dredging for scallops	280	
161	Kirkcudbright Bay	Creeling	250	
44-47	River Nith - west bank	Haaf netting	180	

Observation number	Location[a]	Activity[a]	Fishing gear	Sediment
288	River Nith near Caerlaverock	Haaf netting	180	
289	River Nith near Caerlaverock	Haaf netting	151	
	Caerlaverock Nature Reserve	**Wildfowling**		**500**
286	River Nith near Caerlaverock	Haaf netting	140	
134	Off the Isle of Whithorn	Dredging for scallops	112	
211	Isle of Whithorn	Creeling	100	
219	Wigtown Bay	Gill netting	90	
129-133	**Isle of Whithorn to Auchencairn Bay and Southerness**	**Collecting winkles and collecting cockles**		**1050**
273	**Along the survey area**	**Collecting winkles**		**960**
48	**Mersehead Sands**	**Collecting cockles**		**608**
278	**Wigtown Bay**	**Wildfowling**		**480**
153	**Sandgreen**	**Bait digging**		**350**
156,160	Kirkcudbright Marina	Fixing moorings		230
260	Kirkcudbright Bay, Southerness and St Mary's Isle	Collecting mussels, winkles and cockles, bait digging		204
94-96	Rascarrel Bay	Collecting crabs		90
42-43	Sandyhills	Stake netting		80
258	Wigtown Bay	Wildfowling		72
262	Kirkcudbright Bay and Southerness	Collecting mussels and winkles, and collecting cockles		72
141	Kirkcudbright Lifeboat Station and various beaches	Collecting crabs and bait digging		60
217	Wigtown Bay	Wildfowling		60
267	Wigtown Bay	Wildfowling		54
207-208	Isle of Whithorn Harbour	Bait digging		50
242	Cardoness	Collecting cockles and stake netting		41
147-151	Various beaches	Bait digging		24
249	Sandgreen	Collecting cockles and mussels		21
280-282	Garlieston	Bait digging		20
84-85	Kirkcudbright Bay area and Torrs Point	Bait digging, collecting mussels		8
101,103	Balcary Bay	Bait digging		6
212	Garlieston	Bait digging		6
97-100	Southerness Point	Bait digging		3

Notes

Emboldened observations are the critical group members.

[a]The forward slash (/), separates the locations of, and activities taking place on, the separate substrates for that individual.

Water based activities

Activities taking place in or on the water can potentially lead to ingestion of water and/or inhalation of spray. These pathways are generally considered to be minor in comparison with other exposure pathways such as the ingestion of foods produced in the vicinity of a nuclear site. However, in order to allow for their assessment, relevant data have been collected. Activities where there is a high potential of an individual's face going under the water have been classified as activities in water since they are likely to lead to ingestion of water. All other activities have been classified as activities on water.

Occupancy rates for activities taking place in or on water are shown in Table 18. No further manipulation of the data (for example, calculating critical group mean rates) has been carried out. It should be noted that interviews were conducted with fishing boat skippers and with representatives from sailing clubs, angling clubs, the RNLI and haaf netters who provided data for their members and crew.

Activities in the water

Activities in the water included jet skiing, kayaking and swimming. The maximum rate spent in water was 160 h y^{-1} by a jet skier.

Activities on the water

Activities on the water included commercial fishing (creeling, dredging for cockles, dredging for scallops, haaf netting and gill netting), boat angling, sailing, canoeing, motor cruising, working on the river, hobby fishing (creeling), boat maintenance, paddling, wading while angling, RNLI and coastguard duties. The maximum rate spent on water was 2700 h y^{-1} by a commercial creel fisherman.

Table 18 Occupancy rates in and on water (h y^{-1})

Observation number	Location	Activity	In water	On water
191	Brighouse Bay	Jet skiing	160	
240-241	Garlieston Bay	Kayaking	25	
271-272	Sandgreen and Carrick	Swimming	10	
242-246	Cardoness Estate	Swimming/Canoeing	6	6
94-96	Rascarrel Bay	Swimming	6	
172-173	Nun Mill Bay	Swimming	4	
274	Garlieston to Isle of Whithorn	Creeling		2652
214	Off the Isle of Whithorn	Creeling		2200
70	Kirkcudbright Bay	Creeling and boat angling		1950
134	Dee Estuary, Kirkcudbright Marina, off the Isle of Whithorn	Motor cruising, boat maintenance, dredging for scallops		1818
152	Torrs Point to Auchencairn Bay	Creeling		1155
74	Kirkcudbright Bay	Creeling		1120
76-81	Solway Firth	Dredging for cockles		960
49-69	Off the Isle of Whithorn	Dredging for scallops		840
161	Kirkcudbright Bay	Creeling		812
27	Solway Estuary	Charter boat skipper		810
86-87	Balcary Bay	Boat angling		780
226	Isle of Whithorn	Creeling		420
136-140	Kirkcudbright Bay	Sailing		364
211	Isle of Whithorn	Coastguard duties, creeling		345
156	Dee Estuary, Kirkcudbright Bay	Working on the river, sailing		308
17-26	Kippford	Sailing		260
160	Dee Estuary	Working on the river		230
289	Solway Estuary, River Nith near Caerlaverock	Boat angling, haaf netting		184
36	River Nith - west bank	Haaf netting		180
44-47	River Nith - west bank	Haaf netting		180
288	River Nith near Caerlaverock	Haaf netting		180
286	River Nith near Caerlaverock	Haaf netting		140
207	Isle of Whithorn	Boat angling		114
208	Isle of Whithorn	Boat angling		114
163-167	Kirkcudbright Bay	RNLI duties		105
219	Wigtown Bay	Gill netting		100
234	Garlieston	Boat angling		96
254	Garlieston Bay	Boat angling		90
212	Garlieston	Boat angling		70
142-146	Kirkcudbright Bay	Boat angling		64
253	Garlieston Bay	Boat angling		50
260	Kirkcudbright Bay	Boat angling		42
168	Dee Estuary	Angling (wading)		25
117-120	Balcary beach and Nun Mill Bay	Paddling		15
258-259	Isle of Whithorn	Sailing		12

5 COMBINED PATHWAYS

In determining habits data for the purposes of assessing radiological doses to the public, it may be necessary to consider a combination of pathways. Data are provided data in Annex 1 and Annex 2 so that the full effect of combining pathways can be assessed for individual observations, given the concentrations and dose rates for a particular assessment. In some circumstances, it will be possible to make simplifying assumptions and define the consumption and external exposure rates appropriate to a series of potential critical groups. Such assumptions will depend on the assessment in question but some initial observations are provided here as a starting point for those undertaking assessments. The most extensive combinations of pathways for adult dose assessment are shown in Table 19. Each of the 15 combinations shown in this table represents an actual individual (or individuals) from Annex 1 who has positive data (irrespective of the magnitude), for each pathway marked with an asterisk. It should be noted that combination numbers in Table 19 do not correlate directly with observation numbers in Annex 1. Other individuals from Annex 1 have combinations that are not listed in Table 19 because they have fewer pathways and a dose assessment for them would be adequately covered by one of the 15 listed combinations. Combinations of pathways at critical group rates may be achieved by considering the data in Annex 1 and Annex 2. Although critical group rates are not given in the tables, the rates for individuals making up the groups are shown emboldened. Possible combinations of pathways and their associated critical group rates are therefore apparent.

Table 19 Combinations of adult pathways for consideration in dose assessments

Combination number	Fish	Crustaceans	Molluscs	Wildfowl	Salt marsh grazed cattle meat	Intertidal occupancy over mud	Intertidal occupancy over mud and sand	Intertidal occupancy over rock	Intertidal occupancy over sand	Intertidal occupancy over salt marsh	Handling fishing gear	Handling sediment	Occupancy in water	Occupancy on water
1	*			*						*	*	*		*
2	*	*	*	*				*	*		*	*		*
3	*					*					*	*		*
4	*	*					*	*	*		*	*		*
5	*							*		*				
6	*	*	*				*	*	*			*		*
7						*	*				*	*		*
8								*				*	*	
9		*	*			*					*			*
10	*	*	*			*						*		*
11									*				*	
12	*		*				*					*	*	*
13	*			*			*		*	*		*		
14				*				*		*		*		
15					*					*				

6 COMPARISONS WITH THE PREVIOUS SURVEY

The results from this 2007 survey can be compared with results from the last habits survey undertaken in 2002 along the Dumfries and Galloway coast, since the survey area (the Caerlaverock National Nature Reserve to the Isle of Whithorn and the waters offshore) was identical in both surveys.

Internal exposure

The adult critical group mean consumption rates obtained in 2002 and 2007 are shown below in Table 20.

Table 20 Comparison between 2002 and 2007 aquatic internal exposure pathways

	2002			2007		
Food group	**Number in the critical group**	**Maximum rate (kg y^{-1})**	**Critical group mean (kg y^{-1})**	**Number in the critical group**	**Maximum rate (kg y^{-1})**	**Critical group mean (kg y^{-1})**
Fish	20	74.0	43.0	8	67.6	50.8
Crustaceans	6	27.4	19.6	11	29.1	15.1
Molluscs	6	15.0	10.9	6	8.8	5.7
Wildfowl	14	15.7	8.8	3	35.4	21.5
Salt marsh grazed cattle meat	7	62.4	53.8	5	31	31.0
Salt marsh grazed sheep meat	10	5.7	4.5	-	-	-

The adult critical group mean consumption rate for fish has increased from 43 kg y^{-1} in 2002, to 51 kg y^{-1} in 2007. The types of fish consumed have undergone significant change. Haddock and plaice contributed to nearly 60% of the critical group fish consumption in 2002 but in 2007, haddock was no longer being consumed by the critical group and plaice was only consumed in very small quantities. In 2007, the predominant consumed species were cod (46%) and mackerel (37%), whereas the 2002 survey had found only very low consumption of cod and no mackerel consumption in the critical group at all.

Crustacean consumption within the adult critical group has decreased from 20 kg y^{-1} in 2002 to 15 kg y^{-1} in 2007. The species most commonly consumed by the crustacean critical group has undergone change; *Nephrops* has reduced from 64% in 2002 to 27% in 2007, whilst crab has increased from 14% in 2002 to 55% in 2007.

Mollusc consumption within the adult critical group has almost halved, from 11 kg y^{-1} in 2002 to 5.7 kg y^{-1} in 2007. Again significant changes were observed in the most commonly consumed species. Whelks were the most commonly consumed mollusc in 2002 (43%) but were not consumed

by the 2007 critical group. Mussels (62%) and cockles (25%) represented the most commonly consumed mollusc species in 2007. This represents an increase from 8% for mussels and from zero consumption of cockles (collection of cockles was banned during the 2002 survey).

The adult critical group mean consumption rate for wildfowl has increased from 8.8 kg y^{-1} in 2002 to 21 kg y^{-1} in 2007. In 2007, there were fewer members of the critical group (three compared with 14 in 2002).

The adult critical group mean consumption rate for salt marsh grazed cattle meat has decreased from 54 kg y^{-1} in 2002 to 31 kg y^{-1} in 2007.

The consumption of salt marsh grazed sheep meat occurred at a low level in 2002 but was not identified in 2007.

External exposure

For external pathways, it should be noted that the methodology for determining critical groups has changed since the 2002 survey so care is needed when comparing results. In previous surveys a factor of 1.5 instead of 3 was used to define the cut-off value for intertidal occupancy and handling rates. However, it is now considered appropriate that a factor of 3 is used.

The critical group mean intertidal occupancy and handling rates for 2002 and 2007 are shown below in Table 21. The 2002 rates have been re-calculated using the new methodology for ease of comparison.

Table 21 Comparison between 2002 and 2007 aquatic external exposure pathways

	2002			2007		
Intertidal occupancy and handling	**Number in critical group**	**Maximum occupancy or handling rate (h y^{-1})**	**Critical group Mean (h y^{-1})**	**Number in critical group**	**Maximum occupancy or handling rate (h y^{-1})**	**Critical group mean (h y^{-1})**
Mud	1(3)	888	888 (425)	4	1120	775
Mud and sand	16(6)	1050	705 (1024)	4	1035	570
Rock	12(5)	382	250 (322)	10	960	669
Sand	7(4)	600	450 (540)	13	608	306
Sand and stones	3(3)	270	212 (212)	-	-	-
Salt marsh	4(2)	828	644 (757)	4	857	665
Fishing gear	9(2)	2320	1321 (1948)	8	2228	1309
Sediment	16(7)	1054	720 (1006)	10	1050	815

Numbers in parenthesis were calculated using the former method of dividing by 1.5.

For intertidal occupancy, the rates over some substrates have increased while others have decreased; with the exception of occupancy over rock, no major changes in occupancy were noted. The intertidal occupancy activities undertaken by the individuals in the critical groups in 2002 were; tending stake nets over mud; winkle collecting and bait digging and over mud and sand; winkle collecting and angling over rock; haaf netting, wildfowling, coastguard/marsh warden duties and tending livestock by farmers over salt marsh; long netting, people relaxing on the beach, dog walking and winkle collecting over sand; and dog walking and bird ringing/netting over sand and stones. The activities undertaken by the individuals in the critical groups in 2007 were; tending stake nets over mud; tending stake nets and cockle collecting over mud and sand; winkle collecting, angling, mussel collecting and crab collecting over rock; wildfowling and coastguard/marsh warden duties over salt marsh; dog walking, cockle collecting, bird watching, beachcombing and working on the beach over sand. No activities over sand and stones were noted in 2007.

For handling of fishing gear and sediment, the rates were similar in both 2002 and 2007. In 2002 the critical group activities comprised winkle collecting, bait digging, wildfowling and checking stake nets. The critical group activities were similar in 2007 except that checking stake nets was not included, and cockle collecting was added.

7 MAIN FINDINGS

Exposure pathways were investigated for 242 adults and 60 children. The survey considered pathways relating to liquid discharges to the Solway, principally from the Sellafield nuclear site in Cumbria.

The critical group mean consumption rates were calculated using the 'cut-off' method as defined in Section 3.4.

The adult critical group mean consumption rates of aquatic foods were:

- 51 kg y^{-1} for fish
- 15 kg y^{-1} for crustaceans
- 5.7 kg y^{-1} for molluscs
- 22 kg y^{-1} for wildfowl
- 31 kg y^{-1} for salt marsh grazed cattle meat

The predominant foods consumed by the critical groups for fish species were cod, mackerel and bass, for crustacean species were crab and *Nephrops* and for mollusc species were cockles and mussels. The predominant foods consumed by the wildfowl critical group were geese and duck, the main known duck species being mallard, pintail, teal and wigeon. Consumption of salt marsh grazed beef was noted. The consumption of marine plants/algae and salt marsh grazed sheep meat was not identified.

The critical group mean occupancy rates over intertidal areas were:

- 780 h y^{-1} for mud
- 570 h y^{-1} for mud and sand
- 670 h y^{-1} for rock
- 670 h y^{-1} for salt marsh
- 310 h y^{-1} for sand

The critical group mean rates for handling fishing gear and sediment were 1300 h y^{-1} and 820 h y^{-1}, respectively.

The maximum rates for occupancy in and on water were 160 h y^{-1} and 2700 h y^{-1}, respectively.

8 RECOMMENDATIONS

Information collected during the 2007 Dumfries and Galloway habits survey can be used to make recommendations for changes to the current monitoring programme.

8.1 Current environmental monitoring programme

The 2007 SEPA monitoring programme for the area covered by this survey comprised sampling of sediments, seawater, seaweed and various seafood (including crab, lobster, winkles, cockles, mussels, king and queen scallops, plaice, sole and whiting) for aquatic pathways (EA, EHS, FSA and SEPA, 2007). No milk, beef or lamb from animals that graze on salt marsh is currently sampled from the within the area covered by this survey. Gamma dose rate measurements are taken at 14 points in the bays and estuaries.

8.2 Recommendations for environmental monitoring

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

- An annual sample of cod and mackerel could replace the current samples of plaice and sole. This suggestion is based on the percentage breakdown of species consumed by the critical group for fish. The fish species consumed in the highest quantities by the critical group were cod (45%) and mackerel (35%). Therefore, cod would be recommended to replace plaice or sole, followed by mackerel.
- For reassurance purposes, an annual sample of beef taken from cattle grazed on salt marsh could be analysed. Similarly, a quarterly sample of milk taken from the dairy cattle grazed on salt marsh could be considered.

9 ACKNOWLEDGEMENTS

Thanks are due to representatives of local authorities and associations and members of the public who offered helpful advice and information during the survey. In particular, gratitude is expressed to Dumfries and Galloway Council and to the Wigtown Bay Local Nature Reserve Ranger. This survey was undertaken on behalf of the Scottish Environment Protection Agency.

10 REFERENCES

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. Off. J. Eur. Commun., 39 (L159): 1-114.

EA, EHS, FSA and SEPA, 2007. Radioactivity in Food and the Environment, 2006. EA, EHS, FSA and SEPA, Warrington, Belfast, London and Stirling. (12), 237 pp.

Hunt, G. J., Hewett, C. J. and Shepherd, J.G., 1982. The identification of most exposed groups and its application to fish and shellfish consumers in the coastal area of the north-east Irish Sea. Health Physics, Vol. 43, No 6, pp. 875-889.

ICRP, 1991. 1990 Recommendations of the International Commission on Radiological Protection. Annal. ICRP 21 (1-3). Pergamon Press, Oxford, 201 pp. (ICRP Publ. 60.).

ICRP, 1996. Age-dependant doses to members of the public from intake of radionuclides. Annal. ICRP 26 (1). Elsevier Science, Oxford, (ICRP Publ. (72)).

Leonard, D. R. P., Hunt, G. J. and Jones, P. G. W., 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.
Scottish Executive, 2000. Radioactive Substances (Basic Safety Standards) (Scotland) Direction 2000. Scottish Executive, Edinburgh.

Smith, K.R. and Jones, A.L., 2003. Generalised habit data for radiological assessments. NRPB-W41. NRPB, Chiltern.

Sherlock, M., Tipple, J.R. and McTaggart, K.A., 2003. Radiological Habits Survey, Dumfries and Galloway Coast, 2002. Environment Report RL 04/03. Cefas, Lowestoft.

UK Parliament, 1993. Radioactive Substances Act, 1993. HMSO, London.

Annex 1. Adults' consumption rates (kg y^{-1}) and occupancy rates (h y^{-1})

Observation number	Sex	Age in years	Fish	Crustaceans	Molluscs	Wildfowl	Salt marsh grazed cattle meat	Intertidal occupancy over mud	Intertidal occupancy over mud and sand	Intertidal occupancy over rock	Intertidal occupancy over salt marsh	Intertidal occupancy over sand	Handling fishing gear	Handling sediment	Occupancy in water	Occupancy on water
1	M	41									10					
2	M	U									10					
3	M	U									10					
4	M	U									150					
5	M	U									150					
6	M	61									260					
7	M	35				**14.5**					**857**					
8	M	U									**821**					
12	F	37				**14.5**										
13	M	55									75					
14	M	40									146					
17	M	U														260
18	M	U														260
19	M	U														260
20	M	U														260
21	M	U														260
22	F	U														260
23	F	U														260
24	F	U														260
25	F	U														260
26	F	U														260
27	M	48		7.5												810
28	F	48		7.5												
29	M	42										80				
30	M	U										**240**				
31	M	U										**240**				
32	M	U										**240**				
33	M	U										**240**				
34	F	U										**240**				
35	F	U										**240**				
36	M	61	11.8					**430**					530	80		180
37	F	60	11.8													
38	F	32	11.8													
39	M	33	11.8													
41	M	50						**430**					350	80		
42	M	U						80						80		
43	M	U						80						80		
44	M	U											180			180
45	M	U											180			180
46	M	U											180			180
47	M	U											180			180
48	M	39										**608**		**608**		
49	M	U	2.7		0.1								280			840
50	M	U	2.7		0.1								280			840

Annex 1. Adults' consumption rates (kg y^{-1}) and occupancy rates (h y^{-1})

Observation number	Sex	Age in years	Fish	Crustaceans	Molluscs	Wildfowl	Salt marsh grazed cattle meat	Intertidal occupancy over mud	Intertidal occupancy over mud and sand	Intertidal occupancy over rock	Intertidal occupancy over salt marsh	Intertidal occupancy over sand	Handling fishing gear	Handling sediment	Occupancy in water	Occupancy on water
51	M	U	2.7		0.1								280			840
52	M	U	2.7		0.1								280			840
53	M	U	2.7		0.1								280			840
54	M	U	2.7		0.1								280			840
55	M	U	2.7		0.1								280			840
56	M	U											280			840
57	M	U											280			840
58	M	U											280			840
59	M	U											280			840
60	M	U											280			840
61	M	U											280			840
62	M	U											280			840
63	M	U											280			840
64	M	U											280			840
65	M	U											280			840
66	M	U											280			840
67	M	U											280			840
68	M	U											280			840
69	M	U											280			840
70	M	44	**67.6**	**14.8**	**4.7**	6.9				75		150	**1500**	75		1950
71	F	42	**67.6**	**14.8**	**4.7**	6.9						150				
72	M	21	**67.6**	**10.7**	**4.7**	6.9										
73	F	17	**67.6**	**10.7**	**4.7**	6.9										
74	M	U	11.8	**13.8**					9	45		88	**770**	18		1120
75	F	U	11.8	**13.8**								88				
76	M	U											600			960
77	M	U											600			960
78	M	U											600			960
79	M	U											600			960
80	M	U											600			960
81	M	U											600			960
82	F	57	6.4							225	225					
83	F	58	6.4													
84	M	38	15.6		0.7				6	20				8		
85	F	36	15.6		0.7				6	20				8		
86	M	U						**1120**	180				**1120**	180		780
87	M	U						**1120**	180				**1120**	180		780
88	M	U								24						
89	M	U								24						
90	M	47	**30.8**							**480**						
91	F	42	**30.8**							240						
94	M	U								90				90	6	
97	M	U	3.4						3	42				3		
98	M	U	3.4						3	42				3		

Annex 1. Adults' consumption rates (kg y^{-1}) and occupancy rates (h y^{-1})

Observation number	Sex	Age in years	Fish	Crustaceans	Molluscs	Wildfowl	Salt marsh grazed cattle meat	Intertidal occupancy over mud	Intertidal occupancy over mud and sand	Intertidal occupancy over rock	Intertidal occupancy over salt marsh	Intertidal occupancy over sand	Handling fishing gear	Handling sediment	Occupancy in water	Occupancy on water
99	M	U	3.4						3	42				3		
100	M	U	3.4						3	42				3		
101	M	U	1.8						6	24				6		
102	F	U	1.8													
103	M	U	1.8						6	24				6		
104	F	U	1.8													
105	M	28										24				
106	F	29										24				
109	M	U										24				
110	F	U										24				
113	F	U										24				
115	M	35										45				
116	F	33										45				
121	M	U										15				
122	F	U										15				
123	M	35	2.6							210						
124	F	U	2.6													
125	M	U			1.1					60						
126	F	U								60						
129	M	U							300	**750**				**1050**		
130	M	U							300	**750**				**1050**		
131	M	U							300	**750**				**1050**		
132	M	U							300	**750**				**1050**		
133	M	U							300	**750**				**1050**		
134	M	U		**16.3**	**8.8**			130					112			1818
135	F	U		**16.3**												
136	M	U						3								364
137	M	U														364
138	F	U														364
139	M	U														364
140	F	U														364
141	M	U	**43.3**						45	**453**				60		
142	M	U														64
143	M	U														64
144	M	U														64
145	M	U														64
146	M	U														64
147	M	U							24	100				24		
148	M	U							24	100				24		
149	M	U							24	100				24		
150	M	U							24	100				24		
151	M	U							24	100				24		
152	M	U							**355**			**312**	**1050**	250		1155
153	M	U	**30.9**						**350**	**500**		**500**		**350**		

Annex 1. Adults' consumption rates (kg y^{-1}) and occupancy rates (h y^{-1})

Observation number	Sex	Age in years	Fish	Crustaceans	Molluscs	Wildfowl	Salt marsh grazed cattle meat	Intertidal occupancy over mud	Intertidal occupancy over mud and sand	Intertidal occupancy over rock	Intertidal occupancy over salt marsh	Intertidal occupancy over sand	Handling fishing gear	Handling sediment	Occupancy in water	Occupancy on water
156	M	U	1.6	1.7	0.9			230						230		308
157	F	U	1.6	1.7	0.9											
158	M	18	1.6	1.7	0.4											
160	M	U						230						230		230
161	M	U		4.9									250			812
162	F	U		4.9												
163	M	U														105
164	M	U														105
165	M	U														105
166	M	U														105
167	M	U														105
168	M	U	4.3													25
169	F	U	4.3													
170	M	U										10				
171	F	U										10				
174	M	U										**225**				
175	F	U										**225**				
176	M	U										12				
177	F	U										12				
178	M	U										6				
179	F	U										6				
182	M	U										24				
183	F	U										24				
186	M	U										48				
187	F	U										48				
190	M	U										140				
191	F	U										140			160	
194	M	U							8			42				
195	F	U							8			42				
198	M	U										18				
199	F	U										18				
202	M	35										65				
203	F	37										65				
207	M	U	6.9						50	50				50		114
208	M	U	6.9						50	50				50		114
209	F	U	6.9													
210	F	U	6.9													
211	M	U											100			345
212	M	38	2.9						6	70				6		70
213	F	U	2.9													
214	M	U											**1650**			2200
215	M	U							**1035**				**1035**	40		
216	M	U							**540**				540			
217	M	U				2.2					60			60		

Annex 1. Adults' consumption rates (kg y^{-1}) and occupancy rates (h y^{-1})

Observation number	Sex	Age in years	Fish	Crustaceans	Molluscs	Wildfowl	Salt marsh grazed cattle meat	Intertidal occupancy over mud	Intertidal occupancy over mud and sand	Intertidal occupancy over rock	Intertidal occupancy over salt marsh	Intertidal occupancy over sand	Handling fishing gear	Handling sediment	Occupancy in water	Occupancy on water
218	F	U				2.2										
219	M	U	12.9	**11.1**									90			100
220	F	U	7.8	7.8												
221	F	U	5.1	5.2												
222	F	66										140				
225	F	69										**308**				
226	M	U	11.4										336			420
227	M	28	7.0							96						
228	M	28	7.0							96						
229	M	68								36						
230	M	53								36						
231	M	U	6.9							140						
232	M	U	6.9							140						
233	M	U	6.9							140						
234	M	U	10.0													96
235	M	76							100							
236	F	69							100							
237	M	43	1.4							30						
240	M	45							50						25	
241	F	41							50						25	
242	M	41	2.4		0.1				170					41	6	6
243	F	U	2.4		0.1				104						6	6
247	M	58										200				
248	M	49										200				
249	F	43			0.8				14	7				21		
250	M	U			0.8											
251	M	U			0.8											
252	F	U									43					
253	M	66	15.5													50
254	M	73	15.5													90
255	F	45							42							
258	M	U				5.8					72			72		12
259	F	U				5.8										12
260	M	41	6.0	0.9	**6.5**				156	**543**		165		204		42
261	F	45	6.0													
264	M	17	6.0													
266	M	U									26					
267	M	U	0.6			4.3			32		54	**365**		54		
268	F	U	0.6			4.3										
269	F	68							84							
270	F	43							110							
273	M	U			2.0					**960**				**960**		
274	M	U		**29.1**									**2228**			2652
275	F	17		**14.6**												

Annex 1. Adults' consumption rates (kg y^{-1}) and occupancy rates (h y^{-1})

Observation number	Sex	Age in years	Fish	Crustaceans	Molluscs	Wildfowl	Salt marsh grazed cattle meat	Intertidal occupancy over mud	Intertidal occupancy over mud and sand	Intertidal occupancy over rock	Intertidal occupancy over salt marsh	Intertidal occupancy over sand	Handling fishing gear	Handling sediment	Occupancy in water	Occupancy on water
278	M	U				**35.4**				160	**480**			**480**		
279	F	U				6.4										
280	M	33							20	55				20		
281	M	37							20	55				20		
283	M	51							112							
284	F	50							112							
285	M	66			1.4											
286	M	65	4.7										140			140
287	F	65	4.7													
288	M	22											180			180
289	M	38	6.6			5.3					**500**		151	**500**		184
290	F	38	6.6			5.3										
291	M	U									104					
292	M	U									104					
293	M	U									104					
294	M	U									104					
295	M	U									104					
296	M	U					**31.0**				104					
297	M	U					**31.0**				104					
298	F	U					**31.0**									
299	M	U					**31.0**									
300	F	U					**31.0**									

Notes

U = Unknown

Emboldened data are included in the critical groups.

Annex 2 Children's consumption rates (kg y^{-1}) and occupancy rates (h y^{-1})

Observation number	Sex	Age in years	Fish	Crustaceans	Molluscs	Wildfowl	Salt marsh grazed cattle meat	Intertidal occupancy over mud and sand	Intertidal occupancy over rock	Intertidal occupancy over salt marsh	Intertidal occupancy over sand	Handling sediment	Occupancy in water	Occupancy on water
15-year-old age group														
9	M	14				**14.5**								
10	M	12				**14.5**								
11	F	12				**14.5**								
16	F	14								26				
92	M	13							240					
93	F	15							240					
117	M	12									30			15
127	M	13							60					
154	F	14	**15.4**						250					
155	F	12	**15.4**						250					
159	M	14	0.7		0.4									
172	M	13									6		4	
173	M	12									6		4	
196	M	13						8			42			
239	M	12	1.4						30					
256	F	13						42						
262	M	13	**6.0**	0.9	**6.5**			24	48			72		
263	M	14	**6.0**											
271	M	13						110					10	
276	F	14		**7.3**										
277	M	12		**7.3**										
282	M	15						20	55			20		
301	M	12					**15.0**							
10-year-old age group														
15	F	11								26				
40	F	8	**11.8**											
95	F	11							90			90	6	
96	M	8							90			90	6	
107	F	7									24			
111	M	9									24			
112	F	7									24			
114	M	8									24			
118	F	10									30			15
119	F	8									30			15
184	M	11									24			
185	M	7									24			
188	M	11									48			
192	F	11									**140**			
197	F	11						8			42			

Annex 2 Children's consumption rates (kg y^{-1}) and occupancy rates (h y^{-1})

Observation number	Sex	Age in years	Fish	Crustaceans	Molluscs	Wildfowl	Salt marsh grazed cattle meat	Intertidal occupancy over mud and sand	Intertidal occupancy over rock	Intertidal occupancy over salt marsh	Intertidal occupancy over sand	Handling sediment	Occupancy in water	Occupancy on water
200	F	8									18			
201	F	7									18			
204	F	9									65			
205	M	8									65			
223	M	10									20			
224	M	10									20			
238	M	10	1.4						30					
244	F	9	1.2					104					6	6
245	M	9	1.2					104					6	6
246	M	7	1.2					104					6	6
257	F	10						42						
272	F	11						110					10	
302	F	8					**7.5**							
5-year-old age group														
108	F	4									24			
120	M	5									30			15
128	F	5							60					
180	F	6									6			
189	F	6									48			
193	M	4									**140**			
206	F	6									65			
265	M	2	**0.3**											
1-year-old age group														
181	M	1									6			

Notes

Emboldened data are included in the critical groups.

This page has been intentionally left blank