ENVIRONMENT AGENCY

DEVELOPMENT OF DATA AND INFORMATION SOURCES ON NATURA 2000 ESTUARINE SITES IN THE NORTH WEST

Morecambe Bay: Final Report

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1 Introduction

1.1 Background to Project

A number of sites in the UK are designated as special protection areas (SPA) and/or candidate special areas for conservation (cSAC) and thus enjoy protection at an international (European) level. These sites together comprise the Natura 2000 network of sites throughout Europe. The Environment Agency, as competent authority in England and Wales, has a responsibility to safeguard the interest features of Natura 2000 sites through its function in regulating a number of activities that take place in and around these sites. In response to this, the Agency is undertaking a review of consents (authorisations to discharge effluent, abstract water, release atmospheric emissions etc.) process. All consents that could potentially influence protected species and/or habitats at Natura 2000 sites are being reviewed, a process that can involve many thousands of consents at a single site. In order to carry out this task, the Agency identified that it needed an up to date source of information on scientific knowledge for a number of the sites. This project provides that resource for Duddon Estuary SPA in north west England.

Related projects have been undertaken for Ribble and Alt Estuaries SPA and Morecambe Bay SPA/cSAC (Fig. 1). These, together with a phase 1 project for Ribble and Alt estuaries, have developed a database of information, the North West Natura 2000 database (version 2). Section 2 provides an overview of the database, including instructions for use.

1.2 Objectives

With an overall aim of providing a resource to assist with the review of consents process, the specific objectives were as follows:

1. Identify sources of information
2. Obtain information and consult with information holders
3. Develop a database for the Information Directory
4. Review and Summarise Existing Information
5. Identify Gaps in current knowledge
6. Suggest projects to fill gaps

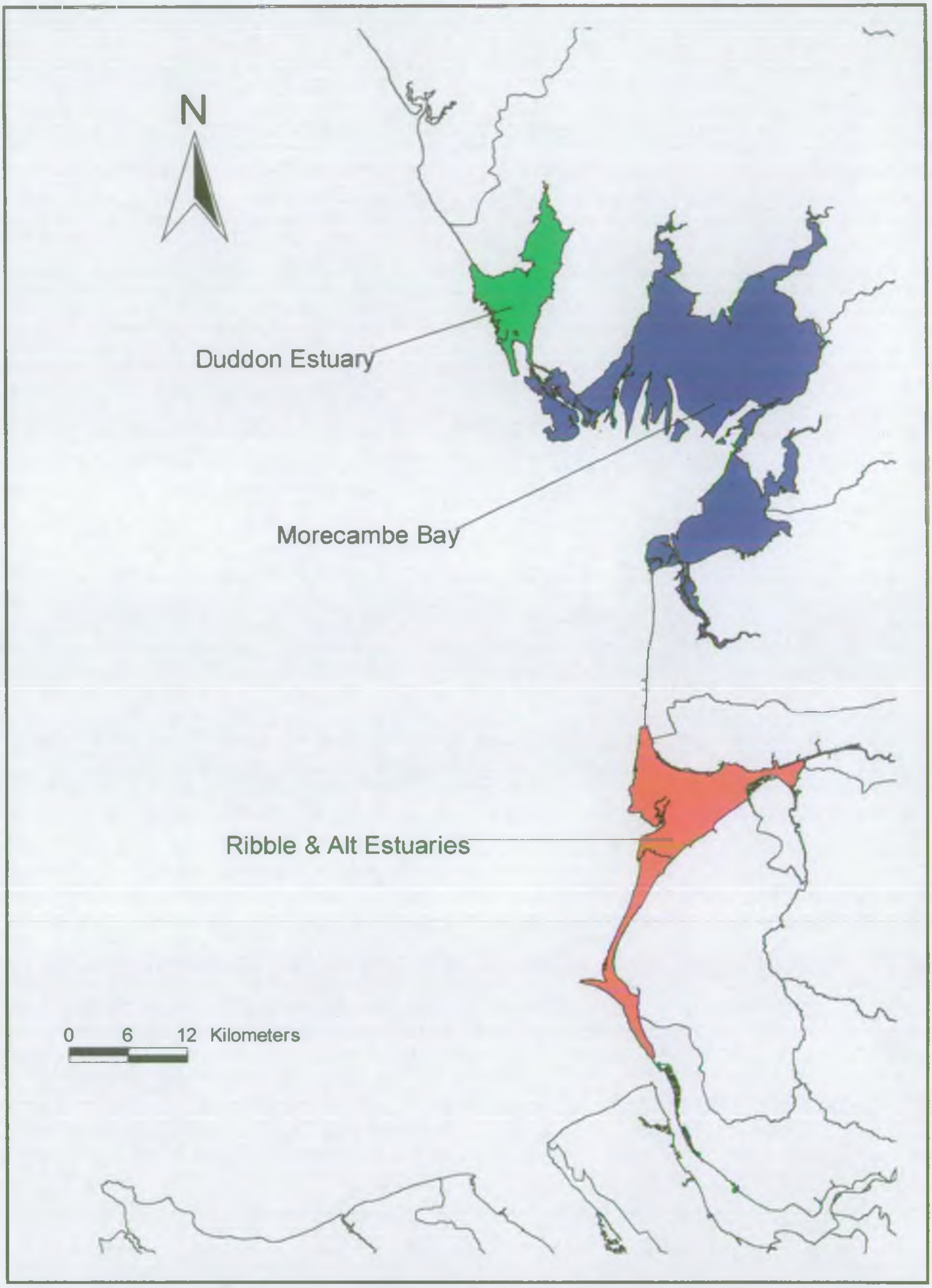


Figure 1 SPA Sites covered by the North West Natura 2000 Information Collation Project

1.3 Duddon Estuary

The Duddon Estuary, on the coast of Cumbria in north-west England (Fig. 2), is a complex site, dominated by intertidal sand and mudflats (74% of the estuary area, Bayliss 1994). It is a large coastal plain estuary formed by the River Duddon and the smaller Kirby Pool. At the mouth there are extensive, highly mobile, flat sand plains. Sands extend beyond high water to form large sand dunes while the mid and upper reaches are muddier and flanked by saltmarsh. Walney Island forms a low-lying barrier island at the SW limit of the estuary.

The sand and mud flats and saltmarsh are important habitats for large numbers of wading birds and wildfowl that winter and/or pass through the site. There are also large areas of calcareous dunes at Sandscale and Haverigg Haws and acid dunes on North Walney. The saltmarshes, sand dunes and Hodbarrow Lagoon, are important roosts for wading birds over high tides. A flooded iron-ore working, Hodbarrow also supports roosting terns at high tide that nest in dunes and areas of slag from former industrial sites. The extensive sand and mudflats support numerous waders during their migration passage and also over winter, providing important invertebrate prey.

North Walney Island has both exposed and vegetated shingle areas, in addition to its acid dunes that together support an abundant and diverse flora. Duddon estuary is also home to over 20% of the British breeding population of natterjack toad *Bufo calamita*.

Although the estuary is not extensively industrialised, there are examples of current and former industrial practices at local centres. In the 19th Century, iron ore deposits were worked next to the estuary and have left a series of saline lagoons at Hodbarrow. At Askam, dumping of 'slagcrete' waste has created a 'pier'. Docks are located at Barrow and Millom with chemical industries and shipbuilding at Barrow-in-Furness. Historically, ironstone mining and steelworks were located at Millom but little industry now remains in the area. A more recent industry is tourism and the local population is swelled in the summer holiday periods.

Because of the important bird populations, Duddon Estuary is a key wildlife conservation area with both national and international conservation designations. At the European level it is a Special Protection Area (SPA). The SPA designation is based upon:

- Populations of European importance of the following species listed on Annex I of the Directive:

During the breeding season; Sandwich Tern *Sterna sandvicensis*.

- Populations of European importance of the following migratory species:

On passage; Ringed Plover *Charadrius hiaticula*, Sanderling *Calidris alba*. Over winter; Knot *Calidris canutus*, Pintail *Anas acuta*, Redshank *Tringa totanus*.

- Regularly supporting at least 20,000 waterfowl **A wetland of international importance**

Over winter, the area regularly supports waterfowl including: Curlew *Numenius arquata*, Dunlin *Calidris alpina alpina*, Sanderling *Calidris alba*, Oystercatcher *Haematopus ostralegus*, Red-breasted Merganser *Mergus serrator*, Shelduck *Tadorna tadorna*, Redshank *Tringa totanus*, Knot *Calidris canutus*, Pintail *Anas acuta*.

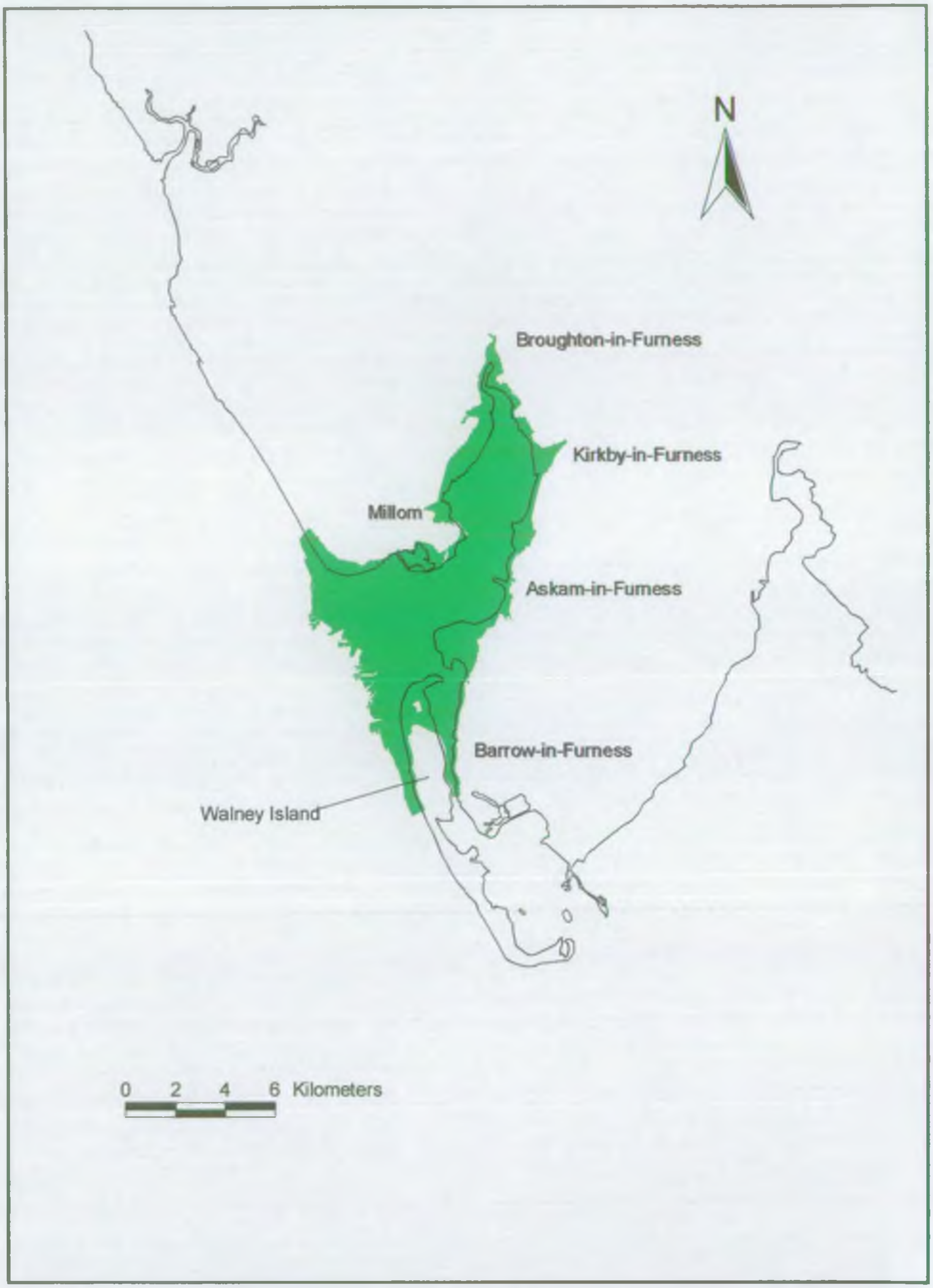


Figure 2 Duddon Estuary Site Map Showing SPA Boundary

2 Study Methods

The project was carried out in 5 distinct phases:

1. identification of information sources;
2. consultation with Agency staff/external organisations
3. development of information directory (database);
4. summarising findings of key studies;
5. identification of significant gaps in knowledge and projects required for bridging.

2.1 Identification of Information Sources

A list of known and potential sources of information was prepared. This list comprised the consultees who included statutory bodies, Environment Agency and English Nature; academic researchers; conservation groups; local authorities; industry and consultancy organisations.

The initial list was expanded as further sources became known to the project team. All organisations consulted during the information collation exercise for Duddon Estuary are indicated in the information directory (Section 3 this report and Database Directory).

2.2 Consultations

Key consultees were visited by members of the project team. This was the case for The Agency and English Nature whose information archives were searched as part of the study. Other consultees with significant information archives were also visited and materials loaned or photocopied. The remaining consultations were by written letter with follow up phone calls and/or emails as necessary. Information was requested on research, reports, programmes of survey and monitoring, scientific models, and management strategies/plans. Only existing interpreted material was included, raw datasets were beyond the scope of this study.

The geographical limit applied to the information collection exercise was taken as the boundary of the SPA. However, information from outwith this immediate area was obtained if it contributed to the study. This was especially the case for water quality information where pollution from both landward and seaward sources can affect the study site.

We attempted to collate all available information sources dating from 1990. However, there was pertinent material that pre-dated 1990, this was incorporated where it added significantly to the value of the project.

Where specific information was not available for Duddon Estuary itself, relevant studies from other sites were considered. This aspect is developed further in Section 5 (Identification of Gaps and Projects Required for Bridging).

In order to ensure that information reviewed could be accessed again in future by the Agency, full details of authorship/ownership was to be collated. In many cases, hard copies of reports, scientific papers etc. were obtained.

2.3 Information Directory

A MS Access 1997 database was constructed to maintain records of:

- People: key contacts with any organisational affiliations shown
- Organisations: key organisations with contact persons indicated
- References: reports, papers, theses, dissertations etc. linked to people and organisations to indicate availability.
- Models: summary of scientific models applied to the site with details on output, propriety products used, availability, costs for use and an assessment of quality.
- Programmes: research programmes, monitoring programmes and other resources, such as databases, with availability indicated.

The information database is shared by several related projects. There have been related studies for Ribble and Alt Estuaries SPA and Morecambe Bay cSAC/SPA. Information within the database is assigned descriptive keywords that include site identifiers, these are provided in Appendix 1.

Information already available internally within the Agency is clearly identified within the database.

Further information on the design and use of the database is provided in Section 3.

2.4 Summary of Key Studies

The review of key studies (Section 4) seeks to build into a description of the 'ecosystem' linkages of the site and the adjacent river catchment use and coastal/marine properties where these affect the site. All material used is references in the information directory, often there are additional notes alongside individual records that provide further details and summaries.

2.5 Identification of Gaps and Projects Required for Bridging

The structured approach adopted in the summary of key studies (Section 4) has facilitated identification of gaps in knowledge. Where gaps were suspected, the database was queried for relevant information before a gap was confirmed.

Outlines of potential projects to fill gaps are given in Section 5. When recommending such work, it has been borne in mind that the review of consents process is underway and limited time will be available for future studies to deliver results that can be incorporated into the process.

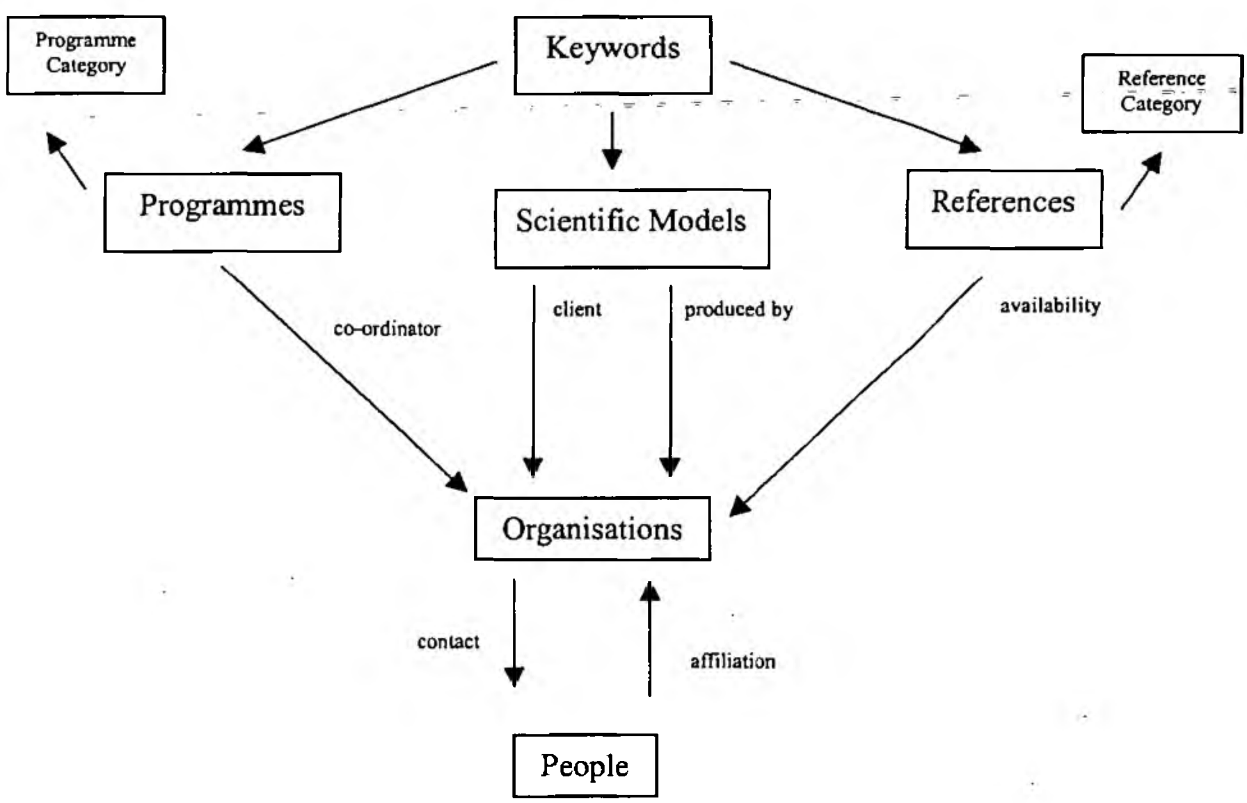
3 Database Information Directory

3.1 Overview of Database

The database is a directory of scientific information relevant to several estuarine Natura 2000 sites in North West England, namely Ribble and Alt Estuaries SPA, Morecambe Bay cSAC/SPA and Duddon Estuary SPA. At the core of the database are 5 tables containing information on scientific programmes (e.g. research and monitoring activities), scientific models, references (scientific papers, reports, plans etc.), organisations and people. There keywords that describe entries in the database according to geographical location and subject area. The same suite of keywords is shared throughout the database and forms the basis of searching outlined in Section 3.2. Further tables hold information on the category of programmes and references and the assessed quality of scientific models.

Links between the various tables permit relationships between information and people/organisations to be referenced. For example, the clients for whom scientific models were produced and the organisations who undertook the work can be seen on the form that describes each model. The main tables and relationships are summarised in Fig. 3.

Figure 3 Key tables and relationships (NB this is a simplified representation of the structural relationships within the database).



3.2 Using the Database

The database is provided in 'read only' format. This is necessary to ensure that the integrity of the database is maintained when it is accessed by multiple users. Database administrators are provided with a version that has both read and write capability, this must be updated centrally before new or amended records can appear in the database.

There are two main ways to find information in the database, custom search functions and MS Access's internal search capabilities. The custom search functions searches for specific occurrences or combinations of keywords in Programmes, References and Models and produce a report based on the selected sub-set of records that can be viewed or exported into another package, such as MS Word or Excel. The internal search function of Access can be used to find individual records by searching for any occurrence of text (or numbers) within a particular field in the database.

3.2.1 Custom Search Functions

Simple and advanced search options are provided within the database, accessed via the 'Search Database' from the main switchboard. These allow queries of References and Programmes to be made.

The simple search allows the user to enter a single keyword (cf. Appendix 1) to retrieve relevant records. The keyword must be entered in the correct format, namely:

Keyword

This will bring up all occurrences of references/programmes that are described by the particular keyword. Please note that keywords must be typed in *exactly* as in Appendix 1 and that the * before and after is essential.

The advanced search allows up to 3 keywords to be combined in a search in the format:

Keyword 1 AND *Keyword 2* AND *Keyword 3*

Automatic dialogue boxes guide the user through the process. If less than 3 keywords are required, simply enter * into the second and/or third dialogue box.

There is also an option to exclude a keyword in the final (fourth) dialogue box. The format is the same (*Keyword*). If there is no requirement to exclude a keyword, simply enter *none* in the box.

All these searches bring up a sub-set of forms which can be printed or exported into another package.

3.2.2 Access Search Functions

From the main switchboard go to the part of the database you wish to search.

Click in the field you wish to search in (e.g. 'Author' or 'Notes').

Use the 'Find' icon (below), or CTRL + F, to bring up the 'Find in Field' dialogue box

Set the options for search and match as required (typically search only current field and match any part of field provides results most readily).

Run the search until the desired record(s) is located.

The current (i.e. displayed) record can be printed, ensuring that 'current record' is checked to avoid printing all recorded.

3.3 Hard Copy of Database

Summaries of the database contents are provided in Appendix 2.

4 Information Review

4.1 Physical Environment

A summary of the physical environment of Duddon Estuary was provided by Fahy *et al.* (1993). This and other information is well summarised by Bayliss (1994). The following summary is compiled from those sources:

> The general form of the coast is the result of tectonic movements but the land-sea boundary is the result of sea-level rise relative to the land over the last 5000 years. This has resulted in large expanses of flat sand covered areas which are 4-5 km wide at the mouth of the estuary. These sand flats are highly mobile. Upstream, beyond Foxfield, sediments become muddier in the more sheltered environment there. At low tide the estuary is an extensive tract of sand and silt dissected by narrow channels of water.
>
> Sand dunes bound the estuary to the north and south while the middle and upper reaches of the estuary are fringed with saltmarsh backed by agricultural land at the base of the Lakeland fells. The southern seaward limit of the estuary is formed by Walney Island, a narrow low-lying barrier island just off the Furness Peninsula.
>
> The geology of the estuary is complex but includes carboniferous rocks broken by northwest trending faults along both sides of the estuary. Limestone is present on the mainland opposite Walney whereas the island itself, a result of both coastal deposition and re-working of glacial deposits, is underlain by Triassic mudstone and Keuper Marl.

The estuary has coastal defences; outside the Duddon Estuary are predominantly hard defences such as masonry/concrete revetments whereas those within the estuary comprise a mixture of unprotected and armoured embankments in combination with natural dunes and salt marshes. The defences provide mainly coastal protection outside the Duddon Estuary while the defences within the estuary provide mainly flood protection (Bullens 1998).

4.2 Coastal Processes

As with other parts of the Cumbrian and Lancashire coasts, the Duddon estuary is sheltered by the Isle of Man and Ireland from the Atlantic. No data are available on wave conditions within the estuary itself but there is little capacity to generate significant wave heights due to the limited fetch, sheltering sand banks and greatly narrowed channel at low tide.

The estuary is macrotidal with a mean spring tidal range of 7.4 m and a mean neap tidal range of 3.4 m. Maximum tidal range is 10.4 m although ranges up to 30% higher are apparently possible depending on wind, tide and atmospheric conditions and NERC 1992 (cited in Bayliss 1994) shows a 2 m storm surge elevation with a return period of 50 years for the mouth of the estuary.

Because of its shallow depth and large tidal range the estuary is vertically well mixed (ETSU 1994). Although no studies of basic physicochemical conditions have been identified, it is clear from the known dominance of tidal activity in the estuary that salinity conditions will closely reflect those of coastal waters while stratification is unlikely except at the head of the estuary around high spring tides and around the main river channel during the lower half of the tidal cycle (NWW 1990 survey cited in Bayliss 1994). The same situation pertains for temperature conditions; no direct data are available but variations from the coastal average of 5 °C in February to 16 °C in August are most likely in summer through the heating of shallow estuarine waters and in winter from the effects of elevated river flows.

Similarly, currents are tidally dominated and the net movement of water is northwards across the mouth of the estuary. Import of sediments from the catchment is minimal compared to what the tides deliver from erosion of the Irish Sea bed and it seems likely that the Duddon is a net receptor of sediments from both north and south (Bayliss 1994).

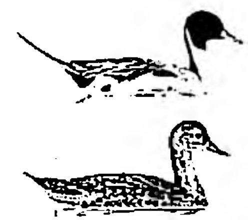
4.3 Designated Species Information

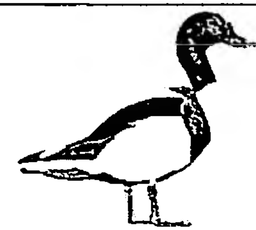
Table 1 provides summary information on avian interest features of the site.

Table 1 Summary information on avian interest feature of the site

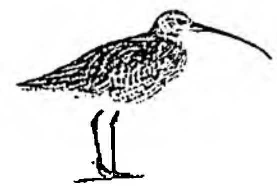
Images are from the following website: http://www.birdcheck.co.uk provided by Ash Midcalf.

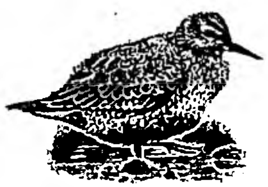
Wildfowl

Species	Length & Wingspan	Activity on Site	Movements	Diet	General Habitats	Photo
Pintail *Anas acuta*	51-66 cm & 51-66 cm, two thirds is body, excluding tail feathers. 80-95 cm.	Winters Occasionally breed on Millom marsh.	Mainly migratory. Breeders from Iceland/northern Scandinavia winter mainly in Britain and Ireland. Degree of movement by small British population is unknown. Birds arrive in mid August, leave March.	Wide variety of plant and animal foodstuffs obtained from depths up to 30 cm. Occasionally dives for food. Picks up grain and digs for rhizomes and tubers.	From west Palearctic to Northern tundra. Shallow open aquatic habitats, open and spacious lowland pasture. Winter sheltered coasts and estuaries, floodland, also on fields with crop stubble.	
Red-breasted Merganser *Mergus serrator*	52-58 cm & 67-82 cm	Winters moult July/August Some breed in estuary tributaries and on North Walney NNR.	Peak arrival period August / September	Pisciverous	Generally breeds in northern taiga and mountains/tundra. Feeds and breeds on coasts and inland waters.	

Shelduck *Tadorna tadorna*	58-67cm, of which two thirds body. 110-133cm.	Winters	Migratory, partly migratory and dispersive. Mainly to northwest Europe, and Britain. Starts in June and return to breeding ground in March.	Mainly invertebrates, especially molluscs (especially *Hydrobia*) and crustaceans. Also feed on algal mats when these occur.	Favours warm, semi-arid and mild maritime climate, almost wholly avoids boreal and subarctic. Breeding ground near salt or brackish waters, or shallow coasts, estuaries, inland seas and lakes.	

Waders

Curlew *Numenius arquata*	50-60 cm, bill 10-15 cm. 80-100 cm.	Winters Duddon Autumn passage peaks August. Spring passage mid March. Small summer population breeds on saltmarshes. Some feed inland during winter, roost on saltmarsh.	Mostly migratory, some birds resident in west of range. Winters in Europe and widely on coasts, (locally inland) in Africa to southern Asia. Arrives at North sea estuaries late June.	Principally inverts from intertidal mud.	Chooses damp or wet terrain with dry patches, near water. Upland bird in Britain, breeding freely as high as 760M. After breeding season moves to mainly marine coastal habitat, with mudflats and sand exposed at low tide.	

Dunlin *Calidris alpina*	16-20 cm. 38-43 cm.	Winters Passage birds arrive mid-July, peaking August. Wintering population arrives late Oct/Nov. Spring passage starts March. A small summer population is spread throughout the estuary.	Migratory, wintering on most ice free coasts of northern hemisphere, but few south of c. 15o N.	Chiefly invertebrates, on breeding ground primarily insects. On mud flats the birds probe for food close together.	In breeding season restricted climatically, range from Arctic Ocean islands, high arctic continental fringe joining oceanic coasts through subarctic to boreal and temperate lands. Prefers moist boggy ground, standing or flowing water. Upland moors in Britain. Outside breeding season like coastal beaches and mudflats.	
Knot *Calidris canutus*	23-25 cm. 57-61 cm.	Winters Roosts on the Duddon, feeds on flats at low water (Roosecote Sands near South Walney, Askam and North Walney Channel). Winter population arrives August/Sept, peaking January.	Migratory. The British wintering population leaves its breeding grounds in Canadian high arctic islands and Greenland to utilise estuaries. Palearctic probably return to breeding grounds, but a good number will	On breeding grounds varying proportions of insects and plant material. Outside breeding season feeds on inter-tidal inverts', chiefly molluscs. Favour *Macoma* and *Nephtys* (744).	Breeds in high Arctic usually near but not to close to the coast. Nests in areas ranging from marshy slopes to flats in the foothills and well-drained clay. In summer marine intertidal areas are used, mud flats, sandy and pebbly	

		Spring passage starts March/April	remain in winter quarters. Arrives Duddon Aug/Sept., peaks January. Departs March/April		beaches.	
Oystercatcher *Haematopus ostralegus*	40-45 cm, bill 8-9 cm. 80-86 cm.	Winters and some breeding on saltmarsh over summer. Poplation peaks between August and Ocotber, declining to a lower mid-winter population.	Mainly migratory, but small numbers dispersive to resident in west, English channel to Iberia. Post breeding birds from west Europe arrives on wintering grounds from late July. Peak numbers on Duddon Aug-Oct. Return to breeding grounds Jan' – April.	Predominately bivalve molluscs, particularly cockles, mussels and Baltic tellin, mainly earthworms inland. Has been stated as 'monophaging' on *Cerastoderma* (744)	Avoids freezing conditions. Tied to shorelines colonised by marine molluscs, crustaceans. Also feeds on lakesides, riversides and open ground.	
Redshank *Tringa totanus*	27-29 cm, bill 3.7-5, legs 4-5.5 cm. 59-66 cm.	Autumn passage starts late July, continuing until late October. Numbers decrease in winter and a small summer breeding population remains on the saltmarsh.	Mainly migratory though some resident in maritime countries of western Europe. European migration mainly SW-SSW, in autumn, reversed in spring. Concentrations along coasts, but	Crustaceans, molluscs, polycheate worms on estuaries, earthworms and cranefly larvae inland. Favour *Macoma* and *Nephtys* (744).	Breeds in continental middle latitudes, mainly temperate. Moist or wet grasslands in open, flat gently sloping lowlands and valleys. Inland distribution linked to depressions, lake and river	

			also overland.		basins, wetlands free of dense veg'. Predominately coastal out of season.	
Ringed Plover *Charadrius hiaticula*	18-20 cm, tail 4-6 cm. 48-57 cm.	Passage migrant, peak numbers late May. Autumn passage peaks late August. Significant breeding population at Sandscale Haws and Haverigg.	Largely migratory, Europe, extreme south Africa and south-west Asia. The southernmost population (Britain) is almost resident. Autumn movements Aug'-Sept', return to breeding grounds mainly March-May.	On breeding ground terrestrial and coastal inverts'. Outside, principally marine polycheates worms, crustaceans and molluscs.	Sea coasts, in arctic, subarctic and north temperate waters. Secondly hinterlands near estuaries, rivers, lakes, tundra, sand bars, sparse growth on grasslands. Most popular on wide sandy or shingle tidal beaches with access to nesting / resting places above high water.	
Sanderling *Calidris alba*	20-21 cm. 40-45 cm.	Passage migrant, some overwintering. Autumn passage peaks August, spring passage starts mid-April, peaking May. Roost mainly at North Walney and Haverigg, feed over much of the estuary.	Migratory. With Holarctic breeding range, winter distribution very large, both sides of Americas, western Africa, southern Europe, southern Asia to Micronesia and Australia.	Chiefly small inverts', larval dipteran flies, beetles, lepidopterans, spiders, crustaceans.	Brief breeding season high Arctic, on island peninsulas, along coastal tundra. After breeding, tidal sandy beaches. In Europe also mud flats and estuaries.	

			Europe winters regular north to Denmark. Spring at the Wash, prefer open coast.			

Seabirds

Sandwich Tern *Sterna sandvicensis*	37-43 cm & 85-97 cm.	Duddon is an important breeding area. Birds arrive late March/April from West Africa, depart by September.	Migratory- winters southern Europe and Africa, breeding N Europe.	Fish, including sandeels and other small fish.	Coastal- nests in scrape on the ground.	

4.4 Other Species and Groups

4.4.1 Invertebrates

Davies (1992) reported on invertebrate communities in the Duddon estuary as part of the Marine Nature Conservation Review (MNCR). Sampling stations were located at Greety Gate, Lady Hall, mid Millom Marsh, Haverigg, Lowsey Point, south of Askam, Dunnerholme and Angerton. Overall, the invertebrate communities reflect the predominantly sedimentary characteristics of the habitats present.

At its mouth, where the estuary is exposed to prevailing wind and waves potential invertebrate habitats were dominated by extensive mobile sand flats of clean medium and fine sand. These extend into the estuary but are restricted to the lower shore adjacent to main channels. All MNCR sampling stations at such habitats had low species richness with no epibiota (i.e. only burrowing infauna present) and were characterised by polychaetes and crustaceans.

At Haverigg and the entrance to Walney channel small embayments with decreased wave exposure and hence muddier sediments had elevated species richness. Infauna were characterised by polychaetes, crustaceans and bivalves. Lower Duddon estuary habitats were predominantly fine sand subject to variable salinity but with higher species richness than the mobile sediments but still characterised by polychaetes and crustaceans. Large areas of sediments had dense *Arenicola marina*. Mud communities of oligochaetes, polychaetes and crustaceans characterised areas where saltmarsh bounded the upper shore.

Dense *Crophium volutator* aggregations occurred at some MNCR sites, although not necessarily in a predictable manner. Sand extended into the upper estuary and was replaced by mud only above the railway bridge at Foxfield. Hard substrata were uncommon and the only natural outcrop was adjacent to Hodbarrow lagoon. Artificial substrata were present in coastal protection walls, iron ore waste ('slagcrete' at Askam Pier). All hard substrate communities were similar and low in species richness and abundance, probably because of low salinity, siltration and/or tidal scour. The upper shore comprised fucoid and green algae with barnacles and the mid shore fucoid algae and barnacles with small mussels. At the mid and upper shore at Haverigg and at entrance to Walney channel were natural accumulations of small stones on surface sediments. These were colonised by barnacles, littorinid snails and small mussels.

A report by Goss-Custard & McGrorty (1991) is a feasibility study for an intensive research programme to look at the possible ecological effects of laying a gas pipeline beneath the intertidal flats of the Duddon estuary. This was to be a second pipeline, a first having been laid in 1987. The authors considered that any effects (positive or negative) was considered most likely to be mediated through changes to sediment characteristics on invertebrate community composition, particularly densities and body sizes of invertebrates, and how this affects bird feeding opportunities.

Duddon estuary and Walney flats were surveyed separately during single visits. As described elsewhere, the Duddon was primarily sandy, Walney flats more muddy. Invertebrates were surveyed across the estuary from Askam to Millom. Intertidal areas consisted of sandflats with high densities of *Arenicola marina*, also *Macoma balthica*, *Phyllodoce* spp, *Scolopus armiger*, *Nephtys* spp and (low density) *Hediste diversicolor*. The main crustaceans found were *Bathyporeia* spp., *Urothoes* spp. and *Corophium arenarium*. Spionid worms occurred in some areas. Densities of all species were generally low, with exception of the bottom of the shore alongside the channel and at the top of the shore that may be sheltered by the pier.

Walney island flats had a much more muddy substrate and contained a considerably higher density and diversity of invertebrates:

Roosecote sands- upper zone above mussel bed firm muddy sand with many lugworms and *Scrobicularia plana*. Low densities of cockles and *Scoloplos*. Eelgrass was present and this may support wintering wildfowl, notably wigeon and brent geese. Below the mussel bed was firm mud with very high densities of cockles and *Scrobicularia plana*. Some *Macoma balthica* and *Nephtys* spp. were also present here. The lower zone was more sandy, wet and unstable with fewer inverts.

The main study was undertaken by Warbrick, Burton & Clark in 1992. Their report comprises:

1) A Baseline survey of birds at low water on the whole intertidal area during winter and spring of 1991/92. This was undertaken to establish areas of importance for feeding waders in relation to both the proposed and existing pipeline routes. The key results were that all species except ringed plover reached peak abundance in winter (Ringed Plover peaked in spring). Highest number of birds generally occurred on south shore of the estuary, north and south of Askam. High proportions of dunlin, redshank, oystercatcher and curlew were present in the vicinity of the pipeline route.

2) A detailed survey of birds around the existing pipeline in winter of 1991/92. To determine whether local distribution of birds was affected by pipeline construction 4 years earlier.

3) A detailed survey of birds in the area of the proposed new route to provide baseline for post-construction surveys following completion of second pipeline.

There was no apparent evidence of any residual effects of the existing pipeline on the distribution of birds in the area. The report recommended that future work should seek to correlate bird densities with invertebrate data collected by ITE previously (Goss-Custard & McGrorty 1991). The report did state that the pipeline could affect sediment characteristics and therefore invertebrates and birds, but that there was no evidence this has happened.

4.4.2 Fish and Fisheries

The Duddon supports a modest run of migratory salmonids (*Salmo trutta* and *Salmo salar*) and eels (*Anguilla anguilla*). However, it is the marine fishery which is of greater significance here, particularly as the nesting sandwich tern colony is dependent upon a supply of sandeels and other small fish. Unfortunately, there is very little reviewed data available on the stocks present.

4.4.3 General and other surveys

Hill, Cameron and Hawkins (1987) undertook mainly quantitative survey of flora and fauna of saline lagoons on the Cumbria coast with some measurement of pH, salinity, temperature and dissolved oxygen. In the Duddon estuary area they surveyed Hodbarrow lagoon which was created following cessation of extraction of iron ore and is separated from the estuary by an artificial sea wall through which salt water percolates at high tide. Salinity within the lagoon 6-10 ppt. There were few marine species and the primary conservation interest was described as the populations of aquatic and terrestrial birds.

Little information is available on phytoplanton in the Duddon estuary. It is known that algal blooms (*Phaeocystis*, *Gyrodinium* and *Noctiluca*) that occur in Morecambe and Liverpool Bays have also ocured in the Duddon (Carty 1993, cited in Bayliss 1994) but there have been no studies assessing the significance of these events locally. No information is available for zooplakton.

4.5 Scientific Models

Offshore wave conditions were analysed for the St Bees Head to Earnse Point, Isle of Walney Shoreline Management Plan (sub-cell 11d database ref. 518). The majority of waves approach the Cumbria Coastline from the south-west. This coincides with the largest waves which are generated over fetches reaching out to the Atlantic Ocean. Fewer waves approach from the north-west quadrant and these are typically smaller than 0.5m. A further analysis providing inshore wave roses for the Cumbria coastline was based on a wave refraction model (52). Inshore wave conditions were determined based upon the offshore Met Office wave model data and accounted for wave refraction as the wave travelled landward. The wave refraction analysis did not take account of tidal currents but did include varying sea levels with the normal tide range experienced along the coast. Similarly to the offshore wave values, the majority of inshore waves occur from south-west quadrant, with minimal wave activity from the north-east and south-east Quadrants. Estimates of the annual average inshore significant wave height and direction of travel are shown in Figure 4.

Direct modelling of offshore wave conditions is also provided by the Meteorological Office's Wave Prediction Model (Database ref. 49). This is a commercial product (1 year costs £600; 5 years costs £2225. Every additional year costs £300 thereafter.) The nearest points inshore for which conditions are available relevant to Morecambe Bay and the Duddon Estuary are: 3°35'W, 54°50'N. This model quite often provides the only estimate of offshore wave conditions available. The model archive consists of the hindcast fields of wind and waves produced during the operation of the atmospheric and wave model forecast suite. To produce the best possible analysis of surface wind, all available reports of surface pressure, wind speed and direction (from ships, buoys, platforms and land stations) are subjected to a range of consistency checks before being assimilated into the model's analysis. The resulting wind field is then used to modify the wave field derived from earlier time steps. For each of the 16 directional and 13 frequency bands, the changes in wave energy are computed at each grid point, using the local wind energy input, and allowing for propagation, dissipation and transfer between spectral bands. The model is a so-called 'Second Generation' model, where the spectral shape is empirically defined, rather than being calculated in run time. For this section of the Irish Sea the model does not include the effects of Anglesey or the Isle of Man. No summary of trend in the data produced has been found.

Several models to describe wave conditions and tidal flows in Walney channel related to waste water discharges, bathing water quality and sediment dispersal (60, 61 & 62). The layout grid for the Delft Hydraulics Walney Channel Model (Database ref. 62) produced for ABP is provided in Figure 5.

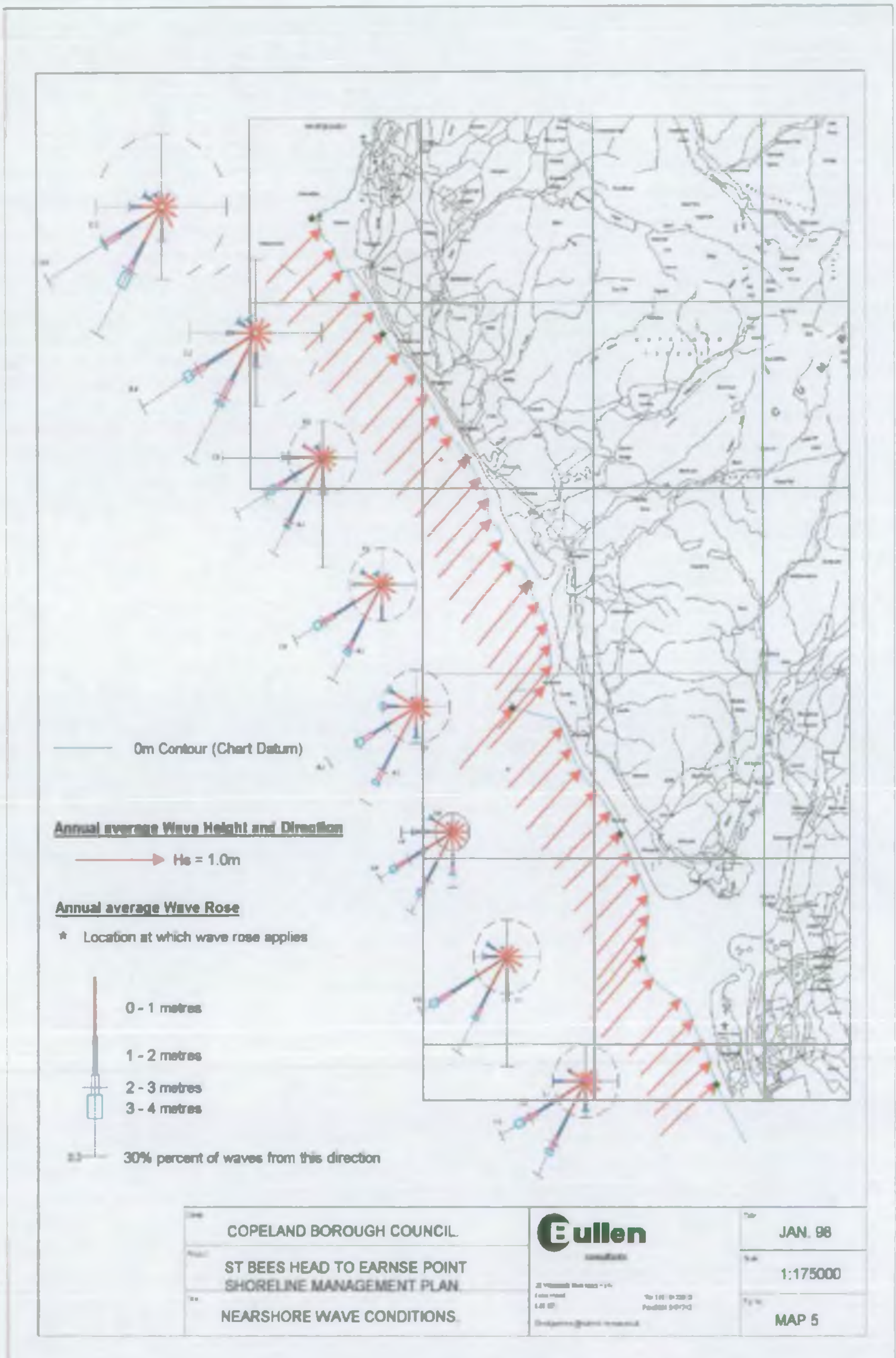


Figure 4 Nearshore Wave Conditions (from Bullen Consultants 1997, database reference 517).

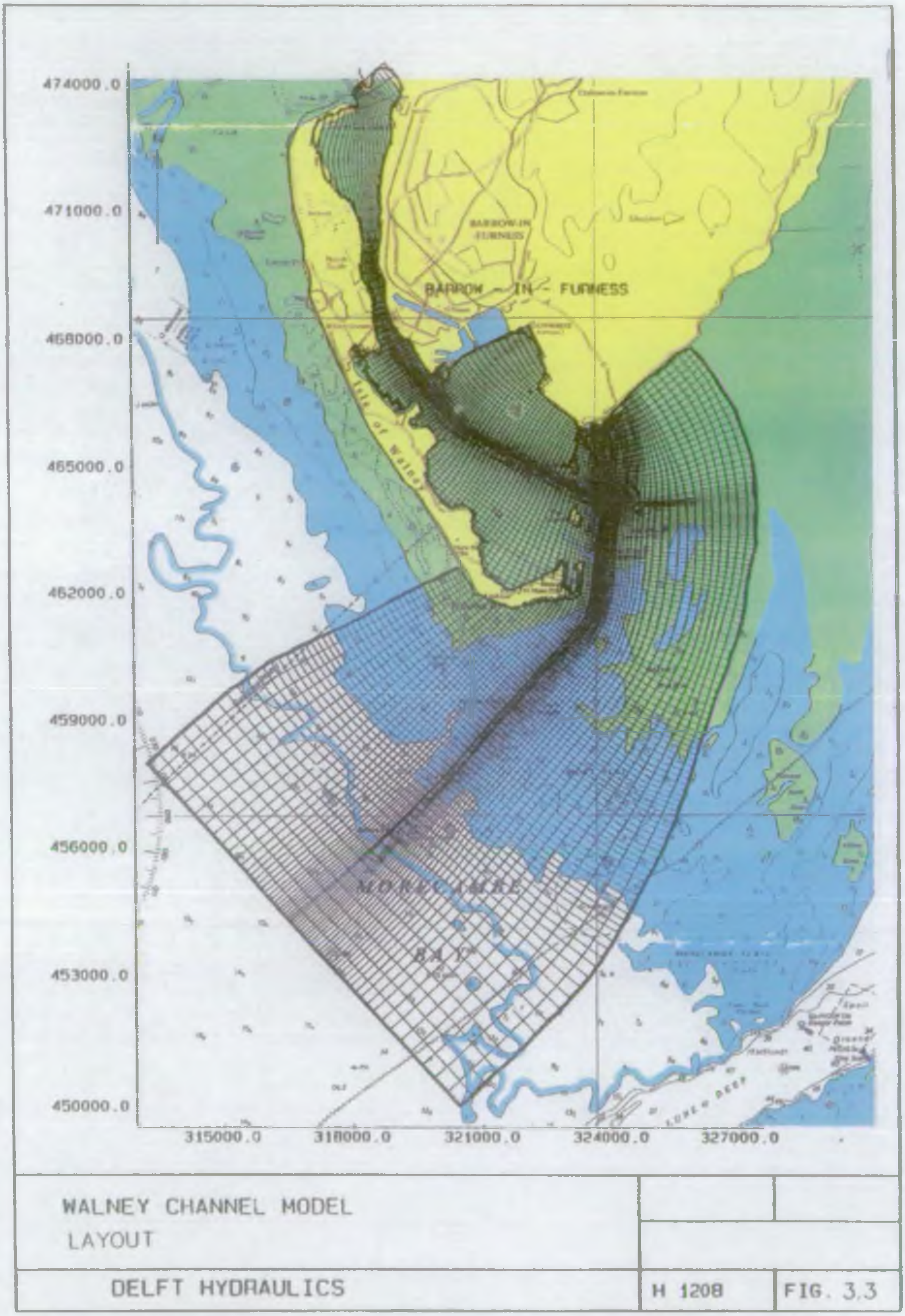


Fig. 5 Layout of WL DELDT Hydraulics Walney Channel Model (Database ref. 61) for ABP

4.6 Water Quality and Water Resource Information

Freshwater runoff exerts a very small influence on the total hydrodynamic regime of the estuary (Fahy et al. 1993, ETSU 1994). Therefore we expect water quality to be influenced primarily by the tides rather than incoming river water. For the same reason, hydrological issues relating to water abstraction are not considered to be of significance as far as the interest features of the SPA are concerned. Similarly, oxygen saturation is to be expected because of high tidal volume and strong currents; however, no reviewed data are available.

Bathing beaches at Haverigg, Askam and Roanhead have a history of struggling to meet mandatory bacteriological standards. This was investigated in a study by Entec (1999) who quantified and characterised bacterial inputs into the Duddon Estuary in relation to the potential effects on bathing waters. The study showed that faecal indicator bacterial concentrations in riverine samples increased markedly (4 to 17 fold from baseline) during storm events for all watercourses. Concentrations in treated sewage from WWTW at Askam and Millom also increased during storm events but to a much lesser degree than for riverine inputs.

The principal sources of faecal bacteria, responsible for over 70% of faecal coliforms during the study period, were (baseflow and high flow faecal coliform counts):

- Millom WWTW and associated overflows (2.77E+14, 6.85E+14)
- Soutergate WWTW (3.04E+14, 1.36E+14)
- Broughton Tank (2.41E+14, 9.43E+13)
- Askam WWTW and associated overflows (7.63E+13, 1.83E+14)

The two principal river inputs contributed only an additional 15% of faecal coliform load.

The study did not consider inputs from diffuse sources such as saltmarshes and inputs to the estuary from the sea were also not assessed.

Burton et al. 2002 (726) reviewed the research on the effects of organic and nutrient loading on the distribution of biota, especially invertebrates, fish and birds, within coastal and estuarine areas. The review aimed to identify the potential effects of improving discharges as encouraged by the adoption of Directives such as the Urban Waste Water Treatment Directive. The following is a summary of relevant information from this report:

> The effect of a discharge on the receiving waterbody depends on many factors which include, but are not limited to, the organic and nutrient loading of the discharge, the discharge volume, the volume of the receiving waterbody, the organic and nutrient loading of the receiving waterbody, processes within the aquatic system such as tides and currents and the regularity with which the discharge occurs. Following discharge, the receiving waters disperse the organic load and nutrient load. The heaviest organic matter is deposited close to the discharge point and the currents then transport the remaining material (suspended solids and dissolved nutrients) to other areas of the waterbody. Deposition of the remaining material will occur in areas where the water velocity is sufficiently reduced, such as the areas where mud flats develop, and as a result of processes such as flocculation. In all but the most grossly polluted environments, organic and nutrient enrichment of these areas encourages algal growth and provides a food source, either directly or as a result of increases in the number of organisms at lower trophic

levels, for a wide range of biota, including benthic macroinvertebrates (both infaunal and epibenthic), fish and birds.

Studies have shown that the effects of reductions in the organic and nutrient enrichment that invertebrate and algal communities are exposed to depend on the extent of the loading to which they are exposed. In grossly polluted environments, a reduction in the nutrient and organic load leads to the gradual recolonisation of previously barren mudflat sediments by tolerant species (Rebele, 1994 – cited in 726). In less polluted environments, such as the mudflats of the Clyde Estuary, a reduction in nutrient load led to a decrease in organism abundance and an increase in species diversity (Thompson et al, 1986 – cited in 726). These changes are much less apparent in invertebrate and algal communities living on hard substrates such as rocky shores (Underwood and Chapman, 1997 – cited in 726).

Similar patterns are seen in fish populations with diversity and abundance being determined by the degree of organic and nutrient loading. At very high loadings, the high Biochemical Oxygen Demand (BOD) causes severe depletion, and complete removal in some cases, of the dissolved oxygen. If this high BOD results from an accidental or extremely irregular discharge into an otherwise 'clean' area of a waterbody then fish kills are the likely result. However, areas subject to continuously high BOD and the resultant severe oxygen depletion are unlikely to support fish at any time. In the latter case, improvements in the quality of discharges into this grossly polluted environment are likely to allow tolerant fish to gradually return to these areas. The potential benefits of discharge improvement for fish in moderately polluted areas are less clear. Whilst the level of dissolved oxygen may no longer be limiting, the reduction in invertebrate abundance is likely to reduce the number of fish due to competition for prey items.

Bird distribution and abundance in estuarine and coastal regions may also be influenced by organic and nutrient load. Some birds feed directly on the waste matter contained within effluent whilst others feed on the invertebrates and fish whose distribution, as has already been discussed, is influenced by the organic and nutrient load. Improvements in the quality of effluent being discharged into all but the most grossly polluted sites have been identified as causing a potential reduction in the abundance and biomass of the invertebrate, algal and fish populations at those sites. The available waste matter in the effluent may also be reduced. Following discharge quality improvements, a reduction in the number of birds that use waste matter in the effluent as a food source has been demonstrated but there is no evidence that this has impacted on the national populations of these species. For birds that feed on biota, there is limited evidence that the numbers of some waders and wildfowl have been reduced as a result of reduced invertebrate abundance and biomass following improvements in discharge quality. Birds that are most likely to be affected by the reduction in invertebrate abundance include the following species which are interest features at the site: Dunlin, Knot, Oystercatcher and Redshank.

In summary, the review concludes that reductions in the organic and nutrient load of discharges may have a negative impact on bird populations in all but the most grossly contaminated sites. However, there are clearly strong imperatives to tackle organic pollution of waterbodies and it needs to be understood that organic enrichment can lead to the maintenance of artificially high densities of organisms. Reduced organic loadings may lead to diminished numbers of some species but this should be compensated for by increased diversity, and of course reduced risk of non-compliance with bathing water standards.

There is some evidence that the Duddon estuary has previously experienced localised organic enrichment that supported elevated bird populations. Bayliss (1994) reports that the closure of the British Cellophane plant (date unknown) led to improved water quality but a loss in birds feeding in the area. The discharge, initially to the foreshore but into deep water at Scarth Hole after 1977 had led to elevated phosphate levels, low dissolved oxygen and high BOD.

Radioactivity is a well voiced concern along the Cumbrian coast, in particular regarding radionuclide releases from the Sellafield nuclear power station. Unfortunately, there is relatively little information available on radioactive pollution within the Duddon estuary itself. Clearly, the total radiation dose to the environment will derive from a combination of natural and anthropogenic sources. Radionuclides from Sellafield are detectable in sediments from the Duddon estuary, sampled by MAFF/DEFRA at Haverigg, but are at 'low levels' (Baylisss 1994).

Information on contamination by heavy metals is restricted to Environment Agency and North West Water/United Utilities datasets. Bayliss (1994) summarised some NWW data from samples of *Enteromporpha* and noted that there were slight elevations in Chromium concentration at Millom, reflecting the influence of the old iron industry there. There were also elevated concentrations of lead at North Walney and zinc at Haverigg, the latter most likely from historic tannery effluent and crude sewage discharge. There has been a problem with zinc and chromium which have exceeded EQS; this may be related to the release of pollutants from old mine workings under flood conditions.

4.7 Biological Effects of Exposure to Persistent Contaminants

The ecological significance of metals in estuaries was reviewed by Bryan and Langston (1992). The authors noted that concentrations and bioavailability of metals in estuarine sediments depend on many different processes, e.g.:

1. mobilisation of metals to the interstitial water and their speciation;
2. transformation, e.g. methylation, of metals including As, Hg, Pb and Sn;
3. binding to oxides of Fe and organics;
4. competition between metals for uptake sites in organisms;
5. influence of bioturbation, salinity, redox and pH on these processes.

Bryan and Langston (1992) considered it likely that the combination of metals in many estuaries that are only moderately contaminated contributes to the overall stress on organisms caused by substances requiring detoxification. Sublethal effects on sediment infaunal populations are as important as direct toxicity if, for example, prey species disappear from a mudflat. This is also a risk for sites contaminated with TBT which has been shown to have deleterious effects on the recruitment of several species of bivalve. Bryan and Langston (1992) also pointed out that some bird species, e.g. dunlin, can adapt to a wide variety of prey species whereas other are less flexible. Knot feed primarily on bivalves and may therefore be especially vulnerable.

Although there are very few instances in which deleterious effects can unequivocally be attributed to metals or their compounds, the Mersey bird kill was caused by ingestion of invertebrate prey species, such as *Macoma balthica* contaminated with alkyllead from industrial sources. Lack of evidence for other metals may simply reflect the limited research that has been undertaken and it is dangerous to rule out the possibility that there are potentially damaging effects from accumulations of Ag, As, Cr, Cu and Zn, especially on juveniles and individuals subject to, for example, food-shortage stress.

McLusky *et al.* 1986 demonstrated that exposure to contaminants that have sub-lethal effects under optimal conditions may reduce temperature and salinity tolerance under sub-optimal conditions. There is therefore the *potential* for invertebrates, and therefore birds, to be affected by contamination of the environment.

Certain invertebrates have been shown capable of developing resistance to pollutants. For example, Nedwell (1997) demonstrated that *Nereis diversicolor* and *Corophium volutator* collected from contaminated sediments had a much higher resistance to copper and zinc than animals from clean sediments. In the tolerant populations, metals were being sequestered in a non-toxic way. Walker et al. (1997) described how toxicity can be reduced by the production of metallothionein, a protein that binds to metals to reduce their availability or monooxygenases which enhance metabolism of a pollutant to increase its solubility and excretion.

No direct assessment of the impact of radionuclide contamination at the site for wildlife groups is available. This is not an uncommon situation because the International Commission on Radiological Protection (ICRP) has historically viewed environmental protection as being achieved as a by-product of ensuring that man is protected (ICRP, 1977; ICRP, 1991). The majority of work has therefore focussed on radiation doses to humans. Inferences must be drawn from work for other sites, generic assessments and assessments made for human site users.

Curtis et al. (1991) analysed seaborne sediments deposited in the estuaries of the Esk, Duddon, Leven and Kent for fission products and actinides discharged in waste from the Sellafield processing works in west Cumbria and compared the values with the generally expected levels due to fallout from atmospheric nuclear weapons tests. Analysis of tissues from sheep grazing the marshes of these estuaries showed that the internal radiation dose of the general public through eating mutton or liver from these animals would be at most a few percent of recommended limits. Analytical data are presented on the actinide content of cattle, and on potato crops grown under field conditions; these data showed that, as with sheep, the radiation dose to the consumer would be small.

Various studies have been undertaken at nearby sites, notably around the low level waste repository at Drigg on the Ravenglass estuary. Here, Lowe (1987) assessed radionuclide concentrations in bird tissues, their foods and feeding areas in a study that arose from concern that the apparent decrease in waterfowl, wader and gulls in the Ravenglass Estuary, especially black headed gulls on Drigg Dunes, was linked to radiation. Lowe reported that Oystercatcher and Shellduck had highest levels of 137Cs but numbers and breeding were unaffected. Overall, radionuclide levels at Ravenglass were considered approximately 3 orders of magnitude too low to have any effect. Radionuclides in marine invertebrates were also studied. There was no evidence that concentrations were of potential harm to birds and no evidence that radionuclides from Sellafield were accumulating in invertebrates.

Lowe's work was conducted in response to a specific perceived problem. However, there has been an acceleration in scientific research into the effects of ionising radiation on wildlife in recent years as the ICRP's position has been increasingly challenged (Thompson, 1988; Pentreath, 1998). It has become apparent that different types of organism, and even different species, exhibit different levels of radiosensitivity. There is a general increase in radiosensensitivity with increasing organism complexity. Furthermore, the radiobiological effects of radionuclides is different depending on the element and the ecosystem in which it is found (Copplestone et al, 2001). Research effort is now being focussed on developing assessment methods for specific ecosystems and biota in relation to specific radionuclide exposures. A review of current research and the development of models to calculate doses to wildlife is provided in Copplestone et al., 2001.

The exposure of wildlife to ionising radiation can either be acute, transitory or chronic. Acute exposure is received within a very short time period (eg. <1 hour) so the resulting dose can be treated as instantaneous. Transitory exposure is too protracted to be described as acute but it does not persist for many years either. Chronic exposure is exposure which persists for a long time and the term is normally used to refer to continuous, low-level exposure. The exposures associated with environmental radioactivity in the Duddon estuary is likely to be chronic. Doses from anthropogenic sources are generally below those from the natural background; however, exceptions include Sellafield which typically result in an exposure 1-2 orders of magnitude higher than the likely natural background exposure. Anthropogenic inputs are therefore likely to be of importance when considering the doses to wildlife in the Duddon estuary with its proximity to BNFL Sellafield.

Woodhead 1998 (636) reviewed the impacts of radioactive discharges on native wildlife and the implications for environmental protection. The review indicated that there were particular chronic dose rates below which significant biological effects were unlikely to be induced:

Terrestrial animal populations	40µGy.h-1
Terrestrial plant populations	400µGy.h-1
Freshwater and coastal organisms	400µGy.h-1
Deep sea organisms	1000µGy.h-1

The guideline values from Woodhead 1998 have formed the basis for the Environment Agency's approach to assessing the impact of ionising radiation from authorised discharges. However, the Environment Agency's Research and Development Publication 128 (by Copplestone et al, 2001) is aiding the development of a more comprehensive assessment system which will attempt to take account of the different radiosensitivities of organisms and the different radiobiological effects of different radionuclides in different ecosystems.

Contamination of the site by release of toxic materials from past industrial waste deposits is a potential risk to wildlife. The risk is believed to be low, unfortunately, there is no evidence available to support this assumption within the scientific information reviewed.

4.8 Habitat Requirements of Protected Species and Sensitivities of Species and Communities

Saltmarsh is an important habitat for birds on the site. In particular, it provides feeding opportunities for wildfowl that graze saltmarsh vegetation, undisturbed roosts over the high tide period for both waders and wildfowl and breeding habitat for a number of species, such as redshank. Much of the saltmarsh on the Duddon is grazed by cattle and sheep. A range of grazing types and pressures leads to a mosaic of sub-habitats, for example short-sward, dry marsh on sheep grazed areas, tussocky sward, wet marsh on cattle grazed areas and a rank sward on ungrazed areas. Wintering wildfowl and breeding birds exhibit preferences within this diversity of sub-habitats which is therefore important to allow maximum diversity of species of breeding birds and wintering wildfowl.

The condition of saltmarsh on the site is the subject of a study by ERC, University of Liverpool on behalf of English Nature. This will be reporting in Spring 2003 to support condition assessments and provide management recommendations in relation to grazing on the SPA. In overview, this study has so far highlighted range of grazing types and pressures on the estuary. There is evidence of overgrazing; however, in general a range of grazing levels provides the diverse habitat structure required by the interest features.

Habitat management includes control of invasive *Spartina anglica* at Sandscale (JNCC 1993); however, *S. anglica* does not present major problems on the Duddon at present (Pers. Obs.).

Waders require large areas of undisturbed, invertebrate-rich , low tide mudflat to feed and secure (i.e. largely predator and disturbance free) high tide roosts which may be located along the seaward edge of saltmarsh areas (Lambert 1998).

Wildfowl require remote, undisturbed roosts in the outer estuary, for example exposed sand bars. Disturbance of such areas is a potential threat to the birds. No information is available specifically for Duddon estuary; however, useful reference can be made to studies elsewhere (summary adapted from UK Marine SAC Project (database ref. 641)):

> Smit & Visser (1993) noted that human disturbance changes bird behaviour in accessible areas such as intertidal sand and mudflats. Disturbances to waterfowl in estuaries include movements by people, dogs and horses, helicopters and light aircraft, and from water sports such as windsurfing, sand yachting and boating. The intensity of disturbance is related to the species of bird and the speed and duration of the stressor and the direction in relation to bird flocks. For example, aircraft cause widespread and long lasting disturbance and, on tidal flats, moving people and dogs generally create greater disturbance than stationary ones. Furthermore, the impact of human disturbance requires to be assessed in relation to other activities such as land-claim. Industrial and urban development may restrict the adjacent areas suitable receiving displaced birds.
>
> The impact of disturbance has been quantified although this differs according to species, type and scale. For example, for some shy species such as the curlew as few as twenty evenly distributed people could prevent birds from feeding on over 1,000 ha of estuary Goss-Custard & Verboven, 1993).
>
> The reaction to disturbance can vary, even for the same species of bird at different times and in different areas - for example, sometimes by habituating to repeated disturbance and at others becoming increasingly nervous. Species such as the redshank, bar-tailed godwit and curlew are more 'nervous' than others such as oystercatcher, turnstone and dunlin. One person on a tidal flat can create a large disturbance in which birds stop feeding or fly off, affecting approximately 5 ha for gulls and 13 ha for dunlin up to 50 ha for curlew (Smit & Visser, 1993). In some cases,

for example wigeon on parts of the Exe Estuary, a single disturbance incident at the wrong time can deter birds from feeding until the next tidal cycle (Fox *et al*, 1993).

Disturbance will cause birds to fly away and in response they could either (i) increase their energy intake at their present (disturbed) feeding sites when undisturbed, or ii) move to an alternative feeding site. Such a response will affect energy budgets and thus survival, with particular consequences for overwintering wading birds (Davidson & Rothwell, 1993). There may be little overlap of use by overwintering birds as recreational activities occur mainly in the summer and early autumn. However, in late summer/early autumn, (and sometimes spring) when most recreational activities take place, intensity of use is greatest, and waterfowl are more vulnerable. This period coincides with the latter part of the breeding period for some species and the arrival and moulting of the more northerly breeding populations.

All species on site require adequate food resources to be available. The productivity of sand and especially mudflats is vitally important to this. This is potentially threatened by any activities that reduce the extent of such habitats, alter the trophic basis of production (e.g. nutrient reduction/enrichment) or remove prey species (e.g. release of toxic substances).

It is not believed that water resources are an issue on the site as the system is primarily influenced by marine processes.

4.9 Linkages Between Physical Features and Habitats/Species

Prey resources are important in determining the distribution and abundance of shorebirds during the non-breeding season (e.g. Goss-Custard *et al.* 1984). The summary below, Table 2, relates the known feeding preferences of birds cited in the SPA designation.

The importance of other factors, such as the role of sediment characteristics in influencing invertebrate populations that in turn drive wading bird distributions during feeding have been studied and reported for other sites, e.g. McLusky (1989). However, no direct work on Morecambe Bay is known of. Some modelling work that may be relevant has been undertaken by CEH, Dorset, notably on the Exe estuary and is included in the information directory.

Table 2. Overview of known dietary preferences of estuarine waterfowl. Data drawn from a variety of sources to act only as a guide to the general dietary preferences. Adapted from McLusky (1989); Goss-Custard et al. 1997; Goss-Custard et al. 1991; Wilson and Marsh (1987) and English Nature 2001.

	Polycheaetes*	Nereis	Oligochaeta	Arenicola	Tubifex	Crustaceans*7	Bathyporeia	Corophium	Gammarus	Crangon	Carcinus*6	Balanus	Cerastoderma	Macoma	Hydrobia	Mytilus	Tellina	Tipulidae*9	Puccinellia	Enteromorpha	Agrostis
Knot*1*5	•	•		•				•					•	•	•	•					
Dunlin*2	•	•	•			•		•		•	•		•	•	•						
Redshank*3*8	•	•	•			•		•		•	•			•	•						
Shelduck*3*5	•	•	•																		
Eider*4																•					
Bar-tailed godwit	•	•	•	•									•	•	•		•				
Grey plover*7	•	•		•		•															
Curlew	•	•									•										
Black-tailed godwit		•											•	•							
Oystercatcher			•	•						•	•		•	•		•					
Turnstone									•		•	•				•					
Ringed plover					•			•	•						•						
Sanderling							•	•							•	•					
Wigeon																			•	•	•
Pintail															•						
Mallard															•						
Shelduck		•						•							•						

*1 knot feed almost exclusively on bivalves; *2 dunlin adapt to a variety of prey species; *3 feed mainly on the intertidal zone at low water;
*4 feed in shallow water at low tide; *5 knot and shelduck rely on re-emergence of Hydrobia as mudflats are covered by the rising tide;
*6 *Carcinus* move offshore in winter so feature in shorebird diets only in summer; *7 not including Crangon and Carcinus;
*8 feeding rate depends mainly on the density of the amphipod *Corophium volutato;* *9 from terrestrial feeding grounds.

5 Identification of Gaps and Projects Required for Bridging

The following outline the main gaps identified during this project and suggest potential projects to fill them.

Gap 1: *Differentiating anthropogenic and natural change*

Detail: In its current state, Duddon Estuary supports the interest features (i.e. community assemblages) that are protected through its designation as SPA. At the same time, the estuary is a dynamic system that is subject to both natural and anthropogenically induced change and it is very clear that some features, such as the outer sandbanks, are highly mobile. Jeffers (1990) points out that major events, triggered by global climate change, could significantly alter conditions. Such changes, and other more subtle ones, may or may not favour the currently designated interest features.

Suggestion for filling: Site condition monitoring needs to be developed to have the capability to differentiate between natural and anthropogenically induced change and to take account of the natural variability of populations. This is a difficult task that represents a challenge to management of all sites that are currently important for conservation.. However, the current approach whereby individual components of systems (e.g. invertebrates, birds, water quality) are measured in isolation is doomed to fail as change will only be perceptible once it has happened. Predictive ecological approaches are required and this will only be found through extensive collaboration between various interested parties; e.g. regulators, researchers and central governments at an international level.

NB Gap 1 is common to both Duddon Estuary and Morecambe Bay reports.

Gap 2: *Invertebrate monitoring*

Detail: Intertidal benthic invertebrates, together with undisturbed roosting areas, are central to the use of Duddon Estuary by the key protected bird species. There is a reasonable background of data relating to intertidal invertebrates (cf Section 4.4.1) which could be usefully built on and developed into a sound monitoring programme. Good knowledge of these communities would feed into solutions developing for Gap 1, above.

Suggestion for filling: Regular (minimum annual) surveys using standard (coring) techniques should be used to sample intertidal invertebrates at a series of sites. A number (minimum 2) should be fixed sites along the Bay. The remainder (2-3) should be flexible to allow samples to be taken from areas of high bird usage; these may be stable for several years but may shift rapidly if environmental conditions change. The assessment of invertebrate community status should include estimates of both production and biomass, in addition to diversity and abundance that are normally measured.

NB Gap 2 is common to both Duddon Estuary and Morecambe Bay reports.

Gap 3: *Biological impacts of pollution*

Pollution by heavy metals/TBT not believed to be a major issue for Duddon Estuary in relation to Review of Consents process; however other trace pollutants, in particular acting as endocrine disrupters have an unknown effect and the following is copied from the Morecambe Bay report:

The impact of trace pollutants causing sub-lethal effects such as endocrine disruption is only recently coming to be understood as a potential environmental concern. There are current research programmes and these should be supported and applied to the site.

Gap 4: *Nutrient enrichment*

Detail: The estuary is threatened by elevated nutrient levels in the Irish Sea as a whole. Risks include eutrophication, toxic blooms and potential collapse of all or parts of the ecosystem. Inputs arise from outwith the immediate bounds of the site, including diffuse nutrient inputs from agricultural areas.

Suggestion for filling: The situation can only be addressed by increased knowledge of the problem and wider regulatory control of sources. A one-off project to establish an 'inputs budget' for the estuary would be very worthwhile and should also recommend appropriate action dependant upon results.

Gap 5: *Disturbance through major works*

Detail: Sea defences and other coastal works create inevitable disturbance to roosting and feeding birds.

Suggestion for filling: Commissioning of development of 'best practice' guidance for such activities and appropriate review of all such activities in light of potential impacts. This includes activities such as manual maintenance to installations such as outfalls. Clearly a key recommendation would likely be to time works so as to avoid conflict with major concentrations of birds.

NB Gap 5 is common to both Morecambe Bay and Duddon Estuary reports.

6 References

All references are provided in the information directory.

Appendix 1

Keywords used in database:

Keyword	
Algae	Management
Alt Estuary	Mersey Estuary
Atmospheric Deposition	Metals
Birds	Microbiology
Conservation	Morecambe Bay
Currents	Nutrients
Dispersal	Plankton
Dredging	Radionuclide
Duddon Estuary	REQUIRED
Ecosystem	Residual Flows
Energy	Ribble Estuary
Environmental Assessment	River Flows
Environmental Change	Salinity
Fish	Saltmarsh
Flooding	Sand Dunes
Floodplain	Sandwinning
Freshwater	Sediment Contamination
Fylde	Sediments
Geomorphology	Sefton Coast
Groundwater	Survey
Habitats	Tidal Flows
Hydrodynamics	Vegetation
Hydrographic	Water Chemistry
Hydrology	Water Quality
Invertebrates	Waves