Pollution Control RBH6
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NATIONAL RIVERS AUTHORITY
BIOLOGY
ESTUARINE FISH SURVEY 1989

Inferences on the Pollution Status of the Thames Estuary

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Report compiled by Myles Thomas, Senior Biologist
December, 1990

The assistance given by Kevin Farmer, Water Quality Planner with the regression analysis of the data is acknowledged

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SUMMARY

1. This report makes inferences on the pollution status of the Thames Estuary based on the analysis of fish data collected at 8 sites along the length of the estuary from Teddington Weir to Sea reach No.1 mainly during 1989.

2. Species composition and total abundance data was used extensively throughout. Abundance of selected species in the mid-estuary during the early summer and long term trends in species composition and abundance as shown by regression analysis of past data were also considered. Diversity and evenness indices were calculated.

3. The data collected from the upper estuary was found to be insufficient for definitive conclusions on water quality to be made. However, the presence of dace of the year at all four sites suggests that water quality is sufficiently good to allow this species to spawn.

4. Although the abundance of certain species in the mid-estuary was lower than usual, the number of species and the relative proportion of individuals within those species was similar to previous years.

5. Regression analysis of past data revealed a number of interesting trends. An increase in the number of species per sample at West Thurrock since sampling began was confirmed. However, no significant trend could be detected in recent years. Also, a significant decline in the abundance of smelt was apparent. The rate of decline is low and unlikely to be linked to changes in water quality. However, smelt abundance should be closely monitored in future.

6. The fish species found in the outer estuary were much as would be expected which suggests that water quality is sufficiently good to support a marine fishery. The lack of past data from this part of the estuary makes further

deductions on water quality difficult.

7. Comparisons were made with various physical parameters and recent fish data. A tenuous link between reductions in dissolved oxygen and species number was illustrated in the mid-estuary. There is evidence to suggest that higher water temperatures recorded at the beginning of 1989 may have kept the number of species present in the estuary a little higher than normal at this time. It does not appear that the low freshwater flows are having any effect on the fish community in the mid and outer estuary.

8. A number of disadvantages in the method of fish sampling were apparent, particularly the lack of quantitative, comparative data throughout the estuary. A method of sampling that would allow spatial and temporal comparisons to be made was outlined.

1. INTRODUCTION

Thames Water biologists first began regular fish sampling in the Thames Estuary in 1974 as a method of monitoring the recovery of the tideway biota after improvements to the sewage treatment works at Beckton and Crossness. Much of this work consisted of monitoring fish entrapped on the cooling water intake screens at West Thurrock Power Station and, with the exception of the mid-80s, has continued upto the present day. This monitoring is being continued by the National Rivers Authority.

Fish surveys were carried out at a total of eight sites between Teddington Weir and Sea Reach No.1 (Figure 1) during 1989; four seine netting sites in the Upper Estuary (Teddington, Petersham, Isleworth and Kew); one cooling water intake site at West Thurrock Power Station in the Mid-Estuary; and three beam-trawl sites in the Outer Estuary (Southend, Sea Reach and Blyth Sands).

The aim of this report is to make an assessment of water quality mainly from the data collected during fish surveys in 1989. The methods and results of the 1989 surveys are presented in an earlier report. This approach to reporting parallels that being taken with estuarine macroinvertebrate and meiofaunal data.

Due to to the considerable database that exists for the Mid-Estuary and the comparative nature of the data, a bias towards the results obtained from this area will be detected throughout the report.

THAMES FISH SAMPLING 1989

● SEINE NETTING SITES
— TRAWLS

Figure 1

2. COMMUNITY STRUCTURE

The simplest method of describing a fish community is to look at the structure of the community in terms of the number of species and the abundance of individuals. A knowledge of this structure can be used to indicate water quality. In general terms, few species and few individuals are indicative of poor water quality, whereas many species and many individuals are indicative of good water quality.

2.1. UPPER ESTUARY

No definitive conclusions can be made on the fish community structure in the Upper Estuary from the limited number of samples collected in 1989.

However, the presence of dace of the year does indicate that the water is of a sufficiently good quality to support a population of cyprinid fish capable of reproducing.

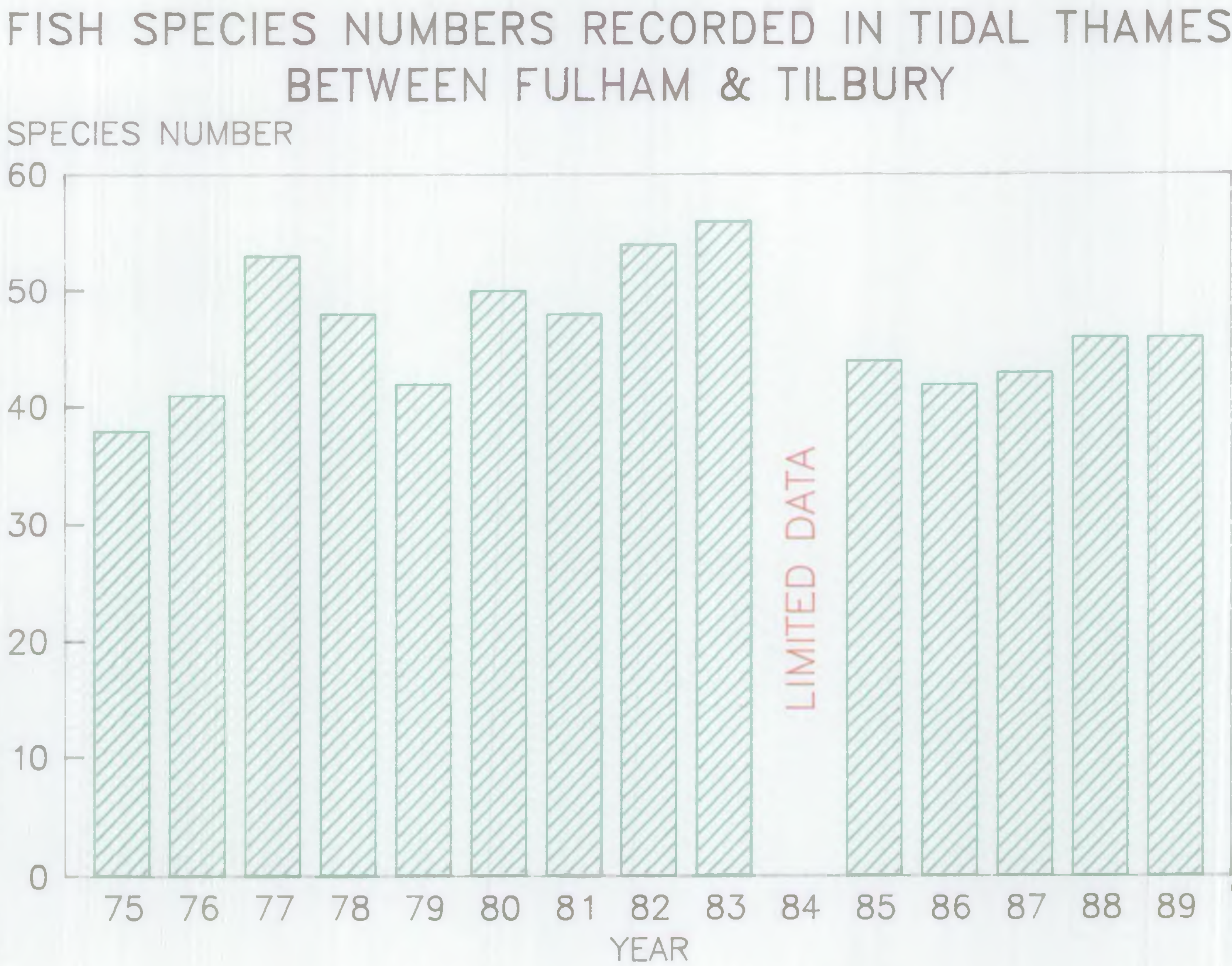
The method and frequency of sampling does not allow reliable conclusions to be made on any spatial differences. Neither can any temporal changes within the fish community be detected due to the lack of comparative historical data.

2.2. MID-ESTUARY

2.2.1. Species Distribution

The fish species found and their abundance in samples at West Thurrock Power Station were, with some exceptions, similar to previous years. The forty-six species recorded was consistent with past results and the total is within the range of 42 to 56 species found annually since the 'clean-up' of the Thames in the late 70's (Figure 2).

The appearance for the first time of a solenette (*Buglossidium luteum*) in the Thames was of interest


FISH SPECIES NUMBERS RECORDED IN TIDAL THAMES
BETWEEN FULHAM & TILBURY
SPECIES NUMBER
60
50
40
30
20
10
0
LIMITED DATA
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
YEAR
Figure 2

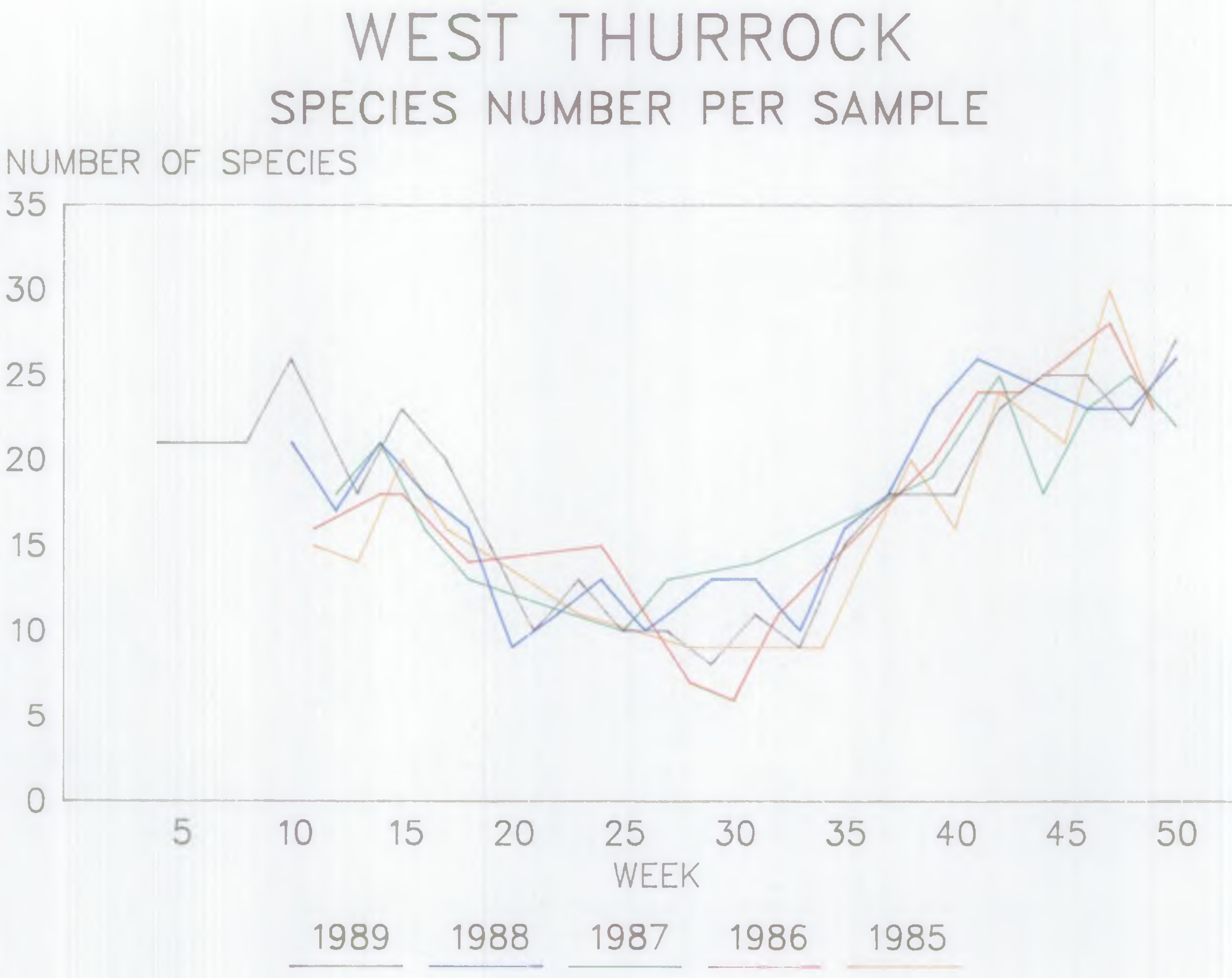

WEST THURROCK
SPECIES NUMBER PER SAMPLE
NUMBER OF SPECIES
35
30
25
20
15
10
5
0
5
10
15
20
25
30
35
40
45
50
WEEK
1989
1988
1987
1986
1985

Figure 3

but cannot be attributed to any improvement or otherwise in water quality.

The number of species in each sample followed the usual seasonal trend of high numbers in the Autumn/Winter and low numbers in the Summer (Figure 3). This is largely due to the normal migratory patterns of juvenile marine species entering the estuary in the autumn to over-winter and confirms the importance of the Thames Estuary as a nursery area for North Sea fish.

2.2.2. General Species Abundance

The total number of individuals recorded over the year was markedly lower than in previous years. In total, five species, including the estuarine resident species flounder (*Platichthys flesus*) and smelt (*Osmerus eperlanus*), showed a major decline in numbers. The decline of these two species may be of particular importance as they spend much of their life-cycle within the estuary and are more likely to be directly influenced by any changes in water quality than other species.

It is too soon to conclude whether the decline in abundance of both species is due to natural population changes or anthropogenic effects. The decline in smelt will be referred to again in 3.2.3.2

Conversely, there has been a major increase in the abundance of bass (*Dicentrarchus labrax*) in the estuary during 1989. This is primarily due to good recruitment in the North Sea over recent years (MAFF, pers.comm.). However, bass are thought to prefer warm water (MAFF, pers.comm.) and the generally high temperatures, particularly at the beginning of 1989, may be important in attracting individuals of this species to the Thames. Moreover, a major increase in the abundance of a single species such as bass will have an influence on the ecosystem as a whole, possibly resulting in a decline in other species due to predation or competition for food.

2.2.3. Species Abundance During Early Summer

The critical period for fish species in the Thames tends to be during June and July when water temperatures are at their highest and dissolved oxygen levels are normally low. A comparison of results from West Thurrock at this time of year for 1987, 88 and 89 is shown in Table 1. The results are compared with the ranges and averages for the period 1978-83. All results are taken from Week 30 (late July). There are no obvious differences in the abundance of the selected species between the years. Although this is a very basic comparison, the results do suggest that water quality during this critical period in 1989 was sufficient to support a fish community typical of this time of year.

Table 1

COMPARISON OF SUMMER CATCHES
(WEEK 30 OR NEAREST)

FISH PER 100 MILLION GALLONS

	1978-83 Ave.	1978-83 Range	1987	1988	1989
SAND GOBY	131	14 - 338	10	327	586
FLOUNDER	1000	478 - 1348	1946	677	580
SPRAT	32	2 - 78	67	29	26
EEL	17	0 - 35	12	19	18
HERRING	49	0 - 189	322	176	59
DOVER SOLE	26	0 - 116	3	7	19
SMELT	293	12 - 773	118	97	80
3-SPINED STICKLEBACK	6	0 - 15	13	3	2

2.3. OUTER ESTUARY

2.3.1. Species Distribution

The species recorded at the three Outer Estuary sites were much as would be expected for this part of the estuary, suggesting that water quality is sufficiently good to support a marine fishery. Some marine species frequently found at West Thurrock were, however, absent. This is likely to be due to the sampling technique being biased towards larger bottom living fish, hence the almost total absence of normally common species such as bass (*Dicentrarchus labrax*), sand goby (*Pomatoschistus minutus*) and Nilssons pipefish (*Sygnathus rostellatus*).

2.3.2. Species Abundance

The temporal variations in species abundance at each site are due to known natural recruitment and migration patterns.

2.4. Comparison With Other Estuaries

The species list for the mid and outer Estuary in 1989 compares well and is often more diverse than similar reaches of the Medway (Wharfe, 1984), Clyde (Henderson and Hamilton, 1986), Tyne (Pomfret et al, 1988) and Forth (Poxton, 1987). However, there are a number of differences in the actual species found; reflecting differing geographical distributions of species rather than any variations in water quality. Eelpout (*Zoarces viviparus*) and pollack (*Pollachius pollachius*), for example, would appear to be more common in northern estuaries whereas smelt (*Osmerus eperlanus*) is more common in the Thames and Medway.

3. COMMUNITY ANALYSIS

Sampling the fish populations of the Thames Estuary generates a considerable amount of data on the numbers of species present in each sample and the abundance of those species. The sheer volume of this data can make conclusions difficult.

There are a number of mathematical methods that will assist in the interpretation of this data. Three techniques have been used below. The first two, diversity and evenness, are measures of community structure, whilest the third technique examines the long term trends in the abundance of smelt and in the number of species per sample by the use of regression analysis.

3.1. UPPER ESTUARY

The sampling of the Upper Estuary was not comprehensive enough for further analysis to be made.

3.2. MID-ESTUARY

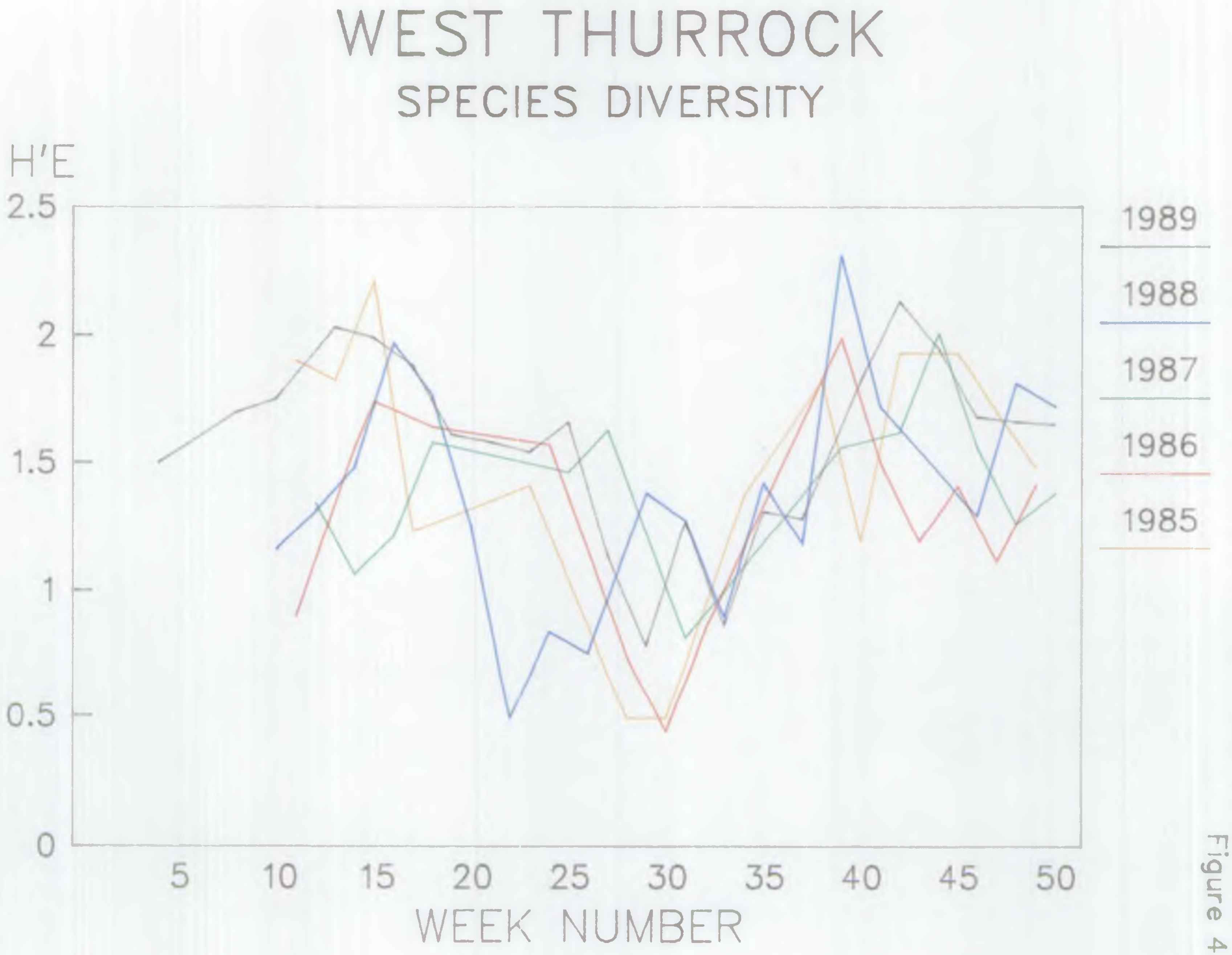
3.2.1. Diversity

Diversity indices use the species number in a sample and the distribution of individuals among those species as a measure of community structure. One of the most frequently used indices is the Shannon-Weaver Index (H'). This index will increase with an increase in both the species number and the equitability of species abundance. The equation is:

$$H' = -\Sigma \, Pi \log Pi$$

where Pi is the proportion of individuals in the ith species.

The results for the period 1985-89 are summarised in Figure 4. An annual trend of high diversity in autumn/winter and low diversity in spring/summer is



WEST THURROCK
SPECIES DIVERSITY
H'E
2.5
2
1.5
1
0.5
0
5
10
15
20
25
30
35
40
45
50
WEEK NUMBER
1989
1988
1987
1986
1985

Figure 4

WEST THURROCK

SPECIES EVENNESS

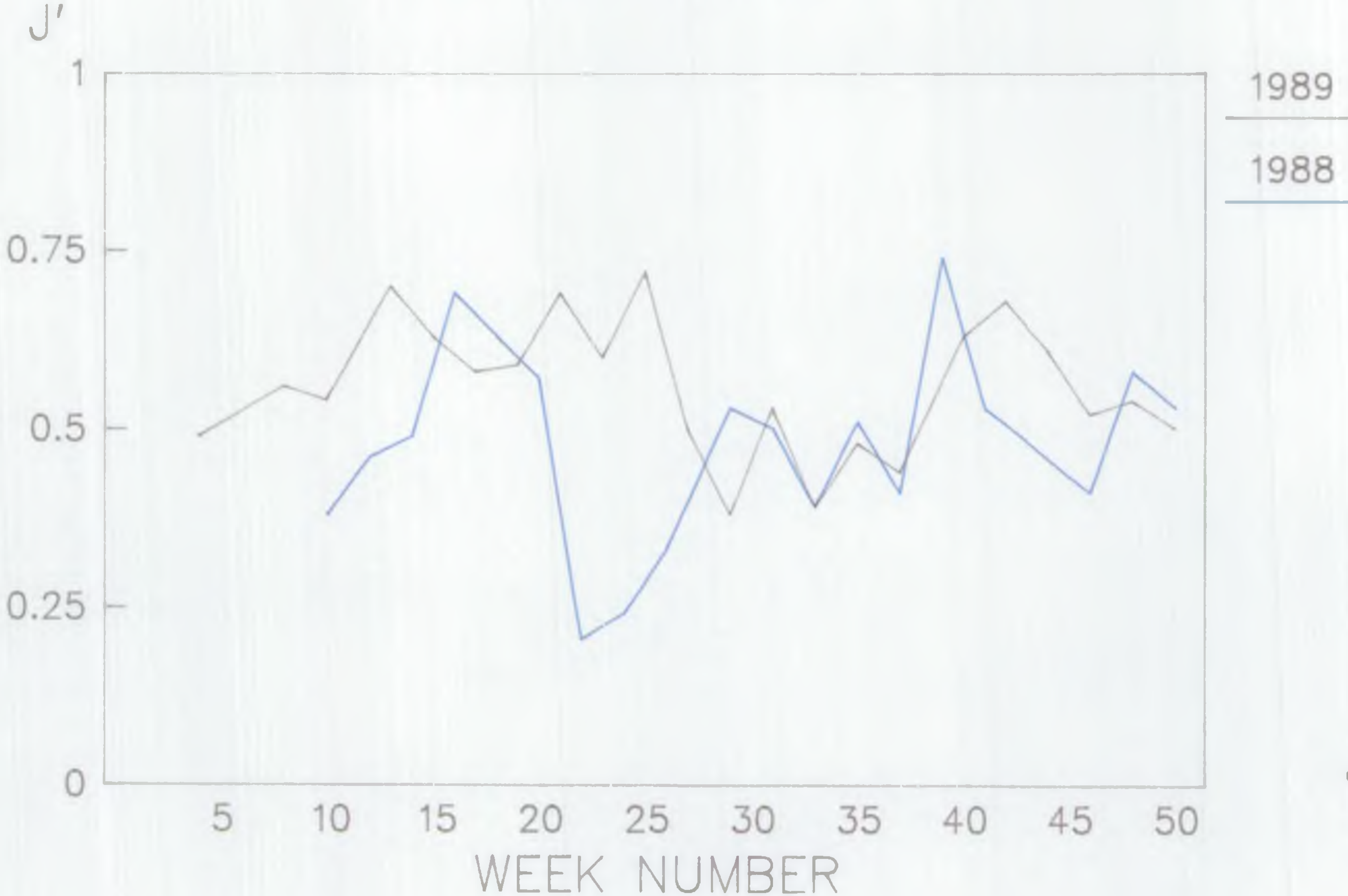
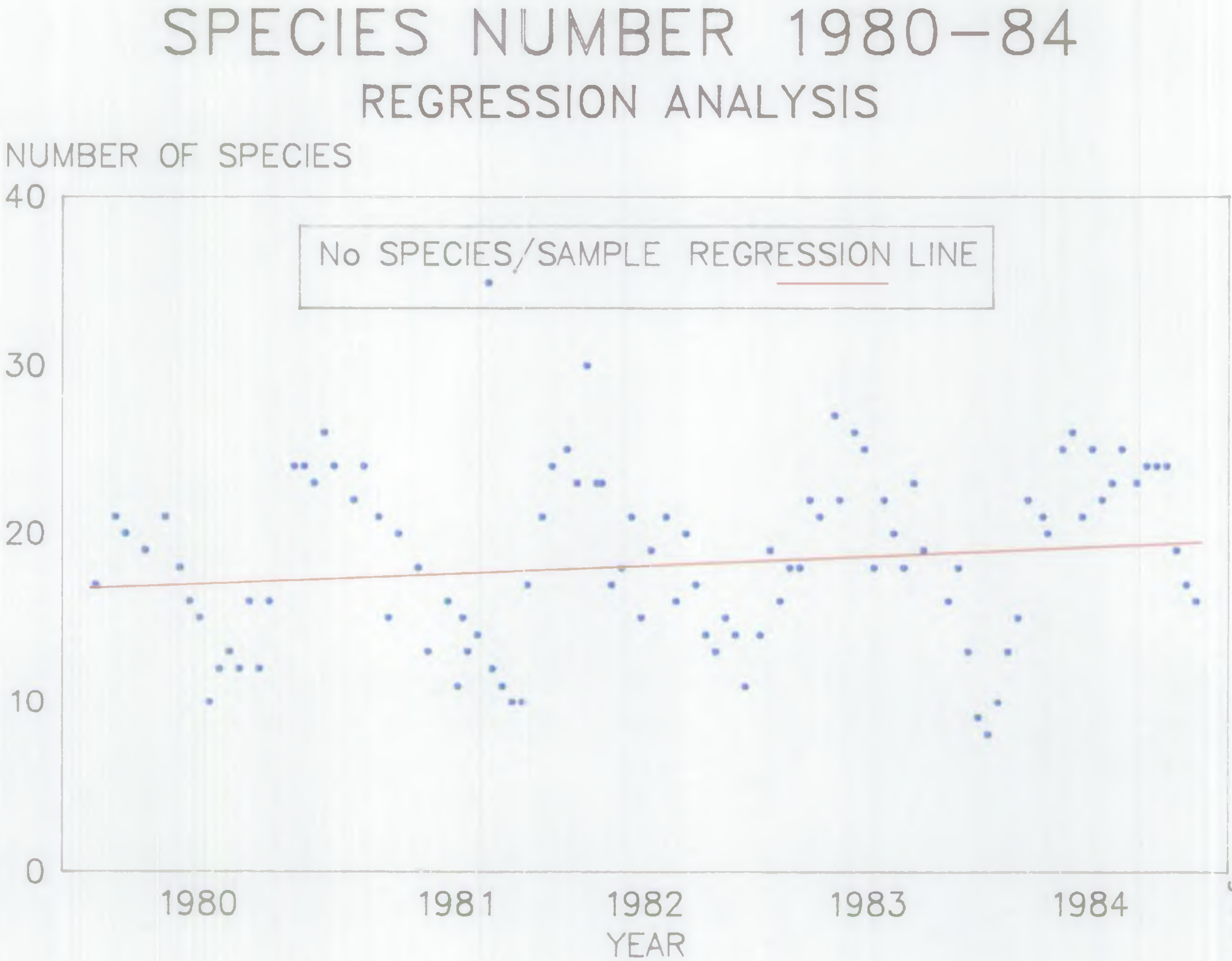


Figure 5


SPECIES NUMBER 1980–84
REGRESSION ANALYSIS
NUMBER OF SPECIES
No SPECIES/SAMPLE
REGRESSION LINE
40
30
20
10
0
1980
1981
1982
1983
1984
YEAR
Figure 6

apparent.

Species diversity during 1989 compared favourably with previous years, although, with the exception of 1985, diversity at the beginning of the year was considerably higher than the other years studied.

In a number of cases the reductions in diversity correspond with reductions in dissolved oxygen in a similar way as species number in 4.2.2. However, each year during the early summer, species numbers are low and the abundance of flounder, and occasionally herring, is high due to juveniles migrating into the estuary. This migration will result in a reduced H' value. The reductions in diversity during early summer, therefore, are not due to changes in water quality.

3.2.2. Evenness

Evenness (J') is used as a measure of the evenness with which the individuals are distributed amongst the species. H' can be effected by seasonal changes, whereas J' avoids this problem by relating the observed diversity to its potential maximum. The equation is:

$$J' = H'/H'max$$

where H'max= log(Number of Species)

Data for the period 1988-89 shows a similar trend to H' with the usual seasonal summer paucity (Figure 5). This is again due to high numbers of flounder and occasionally herring in the summer.

3.2.3. Long-Term Trends

Fish data has been collected at West Thurrock Power Station for over 15 years. Regression analysis was undertaken on the data in an attempt to identify any long term trends in the fish community.

3.2.3.1. **Number of Species**

Initially, the number of species per sample during the period from 1974 to 1989 was analysed and a significant increase of 3.5 species every 20 years was detected. The data for this period is likely to be heavily influenced by the major increase in species numbers during the late 70's following the improvement to Beckton and Crossness Sewage Treatment Works and is therefore unlikely to be indicative of recent trends. In an attempt to remove this influence the data was split into five year groups.

No significant trend in the number of species could be detected during the periods of 1975-79 ($p=0.214$) and 1985-89 ($p=0.44$), although the average number of species per sample increased from 16.2 to 17.6. For the period 1980-84 a significant increase ($p=0.09$) of one every two years was detected (Figure 6).

Species number per sample has increased over the past 15 years and may still be increasing. It should be noted that the number of species likely to occur in the Thames is limited and that, even with further improvements in water quality, species numbers may not increase significantly. The abundance of certain species may be an alternative indicator of water quality. Therefore, similar analysis to that carried out on species number was undertaken on the smelt abundance data.

3.2.3.2. **Smelt**

Smelt are known to spend much of their life cycle in or near the estuary and are therefore likely to be a good indicator of changes in water quality.

The low number of smelt in 1975 and 1976 is likely to mask any overall trend in the data and was therefore ignored. When the data from 1977-89 was analysed a significant decrease (p=0.0) of 25 fish per year was detected. The reason for the reduction in the number of smelt over this thirteen year period is not clear. At this rate of decrease it would be sometime before smelt numbers reached a level to be of concern.

An obvious increase in smelt abundance was confirmed by the regression analysis (p=0.0) between 1975-79 (Figure 7) and although no trend could be determined between 1980-84 (p=0.901), a significant decrease (p=0.075) of 24 fish per year was detected between 1985-89 (Figure 8).

The abundance of smelt in 1989 was so low that it may have been having an adverse effect on the 1985-89 dataset. With this in mind the data for 1985-88 was reanalysed and no significant trend was detected. This degree of uncertainty about the decrease suggests that, as in the analysis of the 1977-89 data, the rate of decline is unlikely to be of importance at present.

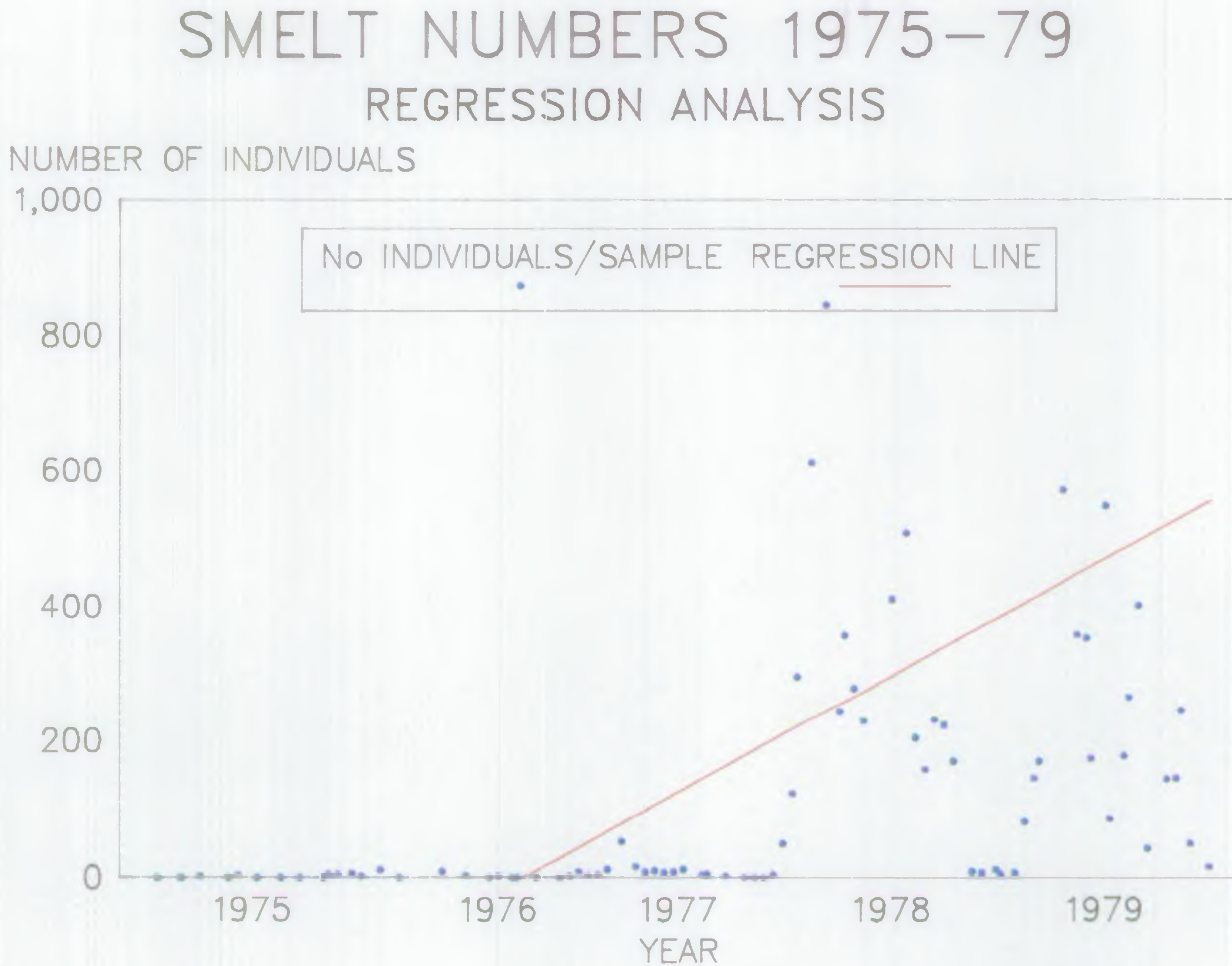

SMELT NUMBERS 1975–79
REGRESSION ANALYSIS
NUMBER OF INDIVIDUALS
1,000
800
600
400
200
0
No INDIVIDUALS/SAMPLE
REGRESSION LINE
1975
1976
1977
1978
1979
YEAR

Figure 7

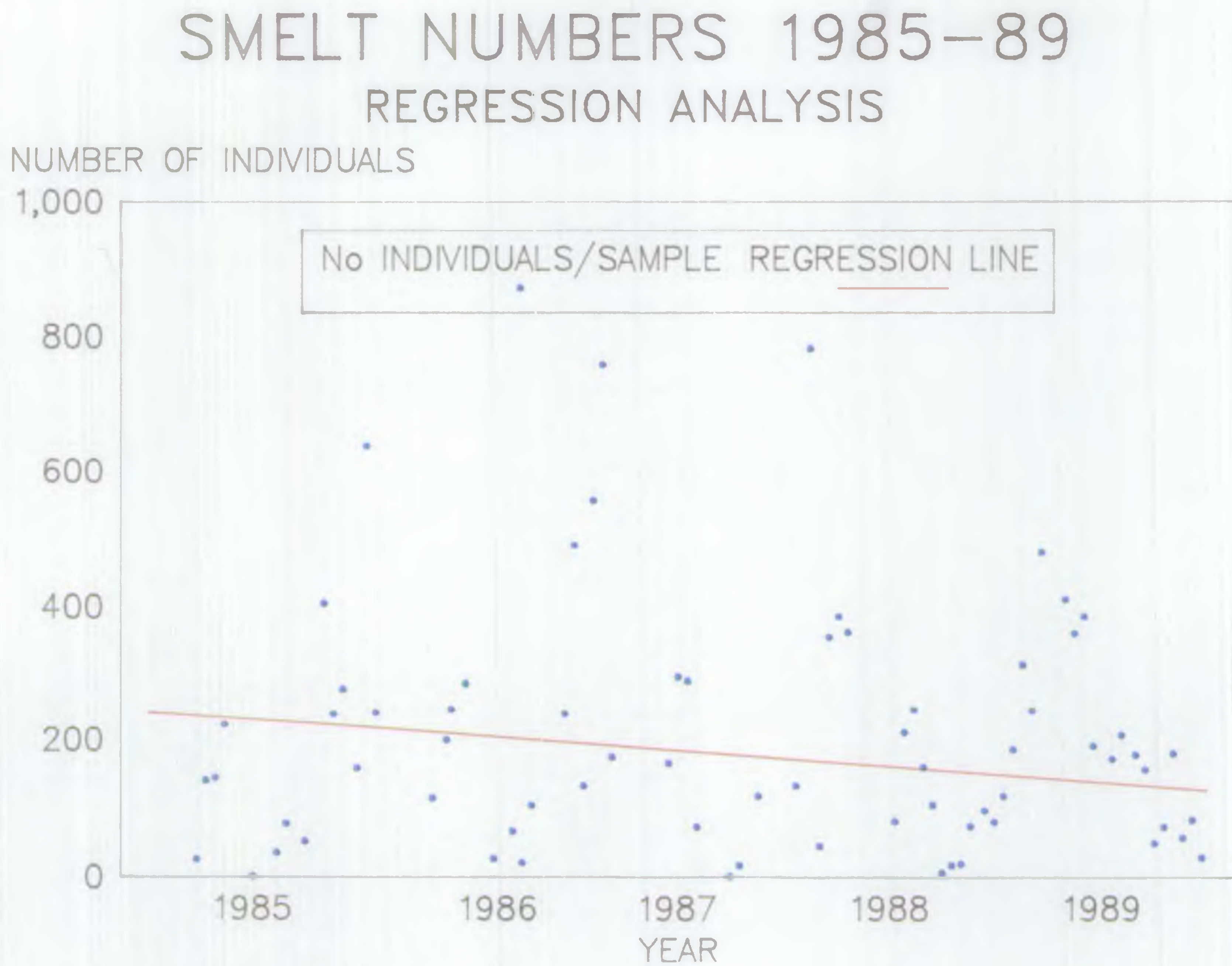

SMELT NUMBERS 1985-89
REGRESSION ANALYSIS
NUMBER OF INDIVIDUALS
1,000
800
600
400
200
0
No INDIVIDUALS/SAMPLE
REGRESSION LINE
1985
1986
1987
1988
1989
YEAR

Figure 8

3.3. OUTER ESTUARY

3.3.1. Diversity (Figure 9)

Of the three sites sampled Blyth Sands was the least diverse due to the high numbers of flounder in the samples, particularly in the sample of 18/12/89.

Sea Reach was the most diverse site and appeared the most stable from the samples obtained.

The reduction in diversity at Southend and Blyth Sands in the 18/12/89 sample was due to the seasonal migratory patterns of plaice and flounder at the two sites respectively.

3.3.2. Evenness (Figure 10)

The evenness of the samples is very similar to that of diversity and reinforces the comments made in 3.3.1 above.

These results suggest that the water quality of the outer estuary is at such a sufficiently high level as to support a fairly diverse, stable marine fish community.

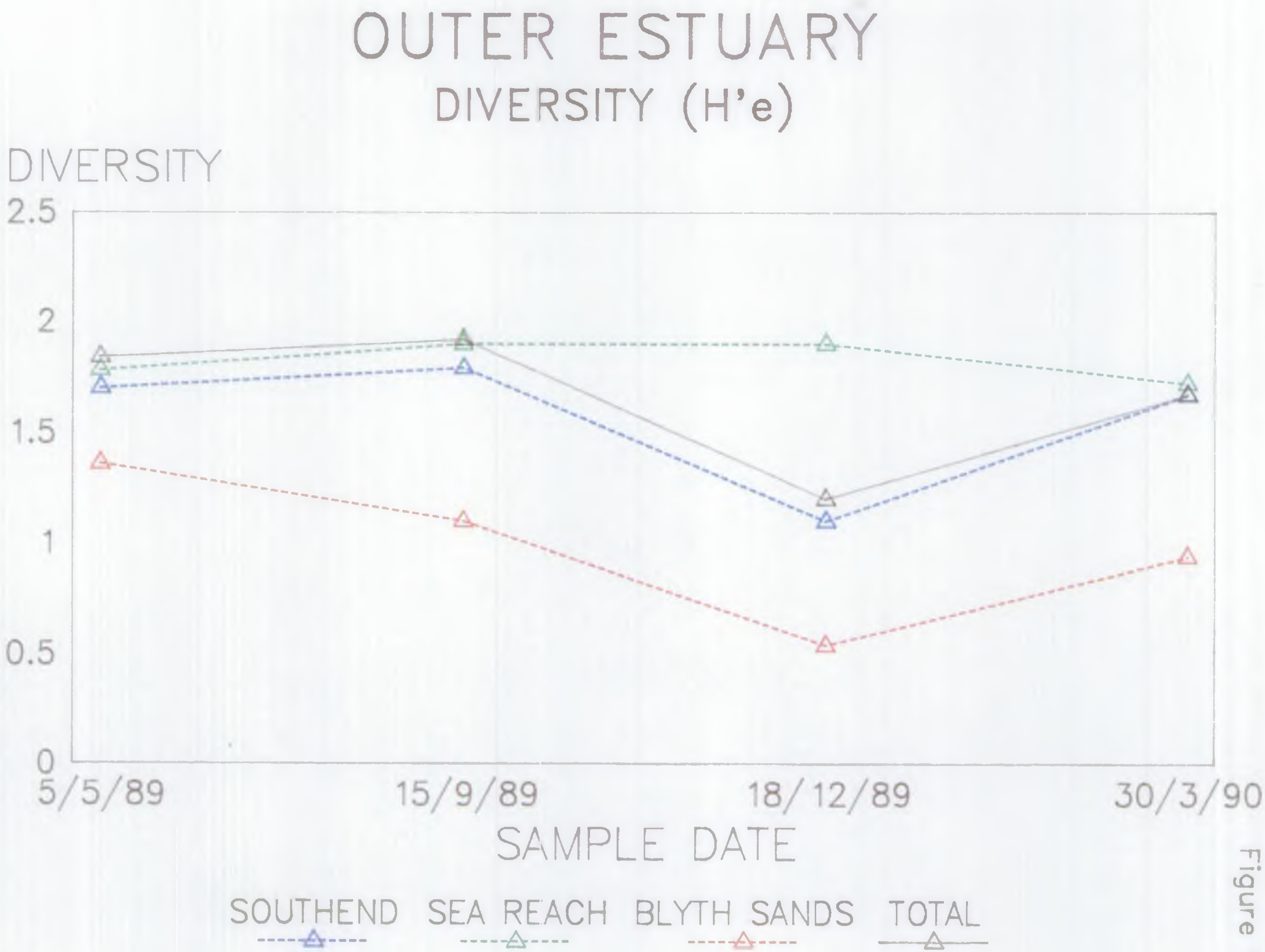

OUTER ESTUARY
DIVERSITY (H'e)
DIVERSITY
2.5
2
1.5
1
0.5
0
5/5/89
15/9/89
18/12/89
30/3/90
SAMPLE DATE
SOUTHEND
SEA REACH
BLYTH SANDS
TOTAL

Figure 9

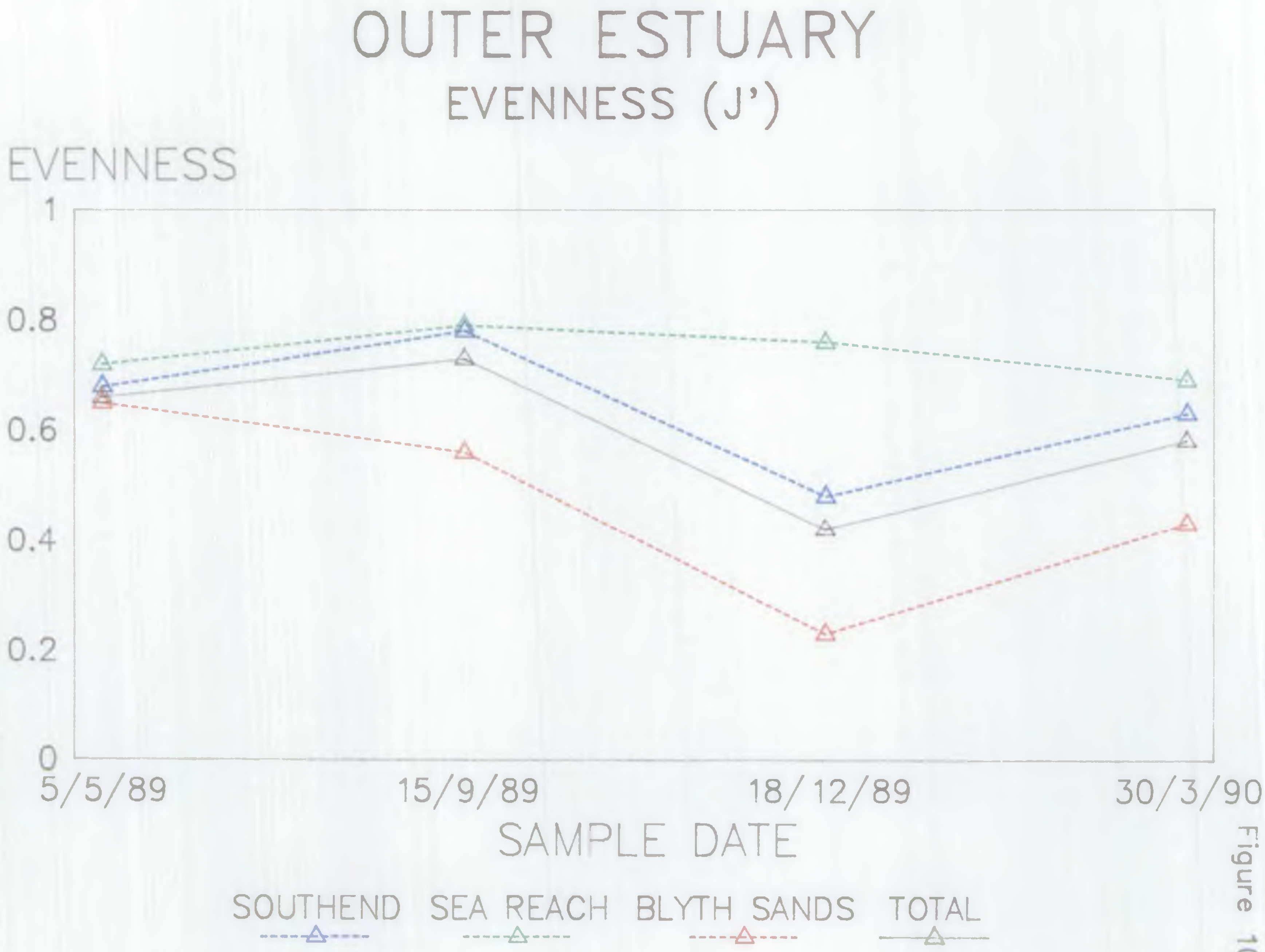

OUTER ESTUARY
EVENNESS (J')
EVENNESS
1
0.8
0.6
0.4
0.2
0
5/5/89
15/9/89
18/12/89
30/3/90
SAMPLE DATE
SOUTHEND
SEA REACH
BLYTH SANDS
TOTAL

Figure 10

4. SPECIES NUMBER AND ENVIRONMENTAL PARAMETERS

In this section the intention is to look at whether or not changes inspecies number can be correlated with changes in environmental parameters.The parameters to be examined are:

Temperature - due to the proposed increase in cooling water effluents to the estuary.

Dissolved Oxygen - due to the historical effects on the fish populations of the estuary.

Salinity - due to the presently low freshwater input to the Thames.

The use of mathematical techniques for analysing the data has not been explored. All conclusions are made from visual comparisons of the data.

4.1. UPPER ESTUARY

The sampling of the Upper Estuary was not comprehensive enough for any connections between numbers of species and environmental parameters to be made.

4.2. MID-ESTUARY

4.2.1. Species Number and Temperature

Temperatures during 1989 followed the usual seasonal trend but were slightly higher than in recent years, particularly during January and February (Figure 11).

Historical records of fish species found during January and February at West Thurrock Power Station are limited. It would appear, however, that the number of species present at the beginning of 1989 was higher than usual. It is unclear whether this is just natural variation or whether the elevated temperatures caused certain species to remain in the estuary for longer.

WEEKLY MINIMUM TEMPERATURE

ZONE 20

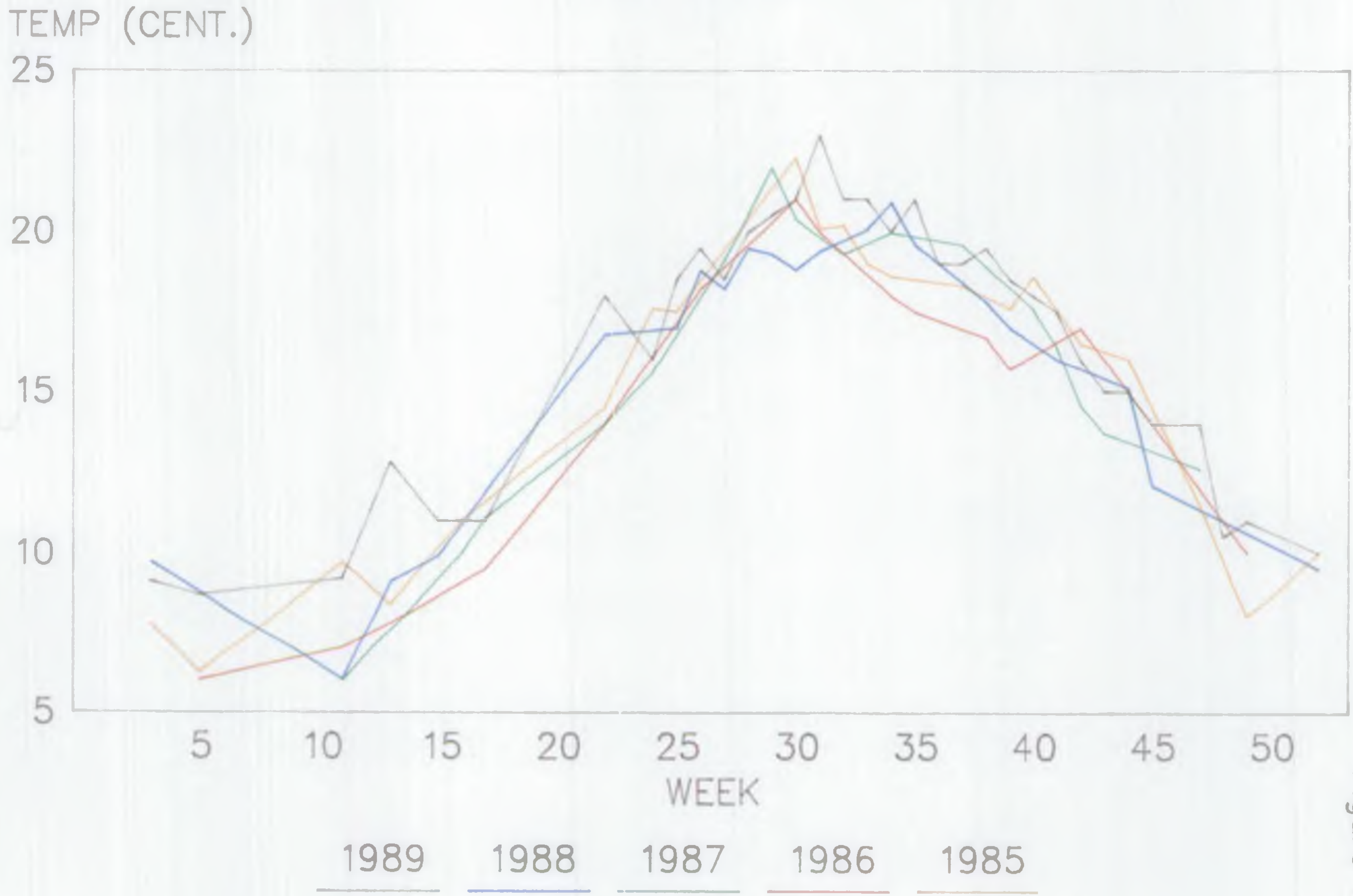


Figure 11

It is unlikely that elevated temperatures of one or two degrees above normal at this time of year would have a detrimental effect on the fish populations. During more critical periods of the year, such as June and July, higher temperatures may have a sublethal effect on many species and will effect dissolved oxygen levels.

4.2.2. Species Number and Dissolved Oxygen

The variations in the percentage dissolved oxygen had little obvious effect on species number or abundance during 1989. Alabaster and Lloyd (1980) and Andrews (1984) have suggested that 50% dissolved oxygen is the minimum level required for a successful fish life-cycle. From the data collected from West Thurrock over recent years it would appear that the number of species could be affected if dissolved oxygen levels are at or below 50% and then quickly fall. This effect will be masked if levels drop during spring when species numbers are falling due to natural fish migrations.

A tenuous effect can be illustrated by comparing species number with the major reductions in dissolved oxygen over recent years. It should be emphasised that a reduction in dissolved oxygen with a corresponding reduction in the number of species may be coincidental and further analysis of the data is needed.

1989 a) Between weeks 27 and 30 dissolved oxygen dropped from around 50% to 35% resulting in a minor species number reduction from 10 to 8. Species number then increases with the increase in dissolved oxygen.

b) Between weeks 46 and 48 dissolved oxygen dropped from 65% to 50% with a reduction in

COMPARISON %DO TO SPECIES NUMBER
MID-ESTUARY

Figure 12

species number from 25 to 22. Again, an increase in species number occurs as dissolved oxygen levels increase (Figure 12).

1988 a) The decrease in oxygen levels during week 13 to 15 is difficult to assess due to the natural decline in species number.

b) Between weeks 39 to 43 dissolved oxygen dropped from 50% to 40%. No fish samples were taken between weeks 41 to 46 and although a slight drop in species number was detected more samples would need to have been taken before any connection with dissolved oxygen levels could be made (Figure 12).

1987 a) Between weeks 28 and 30 dissolved oxygen dropped from 40% to 25%. Species number however increased from 10 to 13. This difference may be due to natural sample variation as the increase in species number in this case was due to the presence of three additional species each represented by a single individual.

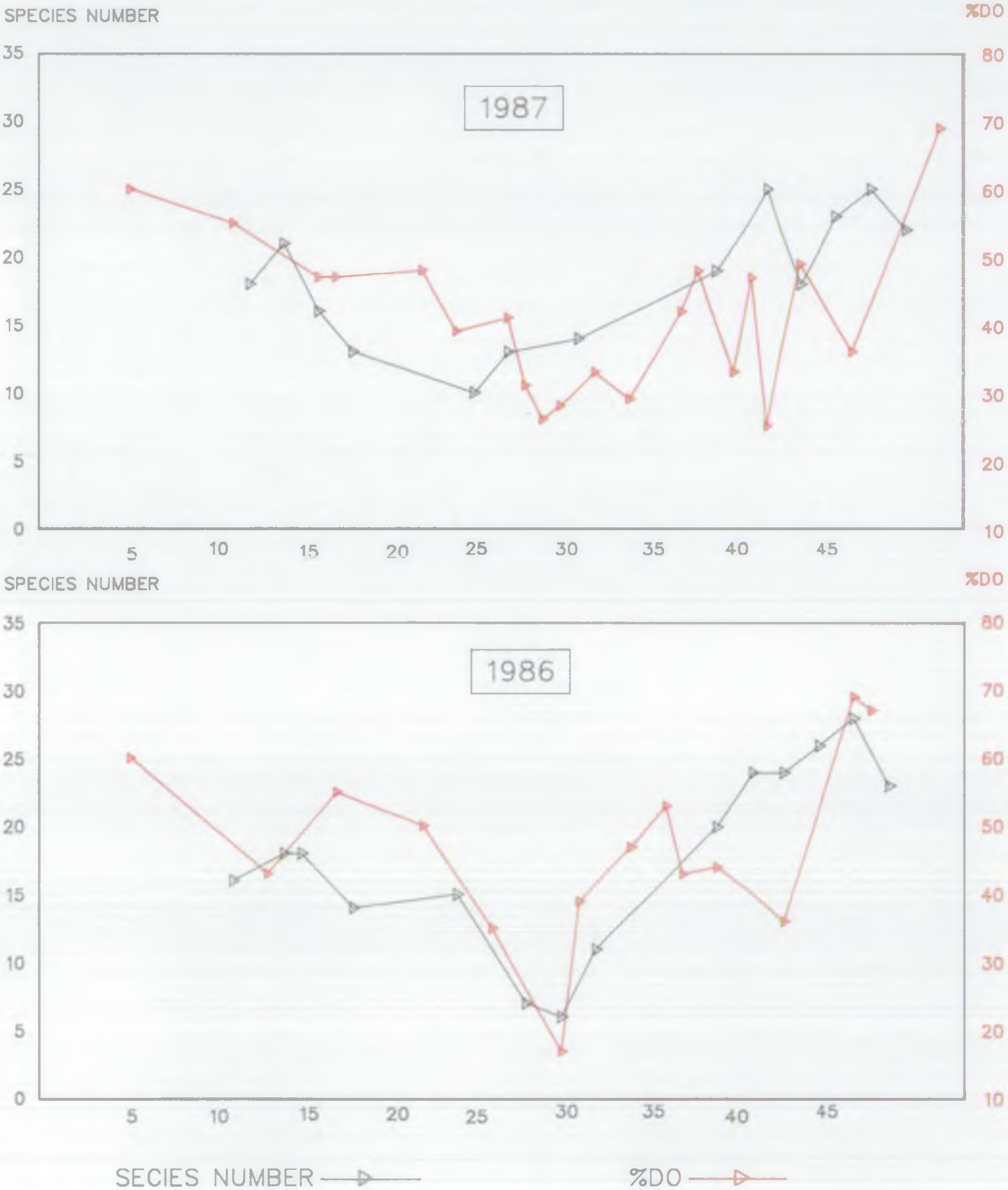
b) Around week 43 dissolved oxygen dropped from 45% to 25% with a reduction in species number from 25 to 18 in week 44. An increase in species number occurs as dissolved oxygen levels increase (Figure 13).

1986 Between weeks 27 and 31 dissolved oxygen dropped from 35% to 15% with a reduction in species number to 6 in week 31. An increase in species number occurs as dissolved oxygen levels increase (Figure 13).

1985 The decrease in oxygen levels during week 15 to 23 is difficult to assess due to the natural decline in species number (Figure 14).

COMPARISON %DO TO SPECIES NUMBER
MID-ESTUARY

Figure 13



4.2.3. Species Number and Salinity

Salinity levels tended to be higher than in recent years due to the low freshwater flows in the Thames catchment (Figure 15). Higher salinity could lead to an increase in the abundance of marine species and a reduction in freshwater species. As the number of marine species that could occur in the estuary is finite any minor increase in salinity is unlikely to significantly increase the number of marine species found at West Thurrock.

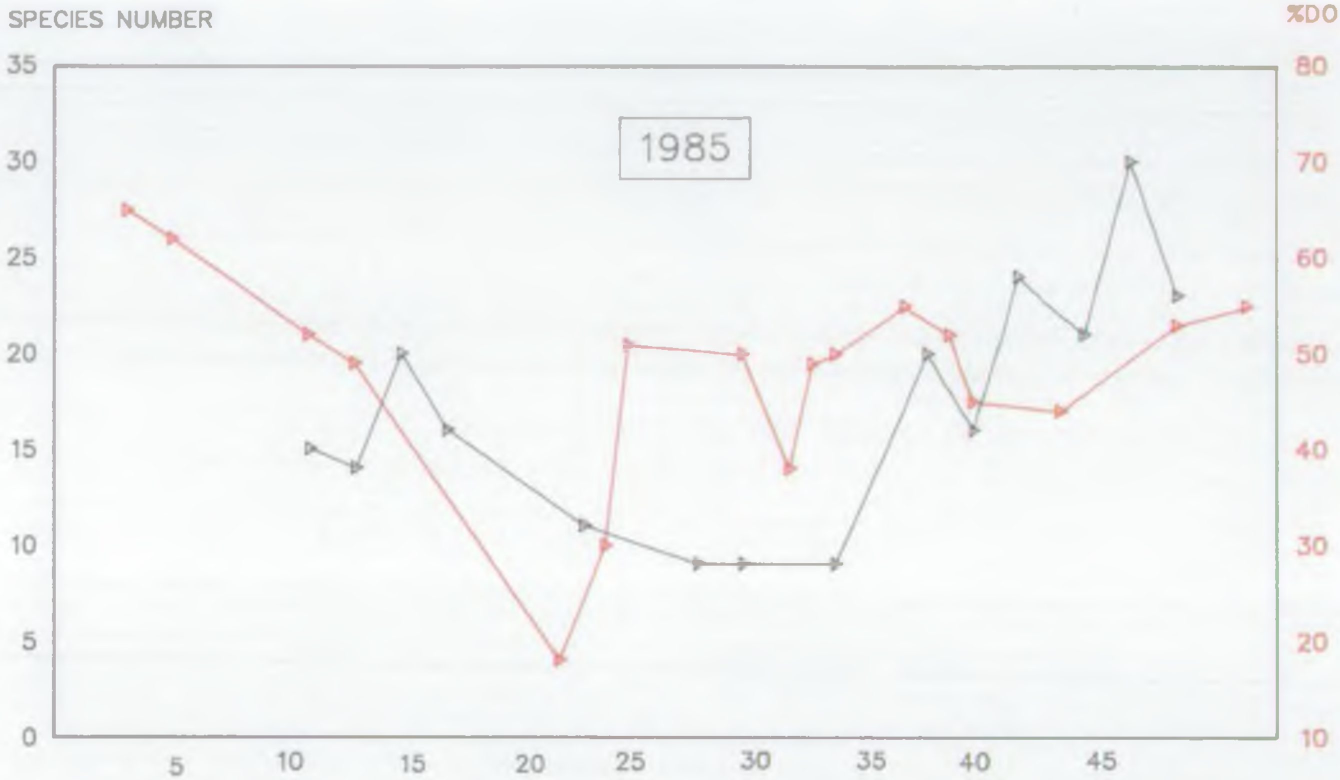
4.3. OUTER ESTUARY

The lack of past data on fish in the outer estuary means that comparisons with various environmental parameters cannot be made. However, certain differences between the samples can be explained by the variations in salinity. This will vary with the volume of freshwater input into the Thames and with tidal state. The salinity at Blyth Sands for example ranged from 18.8 ppt in the first quarter to 24.7 ppt in the third, whereas Southend ranged from 28.7 ppt to 27.8 ppt in the same quarters respectively.

Flounder can withstand lower salinity levels than other flatfish species and will therefore have an advantage in areas such as Blyth Sands; hence the abundance of this species at this site. Conversely, plaice (*Pleuronectes platessa*), a more marine species, was found to be most common at Southend.

COMPARISON %DO TO SPECIES NUMBER
MID–ESTUARY

Figure 14



WEEKLY MINIMUM SALINITY

ZONE 20

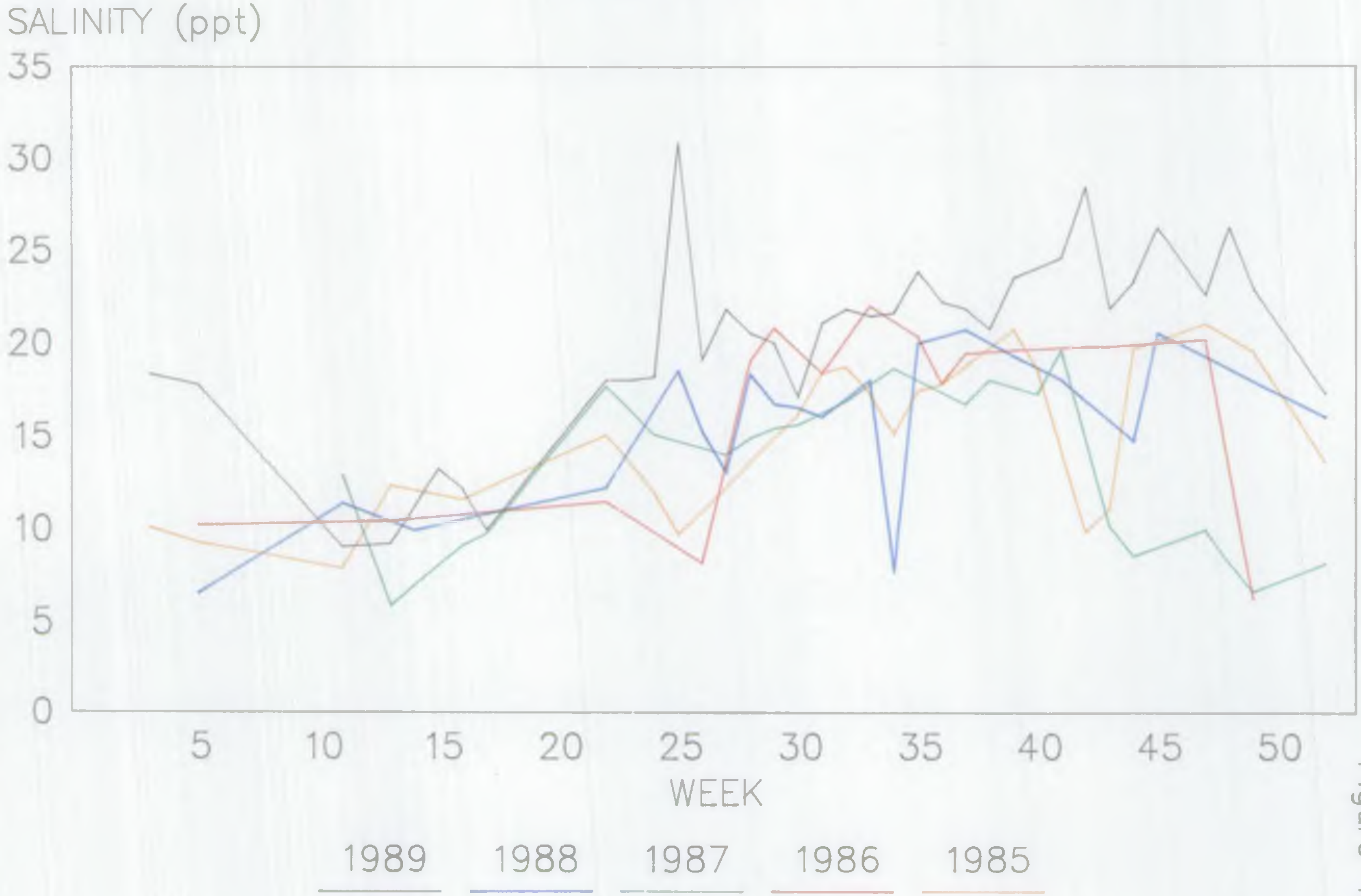


Figure 15

5. **ENVIRONMENTAL QUALITY STANDARDS**

The Environmental Quality Standards for the Thames Estuary can be found in Appendix A. The 1989 results compared with these standards are outlined below.

5.1. Upper Estuary, Teddington to Battersea

The guideline biological standard of a self supporting dace fishery is achieved by the presence of dace of the year at all four sites in this part of the estuary.

5.2. Mid Estuary, Battersea to Mucking

Only 8 fish species were found in the sample taken from West Thurrock on the 20th July. This is below the minimum of 9 species suggested in the biological standard for this part of the estuary.

5.3. Outer Estuary, Mucking to Sea Reach No.1

No standard has yet been set for the Outer Estuary, however, the samples taken suggest that the objective of "a marine fishery consistent with the physical characteristics of the estuary" is being achieved.

6. THE FUTURE

6.1. Sampling

Seine netting, beam trawls and cooling water intakes are widely used as methods for monitoring estuarine fish populations and they have proved useful to date in providing valuable semi-quantitative data on the tidal Thames. However, these techniques do have limitations. The use of a commercial beam trawler and associated equipment during 1989 necessitated the use of nets of a large mesh size and was therefore likely to be selective for larger fish whilst, conversely, the cooling water intakes at West Thurrock are likely to be selective towards smaller fish. In addition to this, the number of samples taken in the upper estuary was so limited that accurate deductions could not be made.

For a complete picture of the fish community in the estuary, data should be collected from a number of sites by the same quantifiable technique. Perhaps the best way of collecting quantitative data at present is by monitoring the fish entrapped on the cooling water intake screens at West Thurrock, but this technique cannot be extended to cover other parts of the estuary due to the lack of suitable water intakes.

The obvious alternative to the above is to undertake a trawling programme throughout the length of the estuary. The results from a number of different trawling techniques are inherently difficult to compare. A single technique needs to be standardised on if possible. Trials by the Biology Section using a Lowestoft Frame Trawl supplied by the MAFF Fisheries Laboratories in Lowestoft have proved successful in sampling the fish populations in both the mid and outer estuary. With some minor alterations to the equipment quantitative samples could be obtained from sites throughout the estuary.

It is anticipated that sampling in the mid and outer estuary using this new technique will begin in the first quarter of 1991. Sampling in the upper estuary will begin once a suitable sampling vessel has been found. It is important that this sampling should continue at sites along the estuary at regular intervals to allow spatial and temporal comparisons to be made with any accuracy.

6.2. Data Storage

Analysis of the data is made much easier by efficient storage. If resources will allow, a simple PC database will be constructed for the storage of past and future results.

6.3. Analysis of Data

A major difficulty in interpreting the results is quantification of natural and pollution derived changes on the population. Andrews (1984) has suggested cluster and principle components analysis as possible solutions to this problem. The use of various statistical analyses to aid interpretation should therefore be examined.

TIDEWAY OBJECTIVES AND INTERIM STANDARDS

Reach	Quality Objective	Chemical Standard (See notes 1 and 3)	Biological Standard(Guideline
Teddington to Battersea (Estuary freshwater, EF)	Passable to migratory fish. Maintenance of a coarse fishery within the physical constraints of the estuary. Aesthetically pleasing appearance.	In any quarterly period the dissolved oxygen value to exceed 40% sat for 80% of the time and 10% sat for 95% of the time at all points. Minimum DO 5% sat. Maximum temperature 28°C. Compliance with the requirements of EC Directives as laid down in the appropriate Statutory Instruments.	Self supporting dace fishery as indicated by presence of fish of the year. BMWP score greater than 25.
Battersea to Mucking (Estuary euryhaline, EE)	Passable to migratory fish. Maintenance of a euryhaline fish population consistent with the physical characteristics of the estuary. Maintenance of a commercial eel fishery. Aesthetically pleasing appearance.	In any quarterly period the dissolved oxygen value to 30% sat. for 80% of the time and 10% sat. for 95% of the time at all points. Min. DO 5% sat. Max. temperature 28°C. Compliance with the requirements of EC Directives as laid down in the appropriate Statutory Instruments.	Minimum of 9 species of fish to be idenfied during West Thurrock surveys. Data from commercial eel returns to be examined as a potential future standard.
Mucking to Seaward Limit (Estuary Marine, EM)	Passable to migratory fish. Maintenance of a marine fishery consistent with the physical characteristics of the estuary. EC Designated Bathing Beaches to be satisfactory. Aesthetically pleasing appearance.	In any quarterly period the dissolved oxygen value to 60% sat. 80% of the time and 10% sat. for 95% of the time at all points. Min. DO 5% Maximum temperature 28°C. Compliance with the requirements of EC Directives as laid down in the appropriate Statutory Instruments.	Suitable standards to include measure of commercial fish catches and protection of marine nursery grounds to be evolved over the next 2 years.

Notes:
1. Dissolved oxygen to be assessed from automatic quality monitoring station data, half tide corrected.
2. The objectives and standards of creek waters are the same as those of the adjacent tideway.
3. Minimum DO and maximum temperatures may be exceeded by extreme natural events. They are set at the lethal limits to fish. Planning limits will be set within these limits to prevent both acute and chronic toxicity to aquatic life.

APPENDIX A

REFERENCES

ALABASTER, J.S. & LLOYD, R., 1980, Water Quality Criteria for Freshwater Fish. Pub.Butterworths. 127-142.

ANDREWS, M.J., 1984, Thames Estuary: Pollution and Recovery. Effects of Pollutants at the Ecosystem Level. Pub. John Wiley & Sons Ltd.

HENDERSON, A.R. & HAMILTON, J.D., 1986, The Status of Fish Populations in the Clyde Estuary. Proc. of Royal Society of Edinburgh, 90B, 157-170.

POMFRET, J.R., TURNER, G.S. & PHILLIPS, S, 1988, Beam Trawl Surveys as a Monitoring Tool in Polluted Estuaries in North-East England. J.Fish Biol.,33A, 71-77.

POXTON, M.G., 1987, Fishery Studies in the Estuary and Firth of Forth, Scotland. Proc. of Royal Society of Edinburgh, 93B, 495-508.

WHARFE, J.R., WILSON, S.R. & DINES, R.A., 1984, Observations on the Fish Populations of an East Coast Estuary. Marine Pollution Bulletin, 15,133-136.