THE MERSEY GATEWAY PROJECT

AQUATIC ECOLOGY

CHAPTER 11.0

AQUATIC ECOLOGY

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11. AQUATIC ECOLOGY

11.1 Introduction

11.1.1 This Chapter assesses the effects of the construction and operational phases of the Project on aquatic organisms in the Upper Mersey Estuary and other watercourses which fall within the alignment of the Project.

11.1.2 Details of the location of the Mersey Gateway Project (the Project), the proposed alignment of the New Bridge and a route description are provided in Chapter 2 (The Mersey Gateway) and the Project location is illustrated in Figure 1.3, Chapter 1: Introduction. A wider view of the location of the Silver Jubilee Bridge (SJB) and the area of the Project in relation to the Middle and Upper Mersey is provided in Figure 4.3, Chapter 4: Description of EIA Study Areas.

11.1.3 The main aspects of the Project which could have an impact on aquatic ecology are the construction processes required to build the New Bridge (discussed in detail in Section 11.7 of this report, Paragraphs 11.7.11 to 11.7.71) and the presence of the New Bridge which could have a localised impact on some waterways. Once constructed the New Bridge would cross the Upper Estuary. Therefore, the main estuarine study area for this ecological assessment for the Project stretches between Hale Head which is downstream of the existing SJB, and Fiddlers Ferry power station located upstream. (Figure 11.1, Appendix 11.1).

11.1.4 In addition, the New Bridge would pass over the freshwater watercourses of Bowers Brook, the St. Helen's Canal, the Runcorn to Latchford Canal (i.e. Latchford Canal) and the Bridgewater Canal (Figure 11.1, Appendix 11.1). Part of the Project near the Ditton Roundabout Junction (A562 and A533) would also be in the vicinity of Stewards Brook, and works required to connect the New Bridge with the South Junction could potentially impact the Bridgewater Canal (Figure 1.3, Chapter 1: Introduction). Consequently, in addition to the main estuary, each of these freshwater waterways has been included in the aquatic ecology impact assessment. The Manchester Ship Canal would also be crossed by the Bridge. However, this waterway has been subjected to high levels of pollution. The most recent data for the Manchester Ship Canal indicates that the water has an overall GQA grade of 'poor' (Chapter 8: Surface Water Quality). Consequently, this canal has an impoverished flora and fauna and, in terms of the aquatic ecology it is considered that an investigation of the impacts of the New Bridge on the Manchester Ship Canal would not be required as any potential impacts would be negligible in relation to the water quality issues associated with this waterway. In addition, during the operational phase of the Project it is likely that there will be runoff from the road network into Flood Brook in the southern part of Runcorn. However, this would be no different to the current situation as water from the road network is already discharged into Flood Brook. As such it was not considered necessary to include this watercourse in the aquatic ecology survey.

11.2 Purpose of Study

11.2.1 Estuaries are complex ecosystems that link aquatic and terrestrial environments. They are comprised of an interdependent mosaic of subtidal, intertidal, saltmarsh, freshwater and associated habitats. The intertidal and subtidal components support biological communities that vary according to geographical location, the type of and contamination status of the sediment, tidal currents and salinity gradients within the estuary. This aquatic ecology report considers the intertidal and subtidal components of the ecosystem but in so doing considers the flora and fauna of the three-dimensional space i.e. within the benthos, on top of the benthos and above the benthos within the overlying water. The report also assesses potential impacts on the aquatic ecology of freshwater canals and brooks within the region of the Upper Mersey Estuary. The saltmarsh habitat together with the avian component of the ecosystem are covered within Chapter 10 (Terrestrial and Avian Ecology). The ecology chapters are interlinked which in turn are inextricably connected to Chapters 7 (Hydrodynamics and Estuarine Processes Movement), 8 (Surface Water Quality), and 14 (Contamination of Soils, Sediments and Groundwater) of the Environmental Statement.

11.2.2 The intertidal habitat is defined as the area of sand and mud, which is submerged by the tide for at least some time during the tidal cycle and is not covered by seawater at low tide. This habitat type is listed in Annex I of the EC Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora). These intertidal flats can create an important habitat for algae, invertebrates and provide a rich food source for fish and birds. They represent a widespread habitat type on the coasts of Atlantic Europe. Within the United Kingdom (UK) there is approximately 300,000 hectares (ha) of estuarine intertidal habitat (Ref. 1). The estuarine subtidal habitat consists of deep permanent water channels that flow through the intertidal areas.

11.2.3 There are approximately 9,000 hectares (3% of the UK total) of intertidal and subtidal habitat in the Estuary (Ref. 2) of which 1,000 hectares are within the administrative area of Halton Borough Council. The intertidal and subtidal habitat downstream of the SJB is of international importance as it supports large populations of waterfowl and waders, particularly during spring and autumn migration periods. For these reasons the area is designated as a Site of Special Scientific Interest (SSSI), Special Protection Area (SPA) and Ramsar Site (Figure 4.4, Chapter 4: Description of EIA Study Areas). These birds predominantly feed on intertidal macroinvertebrates within the Estuary and the abundance of these invertebrates is intrinsically related to other components of aquatic ecology such as benthic algae and benthic feeding fish, as well as the surrounding water quality and physical processes within the Estuary.

11.2.4 There are also a number of commercially important fish species present within the Upper Mersey Estuary and it also acts as a migratory corridor for salmon, lamprey, eel and sea trout. Salmon and lamprey are designated protected species under Annex II of the Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora).

11.2.5 In addition, a number of freshwater watercourses are present within the aquatic ecology study area. The St. Helen's Canal runs along the northern bank of the Upper Mersey Estuary and the Bridgewater Canal runs parallel to the southern banks. Both are important for recreational angling and data regarding fish species within the canals were collected during the study. It was also important to identify the presence/absence of protected species of invertebrates and macrophytes within these freshwater systems and within Stewards and Bowers Brooks and the Latchford Canal.

11.2.6 The main aim of the aquatic survey was to gather a comprehensive data set and describe a baseline for the key ecological components of the estuarine ecosystem including benthic algae, benthic invertebrates and fish. Within the freshwater ecosystems the main components studied were macrophytes, invertebrates and fish. In all cases particular emphasis was placed on the presence/absence of rare species or those protected by national or international legislation.

11.2.7 This Aquatic Ecology Chapter details the findings from intertidal and subtidal estuarine surveys and freshwater surveys undertaken between 2002 and 2007 together with available historic data. The baseline information will provide an important contribution to the overall Environmental Impact Assessment (EIA) for the Mersey Gateway Project. This report examines objectively the potential impacts of the Project and examines mitigation measures that would be required if the Project proceeds.

11.3 Study Area

Main Estuary

11.3.1 The study area for this ecological assessment of the New Bridge stretched between Hale Head (NGR SJ48000 81000) and Fiddlers Ferry power station (NGR SJ57398 86505). The area was split into three zones covering approximately 286 hectares of intertidal/subtidal habitat (Ref. 3), (Figure 11.1: Appendix 11.1).

a. Zone 1 (Lower Zone) extended from Hale Head to the existing SJB. This zone was downstream of the SJB and the proposed site of construction for the New Bridge;
b. Zone 2 (Middle Zone) extended from the existing SJB to Round Cherval. The proposed construction site for the New Bridge is within this zone; and
c. Zone 3 (Upper Zone) extended from Round Cherval to just downstream of the confluence with Whittle Brook. This zone was upstream of the site of the proposed construction.

Freshwater watercourses

11.3.2 In addition, several freshwater watercourses which could potentially be impacted by the Project were sampled. They were Stewards and Bowers Brook, and the St. Helen's, Bridgewater and Latchford Canals. Their locations are indicated on Figure 11.1, Appendix 11.1.

11.4 Relevant legislation and planning policy

11.4.1 A range of local, regional, national and international legislation and policy is relevant to the impact assessment conducted for aquatic ecology for the Project and has been examined and considered during the production of this Chapter.

11.4.2 The EU Directive on Environmental Impact Assessment 85/33/EEC (as amended by 97/11/EC) sets out the procedure to follow for certain types of development before they are granted development consent. Implementation of this Directive requires the compilation of an Environmental Statement describing the likely significant impacts of the development and proposed mitigation measures which is conducted under the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999.

11.4.3 The most important sites for biodiversity are those identified through international conventions and European Directives.

International/National Legislation

Ecological Designations

Habitats Directive 92/43/EEC

11.4.4 European Directive 92/43/EEC, which refers to the "*conservation of natural habitats and wild fauna and flora*" requires that an appropriate assessment is undertaken to assess plans and development projects that may have an impact on European (Natura 2000) Sites.

11.4.5 Natura 2000 is the name given to the EU wide network of protected areas, recognised as 'sites of community importance'. This includes Special Areas of Conservation (SAC) and Special Protection Areas (SPA). The purpose of the appropriate assessment is to consider the impacts of a land-use plan or an application for planning permission (or other consent) against conservation objectives of the site and to ascertain whether it would adversely affect the integrity of the site. Where significant negative effects are identified, the directive requires that alternative options should be examined. Only if no alternatives exist and for imperative reasons of overriding public interest can a plan or project be authorised if it has an adverse effect on the integrity of a SAC or SPA.

11.4.6 Under Regulation 48(1) of the Directive, an appropriate assessment needs to be undertaken in respect of any plan or project which:

a. Either alone or in combination with other plans or projects would be likely to have a significant effect on a European Site, and
b. Is not directly connected with the management of the site for nature conservation.

11.4.7 Appropriate assessment is also required, as a matter of Government policy, in considering development proposals which may affect potential SPAs, candidate SACs and listed Ramsar Sites for the purpose of considering development proposals affecting them. The plan or project to be assessed does not have to be located within the designated area.

11.4.8 The appropriate assessment must be undertaken by the "competent authority", as defined in Regulations 6(1) of the Habitats Regulations which includes any Minister, Government Department, public of statutory undertaker, and public body of any description or person holding a public office. The developer or promoter of the plan or project is required to provide information to satisfy these requirements. Natural England will advise, on request, as to whether any particular plan or project may be likely to have a significant effect on any of these sites. If the decision as to whether or not the development would have a significant effect on the designated site is inconclusive, on the information available, the competent authority is required to make a fuller assessment; in doing so they may ask the developer or other parties for more information.

Ramsar Site

11.4.9 The Project will not be constructed within a protected area. However, 1,770 m downstream of the Project the SJB marks the eastern boundary of a Wetland of International Importance under the Ramsar convention (Ramsar Site), (Figure 4.4, Chapter 4: Description of EIA Study Areas). This is an intergovernmental treaty which provides the framework for national and international action and international cooperation for the conservation and sustainable utilisation of wetlands and their resources.

Special Protection Area

11.4.10 The Ramsar Site is also a Special Protection Area (SPA) under the EC Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds due to its important population of wading birds (Figure 4.4 in Chapter 4: Description of EIA Study Areas). A number of habitats (Annex I) and species (Annex II) in the UK are listed under the Habitats Directive. This Directive is translated into national law as the Conservation (Natural Habitats, & c.) Regulations 1994 (as amended). The main aim of the EC Habitats Directive is to promote the maintenance of biodiversity by requiring Member States to take measures to maintain or restore natural habitats and wild species at a favourable conservation status. Each Member State is required to prepare and propose a national list of sites for evaluation in order to form a European network of Sites.

11.4.11 Salmon are listed as Annex II species under the Habitats Directive. The River was once an important salmon river, however, like many rivers throughout the UK, salmon populations declined following the industrial revolution and in the case of the River the system became devoid of salmon. Recently, however, salmon have been seen returning to and migrating through the Upper Mersey Estuary to spawn in the head waters. Currently salmon are not cited in any of the conservation designations for the Estuary although this may change over the duration of the Project.

11.4.12 Moreover, whilst the river is not currently classified as a salmon river under the Salmon and Freshwater Fisheries Act 1975 (as amended) this is likely to change during the life time of the Project (this Act enables the Environment Agency (EA) to create byelaws to protect salmon stocks). The increasing importance of salmon in the River has thus been considered when completing the Aquatic Ecology Chapter. Lamprey species found in the UK are also designated as Annex II species under the Habitats Directive. Whilst not cited in any of the conservation designations for the Estuary, they are known to be found within the Estuary and have also been considered in this assessment.

11.4.13 In addition, to protect wildlife and habitats with particular emphasis on Natura 2000 sites the EA undergoes a review of consents to assess waste management licences, consents to discharge, licences to abstract water and to integrate pollution control. The EA has recently completed the Stage 3 Review of Consents process for the Estuary as required under Regulation 50 of the Habitats Regulations 1994. This review was conducted to ensure that discharges into the Estuary met the required standards and to identify areas in which the impact of discharges on water quality could be reduced further, and was considered when assessing future changes in water quality and aquatic ecology within the Estuary.

Site of Special Scientific Interest

11.4.14 The Ramsar Site is also recognised as a Site of Special Scientific Interest (SSSI) under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000), (Figure 4.4, Chapter 4: Description of EIA Study Areas). The SSSI designation is also based on the presence of large areas of intertidal sand/mud flats and saltmarsh, in addition to the important bird populations.

11.4.15 Both the Ramsar and SPA sites are designated due to the presence of internationally important bird communities (especially for passage and wintering wildfowl and waders) Macroinvertebrates within intertidal mudflats provide an extremely rich food source for birds within the region. As the bird community is the primary reason for the designation of the protected sites detailed above, any negative impacts on invertebrates and other components of the aquatic ecosystem due to construction and operation of the New Bridge could potentially impact the numbers and diversity of birds. Consequently, such impacts have the potential to adversely affect the integrity of these European Sites. They must therefore be assessed to ensure this is avoided.

11.4.16 The main aims of each of these ecological designations have been considered when completing the Aquatic Ecology Chapter.

Water Resources

EC Water Framework Directive

11.4.17 The EC Water Framework Directive (WFD) (Directive 2000/60/EC) came into force in December 2000 and is a particularly important piece of water legislation. It represents a new approach to the management of water resources and water bodies (i.e. rivers, lakes, estuaries, coastal waters and groundwater) within all Member States. In addition to promoting improvements in water quality (e.g. by setting limits for effluent discharges) the WFD emphasises the importance of the ecological characteristics of aquatic habitats with the aim for water bodies to be classed as having 'good' ecological status and 'good' surface water chemical status (or better) by 2015.

11.4.18 The development and implementation of River Basin Management Plans (RBMPs) is a key requirement of the Water Framework Directive and these will be published by December 2009. The RBMPs are strategic long-term plans. They will define the criteria used to assess the ecological and chemical status of water bodies and will include a programme of measures outlining the on-going monitoring and management actions required for water bodies to achieve 'good' status. Importantly, the RBMPs provide scope to facilitate the balancing of economic, social and ecological issues by allowing the setting of reduced environmental standards for some water bodies e.g. specific heavily modified water bodies. RBMPs will be cyclical and reviewed every six years.

11.4.19 The River Mersey Catchment falls within the North West River Basin District. The EA has currently identified five Significant Water Management Issues for this District:

a. Diffuse pollution from rural areas;
b. Diffuse pollution from roads and urban areas;
c. Pollution caused by discharges from industry;
d. Pollution caused by discharges from sewerage systems; and
e. Physical modification of rivers and coastline.

11.4.20 Issues of particular relevance to the Project are points b) and e). Therefore, a key concern of the Project should be to mitigate runoff of potential contaminants (e.g. oil, organic matter, toxic metals, pesticides and contaminated sediments) from the Bridge and road network and implement ongoing monitoring to ensure mitigation measures are effective. The effect of the Project on physical attributes of the Mersey Estuary is also likely to be a future issue of concern, however, this has been addressed thoroughly within Chapter 7: Hydrodynamics and Estuarine Processes Movement.

11.4.21 With respect to aquatic ecology, five components are used to assess ecological status of coastal and estuarine water bodies under the WFD: angiosperms (e.g. eelgrass), macroalgae, phytoplankton, invertebrates and fish. Angiosperms and macroalgae are absent from the section of the Estuary within the Study Area and the Aquatic Ecology Chapter includes baseline information for invertebrates and fish. For the aquatic ecology impact assessment it was decided to sample benthic algae due to the fact that phytoplankton within the water column are highly mobile, their dispersal being influenced by tidal water movement within the estuary in addition to vertical and horizontal migration of individuals. Consequently, recirculation of individual phytoplankton throughout the Study Area and the rest of the Estuary would ensure a given phytoplankton community would be unlikely to remain within a potential area of impact for prolonged periods of time. As such it is considered that overall the phytoplankton within the Upper Estuary would be unlikely to be impacted by the Project. However, in the future, to ensure compliance with the WFD it is recommended that monitoring phytoplankton in addition to benthic algae is considered. Similarly, a detailed on-going monitoring programme assessing water quality within the Study Area should be a requirement of the Project to complement the objectives of the WFD.

EC Urban Wastewater Treatment Directive

11.4.22 The EC Urban Wastewater Treatment Directive 91/271/EEC has an influence on the assesment of overall quality of water within the Mersey and the Estuary. It covers the collection and treatment of urban wastewater and the disposal of sewage sludge and sets down minimum standards for the discharge of treated effluent from wastewater treatment works (WWTWs). The Regulations require that all significant discharges of sewage be treated whether the discharge is to inland surface waters, groundwater, estuaries or coastal waters. Significant discharges are those to freshwaters or to estuaries serving communities with a population equivalent (PE) of more than 2,000 and coastal waters serving communities of more than 10,000 PE. The treatment standards and the deadlines set for in the Directive for treatment vary according to the sensitivity of the receiving water, the type of receiving water (i.e. fresh waters, estuaries or coastal waters) and the size of the agglomeration (usually urban areas). The Directive stated that all WWTW discharges less than 2,000 PE, and discharges of between 2,000 and 10,000 PE to coastal waters must receive 'appropriate treatment' by the end of 2005 as defined by the Directive. This is relevant to the aquatic ecology impact assessment as this Directive promotes an improvement in the water quality of the Estuary. Such improvements were considered when predicting future potential baseline conditions within the Estuary.

Water Resources Act

11.4.23 The Water Resources Act 1991 (WRA) came into effect in 1991 and replaced the corresponding sections of the Water Act 1989. The WRA sets out the responsibilities of the EA in relation to water pollution, resource management, flood defence, fisheries, and in some areas, navigation. The WRA regulates discharges to controlled waters, namely rivers, estuaries, coastal waters, lakes and groundwaters. This is distinct from the drainage of water or trade effluent from trade premises into a sewer. Discharge to

11.4.24 Section 85 of the WRA states that 'no person shall cause or knowingly permit any poisonous, noxious or toxic material or solid waste to enter a controlled water'. 'Causing' means not only deliberately releasing any polluting matter but also causing the pollution accidentally, by being the operator of a plant or process.

11.4.25 Companies may also be liable for prosecution under Section 85, if they fail to take adequate precautions to prevent unauthorised personnel discharging pollutants from the premises into controlled waters. In addition to unauthorised discharges direct into controlled waters, companies are held liable for an unauthorised discharge to controlled waters occurring via surface water drains, or by discharge onto the land.

11.4.26 An offence is not committed where a discharge is made in accordance with a discharge consent. The procedures for obtaining a consent from the EA are contained in Schedule 10 of the Water Resources Act 1991 and the Control of Pollution (Applications, Appeals, and Registers) Regulations 1996 - SI 1996/2971. Consents to discharge effluent are subject to conditions such as biological oxygen demand, pH, temperature, concentration of suspended solids and toxicity.

11.4.27 The Anti-Pollution Works Regulations were enacted into Section 161A of the WRA, to enable the EA to serve Works notices on polluters or prospective polluters. The purpose of the regulations is to provide the EA with additional powers to prevent water pollution. Notices may be served on anyone who has 'caused or knowingly permitted' or potentially may 'allow' polluting matter to enter controlled waters.

11.4.28 The EA is entitled to recover the costs of any investigations needed, to determine the source of the pollution from the person(s) on whom the notice was served. The EA conducts a risk assessment to determine whether a Works Notice should be served. The storage and handling of chemicals should be undertaken in a manner in which the risk of spillages and leakages are reduced as far as practicable.

Asset Management Plan (AMP) Programme

11.4.29 The asset management plan promotes investment by water companies to improve water quality and quality of the aquatic environment. The current stage of the plan is AMP which runs from 2005 -2010.

11.4.30 During the programme regulatory bodies set a number of objectives for water companies. These include: the provision of water for customers while considering the environment impacts; assessing and reducing the impacts of abstraction and discharges; protecting habitats and contributing to habitat improvements in aquatic habitats including coastal waters, fisheries and internationally/nationally important sites of nature conservation; and controlling discharges to the environment. All of which have contributed to improvements to aquatic ecosystems throughout the UK.

Waste

Duty of Care

11.4.31 Under S.34 of the Environmental Protection Act 1990 anyone who imports, produces, carries, keeps, treats, disposes of or is a broker of controlled waste has as duty to take all reasonable and applicable measures to:

a. Prevent anyone else whom they may or may not know from illegally depositing, keeping, treating or otherwise disposing of the waste;
b. Prevent the escape of waste;
c. Ensure that waste transfer only occurs to an authorised person or for authorised transportation purposes; and to
d. Enable other, by a written waste description, to avoid contravention of S.33 of the EPA 1990 (this relates to illegal deposit of Controlled waste) and comply with the Duty of Care.

11.4.32 Carriers of Controlled waste must be registered under S.2 of the Control of Pollution (Amendment) Act 1989. It is the consignor's duty to check with the EA or SEPA that the carrier is registered or exempt from registration.

11.4.33 As part of the overall impact assessment the Aquatic Ecology Chapter has taken into account the above legislation associated with water quality of the River and the Estuary.

National Planning Policy

Planning Policy Statement 9: Biodiversity and Geological Conservation (2005)

11.4.34 PPS9 (Ref. 4) sets out the Government's vision for conserving and enhancing biological diversity in England, together with a programme to achieve it. It establishes a series of key principles that regional planning bodies and local planning authorities should adhere to in order to ensure that the potential impacts of planning decisions on biodiversity and geological conservation are fully considered. This is accompanied by ODPM *Circular 06/2005* which provides administrative guidance on the application of the law relating to planning and nature conservation.

11.4.35 This guidance advises that planning policies and decisions should aim to maintain and enhance, restore or add to biodiversity and geological conservation interests. A strategic approach to the conservation, enhancement and restoration of biodiversity and geology should be taken, recognising the contribution that sites, areas and features, both individually and in combination, make to conserving these resources. Development should contribute to rural renewal and urban renaissance by enhancing biodiversity in green spaces and among developments so that they are used by wildlife and valued by people.

11.4.36 PPS9 details planning policies designed to protect biodiversity and geological conservation through the planning system. The UK Biodiversity Action Plan (UK BAP) provides a detailed plan for the protection of biological resources and involves the implementation of Species Action Plans, Habitat Action Plans and Local BAPs. Eel (*Anguilla anguilla*) populations are at an all time low across Europe and this species was recently added to the UK BAP as a priority species. Eel are known to migrate through the Estuary.

11.4.37 PPS9 advises that a key aim of planning decisions "*should be to prevent harm to biodiversity and geological conservation interests.*" Adequate mitigation measures should be put in place where necessary. Where a planning decision would result in significant harm to biodiversity and geological interests which cannot be prevented or adequately mitigated against, "*appropriate compensation measures should be sought*".

11.4.38 With regard to SSSI designation the guidance states that where a proposed development on land within or outside a SSSI is likely to have an adverse effect, planning permission should not normally be granted. Where an adverse effect on the site's notified special interest features is likely, PPS9 advises that an exception "*should* *only be made where the benefits of the development clearly outweigh both the impacts that it is likely to have on the features of the site that make it of special scientific interest and any broader impacts on the national network of SSSIs*"

11.4.39 Networks of natural habitats are considered within PPS9 to represent a valuable resource. To reflect their importance, emphasis is placed upon Local Planning Authorities to maintain networks by *"avoiding or repairing the fragmentation and isolation of natural habitats through policies in plans*."

Regional Planning

11.4.40 The Cheshire Environmental Action Plan 2005 – 2020 (Ref. 5) includes an action plan for water quality which promotes the recreational use of ponds, canals and other water bodies. One of the aims is to increase the salmon population in Cheshire river catchments which is of particular relevance to the Project as salmon have recently been recorded within the Mersey catchment (see Paragraph 11.6.194).

11.4.41 Regional Planning Guidance for the Northwest (RPG 13) (Ref. 6) is designed to promote sustainable patterns of spatial development and physical change within the region. One aspect addressed by RPG 13 which is relevant to the Project is enhancing the coastal zone (Coastal Zone Development – Policy CZ2A). This involves ensuring there is co-ordination between development plans, coast and estuary management plans, European marine site management plans and other relevant plans or strategies affecting the coastal zone, and it supports the sustainable planning and management of adjacent coastal regions. Also of relevance is the promotion of high environmental quality (Water Quality Policy – EQ3). Requirements include avoiding developments that pose an unacceptable risk to the quality of groundwater, surface or coastal water; ensuring that adequate pollution control measures to reduce the risks of water pollution are incorporated into new developments; and ensuring that the construction of roads and other transport infrastructure does not unnecessarily add to diffuse pollution.

11.4.42 The Draft Regional Spatial Strategy (RSS) for the North West of England (Ref. 7) provides the broad development strategy for the Region until 2021. The key policies contained within the Draft RSS of relevance to the Project are Policy RDF4 – The Coast, Policy EM5 – Integrated Water Management, and Policy EM6 – Managing the North West's Coastline.

11.4.43 Policy RDF4 - The Coast, states that enhancement of the economic importance of the coast and the regeneration of coastal communities should be conducted in ways that safeguard, restore or enhance and make sustainable use of the assets of the North West Coast. Requirements include protecting the functional integrity of estuaries, promotion of the conservation and enhancement of cultural, historical and natural environmental assets (including land and seascapes) in the marine and coastal environment, and facilitation of co-ordination between Local Development Frameworks and the wide range of plans, strategies and schemes which apply to the coastal zone.

11.4.44 Policy EM5 – Integrated Water Management, is more focussed on management of flood risk. This policy states that plans and strategies should have regard to RBMPs, assist in achieving integrated water management and delivery of the WFD and amongst other requirements plans should contribute to the protection of the quantity and quality of surface, ground and coastal waters.

11.4.45 Policy EM6 - Managing the North West's Coastline, is also primarily associated with management of flood risk and coastal erosion. Requirements include avoidance of damage to existing defences and the capacity of the coast to form natural defences or to adjust to future changes, minimising the loss of coastal habitats, and avoiding damage to coastal processes.

Local Planning

Mersey Estuary Pollution Alleviation Scheme (MEPAS)

11.4.46 The Mersey Estuary Pollution Alleviation Scheme (MEPAS) was devised to improve the water quality of the Estuary and was completed in the 1990s. It involved the installation of a 14 mile-long interceptor sewer that ran from Crosby to Speke, the closure of numerous crude outfalls to the Estuary and the completion of a new WWTW at Sandon Dock.

Halton's Local Biodiversity Action Plan

11.4.47 Halton's Local Biodiversity Action Plan (BAP) (Ref. 8) was examined in relation to the proposed Mersey Gateway Project. The main habitats included in the BAP for which Habitat Action Plans have been developed are reedbeds and coastal saltmarsh. Of the species targeted in the Mersey Estuary BAP it is mainly redshank that have the potential to be impacted by changes in aquatic ecology of the Upper Estuary. There are no aquatic Halton BAP species within the main estuary or the freshwater watercourses surveyed for the aquatic ecology impact assessment. Halton BAP species present on saltmarsh or other terrestrial habitats are considered within Chapter 10 (Terrestrial and Avian Ecology).

Halton Unitary Development Plan

11.4.48 The Halton Unitary Development Plan (UDP) (Ref. 9) was adopted on 7 April 2005. The Halton UDP provides the strategic policies and proposals which could affect HBC Areas. The principal policies/proposals of relevance to the Upper Mersey Estuary and consequently the Aquatic Ecology Chapter for the proposed Mersey Gateway Project are summarised below.

11.4.49 Policy GE17 is applicable to the protection of sites of international importance for nature conservation. It explains that development or land-use change not directly connected with, or necessary to, the management of the site will not be permitted if it is likely to have a significant effect on the site unless three specified criteria can be satisfied: a) there is no acceptable alternative; b) there are imperative reasons of over-riding public interest for the development of the land or land-use change; and c) the development is necessary for reasons of human health or public safety or for beneficial consequences of primary importance for nature conservation. The development site for the Project is just upstream of the Mersey Estuary Ramsar and SPA sites which are of international importance. Therefore, assessments are required to identify whether the development would be likely to have an adverse effect on the integrity of these protected sites.

11.4.50 Policy GE18 is applicable to sites of national importance for nature conservation. This policy states that development in, or likely to affect, SSSIs requires stringent examination, and development likely to cause a significant effect should not be permitted unless the reasons for the development outweigh the nature conservation value of the sites (and the national policy to protect such sites). The New Bridge would be situated 1,770 m upstream of the Mersey Estuary SSSI which is a site of national importance. It should therefore be assessed whether the Mersey Gateway Project would potentially impact this SSSI.

11.4.51 Policy GE19 describes the requirement to prevent development and land use change which is likely to have a significant negative impact on Local Wildlife Sites (LWS). LWSs are local, non-statutory sites and the importance of regional and local sites is noted in PPS9. Sites covered in the UDP are based on a number of characteristics and community factors and include the Manchester Ship Canal bank, Astmoor, Upper Mersey Estuary: Widnes Warth and Fiddlers Ferry saltmarsh, Upper Mersey Estuary: Astmoor saltmarsh and swamp, Upper Mersey Estuary: Intertidal areas and open water.

11.4.52 Policy GE23 Protection of Areas of Special Value – a development 'should not have an unacceptable effect on the visual and physical characteristics for which an area was designated as having special landscape value. The development should be in character with the area, sensitively sited and designed and constructed of appropriate materials. It should be integrated and landscaped to a high standard. It should be accommodated without affecting the overall quality of the area'.

11.4.53 Policy GE30 The Mersey Coastal Zone – This mentions criteria that must be satisfied before development within the Undeveloped Coastal Zone can occur, including:

a. It requires a coastal location; or
b. It clearly relates to the recreational use of the zone and is of a scale and nature which will not affect the landscape quality, nature conservation and archaeological value of the coast; or
c. It is necessary for reasons of human health or public safety or for beneficial consequence of importance for nature conservation.

11.4.54 This only applies to an area immediately upstream of the SJB and an area bordering the southern bank downstream of the SJB. The Project meets at least one of these objectives.

11.4.55 Saltmarsh bordering the northern banks of the Upper Mersey Estuary in the region of the proposed Mersey Gateway Project is protected by a number of Greenspace policies including GE8 Development within Designated Greenspace. Saltmarsh on the southern bank is also within the Green Belt (S21 Green Belt) and developments within this region are in line with policy GE1 Control of Development in the Green Belt.

11.4.56 Policy PR5 Water Quality states that "Development will not be permitted if it is likely to have an unacceptable effect on the water quality of water bodies including rivers, lakes and canals or pose an unacceptable risk to the quality of groundwater". Water is an essential resource and any pollution can have a serious effect on drinking water supply, industrial and agricultural practices. Therefore, pollution to water supplies not only poses a threat to humans but also flora and fauna. PR5 is designed to ensure that adequate pollution control measures are incorporated into new developments to reduce the risks of water pollution.

11.5 Assessment Methodology

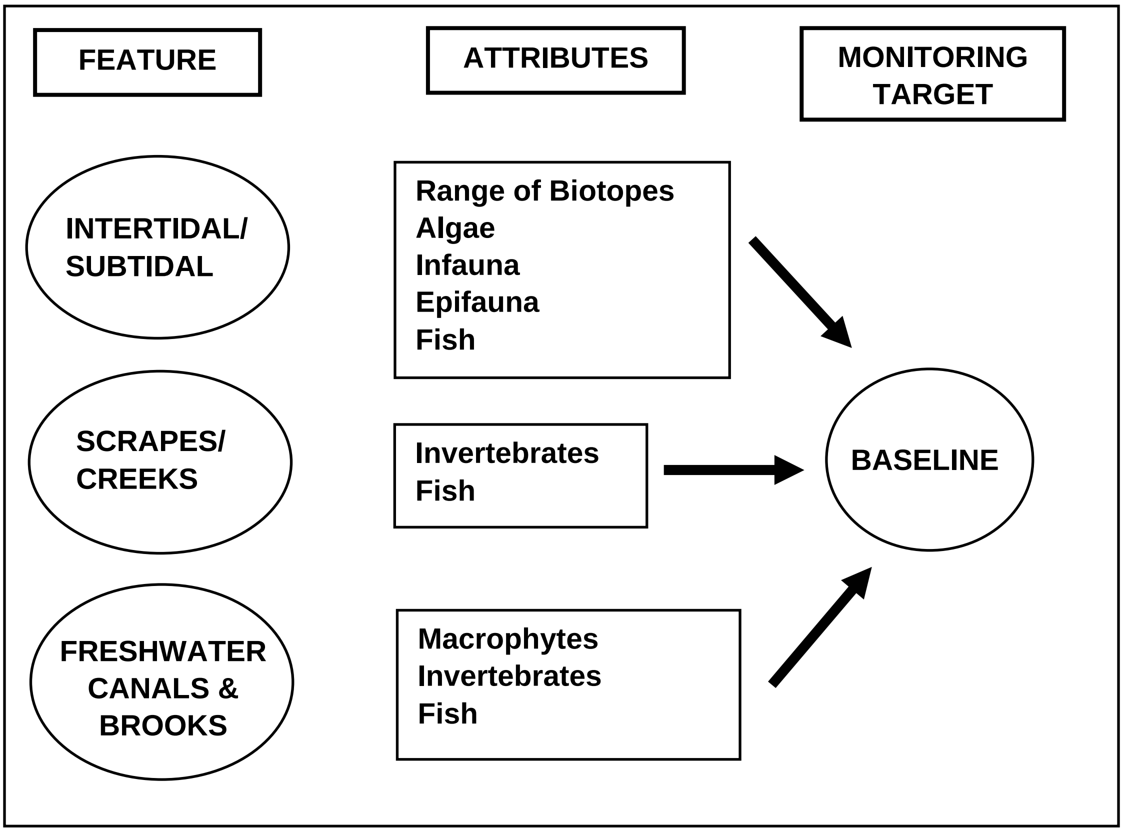
Methodology

11.5.1 The overall approach was to establish a baseline for the intertidal and subtidal habitats in the Upper Mersey Estuary and surrounding area using methods outlined in the "Marine Monitoring Handbook" (Ref. 10). This incorporates the recommendation of Countryside Council for Wales "Handbook for Marine Intertidal Phase 1 Survey and Mapping" (Ref. 11). Aspects of the UK National Marine Monitoring Programme "Green Book" (Ref. 12) were also considered. These documents provide detailed standard methodologies for intertidal sampling (e.g. coring), subtidal sampling (e.g. the use of grabs) and fish sampling (e.g. using beam trawls). They also provide advice regarding where sampling should be undertaken and the importance of replicate sampling. The Marine Monitoring Handbook (Ref. 10) suggests sampling during a number of seasons, including summer sampling. Methods outlined have been incorporated into the aquatic ecology survey and are detailed in Section 11.5, Assessment Methodology.

11.5.2 The 'Marine Monitoring Handbook 2001' (Ref. 10) was developed by the Joint Nature Conservation Committee for monitoring and setting conservation objectives for marine SACs (Special Areas of Conservation), of which intertidal areas are defined as Annex I habitats under the EC Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora). Baseline conditions within potentially affected freshwater habitats were also assessed to examine invertebrate and macrophyte community structure and identify whether any Red Data Book species were present.

11.5.3 At present, there are a number of marine SACs in the UK including the Dee Estuary located near the Mersey. It should be stressed that the section of the Estuary under study is neither a SAC nor candidate SAC. However, the proposed site of construction is close to a Ramsar/SPA site located within the Estuary immediately downstream of the SJB and Mersey Gateway Project sites (Section 11.1 of this Chapter and Figure 4.4, Chapter 4: Description of EIA Study Areas. Therefore, it was considered appropriate to adopt a rigorous monitoring approach for the baseline study for the Mersey Gateway which would be comparable to surveys undertaken for environmental assessments in protected areas. The approach used to monitor intertidal habitats is represented diagrammatically in Diagram 11.1, below.

Diagram 11.1 - Diagrammatic representation adapted from the UK's approach to monitoring marine SAC habitat features (Davies *et al*., 2001)



11.5.4 The ability of a monitoring programme to meet its aims successfully, hinges on the selection of appropriate study methods, together with an effective deployment strategy. In order to measure each attribute it was vital that the sampling techniques used were sensitive (i.e. accurate and precise) and recorded information over a given time period within the study area.

11.5.5 Traditional theories of community ecology have considered ecosystems to be in equilibrium. These theories have been challenged by the results of ecological studies that demonstrated a high frequency of natural disturbance, and have noted that environmental change can occur more rapidly than the system's ability to return to equilibrium (Ref. 13). The current view is that marine ecosystems are constantly changing and the sampling strategy behind any monitoring programme must be sufficiently robust to take account of both the magnitude of change and the processes behind such a change (Ref. 10). In addition, the communities of freshwater habitats such as canals and brooks can vary significantly over time. As such seasonal sampling is an essential aspect of a comprehensive baseline survey of the freshwater watercourses in the area surrounding the Upper Mersey Estuary.

11.5.6 The accuracy of the baseline will be determined by the level of monitoring as natural systems change over several years. The current monitoring programme commenced in summer 2004 (i.e. in terms of sites and the range of organisms sampled). The more comprehensive studies conducted from 2004 onwards follow on from two previous years of less intensive monitoring which also provide important ecological information. The time period of a study can be limiting in terms of measuring the baseline ecology, especially if the ecosystem is characterised by a high frequency of change. However, it is considered that the sampling undertaken in relation to the Project has adequately accounted for temporal variation due to the overall duration of the sampling programme and the fact that sampling was conducted during spring, summer and autumn. As such it is believed that the baseline information gathered is sufficiently robust to gain an understanding of natural temporal variation in the system and inform the aquatic ecology impact assessment.

11.5.7 The surveys undertaken to examine the baseline ecology of intertidal and subtidal habitats are covered by this report. They involved the monitoring of the three main biological components of the estuarine ecosystem:

a. Benthic algae;
b. Invertebrates (infauna and epifauna); and
c. Fish.

11.5.8 In addition, surveys were conducted to monitor the fish populations in the shallow flooded ponds (scrapes) on Wigg Island. Invertebrates were also sampled in a waterbody formed by sectioning off the Latchford Canal on Wigg Island. Further surveys were conducted to monitor freshwater biotic (invertebrate and macrophyte) communities within the Bridgewater and St. Helen’s Canal as both of these canals would be crossed by the New Bridge, and information regarding fish communities in these canals was collated. Stewards and Bowers Brooks were also surveyed for macroinvertebrates and macrophytes as habitats within these waterways could be disturbed by the wider development footprint.

11.5.9 Over the course of the survey the data collected has been analysed and projected to assess the likely impact of construction and operation of the Project on the ecology of the Upper Mersey Estuary. This involved the identification of the significance of effects on the aquatic community caused by factors such as construction, contamination and the presence of new structures. This was related to the ecological sensitivities of the organisms surveyed and the magnitude of the potential impacts expected.

11.5.10 The cumulative effect of impacts should also be considered i.e. those potentially resulting from the Project in combination with effects from other developments not related to the Project. Whilst the Project in isolation may result in an insignificant impact on the aquatic ecology of an area, when combined with other impacts (both significant or insignificant) in the same geographical region, there could still be a cumulative impact on estuarine ecology. For the purposes of this Environmental Assessment cumulative effects are considered within Chapter 21 (Residual and Cumulative Effects Assessment).

11.5.11 Having identified factors which could have a potential impact upon the aquatic ecology of the study area, mitigation measures likely to remove or significantly reduce these impacts were identified though consultation with members of other relevant groups such as engineers, construction teams and other consultees.

11.5.12 During the period over which the baseline surveys were conducted, aquatic ecology data were presented to, and consulted upon with, a number of relevant bodies including:

a. Environment Agency;
b. Natural England (NE); and
c. North West and North Wales Sea Fisheries Committee.

11.5.13 Minutes from the meetings with the EA and NE are provided in Appendix 10.3, Chapter 10 (Terrestrial and Avian Ecology). A letter to the North West and North Wales Sea Fisheries Committee is provided in Appendix 11.4.

11.5.14 These consultations formed a forum for the discussion of all post-monitoring survey results and provided an opportunity to address issues relating to the output of the final Aquatic Ecology Chapter and the eventual completion of the overall Environmental Statement. Chapters covering many technical areas are included in the Environmental Statement and those of particular relevance to aquatic ecology are Chapters 7 (Hydrodynamics and Estuarine Processes Movement), 8 (Surface Water Quality), 10 (Terrestrial and Avian Ecology), and 14 (Contamination of Soils, Sediments and Groundwater).

Sampling Program and Sites

11.5.15 The broad study area for the ecological assessment for the proposed Mersey Gateway is summarised in Section 11.1.

11.5.16 Sampling began in spring and autumn of 2002 with the collection of fish and macroinvertebrate samples from within the central study area (Zone 2). Initial sampling of invertebrates at a small number of sites within Zone 1 and 3 was also conducted during this period. In 2003 a similar program was undertaken, however, as it was uncertain at this time whether the Project would be taken forward, the sampling program was not as intense (Table 11.1).

11.5.17 In 2004 it was decided to extend the scope of the survey area to include more sites within the area from Hale Head downstream of the SJB (Zone 1) and upstream of Fiddlers Ferry to just where the Sankey and Whittle Brooks enter the Mersey (Zone 3). This was to gain a better understanding of natural variability in ecological characteristics within the Upper Mersey and gather a more robust baseline data set for the full extent of the Upper Mersey potentially impacted by the Project. In particular, it was considered important to sample Zone 1 as this Zone was within the Mersey Estuary Special Protection Area and Ramsar Sites and impacts on aquatic ecology in this area had the potential to affect bird populations of conservation importance (Figure 4.4, Chapter 4: Description of EIA Study Areas).

11.5.18 In order to account for seasonal variation in the abundance and community composition of estuarine invertebrates and fish, sampling was conducted in spring and autumn of 2002 and 2003. In 2004, 2005 and 2006 a summer survey was also conducted in addition to the spring and autumn surveys to gain a wider overview of temporal changes in aquatic ecology. This ensured that species were sampled during the summer months which could otherwise have been missed or underrepresented in samples taken at other times of year.

11.5.19 In addition, from summer 2004 to spring 2007 the community of invertebrates at the exact locations of the bridge towers (following confirmation of where towers would be located) was examined in order to see what organisms would be directly impacted by their placement. Fish and mobile epifauna would be able to move away from the tower sites so only sediment dwelling invertebrates were investigated.

11.5.20 Algal sampling commenced in 2004. Algae were included as they are a principal component of the food chain in intertidal mudflats, and are considered important within the JNCC and UK National Marine Monitoring Programmes. It was important to assess seasonal patterns of algal abundance and species composition. Therefore, algal sampling for the 2004 survey was conducted in both summer and autumn, and from 2005 onwards the survey was extended to include the spring period.

11.5.21 Following the intensive survey period between 2004 and 2005 the data gathered was examined in conjunction with data collected by the hydrodynamics team and as such the number of sites which needed to be sampled in each zone was reassessed. This was required to optimise sampling efficiency while still gathering the baseline data necessary to complete a detailed impact assessment for the Project. Following this assessment it was decided that the number of sites sampled could be decreased in spring 2006 (and for the remainder of the main estuarine survey up to spring 2007) without compromising the overall baseline data set. Consequently, from 2006 onwards no sampling for estuarine fish, invertebrates and algae was conducted in Zone 3 and the number of sites sampled in Zone 1 for each of these groups was halved. The number of sample sites in Zone 2, however, remained the same as this was the area expected to be subjected to the greatest potential impact due to construction of the New Bridge.

11.5.22 The Bridgewater and St Helen's Canal were monitored from summer 2004 to summer 2007. It was considered necessary to identify whether Red Data Book species (rare, threatened or legally protected species) or BAP species were present within them due to their conservation value. Three sites (site of proposed bridge crossing and upstream and downstream of this site) were sampled for macroinvertebrates and macrophytes in each of these canals (Table 11.1). Information regarding fish species commonly found in the canals was gathered from local angling clubs.

11.5.23 In spring and summer 2007 macrophytes and macroinvertebrates were also sampled in Bowers Brook and Stewards Brook. A survey of Halton Brook was conducted in March 2007 but this was found to be permanently dry and was not visited during the subsequent summer surveys. The invertebrate community of the waterbody on Wigg Island which used to be the Latchford Canal was also surveyed from in spring and summer 2007 (Table 11.2).

Table 11.1 - Summary of aquatic ecology sampling undertaken within the Upper Mersey Estuary (not including surveys of freshwater environments).

ALGAE	Surface Cores & Chl a		
	Zone 1 (Z1)	Zone 2 (Z2)	Zone 3 (Z3)
Spring 03			
Summer 03			
Autumn 03			
Spring 04			
Summer 04			
Autumn 04			
Spring 05			
Summer 05			
Autumn 05			
Spring 06			
Summer 06			
Autumn 06			
Spring 07			
Summer 07			

INVERTEBRATES	Intertidal Cores				Subtidal Grabs				Epifauna Hand Trawl				Tower Cores		
	Z1	Z2	Z3		Z1	Z2	Z3[1]		Z1	Z2	Z3		T1	T2	T3
Spring 02															
Summer 02															
Autumn 02															
Spring 03															
Summer 03															
Autumn 03															
Spring 04															
Summer 04															
Autumn 04															
Spring 05															
Summer 05															
Autumn 05															
Spring 06															
Summer 06															
Autumn 06															
Spring 07															
Summer 07															
FISH	**Beam Trawl**				**Seine Nets (replicates in Zone 3)**				**Larval Trawl**				**Scrape (Astmoor) (replicates)**		
	Z1	Z2	Z3[2]		1	2	3		Z1	Z2	Z3		1[3]	2	3
Spring 02															
Summer 02															
	Z1	Z2	Z3[2]		1	2	3		Z1	Z2	Z3		1[3]	2	3
Autumn 02															
Spring 03															
Summer 03															
Autumn 03															
Spring 04															
Summer 04															
Autumn 04															
Spring 05															
Summer 05														Dry	Dry
Autumn 05															
Spring 06															
Summer 06														Dry	Dry
Autumn 06														Dry	Dry
Spring 07															
Summer 07															

[1] Was not possible to take subtidal grabs in Z3, however, intertidal macrofauna and epifauna samples were both taken.
[2] When sampled, Z3 was sampled with Seine nets instead of beam trawling.
[3] In Spring 2006 bank erosion caused Scrape 1 to drain into the Mersey estuary and dry out permanently preventing further sampling of this scrape.

[4]Stewards Brook could not be accessed in summer 2007 due to Health and Safety reasons.

Table 11.2 - Summary of aquatic ecology sampling undertaken within freshwater environments within the Upper Mersey Estuary.

	Macrophyte & invertebrate survey		Macrophyte & invertebrate surveys			Invertebrate survey
	Bridgewater Canal	St. Helen's Canal	Stewards Brook[4]	Bowers Brook	Halton Brook	Latchford Canal
Spring 02						
Summer 02						
Autumn 02						
Spring 03						
Summer 03						
Autumn 03						
Spring 04						
Summer 04						
Autumn 04						
Spring 05						
Summer 05						
Autumn 05						
Spring 06						
Summer 06						
Autumn 06						
Spring 07					Permanently dry	
Summer 07						

Estuarine Algae

11.5.24 As part of the ecological survey to assess the environmental impact of the Mersey Gateway Project, surveys of the algal population in the Upper Mersey Estuary were undertaken.

11.5.25 The main objective was to undertake a full baseline survey of the benthic algal population associated with the surface sediments located within the intertidal habitats of the Upper Mersey Estuary. In order to fulfil this objective a qualitative survey of the benthic algal associations within the intertidal habitats of the Upper Mersey Estuary was undertaken. It is standard practice to use algal biomass in conjunction with community composition data to estimate abundance of algal populations. Algal biomass was determined quantitatively via chlorophyll extraction in the laboratory. Data regarding community composition was gathered during summer and autumn in 2004, in spring, summer and autumn from 2005 to 2006 and in spring 2007.

Sampling Locations

Main Estuarine Survey

11.5.26 Algal sampling commenced in summer 2004. During 2004 and 2005 Zones 1-3 were sampled, from spring 2006 to spring 2007 only Zones 1 and 2 were sampled.

11.5.27 Sites within zones were selected by dividing each zone into grids of evenly sized square units and then selecting sites to give an even coverage of the zone as a whole. A number of sites were chosen to account for the range of potential benthic habitats present within each zone. Zones are described in Section 11.3.

11.5.28 All sites sampled were intertidal and a total of nineteen were selected which were located throughout the three zones (Table 11.3 and Figure 11.2, Appendix 11.1). Their positions were recorded via GPS and the distribution of the sites was as follows:

a. Zone 1 (Lower Zone): Intertidal sites 18, 20, 21, 22, 23, 24 and 25;
b. Zone 2 (Middle Zone): Intertidal sites 3, 4, 6, 7, 10, 11, 12, 15 and 17; and
c. Zone 3 (Upper Zone): Intertidal sites 1A, 1B and 1.

11.5.29 Only three sites were located in Zone 3. This was because within this zone the overall area of available habitat was much smaller than in the other two zones and hovercraft access to this area of the channel was restricted.

11.5.30 For the reasons described above, from the beginning of 2006 onwards there was no sampling of algae in Zone 3. In addition, the number of sites sampled in Zone 1 from January 2006 onwards was reduced from seven intertidal sites to four sites (18, 21, 23 and 25), (see Paragraph 11.5.21).

Table 11.3 - Location and description of the algae sampling stations in the Upper Mersey Estuary.

Zone	Site	NGR	Location	Description
Zone 1	18	SJ 50512 83726	d/s SJB	Intertidal mid channel
(Lower Zone)	20	SJ 50312 83425	d/s SJB	Intertidal mid channel
	21	SJ 49063 83411	d/s SJB	Intertidal mid channel
	22	SJ 49403 83000	d/s SJB	Intertidal mid channel
	23	SJ 49003 82002	d/s SJB	Intertidal mid channel
	24	SJ 48980 81095	d/s SJB	Intertidal mid channel
	25	SJ 48000 81000	d/s SJB	Intertidal mid channel
Zone 2	3	SJ 53811 85114	d/s Fiddlers Ferry	Intertidal north channel
(Middle Zone)	4	SJ 53525 84773	Hempstones Point	Intertidal south channel
	6	SJ 53252 84513	Hempstones Point	Intertidal south channel
	7	SJ 52983 84749	Widnes Warth	Intertidal north channel
	10	SJ 52831 84543	Runcorn Sands	Intertidal mid channel
	11	SJ 52324 84396	Runcorn Sands	Intertidal mid channel
	12	SJ 52396 84003	Runcorn Sands	Intertidal mid channel
	15	SJ 51758 83879	Runcorn Sands	Intertidal mid channel
	17	SJ 51279 83534	u/s SJB	Intertidal mid channel
Zone 3	1A	SJ 57398 86505	u/s Fiddlers Ferry	Intertidal mid channel
(Upper Zone)	1B	SJ 57483 86869	u/s Fiddlers Ferry	Intertidal mid channel
	1	SJ 55637 84746	u/s Fiddlers Ferry	Intertidal mid channel

Field Sampling Methods

Intertidal samples

11.5.31 Benthic algal samples were collected by hand at low tide using a core (internal diameter 28 mm) inserted to a depth of 2 cm. Four replicate cores were collected within a 2 m^2 quadrat at each site. Three of these were randomly selected for chlorophyll analysis and the remaining core was used to collect a sample of benthic algae for the identification and enumeration of algal species. A hovercraft supplied by the EA provided access to all intertidal sites (Plate11.1, Appendix 11.2).

11.5.32 The use of coring to sample benthic algal populations is a standard technique accepted across the assessment industry and by the relevant authorities. Benthic algae is patchily distributed and biomass was highest in areas less prone to tidal erosion in which the diatoms and other benthic algae tended to form algal mats. Therefore, within a relatively small area, a core had the potential to indicate a high or low biomass for a given site (if the site was near areas of dense algal coverage). It was for this reason that a relatively high number of samples were taken across a number of seasons so as to ensure that an overall representation of the variety of benthic algal species and biomass range in the Upper Mersey Estuary was obtained.

Laboratory Treatment of Samples

Sample Preservation and Preparation

11.5.33 Samples were taken to the laboratory and all replicate cores which had been randomly selected for chlorophyll analysis were immediately frozen to preserve their ecological state. These cores were then kept frozen until the extraction process could take place.

11.5.34 The preparation of benthic algae for qualitative identification followed techniques developed by Eaton and Moss (Ref. 14). Cores collected for the identification of benthic algae were mixed thoroughly to disperse the algae before being transferred to pre-labelled petri dishes. Once the sample was in a dish, 3 x 2 cm^2 pieces of Grade 105 lens tissue were placed on the surface of the sediment and the samples themselves were then left in an artificially lit area for a period of 24hrs. During this time the algae migrated to the surface of the sediment and became trapped in the lens tissue. After this period all tissue pieces were removed to a glass MacCartney tube (one tube per sample i.e. three pieces of tissue per tube) and then placed in 3 ml 40% glycerol in Lugol's iodine solution in order to kill, stain and preserve the algae. Samples were then stored in the dark until the identification stage.

Identification

11.5.35 To prepare samples for identification the three pieces of replicate lens tissue in each sample were torn up using a pair of dissecting needles and the tube was vigorously shaken. A drop of the suspension was then transferred to a gridded microscope slide, the algae were identified and enumerated until 150 cells were counted. As samples were dominated by diatoms, diatoms were enumerated during this count but were not identified to species level, whereas the species of all other algal types were identified. The main purpose of this count was to provide an estimate of the proportion of diatoms in the sample relative to other algal types.

11.5.36 In order to accurately identify diatoms their silica frustules have to be acid-digested to facilitate identification of various taxonomic features. The digestion process removes the organic component of the diatom but also destroys other algal taxa which is why other algal species were enumerated during the first sample count.

11.5.37 To clean the diatoms the remainder of each sample was placed in a beaker and 10 ml of 30% hydrogen peroxide was added. The beaker and its contents were then left on a hot plate at 90°C for approximately 2 hours, or until all the lens tissue and other organic material was destroyed. At this point the sample was transferred to a centrifuge tube, topped up with distilled water and centrifuged for 5 minutes. The supernatant was then discarded and the tubes refilled with distilled water. This process was repeated a further three times.

11.5.38 The resultant washed diatom frustules were mounted in naphrax refractive mountant and the valves identified until 300 cells had been counted. All identifications were carried out using either a high power light microscope or a phase contrast microscope (depending on the key features that needed to be examined).

Chlorophyll Extraction and Analysis

11.5.39 A technique commonly used to generate quantitative estimates of benthic algal biomass is to measure the phytopigment concentrations (especially chlorophyll *a*, *b* and *c*) within samples. To analyse phytopigment concentrations, the three cores which had been selected for chlorophyll analysis (i.e. had been immediately frozen in the laboratory following collection) were removed from the freezer, crushed into glass MacCartney tubes and freeze dried. The dry sediment was then placed in 90 % acetone-washed bottles, shaken with 20 ml of 90 % acetone and left overnight in a dark refrigerator at 3°C. The next day samples were shaken and centrifuged at 4,000 rpm for 30 minutes. The resulting supernatant was then decanted and an aliquot placed in a 1cm pathway glass cuvette.

11.5.40 Absorbance readings of the extract were taken using a recording spectrophotometer at the following principal wavelengths: 750 nm, 664 nm, 647 nm, and 630 nm. Where 750 nm was the level of background absorbance, 664 nm was the absorption peak of chlorophyll *a*, 647 nm was the absorption peak of chlorophyll *b* and 630 nm was the absorption peak of chlorophyll *c*. Chlorophyll *a* concentrations were then calculated using the equation of Jeffrey and Humphrey (Ref. 15):

Chlorophyll $a = 11.85_{664} – 1.54_{647} – 0.08_{630}$

Data Analysis

Biomass

11.5.41 Algal biomass data were examined graphically by plotting the mean chlorophyll concentration within samples collected for each zone and for each of the five sample seasons. As data were not normally distributed, either before or following transformation, an ANalysis Of VAriance (ANOVA) test, where proportions of the observed variance are assigned to different explanatory variables, could not be used to analyse the results. Therefore, a non-parametric Mood’s median test was conducted to assess variation in chlorophyll concentration among zones, seasons and years.

11.5.42 In order to map the distribution of algae within the estuary during each of the sample seasons a contour map was created using Surfer 7.0. This programme used the data from the 19 spot samples and generated interpolations between them to create contours linking areas of similar algal biomass. Maps were generated for each of the seasons in which sampling occurred. It should be noted that the contour lines on the map are created from computer interpolation algorithms rather than actual measured boundaries between levels of chlorophyll present.

11.5.43 Surfer plots of algal biomass involved the extrapolation of data from core samples to the wider area. It is known that benthic algae can be patchily distributed and therefore a core placed in an area of particularly low or high biomass would have the potential to bias results. However, the high number of samples taken across many sites and numerous seasons ensured that the overall trends in algal biomass were clear from the results.

Community composition

11.5.44 From the counts of all algal cells, and subsequent identification of diatoms (following cleaning of the silica frustules), it was possible to generate an estimate of the proportion of each type of diatom within the original algal sample, and the relative proportions of other algal species. Histograms were then generated to indicate the proportion of each algal species within samples for each site to provide a visual representation of the dominant and less abundant species present. Histograms were generated for each season sampled during each year of sampling to indicate changes in community composition among sites and seasons.

11.5.45 A correspondence analysis was also conducted on raw data which allowed the complex multivariate species composition data to be represented in a simple bi-plot. The position of a sample data point on the bi-plot represented the species composition within that sample and data points were separated by season. Sample data points located close to one another on the bi-plot had a similar species composition, and the greater the distance between points the greater the difference in their community structure. The bi-plot facilitated the examination of seasonal variation in algal communities within the estuary.

Species richness and diversity

11.5.46 In order to express the algal community in terms of species richness and diversity, two numerical values were used. Firstly, species richness was simply expressed as the number of different species identified within a given sample. These were then tabulated to enable a comparison of the number of species within the different zones during different seasons.

11.5.47 This, however, does not indicate how species are distributed within the sample. For example, two samples may each contain the same number of individuals representing five species and therefore have the same species richness score. However, one of those samples may contain 96 individuals of Species 1 and only one of the other four species, whereas the other sample may contain 20 of each of the five species. Clearly the first sample is dominated by species 1, whereas the second sample has a much more even distribution of the five species and therefore has greatest species diversity. Therefore, to account for this, a second value was calculated which is known as the Shannon-Wiener Index:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where H'=Shannon-Wiener Index, s=total number of species (i.e. species richness) and p_i = proportion of total sample belonging to ith species.

The higher the Shannon-Wiener index the greater the diversity of the algal community within the samples. This information was tabulated for each zone and season sampled.

Freshwater Macrophytes

11.5.48 Macrophytes are an integral component of freshwater ecosystems. They provide habitat and a food source for fish and invertebrates and play an important role in the oxygenation of waterways. As such, a study was required of freshwater macrophyte assemblages present within selected waterways in the Upper Mersey Estuary.

11.5.49 The main objectives of the freshwater macrophyte study were to:

a. Conduct a baseline investigation of macrophyte species found within the St. Helen’s and Bridgewater Canals, and Stewards, Bowers and Halton Brooks (all of which could potentially be impacted by the Project). Sites selected on these waterways were those most likely to be impacted by the construction and operation of the New Bridge; and
b. Examine the spatial and temporal distribution of macrophytes within the proposed development sites and at locations 150 m upstream and downstream of construction areas. Community composition was assessed and any rare species were noted.

11.5.50 Sites on both the Bridgewater and the St. Helen’s Canal were selected to correspond with the location of the Project (i.e. the point at which the New Bridge would cross the canals), and sections of canal 150 m upstream and downstream of that location. The exact locations of all six survey stations are shown in Table 11.4. GPS was used to record grid references for each site, and the same sites were surveyed during each sample season. Macrophyte sampling commenced in the summer of 2004 and was conducted during each subsequent sample season. In addition, in spring and summer 2007 sampling was also conducted on the body of water which was formerly the Latchford Canal.

11.5.51 Sites on Bowers Brooks and Stewards Brooks were selected to correspond with the location of the Project (i.e. the point at which the New Bridge would cross the brooks), and sections of the brooks 150 m upstream and downstream of the construction works. The exact location of the survey stations is given in Table 11.4. GPS was used to record the grid references for each site. Macrophyte sampling was conducted at the brooks in spring and summer 2007. A site was also visited on Halton Brook (SJ 525825 825500), however this was found to be permanently dry and therefore this brook was not sampled.

Field Sampling Methods

Canal sites

11.5.52 Macrophytes were sampled at three stations along each canal (Table 11.4 and Figure 11.1, Appendix 11.1). These were 150 m upstream of the potential impact; at the site of potential impact; and 150 m downstream of the potential impact. On the Latchford Canal this was modified to 50 m north and south of the New Bridge location due to the termination of the canal near the site at which it would be traversed by the New Bridge. Channel plants were retrieved via a grapnel trawl. At each sample station the grapnel was thrown across the channel a minimum of three times until the full range of macrophyte species had been sampled. Emergent herbs and reeds were recorded along the right and left margins of the canal for a distance of approximately 5 m either side of each sample station. To provide a precise description of macrophyte communities all macrophytes and macro-algae were identified to species level.

11.5.53 A one-off charophyte survey was undertaken in April 2005 of 20 sites both upstream and downstream of the regular sample stations to establish the extent of populations.

Table 11.4 - Location and description of the macrophyte sampling stations for canals and brooks.

Site	Site	NGR	Location
Bridgewater Canal	1	SJ 53586 82846	150 m downstream of proposed New Bridge
	2	SJ 53343 82588	Site of proposed New Bridge
	3	SJ 53126 82918	150 m upstream of proposed New Bridge
St. Helen's Canal	1	SJ 51886 84821	150 m downstream of proposed New Bridge
	2	SJ 51764 84763	Site of proposed New Bridge
	3	SJ 57643 84706	150 m upstream of proposed New Bridge
Latchford Canal	1	SJ 53178 83589	Site 50 m north of proposed New Bridge (upstream/downstream not applicable)
	2	SJ 53215 83650	Site of proposed construction New Bridge
	3	SJ 53225 83685	Site 50 m south of proposed New Bridge (upstream/downstream not applicable)
Stewards Brook *(upstream and downstream extent)*	1	SJ 50024 84936	250 m downstream of proposed New Bridge
	2	SJ 49880 85044	100 m downstream of proposed construction for the New Bridge
	3	SJ 49824 85100	Site of proposed New Bridge
Bowers Brook	1	SJ 52015 84535	150 m downstream of proposed New Bridge
	2	SJ 52050 84645	Site of proposed New Bridge
	3	SJ 52058 84830	150 m upstream of proposed New Bridge

11.5.54 One of the limitations to the macrophyte surveys in the canals and brooks was the turbidity of the water which made it difficult to confirm if the macrophytes sampled using the grapnel trawl technique were representative of the whole macrophyte community within the waterways. However, by deploying the grapnel three times it is considered that the majority of the species within the waterways would have been effectively sampled and this is a standard macrophyte sampling technique. The trawl technique is not quantitative and provides more qualitative information such as presence/absence of various macrophyte species.

Brook sites

11.5.55 Macrophytes were sampled at three stations along each brook. It was the intention of this survey to locate the stations at the site of impact and 150 m upstream and downstream of the impact site. However, the presence of culverted sections of watercourse resulted in the stations being located as described in Table 11.4, with modified distances for Stewards Brook. At each sample station, the Mean Trophic Rank (MTR) method (Ref. 16) was employed. This involved regularly transversing a 50 m stretch of waterway whilst recording and mapping all channel and marginal vegetation features (the grid reference in Table 11.4 indicates the upstream extent of each 50 m stretch). A reduced sample length of 50 m was deemed more appropriate for the sites in question than the standard 100 m stretches as described in Holmes *et al.* (Ref. 16) due to the presence of culverted sections of the watercourse and the fact that surveyed stretches would have overlapped if 100 m had been used. All macrophytes were identified to species level.

Data Analysis

11.5.56 Species presence/absence data were tabulated and any variation in species composition between surveys interpreted.

Estuarine Invertebrates

11.5.57 Estuarine invertebrates are an important component of the estuarine ecosystem and were monitored to assess the ecological impact of construction of the New Bridge. Most biological investigations of invertebrates generally target the macrofauna (i.e. ≥ 500 μm in size) which include animals living on the surface of, or within, sediments (epifauna and infauna, respectively) as they can be readily counted and identified. However, the group of smaller organisms known as meiofauna (~63-500 μm in size) have an equally important role in ecosystem function.

11.5.58 For the purposes of this study it was decided to sample meiofauna in addition to macrofauna. Numerous macrofaunal species feed on meiofauna and examining both groups of invertebrates provides a more detailed view of invertebrate communities within the Upper Mersey Estuary. For the purposes of this study meiofauna was defined as organisms within the size range 125-500 μm (i.e. pass through a 0.5 mm sieve and retained by a 0.125 mm sieve). Although organisms between 0.063 and 125 μm can also be classed as meiofauna the 125-500 μm size range is commonly used for monitoring purposes. Macrofauna was comprised of organisms which could not pass through a 0.5 mm sieve.

11.5.59 Benthic macroinvertebrates provide an extremely important food source for fish and birds, and the smaller meiofauna are far less important in terms of bird diet. Bird species which are the primary reason for the SPA and Ramsar designations downstream of the Mersey Gateway Project are dunlin, redshank, shelduck, teal, widgeon, pintail and black-tailed godwit (Chapter 10: Terrestrial and Avian Ecology). The diet of these species comprises annelid worms, crustaceans and molluscs. Therefore, any significant reductions in macroinvertebrate numbers within bird feeding areas could potentially impact bird populations. For some of these internationally important bird species the number of individuals recorded during the bird surveys conducted for the Mersey Gateway Project within the potentially impacted area was negligible. Therefore, diet information is provided here for the four more abundant bird species of international importance which were recorded during these surveys (Chapter 10: Terrestrial and Avian Ecology):

a. Dunlin: Major prey items include Hydrobia ulvae, Macoma balthica, Cerastoderma edule, Hediste diversicolor and oligochaeta;
b. Redshank: Typically this species feeds on Corophium spp., H. diversicolor, Nephtys spp., H. ulvae and M. balthica;
c. Shelduck: This species reaches moderate numbers throughout the Upper Mersey Estuary (Chapter 10: Terrestrial and Avian Ecology) and primarily feed on molluscs (e.g. H. ulvae, C. edule and M. balthica), crustaceans (e.g. Corophium spp.) and polychaetes and oligochates (Ref. 17); and
d. Teal: Teal counts were fairly high mainly on the wetland on Astmoor Saltmarsh (Chapter 10: Terrestrial and Avian Ecology). Teal diet varies considerably according to habitat although it is known to include a wide range of molluscs, crustaceans and oligochaetes.

11.5.60 A full baseline study of the invertebrate population in the Upper Mersey Estuary was conducted and the data collected were used to estimate the potential impacts of the construction and operation of the New Bridge on the invertebrate community. Data derived in this study were compared with those obtained by other published studies of estuarine invertebrates.

Sampling locations

Main estuarine survey

11.5.61 The zones sampled for the invertebrate survey were the same as those sampled during the algal survey (Figure 11.3, Appendix 11.1) and are described in Section 11.1.

11.5.62 In 2002 and 2003 there were 16 sample sites in Zone 2 (9 intertidal and 7 subtidal), (see Table 11.5). During these first two years of sampling only three sites were sampled in Zone 1, two of these were intertidal sites (18 and 20) and one was a subtidal site (Site 19). Only Site 1 (intertidal) was sampled in Zone 3.

11.5.63 From 2004 onwards the same sites were sampled in Zone 2, the number of sites sampled in Zone 1 was increased to 12 (7 intertidal and 5 subtidal) and three sites were sampled in Zone 3 (all intertidal), (see Table 11.5). This was in order to increase the scope of the survey to gain a better understanding of natural variation in communities of aquatic organisms throughout the area potentially impacted by the Project and to provide a more detailed and robust baseline data set for the Upper Mersey Estuary.

11.5.64 A systematic grid sampling technique was considered appropriate for the identification of sample sites as invertebrates are often distributed in relation to variables such as water quality or sediment characteristics. Consequently, in this situation, grid sampling is a more robust method than random sampling. As this method was also used for the algal survey the nineteen intertidal sites sampled for invertebrates were the same as the intertidal sites sampled for benthic algae (Table 11.5, see Table 11.3 for comparison).

11.5.65 For the purposes of invertebrate sampling, however, subtidal sites were sampled in addition to the intertidal sites. Only Zones 1 and 2 were sampled in the subtidal survey as Zone 3 could not be reached by boat due to the large expanse of mud flats and shallow water in this area. Therefore, intertidal sites were positioned within Zones 1-3, and subtidal sites within Zones 1 and 2. Positions of all sites were recorded via GPS (Figure 11.3, Appendix 11.1 and Table 11.5).

11.5.66 The distribution of the sites was as follows:

a. Zone 1 (Lower Zone) : Intertidal sites 18, 20, 21, 22, 23, 24 and 25
Subtidal sites 19, 26, 27, 28, 29;

b. Zone 2 (Middle Zone): Intertidal sites 3, 4, 6, 7, 10, 11, 12, 15 and 17
Subtidal sites 2, 5, 8, 9, 13, 14,16; and

c. Zone 3 (Upper Zone): Sites 1A, 1B and 1.

Table 11.5 - Location and description of the infauna sampling stations in the Upper Mersey Estuary.

Zone	Site	NGR	Location	Description
Zone 1 (Lower Zone)	18	SJ 50512 83726	d/s SJB	Intertidal mid channel
	19	SJ 49835 83898	d/s SJB	Subtidal main channel
	20	SJ 50312 83425	d/s SJB	Intertidal mid channel
	21	SJ 49063 83411	d/s SJB	Intertidal mid channel

Zone	Site	NGR	Location	Description
	22	SJ 49403 83000	d/s SJB	Intertidal mid channel
	23	SJ 49003 82002	d/s SJB	Intertidal mid channel
	24	SJ 48980 81095	d/s SJB	Intertidal mid channel
	25	SJ 48000 81000	d/s SJB	Intertidal mid channel
	26	SJ 49270 83727	d/s SJB	Subtidal main channel
	27	SJ 48840 83200	d/s SJB	Subtidal main channel
	28	SJ 48500 82500	d/s SJB	Subtidal main channel
	29	SJ 48400 81500	d/s SJB	Subtidal main channel
Zone 2 (Middle Zone)	2	SJ 54529 84679	d/s Fiddlers Ferry	Subtidal main channel
	3	SJ 53811 85114	d/s Fiddlers Ferry	Intertidal north channel
	4	SJ 53525 84773	Hempstones Point	Intertidal south channel
	5	SJ 52600 84691	Hempstones Point	Subtidal main channel
	6	SJ 53252 84513	Hempstones Point	Intertidal south channel
	7	SJ 52983 84749	Widnes Warth	Intertidal north channel
	8	SJ 52994 84664	Widnes Warth	Subtidal side channel
	9	SJ 52902 84153	Astmoor	Subtidal main channel
	10	SJ 52831 84543	Runcorn Sands	Intertidal mid channel
	11	SJ 52324 84396	Runcorn Sands	Intertidal mid channel
	12	SJ 52396 84003	Runcorn Sands	Intertidal mid channel
	13	SJ 52332 83487	Astmoor	Subtidal main channel
	14	SJ 51744 84499	Spike Island	Subtidal side channel
	15	SJ 51758 83879	Runcorn Sands	Intertidal mid channel
	16	SJ 51630 83402	Swing-Bridge	Subtidal main channel
	17	SJ 51279 83534	u/s SJB	Intertidal mid channel
Zone 3 (Upper Zone)	1A	SJ 57398 86505	u/s Fiddlers Ferry	Intertidal mid channel
	1B	SJ 57483 86869	u/s Fiddlers Ferry	Intertidal mid channel
	1	SJ 55637 84746	u/s Fiddlers Ferry	Intertidal mid channel

11.5.67 Only three sites were located in Zone 3 as within this zone the overall area of available habitat was much smaller than in the other two zones, and hovercraft access to this area of the channel was more restricted.

11.5.68 From 2006 onwards no sampling was conducted in Zone 3. The reason for this was that baseline data collected for this zone during previous sample seasons and knowledge of the construction and operational details of the Project indicated that Zone 3 and the organisms within it would not be expected to be impacted by the Project. In addition the number of subtidal grab sites and intertidal core sites in Zone 1 was reduced in order to focus sampling efforts on Zone 2 which was more likely to be impacted by the Project. From 2006 onwards the subtidal sites sampled were 19, 27 and 29, and the intertidal sites sampled were 18, 21, 23 and 25 (which were also the four sites used for algal sampling from 2006 onwards).

Table 11.6 - Location and description of the epifauna sampling stations in the Upper Mersey Estuary.

Zone		
Zone 1 (Lower Zone)	1	SJ 482 815
	2	SJ 482 815
	3	SJ 482 816
	4	SJ 482 816
	5	SJ 482 817
	6	SJ 483 817
	7	SJ 482 818
	8	SJ 483 818
	9	SJ 482 819
	10	SJ 482 820
Zone 2 (Middle Zone	1	SJ 510 836
	2	SJ 511 836
	3	SJ 512 836
	4	SJ 513 836
	5	SJ 513 837
	6	SJ 514 837
	7	SJ 514 838
	8	SJ 514 839
	9	SJ 514 840
	10	SJ 515 841
Zone 3 (Upper Zone)	1	SJ 558 856
	2	SJ 558 857
	3	SJ 558 858
	4	SJ 559 859
	5	SJ 559 860
	6	SJ 559 861
	7	SJ 560 861
	8	SJ 560 862
	9	SJ 561 863
	10	SJ 561 864

Epifauna sample sites

11.5.69 The location of epifauna survey sites was mainly dependant on the availability of sufficient consolidated sandy substrate (locations of the sample sites are given in Table 11.6). Epifauna was sampled via trawling with a dredge (Paragraphs 11.5.78-79). A total of ten replicate 10 m transects were sampled using the dredge within each of the three survey zones during spring, summer and autumn months. As explained in Paragraph 11.5.20, Zone 3 was not sampled from 2006 onwards.

Intensive survey of tower sites

11.5.70 In addition to these main invertebrate sample sites, it was decided to conduct more intensive monitoring from 2004 to 2007 at the proposed locations for the bridge towers. The area of the intertidal zone on which the towers would be constructed would effectively no longer be available for colonisation following the construction of the towers. Therefore, it was important to gain an understanding of the invertebrate community within these specific areas. Three extra intertidal sites were sampled which corresponded to the proposed locations for the three bridge towers (Table 11.7, Figure 11.3). All three of these sites fell within Zone 2 of the study area, and a total of 9 replicate cores were collected from each site during the summer and autumn of 2004.

Table 11.7 - Location and description of the infauna sampling stations for the tower construction sites.

Site	NGR	Location	Description
A	SJ 52397 84423	Runcorn Sands 5	Intertidal main channel
B	SJ 52634 84208	Runcorn Sands 6	Intertidal main channel
C	SJ 52870 83992	Runcorn Sands 7	Intertidal main channel

Saltmarsh Scrape and Creek sites

11.5.71 In spring 2005 a small ad-hoc survey of the invertebrate composition of the Wigg Island saltmarsh scrapes and tidal creek was carried out in order to investigate whether they provided significant alternative habitats for estuarine invertebrates.

Field Sampling Methods

11.5.72 During the study it was important to use a range of sampling equipment in order to effectively sample the diverse range of habitats and organisms present within the estuary, be aware of the limitations of the sampling and processing techniques, and understand the types of organisms which could be undersampled by such methods (Ref. 18).

11.5.73 Various types of grabs and corers are commonly used to sample invertebrates in intertidal and subtidal habitats (Ref. 18). However, the effectiveness of these methods can be limited if there is insufficient penetration into the sediment. In addition, deeper burrowing species can be missed. Appropriate methods were used during this survey based on the sediment types present. It was considered that the depth of sediment sampled during the aquatic ecology surveys was sufficient to contain the majority of fauna living in the sediment and would have sampled all of the major food items which can be consumed by fish and birds (Ref. 19).

11.5.74 Grabs and cores are also of limited use for the collection of mobile epibenthic species, therefore trawls were used to sample these species (Ref. 10).

11.5.75 As techniques used to sample invertebrates are specific to certain invertebrate groups (e.g. epifauna and infauna) and no single technique can sample all components of the invertebrate community, a range of methods were used within the Upper Mersey Estuary. Three separate survey techniques were used to maximise the diversity of fauna sampled at each site. These were:

a. Intertidal sediment core sampling with the aid of a hovercraft: Infauna (macrofauna and meiofauna);
b. Subtidal grab sampling deployed from a boat: Infauna (macrofauna and meiofauna); and
c. Sampling using a dredge or trawl at low tide: Epifauna (macrofauna only).

Collection of Infauna (Macrofauna and Meiofauna)

Intertidal samples

11.5.76 These were collected at low tide using a 0.0038 m^2 core (internal diameter 7 cm) inserted to a depth of 10 cm (0.0004 m^3). Three replicate core samples were collected within a 2 m^2 quadrat at each site. A hovercraft supplied by the EA provided access to the intertidal sites (Plate 11.1, Appendix 11.2). Once collected, the sediment retained by the core was placed in pre-labelled plastic containers for return to the laboratory.

Subtidal samples

11.5.77 Subtidal samples were collected at high tide using a boat-deployed Eckman grab (Plate 11.2a, Appendix 11.2). The open Eckman grab was lowered vertically through the water column from a stationary boat until positioned on the sediment surface. A small metal messenger was then deployed from the boat to travel down a rope to the grab where it triggered the jaws of the grab to snap shut. The grab captured slow moving and sedentary members of the epifauna and infauna down to a depth of approximately 15cm below the sediment surface. Sediment up to a depth of ~2 m AOD or greater depending on the position within the Estuary is expected to be repeatedly resuspended due to the tidal regime within the Upper Mersey Estuary (Chapter 7: Hydrodynamics and Estuarine Processes Movement). Once sediments have settled, however, most organisms are expected to occupy the top 15 cm in order to feed near the sediment surface and sampling to this depth is standard practice. It is considered, therefore, that the community sampled within the top 15 cm is representative of the community within mobile sediments and the majority of organisms would be present at this depth or shallower.

11.5.78 The overall surface area of sediment sampled by the Eckman grab was 0.0225 m^2. Once collected, the sediment was hauled to the water surface and then placed in pre-labelled plastic containers for return to the laboratory. Three replicate grabs were collected at each site. If the grab misfired then it was set again and re-deployed.

Collection of Epifauna (Macrofauna only)

11.5.79 Sampling of epifaunal macrofauna was semi-quantitative and was conducted using dredges which captured members of the epifauna (organisms inhabiting the sediment surface). As the speed and duration of each tow was standardised (10m transect at approximately 1 m/s against the current) the results of these dredges provided a basis on which to estimate population densities of different epifaunal taxa which could then be compared among sites (Ref. 18).

11.5.80 In 2002 and 2003, a modified push net was used for these dredges (Plate 11.2b, Appendix 11.2). In 2004, however, the performance of the modified push net was trialled against a smaller lightweight aluminium dredge (Plate 11.2c, Appendix 11.2 and Table 11.8). Results indicated that the lightweight dredge was easier to haul across the sediment than the net and was less inclined to snag or skip over the sediment surface. The dredge also sampled a greater range of taxa than the push net. Therefore, it was decided that the aluminium dredge should be used for all of the 2004 and subsequent surveys.

Table 11.8 - Dimensions of the Modified Push Net as compared with those of the Lightweight Dredge

Dimensions	Modified Push Net	Lightweight Dredge
Net Bag	1mm polyester mesh	1mm polyester mesh
Net Frame	0.75m across x 0.25m depth D-frame opening	0.30m across x 0.18m depth Rectangular frame opening
Weight of sampler	4.5 kg	1.5 kg
Steel towing harness attached to front section of the frame	Yes	Yes
Attached rope	10 m in length	10 m in length

Laboratory Treatment of Samples

Sample Preservation and Preparation

11.5.81 Invertebrate material was preserved in a 10% solution of commercial formalin (equivalent to 4% aqueous formaldehyde), and a buffer (e.g. borax or hexamine) was added to prevent the formalin from becoming acidic and damaging specimens during storage (Ref. 18). Following identification of specimens, sample material was transferred to an aqueous solution of 70% industrial methylated spirit (IMS) and 5% glycerol (Ref. 18). Stored preserved samples were kept at cool temperatures, away from room heaters or radiators. They were also kept in the dark to minimise the loss of colour from specimens.

11.5.82 Invertebrate samples were washed in a fume cupboard and then sieves were used to separate the different fractions of the sample for analysis. In between the washing of different samples, sieves were cleaned thoroughly to avoid cross contamination. Samples were washed through a 500 micron sieve to retain macrofaunal organisms of 500 microns and greater. A smaller mesh size of 125 microns was then used to sample meiofauna between 125 and 500 microns.

11.5.83 Macrofauna and meiofauna samples were processed using different methods as the meiofauna are smaller and tend to be present at much higher numerical densities than macrofauna (Ref. 18).

Sorting of Macrofauna

11.5.84 Macrofauna were sorted using small 100 cm^2 trays with a superimposed grid and Nikon binocular microscopes (Ref. 20). This ensured that smaller specimens of polychaete and oligochaete worms and other organisms were included in the counts. Counts of organisms obtained from the analyses were expressed as numbers per m^2.

Sorting of Meiofauna

11.5.85 For each sample, all material which passed through a 500 micron mesh sieve but was retained by a 125 micron mesh sieve, was transferred to a sorting tray where it was spread out evenly over the base of the tray. The tray was divided equally into a series of squares and material from one of these randomly chosen squares was transferred to a beaker. Within the beaker the sediment was stirred into a uniform 100 ml suspension using water and a 1ml sample was removed using a pipette. The 1 ml suspension was then placed into a Sedgewick Rafter Counting Cell and viewed under a high power light microscope in order to count and identify the meiofauna present.

11.5.86 If there were too many organisms in a sample to be counted accurately, then a sub-sample was taken from a homogenous suspension of the larger sample which was then used to enumerate organisms (Ref. 21). The volume sub-sampled was related to the size of the sorting dish so that it covered the bottom of the dish with a layer only a few grains thick. Counts from the sub-sample were then adjusted to give an eventual estimate of numbers per m^2.

Identification

11.5.87 Where possible macrofauna were identified to species level using a variety of identification keys (Table 11.9). Meiofauna, were identified to the level of the main groups which were the nematodes (phylum nematoda), gastrotrichs (phylum gastroticha) and copepods (phylum arthropoda: sub class copepoda). Nomenclature was in accordance with ‘The Species Directory of the Marine Fauna and Flora of the British Isles and Surrounding Seas’ (Ref. 22).

Table 11.9 - Taxonomic keys which were frequently used for the identification of estuarine invertebrates in the Upper Mersey Estuary

Title	Authors
1) Guide to inshore marine life (2nd edn.)	Erwin and Picton (Ref. 23)
2) Handbook of the marine fauna of North-West Europe	Hayward and Ryland (Ref. 24)
3) The brackish-water Fauna of North Western Europe	Barnes (Ref. 25)
4) Guide to marine coastal plankton and marine invertebrate larvae (2nd edn.)	Smith and Johnson (Ref. 26)
5) Marine plankton a practical guide (5th edn.)	Newell and Newell (Ref. 27)
6) Porifera	Ackers (Ref. 28)
7) Cnidaria and Ctenophora	Cornelius (Ref. 29), Manuel (Ref. 30)
8) Polychaetes	Garwood (Ref. 31, Ref. 32)
9) Oligochaetes	Brinkhirst (Ref. 33)
10) Amphipods	Lincoln (Ref. 34), Makings (Ref. 35)
11) Isopods	Naylor (Ref. 36)
12) Mollusca	Fretter and Graham (Ref. 37, Ref. 38, Ref. 39, Ref. 40, Ref. 41, Ref. 42, Ref. 43, Ref. 44), Graham (Ref. 45)

Analytical Quality Control

11.5.88 The macroinvertebrate sorting and identification methods used were subject to strict quality control procedures with internal quality control checks being performed on randomly chosen samples. These quality control procedures were fully compatible with the EA’s invertebrate AQC procedures. That is, 1 in 10 samples were re-sorted and taxa identified by an AQC biologist. A maximum of 2 ‘misses’ per sample were allowed per sample. A miss being defined as a taxon recorded but not found in the sample or vial, a taxon found in the sample or vial but not recorded, or a taxon misidentified at family level. If the AQC sample had more than two misses, then the batch of 10 samples was resorted (Table 11.10).

Table 11.10 - Criteria used to assess AQC compliance for sorting infauna samples from the Upper Mersey Estuary

Criteria used to assess AQC compliance:	
Total number of taxa	+/- 10% or two taxa of the auditors figure, whichever is the greater.
Total abundance	+/- 10% or two taxa of the auditors figure, whichever is the greater.
Taxa misidentified	5% of all taxa.

Data Analysis

Macrofauna

11.5.89 As the meiofauna data were not normally distributed, either before or following transformation, an ANOVA test could not be used to analyse the results. Therefore, a non-parametric Mood’s median test was conducted on data collected for intertidal and subtidal macrofaunal communities, and for the epifauna samples. A more detailed examination of the spatial and temporal variation occurring among the intertidal (main estuary, tower sites and creek/scrapes sites) and epifaunal benthic invertebrate communities was conducted using Principal Components Analysis (PCA). PCA is a linear multivariate ordination technique that was used to examine between-site and between-year variation of the macroinvertebrate community and identify the species or taxa contributing to this variation. Data were log (n+1) transformed prior to PCA analysis.

11.5.90 A PCA multivariate analysis could not be conducted on the data gathered for subtidal macrofauna as the majority of samples did not contain any organisms.

Meiofauna

11.5.91 A Mood's median test was conducted which enabled the identification of significant differences in meiofauna between zones, seasons and years. A PCA was conducted to examine the variation, and sources of variation, between meiofauna communities among sites and seasons. As with the analysis of intertidal macrofauna, all samples from the estuary, tower sites and creek/scrapes were combined in a single analysis and intertidal meiofaunal communities for a specific season were compared among 2004, 2005 and 2006. For the PCA analyses of subtidal meiofauna, comparisons were made between samples from Zones 1 and 2 only, which had been collected in autumn 2004, 2005 and 2006. Data were log (n+1) transformed prior to analysis.

Biotope Analysis

11.5.92 Biotopes can be assigned to aquatic habitats based on the habitats and fauna present. Identifying and mapping biotopes around the UK can help provide a better understanding of the distribution and extent of specific marine habitats and can, therefore, be used as a useful tool to aid the management and conservation of marine habitats. The aim of this section was to identify the biotope composition of the Upper Mersey Estuary (i.e. study area) and produce maps illustrating the extent of the different biotopes present.

11.5.93 The Joint Nature Conservation Committee (JNCC) Marine Habitat Classification for Britain and Ireland provides an extensive list of all possible biotopes, from broad habitat level to sub-biotope level, in hierarchical order. The results of the surveys were used alongside this hierarchy to assign a biotope code to each sample point. This code was based on the habitat type and the high abundances of certain key organisms mentioned in the Marine Habitat Classification. Therefore, organisms which were found at particular sites in small numbers were not used to define the biotopes.

11.5.94 Biotope mapping was conducted using the GIS package Arc View 3.3. Each of the sites was labelled with the relevant biotope code and marked on an outline map of the study area. This allowed areas to be grouped according to habitat type and biotope type, thus allowing the overall biotope distribution for the study area to be assessed.

Freshwater Invertebrates

11.5.95 Organisations such as the EA routinely utilise macroinvertebrates to assess the water quality of rivers and canals in the UK. As part of the ecological survey work related to the environmental impact of the Project, macroinvertebrate surveys of both the Bridgewater and St. Helen's Canal, and of Stewards and Bowers Brooks were undertaken.

11.5.96 The main objectives of the freshwater invertebrate study were to:

a. Conduct a baseline investigation of benthic invertebrates currently inhabiting both the canals and brooks potentially impacted by the Project. Sites selected on these waterways were those most likely to be impacted by construction and operation of the New Bridge; and

b. Examine the spatial and temporal distribution of macroinvertebrates within proposed development sites as well as at locations upstream and downstream of construction areas.

Sampling locations

11.5.97 Sites on the Bridgewater and St. Helen's Canals, and on Stewards and Bowers Brooks were selected to correspond with the location of the proposed New Bridge, and 150m upstream and downstream of this point. The exact location of all fifteen freshwater invertebrate survey stations were the same as those surveyed for freshwater macrophytes (Table 11.4). GPS was used to record grid references for each site, and the same sites were sampled during each sample season. In addition, in spring and summer 2007 invertebrates were sampled in Stewards and Bowers Brooks and a section of waterway which used to be the Latchford Canal. Grid references for sites sampled at each canal and brook are provided in Table 11.4.

Field Sampling Methods

11.5.98 For the canal and brook surveys all procedures for the collection and analysis of macroinvertebrate samples followed the standard procedures used by the EA (Ref. 46). Therefore, the data collected were directly comparable with the EA's data and GQA biology gradings of surface waterbodies. To account for seasonal variation, macroinvertebrates were collected in the three sampling seasons that are recognised by the EA; Spring (March-May), Summer (June-August), Autumn (September-November. Winter sampling (December-February) is not advocated by the EA (Ref. 46). Samples from the Bridgewater and St. Helen's Canals were collected in summer and autumn 2004, and spring, summer, autumn from 2005 onwards. Sampling of Stewards and Bowers Brooks and the Latchford Canal commenced in 2007. Halton Brook was also visited in March 2007 as it was considered to be a potential sample location. However, it was found to be permanently dry and was not visited during any future surveys. Sampling in the three brooks was conducted in spring and summer 2007. When the same canal or brook site was sampled over consecutive seasons a period of at least two months was left between visits in order to allow communities to recover from the sampling process.

11.5.99 The Bridgewater, St. Helen's and Latchford Canals were too deep for conventional macroinvertebrate kick sampling to take place. Therefore, based on the requirements of the EA (Ref. 46), trawls were employed to obtain samples of the benthos. A lightweight dredge was used which was the same as that utilised to sample invertebrate epifauna (Paragraphs 11.5.78-79). The dredge was thrown into the main channel at an angle perpendicular to the bank. After allowing the dredge time to sink to the sediment surface it was then trawled back to the bank and the contents were emptied into a collecting tray. This process was repeated between 3 and 5 times to allow the trawl to be hauled across all representative habitats, with at least one of these trawls being taken parallel to the bank. Once the trawls were completed, silt and any larger stones were washed from the contents of the tray through the mesh of the dredge. No more than three litres of the remaining sample were then transferred to a pre-labelled plastic pot for return to the laboratory.

11.5.100 As well as using a dredge to collect samples of the benthos, a standard FBA pattern long-handled pond net, fitted with a 1mm mesh, was used to collect samples of any free swimming animals such as beetles or pond skaters present on the water surface and organisms which lived in emergent or submerged vegetation parallel to the bank.

The net itself was swept through both these habitats for a period of one minute and the contents of the net transferred to the same pre-labelled plastic sample pot which was used for the trawls.

11.5.101 Due to the shallower depth of Stewards and Bowers Brook sampling was conducted by sweeping with a standard FBA pattern long-handled pond net for 3 minutes, fitted with a 1mm mesh.

Laboratory Treatment of Samples

Sample preservation

11.5.102 On return to the laboratory, samples were rinsed through a 500 micron mesh sieve to remove excess fine material and placed in an aqueous solution of 90% industrial methylated spirit (IMS) and 5% glycerol. The preservative was evenly distributed throughout the sample by gently tumbling it in its container with the lid firmly attached (Ref. 46). An air space of about one fifth of the container's volume was sufficient for this procedure, however, due to their large volume it was sometimes necessary to split dredge samples into two or more containers to effectively preserve samples containing a large amount of silt (Ref. 46). Preserved samples were kept at cool temperatures, away from room heaters or radiators and stored in a dark environment to minimise the loss of colour from specimens.

Sample Washing

11.5.103 Samples of freshwater invertebrates were washed within a fume cupboard to remove preservatives or fine sediments at the laboratory (as was conducted for estuarine samples). Samples were washed through a 500 micron mesh sieve (mandatory practice for this type of sample, Ref. 46) and everything retained on this mesh was kept ready for the identification process. Great care was taken to make sure sieves were kept clean between the washing of different samples in order to minimise the risk of cross contamination.

Sample Sorting

11.5.104 Once a sample was washed it was more effective to sort small portions of the sample at a time rather than the whole sample in one go (Ref. 46). Fractions of the sample (equivalent to the volume of a teaspoon) were transferred to sorting trays and sufficient water was added to evenly distribute the contents within the tray. The fraction was then systematically sorted and the animals counted and identified. Labelled taxa tubes were made up which contained up to three good quality examples of each taxon. These organisms could be checked by a second sorter as a means of quality control to ensure that all identifications were correct.

Taxonomic Identification

11.5.105 All specimens were identified to species level where possible, with the exception of the Sphaeriidae and Chironomidae (identified to genus and family level, respectively) and any worms (identified to class). All identifications were carried out using both low power dissection and high power light microscopes (depending on the main features which needed to be observed to identify taxa) and identification was aided by the use of keys. Enumeration of each taxon was based on the absolute count data rather than recording abundances on a logarithmic scale. Analytical quality control procedures such as those used for the estuarine invertebrate samples were in place (Table 11.10). The macroinvertebrate sorting and identification methods were subject to strict quality control procedures with internal quality control checks being performed on randomly chosen samples (Paragraph 11.5.87).

Data Analysis

11.5.106 Biotic indices were calculated for each site in the form of BMWP (Biological Monitoring Working Party) Scores and ASPT (Average Score Per Taxon) Scores. BMWP and ASPT scores were designed to give non-biologists, unfamiliar with the ecological requirements of different macroinvertebrate groups, a broad indication of the biological condition of a brook, river or canal. Each invertebrate family was given a score between 1 and 10, depending on their perceived susceptibility to pollution with pollution intolerant taxa scoring 10 and pollution tolerant taxa 1.

11.5.107 A BMWP score was calculated for the Bridgewater, St. Helen's and Latchford Canals and each of the brooks sampled by adding up the individual BMWP scores for each taxon found within them. The ASPT score was then provided by dividing this value by the number of scoring taxa sampled from each canal. BMWP and ASPT scores, and the number of taxa sampled, was compared among the different canals and brooks using ANOVA.

Estuarine Fishes

11.5.108 Fish are a highly mobile component of the estuarine ecosystem, and in terms of biomass are the most significant vertebrate group in estuaries (Ref. 47).

11.5.109 The sampling effort required to survey fish communities is considerably greater than for algae and invertebrates. It is extremely important, however, to sample fish in addition to these other groups as they are one of the top-end predators in the estuarine food chain and changes in the fish community can reflect variations in other components of the estuarine ecosystem (e.g. invertebrates, algae), (Ref. 48).

11.5.110 The aim of this section of the study was to complete a baseline survey of the fish inhabiting intertidal and subtidal habitats of the Upper Mersey Estuary. This required an assessment of variation in the abundance and community composition of the Upper Mersey Estuary fish population on both temporal and spatial scales. This information was used to assess the possible impact of construction of the New Bridge on fish populations. Where possible the data collected was assessed in relation to previous published studies of estuarine fish communities.

Sampling locations

Main estuarine survey

11.5.111 In 2002 and 2003, fish were only sampled in Zone 2 (Middle Zone) and Zone 3 (Upper Zone) of the study area. To increase the scope of the fish survey, and ensure that data collected was comparable to that derived for algae and invertebrates, the study area was extended in 2004 to encompass Zone 1 as well as Zones 2 and 3 (Figure 11.4, Appendix 11.1 and Table 11.11). Specific study areas were as follows:

a. Zone 1 (Lower Zone) extended from Hale Head to the SJB and contained twelve beam trawl sites;
b. Zone 2 (Middle Zone) extended from the existing SJB to Round Cherval, and included twelve beam trawl sites previously sampled as part of the 2002/03 programme. The locations for the saltmarsh scrape sites were also found within this zone; and

c. Zone 3 (Upper Zone) extended from Round Cherval to just downstream of the confluence with Whittle Brook. No beam trawl sites were located within this zone as the water was too low so instead this zone was sampled via seine net at three low water sites.

11.5.112 As with the invertebrate survey, several different types of sampling equipment were required to sample the range of habitat types and species in the Upper Mersey Estuary (Ref. 18), and certain methods were used within specific zones. The main sampling methods were beam trawling (Paragraphs 11.5.126-129) and seine netting (Paragraphs 11.5.130-132) and some fish were also sampled as by-catch from the epifaunal invertebrate surveys (Paragraph 11.5.78). GPS was used to record the location of each fisheries survey site to ensure the same location was sampled during each season.

Table 11.11 - Beam Trawl Locations in the Upper Mersey Estuary (from 2006 onwards the only sites sampled in Zone 1 were 1, 4, 5, 8, 9 and 12)

Zone	Site	Location	Start NGR
Zone 1 (Lower Zone)	1	d/s SJB	SJ 48345 81475
	2	d/s SJB	SJ 48940 81545
	3	d/s SJB	SJ 48520 82350
	4	d/s SJB	SJ 49135 82280
	5	d/s SJB	SJ 48955 83060
	6	d/s SJB	SJ 49375 82995
	7	d/s SJB	SJ 49245 83580
	8	d/s SJB	SJ 49680 83325
	9	d/s SJB	SJ 49980 83870
	10	d/s SJB	SJ 50145 83530
	11	d/s SJB	SJ 50540 83885
	12	d/s SJB	SJ 50630 83580
Zone 2 Zone (Middle Zone)	1	Runcorn Sands	SJ 51685 83585
	2	Astmoor	SJ 52265 83725
	3	Astmoor	SJ 52760 84185
	4	Hempstones Point	SJ 53160 84650
	5	Hempstones Point	SJ 53615 84860
	6	d/s Fiddlers Ferry	SJ 54265 84760
	7	d/s Fiddlers Ferry	SJ 55170 84485
	8	Widnes Warth	SJ 53170 85090
	9	Widnes Warth	SJ 52770 84720
	10	Widnes Warth	SJ 52055 84450
	11	Runcorn Sands	SJ 51500 83500
	12	Runcorn Sands	SJ 52195 84060
Zone Zone 3 (Upper Zone)		No beam trawls undertaken	

Beam trawl sampling sites

11.5.113 For the 2004 survey programme a total of twenty-four beam trawl transects were identified as suitable sample sites in the Upper Mersey Estuary (Table 11.11), (for details of trawl transects see Section 11.5.129). Twelve of the sites were located downstream of the SJB in Zone 1 and a further twelve sites were situated upstream of the bridge in Zone 2 (Figure 11.4, Appendix 11.1). As the beam trawls were carried out from a boat it was not possible to safely and routinely complete beam trawls in Zone 3 and so seine net sampling was used instead.

11.5.114 For the reasons explained in Section 11.5.67, from 2006 onwards the number of beam trawl sites sampled was halved so that just sites 1, 4, 5, 8, 9 and 12 were used for future sampling.

Seine netting sampling sites

11.5.115 Seine netting was conducted in areas of hard standing substrate in which beam trawls could not be used. The three seine netting sites were all located in Zone 3 only (opposite Fiddlers Ferry power station), (Table 11.12) and were sampled from a shoreline position at low tide.

11.5.116 From 2006 onwards fish in Zone 3 were no longer sampled (for reasons see Paragraph 11.5.20).

Table 11.12 - Seine Netting Locations in the Upper Mersey Estuary (no hard standing seine netting sites (Zone 3) were sampled from 2006 onwards)

Type of Seine netting undertaken	Transect	Start NGR
Hard Standing Seine Netting	1	SJ 55755 85490
	2	SJ 55885 85935
	3	SJ 56075 86345
Saltmarsh Seine Netting	1	SJ 52735 83735
	2	SJ 53000 84000
	3	SJ 53270 84300

By-catch sampling sites

11.5.117 Some further information was gained from an examination of fish by-catch data obtained by the lightweight dredge used during the epifaunal invertebrate surveys (Paragraphs 11.5.78-79). Fish species (especially large numbers of small flounder) were often caught during these trawls. The location of these epifaunal survey sites was highly dependant on the availability of sufficient consolidated sandy substrate over which the lightweight dredge could be hauled. Therefore, one set of trawls was located in each survey zone (Table 11.12).

Saltmarsh scrape sites

11.5.118 Seine netting was also conducted in Astmoor saltmarsh in Zone 2 (these were known as saltmarsh scrapes). The saltmarsh scrapes located on Wigg Island in Zone 2 were dug out by local wildfowlers to create pond habitat for various species of duck. Fish enter these shallow depressions at high tide and are then trapped as the tide falls, remaining there until the next high tide. A total of three saltmarsh scrapes were sampled, again at low tide (the grid references for each location are provided in Table 11.12). Before the spring 2006 sample period, water within saltmarsh Scrape 1 drained into the estuary due to severe bank erosion. This scrape was permanently dry after the draining event and could no longer be sampled.

Field Sampling Methods

11.5.119 As with the invertebrate survey, several different types of sampling equipment were required to sample the range of habitat types and species in the Upper Mersey Estuary (Ref. 18). The sampling limitations imposed by the physical conditions in the Mersey were compounded by the complexity of fish behaviour and the diversity of fish species entering the estuary. Fishing techniques suitable for catching flatfish such as beam trawling were unlikely to catch larger pelagic species such as mackerel and anadromous fish (e.g. salmon) for which seine and gill netting are more effective. In addition, behavioural factors such as shoaling could also affect the accuracy of trawl data (Ref. 49, Ref. 50).

11.5.120 The use of certain sampling techniques was also restricted in some areas due to the complexity and variability of the estuarine environment. The main obstacle encountered within the Upper Mersey Estuary was the very rapid and considerable variation in physical and environmental conditions e.g. estuary topography and water current velocities (Ref. 51). Such problems are common to estuarine sampling in general and Cole (Ref. 52) noted that it is impossible to sample even a small estuary quantitatively and obtain an unbiased estimate of fish abundance.

11.5.121 Once a technique has been decided upon there is also considerable variation in how the method is deployed which makes it difficult to compare results among studies. For instance, Delacy and English (Ref. 53) found that the capture efficiency of beach seine nets increased to 75% when a 40m net was compared to a 20m net. Similarly, the catch efficiency of beam trawls can increase for juvenile demersal and flatfish with an increase in trawl size. The capture efficiency of beam trawls has been investigated by many workers involved in flatfish surveys (Ref. 54, Ref. 55). These studies show that the efficiency of fish capture with a 4m beam trawl for juvenile plaice ranged from 33% for 10 mm fish, 57% for 50-60 mm juveniles and to 46% for 70 mm juveniles. Comparison with studies using a 2m beam trawl indicate that the catches are greater with the larger and more efficient beam trawls (Ref. 56). Another study identified that by modifying the tickler chains with heavier spiked chains, the catch efficiency for juvenile flatfish increased by a factor of almost two (Ref. 57).

11.5.122 It was for these reasons that the beam trawling technique was kept consistent between 2004-07 for each sample period in terms of the type of beam trawl used and the length of the trawl (see Paragraphs 11.5.127-129).

11.5.123 Therefore, the use of a variety of fish sampling techniques together with consistency with respect to their use over the entire sampling period ensured the survey results provided a good representation of the fish community in the Upper Mersey.

11.5.124 When analysing the data gathered during the sampling programme it was important to understand the various limitations of the techniques used. As fish are highly mobile they can be distributed heterogeneously within estuaries. True estuarine resident species are the most likely species to be consistently sampled effectively. Other fish sampled in estuaries, however, include:

a. Marine visitors which do not have estuarine requirements;
b. Diadromous migratory species which pass between salt and freshwater for spawning purposes;
c. Marine seasonal migrants which visit estuaries on a seasonal basis;
d. Species which use the estuary as a juvenile nursery ground but spend most of their adult life at sea; and
e. Freshwater species which enter brackish waters.

11.5.125 It is the combination of different groups of fish that contribute to the species richness observed but only the best adapted to the environment are sampled regularly and in high numbers.

11.5.126 In order to make a broad assessment of the fish communities inhabiting the Upper Mersey Estuary four separate data sources were used, they were:

a. Beam trawling using a 2m trawl at high tide from a boat;
b. Seine netting from areas of hard standing substrate at low tide;
c. Seine netting of saltmarsh scrapes at low tide; and
d. Assessing by-catch data from epifauna (macrofauna) surveys collected using a dredge at low tide.

11.5.127 It was important to consider the possible effects of seasonal changes on community composition. Therefore, for the 2004 surveys and each subsequent year, sampling occurred during spring, summer and autumn (with the exception of 2007 in which sampling was conducted in spring only). This was an extension of the 2002/2003 survey in which sampling occurred during spring and autumn only. All fish captured during the survey were identified to species level, counted, measured and weighed.

Beam Trawling

11.5.128 Beam trawling is one of the most regularly applied estuarine sampling techniques for the assessment of flatfish (Ref. 58), and formed the main technique for the capture of fish in the aquatic ecology survey from 2004 onwards.

11.5.129 The surveys utilised a narrow beam trawl with an opening of 1.2 m (Plate 11.3, Appendix 11.2), a narrow trawl was considered to be the most effective for the study area as it was characterised by narrow subtidal channels and mobile sandbanks.

11.5.130 The net was fixed in an open position at a height of 0.6 m by attaching it to a rigid metal frame (the front bar of which was 1.2 m in length and 0.06 m in diameter). The net itself consisted of a mesh, with a bar length of 10 mm, and a cod end of 2 mm mesh. The overall length of the net from opening to tip was 2.4 m and the weight of the trawl was in excess of 5 kg. All beam trawls were taken from a 5 m RIB survey vessel.

11.5.131 The length of beam trawls was variable in 2002/2003. To generate results which could be compared among sites it was decided to standardise the length of trawls, and trials were conducted to identify the most appropriate length. It was considered that a 50m trawl was the best practical option as it was time-effective, reduced chances of the trawl snagging and produced a representative fish catch. Therefore, in 2004 and for each subsequent year, beam trawls were 50m in length and started at the grid reference given in Table 11.11. The direction of each trawl was dependent on tide and wind conditions, with each trawl taking place against the prevailing direction of the tide.

Seine Netting

Main survey

11.5.132 This method was used in areas of hard substrate in which beam trawling was not an effective sampling technique. Therefore, seine netting was the technique employed within Zone 3 only, at three sites located opposite Fiddlers Ferry power station. The locations of seine netting sites in the Upper Mersey Estuary were chosen in relation to topographical characteristics, and sites also had to have suitable access from the shoreline to comply with strict health and safety policy and risk assessment criteria. Due to the size, weight and drag of the net, it was only possible to carry out this sampling safely and efficiently during the slack water period and under good weather conditions.

11.5.133 The main advantage of seine netting in shallow water was that they fished the whole water column and were relatively simple and easy to operate (Ref. 59). A disadvantage associated with seine netting, however was that it was difficult to determine catch efficiency, therefore, estimates of total abundance derived from seine netting should be interpreted based on expert judgement.

11.5.134 At each site a 50m long seine net was set by field scientists. The net was deployed by using a boat to row out from the shore a distance of approximately 40m. The net was then hauled by hand in an even loop back toward the shore taking care to ensure that the fish were retained and concentrated into the middle section of the net. A single haul was taken at each site and all fish collected were identified, measured and counted. The seine net had a 5mm mesh and was 3m deep. It had a 6 mm nylon headline rope with floats and a 6 mm foot rope with leads.

Saltmarsh scrapes

11.5.135 Seine netting was also used to sample the fish population in Astmoor saltmarsh on Wigg Island (within Zone 2). This involved sampling at a total of three shallow scrape locations (Table 11.12). No boat was required for the deployment of nets in the saltmarsh scrapes as the water level at the time of sampling was within wading depth. Each suitable area of saltmarsh habitat appeared as a relatively small discrete unit (Plate 11.4, Appendix 11.2), therefore a seine net of only 25 m in length was required for the survey as opposed to the 50 m long net used for the sites in Zone 3. This smaller seine net was 1.5 m in depth with a 10 mm nylon headline rope with floats, a 10 mm foot rope with leads and a 5 mm mesh size. A single haul was taken at each site with all fish collected being identified, measured and counted.

11.5.136 In order to determine the extent of its use by estuarine fish, a creek located to the back of Wigg Island was also surveyed in spring 2005 using fyke nets positioned at low tide. Three nets were set and left until high tide, they were then retrieved and fish identified.

By-catch from epifauna survey

11.5.137 As described previously, invertebrate epifauna was sampled semi-quantitatively using dredges (Paragraphs 11.5.78-79). Juveniles of a range of fish species (e.g. flounder) were often caught as a by-catch during the invertebrate epifauna surveys. Therefore, records were made of the size, number and species of the fish caught during epifaunal trawls.

Field Treatment of Samples

11.5.138 All fish were processed in the field, with entire catches being retained and emptied into a tray for sorting. Individual fish were separated into the following categories during sorting:

a. Juvenile fish such as flounder, and adults of small species such as goby and pipefish;
b. Adult flatfish; and
c. Other fish.

11.5.139 All fish collected by beam trawling and seine netting were identified in the field to species levels and then counted, measured and returned to the water. Occasionally when the identification of a fish required clarification, the individual was preserved on site within a 10% solution of commercial formalin (equivalent to 4% aqueous formaldehyde) which was neutrally buffered to prevent damage to the specimen. Samples were then returned to the laboratory to be identified. Those fish collected as a by-catch from the invertebrate epifauna surveys were removed from the invertebrate sample material and identified once the samples had been returned to the laboratory.

Data Analysis

11.5.140 The numbers (and weights) of the different species in each sample were used to describe the species composition and community structure of fishes in the Upper Mersey Estuary. Estimates were derived of the relative abundances of different species of fish in Zones 1, 2 and 3 for each season within each sample year.

11.5.141 As the abundance and species richness data were not normally distributed, either before or following transformation, an ANOVA test could not be used to analyse the results. Therefore, a non-parametric Mood's median test was conducted which enabled the identification of significant differences in fish abundance and species richness between zones, seasons and years.

Freshwater Fishes

11.5.142 The plans for the New Bridge indicate that it would pass over the Bridgewater and St. Helen's Canals which contain freshwater fish. A section of the St. Helen's Canal runs adjacent to the northern bank of the Upper Mersey Estuary, while a section of the Bridgewater Canal runs adjacent to the southern bank.

11.5.143 The section of the St. Helen's Canal of relevance to this study runs from the point at which the canal meets the Estuary to Fiddlers Ferry. The Bridgewater Canal runs adjacent to the southern bank of the Estuary and the main section which could be potentially impacted by the development runs from Preston Brook to Waterloo Bridge.

Fish Sampling Methods

11.5.144 Fish within the canals are highly mobile and are extremely unlikely to be significantly adversely affected by the construction of the New Bridge across small parts of the canal. Consequently, it was considered appropriate to simply collate a species list for freshwater species within the canals to assess potential impacts.

11.5.145 Instead of conducting quantitative fish surveys it was decided that an equally effective approach would be to contact local angling clubs for information regarding the species present in each canal. For the Bridgewater Canal the secretary of Halton Joint Anglers was contacted who provided a species list for the Preston Brook – Waterloo Bridge section of the canal which was the main section of relevance to this study. The secretary of the Warrington Anglers Association provided a species list of the section of the St. Helen's Canal which runs from the point at which the canal meets the Estuary to Fiddlers Ferry.

Marine Mammals

11.5.146 Information currently available regarding marine mammal species in the Upper Mersey Estuary is very limited and has been mainly derived from a relatively small number of public sightings and strandings. A presentation by the Mersey Basin Trust on cetaceans in the Mersey was attended in March 2006, further information for this aspect of the Environmental Impact Assessment was also provided by the Mersey Basin Trust (Cooper pers. comm.) and the Mersey Estuary Conservation Group (Ref. 60).

Evaluation and Assessment

11.5.147 Impacts potentially occurring as a result of either the construction or operation of the New Bridge on aquatic ecology were identified. Potential impacts during the construction and operation phases are discussed in more detail in Section 11.7.

11.5.148 The impact assessment was undertaken in line with the IEEM Guidelines for Ecological Impact Assessment in the UK (Ref. 61). The main assessment criteria are described below and are derived from the IEEM guidelines. The assessment of ecological impacts was qualitative, impacts were assessed based on a combination of empirical data, expertise, professional judgement, experience and anecdotal information from relevant schemes.

11.5.149 In the absence of quantitative probability data expert judgement was required to assess the likelihood of impacts. Assessments were expressed using the terminology referred to in the IEEM guidelines. The likelihood of an impact occurring was, therefore, described using the following terms;

a. Certain (probability estimated at 95% chance or higher);
b. Probable (probability estimated above 50% but below 95%);
c. Unlikely (probability estimated at above 5% but less than 50%); and
d. Extremely unlikely (probability estimated at less than 5%).

11.5.150 A number of parameters were considered when making assessments of significance. Although reference was not necessarily made to them directly, appropriate aspects which were considered included:

a. Whether any impacts were positive or negative;
b. The magnitude of any impacts;
c. The extent of the impacted zone;
d. The duration of the impact (short (<40 months), medium (40 months to 10 years) or long term (>10 years);
e. The reversibility of impacts (i.e. permanent/temporary); and
f. The timing and frequency of impacts in relation to key environmental sensitivities.

11.5.151 As outlined in the IEEM guidelines the value or sensitivity of the site or feature involved, and the anticipated magnitude of the resulting impact, were also key considerations when assessing potential impacts of the Project on aquatic ecology.

Importance of Receptor

11.5.152 In accordance with terrestrial ecological assessments the importance of the receptor site for aquatic ecology was determined via professional judgement based on available information.

11.5.153 Overall, the value of the receptor site was determined based on numerous considerations including:

a. Biodiversity value;
b. Social/community value; and
c. Economic value.

11.5.154 Biodiversity value was the key concern of the Aquatic Ecology Chapter and a number of key aspects were considered when assessing this value. Firstly, the geographical context was determined based on the following frame of reference:

a. International;
b. UK;
c. National (i.e. England/N. Ireland/Scotland/Wales);
d. Regional;
e. County (or Metropolitan);
f. District (or Unitary Authority, City or Borough);
g. Local or Parish; and
h. Within zone of influence only.

11.5.155 Ecological designations within the area potentially impacted by the Project were then identified. Sites of international importance include Ramsar Sites, SACs and SPAs. Candidate SACs and potential SPAs should also be given the same consideration as designated sites. Sites of national importance include SSSIs and National Nature Reserves. Numerous sites are designated by Local Authorities and The Wildlife Trusts on a local scale.

11.5.156 When designated sites are present with different values, the highest level present is the one on which the assessment is based. Although the site of the Project is upstream of the Mersey Estuary SPA and SAC, it was considered best practice to apply the value of these internationally important designated areas when conducting the impact assessment.

11.5.157 As outlined in the IEEM guidelines, biodiversity value was also assessed based on specific species of interest which were considered to be likely to be present within the area potentially impacted by the Project. Specific consideration was given to protected species (for example Annex II species as designated by the EC Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora) and other species considered to be of biodiversity value.

Magnitude of Impact

11.5.158 Impacts were assessed as having a direct or indirect effect on the receptor in question. The magnitude of the impacts on ecology and nature conservation were then categorised as follows following the IEEM guidelines and were classed as being positive or negative:

High:	an extensive and irreversible effect on the numbers of species present and/or extensive and irreversible loss or alteration of habitats.
Moderate:	a measurable effect on the numbers of species present or loss/alteration of habitats, which is extensive, affecting beyond the immediate area surrounding the site of the proposed scheme.
Low:	a measurable effect on the numbers of species present or loss/alteration of habitats, which is restricted to the local area surrounding the site of the proposed scheme.
Negligible:	no measurable effect on the numbers of species present or loss/alteration of habitats.

11.5.159 Based on the above information it was assessed whether an impact was significant or non-significant. When a significant impact was identified it was classified as having high, moderate or low significance.

11.5.160 Where appropriate outputs from other Chapters were used to inform the assessment of ecological impacts. The impact was determined based on the value or sensitivity of the site or feature being assessed, whether the impact was positive or negative and the anticipated magnitude of the resulting impact.

Mitigation and Enhancement Measures

11.5.161 Appropriate mitigation measures were suggested to reduce the significance of all impacts identified for aquatic ecology and for cumulative impacts.

11.5.162 The ‘mitigation hierarchy’ produced by the DETR (Ref. 62) was used to address impacts (Table 11.13). Options for mitigation at the higher end of the hierarchy were the first to be considered. If these were not appropriate, potential forms of mitigation lower in the hierarchy were examined until a successful form of mitigation was identified which was as high up the hierarchy as possible. This was undertaken for impacts created during all stages of the project development (design, construction and operation). In some cases mitigation measures themselves may create impacts, all of which were assessed.

11.5.163 Enhancement measures which would be beneficial to the aquatic ecology of the study area were suggested where appropriate. These would enhance positive impacts created by the development of the Mersey Gateway Project and form the lower stages of the Mitigation Hierarchy.

11.5.164 It was known that the direct avoidance of potential impacts associated with the construction phase would be difficult. The use of sensitive construction methods within the estuary would contribute towards minimising the impact of construction on the aquatic environment.

Table 11.13 - The Mitigation Hierarchy

Mitigation Hierarchy
Avoid at source
Minimise impacts at source
Abate impacts on site
Abate impacts at receptor
Repair impacts
Compensate in kind
Other compensation and enhancement

Residual Impacts

11.5.165 Residual impacts on aquatic ecology following mitigation measures were identified and their significance determined.

11.6 Baseline and Results

Estuarine Algae

Algal Biomass

11.6.1 A quantitative estimate of algal biomass was determined from the concentration of chlorophyll in samples taken from 19 sites for 2004 and 2005 and 13 sites for 2006 and 2007 in the Estuary taken across several seasons (Chart 11.1, below). Samples from all sites and all seasons were always dominated by diatoms which in many instances accounted for >90% of species within a sample. As diatoms contain a very high proportion of chlorophyll *c* relative to chlorophyll *a*, total chlorophyll was measured in all samples (as opposed to just chlorophyll *a*) and the results are displayed in Chart 11.1. A Mood's median test was used to analyse the temporal and spatial variation in biomass data.

Spatial variation

11.6.2 There was a significant difference in chlorophyll concentration (i.e. algal biomass) among zones (Table 11.14), as concentrations in Zone 2 and 3 were significantly greater than in Zone 1 ($p \leq 0.001$), (Table11.14, Chart 11.1).

Chart 11.1 - Mean total chlorophyll measurements within Zones 1-3 for each sample season.

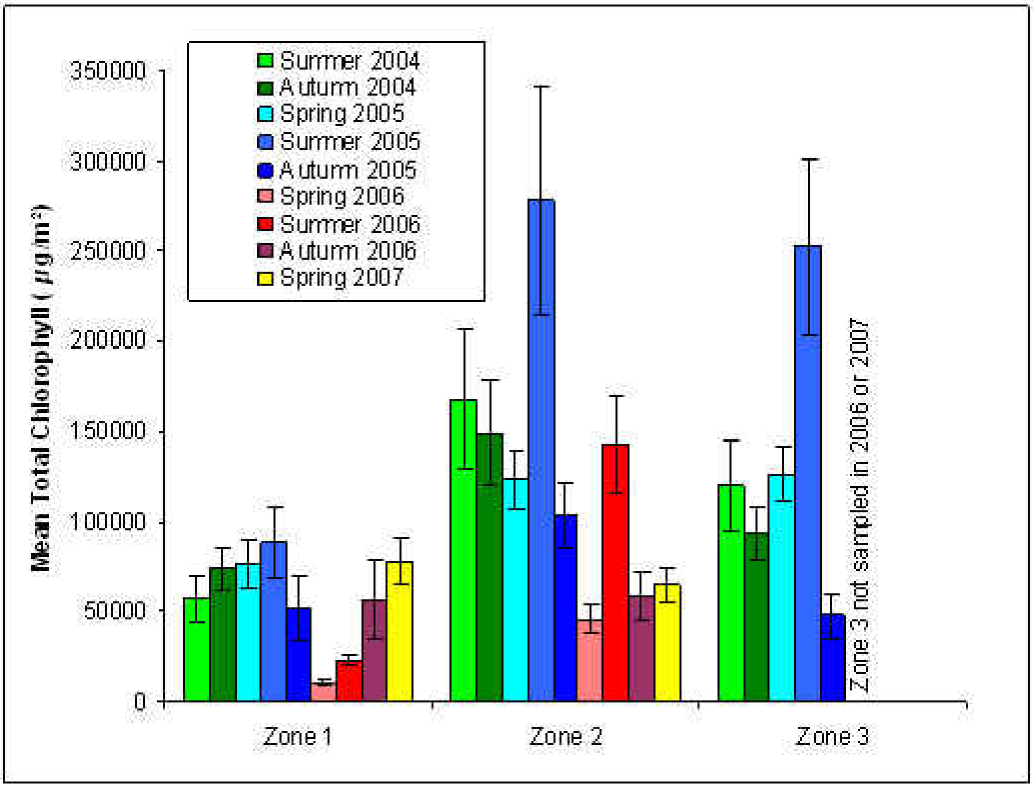


Table 11.14 – Comparisons of median values for species concentrations of total chlorophyll ($\mu g\ m^{-2}$) between zones, seasons and years for the Upper Mersey Estuary. Chi squared output is the result of separate mood median tests performed on each of the variables. Letters denote significant differences (e.g. values with the same letter are not significantly different from each other). *p<0.05, ** p<0.01, *** p<0.001

	Zone				Season				Year				
	1	**2**	**3**	**X^2**	**Spring**	**Summer**	**Autumn**	**X^2**	**2004**	**2005**	**2006**	**2007**	**X^2**
Chlorophyll conc.	35210 a	74767 b	108657 b	29.48***	56405.6	72136.6	58401.9	2.56 NS	78583.3 a	78902.1 a	28492.5 b	57223.5 a	24.26***

Temporal variation

11.6.3 When median chlorophyll concentrations were considered across all years concentrations in summer were higher than in spring and autumn, however, this difference was not significant (Table 11.14). In contrast, a significant difference was noted among years with concentrations being lower in 2006 than during any of the other years.

11.6.4 Chlorophyll concentrations tended to reach a peak in the summer for Zone 2, and to a lesser extent in Zone 3 (based on the five seasons of sampling within Zone 3), (Chart 11.1). In Zone 1, the seasonal trend was less apparent, with peaks in chlorophyll concentration in 2004 and 2006 occurring in autumn, but in 2005 peak concentrations were measured in summer.

11.6.5 Contour maps generated for the entire study area within the Estuary provided a graphical depiction of changes in algal biomass over time (Figures 11.5a-j, below). These maps reveal that for some sampling occasions, the highest biomass of algae was in Zone 2 (Mid Zone of the estuary) reaching concentrations of up to 500,000 – 600,000 μg m^{-2} during summer and autumn in 2004, and during summer in 2005 and 2006. In spring and autumn 2005, spring and autumn 2006 and spring 2007 chlorophyll concentrations in Zone 2 were lower and a more uniform distribution was observed across zones.

11.6.6 It is important to note that these contours can be strongly influenced by very high levels of algal biomass recorded at individual sites, which occurred at Sites 11 and 12 within Zone 2 during 2004 and 2005. The contour lines on the map result from computer interpolation algorithms rather than actual measured boundaries between the levels of chlorophyll present. Therefore, these patterns can be generated when there is very high biomass at just one or two sites and very low biomass at all other sites. This explains why the contour maps suggest algal abundance is consistently greatest in Zone 2 during 2004 and 2005 when in fact the mean abundance between Zones 2 and 3 was actually very similar (Figures 11.5a-i).

11.6.7 Mean algal biomass further indicates that biomass tends to be slightly higher in Zones 2 and 3 in all seasons (chlorophyll concentrations of ~150,000 to 250,000 μg m^{-2}), than in Zone 1 (~5,000-150,000 μg m^{-2}), (Figure 11.5j).

Figure 11.5a - Plot of algal biomass within the Upper Mersey Estuary for summer 2004

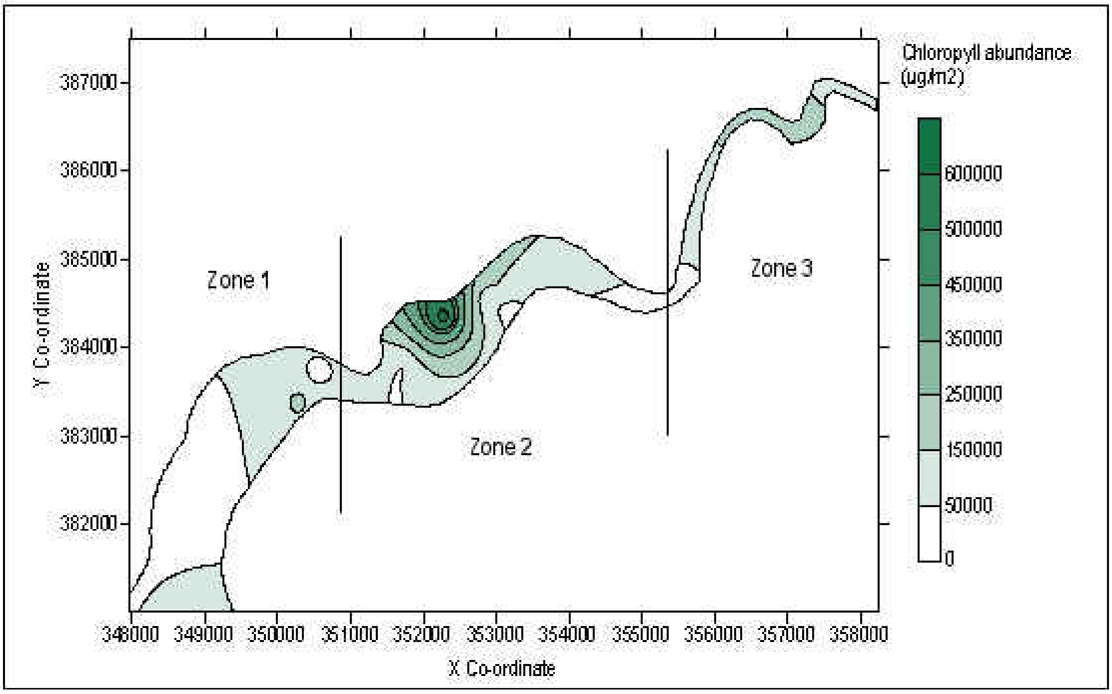


Figure 11.5b - Plot of algal biomass within the Upper Mersey Estuary for autumn 2004

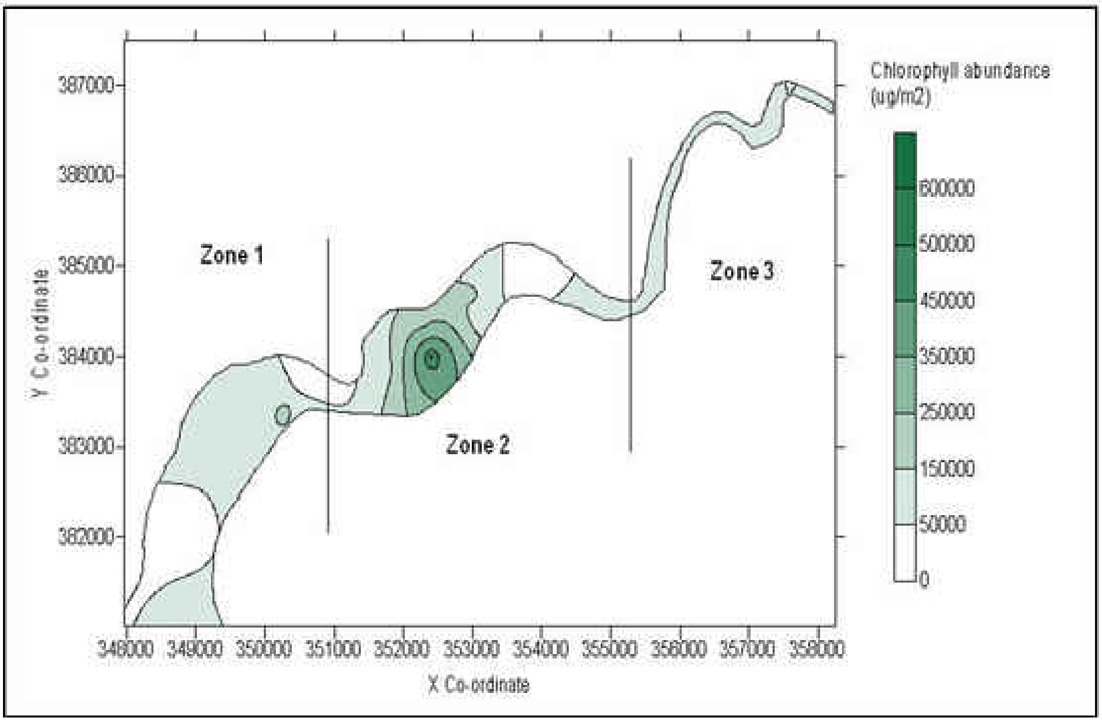


Figure 11.5c - Plot of algal biomass within the Upper Mersey Estuary for spring 2005

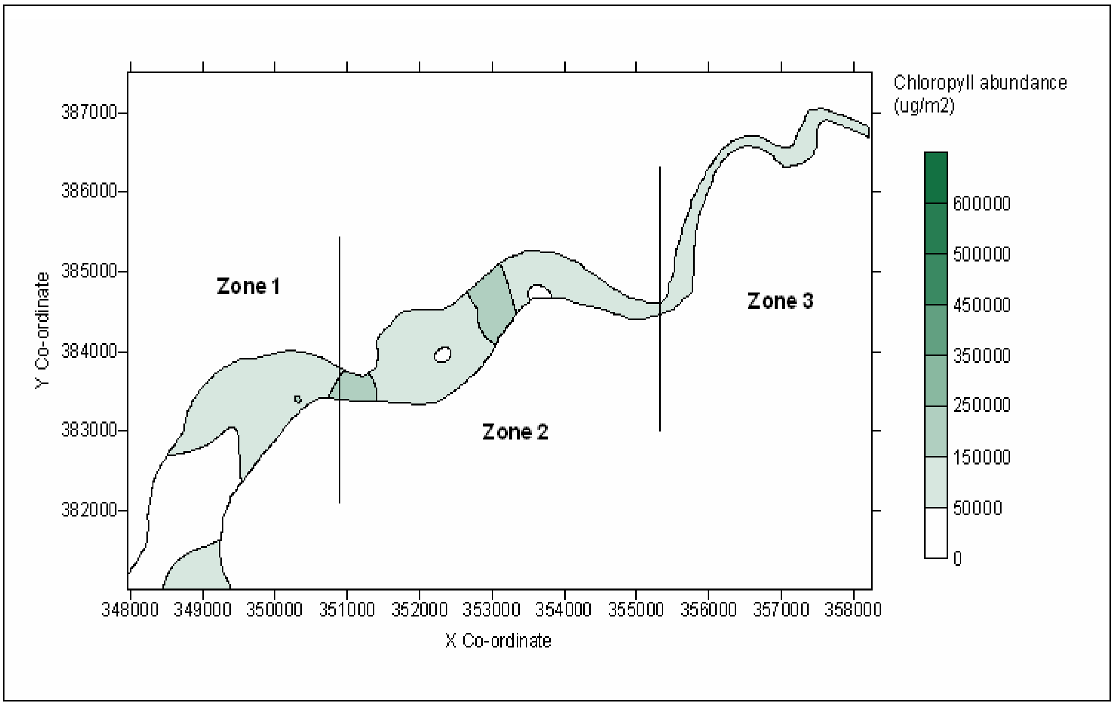


Figure 11.5d - Plot of algal biomass within the Upper Mersey Estuary for summer 2005

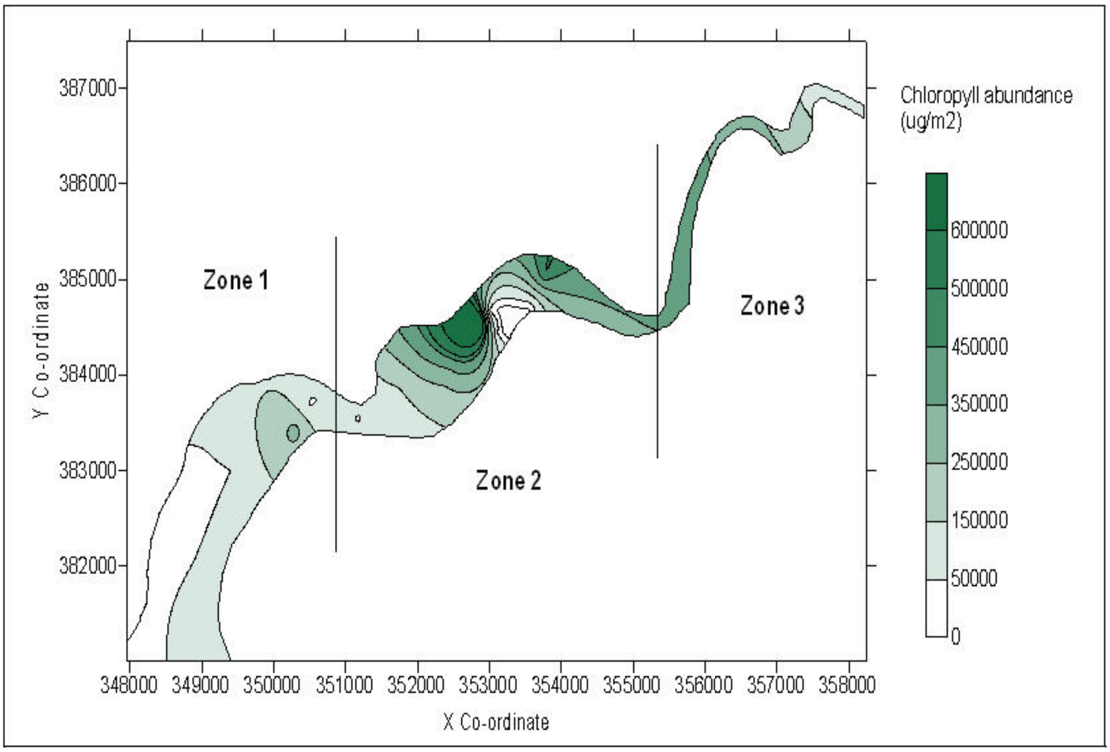


Figure 11.5e - Plot of algal biomass within the Upper Mersey Estuary for autumn 2005

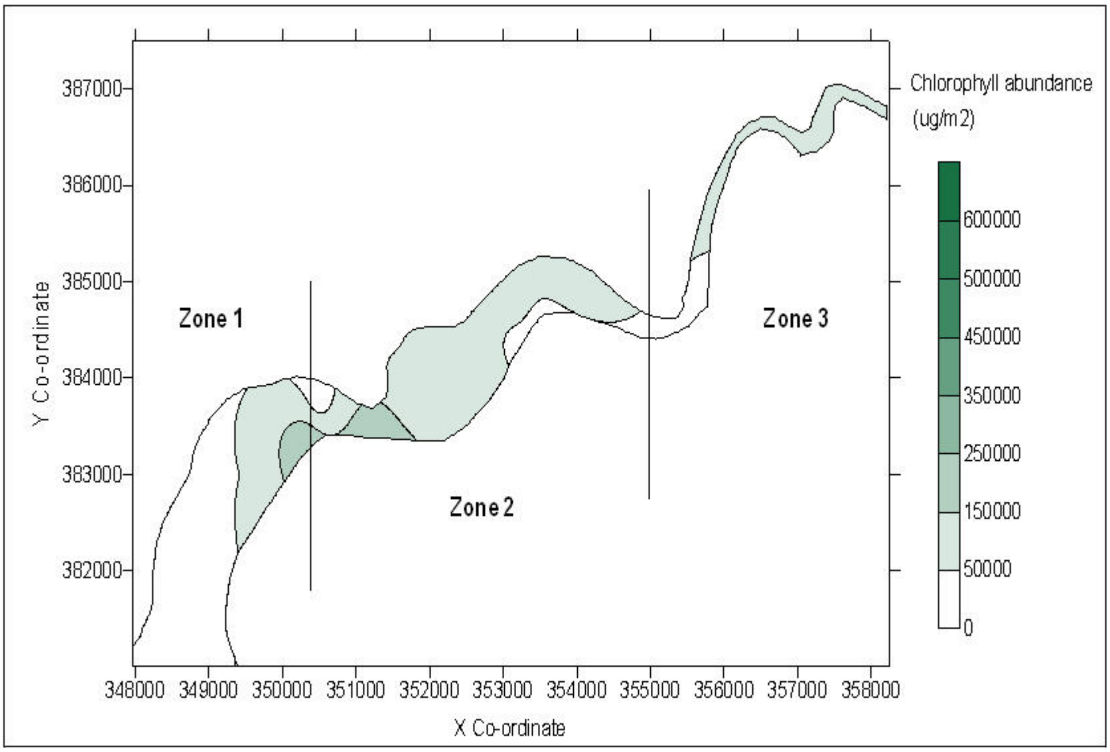


Figure 11.5 f - Plot of algal biomass within the Upper Mersey Estuary for spring 2006

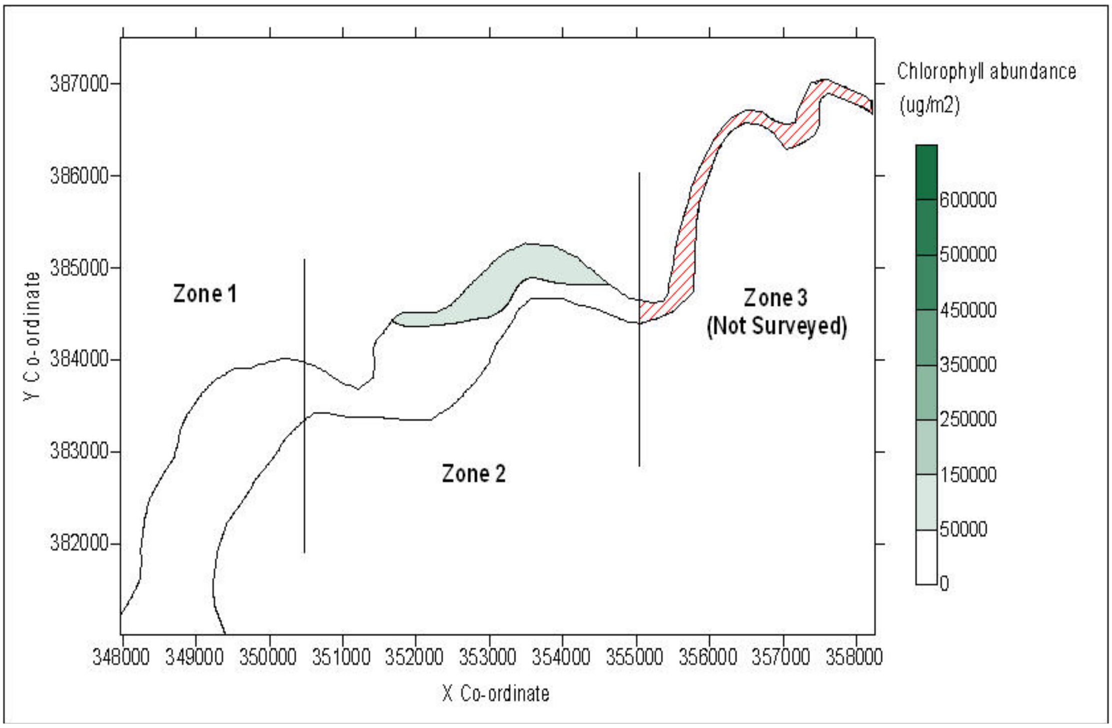


Figure 11.5g - Plot of algal biomass within the Upper Mersey Estuary for summer 2006

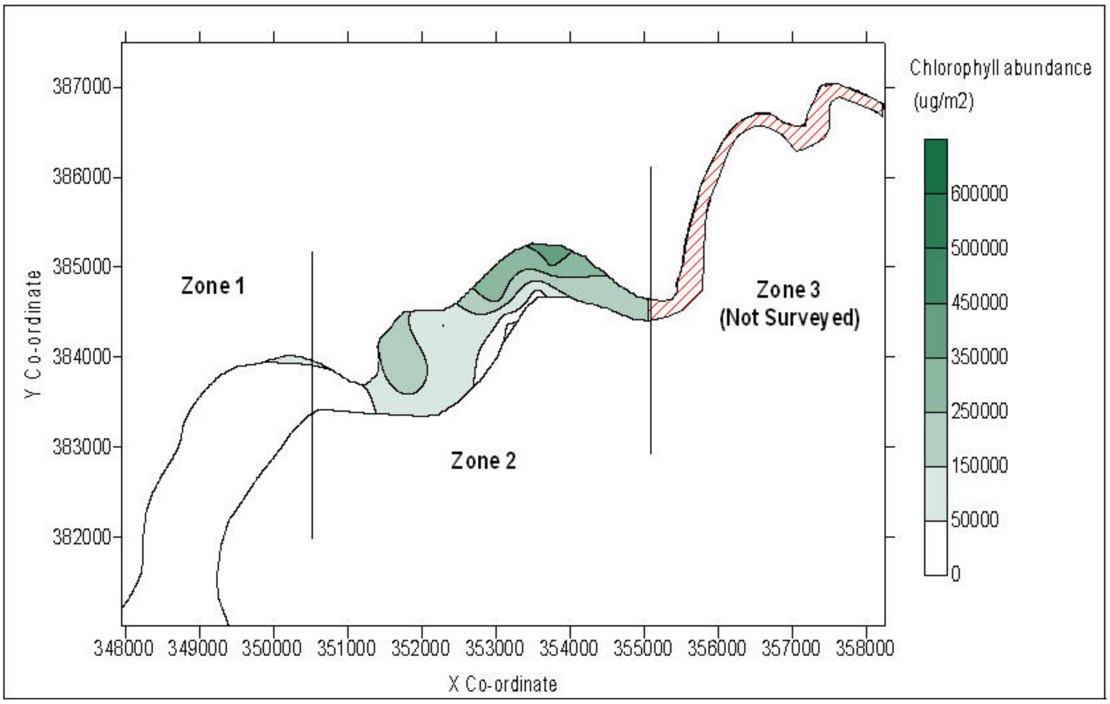


Figure 11.5h - Plot of algal biomass within the Upper Mersey Estuary for autumn 2006

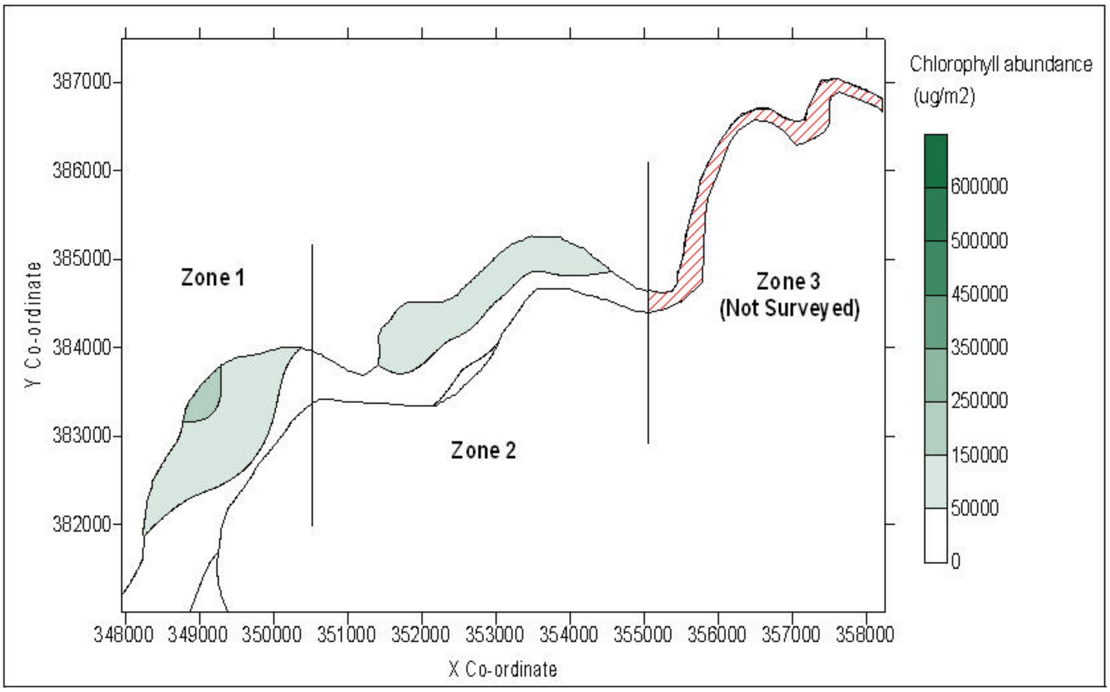


Figure 11.5i - Plot of algal biomass within the Upper Mersey Estuary for spring 2007

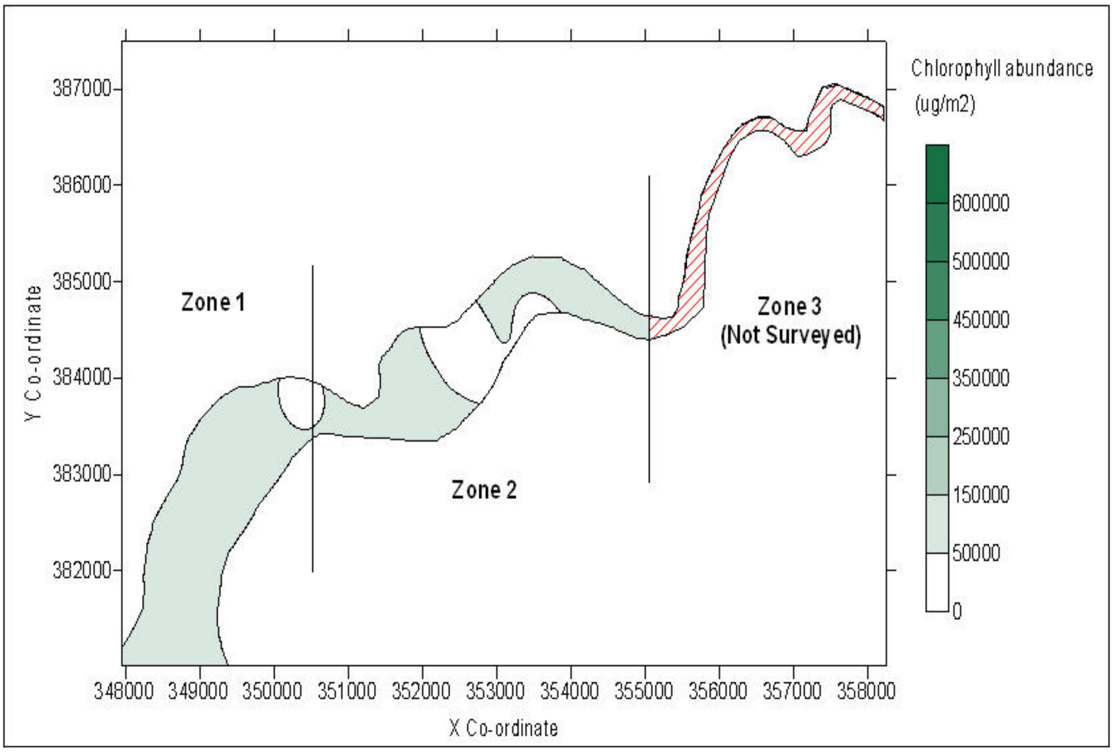
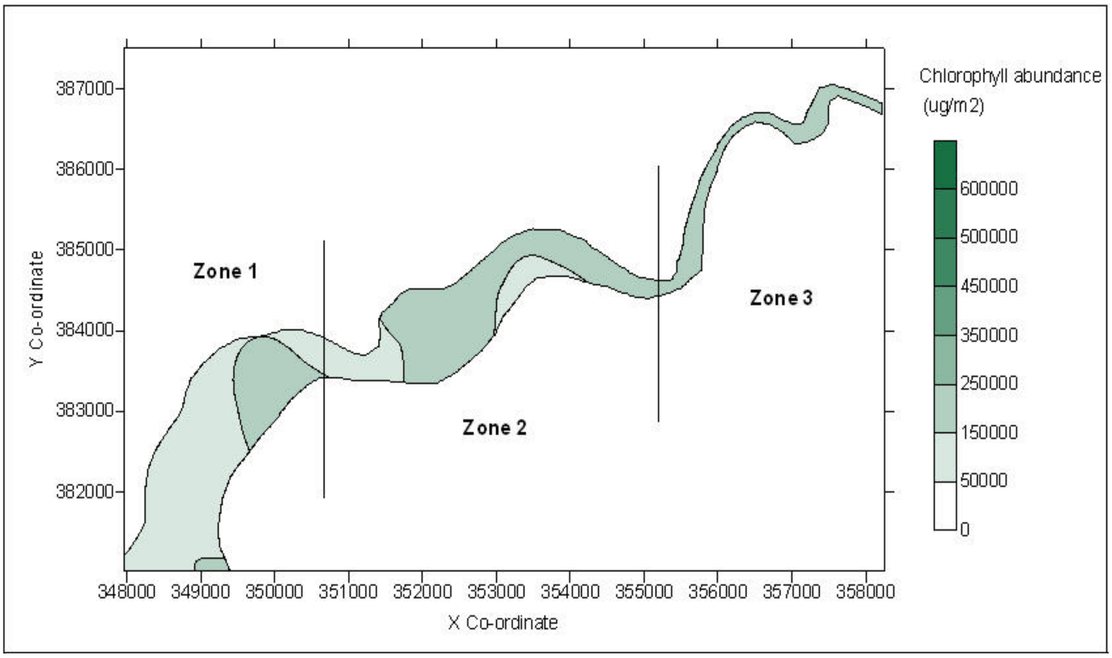


Figure 11.5j - Plot of mean algal biomass within the Upper Mersey Estuary between summer 2004 and spring 2007



Community Composition

11.6.8 Identification of taxa present within zones during different times of year enabled an assessment of temporal and spatial changes in the community composition of algae.

Spatial variation

11.6.9 Correspondence analysis was carried out to investigate the differences in algal species composition over the three zones. When the three zones were grouped according to their species composition there was a large overlap in the sites within the ordination indicating that many sites from each of the zones had a similar algal composition (Chart 11.2, below). There was, however, some separation of the Zone 3 sites from the Zone 2 and Zone 1 sites. It should be noted that the axes of the charts derived from correspondence analysis do not have a scale as the results indicate relationships of points (e.g. zones, seasons or species) to one another in two dimensional space.

11.6.10 By examining the position of various species in relation to the axes in Chart 11.3, below, and comparing them to the position of data points for sites within zones in Chart 11.2, the relative influence of various species on community composition within different zones was determined. For example, it can be seen that the Zone 1 and 2 sites had slightly higher proportions of flagellated Cryptophyta (*Rhodomonas spp*) and chlorophytes (unidentified flagellates) than sites in Zone 3. The algal species in Zone 1 and 2 were predominantly *Nitzschia* species (which are tolerant of nutrient and organic pollution) and motile *Nitzschia* and *Navicula* species. Zone 3 was characterised by mainly motile, but also some non-motile, diatom species with differing nutrient tolerances.

<u>Chart 11.2 - Correspondence analysis for each sampled site from summer 2004 to spring 2007. Data points are plotted according to algal species composition</u>

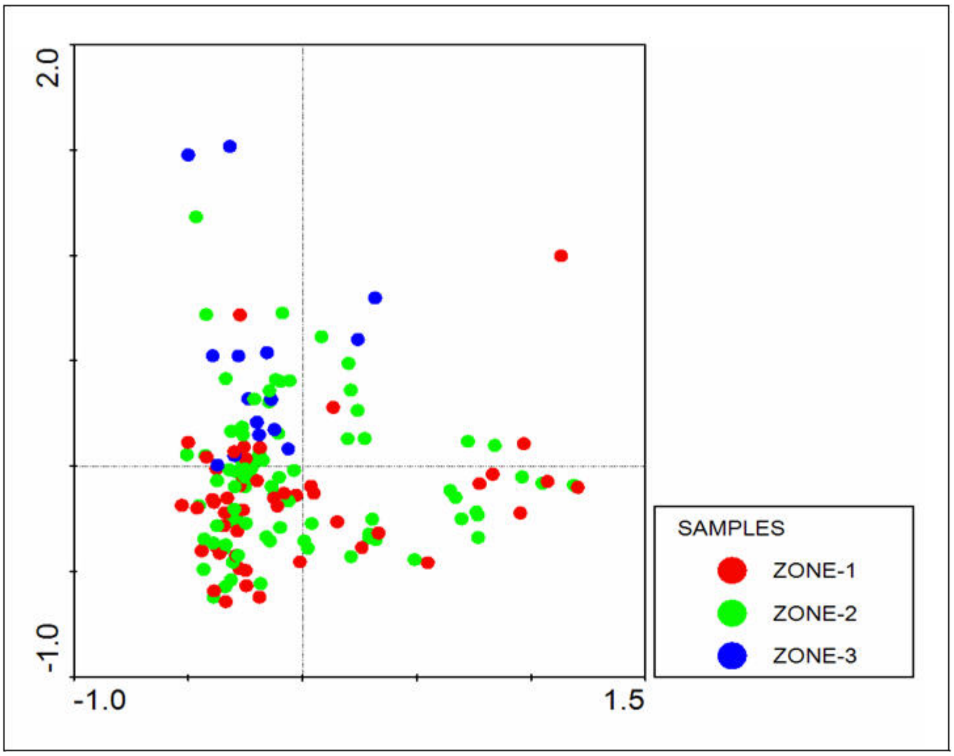
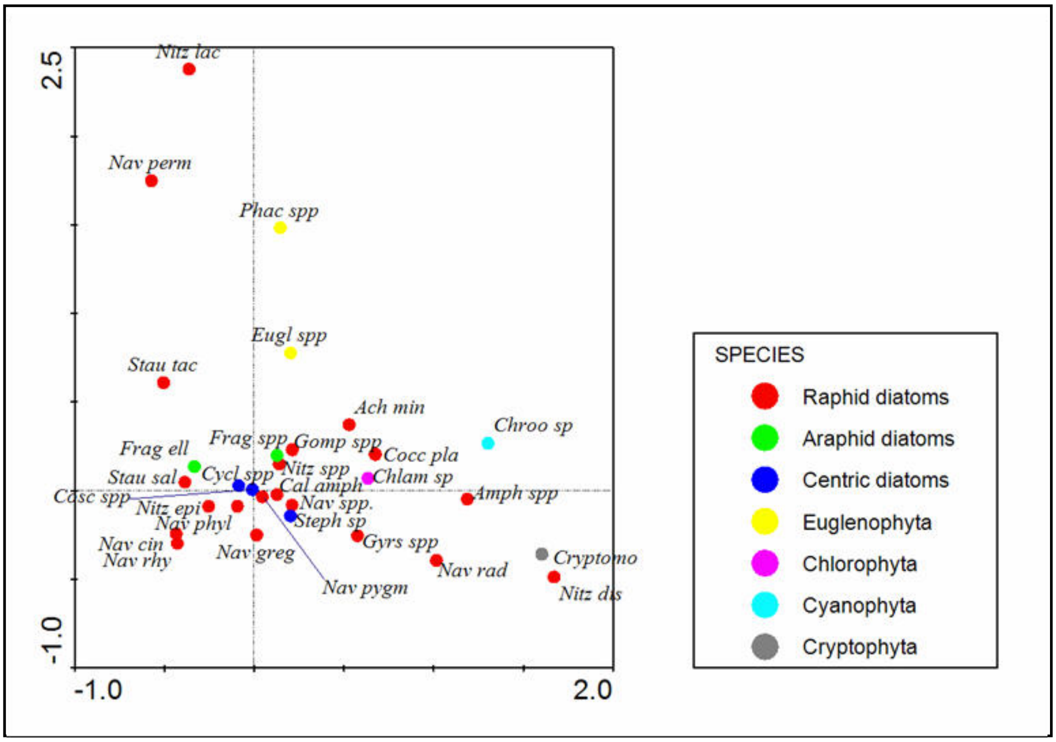


Chart 11.3 - Correspondence analysis indicating the relationships between algal species in samples from all zones from 2004 to 2007



11.6.11 Histograms were produced to indicate the number of specimens identified for each algal species for all zones and seasons (Figures 11.6a-I, Appendix 1.1). Species with particularly low abundances at all sites were omitted from the histograms, as was information regarding the algal assemblage at Site 18 in autumn 2004, and Site 17 in summer 2005 and spring 2006 as counts were particularly low.

11.6.12 In the autumn 2004 survey, *Navicula cinta* accounted for the greatest percentage of the algal community in Zones 1 and 2, but very few were sampled in Zone 3. In the spring 2005 survey, Zones 1 and 2 were dominated by *Navicula rhynchocephala* and *N. cinta*, whereas in Zone 1 these species formed a very small proportion of the algal assemblage. In the summer 2005 survey the most notable zonation was displayed by *Nitzchia dissipata*, which was absent in Zones 2 and 3 but dominated the algal population in Zone 1 (Figures 11.6a-I, Appendix 1.1).

11.6.13 In the spring and summer of 2006 *Navicula* and *Nitzschia* species predominated in both Zones 1 and 2 (Zone 3 was no longer sampled) but these species accounted for a greater proportion of the diatom community in Zone 2 than in Zone 1 during autumn 2006 (Figures 11.6g-h, Appendix 1.1). In spring 2007 *N. rhyncocephala* dominated in both Zones 1 and 2.

11.6.14 Species richness (i.e. total number of species sampled), for each zone and season is indicated in Table 11.15. Across the whole of the sampling period, species richness was relatively low ranging from 13 to 35 species. In general the number of species present was lowest in Zone 1, slightly higher in Zone 2 and Zone 3 had the greatest species richness. Species richness was particularly low in spring 2007 with only 6 taxa recorded in Zone 1 and 9 taxa recorded in Zone 2.

Table 11.15 - Mean species richness of sites within each zone during each sample season

Zone	Mean species richness scores								
	Summer 2004	Autumn 2004	Spring 2005	Summer 2005	Autumn 2005	Spring 2006	Summer 2006	Autumn 2006	Spring 2007
1	17	14	13	13	16	16	33	18	6
2	17	15	18	17	25	13	35	18	9
3	23	16	20	19	24	N/A	N/A	N/A	N/A

11.6.15 Diversity of the communities present was measured using the Shannon-Wiener index (Table 11.16). The value of this index ranged from 0.5 to 2.7 among sites across all seasons. In general, the diversity of species increased moving upstream from Zone 1 to 3. In 2006 and 2007, however, species richness in Zone 1 was found to be greater than in Zone 2. In spring 2007 diversity indices were particularly low in the two sampled zones which mirrored the low species richness recorded during this period and reflected the fact that the algal community was dominated by a single species (*N. rhynchocephala*). The shifting nature of species diversity is typical of estuarine environments and can be caused by a variety of environmental influences, as discussed in Paragraphs 11.6.33 to 11.6.38.

Table 11.16 - Mean species diversity scores of sites within each zone during each sample season

Zone	Mean Shannon Wiener Index scores								
	Summer 2004	Autumn 2004	Spring 2005	Summer 2005	Autumn 2005	Spring 2006	Summer 2006	Autumn 2006	Spring 2007
1	2.2	1.9	1.6	1.6	1.8	1.6	2.7	2.2	0.5
2	2.2	2.1	1.9	1.9	2.6	1.2	2.3	2.1	0.8
3	2.6	2.2	2.3	2.2	2.6	N/A	N/A	N/A	N/A

Temporal variation

11.6.16 There was no consistent trend with regards to species richness among seasons for each zone, although a relatively higher number of species was recorded for each site in autumn 2005 and summer 2006.

11.6.17 There was no obvious relationship between species diversity and season and the highest level of diversity (2.7) was recorded in Zone 2 in summer 2006 (Table 11.16).

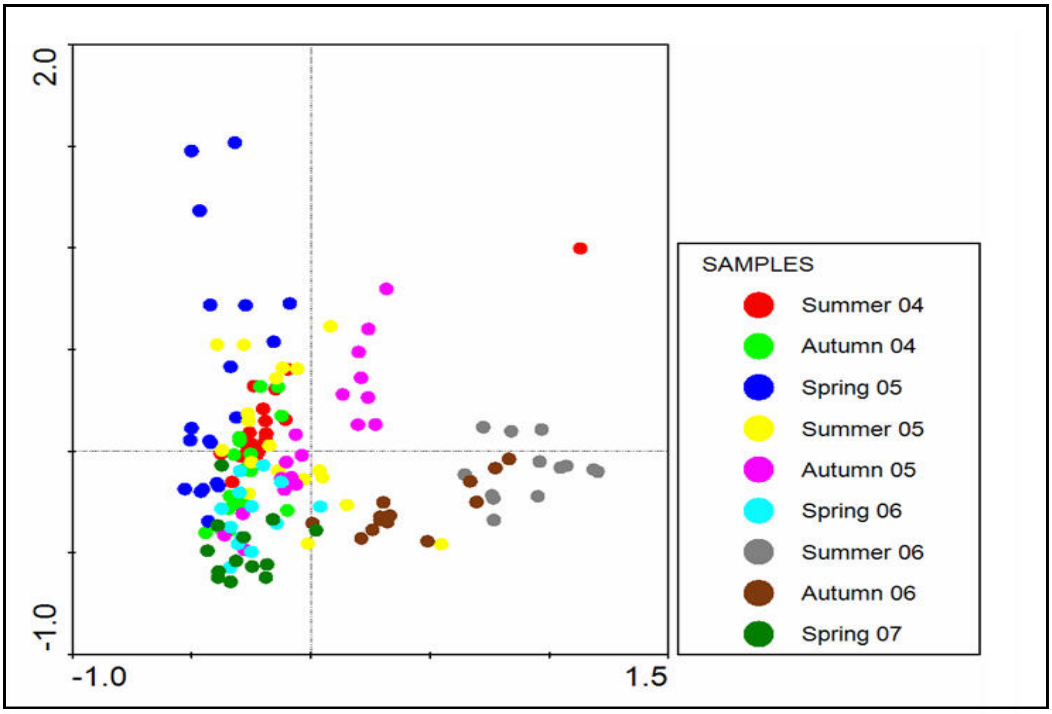
11.6.18 There was considerable variation in the composition of the algal community among both seasons and years. For example, in summer 2004 *Navicula phyllepta* was the dominant species across all zones. By autumn 2004, however, the abundance of *N. phyllepta* had decreased considerably and *N. cinta* had become the dominant species. In the spring 2005 survey there was still a relatively high proportion of *N. cinta* but the population of *N. rhynchocephala* had increased dramatically from relatively low numbers in summer and autumn 2004 (Plate 11.5, Appendix 11.2). During the spring 2005 period *N. rhynchocephala* accounted for 20-80% of the algal assemblage at most sites (Figure 11.6c, Appendix 11.1).

11.6.19 Further shifts in community composition were evident in summer 2005 as the dominance of *N. rhynchocephala* decreased significantly and *N. phyllepta* emerged as a dominant species at many sites. In addition, *Nitzschia dissipeta* (which had not been recorded in previous surveys) was the dominant species in Zone 1. *Chlamydomonas spp.* and *Stauroneis tackei* were other species which were recorded for the first time in summer 2005, attaining relatively large population sizes at a few sites. *N. rhynocephala* returned as a co-dominant species alongside *Navicula gregaria* in autumn 2006 (Figures 11.6d & h, Appendix 11.1). In spring 2007, *N. rhynchocephala* dominated to a far greater extent than previously seen accounting for over 80% of the algal community at most sites (Figure 11.6i, Appendix 11.1).

11.6.20 The algae sampled in the autumn 2005 survey reflected the community sampled in spring 2005 in that *N. rhynchocephala* was dominant. However, *Achnanthes minutissima* which had not been recorded previously was observed to dominate at least one site in each of the sampled zones in autumn 2005 (Figures 11.6c-h, Appendix 11.1). *N. rhynchocephala* dominated again in spring 2006 but gave way to a mixed community of *Navicula* and *Nitzschia* species in the summer. In autumn 2006 the algal community was dominated by *N. rhynchocephala*, *N. phyllepta*, *N. gregaria* and *N. cinta*. *Crytomonas* spp. (first detected during the summer 2006 survey) were also present in high numbers at some sites during this period.

11.6.21 Correspondence analysis was used to create a scatter plot of the algal data collected at different sites during the nine sample seasons (Chart 11.4, below). The sites sampled in summer and autumn 2004 were grouped relatively close together indicating similar algal assemblages. In general, there is a degree of crossover of algal assemblage for most sampling occasions, with the exception of summer and autumn 2006. These data points were spread out towards the right of the scatter-plot indicating a period of differing species composition. Analysis of histograms and Chart 11.3 indicated this shift was largely due to the emergence of *Nitzchia dissipata* and *Navicula gregaria* along with the reduced dominance of *N. rhynchocephala.*

Chart 11.4 - Correspondence analysis scatterplot of sites as determined by their algae species composition during each sample season (Site 18 was omitted from autumn 2004 analyses and Site 17 was omitted for summer 2005 and spring 2006 analyses due to insufficient data)



Discussion of baseline data (Estuarine Algae)

11.6.22 Primary producers such as algae collectively constitute the largest percentage of food web biomass in estuaries. Benthic algae (along with other photobenthic groups) are essential for estuarine productivity providing food for primary consumers (e.g. zooplankton and filter feeders). Therefore, it is essential to establish the presence and biomass of these organisms when assessing the quality and status of aquatic environments (Ref. 48). Benthic algae biomass and composition is dependent upon water quality, substrate stability and sedimentation rates, flow velocities and the amount of light penetrating through the water column. They are, therefore, effective indicators of ecological status and of environmental change and their composition changes more rapidly in response to environmental perturbation than invertebrates (Ref. 63, Ref. 64). Consequently, benthic algae are likely to be important monitoring tools for the implementation of the Water Framework Directive in estuaries and coastal waters as well as in freshwater environments.

11.6.23 Benthic algae, including microalgae, are often found within habitats at the interface between solid surfaces and the surrounding water. The greatest biomass of these organisms usually occur in the intertidal and shallow subtidal regions where light can still penetrate the water column and be used for photosynthesis (Ref. 18).

11.6.24 Of all the habitats represented in the Upper Mersey Estuary, the intertidal sediments of sand and silt (in terms of surface area) are the largest habitats available for the colonisation of algae, which is why sampling was concentrated within the intertidal zone.

Algal Biomass

11.6.25 In general, it was observed that the chlorophyll concentration, and hence algal biomass, was similar in Zones 2 (mid section of survey area) and 3 (upstream section of survey area) but the biomass of algae was significantly greater in both of these zones than in Zone 1 (downstream section of survey area). Due to the wide range of factors contributing to algal growth and the unpredictability of sediment movement (as discussed in Chapter 7: Hydrodynamics and Estuarine Processes Movement) within the Estuary the causes of specific patterns of algal distribution and abundance are likely to be numerous and complex.

Spatial variation

11.6.26 Spatial trends in chlorophyll concentrations (i.e. algal biomass) often reflect distributions of nutrients in the water column. Acceptable levels for nitrate and phosphate concentrations have not yet been described for estuaries and therefore within Chapter 8: Surface Water Quality concentrations have been assessed using the EA's GQA classification for rivers. These results indicate that the nitrate concentrations within the Upper Mersey Estuary fall within the moderately low to very low categories of the EA GQA river classification. Phosphate levels, however, are classified as being high to very high under the EA GQA system. Importantly, results indicate that concentrations of both nitrate and phosphate do not vary significantly throughout the Upper Mersey Estuary. Therefore, within the area sampled the concentrations of nutrients available for photosynthesis and algal biomass production do not appear to influence spatial variation in algal biomass.

11.6.27 Another important consideration is turbidity of the water column due to the suspension of sediments by tidal action. This has an impact on algal photosynthesis due to attenuation of sunlight through the water column increases with an increase in turbidity. However, the results of the SWQ assessment reveal that there is no consistent trend among zones in terms of the levels of suspended solids. Suspended solid concentrations were highly variable between locations and between surface and bottom waters. Therefore, although turbidity is likely to have an impact on algal productivity it is not expected to result in the lower algal biomass within the zone furthest downstream (Zone 1) when compared with Zones 2 and 3. Because of the Mersey's large tidal range and associated high turbidity, light attenuation during high tide may be greater in the Mersey than other less turbid estuaries, therefore having a greater impact upon algal biomass.

11.6.28 The data shows that diatoms dominated the algal assemblage within the estuary, regularly accounting for over 90% of the algae sampled. One of the main influences on diatom abundance is the availability of dissolved silicate which is required for the formation of silica frustules. In UK estuaries the majority of silicate within the water column is derived from the input of rivers and streams (e.g. up to 90% in the Severn estuary (Ref. 3)), consequently its availability can potentially decrease moving from the Upper to Lower Estuary which could contribute to the decrease in diatom abundance observed at the sites furthest downstream (Zone 1).

11.6.29 Reasons for the particularly high biomass of algae at Sites 11 and 12 during the summer months are not entirely clear. It was noted that this area tends to remain moist at all stages of the tide (unlike other sites within Zone 2), which may be beneficial for algal growth. Other potential reasons are that the substrate may be more suitable for algal growth, or sediments at these sites may be less prone to shifting with tidal water movement. Furthermore Chapter 8: Surface Water Quality discusses how the area upstream of SJB (encompassing these Sites 11 and 12) tends to be relatively stable in terms of river channel movement. There was no indication that water quality and suspended solid concentrations at Sites 11 and 12 were significantly different to the other sites.

11.6.30 It is also important to recognise the importance of grazers on the biomass of algae. The abundance of grazers and browsers impacts upon the amount of algae present, and grazers are expected to be attracted to areas of high algal biomass. High proportions of *Cocconeis placentula*, for example, can be indicative of invertebrate grazing pressure (Ref. 65). *Hediste diversicolor* (rag worm) grazes on algae and this species was found in much higher abundances in Zones 1 and 2 than in Zone 3.

Temporal variation

11.6.31 When all sample periods were considered there was found to be no significant difference between data from each season. However, rapid changes in the abundance of algae were noted from season to season even though the changes observed were not necessarily consistent among years. Biomass estimates for summer 2005 and summer 2006 appeared to be considerably higher than for the preceding spring seasons. Local variation was also observed and this was notable for Sites 11 and 12 during the summer and autumn 2004 and summer 2005 (very high chlorophyll concentrations were recorded at these sites during these periods). However, in the spring and autumn in 2005 and 2006, and spring in 2007, the algal biomass at these sites was relatively low. This analysis illustrates the great natural variation in algal biomass that occurs on an annual and seasonal basis. Such observations are common in estuarine environments and observed elsewhere in the UK, such as in the Trent estuary, where Skidmore *et al.* (Ref. 66) found large fluctuations in algal biomass between seasons.

11.6.32 Two of the most important factors determining temporal variation in algal biomass are changes in temperature and light availability. For example, warm, sunny conditions can encourage growth and stimulate algal blooms. A very high algal biomass was noted during summer 2005 in Zones 2 and 3. For the region of the Estuary studied there were 56 more hours of sunshine during summer 2005 than in summer 2004. However, the amount of sunshine increased again during summer 2006 by a further 74 hours (Ref. 67), although algal biomass was significantly lower in summer 2006 than during the same period in 2005. Therefore, the mean amount of sunshine may have only played a partial role in determining the particularly high algal abundances recorded during summer 2005 in Zones 2 and 3.

Community Composition

11.6.33 Perhaps the most striking aspect of the algal community is that diatoms dominated the samples. Sullivan (Ref. 68) stated that diatoms are often the dominant component of an estuarine benthic microalgal assemblage, and this is the case for the Upper Mersey Estuary. Many diatom species are classified as ruderals under the life history traits identified by Grime (Ref. 69) as they have a high reproduction rate and predominate in environments where perturbations such as sediment movement, water turbulence or grazing limit the productivity of other algae. Many diatom taxa are able to attach to benthic sediments and therefore can persist against the flow which would carry other algal taxa out to sea, resulting in the domination of diatom species within estuarine environments.

Spatial variation

11.6.34 There was considerable variation in species composition between zones. Species composition in Zone 3 differed notably from that within Zones 1 and 2 in the autumn 2004 and spring 2005 surveys. In both surveys, *Navicula cinta* formed a very low proportion of the total algal population in Zone 3, but constituted a much larger proportion in Zones 1 and 2. In summer 2005 *Nitzchia dissipata* was prevalent in Zone 1 but notably absent in Zones 2 and 3. It appears, therefore, that different environmental conditions among zones may promote the growth, survival and reproduction of certain species and be detrimental to the growth of others.

11.6.35 Environmental variables such as water residency time may influence species composition. Since residency time is greater in Zone 1 due to the balance between water flowing in from the river and the incoming tide causing water to persist longer, higher proportions of planktonic flagellated species such as *Cryptomonas, Rhodomonas* and *Peridinium* spp. may be expected. These species are also indicative of greater depths of water above the sediment. However, while such species are found in Zone 1 there does not appear to be any clear variation between the zones. Upstream in Zone 3 some non-motile diatom species were present. These may be due to the reduced sediment deposition and water turbidity within this zone. Motile *Navicula* and *Nitzschia* species predominated throughout the estuary. These species are able to avoid burial by the sediments that occur in most parts of the estuary, but to a greater extent in the downstream zones.

11.6.36 A further gradient in algal composition was due to variation in preferences of algal species for different eutrophic states. Zones 1 and 2 were characterised by their predominance of *Navicula* species, *Nitzschia dissipata, Rhoicophenia abbreviata* and *Stauroneis* spp. which are indicators of high nutrient concentrations (Ref. 70, Ref. 71). Zone 3, was also characterised by algae which indicate high nutrient concentrations, however, in addition it contained *Fragilaria* species and *Frustulia* species which prefer lower nutrient concentrations (Ref. 70, Ref. 71).

11.6.37 Salinity variation is likely to be one of the most important environmental variables when explaining differences in the algal community and the biomass of different species among zones. Even small changes in salinity can be reflected in the diatom community. A variation in salinity of as little as 1% has been shown to be reflected in the diatom assemblage (Ref. 72). Those species which can tolerate low average salinities (and a relatively large salinity range) would be most likely to reach a high biomass in Zone 3 and to a lesser extent Zone 2, and would be the least likely to survive in Zone 1. Similarly, species well adapted to the higher salinities experienced in Zone 1 would be less well adapted for conditions in Zone 2 and especially Zone 3 resulting in reduced likelihood of survival.

11.6.38 In addition to differences in water quality, the distribution of different algal species can also be greatly influenced by the hydraulic regime within the estuary. Although there are areas of stable algal growth in the estuary, significant amounts of algae are also moved by the currents of the flood and ebb tides. In some areas algae are deposited along with sediment causing the build up of beds of deposited algae, whereas in others the sediment and algae are eroded by water movement and taken up into the water column. The location of beds of deposition undergoes constant change as the morphology of the estuary changes. However, as discussed in Chapter 7 (Hydrodynamics and Estuarine Processes Movement), the greatest deposition generally occurs on the large sand beds in the Mid Mersey Estuary and therefore, due to their location more likely to occur within Zones 1 and 2.

Temporal variation

11.6.39 During the summers of 2004, 2005 and 2006 the algal community was generally characterised by a mixed community of *Nitzschia dissipata*, *Navicula phyllepta*, *Navicula cinta, Fragilaria elliptica* and *Caloneis amphisbaena*. In contrast, the spring and autumn seasons of each of the three years tended to be dominated by only one or two diatom species, often *Navicula gregaria, N. phyllepta, N cinta* or *N. rhynocephala*. In the spring 2007 *N. rhynchocephala* displayed a level of dominance previously unseen within the current study, with many of the samples comprising in excess of 80% of this species. It is not clear whether this could be related to the fact that spring samples in 2007 were collected a few weeks earlier than in previous years.

11.6.40 Such seasonal succession in the composition of algal assemblages at different times of year is a common and natural occurrence, particularly in the case of diatoms (the dominant phylum in the Upper Mersey Estuary). Each diatom species has a particular ecological niche and many species can be very sensitive to environmental change. Some species are known to be colonisers, and these will predominate in the spring as the growing season begins, being replaced by faster growing, more competitive species in summer and autumn. In addition to seasonal succession, changes in species composition also occur in response to light, temperature, water quality and the physical constraints imposed by the tide and sediment movements. The major environmental conditions that affect the species composition are those such as temperature, salinity, pH, nutrient input and concentration of metals as well as the availability of light. In order to get an accurate representation of the benthic algal flora, therefore, it is recommended to sample at least three times a year to take account the effects of seasonal succession (Ref. 70).

11.6.41 With each survey there appears to be a certain degree of variation in species composition which doesn't appear to be associated with a seasonal pattern. For example the summer 2004 species composition shows a markedly different algal assemblage to summer 2005 and the autumn 2004 sample is very different to the autumn 2005 assemblage. Although there appears to be a number of core species that are always present the proportions in which they are found differs considerably. In addition the emergence of new species was recorded which had not been collected during any of the previous surveys, such as the presence of *Achnanthes minutissima* in the autumn 2005 survey. *Achnanthes minutissima* is a ruderal species and is an early coloniser of sediment. It is postulated that its appearance in 2005, may have followed enhanced sediment deposition in the estuary, although no actual annual sedimentation records exist to confirm this. In the summer of 2006 *Pleurosigma* spp. was sampled for the first time. This is a salt water genera and therefore its inclusion in the diatom flora may have been related to an increase in the influence of salt water during the low river flows in summer 2006.

Freshwater Macrophytes

Canals (including Charophyte survey)

Spatial Variation

11.6.42 The number of macrophyte species recorded was generally greater in the Bridgewater Canal than in the St. Helen’s Canal (Chart 11.5a and b, 11.6a and b). This was partly due to the fact that the Bridgewater Canal contained both channel and marginal vegetation whilst no channel plants were found in the St. Helen’s Canal.

11.6.43 During most sample seasons, species richness was slightly higher at Site 1 in the St. Helen's Canal than at Sites 2 and 3, whereas in the Bridgewater Canal there was no consistent variation in species richness among sites. No submerged macrophyte species were recorded at the St Helen’s Canal sites. Site 1 generally contained a greater number of marginal and terrestrial species than Sites 2 and 3, and it is thought that this may reflect the larger area of suitable habitat available to these species at Site 1 compared to the other two sites.

11.6.44 The charophyte survey of the Bridgewater Canal in 2005 found that *Nitella mucronata* var *gracillima* was present immediately upstream of the regular survey reach. This species is listed in the Red Data Book (Ref. 73). However, its status in Britain is described as ‘not threatened’. *Chara globularis* was distributed both upstream and downstream of the regular survey reach (i.e. 150 m either side of the proposed bridge site). This species is not in the Red Data Book and is described as being 'frequent in Europe, including Britain and Ireland' (Ref. 74).

Temporal Variation

11.6.45 There were seasonal differences in the number of species recorded with slightly fewer macrophyte species found during spring surveys (11.6a & b). There was some interannual variation in the numbers of species recorded for a specific season but no consistent pattern of variation in species number among years was evident.

Chart 11.5a - Total number of macrophyte species recorded per season at each sample site on the St Helen's Canal between summer 2004 and spring 2007

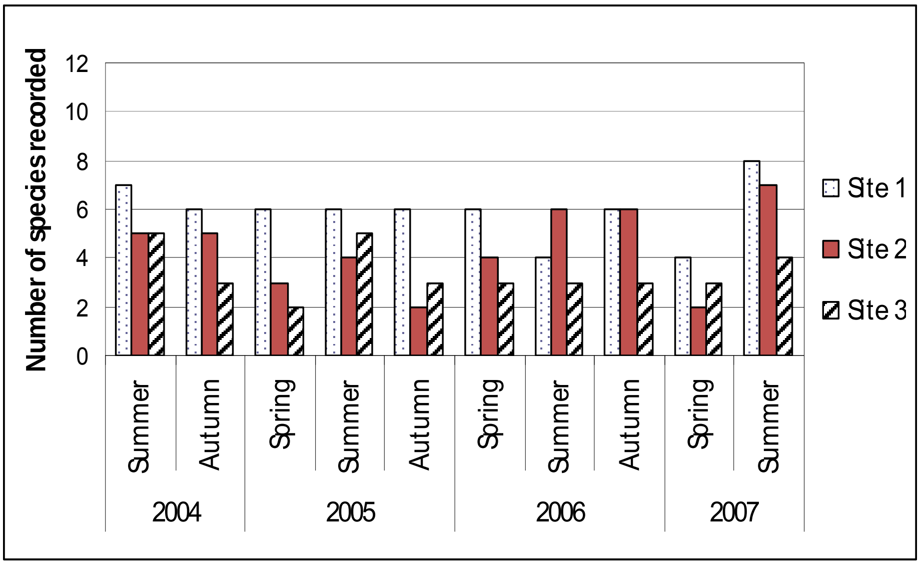


Chart 11.5b - Total number of macrophyte species recorded per season at each sample site on the Bridgewater Canal between summer 2004 and spring 2007

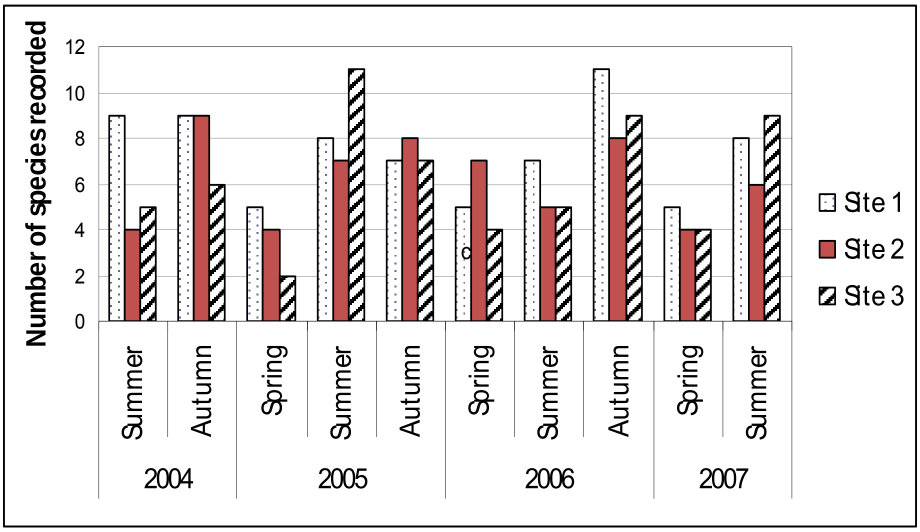


Chart 11.6a - Total number of macrophyte species recorded per season across all sample sites on the St Helen's Canal between summer 2004 and spring 2007

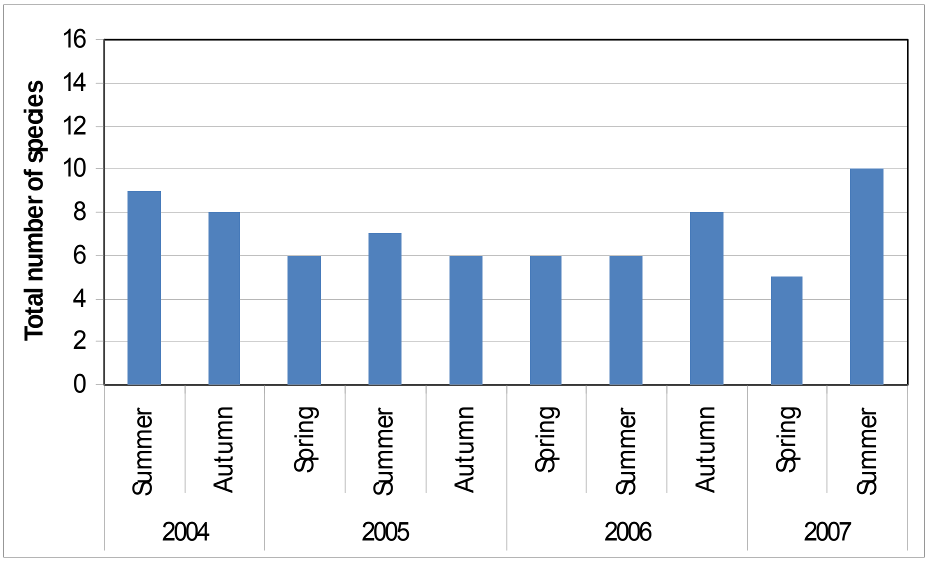
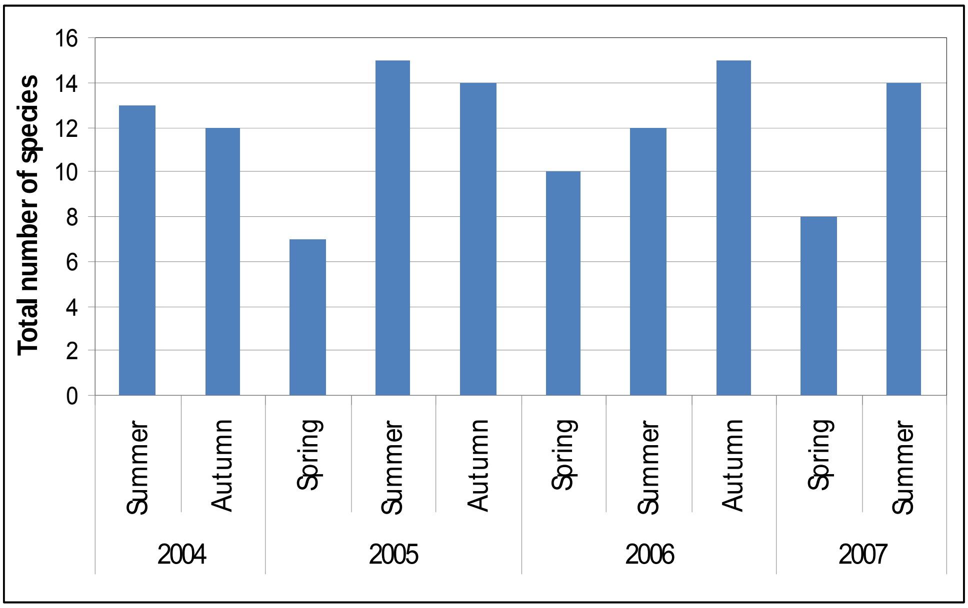


Chart 11.6b - Total number of macrophyte species recorded per season across all sample sites on the Bridgewater Canal between summer 2004 and spring 2007



Brooks

11.6.46 Stewards Brook was surveyed in spring 2007 but was not accessible during the summer survey period for Health and Safety reasons. Macrophytes in Bowers Brook were in the early stages of development during spring and an MTR survey could not be conducted at this time, however, a full MTR survey was conducted at Bowers Brook in the summer. Halton Brook was found to be permanently dry and subsequently was not included in future surveys.

Spatial Variation

11.6.47 During the full MTR survey undertaken at Stewards Brook during March 2007 few young plants were found to be emerging, and some species could not be readily identified. Those that were possible to identify were either identified from the previous year's dead growth (although only where new growth was showing) or were early growing species such as the umbellifers *Apium nodiflorum* and *Oenanthe crocata*. Only four species were recorded along Stewards Brook. At Bowers Brook during September 2007 it was found that the channel was dominated by *Aster tripolium.* Water level was seen to fluctuate between 0.25 m and 2.0 m depending on the position of the tide.

Temporal Variation

11.6.48 As the brooks were surveyed for the first time as part of this study in 2007, there was insufficient data to establish any trend in temporal variation.

Discussion of baseline data (Freshwater Macrophytes)

Spatial Variation

11.6.49 The results of the baseline surveys of the St. Helen's and Bridgewater Canals revealed that the Bridgewater Canal contained a high number of nutrient tolerant channel macrophyte species (*Potamogeton pectinatus*, *Elodea nuttallii*, *Myriophyllum spicatum*, *Ceratophyllum demersum*, *Lemna trisulca* and *Potamogeton crispus*), whilst the St. Helen's Canal contained only marginal herbs and reeds. The substrate in the main channel of the St. Helen's Canal was found to be very coarse, with large gravels and pebbles which would not be conducive to macrophyte growth.

11.6.50 One rare charophyte species, *Nitella mucronata* var. *gracillima,* was recorded in 2004, 2005 and 2007 in the Bridgewater Canal, and is considered to be an under-recorded species within the UK. It is becoming more frequently found in canals where it is often a primary colonising species. It was found to occur in high biomass in the Bridgewater Canal.

Temporal Variation

11.6.51 The majority of aquatic macrophyte species are very seasonal, with growth beginning in late May/early June and die-back commencing late September/early October. Consequently, biomass of macrophytes is lower in spring than in summer and autumn which could explain the slightly lower numbers of species recorded in spring.

11.6.52 The charophyte *Chara globularis* was recorded at low biomass in the Bridgewater Canal between summer 2004 and autumn 2005.

Estuarine Invertebrates

11.6.53 In total, 22 taxa were collected in the 2004 survey of intertidal, subtidal and epifaunal habitats, 29 were collected in the 2005 survey, 22 in 2006 and 24 in 2007. This was significantly more than identified in either of the 2002 and 2003 surveys (Table 11.17), which is mainly due to the fact that less sites were sampled within Zones 1 and 3 during these years. Of the new taxa found in 2004 many were found in Zone 1 (including *Bathyporeia pilosa*, *Gammarus zaddachi* and *Cyathura carinata*). However, other new taxa present (which included a number of freshwater dipteran larvae), occurred much further upstream in Zone 3. In 2005 several further taxa were collected which were not found in 2004. They included the gastropod *Skenea serpuloides* which was collected in Zone 1 in spring 2005, the oligochaete family Naididae which was collected in Zone 1 in spring and summer 2005 and *Limnodrilus hoffmeisteri* which was found in both Zones 1 and 2 in spring and summer. In autumn 2005, the bristle worm, *Eteone longa*, and the sea spider, *Nymphon sp*., were sampled in Zones 1 and 2, respectively. In 2006, new taxa included a freshwater leech, *Erpobdella sp.* and hydrobiid snails which were both sampled in Zone 2. The shore crab, *Carcinus maenus*, was collected for the first time in a hand-trawl in Zone 1 in 2006. New taxa collected in 2007 included the shrimp, *Corophium multisetosum* and the sea-slater, *Sphaeroma rugicauda*, which were both found in Zone 2. Several new freshwater invertebrate taxa were collected in 2007 which were the snail, *Planorbis albus*, Dolichopodidae and Psychodidae (Diptera or true-fly larvae, i.e. insects with two wings and complete life cycle) and Orbatei (mites). Across these surveys, all the invertebrate taxa that were collected are common and widely distributed throughout the UK.

11.6.54 The meiofauna collected comprised mainly of nematode (round worms) and small tubificids (oligochatete worms). Individual copepods and hydrobid veligers were also found in some samples. Large numbers of foraminifera were found in almost all of the samples and empty tests were present in large numbers throughout the study area and often dominated samples. As it was not possible to differentiate between the tests of living foraminiferans and dead individuals they could not be included in data analyses. As expected, the abundance of meiofauna was considerably higher than that of macrofauna although the biomass of macrofauna was far greater.

Intertidal Macrofauna Abundance

Spatial variation

11.6.55 Non-parametric Mood's median tests indicated that over the duration of the sampling programme Zone 1 had significantly higher median invertebrate abundance ($p \leq 0.001$) than Zones 2 and 3 (Table 11.18). Abundance of invertebrates in individual samples was generally low across all zones, however, and many samples contained no organisms.

11.6.56 Contour maps illustrate the spatial distribution of macrofauna within study zones. During some sample seasons abundances were on occasion higher in Zones 2 and 3 than in Zone 1 (Figures 11.7a-j). The contour plot of mean abundance across all seasons, however, indicates Zone 1 had the higher abundances of macrofauna across the whole sample period (Figure k). During summer 2005 the greatest abundances of macroinvertebrates were within Zone 2 although the main sites at which high abundances were recorded were towards the upstream section of Zone 2. The results for summer 2005 also differed from each of the other seasons in that a relatively high abundance of macroinvertebrates was evident in Zone 3, the zone furthest upstream. During spring 2004, and autumn 2005/2006 macroinvertebrate abundance was highest within Zone 1 and numbers were very low in both Zones 2 and 3. During spring 2004, and autumn 2005/2006 macroinvertebrate abundance was highest within Zone 1 and numbers were very low in both Zones 2 and 3.

Table 11.17 - Annual macrofaunal species list from 2002 to 2007

	2002	2003	2004	2005	2006	2007
Annelida	Tubificidae Oligochaeta *Hediste diversicolor*	Nereidae *Hediste diversicolor*	*Tubificoides* spp Oligochaeta *Hediste diversicolor*	*Tubificoides* spp Oligochaeta *Hediste diversicolor* *Limnodrilus hoffmeisteri* Naididae *Eteone longa*	Nereidae Tubificidae Oligochaeta *Hediste diversicolor* *Limnodrilus sp.*	Nereidae Oligochaeta *Hediste diversicolor* Naididae
Crustacea	*Neomysis integer* (Mystidae shrimp)	*Neomysis integer* *Crangon crangon* *Chironomidae* *Asellus aquaticus* (Isopod) Corophidae (Amphipod)	*Neomysis integer* *Crangon crangon* Calanoida (Copeopod) *Bathyporeia pilosa* *Gammarus zaddachi* *Corophium volutator* *Cyathura carinata* (Isopod) Collembola (Springtail) *Balanus improvisus* *Semibalanus balanoides* (Barnacles)	*Neomysis integer* *Palemons elegans* *Crangon crangon* Cladocera Calanoid copeopod Cyclopoid copeopod *Gammarus zaddachi* *Corophium volutator* *Corophium arenarium* *Asellus aquaticus* Collembola (Springtail) *Balanus improvisus* *Carcinus maenas* *Bathyporeia pilosa* *Nymphon sp.*	Mysidae *Neomysis integer* *Palemons elegans* *Crangon crangon* Calanoid copeopod Cyclopoid copeopod *Gammarus zaddachi* *Corophium volutator* Collembola (Springtail) *Bathyporeia pilosa* Balanidae *Balanus improvisus* *Carcinus maenus* Harpacticoida	*Palemons elegans* *Crangon crangon* Calanoid copeopod Cyclopoid copeopod Gammaridae *Gammarus zaddachi* *Corophium volutator* *Corophium multisetosum* Corophidae *Corophium sp.* Collembola (Springtail) Balanidae *Balanus improvisus* *Sphaeroma rugicauda* Harpacticoida
Mollusca			*Mytilus edulis* (Common mussel) *Malcoma balthica*	*Mytilus edulis* (Common mussel) *Malcoma balthica* *Hydrobia ulvae*		
Gastropoda				*Skenea serpuloides*	Hydrobiidae	*Planorbis albus*
Others, including fresh water spp.			*Isotomidae* Pericoma Nematocera Chironomidae Stratiomyiidae Oribaetei Staphyliinidae Muscidae	Chironomidae *Diptera* Scatopsidae Chaoboridae	Chironomidae *Erpobdella sp.*	Chironomidae Dolicopodidae Psychodidae Orbatei

Intertidal Macrofauna Abundance

Spatial variation

11.6.57 Non-parametric Mood's median tests indicated that over the duration of the sampling programme Zone 1 had significantly higher median invertebrate abundance ($p \leq 0.001$) than Zones 2 and 3 (Table 11.18). Abundance of invertebrates in individual samples was generally low across all zones, however, and many samples contained no organisms.

11.6.58 Contour maps illustrate the spatial distribution of macrofauna within study zones. During some sample seasons abundances were on occasion higher in Zones 2 and 3 than in Zone 1 (Figures 11.7a-j). The contour plot of mean abundance across all seasons, however, indicates Zone 1 had the higher abundances of macrofauna across the whole sample period (Figure k). During summer 2005 the greatest abundances of macroinvertebrates were within Zone 2 although the main sites at which high abundances were recorded were towards the upstream section of Zone 2. The results for summer 2005 also differed from each of the other seasons in that a relatively high abundance of macroinvertebrates was evident in Zone 3, the zone furthest upstream. During spring 2004, and autumn 2005/2006 macroinvertebrate abundance was highest within Zone 1 and numbers were very low in both Zones 2 and 3.

11.6.59 It is important to note that these contours can be strongly influenced by very high densities of macroinvertebrates at individual sites. The contour lines on the map result from computer interpolation algorithms rather than actual measured boundaries between the densities of macroinvertebrates present. Therefore, these patterns can be generated when there is very high biomass at just one or two sites and very low biomass at all other sites.

11.6.60 The patterns observed for macroinvertebrate abundance during different seasons are similar to those evident from contour plots of algal abundance and in some cases higher abundances of benthic algae appear to correspond to higher abundances of macroinvertebrates (Figures 11.5a-j and 11.7a-k). For example, the abundance of macroinvertebrates as a whole was greater in Zone 2 than in Zones 1 and 3 during summer and autumn 2004 (Figure 11.7b and c). Such a pattern was also indicated by the algal contour plot for these sampling periods and was predominantly due to particularly high algal biomass and macroinvertebrate abundances at Sites 11 and 12. In addition, there were high abundances of macrofauna within Zone 2 and 3 in summer 2005. Within some sections of these zones this was mirrored by a high biomass of algae but in the downstream section of Zone 2 this was not the case (Figures 11.5d and 11.7e). The relatively higher abundances of macroinvertebrates within Zone 1 in autumn 2005 and 2006 when compared with the other zones were less clearly correlated with the spatial distribution of algae (Figures 11.7f & i and 11.5e & h).

Table 11.18 - Sources of variation in median richness and abundance m^{-2} between zones, seasons and years for the intertidal benthic invertebrate data. Chi squared output is the result of separate Mood's median tests performed on each of the variables. Letters denote significant differences (e.g. values with the same letter are not significantly different from each other). *p<0.05, ** p<0.01, *** p<0.001

	Zone				**Season**				**Year**				
	1	**2**	**3**	**X^2**	**Spring**	**Summer**	**Autumn**	**X^2**	**2004**	**2005**	**2006**	**2007**	**X^2**
Meiofauna													
Abundance	207876	415752	265908	4.43 NS	207876 a	537013 b	138584 a	15.25***	692919 a	410555 ab	103938 b	69292 b	20.67***
Macrofauna													
Richness	1.0 a	0.0 b	0.0 b	17.64***	0.5	1.0	0.0	1.36 NS	0.0	1.0	1.0	1.0	3.19 NS
Abundance	87.0 a	0.0 b	0.0 b	21.77***	87.0	87.0	0.0	1.45 NS	0.0 a	43.0 b	87.0 b	87.0 b	7.59*

Figure 11.7a - Plot of macrofaunal abundance within the Upper Mersey Estuary for spring 2004

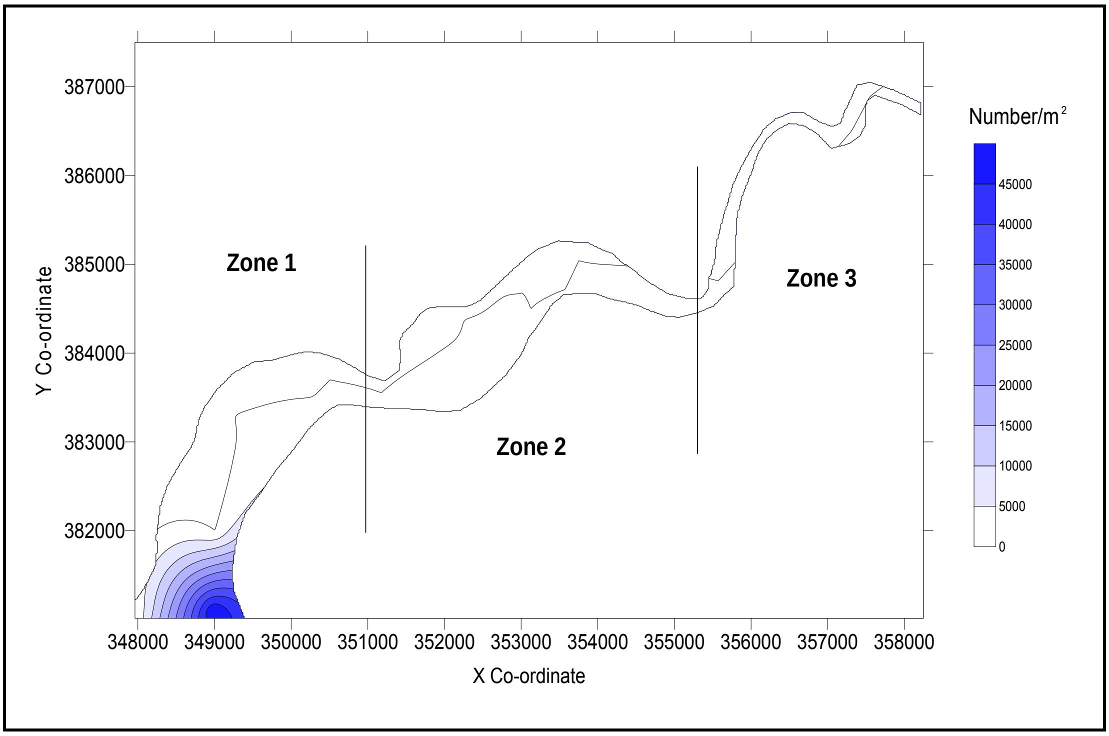


Figure 11.7b - Plot of macrofaunal abundance within the Upper Mersey Estuary for summer 2004

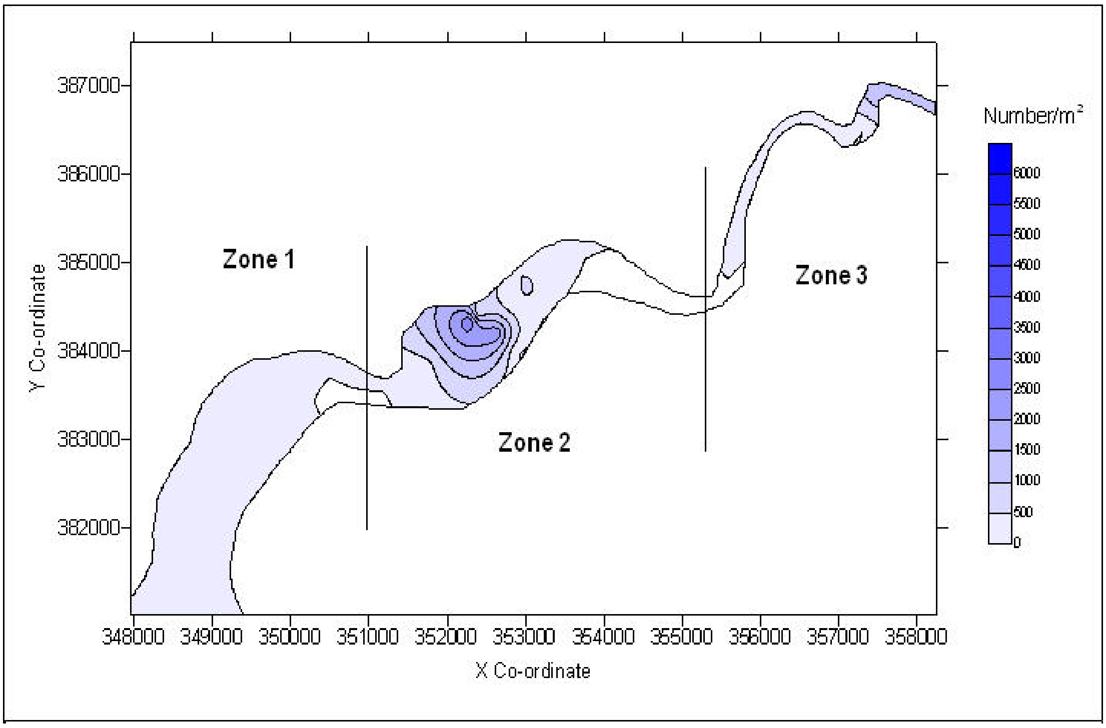


Figure 11.7c - Plot of macrofaunal abundance within the Upper Mersey Estuary for autumn 2004

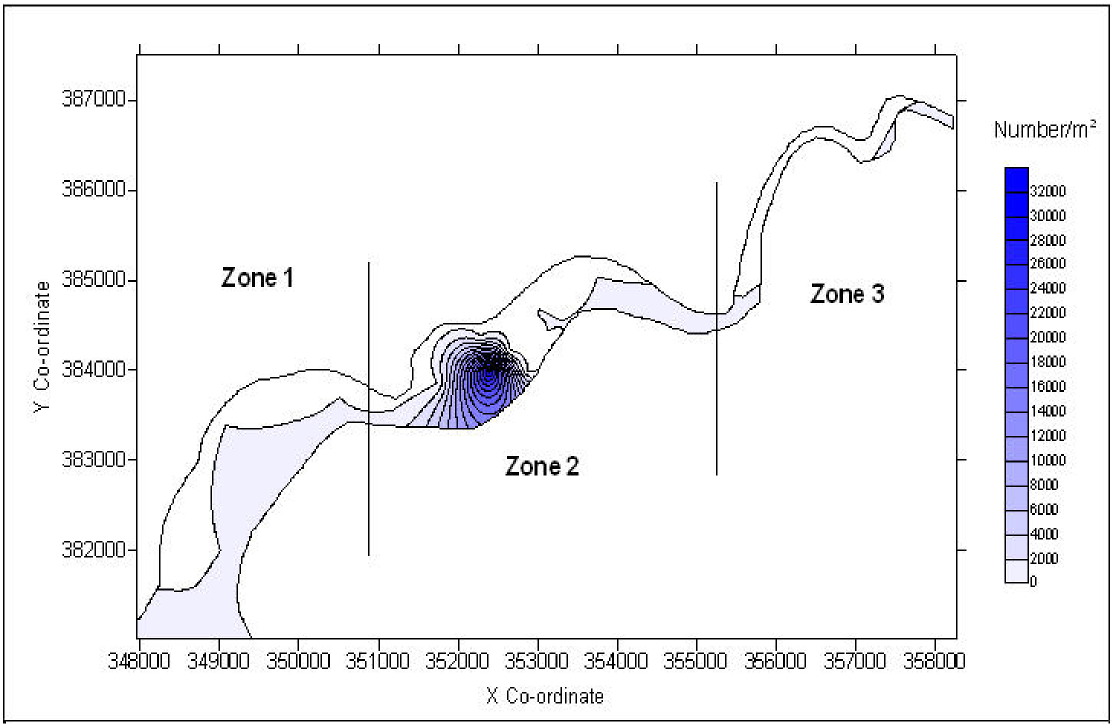


Figure 11.7d - Plot of macrofaunal abundance within the Upper Mersey Estuary for spring 2005

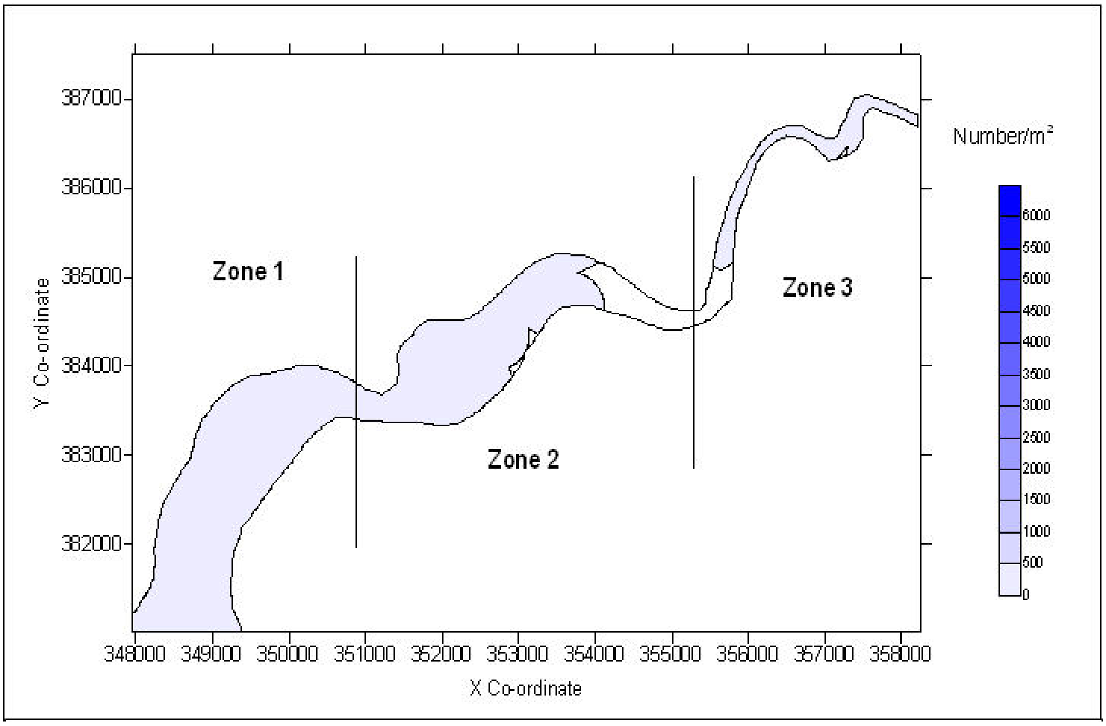


Figure 11.7e - Plot of macrofaunal abundance within the Upper Mersey Estuary for summer 2005

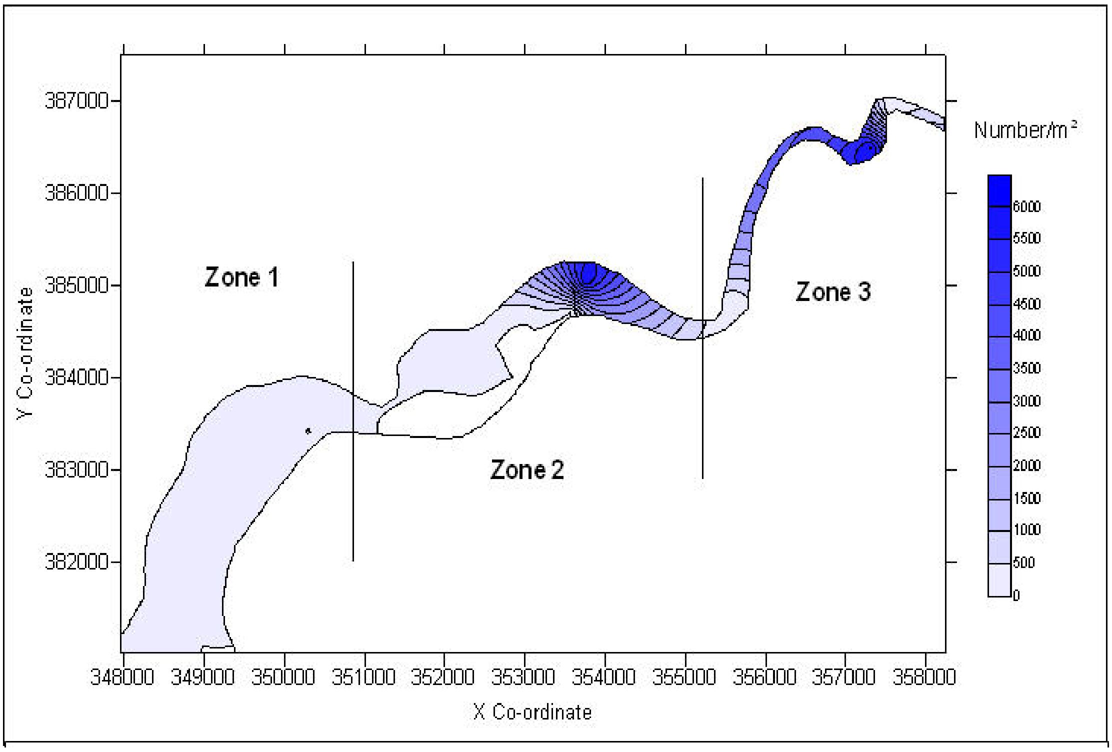


Figure 11.7f - Plot of macrofaunal abundance within the Upper Mersey Estuary for autumn 2005

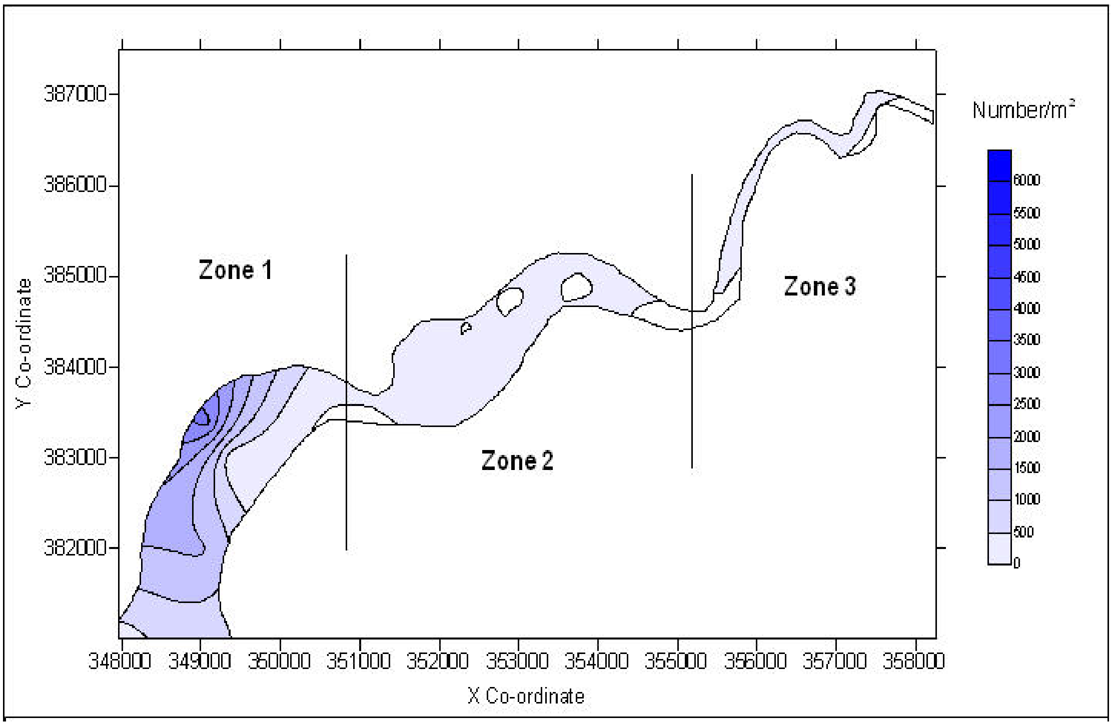


Figure 11.7g - Plot of macrofaunal abundance within the Upper Mersey Estuary for spring 2006

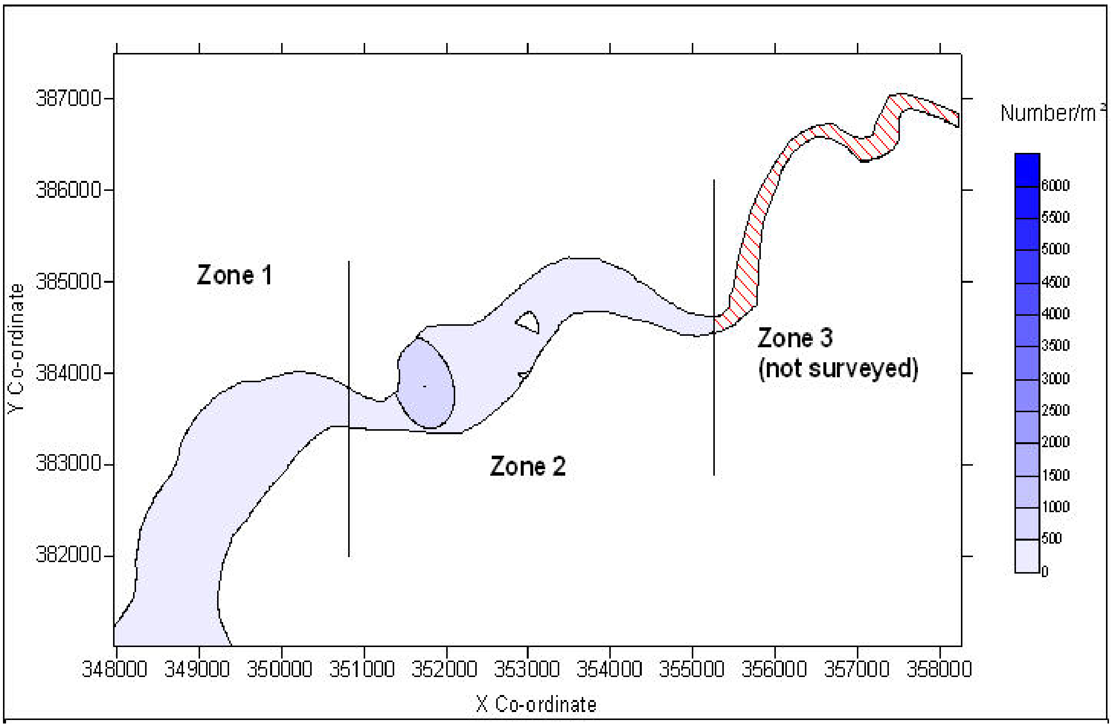


Figure 11.7h - Plot of macrofaunal abundance within the Upper Mersey Estuary for summer 2006

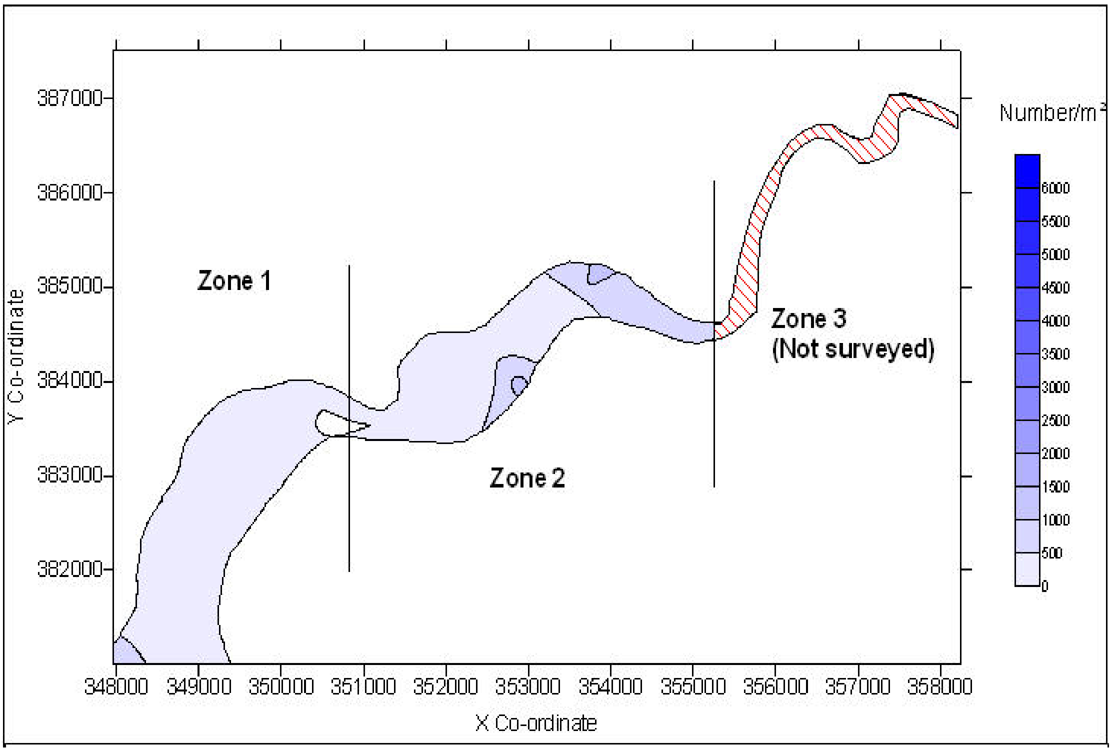


Figure 11.7i - Plot of macrofaunal abundance within the Upper Mersey Estuary for autumn 2006

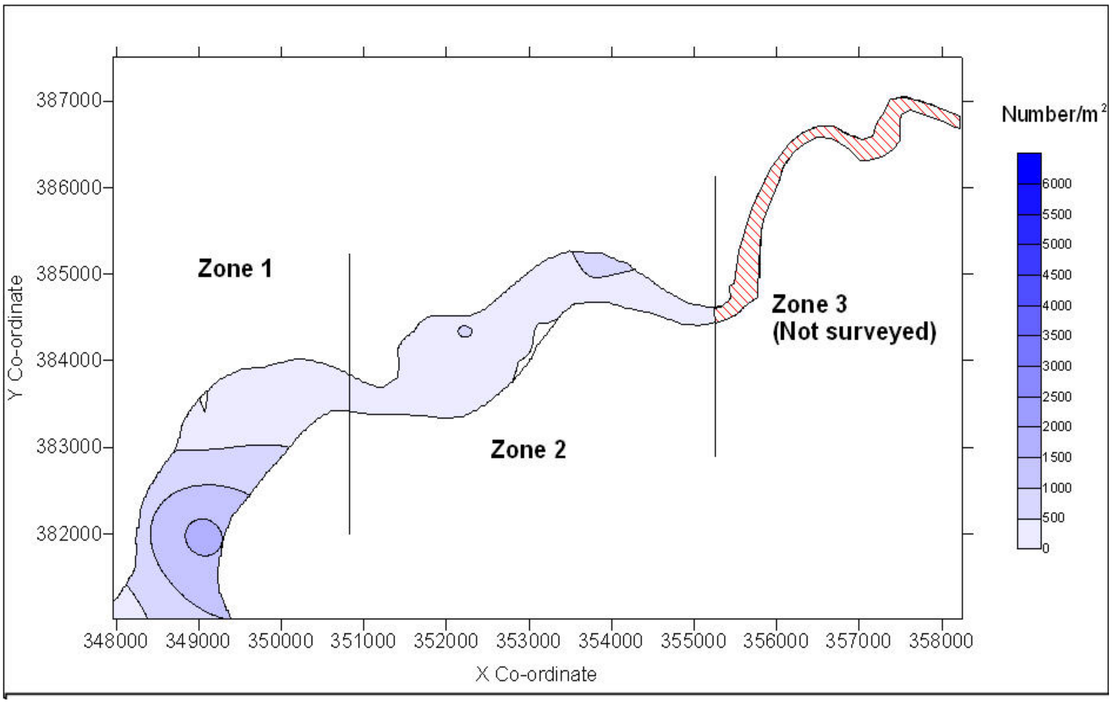


Figure 11.7j - Plot of macrofaunal abundance within the Upper Mersey Estuary for spring 2007

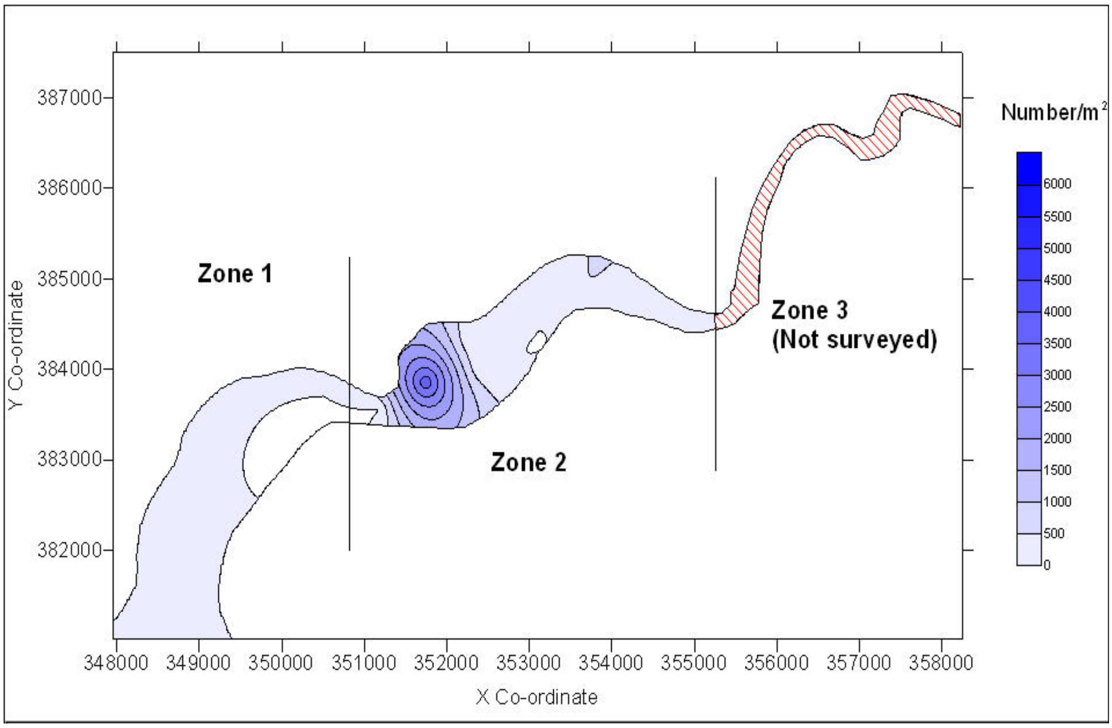
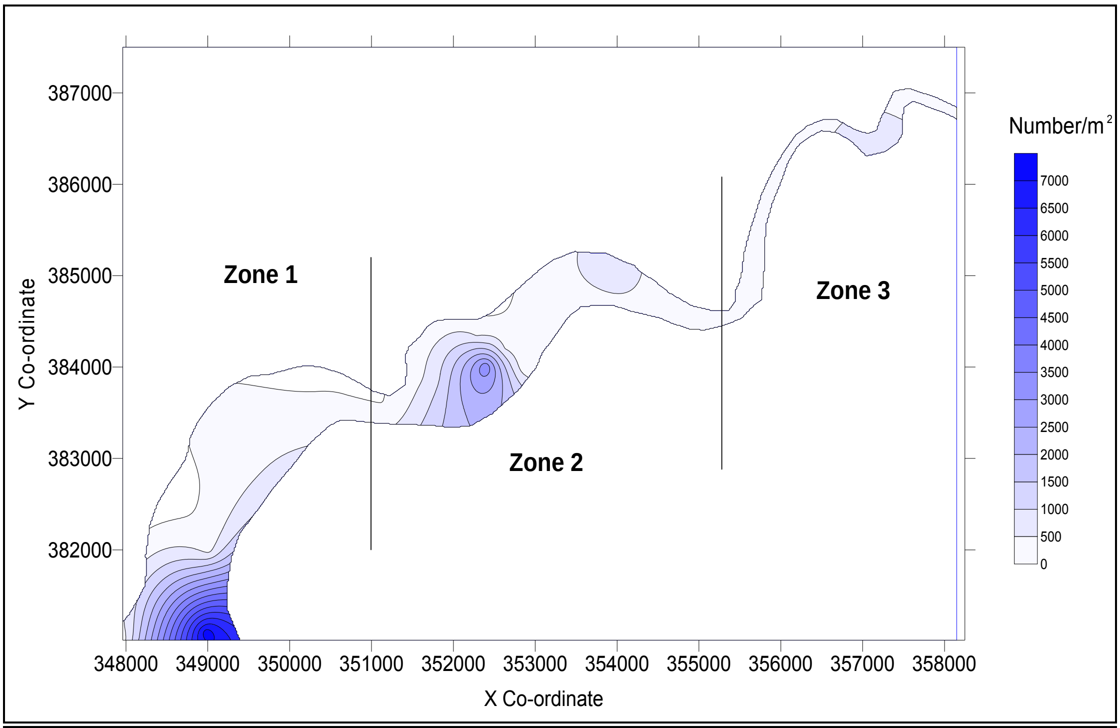


Figure 11.7k - Plot of mean macrofaunal abundance within the Upper Mersey Estuary between spring 2004 and spring 2007



Temporal variation

11.6.61 There was a significant difference in invertebrate abundance between years ($p \leq 0.001$), with generally higher abundances across all zones recorded in 2005, 2006 and 2007 when compared to 2004 (Table 11.18). However, despite the relatively low abundances of invertebrates collected in 2004 when comparing all years, two notable peaks in macrofauna abundance were identified in 2004. One of these was in spring in Zone 1 which resulted from a large number of *Gammarus zadacchi* and one was in autumn in Zone 2 which was contributed to by a swarm of collembola (springtails). High numbers of collembola were also sampled in 2005 during the summer, at sites in Zones 2 and 3.

11.6.62 There were no significant differences in intertidal macrofaunal abundance among seasons, although median values suggested that abundances were higher in spring and summer than in autumn.

11.6.63 Contour maps generated indicated variation in intertidal macrofaunal abundance within study zones in 2004, 2005, 2006 and 2007 (Figures 11.7a-k). It is important to note that the abundance scale for the spring and autumn 2004 plot differs from the other plots due to the very high numbers of individuals sampled during these seasons in comparison to each of the others. As with algae, abundances across all zones were particularly low during spring in 2005 and 2006, and within Zones 2 and 3 in autumn 2005 (Figure 11.7d, f and g). In summer 2006 the abundances of macrofauna were lower than during previous summers (Figure 11.7h), (this was also the case for algal biomass).

Intertidal Macrofauna Community Composition

Spatial variation

11.6.64 Species richness of macrofauna in the intertidal sites was higher than at the subtidal sites and during many sample periods there were about five species per sample zone.

11.6.65 Non-parametric Mood's median tests indicated that species richness in Zone 1 was significantly higher than in Zones 2 and 3 ($p \leq 0.01$), (Table 11.18).

11.6.66 Although patterns were observed for overall taxon richness, PCA analysis indicated that there were no apparent spatial patterns in the distribution of macrofauna taxa in the intertidal zone. This was evident on the PCA plot provided which shows the composition of spring samples from 2004, 2005, 2006 and 2007 in relation to each other (Chart 11.7). The PCA axes were strongly influenced by a few samples that contained a different range of taxa or contrasting invertebrate densities to the other samples. Overall, there was inconsistent variation among samples between different zones, habitats and years which prevented any patterns emerging from the data. This PCA plot is very similar to those produced for the summer and autumn communities, and as no distinct patterns were again observed within these plots they have not been reproduced here.

Temporal variation

11.6.67 There was no significant difference in species richness among years (Table 11.18).

11.6.68 There were no significant differences in species richness among seasons. Some species, however, were only found at specific times. For example, both the bristle worm *Eteone longa* and the amphipod *Corophium arenarium* were recorded for the first time during an intertidal survey of Zone 1 in autumn 2005.

11.6.69 PCA analysis indicated that no consistent temporal patterns in the distribution of macrofaunal taxa were evident within the intertidal zone (Chart 11.7).

Tower Sites

11.6.70 From 2004 onwards the intertidal surveys were extended to include the sampling of the proposed locations for the towers for the proposed New Bridge. Nine samples were taken at each of the sites. A total of 12 macrofauna taxa were collected throughout the study period including Oligochaeta, *H. diversicolor*, Nereidae, Collembola, *Corophium volutator*, *Mytilus edulis*, Tubificoides and several species of Diptera (larvae of true-flies). None of the animals collected were of restricted distribution or of conservation interest. There were no significant differences in abundance or richness between different seasons (Table 11.19).

11.6.71 A significantly greater number of macrofaunal taxa were collected at the Tower 2 sites when compared with Tower 1 and Tower 3 sites ($p \leq 0.001$), (Table 11.19). This was largely due to the fact that no invertebrates at all were collected in many samples from Tower 1 and Tower 3 during the course of the surveys between 2004 and 2007. For example, no macrofauna were found at all at Towers 1 and 3 on a number of sampling occasions (e.g. none were found at Tower 3 in spring 2005, Tower 1 or 3 in summer 2005 or Tower 1 in autumn 2005). Both species richness and abundance were found to be significantly lower in 2005 than 2004 ($p \leq 0.001$), (Table 11.19).

Chart 11.7 - PCA ordination plot of intertidal macrofaunal samples collected in spring 2004, 2005, 2006 and 2007

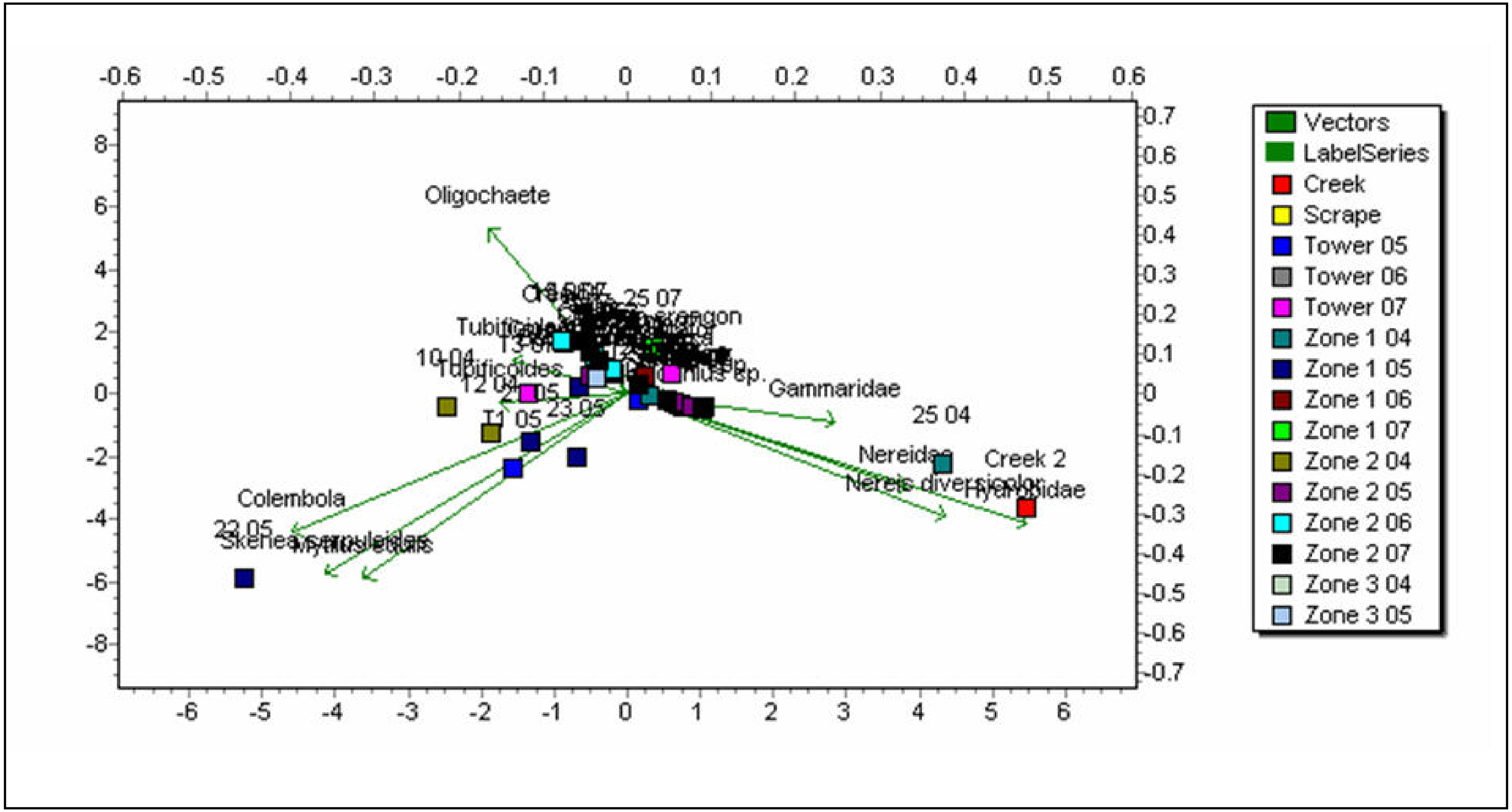


Table 11.19 - Sources of variation in median richness and abundance m^{-2} between zones, seasons and years for the benthic invertebrate data from the tower sites. Chi squared output is the result of separate Mood's median tests performed on each of the variables. Letters denote significant differences (e.g. values with the same letter are not significantly different from each other). *p<0.05, ** p<0.01, *** p<0.001

	Tower				**Season**				**Year**				
	1	**2**	**3**	**X^2**	**Spring**	**Summer**	**Autumn**	**X^2**	**2004**	**2005**	**2006**	**2007**	**X^2**
Meiofauna													
Abundance	103938 a	597643 b	0.0 c	41.91 ***	0.0 a	207876 b	623627 b	15.44 ***	1266743 a	311800 b	0.0 c	0.0 c	15.17 ***
Macrofauna													
Richness	0.0 a	0.0 b	0.0 a	16.49 ***	0.0 a	0.0 b	0.0 a	8.74 ***	0.0 a	0.0 b	0.0 b	0.0 b	13.53***
Abundance	0.0 a	0.0 b	0.0 a	16.49 ***	0.0 a	0.0 b	0.0 a	8.74 ***	0.0 a	0.0 b	0.0 b	0.0 b	13.53***

Saltmarsh scrapes and creek sites

11.6.72 The only macroinvertebrates found in the scrapes were *Hediste diversicolor* which were present in high numbers. The creeks, however, contained tubificides and hydrobidae in addition to *Hediste diversicolor*.

Subtidal Macrofauna Abundance

Spatial variation

11.6.73 Macrofauna was very patchily distributed and some taxa were only recorded to have high abundances at specific sites, during a certain sampling period. For example, a large number of tubificides were found in Zone 2 in the summer of 2004 but not in other zones or during other sampling periods. A peak in invertebrate abundance recorded in autumn 2004 was due to a large number of *N. integer* being sampled at one site within Zone 2. In addition, only in autumn 2005 were large numbers of the barnacle *Balanus improvisus* found at four of the five sampled sites. In 2006, relatively high abundances of *N. integer* were recorded in Zone 2 in spring, summer and autumn. Total abundance of subtidal macrofauna did not differ significantly among zones (Table 11.20).

Temporal variation

11.6.74 Total abundance of subtidal macrofauna did not differ significantly among seasons or years (Table 11.20).

Subtidal Macrofauna Community Composition

Spatial variation

11.6.75 As described in the methods (Paragraph 11.5.64), only Zones 1 and 2 were sampled in the subtidal survey. There were no significant differences in absolute taxon richness among zones (Table 11.20). Overall, taxon richness remained low throughout the study area, with an average of between two and three taxa per zone.

11.6.76 It is important to note, however, that in general the majority of sites throughout the duration of the sampling programme contained no macrofauna at all. Results for the PCA analysis may have been confounded by the many samples containing no organisms, but there were no apparent patterns in the distribution of taxa among zones or years.

Temporal variation

11.6.77 There were no significant differences in absolute taxon richness between seasons or years (Table 11.20).

11.6.78 The majority of sites throughout the duration of the sampling programme contained no macrofauna at all. Therefore, results for the PCA analysis may have been confounded by the many samples containing no organisms, but there were no apparent patterns in the distribution of taxa among years.

Table 11.20 - Sources of variation in median richness and abundance m^{-2} between zones, seasons and years for the subtidal benthic invertebrate data. chi squared output is the result of separate Mood's median tests performed on each of the variables. Letters denote significant differences (e.g. values with the same letter are not significantly different from each other). *p<0.05, ** p<0.01, *** p<0.001. No sampling was undertaken in 2003

	Zone				Season				Year				
	1	**2**	**3**	**X^2**	**Spring**	**Summer**	**Autumn**	**X^2**	**2004**	**2005**	**2006**	**2007**	**X^2**
Meiofauna													
Abundance	6370	18148	NA	1.21 NS	6371	7407	14074	0.89 NS	7334	17778	6296	1163	3.52 NS
Macrofauna													
Richness	0.0	1.0	NA	2.11 NS	1.0	1.0	1.0	0.45 NS	0.5	1.0	0.0	1.0	3.74 NS
Abundance	0.0	14.9	NA	1.12 NS	14.7	7.3	14.7	0.34 NS	7.0	15.0	0.0	44.0	5.04 NS

Epifaunal Macrofauna Abundance

Spatial variation

11.6.79 Abundance of epifauna varied significantly among zones (Table 11.21). There was a steady increase in invertebrate abundance moving from the upstream Zone 3 to the downstream Zone 1 ($p \leq 0.001$). Median invertebrate abundance in Zone 1 was greater than that within Zone 2, largely due to high numbers of *Neomysis integer* collected within Zone 1 and Zone 2 in 2006, while epifaunal abundance in Zone 2 was greater than in Zone 3. The upstream study zone (Zone 3) had a relatively depauperate epifaunal community.

Temporal variation

11.6.80 Epifaunal abundance varied significantly among years and seasons ($p \leq 0.001$) (Table 11.21). Summer abundance was significantly higher than in spring and autumn ($p \leq 0.001$). One reason for this is that all summer trawls were dominated by high numbers of *N. integer* and *Crangon crangon*, particularly in Zone 1 and 2 where numbers of *N. integer* reached as many as 1848 m^{-2} (Zone 1, summer 2006). Significantly higher numbers of epifauna were collected in 2006 and 2007 compared to previous years ($p \leq 0.001$).

Epifaunal Macrofauna Community Composition

Spatial variation

11.6.81 The epifauna consisted of non-parasitic surface living organisms. Taxonomic composition differed between the zones though total richness did not differ significantly (Table 11.21). Zone 3 provided a habitat for a number of freshwater taxa including Diptera (true-fly) larvae and freshwater beetles as well as a few estuarine oligochaetes. Few estuarine crustacea were collected. Zone 1, however, consisted entirely of marine and estuarine taxa including balanidae (barnacle species), Mysidae (shrimp), Crangonidae (shrimp) and the polychaete worm *Hediste diversicolor* (Plate 11.6). Zone 2 had a mixture of freshwater and estuarine taxa.

Temporal variation

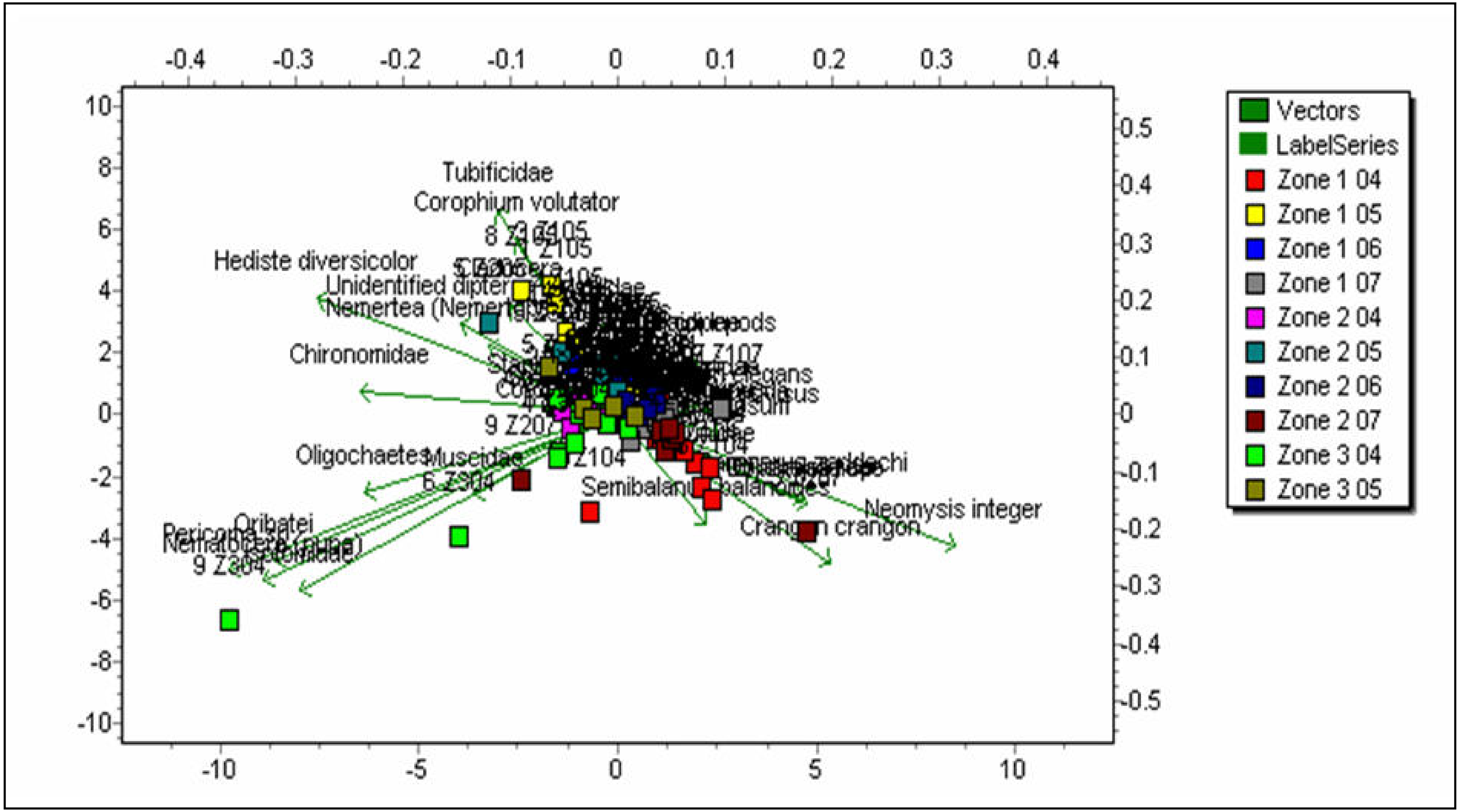
11.6.82 The results of non-parametric Mood's median tests indicated that taxon richness varied significantly between seasons ($p \leq 0.001$) and years ($p \leq 0.001$). Taxon richness in autumn was significantly lower than in spring and summer. Fewer epifaunal taxa were collected in 2003 than in the other years sampled (Table 11.21).

11.6.83 PCA was conducted on samples from comparable sites sampled in 2004, 2005, 2006 and spring 2007, and separate analyses were also performed for the different sampling seasons (spring, summer and autumn). PCA summarised the main major patterns of spatial and temporal variation among respective samples using a small number of dominant axes. Chart 11.8 summarises the major patterns of spatial and temporal variation among epifaunal invertebrates in spring across all years. This is also representative of the PCA plots generated for yearly differences between epifaunal invertebrates communities sampled in summer and autumn. The greatest source of variation was between Zone 1 and Zone 3 in 2004 (which separated out clearly along axis 1 of the PCA plot). A secondary axis of variation was shown between samples from 2004 and 2005 which separated along axis 2 of the PCA plot. Other variations between years and seasons were evident among these larger differences (Chart 11.8).

Table 11.21 - sources of variation in median richness and abundance m^{-2} between zones, seasons and years for the epifaunal invertebrate data. Chi squared output is the result of separate Mood's median tests performed on each of the variables. Letters denote significant differences (e.g. values with the same letter are not significantly different from each other). *p<0.05, ** p<0.01, *** p<0.001

	Zone				Season				Year				
	1	**2**	**3**	**X^2**	**Spring**	**Summer**	**Autumn**	**X^2**	**2004**	**2005**	**2006**	**2007**	**X^2**
Macrofauna													
Richness	0.7	0.7	0.7	4.89 NS	0.7 a	0.7 a	0.5 b	10.47 ***	0.7 a	0.7 a	1.0 b	1.0 b	25.30 ***
Abundance	5.0 a	2.8 a	0.7 b	19.86 ***	2.0 a	65.0 b	1.0 a	71.96 ***	1.3 a	1.7 a	4.8 b	7.8 b	22.70 ***

Chart 11.8 - PCA ordination plot of epifaunal samples collected in spring 2004, 2005, 2006 and 2007



Intertidal Meiofauna Abundance

11.6.84 The meiofauna collected consisted mainly of Nematoda (round worms) and small tubificides. Individual copepods and hydrobid veligers were also found in some samples. Large numbers of foramaniferans were found in almost all of the samples and tests (i.e. shells) were present in large numbers throughout the study area and often dominated samples. When sampling foraminiferans, however, it is impossible to differentiate visually between the tests of living foraminiferans and dead individuals, and the tests of dead foraminiferans can remain intact for thousands of years if buried in sediments. As a result this group is commonly not included in data analyses of benthic communities and was not included in the analyses conducted for the aquatic ecology study. As expected, the abundance of meiofauna was considerably higher than that of macrofauna although the biomass of macrofauna was far greater.

Spatial variation

11.6.85 Meiofaunal abundance was greater in the intertidal sites than the subtidal sites in both zones (Table 11.18 and 11.20). A non-parametric Mood's median test indicated that there were no significant differences in intertidal meiofaunal abundance between zones (Table 11.18). Meiofaunal organisms were found at most sites in all of the zones, with nematodes consistently dominating samples. Across all samples, meiofaunal abundance was higher in Zone 2, but this difference was non-significant.

11.6.86 The spatial distribution of meiofauna across and within the study zones was summarised conveniently in the series of contour plots (Figures 11.8 a-k, below). The only sample periods during which meiofaunal abundance in Zone 1 was relatively high were spring 2004, summer 2005 and spring 2006 (Figure 11.8 a, e and g). Abundances within Zone 2 were higher than in the other zones in summer 2004, autumn 2004 and 2005, and summer and autumn 2006 (Figures 11.8 b, c, f, h and i). The plot indicating mean meiofauna abundances across all seasons was similar to that obtained for intertidal macrofauna in that individuals were concentrated within Zone 2. (Figure 11.8 k).

Figure 11.8a - Plot of meiofaunal abundance within the Upper Mersey Estuary for spring 2004

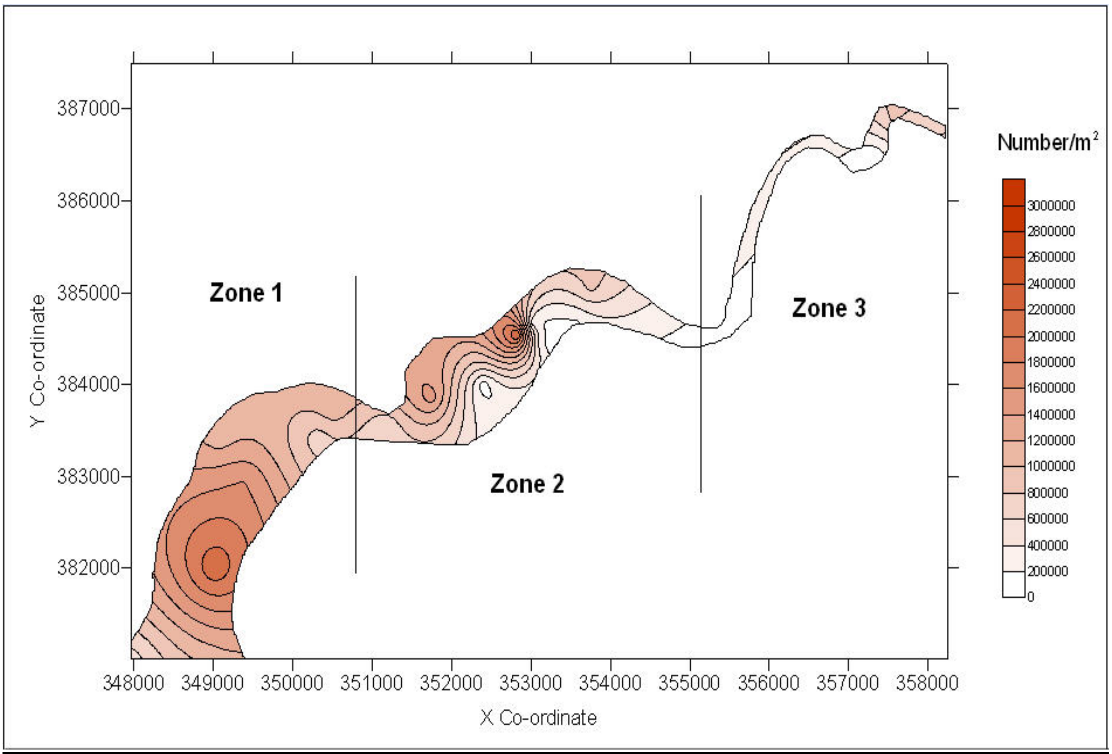


Figure 11.8b - Plot of meiofaunal abundance within the Upper Mersey Estuary for summer 2004

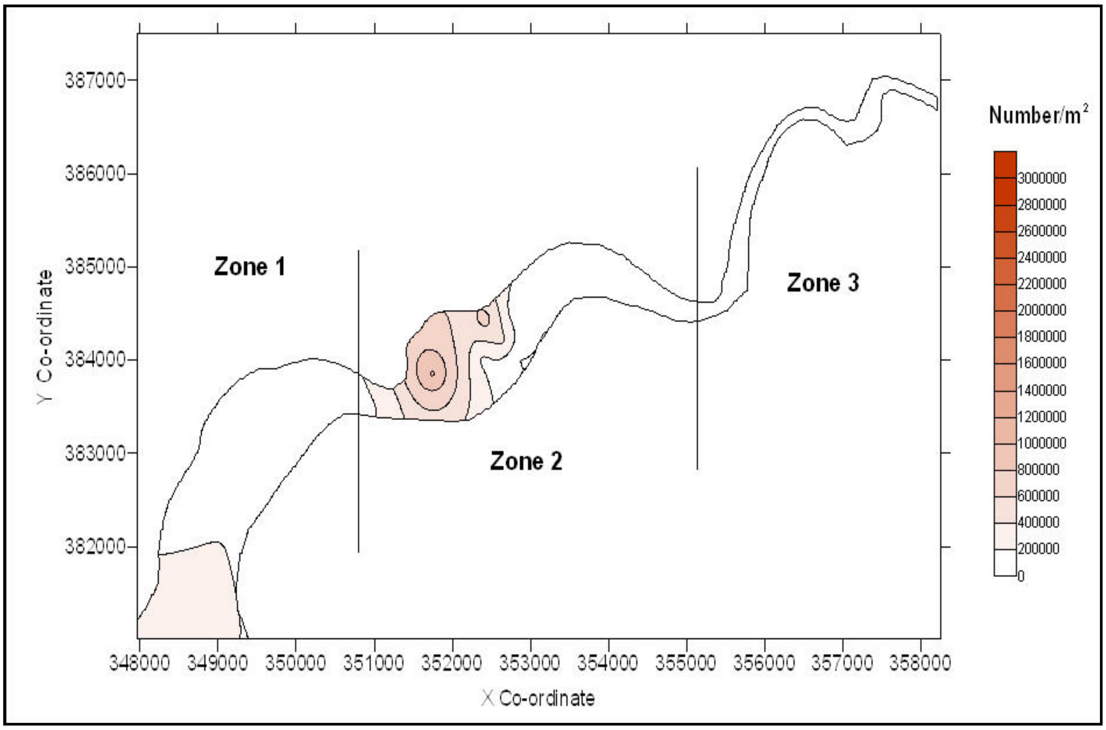


Figure 11.8c - Plot of meiofaunal abundance within the Upper Mersey Estuary for autumn 2004

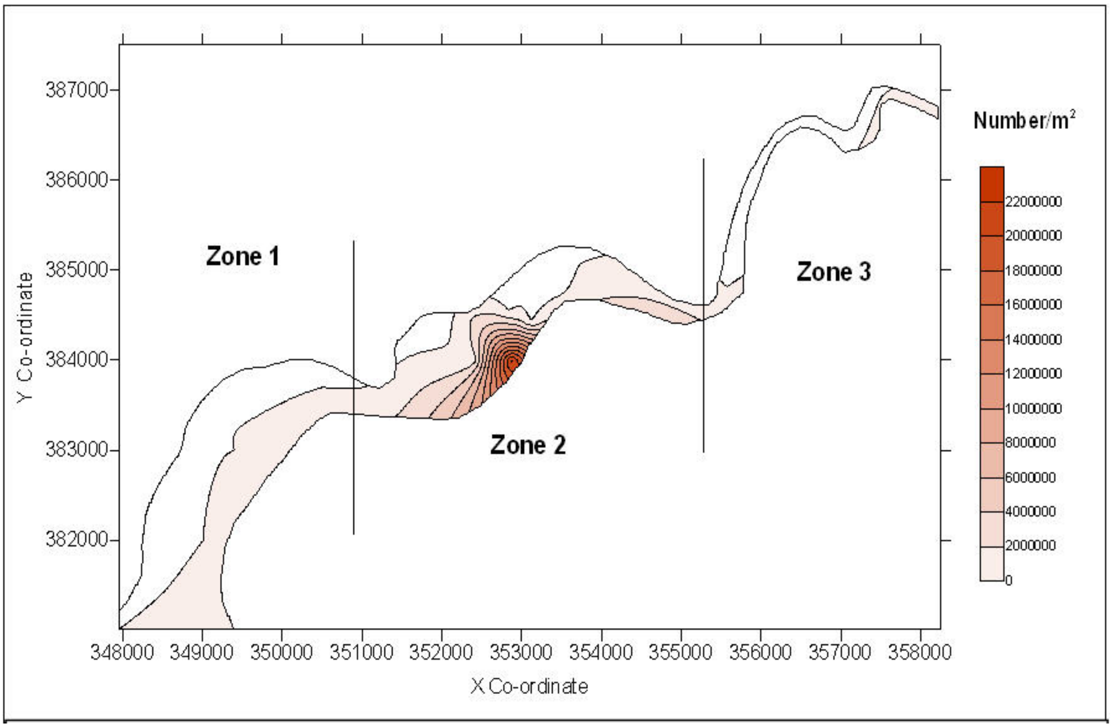


Figure 11.8d - Plot of meiofaunal abundance within the Upper Mersey Estuary for spring 2005

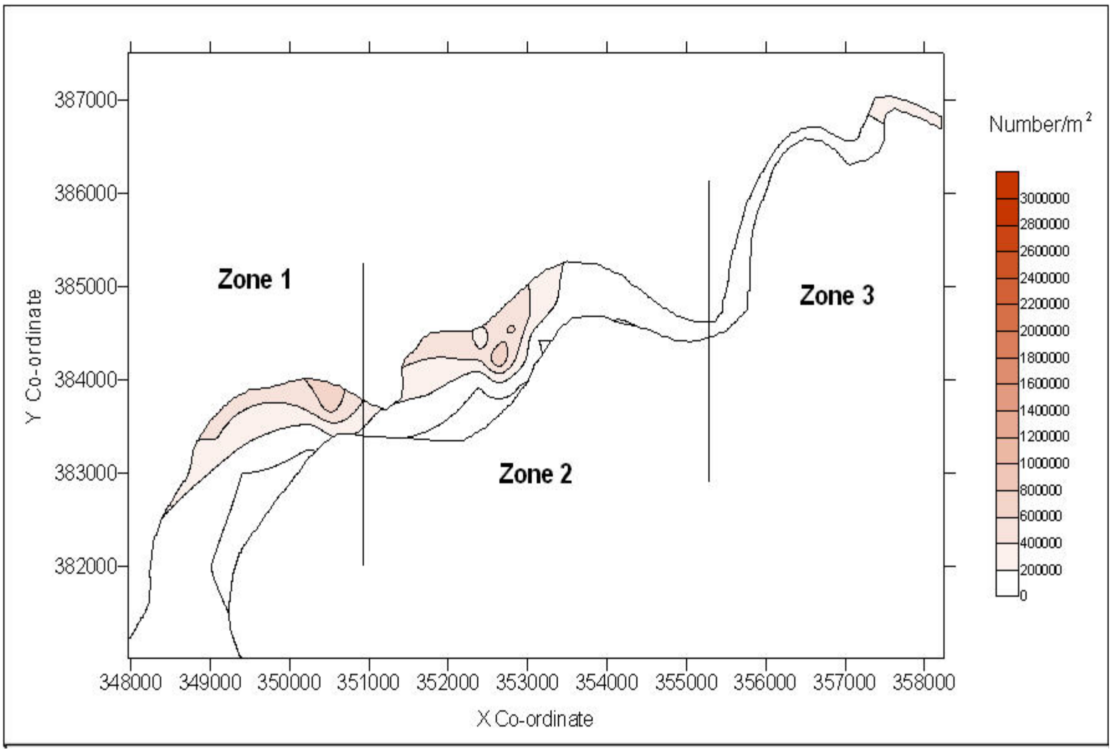


Figure 11.8e - Plot of meiofaunal abundance within the Upper Mersey Estuary for summer 2005

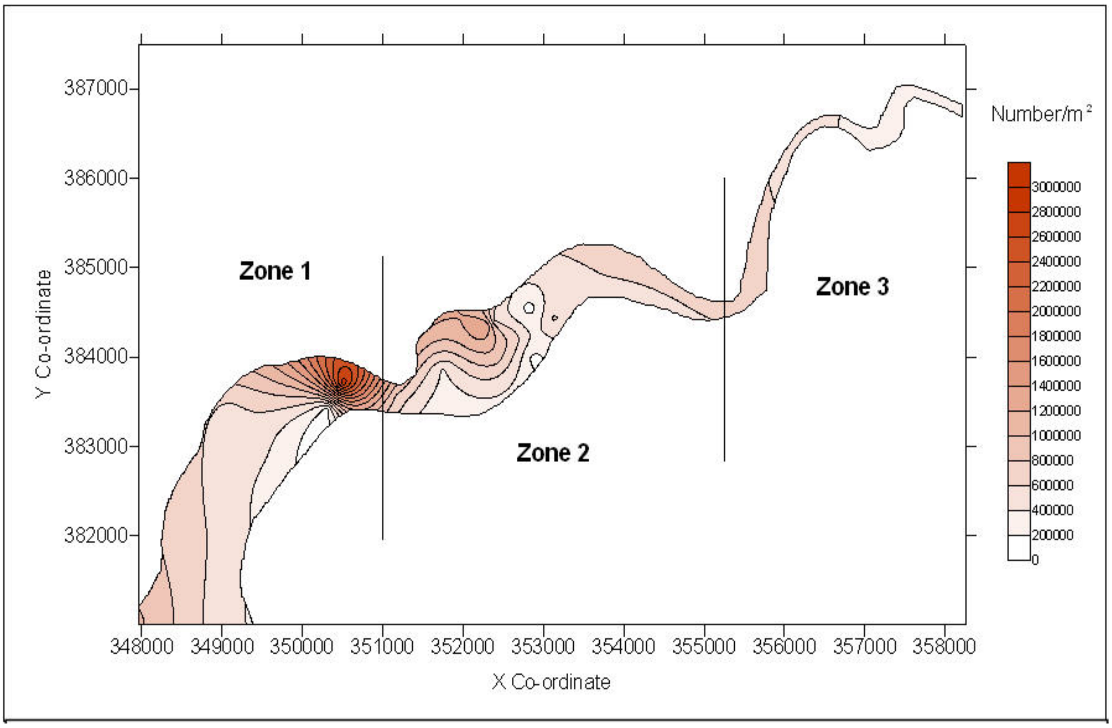


Figure 11.8f - Plot of meiofaunal abundance within the Upper Mersey Estuary for autumn 2005

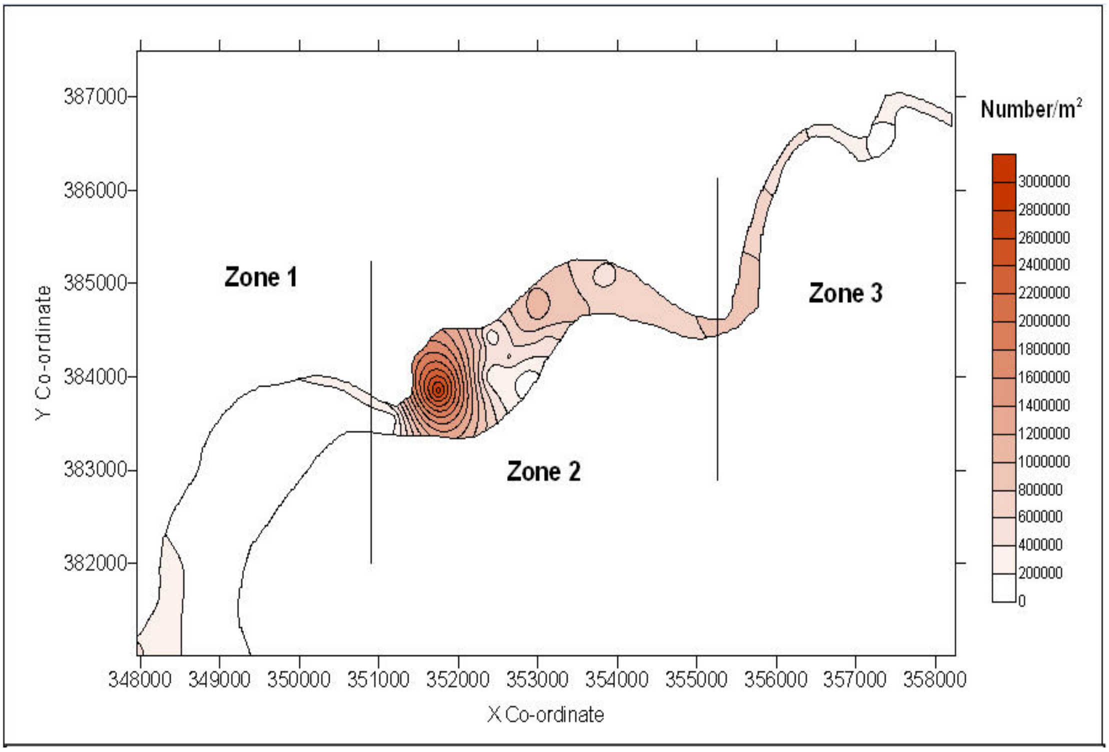


Figure 11.8g - Plot of meiofaunal abundance within the Upper Mersey Estuary for spring 2006

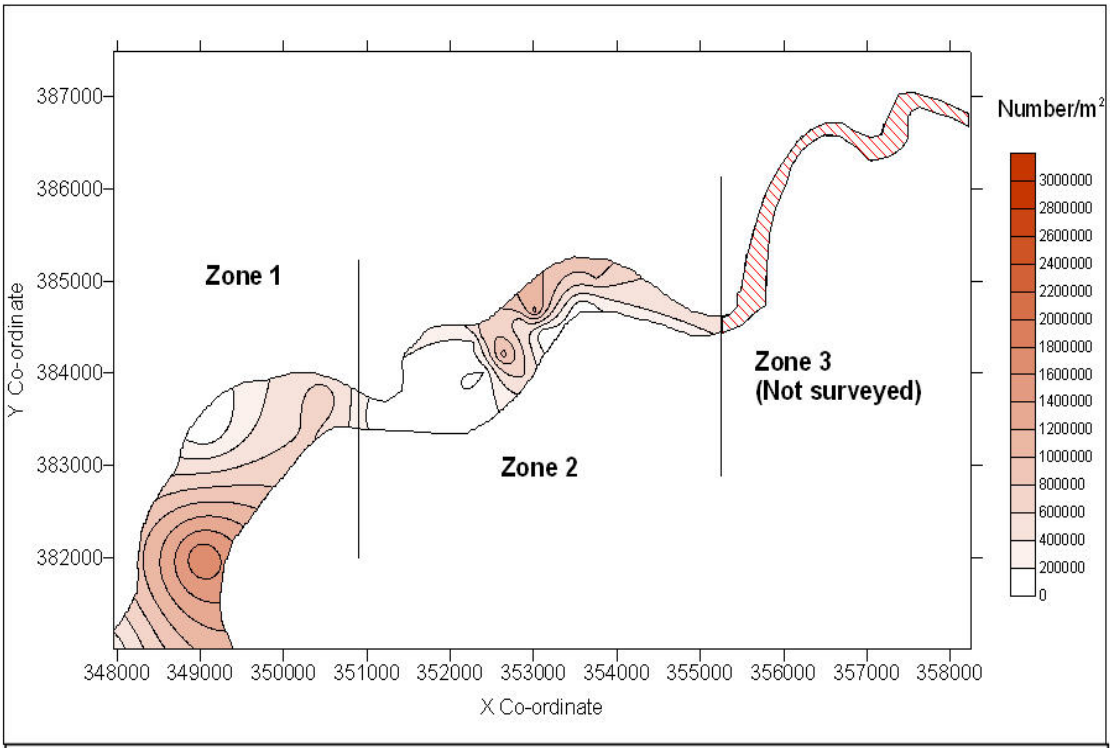


Figure 11.8h - Plot of meiofaunal abundance within the Upper Mersey Estuary for summer 2006

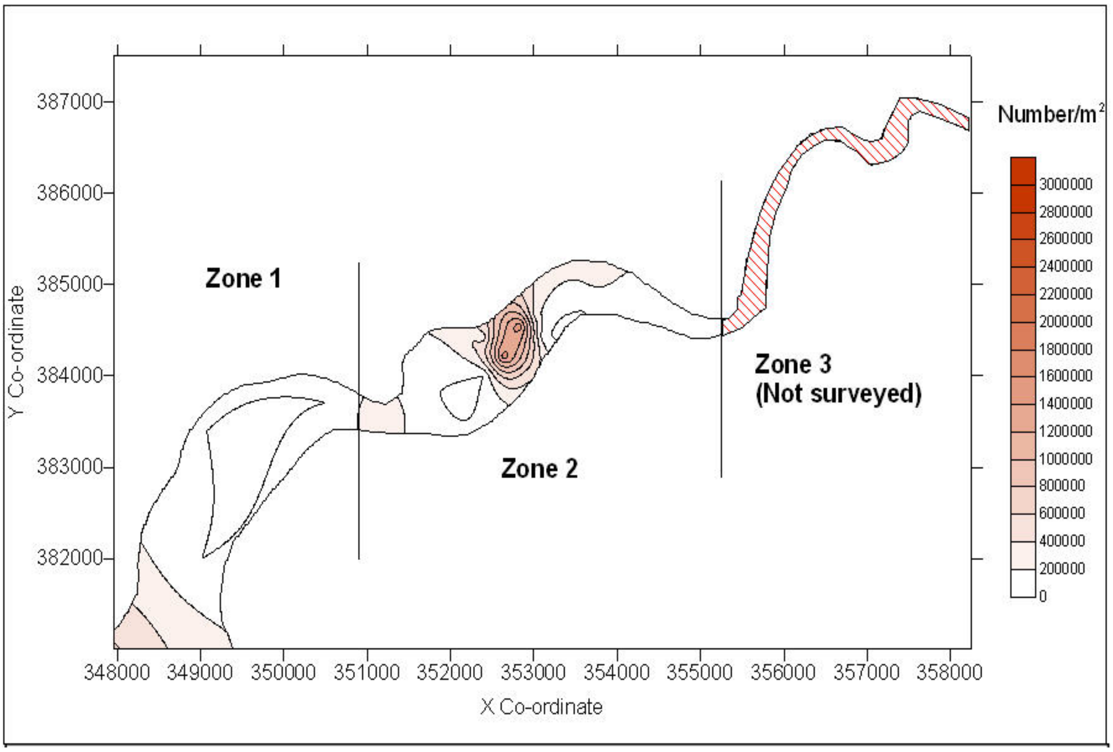


Figure 11.8i - Plot of meiofaunal abundance within the Upper Mersey Estuary for autumn 2006

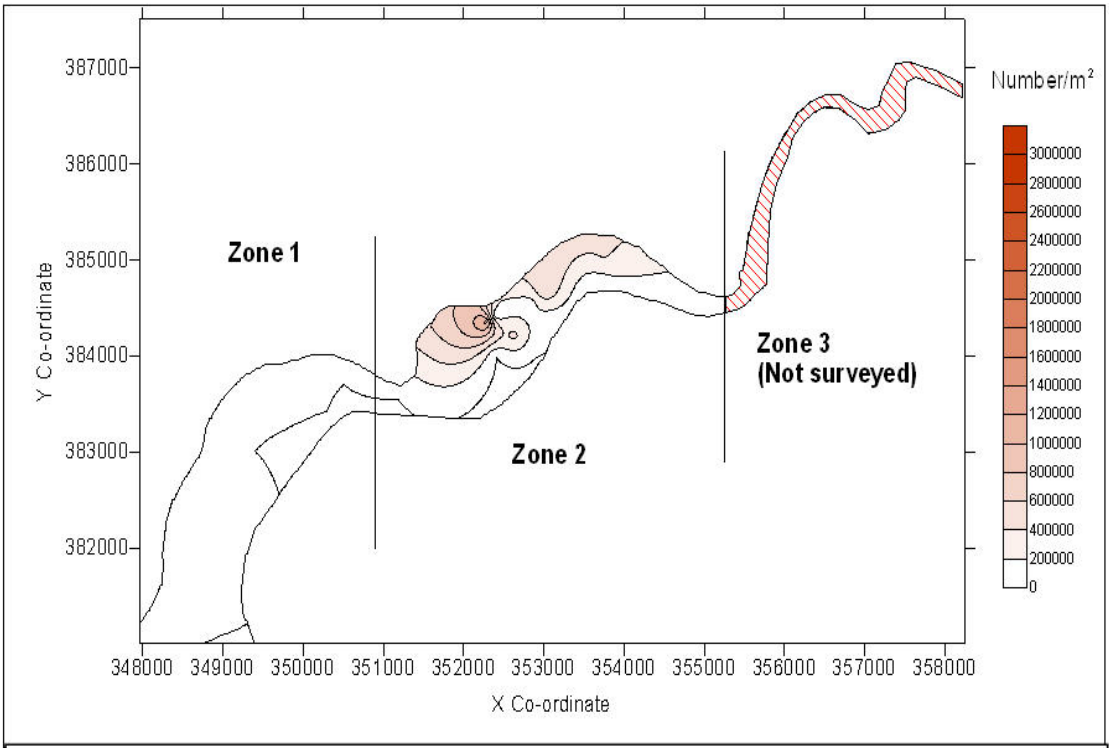


Figure 11.8j - Plot of meiofaunal abundance within the Upper Mersey Estuary for spring 2007

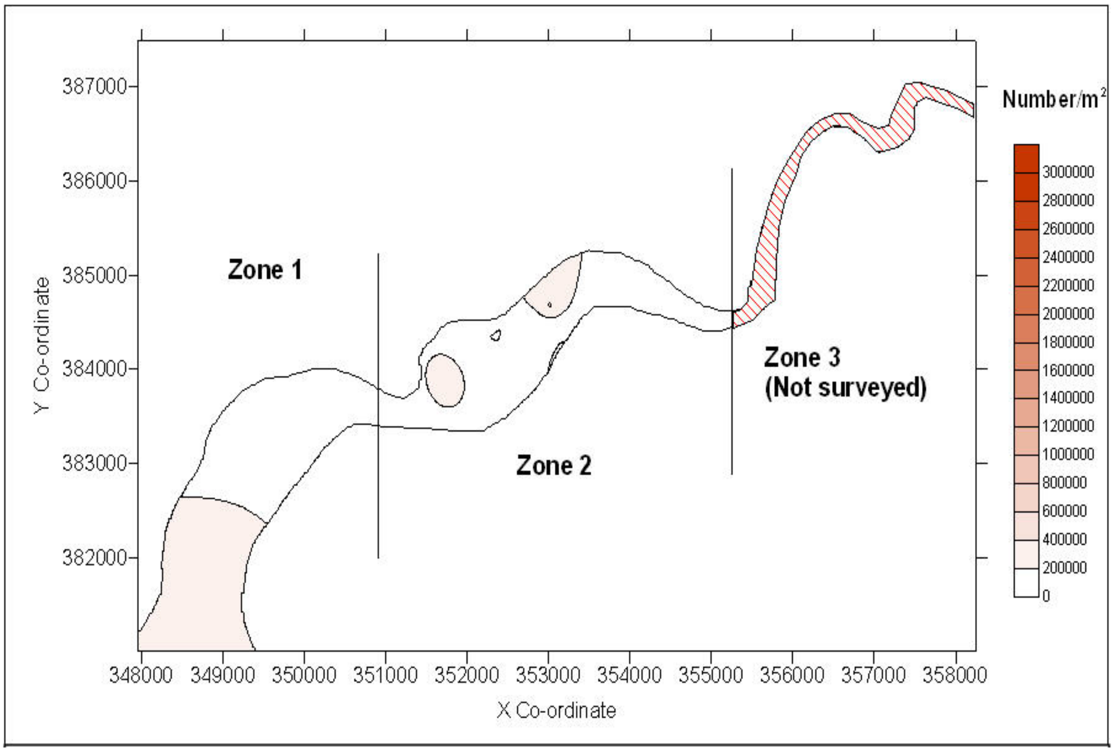
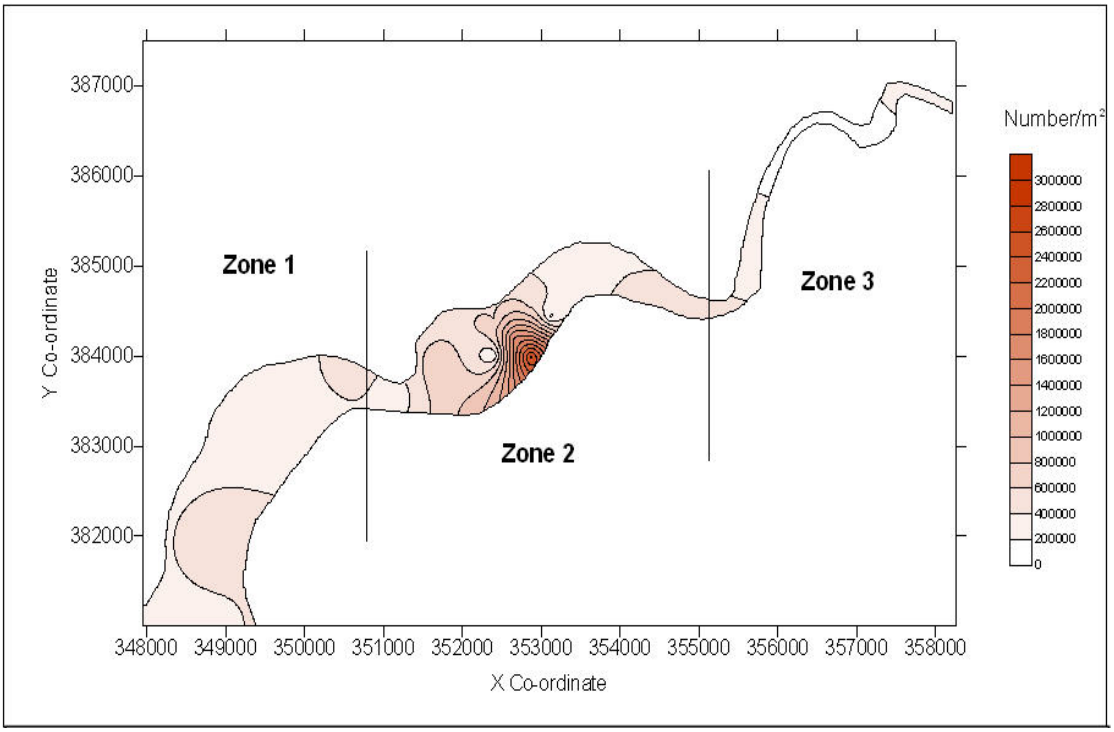


Figure 11.8k - Plot of meiofaunal abundance within the Upper Mersey Estuary between spring 2004 and spring 2007



Temporal variation

11.6.87 There was a significant difference in the abundances recorded between years and seasons. Meiofaunal abundance was less in 2006 and 2007 compared to previous years ($p \leq 0.001$) (Table 11.18). Overall, meiofaunal abundance was greater in summer than in spring and autumn. No analysis was made of meiofaunal species richness due to the very low number of taxa sampled at each site (e.g. 1 or 2 taxa per sample, and they were often dominated by nematodes).

11.6.88 Abundances of meiofauna within the study zones in 2004, 2005, 2006 and 2007 were summarised graphically in a series of contour maps (Figures 11.8a-k). The most notable observations when comparing plots is that in autumn 2004 the abundance of meiofaunal organisms was significantly higher (up to seven times greater) than during any of the other seasons. It should be noted that the scale of the autumn 2004 plot is far higher than that used for the other plots (in fact the lowest sections of the scale on the autumn 2004 plot correspond to the highest abundances indicated on each of the other plots). (Figure 11.8c). This mirrors the pattern identified for macrofaunal abundance. These very high abundances of up to 22 million individuals m^{-2} recorded in autumn 2004 were mainly sampled from Zone 2, with abundances of ~3 million individuals m^{-2} sampled throughout the other zones.

11.6.89 In spring 2004 meiofaunal abundance was relatively high throughout Zones 1 and 2 (Figure 11.8a). Abundances were far lower in summer 2004 and meiofaunal abundance was greater in Zone 2 (up to 800,000 individuals m^{-2}) than in the other zones (mainly 0-200,000 individuals m^{-2}), (Figure 11.8b). Following the extremely high abundances in autumn 2004, numbers decreased considerably to 0-1 million individuals m^{-2} throughout the Upper Mersey Estuary in spring 2005 (Figures 11.8c & d). Sites of highest meiofaunal abundance in summer 2005 were within Zone 1 (up to 3 million individuals m^{-2}) but by autumn 2005 there were very few individuals within Zone 1 (just 0-200,000 individuals m^{-2}) and Zone 2 had become the area with highest meiofaunal abundance (Figures 11.8e & f). In general contour plots indicate the abundances of meiofauna in 2006 and 2007 were less than in previous years (Figures 11.8g-j).

Intertidal Meiofauna Community Composition

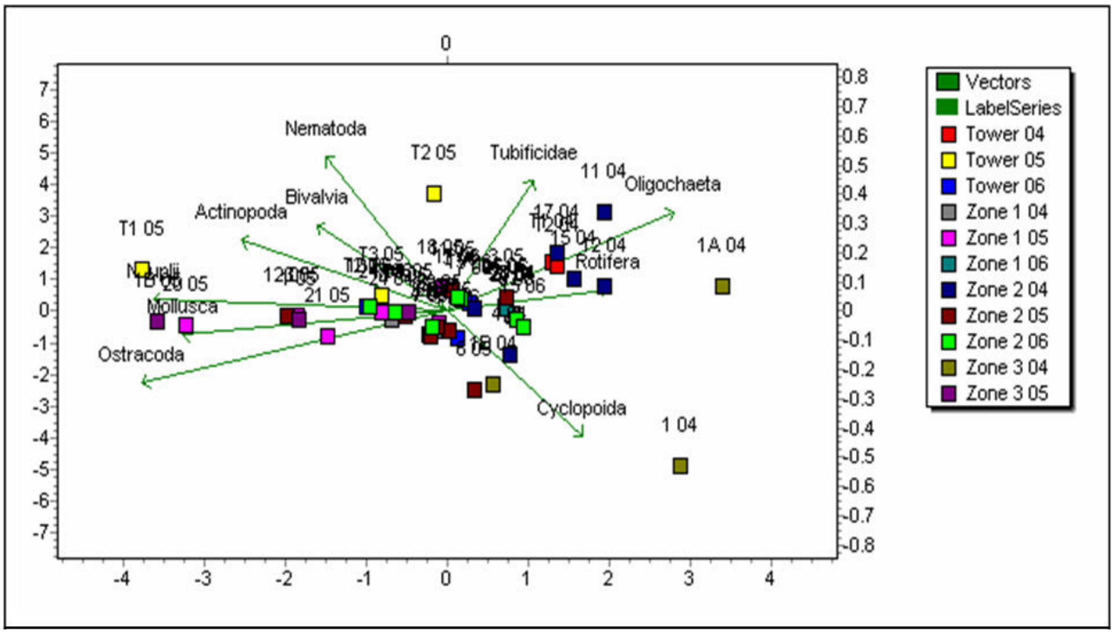
Spatial variation

11.6.90 PCA analyses indicated that interannual variation in community composition between samples was more significant than spatial variation, most particularly between 2004 and 2005. However, samples collected from Zone 3 in 2004 and 2005 consistently separated from samples that were collected from Zones 1 and 2 in both years.

Temporal variation

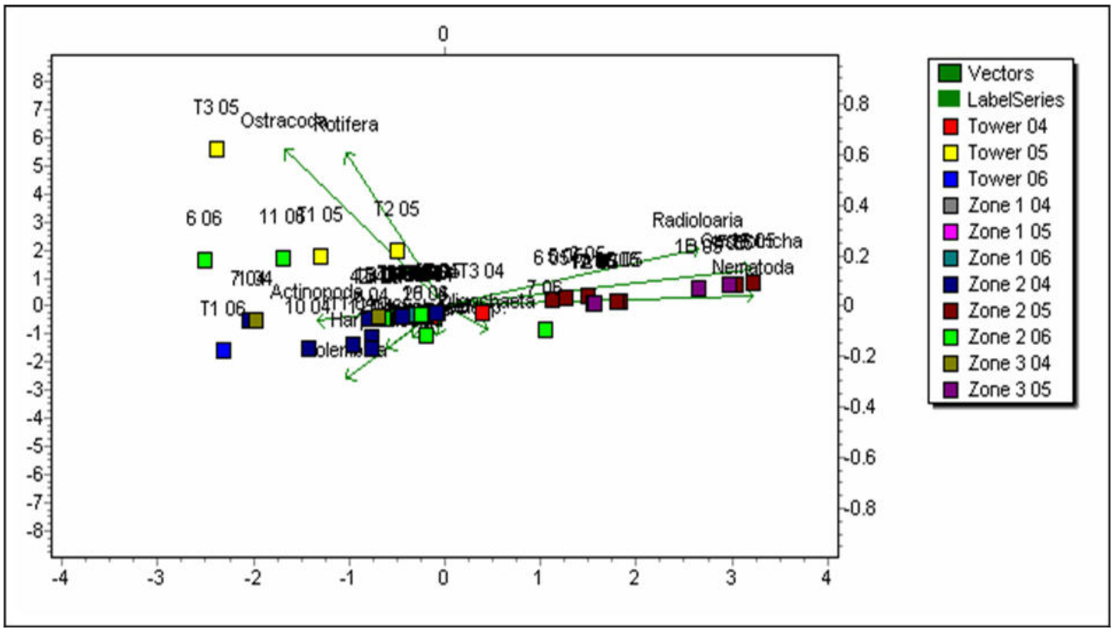
11.6.91 PCA analyses were conducted for spring, summer and autumn in 2004, 2005, 2006 and spring 2007. PCA analysis of samples collected in spring did not show any clear patterns but in summer indicated the dominant (horizontal) axis of variation was temporal, separating samples collected in 2004 and 2005 (Chart 11.9). The main sources of variation were higher abundances of Oliogochaeta, and Rotifera in 2004 than 2005 and greater proportions of Mollusca, nauplii and Ostracoda in 2005 samples when compared with 2004. No clear secondary axis of variation was evident.

Chart 11.9 - PCA ordination plot of intertidal meiofaunal samples collected in summer 2004, 2005, 2006 and 2007



11.6.92 In autumn the main axis of variation again separated samples collected in 2004 and 2005 due primarily to higher numbers of oligochaetes and nematodes in 2005. A secondary axis of variation, however, was evident which separated the three tower sites from the other sites in 2005. The tower sites were characterised by relatively higher densities of Rotifera and Ostracoda compared to the other sites in 2005 (Chart 11.10) Creeks and scrapes were not sampled in autumn so were not included in this PCA plot.

Chart 11.10 - PCA ordination plot of intertidal meiofaunal samples collected in autumn 2004, 2005 and 2006



Tower Sites

11.6.93 Meiofaunal abundance was comparable to that found in the rest of the estuary; taxa comprised of Nematoda, Oligochaeta and Actinopoda as well as small numbers of nauplii and bivalves. Meiofaunal abundance was lower than at other intertidal sites, and Tower 1 had significantly lower densities than Tower 2 or 3 ($p \leq 0.001$) (Table 11.19). Abundance was significantly greater in the autumn than in spring or summer ($p \leq 0.001$). No meiofaunal organisms were found in the summer 2004 sample at Tower 3 (though foramaniferan tests were present in all samples). However, in summer 2005 five meiofaunal taxa were found, and in autumn 2004 four taxa were found. Significantly greater meiofaunal abundance was recorded in 2004 than in 2005, 2006 and 2007 ($p \leq 0.001$) (Table 11.19).

Saltmarsh scrape and creek sites

11.6.94 High meiofaunal abundance was recorded at all scrapes, though taxonomic composition was restricted entirely to nematodes. Meiofaunal density was higher in creeks with an average meiofaunal density of 241,323 m^{-2} compared with 57,743 m^{-2} in the scrapes.

Subtidal Meiofauna Abundance

Spatial variation

11.6.95 There was no statistically significant difference in abundance of meiofauna between the two zones (Table 11.20), however, more individuals were collected in Zone 2 than in Zone 1, which can be largely attributed to higher counts of Tubificidae and copepods in Zone 2.

Temporal variation

11.6.96 A maximum density of almost 4,000,000 meiofaunal organisms m^{-2} was recorded in the subtidal spring survey of 2002. However, a Mood's median test indicated that there was no significant difference in meiofaunal abundances among years (Table 11.20).

Subtidal Meiofauna Community Composition

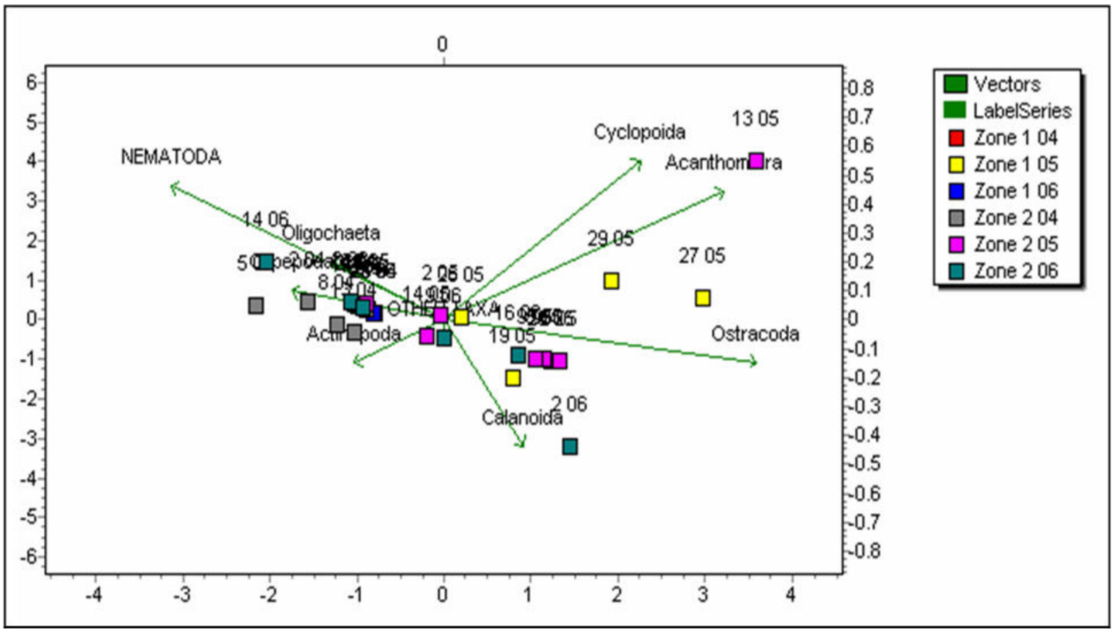
Spatial variation

11.6.97 There was no significant difference in total meiofaunal taxon richness between Zone 1 and Zone 2 across all surveys (Table 11.20). The PCA plots for all seasons indicated that the dominant axis of variation separated samples collected in 2004 and 2005. These plots suggest that temporal variation (between years) among the benthic meiofauna caught during the subtidal survey was more significant than spatial variation (between zones) (Chart 11.9). However, samples from respective zones generally grouped together on the PCA plot, suggesting that spatial variation in community composition of subtidal meiofauna was apparent but secondary to temporal variation.

Temporal variation

11.6.98 The same pattern was observed for PCA analyses for spring, summer and autumn. The PCA plot for autumn only is provided, which is representative of the trends observed for other seasons (Chart 11.11). The association of species with specific sample zones and years are indicated on the plot by the length and direction of arrows and the species associated with the arrow. As illustrated in the PCA for autumn samples Copepoda, Nematoda and Actinopoda were consistently positively associated with subtidal samples collected in 2004 and 2006. In contrast, Ostracoda and Acanthometra (in addition to bivalves during certain seasons) were consistently positively associated with subtidal samples collected in 2005. This pattern was also repeated when PCA analyses were conducted for spring and summer.

Chart 11.11 - PCA ordination plot of subtidal meiofaunal samples collected in autumn 2004, 2005 and 2006

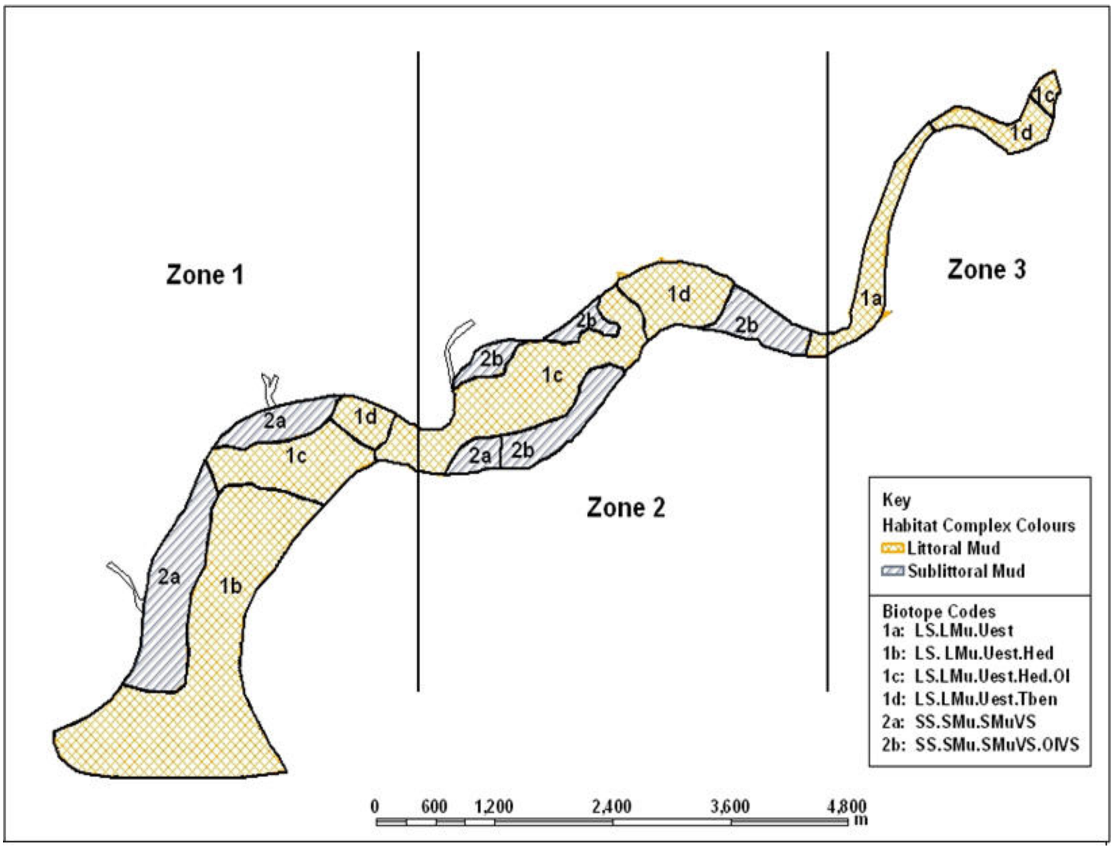


Biotope Analysis

11.6.99 Comparative tables produced by the JNCC for the Marine Habitat Classification for Britain and Ireland were used to classify sediment biotopes. Description was partially based on the mean percentage fractions of different substrate types estimated via particle size analysis. For example, the two main sediment types identified in the Upper Mersey Estuary were LS.Lmu (littoral sediment, littoral mud) and SS.Smu (sublittoral sediment, sublittoral mud).

11.6.100 The full biotopes were then classified by examining the sediment data in combination with the macroinvertebrate data for each sample site. Full biotopes for different sections of the Upper Mersey Estuary are listed below with the corresponding JNCC Marine Habitat Classification definitions. The distribution and extent of coverage of these biotopes within the Upper Mersey Estuary are illustrated in Figure 11.9, below.

Figure 11.9 - Distribution of different biotopes throughout the Upper Mersey Estuary



11.6.101 **LS.Lmu.Uest**: Upper estuarine sandy mud and mud shores, in areas with significant freshwater influence. Littoral mud typically forms mudflats, though dry compacted mud can form steep and even vertical structures, particularly at the top of the shore adjacent to saltmarshes. Little oxygen penetrates these cohesive sediments, and an anoxic layer is often present within millimetres of the sediment surface. The upper estuarine mud communities support few infaunal species and are principally characterised by a restricted range of polychaetes and oligochaetes.

11.6.102 **Ls.Lmu.Uest.Hed:** Sandy mud, usually mid and lower shore of the upper and mid Estuary. Other species that may occur include oligochaetes, polychaetes and mud shrimp, *Corophium* and spire shell *Hydrobia ulvae*.

11.6.103 **LS.Lmu.Uest.Hed.Ol:** Sandy mud, species poor community found in muddy or slightly sandy mud typically at the head of the estuary. Oligochaetes including *Tubificoides benedeni* are found in the most extreme upper estuary biotope.

11.6.104 **LS.Lmu.Uest.Tben:** Extreme upper estuarine fine sandy mud, sometimes with a fine sand fraction, in very sheltered conditions and subject to reduced salinity. An anoxic layer is usually present within the upper 3 cm of the sediment. The infaunal community is extremely poor, consisting almost exclusively of oligochaetes, including *Tubificoides benedii* and, more rarely, *Heterochaeta costata*. The only polychaete species that may occur is *Capitella capitata*, which may be common. The sediment may form steep banks in upper parts of macro-tidal estuaries or along saltmarsh creeks. *Vaucheria* species may form a film on the sediment surface along such creeks, and juvenile shore crabs *Carcinus maenas* may be common. At the very upper end of estuaries, the oligochaetes *Limnodrilus* spp. and *Tubifex tubifex* may be found.

11.6.105 **SS.Smu.SmuVS:** Shallow sublittoral muds, extending from the extreme lower shore into the subtidal in variable salinity (estuarine) conditions. Such habitats typically support communities characterised by oligochaetes, and polychaetes such as *Aphelochaeta marioni*. In lowered salinity conditions the sediments may include a proportion of coarser material, where the silt content is sufficient to yield a similar community to that found in purer muds.

11.6.106 **SS.Smu.SmuVS.OlVS:** Reduced or variable salinity, muddy and sandy mud sediment. *Tubificoides* found here, but very few other spp. Organic loading and poor water exchange. Found at edge of intertidal channel in estuaries where current velocity allows deposition of silt and establishment of infaunal communities.

11.6.107 There was little variation in biotope type throughout the Upper Mersey Estuary. Both littoral and sublittoral sediments were predominantly muddy (silt/clay). The biotope Ls.Lmu.Uest.Hed was only found in Zone 1, however, the other biotopes in Zone 1 (i.e. SS.SMu.SMuVS, LS.LMu.Uest.Hed.Ol and LS.LMu.Uest.Tben) were all also present in Zone 2. The biotope LS.Lmu.Uest was only present in Zone 3 (the zone furthest upstream).

Discussion of baseline data (Estuarine Invertebrates)

11.6.108 In the UK, benthic-dwelling invertebrates are frequently used as indicator organisms for monitoring the biological effects of environmental change in estuarine ecosystems (Ref. 18, Ref. 75, Ref. 76). As a group these invertebrates are largely sedentary and in order to survive they must be able to withstand local extremes of a range of environmental factors (e.g. temperature, pollution etc.) (Ref. 76).

11.6.109 Most biological investigations of invertebrates target the larger macrofauna (i.e. animals that are retained by a 500 micron mesh sieve and which live on or within sediments (epifauna and infauna, respectively). One reason for this is that this group can be readily counted and identified (Ref. 76). However, meiofauna (animals on or within sediments which fall within the size range of 63 to 500 microns) have an equally important role in ecosystem function due to their high abundance, ubiquitous distribution, rapid generation time and fast metabolic rates. As a consequence, over the last 20 years the sampling of the smaller meiofauna in addition to macrofauna has become increasingly common for marine environmental assessments (Ref. 21, Ref. 76). This approach was adopted for the current study as the status of meiofaunal assemblages is often an effective measure of the overall integrity of the marine benthic ecosystem (Ref. 77). Birds primarily feed on macrofauna as opposed to meiofauna.

11.6.110 Benthic estuarine invertebrates are an integral part of the estuarine food web providing a rich food source on which many fish and wetland bird species depend. Consequently, knowledge of their distribution, species richness, abundance and community dynamics is central to the ecological management of water bodies. Benthic macroinvertebrates are commonly used for aquatic monitoring surveys as sampling procedures are well developed, techniques used are relatively rapid and simple, and there are high quality keys for the identification of all major groups. In addition, macroinvertebrates are reasonably sedentary, with comparatively long life-spans, so they can reflect water quality conditions at a single site over a long period of time (e.g. Ref. 78, Ref. 79, Ref. 48).

Estuarine invertebrates

11.6.111 High energy environments such as estuarine sand flats and subtidal mobile sand banks are characterised by a low diversity of species. There is usually a lack of sedentary groups such as bivalve molluscs and invertebrate communities within estuarine habitats, and they are generally dominated by agile swimmers such as amphipods and isopods. In low energy areas such as intertidal sand and mudflats, sessile organisms (e.g. polychaetes) tend to dominate (Ref. 80). Whilst the estuarine fauna collected during this study was sparse, there did appear to be greater abundances of infauna in the intertidal zones, whilst the sublittoral hand trawls were dominated by small motile crustacea and amphipods. It is important to note that invertebrate diversity is an important ecological characteristic of the invertebrate community. In terms of bird food availability, however, it is the abundance and density of organisms per square metre which is the most important aspect for consideration as diversity and density are not necessarily positively correlated.

Estuarine Macrofauna Abundance

11.6.112 The Upper Mersey Estuary is a highly dynamic environment, continuously reworked and under the influence of a range of different stresses including fast flowing currents, shifting sands, salinity pressures and pollution stress. It is a combination of all these factors that have resulted in the highly tolerant, species poor, invertebrate communities found there. The invertebrate community within the sampled area is typical of upper estuarine environments.

Spatial Variation

11.6.113 In general, the median values of invertebrate abundance were significantly higher in Zone 1 than Zones 2 and 3. This statistic reflects the general consistency of invertebrate numbers in Zone 1 although during some sample seasons higher numbers of invertebrates were collected in Zone 2. To an extent macrofauna abundance appeared to be correlated to algal biomass and it is possible that invertebrates moved in response to changes in algae which forms an important food source for many invertebrates. It is also likely, however, that the distribution of both algae and invertebrates are largely driven by physical forces, such as water and sediment movement in the Estuary.

Temporal Variation

11.6.114 Invertebrate abundance was lower overall in 2003 and 2004 compared to other years. However, it was noted in 2004 that there were two distinct peaks in invertebrate abundance. These were due to large numbers of *Gammarus zaddachi* that were collected in Zone 1 in spring 2004 and large numbers of Collembola that were collected in Zones 2 and 3 in autumn 2004. During other years such peaks for individual species were not evident. As described above, it is suggested that physical forces, such as water and sediment movements were likely to be the main drivers determining distribution of the organisms in the Estuary.

11.6.115 Some species of polychaete worms have semelparous or 'boom and bust' life history strategies in which the mature adults spawn synchronously. Therefore, for these species the number of adults present in the sediment would be expected to be dependent on the stage of the reproductive cycle, if this was the case potentially larval settlement and recruitment of juveniles to the population could result in a massive increase in the population size of different species at certain times of the year. However, despite the propensity for these animals to reproduce rapidly, no evidence of these strategies were suggested by the data from the present study. It is suggested that biotic factors, such as reproductive strategies, might be masked by abiotic factors, such as water and sediment movements, in determining the spatial and temporal distribution of macrofauna in the Estuary within the study zones.

Estuarine Macrofauna Community Composition

Spatial Variation

11.6.116 The results of the 2002-2007 surveys revealed that the Upper Mersey Estuary generally has a low macroinvertebrate species richness and organisms were patchily distributed. The dominant taxon was Oligochaeta although other taxa (e.g. the polychaete worm *Hediste diversicolor*) were present at a number of the sites. Some freshwater species were also found although they were likely to have drifted to the sample zones from further upstream.

11.6.117 A key factor reducing the diversity of species in the Upper Estuary is the sandy substratum and fast currents which cause considerable movement of sediment and the formation of channels within the estuary. This is a main feature of the Estuary due to its unique “bottle-neck” shape (the main channel narrows between Runcorn and Widnes and again near the mouth of the estuary at Birkenhead). A result of this “bottle-neck” effect is that the estuary is a highly dynamic environment and this was highlighted by changes observed in the topography of the intertidal zones over time. For example, cliffs were flattened and built up over the course of just a month and channels moved, in one case as much as 30 m in just one month. This makes it very difficult for invertebrates to persist in some areas, particularly benthic bivalves and gastropods.

11.6.118 Another reason why low macroinvertebrate diversity is typical of most upper estuaries is that the extremes of salinity experienced within estuaries allow only the most stress tolerant species to survive. Oligochaetes thrive in low oxygen conditions which typify estuarine mudflats and may become the sole inhabitant of estuarine mudflats in conditions of organic enrichment. Diversity in estuaries generally increases slightly moving downstream from the upper estuary, with the maximum number of estuarine species occurring between salinities of 5 and 18‰ (parts per thousand) (Ref. 1). This trend was observed for most sample periods in this study and Zone 1 was generally found to have the greatest species richness and highest abundances (there were, however, exceptions to this distribution pattern during some sample seasons).

11.6.119 Although species diversity is still relatively low, over recent years there has been significant increase in macrofauna diversity within the Upper Mersey Estuary. The estuary was once the most polluted estuary in the United Kingdom (Ref. 81). This resulted in an environment in which nothing but the most pollution tolerant species could exist (e.g. oligochaetes) and species diversity was very low. In fact, when compared with earlier records of invertebrate life in the Estuary when the Upper Zone consisted only of species of oligochaetes and other annelids (Ref. 82), there are now more species and groups present than for the last 50 years (Ref. 83).

Temporal Variation

11.6.120 There was a significant increase in the number of macrofaunal taxa found in the 2004 and 2005 surveys compared with 2002 and 2003. This was mainly due to the extension of the survey to include a greater number of sites downstream of the SJB where salinity fluctuations were less extreme and conditions for organisms were slightly more stable. Two more sites were also sampled in Zone 3 (zone furthest upstream) from 2004 onwards, these samples included some freshwater species which were able to tolerate brackish conditions.

11.6.121 Algae is an important food source for many macroinvertebrate species. The spatial distribution of total macrofaunal abundance in the intertidal zones did reflect the chlorophyll concentration (i.e. algal biomass) among sites during summer and autumn 2004. It is likely that the patterns observed reflect a combination of a direct trophic link between algae and macrofauna, and the fact that the dynamics of estuarine currents and sediment movements could determine the distribution of both algae and macrofauna. Such a correlation, however, was less evident for samples collected in 2005 and 2006.

11.6.122 Overall, the estuarine invertebrate communities within the study zones were characterised by a high degree of temporal variability as a result of the turnover of taxa between years. In contrast, spatial variability was generally less evident and there were no consistent patterns in species richness or abundance, both between and within the three zones sampled.

11.6.123 Only macrofaunal organisms formed the estuarine epifauna (organisms inhabiting the sediment surface). *Neomysis integer* and *Crangon crangon* were the most commonly caught species. It is suggested that the large areas of sandy substratum provide an ideal habitat for these species as they swim along the surface sifting through the sand and consuming the macro- and meiofauna living within sediments. The species richness was significantly less during autumn than in spring and summer.

11.6.124 It is likely that the seasonal and annual variation observed among the epifauna was largely due to abiotic drivers, such as water and sediment movement, forcing the changing distribution of organisms in this highly dynamic and energetic environment.

11.6.125 The fact that mean macrofaunal abundances were highest in Zone 1 when considering the whole survey period suggests that in terms of potential food source Zone 1 may be more important for bird than Zones 2 and 3. This would appear to support the findings of Chapter 10 (Terrestrial and Avian Ecology) which found that numbers of birds downstream of the SJB were greater than they were upstream near the location of the Project.

Estuarine Meiofauna Abundance

Spatial variation

11.6.126 In contrast to estuarine macrofauna, which decreased in abundance moving upstream, many meiofaunal species have a high tolerance to brackish water (Ref. 84). They can also withstand shifting sandy environments. It is therefore not surprising that large numbers of meiofauna were found at almost all survey sites. Nematodes were particularly widespread and were often the only group to be found at sites. There were significant differences between meiofaunal numbers found during the subtidal survey, with Zone 2 having significantly higher meiofaunal numbers than Zone 1. It is important to note that macrofauna form a key part of the diet of birds in the estuary but meiofauna are considerably smaller and are consequently far less significant in terms of bird diet so meiofaunal abundance is not expected to be related to bird distribution.

11.6.127 Meiofauna are well adapted to surviving in shifting sediment environments and unlike macrofauna have the ability to live between sand grains and adhere to them. As the Upper Mersey Estuary is composed mainly of fine sandy substratum it may explain the greater proportion of meiofauna compared with macrofauna in these surveys. In fact it is not unusual for meiofauna to make up almost 90 % of living biomass in some cases (Ref. 85). It is also known that areas of pollution outfall support larger numbers of nematodes and meiofaunal oligochaetes than macroinvertebrates (Ref. 86).

11.6.128 The distribution of meiofauna is not likely to directly influence the distributions of feeding birds in the Estuary as they do not form a significant part of the diet of birds in this environment as mentioned in Paragraph 11.6.124. The larger macrofaunal organisms are preferentially consumed by birds.

Temporal variation

11.6.129 There was seasonal variation in meiofauna numbers with spring yielding higher densities of organisms. This is consistent with other studies that have found that different meiofaunal species were found at different times of year (Ref. 86, Ref. 84). In some cases these changes also reflected the seasonal variation identified for algae upon which some meiofauna feed (Paragraphs 11.6.3-7 and 11.6.16-21). For example, as with macrofauna, there was a broad correspondence between the distribution of total meiofaunal abundance in the intertidal zones and the distribution of chlorophyll *a* concentration (i.e. algal abundance) in both summer and autumn 2004. However, the distribution of meiofauna and chlorophyll *a* concentration was decoupled in the 2005 and 2006 samples. Considerable dynamism in channel state was recorded during 2005 and 2006, particularly in the zone downstream of Runcorn Gap (Chapter 7: Hydrodynamics and Estuarine Processes Movement). It is possible that the environmental conditions were not sufficiently stable at this time to allow measurable biotic interactions to occur.

11.6.130 Estuarine Meiofauna Community Composition

Spatial variation

11.6.131 No statistical analyses were conducted for the species richness of the meiofaunal community because the diversity of this group was extremely low and only a few categories of meiofauna were regularly identified within samples.

Temporal variation

11.6.132 Diversity of meiofauna was low during all seasons and years.

Tower Sites

11.6.133 The sites chosen as possible tower construction locations were all within the intertidal zone. The results of this study revealed that they were low in terms of both diversity and abundance. The taxa found (*H. diversicolor*, Oligochaeta, Nereidae, Collembola and Tubificidae) were all stress tolerant estuarine species and were patchily distributed on a spatial and temporal scale. Compared with the rest of the intertidal area of Zone 2 the tower sites had a similar low richness and abundance and no invertebrate species were found exclusively at the tower sites.

11.6.134 Meiofaunal abundance varied seasonally at the Tower Sites 1 and 3. However, it was noted during sampling that a channel which was beside the Tower 3 sample site actually moved position by 30 m between visits to the area. Consequently any sediment, and thus organisms within the sediment, could be significantly disturbed by the altered water flow. This channel movement, however, is ongoing due to the dynamic nature of the estuarine habitat.

Scrape and Creek Invertebrates

11.6.135 The creek and scrape sites located on Wigg Island provide a potential habitat for some estuarine invertebrates. Chapter 7 (Hydrodynamics and Estuarine Processes Movement) suggests that there is less physical dynamism within this zone compared to the main estuary, which would favour the development of biotic communities. However, water in the scrapes is prone to evaporation which also leads to salinity changes. When exposed above the tide for long periods of time, scrapes were observed to dry out completely. Therefore, this survey provided evidence that these areas provide a habitat for estuarine invertebrates but both diversity and abundance were low in both the scrapes and the creek. Additionally, Chapter 7 (Hydrodynamics and Estuarine Processes Movement) suggests that another, as yet, unidentified driving variable, might be influencing the physical environment in this zone.

Freshwater Invertebrates

Abundance

11.6.136 A total of 13,705 individual invertebrates were collected and identified from the Bridgewater Canal and 18,290 were collected and identified from the St. Helen's Canal across all surveys from summer 2004 to summer 2007. The most abundant taxa overall across both canals were the hydrobid snail, *Potamopyrgus antipodarum* the bivalve, *Pisidium* spp., the leech, *Helobdella stagnalis*, Oligochaeta (worms) and Chironomidae (non-biting midge larvae). These invertebrate taxa are all typical of canals elsewhere in the UK and are all associated with silty habitats. *Helobdella stagnalis*, oligochaeta (worms) and chironomidae (non-biting midge larvae) are all tolerant of low dissolved oxygen concentrations which is characteristic of the bottom of many silty canals.

11.6.137 During summer and autumn of both 2004 and 2005 the abundance of invertebrates was greater in the Bridgewater Canal than in the St. Helen's Canal (Chart 11.12 a & b). The maximum abundance of invertebrates in the Bridgewater Canal was ~1700 individuals per sample in autumn 2005. This was largely attributed to relatively high abundances of the hydrobid snail, *Potamopyrgus antiporarum* and the shrimp, *Crangonyx pseudogracilis*. The maximum abundance of invertebrates in the St. Helen's Canal was 3,927 individuals per sample in spring 2007. This was largely attributed to relatively high abundances of seed-shrimps (Ostracoda) at the upstream and downstream sites.

Taxonomic composition

11.6.138 Over 100 different invertebrate taxa were collected across all the samples from the Bridgewater and St. Helen's Canal. At all sites and at all times of year the species richness of invertebrates was greater in the Bridgewater Canal than in the St. Helen's Canal, with the only exception being the mid-point site in spring 2005 (Chart 11.12c & d). More invertebrate taxa were collected in 2005 than in other years in both the Bridgewater and St. Helen's Canal (Chart 11.12c & d).

Chart 11.12a - Total invertebrate abundance at proposed construction site in the Bridgewater Canal (150 m upstream of proposed crossing site, mid-point at which proposed bridge will cross the canal and 150 m downstream of crossing site), summer 2004 to spring 2007

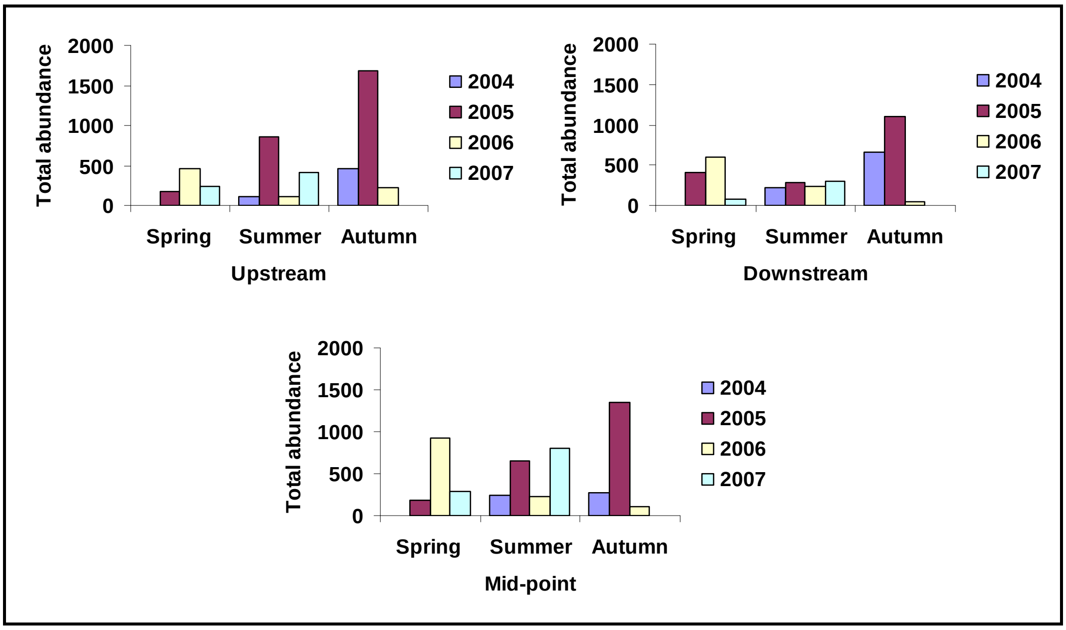


Chart 11.12b - Total invertebrate abundance at proposed construction site in the St Helen's Canal, (150 m upstream of proposed crossing site, mid-point at which proposed bridge will cross the canal and 150 m downstream of crossing site), summer 2004 to spring 2007

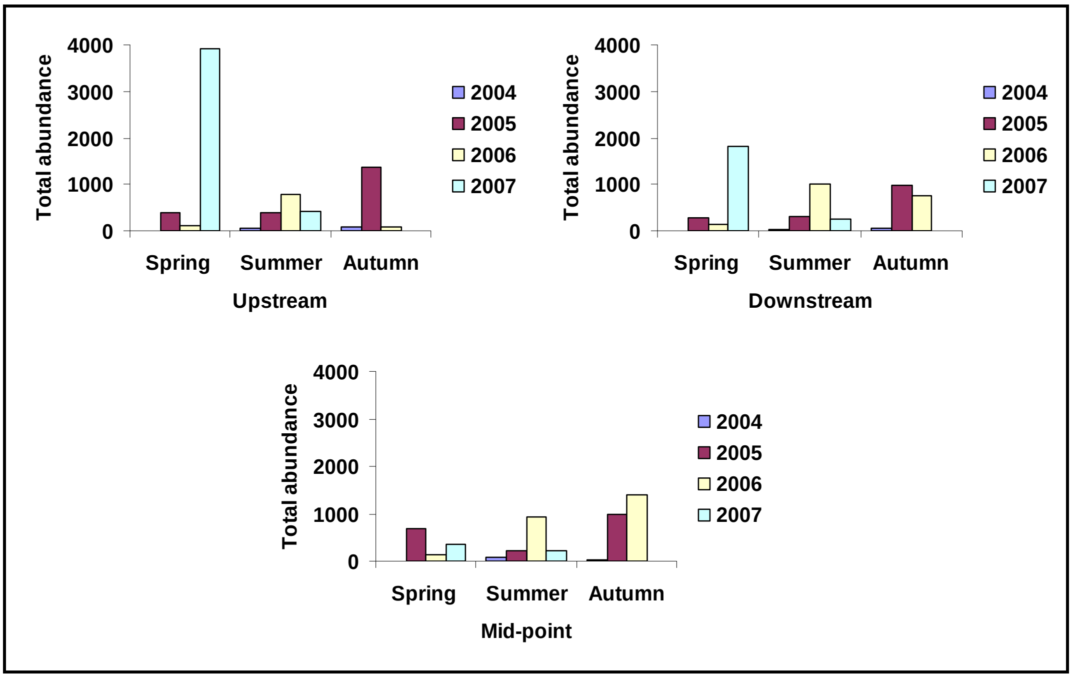


Chart 11.12c - Taxon richness at the proposed construction site on the Bridgewater Canal (150 m upstream of proposed crossing site, mid-point at which proposed bridge will cross the canal and 150 m downstream of crossing site), summer 2004 to spring 2007

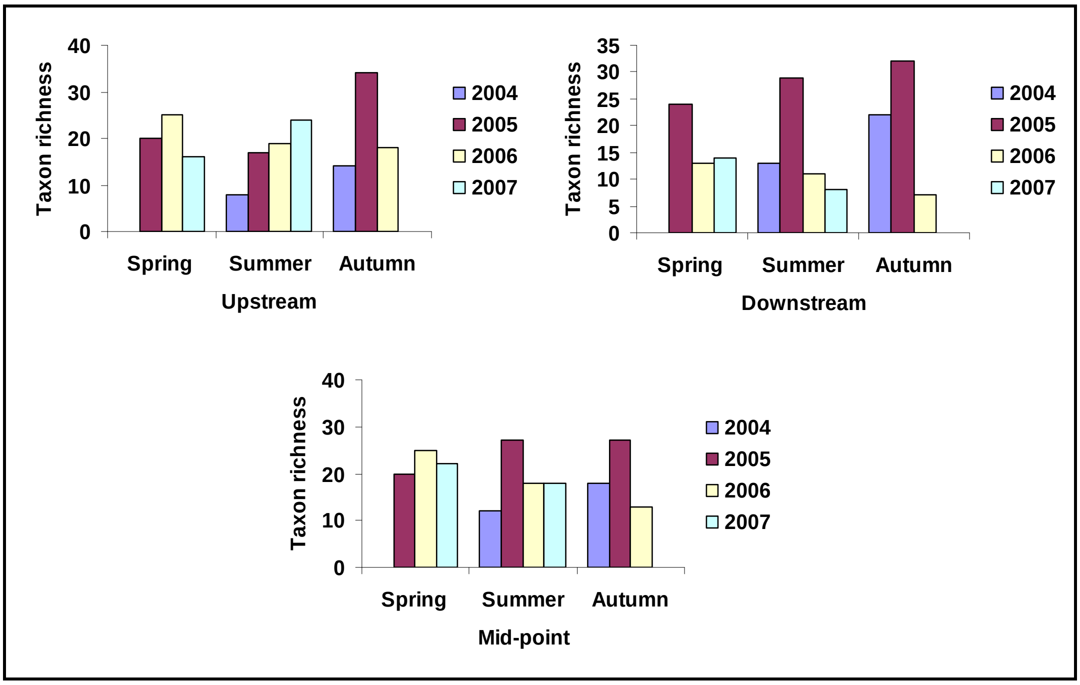
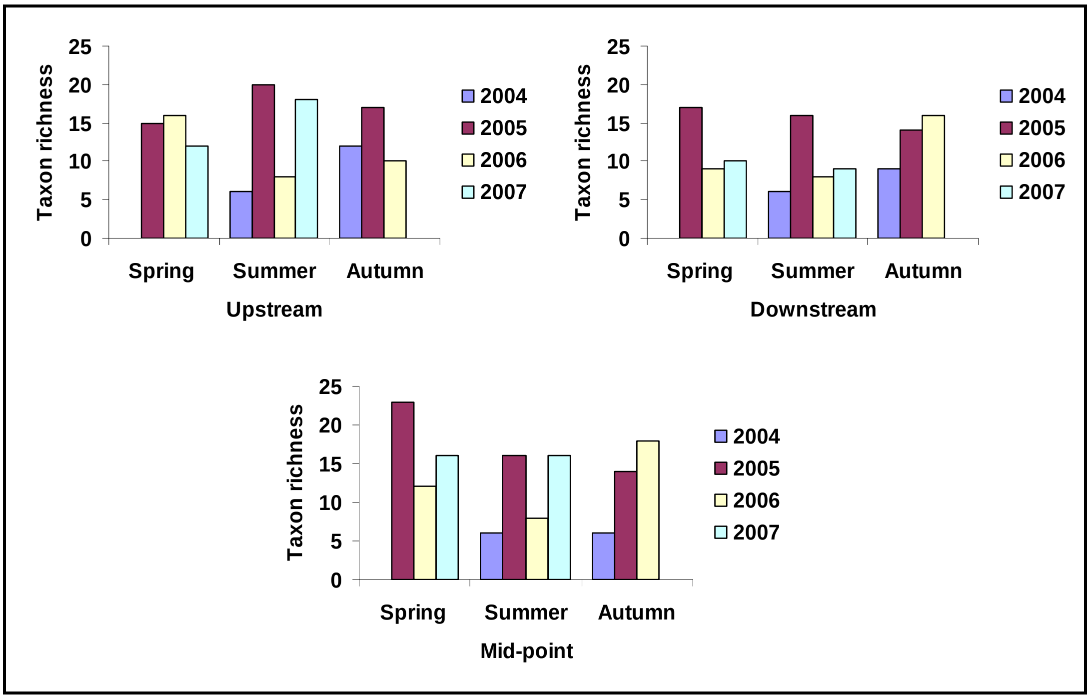


Chart 11.12d - Taxon richness at proposed construction site in the St Helen's Canal (150 m upstream of proposed crossing site, mid-point at which proposed bridge will cross the canal and 150 m downstream of crossing site), summer 2004 to spring 2007



Biological Monitoring Working Party (BMWP) and Average Score Per Taxon (ASPT) Scores

11.6.139 Although the majority of macroinvertebrates that were collected in all the freshwater samples were pollution tolerant, some pollution-sensitive taxa were found in the Bridgewater Canal and St. Helen's Canal (see Table 11.22). *Phryganea bipuntata* (Phryganeidae*)* was found within the Bridgewater Canal across several years and seasons (Plate 11.7, Appendix 11.2), *Mystacides longicornis* (Leptoceridae) was found in both canals across a range of years and seasons (Plate 11.7, Appendix 11.2), five *Oectis ochracea* (Leptoceridae) were found in the St. Helen's Canal over several seasons and one individual *Molanna angustata* (Molannidae) was collected in the autumn 2005 survey. These species are regarded as among the most pollution-sensitive macroinvertebrates in UK freshwaters. The BMWP scoring system assigns each invertebrate family a number from 1 – 10; 10 being the most pollution-sensitive families. The species described above all belong to families that score 10 in the BMWP scoring system.

11.6.140 A comparison was made of the BMWP and ASPT scores calculated for each canal. A two-way ANOVA indicated that there was no significant difference in BMWP scores between the St. Helen's Canal and Bridgewater Canal. In contrast, the ASPT score was significantly greater for the St. Helen's Canal than the Bridgewater Canal ($F = 37.83$, $p \leq 0.001$, $df = 1$). The maximum ASPT recorded for St. Helen's Canal (i.e. across all sites for both 2004 and 2005) was 5.75 and the maximum in the Bridgewater Canal was 4.7. There were no seasonal differences among BMWP or ASPT scores.

Stewards Brook

11.6.141 The spring 2007 data from Stewards Brook revealed an average abundance of 2448 and an average richness of 14. Large numbers of the isopod *Asellus aquaticus*, the freshwater shrimp *Crangonyx pseudogracilis* and the freshwater snails *Lymnaea palustris* and *Physella acuta* group. The average BMWP was relatively low at ~48 and the ASPT was 5.52. In summer 2007, fewer individual invertebrates were collected than in spring, with an average of 1639 per sample. However, more invertebrate taxa were collected in summer 2007, with an average of 21 taxa per sample. The average BMWP and ASPT scores in summer 2007 were 37 and 3.90 respectively.

Bowers Brook

11.6.142 In spring 2007, only three taxa were found at each of the 3 sites sampled on this watercourse. These included *Baetis rhodani*, *Gammarus tigrinus*, Oligochaeta and high numbers of the salt marsh snail *Assiminea grayana*. *A. grayana* specimens were sent to an external expert, Dr Ian Wallace of Liverpool Museum, for validation. These identifications have subsequently been validated. In summer 2007, *Baetis rhodani* was not found, but some additional taxa were collected that were not in spring 2007. These additional taxa were: *Potamopyrgus antipodarum*, *Orchestia cavimana*, *Asellus aquaticus*, Collembola, *Elmis aenea* and Psychodidae.

11.6.143 In spring 2007, the average BMWP score was 8.6 and the ASPT was 2.8. In summer 2007, these scores were 8.0 and 2.3 respectively.

Table 11.22 - List of families found in the canal surveys

	Family	BMWP score
TRICLADIDA	Dendrocoelidae Planaridae	5 5
GASTROPODA	Valvatidae Hydrobiidae Bithyniidae Physidae Lymnaeidae Planorbidae Succineidae Zonitoides	3 3 (including Bithyniidae) 3 3 3 - -
BIVALVIA	Sphaeriidae Dreissenidae	1 -
OLIGOCHAETA		1
HIRUDINEA	Glossiphonidae Erpobdellidae Piscicolidae	3 3 4
HYDRACARINA		-
OSTRACODA		-
BRANCHIURA	Argulidae	-
MALACOSTRACA	Asellidae Gammaridae Crangonyctidae	3 6 (incl. Crangonyctidae)
EPHEMEROPTERA	Caenidae Baetidae	7 4
ODONATA	Coenagrionidae Aeschnidae	6 8
HEMIPTERA	Gerridae Corixidae	5 5
COLEOPTERA	Hydrophilidae Hydraenidae Dytiscidae Haliplidae	5 (incl. Hydraenidae) 5 5
MEGALOPTERA	Sialidae	4
TRICHOPTERA	Leptoceridae Phryganeidae Limnephilidae Polycentropodidae Psychomyiidae Hydroptilidae Molannidae	10 10 7 7 8 6 10
LEPIDOPTERA	Pyralidae	-
DIPTERA	Chironomidae Tipulidae Ceratopogonidae	2 5 -

Discussion of baseline data (Freshwater Invertebrates)

11.6.144 The results of the baseline surveys of the St. Helen’s and Bridgewater Canals indicate that the invertebrate communities consisted mainly of organic pollution tolerant species with some sensitive species present, but only in small numbers. Those species found in the highest numbers were pollution tolerant species. The ASPT scores suggest that the

St Helen's Canal was a less polluted canal than the other waterbodies as there were more pollution sensitive invertebrates in the St. Helen's Canal. These biological indicators are consistent with the water quality data that are reported in Chapter 8 (Surface Water Quality) which suggest that the St. Helen's Canal is classified as 'fair' under the GQA system, whereas Bowers Brook was classified as 'fairly poor' at the time the macroinvertebrate samples were collected. Stewart's Canal was classified as 'bad' downstream of the former St. Michael's Golf Course at the locations that the invertebrate samples were collected, and this is consistent with the biotic scores that were derived from these samples (Chapter 8: Surface Water Quality).

11.6.145 None of the species collected were particularly rare, though some are only found in specific parts of the country, including the Gastropod *Menetus dilatus* which was introduced from America, and the malacostracan *Gammarus tigrinus* which is slowly spreading through the Northwest and Midlands canal system. The large number of pollution tolerant species is typical of a slow flowing polluted water body like that of an urban canal and is reflected in the fairly low biotic score.

11.6.146 The collection of *Assiminea grayana* from Bowers Brook is particularly worth noting. Whilst it has been given a Conservation Score of 2, indicating that it is 'common, occurs in 25-50 % of samples from similar habitat' (Ref. 87) *A. grayana* is also listed as a Red Data Book species. This species has mainly previously been recorded on the east coast of England including the Humber estuary (Ref. 25). It appears its presence on the west coast of England was first recorded in 2007 by Charlton and Ruscoe (Ref. 88) who also found specimens of *A. grayana* near Fiddlers Ferry within the Upper Mersey Estuary. This might be a result of the fact that few previous surveys have been conducted in saltmarsh habitats on the west coast of England. However, it could also indicate the spread of this species westward from more easterly locations, possibly via the Manchester Ship Canal or the Bridgewater Canal.

Estuarine Fishes

11.6.147 A summary of the fish species caught in the Upper Mersey Estuary between 2002 and 2005 is provided in Table 11.23. Twenty one different fish species were caught using different sampling methods and the table illustrates that using one technique was not adequate to effectively sample the whole estuarine fish assemblage. In general the fish sampled were dominated by juveniles (>95% of the fish), however, adult gobies were also regularly sampled.

11.6.148 Due to the nature of the Estuary only seine netting was possible in Zone 3, and this was the only zone in which this method was used.

Table 11.23 - Fish species caught in the Upper Mersey Estuary using beam trawling and seine netting in the main estuary and in the saltmarsh scrapes 2002-2007

Fish Species	Beam Trawling	Seine Netting	Saltmarsh Scrapes
Herring (*Clupea harengus*)	✓	✓	✓
Flounder (*Platichthys flesus*)	✓	✓	✓
Sprat (*Sprattus sprattus*)	✓	✓	
Sand Goby (*Pomatoschistus minutus*)	✓	✓	✓
Common Goby (*Pomatoschistus microps*)	✓	✓	✓
Sole (*Solea solea*)	✓		✓
Nilsson's Pipe Fish (*Syngnathus rostellatus*)	✓		
Three Spined Stickleback (*Gasterostreus aculeatus*)	✓	✓	

Fish Species	**Beam Trawling**	**Seine Netting**	**Saltmarsh Scrapes**
Plaice (*Pleuronectes platessa*)	✓	✓	
Cod (*Gadus morhua*)	✓		
Dab (*Limanda limanda*)	✓		
Whiting (*Merlangius merlangus*)	✓	✓	✓
River Lamprey (*Lampreta fluviatilus*)	✓		
Sand Eel (*Ammodytes tobianus*)	✓		
Eel (*Anguilla anguilla*)	✓	✓	
Mullet (*Chelon labrosus*)		✓	
Roach (*Rutilus rutilus*)		✓	
Trout (*Salmo trutta*)		✓	
Bream (*Abramis brama*)		✓	✓
Chub (*Leuciscus cephalus*)		✓	
Bass (*Dicentrarchus labrax*)		✓	

11.6.149 Although fish surveys have been ongoing since 2002, sampling effort was increased in 2004 and 2005. Most notably, the three beam trawl sites downstream of Runcorn bridge were increased to 12 (Zone 1), and three more trawl sites were added to the survey within Zone 2 (so that there were 12 sites in both Zone 1 and 2). The number of seine net samples in Zone 3 also increased from one to three. This overall increase in sampling effort resulted in the collection of more species. Trout, roach, bream and chub were caught for the first time during the seine netting in Zone 3 in 2004 and bass and eel were caught in the 2005 seine netting survey. Cod was sampled for the first time in Zone 1 during the autumn 2004 beam trawl and eel were also first caught in the 2005 beam trawls in both Zones 1 and 2. Two glass eels were caught for the first time in spring 2007 (these are transparent eel juveniles which become darker before swimming upstream). In addition two sand eels were sampled for the first time in spring 2007.

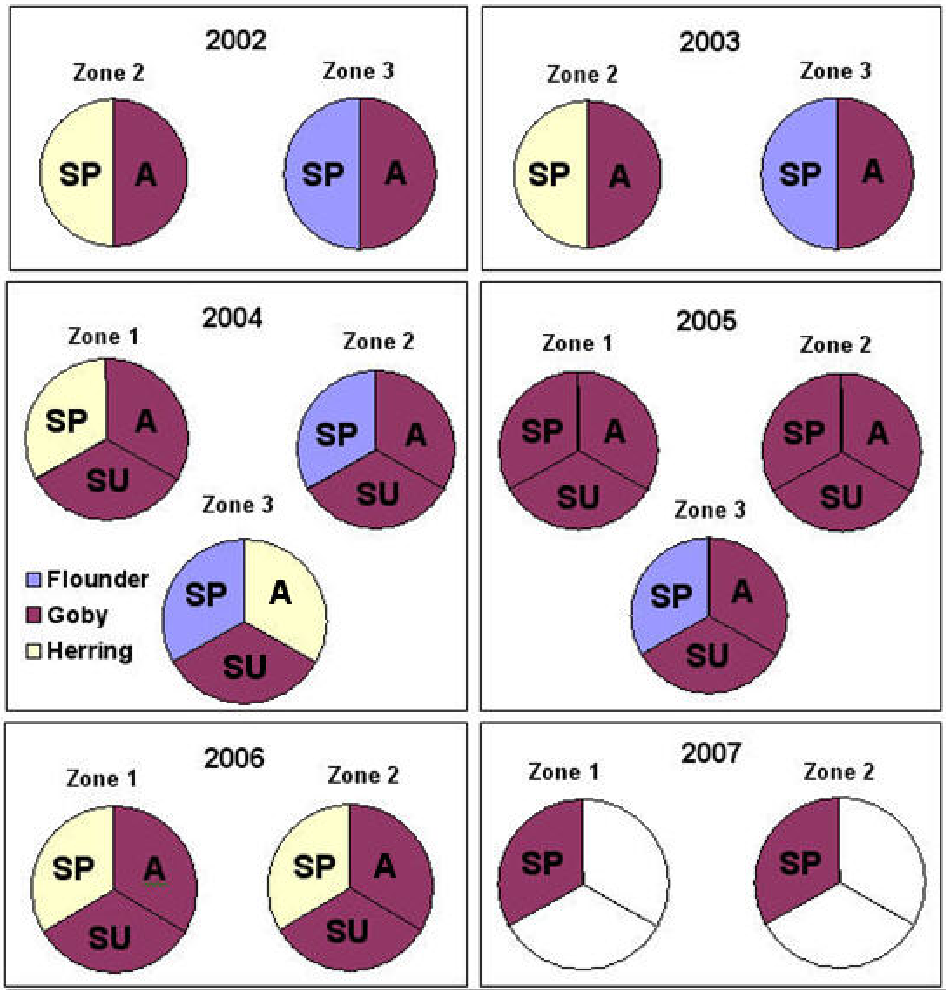
Fish Abundance

Spatial variation

11.6.150 A significant decrease in fish density across zones ($p \leq 0.01$) was evident during the 2004-07 sampling period. The median number of fish $100m^{-2}$ was lowest in Zone 1 (4.4 fish), higher in Zone 2 (16.83) and highest in Zone 3 (77.08), (Table 11.24).

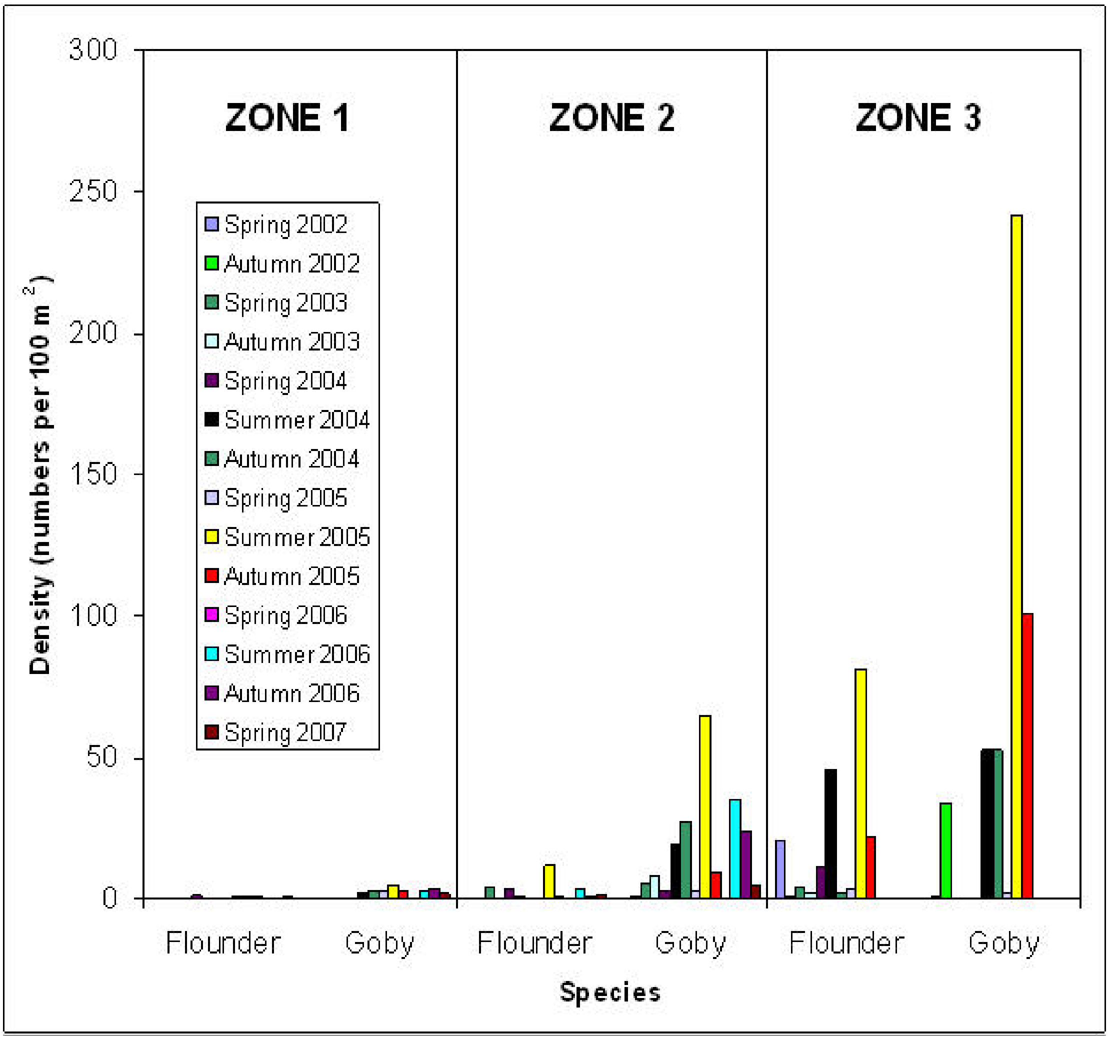
11.6.151 Since the commencement of sampling only four species have dominated the catch within a particular zone and season (flounder, sand and common goby and herring), (Chart 11.13). Sand and common goby are particularly difficult to differentiate in the field (especially juveniles). In terms of habitat requirements both types of goby are very similar, therefore due to a combination of the fact that very large numbers of goby were sampled on numerous occasions, juveniles were regularly sampled, and the time required for enumeration it was decided to group sand and common goby together during counts. They will be collectively referred to as gobies in this document and for the purposes of statistical analysis for this study will be considered as one species. Goby and to a lesser extent flounder (Plate 11.8 a & b), were collected in greater numbers than each of the other species.

Chart 11.13 - Seasonal and zonal variation in the dominant fish species found within the study zone between 2002 and 2006. (SP= Spring, SU= Summer, A= Autumn)



11.6.152 There was a significant increase in median density when moving up the estuary from Zone 1 to Zone 3 for both flounder ($p \leq 0.001$) and goby ($p \leq 0.01$), (Table 11.25, Chart 11.14). In contrast, no significant relationship between sample zone and species density was observed for herring. Goby density was greater than for flounder during most sample seasons within Zones 2 and 3, and densities of both were relatively low in Zone 1 (Table 11.25, Chart 11.14).

Chart 11.14 - Abundance of flounder and goby during different seasons between 2004 and 2007. Zone 3 was not sampled from 2006 onwards



Temporal variation

11.6.153 Median fish density was significantly higher during summer (30.7 fish 100 m^{-2}) than autumn (19.4 fish 100 m^{-2}) and the density of fish in spring was far lower than at the other times of year (median of 5 fish 100 m^{-2}), ($p \leq 0.05$), (Table 11.24). There was no significant difference in fish density among years (although it should be noted that only the spring sampling has been conducted to date in 2007).

11.6.154 Non-parametric Mood's median tests revealed that the number of goby sampled was significantly greater in summer and autumn, than in spring ($p \leq 0.05$), (Table 11.25, Chart 11.14). There were no clear seasonal trends in fish density for flounder and herring.

Table 11.24 - Comparisons of median values for species richness and density (numbers 100 m^{-2}) between zones, seasons and years for the fish in the Upper Mersey Estuary. Chi squared output is the result of separate mood median tests performed on each of the variables. Letters denote significant differences (e.g. values with the same letter are not significantly different from each other). *p<0.05, ** p<0.01, *** p<0.001.

	Zone				Season				Year				
	1	**2**	**3**	**X^2**	**Spring**	**Summer**	**Autumn**	**X^2**	**2004**	**2005**	**2006**	**2007**	**X^2**
Richness	5	5	6.5	0.06 NS	5	4.5	5	0.28 NS	5	5	4	5.5	0.28 NS
Density	3.33 a	13.33 b	65.8 c	26.75 **	4.69 a	20.0 b	11.67 ab	47.07***	7.08	8.33	8.33	5.0	6.76 NS

Table 11.25 - Sources of variation in mean abundance between zones, seasons and years for the specific fish species. Chi squared output is the result of separate mood median tests performed on each of the variables. Letters denote significant differences (e.g. values with the same letter are not significantly different from each other). *p<0.05, ** p<0.01, *** p<0.001.

	Zone				Season				Year				
	1	**2**	**3**	**X^2**	**Spring**	**Summer**	**Autumn**	**X^2**	**2004**	**2005**	**2006**	**2007**	**X^2**
Flounder	0.28 a	0.88 a	20.82 b	9.6**	1.18	1.99	0.64	0.9 NS	1.53	1.17	0.30	1.20	0.9 NS
Goby	2.46 a	14.67 b	52.57 b	8.56*	1.65 a	27.38 b	17.05 b	8.79*	2.58	4.58	2.92	3.43	0.74 NS
Herring	0.23	0.08	0	1.06 NS	0.32	0	0	2.60 NS	0	0	0.35	0.26	3.78 NS

Community Composition

Spatial variation

11.6.155 Non-parametric Mood's median tests indicated that moving up the Upper Mersey Estuary from Zone 1 to Zone 3 there were no significant differences in median species richness (Table 11.24). The maximum number of species sampled within a zone during a particular season was eight (Zone 3 during summer 2004 and 2005). However, during each sampling occasion many of these species were found in relatively low numbers. This is highlighted by percentage composition values for fish species sampled in each zone during each season (Table 11.26).

Temporal variation

11.6.156 There were no significant differences in species richness among seasons with a median of 4.5-5 species sampled during a particular season (Table 11.24).

11.6.157 There was inter-annual variation in the composition of the estuarine fish community during spring (Chart 11.13, Table 11.26). Since 2002 the dominant species in spring has varied between flounder, goby, and herring depending on the year, season and zone sampled (Chart 11.13). Large numbers of pipefish made up a significant proportion of the catch in spring 2005 within Zones 1 and 2, although goby were the dominant species (Table 11.26).

11.6.158 Since summer sampling began in 2004 goby have dominated each zone during this season (Chart 11.13).

11.6.159 Goby were the dominant species in autumn for all zones, years and seasons, with the only exception being Zone 3 in autumn 2004 when herring comprised 95.6% of the catch (Table 11.26). Whiting were usually recorded in low densities, however, this species made up a large proportion of the fish catch within Zone 1 during autumn 2005 (Table 11.26).

By-catch from epifauna survey

11.6.160 The only fish caught as by-catch during the epifaunal invertebrate samples were juvenile flounder and goby. At all times of year, and within all zones, the numbers of gobies sampled using this method were negligible with the exception of summer 2006 in Zone 2 when density of gobies was 2.63 fish m^{-2}. During both summer and autumn, numbers of flounder caught during epifaunal surveys were negligible.

11.6.161 In spring 2004 the mean number of flounder sampled m^{-2} was ~2 within Zone 1, almost negligible in Zone 3 but extremely high in Zone 2 (15 individuals m^{-2}). In spring 2005 numbers caught were relatively high in all zones (4-6 m^{-2}). Sampling of Zone 3 ceased in 2006 and during spring 2006 the density of flounder estimated from the trawl sampling was ~3 individuals m^{-2} in Zones 1 and 2. Flounder density in spring trawls was lowest in 2007 (0.63 fish m^{-2}).

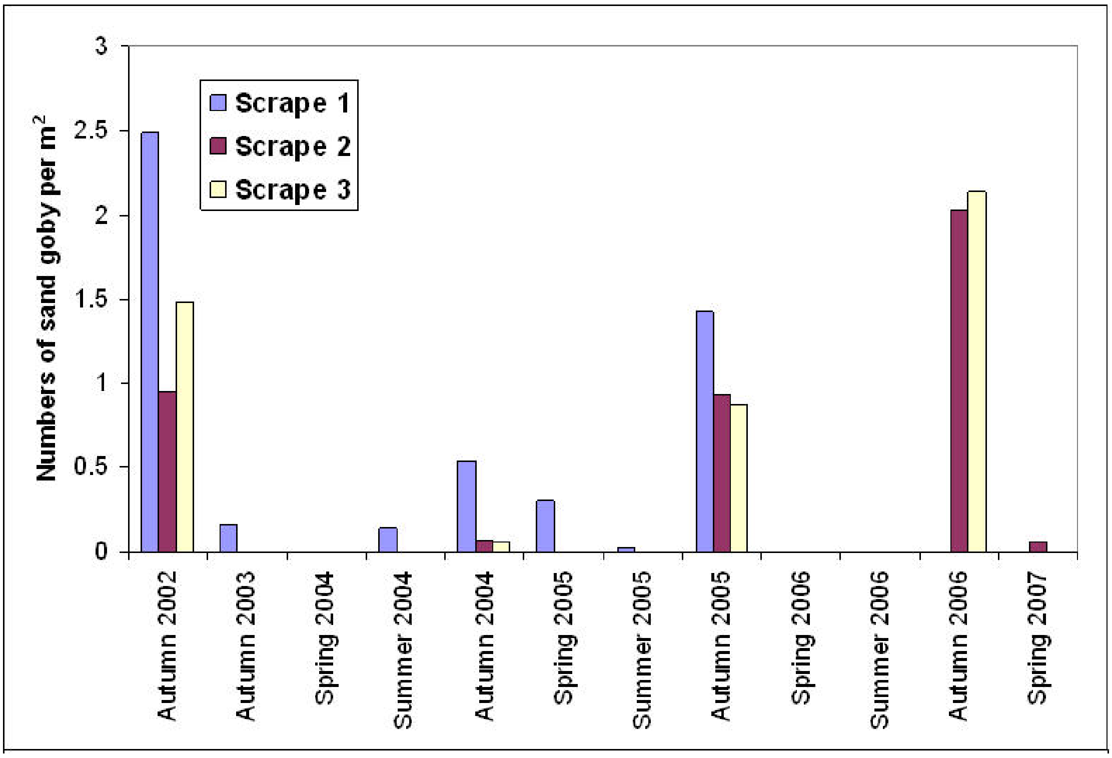
Table 11.26 - Percentage catch of each of the fish species found throughout the survey between 2002 and 2005 in different zones and different seasons. The dominant species is highlighted in yellow. P=present (less than 1% of catch)

Year	2002		2002		2003		2003		2004			2004			2004			2005			2005			2005			2006		2006		2006		2007	
Zone	Z 2	Z 3	Z 2	Z 3	Z 2	Z 3	Z 2	Z 3	Z 1	Z 2	Z 3	Z 1	Z2	Z 3	Z 1	Z 2	Z 3	Z 1	Z2	Z 3	Z 1	Z 2	Z 3	Z 1	Z2	Z 3	Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2
Season	Spr	Spr	Aut	Aut	Spr	Spr	Aut	Aut	Spr	Spr	Spr	Sum	Sum	Sum	Aut	Aut	Aut	Spr	Spr	Spr	Sum	Sum	Sum	Aut	Aut	Aut	Spr	Spr	Sum	Sum	Aut	Aut	Spr	Spr
Flounder	26	75	14	1	26	73	2	1	31	51	96	7	3	46						53	7	21	25	9	7	18	18			8		2	20	20
Goby	6	2	60	99	34		71	99	4	36		93	97	53	57	97	4	67	57	34	75	71	75	35	72	81			60	86	67	96	61	50
Herring	54	9	17		36				39	4				1			96		13		5	1	P	15			71	85			11	1	4	5
Pipefish	14		9		1				12						30	2		26	19		14			13	8		6	15	27	4	6		6	20
Plaice		14			4		12		3	2	2			P																				
Sprat						18	11		10						3	P		3	3			7	P	4	1					2		1		
Whiting							4		1		P				8	1					P			20	11				13	1	17			
Sole																																		
Dab										4																								
Stickleback				P				P		2	2			P		P	P			3			P			P								
Cod															2									4										
Lamprey r/b																											6							
Mullet						9								P						5						P								
Chub														P																				
Trout														P																				
Roach																	P			3			P			P								
Bream																				3						P								
Eel																		3	9				P			P							4	5
Bass																							P											
Sand eel																																	4	

Saltmarsh scrapes

11.6.162 Few fish were found within the scrapes during the study period (Plate 11.9a & b). The dominant species on each sampling occasion were goby, abundance of goby was particularly high during the autumn in 2002, 2005 and 2006 (Chart 11.15).

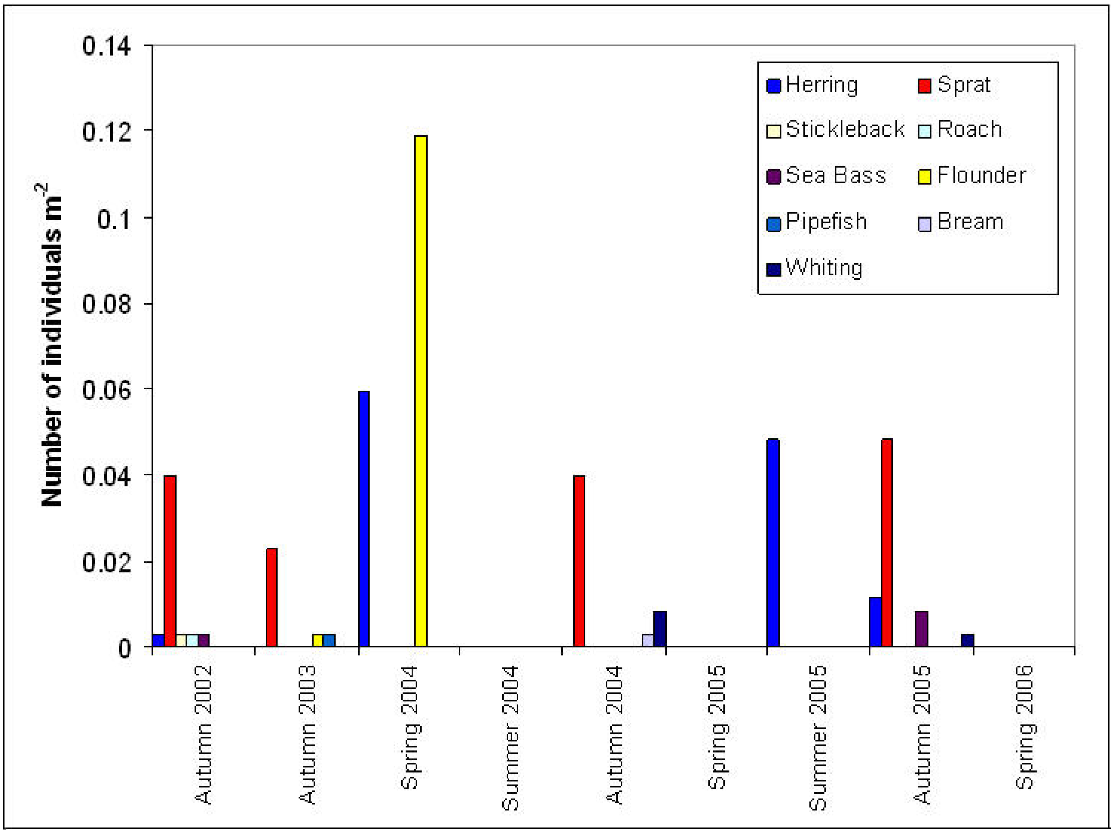
Chart 11.15 - Seasonal densities of gobies in the three main saltmarsh scrapes



11.6.163 Saltmarsh Scrape 1 contained the highest concentrations of gobies and supported the greatest range of fish species other than goby until spring 2006 (Chart 11.16). In spring 2006, the bank separating Scrape 1 and the estuary eroded away due to water movement. The scrape drained completely into the estuary and was no longer able to contain fish, therefore Scrape 1 was not surveyed from spring 2006 onwards (Plate 11.9c & d).

11.6.164 There were no clear patterns describing seasonal and annual variation of the fish species found in Scrape 1, although in some instances they did reflect seasonal variation of species present within the main estuary. For example, flounder had a particularly high density in spring 2004 in Scrape 1 (Chart 11.16) and were also the dominant species in Zone 2 during this period (Table 11.26). Scrapes 2, 3 and 4 contained very few fish.

Chart 11.16 - Seasonal densities of species other than goby caught within Scrape 1, 2002-2005. Scrape 1 permanently drained in spring 2006 due to bank erosion so no fish were caught after this period



11.6.165 Species found in the scrapes were all estuarine (e.g. herring, sprat) with the exception of the 2002 survey, in which fresh water species including roach, bream and stickleback were caught.

11.6.166 The spring 2005 survey of the creek located near the back of Wigg Island revealed a low abundance and diversity of fish. The fish species caught were herring, eel, roach, stickleback and goby. The numbers of these fish caught, however, were relatively low.

Discussion of baseline data (Estuarine Fishes)

11.6.167 There is currently little published information regarding the diversity and abundance of fish in the Upper Mersey Estuary. However, in general, estuaries are characterised by relatively few fish species which are well adapted to the estuarine environment (Ref. 47). The Estuary is a highly dynamic environment and fish species inhabiting the estuary must endure large fluctuations in salinity, temperature, turbidity, nutrient levels and water movement. In 1993 twenty two species were recorded for the Estuary (Ref. 47), whereas, in a more recent study this had increased to forty species (Ref. 89), although only about 10 of these are common and regularly sampled. As these figures are derived from sampling of the whole Mersey Estuary (mainly the Outer Mersey, Narrows and Middle Mersey) it would be expected that a lower number of fish species would be collected by the study (based in the Upper Mersey Estuary only), and that there would be some variation in the species sampled. It is evident that the increase in fish species is at least partly due to improvements in water quality over the last 10-20 years.

11.6.168 In general fish abundance was significantly related to both the zone of the estuary sampled and the season during which sampling occurred. In contrast, no clear patterns were evident relating species richness to either zone or season.

11.6.169 Numerous factors including water quality parameters such as salinity, temperature, turbidity and levels of dissolved oxygen, in addition to the distribution of prey items, are known to influence fish reproduction and survival rates (Ref. 90). Therefore, each of these parameters could influence fish abundance and species diversity within the Upper Mersey Estuary.

11.6.170 The large proportion of juvenile fish sampled during each sampling period indicates the suitability of the Estuary as a nursery ground for a number of fish species, especially flounder.

Fish Abundance

Spatial Variation

11.6.171 In general most of the species were found in very low numbers with a few species dominating the catch composition. This is typical of estuarine assemblages. The dominant species in estuaries are highly adaptable to a wide range of environmental conditions and are able to outcompete many other species for food and space. Many of the species sampled in low numbers during the surveys were likely to be at the extremes of their ecological range and would be expected to reach greater abundances either nearer the estuary mouth or within a fully freshwater environment.

11.6.172 Fish behaviour varies significantly among species and can introduce bias to the sampling process. Shoaling species in particular can distort the information gained from trawl data (Ref. 49, Ref. 50). A good example of this was in autumn 2004 in Zone 3 when herring formed 95.6% of the fish catch although it was either not sampled or was caught in very low numbers during all other sampled periods in this zone. Therefore, this aspect is important to consider when assessing results.

11.6.173 There was a significant gradual increase in fish density as movement was made upstream from Zone 1 (downstream of the SJB) to Zone 3 (upstream zone). Generally, the supply of prey is an important determinant of species abundance within a region. For example, juvenile flounder of less than a year old feed on plankton and insect larvae, while older juveniles and adults feed on benthic macrofauna especially epifauna (e.g. *Crangon crangon* and *Neomysis integer*). Gobies, in contrast, tend to feed on small polychaetes, amphipods (corophids, caprellids), cumaceans and mysids within the sediments. The trend observed for fish density, however, differs from that identified for macrofauna which appear to be more abundant in Zone 1. It appears, therefore, that the relatively low numbers of intertidal invertebrates in Zone 3 is not a limiting factor for fish density in this region (although a lack of food resources has been identified as a potential reason for the low numbers of birds generally utilising the Upper Mersey Estuary, Chapter 10: Terrestrial and Avian Ecology).

11.6.174 Interestingly, a recent study examining the distribution of fish within the Thames Estuary indicated that of all the species sampled only flounder demonstrated a significant spatial overlap with potential invertebrate prey items (Ref. 91). Marshall and Elliott (Ref. 92) also hypothesised that the main factors affecting the distribution of fish species within the Humber Estuary may relate to water quality rather than the prey species available. Within the Upper Mersey Estuary the results in Chapter 8: Surface Water Quality indicate that for suspended solid concentrations, BOD, nutrient levels and other water quality parameters, differences were sometimes observed between surface and bottom waters. However, for some parameters no spatial variation was evident, and for others variation among zones was often not predictable. Therefore, it is unlikely that water quality variation can explain the patterns of spatial variation in fish density.

11.6.175 There is some evidence that very high turbidity levels can be detrimental to fish populations due to reduced numbers of prey items and the clogging of gill filaments by particulate matter (Ref. 93, Ref. 94). As such fish distribution and overall fish abundances in zones within some estuaries may be linked to turbidity gradients, with different fish species favouring different turbidities of water (Ref. 93, Ref. 94). Results provided in Chapter 8 (Surface Water Quality), however, do not indicate a significant variation in suspended solid concentrations among zones.

11.6.176 One possibility is that the sites within Zone 3 are generally more sheltered and are subject to less water turbulence than those further downstream in the estuary. Therefore, the Zone 3 sites may be more suitable for juvenile fish and the reduced water movement could increase the chances of survival for some species, thereby increasing local fish density. In addition, there is greater availability of salt marsh habitat for fish to utilise as a refuge and foraging area within Zones 2 and 3 when compared to Zone 1. Channels through the salt marsh flood to varying degrees during each tide and these can provide sheltered areas for fish. It is only during high water on spring tides that the whole area of salt marsh is covered by water.

Temporal variation

11.6.177 A critical factor in determining fish densities at a given time of year is seasonal ontogenetic shifts in habitat use. For example estuaries not only house resident estuarine fish species but provide nursery grounds for numerous juvenile marine fish including sole, plaice, sprat, cod, flounder, bass and herring all of which were sampled during this study. Therefore, at certain times of year numbers of juveniles of various species can increase significantly.

11.6.178 Fish density as a whole was found to be significantly higher in the summer than in autumn and was very low in spring. This was the case for both flounder and goby which were the dominant fish species within the Upper Mersey Estuary. One of the key determinants of abundance is the particular stage the species is at during the spawning cycle. Gobies spend their whole life cycle within the estuary, this species spawns during the summer and larvae develop rapidly. This explains the very high densities of gobies in summer and autumn of which a large proportion of individuals were juveniles. These fish may be rapidly eaten or not survive to adulthood which could partly explain why densities decreased following the summer months and were considerably lower in spring than in summer and autumn.

11.6.179 Flounder spawn offshore during late winter/spring and juveniles move into estuaries in the summer. This is a main reason why large numbers of small juvenile fish were caught in the spring and summer seine nets and high numbers of juvenile flounder were caught in the epifaunal invertebrate trawls during spring sampling.

11.6.180 Estuaries also provide seasonal feeding grounds for diadromous fish. Juveniles of some species live in shallow coastal waters and estuaries, which provide the summer feeding grounds for adults. For example, young herring assemble in large shoals and head into coastal waters and estuaries where they remain for six months before heading out into deeper water (Ref. 95). This may explain the presence of unusually large numbers of small herring in the fish catch in Zone 2 during spring 2003, in Zone 1 during spring 2004 and both Zones 1 and 2 in 2006. The shoaling behaviour of herring contributed to their dominance of the catch in Zone 3 in autumn 2004 when they constituted 96% of the entire fish catch.

11.6.181 Temperature could also be key in influencing the density of fish species within estuaries. Previous work on resource partitioning in estuarine fish on both spatial and temporal scales has concentrated on various environmental (e.g. physical habitat) and particularly bionomic (e.g. food resources) axes (e.g. Ref. 96, Ref. 97, Ref. 98, Ref. 99, Ref. 100). Atrill and Power (Ref. 91), however, identified temperature-abundance relationships for 16 fish species from the Thames estuary. Significant temperature-abundance models explained >65% of the variability in 13 fish species and such thermal resource partitioning in estuaries was found to have temporal rather than spatial dimensions.

11.6.182 Generally it is considered that temporal changes in food abundances could affect fish densities on a temporal scale. A recent study, however, found that the only species found within the Thames Estuary that appeared to be influenced by the distribution of prey items was flounder (Ref. 91). Although flounder feed on some benthic fauna they mainly consume large numbers of epifauna, for example *Crangon crangon* and *Neomysis integer*. In 2004 flounder were only found in very low numbers in the autumn in Zone 3 which does appear to parallel the significant reduction in *Crangon* and *Neomysis* within this zone at this time. In contrast, both of these species were found in high densities during autumn 2004 in Zone 2 and in this zone numbers of flounder remained high.

11.6.183 A further source of variation in species densities, especially among years, is inter-annual variation in reproductive success caused by relatively stochastic changes in the physico-chemical characteristics or biotic factors within the Upper Mersey Estuary.

Fish Community Composition

Spatial Variation

11.6.184 Many of the factors influencing fish density are also likely to define the distribution of different fish species throughout the Upper Mersey Estuary, as in many ways overall fish abundance and species diversity are closely linked.

11.6.185 There was no significant change in species richness among Zones 1 to 3, however, the actual species which accounted for this value did differ among zones. The distribution of organisms is likely to be related to their ability to endure fluctuating environmental conditions, in particular salinity (Ref. 101), which limits their ability to exploit the large food resources present in estuaries.

11.6.186 The results of this study indicate salinity was likely to be a principal determinant for the zonation of certain species in the Upper Mersey Estuary. For example, a number of species were only collected in Zone 3 (bream, roach and mullet), which was upstream of the proposed construction site. These species were characteristic of freshwater environments and are unable to tolerate the higher salinities present within Zones 1 and 2. Low numbers of stickleback were regularly present in samples taken within Zone 3 and on two occasions this species was sampled within Zone 2 which indicated the range of salinity tolerance for this species was wider than for some of the other freshwater species. It should be noted, however, that the abundances of the freshwater species found within Zone 3 were low. In a comparison with seventeen other European estuaries it was found the proportion of freshwater species within the Estuary was relatively high, second only to Elbe Estuary in Germany (Ref. 102), and many European estuaries were found to contain no or very few freshwater species (Ref. 102).

11.6.187 Although a number of species inhabiting Zone 3 were not found in the other zones, species richness was maintained at a similar level in all zones. This was due to the presence of more euryhaline species in Zones 1 and 2 which were absent from Zone 3 and were more tolerant of the varying environmental conditions found further downstream.

11.6.188 Sediment characteristics, substratum heterogeneity and vegetation can also contribute to the distribution patterns of fish as they can influence prey availability (Ref. 103) and provide a refuge from predators (Ref. 90).

Temporal variation

11.6.189 There are a number of factors that contribute to variations in species distribution throughout the year. Though salinity may be a major influencing factor, both temperature and dissolved oxygen concentration also change throughout the year and can affect fish distribution (Ref. 19).

11.6.190 A study of the fish population in the Middle and Upper Mersey Estuary found that within beam trawls a maximum of six species were caught during any one season at all sites (Ref. 89). This is consistent with the results of this study in which the maximum number of species caught within any one zone during a season was eight although six or less was more common.

11.6.191 Species richness in the Upper Mersey Estuary did not appear to vary significantly among seasons. However, the types of species present did vary from season to season although this variation was not always consistent. For example, no flounder were recorded in any zone for autumn 2004 but during autumn 2005 they formed a relatively high proportion of the sample within all zones. The abundance of epifauna was far greater in summer than in both spring and autumn which is the same seasonal trend identified for the abundance of flounder (see Paragraph 11.6.178).

11.6.192 Gradual changes in aspects of water quality such as turbidity, levels of dissolved oxygen, salinity and temperature can all contribute to seasonal variation in the estuarine fish community. However, as mentioned above temperature is likely to vary the most throughout the course of the year and potentially have the greatest influence on community structure.

11.6.193 In addition to influencing fish abundance the timing of the reproductive cycle of various species (which may vary to an extent from year to year based on environmental conditions and ontogenetic changes in habitat use), can contribute to seasonal variation in species composition within the Upper Mersey Estuary. This is likely to be the case within the area potentially influenced by the Project (for example flounder comprised a very small proportion of the fish caught in autumn when compared with spring and summer).

Fish found within Scrapes and Creek

11.6.194 Fish entered the shallow scrapes at high tide and became trapped as the tide fell remaining there until the next high tide. Some species were sporadically found within the scrapes which reflected the seasonal presence of these species in the main estuary. However, goby and flounder were the most abundant species.

11.6.195 Species found in the scrapes were all estuarine with the exception of the 2002 survey during which fresh water species including roach, bream and sticklebacks were caught, These species would have been washed into the scrapes from upstream in the estuary but would not have been able to survive for long as the silver colour of these fish make them vulnerable to bird predation. One reason gobies and flounder are able to survive in the scrapes longer than other species could be that their mottled colour provides camouflage reducing their chances of being consumed by potential predators.

11.6.196 Despite their camouflage, however, they are still eaten by estuarine birds which is expected to be the main reason for the very low numbers of fish in Scrapes 2 and 3 which were small and very shallow. In addition, temperature and salinity changes in these scrapes may have made it more difficult to survive. During summer 2005, and summer and autumn 2006 Scrapes 2 and 3 actually dried up completely which was a combination of evaporation and the lack of exposure to the neap tide. In contrast, in autumn 2005 sampling occurred between two spring tides (17th October at 23:44 a maximum tide height of 5.9 m; and 18th October at 00:11 a maximum tide height of 6m) and Scrapes 2 and 3 were both full of water and contained high numbers of gobies.

11.6.197 The survey of creek and scrapes revealed that low numbers of some species (herring, eel, roach, stickleback and goby) were present in this habitat. It is suggested that the creek system may be used as a sheltering area from the turbulent waters in the main estuary. There is increasing evidence that such saltmarsh habitats can be extremely important for the feeding, refuge and nursery requirements of fish (Ref. 104).

Migratory Fish

11.6.198 Considerable media interest has been generated over recent years as a result of the return of salmon to the Estuary. In 2002, between late September and late November, 26 salmon (mostly females), were trapped by the EA at Howley Weir in Warrington, about 13 km upstream of the Runcorn Gap. The trap was operated over a shorter period during mid October in 2003 and only one salmon was caught (Figure 11.10, Appendix 1.1). In 2004 the trap was not used at all. An increase in salmon numbers was suggested by the fact that in October 2005 the number of individuals caught was over 40, however, during late October and November 2006 only 8 individuals were caught ((Figure 11.10, Appendix 1.1). These salmon would have swam through the proposed bridge construction area on the way to this location. In addition, salmon have been seen jumping about 10 km upstream of Howley Weir at Heatley Weir on the River Bollin indicating they have been able to traverse the Manchester Ship Canal. Recent evidence for the successful use of the Estuary for migratory fish was a salmon parr caught in autumn 2005 in the River Goyt near Stockport. This provided the first undisputable evidence that salmon are successfully breeding within the Mersey catchment.

11.6.199 During the sampling programme a juvenile sea trout was caught in a seine net in Zone 3 in 2004 (Plate 11.10). A river lamprey transformer was also caught in Zone 1 in spring 2006. In addition adult and juvenile eels were sampled during 2005 and 2007.This indicates that other migratory species are also passing through the Upper Mersey Estuary. River lamprey have also been recorded by the EA in the trap at Howley Weir. Along with salmon, river lamprey is an Annex II species as designated by the EC Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora) and eel have recently been included as a UK BAP species.

11.6.200 Below is a list of sensitive times of year during which diadromous migratory fish species are most likely to be found within the Upper Mersey Estuary. Species migrating from the sea to rivers to spawn are anadromous (e.g. salmon, sea trout and river lamprey) and generally have an upstream and downstream migration period depending on whether smolts (or transformers in the case of lamprey), or adults, are being considered. Eels are catadromous migrating from freshwaters to saltwater to spawn, with adults migrating downstream and juvenile 'glass eels' migrating upstream. Migration, is related to the timing of tidal movements and during suitable flood tides it is equally likely to occur during the night as it is during the day.

a. Salmon

- Downstream: smolt migration in spring, peak time being May.
- Upstream: adult migration in late summer to autumn from August through to November.

b. Trout

- Downstream: smolt migration in spring, peak time being April and May.
- Upstream: adult migration in summer, peak time June and July.

c. River Lamprey

- Downstream: newly metamorphosed adults, peak time being spring but extending from February to June.
- Upstream: adult migration in autumn, September to November.

d. Eel

- Downstream: adults migrating to sea in autumn, usually September to November.
- Upstream: migration of juvenile ‘glass eels’, usually March to May.

Freshwater Fishes

Abundance

11.6.201 Although no quantitative data were available for the abundance of different fish species within the Bridgewater and St. Helen’s Canal the main requirement for the ecological assessment was to obtain a species list for the canals.

Community Composition

11.6.202 A number of fish species have been caught by anglers in the section of the Bridgewater Canal adjacent to the Upper Mersey Estuary including bleak, bream, carp (mirror, common, leather), gudgeon, pike, perch, roach, rudd, tench, and possibly some minnow (M. Webb pers. comm.). Chub have also been caught here but only very small individuals and in low numbers.

11.6.203 For the St. Helen’s Canal some limited catch data were available (F. Lythgoe pers. comm.). The main species found within the section of the canal adjacent to the Upper Mersey Estuary are bream, eel, carp (mirror, common, leather and crucian), perch, pike, roach and rudd.

Discussion of baseline data (Freshwater Fishes)

11.6.204 Most of the species in both canals are common in freshwater habitats throughout the UK, although eel is a species of conservation interest.

11.6.205 It appears that species richness may be slightly lower in the St. Helen's Canal than in the Bridgewater Canal.

Marine Mammals

11.6.206 It appears that of 28 species of cetaceans recorded around the British Isles, 13 have been recorded in the Mersey and East Liverpool Bay over the last 150 years (Ref. 60). Between 1829 and 1980 there were 320 sightings and strandings in this region and between 2002 and 2005 another 50 were recorded and the frequency of reported sightings and strandings appears to be increasing rapidly (V. Cooper pers. comm.). This could partly be due to the increased likelihood of people reporting a dolphin sighting or stranding over recent years but could also be due to an increase in numbers due to improved conditions within the estuary. The most commonly sighted species are harbour porpoise (*Phocoena phocoena*) and bottlenose dolphins (*Tursiops truncates*).

11.6.207 There have, however, been very few sightings of cetaceans within the area of the Upper Mersey Estuary which may be impacted by the construction and operation of the proposed New Bridge. There have been occasional sightings of harbour porpoise (*Phocoena phocoena*) and grey seals in this reach (the most recent seal sighting being in March 2007) although it is thought that when they are present the numbers of individuals are low. It is important to consider, however, that individuals of these species venturing up the Estuary are likely to be following shoals of fish such as herring and sprat and their presence in the upper reaches of the Estuary may become more common if water quality continues to improve in the area. Other marine mammals recorded in the area include a minke whale (*Balaenoptera acutorostrata)* found stranded in 1998 on Hale Bank downstream of the SJB (within Zone 1) and further downstream a killer whale (*Orcinus orca*) was found stranded in 2001 on a sandbank near Speke airport.

Baseline

Current Baseline

11.6.208 The Upper Mersey Estuary is a dynamic ecosystem. The considerable tidal flow along the estuary continually reworks near-surface sediments. Tidal erosion can also cause smaller channels to change position within the intertidal zone over very short timescales. At low tide, the majority of the estuary bed is exposed, and the saltmarsh areas are only covered by water during spring high tides. Overall, the Upper Estuary forms a high energy environment for organisms within the estuarine waters and intertidal sediments. Species found within this area are expected to be well adapted to the constantly changing environmental conditions described in Chapter 7 (Hydrodynamics and Estuarine Processes Movement). In particular, they are required to be tolerant of turbid conditions and significant daily variation in salinity and temperature. All sites sampled during the aquatic ecology study were within the Upper Mersey Estuary, including those furthest downstream within Zone 1 (the area downstream of the SJB).

Estuarine algae

11.6.209 Proportions of different species tended to vary among Zones 1-3 and between some sample seasons, algal biomass and species richness were greater in Zones 2 and 3 than in Zone 1. Species richness and abundance varied considerably across seasons and no consistent trend in variation was observed.

11.6.210 Benthic algal biomass and community composition are dependent on a range of factors including water quality, substrate stability, flow velocities, and light availability. They are, therefore, good indicators of ecological status and environmental change. The benthic algal community was shown to be dominated by diatoms which generally accounted for >90% of species. Within the sites sampled in the Upper Mersey Estuary there was a maximum species richness of 35 during a single sample period and it is considered the estuarine algal assemblage is characteristic of other turbid, high energy UK estuaries.

Freshwater macrophytes

11.6.211 The number of macrophyte species recorded in the Bridgewater Canal during a given sampling period ranged from 2 to 11 and included a high number of nutrient tolerant channel macrophyte species. This represents a greater species richness than in the St. Helen's Canal (range of 2 to 7 species) which mainly contained marginal herbs and reeds but overall is typical of what would be expected for a nutrient rich turbid canal. There was no apparent trend in variation in species richness between years. However, fewer macrophyte species tended to be found in both canals during spring surveys than in summer or autumn.

11.6.212 The charophyte *Nitella mucronata* var *gracillima* was found immediately upstream of the survey reach. This is a Red Data Book species although its status in Britain is described as 'non-threatened'.

11.6.213 Sampling in spring 2007 revealed four species at Stewards Brook including the umbellifer species *Apium nodiflorum* and *Oenanthe crocata* which are characterised by early spring growth. Vegetation was not advanced at the other brooks during this period. During summer 2007 Stewards Brook was inaccessible, however, the survey of Bowers Brook during this period revealed it to be dominated by *Aster tripolium*.

Estuarine invertebrates

11.6.214 Based on the results of the baseline survey up to 30 macrofaunal invertebrate taxa are expected to be found during a given year (including subtidal species). Species were patchily distributed, however, abundance of macrofauna appeared to be greater in Zone 1 than in Zones 2 and 3, although no significant difference was apparent among seasons. Baseline data suggests species richness is greater in Zone 1 than in Zones 2 and 3 but again no consistent significant difference in species richness was observed between years or seasons. The meiofauna consisted primarily of nematodes and tubificids but the size of meiofaunal organisms is too small to form a significant component of the diet of birds. Density of meiofauna appeared in general to be greatest in Zone 1 and during the spring months although no consistent pattern in density variation between seasons and years was observed.

11.6.215 Due to the range of stresses within estuarine environments including fast flowing currents, shifting sands, salinity variation and in some cases, historic pollution (e.g. the Mersey Estuary), species diversity in estuaries is usually lower than that of freshwater or fully marine environments (Ref. 1). However, organisms which are well adapted to these conditions thrive and the density of organisms can be extremely high providing extremely rich feeding grounds for waders and wildfowl. Mud flats in mid and lower estuaries are usually particularly rich and species diversity is expected to decrease moving upstream within an estuary due to a loss of species including the lugworm (*Arenicola marina*) and a number of bivalve species which cannot cope with the reduced salinities of the upper estuary (Ref. 1). In addition, the change in sediment type from sand to more muddy sediments is detrimental for some species (Ref. 1). Consequently mid estuarine muds support rich communities characterised by polychaetes, bivalves and oligochaetes whereas upper estuarine habitats are characterised by a limited range of polychaetes and oligochaetes (Ref. 105), as is the case with the Upper Mersey Estuary. Birds prefer to eat the larger macrofauna as opposed to meiofauna, and in terms of food availability, density/biomass of potential prey items is generally more important for birds than diversity.

11.6.216 Rehfisch *et al*. (Ref. 17) calculated invertebrate densities for the Middle Mersey Estuary. Eight key taxa were regularly found at many of the sites sampled. Densities of most of these species were in the hundreds to thousands per square metre. In particular oligochaetes were regularly found in densities greater than 10,000 m^{-2} with a maximum density of 45,517 m^{-2} recorded at a site just downstream of the Zone 1 area sampled during this study. In contrast, the aquatic ecology invertebrate survey conducted for the Project found that within the Upper Mersey Estuary the intertidal invertebrate community was impoverished in terms of both species diversity and density. The maximum number of intertidal macroinvertebrate taxa found at a site during a specific sampling season was 5, but usually 3 or less taxa were present. Overall, oligochaetes were the most frequently sampled taxa although during a specific sample period they were not found at most sample sites. When they were found it was often in densities of hundreds per square metre, as opposed to thousands. The greatest density for oligochaetes recorded during the aquatic ecology study was 3,896 m^{-2} at Site 16 in Spring 2007.The only other intertidal macroinvertebrates found in greater densities than this were Gammarus *spp*. in spring 2004, and Collembola in autumn 2004 and summer 2005. These findings are supported by a survey conducted on the Mersey in relation to the proposed tidal barrage which found the fauna of the Upper Mersey Estuary to be impoverished in comparison to the Outer Estuary sands (Ref. 106). Overall, it is considered that relative to the Middle and Lower Estuary the Upper Mersey Estuary has a low diversity and density of intertidal invertebrates and is therefore not expected to provide as rich a food source for birds as areas further downstream.

11.6.217 Data regarding the intertidal macroinvertebrate assemblages of the upper estuarine environments in other UK estuaries is sparse. However, Waldock *et al*. (Ref. 107) conducted a survey of subtidal macroinvertebrates within the Crouch Estuary which has historically been contaminated by high concentrations of Tributyltin (TBT). The invertebrate community was sampled within the lower, mid and upper estuary over a period of four years. Contrary to expectation it was found that species number in subtidal upper estuarine sediments was on average higher than at the mid and lower sites (with ~28 species sampled at the upper estuarine sites in 1990 and 1991). In addition, the number of individuals sampled at the upper estuarine sites was greater than within the mid to upper estuary (Ref. 107).

11.6.218 During this study the maximum number of taxa sampled at a subtidal site during a specific sample period was three and densities of taxa were in the tens per square metre as opposed to thousands or even hundreds of individuals per square metre. The evidence suggests that the community of subtidal (and very likely intertidal) macroinvertebrates within the Upper Mersey Estuary appears to be impoverished in relation to the upper estuary of the River Crouch and potentially other UK estuaries subjected to historic pollution. This could in part be related to the particularly strong tidal movements within the Mersey Estuary which constantly resuspend and rework sediments on the estuary bed, and the very high levels of gross pollution to which the Estuary has been historically subjected.

11.6.219 Four bird species contributing to the SPA and Ramsar designations of the Estuary were observed in reasonable numbers in the Upper Mersey Estuary: Dunlin, redshank, shelduck and teal (Chapter 10: Terrestrial and Avian Ecology). Listed below are the preferred invertebrate prey items for these birds and a summary of which of these invertebrates were sampled during the aquatic ecology survey. When considering bird diet it is the availability of intertidal macroinvertebrates which is of prime concern as opposed to meiofauna or subtidal organisms:

a. Dunlin: Key prey items for this species include *Hydrobia ulvae*, *Macoma balthica*, *Cerastoderma edule*, *Hediste diversicolor* and oligochaetes. Of these only *H. diversicolor* and oligochaetes were occasionally sampled in relatively high numbers during the aquatic survey. Generally more *H. diversicolor* were sampled in Zone 1 than in Zone 2, and only on one occasion was this species sampled in Zone 3. When *H. diversicolor* was found numbers were in the low hundreds as opposed to thousands per square metre and this species was absent from the majority of sites on each sample occasion. Patterns observed for oligochaetes in terms of availability for birds were also inconsistent, for example oligochaetes on all sample occasions were absent from the vast majority of sites. In general, numbers were higher in summer than in autumn and spring. Oligochaetes were sampled more often in Zones 1 and 2 than in Zone 3 and when sampled were usually present in the low hundreds per square metre as opposed to thousands. In fact Zone 3 was surveyed on six occasions during 2004 and 2005 and only twice were any macroinvertebrates sampled, and they were only present at Site 1B;
b. Redshank: Typically this species feeds on *Corophium* spp., *H. diversicolor, Nephtys* spp., *H. ulvae* and *M. balthica*. Of these it was mainly the polychaete *H. diversicolor* which was recorded in any great numbers but this was only on certain occasions and no individuals were recorded at most of the sites during the majority of sample periods. See above for summary of the availability of this species;
c. Shelduck: This species reaches moderate numbers throughout the Upper Mersey Estuary (Chapter 10: Terrestrial and Avian Ecology) and primarily feed on molluscs (e.g. *H. ulvae, C. edule* and *M. balthica*), crustaceans (e.g. *Corophium* spp.) and polychaetes and oligochates (Ref. 17). Only *C. edule* was not recorded during the aquatic survey although the other mollusc species were rarely recorded. Oligochaetes and polychaetes (mainly *H. diversicolor*) were found in relatively high numbers at some sites although they exhibited seasonal and spatial variation in terms of abundance and were absent from most of the sites during each sample occasion; and
d. Teal: Teal counts were fairly high mainly on the wetland on Astmoor Saltmarsh (Chapter 10: Terrestrial and Avian Ecology). Teal diet varies considerably according to habitat although it is known to include a wide range of molluscs, crustaceans and oligochaetes. Only on very rare occasions was a mollusc species sampled (*M. balthica* or *H. ulvae*), crustaceans (mainly Collembola) were occasionally sampled in large numbers at a particular site during a particular sample season. However, macrofaunal benthic crustaceans were only sampled at three sites or less during each sample occasion. The availability of oligochaetes has been summarised above.

11.6.220 Overall it is concluded that although a number of important macrofaunal prey species are present in the Upper Mersey Estuary they are very patchily distributed and in general found in low abundances when compared with the Middle Estuary and lower sections of other UK estuaries. Consequently, it is considered that invertebrates in the Upper Mersey Estuary provide a limited potential food source for birds which could be one reason why fewer birds frequent this area in comparison with the Middle Estuary (Chapter 10: Terrestrial and Avian Ecology).

Freshwater invertebrates

11.6.221 The invertebrate community in both the Bridgewater Canal and St. Helen's Canals consisted mainly of organic pollution tolerant species with sensitive species being present in low numbers. Chapter 8: Surface Water Quality, however, indicates that in the St. Helen's Canal the level of organic pollution was not found to be greater than that expected for a slow flowing waterbody and the EA's GQA classification system classified the water quality as being 'fair'.

11.6.222 In general species richness and abundance of invertebrates were greater in the Bridgewater Canal than in the St. Helen's Canal. A considerable increase in species richness at all of the Bridgewater Canal sample sites between summer 2004 and autumn 2005 indicated how the community can rapidly change over a short temporal scale (27-32 taxa recorded in autumn 2005). The average species richness in Stewards Canal was ~14 taxa which is comparable to other turbid, slow flowing waterways in the UK (e.g. the Grand Union and Oxford Canals).

11.6.223 *Assiminea grayana* is a species of note as the first evidence of its presence on the west coast of the Britain was published as recently as 2007 (Ref. 88). It is, however, considered to be 'common, occurring in 25-50% of samples from similar habitat' (Ref. 87). This species was particularly abundant in Bowers Brook.

Estuarine fish

11.6.224 In general fish density was greater in Zone 3 than in Zones 1 and 2, and was lower in spring than in summer and autumn. Species richness among zones and seasons was similar although species composition varied considerably.

11.6.225 Saltmarsh scrapes provide a potentially important habitat for some estuarine fish species and on occasion, freshwater species. Goby were the most common species within these areas.

11.6.226 There is evidence that salmon migrate through the Upper Mersey Estuary to reach spawning grounds within the River Catchment.

11.6.227 In total, twenty one fish species were recorded within the Upper Estuary. Individuals were dominated by juveniles although a high number of adult goby were also present. Fish catch during the past five years of surveying was dominated by flounder, sand and common goby. Herring were also found in high numbers in autumn 2004 and spring 2006. In terms of species richness this was similar to that found in previous studies of the Estuary (Ref. 47, Ref. 89). These studies sampled mainly the Outer Mersey, Narrows and Middle Estuary and therefore there was variation in terms of the species sampled during the fish survey. It is considered that the variety of fish sampled within Upper Estuary is likely to be consistent with the fish communities of other turbid, high energy UK estuaries e.g. the nearby River Dee, and Ribble Estuaries.

Freshwater fish

11.6.228 At least eleven common coarse fish species are regularly caught in the Bridgewater Canal, and at least seven are found in the St. Helen's Canal. The number and type of species present is characteristic of slow flowing waterways throughout the UK and no rare species have been recorded.

Marine mammals

11.6.229 The most likely marine mammals to be sighted in the Upper Mersey Estuary are harbour porpoise and bottlenose dolphins. There have also been occasional sightings of grey seals within this section of the estuary. On two occasions over the last decade there have been whale strandings downstream of the SJB.

Predicted baseline for 2015 (Opening Year)

11.6.230 The predicted changes in the baseline conditions of intertidal and subtidal habitats would be dependent on future natural geomorphological and hydrodynamic changes to the Estuary, and anthropogenic influences. The estuary is naturally a highly dynamic and continuously changing environment, with the specific morphology of the estuary varying with each tide. During the survey period the subtidal channels within the study area have decreased in depth and width, whilst the intertidal/supratidal areas have accreted vertically. There is an area of mud flat in the centre of the study area which has been present over the last 91 years, however, it is not possible to predict whether a low water channel might form here in the future (Chapter 7: Hydrodynamics and Estuarine Processes Movement).

11.6.231 Historically, the position of the low water channel within the estuary has varied considerably. Between 1867 and 1869 the channel was close to the southern shore but between 1870 and 1879 it had migrated to near the northern shore (Ref. 108). Construction of the Manchester Ship Canal in the 1890s along the southern shore changed the hydrology of the estuary and stabilised the low water channel which remained close to the northern shore until the late 1950s. The channel began to migrate once more, however, towards the southern shore in the mid 1980s and it now appears the channel has reached a dynamic equilibrium and can migrate between the two extremes (Ref. 108). It remains difficult to predict future movements of the water channel if left undisturbed (Chapter 7: Hydrodynamics and Estuarine Processes Movement). Changes in the available area of intertidal and subtidal sands could influence the community structure in these regions, however, this would mainly be in terms of the species present and there would not necessarily be a change in species diversity or density as a result of the varying hydrodynamic regimes.

11.6.232 Due to the dynamic nature of the estuary and long-term changes in the hydrological regime as well as day to day tidal water movements, the estuarine environment is mainly suitable for adaptable species. Indeed species diversity is relatively low in most estuaries. The Estuary has also been very heavily polluted reaching a peak pollution level in the mid 1960s during which anoxia within the Upper Estuary was common and fish were largely absent from this region. It was not until the commencement of the Mersey Estuary Pollution Alleviation Scheme (MEPAS) and the subsequent development of the Mersey Basin Campaign in 1985 that improvements were observed.

11.6.233 The main factor which is likely to influence baseline conditions within the Upper Mersey Estuary in the future, is the on-going implementation of measures to improve water quality within the Mersey. This has been aided by the Asset Management Plan (AMP) which has provided funding for water companies to, among other things, improve wastewater treatment. Legislation which has resulted in continued improvements in water quality includes the Water Resources Act 1991 Section 190, and the EC Urban Wastewater Treatment Directive (91/271/EEC) (see Section 11.4). The EA has recently completed the Mersey Estuary Stage 3 Review of Consents process as required under Regulation 50 of the Conservation (Natural Habitats, &c.) Regulations 1994, as amended. This review is conducted to ensure discharges in the Estuary are meeting the required standards and to identify areas in which the impact of discharges on water quality could be reduced further.

11.6.234 The changes in water quality have included significant decreases in ammonia and BOD within the Estuary since the 1970s (Chapter 8: Surface Water Quality). Generally, the ammonia concentrations within the study area of the estuary were considered to be 'fair' to 'good'. A high variability of BOD was observed across the estuary with levels mainly falling within the categories of 'fairly good' to 'good' water quality (Chapter 8: Surface Water Quality).

Estuarine invertebrates and algae

11.6.235 Although the ecological diversity of the estuarine fauna is still limited (particularly the benthic invertebrate populations living within the sediment) the continuing improvements in water quality are likely to gradually lead to a visible improvement in certain aspects of the ecology of the estuary over subsequent decades including the diversity of algae and invertebrates.

11.6.236 For benthic invertebrates there may be an increase in species diversity as pollution levels decrease. However, any increase may be slight as the stresses of living within an estuarine environment limits the number of species which can survive within this habitat. In addition, an increase in species diversity would not necessarily be accompanied by an increase in biomass of macroinvertebrates as some pollution tolerant species can attain very high densities when competition among species is low. Therefore, improvements in water quality may not necessarily lead to a considerable increase in the food resources available for birds in the Upper Mersey Estuary.

Freshwater invertebrates and macrophytes

11.6.237 The water quality in the freshwater habitats may also improve over time but this would mainly be due to improved management of urban development programmes and reduced input of pollutants into the canals and brooks. For example, monitoring data for the St. Helen's Canal from the EA have shown some improvement in water quality since the early 1990s (Chapter 8: Surface Water Quality). Improvements in water quality would also be beneficial for freshwater aquatic communities. Between now and 2015 there is the potential for some increases in the species diversity of macrophyte species and invertebrates in the canals if there is a significant improvement in water quality within these waterways. An increase in species diversity, however, would not necessarily result in increased biomass of macrophytes or invertebrate densities within the canals.

Estuarine fish

11.6.238 It is possible that the diversity of fish species currently within the Upper Mersey Estuary is near the maximum potential value for this habitat following an initial rapid increase in fish species diversity in the late 1900s. This was the case for the Thames Estuary in which a rapid increase in species diversity was recorded between 1964 and 1982 following improvements in water quality, however, data gathered in subsequent years indicated no significant change in species diversity between 1983 to 1991 (Ref. 81). Despite potential slight increases in the diversity of algal and macroinvertebrate communities this may not have a significant impact on the fish community, this is because as described previously an increase in diversity does not necessarily mean there will be an increase in the density and biomass of potential prey items.

11.6.239 Overall, it is likely that there will be no significant increase in fish species diversity between the sampling period (2002-2007) and 2015. In terms of the fish community, the main benefit of improved water quality is expected to be a potential increase in the numbers of salmon migrating through the Upper Mersey Estuary channel to reach spawning grounds further up the Mersey Catchment. Therefore, it is possible that there will be a notable increase in the numbers of migratory salmonids moving up and down the estuary between now and 2015.

Freshwater fish

11.6.240 As described for freshwater invertebrates and macrophytes any increases in the water quality of the canals could lead to a slight increase in the diversity of fish species within them.

Marine mammals

11.6.241 The most likely marine mammals to be sighted in the Upper Mersey Estuary are harbour porpoise and bottlenose dolphins. There have also been occasional sightings of grey seals within this section of the estuary. Whale sightings would be expected to remain very uncommon. If fish numbers do not increase significantly between 2007 and 2015 as expected, it is not envisaged that there would be a considerable increase in numbers of marine mammals during this period.

11.6.242 Overall, it is concluded that in general the baseline ecological conditions of the Upper Mersey Estuary are characteristic of other UK estuaries in terms of the algal and fish communities. As explained in Paragraph 11.6.212, it would be expected that the macroinvertebrate community of the Upper Estuary would have a relatively low species richness and diversity when compared with mid to lower estuarine habitats. However, the density of macroinvertebrates in the intertidal flats of the Upper Mersey Estuary during a given sample period is considered to be low even in relation to some other estuaries with a history of pollution, and it is thought intertidal macroinvertebrates within this section of the Estuary would provide a very limited food source for birds.

11.7 Impact Assessment

Receptors

11.7.1 As described in Section 11.5, impacts were identified and quantified using scientific judgement and the assessment conducted according to the IEEM guidelines for Environmental Impact Assessment in the UK (Ref. 61). The process undertaken to determine the significance of an impact is summarised in Table 11.27.

Table 11.27 - Summary of considerations and terminology used when conducting an ecological impact assessment

	Considerations	Descriptor
Receptor	What is the receptor?	e.g. habitat, group of organisms
Importance of Receptor	Estimate value	Based on biodiversity, social/community and economic value
Predicted Impact	Nature of the impact	Effect and is it Positive/Negative
	Likelihood	Certain; Probable; Unlikely; Extremely unlikely
	Duration	Long; Medium; Short-term
	Reversibility	Permanent; Temporary
	Effect	Direct; Indirect
	Magnitude	High; Moderate; Low; Negligible
Significance	Application of expert judgement based on the above	High; Moderate; Low; Non-significant
If Significant Impact	Potential for mitigation/ enhancement	Description of mitigation/ enhancement
Residual Impact	Significance following mitigation/enhancement	High; Moderate; Low; Non-significant

11.7.2 A number of key receptors were identified for potential impacts which were:

a. Intertidal and subtidal habitat;
b. Infauna and benthic algae;
c. Epifauna and fish;
d. Marine mammals; and
e. Canal fauna and flora.

11.7.3 In order to conduct a comprehensive assessment of impacts on a number of aspects of aquatic ecology within the Upper Mersey Estuary it was important to gather data for each of the key receptors listed above. This has been reported on earlier in this Chapter. Impacts on marine mammals were only considered in relation to underwater noise, however, marine mammals are not considered a key receptor for any of the other potential impacts as very few individuals, if any, are expected to be present within the Upper Mersey Estuary at any given time.

Intertidal and subtidal habitats

11.7.4 Inter- and subtidal habitats have the potential to be influenced both physically and chemically by the works associated with the New Bridge. Impacts on these habitats within the estuary are likely to have knock-on effects on the other receptors considered which inhabit the estuarine environment (e.g. estuarine algae, invertebrates, fish and ultimately birds).

Infauna and benthic algae

11.7.5 Algae are essential primary producers and collectively constitute the largest percentage of food web biomass in estuaries. Benthic algae (along with other photosynthetic groups) are essential for estuarine productivity providing food for primary consumers (e.g. zooplankton and filter feeders including benthic macroinvertebrates). Therefore, it is essential to establish the presence and biomass of these organisms when assessing the quality and status of aquatic environments (Ref. 48). Organisms within this receptor group are relatively sessile and are generally unable to evade areas subjected to environment impact. Therefore changes in community composition or biomass, above and beyond ranges of natural variation, can be a reliable indicator of environmental impact.

11.7.6 Benthic macroinvertebrates in the intertidal zone are very important for protected bird species in the Estuary as a whole as they provide a rich food source, especially within the mid and outer Mersey Estuary. They are also consumed by a variety of benthic feeding fish.

Epifauna and fish

11.7.7 Epifauna (e.g. shrimp) are an extremely important food source for benthic feeding fish. Fish are a visible and important component of aquatic biodiversity. Many of the species within the Upper Mersey Estuary are of commercial value (e.g. flounder) and as secondary/tertiary consumers within the estuary, fish are important for the maintenance of ecological balance within the estuarine ecosystem. Protected species such as Annex II fish species as designated by the EC Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora), (e.g. Atlantic salmon and lamprey) are of prime concern when considering potential impacts.

Canal fauna and flora

11.7.8 The receptors above are related to the ecology of the main estuary channel. The Project, however, has the potential to impact freshwater watercourses including canals and brooks within or near the proposed works. Freshwater invertebrate communities are routinely used to assess water quality within freshwater environments and variations in abundance and community composition can indicate both long and short term incidents of pollution. Similarly, macrophyte communities can reflect water quality and changes in environmental conditions. Impacts of shading due to the presence of the New Bridge can also be assessed via ongoing assessments of macrophyte biomass within potentially impacted areas. The fish community within the freshwater canals is of recreational importance for local anglers and fish are reliant on the abundance of invertebrates and macrophytes to provide them with food, refuge and spawning habitat.

Do Nothing Impact

11.7.9 The predicted impacts of not constructing the New Bridge on the aquatic ecology within intertidal and subtidal habitats and freshwater watercourses are outlined in the predicted baseline conditions for 2015 (Opening Year) (Paragraphs 11.6.226-238).

11.7.10 A summary of the impacts that may occur if the New Bridge was not constructed (Do Nothing Impacts) are indicated in the first section of Table 11.28.

Construction Phase Impacts

11.7.11 A number of possible construction methods are being considered for the Project. A general assessment has been made regarding the types of impacts expected to be common (e.g. release of potential pollutants and chemicals) to a range of proposed construction methods (e.g. stone haul road construction and use, and cofferdam construction). In addition, the impacts of other potential activities such as construction of a jetty and use of large hovercraft for transportation have been assessed.

Impacts

a. Underwater Noise:

- Pile driving.
- Use of large hover barges.

b. Sediment movement/resuspension:

- Changes in hydrodynamics as a result of construction activities
- \- Increase in sediment resuspension due to general construction methods of jetty, cofferdams and towers.

c. Accidental release of pollutants:

- Via erosion of existing sediments (i.e. pollutants locked in saltmarsh/intertidal habitat) due to construction methods.
- Due to spillages of chemicals and materials during construction and runoff from solids such as tar planings; and

d. Habitat loss/disturbance:

- Construction of towers, piers and cofferdams.
- Construction of a stone haul road over/near salt marsh scrapes
- Shading of habitat due to jetty construction
- Infilling of St Helen’s Canal

Underwater Noise

Pile Driving

11.7.12 An impact which is expected to be common to all proposed construction methods is the noise generated by pile driving. Piling would be involved in the construction of a jetty and for cofferdams structure which could be constructed over saltmarsh or over mudflats within the estuary channel. It would also be required for the construction of piers near the sites of tower construction and for the installation of cofferdam sheet piles. It is considered that during the construction period, noise is likely to be one of the key sources of stress for aquatic organisms, in particular fish and marine mammals.

11.7.13 The construction of the access jetty would involve driving a large number of piles into the sediment. If conducted on the saltmarsh, the noise generated would be minimal as it would be absorbed by the sediment. However, piling to construct a jetty into the estuary channel could generate high levels of noise within the water column. There would be an attenuation of noise energy with increased distance from the pile driving source and it is known that low frequency sounds (such as those from pile driving), attenuate more rapidly in shallow water than in deeper waters (Ref. 109).

11.7.14 During pile driving the size and operational power of the hammer, the size and length of the piles, soil conditions, water depth, bathymetry, salinity and temperature all affect the level of sound produced from the impact hammer or vibrator and influence the consequent impact on aquatic organisms. It is currently proposed that vibration hammer techniques would be used with tubular steel piles for the jetty and that installation of the piers and cofferdams would also involve vibro piling (MG_REP_EIA_010: Construction Methods Report). It is known that vibro piling has a lesser negative effect on aquatic organisms than impact piling[5]. In addition, closed end piles usually produce greater sound pressures than those which are open ended/tubular (Ref. 109).

11.7.15 Pile driving can generate sound pressures significantly greater than 192 dB re: 1 μPa[6] (Ref. 110). In a recent study in Southampton, Nedwell *et al.* (Ref. 111) found the sound level at the source of impact pile driving to be 194 dB re: 1 μPa which is higher than the 180 dB re: 1 μPa shown to cause damage to the inner ear of the freshwater cichlid *Astronotus ocellatus* (Ref. 112), and this had decreased to 160 dB re: 1 μPa at 234 m from the source. The level of sound generated can vary in relation to different factors such as the scale of the operation, Feist *et al.* (Ref. 113) predicted that sound pressure levels would attenuate from 189 dB re: 1 μPa at 440 m from an active pile driving operation to 150 dB re: 1 μPa at 4,440 m from the source of the sound. The Feist *et al.* (Ref. 113) study in Puget Sound, USA also examined the effects of pile driving on juvenile salmonids and revealed that there were fewer schools of salmonids in pile driving areas than in regions where there was no pile driving. The authors suggested that within the range measured (i.e. a distance of 440 – 4,440m) salmonids are not likely to suffer sustained injury but normal migratory behaviour could be disrupted by piling.

11.7.16 In another study, a sound pressure of 207 dB re: 1 μPa created using a pile driver energy of 900 kJ, was measured at a distance of 103 metres and 191 dB re: 1 μPa was recorded at a distance of 358 metres (NOAA 2001 as cited in Ref. 114). Pounding of a hoe ram was measured at a continuous 170 dB re: 1 μPa (Dolat 1997 as cited in Ref. 114), and it has been suggested that fish less than 30 metres away could have experienced permanent auditory system damage and loss of equilibrium.

11.7.17 It is important to note that different fish species and aquatic mammals have different frequency ranges over which they can hear noise. Nedwell *et al.* (Ref. 115) summarised audiograms for fish and marine mammal species derived from many different studies. These audiograms indicated hearing thresholds at different frequencies for a number of the species found within the Upper Mersey Estuary (in some instances more than one study was conducted for a given species and in these cases the ranges determined during different studies are provided here). Results for these species were as follows:

[5] Vibro piling uses rapidly alternating force generated by rotating eccentric weights to install the pilings into the ground.
[6] SI unit for the measurement of sound in water, decibels relative (dB re:) to a reference pressure (1 μPa).

a. Sea bass (hearing range of 98-120 dB re: 1 μPa over frequency range of 100-1500 Hz);
b. Cod (65-140/75-110/95-120 dB re: 1 μPa over frequency range of 10-500 Hz);
c. Dab (90 to 105 dB re: 1 μPa over frequency range of 30-200 Hz);
d. Goby (105-140/105-150 re: 1 μPa over frequency range of 80-900 Hz);
e. Herring (75 to 135 dB re: 1 μPa over frequency range of 30-3500 Hz); and
f. Salmon (95 to 130 dB re: 1 μPa over frequency range of 30-350 Hz).

11.7.18 These results indicate that herring display a relatively high sensitivity to noise, hearing it over the widest frequency range and having the greatest threshold level range. Cod have medium sensitivity and dab have low sensitivity to noise with a threshold level range of just 15 dB re: 1 μPa and hearing noises across a narrow frequency range. Such differences are in a large part due to considerable differences in auditory apparatus among species (Ref. 115). The variation in these hearing thresholds indicates the importance of considering the frequency of the noise and the species involved when assessing the potential impacts of noise on fish in the Upper Mersey Estuary.

11.7.19 For this reason Nedwell *et al.* (Ref. 116) proposed the use of a weighted measure $dB_{(ht)}$ *(species)* to model the noise level experienced by a specific species (where ht stands for hearing threshold). This value is a function of the sensitivity of a species to noise and the frequency range over which it can detect noise. It was estimated that 90 $dB_{(ht)}$ was the threshold value above which significant avoidance behaviour could be expected.

11.7.20 A study by Nedwell *et al.* (Ref. 111) aimed to examine whether salmonids exhibit stressed responses at varying distances from a pile driving source. Brown trout have a similar hearing ability to salmon and video footage of caged trout during a pile driving operation was analysed. Two types of piling were used during the study: vibro piling which involves applying a rapidly alternating force to the pile via rotating weights, and impact piling which involves less frequent downward impacts using hammers although the sound generated is usually of lower duration but greater volume than produced during vibro piling. Based on the known range of salmonid hearing it is thought that an impact pile driving operation would be heard up to 600 m away from its source (Ref. 114). For vibro piling, however, it was found that even at a range of just 50 m brown trout showed no reaction and this was also the case for fish caged at 400 m (Ref. 111). When impact piling methods were used no reaction or injury was evident at a range of 400 m, however, no data were provided regarding the reactions of brown trout at a distance of less than 400 m (Ref. 111).

11.7.21 It was noted that during this study the noise level at the source of the impact was about 194 dB re: 1 μPa and after 400 m this had attenuated to 134 dB (a transmission loss rate of 0.15 dB m^{-1}). Other studies have indicated a linear transmission loss of 0.04 dB m^{-1} when the source level for piling was 198 dB re: 1 μPa, and 0.04 dB m^{-1} with a source level of 192 dB re: 1 μPa (Ref. 117).

11.7.22 In addition to auditory problems, the perforation of swim bladders by high-energy underwater noises is another impact that must be considered (Ref. 118). This physical damage can cause fish to sink, lose the ability to orientate themselves, or lead to internal bleeding and fatality. Although more subtle effects such as damaged hearing or internal damage may not lead to immediate fatalities, the decreased fitness of the fish and potential increased susceptibility to predation could have delayed effects on an individual's chances of survival (Ref. 109). In addition, there may be energetic costs for individuals which could reduce survival potential.

11.7.23 During a pile driving operation in Vancouver harbour mortality of Chinook salmon and herring was recorded near the source of the impact (Ref. 109). In this case closed end piles were used and peak pressures were very high reaching ~224 dB re: 1 μPa. A further study of Chinook salmon described in Vagle (Ref. 109) found that there was no mortality of caged salmon at less than 10 metres from impact piling generating pressure of up to 212 dB re: 1 μPa. Although the fish appeared to suffer no physiological effects they were noted to be disorientated afterwards. Although this species is not found in the Estuary it is a salmonid and is likely to exhibit similar reactions towards underwater noise as other salmonids which are found within the Estuary (e.g. Atlantic salmon).

11.7.24 The size of piles and the driving energies utilised by the pile driver need to be considered when assessing potential impacts of the operation. An initial assessment of a number of different impact piling operations was conducted by Vagle (Ref. 109). It was suggested that the use of 8 and 12 inch diameter cedar and steel (open ended) piles in shallow water produced maximum positive pressures far below 209 dB re: 1 μPa (a pressure considered to be potentially damaging to fish i.e. it is recommended for operations to operate below this level). In the absence of direct evidence it was considered that the 212 dB re: 1 μPa produced by hammering 20 inch diameter pile with an input energy of 210 kJ could have a negative effect on fish and when the piles used had a diameter of 42 inches then negative effects on fish near the piling operation were more likely (Ref. 109).

11.7.25 Although there is no conclusive evidence regarding the sound pressure levels (SPL) harmful to marine life other than fish, the National Marine Fisheries Service in the US (NMFS) considers that underwater SPLs above 190dB re: 1 μPa RMS (impulse) could cause temporary hearing impairment in harbour seals and SPLs above 180dB re: 1 μPa RMS (impulse) could cause temporary hearing problems in whales (it should be noted that there have been whale strandings in the Inner Estuary but they are extremely rare (see Paragraphs 11.6.202-203) and it is extremely unlikely that any whales will be in the vicinity of the New Bridge). Audiograms for cetaceans collated in Nedwell *et al.* (Ref. 115) revealed that the hearing range for harbour porpoise differed among studies, ranges were: 10-45 dB re: 1 μPa (at frequency range of 50-180 Hz), 30-115 dB re: 1 μPa (0.2-150 Hz), 30-80 dB re: 1 μPa (1-150 Hz), and 60-105 dB re: 1 μPa (10-130 Hz). For grey seal values recorded were 60-150 dB re: 1 μPa over a frequency range of 1.5-120 Hz, (although one individual exhibited a maximum measured value of 190 dB re: 1 μPa at 120 Hz).

11.7.26 Using a weighted measure $dB_{(ht)}$ (see Paragraph 11.7.19) and a critical value of 90 $dB_{(ht)}$ it was found that during pile driving with a source pressure of 260 dB re: 1 μPa the distance up to which a significant avoidance reaction would be displayed by marine mammals was 2000m for harbour seals, 4600m for bottlenose dolphin and 7400m for harbour porpoise (Ref. 119). Therefore, with regards to marine mammals an impact of pile driving could potentially be evident kilometres from the source.

11.7.27 The impacts on marine mammals of low frequency noise include avoidance of an area, tissue rupture, hearing loss, disruption of echolocation, masking, habitat abandonment, aggression, pup/calf abandonment, and annoyance (Ref. 109). Studies have found that low frequency noise within the water column similar to that resulting from pile driving can deter seals from surfacing in the vicinity. They can also cause porpoise to increase their echolocation activity by a factor of 2, suggesting that the noise may be interfering with their echolocation abilities (Ref. 120). There have been occasional sightings of harbour porpoise and grey seals in the Upper Mersey Estuary, however, generally these species would be expected to be found in the estuary further downstream.

11.7.28 With respect to fish, and particularly in consideration of the potential effects on migrating salmon and lamprey it is considered **probable** that without mitigation elevated noise levels during construction would have an impact of **moderate** magnitude and **moderate** significance. With regards to marine mammals it is thought the number of individuals expected to be in the vicinity of the New Bridge would be very low and overall it is considered that without mitigation there would be an impact of **moderate** magnitude and **moderate** significance. The use of vibro piling will lessen these impacts and, any impacts associated with noise levels during the construction period would be temporary. Following the cessation of activities causing noise disturbance underwater, it would be expected that aquatic organisms which may have exhibited avoidance behaviour (including the most sensitive species) would return to the area or pass through it.

Use of large hover barges during construction

11.7.29 Large vessels such as hovercraft barges are likely to cause an aural, and potentially a visual disturbance for some aquatic organisms. This could cause fish and marine mammals to avoid the areas in which vessels are operating. There are already, however, large vessels operating within these waters and organisms are likely to have become accustomed to a background level of underwater noise resulting from these activities.

11.7.30 Large tankers and container ships can generate sound levels in the range 180-190 dB re: 1 μPa at 1 m which is similar to that generated by pile driving (Ref. 121). However, due to the mode of operation of hovercraft, a hover barge would be expected to generate a significantly lower noise impact below the water surface which is less likely to cause disturbance to aquatic organisms.

11.7.31 Any noise impacts caused by vessel movements would be temporary during the construction period, it unlikely to have long-term effects on aquatic ecology within the area and is not expected to be above and beyond the levels of background noise experienced by organisms due to the operation of other vessels in the area. It is considered **probable** that noise due to large vessels used during the Mersey Gateway Project would have a **non-significant** impact on marine organisms

Sediment movement/resuspension

Changes in hydrodynamics

11.7.32 The presence of the cofferdams enables the construction of towers (and potentially pier structures) within a dry area. As a result of cofferdam construction there could be an increase in current velocity between cofferdam structures (Chapter 7: Hydrodynamics and Estuarine Processes Movement). This change in velocity could lead to a one-off localised incidence of scouring which modelling suggests could be up to a depth of 4.5-5 m which has been assessed in Chapter 14 (Contamination of Soils, Sediments and Groundwater).

11.7.33 The upper layer of sediment in the study area is highly mobile and is resuspended regularly as a result of tidal movements (Chapter 7: Hydrodynamics and Estuarine Processes Movement). Therefore, benthic organisms within the top 1-2 m of sediment (or greater depending on the area of the estuary) are expected to be continually displaced. Initial modelling has suggested that due to scouring, sediment up to a depth of 4.5-5 m or greater could be resuspended. However, most invertebrate species are expected to be found within the upper 15 cm of sediment and any disturbance of sediment deeper than this is likely to have a negligible impact on the macrobenthic community.

Increase in sediment resuspension

11.7.34 Increased disturbance and resuspension of the sediments near the cofferdams is also likely to result in increased density of sediment particles in the water. Physical impacts on fish caused by increased suspended sediment concentrations may include clogging and abrasion of the gills, thickening and proliferation of the gill epithelium, reduced resistance to disease, reduced growth rate and in extreme cases death.

11.7.35 Dependent largely upon the type of solid suspended, varying survival rates have been recorded for a wide range of fish species over extended time periods of up to 200 days. Mortality events have been observed in concentrations of between 200 and 4,250 mg/l in some cases, whereas in others no deaths were recorded in concentrations between 200 and 1,000 mg/l (Ref. 122).

11.7.36 Although fish may survive high concentrations of suspended solids often over prolonged periods they may subsequently suffer reduced fitness through damage of the gill epithelium through particle abrasion and clogging (Ref. 123).

11.7.37 Fish migrating through estuarine environments may frequently encounter high suspended sediment loads which do not appear to impede this behavioural activity. Atlantic salmon for example are known to pass through the Severn Estuary into the River Severn where sediment concentrations in suspension can reach into several thousand mg/l for periods (Ref. 124). Indeed salmonids are likely to have adapted physiologically to the turbid conditions that naturally occur within estuarine and harbour areas (Ref. 125).

11.7.38 In addition, by necessity, other fish species and invertebrates which inhabit estuaries are well adapted to such conditions and have evolved to withstand high sediment loads.

11.7.39 Any physical impacts associated with increased suspension of sediment due to the presence of cofferdams and associated scouring would be temporary and would occur during the construction period. They are also not expected to be above and beyond the level of turbidity naturally experienced within the Upper Mersey Estuary due to tidal movement and resuspension of sediments. However, due to the fact that most organisms potentially impacted are well adapted to sediment resuspension within estuaries (e.g. the majority of fish species caught during the survey including flounder, sand and common goby, herring, sprat, pipefish, plaice and all of the invertebrate and benthic algae species regularly recorded) it is **probable** that the impacts on aquatic ecology within the area would be of **low** magnitude and **low** significance.

Release of pollutants

Erosion of existing sediments

11.7.40 In addition to the direct physical effects of increases in sediment resuspension on aquatic organisms it is also important to consider the potential chemical impacts due to release of pollutants previously locked up in the sediment. As the top couple of metres of sediment is frequently resuspended under normal conditions (Chapter 14: Contamination of Soils, Sediments and Groundwater) it is the release of contaminants from sediments below this depth which is of main concern.

11.7.41 As a result of the historically highly polluted nature of the Estuary sediments, there remains a quantity of persistent pollutants within the intertidal sediment such as heavy metals and poly-aromatic hydrocarbons (PAH). The UK currently has no set guidelines for marine and aquatic sediment contaminants, however, the UK Marine SAC recommend use of the Interim Marine Sediment Guidelines set out by Environment Canada (Ref. 126). Pollutants within the top layer of sediment which is regularly re-suspended are likely to be repeatedly dispersed within the water column. A number of the contaminants in the Upper Mersey Estuary are above the Canadian Environmental Quality Guidelines[7] for the Predicted Effect Levels (PEL) within the sediment, especially PAHs (Chapter 8: Surface Water Quality). The PEL is the upper level and represents the lower limit of the range of chemical concentrations that have been associated with adverse biological effects.

11.7.42 In particular, upstream of the area of the New Bridge construction area there were found to be high concentrations of arsenic (up to 115 mg kg^{-1}) and zinc (up to 149 mg kg^{-1}) in the intertidal sand flats (Chapter 14: Contamination of Soils, Sediments and Groundwater). Due to the fact that these contaminants were at a depth of 2m and were 0.5 km away from the scour zone they would be unlikely to be released due to construction of the New Bridge. In addition, low level heavy metals were found in the saltmarshes on the south shore and elevated levels in the upper 1 m saltmarshes on the north shore, as saltmarsh sediments are cohesive these contaminants are unlikely to be released to intertidal sediments as a results of construction activity (Chapter 14: Contamination of Soils, Sediments and Groundwater).

11.7.43 Chapter 14: Contamination of Soils, Sediments and Groundwater indicates that during phase 5 investigations undertaken in 2006 elevated concentrations of toxic metals in excess of Permissible Exposure Limits (PEL) and Interim Sediment Quality Guidelines (ISQG) values were found at all locations sampled in the intertidal zone. Similarly, PAHs were tested at 14 locations and were greater than Canadian ISQG values at all locations and across the full depth range tested (0.25-7.25m below ground level). In general, of the range of contaminants assessed during the investigations (Chapter 14: Contamination of Soils, Sediments and Groundwater), metals/metalloids and PAHs were the only contaminants detected at potentially significant levels.

11.7.44 Construction of the towers, pier structures and cofferdams could result in the release and resuspension of these pollutants due to excavation of the cofferdams and estuary floor disturbance. It is expected that sediments will be excavated to a depth of 5 m below datum (-5 AOD) within the cofferdam (Construction Methods Report: MG_REP_EIA_010).

11.7.45 In addition, disturbance of sediment on the saltmarshes may lead to further contaminants being leached out into the estuary from surface runoff. Elevated levels of metals/metalloids greater than ISQG and PEL values were detected within saltmarsh sediments at all sampling locations (Chapter 14: Contamination of Soils, Sediments and Groundwater). It was found that concentrations were greatest within the top 2m of sediment. Other contaminants found at potentially significant levels within saltmarsh sediments were PAHs, pesticides (Widnes Warth) and ammonia.

11.7.46 The release of contaminants from intertidal and potentially saltmarsh sediments is an important consideration as the study site is upstream of the Mersey Estuary SPA (this starts immediately downstream of the SJB). Due to the considerable tidal water movement within the Upper and Mid Estuary there is the potential for resuspended pollutants to be dispersed widely and potentially contaminate sediments within the SPA. If this occurred to a significant degree it could have an effect on invertebrates and bird life within the SPA.

[7] The UK has no set guidelines for marine and aquatic sediment contaminants at the moment, however the UK Marine SAC recommend use of the Interim Marine Sediment Quality Guidelines set out by Environment Canada (1999)

11.7.47 The presence of heavy metals and hydrocarbons at elevated levels is of particular concern as they are conservative pollutants and are not subject to bacterial attack or breakdown. Due to their conservative nature they are prone to bioaccumulation in the tissues of individuals of particular species. The degree to which an organism concentrates the pollutant varies according to both the pollutant and the species, however, if the toxin is not continuously excreted it will gradually accumulate within the organism during its life span. Consumers of these plants or animals are often unable to excrete the toxins themselves and, therefore, these conservative pollutants can bioaccumulate along the food chain up to the top predators. Although some annelid worms can bioaccumulate contaminants (see Paragraph 11.7.51) it is mainly bivalve molluscs which tend to accumulate toxins. Only two bivalve species were sampled during the aquatic ecology survey (*Mytilus edulis* and *Macoma balthica*), they were found in 2004 and 2005 only and even then were rarely present (Table 11.17). Only *M. balthica* was present in the intertidal zone in which the birds feed and *M. edulis* was found in subtidal habitats.

11.7.48 Heavy metals and metalloids including lead, mercury and arsenic can accumulate in the tissue of fish species including those of commercial importance. A study conducted in 1991 examined heavy metal concentrations in flounder (*Platichthys flesus*) in the Estuary (Ref. 127). It was found that over 90% of individuals comprising the largest size class exceeded the EC Environmental Quality Standard (EQS) for mercury of 0.3 mg kg^{-1} fish wet weight , 100 % individuals >10 cm in size exceeded the 1959 UK statutory regulations for arsenic concentrations in foodstuffs and a large proportion of fish also exceeded the statutory maximum of 2 mg kg^{-1} fish wet weight for lead. Concentrations of copper, nickel, cobalt, chromium, cadmium and zinc were non-detectable or within the ranges expected for estuarine fish (Ref. 127).

11.7.49 In 1979 there was an incident of lead poisoning among sea birds wintering in the Estuary during which 2400 birds (mainly dunlin) died, and a small number died the following year. The dead birds had more than 10 ppm (dry weight) lead in their liver. These waders accumulated the lead from their food, mainly the invertebrates *Macoma baltica* (1 ppm lead) and *Hediste diversicolor* (0.2 ppm). Lead had been introduced into the estuary via a discharge from a factory which resulted in contamination of the benthic fauna (Ref. 128).

11.7.50 The polychaete, *H. diversicolor*, found throughout most of the study area has been used in numerous studies as a biomonitor of pollutants. As it is a bottom dwelling organism it is closely associated with sediment and is a potential food source for some bottom dwelling fish species (e.g. whiting). Annelid species, such as *H. diversicolor* have been found to be at risk if metals exceed the following concentrations in the water column during 4-14 days of exposure: >0.1 mg Hg l^{-1}, > 0.01 mg Cu l^{-1}, > 1 mg Cd l^{-1}, >1 mg Zn l^{-1},>0.1 mg Pb l^{-1}, >1 mg Cr l^{-1}, >1 mg As l^{-1} and >10 mg Ni l^{-1} (Ref. 129). Concentrations were calculated for a range of heavy metals, metalloids and non-metals in the intertidal sediments of Runcorn sands. Concentrations of copper (5-66 mg Cu kg^{-1}), zinc (121-565 mg Zn kg^{-1}), lead (14-100 mg Pb kg^{-1}), chromium (8-49 mg Cr kg^{-1}) and arsenic (5-115 mg As kg^{-1}) were found to be very high and potentially harmful to organisms such as *H. diversicolor* (Ref. 129). Less elevated, but still potentially harmful, values were also measured for mercury (0.11-1 mg Hg kg^{-1}), cadmium (<1-2.6 mg Cd kg^{-1}) and nickel (5-23 mg Ni kg^{-1}).

11.7.51 *H. diversicolor* is found to bioaccumulate some metals including lead, but is able to regulate the amounts of zinc within its body. Gastropods, however, are known to accumulate zinc in higher quantities. *H. diversicolor* is also known for its ability to become resistant to certain metals (e.g. copper), and worms with 1000 ppm have been found in some studies (Ref. 128).

11.7.52 The time taken for species to recover from an increase in chemical pollutants within the water column would be influenced by the amount of pollutant in suspension and the time it takes for the pollutant to decrease in concentration. If mass mortality occurred due to high contaminant levels another factor to be considered is the speed with which a species can recolonise an area by moving from adjacent habitats and then successfully establish a breeding population (Ref. 130).

11.7.53 However, elevated levels of contaminants are already present within mobile surface sediments in the Upper Mersey Estuary. In addition, in the intertidal zone there is no apparent relationship between the types of contaminant present, contaminant concentration and sediment depth (Chapter 14: Contamination of Soils, Sediments and Groundwater). Therefore, resuspension of deeper sediments would not necessarily increase the concentration of contaminants in near-surface sediments and it is likely, based on the results of Chapter 14 (Contamination of Soils, Sediments and Groundwater), that estuarine sediment within the scour zone would not be any more contaminated that those within the current mobile zone. In addition, it is expected that following scour there will be significant dispersal and dilution of contaminants, therefore the actual change to water quality would be negligible (Chapter 8: Surface Water Quality). This is in agreement with the investigation of estuarine sediments that concluded that sediments within the potential scour zone are no more contaminated than those within the current mobile zone (Chapter 14: Contamination of Soils, Sediments and Groundwater). As such, it is likely that potentially sensitive species would not be subjected to further pollution stress over and above that currently experienced.

11.7.54 When placing the cofferdams substantial amounts of sediment would be removed from the area and without adequate mitigation it is considered that the release of pollutants due to sediment suspension would **probably** have an impact of **low to moderate** magnitude and **moderate** significance.

Spills/leakages of chemicals and materials during construction

11.7.55 Impacts of direct spillage into the intertidal areas would vary according to the tidal state, meteorological conditions and time spent constructing the New Bridge. In addition, the magnitude of a pollution incident would be dependant on the type of chemicals involved. Increased levels of organic matter would raise Biological Oxygen Demand (BOD) resulting in decreased oxygen levels. Oil and grease would deoxygenate the water as they are broken down and could also coat flora and fauna and inhibit oxygen diffusion. Tidal state would also influence the extent of any impact of spills and leakages. For example, pollutants released during a high tide would be subject to very strong dilution, whereas pollutants released during periods of low tide would be more likely to persist within the estuary.

11.7.56 The Construction Phase opens up a potential pathway for pollution with a risk of escape of hazardous materials (Chapter 15: Waste). For example, runoff of material from solids such as planings containing tar would have an environmental risk if they entered the aquatic environment (Chapter 15: Waste).

11.7.57 Although no rare or protected species were recorded within the invertebrate community during the baseline surveys, any contamination of sediment or water may lead to bioaccumulation and biomagnification of potentially harmful compounds which may have an indirect impact on the numerous important species of waterfowl which feed on invertebrates within the estuary, similar to the effects seen in the 1979 lead poisoning incident (Ref. 128). However, bivalve molluscs, which are more prone to bioaccumulation of toxicants than polychaetes and crustaceans were rarely sampled during the aquatic survey.

11.7.58 Pollutants entering the Bridgewater and St. Helen's Canals would also be problematic due to the very low flow rate within these waterways. Spills of substances toxic to aquatic plants within the canals could potentially result in the loss of sensitive species such as the nationally scarce charophyte *Nitella mucronata* var *gracillima* (Red Data Book species) which was found to be abundant in the Bridgewater Canal during the aquatic survey.

11.7.59 The dilution capacity of the estuary is large and therefore spills and leakages of chemicals and materials are not expected to present a major problem. The impact of spillage of contaminants on aquatic organisms could be temporary or long-term depending on the types and quantities of contaminants entering the estuary, and the species affected. If harmful compounds entered the slow flowing canal systems, however, the potential threat to organisms would be increased as would the possibility of long-term damage to aquatic communities. If no mitigation measures are employed it is thought **probable** that spills/leakages of materials during construction would potentially have a negative impact with a **low to moderate** magnitude and **low** significance on the estuary and a **low** magnitude and **low** significance within the canals.

Habitat loss/disturbance

Construction of towers, jetty and cofferdams

11.7.60 The most obvious impact of the construction of the towers, jetty and cofferdams would be a direct loss of, or damage to, organisms living within sediments at the site of construction and the fragmentation of habitat for infaunal benthic invertebrates and algae. In contrast, invertebrates and fish living on the surface of the sediments would be expected to move away from the area of disturbance.

11.7.61 The direct loss of habitat through the physical footprint of the towers is unavoidable. As the towers are expected to have a diameter of approximately 10 m the amount of habitat lost would be about 236 m^2 which is 0.0082% of the subtidal and intertidal area in the Upper Mersey Estuary. However, additional habitat would be provided by the tower walls, which provide hard substrate for colonisation of some invertebrate species such as mussels (*Mytilus edulis*) and barnacles (*Balanus improvisus*) that are already found in low numbers in the study area. These species usually require a hard substratum for settlement and although larvae are present in the plankton they currently have very limited opportunities for settlement.

11.7.62 As construction would be expected to last around 40 months the impact should be temporary and via succession the habitat should gradually return to the condition it was in before the commencement of construction. However, there would be a permanent loss in the areas on which the towers are built.

11.7.63 Construction disturbance and the pier structure both have the potential to disorientate and to a degree act as barriers to fish movement. This is of importance to migratory species such as salmon, which have recently begun to return to the Estuary and the River, and sea trout, river lamprey and eel. However the jetty and construction process are both temporary. Moreover the pier structure itself will be physically passable by fish as the distance between supports would be ~12m. Nonetheless if large numbers of these important migratory species were deterred / prevented from migrating during the bridge construction then this could have an impact upon their populations as a whole.

11.7.64 Overall habitat loss and disturbance due to construction would **probably** be of **low** magnitude and **low** significance when considering the overall status of organisms within the Upper Mersey Estuary. However, impacts would **probably** be of **moderate** significance if anadramous Annex II species (i.e. salmon and river lamprey) were considered in isolation.

Construction of stone haul road over saltmarsh

11.7.65 It is expected that construction of a stone haul road across the saltmarsh leading to the jetty on both the north and south banks of the estuary will predominantly have an impact on saltmarsh communities. Only aquatic saltmarsh communities are dealt with within this Aquatic Ecology Chapter. Scrapes on Widnes Warth and Bowers Brook are the principal aquatic habitats potentially impacted by construction of a stone haul road.

11.7.66 If a stone haul road was built directly over these habitats it would result in a loss of these habitats during the period of construction and they may be damaged (even following subsequent removal of the road). The sampling of scrapes on Astmoor saltmarsh on the southern bank of the Upper Mersey Estuary has indicated that they provide a habitat (usually temporary) for a number of freshwater and estuarine fish species, especially goby and flounder. In general invertebrate communities were not particularly diverse and consisted of pollution tolerant species. The gastropod *Assiminea grayana* was found in high numbers in Bowers Brook and could be impacted by the development.

11.7.67 It is considered **probable** that the construction of a stone haul road would have an impact of **low** magnitude and **low** significance when considering aquatic communities within saltmarsh habitats, especially the snail *Assiminea grayana*.

Shading of habitat due to jetty construction

11.7.68 If a jetty was constructed over the saltmarsh it would cause a temporary shading of plants which may reduce the growth of some plants immediately below the jetty structure. Similarly, the presence of a jetty within the estuary channel would reduce the amount of sunlight reaching benthic algae at low tide potentially decreasing growth and algal biomass within a local area, which has some of the highest recorded abundances of algae from the baseline survey. However, this is likely to have a temporary impact, as once the jetty is removed algae will rapidly attain usual growth rates. The impacts caused by the presence of a jetty would **probably** be of **low** magnitude and of **low** significance to aquatic organisms within the area of construction.

11.7.69 The potential impacts of the construction phase are summarised in the second section of Table 11.28.

Infilling of St Helen's Canal

11.7.70 It is proposed that during construction a section of the St. Helen's Canal would be temporarily filled in to provide access for construction plant over the canal. A large bypass pipe would enable transfer of canal water between either side of the infilled area enabling it to maintain its drainage water transfer function. The main impact of this is likely to be the displacement of aquatic organisms within this section of the canal and a reduction in the amount of canal available for colonisation by macrophytes and invertebrates. It is likely that before infilling fish would need to be removed from the section of the canal to be infilled and relocated either upstream of downstream of the works.

11.7.71 The infilling would be temporary, however, and it is proposed the canal would be reinstated with some minor changes. Overall the St Helen's Canal has a GQA water quality rating of 'fair' (Chapter 8: Surface Water Quality) and the substrate in the St. Helen's Canal is very coarse, with large gravels and pebbles which is not conducive to macrophyte growth. There were no rare species of macrophyte, invertebrates or fish and no species of conservation interest within the St. Helen's Canal. Overall, it is considered the impacts of infilling the canal would **probably** be of **low** magnitude and would have an impact of **low** significance on the aquatic ecology of the canal.

Operational Phase Impacts

11.7.72 A general assessment has been made of the types of impacts expected to be common during the operation of the New Bridge.

Impacts

a. Sediment movement/resuspension;
   - Increased scour around towers.
b. Release of pollutants;
   - Via erosion of existing sediments (i.e. pollutants locked in the saltmarsh habitat) due to presence of towers and scour.
   - Due to road runoff and spillages of chemicals and materials during operation.
c. Habitat loss/disturbance; and
   - Corridor interruption, habitat isolation.
   - Shading of habitat due to presence of bridge; and
d. Guanotrophy.

Sediment movement/resuspension

Increased scour around towers

11.7.73 The placement of the bridge supporting structures in the Mersey has the potential to result in a change in flow which could in turn lead to localised scour and deposition in intertidal areas near the structures (Chapter 7: Hydrodynamics and Estuarine Processes Movement).

11.7.74 It is thought that the current depth of mobile sediments within the Estuary varies from <1 to 2 metres AOD (depending on the location within the Estuary), with fixed sediments below this depth. It is estimated that increased scour due to the presence of the towers could cause the resuspension of sediments to a depth of 4.5-5 m or greater. However, this would be an extremely localised impact in the immediate vicinity of the towers (Chapter 14: Contamination of Soils, Sediments and Groundwater).

11.7.75 As benthic communities are dependent on specific sedimentary conditions, such scouring and sediment movement could result in relocation, reduction or even loss of habitats which could affect benthic community composition. However, the area potentially scoured is very small. In contrast, for species which prefer faster flowing conditions and sediment movement there may be beneficial effects. Fish are not likely to be affected if there is no reduction in prey availability. There may be some potential for clogging of gills if there is a notable increase in sediment load, however, estuarine fish are very well adapted to high turbidity environments (see Paragraphs 11.7.34-39). The Upper Estuary is already a highly dynamic system in terms of sediment erosion and deposition. The hydrodynamics are unlikely to change significantly (Chapter 7: Hydrodynamics and Estuarine Processes Movement) and even if hydrodynamics were altered to a minor degree, species composition in the Upper Estuary as a whole would be unlikely to change significantly as a result.

11.7.76 It is **probable** that any impact of sediment movement/resuspension on the aquatic community during the operation of the New Bridge would be of **negligible** magnitude and would be **non-significant**.

Release of pollutants

Erosion of sediments around towers

11.7.77 The increased levels of scour and associated resuspension of sediments below those usually mobilised by water movement has the potential to release contaminants into the water column which were previously locked in deeper sediments.

11.7.78 However, there is no apparent relationship between contaminant concentration and sediment depth and near surface sediments were found to currently have levels of metals and PAHs which exceed ISQG, and in many cases PEL, values.

11.7.79 Overall, impacts due to contaminant release are thought to be more likely during the construction phase. Scouring during operation will occur once the towers are in place and until an equilibrium is reached.

11.7.80 It is thought that most species sensitive to these elevated levels would already be impacted by the relatively high levels of contaminants in near-surface sediments, and it is **probable** that any impacts on sediment infauna would be of **negligible** magnitude and would be **non-significant**.

Road runoff and spillage

11.7.81 It is proposed to discharge surface water runoff from the Project into the St Helen's Canal and Stewards Brook. As is currently the case, runoff water in the southern part of Runcorn will continue to be discharged to Flood Brook.

11.7.82 It is not proposed to discharge road water runoff from the Project into the Estuary during construction or operation of the Project although spillages are still possible.

11.7.83 During periods of rainfall, substances such as oil and petrol in addition to other chemicals, salt and sediment which would have accumulated on tar planings could, without mitigation measures, wash off into the water below. In addition, accidents on the bridge or maintenance works could result in one-off spillages into the intertidal area. This should not be a major problem when considering the estuary due to the strong potential for dilution with tidal water movement. However, in the slow flowing canals there may be some short to long-term minor pollution problems depending on the type and amount of pollutant involved. Any salt and sediment runoff would be unlikely to impact the macrophyte community within the canals, however, spillages of more toxic compounds could potentially impact the Red Data Book species *Nitella mucronata* var *gracillima* (Red Data Book species) which was recorded in the Bridgewater Canal.

11.7.84 Using the Design Manual for Roads and Bridges (DMRB) assessment methodology, however, the probability of a serious pollution incident for Stewards Brook and the St. Helens Canal are 0.27% and 0.05% respectively (well below the 1% guidance level) (see Chapter 8: Surface Water Quality for details).

11.7.85 Without mitigation, it is **probable** there may be some adverse impacts of **low** magnitude and **low** significance on some components of the aquatic community within the estuary and freshwater due primarily to the potential for spillage and road runoff.

Habitat loss/disturbance

Corridor interruption and habitat isolation

11.7.86 Increased local resuspension of previously fixed sediments in the immediate vicinity of the towers is not likely to cause an increased disturbance to infauna which usually inhabit the top 0.5 to 1m of sediment. These organisms are already regularly displaced due to tidal movements within the estuary channel.

11.7.87 With the well-publicised return of salmon to the Mersey, as well as recordings of other migratory fish species including trout, lamprey and eel within the estuary, it is important to consider the possible impact of the bridge on their migratory routes. A notable recent finding was the sampling of four salmon parr by the EA in 2005 during a routine survey on the River Goyt near Stockport. This is the first evidence for decades that not only are migratory salmonids able to tolerate the current levels of water quality in the Mersey (salmonids generally have a low tolerance to polluted waters), but they are also able to spawn and hatch successfully in this river system. One recent change which has helped migratory salmonids return to the River Goyt was the construction of a fish pass on Northenden Weir in the Upper Mersey which had previously prevented fish from reaching areas further upstream.

11.7.88 As the towers for the Mersey Gateway would not be expected to have a diameter greater than 10 m they would not in themselves form a significant physical barrier to fish migration. However, if the hydrodynamics of the system were to change it is possible that some migratory fish may initially become disorientated while travelling along the migratory route in the Upper Mersey Estuary for the initial groups of individuals encountering the New Bridge. A similar impact would be noted for other migratory fish such as river lamprey and sea trout. However, the results from the Hydrodynamic studies conducted for the Mersey Gateway Project (Chapter 7: Hydrodynamics and Estuarine Processes Movement) indicate that there is no evidence to suggest that channels would 'attach' to bridge towers and it is likely that there would be no significant change to the hydrodynamic regime within the estuary.

11.7.89 There are examples of construction of sizeable bridges over rivers with excellent migratory salmonid routes such as the Tamar Bridge, Spey Fochabers A96 bridge, Tyne Bridge and Tay Road Bridge (Ref. 131, Ref. 132). In addition, large bridges have been constructed over other rivers with excellent marine nurseries including the Severn Estuary Road Bridge and the Dee Estuary Road Bridge. The direct impact of bridge operation is likely to be minimal, although there may be a slight indirect impact on the intertidal and subtidal areas due to changes in sediment dynamics and increased local erosion.

11.7.90 The proposed Tower footprints are relatively small in relation to the width of the Upper Mersey Estuary at the point the Mersey Gateway would cross the estuary channel. It is expected that migratory fish will readily pass under the bridge once it is completed and it is **probable** that the presence of the bridge would have an impact of **negligible** magnitude and have a **non-significant** impact on migratory fish movement and on aquatic ecology in general.

Shading of habitat

11.7.91 A key environmental factor affecting the presence and abundance of algae is the availability of sunlight. The vast majority of the estuary consists of unshaded open expanses of sand beds. As the New Bridge would run south to north it is considered that following its construction, most areas would still receive sunlight at some point during the day. Therefore, increased shading is not expected to be an issue for the vast majority of areas and the overall impact would be expected to be negligible. However, in areas which, following bridge construction, would be subjected to significantly longer periods of shading there could be a localised negative effect on the abundance and diversity of algae present on the intertidal flats. It should be noted that the New Bridge crosses the estuary close to a location where the highest abundance of algae was recorded on several sampling occasions during the baseline survey. However this is not expected to affect either the epifauna or fish communities on which it is **probable** that any impact would be **non-significant**.

11.7.92 Aquatic macrophytes in the canals may be affected by shading (e.g. the nationally scarce charophyte *Nitella mucronata* which is abundant in the Bridgewater Canal).It is **probable** that the magnitude of the impact would be **low**. The impact on the macrophyte community within the canal would be **non-significant**, because the clearance over the St. Helen's Canal would be about 8.30 m and the Bridgewater Canal would require a minimum navigational clearance of 5m. Only a very localised area of the canal would be shaded.

Guanotrophy

11.7.93 The existing SJB acts as a roost site for a large number of starlings. Organic enrichment can occur as a result of birds defecating into water below the bridge. The New Bridge would be expected to attract further roosting birds. In the estuary itself the tidal currents are strong and dilution capacity is high so it is unlikely the accumulation of guano would become a problem. When the New Bridge crosses the St Helen's and Bridgewater Canals, however, guanotrophy has the potential to cause localised long-term problems due to the slow flow rates within the canal and the reduced levels of pollutant dispersal.

11.7.94 The canal surveys detailed in this report which were conducted between in 2004 and 2007 revealed that two invertebrate families highly sensitive to organic pollution (Phryganeidae and Leptoceridae) were found within these canals. Thus, there could be a localised minor impact on these and other species intolerant to decreased oxygen levels due to organic enrichment of the canal waters. It is likely that any impact, if observed, would be very localised and restricted to sections where the New Bridge crosses overhead. This would also be the case for macrophytes.

11.7.95 Without mitigation it is **probable** that guanotrophy would be of **negligible** magnitude and have a **non-significant** impact on estuarine organisms and an impact of **low** magnitude and **low** significance on aquatic life within the canals.

11.7.96 The potential impacts of the operational phase are summarised in the third section of Table 11.28.

Table 11.28 - Summary of Do Nothing, Construction and Operational impacts of the New Bridge

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)
Do Nothing Scenario			
Natural Changes in geomorphology: Dynamic shifting of channel and mudflat location	Intertidal and Subtidal habitat High importance	Unpredictable Negligible Unpredictable Direct	Not significant
Natural Changes in geomorphology: Dynamic shifting of channel and mudflat location	Infauna and Benthic algae High importance	Unpredictable Negligible Unpredictable Direct	Not significant
Natural Changes in geomorphology: Dynamic shifting of channel and mudflat location	Epifauna and fish High importance	Unpredictable Negligible Unpredictable Direct	Not significant

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)
Natural Changes in geomorphology	Canal fauna and flora Moderate importance	No Effect	Not significant
Improvement in water quality	Intertidal and Subtidal habitat High importance	Permanent Moderate Long-term Direct	Low significance Positive
Improvement in water quality: Potential increase in species richness and diversity	Infauna and Benthic algae High importance	Permanent Moderate Long-term Direct	Low significance Positive
Improvement in water quality: Possible increased species richness and diversity of invertebrate prey items. Potential increase in fish species diversity. Likely increase in numbers of salmon migrating through Mersey Estuary.	Epifauna and fish High importance	Permanent Moderate Long-term Direct	Moderate significance Positive

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)
Possible improvements in canal water quality: Possible increased species richness and diversity	Canal fauna and flora Moderate importance	Permanent Moderate Long-term Direct	Low significance Positive
Construction Phase			
Underwater noise	Intertidal and Subtidal habitat High importance	No Effect	Not significant
Underwater noise	Infauna and Benthic algae High importance	No Effect	Not significant
Underwater noise: Potential disturbance, auditory problems, loss of balance and coordination, from pile driving noise. In extreme cases possible mortality near pile driving source. Noise from hover barges.	Epifauna and fish High importance	Temporary Moderate Short-term Direct	Moderate significance Negative
Underwater noise: Potential disturbance, auditory problems, loss of balance and	Marine mammals	Temporary	Moderate significance

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)
coordination, from pile driving noise. In extreme cases possible mortality near pile driving source. Noise from hover barges.	High importance	Moderate Short-term Direct	Negative
Underwater noise	Canal fauna and flora Moderate importance	No Effect	Not significant
Sediment movement/resuspension: Removal and redispersal of sediments which are usually static (i.e. up to ~2m depth). Increased density of sediment particles in water column.	Intertidal and Subtidal habitat High importance	Temporary Low Short-term Direct	Low significance Negative
Sediment movement/resuspension. Possible displacement of organisms within static areas of sediment. Removal/ increased instability of local habitat for macroinvertebrate communities.	Infauna and Benthic algae High importance	Temporary Low Short-term Direct and Indirect	Low significance Negative
Sediment movement/resuspension:	Epifauna and fish	Temporary	Low significance

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)
If disturbance/displacement of benthic macroinvertebrates reduces species diversity/abundance it could impact fish for which they provide a food source. Increased concentrations of sediment particles could affect the functioning of gills and cause respiratory difficulties.	High importance	Low Short-term Direct and Indirect	Negative
Sediment movement/resuspension	Canal fauna and flora Moderate importance	No Effect	Not significant
Release of pollutants: Erosion of sediments/ spillages and leakages of material. Potential release of contaminants within intertidal zone e.g. planings containing tar.	Intertidal and Subtidal habitat High importance	Temporary (poss permanent depending on persistence of pollutant) Low to Moderate Short, medium or long-term (depending on what is released) Direct	Moderate significance Negative
Release of pollutants: Potentially direct damage to organisms if above Predicted No Effect Concentrations (PNECs) for specific taxa. Bioaccumulation of contaminants along	Infauna and Benthic algae High importance	Temporary (poss permanent depending on persistence of pollutant)	Moderate significance Negative

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)
food chain.		Low to Moderate Short, medium or long-term (depending on what is released) Direct and Indirect	
Release of pollutants: Potentially direct adverse effect on epifauna and fish species (depending on type of pollutant and its concentration in sediments/water column). Damage due to consumption of contaminated prey items and bioaccumulation of contaminants.	Epifauna and fish High importance	Temporary (poss permanent depending on persistence of pollutant) Low to Moderate Short, medium or long-term (depending on what is released) Direct and Indirect	Moderate significance Negative
Release of pollutants: Mainly due to spills and leakages of materials. Potentially adverse effect on aquatic fauna and flora depending upon type of pollutant and its concentration. Low flow in canal so low rate of dispersal. Bioaccumulation of contaminants along food chain.	Canal fauna and flora Moderate importance	Temporary (poss permanent depending on persistence of pollutant) Low to Moderate Short, medium or long-term (depending on what is released)	Low significance Negative

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)
		Direct and Indirect	
Habitat loss/disturbance: Construction of tower, piers cofferdams and stone haul road. Direct loss of sediment habitat, tower surfaces would create a small area of new habitat.	Intertidal and Subtidal habitat High importance	Temporary and Permanent Low Short, medium or long-term (i.e. for sediments on which towers were built) Direct	Low significance Negative
Habitat loss/disturbance: Construction of tower, piers cofferdams and stone haul road. Direct loss of sediment habitat, tower surfaces would create a small area of new habitat.	Infauna and Benthic algae High importance	Temporary and Permanent Low Short, medium or long-term (i.e. for sediments on which towers were built) Direct	Low significance Negative
Habitat loss/disturbance: Fish can move away from impacted areas. If stone haul road construction removes saltmarsh scrapes (potentially important habitat) this would decrease availability of potentially important	Epifauna and fish High importance	Temporary and Permanent Low Short, medium and long-term	Low significance for most species but moderate for protected migratory fish. Negative

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)
intertidal refuge areas for fish. Cofferdam and pier structures may disorientate and impede salmon migration.		Direct	
Habitat loss/disturbance: Infilling of section of the St. Helen's Canal. Fish likely to be impacted. Displacement of organisms and reduction of available habitat for aquatic flora and fauna.	Canal fauna and flora Moderate importance	Temporary Low Short-term Direct	Low significance Negative
Operational Phase			
Sediment movement/resuspension: Potential for increased scour around towers. Slight local redistribution of sediments.	Intertidal and Subtidal habitat High importance	Permanent Negligible Long-term Direct	Not significant
Sediment movement/resuspension: Changes to habitat availability for infauna in vicinity of towers. Redistribution/disturbance of infauna within deeper sediments which are usually static.	Infauna and Benthic algae High importance	Permanent Negligible Long-term	Not significant

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)
		Direct	
Sediment movement/resuspension: Reductions in local abundance of infauna community could have knock-on impacts on epifauna and benthic feeding fish species. However, infauna in near-surface sediments not likely to be impacted and epifauna/fish can move to different areas to feed. Potential clogging of gills due to increased local sediment load.	Epifauna and fish High importance	Permanent Negligible Long-term Direct and Indirect	Not significant
Sediment movement/resuspension	Canal fauna and flora Moderate importance	No Effect	Not significant
Release of pollutants: Dispersal of contaminants due to resuspension of deeper sediments. Pollution of intertidal sediments due to road runoff/spillages.	Intertidal and Subtidal habitat High importance	Temporary or Permanent Low Short, medium or long-term Direct and Indirect	Low significance Negative
Release of pollutants: Potential for more contaminants to be released into water column. Concentrations not expected to	Infauna and Benthic algae High importance	Temporary (poss permanent depends on pollutant)	Low significance Negative

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)
exceed levels to which organisms in near-surface sediments are currently exposed. Spillages/runoff could lead to local increase in contaminants. Bioaccumulation of contaminants along food chain.		Low Short, medium or long-term (depending on what is released) Direct and Indirect	
Release of pollutants: Contaminant levels released due to erosion are not predicted to exceed current elevated levels. Spillages/runoff could lead to local increase in contaminants. Fish and epifauna can move away from areas of disturbance. Bioaccumulation of contaminants along food chain.	Epifauna and fish High importance	Temporary (poss permanent depends on pollutant) Low Short, medium or long-term (depending on what is released) Direct and Indirect	Low significance Negative
Release of pollutants: Primarily due to road runoff and spillage. Low rate of dispersal due to slow flow in canals. Contaminants could have adverse impact on infauna. Fish would be expected to move away from impacted area. Bioaccumulation of contaminants along food chain.	Canal fauna and flora Moderate importance	Temporary (poss Perm. depends on pollutant) Low Short, medium or long-term (depending on what is released) Direct and Indirect	Low significance Negative

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)
Habitat loss/disturbance: Presence of towers could cause fragmentation of intertidal and subtidal habitat. Shading of habitat below the bridge.	Intertidal and Subtidal habitat High importance	Permanent Low Long-term Direct	Not significant
Habitat loss/disturbance: Displacement of infauna within sediments up to ~2 m AOD within the immediate vicinity of towers. Shading could reduce productivity of benthic algae at low tide, not expected to have significant knock-on impacts on infauna.	Infauna and Benthic algae High importance	Permanent Low Long-term Direct	Not significant
Habitat loss/disturbance: Loss of habitat would be negligible during the operational phase. Shading could reduce benthic algal biomass and consequently infauna abundance on a very localised scale. Not expected to impact epifauna and fish which can move to other areas to feed.	Epifauna and fish High importance	Permanent Negligible Long-term Direct	Not significant
Habitat loss/disturbance: Primarily due to shading of habitats underneath bridge structures. Potential localised loss or damage to flora as a result of shading, particularly the	Canal fauna and flora Moderate importance	Permanent Low	Not significant

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)
charophyte *Nitella mucronata*. Potential knock-on effect on fauna.		Long-term Direct and Indirect	
Guanotrophy: Organic enrichment of the underlying habitat. However dilution would be considerable	Intertidal and Subtidal habitat High importance	Permanent Negligible Long-term Direct	Not significant
Guanotrophy: Potential increased organic input due to guano from large numbers of birds using the bridge to roost. Increased organic material could increase infauna (e.g. worms). However dilution would be considerable	Infauna and Benthic algae High importance	Permanent Negligible Long-term Direct and Indirect	Not significant
Guanotrophy: Depletion of dissolved oxygen levels in water column due to increased bacterial activity. Impact greatest for fish with low tolerance of reduced oxygen levels. However dilution effects would be considerable	Epifauna and fish High importance	Permanent Negligible Long-term Direct and Indirect	Not significant

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)
Guanotrophy: Potential adverse impact due to increased organic input from roosting birds. Depletion of dissolved oxygen levels in water column due to increased bacterial activity. Potential local reduction in macroinvertebrate diversity.	Canal fauna and flora Moderate importance	Permanent Low Long-term Direct and Indirect	Low significance Negative

11.8 Mitigation, Compensation, Enhancement and Monitoring

11.8.1 This section gives a detailed description of the mitigation and enhancement measures suggested to reduce the significance of those impacts identified in Section 11.7. Mitigation measures were identified following an assessment of impacts and the guidance outlined in Paragraphs 11.5.145-163. Mitigation measures are suggested for impacts with 'low negative significance' and greater.

11.8.2 The effectiveness of mitigation measures would be assessed as part of an overall Environmental Monitoring Plan which would include a Construction Environmental Monitoring Plan (see Chapter 23: Environmental Monitoring Plan).

Construction Mitigation Measures

Underwater Noise

11.8.3 Pile driving can create considerable noise levels. An effective mitigation measure can be to reduce dispersal of sound pressure waves underwater by using bubble screens. Air bubbles attenuate pressure waves from pile driving by making use of both the density difference between air and water and the resonance characteristics of bubbles to extract energy from the outward propagating pulses (Ref. 109).

11.8.4 The EA requested the use of bubble curtains and constant measurements of underwater noise during piling operations at Red Funnel's Southampton terminal in 2003 when it was realised that the timing of the operation would have to be brought forward and would coincide with the presence of salmon in the area. These measures were considered sufficient to decrease the chances of salmon being affected by the piling.

11.8.5 Preliminary studies indicate that acoustic curtains can reduce noise levels underwater by about 20dB (Ref. 109). However, in areas with fast water movement such as the Upper Mersey Estuary, however, a bubble and acoustic curtains or noise reduction blankets are not expected to operate effectively.

11.8.6 The method of pile driving employed can have an effect on the potential impacts on fish and other organisms. At a range of 417m from the source the sound produced by vibro piling (which produces a lower sound level than impact piling but for more prolonged periods) could not be discerned above the background noise level produced by boat activity along Southampton Water (Ref. 111). Even at a range of only 50m salmonids displayed no behavioural reaction to the pile driving when vibro piling was used (Ref. 111). Similarly, no fish were injured during pile driving operations in Vancouver, Canada and Mukilteo ferry dock, Washington, USA when a vibratory hammer was used. This was in contrast to the observed mortality of surfperch in Mukilteo, and juvenile salmon, perch and herring at Vancouver when impact pile driving was employed (Ref. 114). Therefore, in situations in which there is concern for particular aquatic species and when the method is feasible vibro piling is preferable to impact piling.

11.8.7 Analysis of sound waves produced by impact pile driving indicated that there was a initial high level of impulsive sound as the pile was struck and then a couple of seismic waves carried in the sediment (Ref. 111). Only the initial impact fell within the hearing range of salmonids at a range of 96.3 m or more. At a range of 417.4 m fish did not react to the impact piling but there was no reporting of behaviour at distances less than this (Ref. 111). It is expected that with increased proximity to the pile driving source the potential impacts on fish would increase in magnitude.

11.8.8 The level of sound pressure created by the piling operation can also be reduced by varying the material used for the piling. Concrete and wood piles appear to have a greater ability to absorb the impact of the pile driver than steel piles. During impact pile driving with steel piles fish mortality was observed in Vancouver, Canada but no fish were injured when the piling consisted of wood or concrete (Ref. 114). A more detailed comparison of the use of steel and cedar wood piles was described in Vagle (Ref. 109). There were minor differences between the two with cedar piles generating more low-frequency sound but maximum pressure levels generated were comparable between both types of pile (~20 KPa). Although concrete or wood pilings would be likely to have a lower ecological impact than the steel piles which are commonly used it is considered that the mitigation suggested below would be adequate to reduce impacts to an acceptable level even if steel piling was used, as is proposed.

11.8.9 In terms of migratory fish one method of mitigation would be to avoid/minimise pile driving at the most sensitive times of year. For salmon the peak migration period is March to November. Within this period it is considered that May is the most important month for downstream salmon smolt migration and September and October are the most important months for upstream migration of adults. It is generally believed that salmon migrating up estuaries utilise selective tidal stream transport especially in the lower to mid estuary (Ref. 133) and this can occur during the day or night. As such, as long as there was a tidal cycle each night during which no piling occurred then it is likely that any fish that had been potentially delayed, as a result of day time piling activity, would make their passage past the Project area on that incoming tide. Therefore, it is recommended that during the peak periods for potential salmon migration (i.e. May, September and October) there is a period each night when piling is ceased to enable the migration events to occur. It is recommended that the Construction Environmental Management Plan incorporates a Piling Method Statement. This would take into account the migration requirements of salmon, and in addition to the timing of construction activities it would consider the location of the proposed piling activity during a given period in relation to the north and south channels in the Upper Estuary which could potentially be used by migratory salmon (see Chapter 7: Hydrodynamics and Estuarine Processes Movement for the position of these channels in relation to the Project). This piling statement would need to be agreed with the appropriate agencies.

11.8.10 For marine mammals, the best course of action would be to establish a safety zone whilst the pile driving is going on. A boat patrolling the area then alerts the ground crews if a marine mammal is spotted. This is a successful strategy used by the National Marine Fisheries Service in the US (NMFS). If a mammal is observed within the safety zone then pile driving should be delayed until it moves out of the area.

11.8.11 Following implementation of these measures the impact of noise on aquatic organisms during construction would **probably** be of **low** significance.

Sediment movement/resuspension

11.8.12 Dispersal of sediment suspended during piling can be reduced by using silt curtains. Silt curtains normally consist of a circular tarpaulin with a floatation collar at the top and weights at the bottom and made large enough to cover the whole water column around the pile and contain the sediment being mixed up by the driving of the pile. The effectiveness of a silt curtain would be influenced by the presence of strong currents and tides within the estuary channel, however, and it is considered that they would not be effective within the Estuary due to strong tidal water movement.

11.8.13 Appropriate measures should be adopted to ensure sediment is removed from cofferdams and relocated to a suitable disposal site to avoid large volumes of sediment entering the water column.

11.8.14 Any construction expected to generate suspended sediment should be monitored. If elevated sediment loads are detected during construction more than 200m away from the area of construction then work should cease temporarily and improvements to work practices should be identified. Work expected to have greatest impact on sediment loads should be conducted during periods of low tide.

11.8.15 Measures including the potential use of sediment traps should be implemented to minimise sediment entering the estuary channel from the saltmarsh during construction of a stone haul road.

11.8.16 This mitigation should reduce the amount of resuspended sediment dispersing throughout the estuary channel. If these precautions are taken it is **probable** the impact of sediment movement/resuspension on aquatic ecology would be **non-significant**.

Release of pollutants

11.8.17 In order to mitigate against contaminated sediment from recirculating within the estuary due care and attention should be taken when excavating the foundations. Strict controls should be in place for the capture, storage and disposal of the dewater that is extracted from coffers and piles. It would also be advisable to monitor levels of contaminants within the sediment and surrounding water column during construction.

11.8.18 In order to prevent, spills and leakages, it would be appropriate to follow Duty of Care Guidelines as outlined in Paragraphs 11.4.30-32.

11.8.19 Overall, effective mitigation for spills and leakages is to adhere to relevant waste legislation which ensures the safe and appropriate handling of waste. Hazardous materials would be stored in secure containers to avoid spillage and leakage to the surrounding areas.

11.8.20 With these control measures in place it is **probable** that any impacts due to the release of pollutants would be of **low** significance or less.

Habitat loss/disturbance

11.8.21 The direct loss of habitat at the sites of tower location is inevitable and difficult to mitigate against, as is the temporary loss of habitat due to the infilling of St. Helens Canal.

11.8.22 The proposed jetty structure built to aid construction should be designed to have adequate room between piles to facilitate the passing of migratory fish within the Upper Estuary. The current design indicates that this would be the case (MG_REP_EIA_010: Construction Methods Report).

11.8.23 Construction of access tracks, stone haul road and pier structures are also likely to impact heavily on saltmarsh areas and mitigation measures for these construction impacts are discussed in Chapter 10: Terrestrial and Avian Ecology.

11.8.24 It is considered that even with mitigation measures in place the impact of the presence of the pier, and construction of the stone haul road, would **probably** have an impact on the aquatic community of **low** significance.

Operation Mitigation Measures

Release of pollutants

11.8.25 Adherence to relevant waste legislation (e.g. Duty of Care Guidance) and presence of interceptors on the Bridge would prevent road spillages / runoff into the Estuary. With this mitigation it is **probable** that the impact of road runoff and spillages on the aquatic ecology of the Estuary would be **non-significant**.

11.8.26 Surface water runoff from the Project into the St Helen's Canal will be drained via interceptors to a swale (i.e. a shallow sided ditch – see the Flood Risk Assessment (FRA) in Appendix 8.2, Chapter 8: Surface Water Quality for further details) located to the north of the St Helen's Canal. The drainage design for the Project will incorporate proposals to ensure that highway runoff is treated prior to entering surface watercourses (see FRA in Appendix 8.2, Chapter 8: Surface Water Quality).

11.8.27 Road runoff discharged into Stewards Brook will enter two balancing ponds before discharging to the Brook. These will accept surface water runoff from the new carriageway and will be used to control the rate of drainage into Stewards Brook. It is anticipated that balancing ponds will also be used to collect runoff water before entering Flood Brook.

11.8.28 The treated discharged water from the Project is expected to be of a quality which would not decrease the existing water quality in these watercourses (Chapter 8: Surface Water Quality).

11.8.29 With these mitigation measures in place it is **probable** that the impact of road runoff and spillages on the aquatic ecology of freshwater watercourses would be **non-significant**.

Habitat loss/disturbance

11.8.30 In general there are no significant impacts for habitat loss/disturbance during the operational phase so no mitigation is required. The exception is the potential for guanotrophy of the canals due to roosting birds, however, this is **probably** of **low** significance and no mitigation measures are considered necessary.

Monitoring Requirements

11.8.31 In order to be able to conduct future impact assessments regarding the construction and presence of the New Bridge within the Upper Mersey Estuary, further sampling is required to complement the baseline information collected to date.

Pre-construction monitoring

11.8.32 It is recommended that prior to construction, further aquatic ecology sampling is conducted within the Upper Mersey Estuary. This would be required to ensure that no significant change in baseline conditions had occurred since the initial monitoring programme was completed in 2007. For example, if a significant change occurred to a component of the aquatic community between 2008 and prior to the construction phase this would have to be recognised beforehand to ensure the change is not subsequently attributed to the construction process.

11.8.33 The same sampling methods described within this chapter are recommended for the sampling of estuarine algae, invertebrates and fish and freshwater macrophytes and invertebrates.

11.8.34 Benthic estuarine algae would be sampled within intertidal habitats via coring. Intertidal estuarine meio- and macrofauna would be collected by coring and subtidal communities would be sampled using an Eckman grab, in addition epifauna would be sampled using a dredge. Fish communities within the main channel would be surveyed via beam trawling, examination of dredge by-catch, and seine netting would be used to catch fish in the saltmarsh scrapes (Table 11.29).

11.8.35 Freshwater macrophytes would be sampled using a grapnel trawl and *in situ* recording of vegetation, and freshwater invertebrates would be collected using a lightweight dredge (Table 11.29).

11.8.36 It is recommended that monitoring is conducted for at least two or three years prior to the commencement of construction of the Mersey Gateway in order to avoid the problems associated with 'snapshot' sampling.

Main Estuarine Survey

11.8.37 For the number of sites sampled during the aquatic ecology sampling programme see Section 11.5. Baseline data gathered over six years has provided a broad understanding of potential variations in the aquatic community of the Upper Estuary over time. Consequently it is considered that for subsequent survey work the number of sites within the main estuary could be reduced, so that 5 sites are sampled for benthic algae and fish within both Zones 1 and 2, and that this would be adequate to identify major changes in aquatic ecology (Table 11.29). Similarly the number of sites sampled for benthic macroinvertebrates could be reduced to 5 intertidal, 5 subtidal and 5 epifaunal sites within both Zones 1 and 2, as opposed to 10 of each within each zone (Table 11.29).

11.8.38 It is recommended that the fish communities within scrapes continue to be monitored but no further sampling of the creek on Astmoor saltmarsh would be necessary.

11.8.39 It is always preferable to monitor regularly throughout the year to gain a thorough understanding of seasonal population fluctuations. However, it is likely that autumn sampling could be removed from a future monitoring programme and adequate information would be provided by sampling during two seasons (spring and late summer).

Canals and Brooks

11.8.40 It is suggested that the number of sites monitored for the freshwater canals and brooks should be the same as that detailed for the baseline study. It is suggested that Stewards Brook and the Latchford Canal could be removed from the monitoring programme. Bowers Brook and the St. Helen's and Bridgewater Canals have greater potential to be impacted by the development and should continue to be monitored (Table 11.29).

Monitoring during construction

11.8.41 Monitoring is essential during the construction process. This would ensure that any disturbances to aquatic organisms caused during construction would be identified rapidly. The monitoring would enable an on-going assessment of the effectiveness of any mitigation measures in place. The data collected could lead to modifications of mitigation measures, or if required, the implementation of new forms of mitigation. The monitoring of aquatic ecology should also be combined with regular monitoring of water quality within the potentially impacted area.

11.8.42 Such monitoring would be necessary to identify whether particular components of the aquatic ecosystem were being impacted by the development. It is recommended that the same baseline survey methods outlined for pre-construction monitoring (including the proposed number of sites) would be applied (Table 11.29). Therefore, results from pre-construction and during construction surveys would be directly comparable.

11.8.43 As described in Section 11.7, one of the main impacts expected for aquatic fauna is the noise generated by pile driving. It is recommended that during piling, underwater sound levels are monitored using hydrophones. If sound pressures exceed those deemed acceptable for aquatic organisms this will enable the implementation of appropriate measures such a cessation of piling until the issue is remedied.

11.8.44 Two key species to monitor during the construction phase will be salmon and potentially river lamprey (both protected species under Annex II of the EC Habitats Directive). The ability to effectively monitor salmon in the area would be dependant on the time of year and their local abundance. Overall, direct monitoring for this species may not be practical and it is considered more likely that assessment would be undertaken via sampling further up the catchment (e.g. using electric fishing techniques to sample salmon parr/fry). However, it would be difficult to relate the number of parr/fry caught further up the catchment to the number of adults passing the Mersey Gateway site. Further investigation would involve assessment of data from EA's statutory salmonid sampling programme, especially the number of adult salmon caught in fish traps further up the catchment. A similar approach could be adopted to identify the abundance of river lamprey ammocoetes within the Mersey catchment.

11.8.45 Monitoring of phytoplankton may also be a future requirement as this is one of the components used to assess the ecological quality of estuaries under the WFD (See Paragraph 11.4.20).

11.8.46 Measures to identify whether any marine mammals (especially harbour porpoise, bottlenose dolphin and grey seal) are present in the area during periods of pile driving should be implemented including boat-based surveillance.

Table 11.29 - Summary of original baseline monitoring programme and recommended future monitoring programme (pre-, during, and post-construction) for the Mersey Gateway Project. SP=Spring, SU=Summer, AU=Autumn

Recommended future monitoring				
Location	**Flora/fauna**	**Methods**	**No. sample sites**	**Seasons**
Main Estuary Channel	Benthic Algae	Intertidal Coring	5 (Zone 1)	SP, SU
			5 (Zone 2)	SP, SU
	Phytoplankton	Water samples	5 (Zone 1)	SP, SU
			5 (Zone 2)	SP, SU
	Invertebrates	Intertidal Coring	5 (Zone 1: Intertidal)	SP, SU
			5 (Zone 2: Intertidal)	SP, SU

Recommended future monitoring				
		Subtidal Grabs	5 (Zone 1: Subtidal)	SP, SU
			5 (Zone 2: Subtidal)	SP, SU
		Epifaunal Trawls	5 (Zone 1)	SP, SU
			5 (Zone 1)	SP, SU
	Fish	Beam Trawling	5 (Zone 1)	SP, SU
			5 (Zone 2)	SP, SU
		Dredge	5 (Zone 1)	SP, SU
			5 (Zone 2)	SP, SU
Saltmarsh Scrapes	Fish	Seine Netting	2 (Zone 2)	SP, SU
	Invertebrates	Epifaunal Trawl	2 (Zone 2)	SP, SU
Bridgewater Canal	Macrophytes	Grapnel, visual survey	3	SP, SU
	Invertebrates	Dredge	3	SP, SU
St. Helen's Canal	Macrophytes	Grapnel, visual survey	3	SP, SU
	Invertebrates	Dredge	3	SP, SU
Bowers Brook	Macrophytes	Grapnel, visual survey	3	SP, SU
	Invertebrates	Dredge	3	SP, SU

Monitoring post-construction

11.8.47 In order to identify whether or not the construction has had any notable impacts on aquatic flora and fauna it will be necessary to conduct further long-term monitoring once the Mersey Gateway has been constructed.

11.8.48 Annual sampling for the first 4 years post-construction is recommended. The reason for this is that any impact on aquatic ecology due to the presence of the Mersey Gateway is most likely to be detectable within this timescale. Depending upon results of these surveys, conclusions regarding future survey requirements can be made.

11.8.49 Again a reduced sampling programme such as that described for pre-construction would be adequate to assess the impact of the presence of the Mersey Gateway on aquatic organisms (Table 11.29). By retaining the same number and location of sites recommended for monitoring pre-construction and during construction, a cost-effective and comprehensive data set would be gathered. Selection of sites would be based on knowledge gained during the initial baseline study and results of monitoring at all stages of the development process (pre, during and post-construction) would be comparable and amenable to robust statistical analysis.

11.8.50 Continued assessments of the numbers of salmon and lamprey migrating through the Upper Mersey Estuary, would be important during the post-construction period. Data gathered would be used to assess how migratory fish species respond to the presence of the bridge.

11.8.51 In general the shading impact of the bridge on freshwater macrophytes is expected to be negligible. However, within the canals it will be important to continue to assess the status of the rare charophyte *Nitella mucronata* var. *gracillima* which is a Red Data Book species. This would be accomplished by undertaking the monitoring programme detailed above.

11.9 Residual Impacts

11.9.1 Whilst the best form of mitigation is to avoid the impact at source this is not always possible. It is also not always possible or practical to avoid impacts altogether. Therefore the residual impacts, whilst always minimised are not always removed completely. Assuming that all the mitigation measures have been carried out as suggested above the expected residual impacts are outlined in the table below.

11.9.2 The potential residual impacts of the construction and operational phases are summarised in Table 11.29.

Table 11.29 - Residual impacts of the New Bridge

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
Do Nothing Scenario					
Natural Changes in geomorphology: Dynamic shifting of channel and mudflat location	Intertidal and Subtidal habitat High importance	Unpredictable Negligible Unpredictable Direct	Not significant	NA	Not significant
Natural Changes in geomorphology: Dynamic shifting of channel and mudflat location	Infauna and Benthic algae High importance	Unpredictable Negligible Unpredictable Direct	Not significant	NA	Not significant
Natural Changes in geomorphology: Dynamic shifting of channel and mudflat location	Epifauna and fish High importance	Unpredictable Negligible Unpredictable Direct	Not significant	NA	Not significant

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
Natural Changes in geomorphology	Canal fauna and flora Moderate importance	No Effect	Not significant	NA	Not significant
Improvement in water quality	Intertidal and Subtidal habitat High importance	Permanent Moderate Long-term Direct	Low significance Positive	NA	Low significance Positive
Improvement in water quality: Potential increase in species richness and diversity	Infauna and Benthic algae High importance	Permanent Moderate Long-term Direct	Low significance Positive	NA	Low significance Positive
Improvement in water quality: Possible increased species richness and diversity of invertebrate prey items. Potential increase in fish species diversity. Likely increase in numbers of salmon migrating through Mersey Estuary.	Epifauna and fish High importance	Permanent Moderate Long-term Direct	Moderate significance Positive	NA	Moderate significance Positive

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
Possible improvements in canal water quality: Possible increased species richness and diversity	Canal fauna and flora Moderate importance	Permanent Moderate Long-term Direct	Low significance Positive	NA	Low significance Positive
Construction Phase					
Underwater noise	Intertidal and Subtidal habitat High importance	No Effect	Not significant	NA	Not significant
Underwater noise	Infauna and Benthic algae High importance	No Effect	Not significant	NA	Not significant
Underwater noise: Potential disturbance, auditory problems, loss of balance and coordination, from pile driving noise. In extreme cases possible mortality near pile driving source. Noise from hover barges.	Epifauna and fish High importance	Temporary Moderate Short-term Direct	Moderate significance Negative	Maintenance of 'noise free' window during times of peak migration.	Low significance Negative

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
Underwater noise: Potential disturbance, auditory problems, loss of balance and coordination, from pile driving noise. In extreme cases possible mortality near pile driving source. Noise from hover barges.	Marine mammals High importance	Temporary Moderate Short-term Direct	Moderate significance Negative	Establishment of a safety zone to protect marine mammals.	Low significance Negative
Underwater noise	Canal fauna and flora Moderate importance	No Effect	Not significant	NA	Not significant
Sediment movement/resuspension: Removal and redispersal of sediments which are usually static (i.e. up to ~2 m depth). Increased density of sediment particles in water column.	Intertidal and Subtidal habitat High importance	Temporary Low Short-term Direct	Low significance Negative	Removal of sediment to a suitable disposal site. Monitoring of turbidity within 200 metres of the New Bridge with reaction to elevated levels. Work conducted during low tide where possible.	Not significant
Sediment movement/resuspension. Possible displacement of organisms within static areas of sediment. Removal/ increased instability of local habitat for	Infauna and Benthic algae High importance	Temporary Low Short-term	Low significance Negative	As above	Not significant

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
macroinvertebrate communities.		Direct and Indirect			
Sediment movement/resuspension: If disturbance/displacement of benthic macroinvertebrates reduces species diversity/abundance it could impact fish for which they provide a food source. Increased concentrations of sediment particles could affect the functioning of gills and cause respiratory difficulties.	Epifauna and fish High importance	Temporary Low Short-term Direct and Indirect	Low significance Negative	As above	Not significant
Sediment movement/resuspension	Canal fauna and flora Moderate importance	No Effect	Non-significant	NA	Not significant
Release of pollutants: Erosion of sediments/ spillages and leakages of material. Potential release of contaminants within intertidal zone e.g. planings containing tar.	Intertidal and Subtidal habitat High importance	Temporary (poss permanent depending on persistence of pollutant) Low to Moderate Short, medium or long-term (depending on what is	Moderate significance Negative	Removal of excavated material and dewater to appropriate disposal sites. Adhere to relevant waste legislation (e.g. Duty of Care Guidance). Store hazardous materials in secure containers to	Low significance Negative

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
		released) Direct		avoid spillage and leakage.	
Release of pollutants: Potentially direct damage to organisms if above Predicted No Effect Concentrations (PNECs) for specific taxa. Bioaccumulation of contaminants along food chain.	Infauna and Benthic algae High importance	Temporary (poss permanent depending on persistence of pollutant) Low to Moderate Short, medium or long-term (depending on what is released) Direct and Indirect	Moderate significance Negative	As above	Low significance Negative
Release of pollutants: Potentially direct adverse effect on epifauna and fish species (depending on type of pollutant and its concentration in sediments/water column). Damage due to consumption of contaminated prey items and bioaccumulation of contaminants.	Epifauna and fish High importance	Temporary (poss permanent depending on persistence of pollutant) Low to Moderate Short, medium or long-term (depending on what is released) Direct and Indirect	Moderate significance Negative	As above	Low significance Negative

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
Release of pollutants: Mainly due to spills and leakages of materials. Potentially adverse effect on aquatic fauna and flora depending upon type of pollutant and its concentration. Low flow in canal so low rate of dispersal. Bioaccumulation of contaminants along food chain.	Canal fauna and flora Moderate importance	Temporary (poss permanent depending on persistence of pollutant) Low to moderate Short, medium or long-term (depending on what is released) Direct and Indirect	Low significance Negative	As above	Not significant
Habitat loss/disturbance: Construction of tower, piers cofferdams and stone haul road. Direct loss of sediment habitat, tower surfaces would create a small area of new habitat.	Intertidal and Subtidal habitat High importance	Temporary and Permanent Low Short, medium or long-term (i.e. for sediments on which towers were built) Direct	Low significance Negative	None	Low significance Negative

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
Habitat loss/disturbance: Construction of tower, piers cofferdams and stone haul road. Direct loss of sediment habitat, tower surfaces would create a small area of new habitat.	Infauna and Benthic algae High importance	Temporary and Permanent Low Short, medium or long-term (i.e. for sediments on which towers were built) Direct	Low significance Negative	None	Low significance Negative
Habitat loss/disturbance: Fish can move away from impacted areas and relocate to areas away from the site of construction. If stone haul road construction removes saltmarsh scrapes (potentially important habitat) this would decrease availability of potentially important intertidal refuge areas for fish. Cofferdam and pier structures may disorientate and impede salmon migration.	Epifauna and fish High importance	Temporary and Permanent Low Short, medium and long-term Direct	Low significance for most species but moderate for protected migratory fish. Negative	Ensure adequate space between pilings for fish to pass through.	Low significance Negative
Habitat loss/disturbance: Infilling of section of the St. Helen's Canal. Fish likely to be impacted. Displacement of organisms and reduction of available habitat for aquatic flora and fauna.	Canal fauna and flora Moderate importance	Temporary Low Short-term Direct	Low significance Negative	None	Low significance Negative

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
Operational Phase					
Sediment movement/resuspension: Potential for increased scour around towers. Slight local redistribution of sediments.	Intertidal and Subtidal habitat High importance	Permanent Negligible Long-term Direct	Not significant	NA	Not significant
Sediment movement/resuspension: Changes to habitat availability for infauna in vicinity of towers. Redistribution/disturbance of infauna within deeper sediments which are usually static.	Infauna and Benthic algae High importance	Permanent Negligible Long-term Direct	Not significant	NA	Not significant
Sediment movement/resuspension: Reductions in local abundance of infauna community could have knock-on impacts on epifauna and benthic feeding fish species. However, infauna in near-surface sediments not likely to be impacted and epifauna/fish can move to different areas to feed. Potential clogging of gills due to increased local sediment load.	Epifauna and fish High importance	Permanent Negligible Long-term Direct and Indirect	Not significant	NA	Not significant

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
Sediment movement/resuspension	Canal fauna and flora Moderate importance	No Effect	Not significant	NA	Not significant
Release of pollutants: Dispersal of contaminants due to resuspension of deeper sediments. Pollution of intertidal sediments due to road runoff/spillages.	Intertidal and Subtidal habitat High importance	Temporary or Permanent Low Short, medium or long-term Direct and Indirect	Low significance Negative	Adhere to relevant waste legislation (e.g. Duty of Care Guidance). Interceptors on bridge and to prevent road spillages / runoff.	Not significant
Release of pollutants: Potential for more contaminants to be released into water column. Concentrations not expected to exceed levels to which organisms in near-surface sediments are currently exposed. Spillages/runoff could lead to local increase in contaminants. Bioaccumulation of contaminants along food chain.	Infauna and Benthic algae High importance	Temporary (poss Perm. depends on pollutant) Low Short, medium or long-term (depending on what is released) Direct and Indirect	Low significance Negative	As above	Not significant
Release of pollutants: Contaminant levels released due to erosion are not predicted to exceed current elevated levels. Spillages/runoff could lead to local increase	Epifauna and fish High importance	Temporary (poss Perm. depends on pollutant)	Low significance Negative	As above.	Not significant

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
in contaminants. Fish and epifauna can move away from areas of disturbance. Bioaccumulation of contaminants along food chain.		Low Short, medium or long-term (depending on what is released) Direct and Indirect			
Release of pollutants: Primarily due to road runoff and spillage. Low rate of dispersal due to slow flow in canals. Contaminants could have adverse impact on infauna. Fish would be expected to move away from impacted area. Bioaccumulation of contaminants along food chain.	Canal fauna and flora Moderate importance	Temporary (poss Perm. depends on pollutant) Low Short, medium or long-term (depending on what is released) Direct and Indirect	Low significance Negative	Adhere to relevant waste legislation (e.g. Duty of Care Guidance). Interceptors on bridge and to prevent road spillages / runoff. Treatment of runoff before entering St. Helens Canal and Stewards Brook.	Not significant
Habitat loss/disturbance: Presence of towers could cause fragmentation of intertidal and subtidal habitat. Shading of habitat below the bridge.	Intertidal and Subtidal habitat High importance	Permanent Low Long-term Direct	Not significant	NA	Not significant

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
Habitat loss/disturbance: Displacement of infauna within sediments up to ~2 m AOD within the immediate vicinity of towers. Shading could reduce productivity of benthic algae at low tide, not expected to have significant knock-on impacts on infauna.	Infauna and Benthic algae High importance	Permanent Low Long-term Direct	Not significant	NA	Not significant
Habitat loss/disturbance: Loss of habitat would be negligible during the operational phase. Shading could reduce benthic algal biomass and consequently infauna abundance on a very localised scale. However, this is not expected to impact epifauna and fish which can move to other areas to feed.	Epifauna and fish High importance	Permanent Negligible Long-term Direct	Not significant	NA	Not significant
Habitat loss/disturbance: Primarily due to shading of habitats underneath bridge structures. Potential localised loss or damage to flora as a result of shading, particularly the charophyte *Nitella mucronata*. Potential knock-on effect on fauna.	Canal fauna and flora Moderate importance	Permanent Low Long-term Direct and Indirect	Not significant	NA	Not significant

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
Guanotrophy: Organic enrichment of the underlying habitat. However dilution would be considerable	Intertidal and Subtidal habitat High importance	Permanent Negligible Long-term Direct	Not significant	NA	Not significant
Guanotrophy: Potential increased organic input due to guano from large numbers of birds using the bridge to roost. Increased organic material could increase infauna (e.g. worms). However dilution would be considerable	Infauna and Benthic algae High importance	Permanent Negligible Long-term Direct	Not significant	NA	Not significant
Guanotrophy: Depletion of dissolved oxygen levels in water column due to increased bacterial activity. Impact greatest for fish with low tolerance of reduced oxygen levels. However dilution would be considerable	Epifauna and fish High importance	Permanent Negligible Long-term Direct and Indirect	Not significant	NA	Not significant
Guanotrophy: Potential adverse impact due to increased organic input from roosting birds. Depletion of dissolved oxygen levels in water column due to increased bacterial	Canal fauna and flora Moderate importance	Permanent Low	Low significance Negative	None	Low significance Negative

Effect	Receptor and Importance	Nature of Effect (Permanent / Temporary; Magnitude; Duration; Direct/Indirect)	Significance (High, Moderate, Low and Positive/Negative or Not Significant)	Mitigation and Enhancement Measures	Residual Significance (High, Moderate, Low, Non and Positive/Negative)
activity. Potential local reduction in macroinvertebrate diversity.		Long-term Direct and Indirect			

11.10 Conclusions

11.10.1 The Upper Estuary provides a naturally highly variable environment for aquatic organisms. As the tide ebbs and flows very strong tidal currents resuspend near-surface sediments. Moving downstream along the Estuary there are significant changes in salinity, pH and other chemical parameters. The variation in environmental conditions is reflected by differences in biological communities among different zones within the area.

11.10.2 The area downstream of the SJB which is just over 1,770 m downstream of the proposed location for the New Bridge is protected by the following conservation designations: A Wetland of International Importance under the Ramsar convention; a Special Protection Area (SPA) under the Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds due to its important population of wading birds; and a Site of Special Scientific Interest (SSSI) under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000).

11.10.3 The Annex II species Atlantic salmon and river lamprey were sampled during the aquatic survey within the estuary. The Red Data Book species *Nitella mucronata* var *gracillima* was found to be relatively abundant in the Bridgewater Canal.

11.10.4 The Estuary has an historic background of gross pollution and elevated levels of potentially toxic contaminants are still present in estuarine sediments. Consequently, aquatic species resident within the Upper Mersey Estuary are generally highly adaptable to a wide range of environmental conditions and in many cases tolerant to various forms of pollution.

11.10.5 The main aquatic survey was conducted between 2002 and 2007 to gather important baseline information regarding communities of estuarine benthic algae, invertebrates and fish. In addition to sampling aquatic organisms within the channel, surveys were also conducted within saltmarsh scrapes which are filled with water on high spring tides.

11.10.6 As the New Bridge would pass over a number of canals and potentially impact freshwater brooks further sampling was conducted between 2004 and 2007 to obtain baseline data for these habitats.

11.10.7 A great deal of seasonal variation was observed in terms of the aquatic communities present and the abundances of different species.

11.10.8 The benthic algae and invertebrate populations were found to be relatively depauparate in terms of species diversity due to a combination of the harsh environmental estuarine conditions and the history of contamination. The species diversity and abundance of intertidal benthic invertebrates in the Upper Mersey Estuary was found to be low in comparison with intertidal areas within mid and outer sections of the Estuary.

11.10.9 The fish community present within the Upper Mersey Estuary was also characteristic of estuarine habitats with a change in the fish community assemblage moving from upstream to downstream of the proposed site of the New Bridge.

11.10.10 Baseline data were used to identify potential impacts of the construction and operation of the Mersey Gateway Project.

11.10.11 It was considered that during construction the main factor which would be likely to have an adverse impact on aquatic organisms was underwater noise generated by pile driving. A number of fish species could be impacted by the generation of noise and for those in the immediate vicinity of the piling, mortality is a possibility. Effective mitigation measures proposed would be to monitor noise levels during construction, to select appropriate building materials/techniques to minimise noise levels and to provide 'noise free' windows for fish migration which would be outlined in a Construction Environmental Management Plan incorporating a Piling Method Statement.

11.10.12 Due to the continual improvement of water quality within the Estuary there is evidence that over recent years salmon have started to migrate up the Estuary. With regards to aquatic ecology, one key concern is the potential impact of the New Bridge on migratory salmon and lamprey (both Annex II species). Implementation of mitigation measures to reduce sound impacts and ensuring pile driving is conducted outside the periods of peak migration is expected to minimise the likelihood of disorientating or damaging individuals of these species.

11.10.13 In addition, another concern is the temporary impact of noise on marine mammals in the region. Again implementation of mitigation measures including potential buffer zones (within which pile driving would cease if a marine mammal is spotted) would minimise potential impacts.

11.10.14 Other than these considerations it is likely that the construction and operation of the New Bridge will generally have a negligible impact on the overall status of benthic algae, freshwater macrophyte, macroinvertebrate and fish species within the Upper Mersey Estuary.

11.10.15 As the overall impact on macroinvertebrate populations of the Upper Mersey Estuary is likely to be negligible, there is expected to be a negligible reduction in prey availability for internationally important bird populations within the SPA, Ramsar and SSSI downstream of the New Bridge site.

11.10.16 Further monitoring is recommended pre, during and post construction to ensure that the aquatic ecology of the Upper Mersey Estuary can be assessed at all stages of the development. If there are any impacts due to the development, this will increase the likelihood that they will be detected rapidly and further mitigation measures can then be considered in a timely manner.

11.10.17 In conclusion and in terms of impacts on aquatic ecology, after mitigation, the Project is likely to have:

a. No environmental effect with a significance above Low Significance; and
b. No adverse impact on the integrity of the Mersey Estuary SSSI, SPA or Ramsar Site.

11.11 References

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