NRA-Anglian 166

Welland and Witham Estuaries - Ecological Study
Final Report

Part 1 - Ecological Report
Part 2 - Water Quality Report

April 1993

Dr M Dyer, Unicomarine
Dr N Grist, Unicomarine

Dr B Barnett, NRA

Anglian Regional Operational Investigation 501

OI/501/8/A

NRA

National Rivers Authority

WELLAND & WITHAM ESTUARIES

ECOLOGICAL STUDY

PART I

PART II

Tables

Figures

April 1993

UnicoMarine Ltd
7 Diamond Centre
Works Road
Letchworth
Herts.
SG6 1LW

Tel 0462-675559

Fax 0462-483103

CONTENTS

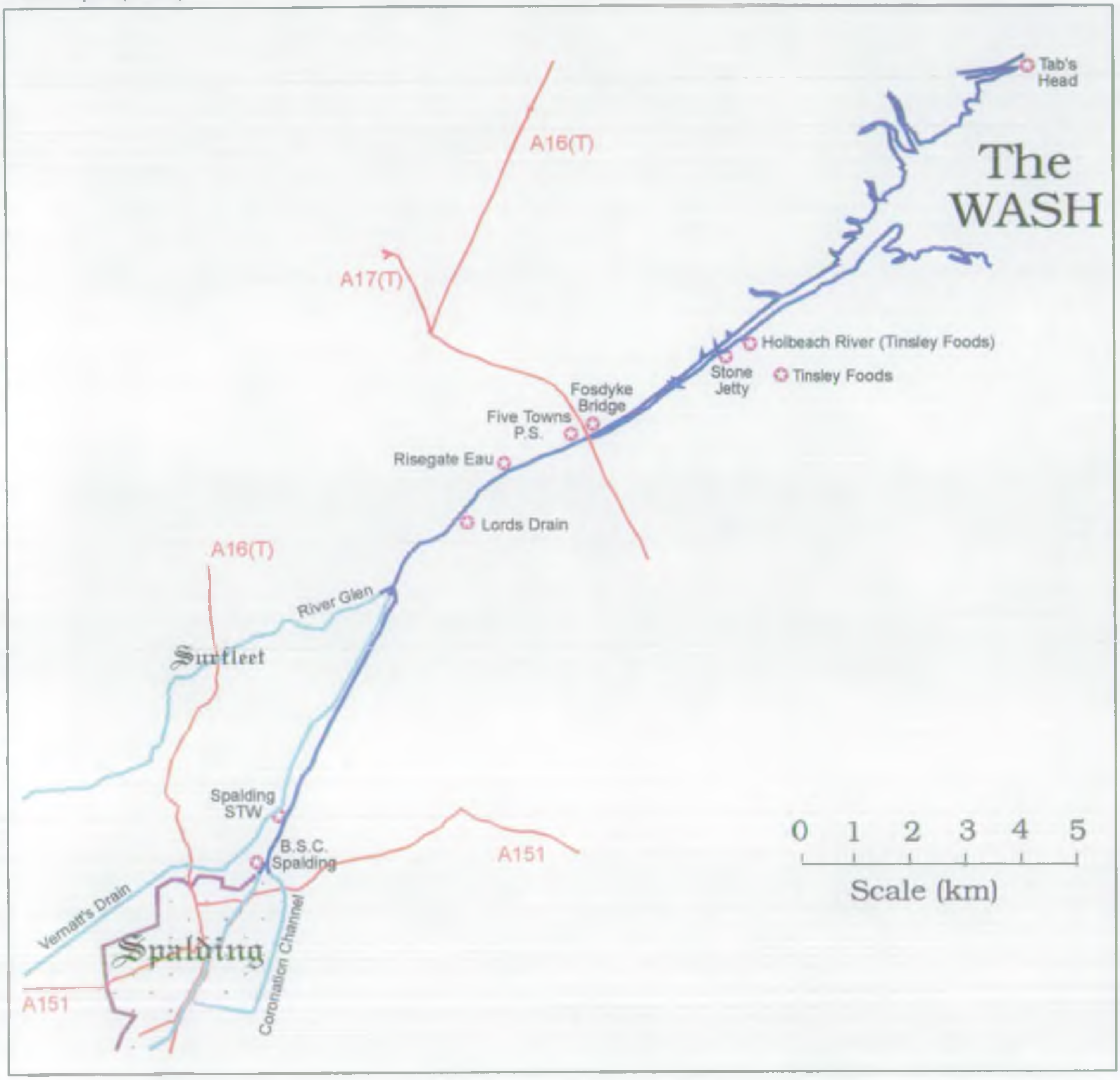


Figure X.1 - Inputs to the Welland Estuary

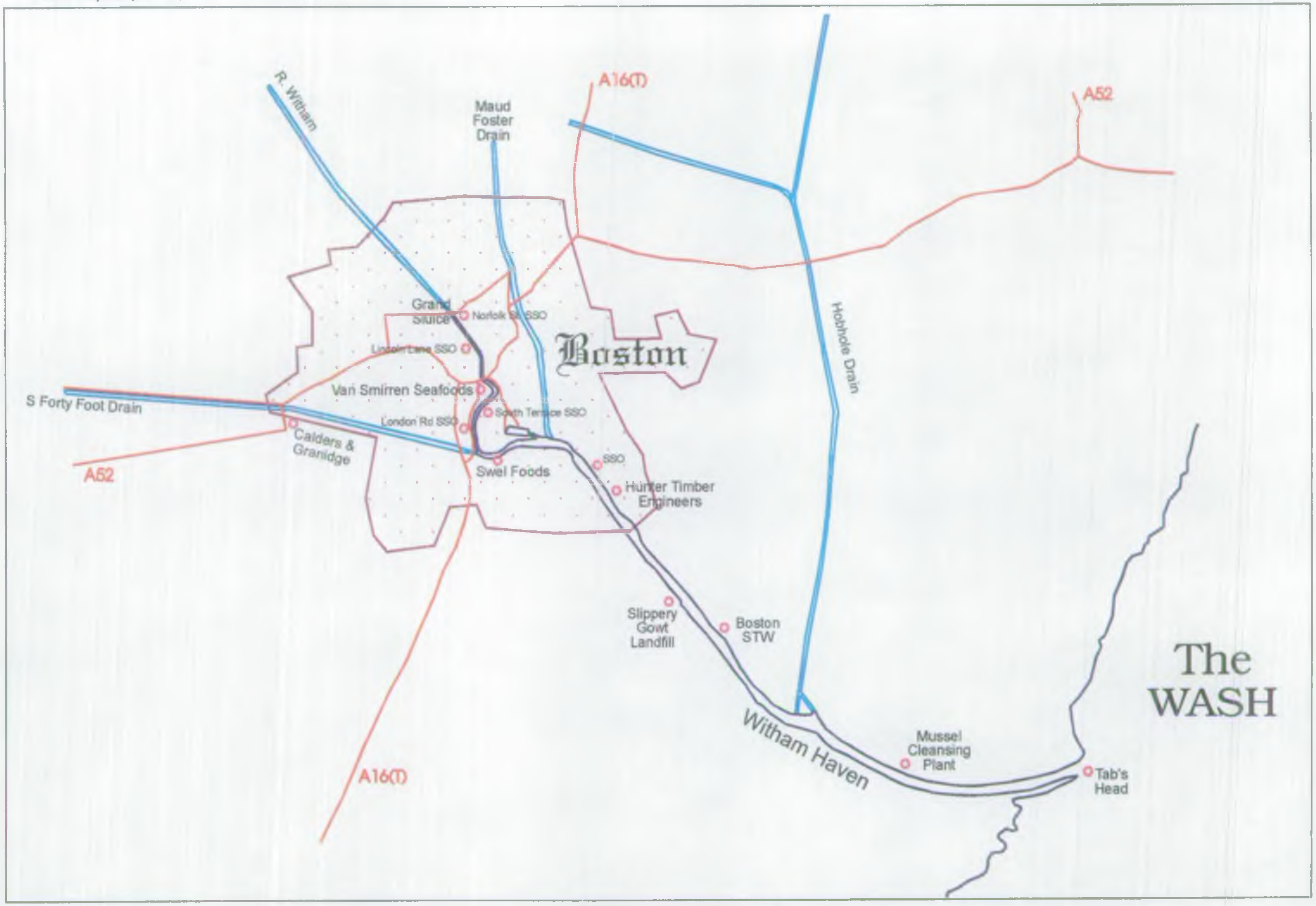


Figure X.2 - Inputs to the Witham Estuary

LIST OF TABLES

LIST OF PLATES & FIGURES

SUMMARY

A series of biological surveys was undertaken between 1989 and 1992 on the Welland and Witham estuaries, Lincolnshire. The study continues a series of studies on the Wash estuaries which began in 1982 and was undertaken in order to complete the assessment of the Wash estuaries.

The water quality of both estuaries is good, although algal blooms were noted occasionally in the upper estuary in summer. These blooms are likely to result in low dissolved oxygen levels at night in the summer months when algal blooms occur.

The benthos and plankton of the Welland and Witham estuaries are relatively diverse compared with the Nene. The Witham sites close to Tabs Head were particularly diverse due to the substratum in this region which had a high shell content. The species richness in other regions may be, at least in part, because of the better water quality of the Welland and Witham compared with the Nene. An additional factor could be that the Welland and Witham may have higher, more stable, salinity regimes compared with the Nene. Continuous water quality monitors are recommended to compare the salinity and dissolved oxygen regimes of all the Wash estuaries.

The Wash mussel fishery is generally unstable. The poor landings in recent years are most likely a result of the warm dry weather resulting in desiccation at low water and low mortality of the chief predator *Asterias rubens* (Starfish). Surveys of sanitary quality gave conflicting results. The survey undertaken by Unicomarine from the ESFJC vessel in autumn 1989 showed several beds to be contaminated with faecal bacteria to such an extent that they were unsuitable for depuration and required relaying. However, routine sampling of a small number of beds by ESFJC for Boston Borough Council repeatedly showed low levels of faecal contamination.

The Wash is not a major fin–fishery, although it is of importance as a nursery area for marine fish. During eight surveys of the estuaries, only small catches of fish and shrimp were made. Towards the end of the study more species were recorded than on the Nene, possibly as a result of recent low freshwater flows and a more stable marine environment.

The training walls are covered in seaweed and samples were analysed for heavy metal contamination. The results were generally consistent with estuaries in regions of relatively low industrial activity, although relatively high levels of lead were found in samples taken on the Witham and this should be investigated further.

A programme of monitoring for the Wash estuaries is recommended.

KEY WORDS

Welland, Witham, Wash, Estuary, Benthos, Plankton, Fish, Seaweed, Shellfish, Water Quality.

PART I

1. INTRODUCTION.

1.1 The Wash Estuaries

A series of studies on the Wash estuaries began in 1982 with a study of the Great Ouse estuary between 1982 and 1985, (Dyer & Grist, 1986; Gould *et al*, 1987) and then the Nene estuary from 1985 to 1988 (Dyer & Grist, 1989a). In order to complete the assessment of the Wash estuaries, and to address questions concerning the potential effects of changes in freshwater abstraction, a study of the ecological status of the Welland and Witham estuaries was started in 1989.

1.2 General description of the area

Photographs of both estuaries taken at low water springs on August 10th 1990 are shown in Plates 1.1–1.4.

Figure 1.1 shows the Welland and Witham catchment area. The Witham rises between South Witham and Wymondham on the Lincolnshire / Leicestershire border and flows north to Lincoln then south–east through the tidal sluice (Grand Sluice) at Boston and finally to the Wash. The non–tidal length is 135 km with tributaries of 285 km and the tidal length from Grand Sluice to the confluence with the Welland at Tabs Head is 11km. The Welland rises at Sibbertoft in Northamptonshire and flows north–east to the tidal sluice at Spalding. The non–tidal length is 103 km with tributaries of 128 km. The tidal length from Spalding Sluice to Tabs Head is 22 km. Both estuaries flow into the Wash at Tabs Head and at low water form a channel extending out into the Wash approximately 10 km to the Freeman Channel.

The catchment area of the Welland and Witham is approximately 5400 km^2, or about 4% of the area of England, with less than 1% of the population of England. It is, therefore, essentially a rural catchment with several small towns. The largest towns on the Witham are Lincoln (pop 81 000) and Boston (52 000). Vessels up to 4 500 tonnes dock at Boston; access on the tidal Witham being gained only near high water. About 80 fishing vessels, involved mainly in the shellfishery, use Boston as their home port (ESFJC, 1990). The Welland catchment population is smaller; the largest towns being Stamford (16 000) and Spalding (18 000). Small vessels use the quay at Fosdyke mainly for unloading fertilisers and a small number of shell fishery vessels use Fosdyke as their home port.

The region is intensively farmed, and the population is increasing. These factors will place an increasing strain on the rivers of the area, because of the parallel increase in demand for water for irrigation and industrial use and the associated increase in the use of rivers for waste removal.

1.3. Project objectives

The main objectives of the study are summarised below:

1. To establish the distribution patterns of benthos and plankton. To consider whether these could be regarded as normal.

2. To determine the ecological impact of current trade and sewage discharges. To assess possible ecological changes if there were to be a significant modification to the nature of some of these discharges.

3. To assess the existing status of the shell fisheries in both estuaries. To locate any area where shellfish are likely to be unsuitable for human consumption.

4. To assess the existing status of the finned fishery together with the freshwater eel fisheries which depend on the estuaries for migratory purposes.

5. To assess the possible ecological changes resulting from changes in freshwater flow.

6. To review, with the NRA, the water quality data collected by the NRA during the survey period.

7. To recommend, with the NRA, water quality objectives and water quality criteria.

8. To assess the suitability of using metal analysis of seaweed as an indicator of environmental contamination.

9. To provide guidance on future monitoring programmes.

1.4 Project design

Following a preliminary survey in spring 1988 (Dyer & Grist, 1989b) routine subtidal surveys were conducted every three months from July 1989 for two years in order to study seasonal population changes.

1.4.1 Biological sampling

Sampling sites were approximately 2 km apart; roughly at similar intervals to those on the Nene and Gtreat Ouse studies, and were sufficient to show distribution patterns and populations throughout the region. Details of sampling times are given in Table 1.1 and sampling positions in Table 1.2. A map of the sampling sites is given in Figure 1.2. Each survey usually involved sampling of the subtidal benthos, fish and plankton.

A series of seaweed and sediment samples were also taken to investigate the extent of metal contamination in the region.

Other studies, including push net sampling and intertidal sampling, were undertaken to provide information for specific questions as they arose.

1.4.2 Water quality sampling

Water quality sampling undertaken during the Nene study showed that a great variation in water quality occurred over a tidal cycle (Dyer & Grist, 1989a). During the Welland and Witham study, therefore, water quality sampling was undertaken at both high and low water. The NRA took monthly samples, at two sites on the Witham and three sites on the Welland, at both high and low water slack. A water quality survey was also arranged between Unicomarine and the NRA over a spring and neap tide in September 1990.

2. TOPOGRAPHY & SEDIMENT

2.1 Introduction

Project objective 1. To establish the distribution patterns of benthos and plankton and consider whether these could be regarded as normal.

Different types of sediment usually contain different faunal assemblages. e.g. muddy areas of upper estuaries often support large populations of oligochaetes, whereas populations in sandy regions are frequently much lower. Information on the sediment type and stability was required so that benthos distributions could be related to the sediment type and thus an assessment might be made as to whether they could be regarded as 'normal'.

2.2 Method

A record of the visual appearance of the sediment found in the grab sample at each site was made on all eight surveys (Table 2.1.). Sediment samples were taken from a Day grab at each site. Full particle size analysis was carried out on the sediment samples from the first survey (Table 2.2) and analysis of the organic content as % organic carbon (%OC) was undertaken for all sites sampled on surveys 1 to 4. As the %OC is usually inversely related to particle size, this was considered a cost effective means of determining seasonal changes in sediment throughout the study area.

2.3 Results

2.3.1 Particle size and % organic carbon

The levels of organic carbon found on surveys 1 to 4 are shown in Figure 2.1. Full sediment analysis was undertaken on samples from survey one and the data are given in Table 2.2.

A fine mud, high in organic carbon, was found at site 12 (Boston Stump) on the Witham throughout the study. Further downstream the sediment was mostly a coarse sand, although sites 13 & 15 varied between mud and sand. It is likely that this variability is related to changes in freshwater flow. The sediment at the entrance to the Witham was mainly mussel shell and stones. The training walls on either side of the channel in this area support large populations of mussels and these are likely to be the origin of the shell. An additional source could be from fishermen washing and sieving (riddling) their shellfish catch in this region whilst waiting for the flood tide. This is discussed in Chapter 4.

On the Welland, site 1 (Spalding) was the only consistently muddy site and it also had a high %OC content. Unfortunately this site was not sampled on survey 2 or 3 due to very low flows making it impossible to take a vessel from Fosdyke.

2.3.2 Analysis of sediment data

Large undulations of the estuary bed (mega-ripples) which were common on the Nene, were only noted occasionally in the vicinity of site 15 (Hob Hole) on the Witham.

Cluster analysis was used to group similar sediment types details of cluster analysis techniques are given in Chapter 4). The following parameters were used:- %silt/clay, mean particle size (phi), sorting and %OC.

The data (not log transformed) were clustered using the Canberra-metric similarity index (Barnett & Pearson, 1982) and the results are shown in Figure 2.2. At a similarity level of 60%, three groupings were detected. Site 16 was isolated, being sand with large mussel shells. No analysis of the sediment from site 17 was undertaken on the first survey because it was formed almost entirely of mussel shell. Sites 16 & 17 have a similar sediment with large amounts of mussel shell and form Group A.

Group B sites were muddy – the upper estuary sites of 1 (Welland) and 12 & 13 (Witham) were grouped (Sites 1 and 12 being most similar) and consisted of very soft mud with high levels of organic carbon. Site 13 was not grouped so closely as the sediments found varied between sand and mud throughout the study; towards the end of the study however, it was mostly mud. Site 20 was isolated having a higher mud content and poorly sorted sediment (indicating little current disturbance).

The other sites (Group C) were closely grouped being mainly of coarse sand, although the sediments in this group often varied from survey to survey (*e.g.* large amounts of coarse gravel were found at sites 10 & 11 in later surveys).

A synoptic map of the Welland, Witham and Nene estuary sediments, based on these analyses and the field records, is given in Figure 2.3.

2.4 Discussion

Both estuaries had a muddy sediment in the upper reaches. Fine mud is often found at the tidal sluice at the head of an estuary due to the lower flows in this region resulting in less sediment disturbance. On the Welland, the mud at site 1 is replaced by a coarse sand from sites 2 to 9. Site 10 and 11 varied between sand and gravel. The Witham was consistently muddy at the tidal limit. The sites further downstream varied from mud to sand up to sites 16 & 17. Sites 16 & 17 were very different, being formed mainly of mussel shell. This shell is likely to be derived from the mussel beds on the banks and from fishing vessels riddling their catch in this region.

The sediments were mostly typical of the other Wash estuaries. The upper reaches of both the Welland and Witham had a sediment of fine mud with high levels of organic carbon. Levels of organic carbon are normally inversely related to particle size because fine sediments have a larger surface area on which fine organic particles and films can attach.

Further downstream, the sediments varied but were mostly coarse sand, again common on estuaries due to large tidal flows resulting in scouring of the bed. One major difference, in comparison to the other Wash estuaries, was the sediment with a very high mussel shell content at the entrance to the Witham estuary. This type of sediment was difficult to sample quantitatively because the Day grab is designed for sampling soft sediments. Shell tended to prevent the jaws of the grab closing fully and so a considerable amount of material was lost whilst retrieving samples from these sites.

These different sediment types are likely to influence benthos distributions. The muddy areas at the head of the estuaries provide an ideal environment for oligochaetes. Sediments with large amounts of shell, such as was found at sites 16 & 17 have not been found on the other Wash estuaries.

3. SALINITY AND OXYGEN REGIMES

3.1 Introduction

Project objective 1. To establish the distribution of benthos and plankton. To consider whether these could be regarded as normal.

Project objective 6. To review the water quality data (salinity and dissolved oxygen) collected by the NRA during the survey period.

Information was required on the salinity and dissolved oxygen regimes of both estuaries to help interpret the biological results.

3.1.1. Major Inputs

Details of major inputs are given in Part II.

3.1.2. Data Sources.

Three principal sources of water quality data for the Welland and Witham estuaries have been utilised for the purposes of the present report:-

1. Data from NRA sampling at three sites on the Welland and two on the Witham sampled at high and low water. Undertaken at regular intervals since September 1989.

2. A water quality survey undertaken by Unicomarine and the NRA over a spring and neap tide in September 1990.

3. Data from the MAFF/NRA JoNuS surveys (Joint Nutrient Study).

3.2 NRA Sampling

Five sites have been sampled at roughly monthly intervals since September 1989. The location of these sites is shown in Figure 3.1. Because of the large tidal fluctuations in salinity and dissolved oxygen (DO) found on the Nene study, it was decided at an early stage of the project to sample at both high and low water.

3.2.1 The Welland

The three sites sampled on the Welland were at Pinchbeck Marsh, Fosdyke Bridge and Moulton Marsh (NRA Stone–barge jetty).

Pinchbeck Marsh. Figure 3.2

DO levels rarely fell below 70%. In the summer of 1990 and 1991, very high DO levels were recorded (the highest was 157% at HW) indicating the presence of an algal bloom. Salinity was generally around 1 ppt, but at high water in late summer 1990 and 1991 it increased to 5 ppt. On one occasion in October 1991 a salinity of 18.8 ppt was recorded at high water.

Fosdyke Bridge. Figure 3.3

The DO levels were slightly lower than at Pinchbeck, but they rarely fell below 60 %. Once again, peaks were recorded in the summer of 1990 and 1991 (the highest being 151%) and high levels of BOD were also recorded at this time. Large fluctuations in salinity were found throughout the sampling period ranging from < 1ppt (mostly at LW) to 25.7 ppt at high water in the autumn.

Moulton Marsh. Figure 3.4

DO was generally stable, rarely falling below 70% with two peaks at low water in the summer, the highest reaching 151%. Peaks in BOD were again found in the autumn, although levels were not as high as at Fosdyke. Salinity ranged from <1 to 31 ppt.

3.2.2 The Witham

Boston Swing Bridge. Figure 3.5

DO was high, rarely falling below 70%. Peaks of over 120% occurred in autumn 1990. Salinity ranged from <1 ppt to 25.5 ppt.

Cut End. Figure 3.6

DO was high and similar to Boston. BOD was generally low with some peaks in early 1990. Salinity range from 2–32 ppt.

3.2.3 Salinity range

The data from the NRA routine sampling have been used to plot the salinity range and the average salinity at each site (Figure 3.7). This information was particularly useful for interpreting the biological results.

3.3 Unicomarine/NRA special survey.

A detailed water quality survey of both estuaries was undertaken on September 14th (neap tide) and September 21st (spring tide) 1990. The aims of these surveys were:-

a. To provide dissolved oxygen and salinity data at high and low water for both estuaries over a tidal cycle.

b. To provide tidal cycle data from several points.

The main advantage to collecting this type of water quality data over the JoNuS data is that the information relates to specific positions on the estuary, rather than to particular salinity levels, and this is useful for interpreting the biological results.

3.3.1 Methods

Sampling was undertaken using two vessels; the NRA 'Sunray' and Unicomarine's 'Starfish', both vessels being launched at Fosdyke slip on the Welland. Starfish sampled the Welland and Sunray the Witham. The sites sampled are shown in Figure 3.8. Site 2 was sampled from the bank, with the sampling probe being pushed out into the channel as far as possible; site 1 was sampled from the bridge sluice at Spalding. The upper Witham was also sampled from the bank at low water when Sunray was unable to penetrate as far as this due to lack of water.

3.3.2 Weather

The weather was overcast on the neap survey (14th September) and cold and windy on the spring survey (21st September).

3.3.3 Results

The unfortunate loss of a salinity probe on a data logger towards the end of the neap survey resulted in an incomplete data set for this survey.

Dissolved oxygen and salinity results at high and low water are given in Figures 3.9 and 3.10. On the spring tide, the upper Welland salinity ranged from 2-10 ppt, although on neaps it was never greater than 1 ppt. The salinity range between high and low water was less at sites on the Witham than on the Welland. The dissolved oxygen levels were high with no obvious difference between the two estuaries. The Witham and the outer Welland had dissolved oxygen levels of about 80% at high and low water. DO on the upper Welland was around 100% (higher on the spring tide). Details of DO at two sampling site over a tidal cycle is given in Figure 3.11 and 3.12.

3.4 JoNuS survey (Joint Nutrient Study).

This project is intended to model nutrient inputs into the North Sea from the estuaries of eastern England, with particular reference to the significance of denitrification in estuaries.

The work undertaken by Unicomarine / NRA for the JoNuS project involves water sampling for DO, salinity, and nutrients from all the main estuaries flowing into the Wash. The requirements for the modelling work are such that about 20 samples are obtained in each estuary at salinity intervals of about 2 ppt. Samples were obtained from a semi-rigid inflatable vessel. Dissolved oxygen and salinity readings were taken using portable meters. Samples for nutrient analysis were filtered and then frozen.

Figure 3.13 shows the DO / salinity profiles for the Wash estuaries for the second JoNuS survey (data from NRA Anglian Region). The Nene had very low levels of dissolved oxygen in lower salinities and this DO sag was common during the Nene Study (Dyer & Grist, 1989a). The levels of dissolved oxygen in the Welland were high and generally >100% with a peak of almost 200% at low salinities. The Witham data was incomplete due to the inability to travel by boat further upstream than Boston Dock at low water. The high DO levels in the upper Welland indicate considerable phytoplankton activity at the time.

Nutrient data from the Welland for JoNuS surveys 2-5 are illustrated in Figure 3.14. This does not represent a complete analysis, but it was considered useful to present some results in this report. Data for the Witham are not given. Survey 3 and 4 did not cover the Witham due to technical problems, and on survey 2 and 5 it was only possible to sample the marine waters of the Witham because of the inability to travel by inflatable in the shallow upstream region at low water.

The graphs for the Welland (Figure 3.14) illustrate the non-conservative removal of nutrients; the implication being that phytoplankton in the estuary modifies nutrient transport from freshwater to the sea at certain times of the year. Such findings have important implications for modelling nutrient loads to the North Sea.

3.5 Freshwater Flow

It is difficult to determine the actual freshwater flow entering the tidal Witham and Welland because of the numerous freshwater inputs e.g. the Glenn, Hob Hole drain etc. However, data have been obtained from a sluice gauge on the non-tidal Welland (Tallington, near

Stamford) and Witham (Claypole, near Newark). Although the freshwater flow to the tidal sections will be greater because of inputs from other drains and rivers, the annual trend at these sluices is likely to reflect the trend of freshwater entering the tidal section. The mean annual flows are shown in Figure 3.15. The decline in freshwater flows after 1987 is evident, with the largest drop in flows occurring between 1988 and 1989.

4. Discussion.

Variations in salinity causes problems with osmoregulation for invertebrates and limits the colonisation of estuaries by benthos. Some species are more adapted to cope than others, but generally, the number of species is reduced in more brackish waters.

The salinity regime of estuaries is often complex and the number of species is not necessarily correlated with mean salinity. The periods of ebb and flood which approximate 6.5 hours in the open sea become more complicated in estuaries, with the ebb taking progressively longer further up the estuaries and consequently the periods of flood becoming progressively shorter. Such conditions make it difficult to determine which salinity conditions are the most stressful to invertebrates.

In common with the other Wash estuaries, both the Welland and the Witham have a large salinity range. The salinity range on the Witham appeared to be less than on the Welland, although complete data from several sites on each estuary over a tidal cycle are only available from one Unicomarine/NRA survey. In the upper region of the Welland, the salinity is usually low and the environment is effectively freshwater for much of the time, but saline intrusion can occur during high water springs. In the muddy regions of upper estuaries, this usually restricts the fauna to oligochaetes. Salinity conditions at Pinchbeck are usually low, but on occasions, saline intrusion does occur. The area has a sediment of coarse sand thus allowing the penetration of the saltwater more quickly than mud. This harsh salinity regime therefore will limit the benthos of the upper Welland.

The mean salinity at Fosdyke and Boston was similar (mean 8.18 and 8.51) although the maximum salinity was higher at Fosdyke. Moulton Marsh with a mean salinity of 13.31 is likely to be less harsh. The salinity regime at Cut End is likely to be the most favourable as the salinity never fell below 3 ppt. It is difficult to know where the equivalent salinity to Cut End on the Witham might be found on the Welland, because the seaward end of the Welland is formed by training walls. Unfortunately there are no routine data from this training wall area as it is a difficult region to sample from the shore.

The dissolved oxygen levels of both estuaries over the study period were generally good compared with the Nene. DO levels on both the Welland and Witham estuaries were generally >70% with little tidal variation. At times the upper Welland, and to a lesser extent the upper Witham, appears to be affected by algal blooms and this is reflected in super-saturation and high BOD. Water samples were not taken as a routine during the early JoNuS surveys and so it was not possible to investigate which algal species were responsible. Several water samples have been taken at other times to investigate the algae responsible for the very high DO levels. Details are given in Chapter 5.

The algal blooms causing supersaturation during the day-time are likely to produce low oxygen levels at night, although there are no data to support this at present. It would be useful to know how low the night-time oxygen levels fall to and which areas are affected. Collection of such data between spring and autumn is recommended.

The entrance to the Nene estuary was very shallow at low water and was almost blocked for about two hours either side of low water springs (Dyer & Grist, 1989a). No corresponding restriction was found at the entrance to the Welland and Witham at Tabs Head. On July 10th 1992, a flight over the area was arranged by the NRA when a video record of the entire tidal section was made. No blocking of the entrance was noted at low water (roughly half way between spring and neap).

4. BENTHOS

4.1 Introduction

Project Objective 1. To establish the distribution patterns of benthos and plankton. To consider whether these could be regarded as normal.

Project Objective 2. To determine the ecological impact of current trade and sewage discharges. To assess possible ecological changes if there were to be a significant modification to the nature of some of these discharges.

Project Objective 5. To assess the possible ecological changes resulting from changes in freshwater flow.

The main sampling programme involved sampling every three months over two years to examine seasonal fluctuations in populations. Additional sampling was undertaken, to answer specific questions that arose during the study.

4.2 Subtidal Benthos.

Eight surveys were undertaken over two years. Routine sampling sites were ca. two km apart between the tidal limits of both the Welland and the Witham and the Wash (see Figure 1.2). Sampling dates are given in Table 1.1. Sites 1 & 2 were not sampled during survey 2 and sites 1, 2, & 3 were not sampled on the third survey due to the inability to penetrate far up the estuary because of low flows. The vessel 'Sheldrake' owned by Drake Towage of Wisbech was used for the subtidal sampling. A hydraulic winch had been constructed for the Nene study and the vessel was particularly suitable for sampling the upper sections of the estuaries. Three Day grabs ($0.1m^2$) were taken at each site. Samples were sieved at 500 μ on-board and fixed in formalin. In the laboratory, samples were washed and examined using low-power stereo-microscopes and the benthos extracted and identified to species where possible. The upper estuary sites (site one on the Welland and 12 on the Witham) had sediments of fine mud. Because this type of site normally has high populations of oligochaetes, they were sampled by taking 20 cores from the Day grabs taken at each site – the technique had been developed during the Nene survey (Dyer & Grist, 1989a).

4.2.1 Results

The benthos found on each survey is given in Tables 4.1 to 4.8. The numbers given refer to the total from three Day grabs – these figures should be multiplied by 3.333 to correct for numbers per m^2.

The variation in total populations, the total number of species, and the most common species at each site over the eight surveys, is shown Figures 4.1 to 4.13. Again, the numbers given are totals for three (0.1 m^2) Day grabs.

Total Individuals. Figure 4.1.

The highest populations recorded were at site 1 (Welland) where large numbers of oligochaetes were found in the soft mud of this region. Unfortunately this site could not be sampled on survey 2 and 3 due to low freshwater flows. The populations fell to zero on surveys 4 and 7. The site was similar to the upper Nene sites where large populations of oligochaetes were found on every survey. The sediment was consistently muddy on every survey (see Table 2.1).

Total Species. Figure 4.2

The total number of species increased towards the marine sites in the Wash. The number of species found at site 17 was particularly high and similar to numbers found at the more seaward sites. In general more species were recorded in the summer surveys, at least at the more seaward sites.

Individual species.

Brief details of the populations of selected common species are given in Figures 4.3 to 4.13.

- *Capitella capitata* Figure 4.3
- *Hydrobia ulvae* Figure 4.4
- *Lanice conchilega* Figure 4.5
- *Macoma balthica* Figure 4.6
- *Neomysis integer* Figure 4.7
- *Nephtys cirrosa* Figure 4.8
- *Nephtys hombergii* Figure 4.9
- *Pygospio elegans* Figure 4.10
- *Scoloplos armiger* Figure 4.11
- *Spio martinensis* Figure 4.12
- *Tubificoides benedeni* Figure 4.13

Many of these species penetrated the entire length of the Witham, but, with the exception of *Hydrobia*, few were found further upstream than Fosdyke on the Welland.

The polychaete *Capitella capitata* and oligochaete *Tubificoides benedeni* were found throughout the eight surveys at site 17, downstream of Boston STW. These are species often associated with organic enrichment.

4.2.2 Cluster analysis – individual years.

Cluster analysis was undertaken for each survey. The data were log transformed (ln+1) using the Bray-Curtis similarity measure (Field & McFarlane, 1968) and the group average sorting strategy (Lance & Williams, 1967). The results for the individual surveys are given in Figures 4.14 to 4.17.

Many of the sites on the dendrogram were isolated due to the great differences in environment from the freshwater upper estuary to the fully marine outer estuary and the resulting change in faunal assemblages found in these different regions. The upper Welland sites (2 to 7) often had no obvious association because few species were found there. The upper sites 1 (Welland), 12 & 13 (Witham) were often grouped e.g. surveys 1,4 & 7. These sites were generally muddy and often had large oligochaete population (see for example survey 1). The upper Welland (site 1) was more freshwater and characterised by oligochaete species such as *Limnodrilus hoffmeisteri* and *Tubifex tubifex* compared to the more saline upper Witham (site 12) where *Tubifex costatus* was the dominant oligochaete. *Paranais litoralis* was common to the upper sites on both estuaries. However on several occasions, the oligochaete populations fell and this resulted in these sites not being closely linked on the cluster dendrogram e.g. survey 2.

Many of the Wash sites grouped with site 17 and 16 on the Witham (*e.g.* surveys 1,5,6,7) because of the diverse marine fauna found at these outer sites on the Witham.

4.2.3 Cluster analysis – Comparison with Nene.

To compare the Welland and Witham sites with the Nene study, a combined cluster of the Nene and Welland & Witham data from four surveys corresponding to a full year (Nene surveys 5 to 8; Welland–Witham surveys 3 to 6) was undertaken (Figure 4.18).

An arbitrary level of similarity must be selected above which meaningful clusters are deemed to exist. In practice a figure of 25–30% may be taken as a rough guide line for biological analysis (Barnett & Pearson, 1982). A level of about 30% produced four groupings. Site 1 on the Welland groups with Site 14 on the Nene (Group A). This is because they are similar muddy sites with large oligochaete populations associated with freshwater with occasional saline intrusion. Most of the canalised Nene (with the exception of site 19) grouped with Welland sites 2 to 7 (Group B), having a generally sparse benthic fauna. Site 12 on the Witham also clusters with this group due to the presence of small populations of the oligochaetes *Tubificoides benedeni* and *Paranais litoralis*. The seaward Nene sites group with much of the Witham and outer Welland (Group C) reflecting the greater benthic diversity of the Welland and Witham compared with the Nene. The most diverse sites were from Witham site 16 seawards and included the most seaward site on the Nene (Group D).

4.2.4 Species comparison with the Nene estuary

A comparison was made of the total number of species found at each site over one year and details of this are given in Figure 4.19. The total number of species was generally higher in the outer Welland and Witham compared with the Nene, although fewer species were found at site 15 – the site of the Hob Hole drain input. The average number of species on the Nene, including four sites in the Wash (i.e. Nene sites 14 to 23) was 13.9. This compares with an average species per site of 22.8 on the Welland and Witham excluding the shell sites of 16 & 17. When sites 16 and 17 are included, the mean species per site on the Welland and Witham increases to 25.9.

The number of species found at site 17 on the Witham was particularly high. The richness of this site is likely to be a result of the high shell content of the substratum which offers a variety of niches to invertebrate fauna. It was also noted during the surveys that fishermen tended to riddle their mussel catch in this area whilst waiting for the flood tide. This process could have resulted in an input of more marine species into this area.

Figure 4.20 shows a comparison of species numbers found at comparable sites at the entrance of each estuary over eight surveys. Witham site 17 is clearly more diverse followed by the Welland site 11 and then Nene site 20.

Because of the contrast in species numbers between the Nene and Welland/Witham, a comparison of the sediment data from these types was made. Cluster analysis was undertaken with the sediment data (Figure 4.21). Site 16 (shell) was isolated – no sediment from 17 was taken as it was pure shell, but it could be considered to group with 16, see Chapter 2. The muddy upper sites were grouped, the remaining sites were generally closely grouped. Sediment data was only available from one survey and inevitably some strange groupings occurred *e.g.* Nene site 18 clusters with the otherwise muddy group – it fluctuated between mud and sand. With the exception of the shell sites (16 & 17) no major differences in sediment type between the Welland and Witham were noted.

4.3 Intertidal surveys

4.3.1 Surveys of the canalised region of the estuaries

A survey of intertidal areas was undertaken in November 1990 and June 1991. Sampling and results are given in Figures 4.22 and 4.23. The intertidal region of the upper estuaries were dominated by oligochaetes, but other species such as polychaetes and bivalves were found, particularly on the Witham. On the Nene study, only oligochaetes were found upstream of Site 18.

4.3.2 Surveys of IMER sites

In the early 1970s, the Institute of Marine Environmental Research (IMER) undertook a series of intertidal surveys in the Wash as part of the Wash barrage scheme (NERC, 1976). The raw data from sites sampled in the vicinity of the Welland and Witham estuaries was obtained from PML (formerly IMER) and these sites were sampled in September 1990.

Method

The site positions obtained from IMER gave compass bearings. These bearings were plotted onto a chart and the latitude and longitude co-ordinates obtained. These co-ordinates were entered into a portable DECCA navigator which was carried in the field and used to locate the sites.

Results

The positions of these sites are given in Figure 4.24. A comparison of results with the IMER data is given in Table 4.9 and graphical representation of the comparison of the most common species is given in Figure 4.25. Oligochaete species were pooled in the IMER study, and so the 1990 oligochaete data were pooled for comparison. At Freiston Low the site closest to the shore (671) was found to be saltmarsh in 1990 and so was not sampled during the survey. At Freiston Low, *Macoma* had a very similar distribution to that found in 1973. At Herring Hill, a larger population was found compared with 1973, although the distribution pattern down the shore was similar. *Hydrobia* and pooled Oligochaetes had very similar distributions in 1990 compared with 1973 at both Freiston Low and Herring Hill.

4.4 Discussion

The fauna of both estuaries seems more diverse than the Nene. A comparison of species at equivalent sites on all estuaries showed the Witham to be the most diverse. The Nene study took place over three years before the Welland and Witham sampling and it could be that species numbers have increased on the Nene in recent years. However, a survey in 1990 of several sites on the Nene indicated a similar limited subtidal benthic fauna as was found on the Nene Ecological Study (Dyer & Grist, 1991).

The outer canalised section of the Witham is particularly species rich and this is largely due to the favourable shell substratum and the possible introduction of marine species from fishermen cleaning their catch at this site. The polychaete *Capitella capitata* and oligochaete *Tubificoides benedeni* were found throughout the eight surveys at one of the species rich sites *i.e* Site 17, downstream of Boston STW. These are species often associated with organic enrichment (Barnett, 1983; Pearson & Rosenberg, 1978). However, water quality conditions appear to be favourable for the very large number of other species found at this site. A deterioration in water quality would be likely to favour these two species to the detriment of the large number of other species.

The non-shell sites also have more species than the Nene and a comparison of sediments showed that, with the exception of the shell sites in the outer Witham, there was no major difference in sediment type between the estuaries. It seems likely, therefore, that the generally higher dissolved oxygen levels of the Welland and Witham are in part responsible for the greater number of species in these estuaries. An additional factor could be that the Welland and Witham are more marine than the Nene. The Nene appears at low water to be separated from the Wash by a longer channel than on the Welland and Witham. Available water quality data indicates that all three estuaries have similar severe salinity regimes, but data from continuous monitors would be required to make an accurate comparison of the salinity regimes of the Wash estuaries.

Compared with the Nene, the dissolved oxygen levels of both the Welland and Witham were generally good and unlikely to restrict the benthos. However, the water quality surveys indicated that algal blooms can occur, particularly on the upper Welland, and these are likely to result in low oxygen levels at night. It is recommended that some night-time dissolved oxygen data is obtained.

The large salinity range of both estuaries is likely to be the major factor limiting the penetration of benthos up the estuaries. The data from the joint Unicomarine/NRA survey indicated that the salinity range on the Witham was somewhat less than on the Welland. Unfortunately data are only available from one survey of this type. It would be useful to obtain long term salinity data throughout a year from several permanent monitors in all the Wash estuaries so that the salinity regime of each estuary could be compared more effectively. Sites with similar salinity regimes could then be monitored biologically and this would provide valuable information about the comparative biological quality of the Wash estuaries.

Site 1, at the head of the Welland, usually had a population of oligochaetes typical of an organically rich upper estuary muddy site with occasional saltwater intrusion i.e. large populations of the oligochaetes *Limnodrilus hoffmeisteri* and *Tubifex tubifex* (Brinkhurst, 1982). However, on two occasions, no animals were found at Site 1. The reason for this is unknown, although it may be related to the occasional intrusion of water of high salinity or possibly the drying out of this region during periods of low freshwater flows.

Site 15 on the Witham generally had fewer species than sites on either side (14 and 16). This site was close to the Hob Hole drain, and possibly large amounts of fresh water from this drain could be the cause of the lower diversity. This site was also the only one where mega-ripples were occasionally recorded, and this could have reduced diversity. An additional factor could be the proximity to Boston STW. This could be investigated further.

IMER sites re-sampled in 1990 had a very similar benthic fauna to that found during the original IMER study. The saltmash seems to have encroached into the intertidal region slightly at Freiston Low, but the populations and distribution patterns were very similar to those found when IMER sampled the region in 1973.

5. PLANKTON.

Project objectives 1. To establish the distribution patterns of benthos and plankton. To consider whether these could be regarded as normal.

Project objective 5. To assess the possible ecological changes resulting from changes in freshwater flow.

5.1 Introduction

Sampling for zooplankton was undertaken on the routine benthos surveys every three months over two years, as on the Nene study. Some additional work was also completed to answer specific questions as they arose, in particular, analysis of plankton living towards the banks that were not effectively sampled from the survey vessel. Phytoplankton samples were also taken to investigate algal blooms.

5.2 Zooplankton

5.2.1 Mid-channel zooplankton

Method

Zooplankton sampling was undertaken at the routine fish sampling sites (Figure 5.1) at high and low water. The selection of these sites is discussed in Chapter 6. Three two-minute trawls with a 30 cm diameter net (250μ mesh) were taken during the fish survey at each fish sampling site covering a distance of approximately 160 m for each trawl.

From earlier studies on the Great Ouse and Nene, it was known that a considerable amount of tidal variation in plankton populations occurred on these canalised estuaries, as plankton moved with the ebb and flow of the tide. The Nene study showed an accumulation of zooplankton occurred at the entrance of the estuary at low water.

Problems were encountered repeating these techniques on the Welland and Witham study. The NRA vessel 'Adventurer II' underwent repairs during the study and was unavailable after survey 2. No vessel was available for survey 3. From survey 4 onwards 'Sheldrake', the vessel used for benthic sampling, was used. This has a deeper draft than Adventurer II and problems were encountered running aground in the region of Tabs Head at the entrance to the two estuaries at low water. Consequently, although it had been planned to sample about five sites at high and low water, the sites were often sampled before or after these times.

Results

The results (total catch from three trawls at each site) are presented in Tables 5.1 to 5.3. Because of the nature of the sampling explained above, it was not possible to analyse tidal movements in the same way as on the Nene study. The number of zooplankton species found on the Welland and Witham is compared with the number of species found on the Nene (data from high and low water and seasonal data combined) in Figure 5.2 Only the larger planktonic species were considered in this comparison, copepods were excluded as they are not all effectively sampled with the 250μ mesh net. It is clear that more species were found on the Welland/Witham than on the Nene.

A comparison with the numbers of common species found in plankton trawls on the Nene study is shown in Figures 5.3 and 5.4. The mysids *Neomysis* and *Mesopodopsis* are shown in Figure 5.3. No major difference, was found, although *Mesopodopsis* was generally more common on the Welland and Witham than on the Nene. *Crangon* (larvae and small adults) were more common on the Welland and Witham (Figure 5.4), but amphipods were more common on the Nene.

5.2.2 Push net samples

Method

Sampling was undertaken to assess the populations of the larger planktonic species not sampled effectively by plankton trawls in mid-channel and to compare the Welland and Witham fauna with that found on the Nene.

Sampling was undertaken using a standard push net by walking along the bank against the direction of flow at about low water for 1 minute. One sample was taken from each site in 1991. In the repeat survey of 1992, three samples were taken at each site (as this seems to be the method adopted by certain regions of the NRA) and the results are presented as the mean catch per minute .

Results

The results for 1991 are shown in Figure 5.5 and those for 1992 in Figure 5.6. Figure 5.6 also shows the results from a sample taken one month earlier at site 3 when large numbers of *Crangon* and *Neomysis* were found.

In 1991 the Nene fauna was generally less diverse than the Welland and Witham and the most upper Nene site was particularly poor. In the repeat survey of 1992 there was no major difference in the number of individuals caught on each estuary and more species were found on the Nene. Several of the species found on the Nene were freshwater species and these are highlighted in Figure 5.6.

5.3 Phytoplankton

5.3.1 Method

The Joint Nutrient Study (JoNuS) project (see Chapter 3) was undertaken to study the extent of de-nitrification in estuaries. From the third JoNuS survey it was decided to take water samples so that phytoplankton could be analysed. A bloom occurred on the second JoNuS survey (see Chapter 3) before the phytoplankton sampling programme had commenced. No blooms were noted on the other JoNuS surveys, but samples from the fifth JoNuS survey (April 1991) were analysed to see what phytoplankton species were present.

The JoNuS samples (ca. 200 ml) were taken at salinity intervals of about 2 ppt, from freshwater to sea water on the Welland, Witham, Nene and Great Ouse estuaries. The samples were fixed in dilute formalin (ca. 1 %). Ten ml from each sample was placed in a rectangular glass observation chamber over-night to settle. The samples were analysed the following day by tracking the bottom of the chamber using an inverted microscope. Several Nene samples proved impossible to analyse because of the large amounts of sediment in the samples.

In addition to the JoNuS samples, other water samples were taken at various sites over the study period when algal blooms were thought likely to occur. These samples were fixed in Lugol's iodine.

5.3.2 Results

The results from the JoNuS survey are given in Tables 5.4–5.7. The data are arranged by salinity from marine to freshwater. Unfortunately no bloom occurred during the time of JoNuS 5. The samples contain a variety of diatoms, but none were present in large numbers.

The results for the other phytoplankton samples taken throughout the study are given in Table 5.8. Some sites are identified by sites codes from the routine benthos sampling sites. Drawings were made of incompletely identified organisms and these are given in Figure 5.7.

More phytoplankton were found in these samples. Large numbers of the freshwater chlorophytes *Chlorella* and *Scenedesmus* were found at Boston Stump in June 1991. Sites 2 and 3 on the Welland in July and August 1992 contained a large number of badly preserved organisms that are thought likely to be freshwater euglenoids.

5.4. DISCUSSION

The mid channel sampling indicated that more zooplankton species were present on the Welland and Witham than on the Nene. The sampling was, of course, undertaken at different times which is not ideal, but as with the benthos sampling, the indications are that a richer fauna is to be found on the Welland and Witham compared with the Nene. The actual number of individuals of common species was similar for both the Welland and Witham and the Nene.

The push net sampling in summer 1991 seemed also to indicate this trend, with more species being found in those samples from the Welland and Witham. However, the 1992 sampling was less conclusive. It is difficult to know if the higher number of freshwater species on the Nene is significant, but recent reports indicate a possible reduction in salinity on the Nene due to tidal restriction at the entrance to the estuary (B Barnett, pers. comm.).

Phytoplankton sampling was undertaken for the first time in this series of studies on the Wash estuaries, because of the growing concern about nutrient enrichment and algal blooms. The large numbers of phytoplankton that were recorded during routine sampling were freshwater species. It was unfortunate that phytoplankton samples were not taken during the second JoNuS survey, but phytoplankton sampling was never part of the original project plan. The samples analysed from one JoNuS survey showed very low amounts of phytoplankton, and it is still not known which species caused the bloom during the second JoNuS survey. No blooms have been recorded on subsequent JoNuS surveys to date (November 1992) but continued phytoplankton sampling in spring, summer and autumn during JoNuS surveys would be useful.

6. FISH

6.1 Introduction

Project Objective 4. To assess the existing status of the finned fishery together with the freshwater eel fisheries which depend on the estuaries for migratory purposes.

Regular sampling using a beam trawl at selected sites at high and low water were planned as on the Nene survey.

A preliminary survey was conducted in March 1988 (Dyer and Grist, 1989b). The muddy regions of the Witham were uneven and unsuitable for trawling because of the risk of damage or loss of the trawl. The sandy regions were difficult to trawl because they were uneven and also contained some large objects dumped in the estuary. The sites considered suitable are shown in Figure 6.1. Site 15 on the Witham was not always sampled as severe net damage was very common at this site.

Additional problems arose with both 'Adventurer II' and 'Sheldrake' (discussed in 5.2.1). Consequently, although it had been planned to sample sites at high and low water, the sites were often sampled before or after these times.

6.2 Method

Ten minute trawls were made as close to slack water as possible using a beam trawl. The distance trawled was approximately 0.8 km. The survey was conducted every three months over two years with the exception of survey three due to problems with 'Adventurer II', the NRA survey vessel. Sampling continued from the vessel used for the benthos surveys (Sheldrake), with low water and high water surveys being made on consecutive days. Details of sampling times are given in Table 1.1.

6.3 Results

The trawls in the Witham, particularly site 15, often contained large amounts of rubbish including tractor tyres.

Fish catches made on the surveys are given in Table 6.1 and were generally low, both in terms of species and numbers. The species found were comparable with those found on the Nene. A comparison of fish species found on the Welland and Witham, Nene and Great Ouse is given in Table 6.2. The table also includes the species found at the most seaward sites on all the estuaries.

In the later surveys, several species which had not been recorded on the Great Ouse and Nene studies were trawled in low numbers. These included the commercially fished pink shrimp *Pandalus montagui*, and two prawns *Palaemon elegans* and *P. serratus*. The likely cause was reduced freshwater flows, resulting in increased salinity, as these species are usually found further offshore in the deeper, more saline regions of the Wash. Similar findings have been made recently on the Great Ouse (Terry Clough, NRA pers. comm.).

6.4 Eels

It was intended to undertake an eel survey as on the Great Ouse and Nene studies. On several occasions, a survey was arranged with Duncan Mackie who undertook the Nene eel survey, but the surveys were later cancelled by him. Discussions with Mr Mackie indicate that very few eels were caught in the tidal reaches of the Welland and Witham in recent years. The consensus amongst the fishermen was that the poor catches resulted from low freshwater flows; eels migrating into the estuary require low salinity to detect the entrance to the estuaries. As one of the main interests with the previous eel surveys on the Nene and Great Ouse had been the shrimps and mysids in the stomach contents, the effort was directed towards push net sampling near the banks (see Chapter 5).

6.5 Discussion

The Wash as a whole is not a major fin–fishery, although it is of importance as a hatching ground and for young fish. It has been calculated that up to 1% of young sole and 2% of young plaice of the North Sea make use of the Wash; of particular importance is the availability of shallow, slightly brackish water over fine sediments. (Riley, 1987).

The catches on the Welland and Witham study were generally poor, although a few species, generally associated with fully saline conditions, were found towards the end of the study, and this most likely reflects the low freshwater flows in the latter part of the study.

The poor fish catches were similar to those found on the Nene. It seems that these narrow canalised estuaries are not ideal environments for fish, with their fluctuating salinities and poor food supplies. Trawls on the Great Ouse (Dyer & Grist 1986) resulted in larger catches of a similar number of species, possibly because the estuary is wider and less canalised.

7. SEAWEED CONTAMINATION

Project objective 8. To assess the suitability of using metal analysis of seaweed as indicator of environmental contamination.

7.1 Introduction

A preliminary survey of the Welland and Witham (Dyer & Grist, 1989b) showed that much of the banks were covered in seaweed. The banks of the Nene and Great Ouse have very little seaweed cover, and so analysis of metal contamination of seaweed was considered useful in order to determine metal contamination in the region. In addition it was considered useful to compare data with the Humber, where Dr Brian Barnett had collected a considerable amount of data on metal contamination in seaweeds (Barnett & Ashcroft 1985).

7.2 Method

Samples were taken and prepared according to methods used by the Humber Estuary Committee. Details are given in Barnett & Ashcroft, 1985. At certain sites, two samples were taken and analysed by separate laboratories (see Chapter 10, Quality control).

Samples of *Fucus vesiculosus* were taken in February and September 1990. The sampling sites are shown in Figures 7.1 In addition, a sample of seaweed was obtained from a relatively clean site on the Lincolnshire coast (Mablethorpe) from Brian Barnett and this was processed and analysed in the same way. Unfortunately, this site contained only the related species *Fucus spiralis*. The available information on comparative uptake of metals of the different *Fucus* species suggests that they are broadly similar (Barnett pers. comm.).

The samples were prepared according to the proposed NRA standard technique. Material was collected from just below the upper shore limit of the *Fucus* cover. Larger plants were selected (minimum 15 cm and generally > 20 cm. badly damaged material or fronds heavily covered in epiphytic growth or sediment were rejected. The samples were prepared by cutting strips (5 mm wide) avoiding the bladders and new growth regions – the technique developed by Brian Barnett (Barnett & Ashcroft, 1985). The samples were cut, using scissors only used for this purpose, directly into sample bags and delivered to the analyst.

Sediment samples were also taken from the seaweed sampling sites. All the samples were analysed by SAC laboratories, Dunton, Bedfordshire.

7.3 Results.

Much of the training walls of both the Welland and Witham is covered in seaweed. The distribution is shown in Figure 7.1. Two species of seaweed were found: a) *Ascophyllum nodosum* (rarer and only at the outer sites on the upper shore), and b) *Fucus vesiculosus*.

The results of the analyses are given in Table 7.1. The control (Mablethorpe) seaweed sample (February 1990) had levels of manganese and iron which were an order of magnitude lower than those from the Welland & Witham. This may reflect the higher turbidity of the Welland and Witham region. Typical figures from the Humber are given in Table 7.2 for comparison. The levels of lead in the seaweed sample at site 6 were higher than at other sites. The results for the seaweed analysis for September 1990 are also given in Table 7.1 and were similar with higher lead levels at sites 6 and 7.

The sediment samples were also analysed for the pesticides endrin, aldrin, dieldrin, lindane, atrazine and simazine and results are shown in Table 7.1. For the 'drins', pesticides which have very restricted use these days – levels were all < 5 μg/kg and for lindane < 2 μg/kg *ie* below the limits of detection. For atrazine and simazine, chemicals used extensively in weed control, levels were all below 0.1 μg/kg with the exception of site 2 which was 0.13 μg/kg.

A further sample of seaweed was taken from Site 6 as this had the highest level of lead contamination. Results are given in Table 7.2. Lead levels of 11 μg/g was found which was lower than found previously, but still higher than at the other sites. Also as a cross–comparison exercise, samples from one site (Tabs Head – site 4) were sent to Brian Barnett (NRA) for analysis and these results are shown in Table 7.2. In addition, a Mablethorpe sample analysed by the NRA was also given to SAC for analysis. Again the results are given in Table 7.2. which includes a comparison of a sediment sample analysed by both the NRA and SAC. The most striking difference in the comparisons is the high levels of arsenic with the Tabs Head seaweed sample analysed by the NRA (Table 7.2).

7.4 Discussion

Finding suitable controls is difficult as *Fucus vesiculosus* is generally found in estuaries and seems to favour a harsh salinity regime. On the coast, *F. spiralis* is generally found. However, one site was found with *F. vesiculosus* on an estuary with no obvious industrial or sewage input (the Blyth) and samples from this site had very similar levels of contamination for metals other than iron and manganese to most sites on the Welland and Witham.

Iron and Manganese were high, probably as a result of the high turbidity of these estuaries. The high levels of Arsenic in the Tabs Head sample analysed by the NRA is likely to be an analytical error (B. Barnett, pers.comm.).

The results indicate that the level of metal contamination in the Welland and Witham is low, and consistent with a region of low industrial activity. However, the high levels of lead from the seaweed samples taken on the Witham should be investigated further.

8. SHELLFISH

Project objective 3:- To assess the existing status of the shellfishery in both estuaries. To locate any area where shellfish are likely to be unsuitable for human consumption.

8.1 Introduction

The Wash shellfishery occupies a position of great importance in relation to the remainder of the shellfish landings in England and Wales (Figure 8.1). The Eastern Sea Fisheries Joint Committee (ESFJC) believe it could be expanded through cultivation of stocks to become a major European fishery.

For this report, information was required on the present shellfish industry and the level of faecal contamination of shellfish in the western Wash.

8.2 The Shellfishery

8.2.1 Mussels

The shellfish beds in the western Wash are shown in Figure 8.2. The mussel beds are confined to the inner, shallower sections around the entrance to the estuaries; cockle beds are found further out, usually in deeper water.

The shellfish catch data presented in the annual ESFJC reports give total landings for the Wash, but do not give details of individual ports. Mr Chris Beach of ESFJC has for some years recorded catch data from the individual ports. Details of these records of landings from Wash ports since 1977 are shown in Figure 8.3. Shrimps (brown and pink data combined) are mostly landed at King's Lynn. Mussels and Cockles are landed in roughly equal proportions at Boston and King's Lynn. Over the last decade the mussel stocks of the Wash have fluctuated greatly. In recent years, the only successful spat fall and recruitment of mussels occurred in 1986 and little or no recruitment has taken place since then. In 1990, landings declined and catches fell by 50% to 3803 tonnes (ESFJC 1990, 1991). On the 6th February 1990 all the main beds in the Wash were closed to the taking of mussels until 24th October 1990. However, some mussel beds (known locally as scalps) were opened for the purpose of seed collection during the interim period. In January 1991 the scalps were again closed between the Nene and Great Ouse and opened in September. The majority of mussel beds were in a very poor state at the end of 1991 with the Trial Bank area of Westmark Knock being the most heavily fished. ESFJC estimated that the recovery of the fishery, to a minimum landing size, will not take place until September 1994.

8.2.2 Cockles

Figure 8.3 shows the total Wash cockle landings (tonnes) from 1977 – 1990. In 1988, 7599 tonnes was landed by 37 vessels, but in 1989 there were insufficient stocks and the lowest landings for a decade were recorded of 1007 tonnes with only 13 vessels actively fishing. In October 1988, Daseleys and Seal Sands were closed for the taking of cockles and remained closed until re-surveyed after summer 1990. The closing of the beds enabled the cockles to spawn and then recover their body weight prior to exploitation. Between 1989 and 1990 there was an 82% increase in fishable stock (1834 tonnes) although it must be remembered that 1989 was the lowest catch in a decade. The 1991 cockle season was extremely successful with 41 vessels bringing in 8911 tonnes. All public beds were closed between February and April 1992 for recovery purposes.

8.3 Sanitary Quality

8.3.1 Field Sampling Methods

A survey of the sanitary quality of the shellfish (mussels and cockles) in the south-western region of the Wash was undertaken on September 18th and 19th, 1989 (Figure 8.4). Details of the site locations are given in Table 8.1. Sampling was undertaken at the time of the autumn equinox (the largest spring tides of the year) which uncovered larger areas of the intertidal region. A similar survey was undertaken during the Gt. Ouse and the Nene studies at the same time of year and thus the data would be comparable.

The ESFJC vessel Protector II was used for the survey, and this had the advantage that the crew were familiar with the positions of the shellfish beds. Sampling was generally undertaken at low water by transporting personnel in an inflatable boat from Protector II. On a few occasions, samples were taken at high water from Protector II using a dredge.

Two samples of 12 animals each were taken at each site. The samples were kept in cool boxes throughout the day and transported for microbiological analysis to Mr Derek Gould of M.E.C. laboratories, Baldock on the evening after each days sampling.

Large cockles were only found in sufficient numbers for a sample at one site (22). The other traditional cockle beds (Long Sand and Friskney Flats see Figure 8.2) had very few mature cockles, although large numbers of cockle spat were found. The adult cockles had been heavily fished during the previous few years with suction dredges (ESFJC pers. comm.).

8.3.2 Laboratory Methods

All analyses were commenced within 12 hours of collection and samples were analysed in order of collection to standardise the delay in analysis. During interim storage, samples were refrigerated at 4 ^{o}C.

The methods employed for thermotolerant coliforms (TTC i.e. *E. coli*) and faecal streptococci (FS) were those currently recommended by MAFF (West & Coleman, 1986; Eastbrook & West, 1987). For TTCs, the most probable number technique was used to give a counting range of 20–18 000 per 100g wet weight of tissue (West & Coleman, 1986). Faecal streptococci were enumerated using the pour technique method (Eastbrook & West, 1987) to give a lower limit of detection of 300 faecal streptococci per 100g of tissue.

The technique employed for enumeration of *Salmonellae* was based on the MPN method currently favoured by WRc for sludges. The WRc method was modified on this occasion to give a lower sensitivity of 2 per 100g of tissue and an upper limit of 1600 per 100g.

8.3.3 Results

The results are listed in Table 8.2. The two replicate samples at each site generally had similar values of faecal contamination. The most notable exception was at site 21 where the replicates had TTC levels of >18 000 and 2400 per 100g. The relationship between TTCs and faecal streptococci was also variable and possibly reflects the age of the source of pollution – faecal streptococci surviving for longer periods in the marine environment. *Salmonellae* were not detected in any sample.

The present EC Shellfish Waters Directive standard for bivalve shellfish (MAFF 1992) is based on TTCs (*E. coli*) and deems that shellfish having counts of less than 230/100g (or <300/100g faecal coliforms) are suitable for human consumption without purification (Category A). Between 230 and 4600 *E.coli*/100g (300–6000 faecal coliforms/100g) they must be depurated, heat treated or relayed (Category B). Shellfish with *E. coli* of greater than 4600/100g and faecal coliforms of greater than 6000/100g (Category C) must be relayed for at least 2 months. Above 60 000 faecal coliforms/100g (Category D) harvesting is prohibited .

A synoptic map of the mean TTC levels found is given in Figure 8.5. For comparison, data from the Gt. Ouse study are shown in Figure 8.6. A considerable number of sites had levels above the level of contamination considered by MAFF to be too high for successful depuration without relaying, although there was no obvious pattern to these sites. Very high levels of contamination were found on either side of the training walls at the mouth of the Welland estuary. The levels of TTCs at the mouth of the Witham were lower.

8.3.4 Monthly Survey Data.

In their 1989 report (ESFJC, 1989), ESFJC gave an assessment of faecal contamination of eastern Wash shellfish surveyed in 1988.

Table 8.3.

MUSSELS	COCKLES
Category B – need depuration 57% > 230 *E.coli*/100g meat	Category B – need depuration 82% > 230 *E.coli*/100g meat
Category C – need relaying 5.8% > 4600 *E.coli*/100g meat	Category C – need relaying 20% > 4600 *E.coli*/100g meat

A sampling programme was initiated by Boston Borough Council in December 1989 in anticipation of the EC Molluscan Shellfish Hygiene Directive due to be introduced in 1993. Concern had arisen over the possibility of category C being introduced for the whole of the Wash leading to relaying and purification prior to human consumption for all the stock.

The monthly sampling of the sanitary quality of a limited number of sites was undertaken by ESFJC on behalf of Boston Borough Council and the samples were analysed by Kings Lynn Borough Council. The data are given in Table 8.4 (see Figure 8.4 for site locations). The Witham North Bank / North Lays (Clay Hole) sampling site has changed slightly through the year, more recent sampling being towards the lower shore which ESFJC found easier to access.

High levels of faecal coliforms were found only at the North Lays site. The high levels at all sites in June 1992 were apparently caused by a rise in temperature of the holding box from the usual 3°C to 7°C causing the coliforms to multiply in the mussels (C. Beach, pers. comm.).

8.4 General Discussion

8.4.1 The Shellfishery

The maximum mussel catch for all Wash ports in recent years was 11 000 tonnes in 1977. ESFJC believe that mussel production alone could be increased to well in excess of 100 000 tonnes per annum and its position as a major fishery, in terms of both the UK and Europe, could be secured and expanded (ESFJC 1989).

The Wash shellfishery is clearly an important source of UK shellfish. The decline in recent years is perhaps not unusual as large fluctuations in annual catches seem common. The decline in mussels has been attributed to the exceptionally warm summers and mild winters in recent years which has resulted in desiccation at low water and a reduction in the mortality rate of predators, in particular the starfish *Asterias rubens* (ESFJC 1990). Although the decline in mussels might be natural, ESFJC have expressed concern about the increased exploitation of cockles due to the new hydraulic fishing methods, and suggest that conservation measures may be required (ESFJC 1990).

ESFJC plan to undertake more research into relaying sub–littoral seed to the traditional scalps. Further surveys of stock assessment and research into possible causes of poor recruitment and limited natural growth have been highlighted as important areas in recent ESFJC reports (ESFJC 1990).

8.4.2. Sanitary Quality

The survey undertaken in September 1989 showed high contamination at many sites. These results contrast with the monthly data obtained from Boston Borough Council which indicate lower levels of faecal contamination, and these differences are difficult to resolve. MAFF have recently classified all the Wash shellfish beds, and the classification was based largely on the monthly sampling programme. The Boston region is classified B (need depuration). Shellfish beds in the Kings Lynn region, in contrast, received one B, one B/C, four C and one D (Category C – 2 months relaying in clean water, D – not to be harvested) (MAFF 1992).

During the many visits to the area during the study it was noted that many fishermen regularly take mussels from the large beds on the training walls of the Welland and Witham in the vicinity of Tabs head. Very large mussels are found in this region as mussels are filter feeders and thrive in the vicinity of sewage outfalls if the salinity conditions are favourable. These mussels contain very high levels of faecal coliforms, and thus the consumption of mussels collected from these areas poses a potential threat to health. The survey indicated that the mussel beds on the Welland training walls were more contaminated than those on the Witham, and this should be investigated further.

9. GENERAL DISCUSSION

9.1 Project objective 1.

- To establish the distribution patterns of benthos and plankton and consider whether these could be regarded as normal.

The upper Welland has a limited benthic fauna largely as a result of saline intrusion and the frequent drying of this sandy region (sites 2–6). Low oxygen levels are likely to occur at night (particularly in summer) adding to the environmental stress. 24 hour monitoring of dissolved oxygen levels during the summer would be useful to provide information on changes in oxygen levels over long periods, particularly at night. The upper sites, at the tidal sluices of both the Welland and Witham (sites 1 and 12), are muddy like the upper Nene, with large numbers of oligochaete worms. Populations fell from time to time on the upper Welland and on one occasion on the upper Witham. This could have been caused by drying at low water springs and this should be investigated further.

The sites with a high shell content on the Witham provide a variety of suitable habitats for marine invertebrates and this area was particularly species rich. These sites (16 & 17) were very difficult to sample with the Day grab, and only small samples were obtained. It is likely, therefore, that the true number of species present has been underestimated. The mussel shell in this area is probably derived mostly from the training walls, where high populations of large mussels are found. However, there may be some input from fishing vessels in this area sieving and washing their shellfish catch (riddling) whilst waiting for the flood tide. The recent decline in the mussel fishery may have limited this activity and future benthos sampling would be useful in order to determine the importance of riddling shellfish catches on the input of species into the area.

The sandy/muddy areas were less rich, but the number of species recorded was still greater than on the Nene, although many of the specimens were small and the total biomass would be low – typical of canalised estuaries. The Nene study took place over three years before the Welland and Witham sampling and it could be that species numbers have increased on the Nene in recent years. However, a survey in 1990 of several sites on the Nene indicated a similar limited subtidal benthic fauna as was found on the Nene Ecological Study (Dyer & Grist, 1991). It seems likely, that the Welland and Witham are more species rich than the Nene, at least in part, because of the better water quality of the Welland and Witham. An additional factor might be salinity differences. The canalised sections of the Welland and Witham are perhaps nearer the fully marine environment of the Wash compared with the Nene which has a longer channel to the Wash at low water. From the salinity data available, the Nene, Welland and Witham appear to have similar severe salinity ranges for sites at similar distances from the sea. However, salinity data from continuous monitors on each Wash estuary would be useful to compare salinity ranges over long periods and to find areas for each estuary which have similar salinity ranges. These sites could then be monitored biologically and the results for each estuary compared. This would allow a more detailed biological comparison of the Wash estuaries, because any biological difference that was found could be compared with factors other than salinity.

The Welland and Witham have a relatively rich benthic and planktonic fauna compared with the Nene. The study involved sampling at sites in the Western Wash, which was also more diverse than the central Wash sampled during the Nene study. It will be useful to compare the biological data from the NRA Wash survey of summer 1991 with the outer Welland and Witham data, to see if the western Wash is more diverse than other regions of the Wash.

9.2 Project objective 2.

- To determine the ecological impact of current trade and sewage discharges and to assess possible ecological changes if there were to be a significant modification to the nature of some of these discharges.

The upper estuary of the Welland has a limited fauna. This is largely because it is a long estuary and the upper reaches are effectively freshwater for much of the time, but saline intrusion does occur at high water springs. This saline intrusion is likely to be the main factor limiting the benthos in this region. An additional factor is that during periods of low freshwater flow, the area dries out. The region around the tidal sluice is muddy and contains large numbers of oligochaetes, but the populations fluctuate considerably, possibly due to drying out at low water springs.

The Witham is species rich, and the region at the entrance to the Witham at sites 16 and 17 is very species rich because of the substratum of shell. The polychaete *Capitella capitata* and oligochaete *Tubificoides benedeni* were found throughout the eight surveys at site 17 and these species are often associated with organic enrichment (Pearson & Rosenberg, 1978). If the quality of the effluent of Boston STW were to deteriorate, the diversity of the sites at the entrance to the Witham might be reduced with *T. benedeni* and *C. capitata* becoming the dominant species.

Few species were found just downstream of Boston STW at site 15. This is likely to be because of the freshwater input from Hob Hole drain and the occasional mega-ripples found in the area, but this should be investigated further.

9.3 Project Objective 3.

- To assess the existing status of the shell fisheries in both estuaries. To locate any area where shellfish are likely to be unsuitable for human consumption.

The shellfishery of the Wash is generally unstable and landings of mussels have been very low this year (1992). This is most likely a result of the warm dry weather in recent years resulting in desiccation at low water and low mortality of the chief predator *Asterias rubens* (Starfish). ESFJC feel that a more controlled approach with regular seeding of mussel beds with spat would provide a more stable shellfishery. The sanitary quality survey of the mussel beds in the region gave conflicting results. The survey undertaken by Unicomarine from the ESFJC vessel in autumn 1989 showed several beds to be contaminated with faecal bacteria to such an extent that they were unsuitable for depuration and required relaying. However, the routine sampling of a small number of beds by ESFJC for Boston Borough Council and analysed by King's Lynn Borough Council repeatedly showed low levels of faecal coliforms. The recent MAFF designations, largely based on these latter results, has cleared the beds on the Boston side with a B grading *i.e.* they do not require relaying but are suitable for human consumption after depuration. When the mussel fishery eventually improves, regular sampling of a larger number of beds would be useful to try and resolve the discrepancy between the high levels of faecal contamination found on the Unicomarine survey compared with the low levels found on the Boston Borough Council survey.

During the survey of September 1989, the mussel beds on the Welland training walls had a higher level of faecal contamination than those on the Witham. In view of the proximity of the Boston STW outfall to the mussels on the Witham training walls, as compared to those on the Welland training walls where the beds are a considerable distance from Spalding STW, these results are difficult to explain. Contamination levels at these sites should be investigated further. Collection of mussels from the training walls was frequently observed during the study and the public health implications of the collection of contaminated mussels from the training walls should also be considered.

9.4 Project Objective 4.

- To assess the existing status of the finned fishery together with the freshwater eel fisheries which depend on the estuaries for migratory purposes.

The present eel fishery proved difficult to estimate, but it seems likely that very few eels have been caught in recent years. The consensus amongst fishermen is that the reduced freshwater flows in recent years (Figure 3.15) has increased the salinity of the estuaries and thus does not attract the migrating eels into the estuaries.

The Wash is not a major fin–fishery, although it is of importance as a nursery area. Of particular importance is the availability of shallow, slightly brackish water over fine sediments (Riley, 1987). Freshwater abstraction would need to be very large to affect the salinity of the Wash as a whole and thus affect the nursery areas, but routine monitoring of the salinity at various sites in the Wash might be advisable.

The fish catches of the two estuaries were limited and no large catches of fish or shrimps was made during the course of the present study. Only towards the end of the study were more species recorded than on the Nene, possibly as a result of reduced freshwater flows. These estuaries are difficult to fish for scientific purposes, the Witham being particularly difficult because of frequent net damage from the large amounts of rubbish in the estuary.

9.5 Project Objective 5.

- To assess the possible ecological changes resulting from changes in freshwater flow.

Reductions in freshwater flow are likely to allow the extension upstream of marine species which are normally found further out into the Wash. More marine fish and shrimps were trawled in the last year of sampling in this project when freshwater flows were reduced. Although a more stable (and higher salinity) regime might increase the number of species in the estuary, the possible problems of lower DO levels due to the reduction in flushing rates are likely to have an adverse effect on the ecology of the region. Monitoring of DO and salinity levels, ideally from permanent monitors, is recommended.

9.6 Project Objective 6.

- To review water quality data collected by the NRA during the survey period.

Routine sampling at approximately monthly intervals was undertaken at several sites on the Welland and Witham. Samples were taken at high and low water because on the Nene study large tidal fluctuations in water quality, particularly dissolved oxygen, occurred. The water quality of the Welland and Witham was generally good compared with the Nene and no large tidal fluctuations were noted. Continuation of the high and low water sampling would be useful because if water quality fell, it would be likely to vary with the tidal state and may not be detected if sampling did not include all tidal states. Detection of trends in water quality would be improved if the data could be easily accessed and presented as a time series on a regular basis.

Sampling at present occurs in daylight hours, but in the summer when phytoplankton blooms occasionally occur, it is likely these blooms cause low levels of dissolved oxygen at night time. Some night-time monitoring of water quality, in particular dissolved oxygen levels and BOD, would be useful in the summer months.

9.7 Project Objective 7.

- To recommend water quality objectives and water quality criteria.
  see also the Water Quality Report in Part II.

The water quality of the Welland and Witham estuaries seems to be generally good. DO levels rarely fall below 60%. Regular sampling of sites at both high and low water produced very useful data, particularly when presented as a time series. The entrance to both estuaries seaward of Tabs Head appears to be unconstricted by sand banks, and this allows a free flow of water at all states of the tide. Dissolved oxygen levels were generally high and stable throughout the tidal cycle (in contrast to the Nene). Algal blooms in summer appear to be a problem in the upper section of both estuaries (particularly the Welland) and this is likely to lead to low levels of oxygen at night when blooms are present.

The entrance to the estuaries should remain clear and be checked *e.g.* aerial photographs at low water springs in summer. DO levels should be maintained above 60%. Monitoring over 24 hours should take place to see if levels fall at night in the summer.

9.8 Project Objective 8.

- To assess the suitability of using metal analysis of seaweed as an indicator of environmental contamination.

Finding suitable controls proved difficult as the only fucoid species found on the Witham and Welland (*Fucus vesiculosus*) tends to favour the harsh salinity regime of estuaries. On the coast, *F. spiralis* is generally found. However, one site was found with *F. vesiculosus* on an estuary with no obvious industrial or sewage input (Blyth, Suffolk) and samples from this site had very similar levels of metal contamination to those from the Welland and Witham.. This could possibly be used as a future control site, but other suitable controls site should be investigated.

Iron and manganese were high probably as a result of the high turbidity of these estuaries. The high levels of arsenic in the Tabs Head sample analysed by the NRA is likely to be an analytical error (B. Barnett, pers.comm.).

The results are consistent with estuaries in regions of relatively low industrial activity. However, the high levels of lead from the seaweed samples taken on the Witham should be investigated further.

As the Welland and Witham are the only Wash estuaries with a considerable covering of seaweed on the banks, regular sampling should be continued in February and September *i.e.* before and after seasonal growth (Barnett and Ashcroft, 1985).

9.9 Project Objective 9

- To provide guidance on a future monitoring programme.

see section 11.

10. QUALITY CONTROL

10.1 Introduction.

Strict quality control was maintained at all times. Pre-prepared labels were added to sediment and biological samples taken in the field. Duplicate numbers were printed on on prepared sheets and the site location and other details was recorded on site. Sample numbers were also written on the sample containers. Details of quality control procedures for each chapter are given below.

10.2 Sediment

Sediment analysis was undertaken by Dr John Pethick of Hull University.

10.2.1 Particle size analysis.

Since most estuarine sediments fall within the size range 1μ-500μ, particle size analysis for the samples was performed using laser diffraction sizing which allows complete size range determination using a single method. Where samples possessed grain sizes >500μ, a wet sieving procedure was used and results incorporated with those from the laser analysis.

Samples were stored in frozen state until immediately prior to analysis when they were removed to a cold room maintained at 2°C. Organic material was removed by oxidation using H_2O_2 solution (note this is not an analytical determination of organic matter). Samples were subsequently dispersed in water using sodium hexametaphosphate and agitated ultra-sonically for 30 seconds. Background determination of particles within the dispersant medium was performed routinely before each sample analysis.

Standard latex particles were used to calibrate the instruments. A range of such particles with known central tendency and variance was used to verify the particle distribution analysis.

10.2.2 Organic Carbon determination.

The method used was wet oxidation using potassium dichromate on an acid solution following the method of Tinsley (1950). Determination of organic carbon by weight was by titration against ammonium ferrous sulphate using diphenylamine as an indicator. Results were expressed as percentage organic carbon by weight.

10.3 Water Quality

Water quality measurements were taken by the NRA. Dissolved oxygen and salinity measurements were taken in the field. Other parameters were determined in the laboratory using their standard techniques.

10.4 Benthos, Plankton and Fish.

10.4.1 Benthos – Sorting Technique.

A combination of sieving at different mesh sizes (minimum mesh 500μm) and differential elutriation was employed to separate samples into more uniform size fractions. Each fraction was sorted in subdivided trays under low power stereo microscopes, with all 'countable' individuals being transferred to 70% alcohol. Generally, identification is carried out after the sample has been completely sorted and all countable individuals picked out (Morris, 1983, Holme & McIntyre, 1984, Baker & Wolfe 1987).

10.4.2 Benthos, plankton and fish taxonomy.

All specimens were identified to species where possible. Unicomarine maintain a comprehensive collection of identification keys, and appropriate taxonomic workshops are attended to ensure we remain up–to–date with changes in nomenclature. We maintain a reference collection of species identified from all samples analysed, to allow subsequent checking of identification if required. This collection currently contains nearly 800 species; a large proportion of the collection has been verified by appropriate experts at British Museums, and these are consulted if taxonomic problems arise.

Identified and counted specimens were stored in 70% IMS, in an appropriately sized and labelled glass vial.

10.5 Seaweed Analysis

The samples were prepared according to the technique used by the Humber Estuary Committee (Barnett & Ashcroft, 1985). Material was collected from just below the upper shore limit of the *Fucus* cover. Larger plants were selected (minimum 15 cm and generally > 20 cm) badlly damaged material or fronds heavily covered in epiphytic growth or sediment were rejected. The samples were prepared by cutting strips (5 mm wide) avoiding the bladders and new growth region. The samples were cut (using scissors only used for this purpose) directly into sample bags and delivered to the analyst. Sediment samples were also taken from the seaweed sampling sites and placed in clean glass jars and frozen. All samples were labelled both on the outside and inside of the bags or containers. All the samples were analysed by SAC laboratories., Dunton, Bedfordshire. At certain sites, two samples were taken and anaysed by separate laboratories (SAC, NRA) - see section 10 Quality control.

Laboratory analysis was undertaken according to techniques described in HMSO 1981 and HMSO 1985 (see reference section).

10.6 Shellfish Sanitary Quality

All analyses were commenced within 24 hours of collection and samples were analysed in order of collection to standardise the delay in analysis. During interim storage, samples were refrigerated at 4^{0} C.

The methods employed for thermotolerant coliforms (TTC ie *E. coli*) and faecal streptococci (FS) were those currently recommended by MAFF (West & Coleman, 1986; Eastbrook & West, 1987). For TTC's, the most probable number technique was used to give a counting range of 20–18000 per 100g wet weight of tissue (West & Coleman, 1986). Faecal streptococci were enumerated using the pour technique method (Eastbrook & West, 1987) to give a lower limit of detection of 300 faecal streptococci per 100g of tissue.

11. FUTURE WORK AND MONITORING

Project Objective 9. To provide guidance on a future monitoring programme.

11.1 Water Quality

11.1.1 Dissolved Oxygen

A large data base of useful water quality data was collected throughout the study. Water quality appears to be generally good, although little is known about the oxygen levels at night in summer months when algal blooms occur. It is difficult to compare the biology of the Wash estuaries without data from permanently mounted water quality monitors. Placing such monitors at at least two sites on each Wash estuary is recommended. Additionally, data from these monitors should be regularly assessed with reports on the water quality of the Wash estuaries produced on an annual basis.

11.1.2. Salinity

It would be useful to obtain long term salinity data throughout a year from several permanent monitors in all the Wash estuaries so that the salinity regime of each estuary could compared more effectively. Sites with similar salinity regimes could then be monitored biologically and this would provide valuable information about the comparative biological quality of the Wash estuaries.

11.2 Benthos

An annual benthos survey of a reduced number of sites on all the Wash estuaries, possibly combined with benthic sampling in the Wash, would provide a very useful comparison of the ecology of these estuaries. Annual reports on these benthic surveys are recommended, and these should ideally include analysis of the data from permanent water quality monitors.

The benthos at sites 16 and 17 (the sites with a sediment comprised largely of shell) should be investigated further to determine the extent to which fishermen riddling their catch in the area introduces species from the Wash. More effective ways of sampling the benthos at these sites should be investigated. It could be that such a species rich region so close to Boston STW could be useful as a monitoring site.

Site 15 should be investigated further. This site had a particularly poor benthic fauna. Possible causes are ***a***.; freshwater input from Hob Hole Drain reducing the salinity or affecting the water quality in other ways, ***b***; Mega ripple formation at this site, or ***c***; the proximity of Boston STW.

The upper region of both estuaries should be regularly photographed, or recorded on video, at low water spring in summer months in order to determine the extent of drying out in this region. It may be that the collapse of the benthic fauna populations from time to time in these upper regions could be explained by frequent drying out in summer months.

11.3 Push nets on banks

The push net sampling in summer 1991 indicated that the Welland and Witham were more species rich than the Nene. The survey in 1992 however, was less conclusive.

The technique of sampling at the banks using push nets provides useful information on the larger planktonic species that inhabit this area. The system has the benefit that the samples are relatively easily obtained and the analysis time for the samples is quite short. Push net surveys, in conjunction with the sub–tidal benthos surveys, would provide useful comparisons of the ecology of the Wash estuaries.

11.4 Algae

In view of the current concern with nutrients and algal blooms, regular monitoring of algae during summer months is recommended. If the JoNuS sampling continues, this would be an ideal source of phytoplankton samples from all the Wash estuaries. Algal samples could be analysed when super saturation of oxygen is noted. If regular JoNuS sampling does not continue, a series of surveys in summer months should be organised. Salinity and dissolved oxygen data should be collected at sites sampled for phytoplankton.

11.5 Seaweed – analysis of heavy metals.

The Welland and Witham are the only Wash estuaries with a considerable covering of seaweed on the training walls. Sampling for metal contamination of seaweed would provide useful information on the metal contamination of these estuaries. The high levels of lead from the seaweed samples taken on the Witham should be investigated further. Sampling should be undertaken in February and September *i.e.* before and after seasonal growth (Barnett and Ashcroft, 1985). Other possible sources of control material need to be investigated in order to provide sufficient comparison data.

11.6 Shellfish

The shellfishery of the Wash is generally unstable. ESFJC feel that a more controlled approach with regular seeding of mussel beds with spat would provide stable shellfishery and it would be useful to review their work on a regular basis and consider if the NRA could usefully contribute to this research.

The sanitary quality surveys of the mussel beds by Unicomarine and Boston Borough Council gave conflicting results. The recent MAFF designations, largely based on Boston

Borough Council data, has cleared the beds on the Boston side with a B grading *i.e.* they do not require relaying but are suitable for human consumption after depuration. These conflicting results should be investigated further in order to provide accurate information for designation purposes.

Regular sampling of mussel beds throughout the Wash would be useful (*e.g.* spring and autumn equinox). It was interesting that during the survey of September 1989, the mussel beds on the Welland were more contaminated than those on the Witham. In view of the proximity of the Witham training wall mussels to Boston STW, this should be investigated further. The possible public health problem of the collection of large numbers of contaminated mussels from the training walls should also be considered.

12. REFERENCES

Baker, J. M. and Wolff, W.J. (1987) Biological surveys of estuaries and coasts, Estuarine and Brackish-Water sciences association Handbook. CUP

Barnett, B.E. (1983) Oligochaetes as Indicators of Pollution in the Humber Estuary, with Special Reference to Tubificoides benedeni. Environmental Pollution Series A 30, 277-291.

Barnett, B. E .and Ashcroft,C.R. (1985) Heavy Metals in Fucus vesiculosus in the Humber Estuary, Environmental Pollution, Series B, 9, 193-213.

Barnett, B.E .and Pearson, M. J. (1982) Cluster Analysis. An Explanatory Guide for Use with a Computer Program. Anglian Water Internal Guide.

Brinkhurst,R.O. (1982) British and Other Marine and Estuarine Oligochaetes, CUP pp 127.

Dyer, M.F. and Grist, N.C. (1986) The Great Ouse Estuary Ecological Study, Volume II, Biological Surveys. Anglian Water 1986.

Dyer, M.F. and Grist, N.C. (1989a) The Nene Estuary Ecological Study, Anglian Water 1989.

Dyer, M.F. and Grist, N.C. (1989b) A preliminary survey of the Welland and Witham Estuaries, Anglian Water, 1989.

Dyer, M.F. and Grist, N.C. (1991) Biological Survey of the Nene Estuary - 1990. Report to NRA

Eastbrook, T.J. and West, P.A. (1987). Comparison of most probable number and pour plate procedures for isolation and enumeration of sulphite reducing *Clostridium* spores and Group D faecal streptococci from Oysters, Journal of Applied Bacteriology, 62, 413-419.

ESFJC (1989) Eastern Sea Fisheries Joint Committee Report 1989

ESFJC (1990) Eastern Sea Fisheries Joint Committee Report 1990

ESFJC (1991) Eastern Sea Fisheries Joint Committee Report 1991

Field J.G . and McFarlane, G. (1968). Numerical methods in marine ecology. 1. A quantitative 'similarity'analysis of rocky shore samples in False Bay, South Africa, Zoologica Africana 3, 119-137.

Gould, D.J., Dyer, M.F. and Tester, D.J.(1986). The Great Ouse Ecological Study. Wat. Pollut. Control, 1986,1; 84–103.

Holme N. A. and McIntyre A.D. (1984) Methods for the study of Marine Benthos, IPB handbook No.16, second edition. Blackwell, Oxford.

HMSO (1981) Cadmium, Chromium, Copper, Lead, Nickel and Zinc in Sewage Sludges by Atomic Absorption Spectophotometry following Digestion with Nitric Acid 1981. Methods for the Examination of Waters and Associated Materials.

HMSO 1985. Mercury in Waters, Effluents, Soils and Sediments etc additional methods 1985. Methods for the Examination of Waters and Associated Materials.

Lance, G.N. and Williams,W.T. (1967) A general theory of classification sorting strategies, 1. Hierarchical systems. Computer Journal 9, 373–380.

MAFF (1992) EC Directive 91/492/EEC: Classification of shellfish harvesting areas in England and Wales. July 10 1992.

Morris, A.W. (1983) Practical Procedures for Estuarine Studies. Institute of Marine Environmental Research.

NERC (1976). The Wash storage scheme feasibility study. A report on the ecological studies. NERC publication series C No.15.

Pearson, T.H. & Rosenberg, R (1978) Macrobenthic succession in relation to organic enrichment and pollution of the marine environment Oceanog.Mar.Biol.Ann.Rev. 16, 229–311.

Riley, J. (1987) The role of the Wash in the biology of the North Sea Fish Stocks (Abstract). In Research & Survey in Nature Conservation, No 7, The Wash and its environment. Nature Conservancy Council

Tinsley, J. (1950) The determination of organic carbon by dichromate mixtures, Trans 4th Int. Congr. Soil Sci 1, pp 161–164.

West, P.A. and Coleman, M.R. (1986) A tentative national reference procedure for isolation and enumeration of *E coli* from bivalve molluscan shellfish by most–probable number method, Journal of Applied Microbiology, 61, 505–516.

PART II

WATER QUALITY IN THE WELLAND AND WITHAM ESTUARIES 1989 - 92

CONTENTS

LIST OF APPENDICES FOR WELLAND-WITHAM QUALITY REPORT

b) Water Quality in the Upper Witham Estuary at Boston Swing Bridge (Low Water). Statistical summaries for 1989, '90, '91 and '92

9. a) Water Quality in the Lower Witham Estuary at Cut End (High Water). Statistical summaries for 1989, '90, '91 and '92

b) Water Quality in the Lower Witham Estuary at Cut End (Low Water). Statistical summaries for 1989, '90, '91 and '92

WELLAND AND WITHAM ESTUARIES
1989 - 92

Preliminary Remarks

Previous reports on the other Wash estuaries have considered only a single estuary/river system. This report differs from these earlier reports in dealing simultaneously with two estuaries. There are therefore two options for the structure/format of this report:

1. Examine all aspects of each river system separately.

2. Consider each aspect under a topic heading (eg. freshwater inputs, sewage discharges etc.), examining each river system in turn.

There are merits to each approach, but on balance the second approach seems preferable since the study is not so much focused on two separate river systems as a dual input to the Wash. This also facilitates a more direct comparison of the different aspects and thus enables the relative contributions of each system to the overall quality conditions.

Throughout the report it is pertinent to bear in mind that the period covered has been exceptional in terms of low rainfall. River flows have therefore been unusually low – of the order of 50% of annual average flow for the previous decade. (In the case of the Welland, flows have probably been nearer to 30% of average).

1. INTRODUCTION

1.1 Catchments

Both river catchments (tidal and non-tidal) are substantially rural with no major conurbations and few of appreciable size. Both catchments are predominantly agricultural and therefore diffuse sources of contamination through run-off are likely to be appreciable. Industrial activity is largely allied to the agricultural economy of the hinterland with no significant chemical industry present. Consequently there is a contrast at least with the Ouse estuary and quality problems are appreciably different from those in the Humber, to the North. (Inputs are discussed in section 4). The entire catchment areas are illustrated in fig. 1.1 (ch. 1) and further description of the catchments is given in chapter 1.

Both estuaries are effectively canalised with resultant influences on hydrography and sediment dynamics, although in this respect they are very similar to the Ouse and Nene. Whilst both are navigable throughout the tidal sections, shipping movements are far greater on the Witham with the thriving commercial activity at Boston Docks. Fishing, and to a lesser extent leisure traffic, are also predominantly based at Boston. In this respect the Witham Estuary is probably more comparable with the Ouse, whilst the Welland is more similar to the Nene. However, the extent to which this impinges on water quality is generally uncertain.

1.2 Flows

The location of flow gauges on the respective river systems is such as to preclude accurate assessment of the freshwater flows into each of the tidal sections. In general, mean annual flow in the non-tidal Welland is of the order of 5 cumecs whilst that in the Witham is approx. 12.5 cumecs. The freshwater inputs to the tidal Welland increase the estimated flow to the Wash to approximately 7.5 cumecs, whilst the somewhat larger inputs to the Witham increase the estimated freshwater flow from this estuary to almost 20 cumecs. Thus the total freshwater flow from the combined Welland-Witham system is around 27 cumecs. This contrasts with a flow of almost 40 cumecs for the Ouse Estuary (Tester, 1986) and 14 cumecs in the Nene.

However, throughout the study period flows have been exceptionally low, being about half, or less than half, of those throughout the preceding decade.

1.3 Bacteriological quality

Bacteriological quality is not determined for any effluent, freshwater input, or in the estuaries themselves. It is therefore not possible to consider this aspect in the sections below. However, it may be noted that in the preliminary classifications of nearby shellfish beds as established under the shellfish hygiene directive, all were designated class B (<6,000 total coliforms but > 300/100g flesh).

Since these beds are all located beyond the mouth of the estuaries a significant bacterial loading is indicated.

This aspect of environmental quality was addressed during the study and the findings considered in chapter 8.

2. <u>FRESHWATER INPUTS</u>

Both estuaries are relatively short in length and consequently there are relatively few freshwater inputs to either. The location of the main freshwater inputs is shown on the Catchment area map - figure 1.1 (ch. 1), and other freshwater inputs are shown on the inputs maps - figures X.1 and X.2.

2.1 Welland

The main input is from the non-tidal Welland via the Coronation Channel. The only other significant freshwater inputs[1] are from the River Glen, the Drove drains, via Vernatt's drain and the Holbeach river. The flow in the latter is mainly derived from an industrial discharge (see industrial discharges, section 4).

Quality conditions for the non-tidal Welland entering the estuary are generally good. The river achieved a 1B classification in the 1990 river quality survey. Data from the harmonised monitoring point at Crowland Bridge (approximately 15 km upstream of the tidal limit) is presented in Appendix 1. For the three year period to the end of 1991 the mean dissolved oxygen was in excess of 100%. The maximum BOD (+ATU) for the same period was 14mg/1 with a mean of approximately 3mg/l.

An extensive range of possible contaminants has been analysed for during the study period although many determinands have only been included infrequently. The vast majority of pesticides were not present at detectable levels, although it may be noted that HCH was consistently present (mean around 10ng/l maximum, 30ng/l), as were the herbicides Atrazine and Simazine.

The River Glen enters the estuary at Surfleet Sluice, about 5km below the tidal limit. It was designated class 2 in the 1990 RQS. (Sewage from Bourne STW, and effluent from a food processing plant enter the upper reaches of the system). During the summer months there is virtually no flow into the estuary due to low rainfall and high demand for spray irrigation. At other times of year the flow and quality are such as to have only minor influences on quality within the estuary.

Flows from the other freshwater inputs are relatively small, and water quality is satisfactory, so that they exert no significant impact on the overall quality of the estuary.

2.2 Witham

As with the Welland, the main freshwater input is from the non-tidal river. There are additional inputs from the South Forty Foot, Maud Foster and Hobhole drains. With the exception of certain industrial discharges, which are discussed below, these drains carry water of a satisfactory quality, and do not exert any appreciable influence on the general quality of the estuary.

The Section of the non-tidal Witham entering the estuary was designated Class 2 in the 1990 RQS. Data for the harmonised monitoring point at Langrick Bridge (approximately 7km upstream of the tidal limit) is presented in Appendix 2.

[1] There are minor inputs of freshwater from the Welland through Spalding (Fulney Lock), Lords DFrain and Five Towns Drain but these are extremely small and often negligible in summer.

For the three year period to the end of the 1991 the mean dissolved oxygen concentration was in excess of 100%. The maximum BOD (+ ATU) for the same period was 11.9mg/l with a mean of around 4mg/l. (High BOD values are invariably associated with algal activity rather than contaminant input). For other contaminants the position is also very similar to that observed for the Welland, with HCH, Simazine and Atrazine being the only pesticides detected with any regularity. Levels of HCH were slightly higher than those for the Welland samples (mean approximately 17ng/l, maximum, 46ng/l). During the study period there have been occasional high levels of some heavy metals at the Witham sampling point. In 1989 the maximum for copper was 160 (mean 17.9) ug/l: for zinc 409 (mean 41) ug/l: and for nickel 40 (mean 7.5) ug/l. In 1990 the maximum for all three metals were less than the means for the previous year, but in 1991 the maximum value for nickel was 87 (mean 18)ug/l and a value of 52 (mean 11.9)ug/l was reported for zinc. It is always tempting to consider such results as anomalies (due to analytical peculiarities) but is perhaps curious that the same phenomenon is not apparent in the data from the Welland sample point. There is no obvious explanation for such a finding which clearly merits further investigation, but there is a suggestion that there may occasionally be higher inputs of metals from the non–tidal Witham, than is the case for the Welland.

Of the drains which enter the estuarine Witham (the Haven) the Hobhole and Maud Foster were both designated Class 2 in the 1990 RQS and the South Forty Foot achieved class 1B. Under normal flow conditions these drains make a significant contribution of water to the estuary. All three together are estimated to contribute slightly more than half of the flow derived from the non–tidal Witham.

However, since the Maud Foster and the South Forty foot enter the Haven only a short distance below the tidal limit, and carry water of similar (or better) quality it is reasonable to consider that they do not appreciably influence quality conditions in the upper reaches of the estuary.

The Hobhole drain discharges much closer to the seaward end of the Haven. It generally carries water of reasonable quality and would be unlikely to have any appreciable influence on the overall quality of the estuary. The salinity DO and BOD results presented in chapter 3 appear to confirm this view. (Depressions in salinity at Cut End sample point do occasionally occur in winter months even at high water – fig 3.6, which may reflect proximity to the Hobhole discharge. However, the DO and BOD results illustrated in the same figure do not suggest any particular changes in water quality associated with the reduction in salinity).

As stated previously, it should be recalled that freshwater flows have been particularly low throughout the study period and inputs from all fluvial sources are likely to have been affected accordingly. Indeed, in the case of the Hobhole, the major quality problem, during the study period, has been saline ingress from the tidal Witham rather than any influence of the drain on the estuary.

3. INPUTS FROM SEWAGE DISCHARGES

Essentially there is one significant sewage discharge to each estuary. Both are of similar size, and comply with consent conditions. The main difference is that on the Welland, the discharge (Spalding) is to the head of the estuary, whilst the discharge to the Witham (Boston) is approximately half way down the estuary.

3.1 Welland

Spalding STW is the only sewage discharge to the Welland estuary.
The works was substantially up–graded in the later seventies to include primary settlement and two–stage filtration with FLOCOR TOWERS. At that time the waste from the nearby British Sugar Corporation plant was accommodated, but the factory subsequently closed in early 1989. Whilst this reduction in influent load did produce some improvement in overall effluent quality it also caused the works to operate at significantly less than design capacity.

The works is consented for both treated effluent and storm overflows. A limit of 15,720m^3/d of treated sewage containing not more that 120mg/l of suspended solids, and 60mg/l BOD (+ATU) was issued in 1988. (Storm sewage has a consent limit of 200mg/l suspended solids). Throughout the study period the plant has generally operated well within the limits. Annual average results for BOD and suspended solids have been consistent at around 25mg/l and 34mg/l respectively.

There is no consent limit for ammonia, which is also consistent in terms of the annual average value, at a concentration of around 13mg/l. The latter represents a significant input of ammonia to the tidal Welland, even though mean annual flows have not exceeded half of the consent figure. Effluent characteristics for each year of the study are included in Appendix 3.

The location of the discharge is shown in figure X.1.

Observations at the routine monitoring point downstream of the works (Pinchbeck) suggests that the works has had no major impact on the upper estuary, throughout the study period.

3.2 Witham

Boston STW is the only major sewage discharge to the estuary. (There are a number of insignificant discharges of crude sewage from domestic sources which have minimal impact on water quality and will shortly be eradicated). The works has a consent to discharge up to 10,000m^3 day (DWF) of fully treated sewage effluent with a limit of 70mg/l suspended solids and 35mg/l BOD (+ATU). It is a relatively modern works constructed in ca 1978, and performs well. On average it achieves an effluent with about half the permitted levels of solids and BOD, and has rarely exceeded either of the consent values on any single occasion. Effluent characteristics are summarised for each year of the study period in Appendix 4.

In addition to the works itself there are five pumping stations which occasionally give rise to storm overflow discharges. The location of these is shown in figure X.2 together with other inputs (both sewage and industrial). The discharges from each of the storm overflows can be summarised as follows:

a) South Terrace: Up to $100m^3/d$ of surface water only
b) Norfolk Street: Operates only when flow in sewer exceeds 50 l/s
c) Lincoln Lane: Emergency overflow when flow in sewer exceeds 300 l/s (or during electrical/mechanical failure).
d) London Road: Occasional problems with pump cut out when flow exceeds normal pump capacity.
e) East Side: Operates frequently during flash floods.

It can be reasonably assumed that none of these overflows will have operated more than a dozen times during the course of the study, largely as a result of the exceptionally low rainfall during the period. At such times the total freshwater flow is usually so great that no water quality problems arise, although the storm discharges do impinge on aesthetic quality.

4. INDUSTRIAL INPUTS

4.1 Introduction

As indicated in the general introduction (Section 1) there are very few industrial inputs to either estuary. In fact, during the study period there were only two direct discharges (both to the Witham Haven) and both have now ceased. However, for completeness certain indirect (including some above the tidal limits), and other inputs need to be considered in this context.

4.2 Welland Estuary

There are by strict definition no direct effluent discharges to the Welland estuary. However, for practical purposes the effluent from Tinsleys (food processing) which discharges to the Holbeach river prior to the point at which the latter enters the tidal Welland is considered here. Also whilst not a discharge in the conventional sense, it is appropriate to include remarks on quay cleaning activities at Fosdyke bridge, which initially gave rise to some concern during the course of the study. There is also a discharge of surface water only from the British Sugar Company's premises at Spalding.

The locations of all inputs are shown in figure X.1.

4.2.1 Tinsley's Discharge

This vegetable washing and food processing effluent enters the Holbeach river a short distance above it's confluence with the tidal Welland. Since the discharge comprises the vast majority of the flow at this point it is generally utilised as a substitute sampling point for the Holbeach river (see comment in section 2). In 1989 the consented maxima for this discharge were 75mg/l BOD for a flow of 8,000m^3/d. Throughout the study period the discharge consistently failed to meet these conditions and consequently the quality of the water entering the Welland was extremely poor. Typical water quality throughout the study period was a dissolved oxygen concentration of 20 to 30% saturation, and BOD in the range of 150 to 400mg/l. Suspended solid concentrations are variable with a mean value of around 100mg/l, although in 1990 the average was over 200mg/l.

From the end of the study period a revised consent was issued which permits a maximum flow of 1,310m^3/d with a BOD limit of 400mg/l, and installing a suspended solids limit of 100mg/l. These consent conditions apply until September 1993, during which time the company will be installing extensive treatment facilities. From October 1993 a limit of 20mg/l BOD (+ATU) and 50mg/l suspended solids will be enforced. Substantial improvements in water quality in the adjacent water courses should ensue.

4.2.2 Fosdyke Port

Quay cleaning operations following unloading of fertilizer resulted in the washing of ammonia into the Welland at this location. However, calculations showed the input was only around 3% of the load from Spalding works and therefore negligible. Since 1990 the washing procedure has been largely replaced by sweeping dry matter up and removing from the quay.

4.3 Witham Haven

During the study period there were two relatively small direct inputs from food processing plants. Water returned to the Haven from a mussel cleansing plant is more aptly described as process water rather than effluent. Of greater concern are the inputs of contaminated surface water from two timber treatment plants, although one of these enters the non-tidal system, rather than the Haven itself. For location of inputs see Figure X.2.

4.3.1 Swel Foods

This company had operated a food processing plant discharging in the upper reaches of the Haven since 1941. Principal operations concerned production of dried foods (meat, vegetables etc.) which yielded a somewhat variable effluent. Occasional high BOD's were recorded (>1,000mg/l), but the discharge was of relatively small volume (up to 250m^3/d) and exerted little impact on the estuary.

From 1987 the discharge operated under an Exemption Order with a period of up to five years being allowed for the implementation of an appropriate Consent. For a variety of reasons the Company has now closed, and the discharge ceased in Spring of 1992.

4.3.2 Van Smirren Seafoods

This company has operated a shellfish processing and bottling plant since 1958. The effluent is comparatively innocuous, and with a flow of less than 100m^3/d had a virtually a negligible impact on the quality of the Haven. As in the case of SWEL Foods, above, the discharge was the subject of an Exemption Order.

Following discussions on proposed consent conditions, the company elected to connect to the foul sewer, and accordingly the discharge to the Haven ceased in October 1992.

The results from sampling at Boston swing bridge show no particular problems with dissolved oxygen or BOD, as discussed in chapter 3, which supports the conclusion that neither of the above discharges exerted any appreciable influence on water quality in the Haven.

4.3.3 Boston Fisherman's Co–operative

This organisation operates a mussel cleansing plant on the lower Haven. Mussel cleansing should not be confused with shellfish processing. The basic principle is that water is withdrawn from the Haven, purified and then used to store live mussels so that they can discharge any bacterial contamination from their digestive tracts. Water discharged at the end of the process is arguably cleaner than that originally withdrawn from the Haven. The operation involves a flow of the order of 75m^3/d and has no influence on water quality in the Haven.

4.3.4 Hunter Timber Engineering

The company occupies a particularly low–lying site off Fishtoft Road, on the seaward (downstream) outskirts of Boston. A variety of timber treatment processes have been deployed on the site over a number of years. Historically, dieldrin was used as a preservative, and more recently 'Protim' (principle constituents include PCP and Lindane) has been used. In addition, the company operate a 'tanalith' plant which utilises salts of copper, chromium and arsenic. These various processes with minor spillages and a significant spillage of Protim in 1989, have resulted in significant contamination of land on the site, which in turn has resulted in the presence of contaminated surface water.

Drainage from the site can only be effected by the Company's own pumped discharge system. Since the incident in March 1989 no discharge has been allowed, and a consent application in 1991 was refused. To the Company's good fortune, low rainfall during the study period avoided the necessity to discharge.

Throughout the period, negotiations between the NRA and the company have continued. Comparatively heavy rainfall since completion of the study has prompted remedial action by the company. Following the implementation of measures to prevent further spillages, and removal of contaminated land, it is expected that a consent with limits, based on 3 times the estuarine EQS will be granted later in 1993.

4.3.5 Calders and Granidge

The company occupies an extensive (14 acre) site off London Road, Boston and has conducted a variety of timber treatment processes for about 100 years. There is no trade effluent discharge from the site, but contaminated surface water drainage percolates into the London Road Dyke and hence to the South Forty Foot Drain. (Approximately 2 km upstream of the confluence with the Haven). Dieldrin and Lindane have been consistently present in the site drainage, although the most frequent cause of complaints has been the visible presence of creosote.

The Company has now embarked on an extensive modernisation and clean up programme including removal of contaminated land. At the insistence of the NRA full treatment of the contaminated surface water will be introduced. A specialised treatment plant designed to ensure that the freshwater EQS is met in the receiving watercourse should be operational by October 1993.

As previously stated, rainfall throughout the study period has been unusually low and it is therefore possible that leaching from the site has not been typical during the study. Results from the routine monitoring point at Boston swing bridge are particularly pertinent to this input: See section 5.

4.3.6 Slippery Gowt Landfill Site

The extent to which this should be regarded as an input is uncertain. The site is owned and operated by Lincolnshire County Council. Little is known of the fate of incident rainfall or leachate. The site operates on the "dilute and disperse" principle. The operators have been asked to provide sufficient information to determine the fate of liquid percolating through the site, which is adjacent to the Witham Haven. It is most likely that the IDB drainage system will influence groundwater/leachate levels within the site. In the past difficulty has been experienced in this system but on each occasion specific pollution incidents have been identified.

5. ESTUARINE WATER QUALITY

5.1 Introduction

Quality monitoring throughout the study period has undergone substantial changes, particularly with respect to the variety of determinands involved. In addition, the frequency of analysis for many determinands has differed from year to year. These variations are largely a consequence of the requirements of red-list screening and monitoring, but the net result of this is to render averages for the entire study period invalid. Data is therefore presented for each year separately. The whole of 1989 is included although the study did not commence until the later half of the year. Such an approach is deemed appropriate for two reasons:

i) Water quality prior to commencement of the study clearly has a potential influence on ambient conditions at the time the study began.

ii) There is appreciably less (quantity and variety of) data for 1989 than subsequent years.

Data for 1992 is only considered to the end of the study period (taken as August 1992), not for the whole year, since neither of the arguments above apply.

It also seems appropriate to examine water quality on a year by year basis in view of possible changes which may have taken place during the study period, bearing in mind the changes in inputs as considered in the preceding sections, and the likely decline in freshwater flows. Statistical summary reports for each sample point, for each year are included as appendices. In view of the limited number of sampling points it is not feasible to produce contaminant profiles for either estuary. Spatial comparisons for all but the most basic parameters are further constrained by the variations in the range of determinands and associated sampling frequencies at different sample points. Similar considerations apply in attempting to draw comparisons with published information on other estuaries. (Comparison with The Gt. Ouse report is limited by: 1) The situation described relates to conditions as they were almost a decade ago; 2) Many determinands currently analysed for were not monitored at that time and; 3) For all but the most routine determinands analytical techniques have advanced enormously).

However, some comparison with data from recent Humber Estuary Committee reports is possible.

It follows from some of the remarks above that, given the extensive range or determinands which have been investigated (up to 100 at some sites), it is impractical to review all the data available. Attention is therefore confined to certain key measures of water quality and substances which have been recorded at levels which merit consideration. (Information for other determinands is available from the appendices).

5.2 Welland Estuary

5.2.1 Introduction

The data for the Welland Estuary is somewhat limited. Three sample points were established specifically for the purposes of the study. (For locations and names refer to fig. 3.1, chapter 3). Sampling was conducted at high and low water approximately six times per year, although in 1989 these sites were only sampled once. Only basic routine determinands were measured (D.O., BOD etc.)

Some additional information is available from the routine monitoring point at Fosdyke Bridge. This site is coincident with the middle one of the three referred to above, but not sampled at a consistent tidal state. It has however been sampled more often (approximately monthly), and for a wider range of determinands.

5.2.2 Principal Quality descriptors

Dissolved oxygen and BOD have already been considered in chapter 3. Since this chapter also includes data from special surveys and additional sources, little further comment is required here. The data from the routine monitoring point at Fosdyke Bridge are consistent with those reported in chapter 3. (A slightly higher maximum DO - 156% in 1991 was recorded, and a BOD maximum of 35 mg/l in 1992 is appreciably higher than the highest value shown in fig. 3.3).

As suggested in chapter 3, there are distinct indications from DO/BOD results of algal blooms in the estuary, which in turn might infer some element of eutrophication. It is interesting in this context that both the DO profile (fig 3.10) and to a lesser extent figs 3.2 to 3.4 show a tendency for D.O to be lower at high water than at low water at least in the upper estuary. Diurnal variations may in part account for this, but, it can also be interpreted as indication that supersaturated water is entering from the freshwater end of the system rather than the seaward end of the estuary. This interpretation is consistent with the observations on freshwater inputs (see section 2.1).

It therefore follows that inferences of eutrophication are associated with the freshwater rather than the marine environment.

Ammonia is the only other principal determinand not previously considered. The average concentration in the non-tidal Welland above Spalding, for the study period was approximately 0.11mg/l. For the nearest equivalent period, corresponding values at the estuary sampling points were: Pinchbeck 1.75mg/l; Fosdyke bridge 0.49mg/l; Moulton Marsh 0.45mg/l. Whilst there is some variability in results the pattern is consistent from year to year, and ostensibly the same for both high and low water sampling. The figures appear to demonstrate an input of ammonia in the upper reaches of the estuary presumably from Spalding works.

Any trend or year on year changes can not be ascertained with any confidence from the study sampling points. The data from the routine monitoring point at Fosdyke is very consistent throughout the period (annual mean 0.59 ± 0.04).

5.2.3 Other determinands

Results for other determinands (metals and organic compounds) are only available for the routine monitoring at Fosdyke Bridge. The range and frequency of analyses only extended in the latter half of the study period. It would therefore be unwise in the extreme to attempt to make any assessment of the estuary as a whole. A few observations relating to results from the one site are offered below.

Amongst the metals copper and zinc are to different degrees conspicuous. In 1989 the annual average for dissolved copper was 5.75ug/l (4 values), which just exceeds the estuary EQS (5.0ug/l). In 1990 the average of 9 results was 2.96ug/l, but for 1991 the annual average was 6.8ug/l, with a maximum value of 29ug/l. The average from the 5 values to Aug '92 was 7.12 ug/l (maximum 16.0). Clearly the margin above the EQS is quite small, and, as in the Humber it is likely that a substantial proportion of the Cu will be complexed. The EQS is therefore in reality almost certain not to have been exceeded, but it is perhaps surprising that it should even appear to be so since there are no inputs of copper.

The annual average concentration of dissolved zinc in 1989 is recorded as 13ug/l (max 17). The average for 1990 was 6.6 ug/l (max 16), but for 1991 the average value was 18ug/l (max 71). Results for 1992 are broadly similar to 1989–90. The average values are comfortably below the estuarine EQS (40 ug/l), but, as with copper, are perhaps higher than expected. (For comparison, it may be noted that average concentrations for different sites in the Humber in 1991 ranged from 7.4 ug/l at Spurn to 29.6 ug/l at Hull). It is somewhat surprising that the average for Fosdyke Bridge in 1991 should be around the mid-range for Humber sites, given the colossal load into the Humber!

From these observations it is suggested that monitoring effort should be increased, and if further elevated levels are detected investigation of potential sources will be required.

The only other result of possible interest was the (first) single value for HCH in 1990. A concentration of 18.6 ng/l was close to the estuarine EQS (20 ng/l), but subsequent analyses have been around half this value, or less.

Statistical summary reports for all determinands for each of the relevant sampling points are presented for each year/period of the study, as Appendices 5 to 7.

5.3 Witham Estuary

5.3.1 Introduction

The two routine monitoring points on the Haven have been sampled at monthly intervals throughout the study. (For names and locations see figure 3.1, chapter 3). Samples were collected at high and low water slack, and analysed for a wide variety of determinands. As discussed in the introduction to this section the range of determinands and associated frequency of analysis has changed appreciably during the course of the study. In some cases there have also been changes in analytical methods, and also changes in emphasis. The latter is most evident in the case of metals data, which in 1989 relates only to "total metals," whilst the most recent results are almost exclusively for "dissolved metals". Such considerations create complications and demand caution in the interpretation of the available data.

It should also be recognised that with only two sample points it is extremely difficult to draw inferences with respect to water movements and inputs. It is already apparent from the data illustrated in chapter 3 that, unlike the tidal Welland, the Witham does not show a very clear distinction between high water and low water. (Comparison of the salinity curves in fig's 3.11 and 3.10 illustrates this point clearly, but inspection of fig's 3.2 to 3.5 endorses the conclusion on a broader basis of data).

The detailed plots of D.O and BOD (fig's 3.5 and 3.6) certainly show no clear or consistent difference between quality conditions for high and low water.

Furthermore, whilst a detailed evaluation of salinity data has not been possible (additional data and a simple computer model would probably be required), there are indications that samples at Swing Bridge HW relate to the same body of water as those at Cut End LW.

This possibility is supported by examination of the data in Table A, below, which shows annual average dissolved oxygen for the non-tidal Witham at each of the sample points for each year of the study (1992 to August only).

TABLE A: ANNUAL AVERAGE DISSOLVED OXYGEN % IN WITHAM SYSTEM 1989 - 92

Year	non-tidal.Witham (Langrick Bridge)	Swing Bridge	Cut End	Tidal State
1989	120	94.6	88.6	H
		85.4	83.1	L
1990	106	91.6	90.5	H
		85.5	90.4	L
1991	103	86.2	94.1	H
		82.2	85.6	L
1992	117	95.5	103.0	H
		105.0	93.5	L

The matrix offers only a very crude framework for assessment, but apart from the 1989 figures, there is a clear suggestion that results for Swing Bridge (HW) and Cut End (LW) match quite well.

Thus, any simplistic assumptions or interpretations of the data should be avoided.

5.3.2 Principal Water Quality Descriptors

As with the Welland, dissolved oxygen and BOD have already been considered in chapter 3 (and to some extent in the introduction above). It is therefore unnecessary to add more than a brief comment. Figures 3.5 and 3.6 show occasional instances of supersaturation, predominantly in the summer months. Although considerably less marked than in the Welland, these peak levels of DO presumably also indicate algal activity. Whilst supersaturated water is evident in the non-tidal river (see Table A) the highest values in the estuary are primarily associated with high water samples. This tends to indicate marine algal activity was responsible, and contrasts with the situation in the Welland in this respect.

As in section 5.2 ammonia results may merit examination. The average concentrations for the study period (as previously defined) are summarised in Table B, below.

TABLE B: AVERAGE CONCENTRATIONS OF NH_3 N (mg/l) IN THE WITHAM SYSTEM

Non-tidal.Witham (Langrick Bridge)	Swing Bridge	Cut End	
	0.355	0.155	HW
0.2	0.370	0.303	LW

Ammonia levels are clearly enhanced at the swing bridge sample point, suggesting some input to the Haven. However, all the values are relatively low and appreciably less than those recorded for the Welland, (see section 5.2.2). They are also, comparable with levels reported for the Great Ouse (Tester, 1986).

5.3.3 Other determinands

From the wide range of determinands analysed the results indicated that copper, zinc and HCH merited closer inspection, which fortuitously coincides with the other determinands discussed for the Welland estuary. Annual average values for each year of the study, at each sampling point (including the non-tidal Witham) are shown in Table C. The table helps to illustrate the points raised earlier with respect to differing frequencies of analysis for different determinands with some sites having no data for some years. It must also be repeated that in a number of cases the values are based on a very small number of analyses and sometimes produced by different analytical methods, even at different sites in the same year. Such considerations may be involved in explaining certain peculiarities in the data. For instance Cut End (HW) had the lowest mean value for dissolved copper in 1990, whilst the same site has the highest value in 1992. Although the influence of previously mentioned factors on this pattern is purely speculative, it serves to emphasise that considerable caution should be applied when attempting any detailed appraisal of the data. Indeed, it may be inadvisable to attempt to scrutinise the data in too much detail, and the following discussion is therefore confined to more general observations.

TABLE C CONCENTRATIONS OF HCH, COPPER AND ZINC IN WITHAM HAVEN (1989–92)

HCH ng/l

	L.B.	S.B.	C.E.	Tide
1989	17.8	38.5	N.D	H
		16.5	16.5	L
1990	19.8	–	–	H
		–	8.8	L
1991	13.7	6.8	4.2	H
		25.1	10.1	L
1992	10.0	–	4.2	H
		–	7.0	L

Cu ug/l

	L.B.	S.B.	C.E.	Tide
1989	17.9	19.9	0.3	H
		9.3	0.3	L
1990	2.2	33.7 **4.1**	3.7 **3.5**	H
		23.0 **14.9**	5.4 **3.7**	L
1991	4.8, 5.2	– **4.7**	– **6.4**	H
		3.7 **7.5**	– **11.6**	L
1992	3.9, 3.6	5.5 **5.2**	– **6.7**	H
		8.5 **3.3**	6.6 **5.7**	L

Zn ug/l

	L.B.	S.B.	C.E.	Tide
1989	41.5	20.4	2.9	H
		13.5	7.4	L
1990		16.6 **12.3**	12.6 **9.9**	H
		25.0 **24.0**	10.3 **13.3**	L
1991	11.9, 8.1	– **7.8**	– **12.8**	H
		10.4 **10.6**	– **19.5**	L
1992	7.4, 3.6	8.6 **10.9**	– **11.0**	H
		8.1 **9.8**	12.0 **11.2**	L

– Not analysed for ND: Not Detected **No: Dissolved Concentrations**
LB: Langrick Bridge SB: Swing Bridge CE: Cut End
H: High Water L: Low Water

HCH exceeds the estuarine EQS (20ng/l) at Swing Bridge, in both 1989 and 1991, although at different states of the tide. (It may further be noted that the 1989 figure is the mean of only 2 results). With the benefit of hindsight it is perhaps surprising and disappointing that more analyses were not conducted in 1990 and 1992. It is apparent that particularly in the earlier years the concentration of HCH in the non-tidal Witham was approaching the EQS (for estuarine water) and therefore relatively little additional input to the estuary would be required to cause exceedance. Whilst the data is somewhat limited it seems more than likely that the inputs of contaminated surface water as described in section 4 would be responsible for the elevated levels in the estuary. Similarly, in so far as can be ascertained, the levels have been generally lower since 1989, which would accord with the lower rainfall and consequently reduced discharge of contaminated surface water during this period.

Copper exceeds the estuarine EQS (5ug/l) at one or more sites in each year for which the relevant data are available. As for HCH it may be inferred that the input from the non-tidal Witham is already close to the (estuarine) EQS. However, unlike HCH there are no known large inputs of copper to the estuary. (Whilst the concentration in the contaminated surface water from Hunter Timber is somewhat higher than that in the estuary there has been no input from this source since 1989).

The situation is further complicated by the fact that the highest annual mean concentration has occurred at a different site in each year. (There is also a curiously inconsistent relationship between total copper and dissolved copper, with two instances where the latter appears to exceed the former). In addition to the elevated mean values there have been some remarkably high maximum values: 40ug/l at Swing Bridge (LW) in 1990, and 66 ug/l at Cut End (LW) in 1991. These occasional very high levels of dissolved copper have been attributed to leaching from sacrificial anodes on vessels in the Haven. Whilst such an explanation is clearly somewhat speculative, the variable location of these maxima is more consistent with such an explanation than with the notion of any unknown fixed point-source discharge.

As observed in discussion of copper in the Welland estuary it can be argued that a proportion of the metal will be complexed and therefore the EQS is unlikely to have been exceeded. Furthermore, the levels recorded in the Witham are substantially lower than those reported for the Humber, although the latter are subject to some analytical uncertainties.

Table C shows that some comparatively high zinc values have been recorded during the study. It is perhaps curious that the most obvious elevated annual means are coincident with those for copper, and as with copper, the rank order of the sites is not consistent from year to year. Unlike the situation with HCH (and possibly copper), levels in the estuary are in general appreciably higher than in the non-tidal Welland. Some zinc is associated with the timber treatment problems but in view of the flows during the period, and the variable location of the maxima this potential source does not seem to provide a likely explanation.

Even the highest annual average value (24.0ug/l at Swing Bridge) is comfortably below the estuarine EQS of 40ug/l. However, as considered in discussion of the Welland estuary, the levels are higher than might have been expected. The higher mean values are very similar to the higher average values reported for the Humber in 1991 (HEC annual report, 1991). Furthermore, all the annual mean values for Cut End (HW) are higher than the mean reported for Spurn Point (7.4ug/l) and in fact much closer to the maximum value (13ug/l) for this site at the seaward end of the Humber. The results seem to indicate the existence of diffuse sources of zinc within the broader catchment of the inner Wash.

In view of the potential inputs of contaminants such as Dieldrin and PCP from timber treatment processes the data have been closely screened, to look for these determinands. However, the vast majority of results are below the limit of detection and even positive results reveal only very low concentrations. Either these chemicals do not escape to the estuary in measurable quantities, or as previously suggested the very low rainfall has effectively prevented any appreciable discharge of contaminated surface water during the study period.

One other particularly curious result is worthy of mention. In 1990 a single value of 83.9ng/l for total organo-tin was recorded at Cut End (LW). All other values for that year were below the detection limit, as have been virtually all subsequent results. The isolated occurrence of a single high value may well indicate contamination or analytical error. However, if the result is genuine, it could conceivably relate to some transient input of TBT. Since this would be most likely to be associated with nautical activities the explanation for the occasional high copper values referred to above (also most evident at Cut End, LW) would receive some support.

Statistical summary reports for all determinands for each sampling point are presented for each year/period of the study, as Appendices 8 and 9.

5.4 Comparison of the Welland and Witham Estuaries

Much of the previous discussion has already drawn comparison between the two estuaries in so far as possible. It is therefore only intended to summarise the situation in the following text. As stated earlier the data for metals and pesticides in the Welland are very limited – confined to a single site on relatively few occasions. Any close comparison is therefore unjustified and may even be misleading. In general it appears that slightly greater inputs to the Wash are likely to arise from the Witham than the Welland. This is not only linked to the existence of more inputs (as identified in section 4), and arguably higher concentrations within the Haven, but also to the appreciably higher flows in the Witham system. The oxygen regimes in both estuaries may be regarded as generally good throughout the study period, and broadly similar. There are some indications that dissolved oxygen conditions in the upper parts of the Welland may occasionally be less favourable than in the Upper Witham, and BOD and ammonia were in general slightly higher in the Welland. However, the differences are relatively small and unlikely to be of consequence.

In overall terms it is reasonable to conclude that the water quality of both estuaries is good, and any differences between them are unlikely to have any significant influence on the respective ecosystems.

5.5 Other Environmental Quality Measurements

There has been no bioaccumulation work on either estuary apart from that undertaken in the course of the study. Consequently no routine data are available. Sediment sampling has only been undertaken at one point on the Witham Estuary (twice per year at Cut End) and not at all on the Welland.

Unfortunately, analyses have not included any metals and, perhaps surprisingly, all results for persistent organics have been below the limits of detection. There are therefore no data from any sources other than the water column sampling considered in the preceding text.

It had been hoped to remedy this situation by introducing a small network of bioaccumulation and sediment sampling sites analogous to that established for the Humber. Unfortunately this has not been possible. It is currently hoped to establish one bioaccumulation and sediment site on the lower reaches of each estuary, together with a shared monitoring point at Tabs Head.

5.6 Input to the Wash (Conclusions)

It is apparent from the presiding sub-sections that reliable assessments of the input(s) from the Welland-Witham system are not straightforward. Basically good quality well oxygenated water enters the Wash, but a few contaminants already give potential cause for concern. HCH and copper have both been shown to exceed the estuary EQS and merit continued and perhaps closer monitoring.

Zinc also appears to be entering the Wash in greater concentrations/quantities than may have been anticipated and therefore also requires monitoring and investigation of possible sources. More data on contaminants in the Welland is required, preferably from more than the one location currently used. The position with respect to nutrient inputs should be clarified as the current JoNuS programme comes to completion. Some monitoring in the body of the Wash, close to the Welland-Witham input may prove worthwhile. In particular some sediment chemistry, and possibly a sediment transport model may be of value. Currently available information should be viewed as incomplete, but in the light of the data available it seems unlikely that the Welland-Witham input to the Wash has any significant detrimental effect on the overall quality of the Wash environment.

6. REFERENCES

Humber Estuary Committee 1992. The Water Quality of the Humber Estuary 1991. Report from the Humber Estuary Committee of the National Rivers Authority, NRA publication.

Tester 1986 – The Gt. Ouse Estuary/Wash Ecological Study 3. Water Quality Report. Anglian Water, Cambridge Division

TABLES

Table 1.1. Biological sampling dates and sample codes.

Site No.	Survey Number 1	2	3	4	5	6	7	8	
Grabs									
1	10/7/89	ns	ns	1/5/90	29/7/90	29/11/90	20/2/91	8/6/91	
2	10/7/89	ns	ns	1/5/90	29/7/90	28/11/90	20/2/91	8/6/91	
3	10/7/89	6/11/89	ns	1/5/90	29/7/90	28/11/90	20/2/91	8/6/91	
4	10/7/89	6/11/89	20/2/90	29/4/90	29/7/90	28/11/90	20/2/91	8/6/91	
5	10/7/89	6/11/89	20/2/90	29/4/90	29/7/90	28/11/90	20/2/91	8/6/91	
6	10/7/89	6/11/89	20/2/90	29/4/90	29/7/90	28/11/90	20/2/91	7/6/91	
7	11/7/89	6/11/89	20/2/90	29/4/90	29/7/90	27/11/90	20/2/91	6/6/91	
8	11/7/89	6/11/89	19/2/90	29/4/90	30/7/90	27/11/90	21/2/91	6/6/91	
9	11/7/89	7/11/89	19/2/90	1/5/90	30/7/90	27/11/90	21/2/91	6/6/91	
10	11/7/89	7/11/89	19/2/90	1/5/90	30/7/90	26/11/90	22/2/91	6/6/91	
11	11/7/89	7/11/89	19/2/90	29/4/90	31/7/90	26/11/90	22/2/91	6/6/91	
12	12/7/89	8/11/89	19/2/90	2/5/90	30/7/90	26/11/90	26/2/91	7/6/91	
13	12/7/89	8/11/89	19/2/90	2/5/90	30/7/90	26/11/90	22/2/91	10/6/91	
14	12/7/89	8/11/89	19/2/90	2/5/90	30/7/90	26/11/90	22/2/91	7/6/91	
15	12/7/89	8/11/89	19/2/90	2/5/90	30/7/90	26/11/90	22/2/91	7/6/91	
16	12/7/89	7/11/89	19/2/90	2/5/90	31/7/90	27/11/90	22/2/91	7/6/91	
17	12/7/89	7/11/89	19/2/90	1/5/90	31/7/90	27/11/90	22/2/91	7/6/91	
18	12/7/89	7/11/89	22/2/90	30/4/90	31/7/90	27/11/90	21/2/91	6/6/91	
19	11/7/89	7/11/89	22/2/90	30/4/90	31/7/90	27/11/90	21/2/91	6/6/91	
20	11/7/89	7/11/89	22/2/90	30/4/90	31/7/90	27/11/90	21/2/91	6/6/91	
21	11/7/89	7/11/89	22/2/90	30/4/90	31/7/90	27/11/90	21/2/91	6/6/91	
Fish / Plankton									
hw	17/8/89	8/12/89	ns	ns	2/8/90	30/11/90	26/2/91	11/6/91	
lw	17/8/89	8/12/89	ns	3/5/90	1/8/90	29/11/90	25/2/91	10/6/91	
Intertidal						29/11/90		10/6/91	
Pushnet								13/8/91	12-13/8/92

Site No.	Survey Number 1	2	3	4	5	6	7	8
1	113/114/115	ns	ns	437	513	661	707	849
2	110/111/112	ns	ns	440/441/442	516/517/518	658/659/660	704/705/706	852/853/854
3	107/108/109	210/211/212	ns	443/444/445	510/511/512	655/656/657	701/702/703	855/856/857
4	104/105/106	207/208/209	340/341/342	434/435/436	507/508/509	652/653/654	710/711/712	858/859/860
5	101/102/103	204/205/206	337/338/339	431/432/433	504/505/506	649/650/651	713/714/715	861/862/863
6	116/117/118	201/202/203	334/335/336	428/429/430	501/502/503	646/647/648	716/717/718	828/829/830
7	119/120/121	213/214/215	331/332/333	425/426/427	519/520/521	643/644/645	719/720/721	801/802/803
8	122/123/124	216/217/218	328/329/330	422/423/424	522/523/524	640/641/642	722/723/724	804/805/806
9	125/126/127	219/220/221	325/326/327	446/447/448	525/526/527	637/638/639	725/726/727	807/808/809
10	128/129/130	222/223/224	322/323/324	449/450/451	528/529/530	601/602/603	752/753/754	810/811/812
11	131/132/135	237/238/239	319/320/321	419/420/421	546/547/548	604/605/606	755/756/757	825/826/827
12	155/156/157	255/256/257	301/302/303	464/465/466	534	607	761	843
13	161/162/163	252/253/254	304/305/306	467/468/469	540/541/542	610/611/612	740/741/742	846/847/848
14	158/159/160	249/250/251	307/ns/ns	461/462/463	537/538/539	613/614/615	758/759/760	840/841/842
15	152/153/154	246/247/248	310/311/312	458/459/460	531/532/533	616/617/618	743/745/746	837/838/839
16	149/150/151	243/244/245	313/314/315	455/456/457	561/562/563	619/620/621	746/747/748	834/835/836
17	146/147/148	240/241/242	316/317/318	452/453/454	543/544/545	634/635/636	749/750/751	831/832/833
18	143/144/145	234/235/236	352/353/354	416/417/418	558/559/560	631/632/633	737/738/739	822/823/824
19	140/141/142	231/232/233	349/350/351	413/414/415	555/556/557	628/629/630	734/735/736	819/820/821
20	137/138/139	228/229/230	346/ns/ns	410/411/412	552/553/554	625/626/627	731/732/733	816/817/818
21	134/135/136	225/226/227	343/344/345	407/408/409	549/550/551	622/623/624	728/729/730	813/814/815

Table 1.2 Location of Welland and Witham routine biological sampling sites.

Site	Description	Grid Reference
1	Confluence of R.Welland and Coronation (relief) Channel, Spalding.	TF259242
2	Telegraph pole (North of Home Farm(East bank) and South of Marsh Farm (West bank)	TF267260
3	(Featureless) - almost between Marsh Fm, Surfleet (West bank) and Whitehorse Fm (East Bank)	TF277280
4	Fence on West bank, South of Pylons, about 400m downstream from R.Glen Confluence	TF284298
5	Opposite house with aerial on West bank (Surfleet Marsh Farm)	TF299312
6	Beneath pylons South of Fosdyke bridge	TF313320
7	Opposite Starboard Light 9, 950m North of pylons	TF338335
8	Opposite Port 8A beacon	TF352346
9	Opposite Starboard L5 beacon	TF372360
10	Opposite Starboard L3 beacon	TF401393
12	Opposite Boston Stump	TF326441
13	Opposite Skirbeck Church	TF336429
14	Opposite Starboard 'Corporation Point' beacon	TF347416
15	Opposite Starboard 'Jolly Sailor' beacon	TF361399
16	Opposite Port 3A beacon Cut End cottages on North bank	TF378390
17	Opposite Tabs Head	TF399394

Table 1:2 cont. Location of Welland and Witham routine biological sampling sites.

18	Next to Buoy 13, mid channel, North of Black Buoy sand 0°07.15'E , 52°56.15'N	TF422401
19	Between Buoys 'Golf' and 11 0°07.73'E , 52°56.51'N	TF434409
20	Between Buoys 'Foxtrot' and 9 0°08.68'E , 52°57.49'N	TF443426
21	Between Buoys 'Echo' and 7 0°10.11'E , 52°58.45'N	TF457444

Table 2.1 Sediment records from field notes.

Site	Survey 1	2	3	4	5	6	7	8
1	mud	ns	ns	mud	mud	mud	mud	mud
2	sand	ns	ns	sand/grit	?	sand	sand	sand
3	sand	sand	ns	sand	sand	sand	sand	sand
4	sand	sand	sand	sand	sand	sand	sand	sand
5	sand	sand	sand	sand	sand	sand	sand	sand
6	sand(clay)	sand	sand	sand	sand	sand	sand	sand
7	sand/shell	sand	sand	sand	sand	sand/shell	sand	sand
8	sand	sand	sand	sand	sand	sand	sand(shell)	sand
9	sand	sand	sand	sand	sand	sand/shell	sand/shell	sand/shell/gravel
10	sand/shell	sand/gravel	sand	shell/sand	sand/gravel	gravel	shell	grit/shell
11	shell/sand	sand/gravel	shell/sand	sand(mud)	sand/gravel	sand/mud/gravel	sand	sand/gravel
12	mud	mud	mud	mud/sand	mud	mud	mud	mud
13	mud(sand)	mud(sand)	mud/clay	mud	sand/mud	mud	mud	mud
14	sand(mud)	mud/sand	mud	sand	sand	mud	sand	sand
15	sand(gravel)	sand	sand	sand	sand/gravel	sand/mud	mud/sand	sand/mud
16	gravel	gravel	sand	shell/gravel	shell/gravel	gravel	sand/shell	shell/gravel
17	gravel/shell	shell	sand/mud	shell	gravel/shell	shell	shell	shell/stone
18	sand/mud	mud	mud	sand	sand/mud	sand/mud	sand/mud	sand/mud
19	sand/mud	sand	mud/sand	sand/shell	sand/mud	sand/mud	mud	sand/mud
20	shell/mud/sand	shell/mud	shell/mud/sand	sand/shell	sand/mud/gravel	mud/shell/stone	shell	shell/gravel
21	mud	mud	mud	sand/shell	sand/mud	mud	sand/mud/(shell)	mud

Table 2.2 Full particle size analysis from survey 1.

Site	Mean (um)	Median (um)	%Clay/Silt	mean phi	sd phi	skew	kurtosis	%OC
1	19.2	22.7	78.5	5.7	1.79	0.59	2.40	2.05
2	181.4	206.4	4.8	2.5	0.91	3.30	20.35	0.00
3	160.7	181.8	6.4	2.6	0.96	2.73	16.16	0.00
4	218.9	241.4	0.8	2.2	0.50	3.73	41.58	0.00
5	188.6	233.6	5.2	2.4	0.99	4.11	23.72	0.00
6	236.8	272.1	2	2.1	0.72	5.34	44.99	0.06
7	358.2	302.9	0.8	1.5	1.43	-1.31	7.45	0.12
8	211.8	243.7	2.8	2.2	0.77	4.88	38.57	0.06
9	235.1	265.9	2	2.1	0.76	5.11	41.91	0.12
10	220.7	214.6	2.3	2.2	1.24	-1.09	12.29	0.06
11	181.7	187.7	6	2.5	1.29	0.67	12.13	0.00
12	11.6	12.1	93.6	6.4	1.57	0.24	2.39	2.30
13	32.8	48.7	58.3	4.9	1.79	0.94	2.96	0.00
14	176.9	165.2	2.6	2.5	0.82	1.95	15.57	0.19
15	290.8	308	0.2	1.8	0.66	-1.97	23.99	0.06
16	1438	1424.8	1.8	-0.5	1.72	1.58	8.69	0.00
17	ND (Shell)							
18	160.1	203	11.3	2.6	1.40	1.66	9.43	0.00
19	159.5	265.8	14.3	2.6	1.58	2.30	8.82	0.00
20	184.5	278.1	30	2.4	3.01	0.24	2.54	0.37
21	168.6	187.7	6	2.6	1.12	1.94	16.08	0.44

KEY
ns: not sampled
ND: no data
( ): small amounts

Table 4.1 Welland and Witham Benthos survey 1. Total number of individuals from three 0.1m2 grabs.

	GEN	SPP	1 S115	2 S112	3 S109	4 S106	5 S103	6 S118	7 S121	8 S124	9 S127	10 S130	11 S133	12 S157	13 S163	14 S160	15 S154	16 S151	17 S148	18 S145	19 S142	20 S139	21 S136
1	Abra	alba	-	-	-	-	-	-	-	-	1	1	-	-	1	-	-	-	3	-	1	51	20
2	Abra	prismatica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
3	Achelia	echinata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
4	Ampelisca	brevicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35
5	Ampharete	sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
6	Ampharete	lindstroemi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	49	39
7	Anoplodactylus	petiolatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	3
8	Aora	gracilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
9	Aphrodita	aculeata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
10	Aricidea	minuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1
11	Asterias	rubens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	86	-	-	16	-
12	Astarte	triangularis	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
13	Bathyporeia	guilliamsoniana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-
14	Bathyporeia	pilosa	-	-	-	-	-	1	5	4	-	1	-	-	-	-	-	-	-	-	1	-	-
15	Bathyporeia	sarsi	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-
16	Bodotria	scorpioides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
17	Capitella	capitata	-	-	-	-	-	-	-	1	-	-	-	-	-	63	99	8	10	50	4	-	-
18	Capitomastus	minimus	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
19	Carcinus	maenas	-	-	-	-	-	-	-	-	-	-	-	-	5	-	1	5	132	-	-	19	-
20	Cerastoderma	edule	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	1	2	1	-	-	-
21	Chaetozone	setosa	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	5	-
22	Corophium	multisetosum	-	1	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	Crangon	crangon	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	1	1
24	Cultellus	pellucidus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
25	Cumopsis	goodsiri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
26	Diastylis	bradyi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
27	Elminius	modestus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	-	-	-	-
28	Ensis	arcuatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	6
29	Ensis	ensis	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	2	1	-	-
30	Eteone	longa	-	-	-	-	-	-	-	-	1	1	1	-	-	2	1	6	2	2	2	43	40
31	Eumida	bahusiensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	-	35	3
32	Gammarus	salinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	57	136	-	-	-	16
33	Gattyana	cirrosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	76	-
34	Harmothoe	extenuata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	1
35	Harmothoe	impar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	13	-
36	Heteromastus	filiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-
37	Hydrobia	ulvae	-	-	-	-	-	-	-	-	-	3	-	88	25	-	-	-	-	-	-	-	-
38	Kefersteinia	cirrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	28	-	1	95	-
39	Lanice	conchilega	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	24	18
40	Limnodrilus	hoffmeisteri	13157	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	Macoma	balthica	-	-	-	-	-	-	-	-	-	1	1	-	3	6	1	1	4	14	2	1	2
42	Magelona	mirabilis	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	7	30	-	7
43	Malacoceros	tetracerus	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	2	7	-	-	-	-
44	Manayunkia	aestuarina	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
45	Mediomastus	fragilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	243	17
46	Melita	palmata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	-	-	-	-
47	Mesopodopsis	slabberi	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
48	Microprotopus	maculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
49	Mya	arenaria	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
50	Mysella	bidentata	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1	-	-	26	2
51	Neomysis	integer	-	-	4	1	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
52	Nephtys	caeca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
53	Nephtys	cirrosa	-	-	-	-	-	-	-	-	9	34	45	-	-	-	6	-	-	1	49	-	-
54	Nephtys	hombergii	-	-	-	-	-	-	-	-	-	1	-	-	-	21	2	-	26	51	5	4	95
55	Nereis	diversicolor	-	2	8	-	-	-	-	-	1	-	-	1	5	1	-	2	7	-	-	-	-
56	Nereis	longissima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	20	-	-	39	3
57	Nucula	nitidosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-
58	Nymphon	gracile	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
59	Ophiura	albida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38	35
60	Ophelia	limacina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
61	Ophiura	ophiura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	10
62	Owenia	fusiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
63	Paranais	litoralis	3392	-	-	-	-	-	-	-	-	-	-	64	11	-	-	-	-	-	-	-	-
64	Pectinaria	koreni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	1	122	83
65	Pholoe	inornata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	77	1
66	Phoronis	muelleri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	108
67	Anaitides	maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	61	-	1	42	51
68	Polydora	ligni	-	-	-	-	-	-	-	-	-	-	-	-	22	1	-	21	124	-	-	51	2
69	Polydora	pulchra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	3
70	Pontocrates	arenarius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	-	-
71	Psammechinus	miliaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
72	Pseudocuma	longicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
73	Pygospio	elegans	-	-	-	-	-	-	-	-	-	-	-	-	8	7	-	5	44	1	1	5	251
74	Sabella	pavonina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	133	1
75	Sabellaria	spinulosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	383	-	-	114	-
76	Scalibregma	inflatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	18
77	Scoloplos	armiger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	49	84	17	1031	196
78	Scrobicularia	plana	-	-	-	-	-	-	-	-	-	-	-	-	2	3	-	-	-	-	-	-	-
79	Semibalanus	balanoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	64	13	-	-	3	1
80	Sphaerodoropsis	minuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
81	Spiophanes	bombyx	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	15	5	2044
82	Spio	martinensis	-	-	-	-	-	-	-	-	9	1	12	-	-	18	116	-	3	112	64	9	-
83	Tellina	fabula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	16
84	Tellina	tenuis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	13	6	4
85	Tharyx	marioni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	57	1	-	30	16
86	Tubificoides	benedeni	-	-	-	-	-	-	-	-	-	-	1	-	8	1	-	3	36	43	1	1	-
87	Tubifex	costatus	-	-	-	-	-	-	-	-	-	-	-	1	6	-	-	-	-	-	-	-	-
88	Tubificoides	pseudogaster	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	22	1	-	41	29
89	Tubificoides	swirencoides	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	2
90	Tubifex	tubifex	6238	-	-	-	-	1	-	1	-	-	-	-	3	-	-	-	-	-	-	-	-
91	ud Anthozoan A		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	129	1
92	ud Aphroditidae		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	122	-
93	ud Bivalvia		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	16	1
94	ud Capetillid		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	22
95	ud Brachyuranid sp.		-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
96	ud Mytilidae spat		-	-	-	-	-	-	-	-	-	9	-	24	49	14	-	50	7087	2	12	24731	117
97	ud Nemertean A		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	126	-	-	1	26	3
98	ud Nephtys (juv.)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	5	-	16	8	56
99	ud Ophiuroid (juv)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	97	34
	Total taxa		3	3	3	1	1	2	1	5	6	13	7	7	14	14	8	24	37	17	28	57	52
	Total individuals		22847	5	18	1	1	2	5	8	22	58	63	180	149	150	227	378	8397	378	265	27766	3478

Table 4.2 Welland and Witham Benthos Survey 2. Total number of individuals from three 0.1m2 grabs.

Site (1&2 not sampled)

	GEN	SPP	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
			S212	S209	S206	S203	S215	S218	S221	S224	S239	S257	S254	S251	S248	S245	S242	S236	S233	S230	S227
1	Abra	alba	-	-	-	-	-	-	-	-	-	-	-	-	-	4	91	3	-	333	455
2	Abra	prismatica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
3	Achelia	echinata	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-
4	Ampelisca	brevicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	15
5	Ampharete	sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	2	5	-	-	-	-
6	Ampharete	lindstroemi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	4
7	Anaitides	mucosa	-	-	-	-	-	-	-	-	1	-	-	-	-	2	24	1	-	2	2
8	Anapladactylus	petiolatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-
9	Aricidea	minuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-
10	Asterias	rubens	-	-	-	-	-	-	-	1	-	-	-	-	-	-	58	-	-	-	-
11	Atylus	falcatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
12	Atylus	guttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1
13	Bathyporeia	elegans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
14	Bathyporeia	guilliamsoniana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
15	Bathyporeia	pilosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-
16	Bodotria	scorpioides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
17	Buccinum	undatum	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
18	Callipallene	emaciata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
19	Cancer	pagurus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
20	Capitella	capitata	-	-	-	-	-	-	-	4	2	-	-	-	1	115	90	12	-	6	-
21	Capitomastus	minimus	-	-	-	-	-	-	-	-	-	-	-	2	23	-	-	-	-	-	-
22	Carcinus	maenas	-	-	-	-	-	-	-	-	-	-	-	-	-	3	25	-	-	1	1
23	Cerastoderma	edule	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
24	Chaetozone	setosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
25	Corophium	arenarium	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	Crangon	crangon	-	1	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	2	-
27	Cumopsis	goodsiri	-	-	-	-	-	-	-	-	15	-	-	-	-	-	-	-	7	-	-
28	Diastylis	bradyi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	6	4
29	Diastylis	rathkei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
30	Elminius	modestus	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
31	Eteone	longa	-	-	-	-	-	-	-	1	2	-	-	-	-	5	5	-	1	-	-
32	Eumida	bahusiensis	-	-	-	-	-	-	-	-	-	-	-	-	-	2	62	-	-	6	-
33	Gammarus	salinus	-	-	-	-	-	-	-	-	-	-	-	-	-	21	2	-	-	-	-
34	Gastrosaccus	spinifer	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
35	Gattyana	cirrosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	4	-
36	Glycera	tridactyla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
37	Goniada	maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
38	Harmothoe	extenuata	-	-	-	-	-	-	-	-	-	-	-	-	-	2	12	-	-	1	-
39	Harmothoe	impar	-	-	-	-	-	-	-	-	-	-	-	-	-	1	14	-	-	-	-
40	Hydrobia	ulvae	-	-	-	-	1	-	1	93	8	-	20	-	-	7	9	1	-	-	-
41	Idotea	linearis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
42	Kefersteinia	cirrata	-	-	-	-	1	-	-	-	-	-	-	-	-	1	24	-	-	30	1
43	Lanice	conchilega	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	1	1
44	Macoma	balthica	-	-	-	-	-	2	-	2	3	-	8	1	1	4	2	8	-	3	1
45	Magelona	mirabilis	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	4	-	-
46	Malacoceros	fuliginosus	-	-	-	-	-	-	-	-	-	-	-	-	-	70	65	-	-	-	-
47	Mediomastus	fragilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-	39	2
48	Melita	palmata	-	-	-	-	-	-	-	1	-	-	-	-	-	9	2	-	-	-	-
49	Microprotopus	maculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
50	Mysella	bidentata	-	-	-	-	-	-	-	2	-	-	-	-	-	4	41	1	-	9	3
51	Mytilus	edulis	-	-	-	-	-	-	-	-	-	-	-	-	-	2	35	-	-	-	-
52	Nephtys	caeca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
53	Nephtys	cirrosa	-	-	-	-	-	14	1	2	12	-	-	7	24	4	-	-	30	-	-
54	Nephtys	hombergii	-	-	-	-	-	-	-	-	2	-	3	4	1	1	3	58	1	35	61
55	Nereis	diversicolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
56	Nereis	longissima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	1	1
57	Nucula	nitidosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
58	Nymphon	gracile	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
59	Ophiura	albida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	99	71
60	Ophiura	ophiura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26	23
61	Owenia	fusiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
62	Pagurus	bernhardus	-	-	-	-	-	-	-	-	-	-	17	4	-	6	20	-	-	-	-
63	Pectinaria	koreni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
64	Pholoe	inornata	-	-	-	-	-	-	-	1	-	-	-	1	-	3	145	-	-	206	2
65	Phoronis	muelleri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	501	212
66	Anaitides	maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
67	Pinnotheres	pisum	-	-	-	-	-	-	-	-	-	-	-	-	-	2	9	-	-	-	-
68	Polydora	ligni	-	-	-	-	-	-	-	-	-	-	1	-	1	39	263	-	-	4	-
69	Polydora	pulchra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
70	Polynoe	scolopendrina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
71	Pomatoceros	triqueter	-	-	-	-	-	-	-	-	-	-	-	-	-	2	5	-	-	-	-
72	Pontocrates	arenarius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
73	Pseudocuma	longicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	33	14	8
74	Pycnogonum	littorale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
75	Pygospio	elegans	-	-	-	-	-	-	-	-	-	-	-	-	-	35	15	-	-	5	-
76	Sabella	pavonina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	6	-
77	Sabellaria	spinulosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-	3	-
78	Scalibregma	inflatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1
79	Scoloplos	armiger	-	-	-	-	-	-	-	-	2	-	-	-	-	9	14	4	-	97	11
80	Scrobicularia	plana	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	1	-
81	Semibalanus	balanoides	-	-	-	-	-	-	-	4	-	-	-	-	-	1	-	-	-	-	-
82	Spiophanes	bombyx	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	8	31
83	Spio	martinensis	-	-	-	-	-	5	-	-	7	-	-	37	19	9	6	4	4	-	-
84	Tellina	fabula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	8
85	Tellina	tenuis	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	21	16	13
86	Tharyx	marioni	-	-	-	-	-	-	-	-	-	-	-	1	14	83	549	30	1	38	-
87	Tubificoides	benedeni	-	-	-	-	-	-	-	2	-	-	-	1	-	6	61	22	-	-	-
88	Tubifex	costatus	-	-	-	-	-	-	-	-	-	13	10	-	-	4	11	-	-	-	-
89	Tubulanus	polymorphus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	8
90	Tubificoides	pseudogaster	-	-	-	-	-	-	-	3	-	-	-	-	-	-	39	6	-	175	7
91	ud Aphroditoidea		-	-	-	-	-	-	-	-	-	-	-	-	-	1	50	-	-	1	-
92	ud Anthozoan A		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2
93	ud bivalve spat		-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-
94	ud Capitellid		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	-
95	ud Mytilidae spat		-	-	-	-	-	-	-	71	-	-	2	-	-	51	39	1	-	16	1
96	ud Nemertean A		-	-	-	-	-	-	-	303	2	-	-	-	-	118	-	-	-	2	-
97	ud Nephtys (juv.)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	36	30
98	ud Ophiuroid (juv)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	62	6
99	ud Pycnogonida		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
	Total taxa		0	1	0	0	3	3	2	18	13	2	8	10	8	35	48	16	19	52	36
	Total individuals		0	1	0	0	3	21	2	495	57	14	62	59	84	629	1847	135	136	1884	1018

Table 4.3 Welland and Witham Benthos Survey 3. Total number of individuals from three 0.1m2 grabs.

	GEN	SPP	Site 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
			S342	S339	S336	S333	S330	S327	S324	S321	S303	S306	S309	S312	S315	S318	S354	S351	S348	S345
1	Abra	alba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	78	378
2	Ampelisca	brevicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
3	Ampharete	sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
4	Ampharete	lindstroemi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
5	Anaitides	maculata	-	-	-	-	-	-	-	1	-	-	-	-	-	-	2	-	-	-
6	Aricidea	minuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
7	Bathyporeia	pilosa	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-
8	Bathyporeia	sarsi	-	-	-	-	3	-	1	-	-	-	-	-	-	-	-	-	-	-
9	Capitella	capitata	-	-	-	-	-	-	7	18	-	-	-	-	-	91	2	-	-	-
10	Carcinus	maenas	-	-	-	-	-	1	1	-	-	-	-	-	-	2	-	-	-	-
11	Cerastoderma	edule	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-
12	Chaetozone	setosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
13	Corophium	sp	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	Corophium	multisetosum	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
15	Crangon	crangon	-	-	-	-	2	-	-	1	-	-	-	-	-	-	-	-	-	-
16	Diastylis	bradyi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	6
17	Elminius	modestus	-	-	-	-	1	-	3	-	-	-	-	-	3	1	-	-	-	-
18	Ensis	arcuatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
19	Eteone	longa	-	-	-	-	-	-	1	5	-	-	-	-	-	4	2	-	21	1
20	Eumida	bahusiensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
21	Gammarus	duebeni	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-
22	Gammarus	salinus	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
23	Glycera	tridactyla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
24	Goniada	maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
25	Harmothoe	impar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
26	Heteromastus	filiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
27	Hydrobia	ulvae	-	-	-	-	-	-	12	-	-	-	-	-	-	1	4	1	-	-
28	Jaeropsis	brevifrons	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-
29	Kefersteinia	cirrata	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	5	-
30	Lanice	conchilega	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
31	Macoma	balthica	-	-	-	-	1	4	6	33	-	-	-	-	2	9	14	2	9	2
32	Magelona	mirabilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	2	-	-
33	Mediomastus	fragilis	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	1	390	59
34	Microprotopus	maculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
35	Mysella	bidentata	-	-	-	-	-	-	-	-	-	-	-	-	-	21	-	1	3	4
36	Mytilus	edulis	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
37	Neomysis	integer	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-
38	Nephtys	caeca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
39	Nephtys	cirrosa	-	-	-	-	-	-	3	2	-	-	-	-	-	-	2	15	-	-
40	Nephtys	hombergii	-	-	-	-	-	-	-	2	-	-	-	-	-	8	39	-	-	51
41	Nereis	diversicolor	-	1	-	1	-	-	-	-	-	-	-	-	-	10	-	-	-	-
42	Notomastus	latericeus	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
43	Ophiura	albida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	51
44	Ophelia	limacina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-
45	Ophiura	ophiura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	9
46	Owenia	fusiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
47	Paranais	litoralis	-	-	-	1	1	-	-	-	-	2	-	-	-	10	8	-	-	-
48	Pholoe	inornata	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	144	11
49	Phoronis	muelleri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	257
50	Anaitides	maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
51	Polydora	ligni	-	-	-	-	-	-	-	1	-	-	-	-	-	9	-	-	3	-
52	Pseudocuma	longicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30
53	Pygospio	elegans	-	-	-	-	-	-	1	-	-	-	-	-	1	2	1	-	3	2
54	Sabella	pavonina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
55	Scalibregma	inflatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	6
56	Scoloplos	armiger	-	-	-	-	-	-	-	1	-	-	-	-	-	1	9	-	120	18
57	Scrobicularia	plana	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-	-	-
58	Sphaerodoropsis	minuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
59	Spiophanes	bombyx	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	54
60	Spio	martinensis	-	-	-	-	-	1	-	15	-	-	-	-	-	-	37	9	-	2
61	Tellina	fabula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	18
62	Tellina	tenuis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	6	3	12
63	Tharyx	marioni	-	-	-	-	-	-	-	3	-	-	-	-	-	205	37	1	60	14
64	Tubificoides	benedeni	-	-	-	-	-	-	3	2	-	1	-	-	-	54	10	4	-	-
65	Tubifex	costatus	1	3	2	-	-	-	-	-	1	8	-	1	-	54	-	-	-	-
66	Tubulanus	polymorphus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	8
67	Tubificoides	pseudogaster	-	-	-	-	-	-	1	2	-	-	-	-	3	-	49	-	174	56
68	Tubificoides	swirencoides	-	-	-	-	-	-	-	2	-	-	-	-	-	5	-	-	-	-
69	ud Anthozoa A		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	7
70	ud Caprellid		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	6
71	ud Mytilidae spat		-	-	-	-	-	-	16	3	-	-	-	-	2	27	38	4	3	21
72	ud Nemertean A		-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-
73	ud Nephtys (juv.)		-	-	-	-	-	-	-	1	-	-	-	-	1	1	12	6	3	40
74	ud Ophiuroid (juv)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	21
75	ud Pholadacea		-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
76	ud Tanaidacea		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	Total taxa		1	2	2	3	7	3	15	17	1	5	1	1	6	25	23	17	28	36
	Total individuals		1	4	3	3	14	6	72	94	1	16	3	1	12	545	278	60	1159	1161
												SL/STONE 1GRAB *3							1 grab *3	

Table 4.4 Welland and Witham Benthos Survey 4. Total number of individuals from three 0.1m2 grabs.

	GEN	SPP	Site 1 S439	2 S442	3 S445	4 S436	5 S433	6 S430	7 S427	8 S424	9 S448	10 S451	11 S421	12 S466	13 S469	14 S463	15 S460	16 S457	17 S454	18 S418	19 S415	20 S412	21 S409
1	Abra	alba	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	2	4	5	95	333
2	Achelia	echinata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
3	Ampelisca	brevicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
4	Ampharete	sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
5	Ampharete	acutifrons	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
6	Ampharete	lindstroemi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	46	-
7	Anaitides	maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	1	-
8	Anoplodactylus	petiolatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	2
9	Aphrodite	aculeata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
10	Arenicola	marina	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-
11	Bathyporeia	pilosa	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
12	Bodotria	scorpioides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3
13	Capitella	capitata	-	-	-	-	-	-	-	2	6	5	3	-	-	-	2	-	24	3	2	-	2
14	Carcinus	maenas	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	13	-	-	1	-
15	Cerastoderma	edule	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	1	-	6	-	-	-
16	Chaetozone	setosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
17	Cheirocratus	assimilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	Corophium	sp	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	Corophium	multisetosum	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	Crangon	crangon	-	-	-	-	-	-	-	-	1	-	-	-	1	1	-	-	-	-	-	-	-
21	Diastylis	bradyi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	5
22	Elminius	modestus	-	1	-	-	-	-	-	1	-	-	-	-	-	1	1	-	-	-	-	-	-
23	Eteone	longa	-	-	-	-	-	-	-	4	-	-	1	-	-	-	-	-	4	-	-	19	5
24	Eumida	bahusiensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4
25	Gammarus	salinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-
26	Gnathia	sp	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	Goniada	maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
28	Harmothoe	impar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-
29	Heteromastus	filiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
30	Hydrobia	ulvae	-	25	11	4	28	21	39	291	156	163	73	3	-	8	82	30	11	80	5	-	1
31	Kefersteinia	cirrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35	1
32	Lanice	conchilega	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
33	Macoma	balthica	-	-	-	1	1	-	-	14	17	12	18	-	1	10	2	3	4	23	14	3	-
34	Magelona	mirabilis	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	7	-	-	1
35	Malacoceros	fuliginosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
36	Manayunkia	aestuarina	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	Mediomastus	fragilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	198	63
38	Melita	palmata	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-
39	Monoculodes		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
40	Mysella	bidentata	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	5	1	3	1	8
41	Mytilus	edulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-
42	Neomysis	integer	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
43	Nephtys	caeca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
44	Nephtys	cirrosa	-	-	-	-	-	-	-	3	1	4	6	-	-	-	1	-	-	17	5	-	-
45	Nephtys	hombergii	-	-	-	-	-	-	-	1	3	-	1	-	-	4	-	2	8	-	4	17	30
46	Nereis	diversicolor	-	-	-	2	-	-	2	-	2	1	-	-	-	-	-	1	1	-	-	-	-
47	Nereis	longissima	-	-	-	-	-	-	-	2	4	-	-	-	-	-	-	-	33	-	-	-	-
48	Notomastus	latericeus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
49	Ophiura	albida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	84
50	Ophelia	limacina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1
51	Ophiura	ophiura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	26	27
52	Owenia	fusiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
53	Paranais	litoralis	-	-	-	-	-	-	-	-	-	-	-	2	5	-	-	-	-	-	-	-	-
54	Pholoe	inornata	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	2	-	-	158	22
55	Phoronis	muelleri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	276	21
56	Pinnotheres	pisum	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	10	-	-	-	-
57	Polydora	ligni	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	9	-	-	6	-
58	Polydora	pulchra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
59	Pseudocuma	longicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2	40
60	Pygospio	elegans	-	-	-	-	-	1	-	-	2	18	2	-	1	-	-	3	21	-	-	3	29
61	Sabella	pavonina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
62	Sabellaria	spinulosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
63	Scalibregma	inflatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	66	244
64	Scoloplos	armiger	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	4	81	30
65	Scrobicularia	plana	-	3	2	1	-	2	1	4	-	2	-	-	-	-	-	-	-	-	-	-	-
66	Semibalanus	balanoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	-	-	-	-
67	Spiophanes	bombyx	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	81
68	Spio	martinensis	-	-	-	-	-	-	-	2	-	1	1	-	-	-	-	-	-	9	9	-	2
69	Tellina	fabula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33
70	Tellina	tenuis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	8	1	2
71	Tharyx	marioni	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	21	-	-	16	33
72	Tubificoides	benedeni	-	-	-	-	-	-	-	3	3	24	2	2	3	2	-	-	17	17	2	2	-
73	Tubifex	costatus	-	3	-	3	-	-	-	-	-	-	-	21	6	-	-	-	1	-	-	-	-
74	Tubulanus	polymorphus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	8
75	Tubificoides	pseudogaster	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	4	1	-	130	141
76	Urothoe	poseidonis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
77	ud Anthozoa A		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3
78	ud Caprellid		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2
79	ud Mytilidae spat		-	-	-	-	-	-	2	1	2	11	2	-	-	3	3	53	36	13	5	12	18
80	ud Nemertean A		-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-
81	ud Nephtys (juv.)		-	-	-	-	-	-	-	2	-	-	1	-	3	1	-	-	5	-	5	19	26
82	ud Ophiuroid (juv)		-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	1	1	23	20
	Total taxa		0	6	5	5	3	4	4	15	13	16	18	4	9	8	7	8	27	16	16	43	44
	Total individuals		0	34	17	11	30	25	44	333	199	251	117	28	22	30	92	96	288	189	77	1319	1330

Table 4.5 Welland and Witham Benthos Survey 5. Total number of individuals from three 0.1m2 grabs.

			Site																				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	gen	sp	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	Abra	alba	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	1	4	-	-	27	10
2	Achelia	echinata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	2	7
3	Ampelisca	brevicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
4	Ampharete	acutifrons	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
5	Ampharete	lindstroemi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-	36	2
6	Anoplodactylus	petiolatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	21	1
7	Aora	gracilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8
8	Arenicola	marina	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
9	Aricidea	minuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
10	Asterias	rubens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-
11	Atylus	guttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
12	Bathyporeia	pilosa	-	-	1	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	Bathyporeia	sarsi	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
14	Capitella	capitata	-	-	-	-	-	-	-	-	1	1	2	-	1	3	15	-	24	-	15	2	6
15	Carcinus	maenas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	39	-	-	-	1
16	Cerastoderma	edule	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
17	Crangon	crangon	-	1	-	-	1	2	1	-	-	-	-	-	-	1	-	2	5	-	2	1	1
18	Crepidula	fornicata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-
19	Cumopsis	goodsiri	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	2	-	-
20	Diastylis	bradyi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
21	Elminius	modestus	-	1	1	-	-	-	3	-	-	1	-	-	7	2	-	1	920	-	-	-	-
22	Ensis	arcuatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	1	-
23	Eteone	longa	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	15	-	-	20	2
24	Eumida	bahusiensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	-	-	8	-
25	Eumida	sanguinea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	-	-	-
26	Gammarus	sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-
27	Gammarus	duebeni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-
28	Gammarus	salinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35	139	-	-	-	-
29	Gibbula	cineraria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
30	Glycera	lapidum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
31	Goniada	maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
32	Harmothoe	extenuata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	5	1
33	Harmothoe	impar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	2
34	Hyas	araneus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
35	Hydrobia	ulvae	-	1	-	1	4	3	16	36	17	57	1	351	7	4	-	6	1	-	-	-	-
36	Kefersteinia	cirrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	21	-	-	16	6
37	Lanice	conchilega	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	9	-	-	5	1
38	Limnodrilus	hoffmeisteri	65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	Macoma	balthica	-	-	-	-	1	-	-	-	-	-	-	-	1	2	1	-	-	1	2	-	-
40	Magelona	mirabilis	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	16	1	2
41	Malacoceros	fuliginosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	-	-	-	-
42	Mediomastus	fragilis	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	17	-	1	235	47
43	Melita	sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
44	Melita	palmata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-
45	Microprotopus	maculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
46	Mysella	bidentata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	4	1	16	71
47	Mytilus	edulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-
48	Neomysis	integer	-	-	7	3	4	3	1	-	-	-	-	-	-	-	-	5	-	-	-	-	-
49	Nephtys	cirrosa	-	-	-	-	-	-	-	2	5	16	3	-	-	-	4	6	-	-	45	-	-
50	Nephtys	hombergii	-	-	-	-	-	-	-	-	-	1	1	-	1	5	-	-	11	14	7	23	26
51	Nereis	diversicolor	-	-	2	-	-	-	-	-	-	1	-	-	-	-	-	7	30	-	-	1	-
52	Nereis	longissima	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	11	-	-	9	3
53	Notomastus	latericeus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
54	Nucula	nitidosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
55	Ophiura	albida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	69	18
56	Ophelia	limacina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
57	Ophiura	ophiura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	10	32	9
58	Owenia	fusiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	44	-
59	Paranais	litoralis	13	2	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1	-	-	-
60	Pectinaria	koreni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	8	2
61	Pholoe	inornata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	7	-	-	33	2
62	Phoronis	muelleri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	11
63	Anaitides	maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43	-	-	4	1
64	Pinnotheres	pisum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
65	Pisidia	longicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	3
66	Polydora	ligni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	92	-	-	92	11
67	Pomatoceros	triqueter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-
68	Psammechinus	miliaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
69	Pseudocuma	longicornis	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	2	3
70	Pycnogonum	littorale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
71	Pygospio	elegans	-	-	1	-	-	-	-	-	-	2	-	-	-	1	-	25	2	-	1	-	1
72	Sabella	pavonina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	51
73	Sabellaria	spinulosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	140	-	-	273	-
74	Scalibregma	inflatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	13	6
75	Scoloplos	armiger	-	-	-	-	-	-	-	-	-	3	-	-	-	-	1	1	141	26	31	457	40
76	Semibalanus	balanoides	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1271	3	-	1	-
77	Sphaeroma	monodi	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
78	Spiophanes	bombyx	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	49	6	226
79	Spio	martinensis	-	-	-	-	-	-	-	2	2	5	1	-	-	9	22	2	2	2	29	1	-
80	Tellina	fabula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	9	1	11
81	Tellina	tenuis	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	6	-	3
82	Tharyx	marioni	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	221	16	4	8	10
83	Tubificoides	benedeni	-	-	1	-	-	-	-	-	-	-	1	-	1	1	-	5	77	12	2	4	-
84	Tubifex	costatus	-	-	-	-	-	-	-	-	-	-	-	31	-	-	-	-	-	-	-	-	-
85	Tubulanus	polymorphus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
86	Tubificoides	pseudogaster	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	1	194	16	4	188	76
87	Tubifex	tubifex	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
88	Urothoe	pulchella	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
89	ud Aphroditoidea		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	8	1
90	ud Anthozoan A		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	8
91	ud Caprellid		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	-
92	ud Glyceroidea		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
93	ud Mytilidae spat		-	-	-	-	-	-	-	-	3	183	10	-	17	1	-	92	199	47	5	81	5
94	ud Nemertean A		-	-	-	-	-	-	-	-	-	29	-	-	-	-	-	42	-	-	1	2	3
95	ud Nephtys (juv.)		-	-	-	-	-	1	-	1	1	11	1	-	2	6	-	1	4	17	10	21	16
96	ud Ophiuroid (juv)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	6	101	3
	Total taxa		3	4	6	4	5	5	5	5	6	17	15	2	9	13	5	27	48	17	29	53	48
	Total individuals		91	5	13	6	12	11	22	43	29	317	29	382	38	39	43	259	3809	169	268	1966	733

Table 4.6 Welland and Witham Benthos Survey 6. Total number of individuals from three 0.1m2 grabs.

survey 6		Site 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
GEN	SPP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1 Abra	alba	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	25	16	-	113	25
2 Ampelisca	brevicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
3 Ampharete	lindstroemi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	6	-
4 Anaitides	maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	3	-	2	-
5 Anoplodactylus	petiolatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
6 Aora	gracilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
7 Aricidea	minuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
8 Asterias	rubens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	67	-	-	1	-
9 Autolytus	langerhansi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
10 Bathyporeia	guilliamsoniana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
11 Bathyporeia	sarsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	-	-
12 Cancer	pagurus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
13 Capitella	capitata	-	-	-	-	-	-	-	-	-	-	9	-	-	-	2	-	7	4	10	1	-
14 Carcinus	maenas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	40	-	-	-	-
15 Cerastoderma	edule	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-
16 Crangon	crangon	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	3	-	-	-
17 Diastylis	bradyi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4	10
18 Elminius	modestus	-	-	-	-	-	-	-	-	-	2	-	-	-	1	-	3	2	-	-	-	-
19 Ensis	arcuatus	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
20 Eteone	longa	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	6	1	-	4	-
21 Eumida	bahusiensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	5	-	-	2	-
22 Gammarus	salinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	3	-	-	-	-
23 Gastrosaccus	spinifer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
24 Glycera	lapidum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
25 Glycera	tesselata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
26 Glycera	tridactyla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
27 Gnathia	sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
28 Harmothoe	extenuata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	6	-	-	-	-
29 Harmothoe	impar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	-	-	-	-
30 Hydrobia	ulvae	-	-	4	-	-	2	4	-	13	21	-	-	1	3	-	-	2	28	-	-	-
31 Kefersteinia	cirrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	14	-
32 Lanice	conchilega	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
33 Lepidonotus	squamatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
34 Limnodrilus	hoffmeisteri	5485	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35 Macoma	balthica	-	-	-	-	-	2	-	-	-	-	-	-	1	3	-	-	-	1	1	-	1
36 Magelona	mirabilis	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	3	6	-	2
37 Malacoceros	fuliginosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	47	-	-	-	-
38 Mediomastus	fragilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-	182	7
39 Melita	sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
40 Melita	palmata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	4	-	-	1	-
41 Microprotopus	maculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-
42 Myrianida	pinnigera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
43 Mysella	bidentata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	94	2	4	5	4
44 Mytilus	edulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55	-	-	-	-
45 Nephtys	caeca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
46 Nephtys	cirrosa	-	-	-	-	-	-	-	5	1	1	-	-	-	1	2	1	-	11	21	-	-
47 Nephtys	hombergii	-	-	-	-	-	-	-	-	-	-	-	-	6	10	-	-	-	14	21	13	50
48 Nereis	diversicolor	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-
49 Nereis	longissima	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	6	-	-	2	-
50 Notomastus	latericeus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	1	-
51 Ophelina	acuminata	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
52 Ophiura	albida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	42
53 Ophiura	ophiura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	16	25
54 Paranais	litoralis	2286	12	1	-	-	-	-	-	1	-	-	34	-	-	-	-	-	-	-	-	-
55 Pectinaria	koreni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
56 Pholoe	inornata	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	10	60	1	1	42	-
57 Phoronis	muelleri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	67	145
58 Phyllodoce	mucosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
59 Pinnotheres	pisum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-
60 Pisidia	longicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	53	-	-	-	-
61 Polydora	ligni	-	-	-	-	-	-	-	-	-	-	3	-	-	1	-	4	23	-	-	-	-
62 Pomatoceros	triqueter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-
63 Praunus	serrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
64 Pseudocuma	longicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	6
65 Pycnogonum	littorale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
66 Pygospio	elegans	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	6	3	-	-	-	1
67 Sabellaria	spinulosa	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	8	-
68 Scalibregma	inflatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
69 Schistomysis	kervillei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-
70 Scoloplos	armiger	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	19	4	9	113	11
71 Semibalanus	balanoides	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-
72 Sphaerodoropsis	minuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
73 Spio	martinensis	-	-	-	-	-	-	-	10	-	-	51	-	-	44	4	-	-	277	305	1	41
74 Spiophanes	bombyx	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	36	-	143
75 Sthenelais	boa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-
76 Tanaissus	lilljeborgi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
77 Tellina	fabula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	4	-	11
78 Tellina	tenuis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	15	2	4
79 Tharyx	marioni	-	-	-	-	-	-	-	-	-	-	2	-	1	1	-	-	243	50	11	75	31
80 Tryphosella	sarsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
81 Tubifex	costatus	-	-	-	1	-	-	-	-	-	-	-	43	1	-	-	-	16	-	-	-	-
82 Tubifex	tubifex	382	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
83 Tubificoides	benedeni	-	-	-	-	-	-	-	-	2	-	2	-	3	-	-	2	123	7	-	2	-
84 Tubificoides	pseudogaster	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1423	7	1	423	134
85 Tubificoides	swirencoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
86 Tubulanus	polymorphus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	3
87 Tubulanus	polymorphus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	3
88 ud Anthozoa A		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	5	-
89 ud Aphroditidae		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	-	-	1	-
90 ud bivalve spat		-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	1	3	-	-	-
91 ud Caprellid		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	-	-	3	-
92 ud Mytilidae spat		-	-	-	-	-	2	-	-	5	102	29	-	-	-	-	145	17	1	1	1	1
93 ud Nemertea A		-	-	-	-	-	-	2	-	57	10	-	-	-	-	-	62	43	-	3	-	-
94 ud Nephtys (juv.)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	5	2	2
95 ud Ophiuroid (juv)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	17	1
96 ud Pycnogonida		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-
97 ud Solenacea		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Total taxa		3	2	3	1	1	3	2	2	7	7	11	2	9	14	3	25	50	26	26	44	29
Total individuals		4153	14	6	1	1	6	6	15	86	138	82	97	16	78	8	291	2761	461	338	1429	708

Table 4.7 Welland and Witham Benthos Survey 7. Total number of individuals from three 0.1m2 grabs.

GEN	SPP	Site 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 Abra	alba	-	-	-	-	-	-	-	-	1	9	-	-	-	-	-	-	11	3	2	340	71
2 Achelia	echinata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3
3 Ampelisca	brevicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2
4 Ampharete	lindstroemi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-
5 Amphipholis	squamata	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1
6 Anoplodactylus	petiolatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	8
7 Aora	gracilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
8 Arenicola	marina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
9 Aricidea	minuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
10 Asterias	rubens	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-	1
11 Bathyporeia	pilosa	-	-	-	-	-	-	-	1	-	-	2	-	-	-	-	-	-	-	-	-	-
12 Capitella	capitata	-	-	-	-	-	-	-	-	1	3	4	-	-	-	1	-	9	7	-	-	-
13 Carcinus	maenas	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	3	10	-	1	-	-
14 Cerastoderma	edule	-	-	-	-	-	-	1	-	-	5	-	-	-	1	-	-	1	2	-	-	-
15 Chaetozone	setosa	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	3	-	-	8	-
16 Corophium	sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
17 Corophium	multisetosum	-	-	-	-	-	-	-	-	-	-	-	-	-	1	9	-	-	-	-	-	-
18 Crangon	crangon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
19 Crepidula	fornicata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
20 Cumopsis	goodsiri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	3
21 Diastylis	bradyi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	8
22 Elminius	modestus	-	7	6	-	23	11	14	1	-	7	-	-	-	4	1	-	-	-	-	-	1
23 Eteone	longa	-	-	-	-	-	-	-	-	-	2	6	-	-	-	-	-	7	17	-	3	1
24 Eteone	picta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
25 Eumida	bahusiensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	-	-	2
26 Eumida	sanguinea	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
27 Gammarus	salinus	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	14	-	-	-	-
28 Gattyana	cirrosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
29 Glycera	tridactyla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
30 Hyale	nilssoni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
31 Hydrobia	ulvae	-	7	5	2	8	5	19	2	50	328	6	-	-	11	-	15	5	13	3	3	-
32 Kefersteinia	cirrata	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	1	2	-	-	45	7
33 Lanice	conchilega	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	2	-	-	1	-
34 Limnodrilus	hoffmeisteri	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35 Macoma	balthica	-	-	-	-	-	-	-	1	-	-	4	-	-	-	-	3	1	4	-	2	3
36 Magelona	mirabilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	3
37 Malacoceros	fuliginosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	79	-	-	-	-
38 Mediomastus	fragilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	1	-	442	8
39 Melita	obtusata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
40 Melita	palmata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
41 Microprotopus	maculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	23
42 Mya	arenaria	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
43 Mysella	bidentata	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	15	109	6	-	33	34
44 Mytilus	edulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	-	-	-	-
45 Neomysis	integer	-	1	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-
46 Nephtys	caeca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
47 Nephtys	cirrosa	-	-	-	-	-	-	-	3	5	-	2	-	-	-	-	3	-	-	-	-	-
48 Nephtys	hombergii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43	-	7	47
49 Nereis	diversicolor	-	-	-	-	-	-	-	-	1	-	-	-	1	-	1	1	7	-	-	-	-
50 Nereis	longissima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
51 Notomastus	latericeus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-
52 Nucula	turgida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
53 Nymphon	gracile	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
54 Ophiura	albida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	38
55 Ophelia	limacina	-	-	-	-	-	-	-	2	2	13	-	-	-	-	1	-	-	2	1	1	-
56 Ophelina	acuminata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
57 Ophiura	ophiura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	23
58 Paranais	litoralis	-	7	6	2	1	-	1	-	-	-	-	46	-	1	17	12	-	18	16	-	1
59 Pectinaria	koreni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
60 Pholoe	inornata	-	-	-	-	-	-	-	-	1	2	-	-	-	-	1	2	13	-	-	241	21
61 Phoronis	muelleri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	126
62 Anaitides	maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	1	4	-
63 Pinnotheres	pisum	-	-	-	-	-	1	-	-	-	3	-	-	-	-	-	-	5	-	-	-	-
64 Polydora	ligni	-	-	-	-	-	-	-	-	-	6	1	-	-	-	-	4	43	-	-	6	6
65 Polydora	pulchra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
66 Pomatoceros	triqueter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
67 Proceraea	cornuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-
68 Pseudocuma	longicorne	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	4
69 Pygospio	elegans	-	-	-	-	-	-	-	-	3	-	-	-	-	-	1	6	30	1	-	2	1
70 Retusa	obtusa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
71 Sabella	pavonina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
72 Sabellaria	spinulosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	111	-
73 Scoloplos	armiger	-	-	-	-	-	-	-	-	1	4	1	-	-	-	-	2	-	9	-	183	5
74 Scrobicularia	plana	-	-	-	-	-	-	2	-	-	3	-	-	-	2	2	1	-	-	3	-	-
75 Sphaerodoropsis	minuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1
76 Spiophanes	bombyx	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	207
77 Spio	martinensis	-	-	-	-	-	-	-	-	1	-	28	-	-	-	-	-	19	78	1	1	19
78 Tanaissus	lilljeborgi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
79 Tellina	fabula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	46	-	-	5
80 Tellina	tenuis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	-	9	17
81 Tharyx	marioni	-	-	-	-	-	-	-	-	1	-	2	-	-	-	1	4	181	163	1	119	8
82 Tryphosella	sarsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
83 Tubificoides	benedeni	-	-	-	-	-	-	-	-	1	5	-	-	-	-	4	5	114	10	3	-	1
84 Tubifex	costatus	-	-	2	12	-	2	-	-	3	1	-	46	5	3	27	7	20	-	-	-	-
85 Tubulanus	polymorphus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	53	3
86 Tubificoides	pseudogaster	-	-	-	-	-	-	-	-	-	1	-	-	-	1	4	4	94	140	73	36	53
87 ud Anthozoan A		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	1
88 ud Bivalvia		-	-	-	-	-	-	-	-	-	35	-	-	-	-	-	-	12	-	-	2	-
89 ud Caprellid		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	33
90 ud Mytilidae spat		-	-	1	-	-	2	1	-	10	122	4	-	-	1	2	65	42	9	-	61	25
91 ud Nemertean A		-	-	-	-	-	-	7	-	386	134	1	-	-	-	5	74	1	-	-	7	5
92 ud Nephtys (juv.)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	11	1
93 ud Ophiuroid (juv)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	3
Total taxa		0	5	5	3	3	5	7	6	15	23	15	2	2	12	18	24	36	27	12	51	50
Total individuals		0	26	20	16	32	21	45	10	467	694	64	92	6	31	81	235	884	617	106	1883	850

Table 4.8 Welland and Witham Benthos Survey 8. Total number of individuals from three 0.1m2 grabs.

	GEN	SPP	Site 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	Abra	alba	-	-	-	-	1	1	-	-	-	-	-	-	3	-	-	-	6	12	19	121	226
2	Ampharete	sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
3	Ampharete	acutifrons	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	-	-	144	12
4	Ampharete	lindstroemi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-
5	Ampelodactylus	petiolatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
6	Ampelodactylus	pygmaeus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
7	Aricidea	minuta	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-
8	Atylus	sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
9	Atylus	guttatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	3	-	-
10	Bathyporeia	sp	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-
11	Bathyporeia	elegans	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-
12	Bathyporeia	sarsi	-	-	-	-	-	3	3	-	1	-	2	-	-	-	-	-	-	-	3	-	-
13	Bodotria	scorpioides	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	3	13	2	-
14	Capitella	capitata	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	1	21	5	2	29	-
15	Carcinus	maenas	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	10	-	-	-	-
16	Chaetozone	setosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	1
17	Corophium	multisetosum	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	Cerastoderma	edule	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-
19	Crangon	crangon	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	2	-	1	-	-	-
20	Crepidula	fornicata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
21	Cumopsis	goodsiri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
22	Diastylis	bradyi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-	3
23	Diastylis	rathkei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
24	Dyopedos	monacanthus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-
25	Eteone	foliosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
26	Eteone	longa	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	23	36	1	7	8	2
27	Eteone	picta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
28	Gammarus	sp	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	3	-	-	-	-
29	Gammarus	salinus	-	-	-	-	-	-	-	-	1	31	-	-	-	-	-	23	115	-	-	-	-
30	Glycera	oxycephala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
31	Glycera	tridactyla	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	1
32	Harmothoe	impar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	63	-	-	14	1
33	Hyas	araneus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
34	Hydrobia	ulvae	-	-	-	-	2	-	7	-	4	17	-	-	2	1	-	-	1	-	-	-	-
35	Kefersteinia	cirrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	34	-
36	Lanice	conchilega	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	47	2	4	43	3
37	Limnodrilus	hoffmeisteri	1054	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	Macoma	balthica	-	-	-	-	-	-	1	1	1	-	1	-	-	1	-	1	-	6	7	-	1
39	Magelona	mirabilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
40	Maja	squinado	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
41	Malacoceros	fuliginosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	-	-
42	Mediomastus	fragilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	5	204	-
43	Melita	sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-
44	Melita	palmata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-
45	Microphthalmus	similis	-	-	-	-	-	-	-	-	-	25	-	-	-	-	-	16	-	-	-	-	-
46	Microprotopus	maculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5	2	3	-
47	Mysella	bidentata	-	-	-	-	-	-	-	-	-	12	-	-	-	-	-	8	-	1	-	10	1
48	Mytilus	edulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23	-	-	-	-
49	Neomysis	integer	-	3	2	1	-	-	-	-	-	-	2	-	-	-	-	-	2	-	-	-	-
50	Nephtys	caeca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
51	Nephtys	cirrosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
52	Nephtys	hombergii	-	-	-	-	-	-	-	-	1	2	31	-	-	1	1	-	6	34	18	12	39
53	Nereis	diversicolor	30	9	-	1	-	-	-	-	1	18	-	-	-	-	-	166	441	-	-	2	-
54	Nereis	longissima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
55	Nymphon	gracile	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
56	Ophelina	acuminata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	10	3
57	Ophiura	albida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	26
58	Ophiura	ophiura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
59	Ophelia	limacina	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	1	-
60	Ophiura	ophiura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	21
61	Paranais	litoralis	640	18	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
62	Pholoe	inornata	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2	20	-	-	187	4
63	Phoronis	muelleri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	22
64	Anaitides	maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	437	-	-	2	13
65	Pinnotheres	pisum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-
66	Polydora	ligni	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	6	72	-	-	6	1
67	Polydora	pulchra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	3
68	Pomatoceros	triqueter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
69	Processa	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-
70	Protodorvillea	kefersteini	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
71	Pseudocuma	longicornis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	61	2	94
72	Pygospio	elegans	-	-	-	-	-	-	-	-	1	11	1	-	-	-	-	379	105	1	6	10	90
73	Sabellaria	spinulosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	-
74	Scalibregma	inflatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5	67	102	72
75	Schistomysis	kervillei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
76	Scoloplos	armiger	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	8	107	21	13	221	38
77	Spiophanes	bombyx	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	7	2	244
78	Spio	martinensis	-	-	-	-	-	-	-	-	-	1	65	-	-	-	-	-	4	34	79	1	-
79	Streblospio	shrubsolii	-	2	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
80	Tellina	fabula	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	19	15	-	1
81	Tellina	tenuis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
82	Tharyx	marioni	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	1	231	55	-	12	2
83	Tubificoides	benedeni	-	-	-	-	-	-	-	-	3	23	-	-	-	2	-	9	75	9	8	4	-
84	Tubifex	costatus	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	9	2	-	-	1	-
85	Tubificoides	diazi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23
86	Tubificoides	pseudogaster	-	-	-	-	-	-	-	-	-	-	2	-	1	2	-	11	204	37	3	207	-
87	Tubificoides	swirencoides	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
88	Tubifex	tubifex	52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
89	Vaunthompsonia	cristata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
90	ud Anthozoan A		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	1
91	ud Barnacles		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37	3870	-	-	-	-
92	ud Bivalvia		-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
93	ud Capitellid		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1
94	ud Chitons		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
95	ud Enchytraeid sp.		-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
96	ud Mytilidae spat		-	-	-	-	-	-	1	1	-	13	-	-	-	-	-	-	102	13	-	3	5
97	ud Nemertean A		-	-	-	-	-	-	-	-	16	33	-	-	-	-	-	-	-	-	-	26	-
98	ud Ophiuroid (juv)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	7	2
99	ud Opisthobranch		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
100	ud Prosobranch		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
101	ud Pycnogonida		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
	Total taxa		4	5	4	5	1	1	9	2	12	18	13	0	3	9	1	24	43	24	24	49	36
	Total individuals		1796	33	5	6	2	3	25	2	34	223	125	0	4	13	1	699	6121	285	354	1413	734

Table 4.9 IMER Survey (Sept. 1973 and 1990)

	GEN	SPP	Sites 671	672	673	716	678	679	680	681
1	Arenicola	marina	6	7	-	10	-	-	-	-
2	Bathyporeia	pilosa	8	-	-	-	-	-	-	-
3	Capitellids		-	-	-	-	-	-	-	4
4	Cerastoderma	edule (adult)	-	-	-	6	-	-	1	2
		(juvenile)	-	2	-	60	-	7	8	1
5	Corophium	arenarium	137	-	-	1	-	-	-	-
6	Corophium	volutator	-	2	-	-	-	1	-	-
7	Crangon	crangon	-	11	-	1	-	-	-	-
8	Eteone		4	1	-	-	-	11	5	4
9	Hydrobia	ulvae	124	103	2	15	35	196	23	1
10	Macoma	baltica (adult)	1	11	-	-	-	13	15	1
		(juvenile)	-	14	-	-	-	17	22	12
11	Nephthys		-	-	-	2	-	1	4	-
12	Nereis		-	-	1	-	-	3	-	12
13	Phyllodoce		-	-	-	2	-	-	-	-
14	Retusa	obtusa	-	-	-	-	-	3	6	1
15	Scoloplos		-	-	-	2	-	-	-	-
16	Scrobicularia	plana	-	-	-	-	-	4	4	-
17	Spionids		13	15	3	58	-	7	36	53
18	"Oligochaetes"						39	300	300	300
	Total taxa		7	8	3	9	1	10	8	8
	Total individuals		293	166	6	157	35	263	124	91

IMER SURVEY RESULTS (September 1973)

	GEN	SPP	Sites 671	672	673	716	678	679	680	681
1	Arenicola	marina	NS	2	-	-	NS	-	-	-
2	Bathyporeia	pilosa		19	-	3		-	-	-
	Carcinus	maenas		-	1	-		-	-	-
4	Cerastoderma	edule (adult)		-	-	-		-	-	-
		(juvenile)		-	1	-		-	-	-
5or6	Corophium			7	-	-		-	-	-
7	Crangon	crangon		-	-	1		-	-	-
8	Eteone	longa		-	1	-		2	-	-
9	Hydrobia	ulvae		157	45	-		127	8	2
10	Macoma	baltica (adult)		7	-	1		9	1	-
		(juvenile)		24	-	-		1	-	-
	Manayunkia	aesturina		-	-	-		-	14	-
11	Nephthys	cirrosa		-	-	3		-	-	1
12	Nereis	diversicolor		-	2	-		3	10	-
17	Pygospio	elegans		15	17	3		3	28	2
15	Scoloplos	armiger		-	-	1		-	-	-
16	Scrobicularia	plana		1	8	-		3	-	-
	Tharyx	marioni		-	-	-		-	-	2
18	Tubificoides	benedeni		-	4	-		129	351	96
	Urothoe	poseidonis		-	-	1		-	-	-
	ud Bivalvia			-	-	-		-	-	1
	ud Collembola			-	-	-		-	2	-
18	ud Enchytraeid			-	-	-		-	90	1
	ud Tanaidacea			-	-	1		-	-	-
	Total taxa		0	7	8	8	0	7	7	7
	Total individuals		0	232	79	14	0	277	504	105

UNICOMARINE SURVEY RESULTS (SEPTEMBER 1990)

The Unicomarine species are numbered the same as the appropriate IMER species

NS: not sampled due to saltmarsh vegetation covering the site

Table 5.1 Plankton from sites 7 and 10.

	Survey		Hw 1	2	3	4	5	6	7	8	Lw 1	2	3	4	5	6	7	8
	Species		NS		NS							NS	NS	NS				
1	Appendicularians			22		-	-	7	-	-	-				-	-	-	-
2	Barnacle	cyprids		-		100+	-	1	-	-	-				34	-	-	-
3	Bathyporeia			-		-	-	-	-	-	-				-	-	2	-
4	Chironomidae			-		-	-	-	-	-	-				-	-	3	-
5	Cladocera			-		-	-	-	-	-	-				-	-	-	7
6	Corophiidae			-		-	-	1	-	-	-				1	1	-	-
7	Crab	megalopa		-		-	2	-	-	-	-				1	-	-	-
		zoea		-		623	2	-	-	2	2				12	-	-	5
8	Crangon crangon	adult		-		1	-	22	-	60	20				-	11	10	11
		juvenile		-		1	8	-	-	-	11				1	-	-	38
9	Ctenophores			-		3	-	-	1	-	-				-	-	-	-
10	Dab			-		-	-	3	-	-	-				-	-	-	-
11	Daphnia			-		-	-	217	-	1	-				-	436	-	-
12	Decapod	larvae		-		-	-	-	-	6	-				-	-	-	-
13	Fish	larvae		-		-	-	-	-	7	-				-	-	-	161
14	Platichthys flesus	Flounder		-		-	-	-	-	1	-				-	-	-	-
15	Gammarids			-		7	-	10	3	39	10				1	16	54	29
16	Gastropoda			-		-	-	1	-	83	-				-	-	-	71
17	Pomatoschistus minutus	Goby		-		5	5	1	-	-	22				2	2	-	-
18	Hydrobia ulvae			-		203	-	-	3	-	-				24	-	-	-
19	Insecta	larvae		-		-	-	-	-	6	-				-	-	-	-
20	Isopoda			-		, 2	1	-	-	5	-				5	1	-	11
21	Mesopodopsis			-		31	21	-	-	136	4				22	-	-	721
22	Mollusca (juv)			-		3	-	-	-	17	-				#	1	-	10
23	Mysid	UD		-		-	-	-	-	-	-				-	-	-	1
24	Nemerteans			-		-	-	1	-	-	-				-	-	-	-
25	Neomysis Integer			-		66	-	10	2	46	2702				38	28	122	27
26	Oligochaetes			-		-	-	1	-	-	-				-	-	-	-
27	Ostracod			-		-	-	-	-	71	-				-	-	-	3873
28	Sygnathus rostellatus	Pipefish		-		-	-	-	-	1	-				-	-	-	-
29	Polychaete larvae			1		-	2	7	20	31	-				3	5	-	8
30	Praunus flexuosus			-		-	-	-	-	-	-				-	-	-	1
31	Sagitta (elegans)			7		-	1	2	32	-	-				-	1	1	5
32	Spionid	larvae		-		-	-	-	-	1	-				-	-	-	-
33	Sprattus sprattus	Sprat (Larvae)		-		134	-	-	-	-	-				-	-	-	-
	Total Taxa		0	3	0	10	7	14	6	16	6	0	0	0	11	10	6	15
	Total individuals		0	30	0	1079	42	284	61	513	2771	0	0	0	144	502	192	4979

WELLAND WITHAM SITE 7

	Survey		Hw 1	2	3	4	5	6	7	8	Lw 1	2	3	4	5	6	7	8
	Species				NS								NS	NS				
1	Appendicularians		-	181		-	13	107	-	-	-	-			1	-	-	-
2	Barnacle	cyprids	-	-		#	-	-	-	-	-	-			6	-	-	-
3	Chironomidae		-	-		-	-	-	-	-	-	-			-	-	3	-
4	Coleoptera		-	-		-	-	-	-	-	-	-			-	-	-	1
5	Corophiidae		-	-		-	-	-	-	-	1	-			-	-	-	-
6	Crab	megalopa	-	-		-	3	-	-	1	-	-			-	-	-	-
		zoea	-	-		86	10	-	-	27	-	-			4	-	-	2
7	Crangon crangon	adult	11	-		-	-	-	-	2	-	-			-	12	15	94
		juvenile	1	-		10	33	-	-	-	2	-			4	-	-	-
8	Crustacea	larvae	-	-		-	-	-	-	-	-	-			9	-	-	-
9	Ctenophores		-	-		2	3	7	1	-	-	-			-	-	-	-
10	Cumacea		-	-		-	-	6	-	1	-	-			-	4	-	-
11	Daphnia		-	-		-	-	-	-	-	-	-			-	270	-	-
12	Decapod	larvae	-	-		-	-	-	-	-	-	-			-	-	-	25
13	Fish	larvae	-	-		-	-	-	-	45	-	-			-	-	-	26
14	Gammarids		5	-		-	2	-	-	45	3	-			-	3	20	25
15	Gastropoda		-	-		-	-	-	-	19	-	-			-	-	1	342
16	Pomatoschistus minutus	Goby	-	-		2	1	-	-	-	2	-			-	-	-	-
17	Hydrobia ulvae		-	-		-	-	-	8	-	-	-			5	-	-	-
18	Insecta	larvae	-	-		-	-	-	-	-	-	-			1	-	-	-
19	Isopoda		1	-		7	6	-	-	1	-	-			5	-	1	24
20	Mesopodopsis		1	-		31	3	6	-	2	35	-			11	-	1	142
21	Mollusca (juv)		-	-		-	-	-	-	1	-	-			2	3	6	9
22	Neomysis Integer		1799	-		-	-	-	-	-	35	-			10	6	33	30
23	Oligochaetes		-	-		-	-	-	-	-	-	-			-	-	-	2
24	Ostracod		-	-		-	-	-	-	573	-	-			-	-	-	2557
25	Sygnathus rostellatus	Pipefish	-	-		1	1	-	-	-	1	-			-	-	-	-
26	Pleurabrachia pileus		-	-		-	-	-	-	14	-	-			-	-	-	-
27	Polychaete larvae		-	1		78	-	-	641	2490	-	-			5	7	-	760
28	Praunus flexuosus		-	-		-	-	-	-	146	-	-			-	-	-	10
29	Sagitta (elegans)		-	15		-	-	14	44	9	-	-			-	12	-	-
30	Sprattus sprattus	Sprat (Larvae)	-	-		8	-	-	-	-	-	-			-	-	-	-
31	Tipulidae		-	-		-	-	-	-	-	-	-			-	-	1	-
32	Tomopteris		-	-		-	-	1	-	-	-	-			-	-	-	-
	Total taxa		5	3	0	9	9	6	4	14	7	0	0	0	12	8	9	15
	Total individuals		1818	197	0	225	75	141	694	3376	79	0	0	0	63	317	81	4047

Key:
NS: Not Sampled
Lw; Low water
Hw: High water

WELLAND WITHAM SITE 10

Table 5.2 Plankton from sites 15 and 17.

	Survey		Hw 1	2	3	4	5	6	7	8	Lw 1	2	3	4	5	6	7	8
	Species		NS		NS								NS	NS				
1	Appendicularians			55		-	1	31	-	-	-	-			1	1	-	-
2	Bathyporeia			-		-	-	-	1	-	-	-			-	-	-	-
3	Chironomidae			-		-	-	-	-	-	-	-			-	-	4	-
4	Cladocera			-		-	-	-	-	3	-	-			-	-	2	60
5	Corophiidae			-		-	-	3	-	-	-	-			-	-	-	-
6	Crab	megalopa		-		-	1	-	-	-	-	-			-	-	-	-
		zoea		-		14	4	-	-	2	2	-			5	-	-	-
7	Crangon crangon	adult		-		-	-	-	-	-	2	-			-	7	8	10
		juvenile		-		-	5	1	-	-	10	-			3	-	-	-
8	Crustacea	larvae		-		7	-	-	-	-	-	-			-	-	-	-
9	Ctenophores			-		-	1	2	-	-	-	-			-	1	-	-
10	Daphnia			-		-	-	-	2	-	-	-			-	-	-	-
11	Decapod	larvae		-		-	-	-	-	23	-	-			-	-	-	17
12	Fish	larvae		-		-	-	-	-	25	-	-			-	-	2	68
13	Gammarids			-		-	-	1	10	2	-	-			-	10	46	5
14	Gastropoda			-		-	-	-	-	15	-	-			-	-	-	4
15	Pomatoschistus minutus	Goby		-		-	-	-	-	-	13	-			-	1	-	-
16	Isopoda			-		1	1	-	-	1	-	-			-	-	2	24
17	Mesopodopsis			-		-	2	-	-	5	1418	-			26	-	-	222
18	Mollusca (juv)			-		-	-	-	4	11	-	-			-	17	-	-
19	Mysid	UD		-		-	-	-	-	-	-	-			-	1	-	-
20	Neomysis Integer			-		-	-	-	10	-	40	-			-	19	1317	54
21	Oligochaetes			-		-	-	-	-	-	-	-			-	-	24	-
22	Ostracod			-		-	-	-	-	503	-	-			-	-	2	2241
23	Sygnathus rostellatus	Pipefish		-		-	-	-	-	-	5	-			-	-	-	-
24	Pleurabrachia pileus			-		-	-	-	-	103	-	-			-	-	-	-
25	Polychaete larvae			-		-	10	5	40	1222	-	-			29	4	-	22
26	Praunus flexuosus			-		-	-	-	1	-	7	-			-	1	-	14
27	Sagitta (elegans)			44		-	3	16	8	7	-	12			1	5	-	-
28	Schistomysis kervillei			-		-	-	-	-	-	-	-			-	4	-	-
	Total taxa		0	2	0	3	8	7	8	13	7	1	0	0	6	12	9	12
	Total individuals		0	99	0	22	28	59	76	1922	1497	12	0	0	65	71	1407	2741

WELLAND WITHAM SITE 15

	Survey		Hw 1	2	3	4	5	6	7	8	Lw 1	2	3	4	5	6	7	8
	Species		NS		NS								NS	NS				
1	Appendicularians			101		-	-	-	-	-	-	2			6	81	-	-
2	Barnacle	cyprids		-		12	-	-	-	#	-	-			-	-	-	-
3	Caprellidae			-		-	-	1	-	-	-	-			-	-	-	-
4	Corophiidae			-		-	-	-	1	-	-	-			-	-	-	-
5	Crab	megalopa		-		-	2	-	-	-	-	-			-	-	-	-
		zoea		-		20	36	-	-	19	7	-			12	-	-	-
6	Crangon crangon	adult		-		-	-	-	-	-	-	-			-	1	-	-
		juvenile		1		5	18	-	-	144	4	-			28	6	-	2
7	Crustacea	larvae		-		12	-	-	-	-	-	-			-	-	-	-
8	Ctenophores			-		9	2	-	1	91	-	-			2	6	-	-
9	Cumacea			-		-	-	5	-	1	-	-			-	-	-	6
10	Daphnia			-		-	-	1	1	-	-	-			-	-	-	-
11	Decapod	larvae		-		-	-	-	-	-	-	-			-	-	-	79
12	Fish	larvae		-		5	-	-	-	43	-	-			-	-	-	376
13	Gammarids			-		-	-	-	3	1	-	-			-	-	1	21
14	Gastropoda			-		-	-	-	-	-	-	-			-	-	-	2
15	Pomatoschistus minutus	Goby		-		-	9	-	-	8	-	-			-	-	-	-
16	Hydrobia ulvae			-		-	-	-	41	-	-	-			-	-	-	-
17	Isopoda			1		6	1	1	-	2	-	-			-	-	-	51
18	Mesopodopsis			-		-	-	-	-	-	1145	-			4	1	-	1542
19	Mollusca (juv)			-		-	-	-	28	-	-	-			-	-	-	-
20	Nemerteans			-		-	-	1	6	-	-	-			-	-	-	-
21	Neomysis Integer			1		-	-	2	1	-	29	1			-	1	17	1
22	Oligochaetes			-		-	-	-	-	-	-	-			-	1	2	-
23	Ostracod			-		-	-	-	-	-	-	-			-	-	-	2908
24	Sygnathus rostellatus	Pipefish		-		-	-	-	-	-	4	-			-	-	-	4
25	Polychaete larvae			1		24	21	3	460	-	-	-			22	16	-	253
26	Praunus flexuosus			-		-	-	-	-	-	-	-			-	-	1	9
27	Sagitta (elegans)			138		-	-	7	17	40	-	15			-	38	4	2
28	Sprattus sprattus	Sprat (Larvae)		-		-	-	-	-	-	18	-			-	-	-	-
	Total taxa		0	6	0	8	6	8	10	9	6	3	0	0	6	9	5	14
	Total individuals		0	243	0	93	89	21	559	349	1207	18	0	0	74	151	25	5256

WELLAND WITHAM SITE 17

Key:
NS: Not Sampled
Lw; Low water
Hw: High water

Table 5.3 Plankton from site 18.

		Hw								Lw							
Survey		1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Species		NS		NS			NS					NS	NS				
1 Appendicularians			197		-	288		-	-	-	1			-	11	-	-
2 Barnacle	cypride		-		-	-		-	-	-	-			-	9	-	-
	nauplii		-		-	8		-	-	-	-			-	-	-	2
3 Bathyporeia			2		-	-		-	-	-	-			-	-	-	-
4 Chironomidae			-		-	-		-	-	-	-			-	-	1	-
5 Cladocera			-		-	-		-	14	-	-			-	-	1	2
6 Crab	megalopa		-		-	4		-	-	-	-			-	-	-	-
	zoea		-		210	28		-	214	2	-			7	-	-	2
7 Crangon crangon	adult		-		-	-		-	-	1	-			-	-	4	9
	juvenile		-		47	14		-	-	8	-			20	-	-	-
8 Ctenophores			-		-	-		11	-	-	-			-	-	-	-
9 Cumacea			-		-	-		1	-	-	-			-	5	-	15
10 Daphnia			-		-	-		-	-	-	-			-	36	-	-
11 Decapod	larvae		-		-	-		-	36	-	-			-	-	-	54
12 Fish	larvae		-		-	-		-	54	-	-			-	-	2	72
13 Gammarids			-		-	-		-	4	-	-			-	5	3	9
14 Gastropoda			-		-	-		-	1	-	-			-	-	-	2
15 Pomatoschistus min	Goby		-		-	2		-	-	12	-			5	-	-	-
16 Hydrobia ulvae			-		-	-		31	-	-	-			-	-	-	-
17 Isopoda			-		2	6		-	-	-	-			1	2	2	69
18 Medusae			-		1	3		-	-	-	-			1	-	-	-
19 Mesopodopsis			-		-	1		-	1	177	-			1	-	-	32
20 Mollusca (juv)			-		-	-		2	-	-	-			-	2	1	5
21 Neomysis Integer			1		-	-		-	-	51	-			1	-	19	-
22 Oligochaetes			-		-	-		-	-	-	-			-	-	1	1
23 Ostracod			-		-	-		-	1431	-	-			-	-	-	805
24 Pleurobrachia pileus			-		-	-		-	7	-	-			-	-	-	15
25 Polychaete larvae			2		57	77		1381	4557	-	-			14	3	-	2349
26 Sagitta (elegans)			87		-	-		24	42	-	16			-	11	7	8
27 Schistomysis kervillei			-		-	-		-	-	-	-			-	-	-	2
Total taxa		0	5	0	5	8	0	6	11	5	2	0	0	8	9	10	18
Total individuals		0	289	0	317	423	0	1450	6361	251	17	0	0	50	84	41	3453

WELLAND WITHAM SITE 18

Key:
NS: Not Sampled
Lw; Low water
Hw: High water

Table 5.4 Phytoplankton results from the Welland on JoNuS 5 (April 1991).

10ml surface samples JONUS 5 Apr-91														
SITE (K)	556	542	532	516	520	557	580	538	515	568	574	559	571	547
SALINITY	31.4	26.9	23.2	21.5	20.1	16.9	15	12.9	10.8	9.8	7	5	3.3	2.9
ESTUARY	well	well	well	well	well	well	well	well	well	well	well	well	well	well
Actinoptychus senarius	1	-	-	-	-	-	-	-	-	-	-	-	1	2
Ankistrodesmus sp.	-	-	-	-	-	-	-	-	-	7	-	-	-	-
Asterionella bleakeleyii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Biddulphia aurita	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Biddulphia regia	2	-	1	-	1	1	-	-	1	-	1	-	-	1
Biddulphia sinensis	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Coscinodiscus sp.	-	1	-	2	1	-	-	1	3	1	2	4	4	2
Flagilaria sp.	4	3	-	-	-	-	-	-	-	-	-	-	1	-
Melosira moniliformis	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Navicula sp.	-	1	3	3	1	5	3	-	5	2	1	6	5	4
Paralia sulcata	1	-	2	2	-	1	-	-	-	-	-	4	4	-
Pleurosigma sp.	4	4	-	1	2	-	2	1	2	-	-	2	2	5
Scenedesmus sp.	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Thalassiosira decipiens	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Round B	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spiral A	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tintinnid A	1	3	-	-	-	-	-	-	-	-	-	1	-	-
Foraminiferid	1	-	-	-	-	-	-	-	-	-	-	-	1	1

Table 5.5 Phytoplankton results from the Witham on JoNuS 5 (April 1991).

10ml surface samples									
Apr-91									
SITE (K)	556	573	566	572	546	575	521	525	563
SALINITY	31.4	28.8	25.6	24.2	23.2	21.1	19	16.3	15.9
ESTUARY	with	with	with	with	with	with	with	with	with
Actinoptychus senarius	-	-	-	-	-	-	-	-	1
Ankistrodesmus sp.	-	-	-	-	-	-	-	-	-
Asterionella bleakeleyii	S	-	-	-	-	-	-	-	-
Biddulphia aurita	E	-	-	-	-	-	-	-	-
Biddulphia regia	E	1	1	1	-	-	-	-	-
Biddulphia sinensis	-	-	-	-	-	-	-	-	-
Coscinodiscus sp.	W	-	1	2	-	-	2	3	3
Flagilaria sp.	E	-	1	4	1	-	-	3	-
Melosira moniliformis	L	-	-	-	-	-	-	-	-
Navicula sp.	L	1	-	3	-	6	1	2	-
Paralia sulcata	A	1	-	1	-	-	1	-	-
Pleurosigma sp.	N	-	1	2	-	-	-	2	2
Scenedesmus sp.	D	-	-	-	-	-	-	-	-
Thalassiosira decipiens	-	-	-	-	-	-	-	-	-
	Tabs								
Round B	Head	-	-	-	-	-	-	-	-
Spiral A	K556	-	-	1	-	-	-	-	-
Tintinnid A		2	2	7	-	-	-	-	-
Foraminiferid	E	2	-	-	-	-	-	-	-

Table 5.6 Phytoplankton results from the Nene on JoNuS 5 (April 1991).

10ml surface samples

Apr-91																				
SITE (K)	518	533	502	504	517	578	531	513	511	562	570	510	503	519	526	514	524	529	558	536
SALINITY	33.6	33.2	32.6	32	31.6	30.6	30.2	26.4	24	21.4	17.9	15.3	13.5	11.5	9.3	7.9	6.7	6.1	4.4	3.3
ESTUARY	nene	nene	nene	nene	nene	nene	nene	nene	nene	nene	nene	nene	nene	nene	nene	nene	nene	nene	nene	nene
Actinoptychus senarius	-	-	-	-	-	-	-	-	-	*	*	*	*	*	*	-	-	*	*	*
Ankistrodesmus sp.	-	-	-	-	-	-	-	-	-							7	17			
Asterionella bleakeleyii	-	-	-	-	-	-	-	-	-							-	-			
Biddulphia aurita	1	-	-	-	-	-	-	-	-							-	-			
Biddulphia regia	-	-	1	1	-	-	-	-	-							-	-			
Biddulphia sinensis	-	-	-	-	-	-	-	-	-							-	-			
Coscinodiscus sp.	1	-	2	1	1	6	-	-	-							1	-			
Flagilaria sp.	4	3	2	1	-	-	-	-	-							-	-			
Melosira moniliformis	-	-	-	-	-	-	-	-	-							-	-			
Navicula sp.	3	1	1	-	7	1	7	2	4							-	-			
Paralia sulcata	2	3	2	-	2	3	1	1	2							-	-			
Pleurosigma sp.	8	2	2	9	4	2	1	1	-							-	-			
Scenedesmus sp.	-	-	-	-	-	-	-	-	-							1	1			
Thalassiosira decipiens	-	-	-	-	-	-	-	-	-							-	-			
Round B	-	-	-	-	-	-	-	-	-							-	-			
Spiral A	-	-	-	-	-	-	-	-	-							-	-			
Tintinnid A	3	1	2	-	4	-	-	-	-							-	-			
Foraminiferid	-	-	-	1	1	2	1	-	-							-	-			

*= analysis not possible due to large amounts of sediment in the samples.

Table 5.7 Phytoplankton results from the Gt Ouse on JoNuS 5 (April 1991).

10ml surface samples																			
Apr-91																			
SITE (K)	553	512	541	551	550	565	539	577	548	501	567	509	522	555	505	544	535	537	507
SALINITY	31.2	30.8	29.3	27.5	26.4	25	22.9	21	18.8	16.7	14.8	14	12	10	8.4	6	4.1	2.1	1.3
ESTUARY	ouse	ouse	ouse	ouse	ouse	ouse	ouse	ouse	ouse	ouse	ouse	ouse	ouse	ouse	ouse	ouse	ouse	ouse	ouse
Actinoptychus senarius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Ankistrodesmus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3
Asterionella bleakeleyii	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Biddulphia aurita	3	1	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Biddulphia regia	1	2	2	-	-	2	-	2	-	-	-	1	-	-	-	-	-	4	-
Biddulphia sinensis	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Coscinodiscus sp.	2	3	-	4	-	-	-	1	-	-	-	-	1	2	1	3	3	3	1
Flagilaria sp.	20	15	3	1	-	-	2	1	-	-	-	-	-	-	1	-	-	-	-
Melosira moniliformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Navicula sp.	-	2	1	4	1	2	3	2	2	-	3	3	-	2	-	1	1	3	1
Paralia sulcata	2	5	4	2	1	5	2	-	1	-	1	-	1	3	1	2	2	4	2
Pleurosigma sp.	11	9	6	2	3	2	2	-	-	-	-	-	-	1	-	-	-	2	1
Scenedesmus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Thalassiosira decipiens	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Round B	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Spiral A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tintinnid A	7	4	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Foraminiferid	-	-	-	-	1	2	-	-	-	1	-	-	-	1	-	-	-	-	-

Table 5.8 Phytoplankton data from the Welland and Witham.

10ml surface samples

DATE	7.6.91	30.7.90	31.7.90	31.7.90	1.8.90	10.8.90	10.8.90	14.7.92	14.7.92	14.7.92	12.8.92	12.8.92	12.8.92	12.8.92	13.8.92	13.8.92	13.8.92	13.8.92	13.8.92	13.6.92
	Boo Stump	Boat Stump	Site 5	Boat Dock	Spald	BOST	FOSD	Boat Stump	Spald Site 1	Site 2	Tabs Head	Site 3	Skirb Church	Tabs Head	Stone Barge	Sutton Bridge	Ferry Farm	Nene Light	Gunth Sluice	L6 *
ESTUARY	WITH	WITH	WELL	WITH	WITH	WITH	WITH	WITH	WELL	WELL	WITH	WELL	WITH	WELL	WELL	NENE	NENE	NENE	NENE	WELL
DIATOMS																				
Actinoptychus senarius	1	-	-	-	1	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Asterionella gracialis	54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bellerochea malleus	-	-	N	-	-	S	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Biddulphia regia	-	-	O	-	-	E	-	-	-	1	-	1	2	1	-	-	1	14	10	-
Ceratualus sp.	-	-	T	-	-	D	-	-	-	-	1	-	-	-	-	-	-	-	1	-
Chaetoceros sp.	-	-	H	-	-	I	-	-	-	-	3	-	-	-	-	-	-	-	-	1
Closterium sp.	-	-	I	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Coscinodiscus sp.	60	2	N	1	3	E	1	-	-	-	-	3	1	2	1	3	1	33	1	1
Cylindrotheca closterium	15	-	G	-	-	N	-	-	-	-	2	7	31	-	6	-	-	-	-	-
Ditylium brightwellii	1	-	-	-	-	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flagilaria sp.	4	-	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptocylindrus sp.	1	-	O	-	-	-	-	1	-	-	-	-	-	-	-	-	3	-	-	-
Navicula sp.	28	2	U	3	6	-	8	72	6	7	9	14	-	7	15	15	4	16	15	6
Nitzschia sp.	5	-	N	-	-	-	-	-	-	-	-	-	18	-	-	-	-	-	-	-
Paralia sulcata	-	3	D	-	1	-	-	1	-	-	1	1	1	2	-	-	3	1	3	-
Pleurosigma sp.	10	-	-	-	7	-	6	2	-	2	11	6	28	5	22	3	8	18	9	5
Rhizosolenia setigera	10	-	-	-	-	-	-	2	-	1	5	1	1	-	-	-	-	2	1	-
Rhizosolenia shrubsolei	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Thalassiosira sp.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Thalassiosira nitzschoides	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tintinnid A	4	2	-	1	-	-	-	-	-	-	5	2	-	-	-	-	-	4	1	-
Tintinnid B	-	-	-	-	-	-	54	-	-	1	-	-	-	-	-	-	-	-	-	1
Rectangle A	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Round A	10	-	-	-	-	-	-	-	4	1	-	-	-	-	-	-	-	-	-	2
Round B	37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spiral A	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
CHLOROPHYTA																				
Actinastrum	21	-	-	-	-	-	-	2	3	1	-	-	-	-	-	-	-	-	-	-
Ankistrodesmus sp.	45	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-
Chlorella	250	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pediastrum sp.	7	-	-	-	-	-	2	-	2	-	-	2	-	-	-	-	-	1	1	-
Scenedesmus sp.	311	-	-	1	5	-	-	2	6	2	-	1	-	-	-	-	-	-	-	-
Euglenoids ?	-	-	-	-	-	-	-	1	14	725	-	1464	-	-	1	-	-	-	-	1
DINOFLAGELLATES																				
Gymnodidium	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ceratium	5	-	-	-	-	-	-	-	2	-	-	4	-	-	-	-	-	-	-	-

* L6 is midway between WW site 8 & 9

Table 6.1 (1 of 2) Fish catch data.

		hw						lw					
	SITE	4	7	10	18	17	15	4	7	10	18	17	15
		NT						NT	NT		NT	NT	NT
Brown Shrimp	Crangon crangon		1248	2080	1500	180	-			1635			
Shore Crab	Carcinus maenas		9	5	13	82	-			47			
Starfish	Asterias rubens		-	-	-	2	-			-			
FISH													
Eel pout	Zoarces viviparus		-	-	-	1	-			-			
Flounder	Platichthys flesus		-	6	13	-	-			3			
Goby	Pomatoschistus sp.		2	1	-	5	-			-			
Pipe Fish	Sygnathus sp.		-	-	-	-	3			-			
Sole	Solea solea		3	-	-	-	-			2			
Whiting	Merlangius merlangus		-	-	-	18	-			-			
TOTAL FISH SPECIES		0	2	2	1	3	1	0	0	2	0	0	0
TOTAL FISH NUMBERS		0	5	7	13	24	3	0	0	5	0	0	0
temp top			18.8	18.4	18.2	19.1	19		19.1	19.3			
temp bottom			18.6	18.4	18	19.1	19.1		19.2	19.3			
sal top			16.5	24	29	24.5	23.3		4	8.3			
sal bottom			16.8	24	30	24.5	23.4		4	8.3			
do top			4.3	5.2	5.8	6.2	6		8.4	4.9			
do bottom			4.3	5.2	5.8	6.2	6		8.6	5			

WELLAND AND WITHAM SURVEY 1

		hw						lw					
	SITE	4	7	10	18	17	15	4	7	10	18	17	15
		NT					NT	NT	NT				NT
Brown Shrimp	Crangon crangon		176	123	94	7				118	82	2	
Shore Crab	Carcinus maenas		-	-	1	4				3	4	8	
FISH													
Cod	Gadus morhua		-	-	1	-				-	-	-	
Flounder	Platichthys flesus		1	-	-	-				1	-	-	
Goby	Pomatoschistus sp.		1	13	3	-				5	1	-	
Plaice	Pleuronectes platessa		-	-	1	-				-	3	-	
Smelt	Osmerus eperlanus		-	-	-	-				-	-	1	
Sprat	Sprattus sprattus		1	-	-	-				1	2	-	
3 spine S.B.	Gasterosteus aculeatus		1	-	-	-				1	-	-	
TOTAL FISH SPECIES		0	4	1	3	0	0	0	0	4	3	1	0
TOTAL FISH NUMBERS		0	4	13	5	0	0	0	0	8	6	1	0
temp top			5.6	5.8	6.5	6.2	5.5			4.8	5.2	5.2	5.2
temp bottom			5.6	6	6.6	6.2	5.8			5	5.2	5.5	5.4
sal top			27	29.8	33.75	33.3	28.5			4	26.5	24.5	22.8
sal bottom			27.5	32	35.8	33.5	30.8			4	27.5	26.3	24.1
do top			9.4	9	9.4	9.4	9.3			9.1	9.5	9.5	9.3
do bottom			9.3	9.3	9.4	9.4	9.4			9.1	9.5	9.3	9.2

WELLAND AND WITHAM SURVEY 2

WELLAND AND WITHAM SURVEY 3

No Survey due to problems with Adventurer II

		hw	(only)				
	SITE	4	7	10	18	17	15
		NT					
Brown Shrimp	Crangon crangon		50	95	5	5	26
Shore Crab	Carcinus maenas		24	12	58	210	21
FISH							
Goby	Pomatoschistus sp.		-	1	-	2	-
Sole	Solea solea		7	-	-	-	-
TOTAL FISH SPECIES		0	1	1	0	1	0
TORAL FISH NUMBERS		0	7	1	0	2	0

WELLAND AND WITHAM SURVEY 4

Key:

NT: Not Trawled

Lw: Low water

Hw: High water

Table 6.1 (2 of 2) Fish catch data.

	SITE	lw 4	7	10	18	17	15	hw 4	7	10	18	17	15
					NT			NT					
Brown Shrimp	Crangon crangon	1	1	30		2	2		15	20	22	2	33
Shore Crab	Carcinus maenas	1	1	16		25	13		1	3	-	27	14
FISH													
Smelt	Osmerus eperlanus	1	-	-		-	-		-	-	-	-	-
Sprat	Sprattus sprattus	-	-	-		-	-		-	-	3	-	2
Whiting	Merlangius merlangus	3	-	1		-	3		10	4	1	3	6
TOTAL FISH SPECIES		1	0	1	0	0	1	0	1	1	3	1	3
TOTAL FISH NUMBERS		4	0	1	0	0	3	0	10	4	4	3	8

WELLAND AND WITHAM SURVEY 5

	SITE	lw 4	7	10	18	17	15	hw 4	7	10	18	17	15
		NT			NT			NT					
Brown Shrimp	Crangon crangon		231	691		23	256		575	788	100	16	152
Pink Shrimp	Pandalus montagui		-	-		20	-		-	-	11	6	-
Shore Crab	Carcinus maenas		4	4		3	8		18	4	-	1	6
Starfish	Asterias rubens		-	1		10	-		-	-	-	23	1
FISH													
Cod	Gadus morhua		-	-		-	2		-	4	-	2	2
Dab	Limanda limanda		39	7		-	-		30	3	2	-	1
Eel pout	Zoarces viviparus		-	-		1	-		-	-	-	-	-
Flounder	Platichthys flesus		-	-		-	-		1	-	-	-	-
Goby	Pomatoschistus sp.		54	57		102	35		21	81	11	16	13
Pogge	Agonus cataphractus		-	1		-	3		-	2	-	1	1
Sea scorpion	Taurulus bubalis		-	3		-	-		-	-	-	3	-
Sea snail	Liparis liparis		-	-		-	-		-	-	-	-	3
3 spine S.B.	Gasterosteus aculeatus		-	-		-	-		1	-	-	-	-
Whiting	Merlangius merlangus		-	1		-	-		1	1	1	1	1
TOTAL FISH SPECIES		0	2	5		2	3	0	5	5	3	5	6
TOTAL FISH NUMBERS		0	113	71		103	40	0	34	93	14	23	21

WELLAND AND WITHAM SURVEY 6

	SITE	lw 4	7	10	18	17	15	hw 4	7	10	18	17	15
		NT						NT					
Brown Shrimp	Crangon crangon		16	73	18	67	22		28	622	139	337	33
Pink Shrimp	Pandalus montagui		-	-	-	-			-	-	1	-	-
Shore Crab	Carcinus maenas		-	-	1	-	14		-	1	3	6	78
Starfish	Asterias rubens		1	-	-	-	-		-	-	3	7	2
FISH													
Butterfish	Pholis gunnellus		-	-	1	-	-		-	-	6	9	-
Cod	Gadus morhua		-	-	-	1	-		-	-	1	-	-
Dab	Limanda limanda		-	-	-	-	-		-	-	-	-	1
Eel pout	Zoarces viviparus		-	-	-	-	-		-	-	-	1	
Flounder	Platichthys flesus		-	-	-	-	-		5	3	2	2	4
Goby	Pomatoschistus sp.		2	7	6	10	2		1	21	22	79	16
Plaice	Pleuronectes platessa		1	-	-	3	-		2	34	3	13	1
Pogge	Agonus cataphractus		-	-	-	-	-		-	-	13	1	-
Smelt	Osmerus eperlanus		3	-	-	-	-		-	-	-	9	-
3 spine S.B.	Gasterosteus aculeatus		1	-	-	-	-		4	11	-	-	2
TOTAL FISH SPECIES		0	4	1	2	3	1	0	4	4	6	7	5
TOTAL FISH NUMBERS		0	7	7	7	13	2	0	12	39	46	114	34

WELLAND AND WITHAM SURVEY 7

	SITE	lw 4	7	10	18	17	15	hw 4	7	10	18	17	15
		NT											
Brown Shrimp	Crangon crangon		834	14	34	73	919	319	611	789	14	111	131
Shore Crab	Carcinus maenas		13	20	3	21	29	-	5	-	-	10	3
	Palaemon elegans		-	-	-	-	-	-	-	3	-	-	-
	Palaemon serratus		-	-	-	-	-	-	-	3	-	-	-
FISH													
Butterfish	Pholis gunnellus		-	-	-	-	1	-	-	1	-	-	-
Cod	Gadus morhua		-	-	-	-	1	-	-	1	-	-	-
Dab	Limanda limanda		2	-	-	-	-	-	-	4	-	-	-
Flounder	Platichthys flesus		3	-	-	-	-	-	-		-	-	-
Goby	Pomatoschistus sp.		-	-	-	1	-	-	-	1	-	-	1
Pipe Fish	Syngnathus sp.		-	-	-	-	-	-	-	7	3	-	-
Plaice	Pleuronectes platessa		-	-	-	-	-	-	-	1	-	-	-
Pogge	Agonus cataphractus		-	-	-	-	17	-	-	7	-	-	-
Sea scorpion	Taurulus bubalis		-	-	-	-	-	-	-	1	-	-	-
Smelt	Osmerus eperlanus		-	-	-	-	-	-	-	-	-	1	-
Sole	Solea solea		3	-	-	-	-	-	-	15	-	-	-
3 spine S.B.	Gasterosteus aculeatus		-	-	-	-	1	-	-	-	-	1	-
Whiting	Merlangius merlangus		-	-	-	-	-	-	-	1	-	-	-
TOTAL FISH SPECIES		0	3	0	0	1	4	0	0	10	1	2	1
TOTAL FISH NUMBERS		0	13	0	0	1	20	0	0	39	3	2	1

Table 6.2 Summary of fish species found on Wash estuary surveys (WW18, Nene 22 and Ouse 12 were the most seaward sites samples.

Fish		Welland	Witham	Nene	Ouse	WW (18)	Nene (22)	Ouse (12)
Bass	*Dicentrarchus labrax*			y	y			
Bullhead	*Cottus gobio*			y				y
Butterfish	*Pholis gunnellus*	y	y			y		
Cod	*Gadus morhua*	y	y		y	y		y
Dab	*Limanda limanda*	y	y	y		y		
Eel pout	*Zoarces viviparus*		y	y	y			y
Flounder	*Platichthys flesus*	y	y	y	y	y	y	y
Goby	*Pomatoschistus sp.*	y	y	y	y	y	y	y
Herring	*Clupea harengus*							
Pipe Fish	*Sygnathus sp.*	y	y		y	y		y
Plaice	*Pleuronectes platessa*	y	y			y	y	
Pogge	*Agonus cataphractus*	y	y			y		
Poor Cod	*Trisopterus minutus*			y				y
Pouting (Bib)	*Trisopterus luscus*			y				
Sea scorpion	*Taurulus bubalis*	y	y					
Sea snail	*Liparis liparis*		y		y			
Smelt	*Osmerus eperlanus*	y	y	y	y		y	y
Sole	*Solea solea*	y	y	y	y		y	y
Solenette	*Buglossidium luteum*				y			y
Sprat	*Sprattus sprattus*	y	y	y	y	y	y	y
3 spine S.B.	*Gasterosteus aculeatus*	y	y	y	y			
Whiting	*Merlangius merlangus*	y	y			y		
Brown Shrimp	*Crangon crangon*	y	y	y	y	y	y	y
Pink Shrimp	*Pandalus montagui*		y			y		
	Palaemonetes varians	(y) (push net)	(y) (push net)	(y) (push net)				

Table 7.1 Seaweed and sediment analysis data.

Metal ug/g	Site 1	2	3	4	5	6	7	Mablethorpe
Fe	2200	1300	610	1000	1290	2600	1950	260
Mn	810	610	420	530	500	800	910	95
Cu	7	7	7	8	8	11	10	8
Cd	0.7	0.8	1.1	0.9	0.7	0.6	0.8	0.8
Zn	102	93	106	83	76	75	86	97
Ni	16	19	18	17	15	17	20	21
Cr	2	1	1	2	2	3	2	1
Pb	10	7	6	7	7	13	8	5
As	0.3	0.3	0.5	1	0.8	0.5	0.3	0.5
Hg	< 0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1
% of Sample Dry Matter	20.4	22.8	24.7	26.8	29.4	28.6	25.1	21.5

SEAWEED SAMPLES - METALS ANALYSIS (FEBRUARY 1990)

Seaweed
Sites 1-7 *F. vesiculosus*
Mablethorpe *F. spiralis*

Metal ug/g	Sites 1	2	3	4	5	6	7	Controls Arran Scotland	Blyth Suffolk	Cleethorpes
Fe	1700	1120	320	820	910	3800	3500	260	1450	450
Mn	1050	450	490	660	720	700	500	190	290	180
Cu	9	8	14	8	16	15	12	5	21	30
Cd	0.4	0.3	0.5	0.6	0.8	0.8	0.6	1.1	1.2	1.3
Zn	64	47	44	49	76	75	55	110	104	310
Ni	16	11	13	13	21	18	14	13	19	27
Cr	2	2	1	2	2	7	7	< 1	2	1
Pb	9	7	5	5	8	21	17	2	7	4
As	3	5	3	7	5	10	4	3	3	5
Hg	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
% of Sample Dry Matter	29.9	34	32.6	32.5	31.6	27.4	29.1	32.9	27.1	29.1

SEAWEED SAMPLES -METALS ANALYSIS (SEPTEMBER 1990)

Seaweed
Sites 1-7 *F. vesiculosus*
Arran: *F. spiralis*
Blyth: *F. vesiculosus*
Cleethorpes: *F. spiralis*

Metal ug/g	Site 1 (ug/g of air dried <63u fraction)	2	3	4	5	6	7	8	9	10
Fe	26000	24000	24000	24000	24000	28000	26000	23000	23000	21000
Mn	970	750	1080	850	790	1270	1090	1310	890	570
Cu	29	23	24	26	24	22	24	25	24	25
Cd	0.5	0.3	0.5	0.5	0.5	0.5	0.3	0.3	0.4	0.4
Zn	153	120	124	133	129	128	120	126	118	122
Ni	28	24	24	24	25	26	23	25	24	25
Cr	18	16	17	15	17	24	12	16	16	19
Pb	80	63	73	77	68	70	61	67	60	72
As	13	13	12	12	12	12	12	14	11	11
Hg	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1
Other Determinands ug/kg										
Endrin	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Aldrin	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Dieldrin	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Lindane	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Atrazine	< 0.10	< 0.13	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Simazine	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10

SEDIMENT SAMPLES - METALS ANALYSIS (FEBRUARY 1990)

Table 7.2 Seaweed and sediment analysis (comparison of results).

Metal ug/g	from seaweed site 6 see Fig 7.1	Tabs Head (September 1990) SAC	NRA	Mablethorpe (February 1990) SAC	NRA	Humber (Typical)
Fe	1700	820	981	260	252	200
Mn	600	660	-	95	137	100
Cu	10	8	11	8	23.8	15
Cd	0.7	0.6	< 1.7	0.8	2.1	1.5
Zn	86	49	106	97	262	200
Ni	16	13	16	21	70.7	40
Cr	2	2	< 4.5	1	4.2	1.2
Pb	11	5	7.2	5	1.4	0.7
As	3	7	51.4	0.5	-	ND
Hg	<0.1	< 0.1	0.017	< 0.1	-	0.01
% of Sample						
Dry Matter	33.1	32.5	-	21.5	21.2	-

SEAWEED SAMPLES - METAL ANALYSIS (Comparison of Results)

KEY
ND : No Data

Metal ug/g	Seaweed Site 6	Tabs Head (February 1990) SAC	NRA	Mablethorpe SAC	NRA	Humber (Typical)
Fe	15000	24000	18600	-	-	x
Mn	480	790	467	-	-	1000+
Cu	13	24	19.6	-	-	50-70
Cd	< 0.1	0.5	< 0.3	-	-	0.5
Zn	73	129	139	-	-	250-300
Ni	15	25	25.4	-	-	50
Cr	11	17	41.2	-	-	100-150
Pb	41	68	57.3	-	-	100-150
As	18	12	-	-	-	ND
Hg	0.1	0.2	0.114	-	-	Seasonal
% of Sample						
Dry Matter	69.3	-	-	-	-	-

SEDIMENT SAMPLES - METAL ANALYSIS (Comparison of results)

KEY
ND : No Data
* : dependant upon proximity of industrial outfalls

Table 8.1. Shellfish sampling sites.

SITE	DATE	DESCRIPTION	LAT N deg	LAT N min	LONG E deg	LONG E min	COMMENTS
1	18/9/89		52	55.03	0	6.83	
2	18/9/89	Mid Toft Northerly	52	56.30	0	9.22	
3	18/9/89	Mid Toft Southerly	52	56.75	0	9.00	
4	18/9/89	ridge beacon	52	56.83	0	9.30	
5	18/9/89		52	56.99	0	9.72	
6	18/9/89		52	57.15	0	10.20	
7	18/9/89	100m south ridge beacon	52	57.37	0	9.44	
8	18/9/89		52	56.06	0	9.66	
9	18/9/89		52	56.46	0	9.20	
10	18/9/89		52	56.42	0	8.80	
11	18/9/89		52	55.81	0	8.33	
12	18/9/89	E bank Welland 200m S Tabs Head	52	55.85	0	5.07	mussels
13	18/9/89	W bank Welland 100m S Tab 100m S Tabs Head	52	55.95	0	4.98	mussels
14	18/9/89	E bank Witham, Tabs Head	52	56.00	0	5.00	mussels
15	18/9/89	just E of buoy 15	52	56.31	0	5.70	
16	19/9/89	west Gatt	52	55.23	0	10.06	D
17	19/9/89		52	55.30	0	10.67	D
18	19/9/89	East Gat	52	55.29	0	11.05	D
19	19/9/89	Main End	52	54.04	0	11.29	D
20	19/9/89	wreck	52	58.52	0	9.25	
21	19/9/89		52	58.86	0	8.94	
22	19/9/89	Friskney Flats	53	1.02	0	15.62	cockles
23	19/9/89	Clay Hole lays	52	56.92	0	7.61	
24	19/9/89	wreck on North Lays	52	56.70	0	5.86	
25	19/9/89	wreck	52	57.26	0	6.94	

D: dredge at high water

Table 8.2. Microbiological analysis of the shellfish samples.

Sample	TTC/100g(MPN)	Mean	FS/100g	Salmonella/100g
1 A	320	270	1200	< 2
1 B	220		900	< 2
2 A	1800	1950	< 300	< 2
2 B	2100		< 300	< 2
3 A	320	280	< 300	< 2
3 B	240		< 300	< 2
4 A	80	70	< 300	< 2
4 B	60		< 300	< 2
5 A	4300	4300	300	< 2
5 B	4300		< 300	< 2
6 A	320	280	< 300	< 2
6 B	240		< 300	< 2
7 A	950	1575	300	< 2
7 B	2200		700	< 2
8 A	60	70	< 300	< 2
8 B	80		300	< 2
9 A	1100	955	< 300	< 2
9 B	810		< 300	< 2
10 A	2100	2550	< 300	< 2
10 B	3000		< 300	< 2
11 A	9200	12600	< 300	< 2
11 B	16000		< 300	< 2
12 A	> 18000	> 18000	3300	< 2
12 B	> 18000		2600	< 2
13 A	> 18000	> 18000	5450	< 2
13 B	> 18000		30000	< 2
14 A	3000	4200	1200	< 2
14 B	5400		1273	< 2
15 A	2800	2300	2400	< 2
15 B	1800		2400	< 2
16 A	210	>9105	300	< 2
16 B	> 18000		8600	< 2
17 A	2800	4100	1090	< 2
17 B	5400		9900	< 2
18 A	5400	2855	1500	< 2
18 B	310		< 300	< 2
19 A	9200	12600	1090	< 2
19 B	16000		1200	< 2
20 A	2800	2500	7636	< 2
20 B	2200		3600	< 2
21 A	> 18000	> 10200	18000	< 2
21 B	2400		< 300	< 2
22 A	9200	7300	13200	< 2
22 B	5400		10100	< 2
23 A	16000	12600	11400	< 2
23 B	9200		1200	< 2
24 A	1100	1020	2000	< 2
24 B	940		1727	< 2
25 A	9200	>13600	3900	< 2
25 B	> 18000		26100	< 2

Table 8.4. MPN E.coli/100g data from the Boston Borough Council Study.

ZONE Date	K Witham N. Bk. (Clay Hole)	M North Gat	L Toft	N Mares Tail
16-Oct-90	9000	20	20	20
6-Nov-90	460	10	110	50
3-Dec-90	10		10	40
20-Jan-91	130	10	80	20
18-Feb-91	50	10	70	70
15-Apr-91	80	10	10	10
28-Apr-91	250	140	130&10	
18-Jun-91	130	10	110	50
31-Jul-91	1700	108	50	10
13-Aug-91	5500		250	20
9-Sep-91	350	10	10	
26-Nov-91	500	750	20	20
7-Jan-92	40	20	20	20
3-Feb-92	110	20	70	70
18-Mar-92		20		40
20-May-92	220	20	70	<1
2-Jun-92	5400	1100	1100	1300

FIGURES

Plate 1.1 Low water spring tide, August 10th 1990.
Spalding, looking towards the lock gates of the relief channel.

Plate 1.2 Low water spring tide, August 10th 1990.
Boston looking towards the tidal limit at Grand Sluice.

Plate 1.3 Low water spring tide, August 10th 1990.
Welland at Wykeham (sampling site 3) looking north.
Evidence of recent bait digging!

Plate 1.4 Low water spring tide, August 10th 1990.
Welland at Wykeham (sampling site 3) looking south.

Plate 1.5 View of the Witham (left) and Welland (right) looking towards Tabs Head.

Plate 1.6 The Witham at Boston.

Plate 1.7 Aerial photograph of the confluence of the Witham (top) and Welland (left) at Tabs Head.
July 10th 1992, Low Water Neap

Plate 1.8 The Witham at Boston Sewage Treatment Works.
July 10th 1992, High Water Neap

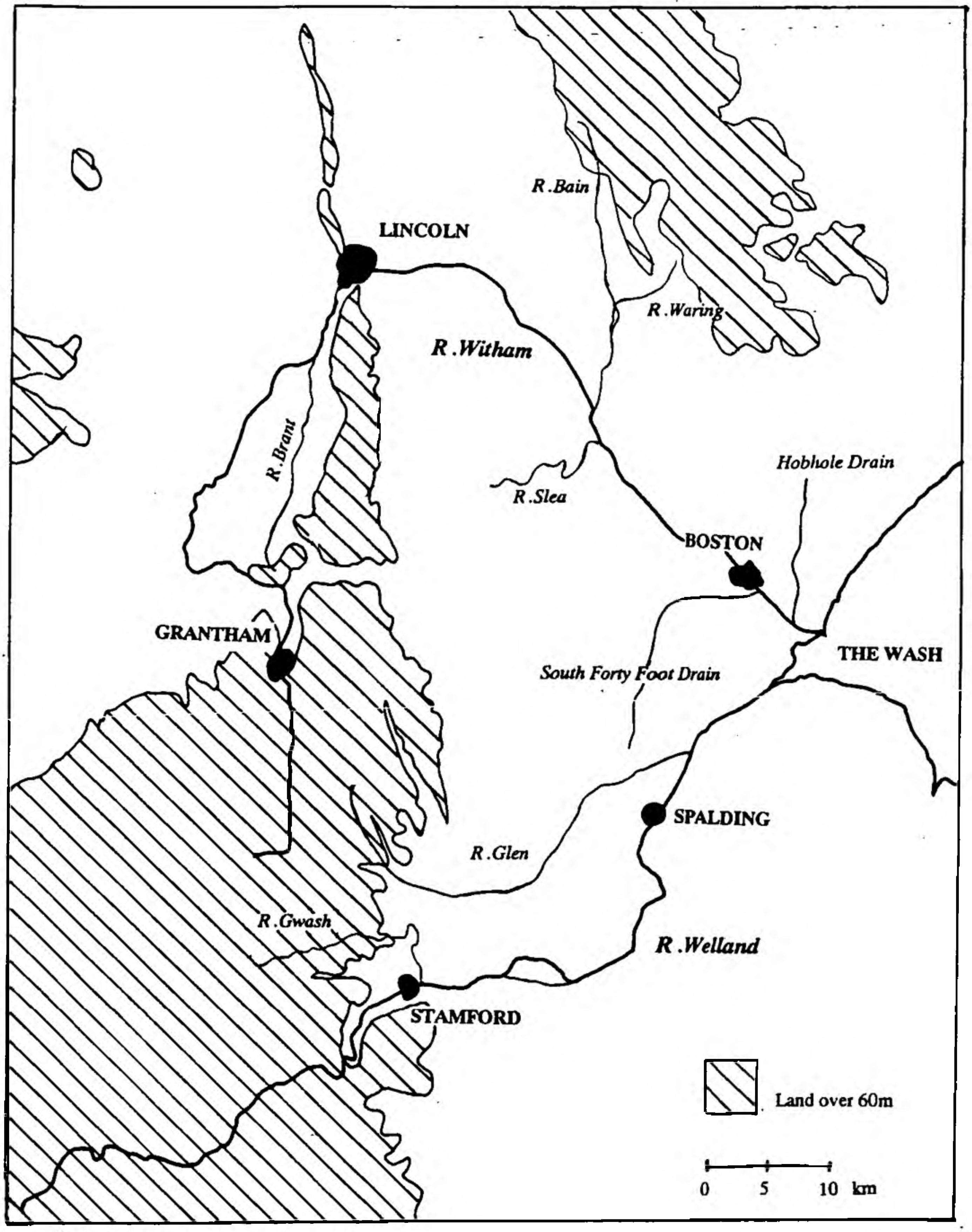


Figure 1.1 Welland and Witham Catchment Area.

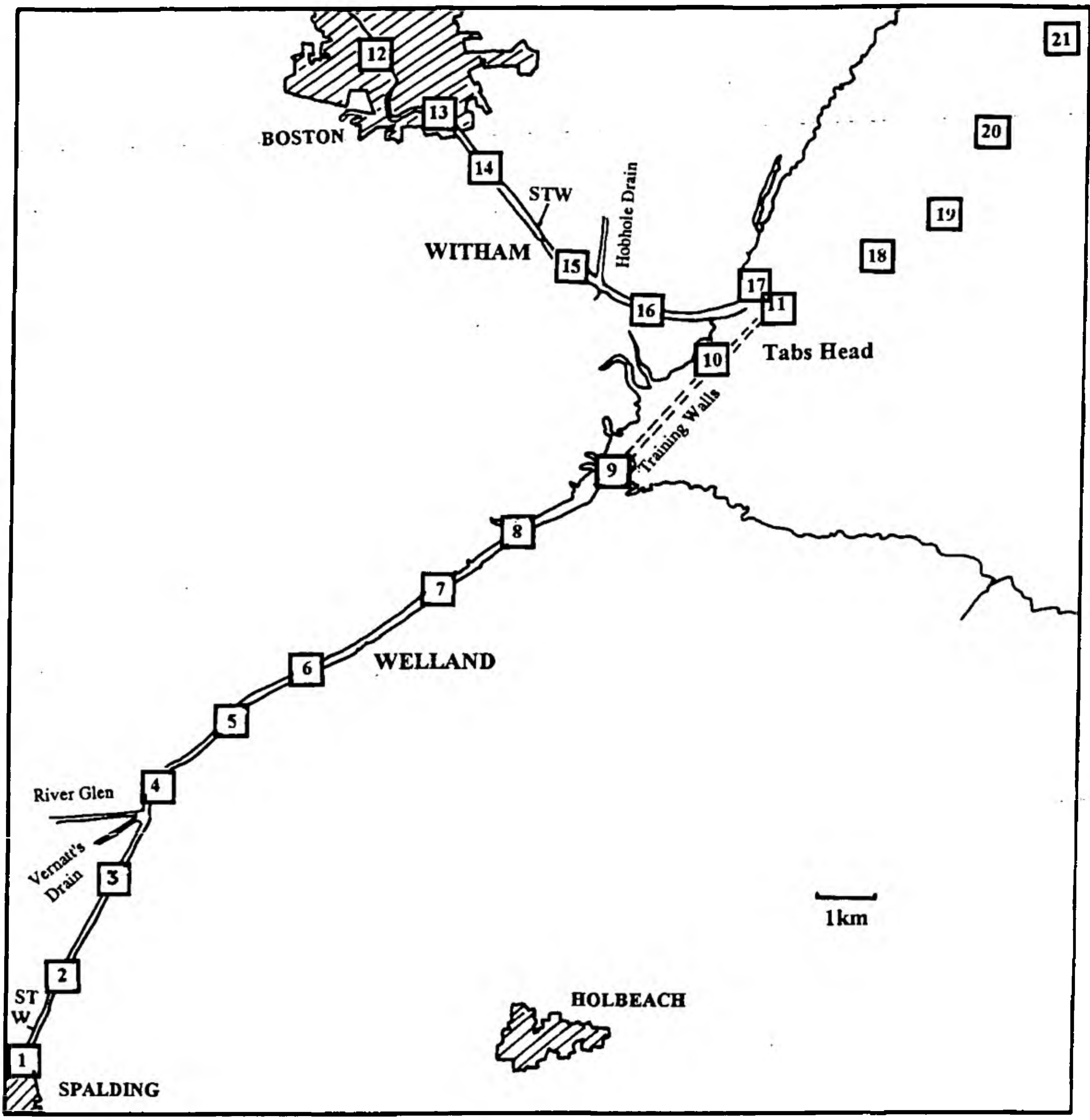


Figure 1.2. The routine Welland and Witham sampling sites.

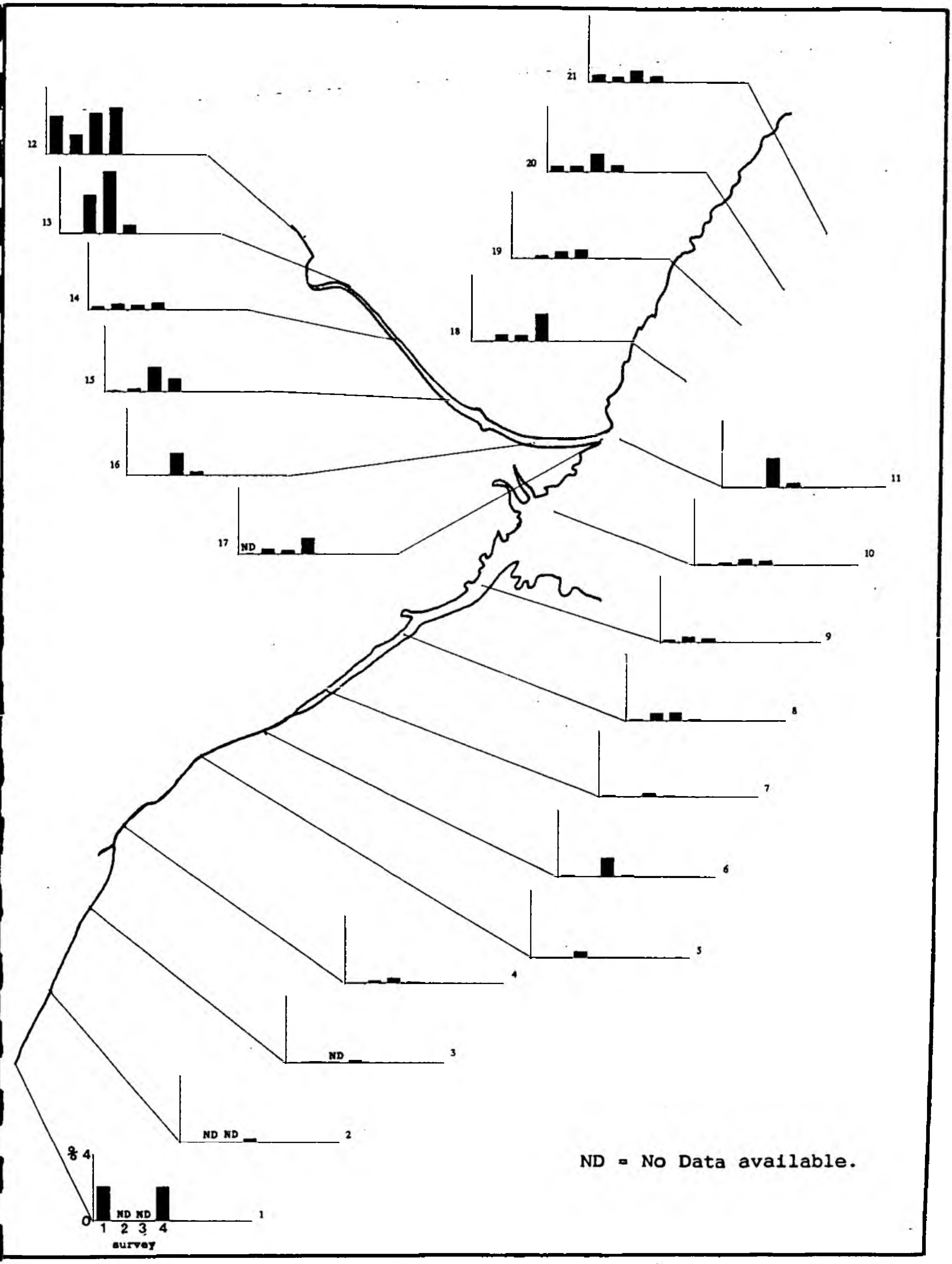
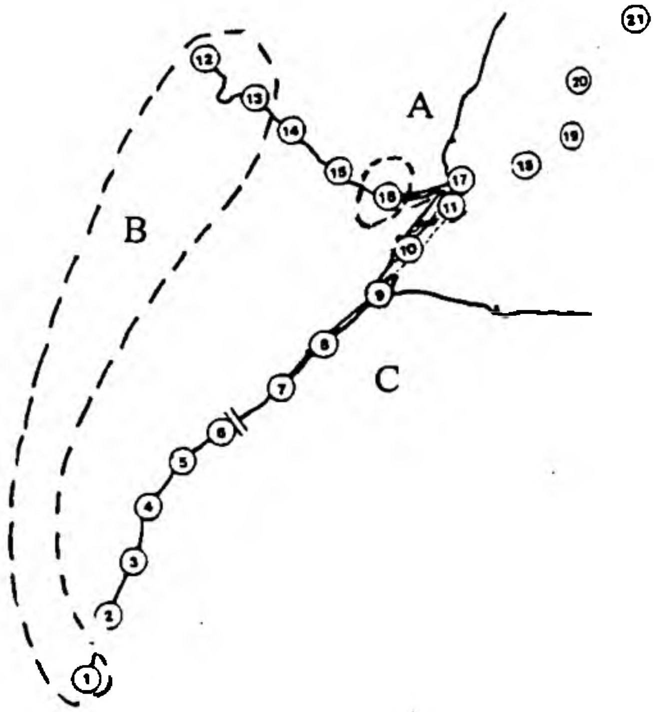


Figure 2.1 % Organic carbon recorded on surveys 1-4.



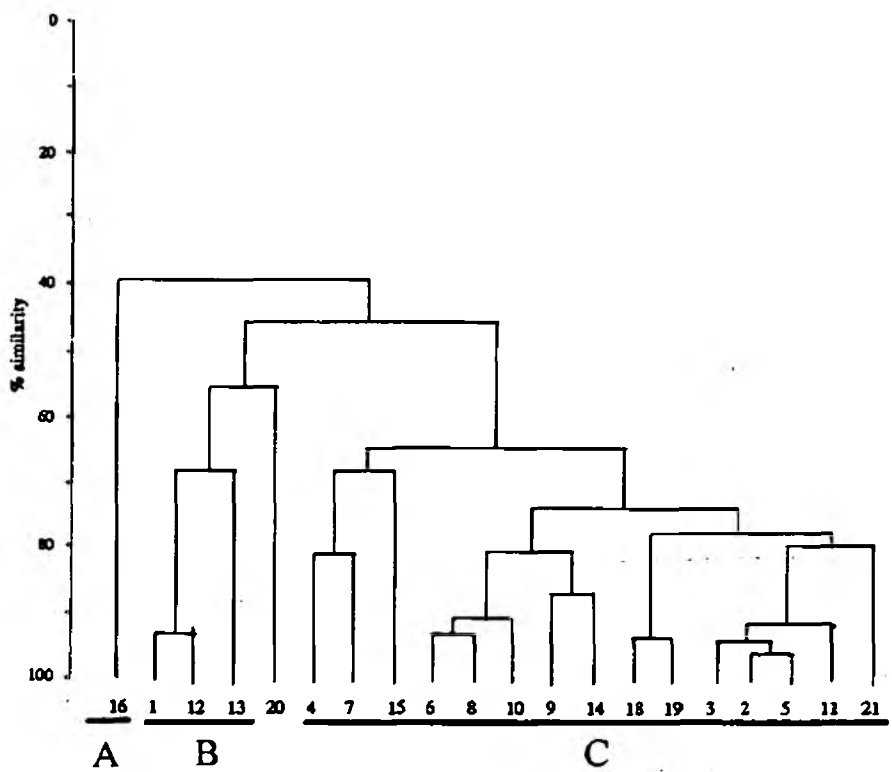


Figure 2.2 Cluster analysis of sediment data from survey 1.

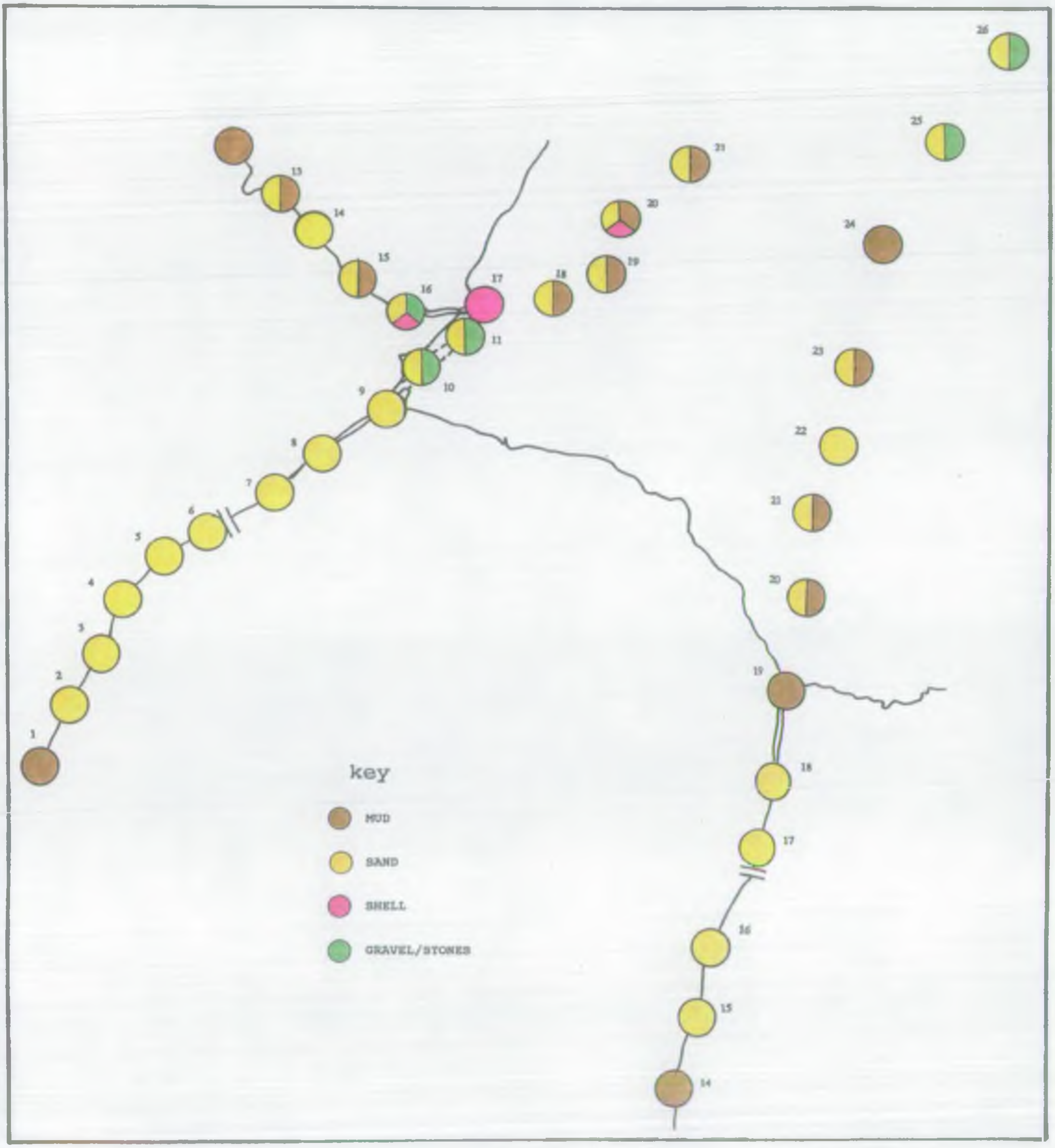


Figure 2.3 Generalised map of sediment types found on the Nene and Welland/Witham studies. The data were obtained from field notes and sediment analysis.

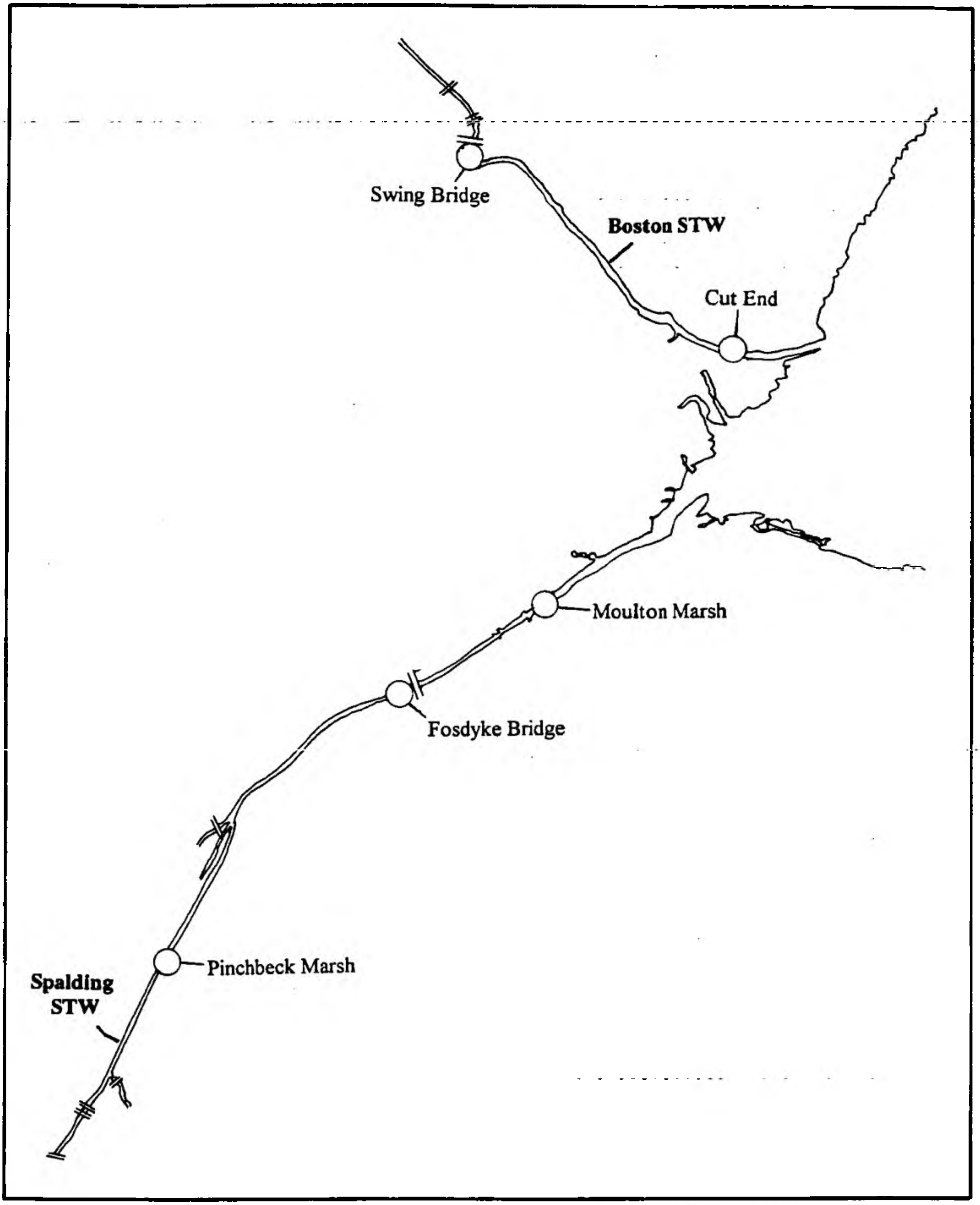
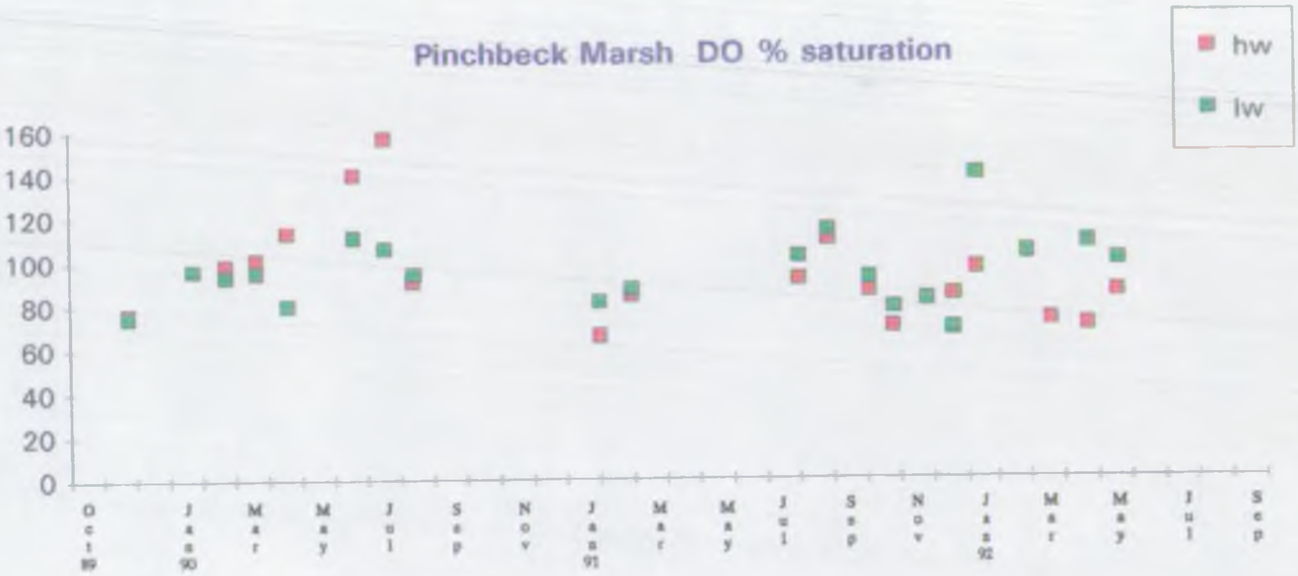
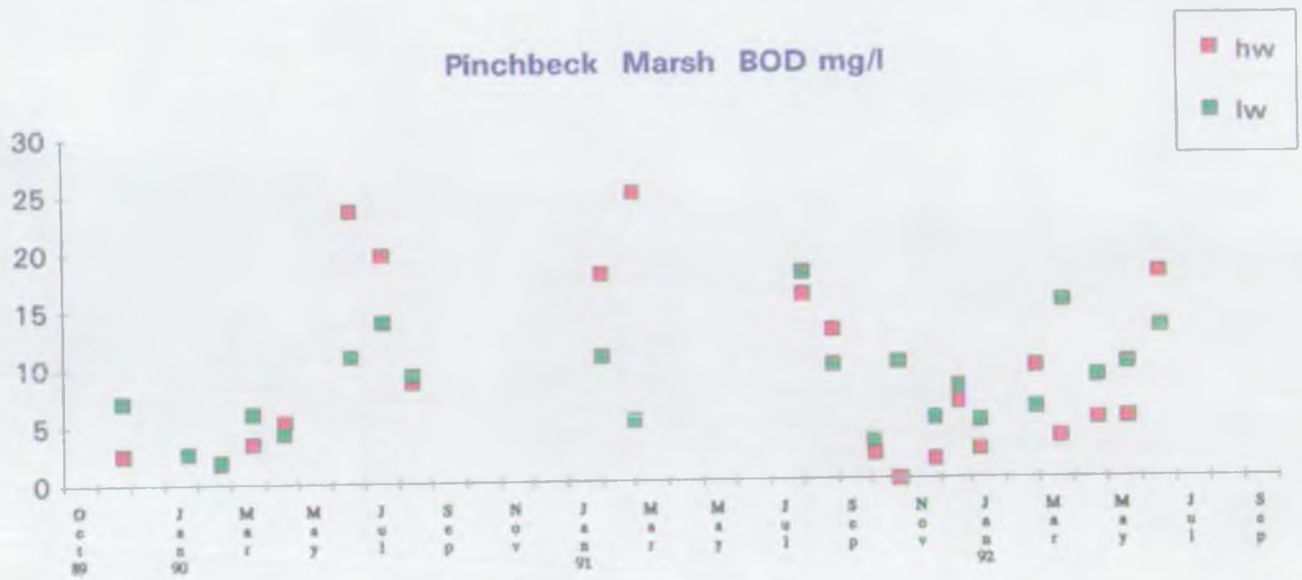


Figure 3.1 Routine water quality sampling sites.





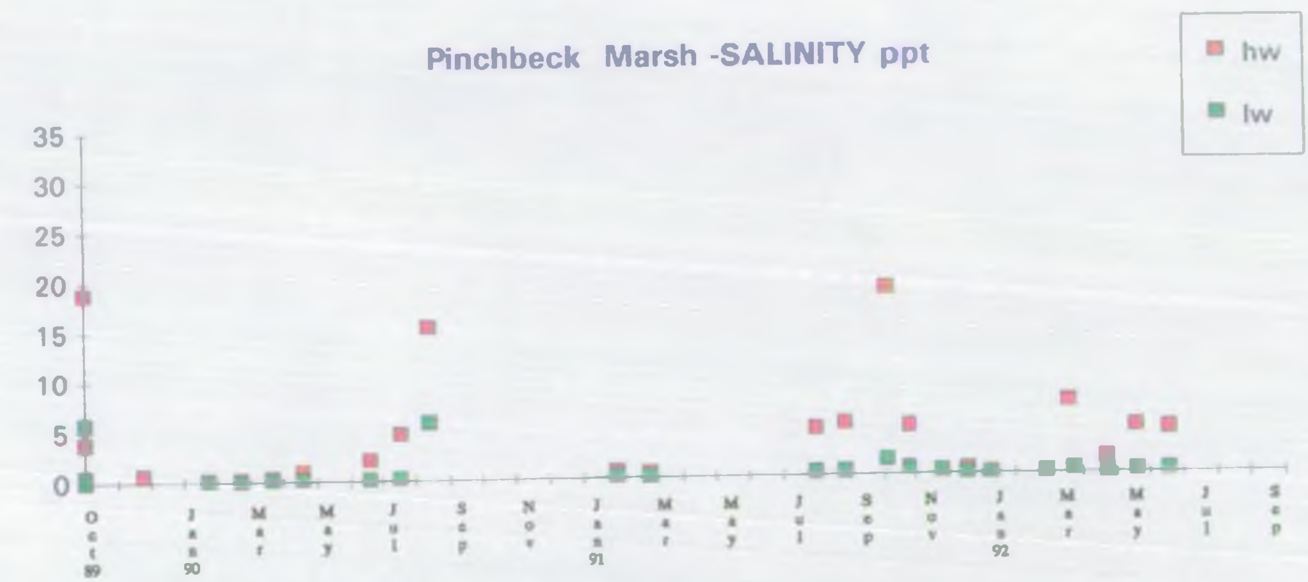
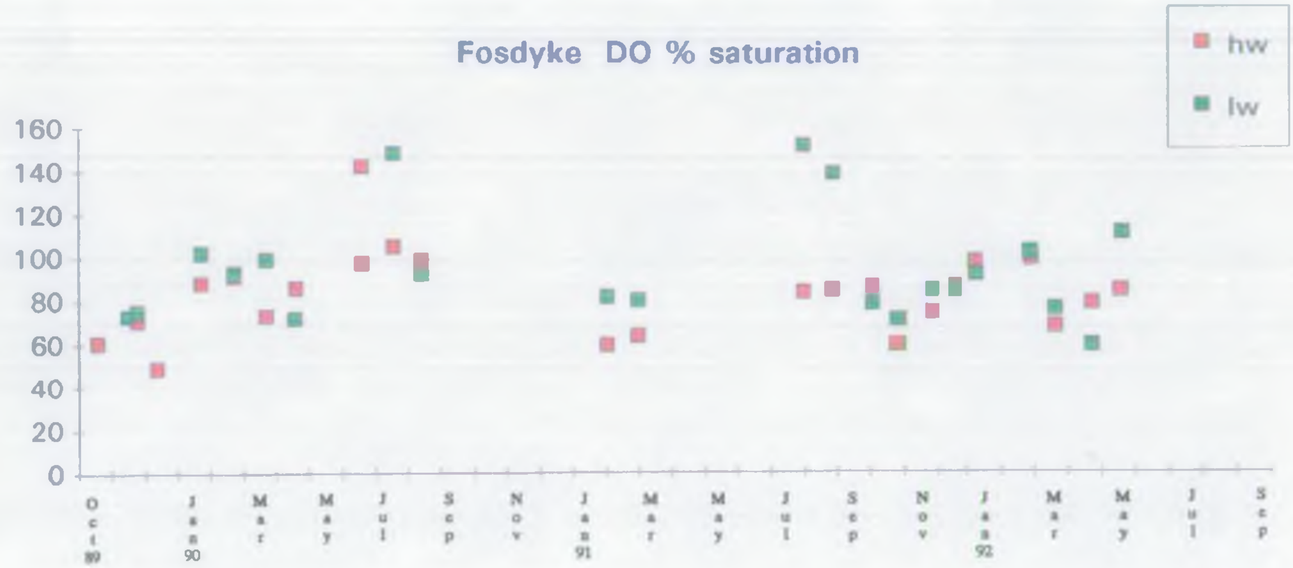
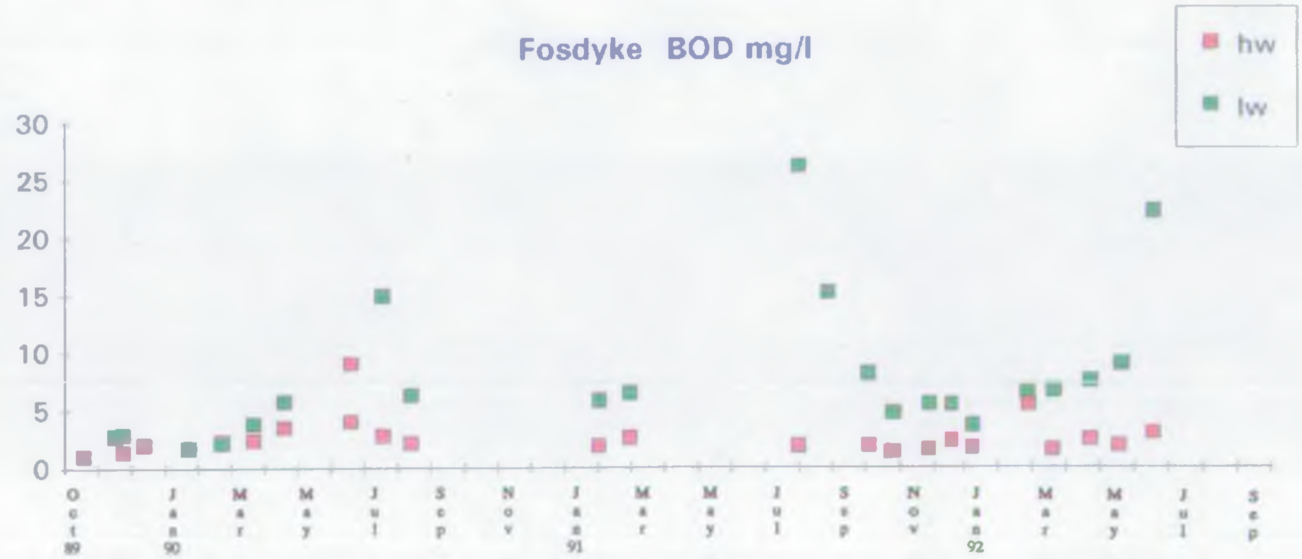


Figure 3.2. Pinchbeck Marsh - water quality.





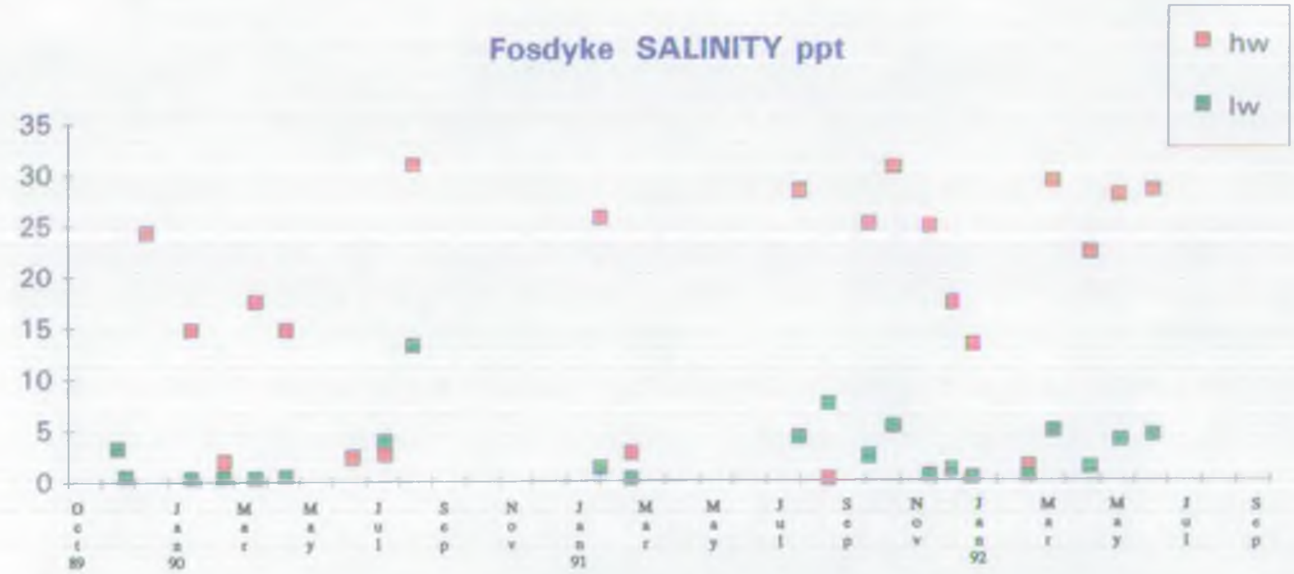


Figure 3.3. Fosdyke Bridge - water quality.

Figure 3.4. Moulton Marsh - water quality.

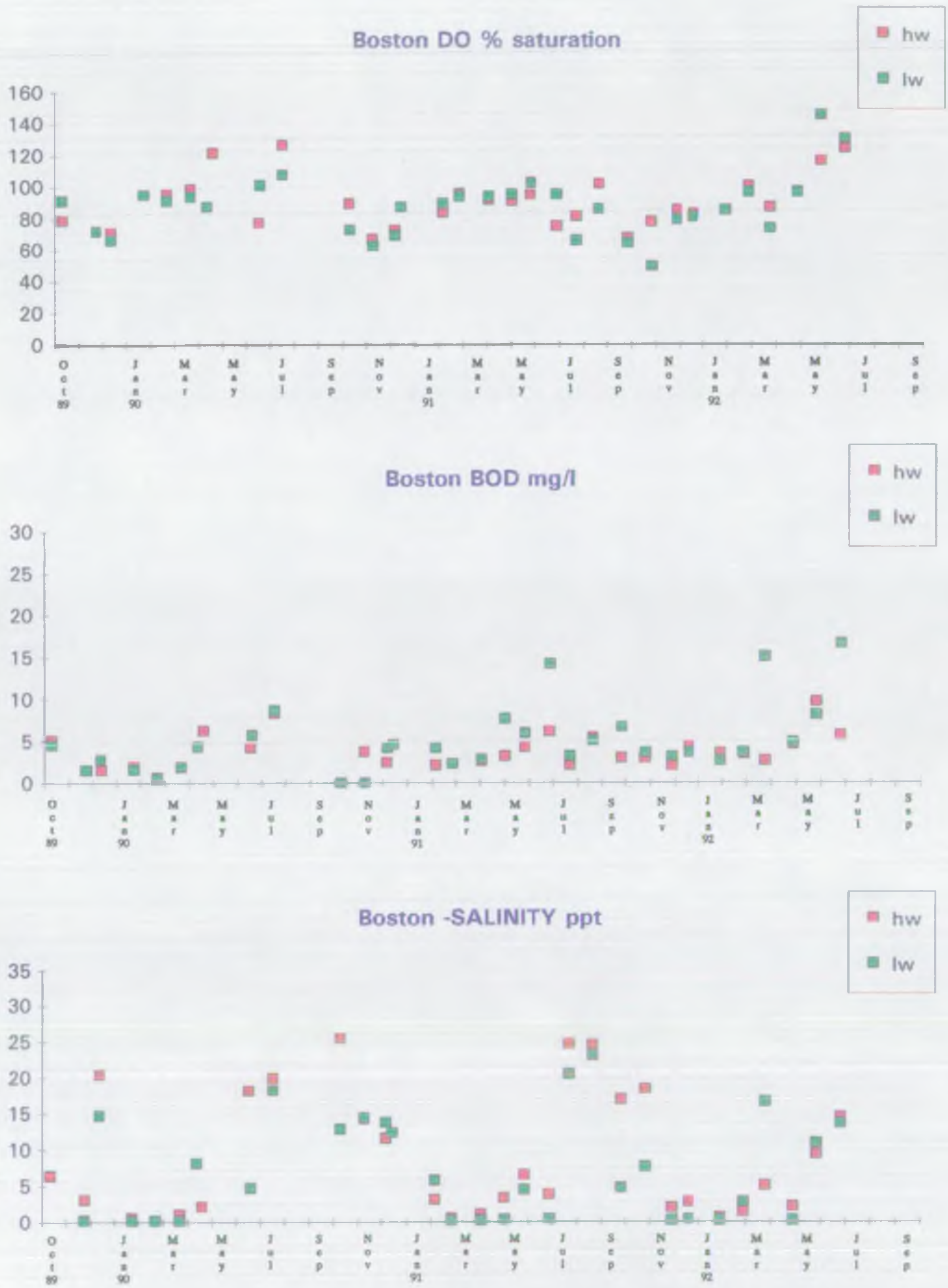
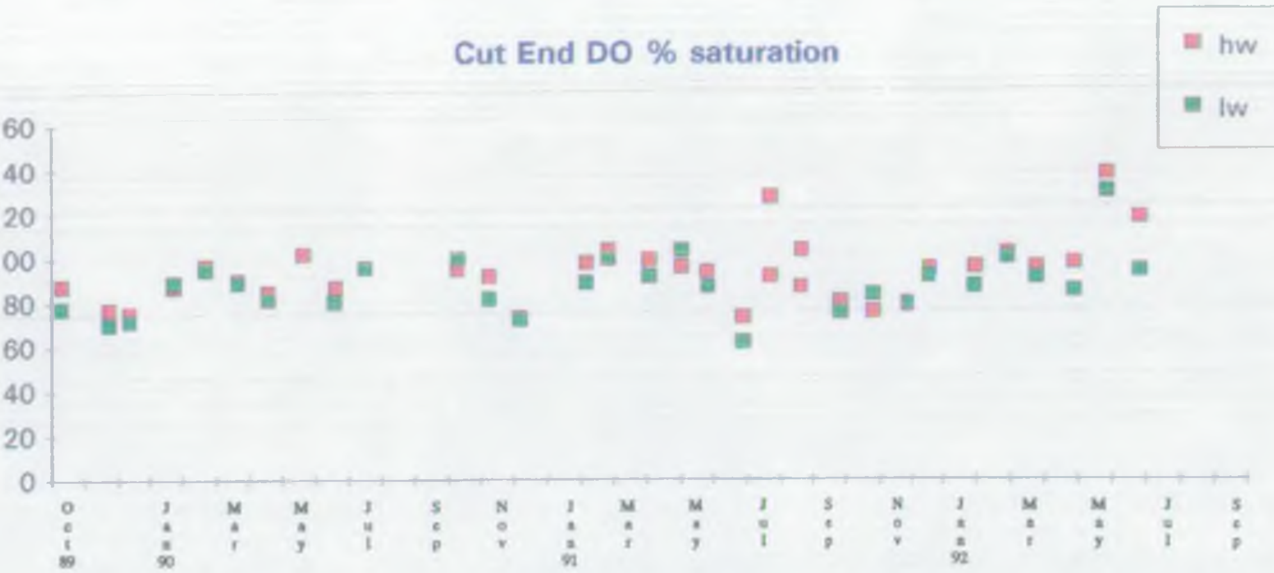
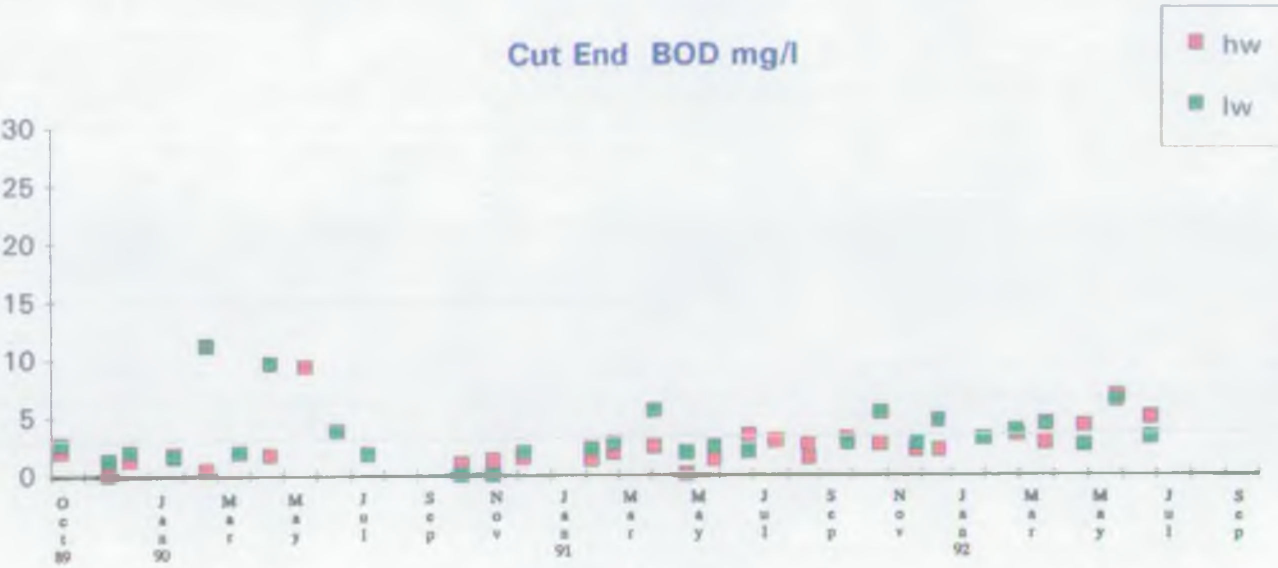


Figure 3.5. Boston swing bridge - water quality data.





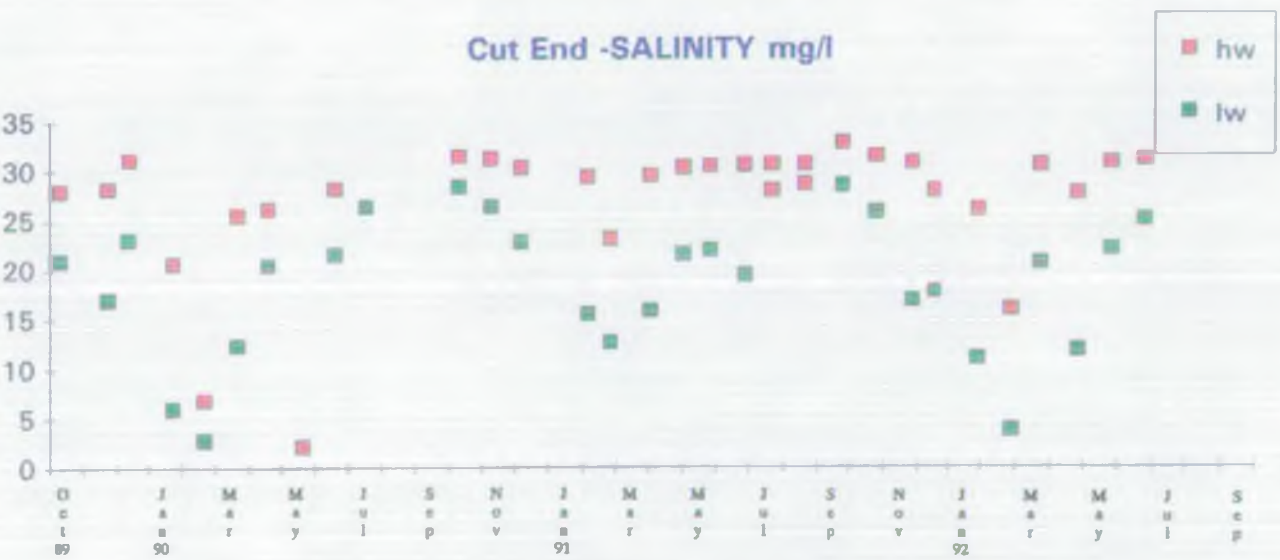


Figure 3.6. Witham Cut End - water quality.

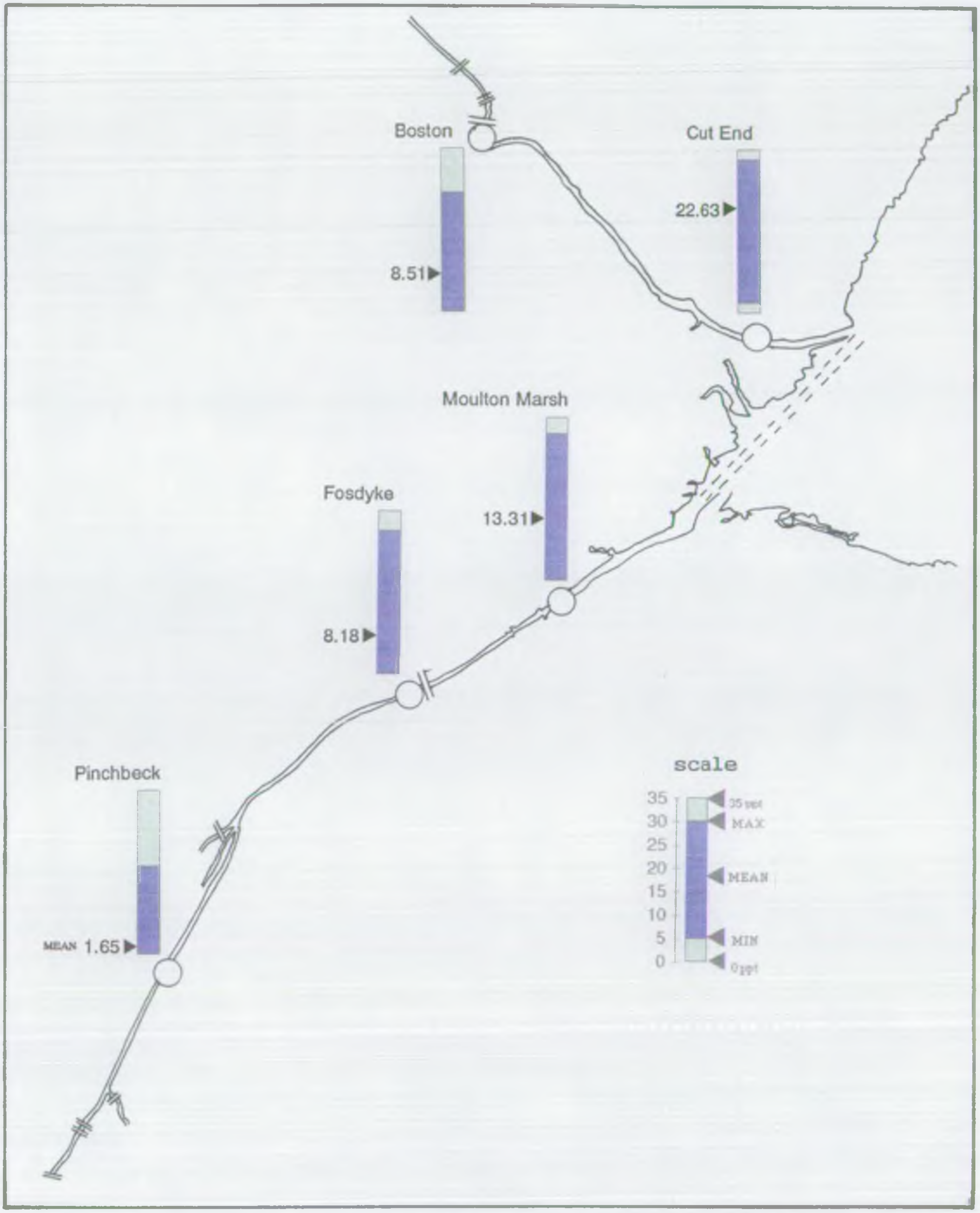


Figure 3.7. Summary of the salinity data from the NRA routine sampling sites.

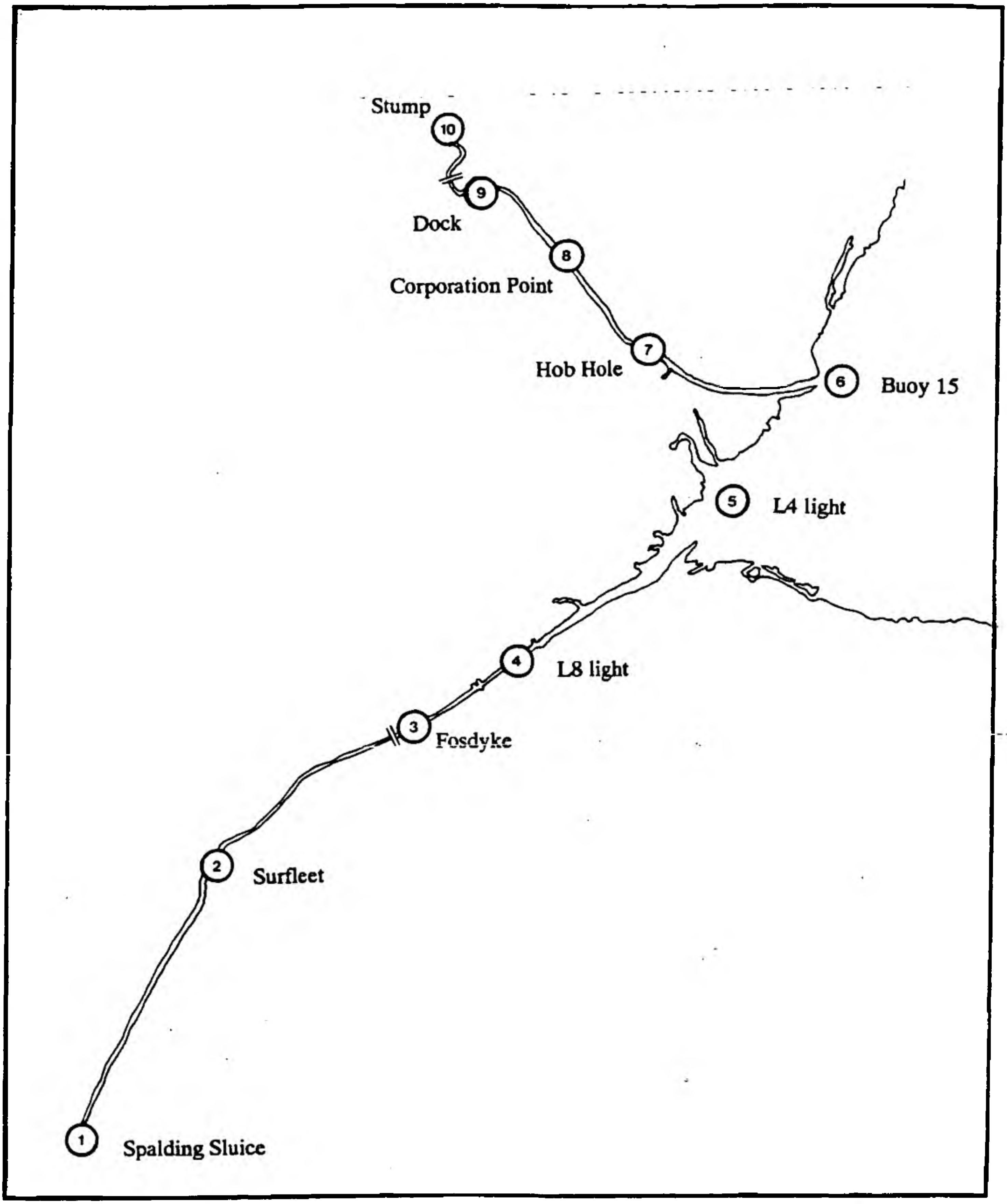


Figure 3.8 Sites sampled during the NRA/Unicomarine water quality survey.

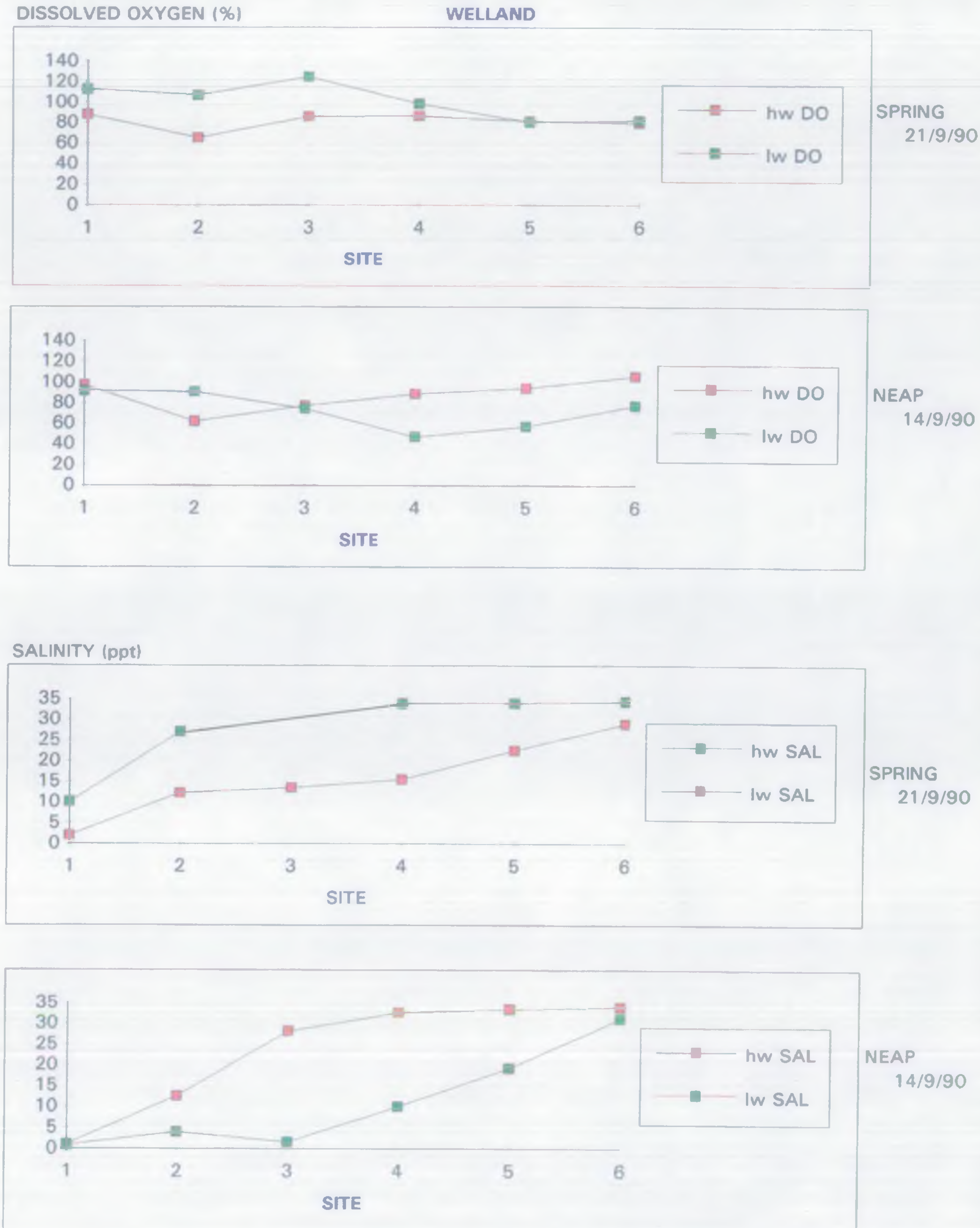


Figure 3.9 . Welland - Salinity and Dissolved Oxygen data from Spring and Neap tides.

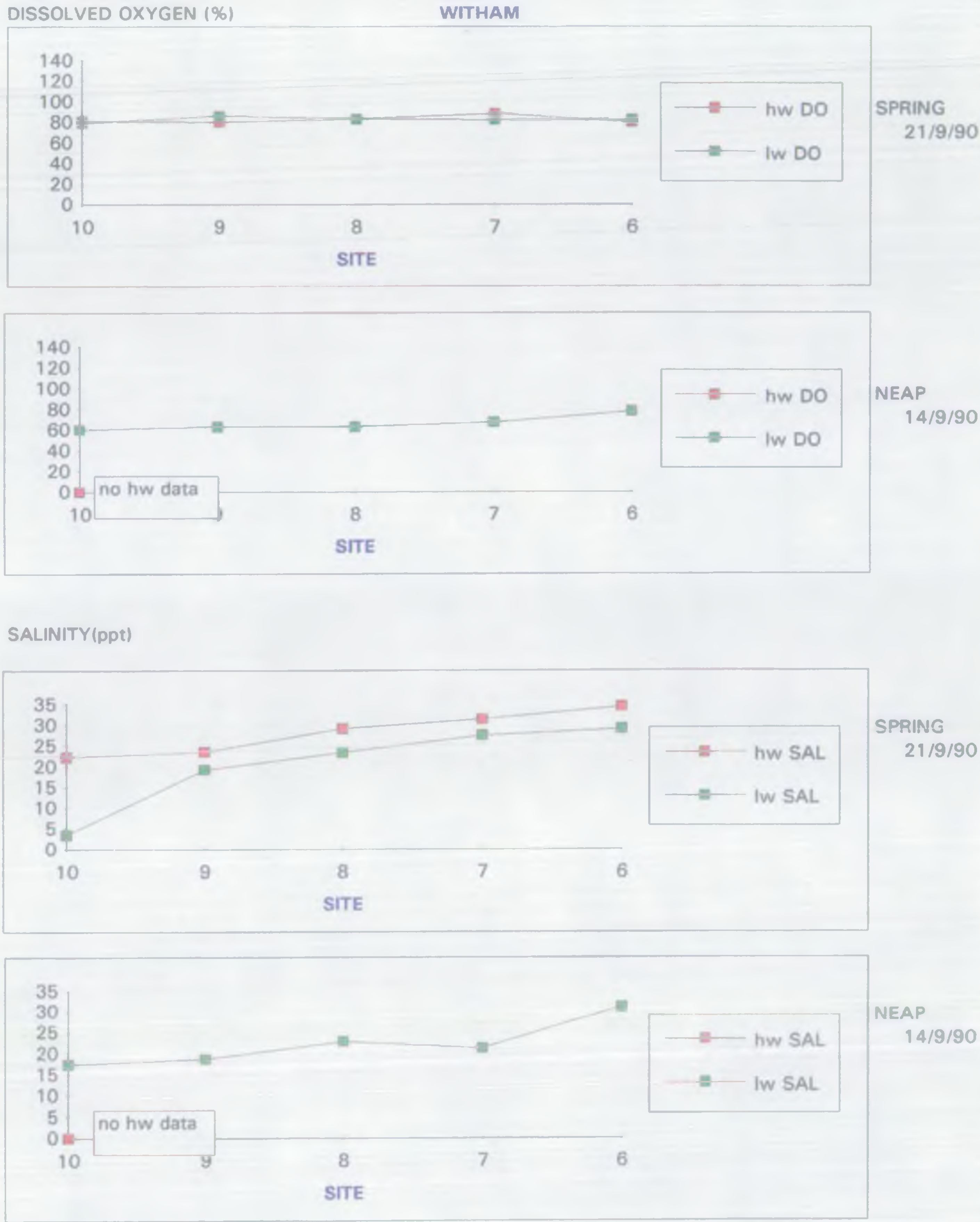


Figure 3.10. Witham - salinity and Dissolved Oxygen data from spring and neap tides.

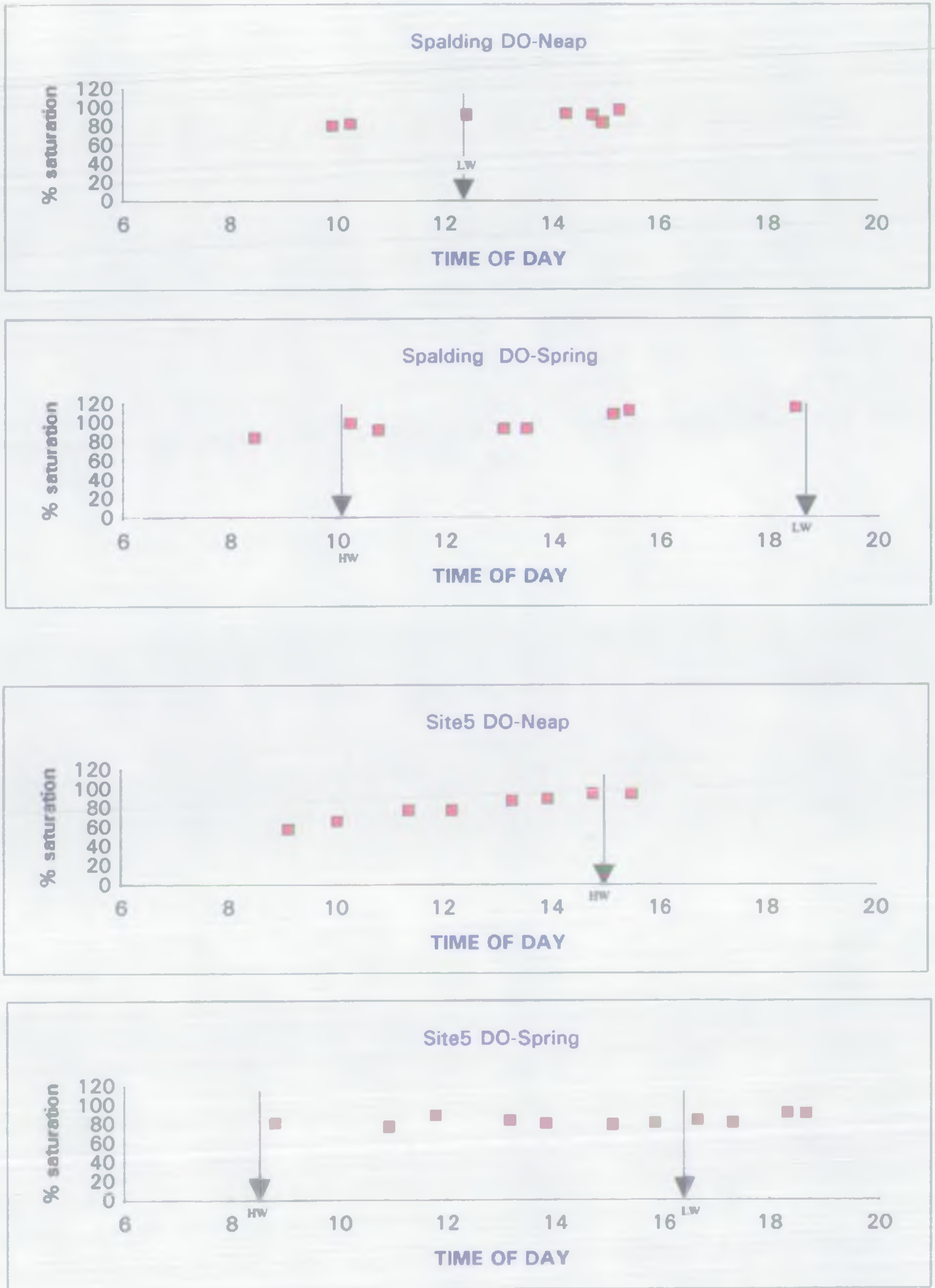


Figure 3.11. Dissolved oxygen (% saturation) at Spalding and Site 5 on the Welland on Spring and Neap tides.

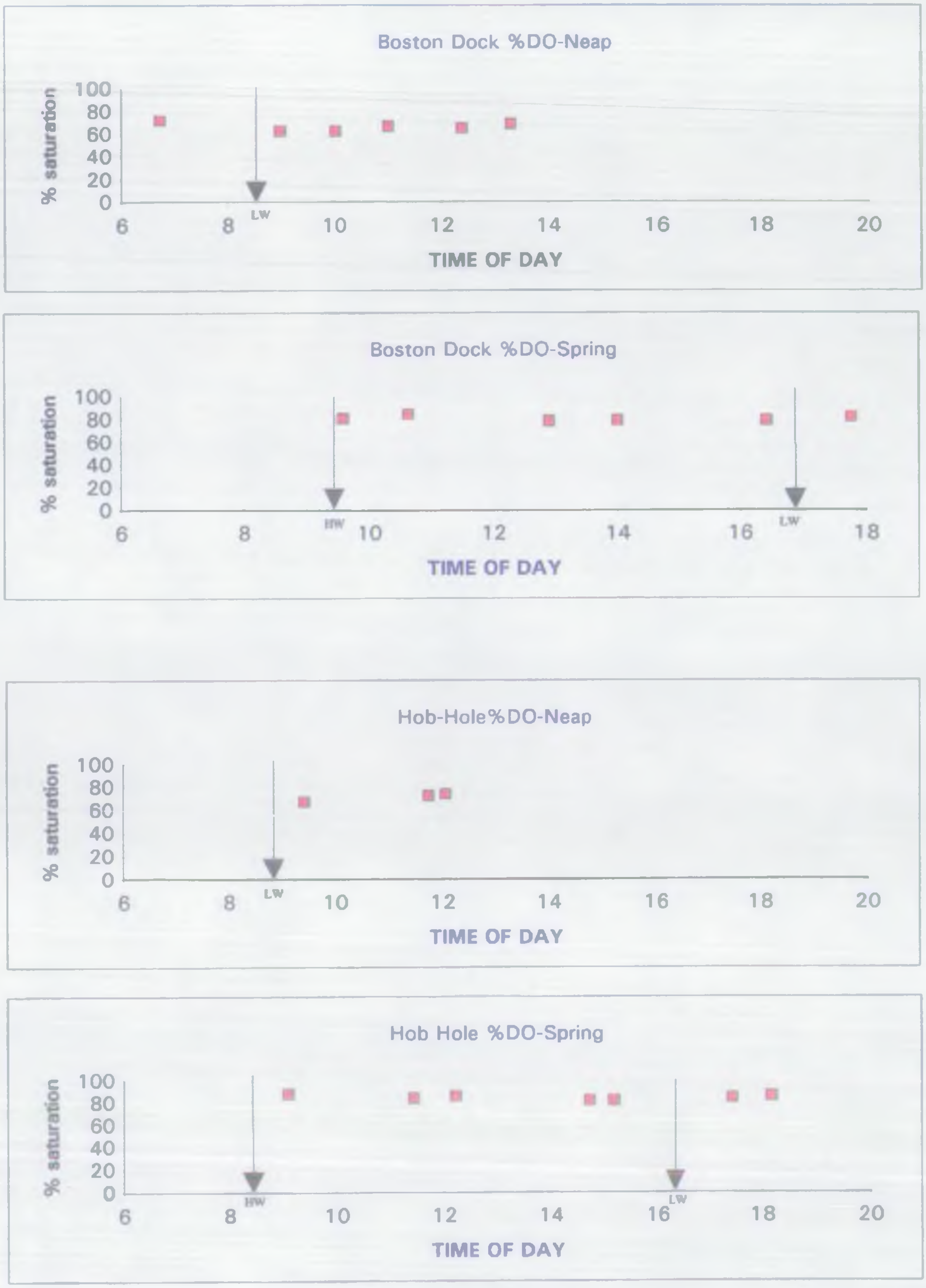


Figure 3.12. Dissolved oxygen (% saturation) at Boston Dock and Hob Hole on the Witham on Spring and Neap tides.

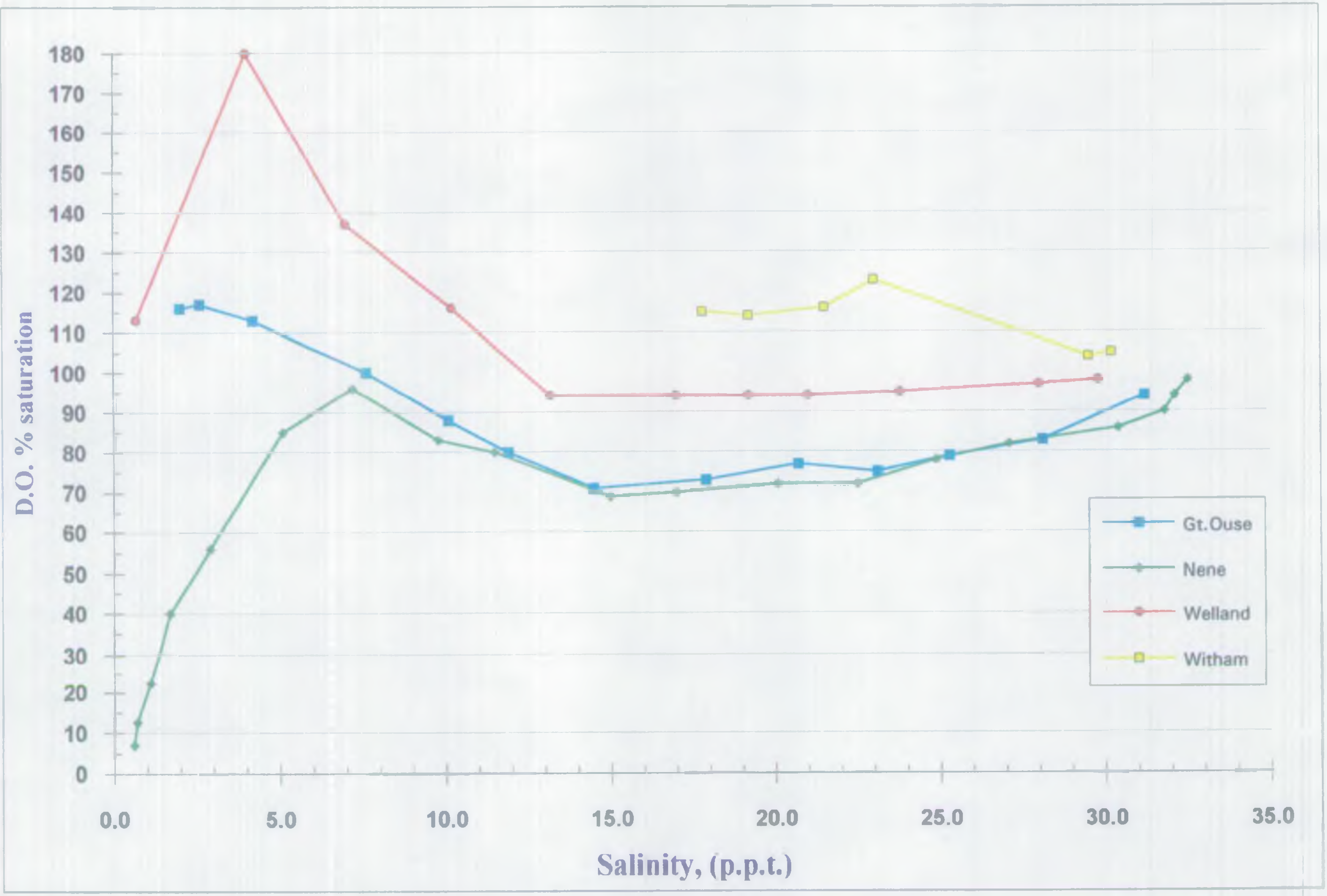


Figure 3.13. Dissolved oxygen on the Wash estuaries from the JoNuS 2 survey, July 1990.

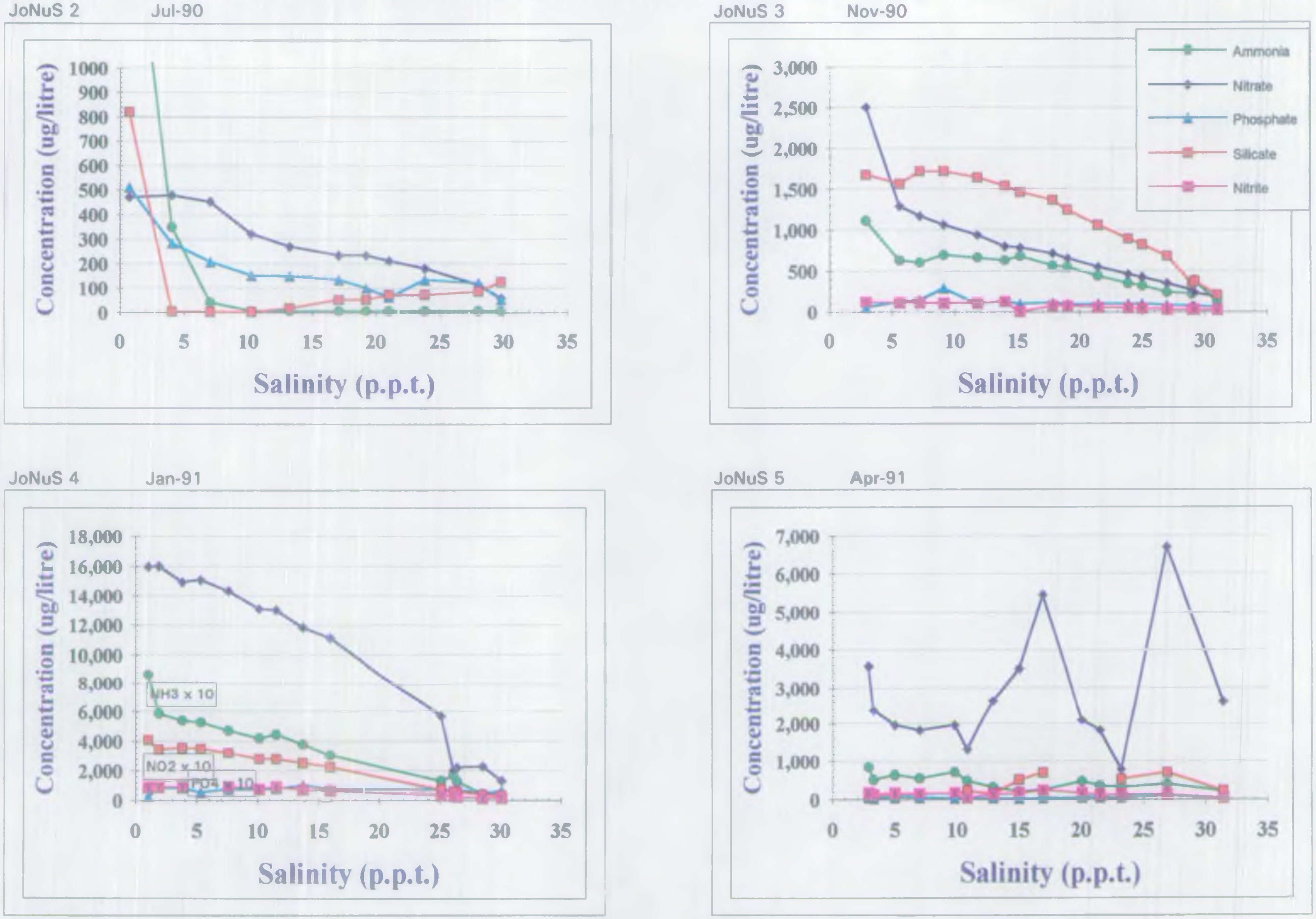
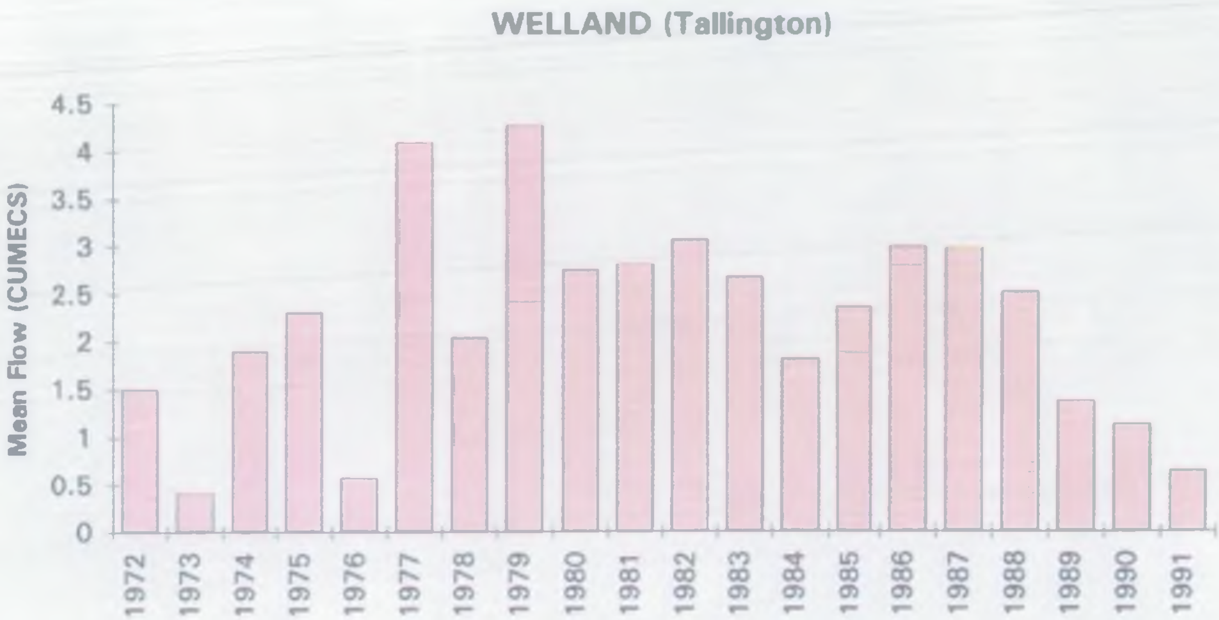


Figure 3.14. Nutrient data from the Welland estuary.



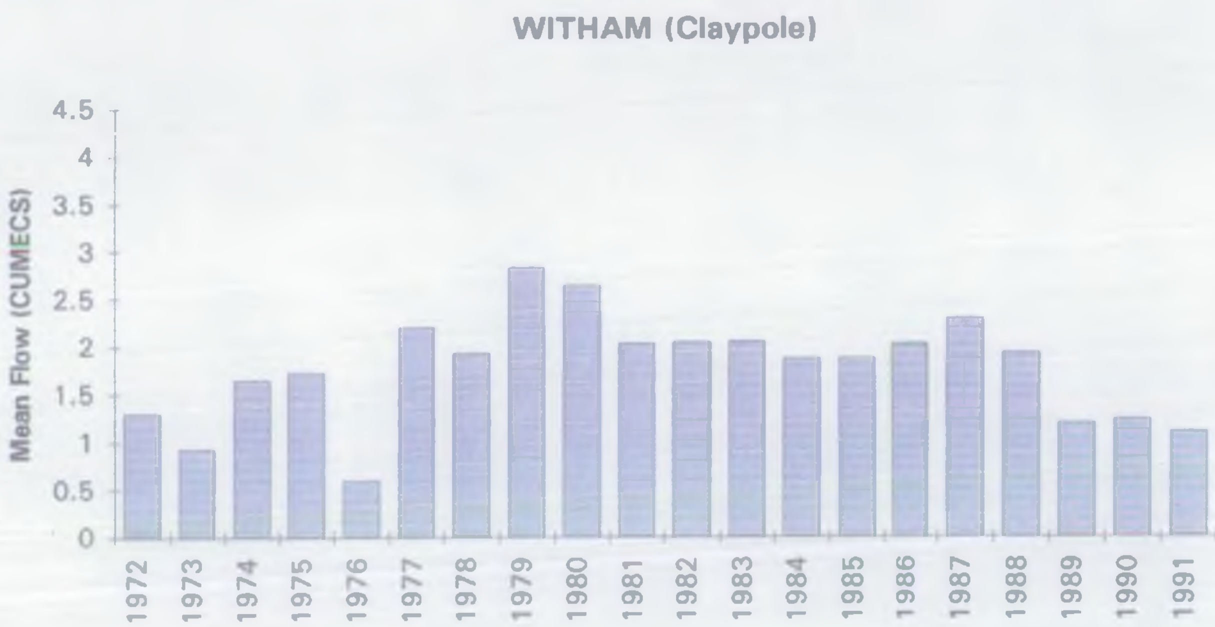


Figure 3.15 . Mean annual flow on the Welland and Witham.

Figure 4.1. Total number of individuals from three 0.1m2 grabs (log10 scale).
ND = no data.

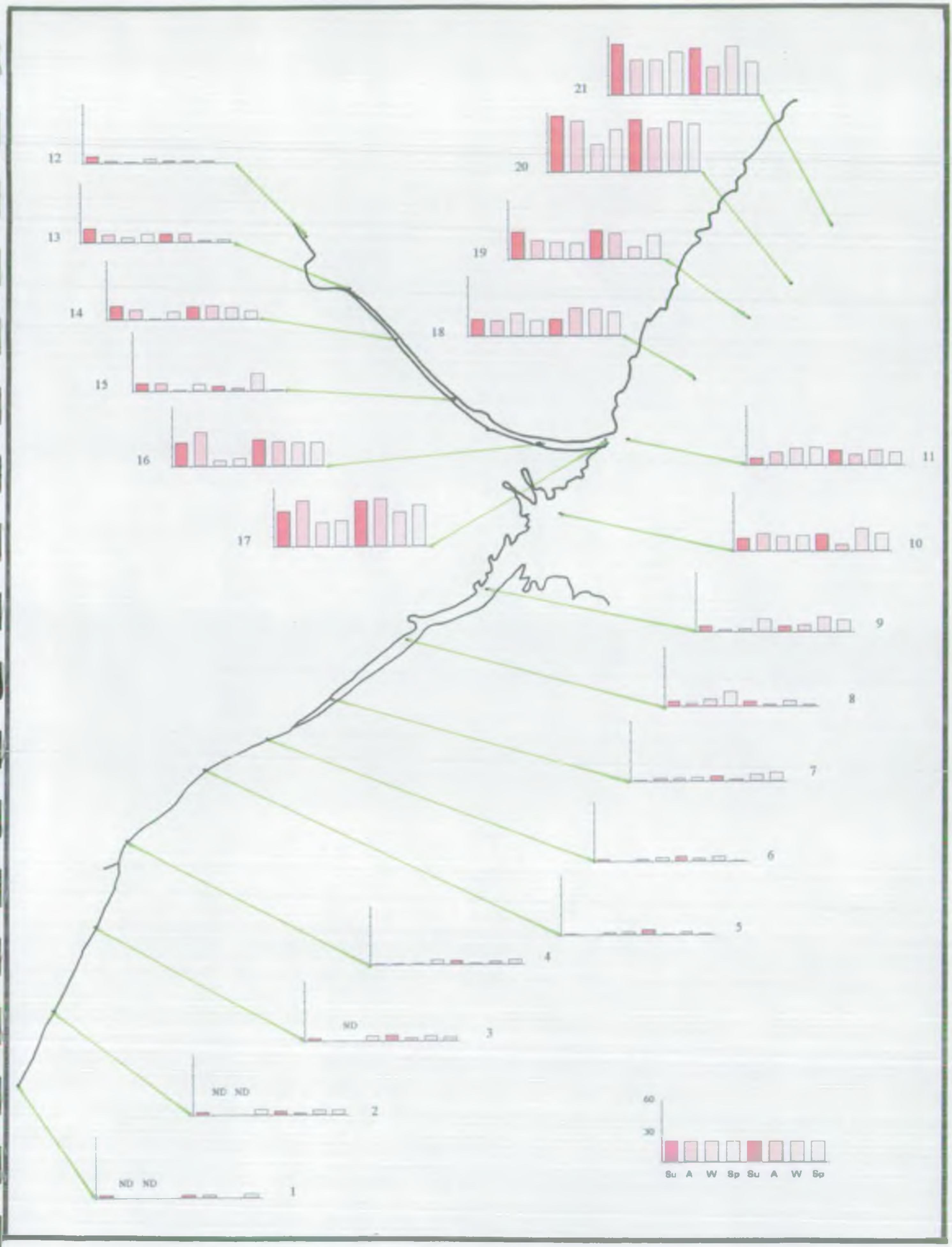


Figure 4.2. Total number of species from three 0.1m2 grabs. ND = no data.

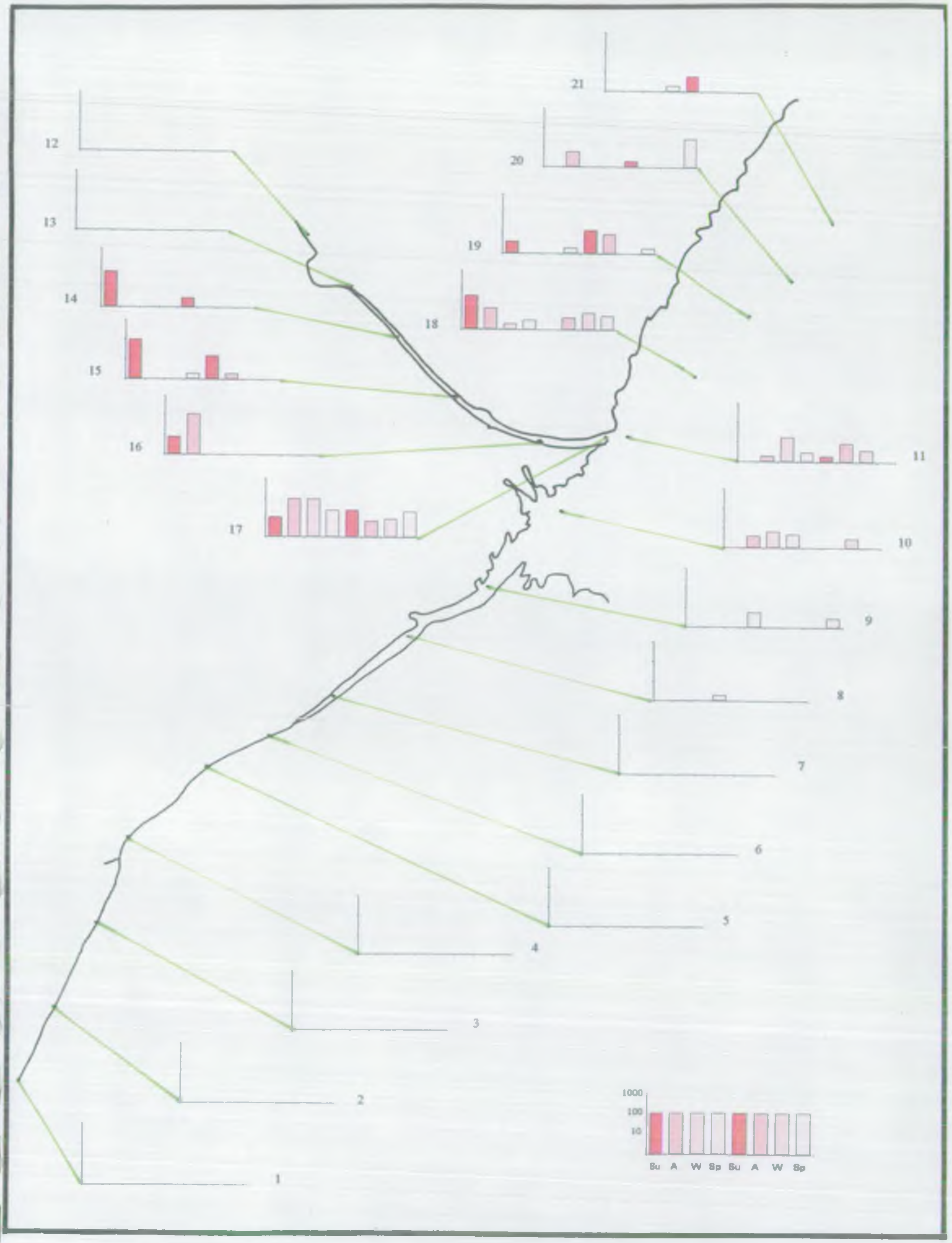


Figure 4.3. Capitella capitata from three 0.1m2 grabs (log10 scale).

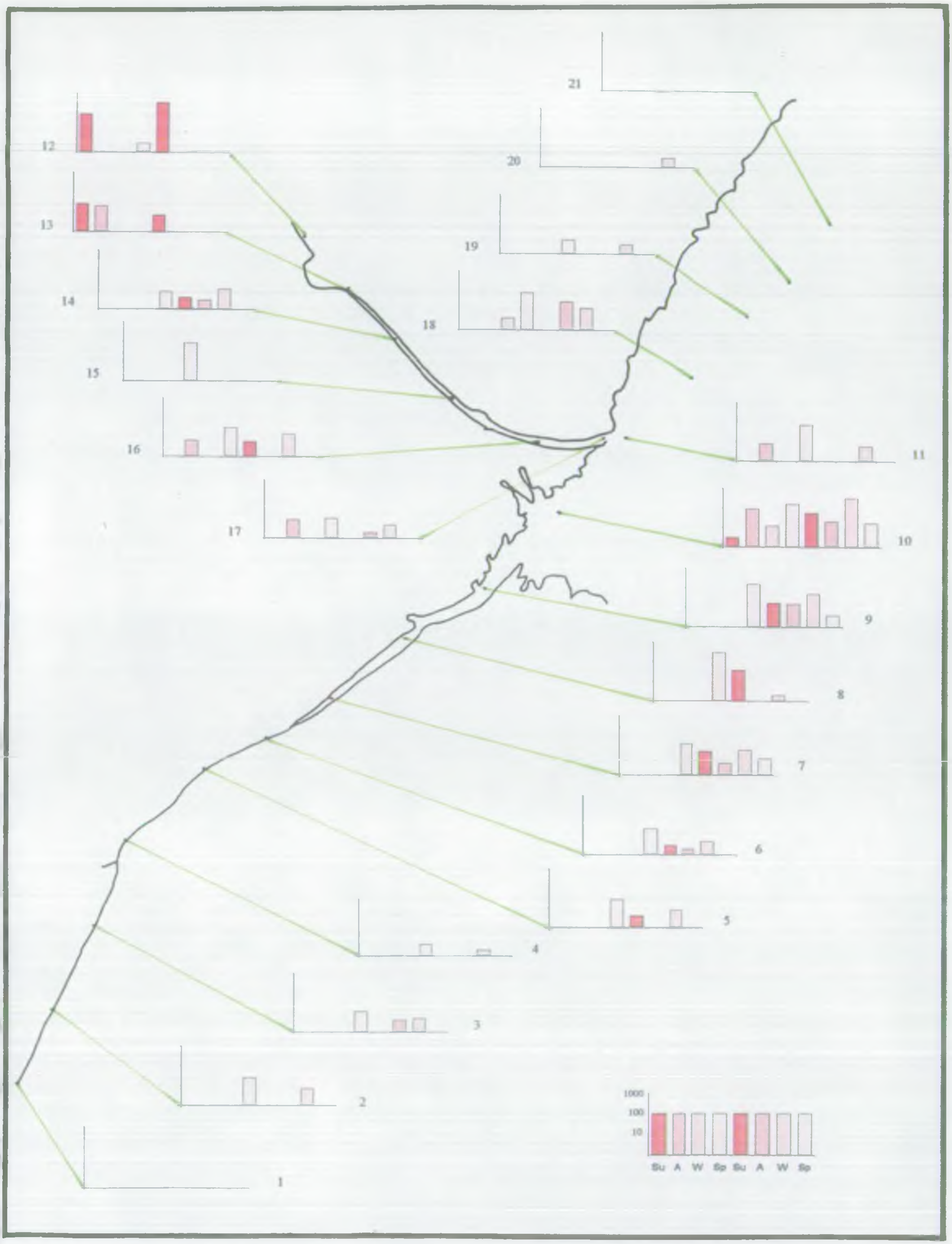


Figure 4.4. Hydrobia ulvae from three 0.1m2 grabs (log10 scale).

Figure 4.5. Lanice conchilega from three 0.1m2 grabs (log10 scale).

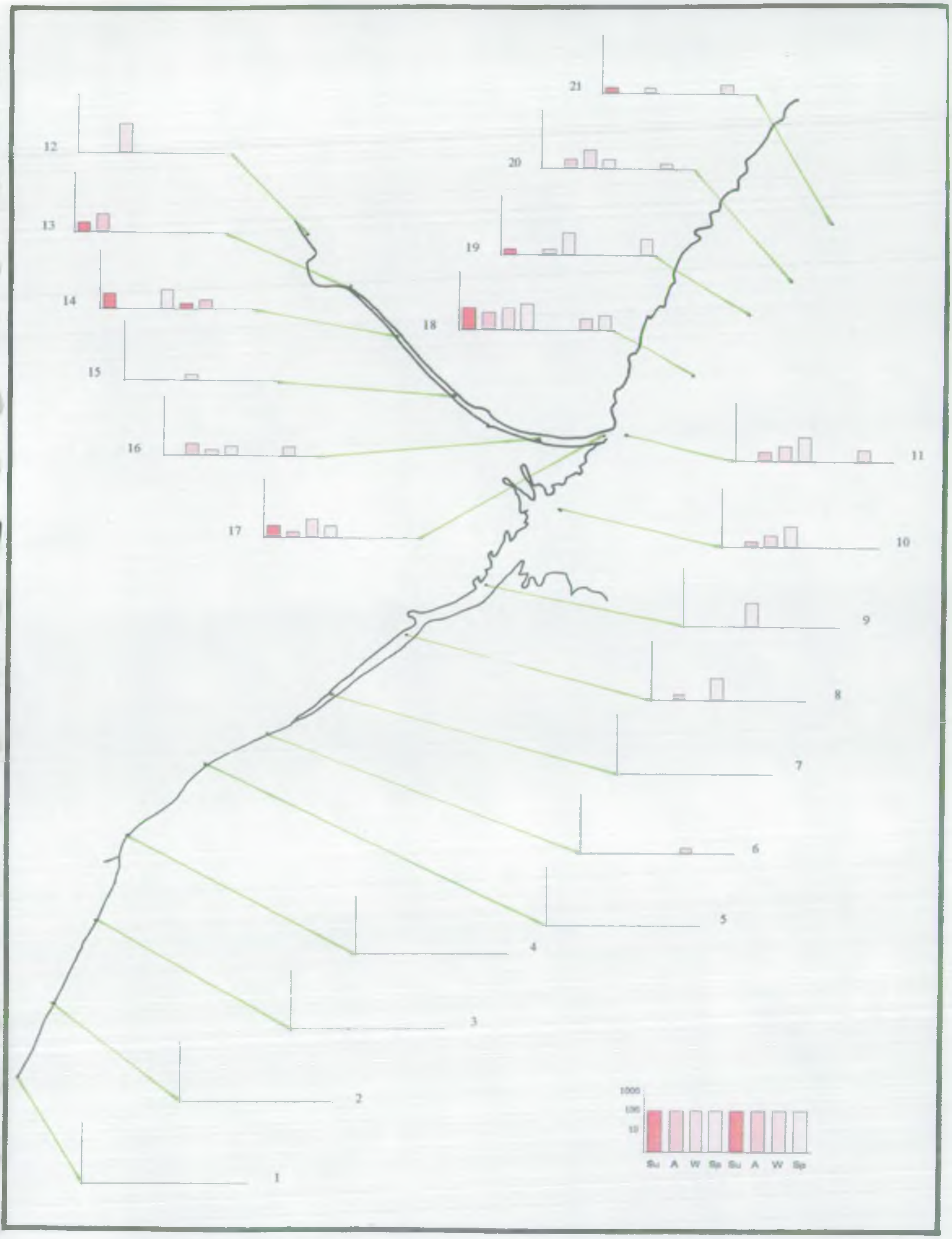


Figure 4.6. Macoma balthica from three 0.1m2 grabs (log10 scale).

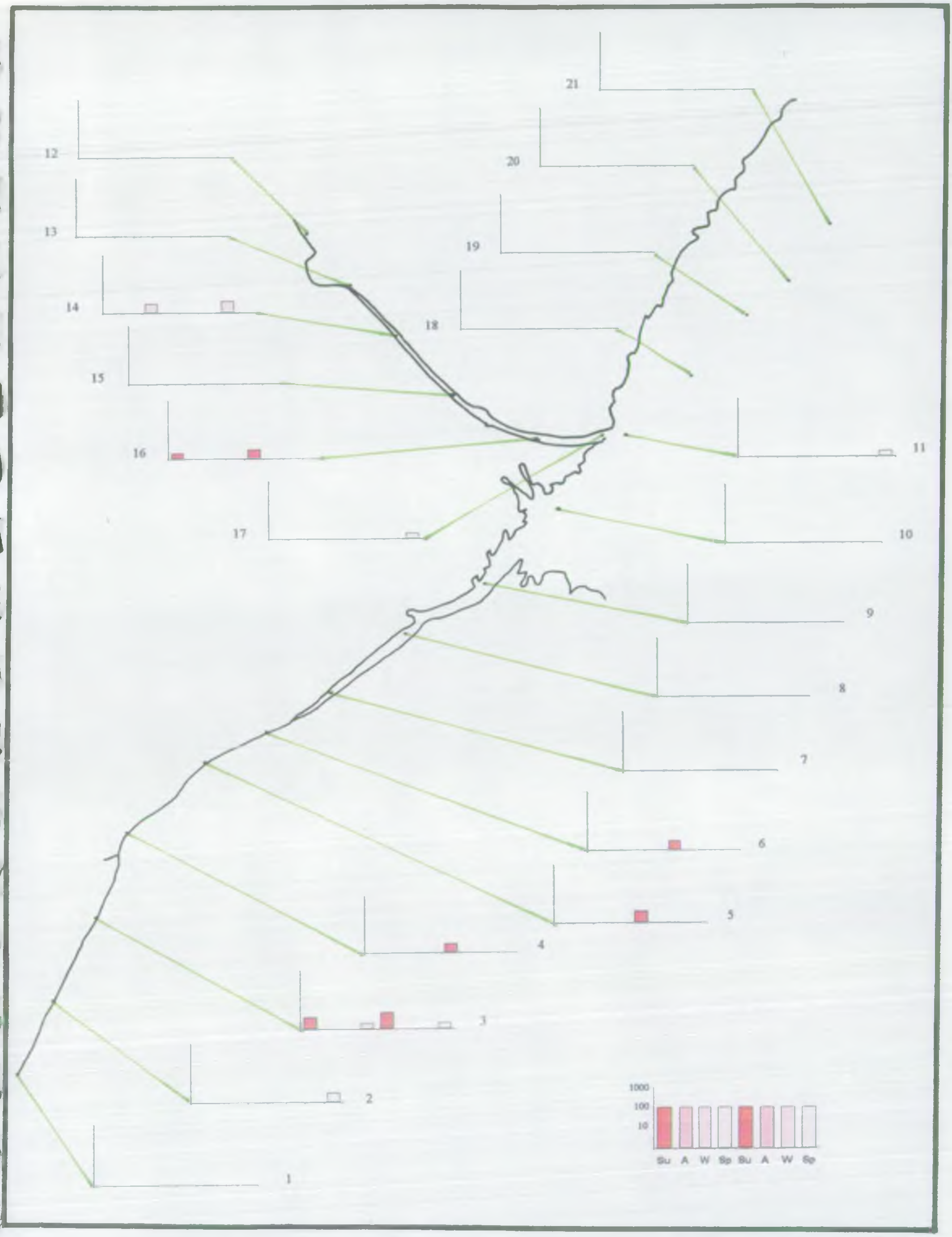


Figure 4.7. Neomysis integer from three 0.1m2 grabs (log10 scale).

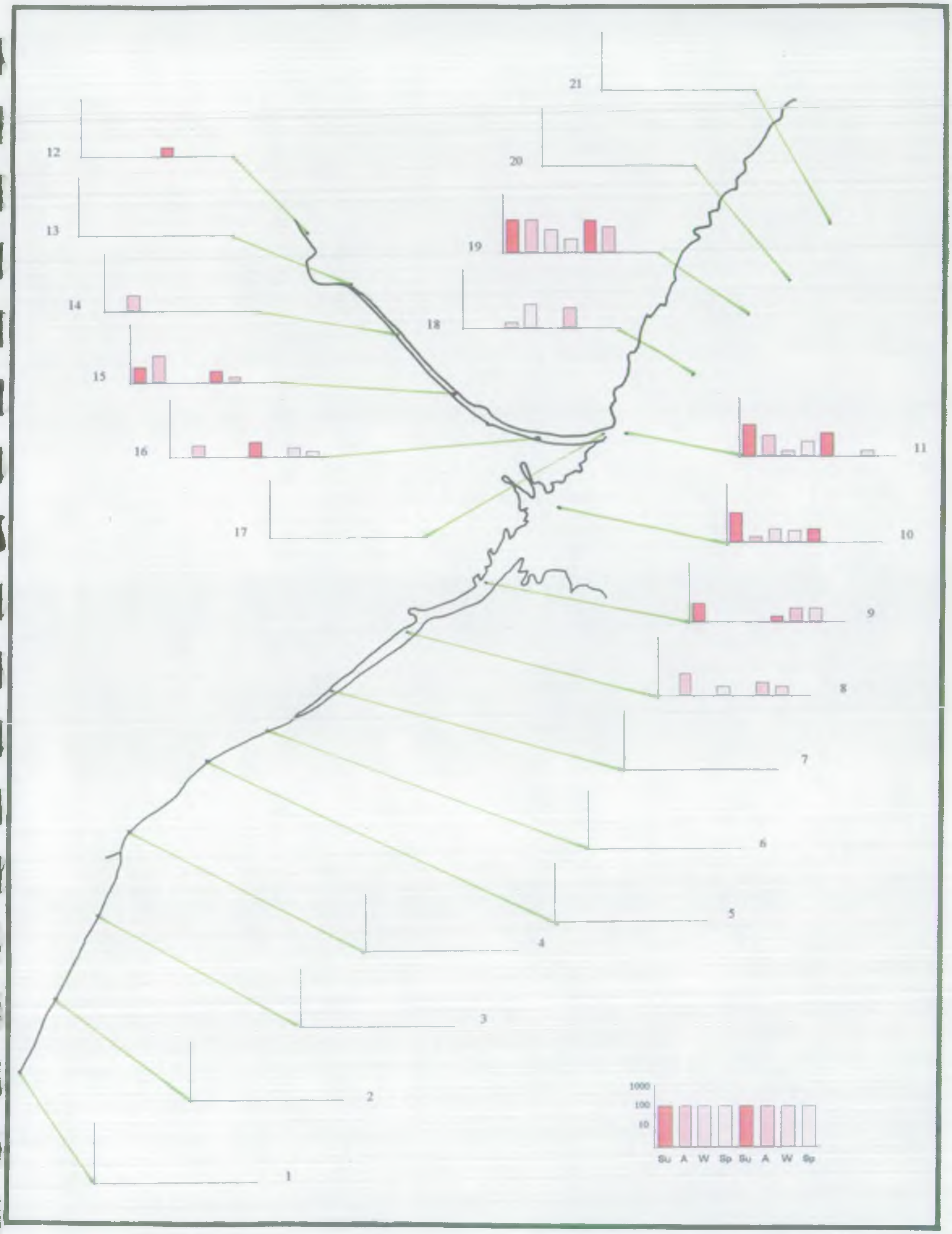


Figure 4.8. Nephtys cirrosa from three 0.1m2 grabs (log10 scale).

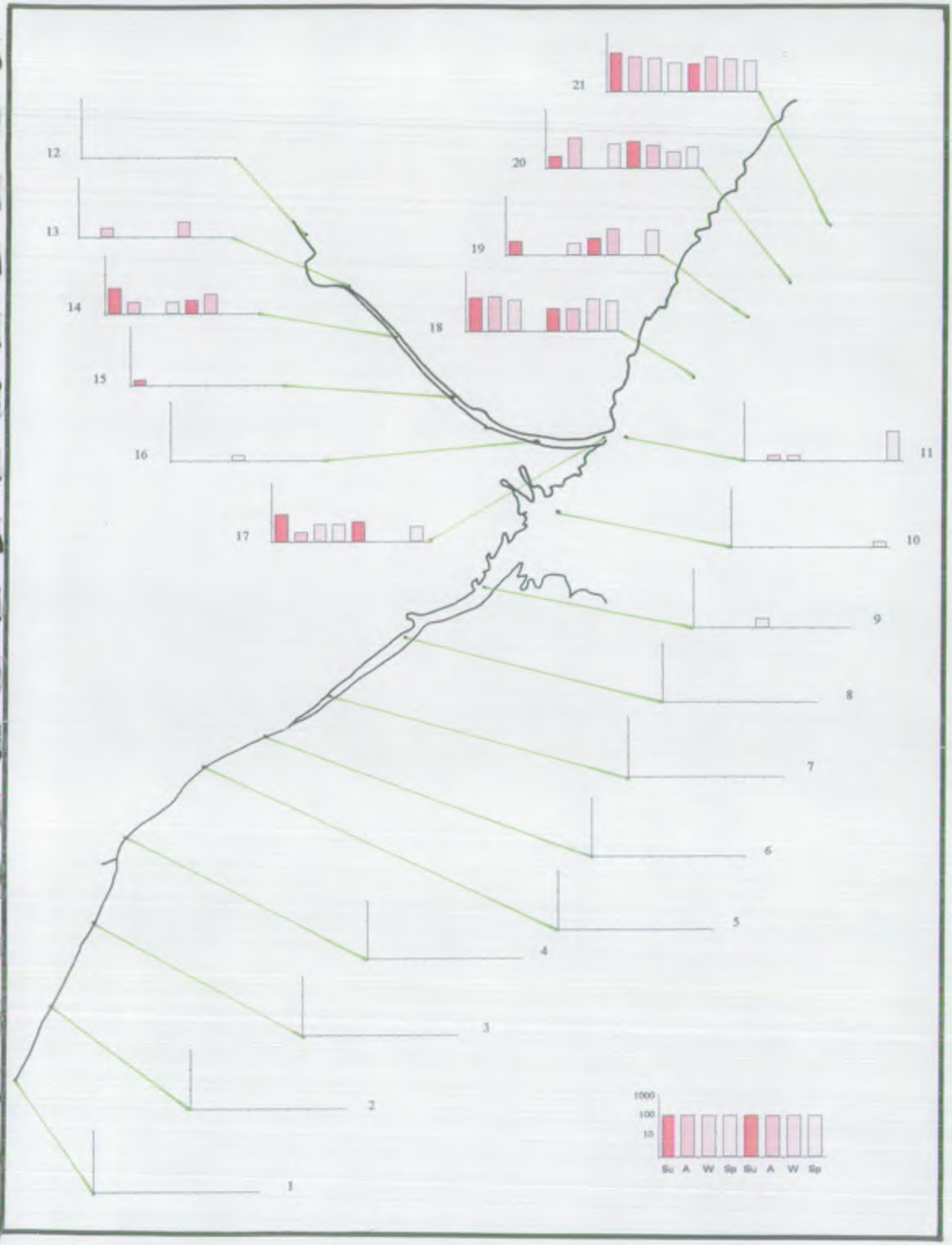


Figure 4.9. Nephtys hombergii from three 0.1m2 grabs (log10 scale).

Figure 4.10. Pygospio elegans from three 0.1m2 grabs (log10 scale).

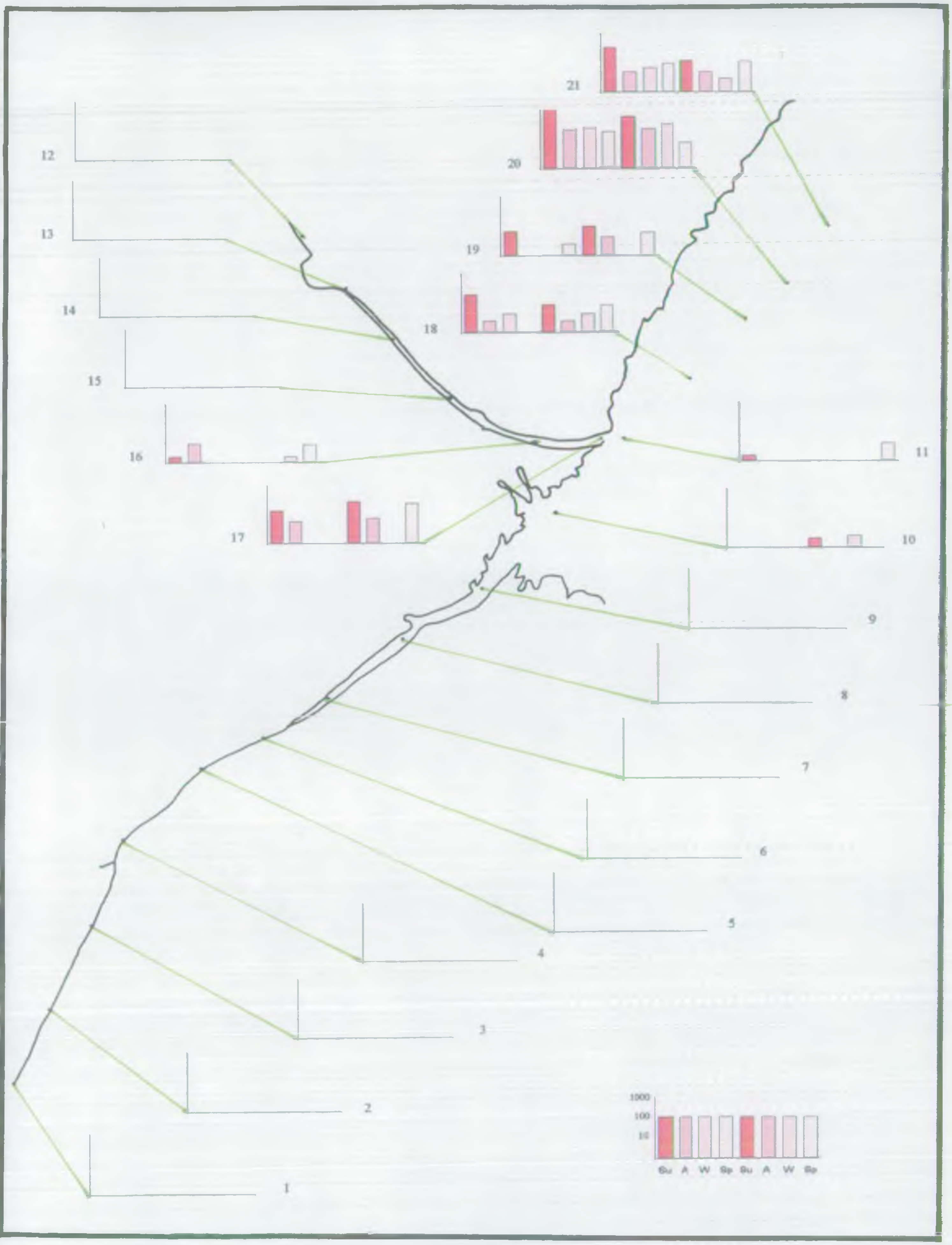


Figure 4.11. Scoloplos armiger from three 0.1m2 grabs (log10 scale).

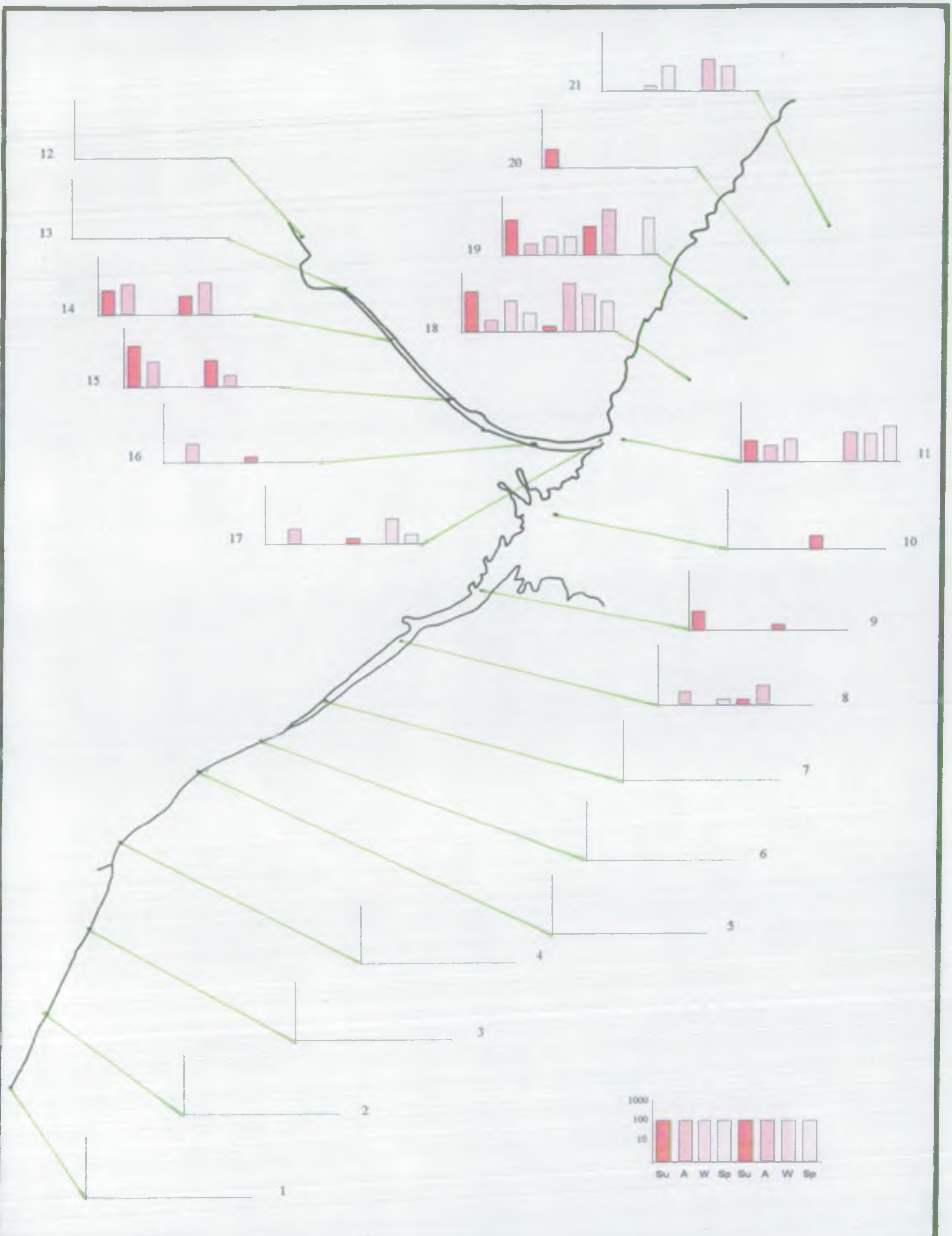


Figure 4.12. Spio martinensis from three 0.1m2 grabs (log10 scale).

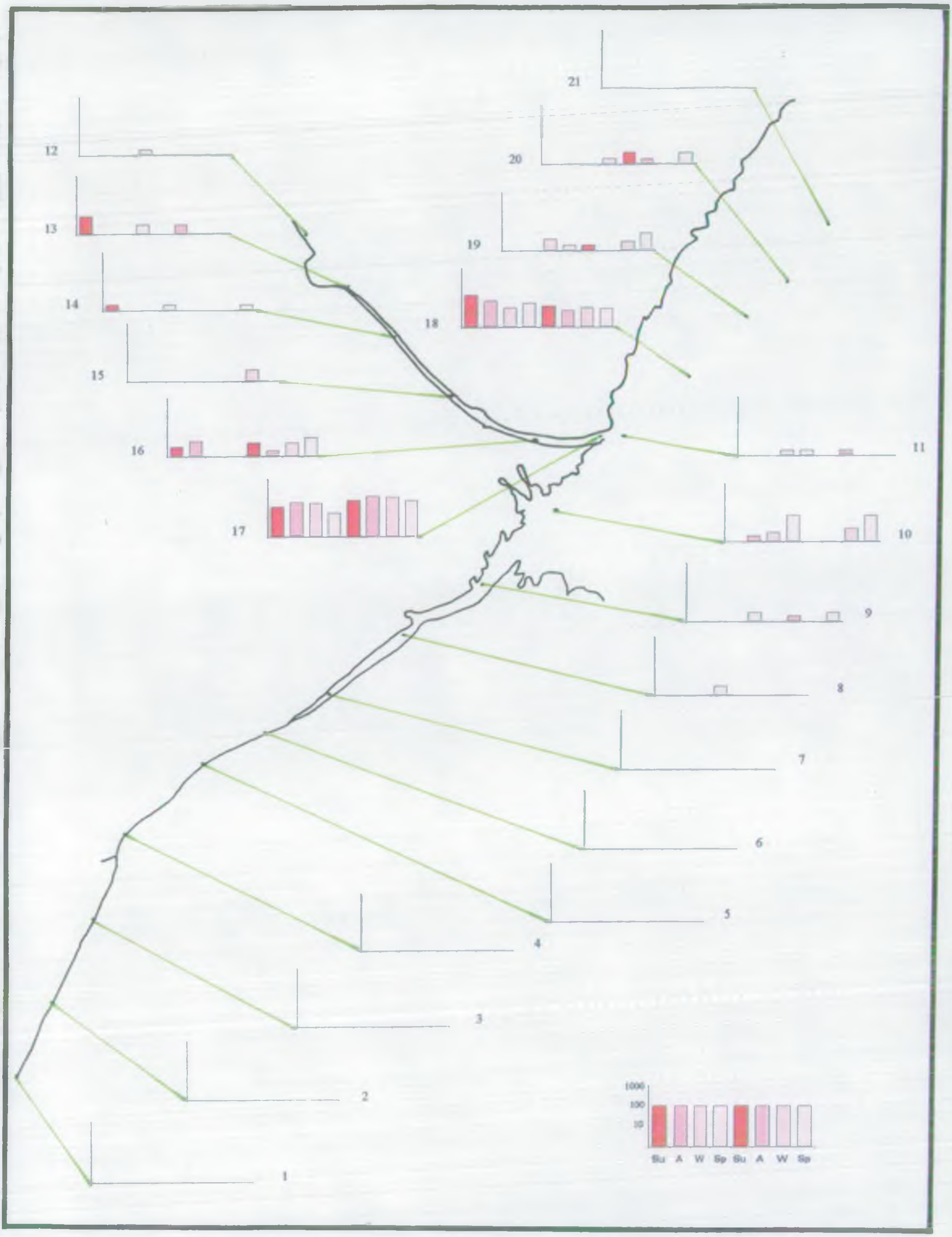


Figure 4.13. Tubificoides benedeni from three 0.1m2 grabs (log10 scale).

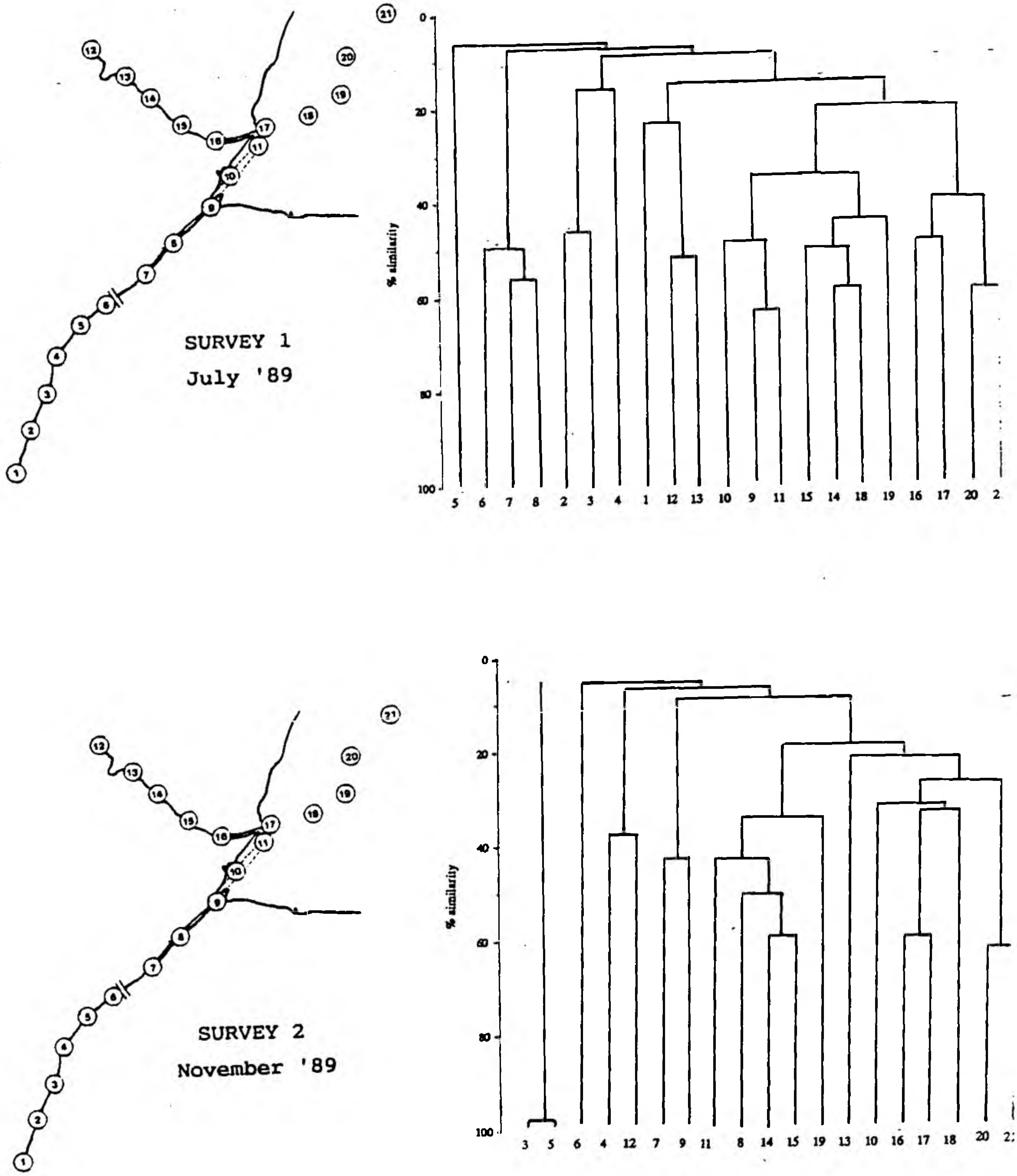
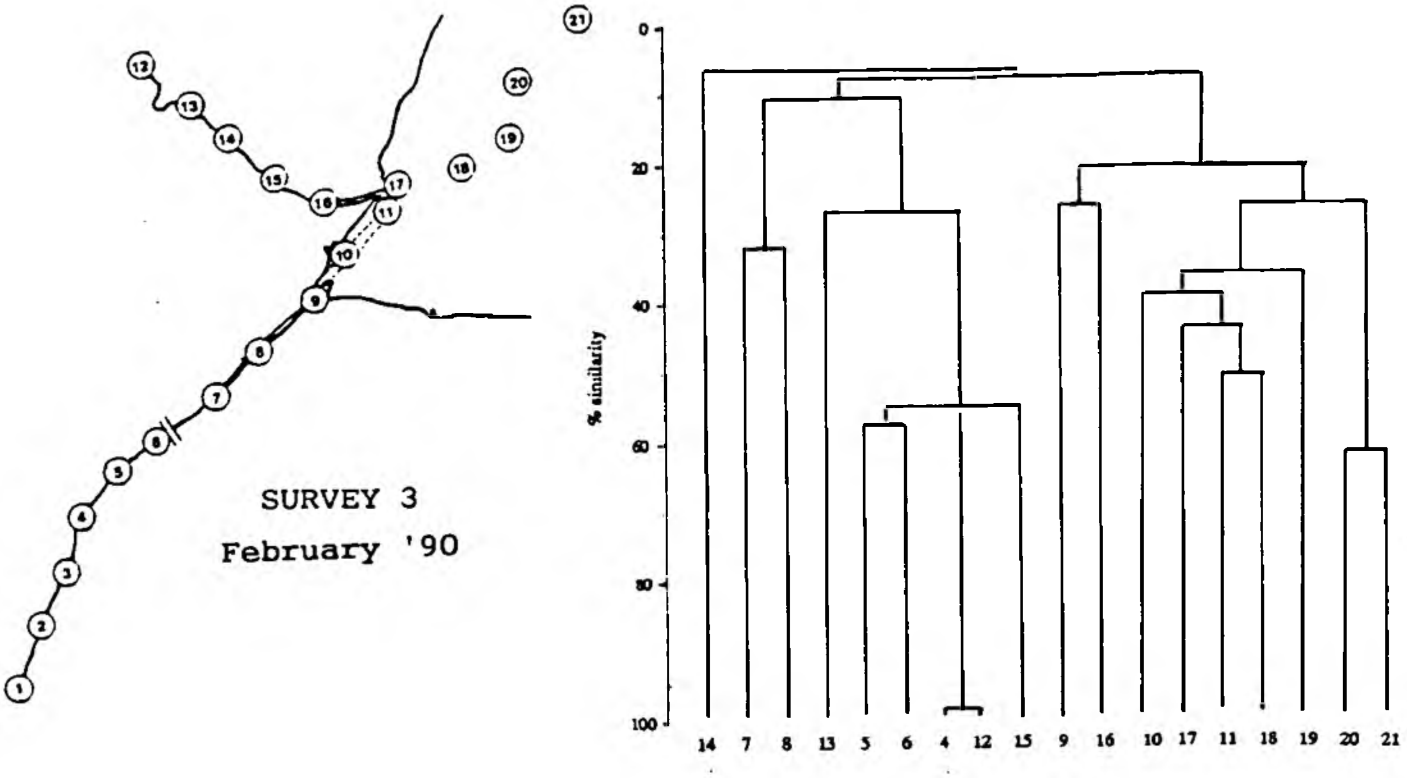


Figure 4.14 Cluster dendrograms of benthos data - survey 1 & 2.



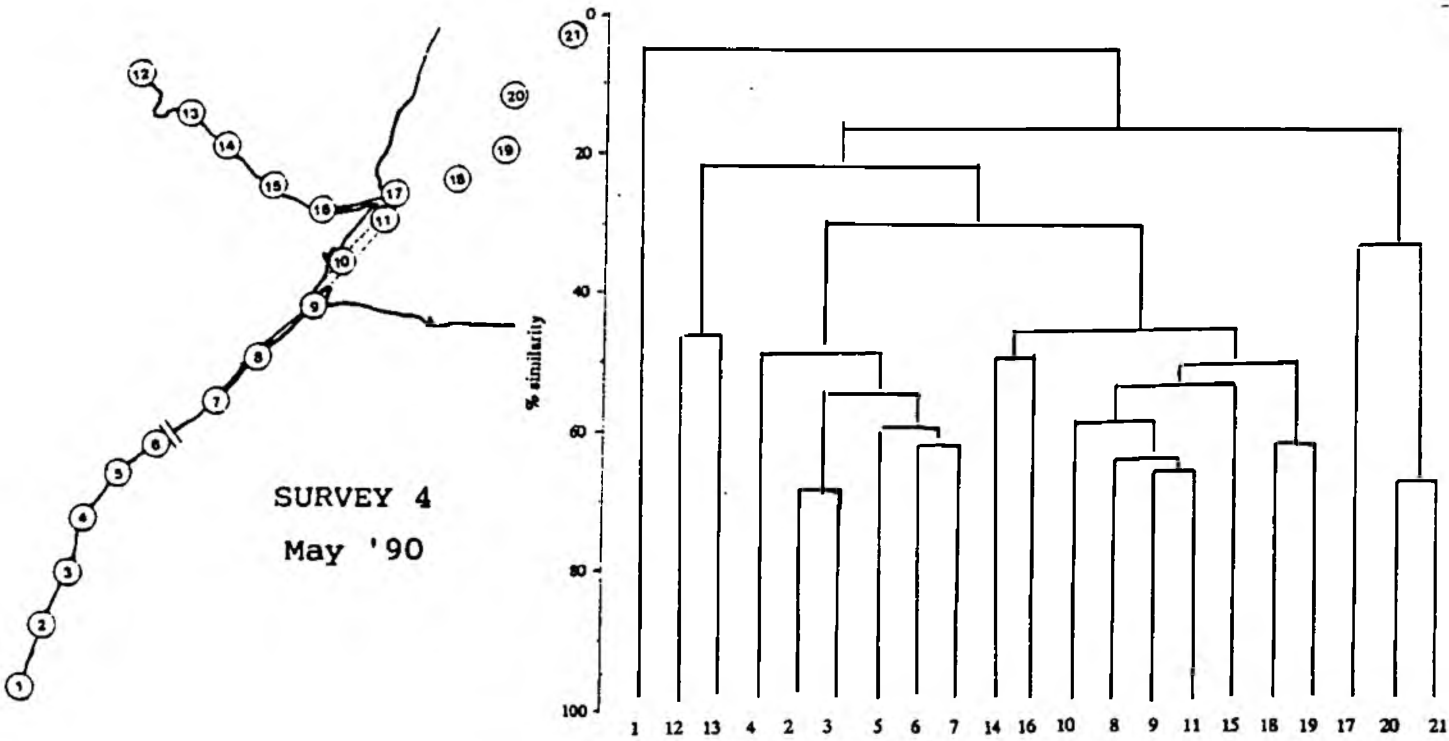


Figure 4.15 Cluster dendrograms of benthos data - survey 3 & 4.

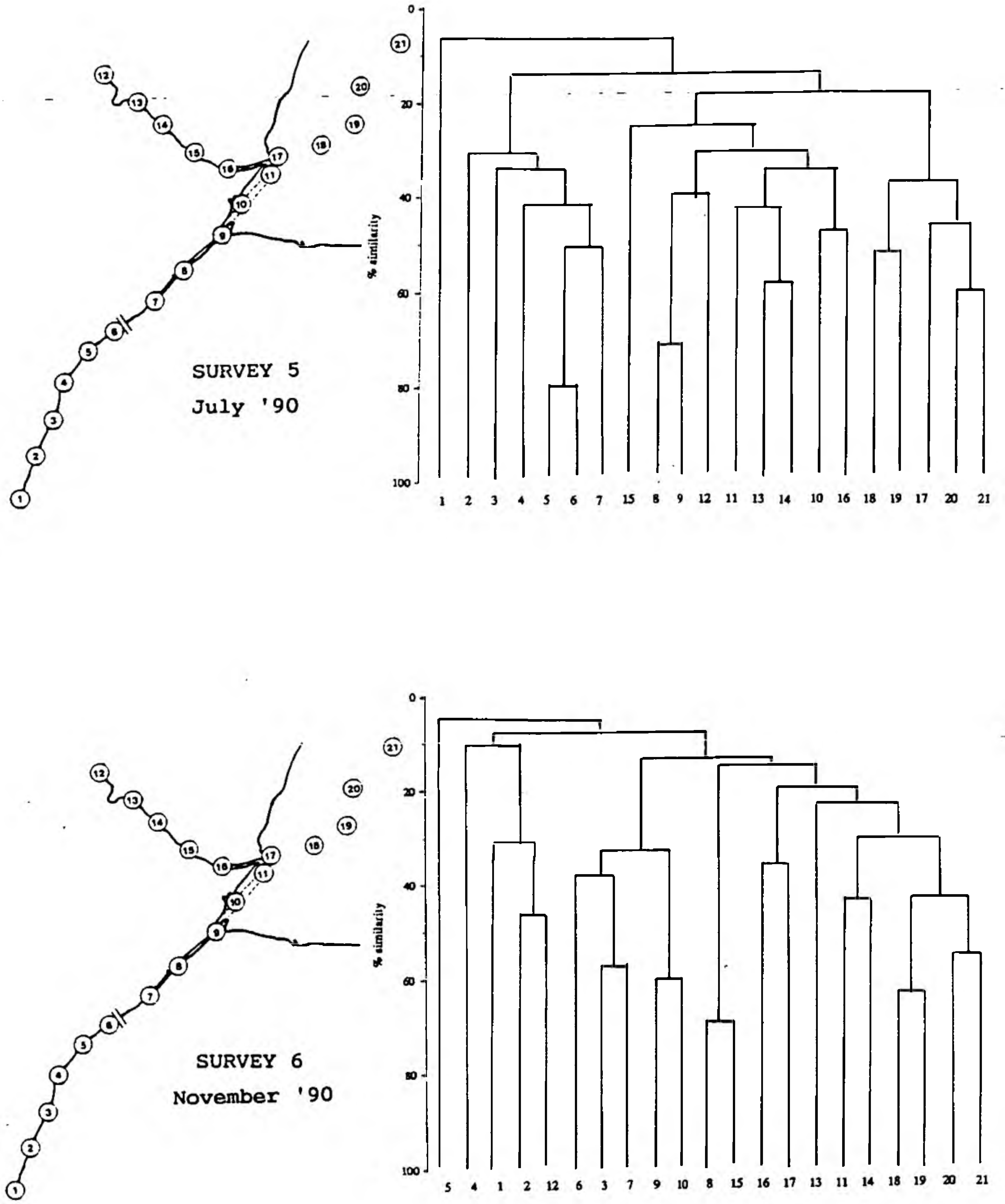


Figure 4.16 Cluster dendrograms of benthos data - survey 5 & 6.

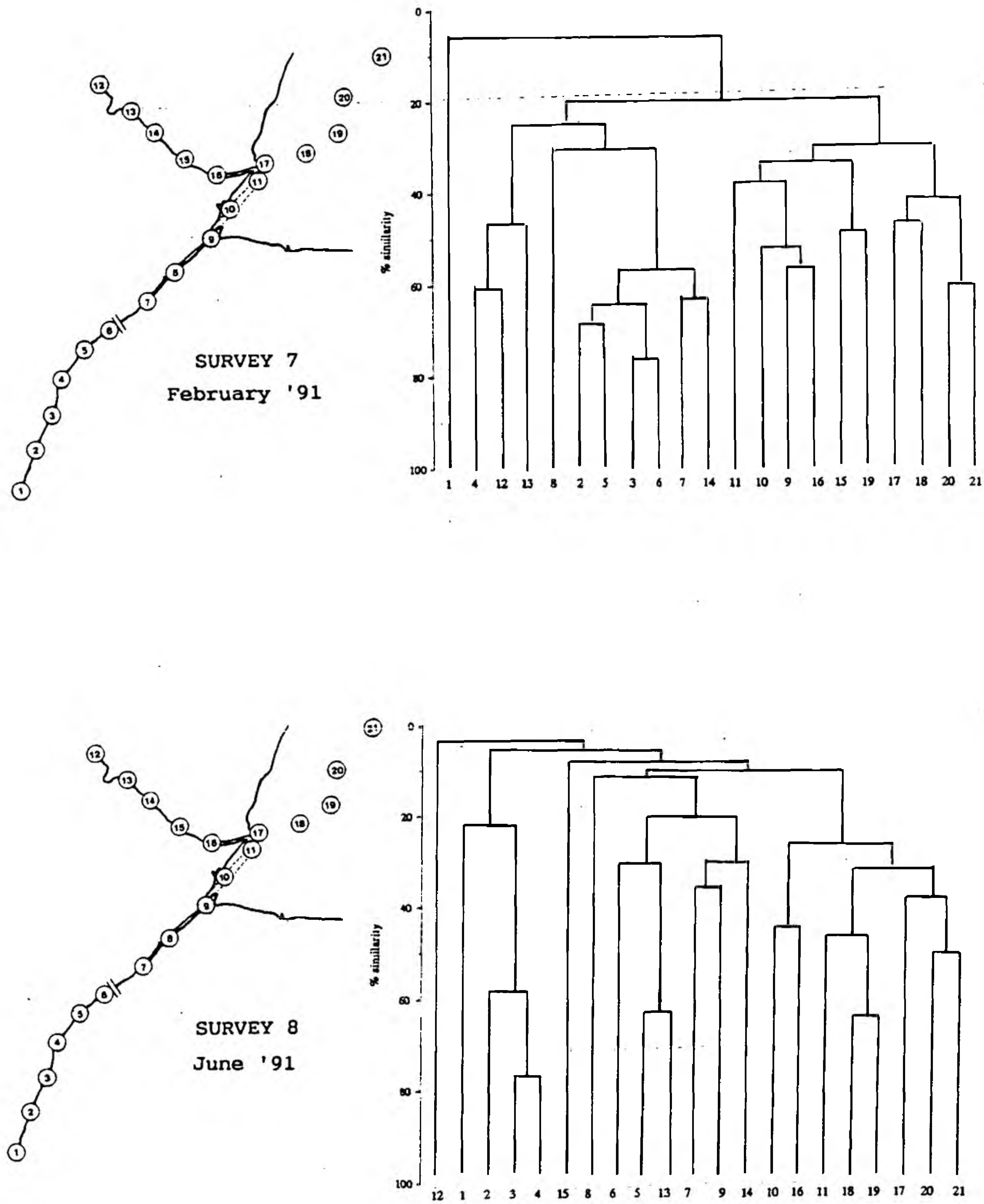
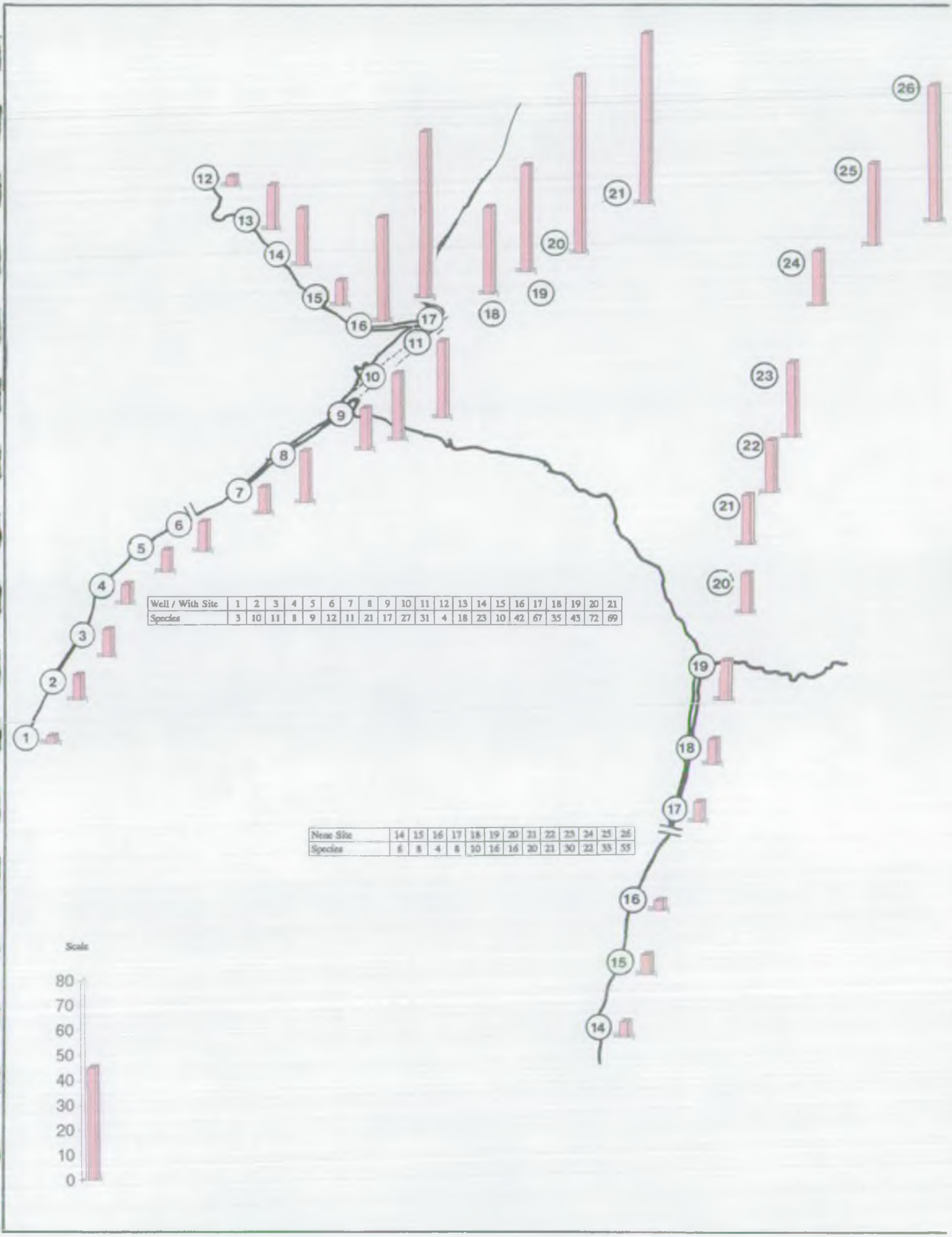


Figure 4.17 Cluster dendrograms of benthos data - survey 7 & 8.

Figure 4.18. Cluster dendrogram of the combined benthos data from four Nene surveys and four Welland and Welland surveys.



Well / With Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Species	3	10	11	8	9	12	11	21	17	27	31	4	18	23	10	42	67	35	43	72	69

Nene Site	14	15	16	17	18	19	20	21	22	23	24	25	26
Species	6	8	4	8	10	16	16	20	21	30	22	33	55

Figure 4.19 The total number of species recorded at each site over one year.

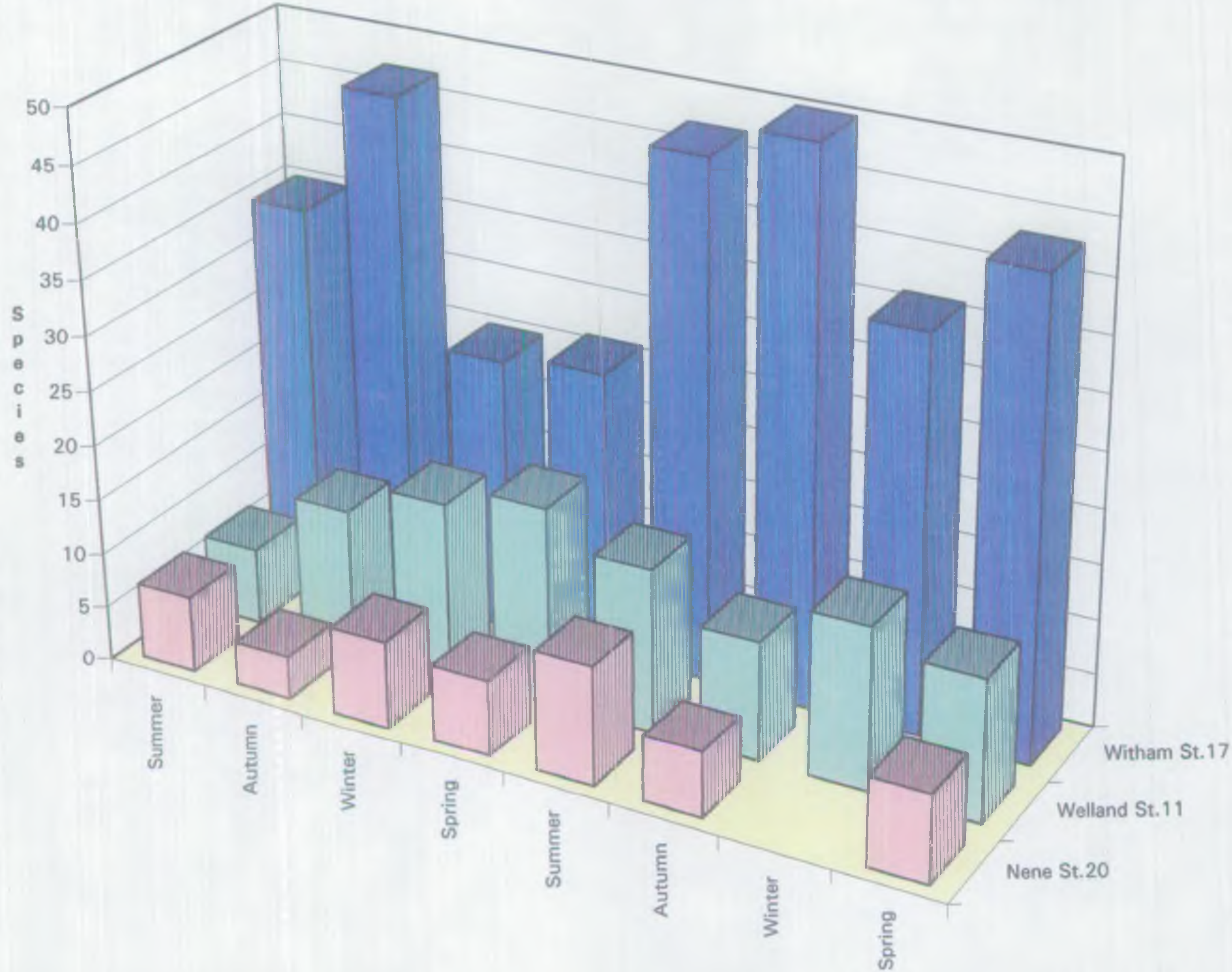


Figure 4.20. A comparison of the number of species found at the entrances to the Nene, Welland and Witham.

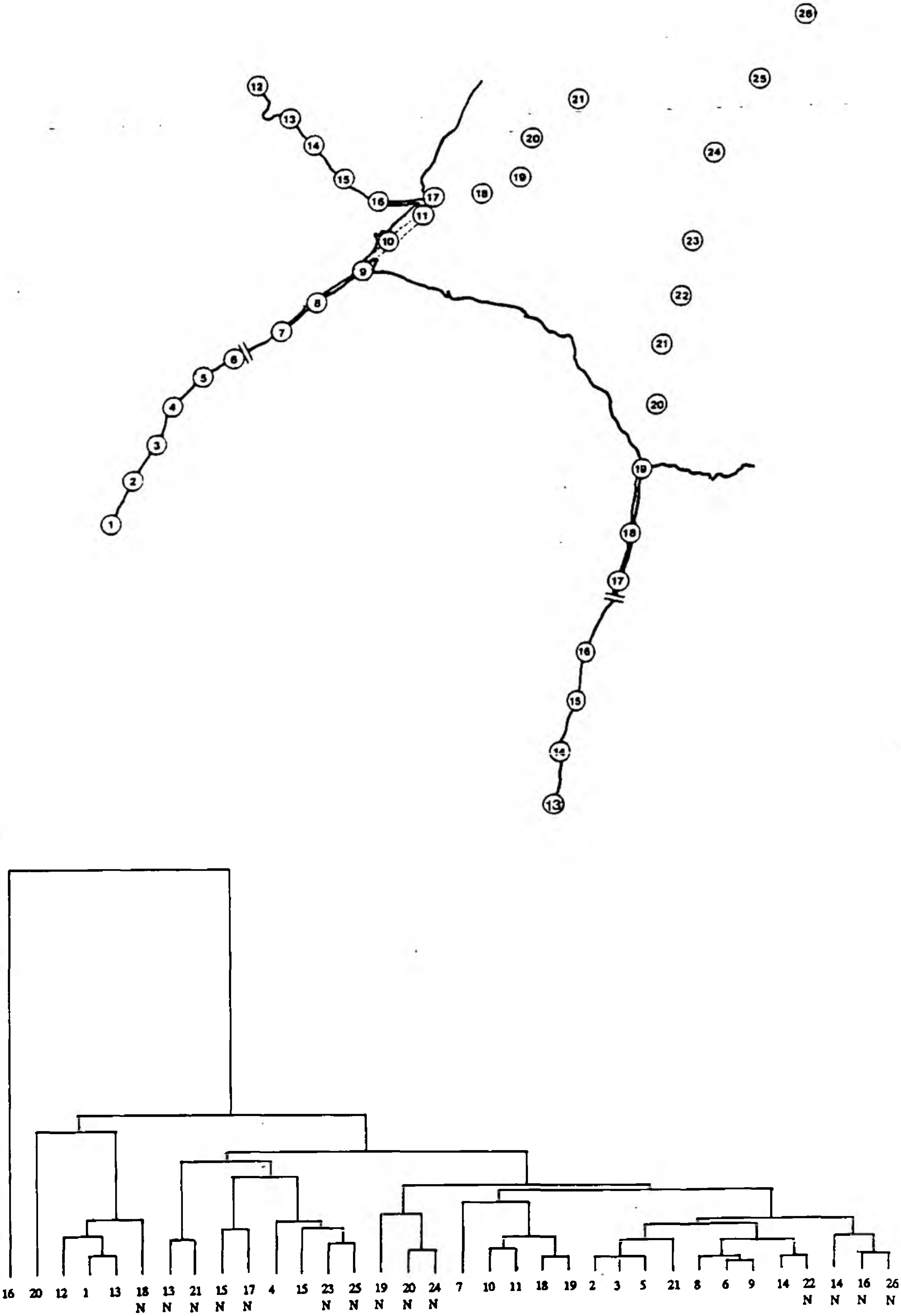


Figure 4.21 Cluster analysis of combined Nene and Welland/Witham sediment data.

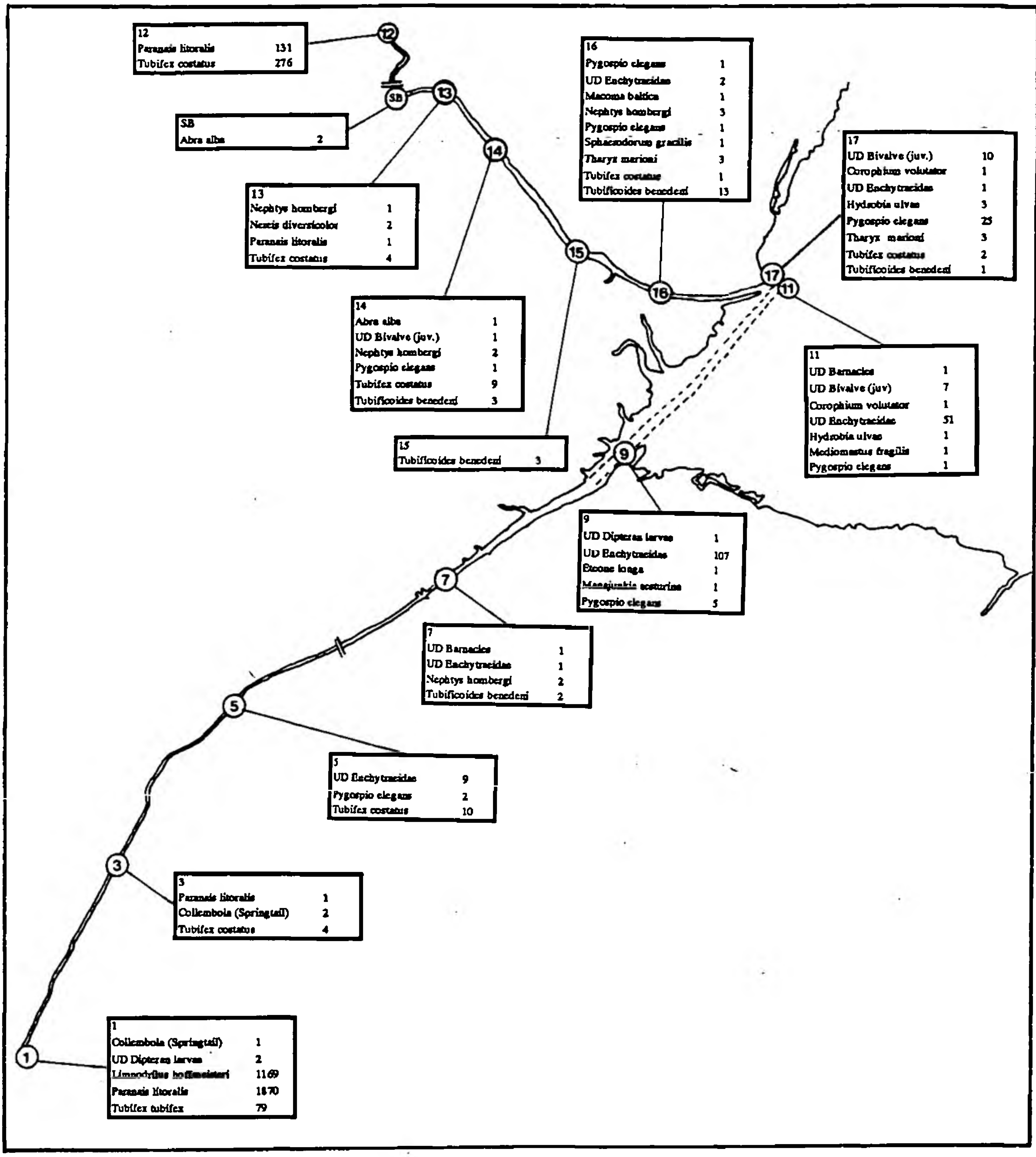


Figure 4.22 Intertidal benthos survey (November 1990).

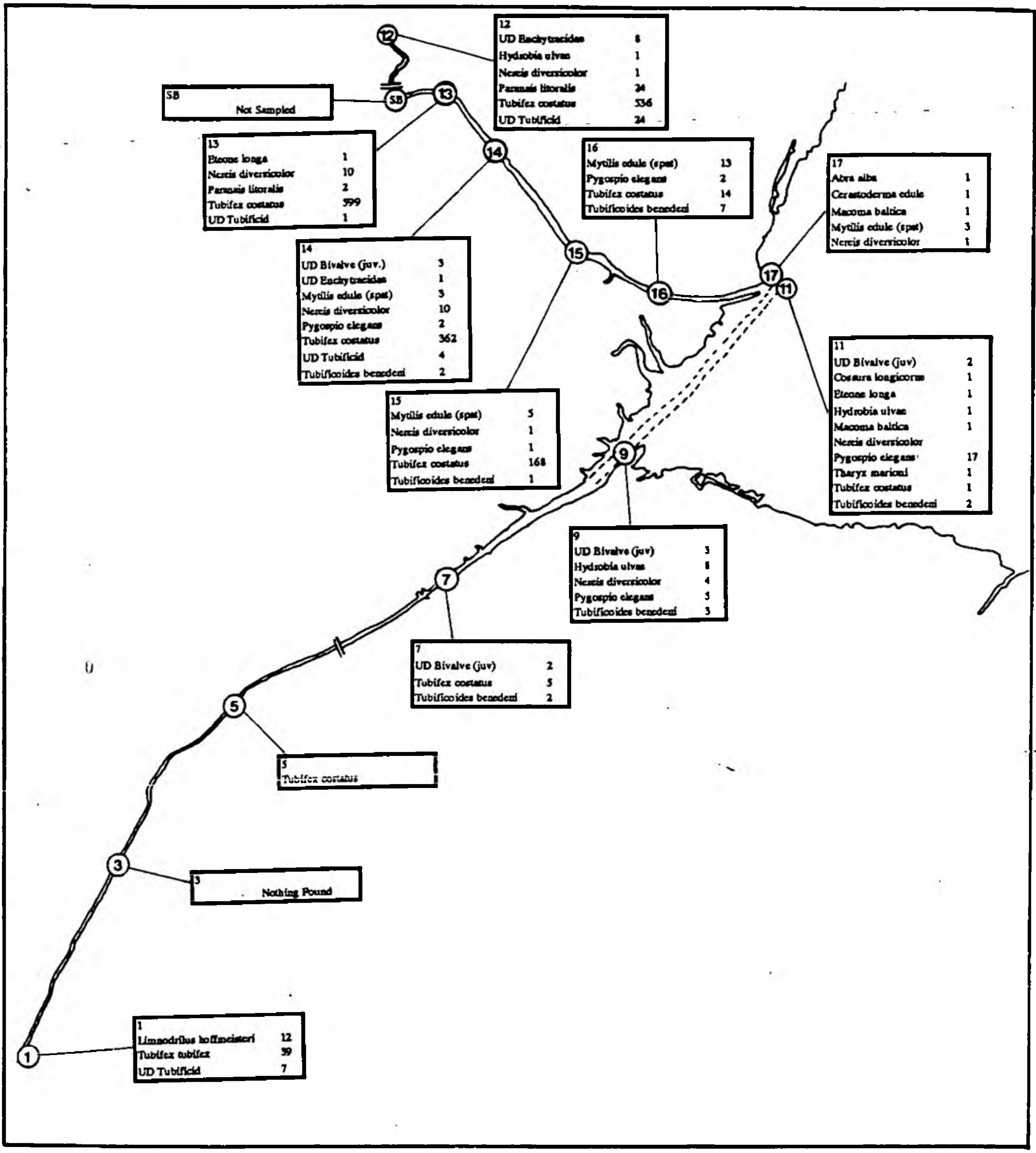


Figure 4.23 Intertidal benthos survey (June 1991).

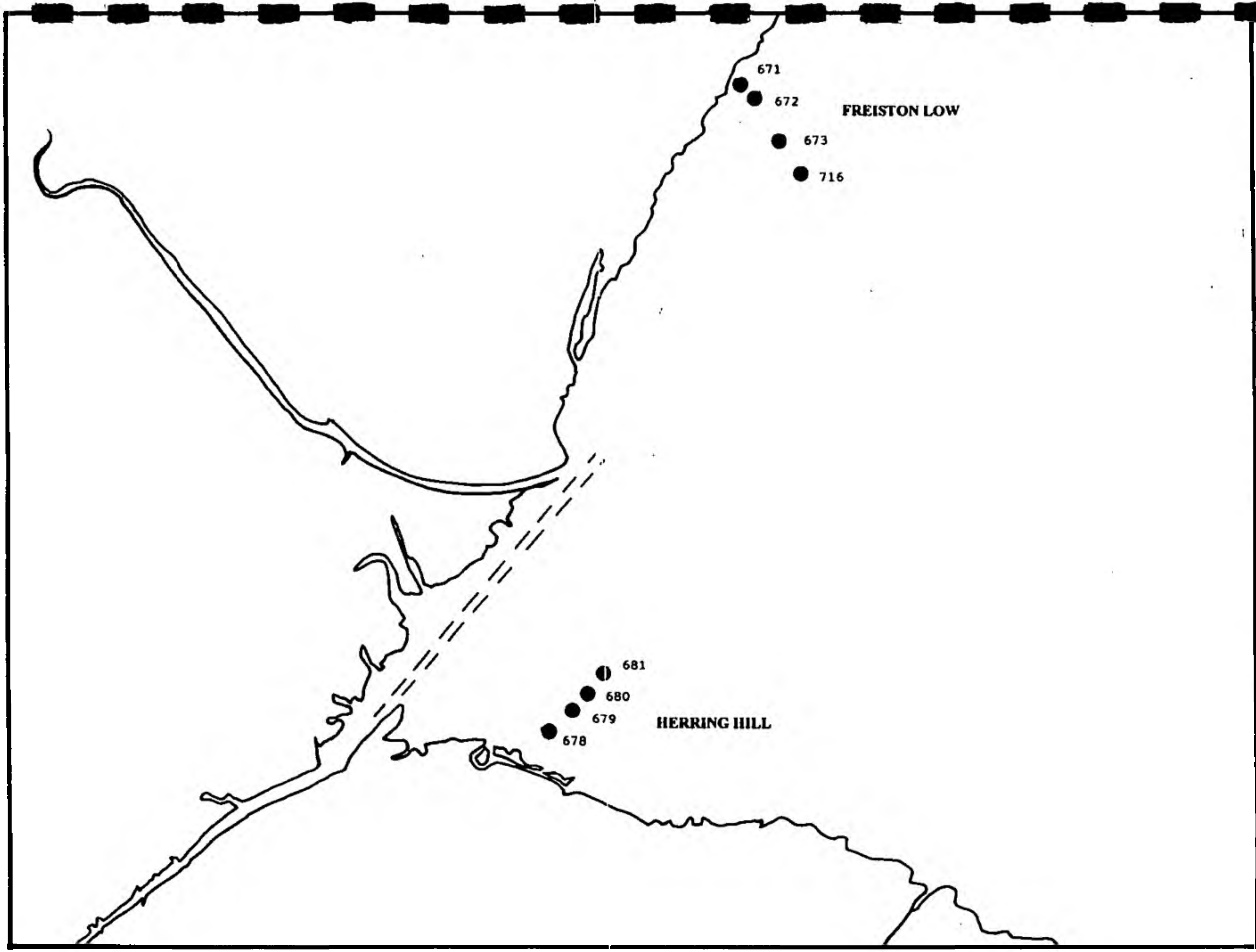
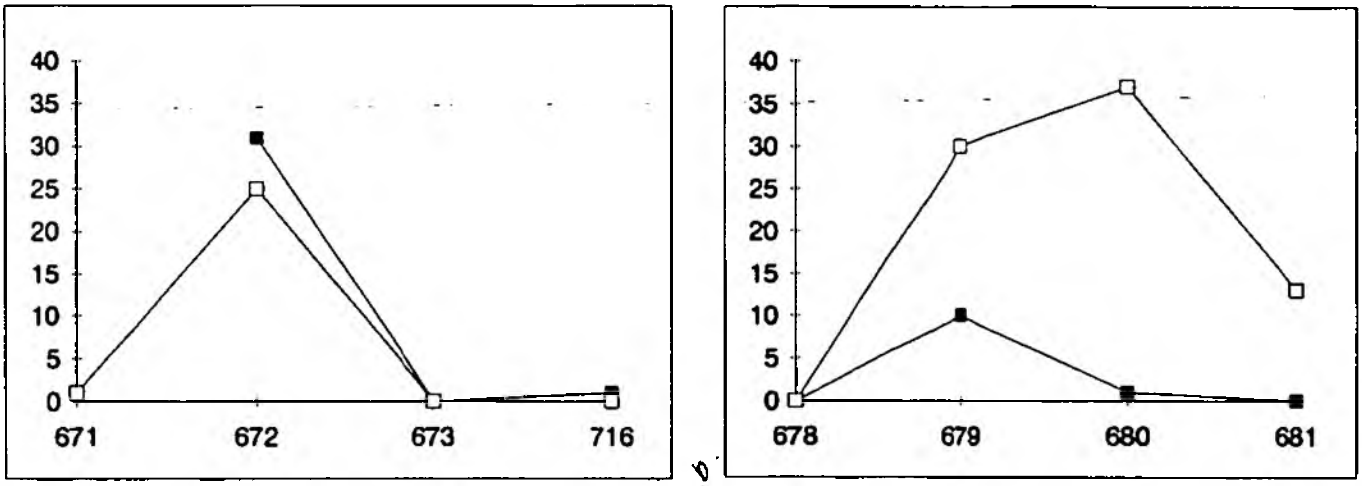
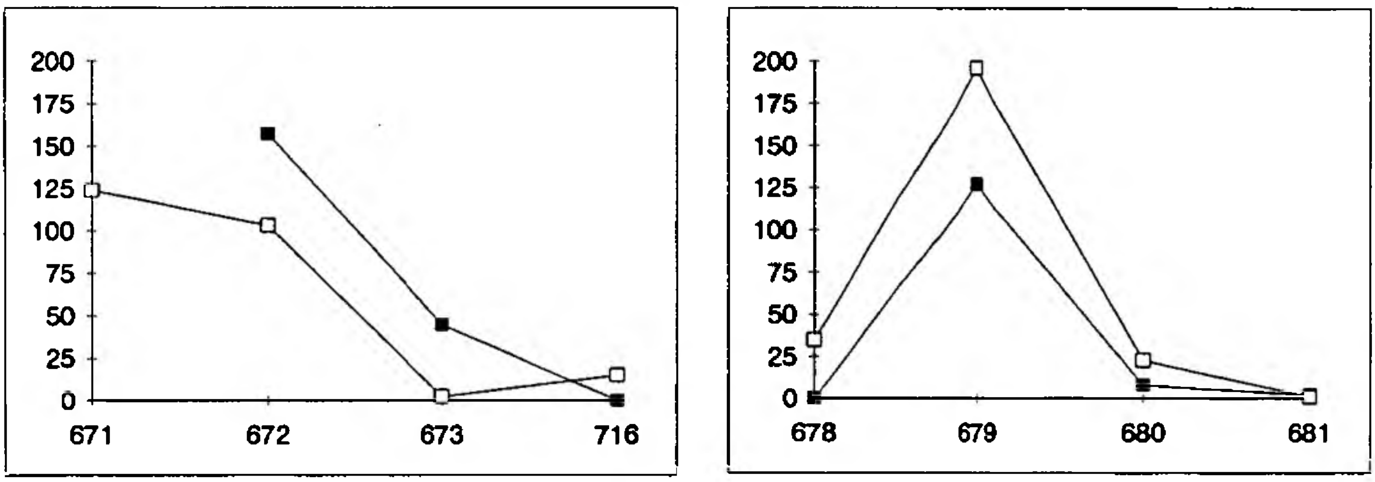


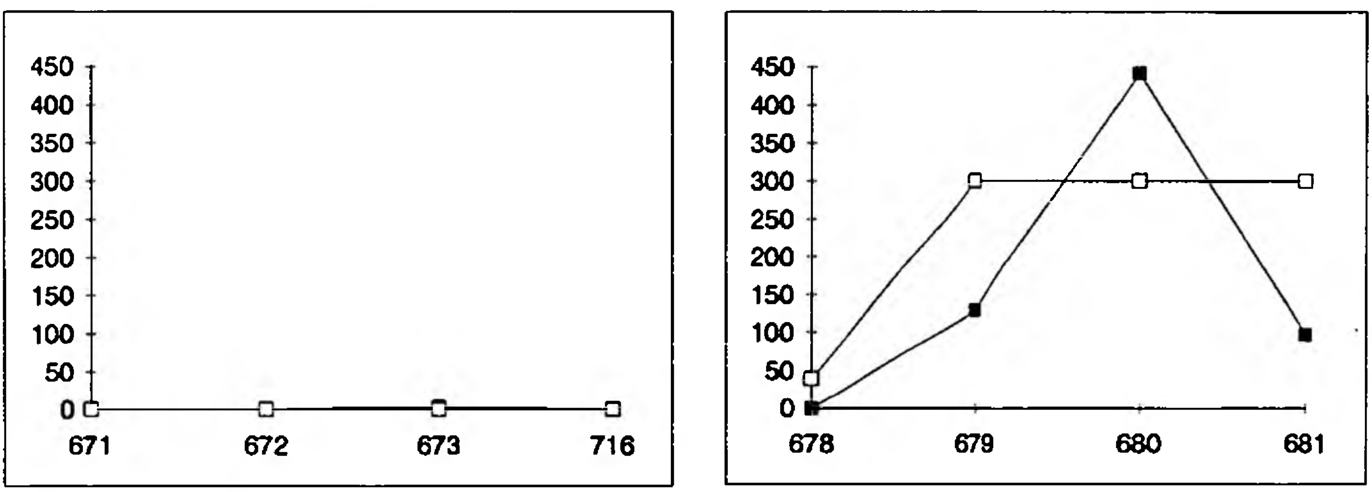
Figure 4.24 Intertidal sites sampled in September 1990 which were previously sampled by IMER in September 1973.



Macoma Balthica



Hydrobia ulvae



"Oligochaetes"

FREISTON LOW **HERRING HILL**

site 671 not sampled in 1990 as it was saltmarsh.

Unicomarine 1990 ■

IMER 1973 □

Figure 4.25 Comparison of Populations (per $0.02m^2$) in September 1973 and 1990.

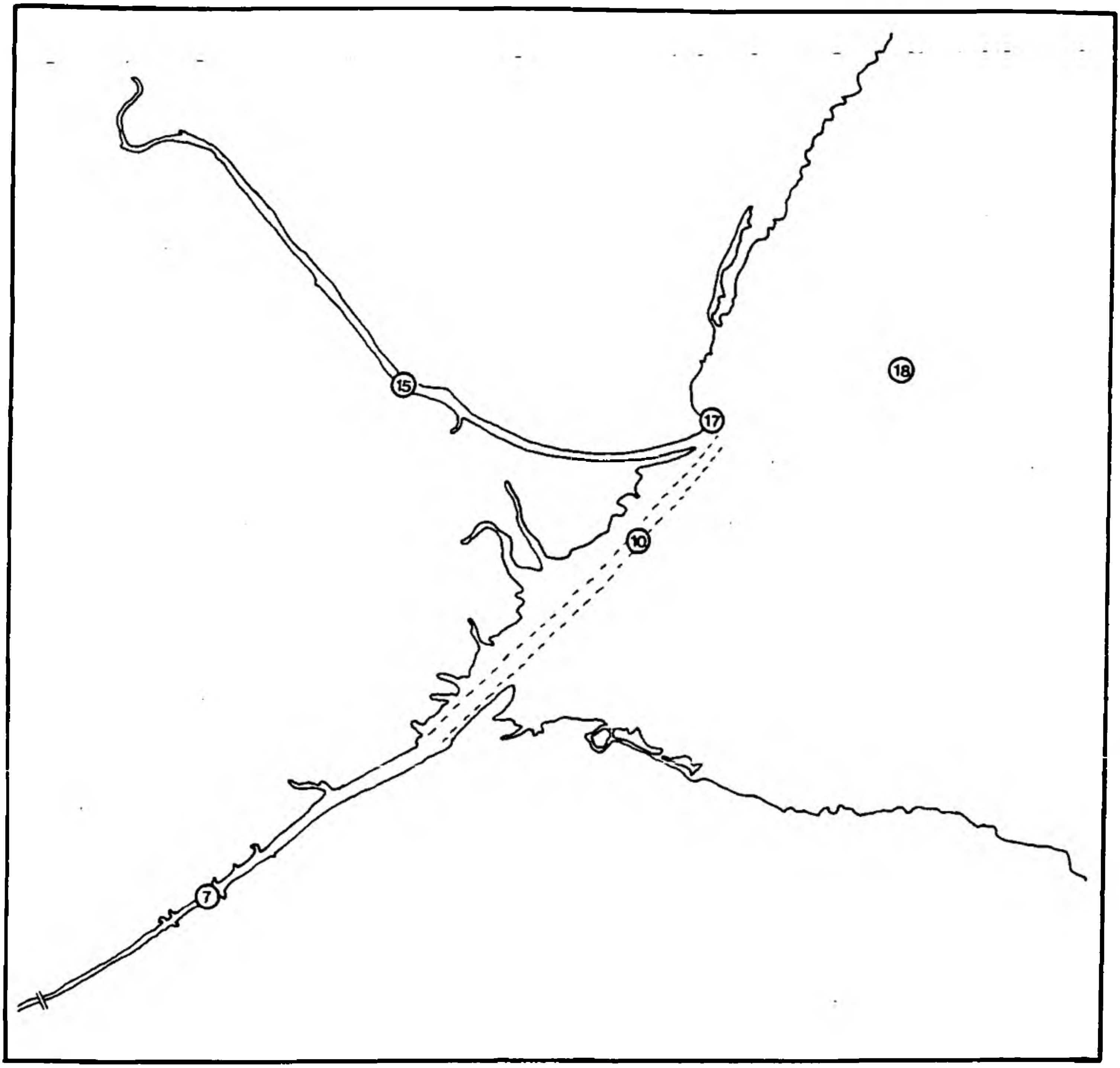


Figure 5.1 Fish and plankton sampling sites.

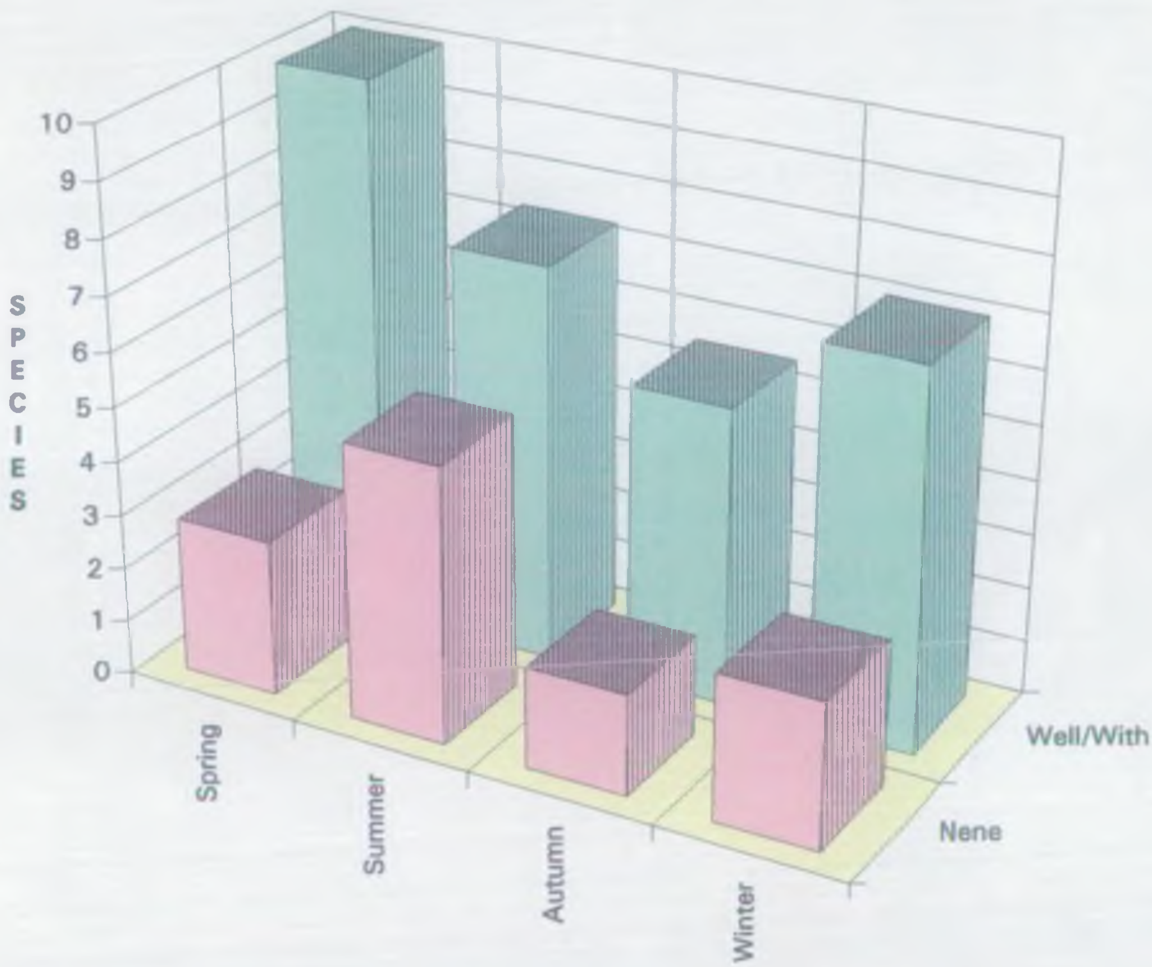
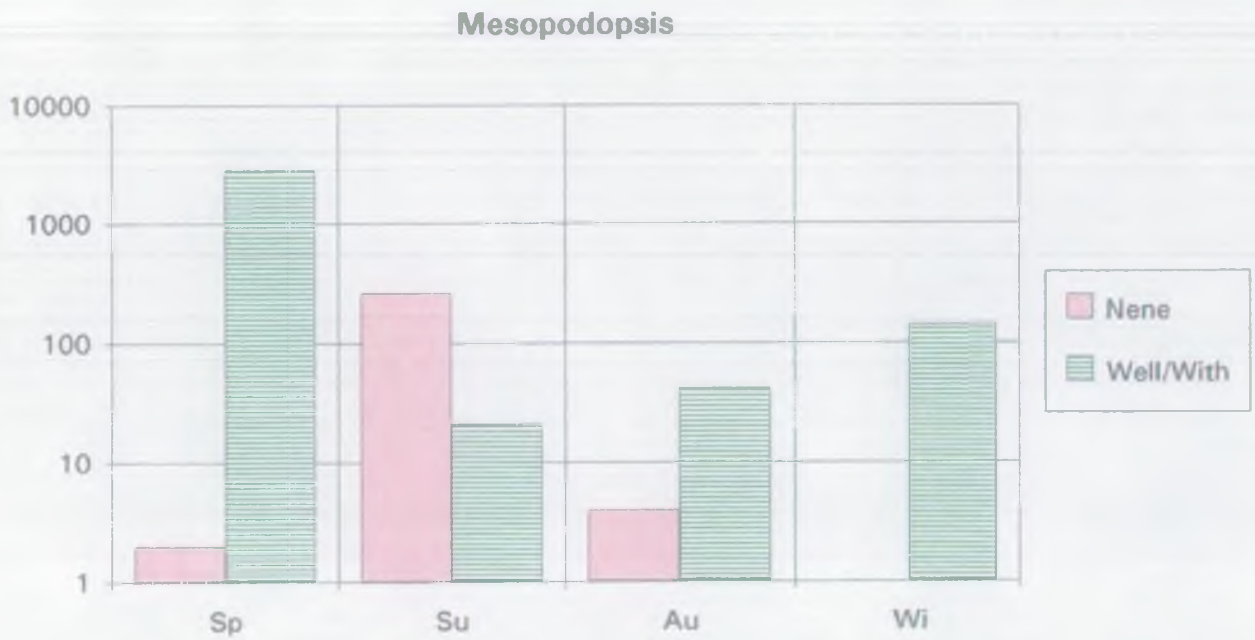


Figure 5.2. The number of species recorded in plankton trawls from the Nene, Wellland and Witham (copepods excluded).



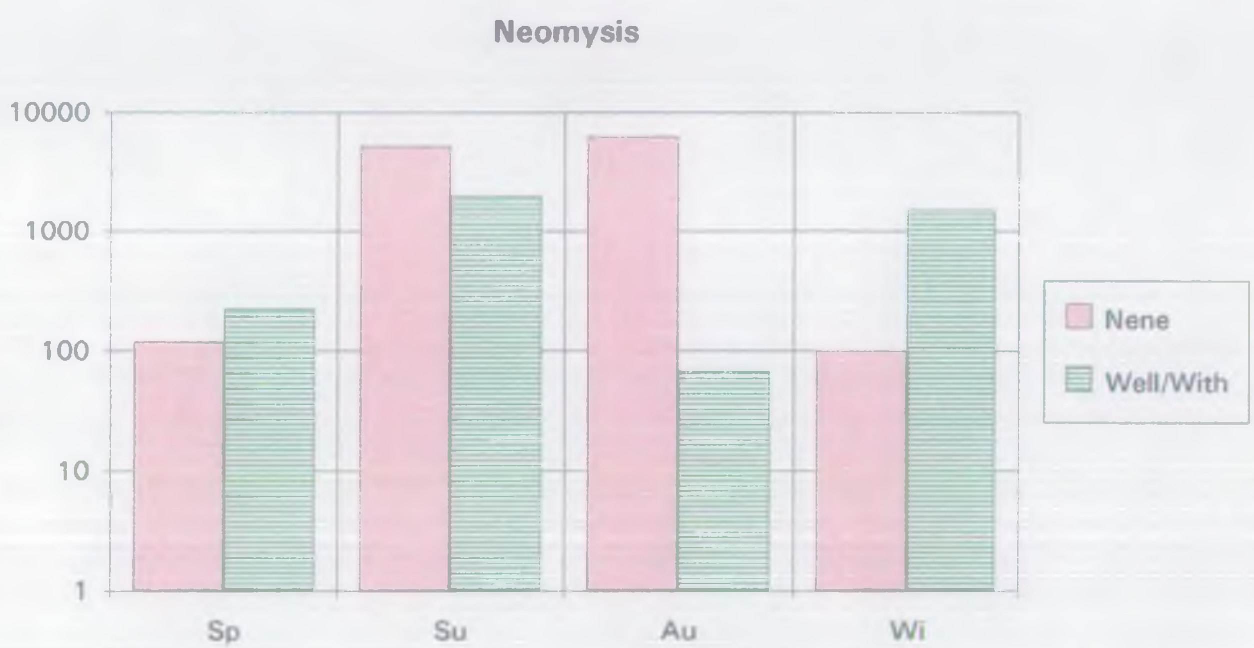
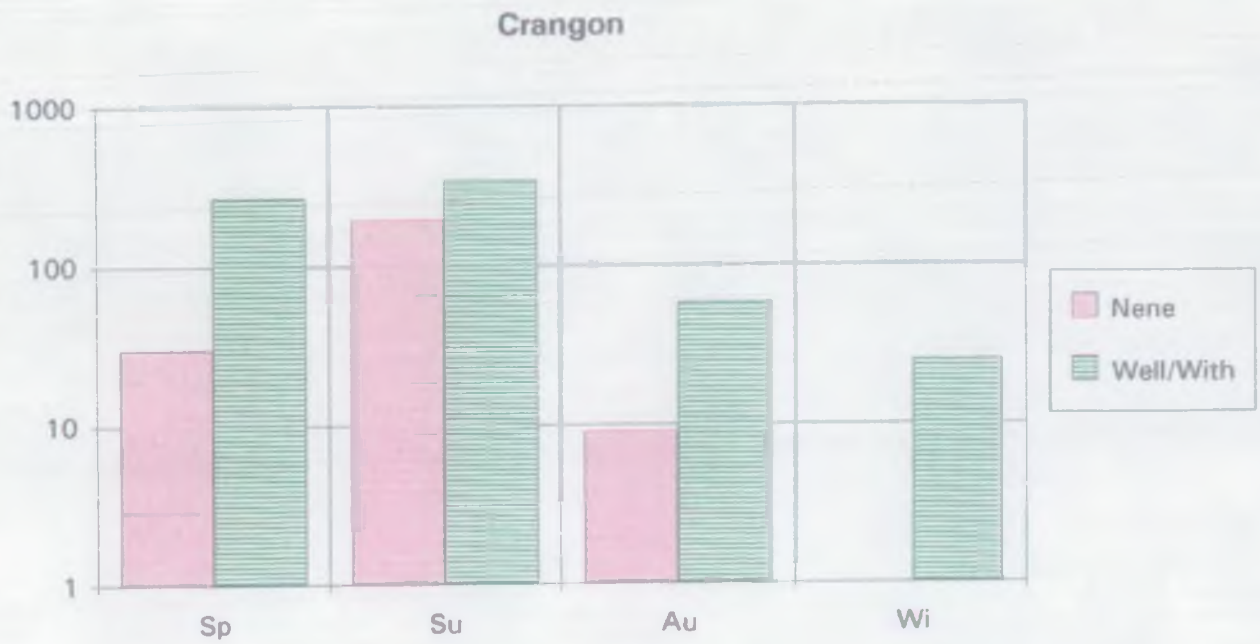


Figure 5.3 The number of Mesopodopsis and Neomysis caught in plankton trawls on the Welland and Witham, and Nene.



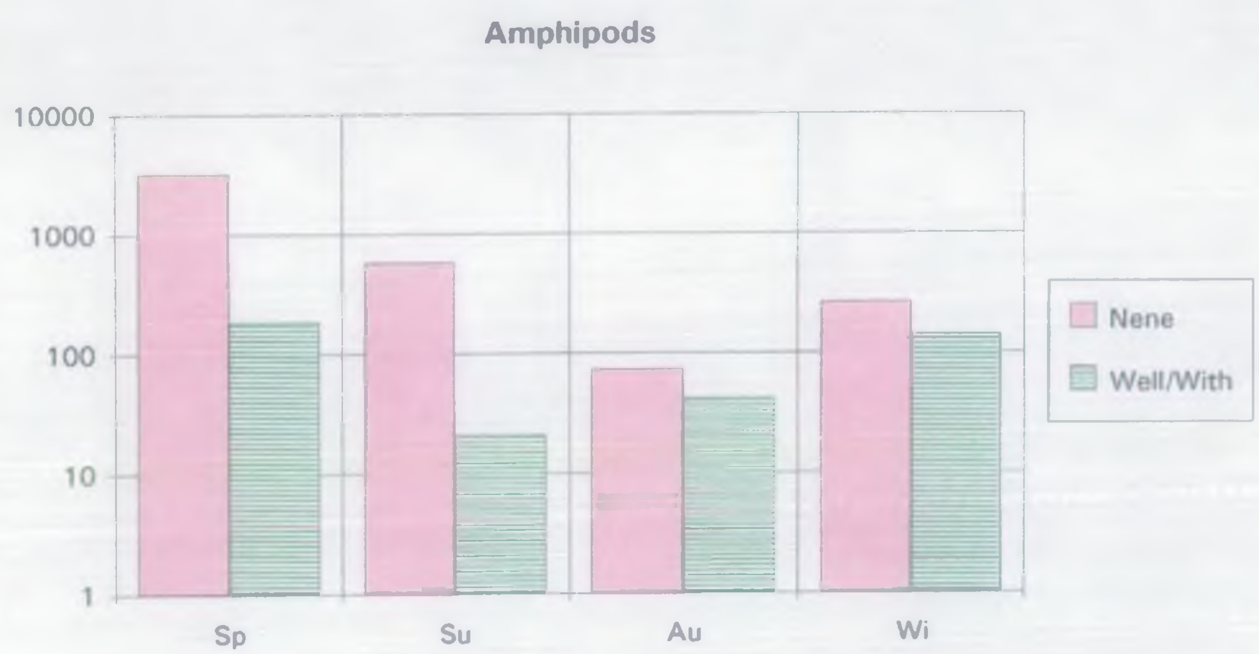


Figure 5.4 The number of Crangon and Amphipods caught in plankton trawls on the Welland and Witham, and Nene.

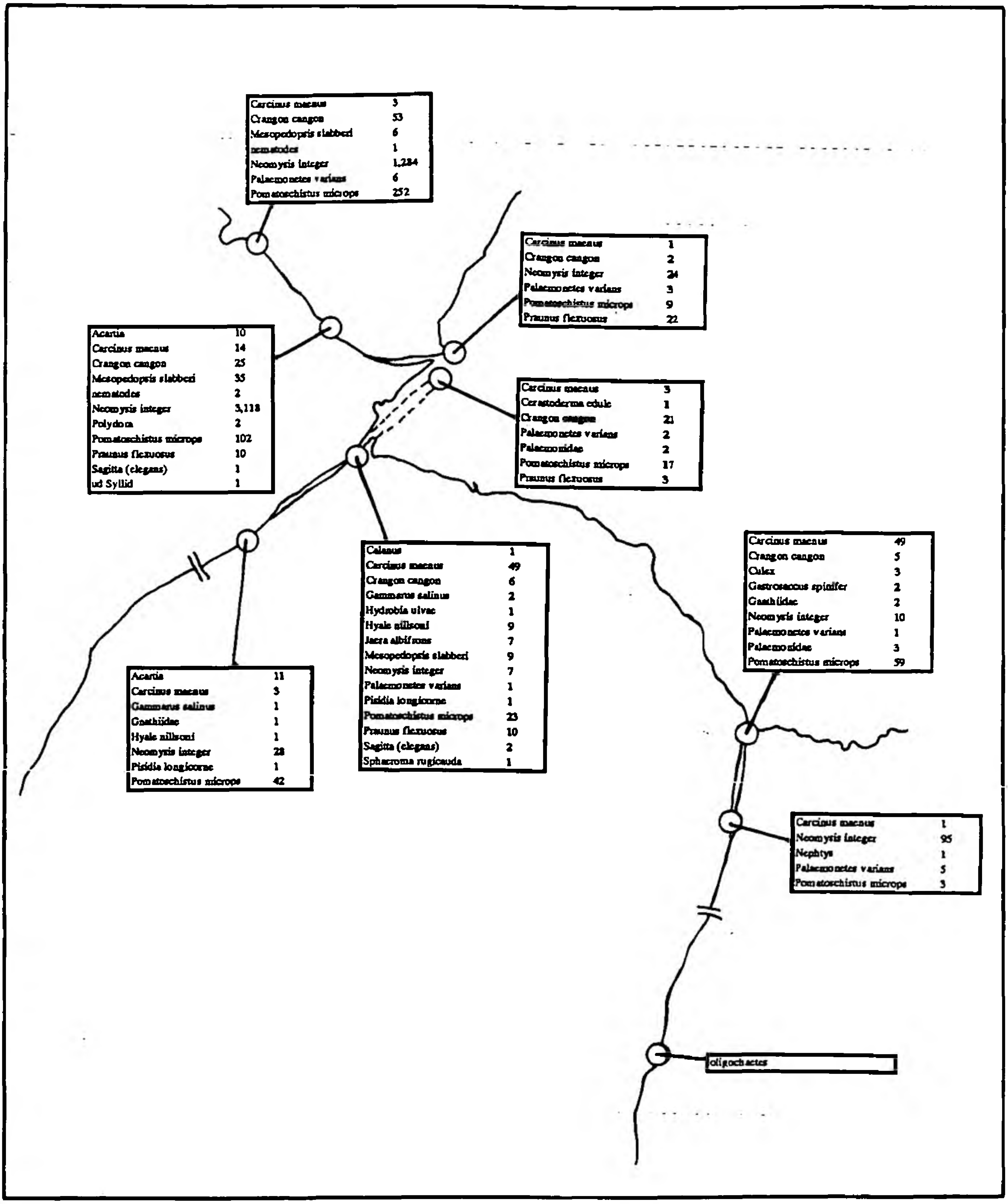


Figure 5.5 Results from the push net samples taken on August 13th 1991.
(n.b. the *Carcinus* are mostly larvae).

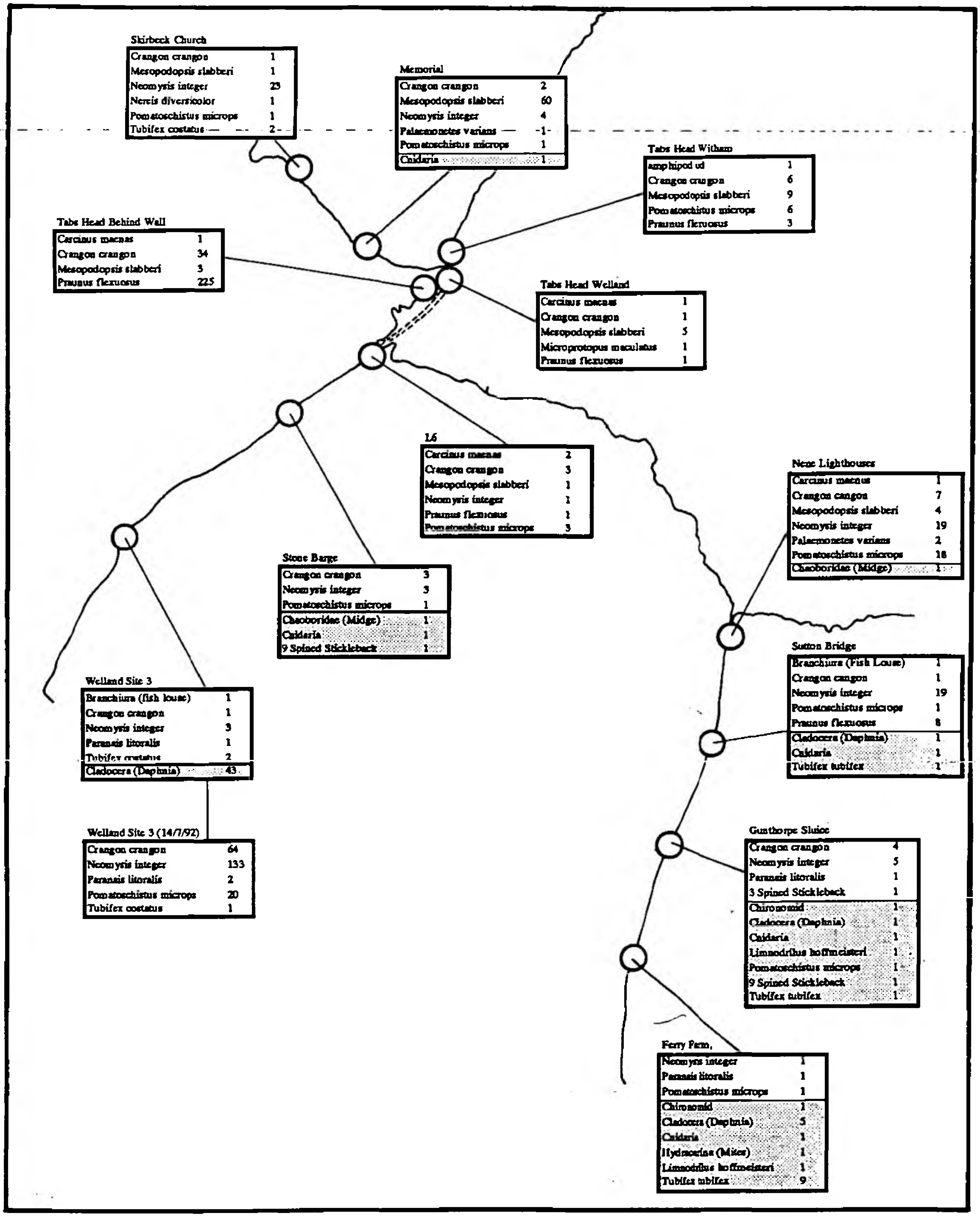


Figure 5.6 Results from the push net samples taken on August 12th & 13th 1992. Freshwater species are indicated by shading.

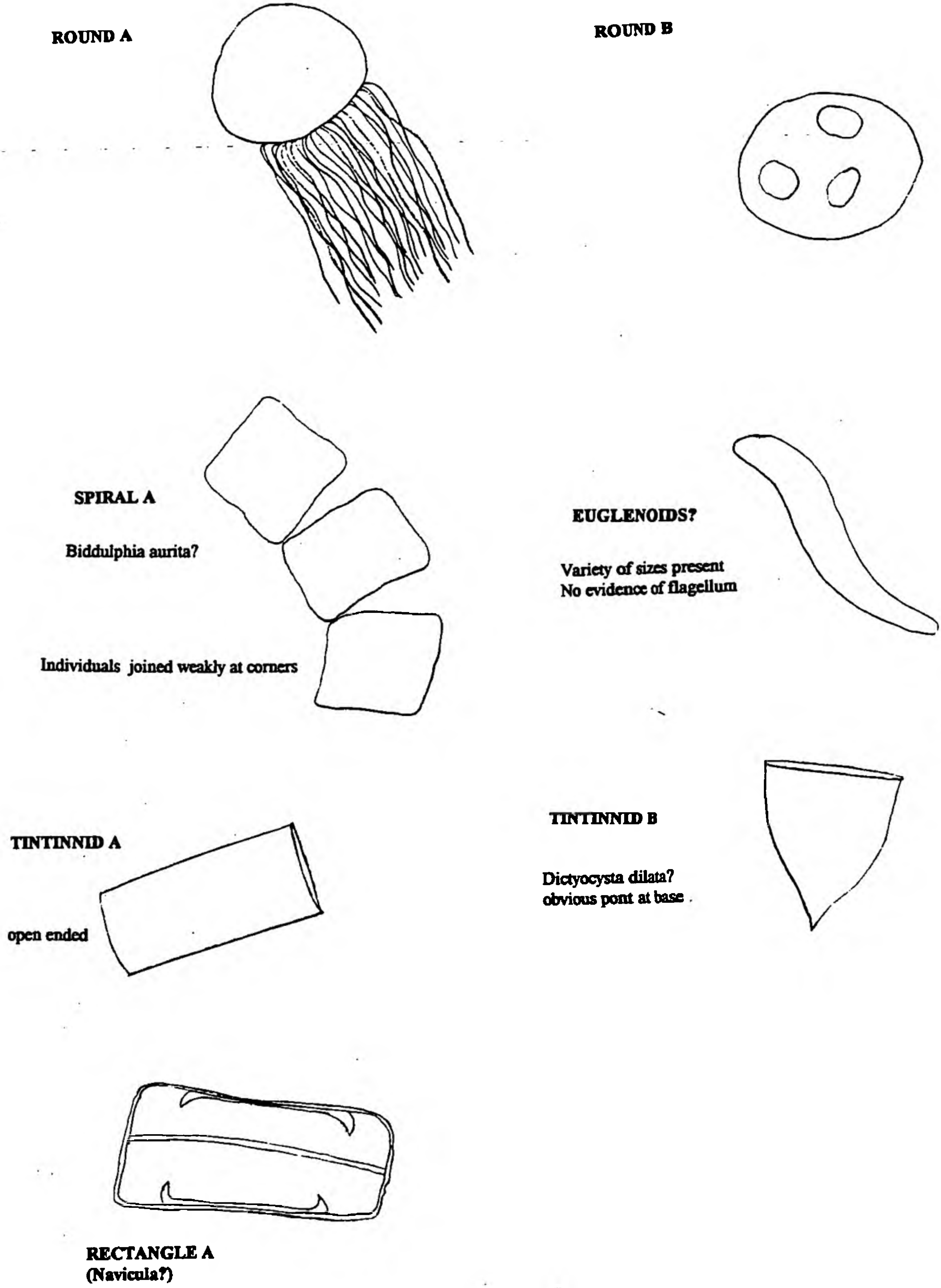


Figure 5.7 Drawings of incompletely identified phytoplankton.

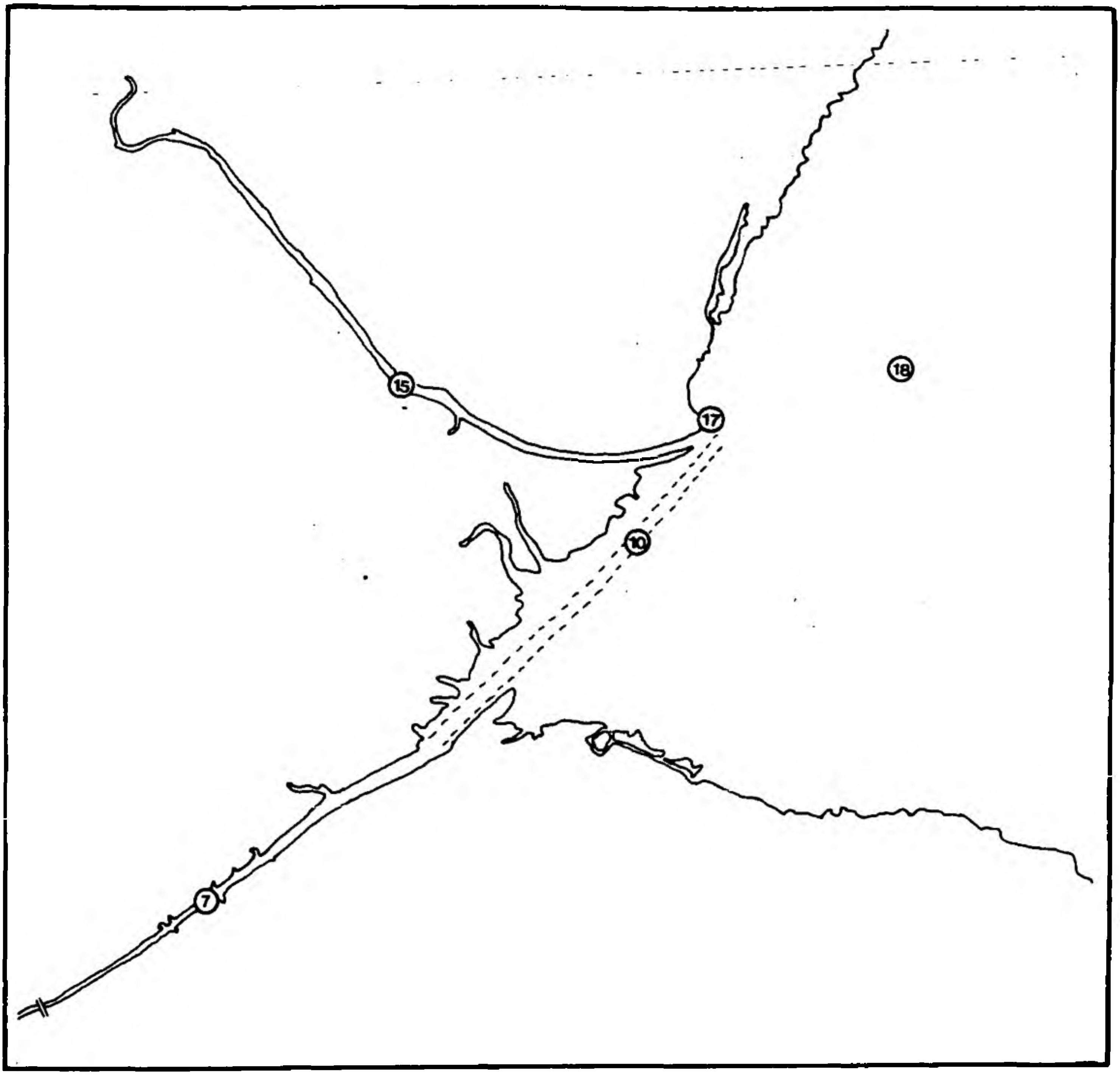


Figure 6.1 Fish and plankton sampling sites.

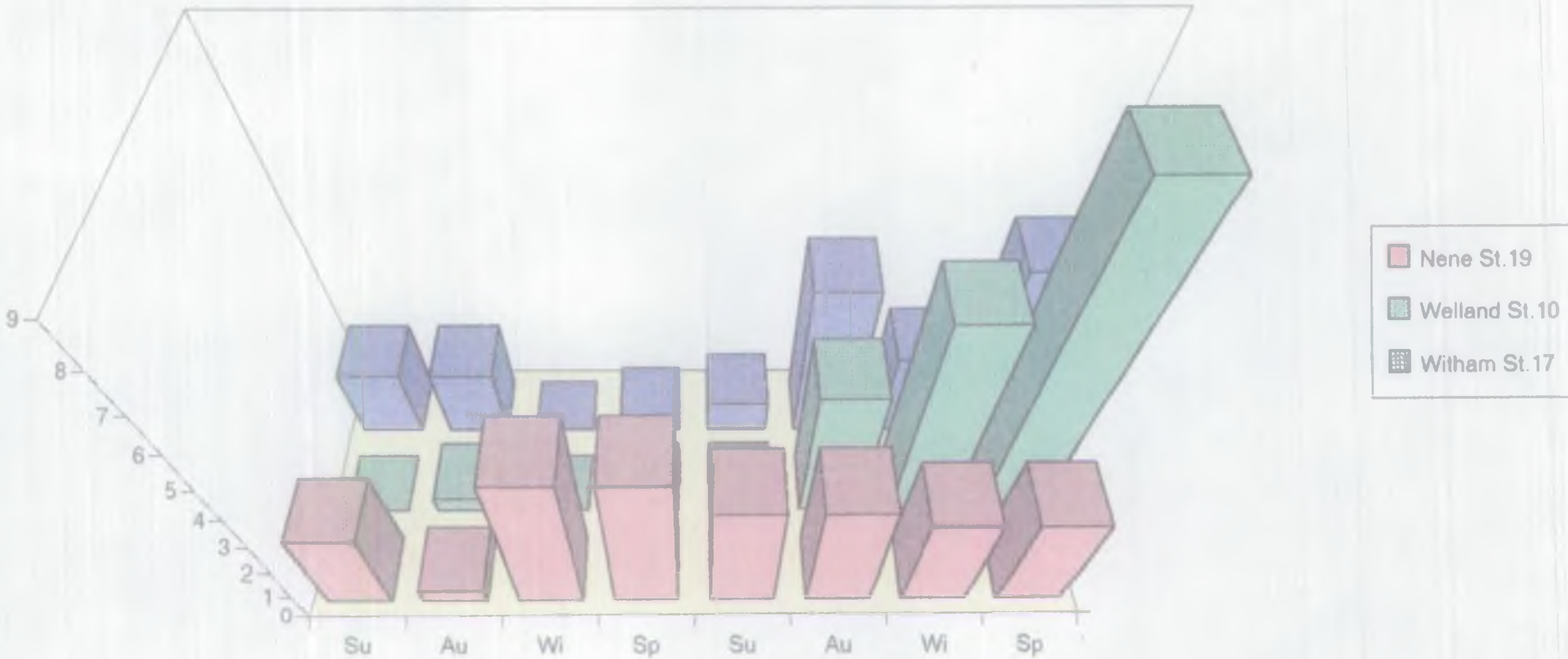


Figure 6.2 A comparison of the number of fish species found at the entrance to the Nene, Welland and Witham.

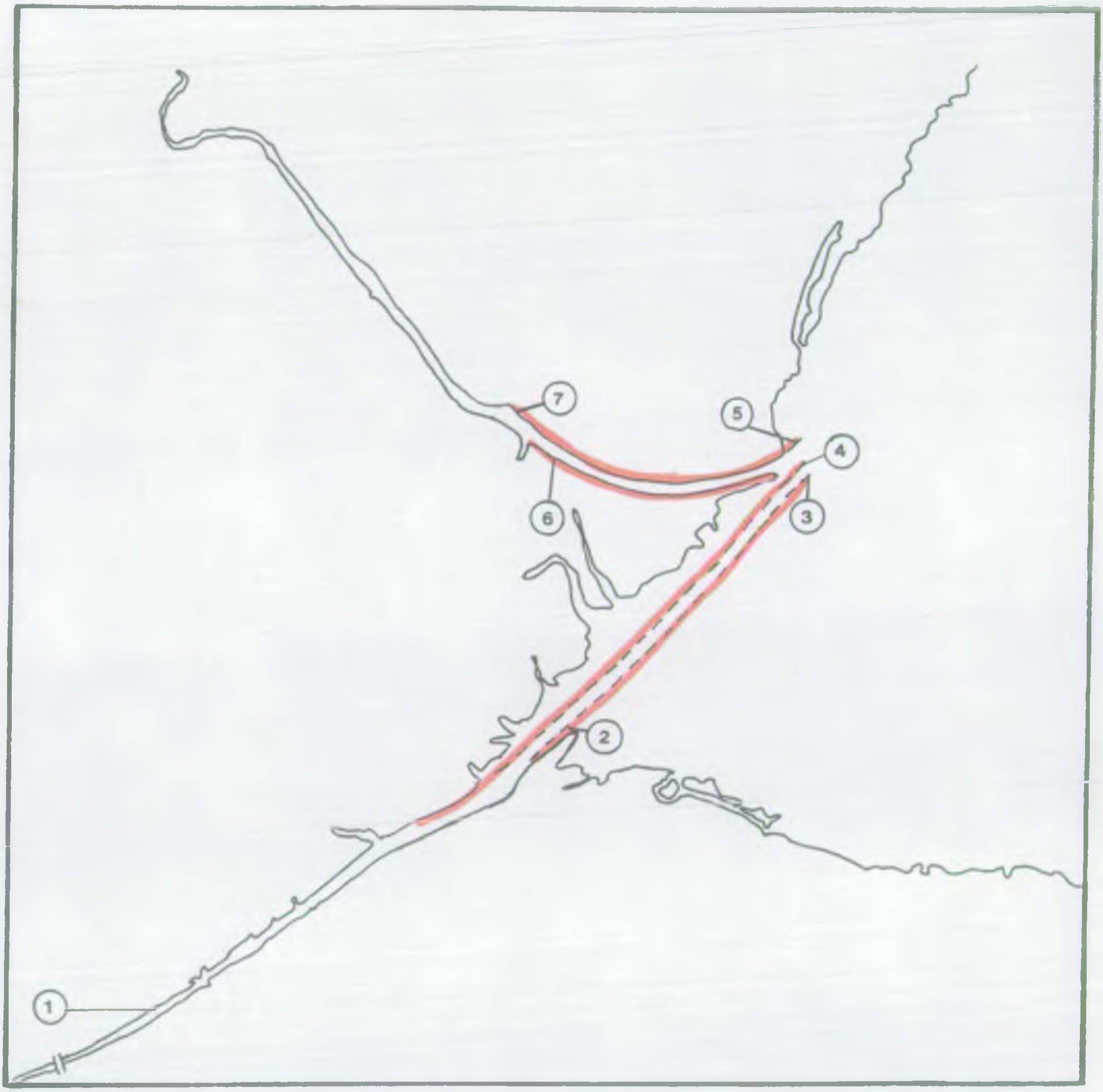


Figure 7.1 Seaweed sampling sites.
The main area of seaweed coverage is shown in red.

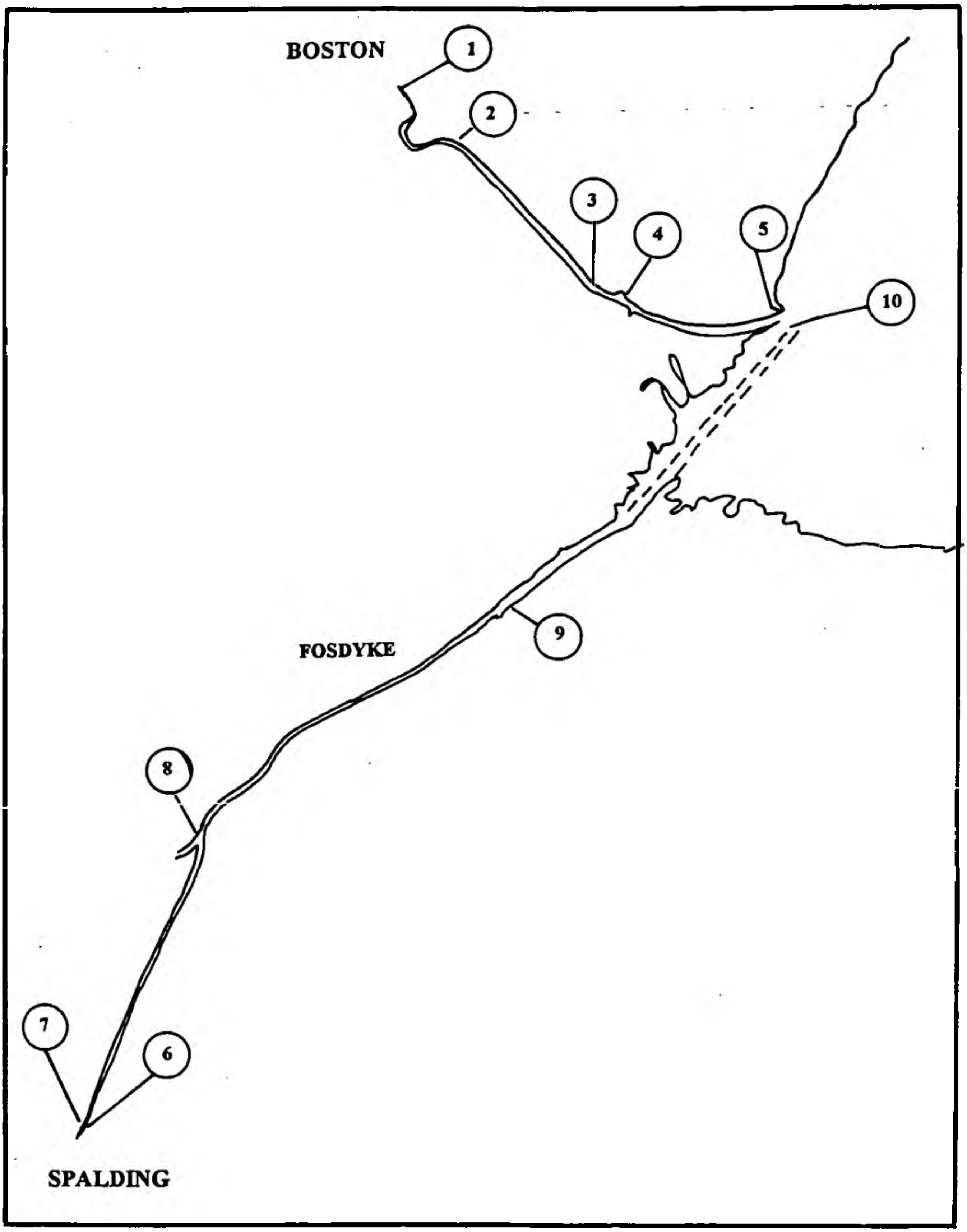


Figure 7.2 Intertidal mud sampling sites for chemical analysis.
Samples taken February 20-23 1990.

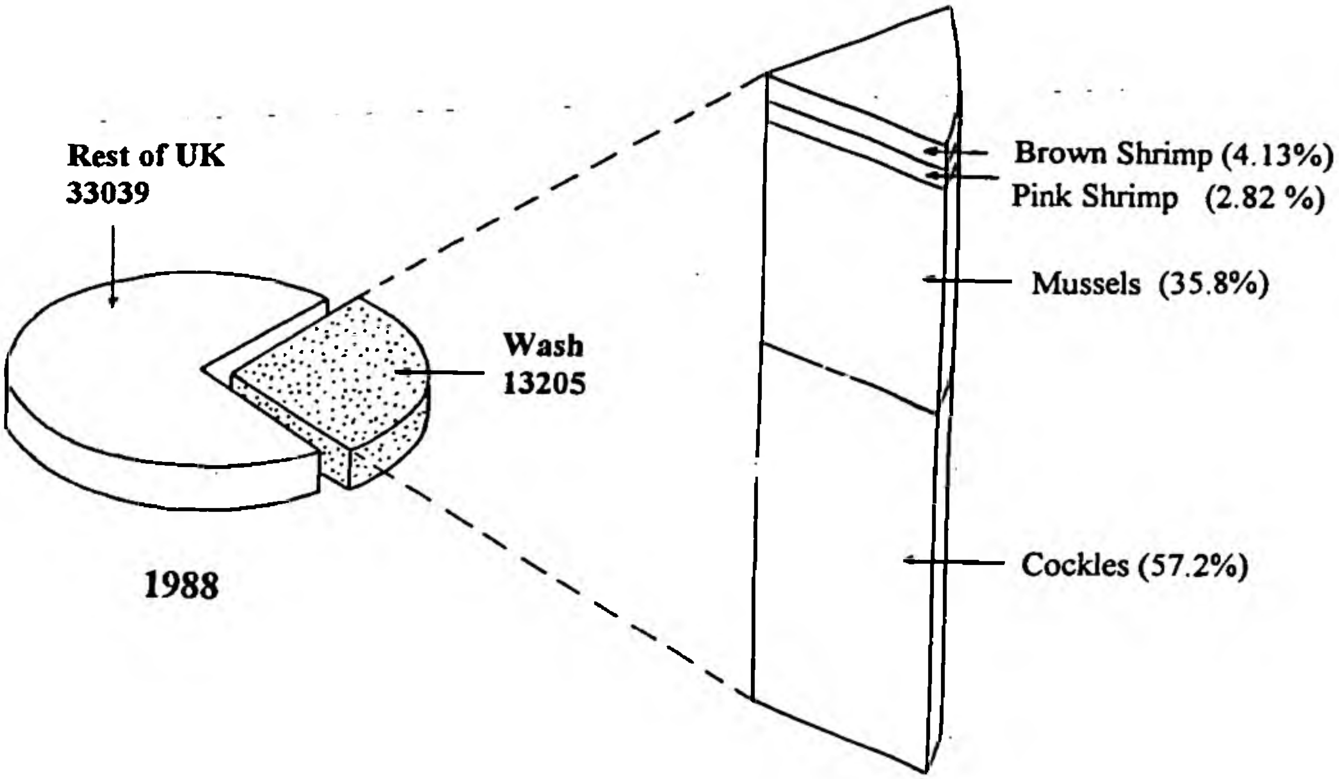


Figure 8.1 UK and Wash shellfish landings (tonnes).
(Information from the ESFJC annual report 1989).

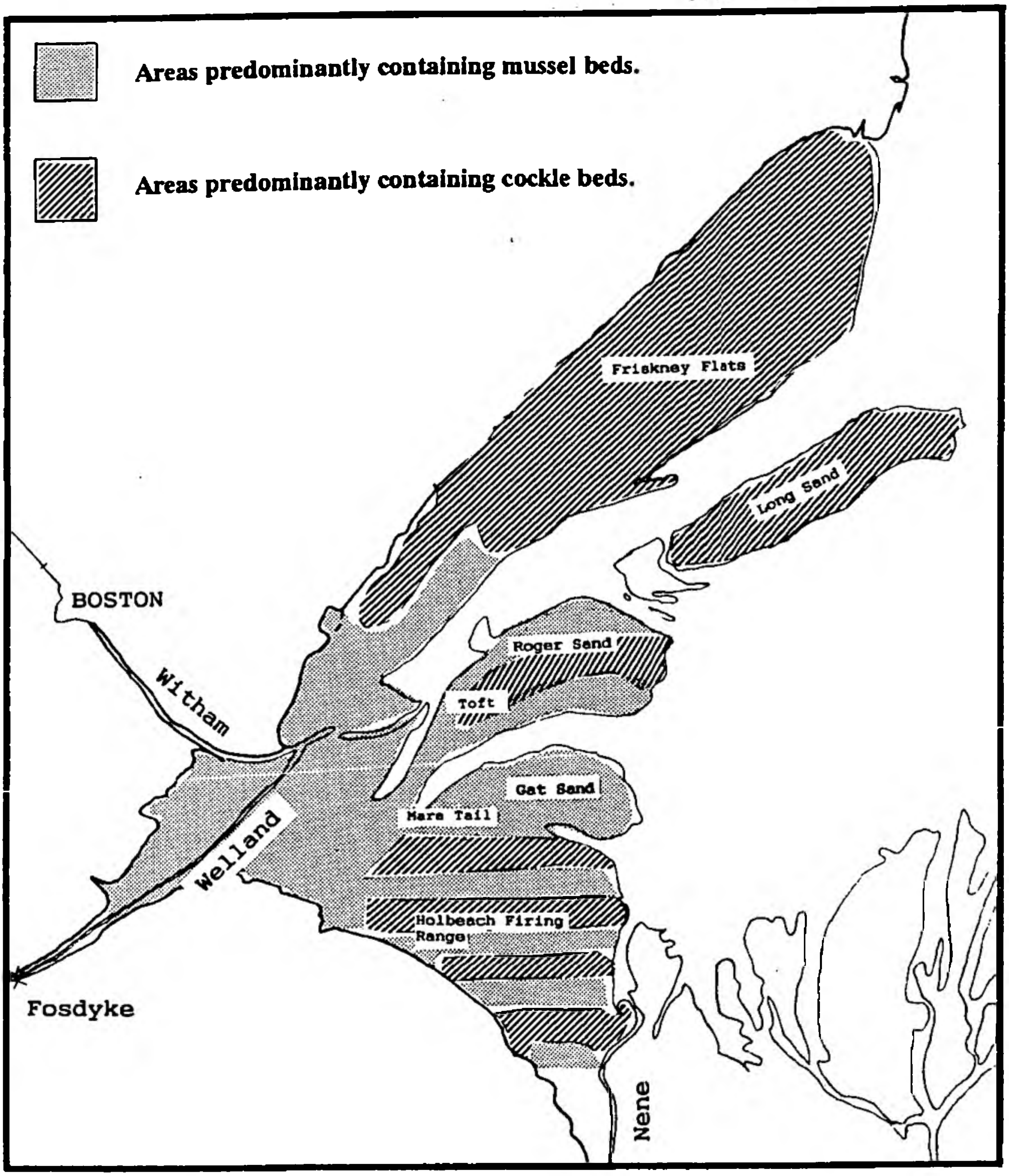


Figure 8.2 Shellfish beds in the Western Wash.
(Information from ESFJC)

Figure 8.3. Shellfish landings from Wash ports (1991 data all ports Jan-Sept)

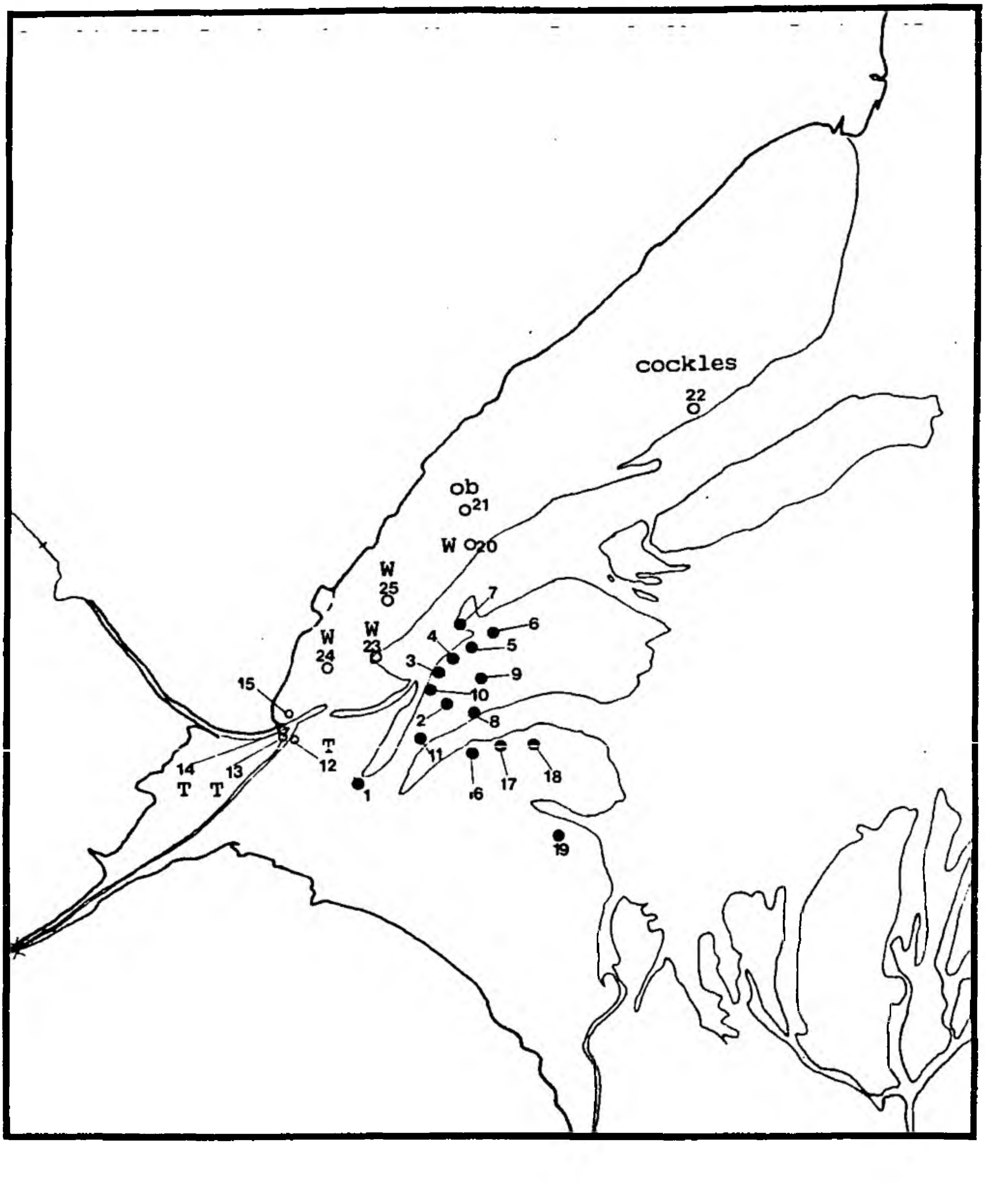


Figure 8.4 Shellfish sampling sites

Key ● = commercial beds, ob= obstruction, W=wreck, T=Training Wall

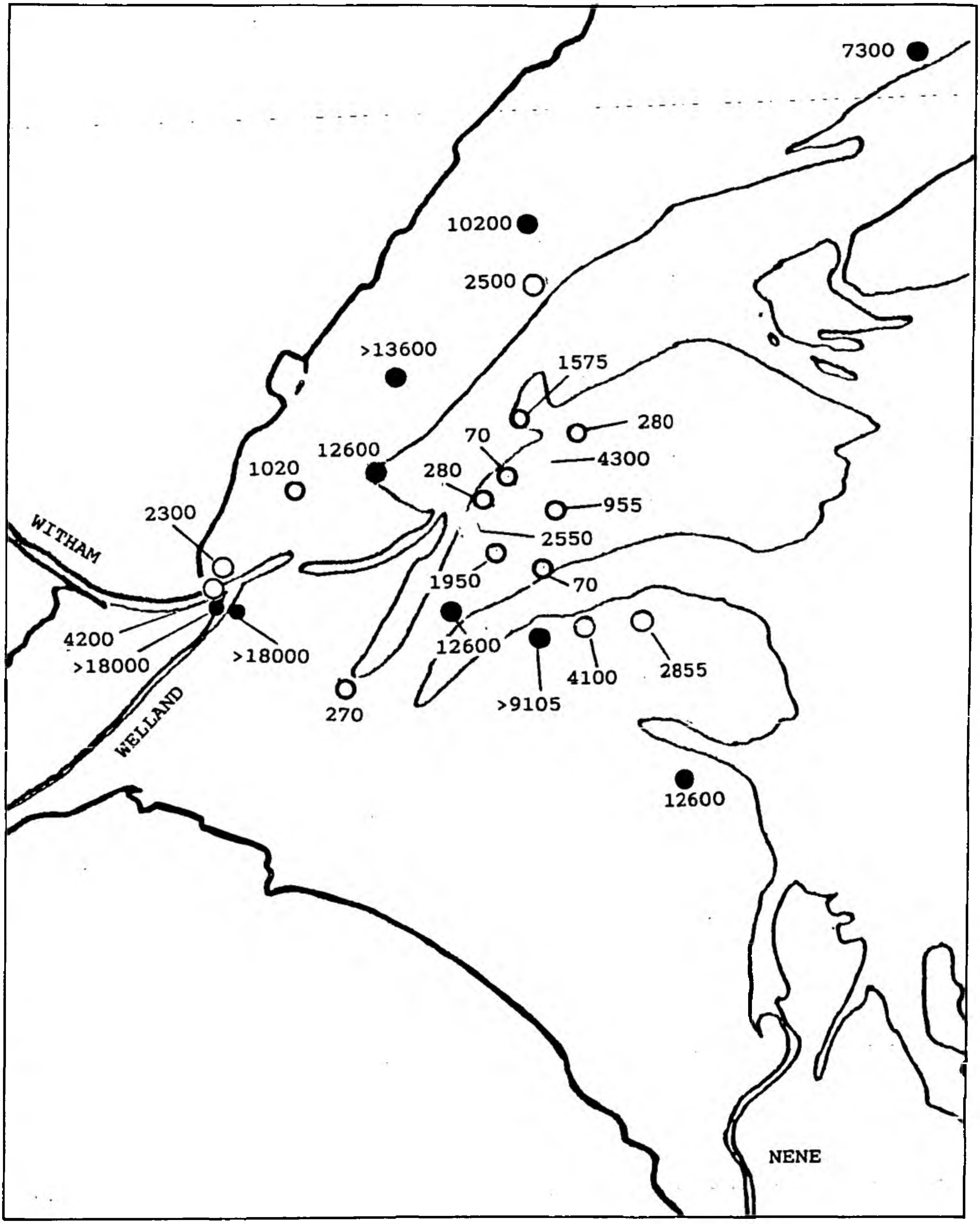


Figure 8.5 Mean TTC/100g at each site sampled. The dark circles indicate levels of contamination above 4600/100g. These would require relaying prior to depuration according to EC directive 9/492.

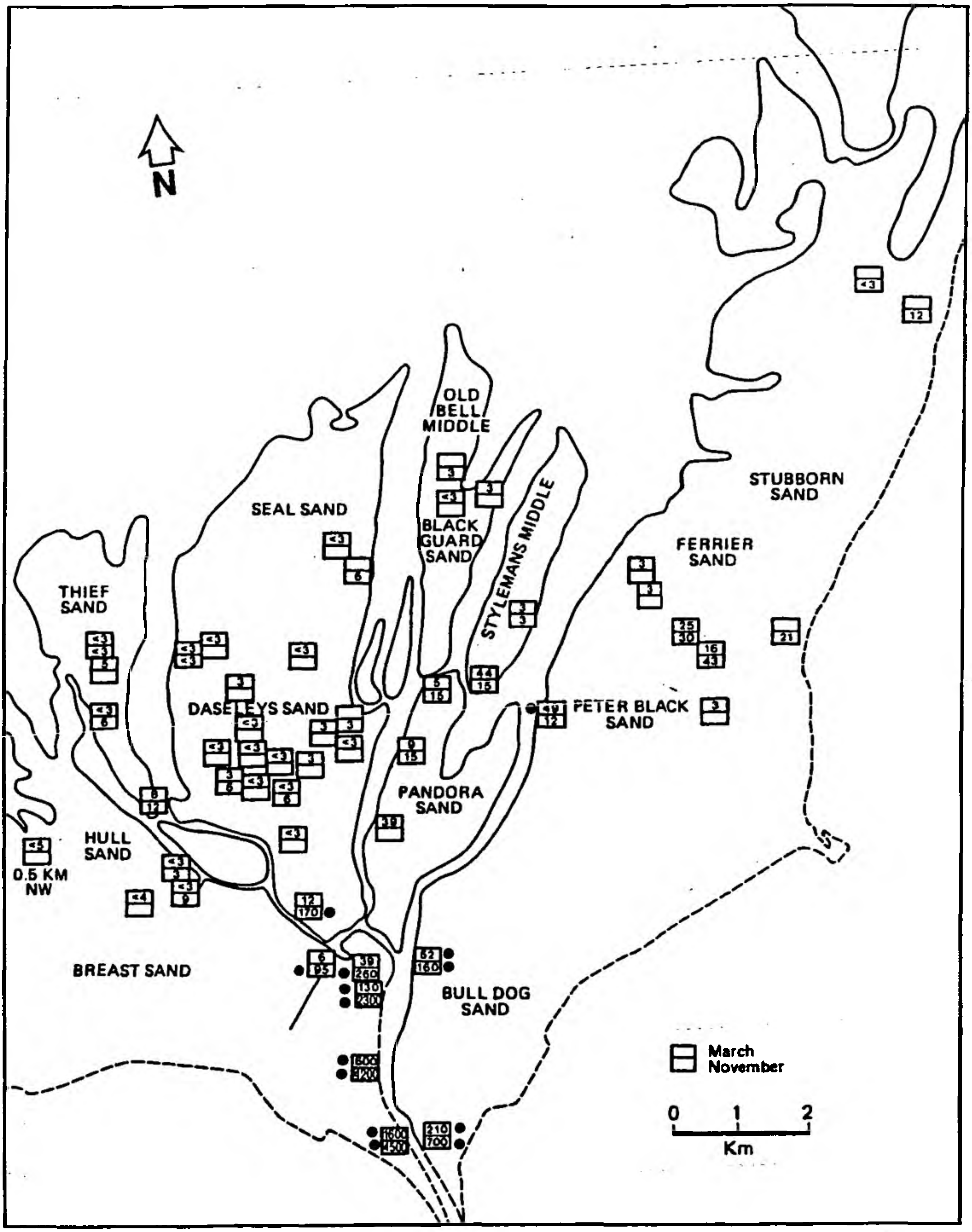


Figure 8.6 Counts of TTc/g in shellfish sampled in 1983 during the Gt Ouse study. n.b. These data must be multiplied by 100 for comparison with previous figures. The dark circles indicate levels above 4600/100g.