NATIONAL RIVERS AUTHORITY THAMES REGION
BIOLOGY

Survey of the biological quality of creek systems in the outer Thames Estuary, with special reference to the impact of STW and landfill site discharges.

NRA
THAMES REGION

Report compiled by Martin Attrill,
Biologist. July 1992.

Meiofauna analysis by *Physalia* Ltd.

Table of Contents.

Summary.

An extensive survey of both the creek system surrounding Canvey Island and Yantlet Creek on the south shore of the outer Thames Estuary was undertaken in October 1991 in order to assess the biological quality and to determine the impact of STW and landfill site discharges on the creek environment.

A total of 44 sites were visited, with sediment samples being taken for benthic macroinvertebrate and meiofauna analysis and water samples for bacteriology and salinity determination.

The results from fish trawls in Holehaven Creek were also reported.

All macroinvertebrate specimens were removed and identified, with abundance and biomass being determined. Univariate, multivariate and graphical techniques were applied to these data to facilitate pollution inference. Meiofaunal analysis was undertaken by *Physalia* Ltd.

A total of 30 benthic macroinvertebrate species were identified from the creek systems, the species number at each site ranging from five to 15. Diversity and evenness were generally low, reflecting the presence of species with large numbers of individuals. The maximum abundance recorded was 23660 individuals/m^2 in Yantlet Creek, the maximum biomass of 124.1 gWetWeight/m^2 in Lower Benfleet Creek.

A total of 53 nematode and 25 copepod species were identified in the meiofauna samples, the abundance of nematodes being generally very high.

Overall, the creek system was found to support a highly productive community which could be an important food source for organisms further up the food chain.

Peaks in *E.coli* concentration coincided with the three STW outfall, the highest value being 1,050,000 cells/100 ml in Benfleet Creek. However, there appeared to be a rapid die-off of bacteria, as bordering sites had low concentrations.

Salinity was generally in the range 26-29 ‰ for the Canvey creeks and 30-32 ‰ in Yantlet Creek. There were marked salinity decreases corresponding to inputs from the STW, although there was evidence that the freshwater spread over the surface of the creek water.

Full descriptions of the macro and meiofaunal communities in each creek are provided.

Analysis of the community structure was undertaken to infer pollution status. This included the use of the PRIMER multivariate statistics package for the first time, the technique proving most satisfactory and providing valuable and graphic results aiding pollution inference.

The input from Basildon STW appears to be a major contributing factor causing a highly stressful, anoxic environment at the top of Pitsea Creek. This site was found to be totally different from the rest of the system due to freshwater and organic inputs from the STW compounding the effects of decaying reeds.

Pitsea STW appeared to be having little notable effect on the environment of Timberman's Creek.

Benfleet STW seemed to be having a detectable overall effect on the Benfleet Creek system rather than a point impact, disturbing the balance in the macroinvertebrate community structure towards a dominance of organisms indicative of organic enrichment.

The discharge from the Cleanaway landfill site appeared to be having a marked point effect. The macrofauna community by the outfall was very poor, the meiofauna dominated by a species indicative of disturbance and the site being separated out from its neighbours during multivariate analysis.

Boat traffic visiting a wharf in Yantlet Creek also appeared to be having a mechanically disruptive effect.

1. INTRODUCTION

1.1 Two creek systems are located at the periphery of the outer Thames Estuary, the Pitsea/Benfleet system surrounding Canvey Island and the small Yantlet Creek on the south shore west of the mouth of the Medway Estuary.

1.2 Yantlet Creek is a small 2 km system surrounded by undeveloped marshland. There are no apparent inputs into the system, either freshwater or anthropogenic, the only evidence of man's influence being the levees on each side of the creek and a small wharf at the top end. No survey of any kind has yet been undertaken in Yantlet Creek.

1.3 Pitsea/Benfleet is a comparatively complex system of several individually named creeks covering a 7 km square on the north bank of the estuary. It has two separate main branches entering the tideway either side of Canvey Island: Pitsea, Vange, Timbermans and a couple of small creeks draining through Holehaven Creek to the west of Canvey, with Benfleet Creek draining through Hadleigh Ray to the Thames east of the Island. The two main systems are linked by the narrow East Haven Creek, the whole system generally bounded by marshland, most of which is used for grazing. In 1982, three flood prevention barriers were constructed to prevent inundation of bankside developments and land in the upper creek system. However, they also removed the necessity for excessive flood defences in the more sensitive areas of the system, preserving the most extensive areas of salt marsh and reed vegetation in the Thames Estuary. In 1984 the Wat Tyler Country Park was opened to the East of Timberman's Creek, part of the upper Pitsea system, providing amenities for bird watching, rambling, picnics etc.

1.4 One of the major potential influences on the creek environment is the large Cleanaway Pitsea Landfill Tip, the largest landfill site in the UK (Oatley & Lloyd, 1978), covering an area of approximately 1300 areas of marshland between Vange and East Haven Creeks. It has been used for some 60 years, with an estimated capacity for a further 40 years and is licensed to receive 200-250,000 tonnes of domestic refuse, 125,000 tonnes of hazardous liquid waste and 212,000 tonnes of hazardous solid waste every year (Maile, 1990). Until the 1980s, most of the domestic refuse was transported to the site by barge, resulting in considerable spillage into the creeks during offloading (Oatley & Lloyd, 1978). Waste now generally arrives by road.

1.5 Liquid waste arriving at the tip was treated in concrete settlement bays and fractionating lagoons previously lined with domestic refuse. The refuse and underlying geology provided a natural filter (Oatley & Lloyd, 1978). However, leachate was regularly breaking out of the tip during the 1970s through weakened points in the sea wall (Cockburn & Lloyd, 1978), so in 1985 Cleanaway installed a full scale effluent treatment plant to treat the landfill leachate. This is collected from perimeter ditches and site lagoons and treated using a Rotating Biological Contractor Plant, in whic biological aerobic treatment takes place. The current consent conditions for the discharge are described in Appendix 1, details from Maile (1990).

1.6 There are no significant natural freshwater flows into the creek system, but the Pitsea/Benfleet system receives discharges of effluent from three Anglian Water Plc sewage treatment works (STW), in addition to the leachate discharge. These works are Basildon (entering the system at the top of Pitsea Creek), Pitsea (top of Timberman's Creek) and Benfleet (upper Benfleet Creek). Appendix 1 outlines the consent conditions for these works, the largest flow being from Basildon STW (Maile, 1990). The largest consented discharge to the creek system is from the Mobil Oil Refinery, discharging cooling water near the mouth of Holehaven Creek. As a result of the wide nature of the creek at this point, the cooling water is subject to a much larger degree of dilution than the STW and leachate discharges.

1.7 The potential problems posed by the tip and the discharges outlined above have resulted in two surveys by Thames Water/NRA Thames Region. The first was undertaken before the leachate treatment plant was commissioned, concentrating on the geology and chemistry of the system (Oatley & Lloyd, 1978). A second survey (Maile, 1990) undertook chemical and bacteriological investigations into both effluents and receiving water. The chemical results of this survey are summarised in Appendix 1.

1.8 No quantitative biological environmental survey and impact assessment has been undertaken in Pitsea/Benfleet Creek system. Gee (1961) undertook a survey in lower Benfleet Creek, concentrating on the *Corophium* communities. Oatley & Lloyd (1978) report a very qualitative, inconclusive, survey at four sites, while Broom (1989) undertook a more thorough survey of Vange Creek but with questionable identifications rendering the data void. Powlesland (1984) carried out an extensive investigation into the effect of leachate from Pitsea landfill site, but concentrated on the freshwater marsh/fleet ecosystem.

1.9 The aim of this report, therefore, is to detail the results of a major comparative survey into the environments of both the Pitsea/Benfleet and Yantlet Creek systems, involving analysis of the macroinvertebrate and meiofauna communities and bacteriological levels. From the data obtained, full descriptions of the creek communities can be made and thus the ecological impact of the discharges on these communities can be assessed.

2. METHODS.

2.1 Sample Area.

2.1.1 The creeks investigated for this report were the system surrounding Canvey Island to the north of the outer Thames estuary and the small Yantlet Creek situated on the south shore west of the Medway estuary (Fig.1).

2.1.2 The Canvey system is composed of several different Creeks that can be roughly divided into two sections: Pitsea/Vange/Holehaven and East Haven/Benfleet/Hadleigh Ray. To the north-west of the system are several small creeks extending from Vange Creek (Fig.2), these being Pitsea and Timberman's Creeks, Parting Gut and Fobbing Creek. Effluent from Basildon and Pitsea STWs discharge into the system at the northern ends of Pitsea and Timberman's Creek respectively. A sizeable timber yard is also present at the top of Vange Creek. The main Vange Creek leads out past the wharf for the Cleanaway landfill site, through the Fobbing Horse flood barrier into Holehaven Creek (Fig.3). This is a much broader water body that widens considerably before meeting the Thames Estuary west of Canvey Island. On its western bank at this point is the large Mobil Oil Refinery, which has a cooling water discharge into Holehaven Creek.

2.1.3 A further flood barrier to the east of Fobbing marks the entrance of East Haven Creek, a narrow creek that winds its way through marshland and connects Holehaven to the Benfleet system (Fig.3). Benfleet STW discharges into the top of Benfleet Creek (Fig.3), the creek itself widening slightly as it passes through a flood barrier and eastward into Hadleigh Ray (Fig.4). This creek joins the Thames Estuary east of Canvey Island and is surrounded by marshland. A small creek (Leigh) demarcates Two Tree Island on the north side of Hadleigh Ray.

2.1.4 Yantlet Creek on the south shore of the Thames Estuary is a small creek surrounded by undeveloped marshland and fleets (Fig.5), the only potential impact being from a small wharf to the south-east of the creek. This creek was studied as a potentially low-impact system for comparison with the creeks around Canvey Island.

2.1.5 All the creeks studied, with the exception of outer Holehaven, are only navigable over the high-tide period, most being almost totally drained at low-tide. The majority are bordered by some form of flood defense, usually a levee, in addition to the three moveable flood barriers.

2.2 Sample Sites.

2.2.1 Sites were selected to give as full a coverage of the creek systems as possible. A total of 44 sites were designated, their positions being represented in Figs.2-5.

2.2.2 Macrofauna samples were taken at all sites except three in outer Holehaven where the water was too deep for comparative benthic samples to be taken. Water and meiofauna samples were spaced out over the system, the meiofauna in particular being sampled around potentially influential outfalls. Table 1 lists all sites, their names and the type of samples taken at each.

2.2.3 For comparison, data collected during the same quarter from the two nearest main estuary sites (Canvey Beach & Allhallows) as part of the Thames Estuary Benthic Programme (Attrill, 1992) were utilised. The position of these sites is indicated in Fig.1

2.3 Timing of samples.

2.3.1 Samples were taken on 22nd and 23rd October 1991 over a period two hours each side of high tide. This followed a preliminary survey for benthic macroinvertebrates on 5th September 1991 at 11 sites (Nos. 5, 8, 12, 17, 20, 22, 24, 26, 29, 32 and 35).

2.4 Sampling method: Benthic macroinvertebrates.

2.4.1 Field sampling method.

2.4.1.1 Sediment samples for benthic macroinvertebrate community analysis were obtained using a 0.02 m^2 hand-operated Gulley grab from a 4.8 m rigid-hulled inflatable. All samples were taken from a position equivalent to Mean Tide Level (MTL) and sampled 2 hours either side of high tide. Positions were fixed using landmarks and recorded on a chart.

2.4.1.2 Five grabs were taken at each site and sieved through a 1.0 mm mesh. When aggregated, the total area sampled was 0.1 m^2. The macroinvertebrates retained on the sieve were fixed using a final 10% formalin solution and stored in sealed plastic bags.

2.4.2 Sample sorting and species identification.

2.4.2.1 Each sample was sieved again in the laboratory through both 1 mm and 500 μm sieves to remove the formalin and any remaining sediment, the residue being transferred to a large, graduated sorting tray. All organisms were removed, counted and identified to species level where possible using the appropriate keys. Some problematic freshwater taxa, such as dipteran larvae, were not routinely specified. Decalcified wet weight was recorded for each species.

2.4.2.2 Small organisms present in large numbers (e.g. tubificids, *Corophium* spp.) were enumerated by counting/weighing a subsample present in a random two of the 10 tray graduations and multiplying by five to give a total value for the sample. Where necessary, a subsample of oligochaetes was removed for identification, the worms being mounted in polyvinyl lactophenol and placed on a hot plate to clear. The species proportions recorded in the subsample were then related to the total oligochaete figure to achieve abundance and biomass values for each species.

2.4.2.3 Examples of each species have been preserved to maintain a species library.

2.4.3 Analysis.

2.4.3.1 From the raw data recorded above, several community statistics for each site were calculated.

2.4.3.2 The number of species present in each sample was recorded, giving the **total number of species** recorded for the site.

2.4.3.3 Figures for **total abundance** and **total biomass** were recorded for each species in each sample, with this figure being calculated into the 1 m^2 equivalent thus (example for abundance):

$$\text{Abund.}/m^2 = \underline{\text{Total Abundance}} \times 10$$

2.4.3.4 The total abundance and biomass figures for each species were summed to give total abundance and biomass for the whole sample. This can be related to values/m^2 using the above formula.

2.4.3.5 The total abundance figures were used to calculated the **diversity** of the community at each site, using the Shannon-Weiner equation with $\log_e$ (ln):

$$\text{Diversity } (H'e) = -\Sigma P_i . \ln P_i$$

where P_i = the proportion of the total abundance represented by the abundance of the "*i*th" species.

2.4.3.6 Evenness (J) is a function of diversity and reflects the degree of dominance in the community, the lower the evenness, the greater the degree of dominance. It is calculated as a proportion of the diversity that would result from a community made up from equal numbers of each species represented (H_{max}):

H_{max} = ln.Tn, where Tn is the total number of species.

$$J = \frac{H'e}{H_{max}} \qquad J \leq 1.00$$

2.4.3.7 Species indicative of organic enrichment (oligochaetes, Spionidae, Capitellidae, Cirratulidae) were clumped together in order to calculate their percentage composition (% comp) of the community. This allows easy observation of the dominance of these groups (in terms of both abundance and biomass).

2.4.3.8 Multivariate analysis of the relationships between the communities present at each site was undertaken on the data using the PRIMER package from PML, involving cluster analysis (Bray-Curtis similarity indices and group average linkage), multi-dimensional scaling (MDS) and biomass/abundance relationships (ABC curves).

2.5 Sample Method: benthic meiofauna.

2.5.1 Sediment for analysis of the meiofaunal community was obtained using an additional 0.02 m^2 gulley grab sample. Sediment from the grab was transferred to a 500 ml plastic container and fixed immediately with 50 ml of undiluted formalin. The samples were transported to *Physalia* Ltd for analysis.

2.5.2 Initial separation was carried out using a modified Boisseau apparatus (after MacIntyre & Warwick, 1984) and fractions collected at increasing water velocities onto 38, 50, 75, 100 and 150 µm sieves immersed in flowing tapwater. Pooled meiofauna/fine sediment fractions for each sample were further separated using density separation techniques and the meiofauna collected onto 38 µm sieves. Residual material was examined to confirm complete elution of infauna.

2.5.3 During the sieving process, descriptive notes on the sediment type were made, particularly the proportion of the silt/clay fraction.

2.5.4 Harpacticoid and calanoid copepods were removed by hand and dissected for identification by means of 5th limb setotaxy. Acari were also removed at this stage and mounted in polyvinyl lactophenol. After clearing, specimens were identified and enumerated. The remaining fauna, principally Nematoda, was processed to glycerol using the Seinhorst method (Seinhorst, 1959) and mounted on slides for identification under Zeiss Normarski and Nikon differential interference contrast microscopes. For nematodes, the first 100 specimens encountered in a standardised box scan were identified and counted.

2.5.5 Data were transformed to number of individuals per litre of sediment sampled for each species, the abundances of each species being summed to give the total abundance at each site. Nematodes were classed into feeding types to enable calculation of the 1B:2A ratio (Appendix 2).

2.6 Sample Method: water samples.

2.6.1 Water samples for coliform analysis were obtained using a standard 200 ml glass bottle at a depth of approximately 25 cm and returned to the laboratory in a cool box.

2.6.2 Presumptive bacterial counts for both total coliforms and ***Escherichia coli*** were obtained using the standard membrane filtration technique with incubation in sodium lauryl sulphate broth as a growth medium (HMSO, 1982). The resulting counts were expressed as number of colonies/100 ml.

2.6.3 Salinity (‰) was measured using a WTW LF196 conductivity salinometer with a Tetracon 96/T electrode.

2.7 Sampling Method - Fish Trawls.

2.7.1 Fish samples were taken from Holehaven Creek on 18.2.92 as part of an investigation into a pollution incident. As the trawls were undertaken within the area covered by this report, the results have been included.

2.7.2 Two transects were trawled, these situated either side of Upper Horse Island (Fig.3). Twin 2 m^2 Lowestoft Frame Trawls with 20 mm stretched mesh cod-end were deployed, each haul lasting 15 minutes. Each trawl was fitted with a flow meter, enabling the volume of water filtered to be calculated.

2.7.3 The fish caught were identified to species, counted and the total length of commercially important species (flatfish, gadoids, clupeiods, smelt, bass) recorded.

3. RESULTS

3.1 Benthic macroinvertebrates.

3.1.1 The results of the macroinvertebrate community analysis for each site are presented in Tables i-x in Appendix 3. The abundance and biomass for each species recorded are listed, together with the community statistics described in Section 2.3.3.

3.1.2 The total number of species recorded in the individual creek samples ranged from 5 (sites 3 & 11) to 15 (sites 38 & 43), the species numbers for each site being graphically presented in Fig.6. Overall, a total of 30 benthic macroinvertebrate species were recorded at the 41 sites.

3.1.3 Total abundance was generally high, due to large numbers of oligochaetes, *Nereis (Neanthes) diversicolor*, *Corophium volutator* or *Hydrobia ulvae*. The maximum abundance recorded was 23660 individuals/m^2 at site 43 in Yantlet Creek, due to large populations of *Tubificoides benedeni* (12,000/m^2), *Hydrobia ulvae* (5170/m^2) and small *Scrobicularia plana* (4790/m^2). No site registered an abundance of <1000 I/m^2, the lowest being 1510/m^2 at site 23 in East Haven Creek. Biomass figures were highly dependant on the size of *Nereis (Neanthes) diversicolor* present, ranging between 4.4 gWetWeight/m^2 (site 44, Yantlet Creek) and 124.1 gWetWeight/m^2 (site 32, Lower Benfleet Creek). Site 1 was the only site where no *Nereis* or *Tubificoides benedeni* were recorded.

3.1.4 Diversity and evenness were generally low, reflecting the presence of species with large numbers of individuals. Diversity varied comparatively little, with most samples falling in the range 0.80-1.20. The lowest diversity and evenness values were recorded at site 41 in Yantlet Creek (0.19 & 0.10) due to vast numbers of *Hydrobia ulvae*.

3.1.5 Several species were present in the vast majority of samples. *Tubificoides benedeni* and *Nereis (Neanthes) diversicolor* were only absent from site 1, *Hydrobia ulvae* from sites 1 & 29 and *Macoma balthica* from four site. In addition, *Tubifex costatus* was common at sites in the upper reaches of the creeks and *Caulleriella* sp. usually present at sites nearer to the main estuary. Many species (Nemertea sp., *Limnodrilus hoffmeisteri*, Enchytraeidae sp., *Ampharete acutifrons*, *Anaitides mucosa*, *Polydora* sp., *Idotea chelipes*, *Sphaeroma rugicauda*, Diptera sp., Chironomidae sp., *Cerastoderma edule*, Opisthobranch sp. and *Retusa obtusa*) were only recorded in one sample, highlighting the relatively limited fauna that comprises the macroinvertebrate community at most of the creek sites. The specific composition of the sites in each creek is described in Section 4.

3.2 Meiofauna community.

3.2.1 The results from the 13 sites where meiofauna analysis was undertaken are presented in Tables xi-xxiii in Appendix 4. These data are summarised in Table 2.

3.2.2 Nematode species number ranged from 10 (site 1) to 20 (sites 6 & 38), with copepod species present ranging from 0 (site 1) to 13 (site 42). Fig.7 illustrates the number of meiofauna species at each site. Abundances of nematodes were generally very high, reaching a peak at site 38 of 125,373 individuals/ℓ of sediment. This value has only been exceeded on one occasion during surveys in the main Thames estuary, with 153,403 I/ℓ being recorded from the intertidal flats at Southend during the first quarter of 1990 (Trett & Feil, 1990). Site 38 is situated on Leigh Sands at the eastern end of the Southend expanse of mud flats. Abundances of the Copepoda were more variable, reaching a peak of 1284 I/ℓ at site 42 in Yantlet Creek.

3.2.3 The nematode species *Ptycholaimellus ponticus* and *Metachromadora remanei* was present at all sites except site 1, while *Leptolaimus papilliger* was recorded at all sites except site 38, where it was replaced by *L.limicola*. The specific composition of the sites in each creek is described in Section 4.

3.3 Bacteriology.

3.3.1 The resulting counts for *E.coli* taken from the 22 sites surveyed are presented in Table 3 and Fig.8 (Site recording concentrations of <1000 cells/100 ml are represented as 1000 cells/100 ml, but displayed in a lighter shade). Most sites recorded low levels of *E.coli* contamination, although three peaks in *E.coli* concentration were apparent, coinciding with the three sewage works at sites 1, 6 and 26. By far the highest concentration was from Benfleet Creek by the outfall of Benfleet STW (site 26), recording an *E.coli* concentration of 1,050,000 cells/100 ml. However, the bacteriology sites bordering site 26 had comparatively low values, suggesting a rapid mixing/die-off of the bacteria entering the creek from Benfleet STW.

3.4 Salinity and sediment descriptions.

3.4.1 Table 3 and Fig.9 present the salinity concentration recorded for each site measured. The creek system around Canvey Island had a salinity regime generally between 26-29 ‰, although the upper Vange sites (3 & 4) were somewhat lower (17.8 & 22.4 ‰ respectively). In addition, there were marked decreases in salinity corresponding to inputs from the sewage treatment works (sites 1, 6 and 26). Sites bordering the Thames Estuary (19, 36 & 38) and sites in Yantlet Creek (40-44) had slightly higher salinities of 30-32 ‰.

3.4.2 The descriptions of sediment recorded during meiofauna analysis are presented in Table 4. All samples were mud, with a few subtle variations. Sites 4, 6, 21 and 23 had high silt/clay fractions, the sediment at sites 1, 40 and 42 contained plant material and sites 26, 30 and 34 contained an iron oxide scum. Site 38 was the only sample containing significant amounts of fine sand, while sites 11 and 44 contained some grit.

3.5 Fish Trawls.

3.5.1 The results obtained from the fish trawls in Holehaven Creek are presented in Table 5, listing both the fish and invertebrate species caught in each haul.

3.5.2 A total of eight fish and six invertebrate species were recorded in the trawls, the most abundant fish species being the sand goby (*Pomatoschistus minutus*). Much higher numbers of flounder (*Platichthys flesus*) were caught on transect B than transect A, while somewhat surprisingly no sole (*Solea solea*) were caught in any of the hauls.

3.5.3 A mussel bed appears to be present in the south half of transect A, with 29 *Mytilus edulis* being recorded here, this species not appearing in any other haul. Shore crabs (*Carcinus maenas*) were present in similarly high numbers in each benthic haul.

4. Community Descriptions.

4.1 Pitsea Creek. (Fig.2).

4.1.1 Macroinvertebrates (sites 1 & 2).

4.1.1.1 Pitsea Creek represents the upper reaches of the system surrounding Canvey Island and has a definite division into two habitats. Nort West of site 2, the creek is surrounded by *Phragmites* beds that extend into the intertidal region. These beds terminate by site 2 (due to increasing salinity), giving way to salt-marsh vegetation common to most of the sites in the creek system. Basildon STW discharges into the top end of Pitsea Creek, decreasing the salinity and resulting in relatively fetid conditions with deposited plastics and assorted toiletries. The mud here was black and anoxic, containing a high content of decomposing *Phragmites* leaves.

4.1.1.2 Consequently, the two sites in Pitsea Creek had markedly different faunas. Of the six species present at site 1 (Table i), three were found at no other site (Enchytraeidae sp., *Limnodrilus hoffmeisteri* and *Sphaeroma rugicauda*). In addition it was the only site where *Nereis (Neanthes) diversicolor* and *Tubificoides benedeni* were absent. The Enchytraeidae sp. present was the dominant in terms of both abundance and biomass, recording a density of $2060/m^2$ (78% of abundance). However, the total biomass was one of the lowest recorded (5.1 $gWetWeight/m^2$).

4.1.1.3 Site 2 demonstrated a community structure common to most sites in the creek system, being composed of seven regularly occurring species (Table i). *Nereis (Neanthes) diversicolor* was the dominant, representing 97.5% of the biomass and 75% of the abundance, this figure being supplemented by *Tubifex costatus* and *Corophium volutator*.

4.1.2 **Meiofauna (Site 1).**

4.1.2.1 In parallel with the macrofauna, the meiofauna composition of site 1 was quite different to other sites in the creek system, highlighting the conditions peculiar to this site. The community of 10 nematode species was dominated by *Adoncholaimus thalassophygas*, an oncholaimid species. This is unusual, as generally this group are comparatively large nematode species whose populations take several years to establish fully. However, where high relative densities have been recorded, this has usually been associated with elevated levels of organic material (e.g. sludge dumping grounds, large STW outfalls). At site 1, this organic material is likely to originate from a mixture of the decomposition of the *Phragmites* and the input from Basildon STW. This site also had the highest densities of *Leptolaimus papilliger* (10985/ℓ), a microbivorous species that would suggests the sediment here has a high level of bacterial activity. *Ptycholaimellus ponticus* and *Metachromadora remanei* were the dominant nematode species at many of the creek sites, but were absent from site 1. Both were present at all the other sites.

4.1.2.2 Site 1 was the only site where no copepod species were recorded. The reason for this is unclear, although it may relate to the release of methane from the rhizosphere of the reed bed, which in turn can bring sulphides to the surface. Harpacticoid copepod densities are low in areas of marine methane seeps, for example (Trett, pers. obs.).

4.2 Vange Creek. (Fig.2).

4.2.1 **Macroinvertebrates (sites 3,4,5,9,11,12).**

4.2.1.1 Vange is the main arterial creek in the upper part of the system illustrated in Fig.2. Sites 3, 4 and 5 are situated between Pitsea and Timbermans Creeks, while 9, 11 and 12 cover the southern half between Timbermans and Holehaven Creeks. Site 3 was in an upper side creek bordering a large timber yard, while site 11 was situated near Cleanaway wharf where treated leachate from the tip is discharged into the creek.

4.2.1.2 Site 3 recorded only five species (Table i), the lowest in the survey. It was one of the only sites (excluding site 1) where *Macoma balthica* was absent. However, it had the highest abundance of any Vange site due to the presence of 4400 *Corophium volutator*/m^2 (60% of abundance), supplemented by 2180 *Nereis (Neanthes) diversicolor*/m^2, the latter being the biomass dominant (66%). Sites 4 and 5 (Tables i & ii) were extremely similar, differing only due to the absence of *Corophium volutator* from site 4. Both sites had equally high abundances of *Tubifex costatus* and *Nereis (Neanthes) diversicolor*, although due to its size the polychaete was the biomass dominant (91% and 88%). Both sites recorded the larva of a Tipulidae sp. This species was present at many creek sites, including those of higher salinities, although it has only ever been recorded once in the main estuary (West Thurrock intertidal, quarter 1.90, Attrill 1992).

4.2.1.3 Sites 9, 11 and 12 (Table iii) demonstrated greater variation than the upper Vange sites. Site 9, near the sluice to Pitseahall Fleet, recorded both the highest species number (9 species) and the lowest total abundance (1570/m^2) in Vange Creek. Additional species to those recorded higher up Vange Creek were *Eteone longa*, *Abra tenuis* and *Pygospio elegans*, although the latter was present at site 2 in Pitsea Creek. The dominant in terms of abundance (61%) and biomass (92%) was *Nereis (Neanthes) diversicolor*. Site 11 was situated adjacent to Cleanaway wharf and recorded the joint lowest species number (five). Unlike site 3, which also recorded five species, *Corophium volutator* was absent, the extra species being *Macoma balthica*. Here the numerical dominant was the small gastropod *Hydrobia ulvae* (65%), although *Nereis (Neanthes) diversicolor* was still the biomass dominant (61%). Overall, however, site 11 had a low total biomass (15.9 gWetWeight/m^2) and may be indicating an influence from the leachate discharge. Site 12, situated on Fobbing Horse, recorded seven species, with *Corophium volutator* and Tipulidae sp. extra to site 11. However, abundance and biomass were higher, with several common species resulting in no overall dominance of the abundance, the predominant species being *Nereis (Neanthes) diversicolor* (46%) and *Tubificoides benedeni* (23%) with *Nereis* providing the main input to the biomass (93%).

4.2.2 **Meiofauna (sites 4 and 11).**

4.2.2.1 Sites 4 and 11 demonstrated different communities (Tables xii & xiv), with *Ptycholaimellus ponticus* being the most abundant nematode at site 4 and *Sabatieria punctata* at site 11 (Table 2). *P.ponticus* is a diatomivorous species feeding on the epigrowth of sediment particles, the development of such growths tending to need relatively stable conditions. However, *S.punctata* is an opportunistic nematode species that appears to thrive under the reduced competition associated with disturbed or stressed sediments and may be responding to inputs from the leachate discharge. Despite this, site 11 recorded 13 nematode species compared with 11 species present at site 4, although this site recorded the highest densities of nematodes in the whole Vange system (89117/ℓ).

4.2.2.2 Site 11 recorded the highest species number (10) and density (608/ℓ) of copepods in the Vange system (Table 2), with *Stenhelia palustris* the most common species. This copepod was frequently recorded in the creeks, predominating at four sites. Site 4 recorded five copepod species, with another *Stenhelia* sp., *S.aemula*, the dominant. This was also the only site in the Canvey system to record the presence of Oribatidae mites, and the only site in any creek with a Halacaridae mite (*Copidognathus dentatus*).

4.3 Timberman's Creek. (Fig.2).

4.3.1 **Benthic Macroinvertebrates (Sites 6, 7 and 8).**

4.3.1.1 Timberman's is a relatively narrow creek branching from the upper reaches of Vange Creek. Pitsea STW discharges into the creek at its top end (site 6), which is bordered on its eastern side by Wat Tyler Country Park.

4.3.1.2 Despite the input from the STW the three sites have overall similar communities (Table ii), with site 6 recording seven species and sites 7 & 8 eight species, the species present at site 6 also being recorded at the two other sites. However, there are subtle differences between site 6 and sites 7 and 8. The dominant species at site 6 was *Corophium volutator* (69% of abundance, 52% of biomass), the 5350/m² recorded being the highest density for this species in the survey. At both sites 7 and 8, the dominant was *Nereis (Neanthes) diversicolor*, with densities 10-20 times that at site 6. Site 8 recorded the highest biomass for this species of any site in the survey (102.4 gWetWeight/m²). There was also a trend of decreasing numbers of Tipulidae larvae down the creek, the 170/m² present at site 6 being the highest density recorded in the survey. The two species present at sites 7 and 8 that were not recorded at site 6 were *Eteone longa* and *Polydora* sp. respectively, the latter being the only record of this small polychaete in the survey.

4.3.2 **Meiofauna (site 6).**

4.3.2.1 The site in Timbermans Creek recorded a total of 20 nematode species (Table xiii), the joint highest species number in the survey (Table 2). The dominant species was *Ptycholaimellus ponticus*, a relatively specialised diatomivorous species that feeds on the epigrowth of sediment particles. This group of species (2A) tends to favour stable mud conditions where the epigrowth can establish. However, site 6 had the second highest abundance of *Leptolaimus papilliger* behind site 1. This microbivorous species would suggest a level of bacterial activity in the sediment, perhaps originating from the sewage works.

4.3.2.2 Five copepod species were recorded at site 6 in relatively low abundances, the predominant species being *Itunella* sp. The only other site where this species was the most abundant was site 40 in the Yantlet Creek. Only one other group of the holomeiofauna (permanent members of the meiofauna) was recorded here, the Foraminifera.

4.4 <u>Parting Gut.</u> (Fig.2).

4.4.1 **Benthic Macroinvertebrates (site 10).**

4.4.1.1 Parting Gut is a small, narrow side arm originating from the lower half of Vange Creek. It is surrounded by fleets and marshland. The site here recorded 12 species (Table iii), the highest number in this part of the creek system (Fig.6), with a species complement subtly different to the other sites in or around Vange Creek.

4.4.1.2 The site recorded several species generally occurring nearer the main Thames Estuary or in higher salinities and not found in any of the other surrounding sites. These included *Nephtys hombergi*, *Scrobicularia plana* and *Caulleriella* sp. The dominance structure of the site was also different, with the oligochaete *Tubificoides benedeni* predominating both the abundance (47%) and biomass (47%). Large numbers of *Hydrobia ulvae* (2570/m^2) were also present (similar to site 11), together with a comparatively high density of *Macoma balthica*. *Nereis (Neanthes) diversicolor* provided a comparatively low contribution to abundance (3.5%) and biomass (23%). A larva of a Diptera sp. was also recorded at the site, the only record in the survey.

4.4.1.3 The reasons for this different community are far from clear. There is no obvious difference in the salinity regime in Parting Gut (Table 3, Fig.9) and the surrounding influences are similar to those for Fobbing Creek. It is possible that Parting Gut may have either a greater stability or a different drainage pattern, thus influencing the stability of the faunal community, although this seems unlikely. It would appear that the Gut provides an incongruous pocket of organisms that have not been picked up in samples from the other sites.

4.5 Fobbing Creek. (Fig.2).

4.5.1 **Benthic Macroinvertebrates (site 13).**

4.5.1.1 Fobbing Creek originates from the same point on the western side of Vange Creek as Parting Gut, curving round to the south. Like Parting Gut it is surrounded by fleets and marshland with no obvious anthropogenic influences.

4.5.1.2 A total of seven species were recorded at site 13 (Table iv), although abundances of the species present were generally low. The exception was *Nereis (Neanthes) diversicolor*, which dominated both the abundance (68%) and biomass (91%). This site was one of the few not to record *Macoma balthica*, although the tiny sabellid polychaete *Manayunkia aesturina* was present, the only record in the Vange/Holehaven system. The oligochaete *Tubificoides benedeni* was present in low numbers, similar to the upper Vange sites (2-5).

4.5.1.3 Sites 10 and 13 make a very interesting comparison, considering they are very similar small creeks bordering each other. Parting Gut had a comparatively species rich fauna, with several more marine representatives, while Fobbing Creek had a low abundance community of fewer species similar to fauna structures recorded in the upper creeks.

4.6 Holehaven Creek. (Fig.3).

4.6.1 Benthic Macroinvertebrates (sites 14, 15 and 17).

4.6.1.1 Holehaven Creek extends from the Fobbing Barrier out to the Thames estuary to the west of Canvey Island, broadening considerably over its outer half. Macroinvertebrate samples were only taken in the upper half of this creek; sites 14 and 15 situated on the east side either side of the entrance to East Haven Creek, while site 17 is positioned to the west of a small salt-marsh island (Upper Horse) adjacent to the cooling water outfall from the extensive Mobil Oil Refinery.

4.6.1.2 Sites 14 and 15 recorded very similar communities of 8 species (Table iv), while site 17 registered a total of 10 species. The upper two sites had seven species in common, both being dominated by the oligochaete *Tubificoides benedeni* in terms of both abundance (site 14: 92%, site 15: 83%) and biomass (site 14: 83%, site 15: 84%). *Nereis (Neanthes) diversicolor* was only represented by small individuals at both sites, although it was still the subdominant in terms of biomass at site 14. The lack of large individuals present at site 15 resulted in a low total biomass figure of 9.0 gWetWeight/m^2. The difference in species complement was due to the presence of Tipulidae sp. at site 14 and *Abra tenuis* at site 15.

4.6.1.3 Site 17 recorded all seven of the species common to both sites 14 and 15. Here, however, *Tubificoides benedeni* was only predominant, representing 40% of the abundance and 29.5% of the biomass. *Nereis (Neanthes) diversicolor* made up a more significant part of the biomass at this site, together with larger contributions from *Macoma balthica*, *Hydrobia ulvae* and *Eteone longa*, a species that was absent from site 14 and 15. *Hydrobia ulvae* was also a major contributor to the abundance (36%), with the highest numbers of *Caulleriella* sp. in the Vange/Holehaven system (550/m^2) also being recorded. This site also provided the only records in this system of *Carcinus maenas* and Capitellidae sp. Many of these variations are likely to be due to the more seaward position of the site, there being a tendency towards increasing species number with salinity in each of the creek systems (Fig.6).

4.6.1.4 There was a notable change in the overall structure of the macroinvertebrate community either side of the Fobbing Horse flood barrier. *Tubifex costatus*, present in all samples above this point, was absent from the three Holehaven samples, these in turn demonstrating increased abundances of *Tubificoides benedeni*. The previously dominant *Nereis (Neanthes) diversicolor* was much less influential in Holehaven, being supplemented by a wider range of species (e.g. *Nephtys hombergi*, *Caulleriella* sp.) recorded only in Parting Gut above Fobbing Horse. Conversely, *Corophium volutator* was not recorded in Holehaven. This would appear quite a major shift in community structure over a salinity increase of 2-3 ‰ (26-29 ‰), suggesting this could be the critical salinity band for the shift between estuarine and more marine faunas.

4.7 <u>East Haven Creek.</u> (Fig.3).

4.7.1 **Benthic Macroinvertebrates (sites 20,21,22,23,24).**

4.7.1.1 East Haven is a long, winding, narrow creek that links Benfleet Creek with the Vange/Holehaven system. It is extremely uniform in appearance, being bordered on either side by salt marsh and marshland areas. On the northern border of the western half of the creek is the Cleanaway landfill site. Apart from the flood barrier at the entrance to Holehaven Creek and the road bridge crossing its northern limit, this landfill site is the only other conceivable direct anthropogenic impact bordering East Haven. However, it is likely that tidal movement would disperse effluent from Benfleet STW up East Haven Creek.

4.7.1.2 Species numbers recorded in East Haven Creek varied from six to nine (Table v). Sites 20-22 registered similar communities with six species common to all three sites. At each of these sites, *Tubificoides benedeni* was the predominant species in terms of abundance at sites 20 and 22, with *Nereis (Neanthes) diversicolor* being the biomass dominant. However, the higher numbers of *T.benedeni* present at site 21 resulted in absolute dominance here, this species representing 69% of the abundance. The *Nereis* here were smaller, resulting in the oligochaete contributing to 50% of the biomass. All the sites recorded remarkably similar values for *Macoma balthica*, with 330/m² being registered at each site. *Caulleriella* sp. and Tipulidae sp. were present in low numbers at all sites, while *Hydrobia ulvae* was also omnipresent, although in varying abundances. Site 21 provided the only record of *Scrobicularia plana* in East Haven Creek.

4.7.1.3 Sites 23 and 24 (Tables v and vi) recorded subtly different communities, with six and seven species respectively. At both sites *Nereis (Neanthes) diversicolor* was the biomass dominant, with this species also being the most common at site 23. The predominant species at site 24 was *Hydrobia ulvae* (41.5%), with both sites recording low numbers of *Tubificoides benedeni* in comparison to the other three sites. This resulted in generally low total abundances, with the 1510 individuals/m² at site 23 being the lowest density recorded in the survey. Site 24 recorded higher abundances of *Tubifex costatus*, comparable with adjacent sites in Benfleet Creek, probably relating to the decreasing salinity at this point (Table 3). Site 24 recorded *Carcinus maenas*, the only site to do so in either East Haven or Benfleet Creeks.

4.7.2 Meiofauna (sites 21 and 23).

4.7.2.1 Sites 21 and 23 in East Haven Creek had similar nematode communities, recording 13 and 12 species respectively (Tables xv and xvi). At both sites the predominant species was *Ptycholaimellus ponticus*, a species recording the highest abundance at seven of the 13 sites studied, including five of the six in the East Haven/Benfleet/Hadleigh system. As discussed previously, this is a 2A type species, selectively feeding on particle epigrowths. At site 21, the subdominant species was *Metachromadora remanei*, another 2A species. However, there were significant numbers of *Sabatieria punctata* at site 23 (1354/ℓ), this opportunistic, non-selective detritivore possibly indicating some influence from the Benfleet STW effluent.

4.7.2.2 There was a considerable difference in the copepod communities between the two sites, with site 23 recording 11 species (the second highest), while only four species were present at site 21. This site also recorded the lowest copepod abundance of sites where copepods were present (58/ℓ). The predominant species at each site were different, *Tisbe gracilis* at site 21 and *Stenhelia palustris* at site 23. The reasons for the different copepod communities are not clear as the sediment at the sites was similar (Table 4), both containing a high silt/clay fraction, although the influence of the landfill site next to site 21 is a possibility.

4.7.2.3 Both sites recorded other, though different, holomeiofauna groups. Foramanifera and Turbellaria were present at site 21, while an Ostracoda (*Cyprideis* sp.) was recorded at site 23. Filamentous algae were also present in the sample from site 21.

4.8 Upper Benfleet Creek. (Fig.3).

4.8.1 **Benthic Macroinvertebrates. (sites 25,26,27,28,29,30).**

4.8.1.1 The upper part of Benfleet Creek runs from its conjunction with East Haven Creek by the A130 road bridge roughly eastward to a flood barrier and a further road bridge. To the south of the creek are several small inlets and creeklets spreading over a small area of salting. To the north is the village of Benfleet, a railway line, some boatyards and most significantly the comparatively large effluent from Benfleet STW, which discharges near the top end of the creek at site 26. As a result, there are several anthropogenic sources of influence on this part of the creek system.

4.8.1.2 The species numbers recorded from the sites in the upper part of the creek range from seven to 11 (Tables vi and vii). The three sites surrounding the outfall (25-27) record similar species numbers of 7 or 8, comparable with the last site in East Haven Creek (site 24). Site 26 was situated directly opposite the outfall from the STW, where the effluent enters the creek and flows across to the far bank. Sites 25 and 26 were positioned above and below the outfall respectively, so there is no evidence that the outfall is having a direct local effect on species richness. In terms of species composition, sites 26 and 27 were very similar, having seven species in common and both being numerically dominated by the oligochaete *Tubificoides benedeni*. For site 27, this species was also the biomass dominant (60.5%), although the presence of large *Nereis (Neanthes) diversicolor* at site 26 resulted in the polychaete dominating the biomass (76%) at that site. Site 25 demonstrated a different community, however, the abundance dominant at this site being the oligochaete *Tubifex costatus* (58%). The 6300/m^2 recorded for this species was by far the highest density in the survey. However, comparatively large numbers of *Nereis (Neanthes) diversicolor* were present at this site (2200/m^2), resulting in this species dominating the biomass (80%). Some more marine species (*Eteone longa*, *Caulleriella* sp.) present at sites 26 and 27 were absent from site 25 (Fig.10).

4.8.1.3 Sites 23-28 all recorded varying concentrations of *Tubifex costatus*, peaking at site 25 (Fig.10). This shift in oligochaete dominance from *Tubificoides benedeni* to *T.costatus* is generally due to a decreasing salinity, the latter species being most common in the upper reaches of the Vange system. This is likely to be due to the effects of freshwater input from the STW making conditions more favourable for *T.costatus* to exploit. The water affecting the intertidal region at site 25 would cover the site on the incoming tide via the STW outfall. As a result, the dilution factor of freshwater into salt would be smaller due to the lack of water in the creek, resulting in lower salinity water passing over the site. Conversely, sites below the STW would be influenced by the outfall on the ebbing tide, when there is a greater body of water in the creek to negate the effect of freshwater. By the time the water reaches an equivalent low salinity, it will be below the MTL where the sites are situated.

4.8.1.4 This would also suggest that the effects of the STW are not discreet, but, due to the tidal movement in the creek, spread over a wider area. This is reinforced by the comparatively good community present directly opposite the outfall. The surface salinity at this point measured only 4.6 ‰, but most of the species present in the community (e.g. *Eteone longa*, *Macoma balthica*, *Caulleriella* sp., *Hydrobia ulvae*) are unable to tolerate salinities this low. The overall salinity regime affecting the benthos at this point must therefore be much higher (>20 ‰), the freshwater effluent dispersing over the top of the seawater creek and being distributed over a wider area. This would not only have the effect of spreading the influence of the freshwater (as suggested by the *T.costatus* distribution) but also spread any effects of suspended organic material originating from the sewage works over a wide area. The result would be no obvious point impact, but a general, less obvious impact on the surrounding communities.

4.8.1.5 Sites 28, 29 and 30 recorded a community based around *Tubificoides benedeni*, with 11, nine and eight species respectively (Table vii). All were seaward of the STW, with site 28 positioned just inside the main creeklet, 29 beneath the series of small boatyards and 30 just above the roadbridge at the mouth of another small inlet. *T.benedeni* was the abundance and biomass dominant at each site, reaching an abundance of 10100/m^2 at site 28, the highest value for this species in the system around Canvey Island. This was supplemented by 350 *Tubifex costatus*/m^2, this species being absent from the other two sites. At all sites *Nereis (Neanthes) diversicolor* was the subdominant. The three sites had six species in common, including the polychaetes *Eteone longa* and *Caulleriella* sp. and the amphipod *Corophium volutator*. This species had a patchy distribution in all other areas of the survey. The isopod *Cyanthura carinata* was recorded at site 29, although this was one of the only sites where *Hydrobia ulvae* was absent. The bivalve *Scrobicularia plana* was present at sites 28 and 29, this being replaced by the similar *Abra tenuis* at site 30.

4.8.2 **Meiofauna (sites 26 and 30).**

4.8.2.1 Sites 26 and 30 had, overall, similar meiofaunal communities (Tables xvii and xviii), recording similar total abundances of 12 and 11 nematode species respectively (Table 2). *Ptycholaimellus ponticus* was again the most common species, dominating the community at site 30. As discussed previously, this species is a selective feeder on the epigrowth of sediment particles (2A group) which usually require stable sediment conditions. However, the subdominant species at site 26 (by the outfall) was *Sabatieria punctata* (12906/ℓ), this species being absent from site 30. This is a non-selective deposit feeder (2B group) often associated with stressed situations and its increase in abundance at this site is likely to be linked to the increasing stress on the environment from the outfall due to a combination of organic loading and low salinity.

4.8.2.2 The community statistics for the copepods at each site were similar, with site 26 recording eight species and site 30 seven species. However the specific composition at the sites was quite different. Site 26 had two species (*Amphiascus angusticeps* and *Paramphiascella intermedia*) with equally high abundances (208/ℓ), whereas the predominant species at site 30 was *Stenhelia aemula*. Few other holomeiofaunal groups were recorded at the two sites, Foramanifera being present at site 30 and ostracod (*Cyprideis* sp.) at site 26. Filamentous algae were also present at site 30.

4.9 Lower Benfleet Creek. (Fig.4).

4.9.1 **Benthic Macroinvertebrates** (*sites* 31,32,33,34,35).

4.9.1.1 The lower half of Benfleet Creek extends from the flood barrier at Benfleet eastward to Two Tree Island, where it widens significantly and becomes Hadleigh Ray. Along most of its length, the lower creek is of similar width, split in two at its eastern end by a small salt-marsh island. The southern channel is a designated water-ski area. The creek is bordered on each site by marshland, though this is more extensive to the south where several inlets and small creeklets meander into Canvey Island. Behind the marshland to the north lies Hadleigh Castle Country Park. On the south bank just east of the flood barrier is Benfleet Yacht Club, which has several slipways and a small dock. Many yachts moor here.

4.9.1.2 The sites in Lower Benfleet generally recorded comparatively high species numbers from nine to 11 (Tables vii an viii), although site 32 was an anomaly, with only six species present in the sample. *Tubificoides benedeni* was the dominant species in terms of abundance at sites 31, 32, 34 and 35, continuing the trend from the upper part of the creek, with the peak in abundance at site 34 (10000/m^2). The oligochaete was also the biomass dominant at sites 31 and 34 and predominant at site 25. *Nereis (Neanthes) diversicolor* decreased in abundance down the creek, although the high numbers of large individuals at site 32 resulted in this site recording the highest total biomass figure in the survey (124.1 gWetWeight/m^2), the 92.4 gWetWeight/m^2 of *Nereis* being supplemented by large numbers of *Tubificoides benedeni* and *Macoma balthica*. The 1350/m^2 of this bivalve species recorded at the site was the highest density in the survey and greater than any abundance recorded for *Macoma* in the main Thames Estuary (Attrill, 1992). *N.diversicolor* dominated both the biomass and abundance at site 33, where *Tubificoides benedeni* was in comparatively low numbers. The two sites either side of the small island (34 and 35) registered very similar communities with nine species in common, site 34 recording a few individuals of *Nephtys hombergi* and Tipulidae sp.

4.9.1.3 It is unclear why there is a dip in species number at site 32 (Fig.6), considering this site recorded the highest biomass in the survey. Several species (*Eteone longa*, *Pygospio elegans*, *Abra tenuis*) were absent from this site but present at all the other locations in this part of the creek system. There are no obvious influences in the vicinity of site 32, though it is the only site that is directly located on the northern bank. It is therefore possible that scouring patterns differ, resulting in a decreased species richness but providing a stable sediment for the proliferation of those species unaffected by any differential in water movement.

4.9.2 Meiofauna (site 34).

4.9.2.1 The meiofauna site in the Lower Benfleet Creek recorded a diverse meiofauna community of 19 nematode and 10 copepod species (Table xix), giving the highest total species number in the survey (Fig.7).

4.9.2.2 Site 34 was the only site in the East Haven/Benfleet/Hadleigh system with a different predominant nematode species, *Metachromadora remanei*, although the species with the highest abundance at the other sites, *Ptycholaimellus ponticus*, was the subdominant. Both species are type 2A selective diatomivorous species generally requiring stable sediments to enable the development of sediment epigrowths.

4.9.2.3 Of the 10 copepod species present, *Paramesonchra intermedia* was the predominant, site 34 being the only location where this species was the most abundant. Foramanifera were the only other representatives of the holomeiofauna present.

4.10 Hadleigh Ray. (Fig.4).

4.10.1 **Benthic Macroinvertebrates** (sites 36,37,38,39).

4.10.1.1 Hadleigh Ray represents the outer reaches of Benfleet Creek leading into the main Thames Estuary. To the north of the Ray is Two Tree Island, a small, low island separated from the mainland by Leigh Creek, which is dry over most of the tidal period. A slipway leads across the intertidal area from Two Tree Island to the Ray allowing access to the water at low tide. To the south is a continuation of the marshland area present along the length of Benfleet Creek. Sites 36 and 37 are positioned in this region on the south and north sides respectively. At the eastern end of Canvey Island a small creek (Oyster Creek) leads to a boatyard and yacht marina on the edge of the island, the boats only navigating the creek at high tide. To the east of Hadleigh Ray are the extensive sand/mud flats of the Southend region (site 38) and a large, long sand bank separating the Ray from the main Thames Estuary (site 39).

4.10.1.2 The sites in Hadleigh Ray recorded some of the highest species numbers in the survey (Table ix, Fig.6), site 38 registering the joint highest species number of 15. This reflects the increasing salinity (Table 3). Despite this, there was some variation in species composition between the sites, with only six species common to all sites. This may reflect the change to more sandy conditions (site 38, Table 4). *Tubificoides benedeni* remained the abundance dominant at sites 38, 39 and 37, where it was also the biomass dominant. *Nereis (Neanthes) diversicolor* demonstrated a decreased influence towards the mouth of the creek. It predominated the biomass at site 36, but the average size decreased until it was a marginal species at sites 38 and 39. There was a converse increase in the abundance of the small polychaete *Caulleriella* sp., recording a density of 2200/m^2 at site 38, the highest in the survey.

4.10.1.3 Several marine species were only recorded in Hadleigh Ray: *Ampharete acutifrons* (site 39), *Anaitides mucosa*, *Idotea chelipes* and *Cerastoderma edule* (site 38), though it was somewhat surprising that cockles were not more widespread, appearing to be confined to the more saline, sandy areas. Interestingly, *Tubifex costatus* was present in low numbers at sites 36-38. This is generally found in lower salinity conditions (see upper Benfleet, Vange system) and was absent along the whole length of lower Benfleet from sites 29-35.

4.10.2 **Meiofauna (site 38).**

4.10.2.1 Twenty nematode species were recorded at site 38 (Table xx), the joint highest in the survey, this site also recording the highest total nematode abundance of 125,373/ℓ. This density has only been exceeded on one occasion in the main estuary, at a site situated on the same expanse of mud/sand flat at Southend. It would therefore appear that these extensive intertidal areas on the northern edge of the outer Thames estuary have the potential to support vast communities of nematodes, an important food source near the base of the foodchain. The predominant species was *Ptycholaimellus ponticus*, in common with most other sites in this system, with *Metachromadora remanei* subdominant.

4.10.2.2 Only six copepod species were recorded at site 38, the lowest in the Benfleet/Hadleigh system. However, this could be explained by the appreciable quantities of fine sand in the sediment (Table 4); sandy sediments are generally expected to support lower densities of copepods, which may influence species richness. The predominant species was *Stenhelia palustris*. Representatives of the holomeiofauna present at the site were members of the Foramanifera and Ostracoda.

4.11 Yantlet Creek. (Fig.5).

4.11.1 Benthic Macroinvertebrates (sites 40,41,42,43,44).

4.11.1.1 Yantlet Creek is a comparatively small system on the south side of the outer Thames Estuary, situated between Allhallows-on-Sea and the Medway Estuary. The creek becomes practically dry at low water, with a substantial mud flat separating the entrance of the creek from the main Thames Estuary at low tide. Some shelter for the creek is provided by a barrier of cockle shells extending across the creek mouth from the eastern side. The creek is surrounded by undeveloped marshland, though flooding is prevented by a series of levees. The only obvious anthropogenic influence is from a wharf situated near the end of the creek on the east bank, although there is a very small sewage works to the west of the creek. Sites 40-44 extend from the head of the creek to the mouth, with site 41 adjacent to the wharf and site 44 just seawards of the creek mouth.

4.11.1.2 The sites in Yantlet Creek recorded an general increase in species number from head to mouth (Fig.6), with site 43 registering 15 species (Table x), the joint highest total in the survey. There was variation in the dominance structure between the sites. At sites 40, 41, 42 the abundance was dominated by *Hydrobia ulvae*, this species also predominating at site 44, with a peak abundance at site 40 (16500/m^2). At site 43, the abundance dominant was *Tubificoides benedeni* (12000/m^2, the highest in the survey), the total abundance at this site of 23660/m^2 also being the highest in the survey. *Hydrobia ulvae* also dominated the biomass at sites 40 and 41, this species being replaced as the dominant by *Scrobicularia plana* at sites 42 and 43. Site 43 recorded 4790/m^2 of this species, by far the highest density in the survey or in surveys of the main Thames Estuary (Attrill, 1992).

4.11.1.3 Several species (*Tubificoides benedeni*, *Nephtys hombergi*, *Hydrobia ulvae* and *Nereis (Neanthes) diversicolor*) were recorded at each site, although *Nereis* was present in overall lower numbers than the other creek systems, perhaps indicating the higher salinity (Table 3). Site 41 was anomalous, being the only site in the creek where bivalves were absent and oligochaetes present in low numbers, resulting in the lowest species number of seven and the lowest diversity in the survey (0.19). The site at the mouth of the creek (44) recorded comparatively low abundances of small individuals, resulting in the lowest total biomass of the whole survey (4.4 Gwetweight/m^2). This could reflect the different conditions inside and outside the creek, the creek itself being sheltered and more favourable for settlement, while the scouring effect of water flowing in and out of the creek through its narrow entrance affecting the stability of the population at site 44.

4.11.1.4 Three species recorded in Yantlet Creek were unique to the survey: *Retusa obtusa*, an Onchidoriid opisthobranch (site 43) and a nemertean species (site 44).

4.11.2 Meiofauna (site 40,42,44).

4.11.2.1 The three samples from Yantlet were spaced along the length of the creek and recorded between 12 and 15 nematode species (Tables xxi-xxiii), with site 40 registering the second highest nematode abundance (Table 2). Unlike the other creek systems, *Ptycholaimellus ponticus*, although present in all three samples, was dominant at none of the stations. *Metachromadora remanei* (another 2B type nematode) was the predominant species at sites 40 and 44, whereas *Sabatieria punctata* was the most abundant species at site 42. In the creek system around Canvey Island, meiofauna populations with high numbers of *Sabatieria punctata* correlated well with the presence of outfalls (sites 11, 26). There is no obvious input to the creek at site 42, although the fate of the sewage from the small works to the west is unknown.

4.11.2.2 The copepods at the three Yantlet sites also indicated an alteration in community structure at site 42, which recorded the highest species number and abundance in the survey (13 species, 1284/ℓ). The other two sites recorded some of the lowest species numbers and abundances (Table 2), with each of the three sites having a different predominant species.

4.11.2.3 Sites 42 and 44 recorded other members of the meiofauna, with Foraminifera, Ostracoda and Oribatidae mites present at site 42 and free-swimming ciliates and Foraminifera at site 44. A springtail (Collembola) was recorded at site 40.

5. Pollution inference from community structure analysis.

5.1 Species composition: % contribution to biomass and abundance.

5.1.1 The actual species present in both macrofauna and meiofauna samples at each site can yield valuable information on the pollution status of the creeks when the inter-species relationships in terms of abundance and biomass are investigated. Certain species, or groups of species, appear to be indicative of organic enrichment, exploiting the conditions when more sensitive species are stressed or excluded. A site influenced by organic enrichment would have a community dominated by such species.

5.1.2 The dominance can be expressed in terms of either abundance or biomass, although abundance is the only available parameter for meiofauna analysis. All macrofauna species responding to enrichment gradients tend by their nature to be small (e.g. oligochaetes, small polychaetes such as Capitellidae, Spionidae, Cirratulidae), with short generation times and high tolerance levels enabling the species to exploit the conditions. As a result, they can be present in very large numbers, so would be the abundance dominant in a community where the natural balance has only partially been disturbed. Dominance of the biomass is a much more important figure as it describes a two-way disturbance of the community, with both an increase in the "indicator" population and a decrease in the number of larger species that would under normal conditions be present.

5.1.3 The percentage representation of both the biomass and abundance can therefore be useful. If >50% of the biomass is represented by the indicator organisms it suggests that the site may be influenced by organic enrichment to such an extent that the balance within the macrofauna community has been disrupted, decreasing the influence of the larger, high biomass species. Sites not pinpointed by this parameter may have >50% of the abundance represented by the indicator species. This suggests an underlying influence from organic enrichment, with high numbers of indicator species present, but the community has not, as yet, been so destabilised as to cause biomass dominance.

5.1.4 Figs.11 and 12 display the results for %biomass and %abundance respectively, with sites demonstrating >50% representation shaded darker. Fig.11 highlights 10 sites with >50% of the biomass represented by organisms indicative of organic enrichment. These can be divided into three groups: Pitsea Creek by Basildon STW, Benfleet Creek seawards of Benfleet STW and two sites at the top of Holehaven Creek. It would appear from these results that both Basildon and Benfleet STW are having an impact on the community structure in their respective creeks, while Pitsea STW shows no effect on Timberman's Creek. The reason for the dominance present at the top of Holehaven Creek is unclear, though possible effects from the landfill site to the north cannot be discounted. However, the three other sites bordering the landfill area had lower %biomass figures.

5.1.5 When Fig.12 is compared to Fig.11, several more sites show a >50% dominance of the abundance by the indicator species. Most of the remaining sites in Benfleet Creek (e.g. 25, 26, 32) exhibit such dominance, indicating some additional influence on these sites from the STW. Again, Pitsea STW shows no apparent detrimental effect on Timberman's Creek.

5.2 Species composition: Absolute abundances.

5.2.1 A similar inference to that obtained from the %abundance technique is to investigate the absolute abundances of oligochaetes (generally the most common indicator species present) present at each site. Large numbers of these small species require an additional input of organic material to sustain the high population levels, so indicating the influence of organic enrichment.

5.2.2 Fig.13 illustrates the absolute abundance of oligochaetes at each site, with the highest densities being recorded in Benfleet and Yantlet creeks. There is a distinct cluster of high values around Benfleet STW (sites 25, 27, 28, 29), with two high peaks further down Benfleet Creek and the sole peak in Yantlet Creek. The nearby Thames Estuary site at Allhallows generally records high densities of oligochaetes (Attrill, 1992). All these high values are due to *Tubificoides benedeni*, with additional *Tubifex costatus* around Benfleet STW.

5.2.3 Densities were consistently lower in the Vange system, where *T.benedeni* was not so prevalent due to the slightly lower salinities (Table 3). However, the most common oligochaete here, *Tubifex costatus*, has been recorded in very high densities (>100,000/m^2 at Crossness intertidal) in the main Thames estuary. These lower abundances reflect the %biomass results for the creek system, suggesting an overall lower organic loading than Benfleet Creek. The notable exception is site 1 (Pitsea Creek). Even though the abundance of oligochaetes is comparatively low, the main species here is *Limnodrilus hoffmeisteri*. In TEBP surveys this species has not been recorded in quite such vast numbers as either *T.costatus* or *T.benedeni*, so this peak of over 2000/m^2 may be more significant than others for this part of the system. The dominance of the oligochaetes is certainly obvious from Fig.11 and contrasts sharply with sites 2-9.

5.3 Abundance Biomass Comparison Curves.

5.3.1 As alluded to above, under stable unpolluted conditions, the biomass of the community tends to be dominated by one or a few large species, each represented by few individuals characterized by a large body size and long lifespan, so requiring stability to develop a population (Warwick, 1987). As disturbance increases, the large species become the first casualties, while the opportunistic species in the community become more favoured. The consequent result of the disturbance is a change in the abundance/biomass relationship, from a stable community of a few biomass dominants and an even spread of numbers over all species to a state of a more even biomass distribution with numerical dominance of smaller organisms.

5.3.2 Warwick (1986, 1987) has devised a method of illustrating the relationship between the distributions of biomass and abundance within a single community by constructing curves in which the species are ranked in order of importance on the x-axis with cumulative percentage dominance on the y-axis (Abundance Biomass Comparison Curves). The use of this method in the Thames was discussed in Attrill (1990), with examples of unpolluted, polluted and transitional conditions illustrated in Fig.14 a-c.

5.3.3 ABC curves were constructed for each site sampled in the creek survey, and the resulting plot classified into one of the above categories. Table 6 indicates which site fell into which pollution status category. For comparison, the samples taken from the nearest TEBP sites (Canvey and Allhallows) were also analyzed. Fig.15 illustrates three examples from the actual survey, one for each category of ABC.

Table 6.

OUTER ESTUARY CREEK SURVEY, 1991

SITES FALLING INTO EACH CLASS OF ABC PLOT

BIOMASS > ABUNDANCE Figs.14a & 15a.	BIOMASS = ABUNDANCE Figs.14b & 15b.	ABUNDANCE > BIOMASS Figs.14c & 15c.
2,3,4,5,7,8,9,12 13,20,22,23,24,25,32 CB	6,14,15,21,26,27 28,29,31,33,34,36, 37,41	1,10,11,17,30,35 38,39,40,42,43,44 AH

5.3.4 The relatively low species present in each sample often caused the curves to be hardly separated for much of their length, resulting in many sites receiving the "moderately polluted" designation despite, for example, the abundance curve being well above the biomass curve at the beginning. However, the sites classified at the two extremes had clear-cut curves allowing confident designation.

5.3.5 It is interesting to compare Table 6 with Fig.11 (%Biomass). All sites highlighted by the %biomass method fall into either moderately polluted or grossly polluted classification for ABC. Conversely, sites in East Haven Creek were all designated unpolluted, suggesting very stable conditions, as were all sites in Vange and Timberman's Creeks with the exception of site 11. This site was situated near the leachate outfall from the landfill site and was the only one in the system (excluding the small side creek of Parting Gut) to be classified as polluted. This site was not pinpointed by the %biomass method, there being generally low abundances of few species at this site.

5.3.6 It is important to confirm the relevance of the curves by relating the results to the species complement. Warwick (Pers.Comm.) stressed that on a few occasions, particularly in the intertidal area, the curves may be distorted by the presence of a small numerous organism that is not necessarily reflecting changing conditions. The major culprit is the small gastropod *Hydrobia ulvae* which can be present in vast numbers. This is true for sites in Yantlet Creek, where sites 40, 41 and 42 have been classified as polluted due to the *H.ulvae* population, casting doubt on the validity of their ABC classification. The remaining Yantlet sites, however, had different structures, site 43 with a high oligochaete abundance and site 44 with generally low biomass and abundance figures.

5.3.7 Several points can be concluded from the ABC curves.

- There is a shift in pollution status from East Haven Creek (unpolluted) into Benfleet Creek (moderately-grossly polluted) coinciding with Benfleet STW.
- Site 1 by Basildon STW and site 11 near the Cleanaway outfall are classed as grossly polluted while the rest of the sites in Vange and Timberman's Creeks, including those by Pitsea STW, remain undisturbed.
- The curves confirm the positive results from the %biomass investigation.

5.4 Multivariate Analysis.

5.4.1 Multivariate statistical techniques can be used to discriminate between samples on the basis of their faunistic attributes and investigate more complex or subtle inter-relationships within and between communities. The methods of classification and/or ordination are widely used in the analysis of benthic survey data (e.g. 11 of the 16 sludge dumping studies (Warwick, 1987)) and indicate the degree of similarity or dissimilarity in species composition between sites, or at the same station over time. The station groupings obtained can then be related to measured pollutant loadings or some indirect measure of pollution intensity (e.g. distance from source), thus providing strong correlative evidence of cause and effect.

5.4.2 Two stages of multivariate analysis are generally employed, the methods utilised in this study having been extensively tested and developed by Plymouth Marine Laboratories (e.g. Warwick, 1987, 1988; Warwick & Clark, 1991; Clarke & Green, 1988; Clarke & Ainsworth, in press.). Classification involves hierarchical agglomerative clustering based on group-averaging sorting of a matrix of sample similarities, using the Bray-Curtis similarity measure giving a degree of similarity between each pair of sites. The species abundance or biomass data was initially double square root transformed, which restricts the biasing effect of one dominant species. The results of the cluster analysis were presented in the form of a dendrogram, highlighting the resulting groupings and giving a scale of similarity. It must be stressed that there is no spatial difference illustrated in a dendrogram, the whole should be viewed like a mobile, with the ability to swivel about each vertical line. This would not, however, alter the cluster, but could change the order at which sites lie next to each other.

5.4.3 Ordination techniques present the similarity matrix as a two-dimensional array in which similarities between samples are represented by physical distance. Multi-dimensional Scaling (MDS) was employed, which has certain theoretical advantages (Clark & Green, 1988) and is empirically more robust (Warwick *et al.*, 1988). The result is a similarity picture allowing the differences between sites to be easily observed. However, there is an unavoidable logistic difficulty in displaying multi-dimensional data in a 2-D form, so a measure of stress is given to indicate the goodness-of-fit of the regression. The relevance of stress values is as follows:

STRESS < 0.05 implies excellent representation
< 0.10 good
< 0.20 still useful
> 0.30 little better than random points, so reject.

5.4.4 Classification and ordination were undertaken on both abundance and biomass data for all the sites surveyed in the study. Figs.16 and 17 represent the dendrograms produced by the cluster analysis for abundance and biomass respectively. Arbitrary lines of similarity of 50 and 60% have been added in order to define clusters of sites, the lines under the site numbers indicating the clusters formed at 60% similarity. As can be seen, analysis of both biomass and abundance define sites 1 and 41 as being quite separate, with there being some extra division on the biomass dendrogram at the same level of similarity.

5.4.5 MDS plots were also produced for both biomass and abundance, the resulting 2-D plots forming Fig.18. The clusters produced at the 50 and 60% similarity level have been superimposed on top of the site ordination, giving a spatial description of the degree of dissimilarity/similarity between each pair of sites. Both plots highlight how different site 1 is from the rest of the creek samples, with site 41 also forming a discrete cluster. However, there is little to be obtained from the large cluster produced by the rest of the sites on the abundance plot, while there are more discrete clusters resulting from the biomass analysis. A group of Vange system sites is separate at even the 50% level, while within the large cluster of remaining sites there is evidence of some separation at the 60% level not obvious from the abundance data.

5.4.6 This emphasises the importance of obtaining biomass data. As discussed earlier, the size of the species present can provide valuable information on the stability of the site. This can also relate to the size distribution within a species. *Nereis (Neanthes) diversicolor* or *Macoma balthica*, for example, reach large sizes in stable conditions, but in more unstable areas may be represented by small individuals that have managed to settle but perhaps cannot consolidate due to environmental restrictions. The two cases would not be separated by using abundance alone, but would be differentiated using biomass. For this reason, and the resulting pattern produced by the biomass analysis, further interpretation will concentrate on the distribution of sites produced by the biomass classification and ordination.

5.4.7 Further examples of the biomass ordination have been produced to graphically highlight where each creek system has been positioned in the plot and conclusions that can be derived. These are:

- Fig.19a: Biomass ordination highlighting sites above Fobbing Horse Flood Barrier.

- Fig.19b: Biomass ordination highlighting sites located in East Haven and Upper Benfleet Creeks.

- Fig.20a: Biomass ordination highlighting sites located in Yantlet Creek.

- Fig.20b: Biomass ordination highlighting sites forming a transect from the top of Pitsea Creek to Holehaven Creek.

5.4.8 Several interesting features are illustrated in Fig.19a. Site 1 at the top of Pitsea Creek is totally different from the rest of the creek sites (note the separation between it and the next site in Pitsea, site 2). This graphically emphasises the different environment at site 1, a relatively stagnant reed-bed area with a significant input of both freshwater and organic material from Basildon STW resulting in a different community from the rest of the system. The rest of the sites in the Vange/Timbermans system form a discrete cluster of their own, indicating the difference in environments between sites above and below the Fobbing Horse barrier. Pitsea STW, as before, seems to be having no obvious effect, with all Timberman's sites closely aggregated (6-8).

5.4.9 However there are two notable exceptions. sites 10 and 11, which fall outside this cluster and are hence dissimilar to the sites surrounding them. Site 10 is Parting Gut, the small side creek which recorded a rich community of more marine species that the other sites in the area. As a result, it has been classified with other sites of similar characteristics (Benfleet Creek), although as discussed earlier the reason for this small pocket of species is far from clear. It is certainly interesting to compare site 10 to site 13, Fobbing Creek, which lies just to the south of Parting Gut (Fig.2). The more notable omission from the Vange cluster is site 11. This site was situated near the leachate outfall from the cleanaway landfill site and recorded a low diversity community that was significantly different from the rest of the Vange sites (e.g. sites 9 and 12 above and below the site) to warrant classification outside of the main cluster. Fig.19a therefore graphically suggests that the outfall may be having an effect on the community at site 11, altering the community structure away from that recorded in the rest of creek.

5.4.10 The sites located in East Haven and upper Benfleet Creeks (Fig.19b) are relatively closely grouped, although two sites (25 and 29) fall into separate cluster on a 60% similarity level. This indicates no discrete effect of Benfleet STW, as discussed previously, the influence of the effluent being spread over a wider area resulting in similarities between the sites in the locality. However, the sites seaward of the outfall (27-30) are spread out in a line, compared to the neater clustering of sites in East Haven. The wider spread of points may suggest some disruptive influence, perhaps illustrating the changes in the %biomass structure. The aberrant sites 25 and 29 probably were separated by small, but significant, species variation. Site 25 was situated directly above the outfall and had a high abundance of *Tubifex costatus*, resulting in closer ties with Vange sites and pulling the site away from the others. Site 29 was one of the only sites not to record *Hydrobia ulvae*, which may have been significant.

5.4.11 The Yantlet site (Fig.20a) show an interesting distribution. Three sites (40, 42, 43) are closely clustered, but the other two are quite separate. Site 44 was situated in the scoured mouth of the creek and recorded a very low biomass community. It has been linked at the 60% level with site 38, another low biomass site situated in a similar position at the mouth of Hadleigh Ray on the north shore. Site 41 remains a great enigma, not only being quite separate from the rest of the Yantlet sites but forming a outlying cluster of its own, separated from its nearest neighbour at a similarity of only 43% (Fig.17). The site recorded an unusual high abundance/low biomass community (Table x), resulting in the lowest diversity in the survey. Oligochaetes and polychaetes were low in numbers, the dominant being *Hydrobia ulvae*. It was also one of the only sites to not record *Macoma balthica*. There must be some cause for these considerable differences from the surrounding sites, and as suggested previously the situation next to a wharf cannot be considered coincidental. The generally low numbers of infaunal species and lack of indication of organic enrichment suggests mechanical disturbance, presumably from boats moored at the wharf scouring the bed of the creek. It would appear this is the only site where mechanical disturbance is occurring, hence the discrete cluster formed on the ordination.

5.4.12 Fig.20b illustrates the transect of sites down Pitsea, Vange and Holehaven Creeks. As well as indicating the anomalous position of site 11, it displays the overall movement on the ordination from left to right with increasing salinity. This would suggest, as would be expected, that the major force controlling species distribution is salinity, with other variations superimposed on this main parameter, allowing interpretation of influences additional to salinity-induced effects.

5.4.13 The use of the PRIMER package has allowed variations between sites to be graphically displayed and further interpretations in terms of pollution/disturbance to be made, the package in general and the results obtained from it proving very satisfactory.

5.5 <u>Nematode feeding type ratios.</u>

5.5.1 Appendix 2 details the different feeding nematode feeding types, the analysis of which can provide information relating to pollution status due to the particular physico-chemical conditions favouring each feeding group.

5.5.2 The key feeding ratio used when determining pollution status is the relationship between 1B:2A feeding types. The former are non-selective deposit feeders and detritivores, opportunist nematode species that appear to thrive under reduced competition often associated with disturbed or stressed sediments. The classic species in this group is *Sabatieria punctata*. Type 2A species are specialist feeders exploiting the epigrowth formed on sediment particles and were usually the dominant group in the creeks. The formation of such a food source generally requires stable conditions. As a result, a high 1B:2A ratio tends to suggest a stressed situation.

5.5.3 Table 2 details the ratios for each site where meiofauna analysis was undertaken, the highest values being recorded at sites 11, 42 and 26, suggesting some disruptive influence at these sites. Site 11 is near the outfall from the landfill site, while site 26 is positioned by the outfall from Benfleet STW, confirming macrobenthic results that suggested an impact from these two discharges. Again Pitsea STW (site 6) shows no effect, although there was also a low ratio for site 1 (Basildon STW). This is probably due to the low salinity regime at the site, the top of Pitsea Creek having a meiofauna community as disparate from the other creek sites as the macrofauna (Section 4).

5.5.4 The reason for the high ratio obtained from site 42 is unclear, as discussed in Section 4, the rest of the meiofauna and macrofauna community being rich. It is possible that there is some small input to the creek in this area which may be worth investigating, although the overall impact on the environment is small.

6. Conclusions on the impact of the major outfalls.

6.1 Basildon STW.

6.1.1 The effect of Basildon STW is compounded by the particular environment into which it discharges at the top end of Pitsea Creek. The creek is relatively long, narrow and bordered by *Phragmites* reed beds. Due to its position, the site would have a comparatively long flushing time, as water moving out on the tide would be swept back up to a large extent when the tide turns. In addition, the site will be constantly under the influence of freshwater and organic material discharging from Basildon STW.

6.1.2 The net result is to cause a comparatively stagnant area of creek, with an anoxic, fetid sediment. The stressful conditions are exaggerated by the influence of the freshwater from the STW outfall. It is hard to determine the extent to which the outfall is responsible for the poor conditions to be found at the top of the creek as there would naturally be some input to an anoxic sediment from the decaying leaf material. However, it seems highly likely that the effects are made more extreme by both the organic input (increasing the anoxia), the freshwater and the physical position of the outfall.

6.1.3 The overall outcome is a site completely different from any other sampled in the creek system. It would be interesting to do a more detailed survey of the area to determine the zone of impact and to demarcate the change from the community at site 1 to that in the rest of the Vange Creek system.

6.2 Pitsea STW.

6.2.1 Of all the outfalls present in the creek system, the Pitsea STW outfall at the top of Timberman's Creek seems to show the least effect on the community of the creek. Any effects at the discharge site (site 6) were small, subtle changes in species composition (nematode spp, Tipulidae sp.) that may be as much to do with the freshwater input than the effluent itself and can basically be discounted as a significant impact.

6.3 <u>Cleanaway Landfill Site Leachate Discharge.</u>

6.3.1 From the results of the overall survey, this discharge would appear to be having as great an effect on the local environment as any of the STW. The macrofauna site here was poor, with the joint lowest species number and low biomass, resulting in the site being separated out from its neighbours on the MDS plot. Sites in Vange Creek above and below the site showed a markedly improved macrofauna community.

6.3.2 The macrofauna results were supported by the meiofauna nematode community analysis, with the most abundant species, *Sabatieria punctata*, being regarded as indicative of disturbance.

6.4 <u>Benfleet STW.</u>

6.4.1 Unlike the observed effects associated with the other outfalls, the effluent from Benfleet STW appears to be having a detectable overall effect on the Benfleet Creek system rather than a point impact. Most of the sites seawards of the STW show a dominance of the biomass by organisms indicative of organic enrichment that is not apparent in similar sites in East Haven Creek to the west and there is some evidence of scatter on the ordination.

6.4.2 This widespread effect extends a considerable distance down the creek, indicating that organic material from the STW is influencing a larger area of creek than the other outfalls, but to a lesser degree.

6.5 <u>Other impacts.</u>

6.5.1 Somewhat unexpectedly, a site in Yantlet Creek (site 41) recorded a highly disturbed community. The site was positioned next to a wharf, and it would appear that any boat traffic visiting the wharf is causing a marked, but localised, mechanical disturbance.

7. References.

Attrill, M.J. (1990). Thames Estuary Benthic Programme. Inferences on the pollution status of the Thames Estuary from the macrobenthic community structure.
NRATR Biology Report. 24 pp.

Attrill, M.J. (1992). Thames Estuary Benthic Programme. A site by site report on the results of macroinvertebrate surveys undertaken during 1990-91.
NRATR Biology Report. 82 pp.

Broom, D. (1989). Vange Creek Soft Sediment Macroinvertebrate Study.
M.Sc. thesis, Wye College.

Clark, K.R. & Ainsworth, M. (in press). A method of linking multivariate community structure to environmental variables.
Mar.Ecol.Prog.Ser.

Clark, K.R. & Green, R.H. (1988). Statistical design and analysis for a "biological effects" study.
Mar.Ecol.Prog.Ser., 46: 213-226.

Cockburn, A.G. & Lloyd, P.J. (1979). Pollution control in the Thames creeks.
TWA Metropolitan Pollution Control Report. 44 pp.

Gee, J.M. (1961). Ecological Studies in South Benfleet Creek with special reference to *Corophium*.
Essex Naturalist, 6: 291-308.

HMSO (1982). The bacteriological examination of drinking water supplies 1982.
Report on Public Health and Medical Subjects. No. 71. 111 pp.

McIntyre, A.D. & Warwick, R.M. (1984). Meiofauna techniques. In *Methods for the study of marine benthos*. 2nd Edition. Ed.Holme, N.A. and McIntyre, A.D. pp. 217-244. Blackwell, Oxford.

Maile, R. (1990). Pitsea Creek.
NRATR Pollution Control Report. 25 pp.

Oatley, R.A. & Lloyd, P.J. (1978). Pitsea Creek.
TWA Directorate of Sci.Serv., Met.Poll.Control. MPC 78/3. 44 pp.

Powlesland, C.B. (1984). The effects of leachate from a landfill site on the surrounding marsh ecosystem.
Ph.D thesis. Polytechnic of Central London. 316 pp.

Seinhorst, J.W. (1959). A rapid method for the transfer of nematodes from fixative to anhydrous glycerin.
Nematologica, 4: 67-69.

Trett, M.W. & Feil, R.L. (1990). The meiofaunal assemblages of the Thames Estuary, Modules I to IV.
Physalia Ltd. report for NRATR Biology.

Warwick, R.M. (1986). A new method for detecting pollution effects on marine macrobenthic communities.
Mar.Biol., 92: 557-562.

Warwick, R.M. (1987). Evaluation of techniques for detecting pollution effects on benthic communities.
DoE contract report, PECD 7/7/179. 50 pp.

Warwick, R.M. (1988). The level of taxonomic discrimination required to detect pollution effects on marine benthic communities.
Mar.Pollut.Bull., 19: 259-268.

Warwick, R.M. & Clarke, K.R. (1991). A comparison of some methods for analysing changes in benthic community data.
J.mar.biol.Ass.U.K., 71: 225-244.

Summary.

An extensive survey of both the creek system surrounding Canvey Island and Yantlet Creek on the south shore of the outer Thames Estuary was undertaken in October 1991 in order to assess the biological quality and to determine the impact of STW and landfill site discharges on the creek environment.

A total of 44 sites were visited, with sediment samples being taken for benthic macroinvertebrate and meiofauna analysis and water samples for bacteriology and salinity determination.

The results from fish trawls in Holehaven Creek were also reported.

All macroinvertebrate specimens were removed and identified, with abundance and biomass being determined. Univariate, multivariate and graphical techniques were applied to these data to facilitate pollution inference. Meiofaunal analysis was undertaken by *Physalia* Ltd.

A total of 30 benthic macroinvertebrate species were identified from the creek systems, the species number at each site ranging from five to 15. Diversity and evenness were generally low, reflecting the presence of species with large numbers of individuals. The maximum abundance recorded was 23660 individuals/m^2 in Yantlet Creek, the maximum biomass of 124.1 gWetWeight/m^2 in Lower Benfleet Creek.

A total of 53 nematode and 25 copepod species were identified in the meiofauna samples, the abundance of nematodes being generally very high.

Overall, the creek system was found to support a highly productive community which could be an important food source for organisms further up the food chain.

Peaks in *E.coli* concentration coincided with the three STW outfall, the highest value being 1,050,000 cells/100 ml in Benfleet Creek. However, there appeared to be a rapid die-off of bacteria, as bordering sites had low concentrations.

Salinity was generally in the range 26-29 ‰ for the Canvey creeks and 30-32 ‰ in Yantlet Creek. There were marked salinity decreases corresponding to inputs from the STW, although there was evidence that the freshwater spread over the surface of the creek water.

Full descriptions of the macro and meiofaunal communities in each creek are provided.

Analysis of the community structure was undertaken to infer pollution status. This included the use of the PRIMER multivariate statistics package for the first time, the technique proving most satisfactory and providing valuable and graphic results aiding pollution inference.

The input from Basildon STW appears to be a major contributing factor causing a highly stressful, anoxic environment at the top of Pitsea Creek. This site was found to be totally different from the rest of the system due to freshwater and organic inputs from the STW compounding the effects of decaying reeds.

Pitsea STW appeared to be having little notable effect on the environment of Timberman's Creek.

Benfleet STW seemed to be having a detectable overall effect on the Benfleet Creek system rather than a point impact, disturbing the balance in the macroinvertebrate community structure towards a dominance of organisms indicative of organic enrichment.

The discharge from the Cleanaway landfill site appeared to be having a marked point effect. The macrofauna community by the outfall was very poor, the meiofauna dominated by a species indicative of disturbance and the site being separated out from its neighbours during multivariate analysis.

Boat traffic visiting a wharf in Yantlet Creek also appeared to be having a mechanically disruptive effect.

Table 1. **Creek Survey Samples Sites with types of samples taken at each site.**

Site No.	Site Name.	Macro	Meio	Bacto	SED
1.	Upper Pitsea	*	*	*	*
2.	Lower Pitsea	*			
3.	Lower Vange Wharf	*		*	
4.	Upper Vange I	*	*	*	*
5.	Upper Vange II	*			
6.	Upper Timbermans	*	*	*	*
7.	Mid-Timbermans	*			
8.	Lower Timbermans	*		*	
9.	Vange at Wat Tyler Pk	*			
10.	Parting Gut	*		*	
11.	Cleanaway Wharf	*	*	*	*
12.	Fobbing Horse	*			
13.	Fobbing Creek	*		*	
14.	Upper Holehaven - Landfill south	*		*	
15.	Upper Holehaven East	*			
16.	Upper Holehaven West			*	
17.	Upper Horse West	*			
18.	Mid-Holehaven North			*	
19.	Outer Holehaven East			*	
20.	East Haven - East of flood barrier	*			
21.	East Haven - edge of landfill site	*	*	*	*
22.	Mid-East Haven I	*			
23.	Mid-east Haven II	*	*	*	*
24.	East Haven - south of A130 road bridge	*			
25.	Benfleet STW West	*			
26.	Benfleet STW outfall	*	*	*	*
27.	Benfleet STW East	*			
28.	Upper Benfleet - south fork	*			
29.	Upper Benfleet - boatyards	*			
30.	Mid-Benfleet - west of road bridge.	*	*	*	*
31.	Mid-Benfleet South	*			
32.	Lower Benfleet North	*			
33.	Lower Benfleet South	*		*	
34.	Upper Hadleigh Ray - north fork	*	*		*
35.	Upper Hadleigh Ray - south fork	*			
36.	Mid-Hadleigh South	*		*	
37.	Two Trees Island	*			
38.	Outer Hadleigh - Leigh Sands	*	*	*	*
39.	Outer Hadleigh - Clock Bank	*			
40.	Upper Yantlet	*	*	*	*
41.	Yantlet Wharf	*			
42.	Mid-Yantlet	*	*	*	*
43.	Lower Yantlet	*			
44.	Yantlet Mouth	*	*	*	*

SED = sediment description from meiofauna work.

Table 2.
Outer Estuary Creek Survey. 1991.
Summary of Meiofauna Results.

Abundance in No.Individuals/litre of sediment

Site	Nematodes				Copepods			Other
	No.Spp	Abundance	1B:2A	Dominant	No.Spp	Abundance	Dominant	Groups
1.	10	67201	0.05	Adoncholaimus thalssophygas	0	0	n/a	None
4.	11	89117	0.08	Ptycholaimellus ponticus	5	366	Stenhelia aemula	4,6,9,11,12
6.	20	37329	0.04	Ptycholaimellus ponticus	5	193	Itunella sp.	3,5,6
11.	13	36600	1.24	Sabatieria punctata	10	608	Stenhelia palustris	1,6,9
21.	13	84825	0.17	Ptycholaimellus ponticus	4	58	Tisbe gracilis	1,3,4,6,9
23.	12	49199	0.17	Ptycholaimellus ponticus	11	606	Stenhelia palustris	5,6,9,10
26.	12	50134	0.63	Ptycholaimellus ponticus	8	784	A.angusticeps + P. intermedia *	5,6,10
30.	11	55286	0.09	Ptycholaimellus ponticus	7	400	Stenhelia aemula	1,3,6
34.	19	69699	0.32	Metachromadora remanei	10	899	Paramesonchra intermedia	3,6,8,9
38.	20	125373	0.52	Ptycholaimellus ponticus	6	400	Stenhelia palustris	3,5,6,10
40.	12	124269	0.03	Metachromadora remanei	3	93	Itunella sp.	5,6,7,13
42.	14	94771	1.39	Sabatieria punctata	13	1284	Paramphiascella intermedia	1,3,5,8,10,12
44.	15	64034	0.39	Metachromadora remanei	4	83	Stenhelia palustris	1,2,3,6.
Nearest Thames Estuary sites. 4th Quarter 1989.								
Canvey	27	39992	1.12	Sabatieria punctata	6	866	Amphiascus angusticeps	3,4,5,7,10,14
Allhallows	26	29782	0.26	Metachromadora suecica	3	208	Amphiascus angusticeps	3,5,7,14,15

* = equal abundances of Amphiascus angusticeps and Paramphiascella intermedia.

Other Meiofauna groups: 1=Filamentous algae, 2=Protozoa, 3=Foramanifera, 4=Turbellaria, 5=Oligochaeta neochaetes, 6=Polychaeta neochaetes, 7=Bivalvia (newly settled spat), 8=Gastropoda, 9=Crustacean nauplii (mostly copepods), 10=Ostracoda, 11=Acarina:Halacaridae, 12=Acarina: Oribatidae, 13=Collembola, 14=Diatoms, 15=Kinorhyncha.

Table 3.
Outer Estuary Creek Survey, 1991.
Escherischia coli concentrations (/100 ml) and
measured salinity (‰).

Site number	Site name.	Salinity (‰)	*E.coli*/100 ml.
1	Upper Pitsea	1.0	17,000
3	Lower Vange Wharf	17.8	5,000
4	Upper Vange I	22.4	4,000
6	Upper Timbermans	8.1	100,000
8	Lower Timbermans	26.8	<1,000
10	Parting Gut	26.4	<1,000
11	Cleanaway Wharf	26.8	1,000
13	Fobbing Creek	24.9	1,000
14	Upper Holehaven - landfill south	28.3	<1,000
16	Upper Holehaven West	28.0	1,000
18	Mid-Holehaven North	29.1	<1,000
19	Outer Holehaven East	29.9	<1,000
21	East Haven - edge of landfill	27.9	<1,000
23	Mid-East Haven II	25.6	<1,000
26	Benfleet STW outfall	4.6	1,050,000
30	Mid-Benfleet - west of road bridge	27.0	6,000
33	Lower Benfleet South	28.1	<1,000
36	Mid-Hadleigh South	31.4	<1,000
38	Outer Hadleigh - Leigh Sands	30.6	1,000
40	Upper Yantlet	30.9	<1,000
42	Mid-Yantlet	32.4	<1,000
44	Yantlet Mouth	31.2	<1,000

Table 4.
Outer Estuary Creek Survey, 1991.
Sediment descriptions from meiofaunal sieving.

SITE	DESCRIPTION	HIGH SILT/ CLAY FRACTION?	FURTHER COMMENTS
1	Anoxic Mud	No	Partially decomposed plant material
4	Mud	Yes	
6	Mud	Yes	Beetle elytra present
11	Cohesive Mud	No	Some grit present
21	Flocculant Mud	Yes	
23	Silty Mud	Yes	
26	Grey Mud	No	Iron oxide scum
30	Grey Mud	No	Iron oxide scum
34	Grey Mud	No	Silt and iron oxide scum
38	Grey Mud	No	Silt and fine sand
40	Oxidised Grey Mud	No	Plant detritus present
42	Grey Mud	No	Plant detritus present
44	Cohesive Grey Mud	No	Clay/silt & grit

Table 5.
Outer Estuary Creek Survey, 1991.
Results from Fish Trawls (18/2/92).

Transect.	Position.	Species	No.
A - d/s outfall	Bed	*Dicentrarchus labrax*	5
		Bass	
		Osmerus eperlanus	1
		Smelt	
		Platichthys flesus	6
		Flounder	
		Pomatoschistus minutus	37
		Sand Goby	
		Sprattus sprattus	13
		Sprat	
		Asterias rubens	2
		Starfish	
		Carcinus maenas	58
		Shore crab	
		Crangon crangon	Common
		Brown shrimp	
		Mytilus edulis	29
		Mussel	
		Pleurobrachia pileus	4
		Ctenophore	
A - u/s outfall	Bed	*Dicentrarchus labrax*	7
		Osmerus eperlanus	2
		Platichthys flesus	3
		Pomatoschistus minutus	33
		Sprattus sprattus	41
		Asterias rubens	1
		Carcinus maenas	45
		Crangon crangon	Common
		Palaemon longirostris	2
		Prawn	
		Pleurobrachia pileus	5
A - u/s oufall	Midwater	*Dicentrarchus labrax*	2
		Liza ramada	1
		Thin-lipped grey mullet	
		Osmerus eperlanus	2
B - full transect	Bed	*Clupea harengus*	1
		Herring	
		Gobius niger	1
		Black goby	
		Osmerus eperlanus	3
		Platichthys flesus	52
		Pomatoschistus minutus	102
		Carcinus maenas	57
		Crangon crangon	Abundant
		Palaemon longirostris	2
		Pleurobrachia pileus	5
B - full transect	Bed	*Dicentrarchus labrax*	1
		Osmerus eperlanus	2
		Platichthys flesus	49
		Pomatoschistus minutus	87
		Sprattus sprattus	1
		Carcinus maenas	63
		Crangon crangon	Abundant
		Palaemon longirostris	2
		Pleurobrachia pileus	2

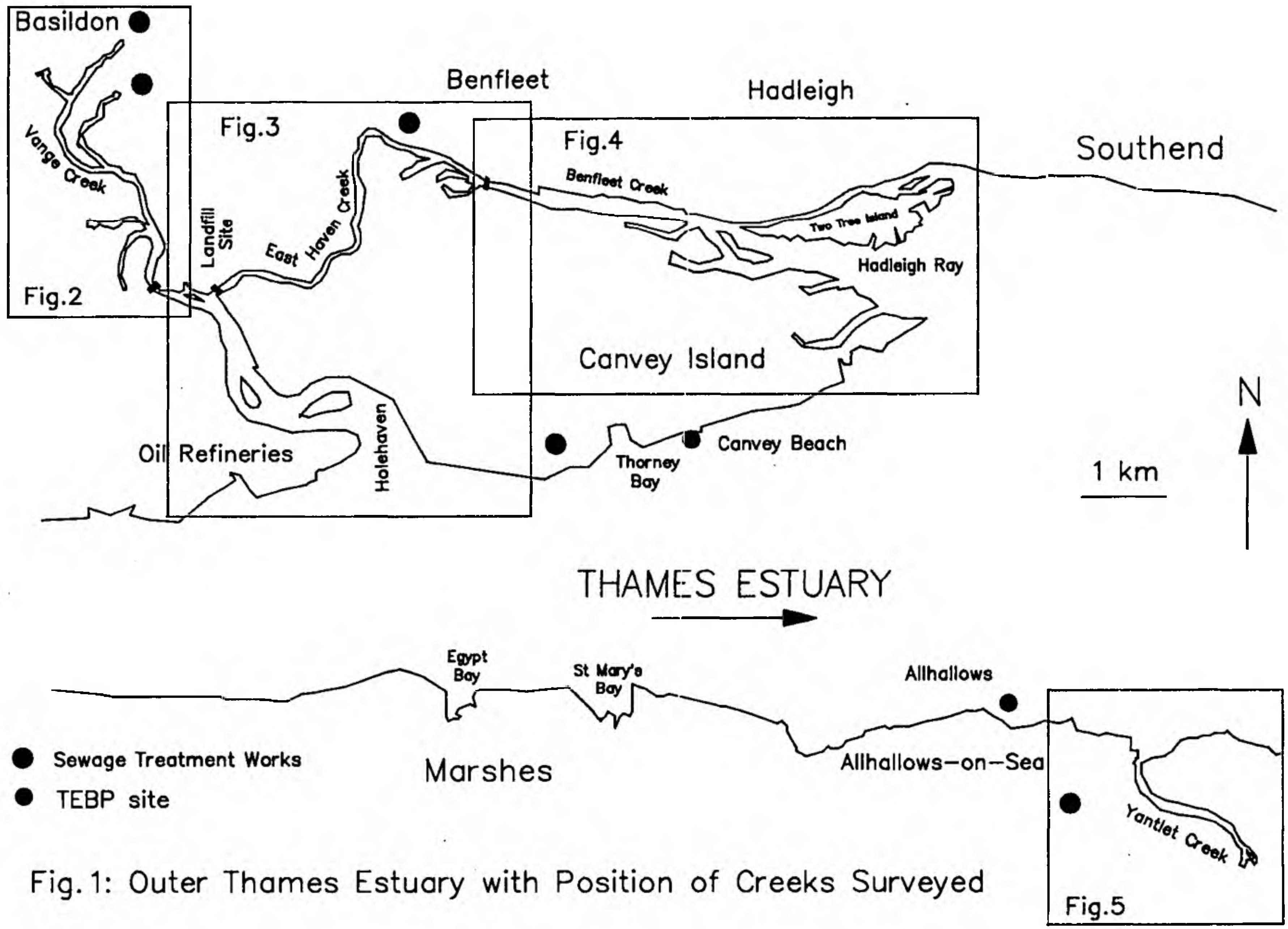


Fig. 1: Outer Thames Estuary with Position of Creeks Surveyed

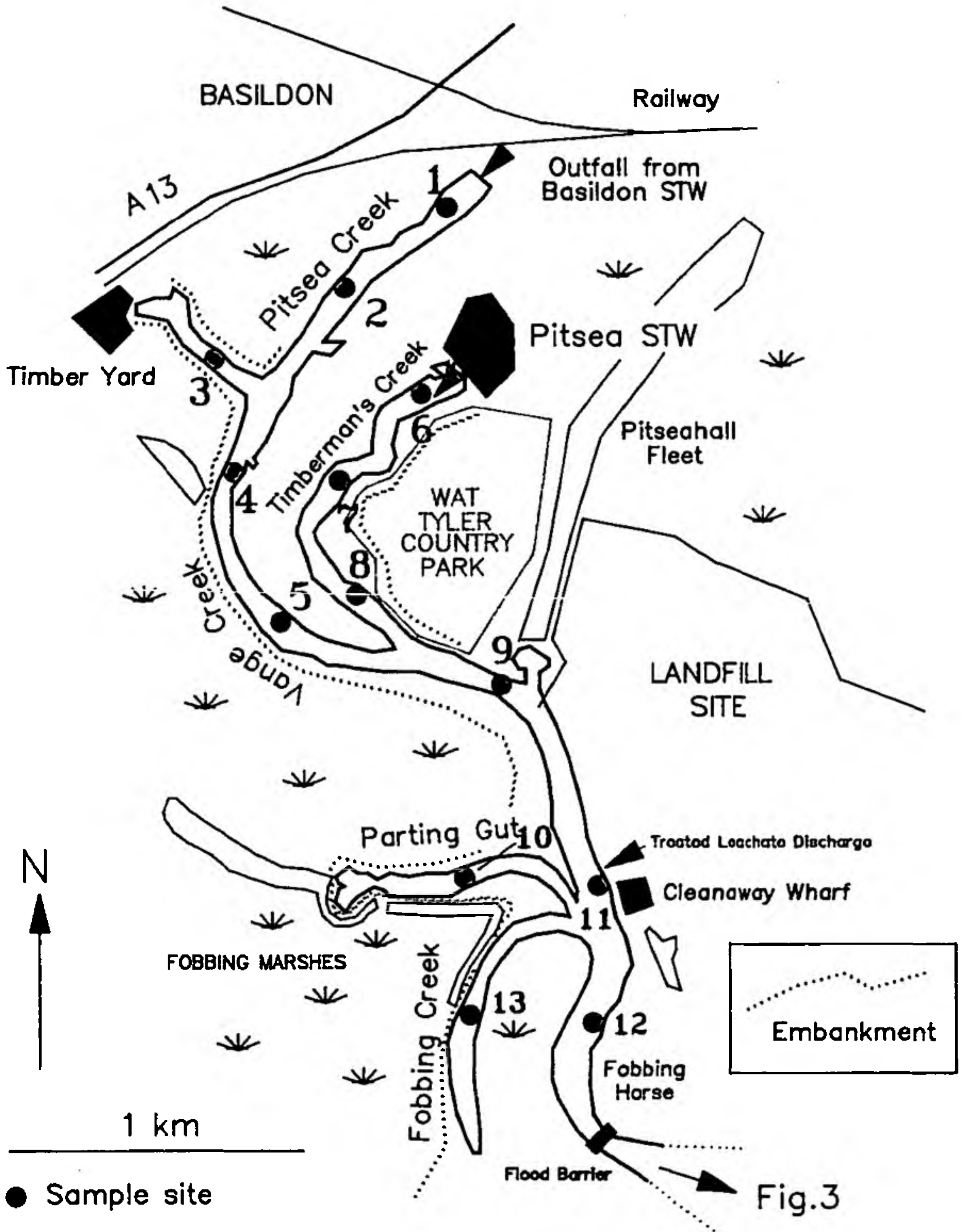


Fig.2: Pitsea/Vange Creek system.

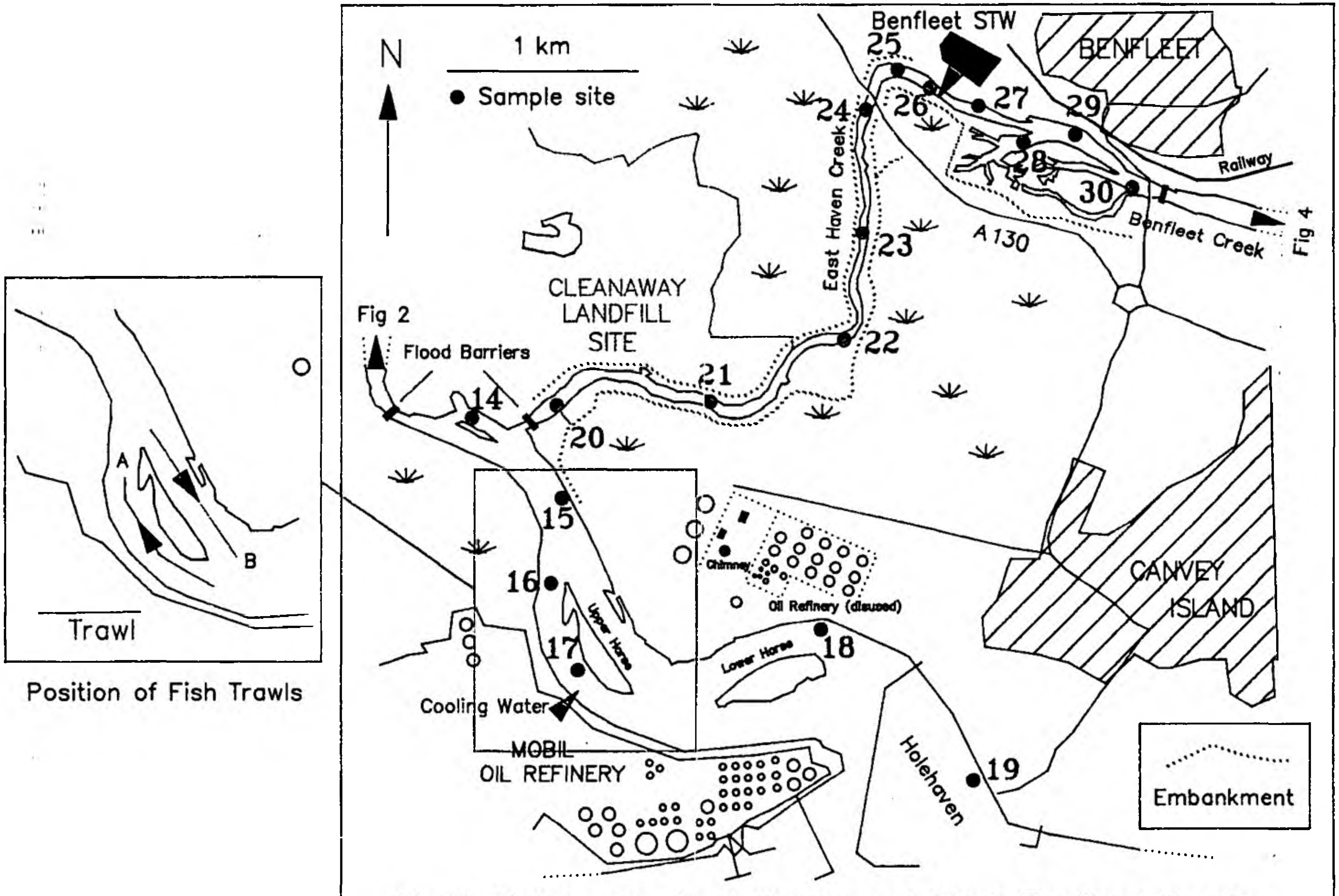


Fig.3: Holehaven, East Haven and West Benfleet Creeks.

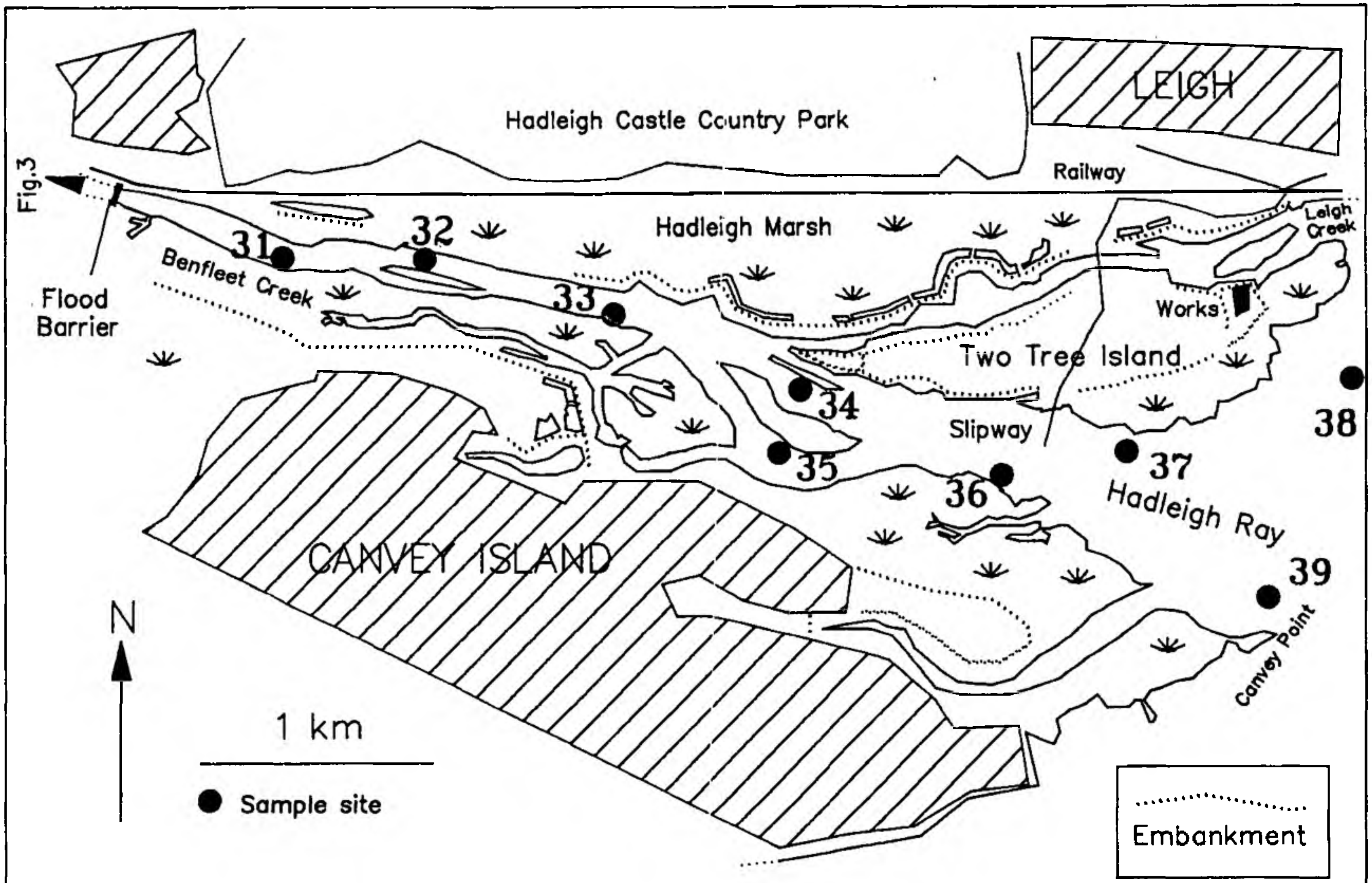


Fig.4: East Benfleet and Hadleigh Ray.

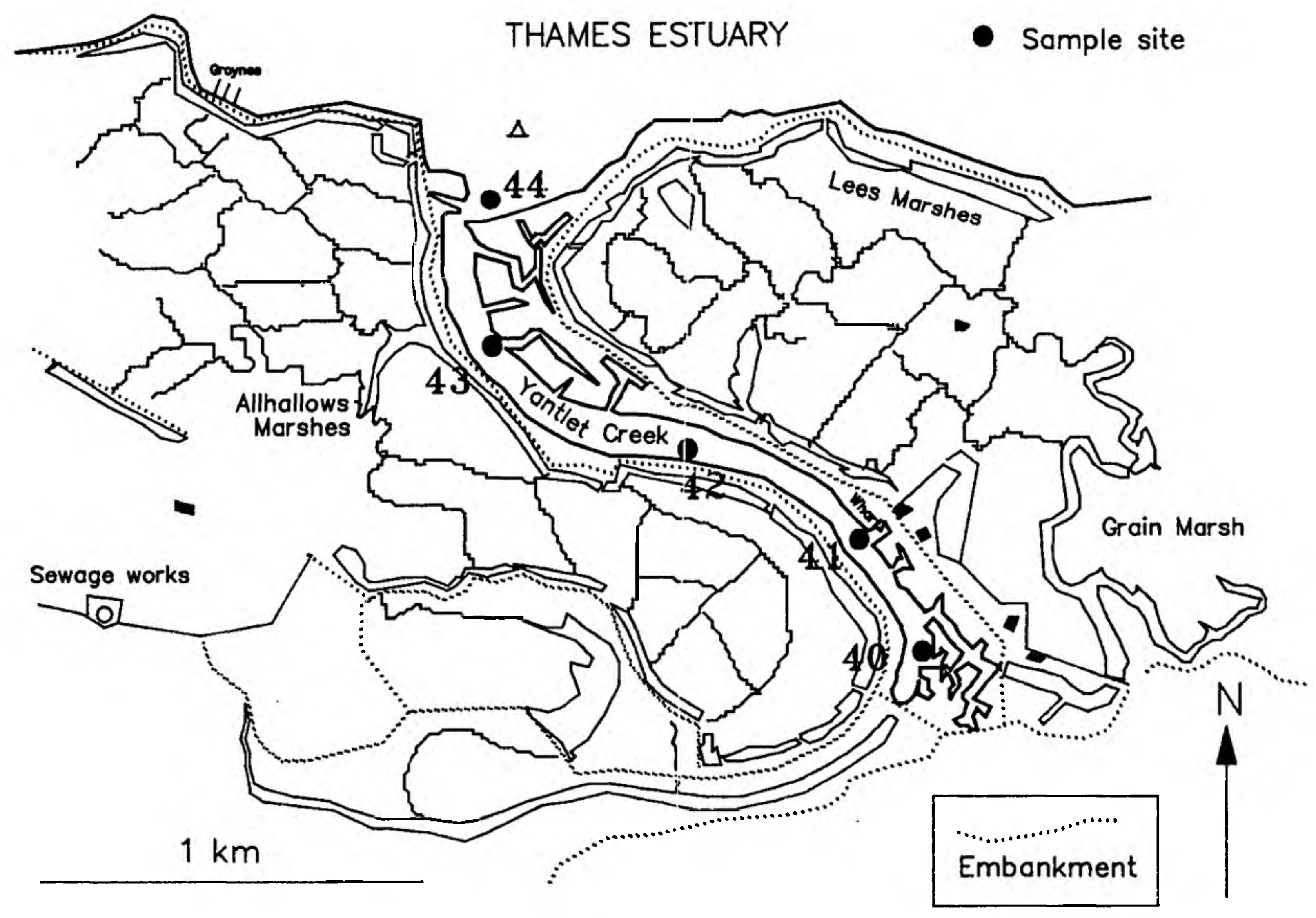
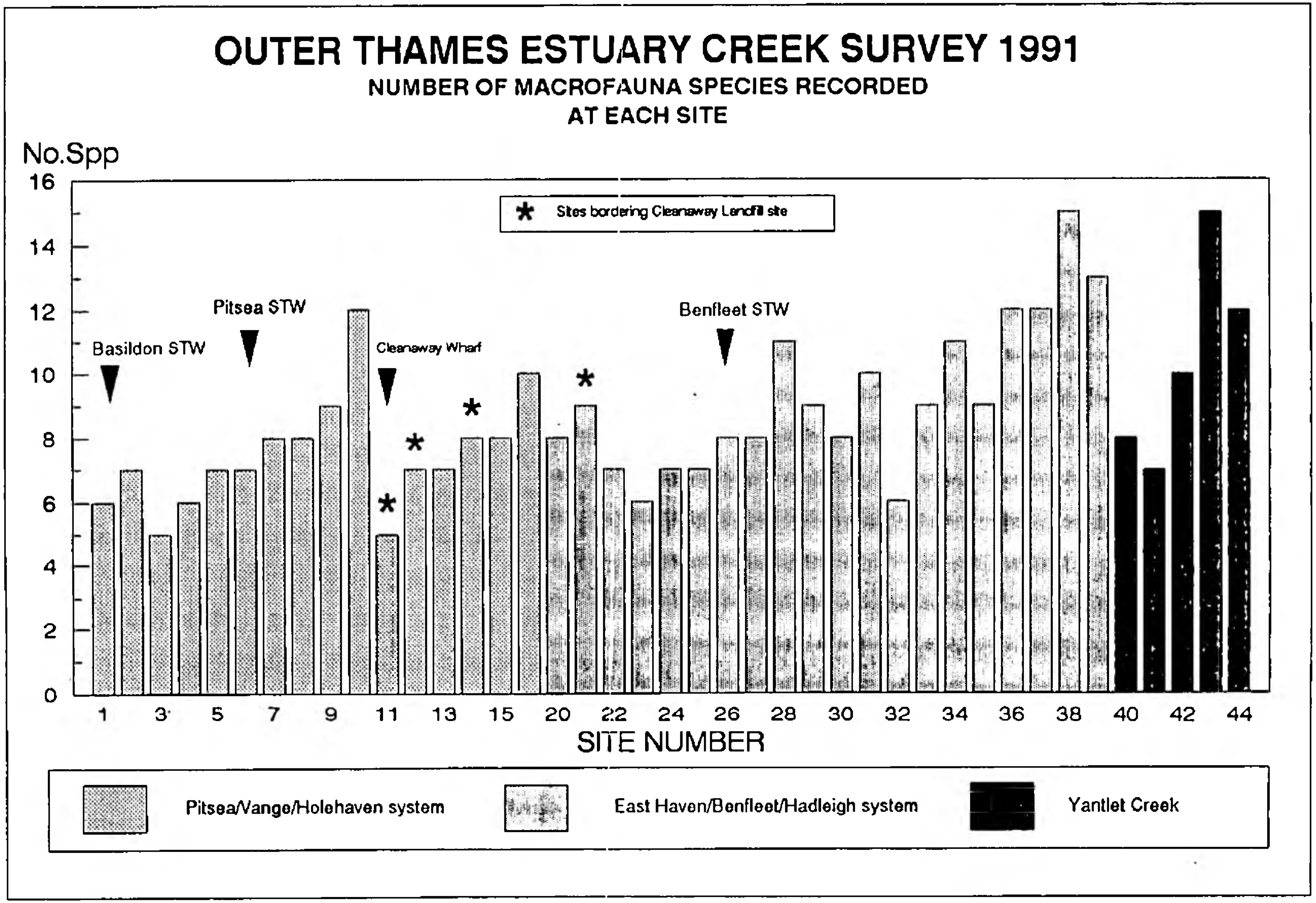


Fig.5: Yantlet Creek and Surrounding Marshes.

Fig.6



OUTER THAMES ESTUARY CREEK SURVEY 1991
NUMBER OF MACROFAUNA SPECIES RECORDED
AT EACH SITE
No.Spp
16
14
12
10
8
6
4
2
0
* Sites bordering Cleanaway Landfill site
Basildon STW
Pitsea STW
Cleanaway Wharf
Benfleet STW
1
3
5
7
9
11
13
15
20
22
24
26
28
30
32
34
36
38
40
42
44
SITE NUMBER
Pitsea/Vange/Holehaven system
East Haven/Benfleet/Hadleigh system
Yantlet Creek

Fig.7.

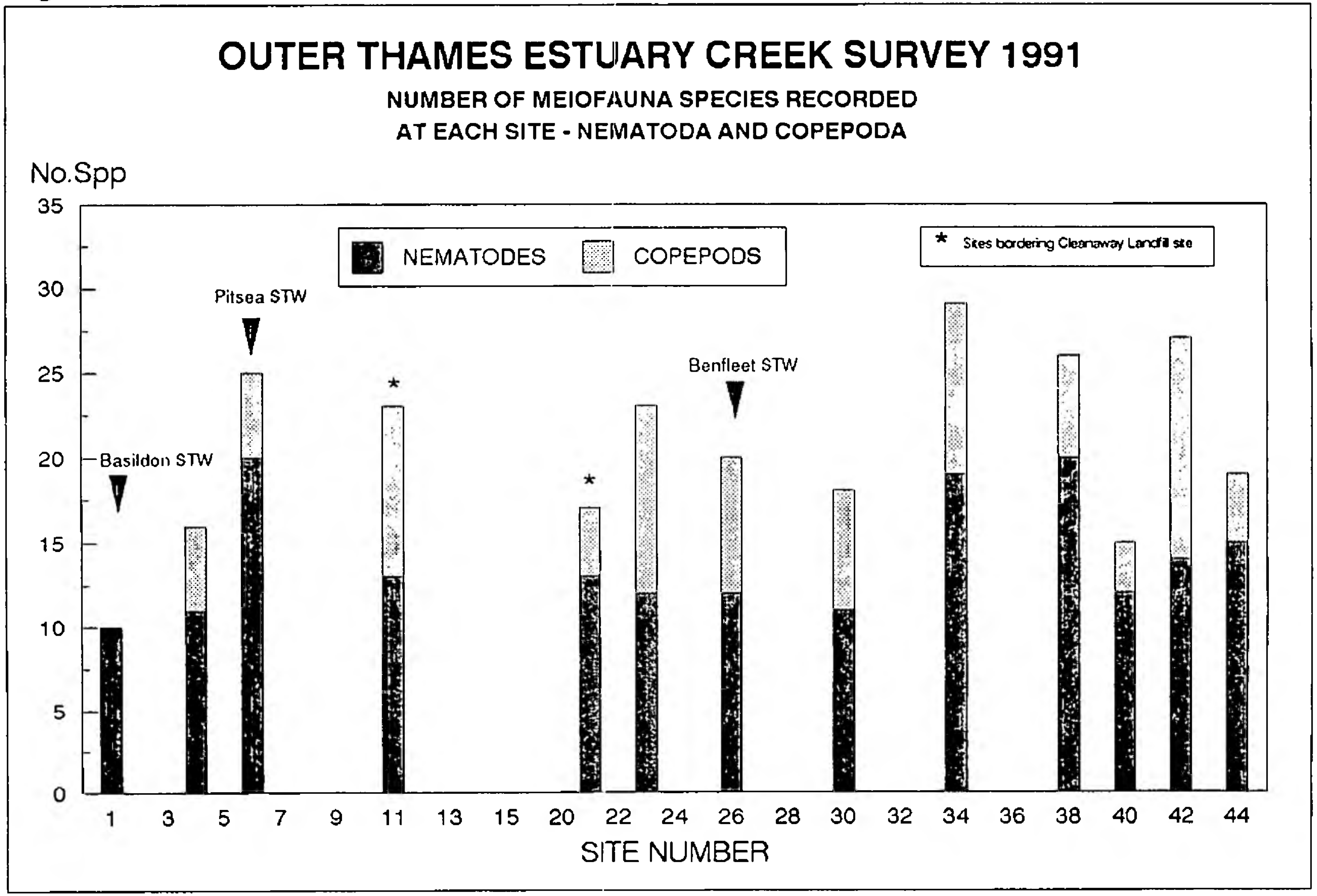

OUTER THAMES ESTUARY CREEK SURVEY 1991
NUMBER OF MEIOFAUNA SPECIES RECORDED
AT EACH SITE - NEMATODA AND COPEPODA
No.Spp
NEMATODES
COPEPODS
* Sites bordering Cleanaway Landfill site
Basildon STW
Pitsea STW
Benfleet STW
35
30
25
20
15
10
5
0
1
3
5
7
9
11
13
15
20
22
24
26
28
30
32
34
36
38
40
42
44
SITE NUMBER

Fig.8

OUTER THAMES ESTUARY CREEK SURVEY 1991

CONCENTRATION OF FAECAL COLIFORMS IN WATER SAMPLES TAKEN AT EACH SITE

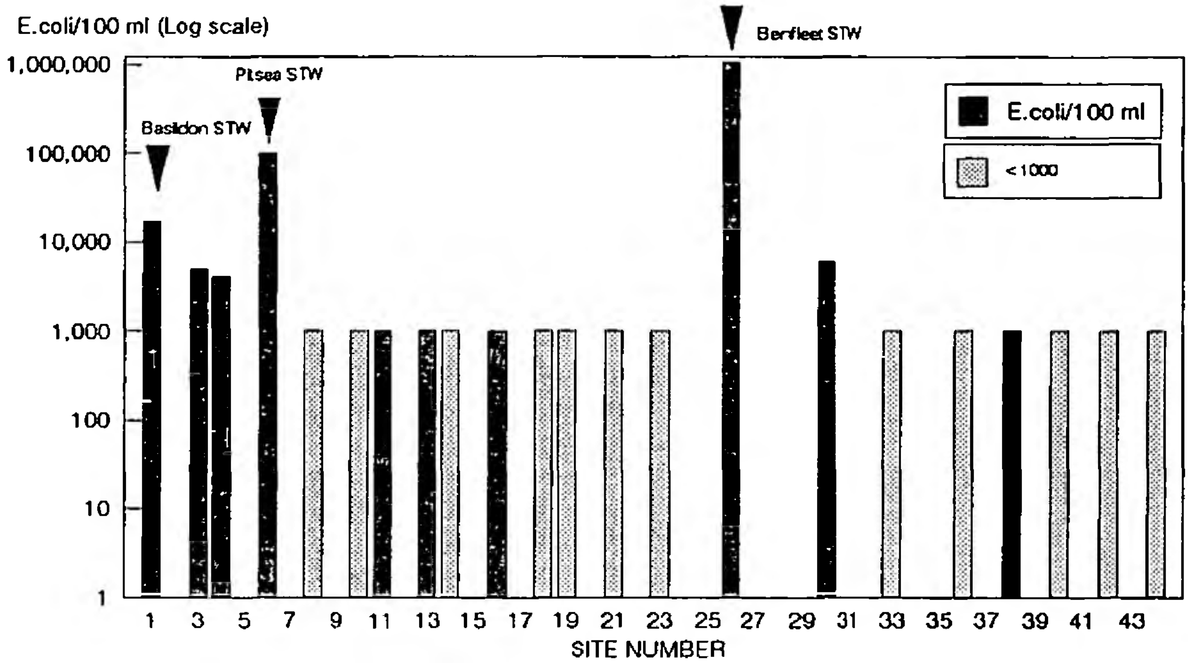


Fig.9

OUTER THAMES ESTUARY CREEK SURVEY 1991

MEASURED SALINITY (g/l) AT EACH SITE

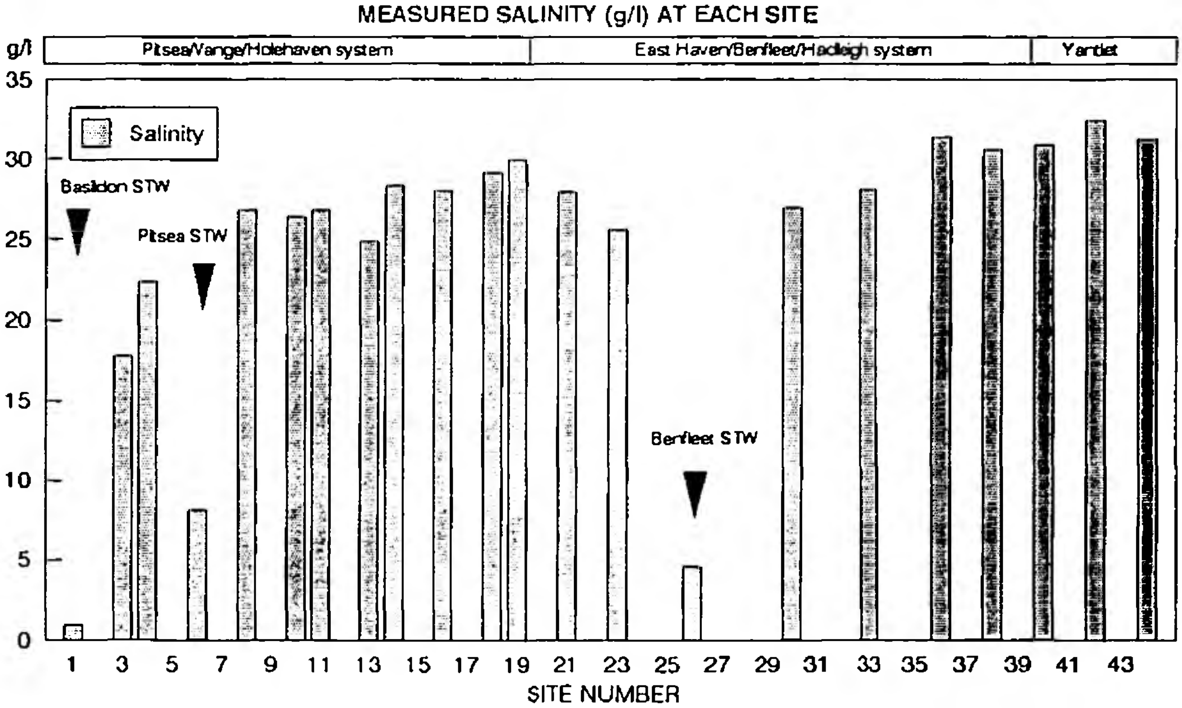
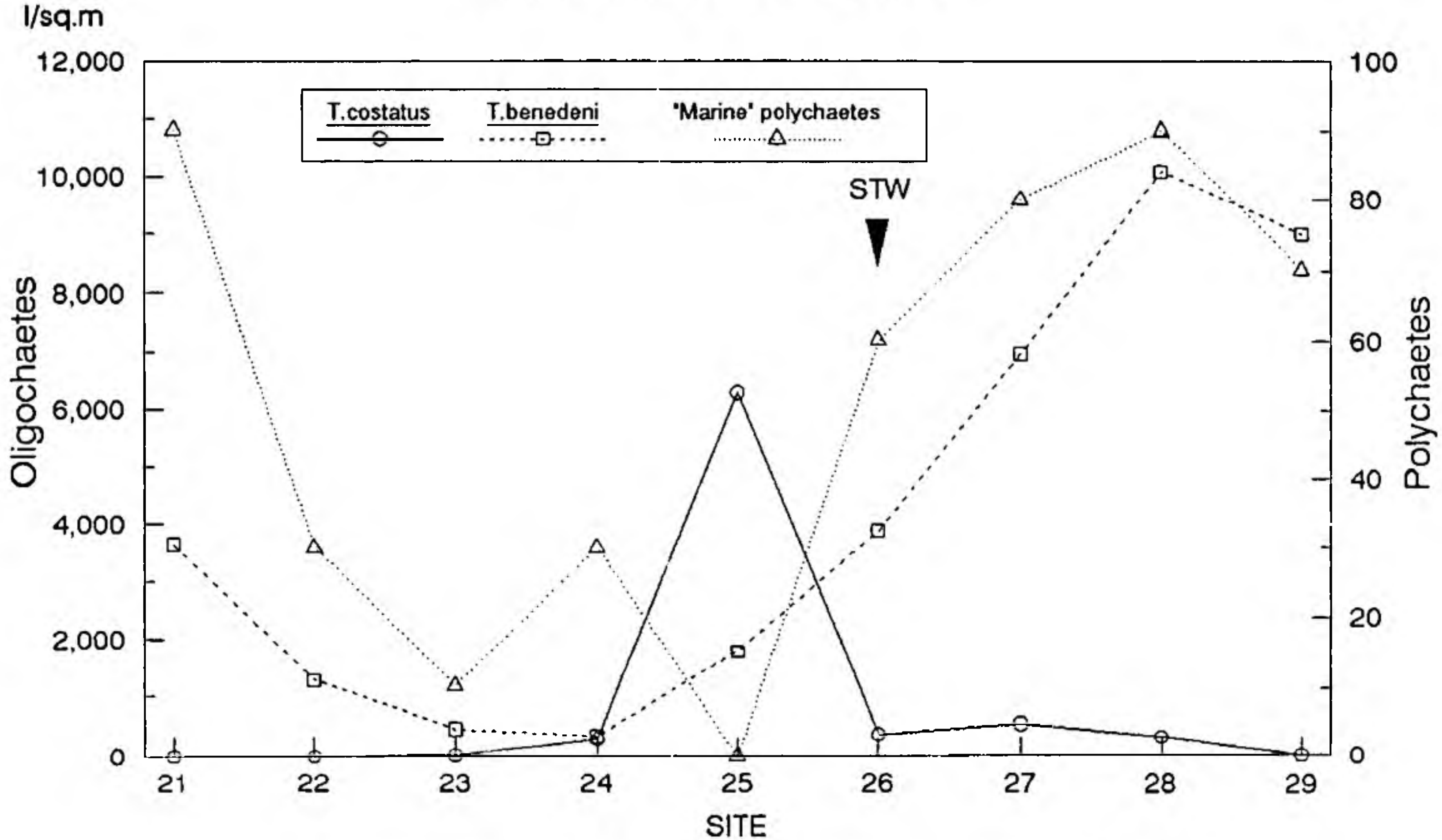


Fig.10 **OUTER ESTUARY CREEK SURVEY, 1991.**

SITES SURROUNDING BENFLEET STW

DISTRIBUTION OF KEY SPECIES



"Marine" polychaetes = Eteone longa, Pygospio elegans, Caulleriella sp.

Fig.11.

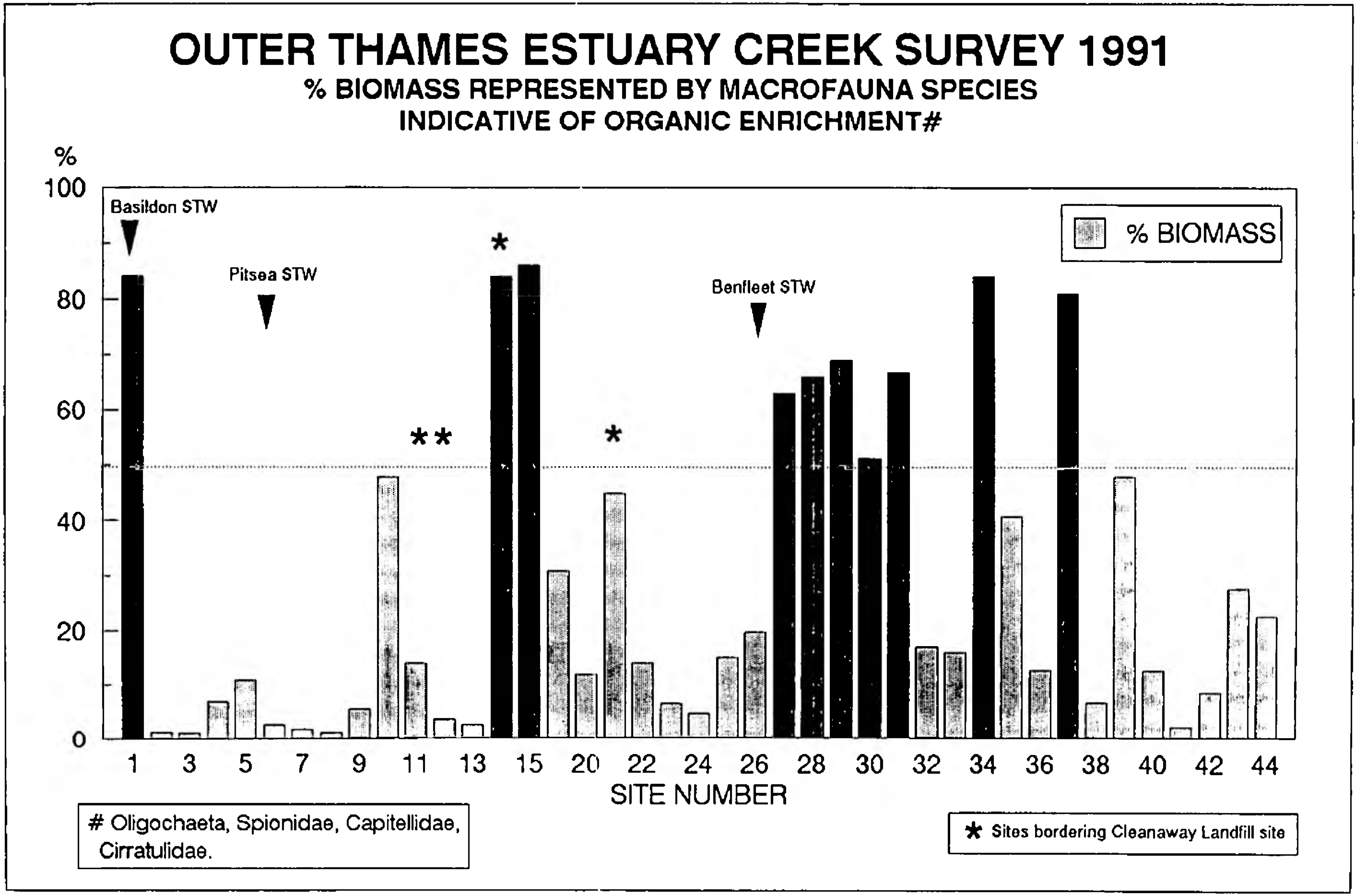
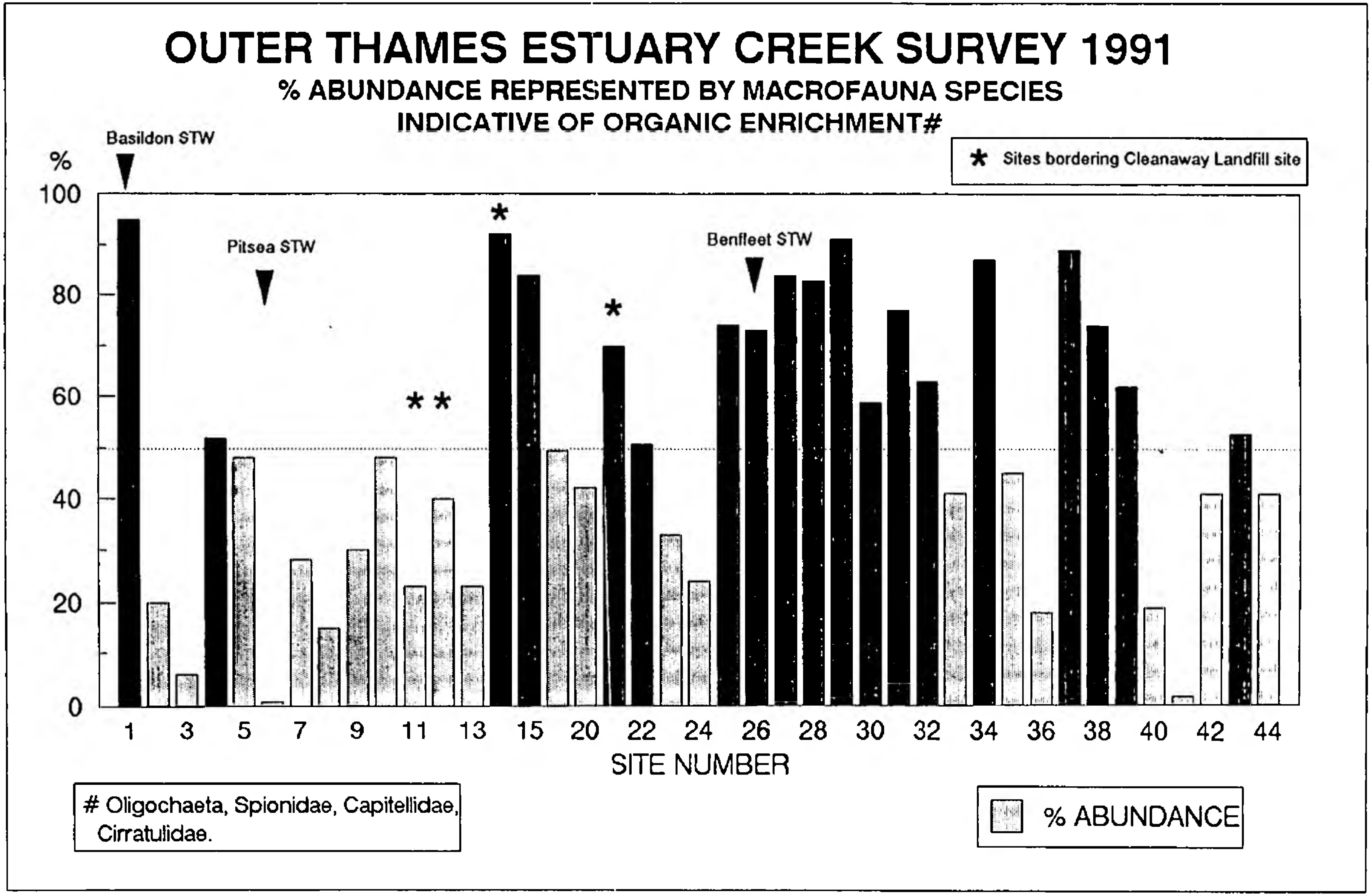

OUTER THAMES ESTUARY CREEK SURVEY 1991
% BIOMASS REPRESENTED BY MACROFAUNA SPECIES
INDICATIVE OF ORGANIC ENRICHMENT#
%
100
80
60
40
20
0
Basildon STW
Pitsea STW
Benfleet STW
% BIOMASS
1
3
5
7
9
11
13
15
20
22
24
26
28
30
32
34
36
38
40
42
44
SITE NUMBER
Oligochaeta, Spionidae, Capitellidae, Cirratulidae.
* Sites bordering Cleanaway Landfill site

Fig.12.



OUTER THAMES ESTUARY CREEK SURVEY 1991
% ABUNDANCE REPRESENTED BY MACROFAUNA SPECIES
INDICATIVE OF ORGANIC ENRICHMENT#
Basildon STW
Pitsea STW
Benfleet STW
* Sites bordering Cleanaway Landfill site
%
100
80
60
40
20
0
1
3
5
7
9
11
13
15
20
22
24
26
28
30
32
34
36
38
40
42
44
SITE NUMBER
Oligochaeta, Spionidae, Capitellidae, Cirratulidae.
% ABUNDANCE

Fig.13.

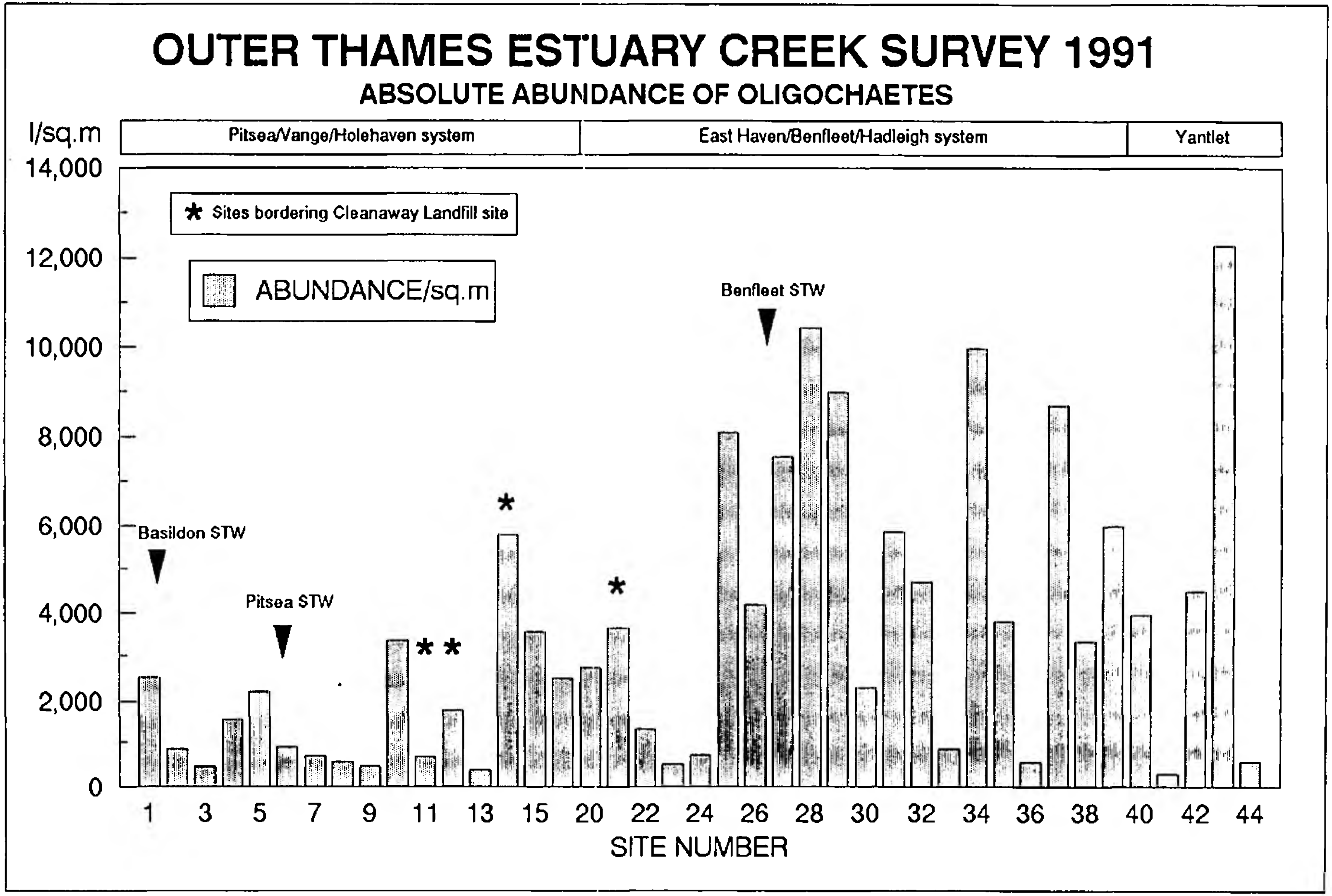

OUTER THAMES ESTUARY CREEK SURVEY 1991
ABSOLUTE ABUNDANCE OF OLIGOCHAETES
l/sq.m
Pitsea/Vange/Holehaven system
East Haven/Benfleet/Hadleigh system
Yantlet
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
* Sites bordering Cleanaway Landfill site
ABUNDANCE/sq.m
Benfleet STW
Basildon STW
Pitsea STW
1
3
5
7
9
11
13
15
20
22
24
26
28
30
32
34
36
38
40
42
44
SITE NUMBER

Fig.14: Hypothetical ABC plots (after Warwick, 1986)

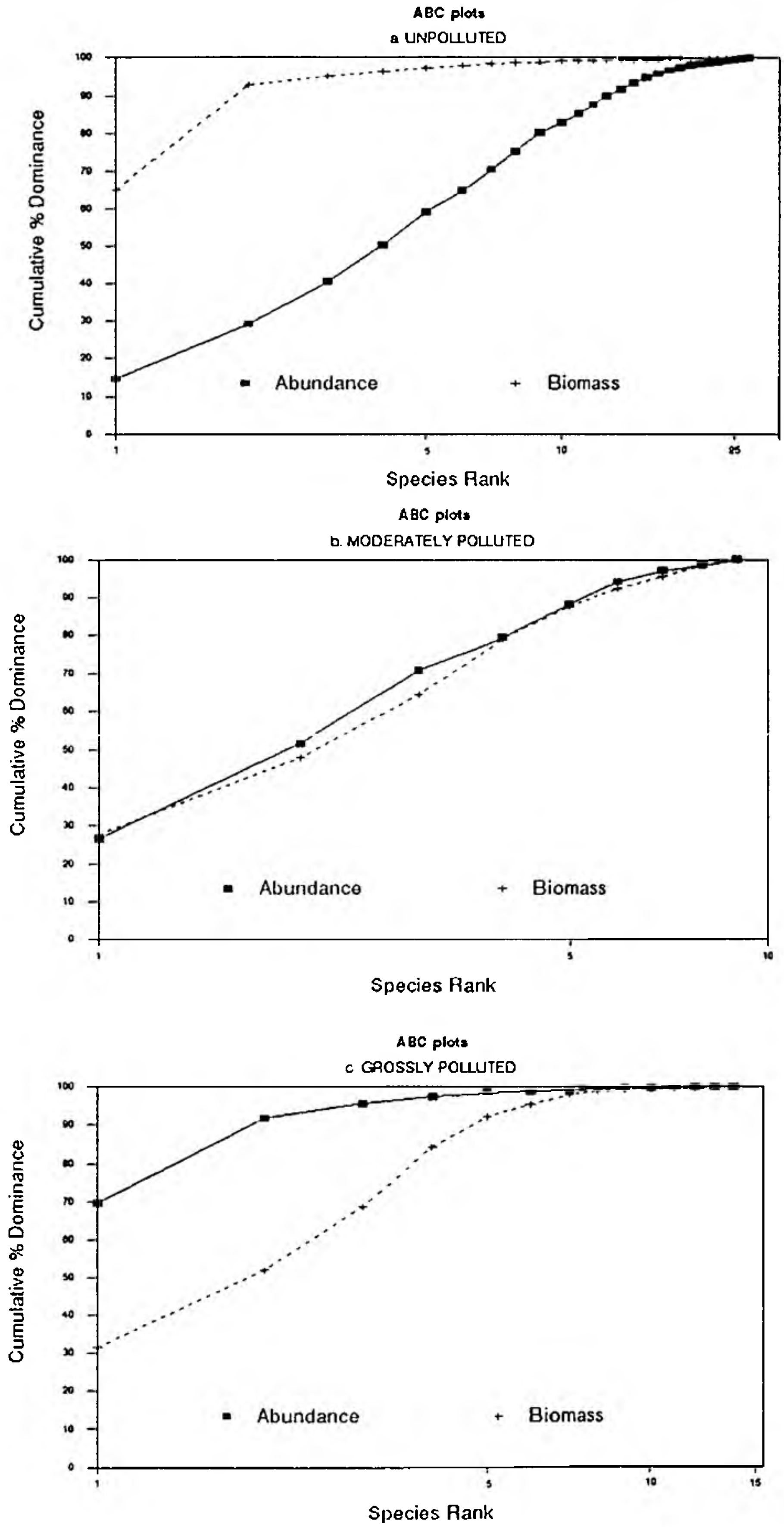
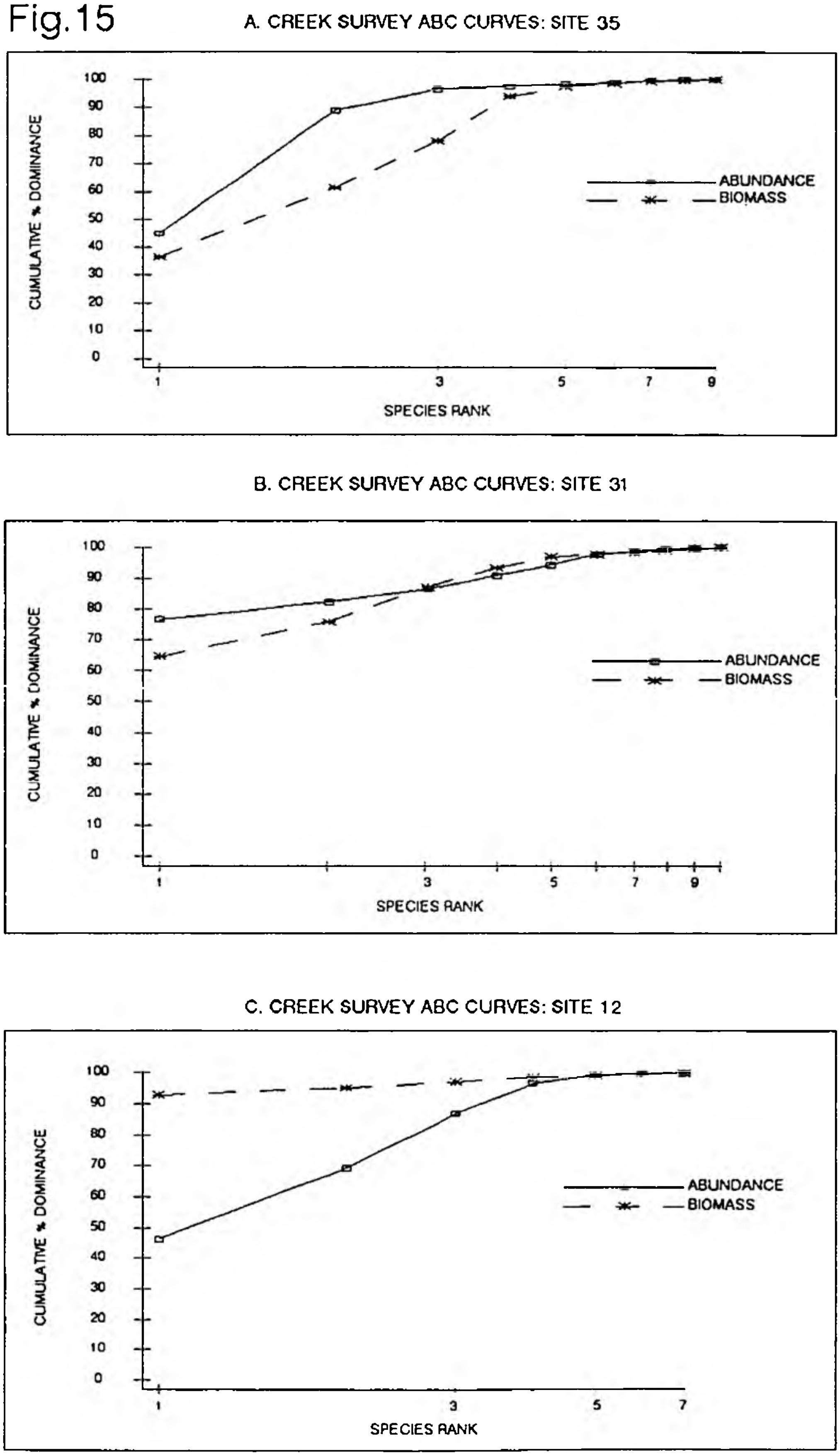


Fig. 15



A. CREEK SURVEY ABC CURVES: SITE 35
CUMULATIVE % DOMINANCE
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
SPECIES RANK
ABUNDANCE
BIOMASS
B. CREEK SURVEY ABC CURVES: SITE 31
CUMULATIVE % DOMINANCE
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
SPECIES RANK
ABUNDANCE
BIOMASS
C. CREEK SURVEY ABC CURVES: SITE 12
CUMULATIVE % DOMINANCE
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
SPECIES RANK
ABUNDANCE
BIOMASS

Fig.16

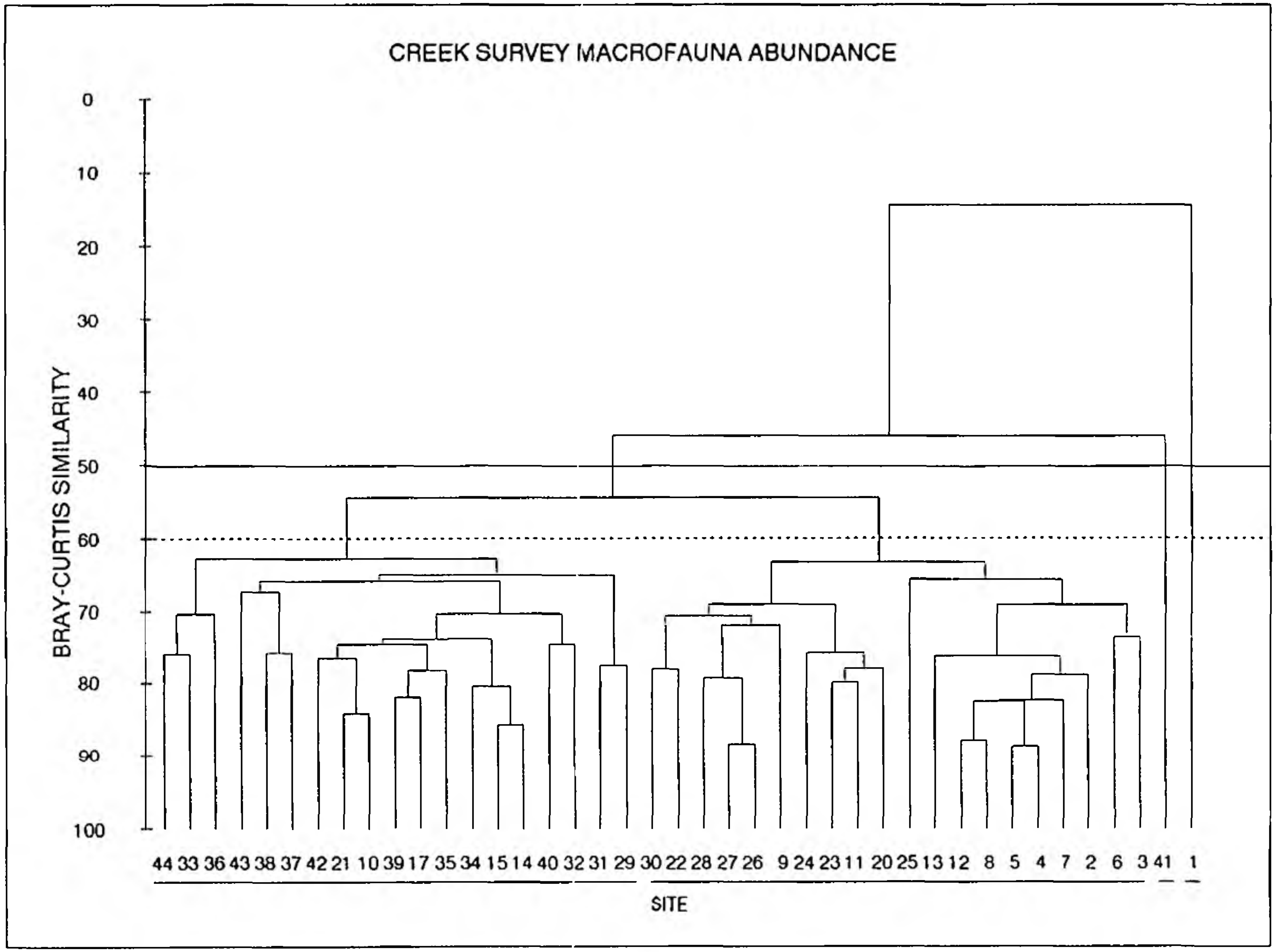
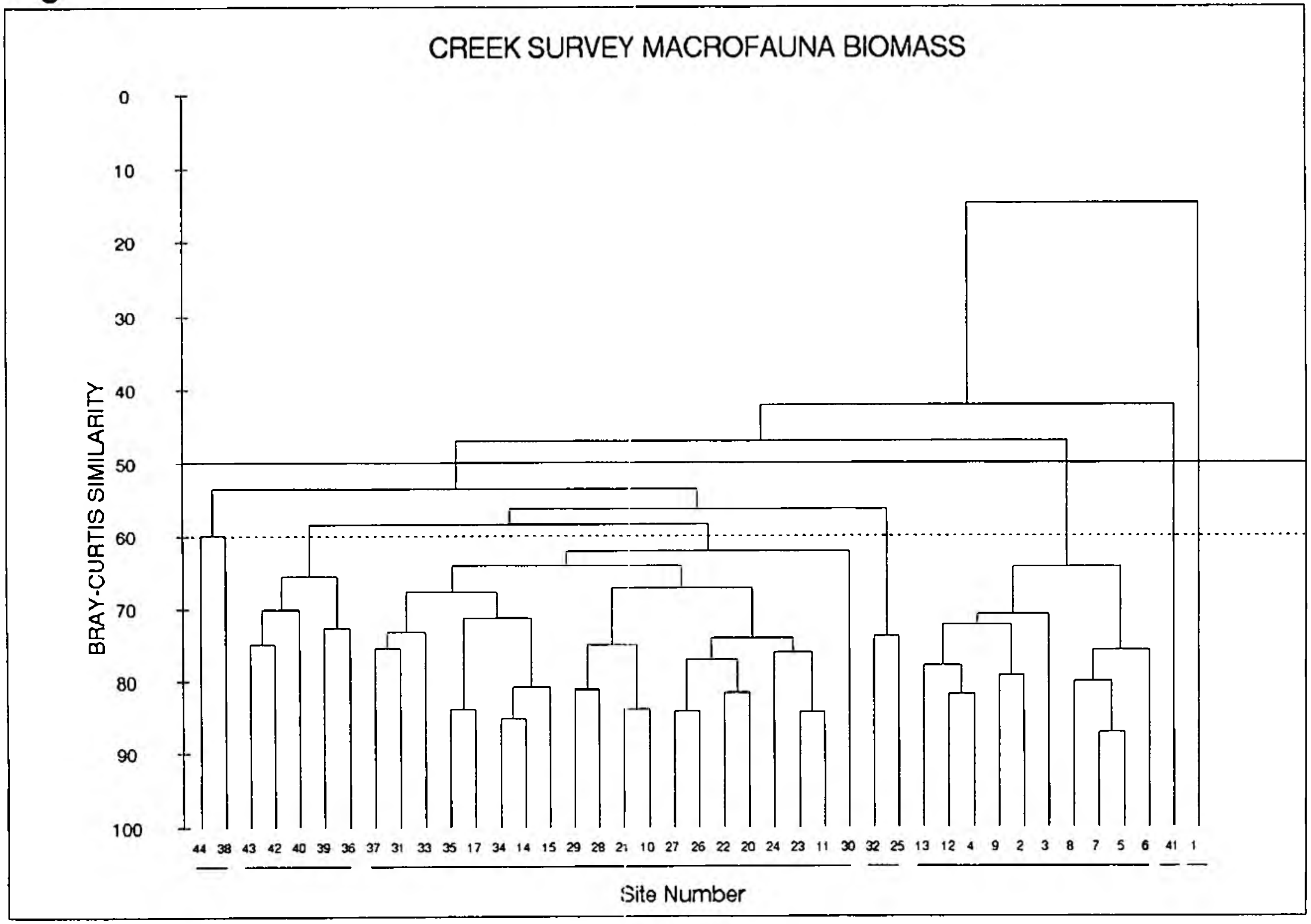

CREEK SURVEY MACROFAUNA ABUNDANCE
BRAY-CURTIS SIMILARITY
0
10
20
30
40
50
60
70
80
90
100
44 33 36 43 38 37 42 21 10 39 17 35 34 15 14 40 32 31 29 30 22 28 27 26 9 24 23 11 20 25 13 12 8 5 4 7 2 6 3 41 1
SITE

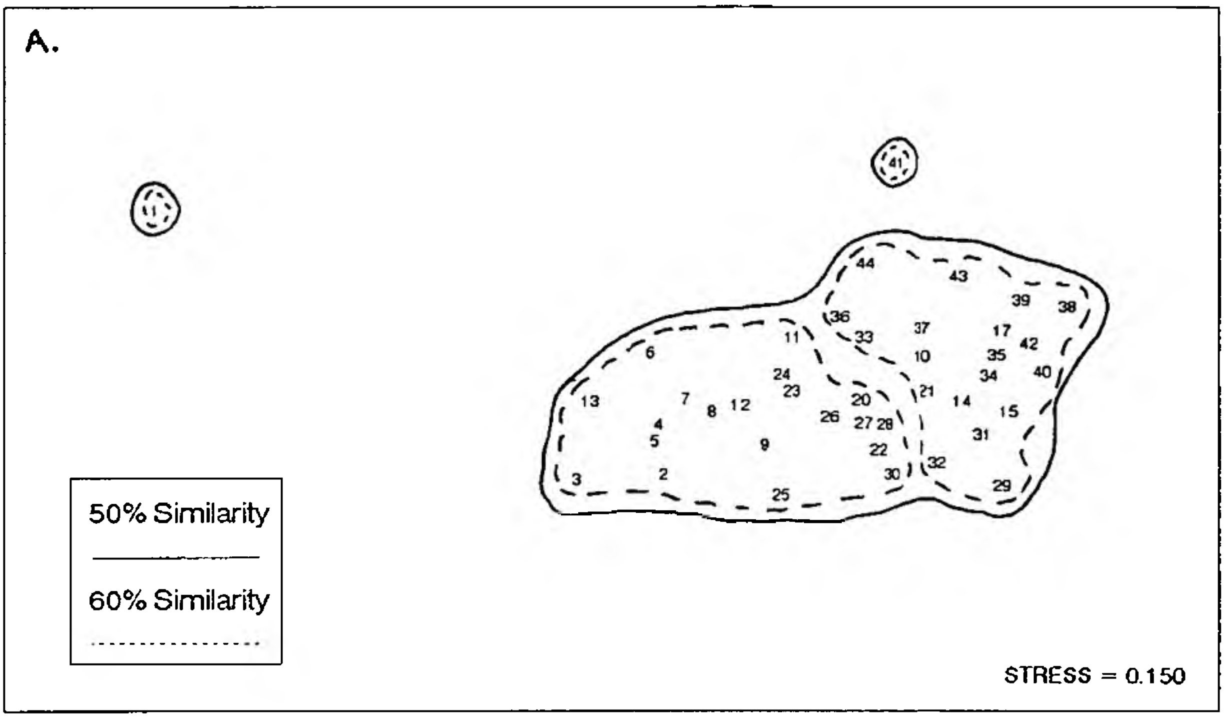
Fig.17



CREEK SURVEY MACROFAUNA BIOMASS
BRAY-CURTIS SIMILARITY
0
10
20
30
40
50
60
70
80
90
100
44 38 43 42 40 39 36 37 31 33 35 17 34 14 15 29 28 21 10 27 26 22 20 24 23 11 30 32 25 13 12 4 9 2 3 8 7 5 6 41 1
Site Number

Fig. 18.

CREEK SURVEY MACROFAUNA ABUNDANCE



CREEK SURVEY MACROFAUNA BIOMASS

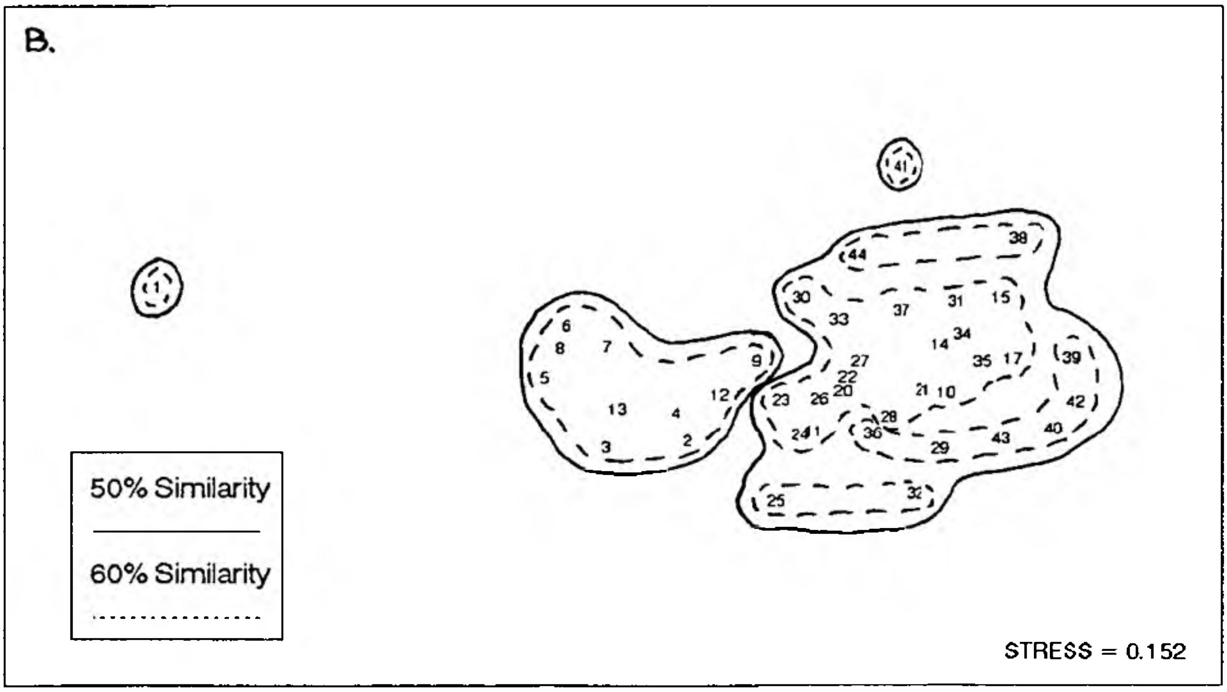
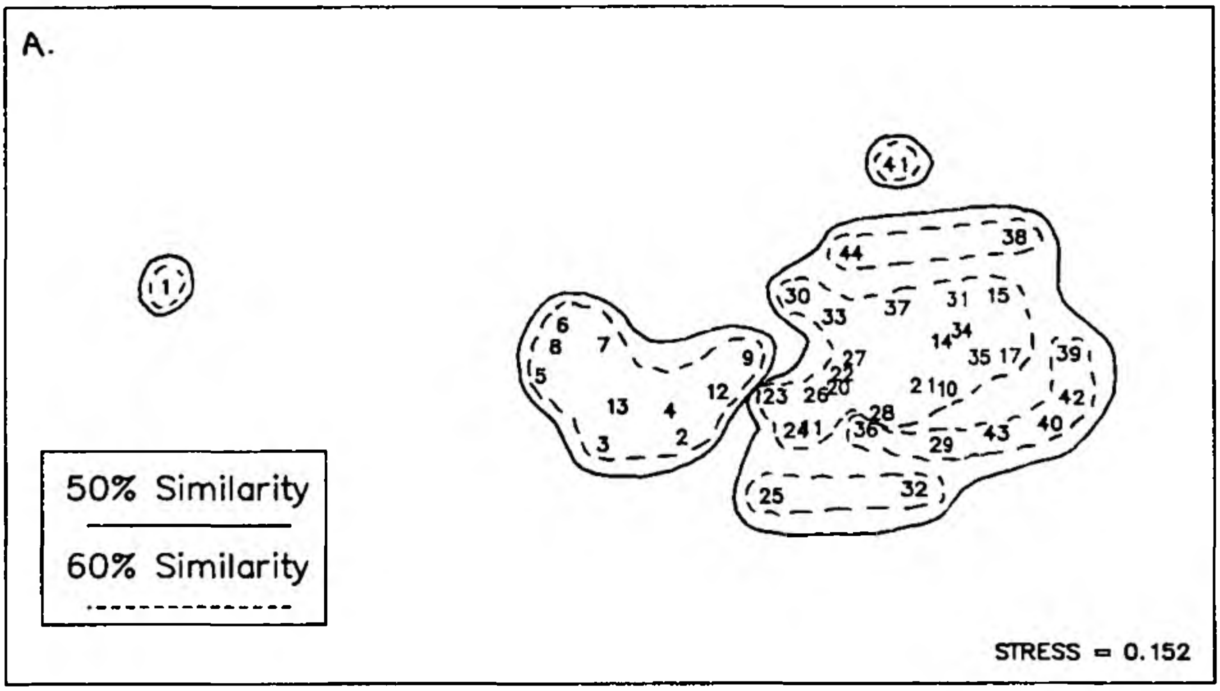


Fig. 19.

CREEK SURVEY MACROFAUNA BIOMASS – SITES ABOVE FOBBING HORSE IN BLACK



CREEK SURVEY MACROFAUNA BIOMASS – EAST HAVEN AND UPPER BENFLEET SITES IN BLACK

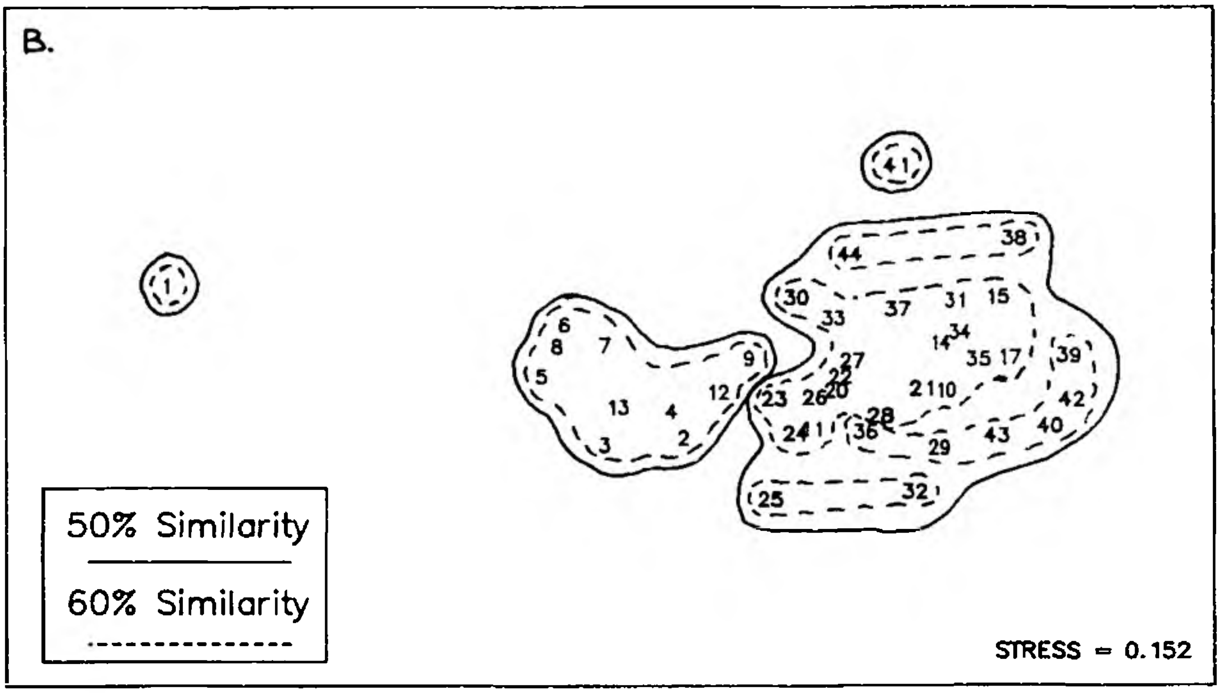
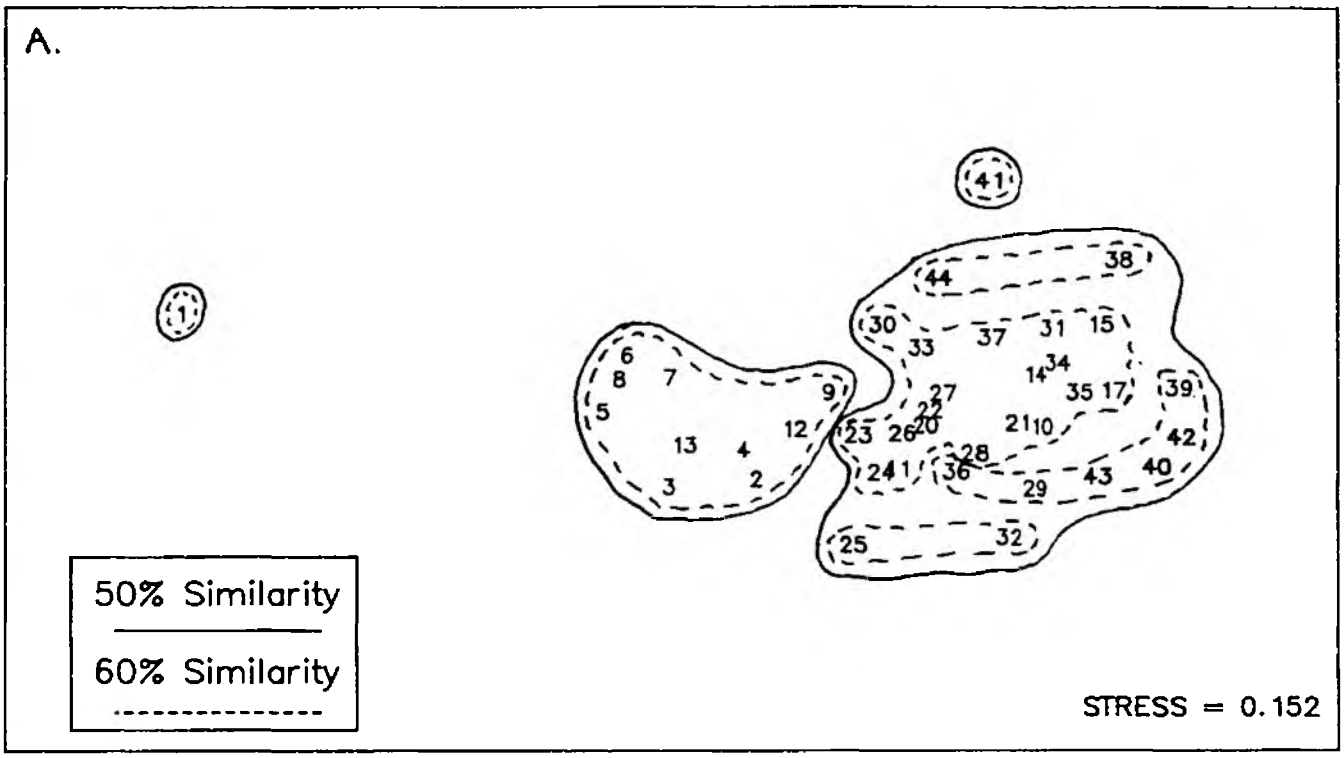
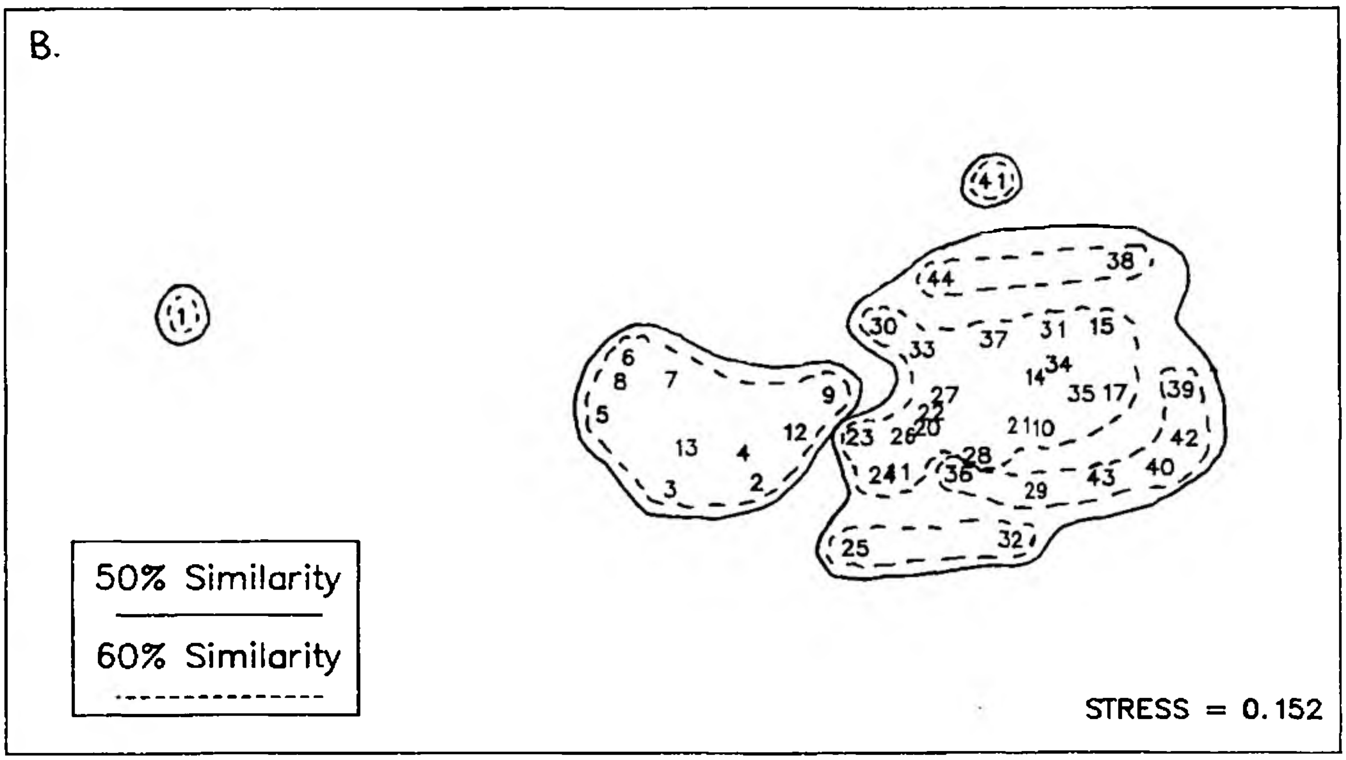


Fig. 20.

CREEK SURVEY MACROFAUNA BIOMASS – YANTLET CREEK SITES IN BLACK



CREEK SURVEY MACROFAUNA BIOMASS – TRANSECT FROM PITSEA–HOLEHAVEN IN BLACK



Appendix 1.

Details of discharge consents and results of chemical survey of discharges (Maile, 1990).

Appendix 1.
Consent conditions for creek discharges.

All from Maile (1990).

a. Cleanaway Pitsea Landfill tip - treated leachate discharge.

BOD = 40 mg/l, Ammoniacal N = 20 mg/l, Ni = 0.5 mg/l, Hg = 20µg/l,
Cu = 200 µg/l, Zn = 1000 µg/l, Cr = 150 µg/l, Pb = 150 µg/l, Cd = 20 µg/l,
Total HCH = 20 mg/l.
Flow = 1095 m^3/day.

b. Sewage Treatment Works.

STW	FLOW (m^3/day)	BOD (mg/l)	Amm.Nitro. (mg/l)	Sus.Solid (mg/l)
Pitsea	6060	40	20	--
Benfleet	6138	40	20	--
Basildon (current)	18000	40	20	--
Basildon (new)	28400	30	10	45

New consents are for new activated sludge plant currently being commissioned.

Inputs from discharges.
Results of survey by Maile (1990).

All results are for survey result mean.

Site.	pH	Temp °C	DO %	BOD	S.S.	Amm.N	TON	Cl.
				------ all mg/l ------				
Basildon STW	7.5	17.3	71.8	36.2	33.3	40.9	2.0	231
Pitsea STW	7.0	17.2	72.0	13.3	25.5	1.9	17.5	163
Benfleet STW	7.1	17.2	69.3	19.3	29.5	5.6	24.4	155
Pitsea Tip Leachate	7.7	23.5	93.5	47.3	67.5	4.8	183.0	1677

Appendix 2.

Nematode Feeding Types and the 1B:2A ratio.
(From Trett & Feil, 1990)

Nematode Feeding Types and the 1B:2A Ratio

Depending on the structure of the buccal capsule, nematodes can be classified into one of four different groups (see Figure 2). These groups appear to relate to their mode of feeding. Type 1 species lack cuticularised teeth whereas type 2 species have between 1 and 3 primary teeth that can be exceptionally large. Type 1 species are sub-divided into 1A species which have small or narrow buccal cavities and 1B species have large unarmed buccal cavities. The type 1A species are believed to be microbivorous or selective deposit feeders and, in the present survey, include species such as the oxystominids and the leptolaimids. Type 1B species are non-selective detritivores and, although they may ingest whole diatoms, they usually ingest 'plugs' of organically rich sediment. Examples found in the Thames Estuary include most of the xyalid nematodes and *Richtersia inaequalis*.

Type 2 species are also sub-divided on the basis of the size of their buccal cavities. 2A species have small cavities armed with teeth. These may be modified to split open frustules of sediment-dwelling diatoms or to rasp epigrowth from the surface of sand grains. Type 2A reach their highest densities in coarse grained sediments and include most of the Chromadoridae, Desmodoridae and Cyatholaimidae. Type 2B species have large armed buccal cavities, occasionally with moveable jaws and include predatory as well as omnivorous species. Oncholaimid species such as *Adoncholaimus thalassophygas* and enoplids such as *Enoplus brevis* belong to this group. These are often large nematode species with life-cycles of up to a year.

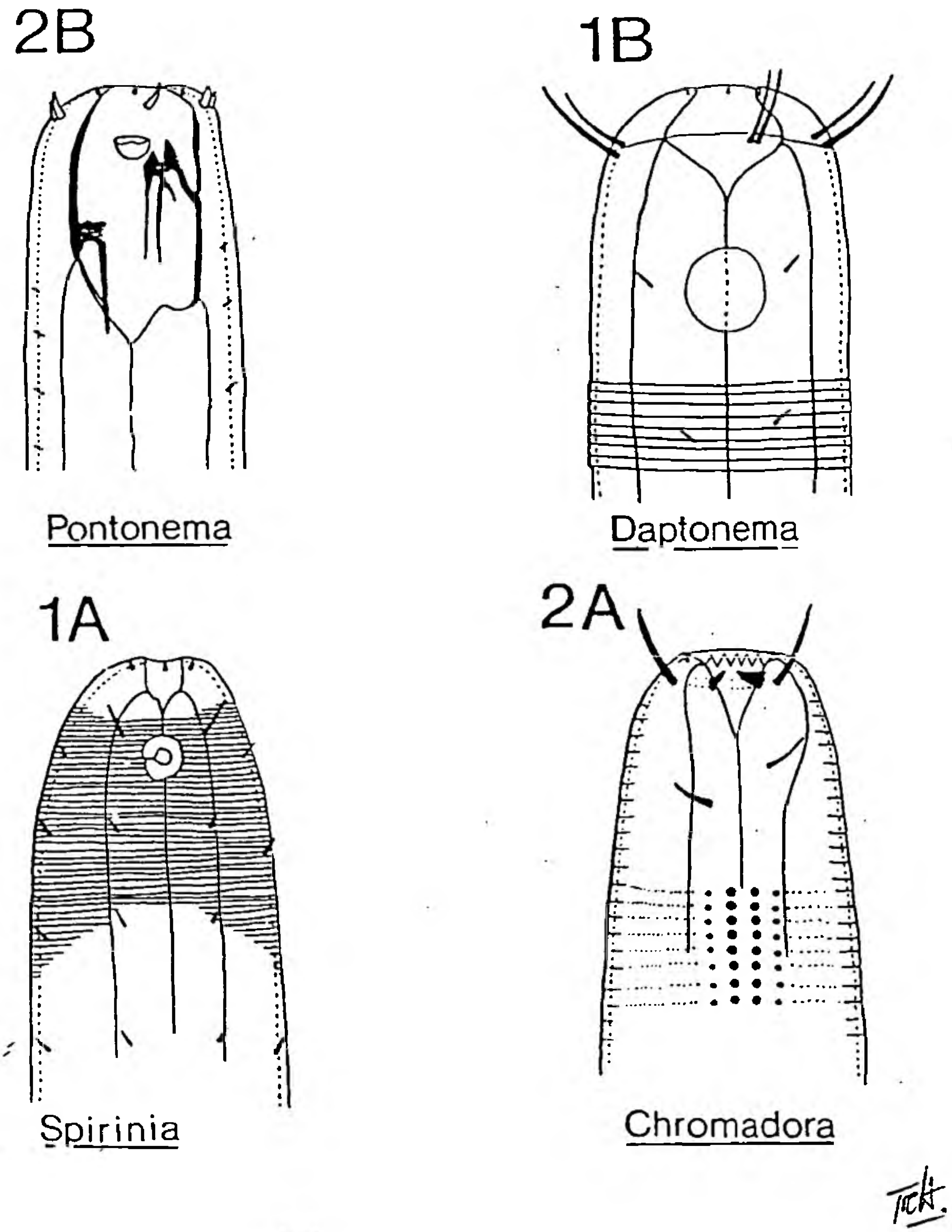


Figure 2. The four principal nematode feeding types.

Consequently, their populations are slow to re-establish following a catastrophic disturbance.

The ratio between 1B and 2A feeding types (1B:2A ratio) is a fundamental index used to describe the trophic composition of nematode populations. This has been used to detect changes in the composition of nematode assemblages with shifts to or from non-selective detritivore-dominated populations or selective epigrowth/diatomivorous populations.

Appendix 3.

Macroinvertebrate results for each survey site.

Table i. Benthic Macrofauna Species Recorded at Each Creek Site.

Abundance = No.Individuals/m²
Biomass = g.WetWeight/m²
Data expressed as Abundance/Biomass in Table.

Pitsea and Upper Vange Creeks.

Species	Site Number			
	1	2	3	4
Nemertea				
Nemertea sp.				
Oligochaeta				
Enchytraeidae sp.	2060/3.70			
Limnodrilus ?hoffmeisteri	300/0.40			
Tubifex costatus	140/0.20	800/0.90	440/0.50	1510/1.30
Tubificoides benedeni		40/0.10	10/0.10	60/0.10
Polychaeta				
Ampharete acutifrons				
Anaitides mucosa				
Capitellidae sp.				
Caulleriella spp.				
Eteone longa				
Manayunkia aesturina				
Nephtys hombergi				
Nereis (Neanthes) diversicolor		3150/71.80	2180/29.30	1290/17.50
Polydora sp.				
Pygospio elegans		10/0.10		
Crustacea				
Carcinus maenas				
Corophium volutator	10/0.10	110/0.50	4400/13.90	
Cyanthura carinata				
Idotea chelipes				
Sphaeroma rugicauda	10/0.20			
Uniramia				
Diptera sp.				
Chironomidae sp.				
Tipulidae sp.	120/0.50			30/0.20
Mollusca				
Abra tenuis				
Cerastoderma edule				
Hydrobia ulvae		40/0.10	330/0.30	50/0.10
Macoma balthica		30/0.10		60/0.10
Opisthobranch sp.(Onchidoriidae?)				
Retusa obtusa				
Scrobicularia plana				
TOTALS	2640/5.10	4180/73.60	7360/44.40	3000/19.30

Community Statistics

	1	2	3	4
Total No.Species	6	7	5	6
Diversity (H'e)	0.77	0.74	0.98	0.98
Evenness (J)	0.43	0.38	0.61	0.56

Table ii. Benthic Macrofauna Species Recorded at Each Creek Site.

Abundance = No.Individuals/m^2
Biomass = g.WetWeight/m^2
Data expressed as Abundance/Biomass in Table

Upper Vange and Timberman's Creeks.

Species	Site Number			
	5	6	7	8
Nemertea				
Nemertea sp.				
Oligochaeta				
Enchytraeidae sp.				
Limnodrilus ?hoffmeisteri				
Tubifex costatus	2200/5.50	270/0.40	560/0.70	350/0.50
Tubificoides benedeni	20/0.10	610/1.40	130/0.20	200/0.80
Polychaeta				
Ampharete acutifrons				
Anaitides mucosa				
Capitellidae sp.				
Caulleriella spp.				
Eteone longa			10/0.10	
Manayunkia aesturina				
Nephtys hombergi				
Nereis (Neanthes) diversicolor	2180/46.10	126/28.90	1420/46.70	2460/102.40
Polydora sp.				10/0.10
Pygospio elegans				
Crustacea				
Carcinus maenas				
Corophium volutator	20/0.20	5350/36.00	100/0.30	10/0.10
Cyanthura carinata				
Idotea chelipes				
Sphaeroma rugicauda				
Uniramia				
Diptera sp.				
Chironomidae sp.				
Tipulidae sp.	10/0.10	170/1.50	120/0.40	10/0.20
Mollusca				
Abra tenuis				
Cerastoderma edule				
Hydrobia ulvae	50/0.10	90/0.10	110/0.20	240/0.40
Macoma balthica	170/0.40	30/0.30	50/0.10	480/3.30
Opisthobranch sp.(Onchidoriidae?)				
Retusa obtusa				
Scrobicularia plana				
TOTALS	4650/52.50	7780/68.60	2500/48.70	3760/107.80

Community Statistics

	5	6	7	8
Total No.Species	7	7	8	8
Diversity (H'e)	0.92	0.99	1.32	1.11
Evenness (J)	0.47	0.51	0.63	0.53

Table iii. Benthic Macrofauna Species Recorded at Each Creek Site.

Abundance = No.Individuals/m²
Biomass = g.WetWeight/m²
Data expressed as Abundance/Biomass in Table.

Vange Creek and Parting Gut.

Species	Site Number			
	9	10	11	12
Nemertea				
Nemertea sp.				
Oligochaeta				
Enchytraeidae sp.				
Limnodrilus ?hoffmeisteri				
Tubifex costatus	160/0.20	50/0.10	10/0.10	780/0.70
Tubificoides benedeni	300/1.00	3300/11.10	650/2.10	1020/1.10
Polychaeta				
Ampharete acutifrons				
Anaitides mucosa				
Capitellidae sp.				
Caulleriella spp.		10/0.10		
Eteone longa	30/0.10	40/0.20		
Manayunkia aesturina				
Nephtys hombergi		20/0.40		
Nereis (Neanthes) diversicolor	960/20.40	250/5.40	160/9.70	2060/43.70
Polydora sp.				
Pygospio elegans	10/0.10	30/0.10		
Crustacea				
Carcinus maenas				
Corophium volutator	10/0.10			10/0.10
Cyanthura carinata				
Idotea chelipes				
Sphaeroma rugicauda				
Uniramia				
Diptera sp.		10/0.50		
Chironomidae sp.				
Tipulidae sp.		10/0.10		20/0.30
Mollusca				
Abra tenuis	20/0.10			
Cerastoderma edule				
Hydrobia ulvae	60/0.10	2570/3.10	1860/2.60	440/0.90
Macoma balthica	20/0.10	670/1.90	190/1.40	120/0.30
Opisthobranch sp.(Onchidoriidae?)				
Retusa obtusa				
Scrobicularia plana		20/0.80		
TOTALS	1570/22.20	6980/23.80	2870/15.90	4450/47.10

Community Statistics

Total No.Species	9	12	5	7
Diversity (H'e)	1.20	1.22	0.98	1.34
Evenness (J)	0.55	0.49	0.61	0.53

Table v. Benthic Macrofauna Species Recorded at Each Creek Site.

Abundance = No.Individuals/m^2
Biomass = g.WetWeight/m^2
Data expressed as Abundance/Biomass in Table.

East Haven Creek.

Species	Site Number			
	20	21	22	23
Nemertea				
Nemertea sp.				
Oligochaeta				
Enchytraeidae sp.				
Limnodrilus ?hoffmeisteri				
Tubifex costatus	30/0.10			20/0.10
Tubificoides benedeni	2700/8.90	3650/8.30	1300/5.50	480/1.20
Polychaeta				
Ampharete acutifrons				
Anaitides mucosa				
Capitellidae sp.				
Caulleriella spp.	20/0.10	30/0.10	20/0.10	10/0.10
Eteone longa		40/0.40	10/0.20	
Manayunkia aesturina				
Nephtys hombergi				
Nereis (Neanthes) diversicolor	2380/61.90	530/7.30	910/31.60	590/16.60
Polydora sp.				
Pygospio elegans	10/0.10	20/0.10		
Crustacea				
Carcinus maenas				
Corophium volutator				
Cyanthura carinata				
Idotea chelipes				
Sphaeroma rugicauda				
Uniramia				
Diptera sp.				
Chironomidae sp.				
Tipulidae sp.	10/0.10	10/0.10	10/0.10	
Mollusca				
Abra tenuis				
Cerastoderma edule				
Hydrobia ulvae	1040/1.60	610/0.30	20/0.10	330/0.30
Macoma balthica	330/1.30	330/1.20	330/1.20	80/0.30
Opisthobranch sp.(Onchidoriidae?)				
Retusa obtusa				
Scrobicularia plana		50/0.80		
TOTALS	6520/74.10	5270/18.60	2600/38.80	1510/18.60

Community Statistics

Total No.Species	8	9	7	6
Diversity (H'e)	1.23	1.05	1.10	1.30
Evenness (J)	0.59	0.48	0.57	0.73

Table vi. Benthic Macrofauna Species Recorded at Each Creek Site.

Abundance = No.Individuals/m²
Biomass = g.WetWeight/m²
Data expressed as Abundance/Biomass in Table.

East Haven/Upper Benfleet around Benfleet STW.

Species	Site Number			
	24	25	26	27
Nemertea				
Nemertea sp.				
Oligochaeta				
Enchytraeidae sp.				
Limnodrilus ?hoffmeisteri				
Tubifex costatus	320/0.60	6300/10.80	400/0.80	590/0.60
Tubificoides benedeni	380/1.30	1800/2.50	3900/16.80	6970/15.80
Polychaeta				
Ampharete acutifrons				
Anaitides mucosa				
Capitellidae sp.				
Caulleriella spp.			20/0.10	20/0.10
Eteone longa	30/0.50		40/0.70	60/0.50
Manayunkia aesturina		20/0.10		
Nephtys hombergi				
Nereis (Neanthes) diversicolor	700/29.90	2200/69.50	610/66.70	820/7.90
Polydora sp.				
Pygospio elegans				
Crustacea				
Carcinus maenas	20/0.50			
Corophium volutator			10/0.10	
Cyanthura carinata				
Idotea chelipes				
Sphaeroma rugicauda				
Uniramia				
Diptera sp.				
Chironomidae sp.				
Tipulidae sp.				
Mollusca				
Abra tenuis				20/0.10
Cerastoderma edule				
Hydrobia ulvae	1210/2.10	260/0.20	490/1.10	340/0.30
Macoma balthica	250/2.20	230/0.60	440/1.70	200/0.80
Opisthobranch sp.(Onchidoriidae?)				
Retusa obtusa				
Scrobicularia plana		70/3.30		
TOTALS	2910/37.10	10880/87.00	5910/88.00	9020/26.10

Community Statistics

Total No.Species	7	7	8	8
Diversity (H'e)	1.49	1.14	1.13	0.83
Evenness (J)	0.77	0.59	0.54	0.40

Table vii. Benthic Macrofauna Species Recorded at Each Creek Site.

Abundance = No.Individuals/m^2
Biomass = g.WetWeight/m^2
Data expressed as Abundance/Biomass in Table.

Upper and Mid-Benfleet Creek.

Species	Site Number			
	28	29	30	31
Nemertea				
Nemertea sp.				
Oligochaeta				
Enchytraeidae sp.				
Limnodrilus ?hoffmeisteri				
Tubifex costatus	350/0.40			
Tubificoides benedeni	10100/29.50	9000/27.50	2330/5.00	5860/20.70
Polychaeta				
Ampharete acutifrons				
Anaitides mucosa				
Capitellidae sp.				
Caulleriella spp.	30/0.10	20/0.10	20/0.10	80/0.30
Eteone longa	40/0.20	40/0.20	20/0.10	330/3.60
Manayunkia aesturina	70/0.10			
Nephtys hombergi				
Nereis (Neanthes) diversicolor	710/10.90	370/9.90	830/3.20	260/1.10
Polydora sp.				
Pygospio elegans	20/0.10	10/0.10		20/0.10
Crustacea				
Carcinus maenas				
Corophium volutator	300/1.00	30/0.20	450/1.10	60/0.20
Cyanthura carinata		40/0.50		10/0.20
Idotea chelipes				
Sphaeroma rugicauda				
Uniramia				
Diptera sp.				
Chironomidae sp.				
Tipulidae sp.				
Mollusca				
Abra tenuis			60/0.20	430/2.00
Cerastoderma edule				
Hydrobia ulvae	560/0.70		50/0.10	260/0.20
Macoma balthica	350/1.10	370/1.10	170/0.30	330/3.60
Opisthobranch sp.(Onchidoriidae?)				
Retusa obtusa				
Scrobicularia plana	80/1.40	10/0.30		
TOTALS	12610/45.50	9890/39.90	3930/10.10	7680/30.90

Community Statistics

	28	29	30	31
Total No.Species	11	9	8	10
Diversity (H'e)	0.86	0.42	1.19	0.98
Evenness (J)	0.36	0.19	0.57	0.43

Table viii. Benthic Macrofauna Species Recorded at Each Creek Site.

Abundance = No.Individuals/m²
Biomass = g.WetWeight/m²
Data expressed as Abundance/Biomass in Table.

Lower Benfleet Creek & Upper Hadleigh Ray.

Species	Site Number			
	32	33	34	35
Nemertea				
Nemertea sp.				
Oligochaeta				
Enchytraeidae sp.				
Limnodrilus ?hoffmeisteri				
Tubifex costatus				
Tubificoides benedeni	4700/20.70	830/1.50	10000/20.70	3800/9.50
Polychaeta				
Ampharete acutifrons				
Anaitides mucosa				
Capitellidae sp.			20/0.10	70/0.90
Caulleriella spp.			220/0.40	30/0.20
Eteone longa		160/0.70	20/0.10	60/0.30
Manayunkia aesturina				
Nephtys hombergi	20/0.20		30/0.30	
Nereis (Neanthes) diversicolor	1030/92.40	1070/7.90	230/1.90	90/4.10
Polydora sp.				
Pygospio elegans		970/0.90	20/0.10	50/0.10
Crustacea				
Carcinus maenas				
Corophium volutator		10/0.10		
Cyanthura carinata				
Idotea chelipes				
Sphaeroma rugicauda				
Uniramia				
Diptera sp.				
Chironomidae sp.				
Tipulidae sp.		20/0.10	10/0.10	
Mollusca				
Abra tenuis		180/2.60	20/0.10	10/0.10
Cerastoderma edule				
Hydrobia ulvae	310/0.40	630/0.60	230/0.20	3900/6.40
Macoma balthica	1350/6.90	540/1.10	730/0.90	660/4.30
Opisthobranch sp.(Onchidoriidae?)				
Retusa obtusa				
Scrobicularia plana	30/3.50			
TOTALS	7440/124.10	4410/15.50	11530/24.90	8670/25.90

Community Statistics

	32	33	34	35
Total No.Species	6	9	11	9
Diversity (H'e)	1.04	1.77	0.58	1.10
Evenness (J)	0.58	0.81	0.24	0.50

Table ix. Benthic Macrofauna Species Recorded at Each Creek Site.

Abundance = No.Individuals/m^2
Biomass = g.WetWeight/m^2
Data expressed as Abundance/Biomass in Table.

Hadleigh Ray.

Species	Site Number 36	37	38	39
Nemertea				
Nemertea sp.				
Oligochaeta				
Enchytraeidae sp.				
Limnodrilus ?hoffmeisteri				
Tubifex costatus	10/0.10	100/0.10	30/0.10	
Tubificoides benedeni	540/1.20	8600/19.70	3300/0.46	6000/9.50
Polychaeta				
Ampharete acutifrons				10/0.10
Anaitides mucosa			10/0.20	
Capitellidae sp.	10/0.10	80/0.40	20/0.10	30/0.10
Caulleriella spp.		750/2.10	2200/3.50	1130/2.30
Eteone longa	10/0.10	130/0.40	50/0.20	20/0.10
Manayunkia aesturina				
Nephtys hombergi			50/0.60	20/1.30
Nereis (Neanthes) diversicolor	320/4.80	130/0.70	20/0.10	70/0.30
Polydora sp.				
Pygospio elegans	20/0.10	380/0.40	490/0.30	30/0.10
Crustacea				
Carcinus maenas	10/0.30			20/0.50
Corophium volutator	10/0.10	20/0.10		
Cyanthura carinata			10/0.30	
Idotea chelipes			10/0.20	
Sphaeroma rugicauda				
Uniramia				
Diptera sp.				
Chironomidae sp.				
Tipulidae sp.	80/0.20	10/0.10		10/0.10
Mollusca				
Abra tenuis		80/0.50	40/0.50	
Cerastoderma edule			30/0.10	
Hydrobia ulvae	1810/1.90	610/0.60	1250/0.80	4100/3.60
Macoma balthica	370/0.50	270/0.50	660/1.40	100/0.40
Opisthobranch sp.(Onchidoriidae?)				
Retusa obtusa				
Scrobicularia plana	110/2.50			80/2.00
TOTALS	3300/11.90	11160/25.60	8170/13.20	11620/20.40

Community Statistics	36	37	38	39
Total No.Species	12	12	15	13
Diversity (H'e)	1.42	0.94	1.55	1.12
Evenness (J)	0.57	0.38	0.57	0.44

Table x. <u>Benthic Macrofauna Species Recorded at Each Creek Site.</u>

Abundance = No.Individuals/m^2
Biomass = g.WetWeight/m^2
Data expressed as Abundance/Biomass in Table.

Yantlet Creek.

<u>Species</u>	<u>Site Number</u>				
	40	41	42	43	44
Nemertea					
Nemertea sp.				30/1.30	
Oligochaeta					
Enchytraeidae sp.					
Limnodrilus ?hoffmeisteri					
Tubifex costatus				300/0.40	10/0.10
Tubificoides benedeni	3950/5.40	280/0.40	4500/8.40	12000/22.60	560/0.70
Polychaeta					
Ampharete acutifrons					
Anaitides mucosa					
Capitellidae sp.	20/0.10			110/0.20	
Caulleriella spp.	10/0.10	70/0.10		180/0.40	
Eteone longa			10/0.10	80/0.30	130/0.70
Manayunkia aesturina					
Nephtys hombergi	10/0.10	10/0.10	90/4.10	160/4.70	10/0.10
Nereis (Neanthes) diversicolor	160/2.30	30/0.30	20/1.20	180/5.90	90/0.50
Polydora sp.					
Pygospio elegans			10/0.10	30/0.10	350/0.20
Crustacea					
Carcinus maenas					10/0.20
Corophium volutator				20/0.10	
Cyanthura carinata					
Idotea chelipes					
Sphaeroma rugicauda					
Uniramia					
Diptera sp.					
Chironomidae sp.		10/0.10			
Tipulidae sp.		90/0.50	10/0.10	50/0.30	120/0.70
Mollusca					
Abra tenuis			120/1.20		90/0.30
Cerastoderma edule					
Hydrobia ulvae	16500/16.20	14400/15.00	5700/9.30	5170/10.80	850/0.50
Macoma balthica	300/2.70		390/16.00	550/8.70	40/0.30
Opisthobranch sp.(Onchidoriidae?)					10/0.10
Retusa obtusa				10/0.10	
Scrobicularia plana	90/15.30		160/57.10	4790/26.40	
TOTALS	21040/42.20	14890/16.50	11010/97.60	23660/82.30	2270/4.40
<u>Community Statistics</u>					
Total No.Species	8	7	10	15	12
Diversity (H'e)	0.65	0.19	1.01	1.32	1.70
Evenness (J)	0.33	0.10	0.44	0.49	0.68

Appendix 4.

Meiofauna results for each site surveyed.

Table xi

Pitsea Creek: Station 1

Nematoda

Adoncholaimus thalassophygas	23262
Leptolaimus papilliger	10985
Anoplostoma viviparum	1292
Diplogasterid sp.	20031
Microlaimus globiceps	3231
Dorylaimid sp.	646
Butlerius butleri	1292
Dichromadora geophila	2585
Chromadorita tentabunda	646
Species A	646
Indet.	2585
1B:2A	0.05
N	67201
S	10

Copepoda None observed

Table xii

Pitsea Creek: Station 4.

Nematoda

Ptycholaimellus ponticus	40994
Metachromadora remanei	21388
Axonolaimus paraspinosus	6238
Calyptronema maxweberi	3565
Praeacanthonchus sp.	2674
Leptolaimus papilliger	1782
Spilophorella paradoxa	8021
Halalaimus gracilis	1782
Dichromadora sp.	891
Antomicron elagans	891
Haliplectus dorsalis	891
Indet.	0
1B:2A	0.08
N	89117
S	11

Copepoda

Stenhelia palustris	125
Onychocamptus sp.	8
Stenhelia aemula	217
Microarthridion sp.	8
Harpacticella sp.	8
N	366
S	5

Table xiii

Pitsea Creek: Station 6.

Nematoda

Spilophorella candida	6390
Halalaimus gracilis	1345
Calyptronema maxweberi	1682
Ptycholaimellus ponticus	12444
Metoncholaimus remanei	4709
Leptolaimus papilliger	3027
Microlaimus globiceps	1009
Camacolaimus tardus	336
Anoplostoma viviparum	336
Dichromadora geophila	336
Adoncholaimus thalassophygas	336
Praeacanthonchus sp.	2018
Oxystomina elongata	336
Daptonema tenuispiculum	336
Sphaerolaimus gracilis	336
Oncholaimus campylocercoides	336
Antomicron elegans	1009
Diplogasterid sp.	336
Daptonema psammoides	336
Spilophorella paradoxa	336
Indet.	0
1B:2A	0.04
N	37329
S	20

Copepoda

Microarthridion sp.	42
Itunella sp.	50
Stenhelia aemula	42
Laophonte varians	25
Stenhelia palustris	17
Unidentified copepodite	17
N	193
S	5

Table xiv

Pitsea Creek: Station 11.

Nematoda

Leptolaimus papilliger	1464
Ptycholaimellus ponticus	6954
Terchellingia sp.	3294
Praeacanthonchus sp.	1098
Daptonema tenuispiculum	1830
Metachromadora remanei	6588
Sabatieria punctata	11346
Sphaerolaimus hirsutum	732
Desmolaimus zeelandicus	1098
Haliplectus dorsalis	366
Axonolaimus paraspinosus	1098
Leptolaimus limicolus	366
Halalaimus gracilis	366
Indet.	0
1B:2A	1.24
N	36600
S	13

Copepoda

Enhydrosoma propinquum	25
Microarthridion sp.	67
Bulbamphiascus sp.	8
Onychocamptus sp.	17
Harpacticella sp.	75
Stenhelia palustris	300
Tachiduis discipes	33
Enhydrosoma sarsi	42
Cletodes sp.	8
Stenhelia aemula	33
N	608
S	10

Table xv

Benfleet Creek: Station 21.

Nematoda

Pycholaimellus ponticus	38334
Metachromadora remanei	18759
Dichromadora geophila	816
Calyptronema maxweberi	5709
Desmolaimus zeelandicus	3263
Leptolaimus papilliger	1631
Daptonema tenuispiculum	816
Axonolaimus paraspinosus	5709
Microlaimus globiceps	4078
Halalaimus gracilis	1631
Odontophora setosa	816
Cervonema sp.	816
Linhomoeus sp.	816
Indet.	1631
1B:2A	0.17
N	84825
S	13

Copepoda

Enhydrosoma propinquum	17
Tisbe gracilis	25
Amphiascus angusticeps	8
Enhydrosoma sarsi	8
N	58
S	4

Table xvi

Benfleet Creek: Station 23.

Nematoda	
Sabatieria punctata	1354
Praeacanthonchus sp.	10833
Ptycholaimellus ponticus	19861
Leptolaimus papilliger	903
Desmolaimus zeelandicus	903
Halalaimus gracilis	2257
Axonolaimus paraspinosus	4062
Metachromadora remanei	6771
Dichromadora sp.	451
Sphaerolaimus gracilis	451
Microlaimus globiceps	451
Hypodontolaimus balticus	451
Indet.	451
1B:2A	0.17
N	49199
S	12
Copepoda	
Amphiascus sp.	8
Stenhelia palustris	233
Harpacticella sp.	33
Enhydrosoma propinquum	58
Amphiascella debilis	8
Paramphiascella intermedia	92
Tachidius discipes	33
Itunella sp.	33
Microarthridion sp.	25
Stenhelia aemula	75
Amphiascus angusticeps	8
N	606
S	11

Table xvii

Benfleet Creek: Station 26.

Nematoda

Metachromadora remanei	9431
Ptycholaimellus ponticus	18366
Sabatieria punctata	12906
Desmolaimus zeelandicus	993
Daptonema tenuispiculum	496
Leptolaimus papilliger	993
Praeacanthonchus punctata	2978
Leptolaimus limicolus	993
Spilophorella candida	496
Viscosia cobbi	993
Halalaimus gracilis	993
Daptonema psammoides	496
Indet.	0
1B:2A	0.63
N	50134
S	12

Copepoda

Tachidius discipes	67
Tisbe sp.	67
Enhydrosoma propinquum	50
Tisbe gracilis	42
Amphiascus angusticeps	208
Paramphiascella intermedia	208
Thompsonula hyaenae	92
Stenhelia aemula	42
Unidentified copepodites	8
N	784
S	8

Table xviii

Benfleet Creek: Station 70.

Nematoda	
Ptycholaimus ponticus	29300
Leptolaimus papilliger	1106
Calyptronema maxweberi	553
Metoncholaimus remanei	17691
Axonolaimus paraspinosus	1659
Quadricoma sp.	553
Desmolaimus zeelandicus	1659
Antomicron elegans	553
Daptonema tenuispiculum	553
Linhomoeus sp. 2	553
Viscosia cobbi	1106
Indet.	0
1B:2A	0.09
N	55286
S	11
Copepoda	
Stenhelia aemula	142
Microarthridion sp.	8
Stenhelia palustris	42
Thompsonula hyaenae	108
Tachidius discipes	33
Paramphiascus intermedia	33
Amphiascus angusticeps	17
Unidentified copepodites	17
N	400
S	7

Table xix

Benfleet Creek: Station 34.

Nematoda	
Microlaimus globiceps	677
Ptycholaimellus ponticus	16241
Terchellingia sp.	4060
Metachromadora remanei	26391
Oncholaimus campylocercoides	677
Desmolaimus zeelandicus	2030
Calomicrolaimus honestus	1353
Odontophora setosa	677
Calyptronema maxweberi	677
Oncholaimellus calvadosicus	1353
Sabatieria celtica	1353
Axonolaimus paraspinosus	1353
Praeacanthonchus sp.	1353
Terchellingia communis	4060
Linhomoeus sp. 2	677
Leptolaimus papilliger	2030
Sabatieria punctata	1353
Aegialoalaimus sp.	677
Oxystomina elongata	677
Indet.	2030
1B:2A	0.32
N	69699
S	19
Copepoda	
Harpacticella sp.	75
Stenhelia aemula	42
Paramesonchra intermedia	358
Tachidius discipes	33
Stenhelia palustris	167
Itunella sp.	33
Bulbamphiascus sp.	75
Amphiascus varians	33
Ectinsoma melaniceps	50
Thompsonula hyaenae	33
N	899
S	10

Table xx

Benfleet Creek: Station 38.

Nematoda	
Metachromadora remanei	17379
Odontophora setosa	9931
Tripyloides gracilis	4965
Dichromadora sp.	8689
Aegialoalaimus sp.	2483
Ptycholaimellus ponticus	27309
Terchellingia communis	4965
Monoposthia costata	11172
Linhomoeid sp.	1241
Sabatieria celtica	11172
Daptonema tenuispiculum	3724
Southernia zosterae	1241
Cervonema sp.	1241
Sabatieria punctata	6206
Desmolaimus zeelandicus	2483
Leptolaimus limicola	2483
Axonolaimus paraspinosus	2483
Oncholaimellus calvadosicus	2483
Anoplostoma viviparum	1241
Calyptronema maxweberi	1244
Indet.	1244
1B:2A	0.52
N	125373
S	20
Copepoda	
Amphiascus sp.	50
Stenhelia palustris	175
Ectinosoma melaniceps	25
Stenhelia aemula	50
Microarthridion sp.	42
Tisbe gracilis	58
N	400
S	6

Table xxi

Yantlet Creek: Station 40.

Nematoda

Metachromadora remanei	72075
Adoncholaimus thalassophygas	3728
Ptycholaimellus ponticus	33552
Anoplostoma viviparum	1243
Enoplus communis	3728
Leptolaimus sp.	1243
Spilophorella candida	1243
Leptolaimus papilliger	1243
Praeacanthochus sp.	1243
Desmolaimus zeelandicus	2485
Neochromadora sp. (?*paratecta*)	1243
Dichromadora sp.	1243
Indet.	0
1B:2A	0.03
N	124269
S	12

Copepoda

Itunella sp.	33
Enhydrosoma propinquum	25
Stenhelia aemula	17
Unidentified copepodites	8
N	93
S	3

Table xxii

Yantlet Creek: Station 42.

Nematoda	
Praeacanthonchus sp.	5630
Metachromadora remanei	7507
Sabatieria punctata	26274
Terchellingia sp.	18767
Halalaimus gracilis	3753
Ptycholaimellus ponticus	20644
Molgolaimus demani	938
Leptolaimus papilliger	2815
Aegialoalaimius sp.	938
Anoplostoma viviparum	2815
Axonolaimus paraspinosus	938
Sphaerolaimus gracilis	938
Terchellingia communis	938
Dichromadora sp.	938
Indet.	938
1B:2A	1.39
N	94771
S	14
Copepoda	
Stenhelia palustris	175
Amphiascus sp.	100
Amphiascus angusticeps	25
Stenhelia aemula	100
Enhydrosoma sarsi	225
Paramphiascella sp.	25
Bulbamphiascus sp.	25
Canuella perplexa	25
Paramphiascella intermedia	475
Thompsonula hyaenae	50
Microarthidion sp.	25
Enhydrosoma propinquum	17
Onychocamptus sp.	17
N	1284
S	13

Table xxiii

Yantlet Creek: Station 44.

Nematoda

Ptycholaimellus ponticus	15216
Axonolaimus paraspinosus	1268
Desmolaimus zeelandicus	11412
Metachromadora remanei	25994
Calyptronema maxweberi	634
Terchellingia communis	634
Aegialoalaimus sp.	1268
Cervonema sp.	634
Praeacanthonchus sp.	634
Daptonema psammoides	1902
Halalaimus gracilis	634
Oxystomina elongata	634
Daptonema sp.	1268
Leptolaimus papilliger	634
Tripyloides gracilis	634
Indet.	634
1B:2A	0.39
N	64034
S	15

Copepoda

Enhydrosoma propinquum	8
Stenhelia palustris	42
Stenhelia aemula	8
Paramesochra intermedia	25
N	83
S	4