NRA - Water Quality 40

LIST II METALS

EVALUATION OF STANDARDS USING FIELD DATA

NATIONAL RIVERS AUTHORITY

FINAL REPORT

OCTOBER 1993

acer ENVIRONMENTAL

LIST II METALS

EVALUATION OF STANDARDS USING FIELD DATA

NATIONAL RIVERS AUTHORITY

FINAL REPORT

OCTOBER 1993

Acer Environmental
Howard Court
Manor Park
Runcorn
Cheshire
WA7 1SJ

SUMMARY

It has been proposed that the first Statutory Water Quality Objectives for rivers are to be based on Fisheries Ecosystem Use Classes and EC Directives. The Fisheries Ecosystem Use Classes will incorporate standards for List II metals, namely zinc, copper, chromium, lead, nickel and arsenic. The objective of this investigation was to compare a set of recently revised standards for List II metals against the data derived in the field in order to assess if the revised standards are both practical and ecologically relevant.

Data on List II metal concentrations, water hardness, and biological scores were provided by the NRA regions for the years 1990 and 1991. Fisheries information was also provided wherever possible. The data were incorporated into an appropriate electronic database in order to facilitate manipulation and statistical analysis. The final database comprised data from 1311 monitoring sites resulting in over 1800 individual records. In addition to metal and biological data, each record identified pass/fail for the metal variables against four sets of standards: the 'existing' EQSs in DoE Circular 7/89 (both salmonid and cyprinid standards), 'proposed' EQSs and Fisheries Directive standards.

In terms of pass/fail rates, there were comparatively few failures against any of the standards for dissolved arsenic, dissolved lead and dissolved nickel. Although the results for dissolved chromium and dissolved copper in low hardness waters indicated substantial failure rates, inadequate analytical detection limits for these parameters in 1990 and 1991 did not allow for 'real' failure rates to be properly assessed. In relation to zinc, the failure rates appeared to be significantly increased with the 'proposed' EQSs for water hardness bands 51-100 and 101-150 mg/l $CaCO_3$, when compared with the corresponding 'existing' EQSs. There were insufficient data on dissolved zinc with which to evaluate the impact on pass/fail rates of standards set in terms of dissolved compared to total zinc.

There has been concern that the 'proposed' EQSs for some of the metals in low hardness waters may be too stringent. In order to assess the distribution of ecological quality between the pass groups and the fail groups, the results for pass/fail were further broken down into four classes of biological quality based on BMWP.EQI values and six classes of fisheries quality.

Prior to assessing any correlations between metal and biological variables, pairs of variables were checked in order to compare the distribution of data omitted from plots (i.e., for some monitoring sites, there were no data for one of the variables in question) with the data remaining (i.e., monitoring sites for which data on both variables were available). Differences between the groups of data were noted; biological status was apparently poorer at sites for which there were no metal data compared with sites for which metal data were available, and metal concentrations were generally higher at sites for which no biological information was available compared to sites for which biological information was available.

For determining associations between metals and biology, the database was divided into six sections based on the water hardness bands contained within the 'existing' EQS structure. Within each hardness band, the datasets for BMWP score, BMWP.EQI, No. of Taxa and No. of Taxa.EQI and fisheries ranking were tested for an association with each of the metal variables. By dividing the analysis into six sections of different water hardness and including BMWP.EQI as a variable, the effect of water hardness on biological quality and metal toxicity was thus taken into account. Although the Pearson correlation indicated many significant associations, examination of the scatter plots revealed that outliers within the datasets appeared to be a major influence on the correlations. There were few plots for which there was strong evidence for any association between List II metals and biological status below metal concentrations of 100 μg/l.

As a consequence of the large number of confounding factors that influence List II metal concentrations and biological status in freshwater, coupled with limitations of the data available, the results of this investigation were interpreted cautiously. The tentative findings of the study were that:

(i) there was some evidence to suggest that the 'proposed' EQS for dissolved zinc in low hardness waters may be too stringent;

(ii) there was some evidence that the 'proposed' EQS for zinc in high hardness waters may not be sufficiently stringent; and

(iii) there was some evidence to suggest that the 'proposed' EQSs for dissolved copper, particularly in low hardness waters may be too stringent. However, this evidence should be reviewed when data based on improved analytical detection limits are available.

It is suggested that more elaborate statistical techniques could be applied to the data in order to further elucidate any underlying relationships. Moreover, extension of the database to include more recent data, particularly data for sites with higher metal concentrations and poorer biological status, could also be useful in verifying these results and assisting in identifying further relationships not detected by the existing dataset.

It is also suggested that in deriving standards for List II metals that apply to each of the six levels within the Fisheries Ecosystem Use Classes scheme, consideration should be given to the application of specific 'relaxation' factors. Factors may be calculated based on expected ecological quality and pass/fail rates for different water quality classes.

Consideration should be given to funding research on the mechanism of zinc toxicity with particular reference to the roles of total and dissolved zinc in effects on fish and other aquatic life.

CONTENTS

LIST OF FIGURES AND TABLES

FIGURES

Appendix 3

TABLES

Appendix 1

Comparison of Missing Values with Values Remaining:
List II Metals and BMWP Score

1.0 BACKGROUND

The Secretary of State has been empowered under the Water Act (1989) and the subsequent provisions in the Water Resources Act (1991) to define Statutory Water Quality Objectives (SWQOs).

At present, water quality is maintained using an informal system of River Quality Objectives (RQOs). The specification of RQOs was first suggested following the publication of a consultation paper by the National Water Council in 1977 entitled 'River Water Quality - The Next Stage - Review of Discharge Consent Conditions'. In addition, an informal biological classification system known as the Biological Monitoring Working Party (BMWP) score[1], utilising score values for individual aquatic animal families, has been used to reflect the quality of watercourses.

Rivers and canals are currently classified as good [1A and 1B], fair [2], poor [3] and bad [4]. Waters classified as good are suitable for potable supply abstractions, game and high class fisheries and have high amenity value.

A consultation paper issued by the National Rivers Authority (NRA) in 1991 entitled 'Proposals for Statutory Water Quality Objectives'[2] proposed that the informal water quality objectives described above be replaced by a new classification system which would form the basis for setting new SWQOs. Following a consultation period, 'Recommendations for a Scheme of Water Quality Classification for Setting Statutory Water Quality Objectives'[3] was presented to the Department of Environment (DoE) in October 1992. In December 1992, the DoE/Welsh Office published a consultation paper on 'River Quality'[4] drawing together the NRA's proposals and recommendations made by the Royal Commission on Environmental Pollution in its Sixteenth Report on Freshwater Quality[5]. The proposed statutory scheme takes into consideration water end-use, requirements of EC directives and timescales for implementation.

It is currently intended that existing RQOs will remain in place during the phased introduction of SWQOs. It is proposed that the statutory scheme be based upon Use Classes such as Fisheries Ecosystem Use Classes and EC Directives. The standards proposed aim to provide a broad, chemical assessment as an indicator of water quality.

The first proposals for WQOs are to be based on the Fisheries Ecosystem Use Classes as DoE considers these to be the most developed. In parallel to the description for each of the six Fisheries Ecosystem Use Classes shall be values for dissolved oxygen (DO), biochemical oxygen demand (BOD), total ammonia, un-ionised ammonia, pH and List II metals (Table 1).

The NRA is committed to developing and practically applying ecologically relevant standards for List II metals. In this regard, a limited study was carried out by the NRA on the effect of incorporating a set of 'proposed' standards for List II metals into the Fisheries Ecosystem Use Classes scheme. Based on field data gathered from sites with low pH, low hardness and naturally elevated metal concentrations, the study suggested that a set of 'proposed' freshwater standards for List II metals (largely based on laboratory-derived toxicity and bioaccumulation data) would result in a significant apparent downgrading of fishery status if adopted into the Fisheries Ecosystem Use Classes scheme. The NRA therefore sought a detailed investigation of field data for List II metals in order to validate the 'proposed' standards.

Terms of reference for this project were outlined in a letter by Dr Mark Everard (3 March 1993, ref: ME/EAB/1118). Acer Environmental's quotation (SB-EDA-0545-01) was subsequently accepted.

Table 1. Fisheries Ecosystem Use Classes

Class	DO	BOD	TOTAL NH_3	NH_3	pH	LIST II METALS	DESCRIPTION
1	80	2.5	0.2	0.021	6-9		Water quality suitable for high class salmonid and cyprinid fisheries
2	70	4.0	0.6	0.021	6-9		Water quality suitable for sustainable salmonid and high class cyprinid fisheries
3	60	6.0	1.3	0.021	6-9		Water quality suitable for high class cyprinid fisheries
4	50	8.0	2.5	-	6-9		Water quality suitable for sustainable cyprinid fisheries
5	20	15.0	9.0	-	-		Some species may be present
6	<20	-	-	-	-		Fish unlikely to be present

DO	% saturation dissolved oxygen 10% ile
BOD	BOD (ATU) mg/l 90% ile
TOTAL NH_3	total ammonia mg N/l 90% ile
NH_3	un-ionised ammonia mg N/l 95% ile
pH	95% ile

(Extract from Annex A of DoE/Welsh Office proposals on River Quality[4])

2.0 INTRODUCTION

2.1 Environmental Quality Standards (EQSs)

The **Dangerous Substances Directive** (76/464/EEC)[6] is a 'parent' directive and sets the framework for the elimination or reduction of pollution of inland, coastal and territorial waters by particular dangerous substances. Two lists of substances are provided in the Directive. List I substances includes substances selected on the basis of their toxicity, persistence and bioaccumulation. List II substances includes potentially less dangerous substances. All dangerous substances are classified as List II until a 'daughter' directive sets limit values.

The Water Resources Act (1991) incorporates the Directive into law. The requirements of Directive 76/464, together with certain daughter directives, were first given effect by means of Circular 18/85 issued by DoE to the then Water Authorities in September 1985. This has been superseded by Circular 7/89[7] which updated and added to the previous advice.

The Directive requires Member States to *eliminate pollution* by the dangerous substances in List I. All discharges likely to contain List I substances must be authorised, and an emission standard laid down. The Surface Waters (Dangerous Substances)(Classification) Regulations (1989) implement the various EC daughter directives relating to inputs of specific List I substances to inland, coastal and territorial waters.

Member States are also required to *reduce pollution* of waters by List II substances. The emission standards are based on quality objectives and are set nationally, but must, where appropriate, take account of water quality standards laid down in other EC directives.

The DoE Circular (7/89) included EQSs for a group of List II metals namely zinc, copper, arsenic, chromium, lead and nickel. Different standards were published for the protection of sensitive aquatic life (e.g. salmonid fish) and protection of other aquatic life (e.g. cyprinid fish). As the aquatic toxicity of five of the six metals (arsenic being the exception) appeared to vary depending on water hardness, a range of standards was documented, specific values being listed for different bands of water hardness (see Table 2). The standards for List II metals published in this Circular were largely based upon reviews carried out in the early 1980's by the Water Research Centre (WRc).

More recently, the DoE contracted WRc to review, in the light of recent data, the applicability of these 'existing' EQSs for List II metals. As is traditionally the case in assessing the toxicity of substances, both the initial evaluation and the recent review focused largely on laboratory-derived toxicity and bioaccumulation data. The reports were completed in 1992/1993 [8-13] and proposed a number of changes to the EQSs.

Points of particular note with respect to the 'proposed' EQSs are:

(i) zinc is listed as dissolved zinc as opposed to total zinc;

(ii) the separate standards for 'protection of other aquatic life (e.g. cyprinid fish)' have been eliminated;

(iii) there is a reduction in the number of hardness bands with respect to zinc, nickel and chromium;

(iv) there are no changes to the existing salmonid standards for lead and arsenic;

(v) standards for chromium, zinc, copper and nickel have become more stringent.

A summary of the 'proposed' EQSs is presented in Table 3.

2.2 Fisheries Standards

The **Freshwater Fisheries Directive** (78/659/EEC)[14] requires Member States to designate freshwaters needing protection or improvement in order to support fish life. Two categories of water are designated; salmonid (salmon, trout, grayling and whitefish) and cyprinid waters (coarse fish, pike, eel, etc.).

The United Kingdom initially implemented the Directive through administrative action using a number of existing Acts, predominately the Control of Pollution Act (1974). However, this EC Directive was also first formally incorporated into UK legislation under the Water Act (1989) and the subsequent corresponding provisions in the Water Resources Act (1991).

The two metals included in the Directive are total zinc and dissolved copper. At a water hardness of 100 mg/l $CaCO_3$, the Directive specifies imperative values of <0.3 mg/l and <1.0 mg/l for 'total zinc' in salmonid waters and cyprinid waters, respectively. A guide value of <0.04 mg/l 'dissolved copper' is specified for both salmonid and cyprinid waters at a water hardness of 100 mg/l $CaCO_3$. An imperative value is not documented. For water hardness levels between 10 and 500 mg/l $CaCO_3$ corresponding limit values for total zinc and dissolved copper are also listed (Tables 4 and 5). In terms of zinc and copper, the designated waters are deemed to comply with the provisions of the directive if 95% of samples within an effective monitoring programme comply with the values specified.

2.3 Monitoring Data

In order to validate the 'proposed' EQSs using experience gained in the field, it was necessary to compare the concentrations of List II metals measured in watercourses with suitable biological measurements taken at the same, or nearby, sites.

Under the terms of the Dangerous Substances Directive, the Freshwater Fisheries Directive, and other schemes (e.g. UK Red List), NRA monitor a large number of freshwater watercourses in England and Wales for metal contaminants. It was considered that this extensive dataset would be appropriate for use in the study.

In 1990 and 1991, NRA undertook a substantial monitoring exercise in which large numbers of watercourses were sampled for invertebrates. Generally, each site was sampled on three occasions (seasons) in a given year, the number and type of invertebrate families present being recorded. The total number of families present (**No. of Taxa**) at each site in a given year was assessed by taking the number of families recorded on the first sampling occasion and adding any 'new' families observed on subsequent sampling occasions in that year.

Each family was given a score between 1 and 10 based on its sensitivity to pollution, a higher score indicating higher sensitivity. The sum of the scores for the families identified at a site is the Biological Monitoring Working Party **(BMWP) Score**. Dividing the BMWP score by the number of families present gives the **Average Score Per Taxon (ASPT)**.

The actual scores obtained for each site were compared with theoretical scores derived from the RIVPACS (River Invertebrate Prediction and Classification Scheme) model. RIVPACS predicts scores for a given watercourse taking into account a number of physical, chemical and hydrological factors. The index of actual score/predicted score **(BMWP.EQI, No. of Taxa.EQI, ASPT.EQI)** gives an indication of the water quality/pollution status of a watercourse. EQIs of between 0.75 and 1.0 indicate satisfactory water quality. As values drop below 0.75, progressively poorer water quality is indicated.

These invertebrate data are the most comprehensive biological monitoring data available for watercourses in England and Wales and hence were considered to be key criteria for comparison with the monitoring data on metal concentrations.

NRA regions also assess fisheries status of selected watercourses. However, there is no formally agreed procedure for monitoring, assessing and classifying fisheries status within the NRA and hence the number and content of monitoring programmes varies widely from region to region. Despite the difficulties of interpreting such disparate data, it was considered that fisheries status was a fundamental biological parameter and hence should also be included in the study.

Table 2. National Environmental Quality Standards for List II Metals

		Lead	Chromium	Zinc	Copper	Nickel	Arsenic
WRC Report Ref. Nos		TR208	TR207	TR209	TR210	TR211	TR212
Freshwater							
	Total hardness (as mg/l $CaCO_3$)						
Protection of sensitive aquatic life (eg salmonid fish)	0-50	4AD	5AD	8AT(30P)	1AD(5P)	50AD	50AD
	50-100	10AD	10AD	50AT(200P	6AD(22P)	100AD	50AD
	100-150	10AD	20AD	75AT(300P)	10AD(40P)	150AD	50AD
	150-200	20AD	20AD	75AT(300P)	10AD(40P)	150AD	50AD
	200-250	20AD	50AD	75AT(300P)	10AD(40P)	200AD	50AD
	250+	20AD	50AD	125AT(500P)	28AD(112P)	200AD	50AD
Protection of other aquatic life (eg cyprinid fish)	0-50	50AD	150AD	75AT(300P)	1AD(5P)	50AD	50AD
	50-100	125AD	175AD	175AT(700P)	6AD(22P)	100AD	50AD
	100-150	125AD	200AD	250AT(1000P)	10AD(40P)	150AD	50AD
	150-200	250AD	200AD	250AT(1000P)	10AD(40P)	150AD	50AD
	200-250	250AD	250AD	250AT(1000P)	10AD(40P)	200AD	50AD
	250+	250AD	250AD	500AT(2000P)	28AD(112P)	200AD	50AD
Saltwater							
Protection of saltwater life		25AD	15AD	40AD	5AD	30AD	25AD

All metal values given as μg/l.

A = annual average
P = 95 per cent of samples
D = dissolved
T = total

(Taken from DoE/Welsh Office Circular 7/89[7])

Table 3. Proposed Environmental Quality Standards for List II Metals

		Lead	Chromium	Zinc	Nickel	Arsenic
WRc Report Ref. Nos		2718-M/1	2858-M/1	2686/1	2685/1	2633/1
Freshwater	*Total hardness (as mg/l $CaCO_3$)*					
	0-50	4	2	8	8	50
	50-150	10	10	15	20	50
	>150	20	20	50	40	50
Saltwater		10	5	10	15	25

Table 3 Cont.

		Copper
WRc Report Ref. No		2986/1
Freshwater	*Total hardness (as mg/l $CaCO_3$)*	
	<50	0.5
	51-200	3.0
	201-250	8.0
	>250	12.0
Saltwater		5

All annual averages, dissolved metal
All metal values given as µg/l

(Extracted from WRc report series)

Table 4. Fisheries Directive Values For Total Zinc (Imperative)

	Water hardness (mg/l $CaCO_3$)			
	10	50	100	500
Salmonid waters (mg/l Zn)	0.03	0.2	0.3	0.5
Cyprinid waters (mg/l Zn)	0.3	0.7	1.0	2.0

Table 5. Fisheries Directive Values for Dissolved Copper (Guide)

	Water hardness (mg/l $CaCO_3$)			
	10	50	100	300
mg/l Cu	0.005	0.022	0.04	0.112

(Extracted from directive 78/659/EEC[14])

3.0 OBJECTIVES

The requirements of the NRA with regard to the proposed research were outlined in the letter of 5 March 1993 (ref: ME/EAB/1118).

The objectives may be summarised thus:

The investigation shall compare a set of revised EQSs for List II metals recently prepared by WRc against the data derived in the field. The study will identify those stretches of watercourses that do not comply with the revised EQS values. For those watercourses that do not comply, the data for List II metals will be compared with the biological data on water quality to assess if there are any relationships. Such investigations will help to assess the validity of EQSs based on laboratory research when compared with the experience obtained in the field.

4.0 DATA AVAILABLE: DESCRIPTION AND ASSUMPTIONS

?

Data were received from the NRA regions/in various forms, including a range of electronic formats, hard copy, scribbled notes etc. Compilation of the data into a structured database proved to be a difficult and time consuming task.

Table 6 outlines, by region, the numbers of sites for which data have been entered into the database. It can be seen that numbers of sites were not spread evenly across the regions. Given that regions have different patterns of water quality, water hardness etc., the uneven distribution of sites is likely to have introduced some bias into the dataset (see chapter 5).

4.1 Chemical Data

The determinands of interest were as follows:

Total	Zinc	(T Zn)
Dissolved	Zinc	(D Zn)
Dissolved	Copper	(D Cu)
Dissolved	Chromium	(D Cr)
Dissolved	Lead	(D Pb)
Dissolved	Nickel	(D Ni)
Dissolved	Arsenic	(D As)

Metal monitoring data were requested from all regions for the years 1990 and 1991. From the raw data, values for **n** (number of data points), **mean**, **standard deviation** (σ_{n-1}) and 95 **percentiles** were calculated for each metal determinand at each site. Values for 1990 and 1991 were calculated separately. These data were incorporated into the database, each year for each site representing an individual record.

If the number of data points for an individual determinand in a given year was fewer than three, an annual mean was not calculated. In these cases, no values were incorporated into the database.

Less than values (<) were taken as half of the face value, i.e. <10 µg/l was assumed to be 5 µg/l.

Table 6. Breakdown by Region of Numbers of Monitoring Sites Included in the Database

REGION	CHEMICAL DATA Number	1990	1991	HARDNESS DATA Number	1990	1991	BIOLOGICAL DATA Number	1990	1991	FISHERIES DATA Number
ANGLIAN	54	✓	✓	4	✓	✓	49	✓	✓	41
NORTHUMBRIAN	10	✓	✓	10	✓	✓	10	✓	x	2
NORTH WEST	17	✓	✓	17	✓	✓	17	✓	x	16
SEVERN TRENT	61	✓	✓	57	✓	✓	40	✓	x	59
SOUTHERN	27	✓	✓	17	✓	✓	27	✓	✓	27
? SOUTH WEST	788	✓	x	788	✓	x	397	✓	x	24
THAMES	115	✓	✓	114	✓	✓	90	✓	x	57
WELSH	173	✓	✓	173	✓	✓	147	✓	x	79
WESSEX	12	✓	✓	0	✓	✓	8	✓	x	9
YORKSHIRE	54	✓	✓	51	✓	✓	37	✓	x	32

What are the implications of this large data set for S West?

✓ data included for that year
x no data included for that year

∴ Does this mean they excluded it?

Raw data were checked for nine of the ten regions, during which some discrepancies/errors were noted:

(i) for raw data points documented as less than a limit of detection, those values that had clearly been recorded wrongly (e.g. <0.002 μg/l as opposed to <2 μg/l) were omitted from the calculation of annual mean;

(ii) in cases where detection limits had changed substantially in a given year resulting in a significant effect on the annual mean, the earlier values (i.e. at the less sensitive detection limit) were omitted from the calculation of annual mean. For example, with a dataset reading <100, <100, <100, <100, 5, 3, 2, 7, etc., the four earlier values were omitted;

(iii) any notably high data values were included in the calculations as it could not be assumed that these were errors.

X The data for South West region were received in the form of pre-calculated n, mean and variance values and hence raw data were not checked. Standard deviation values were subsequently calculated from the variance.

The coverage of the sites with respect to metal data usually followed one of two patterns: (i) data available for total zinc and dissolved copper only; (ii) data available for all metals. There were relatively few data available on dissolved zinc.

With respect to South West region, all metal determinands were reported as 'totals'. It is understood that this region assesses its compliance with EQSs solely on the basis of 'total' metals as a result of difficulties encountered with measuring 'dissolved' metals in low hardness waters. For the purposes of this study, the metal data from South West region for copper, chromium, nickel, lead and arsenic were assumed to be as 'dissolved' metal.

Water hardness was a key parameter in this investigation and hence hardness data were sought wherever possible. For the majority of chemical monitoring sites, hardness data were available, mean values being calculated separately for 1990 and 1991. Although Anglian region could provide hardness data for only 4/54 sites, following advice from the region, it was agreed that the remaining sites would be classified within the high hardness band. An arbitrary value of 305 mg/l $CaCO_3$ was therefore incorporated into the database in the case of these sites. For Southern region, hardness data were provided for 17/27 sites in the form of pre-calculated values, 1900 and 1991 data having been combined to give a single value for each of the sites. In these cases, the specified value for each site was employed in both the 1990 and 1991 records. The remaining 10 sites were classified as either of moderate hardness (105 mg/l $CaCO_3$) or of high hardness (255 mg/l $CaCO_3$) following advice from the region.

4.2 Biological (Macroinvertebrate) Data

The parameters of interest were:

BMWP score	BMWP.EQI
ASPT	ASPT.EQI
No. Taxa	No. Taxa.EQI

Almost all the data incorporated into the database were extracted from the National Database for 1990. For only two regions were 1991 data readily available. should have been!

In terms of extracting data from the 1990 National Database, the task proved to be a difficult one as chemical monitoring site identifiers and biological monitoring site identifiers were different. Matching of chemical monitoring sites with appropriate biological monitoring sites could only be achieved by regions providing cross reference lists.

The data extracted from the 1990 National Database appeared to be comprehensive in that all six parameters of interest were always available for each biological monitoring site that had been matched to a chemical monitoring site.

Many biological monitoring sites were not matched with chemical monitoring sites. The un-matched biological monitoring sites were not incorporated into the database.

4.3 Fisheries Data

A requirement of this study was to assess fisheries status of given sites in order that fisheries ranking could be compared with measured metal concentrations at those sites. In the absence of a generally recognised scheme for classifying fisheries status, it was therefore necessary to develop a methodology specifically for the purposes of this project.

The extent and variety of the fisheries information provided by NRA regions was the most variable of the datasets. The data ranged from anecdotal notes to lists of species present, to numbers of individuals, total biomass data, separate biomass data for salmonids and cyprinids, separate biomass data for fry and parr, density data, and so on. The nature of the data was the key limiting factor in developing a classification/ranking scheme.

In order to indicate the status of a fisheries site by a simple numerical value it was thought appropriate to utilise the class descriptions as laid down in the proposed Fisheries Ecosystem Use Classes scheme (see Table 1). Sites were therefore ranked as either Class 1, 2, 3, 4, 5 or 6; Class 1 indicating high quality salmonid fishery and Class 6 indicating no fish present.

To facilitate classification of sites, some general guidelines were applied (Table 7). The guidelines were developed following discussion with a number of fisheries specialists within the NRA.

If more than 1 years data were available for a site, the data were averaged. Any data earlier than 1985 were rejected. In matching fisheries sites with metal monitoring sites, any fisheries data for a site more than 10 Km from the matched metal monitoring site were rejected.

It must be emphasised that the approach used was not intended to imply a comprehensive, scientifically precise, assessment of the fisheries status of a watercourse. Its object was to apply a relatively simple classification scheme to a disparate dataset solely for the purposes of this investigation. The limitations of the fisheries data were such that the fisheries rankings incorporated within the database should be interpreted with caution.

Table 7. Guidelines Employed in Classification of Fisheries Status

Class	Biomass ($g\ m^{-2}$)		Number of Species	
	Salmonid	Cyprinid	Salmonid	Cyprinid
1	> 15	-	> 0 very good	-
2	> 1 - 15	-	any	-
3 or	> 0 - 1	-	any	-
3	0	> 20	0	> 2 + > 2 good or very good
4	0	> 10 - 20	0	>2 + 1 very good
5	0	> 0 - 10	0	1 - 3 poor to fair
6	0	0	0	0

5.0 SUMMARY STATISTICS

Once completed, the database was imported into a statistical package, UNISTAT version 4.7 for DOS.

A summary of the descriptive statistics for the entire database is presented in Table 8. 'Size' refers to the number of records in the database containing data on a particular parameter. (Note: each site for which both 1990 and 1991 data were available appears as two records within the database).

Skewness and kurtosis refer to the distribution of the data. Values for skewness and kurtosis of less than 2 generally indicate that the data are normally distributed. As can be seen for these data, the data for the biological variables appear to be normally distributed but the data for the chemical variables are not. The data for total zinc, dissolved copper, dissolved lead and dissolved nickel were not normally distributed even after log transformation. In these cases it was therefore necessary to use non-parametric statistical tests.

The minimum and maximum values reported in Table 8 were used to check for outliers. Any input/coding errors identified were eliminated.

5.1 Missing Data

Prior to evaluating any associations between metals and ecological quality it was important to consider the distribution of the datasets with particular reference to missing data. As records within the database often contained missing data, pairs of variables were checked in order to compare the distribution of values that would be omitted from a plot with the distribution of values that would be included in a plot.

For example, in plotting the dataset for total zinc against BMWP score there were three sets of data:

(i) a dataset containing sites for which values for both total zinc and BMWP score were available (i.e. sites for which T Zn > 0 and BMWP > 0);

(ii) a dataset containing sites for which there were no total zinc data but BMWP scores were available (i.e. sites for which T Zn = 0 and BMWP > 0);

(iii) a dataset containing sites for which total zinc data were available but BMWP scores were not available (i.e. sites for which T Zn > 0 and BMWP = 0).

Table 8. Distribution Characteristics of Dataset

	Mean Hard.	Mean T Zn	Mean D Zn	Mean D Cu	Mean D Cr	Mean D Pb	Mean D Ni	Mean D As	BMWP	ASPT	Taxa	BMWP .EQI	ASPT .EQI	No. of Taxa .EQI	Fish.
Size	1779	1749	275	1593	1202	1191	1193	750	908	908	908	908	908	908	673
Mean	154.1	78.1	53.7	11.4	2.5	5.6	8.1	5.3	166.0	5.64	28.3	0.87	0.95	0.89	3.07
Median	105	13.3	18.5	3.4	1.2	2.5	3.4	5	179.5	5.9	30	0.94	0.99	0.94	3
Standard Error	3.25	10.49	11.5	1.34	0.15	1.16	1.29	0.32	2.18	0.035	0.29	0.011	0.0045	0.0088	0.057
Minimum	3.47	0.62	2.31	0.81	0.25	0.25	0.09	0.25	3	1.5	1	0.016	0.26	0.03	1
Maximum	1548.6	9999.9	2465	1024.8	129.2	1249.8	1472.5	190.8	304	7.3	47	1.77	1.2	1.72	6
Skewness	2.59	14.1	9.85	11.99	15.6	26.3	29.8	13.5	-0.56	-0.81	-0.76	-0.49	-1.45	-0.70	0.34
Kurtosis	17.4	256.2	110.8	168.7	325.1	782.4	971.1	260.6	-0.58	-0.052	-0.17	0.048	2.45	0.59	-1.0
	RESULT OF LOG_{10} TRANSFORMATION OF DATA														
Skewness	-	1.69	0.99	2.23	0.98	1.84	1.24	-0.16	-	-	-	-	-	-	-
Kurtosis	-	4.05	1.68	7.54	1.67	10.4	3.89	0.8	-	-	-	-	-	-	-

Hence, in plotting total zinc against BMWP, the subsets contained within (ii) and (iii) would be omitted. It was therefore essential to compare the distribution of the two subsets for total zinc from (i) and (iii), followed by comparison of the BMWP subsets from (i) and (ii).

During compilation of the database it was apparent that the biological variables No. of Taxa and ASPT were closely associated with BMWP score. Evaluation of missing data was therefore focused upon BMWP score, BMWP.EQI and fisheries ranking.

These biological variables were paired with each of the metal variables as described above. Normally distributed datasets were compared using a parametric statistical test (t-test) and non-normally distributed datasets were evaluated using a non-parametric test (Mann-Whitney).

The results of the analyses for List II metals/BMWP score and List II metals/Fisheries ranking are presented in Appendix 1 in Tables A1 to A14. The results for List II metals/BMWP.EQI are not reported as these were almost identical to the results for List II metals/BMWP score. It is usual to report normally distributed data as a mean and non-normally distributed data as a median. In the tables, P = Probability.

In terms of the data for List II metals/BMWP score and List II metals/BMWP.EQI it would appear that there were significant differences between many of the datasets. In general, the biological scores were significantly lower at sites for which there were no metal data compared with sites for which metal data were available. For metals, there were significant differences in the total zinc, dissolved zinc and dissolved copper datasets, metal concentrations being significantly higher at sites for which no BMWP scores were available compared with sites for which BMWP data were available.

Similarly, fisheries scores were generally lower at sites for which there were no metal data compared with sites for which metal data were available. List II metal concentrations were generally significantly greater at sites for which no fisheries data were available compared with sites for which fisheries data were available.

The results (see Figure 1) suggest that for sites for which there are both chemical and biological data, there may be a bias within the database against sites that have high metal concentrations and poorer biological status.

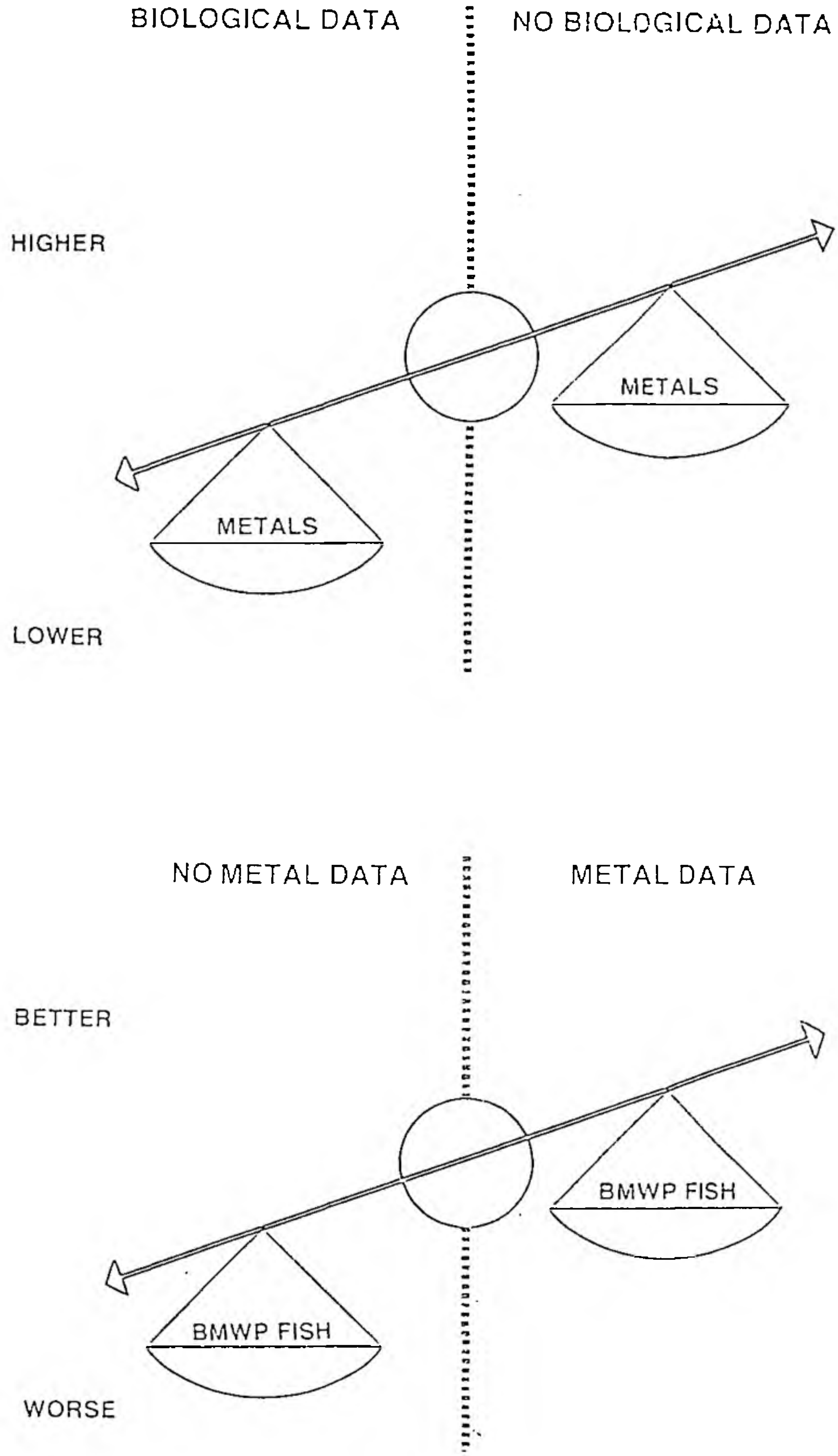


Figure 2 Distribution of Missing Data.

6.0 ANALYSIS OF PASS/FAIL RATES

The database was analysed for numbers of passes and fails with respect to:

(i) Existing EQSs (protection of sensitive aquatic life e.g. salmonid fish);

(ii) Existing EQSs (protection of other aquatic life e.g. cyprinid fish);

(iii) Proposed EQSs;

(iv) Fisheries Directive (salmonid) standards for total zinc and dissolved copper.

Each metal determinand in each record within the database was compared against the relevant standards taking into account the water hardness at the site and the hardness bands incorporated into the standards. The characters **P** (pass), or **F** (fail), or **N** (no data) were incorporated into the database in the appropriate fields.

The following assumptions were made:

(a) for the EQSs, it was assumed that a figure equal to the relevant standard represented a pass;

(b) the 'proposed' EQS for zinc is in terms of dissolved zinc, however, for comparative purposes, passes and fails were also accredited against total zinc values as if the 'proposed' EQSs for zinc had been set in terms of total zinc;

(c) with respect to the Fisheries Directive, 95 percentile values for total zinc and dissolved copper were compared with the appropriate standards for salmonid waters. The standards for total zinc and dissolved copper were interpreted as 95 percentiles according to the scheme described in Table 9.

Table 9. Interpretation of Fisheries Directive

Hardness (mg/l $CaCO_3$)	Total Zinc (µg/l)	Hardness (mg/l $CaCO_3$)	Dissolved Copper (µg/l)
0 - 10	< 30	0 - 10	< 5
11 - 50	< 200	11 - 50	< 22
51 - 100	< 300	51 - 100	< 40
101 - 500	< 500	101 - 300	< 112
> 500	< 500	> 300	< 112

It should be noted that in this investigation all sites were assessed for pass/fail against the fisheries standards i.e., not solely those sites that had been designated as fisheries within the meaning of the Directive.

The hardness bands contained within the structure of the 'existing' standards were chosen as the means of presentation of the data as this banding structure gave the most detailed breakdown of pass/fail results. The water hardness bands and the number of database records within each hardness band were as follows:

Hardness Band A	(0-50 mg/l $CaCO_3$)	393 records
Hardness Band B	(51-100 mg/l $CaCO_3$)	470 records
Hardness Band C	(101-150 mg/l $CaCO_3$)	229 records
Hardness Band D	(151-200 mg/l $CaCO_3$)	117 records
Hardness Band E	(201-250 mg/l $CaCO_3$)	102 records
Hardness Band F	(>250 mg/l $CaCO_3$)	468 records

In order to assess the distribution of ecological quality between the pass groups and the fail groups, the results for pass/fail were further broken down.

Biological quality was classified into four groups based on the following scheme:

Biological Class a	Percentage no. of sites with a BMWP.EQI score greater than 0.75
Biological Class b	Percentage no. of sites with a BMWP.EQI score ranging from 0.51 to 0.75
Biological Class c	Percentage no. of sites with a BMWP.EQI score ranging from 0.26 to 0.50
Biological Class d	Percentage no. of sites with a BMWP.EQI score less than or equal to 0.25.

Fisheries quality was broken down according to the six grades incorporated within the database (see Table 7).

Fisheries Class 1	Percentage no. of sites with a fisheries score of 1
Fisheries Class 2	Percentage no. of sites with a fisheries score of 2
Fisheries Class 3	Percentage no. of sites with a fisheries score of 3
Fisheries Class 4	Percentage no. of sites with a fisheries score of 4
Fisheries Class 5	Percentage no. of sites with a fisheries score of 5
Fisheries Class 6	Percentage no. of sites with a fisheries score of 6

The results of the pass/fail analysis and the breakdown of ecological quality are presented in Appendix 1 in Tables A15 to A21. Additionally, Table 10 summarises the pass/fail results with respect to the 'proposed' EQSs in terms of the specific water hardness bands designated for these standards.

Table 10. Pass/Fail Rates for 'Proposed' EQSs

	Hardness (0-50 mg/l)		**Hardness (50-150 mg/l)**		**Hardness (>150 mg/l)**	
	Pass	Fail	Pass	Fail	Pass	Fail
T Zn	150	234	391	287	553	101
D Zn	4	0	24	28	176	36
D Cr	158	152	540	7	310	5
D Pb	252	58	521	26	301	9
D Ni	293	17	515	32	297	15

Table 10 Cont.

	Hardness (0-50 mg/l)		**Hardness (51-200 mg/l)**		**Hardness (201-250 mg/l)**		**Hardness (>250 mg/l)**	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
D Cu	1	357	289	466	84	9	323	37

Hardness (mg/l $CaCO_3$)

The results of the pass/fail analysis indicate few failures against any of the four sets of standards in the case of dissolved arsenic, dissolved lead and dissolved nickel.

There were few failures for dissolved chromium against the 'existing' standards but failure rate was high in the low hardness band of the 'proposed' standards. However, the high failure rate may, in part, reflect inadequate analytical detection limits in 1990 and 1991 as opposed to 'real' failures. For example, 12 data points in a year, all documented as <10 μg/l, do not allow for effective comparison with a 'proposed' EQS of 2 μg/l. The assumption used in this investigation for estimation of annual average has resulted in the mean for the above being calculated as 5 μg/l, and therefore, a fail.

Significant failure rates were noted for dissolved copper in low hardness waters both with respect to 'existing' and 'proposed' standards. Once again, it is considered that inadequate analytical detection limits for copper in 1990 and 1991 may have had a significant impact on failure rates. These data for both copper and chromium in low hardness waters do not allow for an accurate analysis of failure rates.

In terms of the 'existing' standards, a high failure rate for total zinc was only observed for low hardness water in the case of the salmonid standard. When total zinc concentrations were compared against the 'proposed' EQSs, high failure rates were noted for the following hardness bands: 0-50 mg/l $CaCO_3$, 51-100 mg/l $CaCO_3$ and 101-150 mg/l $CaCO_3$. There were insufficient data on dissolved zinc with which to adequately assess failure rates against the 'proposed' EQSs.

6.1 Distribution of Ecological Quality Between Pass Groups and Fail Groups

There is concern that the 'proposed' EQSs for some of the List II metals, notably zinc and copper, may be too stringent. In order to address this issue, the distribution of ecological quality within the pass groups and their corresponding fail groups were examined. Clearly, if the standards were appropriate one would expect to see a much smaller proportion of sites with good biology in the failed groups compared with the pass groups.

Tables A15 to A21 in Appendix 1 describe the breakdown of ecological quality within the different pass and fail groups.

As biological data were not available for all sites, the numbers of sites on which the percentage breakdowns were based are also recorded. For example, in hardness band A, 151 sites passed the 'existing' EQS (salmonid) for total zinc. Of the 151 passing sites, biological data were available on 88 sites and fisheries data available for only 19 sites. The percentage breakdowns reflect the 88 sites and 19 sites, respectively.

Interpretation of the results of the ecological breakdown was not a straightforward matter. In particular, the occurrence of sites with poor biology in a given group does not necessarily imply that the metal in question was responsible for that poor biology, another factor may have been responsible.

Despite the limitations of the data and the confounding factors, the analysis does indicate some points of particular interest and these are listed below.

Total Zinc

The analysis for total zinc in hardness band A revealed that a high proportion of failed sites had good biology and fisheries status. This would suggest that the 'proposed' EQS of 8 μg/l may be too stringent. There is also evidence, though of a weaker nature, for a similar effect in hardness bands B and C. The failed groups for the 'proposed' EQSs in hardness bands D, E and F have a low proportion of sites with good biology and hence there is no evidence that the standards are too stringent.

Dissolved Zinc

Little could be gleaned with respect to dissolved zinc as few data were available.

Dissolved Copper

Given the influence of inadequate detection limits in low hardness waters, it was only appropriate to consider the results in hardness bands C to F. In general, it would appear that a more appropriate ecological breakdown was apparent with the 'existing' EQSs (salmonid) than the 'proposed' EQSs.

Dissolved Chromium

No interpretation could be made of the results from low hardness waters due to the influence of detection limits. In higher hardness waters the few failures recorded do not allow for an evaluation of the validity of the standards.

Dissolved Lead

In hardness band A the failed groups contained a high proportion of sites with good biology suggesting that the EQS for lead in low hardness water may be too stringent. There were insufficient failed sites in the other hardness bands with which to make an assessment.

Dissolved Nickel

There were too few failed sites for nickel and hence an assessment was not possible.

Dissolved Arsenic

Too few sites failed for arsenic for an assessment to be possible.

7.0 CORRELATIONS BETWEEN PARAMETERS

In order to test for relationships between List II metal concentrations and biological/fisheries quality, the data were divided into six hardness bands, A to F (as listed in Chapter 6) and analysed using an appropriate statistical technique. By dividing the database into six hardness bands and including BMWP.EQI as a variable, the effect of water hardness on biological quality and metal toxicity was thus taken into account.

Within each hardness band, the datasets for (i) BMWP score, (ii) BMWP.EQI, (iii) No.Taxa, (iv) No.Taxa.EQI and (v) fisheries ranking, were tested for an association with the datasets for each of the metal variables. ASPT and ASPT.EQI were not evaluated in detail as preliminary examination of the data revealed that the most significant associations were found with the other ecological variables.

In cases where there were significant numbers of metal failures against 'proposed' EQSs (>10 per metal variable within one hardness band) the failed metal subset was also tested for an association with each of the biological variables.

The statistical test used was the ***Pearson Correlation***. The aim of this test is to establish the degree of linear relationship between two variables. The Pearson correlation coefficient **r** is a measure of the scatter of points around an underlying linear trend. A value of 0 suggests that the two datasets have no association. Negative or positive **r** values can both indicate associations; **r** = +1 or **r** = -1 representing perfect correlations. The effect of outliers on correlations, however, may be considerable.

There are two assumptions necessary for a valid application of the Pearson test, the two variables should be observed on a random sample of data and the data for at least one of the variables should have a normal distribution. To calculate a valid confidence interval for the correlation coefficient, both variables should have a normal distribution.

Using the Pearson correlation coefficient, together with a visual inspection of the data (a scatter plot) was therefore considered to be the most appropriate method of assessing any relationship between metal and biological data.

The results of the Pearson Correlations are presented in Appendix 1 in Tables A22 to A28. In the tables, the symbol * indicates that there were insufficient data points on which to carry out an analysis (i.e., <10). p = probability, n = number of data points.

The tabulated results show many significant associations. The main points are summarised below:

(i) in general, the associations were better in the higher hardness bands compared with the lower hardness bands;

(ii) the associations between List II metals and the following biological variables: BMWP score, BMWP.EQI, No. of Taxa and No. of Taxa.EQI (and their corresponding scatter plots) were almost identical.

(iii) in general, the results for the 'failed' subsets were not significantly different from the corresponding results obtained with datasets containing both passes and fails.

All the scatter plots were subsequently examined. A selection of those found to be most significant and/or representative is included in this report in Appendix 2.

For the majority of those datasets for which significant correlations were obtained, the plots did not provide convincing evidence of such associations. Examination of these plots revealed that outliers within datasets appeared to be an important factor in the correlations obtained.

Plots and correlations that appeared to be of particular interest were:-

(a) An association between dissolved nickel and biology within hardness band D

The 'proposed' EQSs for nickel are 8 μg/l for hardness band A, 20 μg/l for hardness bands B and C, and 40 μg/l for hardness bands D, E and F. Although the plot in question suggests that nickel concentrations above 10 μg/l in hardness band D may have a significant effect on macroinvertebrate populations, the association is based on only a handful of points. Given that associations between nickel and BMWP score within hardness bands B and C were weak, the evidence for a more stringent standard for nickel within hardness band D is not compelling.

(b) An association between Log dissolved zinc and biology within hardness bands E and F

The plots indicate that macroinvertebrate scores may be adversely affected at dissolved zinc concentrations greater than 40 μg/l, suggesting that the 'proposed' EQS of 50 μg/l may not be sufficiently stringent. The 'proposed' EQS of 50 μg/l also applies to hardness band D but there was no significant association between log dissolved zinc and BMWP score in this case. The plots for hardness bands D and E are based on only a limited number of points but that for band F is composed of n = 74.

7.1 Biological status of sites with high metal values

Examination of the scatter plots provides further evidence of the ecological quality at 'failed' sites. The following points noted from inspection of the scatter plots for low hardness waters should be viewed in conjunction with the results obtained from the breakdown of ecological quality of pass/fail groups (section 6.1).

Total Zinc

There were many low hardness sites with good biology which appeared to have zinc concentrations in excess of the 'proposed' EQS. Most of these sites had mean zinc values in the range 8 to 60 μg/l. There were 8 records containing apparent high BMWP scores with zinc concentrations in the range 60-120 μg/l.

Dissolved Copper

There were a number of low hardness sites with good biology and copper concentrations in the range 0.5-10 μg/l. There were 9 records for copper in the range 10-25 μg/l which appeared to have high BMWP scores.

Dissolved Chromium

For dissolved chromium, concentrations up to 5 μg/l were, on occasion, associated with high BMWP scores.

Dissolved Nickel

Records with good BMWP scores were also associated with nickel concentrations in the range 10-20 μg/l on six occasions and nickel concentrations in the range 20-50 μg/l on three occasions.

It should be noted that BMWP scores greater than 150 were generally considered to be indicative of good biology.

8.0 CONCLUSIONS

and still you didn't get it all!!

During the course of this investigation, data were requested, and subsequently received, from all the NRA regions. The format and content of the data varied widely from region to region, the only exception being the data gleaned from the 1990 National Biological Database. Preparation of the List II metals database was therefore a difficult and laborious exercise. – poor wee things!!

For the purposes of this study, a scheme for classifying fisheries status was developed. The six point scale was relatively simple to work with, the only problem area of interpretation applied to sites that had apparently poor fish populations, but for which there was some indication of salmonids being present. The success of the classification scheme, however, was largely dependent on the quality of the raw data, and this proved to be highly variable in content. The data were not sufficiently robust for detailed assessments to be made and hence the fisheries rankings included within the database should therefore be interpreted as indicative only.

The final database comprised data from 1311 monitoring sites resulting in over 1800 individual records. Given that each record may contain data for seven metal variables, water hardness, biological scores, fisheries ranking and pass/fail against four sets of standards, the amount of information within the database was substantial.

The summary statistics for the database provided interesting information on average metal concentrations, plus minimum and maximum values, in freshwaters.

In SW metals were sampled at mostly sites that were considered to have problems.

Prior to assessing any correlations between metal and biological variables, pairs of variables were checked in order to compare the distribution of omitted values with values remaining. Normally distributed datasets were compared using a parametric statistical test and non-normally distributed datasets evaluated using a non-parametric statistical test. Differences between the groups of data were noted. Biological status was apparently poorer at sites for which there were no metal data compared with sites for which metal data were available. Metal concentrations were generally higher at sites for which no biological information was available compared to sites for which biological information was available. The inherent bias within the data may reflect the structure of monitoring programmes. Yes true

All metal data within each record were assessed for pass/fail against four sets of standards; 'existing' EQSs (salmonid), 'existing' EQSs (cyprinid), 'proposed' EQSs and Fisheries Directive standards. There were comparatively few failures against any of the standards for dissolved arsenic, dissolved lead and dissolved nickel. Although the results for dissolved chromium and dissolved copper in low hardness waters indicated substantial failure rates, inadequate analytical detection limits for these parameters in 1990 and 1991 did not allow for 'real' failure rates to be properly assessed.

* No mention of the bias from SWest's dataset – implications etc

In relation to zinc, a high failure rate was observed for low hardness waters when zinc values were compared against the 'existing' salmonid EQS. However, comparison of failure rates between the 'existing' and 'proposed' EQSs for zinc was not a straightforward matter as the 'existing' EQSs are set in terms of total zinc and the 'proposed' EQSs are set in terms of dissolved zinc. If it is assumed that both sets of standards relate to total zinc then it can be seen that failure rates were significantly increased with the 'proposed' EQSs for water hardness bands 51-100 and 101-150 mg/l $CaCO_3$, when compared with the corresponding 'existing' EQSs. There were insufficient data on dissolved zinc with which to evaluate the impact on pass/fail rates of standards set in terms of dissolved compared to total zinc.

The issue of dissolved zinc or total zinc is one that needs to be addressed. The Fisheries Directive set imperative standards for zinc based on total zinc, however, there appears to be no supporting documentation to indicate the basis for total zinc as the parameter of choice. In the WRc review of 1984[16], suggested EQSs for 'protection of other freshwater life', 'saltwater fish and shellfish' and 'other saltwater life' were put in terms of dissolved zinc whilst EQSs for protection of freshwater fish were set in terms of total zinc. There was no clear explanation for this difference in choice of parameter. In their review of zinc in the late 1970's, Alabaster and Lloyd[15] discussed the issue of total versus dissolved zinc and then listed tentative criteria for coarse fish and salmonids based on 95 percentile concentrations of 'soluble zinc'. They stated that "*the toxicity of solutions containing zinc is mainly attributable to the zinc ion and perhaps also to particulate zinc present as the basic carbonate or hydroxide held in suspension*".

Although the literature is unclear, it is possible that high concentrations of insoluble zinc may be toxic to the gills of fish causing asphyxia. However, low concentrations of insoluble zinc are unlikely to have the same effect. At these lower zinc concentrations, dissolved zinc may be a more important influence than insoluble zinc, particularly to aquatic life other than fish. The older Fisheries Directive standards for zinc and the recent proposed standards for all aquatic life may thus, to some extent, be addressing different issues and the choice of parameter could be reflecting this.

There has been concern that the 'proposed' EQSs for some of the metals in low hardness waters may be too stringent. In order to assess the distribution of ecological quality between the pass groups and the fail groups, the results for pass/fail were further broken down into four classes of biological quality based on BMWP.EQI values and six classes of fisheries quality according to the six grades incorporated within the database (see Table 7).

The principal points of note from the analysis were:

(a) for total zinc, the failed groups in hardness bands C, B and notably, band A, contained a high proportion of sites with good biology suggesting that the 'proposed' standards may be too stringent. There was no evidence that the 'proposed' EQSs for hardness bands D, E and F may be too stringent;

(b) for dissolved copper in water hardness bands C to F there would appear to be little justification in changing from the 'existing' to the 'proposed' standards;

(c) there were too few failed sites for chromium (in harder waters), lead, nickel and arsenic for an assessment to be possible.

For determining associations between metal and biology, the database was divided into six sections based on the water hardness bands contained within the 'existing' EQS structure. Within each hardness band, the datasets for BMWP score, BMWP.EQI, No. of Taxa and No. of Taxa.EQI and fisheries ranking were tested for an association with each of the metal variables. By dividing the analysis into six sections of different water hardness and including BMWP.EQI as a variable, the effect of water hardness on biological quality and metal toxicity was thus taken into account.

The results of the statistical analysis (Pearson correlations) indicated many significant associations. However, examination of the scatter plots revealed that outliers within the datasets appeared to be a major influence on the correlations obtained and there were few plots for which there was strong evidence for any association between List II metals and biological status at metal concentrations below 100 μg/l.

new

The statistical analysis gave similar results for the biological variables BMWP score, BMWP.EQI, No. of Taxa and No. of Taxa.EQI. There was no substantive evidence to suggest that No. of Taxa gave better associations with metals than BMWP score.

Of all the plots and correlations, the most interesting were associations between log dissolved zinc and BMWP score within hardness bands 200-250 mg/l $CaCO_3$ and >250 mg/l $CaCO_3$. These data provide some evidence that the 'proposed' EQS of 50 μg/l for dissolved zinc may not be sufficiently stringent.

For low hardness waters, however, there was evidence of sites with apparently good biology but with metal concentrations in excess of 'proposed' EQSs. For total zinc, there were a particularly large number of sites in this category, suggesting that the 'proposed' EQS of 8 μg/l for low hardness waters may be too stringent. Of the other List II metals, there was also evidence that the 'proposed' EQS for dissolved copper in low hardness waters may also be too stringent.

Although low concentrations of dissolved metals may impact on particular invertebrate species, other invertebrate species may take their place thereby sustaining healthy fish populations. The possibility of population dynamics being affected so that metal tolerant species have a competitive advantage but apparent biological status remains high, is a complex issue for standard setting.

Interpreting the results of this investigation was difficult given the large number of confounding variables that influence biological status and List II metal concentrations in watercourses. Some of the factors have been described but it is outside the scope of this report to discuss them all in detail. The findings of the study as outlined below should therefore be viewed as tentative:

(i) there is some evidence that the 'proposed' EQS for dissolved zinc in high hardness waters may not be sufficiently stringent;

(ii) there is some evidence to suggest that the 'proposed' EQS for zinc in low hardness waters may be too stringent;

(iii) there is some evidence to suggest that the 'proposed' EQSs for dissolved copper, particularly in low hardness waters may be too stringent. However, this evidence should be reviewed when new data based on improved analytical detection limits are available.

In terms of further work on the existing information within the database, there are additional statistical procedures that could be of benefit. Further insight into the underlying relationships may possibly be elucidated using a multivariate approach with multiple linear regression analysis. If a biological factor is employed as a dependent variable, all of the metals and hardness data could be added in a stepwise manner in order to find a model that best described the variation in biological activity. Alternatively, analysis of variance could be used. Metal and hardness data would be split into groups thus enabling them to be used as factors. Biological activity could then be compared across factor groups.

There may well be benefit in expanding the database to include 1992 data and further years. The larger the database, the more likely it is that associations can be elucidated. An expanded database could also take into account other factors such as pH.

A significant point to note is the apparent bias within the monitoring data against sites that have higher metal concentrations and poorer biological status. In particular, the values for concentrations of lead, nickel and arsenic in the database were generally low, additional data at higher metal concentrations may allow for the appropriateness of these standards to be assessed in more detail.

With regard to inclusion of List II metals into the Fisheries Ecosystem Use Classes scheme, this study suggests that there is some merit in the argument that 'proposed' EQSs for zinc and copper in low hardness waters would unnecessarily result in a downgrading of fisheries status for many sites.

Defining List II metal standards for different classes of water quality based on toxicity data would be extremely difficult and impractical. However, if it is considered that values for List II metals need to be applied to all six water quality classes, standards would have to be developed on some other rational basis. An alternative approach may be the application of relaxation factors from the Class 1 metal standards, for example a relaxation of the EQSs by a factor of 1.5 for Class 3, a factor of 2 for Class 4, a factor of 3 for Class 5 etc. The choice of factors and their applicability could be evaluated using the existing database and by considering ecological quality and appropriate pass/fail rates against the Class 1 standards. For the different water classes one would expect different ecological quality. Target ecological quality and target failure rates against the Class 1 standards for different water classes could be selected and the database used to predict the concentrations of metals that would give the selected ecological quality and failure rates. In this way, metal concentrations may be calculated for each class that would be in some way relevant to a descriptive class system, as proposed for the Fisheries Ecosystem Use Classes. Such an approach would have advantages, namely ease of use, limiting over-interpretation of 'scientifically-derived' standards, and difficulties with alternatives.

9.0 RECOMMENDATIONS

(i) Apply other statistical procedures to the data in order to further elucidate underlying relationships.

(ii) Expand the database with more recent data, in particular with data containing higher metal concentrations and poorer biological status. In this way, the present findings could be reassessed and other associations may become apparent.

assuming its available

(iii) Consider the case for modifying the 'proposed' EQSs for zinc and copper.

(iv) Consider deriving List II metal values for use with Classes 2, 3, 4, 5 and 6 based on the metal concentrations that would result in selected ecological quality and pass/fail rates for different water classes.

(v) Consider funding research on the mechanism of zinc toxicity with reference to the roles of total and dissolved zinc in toxicity to both fish and invertebrates.

(vi) Based on the evidence from this investigation that the associations between metals and BMWP score were almost identical to the associations between metals and the five other biological variables, it may be worth reassessing the value of the present six biological variables;

REFERENCES

1. Armitage P D, Moss D, Wright J F and Furse M T (1983) The performance of a new biological water quality score system based on macro-invertebrates over a wide range of unpolluted running-water sites. Water Research 17, 333-347.

2. National Rivers Authority (1991) Proposals for Statutory Water Quality Objectives: Report of the National Rivers Authority. Water Quality Series No. 5, December.

3. National Rivers Authority (1992) Recommendations for a Scheme of Water Quality Classification for Setting Statutory Water Quality Objectives. October.

4. Department of the Environment/Welsh Office (1992) River Quality. The Government's Proposals: A Consultation Paper. December.

5. Royal Commission on Environmental Pollution (1992) Sixteenth Report. Freshwater Quality. Cm 1966, HMSO, London.

6. Council of the European Communities (1976) Directive on Pollution Caused by Certain Dangerous Substances Discharged into the Aquatic Environment of the Community. 76/464/EEC, 4 May.

7. Department of the Environment/Welsh Office (1989) Water and the Environment. The Implementation of European Community Directives on Pollution Caused by Certain Dangerous Substances Discharged into the Aquatic Environment. DoE Circular 7/89, 30 March.

8. Smith I N H and Edwards V (1992) Revised Environmental Quality Standards for Arsenic in Water. WRc report to the Department of the Environment, October, DoE 2633/1.

9. Hunt S M and Hedgecott S (1992) Revised Environmental Quality Standards for Nickel in Water. WRc report to the Department of the Environment, September, DoE 2685/1.

10. Hunt S M and Hedgecott S (1992) Revised Environmental Quality Standards for Zinc in Water. WRc report to the Department of the Environment, October, DoE 2686/1.

11. Young W (1992) Revised Environmental Quality Standards for Inorganic Lead in Water. WRc report to the Department of the Environment, September, DoE 2718-M/1.

12. Hunt S M and Hedgecott S (1992) Revised Environmental Quality Standards for Chromium in Water. WRc report to the Department of the Environment, September, DoE 2858-M/1.

13. Smith I N H (1993) Revised Environmental Quality Standards for Copper in Water. WRc report to the Department of the Environment, April, DoE 2986/1.

14. Council of the European Communities (1978) Directive on the Quality of Fresh Waters Needed Protection or Improvement in Order to Support Fish Life. 78/659/EEC, July.

15. Alabaster J S and Lloyd R (1982) Water Quality Criteria for Freshwater Fish. Second Edition. Butterworths.

16. Mance G and Yates J (1984) Proposed Environmental Quality Standards for List II Substances in Water. Zinc. Water Research Centre Technical Report, TR 209, August.

APPENDIX 1

TABLES OF RESULTS

TABLES A1 TO A7

COMPARISON OF MISSING VALUES WITH VALUES REMAINING
LIST II METALS AND BMWP SCORE

Table A1. Total Zinc and BMWP Score

		median T Zn	mean BMWP
T Zn > 0 and BMWP > 0	n=869	11.47	167.4
T Zn = 0 and BMWP > 0	n=39	-	136.4
T Zn > 0 and BMWP = 0	n=880	14.75	-
T Zn values compared using a Mann-Whitney test	P = 0.00001		
BMWP values compared with a t-test	P = 0.0039		

Table A2. Dissolved Zinc and BMWP Score

		mean Log D Zn	mean BMWP
Log D Zn > 0 and BMWP > 0	n=146	1.25	119.7
Log D Zn = 0 and BMWP > 0	n=762	-	174.9
Log D Zn > 0 and BMWP = 0	n=129	1.36	-
Log D Zn values compared with a t-test	P = 0.064		
BMWP values compared with a t-test	P = 0.00001		

Table A3. Dissolved Copper and BMWP Score

		median D Cu	mean BMWP
D Cu > 0 and BMWP > 0	n=749	3.3	174.8
D Cu = 0 and BMWP > 0	n=159	-	124.5
D Cu > 0 and BMWP = 0	n=844	3.5	-
D Cu values compared using a Mann-Whitney test	P = 0.022		
BMWP values compared with a t-test	P = 0.00001		

Table A4. Dissolved Chromium and BMWP Score

		mean Log D Cr	mean BMWP
Log D Cr > 0 and BMWP > 0	n=589	0.22	174.4
Log D Cr = 0 and BMWP > 0	n=319	-	150.7
Log D Cr > 0 and BMWP = 0	n=613	0.25	-
Log D Cr values compared with a t-test		P = 0.2	
BMWP values compared with a t-test		P = 0.00001	

Table A5. Dissolved Lead and BMWP Score

		median D Pb	mean BMWP
D Pb > 0 and BMWP > 0	n=595	2.58	175.1
D Pb = 0 and BMWP > 0	n=313	-	148.8
D Pb > 0 and BMWP = 0	n=596	2.50	-
D Pb values compared using a Mann-Whitney test		P = 0.83	
BMWP values compared with a t-test		P = 0.00001	

Table A6. Dissolved Nickel and BMWP Score

		median D Ni	mean BMWP
D Ni > 0 and BMWP > 0	n=589	3.28	175.4
D Ni = 0 and BMWP > 0	n=319	-	148.7
D Ni > 0 and BMWP = 0	n=604	3.60	-
D Ni values compared using a Mann-Whitney test		P = 0.20	
BMWP values compared with a t-test		P = 0.00001	

Table A7. Dissolved Arsenic and BMWP Score

		mean Log D As	mean BMWP
Log D As > 0 and BMWP > 0	n=354	0.54	174.3
Log D As = 0 and BMWP > 0	n=554	-	160.8
Log D As > 0 and BMWP = 0	n=396	0.56	-
Log D As values compared with a t-test		P = 0.5	
BMWP values compared with a t-test		P = 0.0025	

TABLES A8 TO A14

COMPARISON OF MISSING VALUES WITH VALUES REMAINING LIST II METALS AND FISHERIES RANKING

Table A8. Total Zinc and Fisheries Ranking

		median T Zn	mean FISH
T Zn > 0 and FISH > 0	n=635	15.4	3.02
T Zn = 0 and FISH > 0	n=38	-	3.87
T Zn > 0 and FISH = 0	n=1114	11.9	-
T Zn values compared using a Mann-Whitney test		P = 0.0001	
Fisheries rankings compared with a t-test		P = 0.0005	

Table A9. Dissolved Zinc and Fisheries Ranking

		mean Log D Zn	mean FISH
Log D Zn > 0 and FISH > 0	n=226	1.23	3.66
Log D Zn = 0 and FISH > 0	n=447	-	2.76
Log D Zn > 0 and FISH = 0	n=49	1.64	-
Log D Zn values compared with a t-test		P = 0.0001	
Fisheries rankings compared with a t-test		P = 0.00001	

Table A10. Dissolved Copper and Fisheries Ranking

		median D Cu	mean FISH
D Cu > 0 and FISH > 0	n=529	3.98	2.97
D Cu = 0 and FISH > 0	n=144	-	3.43
D Cu > 0 and FISH = 0	n=1064	3.3	-
D Cu values compared using a Mann-Whitney test	P = 0.51		
Fisheries rankings compared with a t-test	P = 0.0008		

Table A11. Dissolved Chromium and Fisheries Ranking

		mean Log D Cr	mean FISH
Log D Cr > 0 and FISH > 0	n=310	0.25	3.25
Log D Cr = 0 and FISH > 0	n=363	-	2.90
Log D Cr > 0 and FISH = 0	n=892	0.23	-
Log D Cr values compared with a t-test	P = 0.22		
Fisheries rankings compared with a t-test	P = 0.0019		

Table A12. Dissolved Lead and Fisheries Ranking

		median D Pb	mean FISH
D Pb > 0 and FISH > 0	n=301	1.96	3.26
D Pb = 0 and FISH > 0	n=372	-	2.91
D Pb > 0 and FISH = 0	n=890	3.00	-
D Pb values compared using a Mann-Whitney test	P = 0.00001		
Fisheries rankings compared with a t-test	P = 0.0023		

Table A13. Dissolved Nickel and Fisheries Ranking

		median D Ni	mean FISH
D Ni > 0 and FISH > 0	n=308	2.70	3.26
D Ni = 0 and FISH > 0	n=365	-	2.91
D Ni > 0 and FISH = 0	n=885	3.86	-
D Ni values compared using a Mann-Whitney test	P = 0.0008		
Fisheries rankings compared with a t-test	P = 0.0021		

Table A14. Dissolved Arsenic and Fisheries Ranking

		mean Log D As	mean FISH
Log D As > 0 and FISH > 0	n=146	0.22	3.03
Log D As = 0 and FISH > 0	n=527	-	3.08
Log D As > 0 and FISH = 0	n=604	0.63	-
Log D As values compared with a t-test	P = 0.00001		
Fisheries rankings compared with a t-test	P = 0.76		

TABLES A15 TO A21

ANALYSIS OF PASS/FAIL RATES AND BREAKDOWN BY BIOLOGICAL STATUS

Table A15. Hardness Band A (0-50 mg/l $CaCO_3$) 393 Records

	Existing EQSs (Salmonid)		Existing EQSs (Cyprinid)		Proposed EQSs		Fisheries Directive (Salmonid)	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
T Zn	151	233	369	15	150	234	366	18
T Zn and BMWP.EQI	88	90	168	10	88	90	168	10
Biological Class a	95.45%	80.00%	88.10%	80.00%	95.45%	80.00%	88.10%	80.00%
Biological Class b	2.27%	13.33%	8.33%	0%	2.27%	13.33%	8.33%	0%
Biological Class c	2.27%	6.67%	3.57%	20.00%	2.27%	6.67%	3.57%	20.00%
Biological Class d	0%	0%	0%	0%	0%	0%	0%	0%
T Zn and FISH	19	57	74	2	19	57	75	1
Fisheries Class 1	47.37%	57.89%	56.76%	0%	47.37%	57.89%	56.00%	0%
Fisheries Class 2	52.63%	40.35%	41.89%	100%	52.63%	40.35%	42.67%	100%
Fisheries Class 3	0%	0%	0%	0%	0%	0%	0%	0%
Fisheries Class 4	0%	0%	0%	0%	0%	0%	0%	0%
Fisheries Class 5	0%	1.75%	1.35%	0%	0%	1.75%	1.33%	0%
Fisheries Class 6	0%	0%	0%	0%	0%	0%	0%	0%
D Zn					4	0		
D Zn and BMWP.EQI					4	0		
Biological Class a					75.00%			
Biological Class b					25.00%			
Biological Class c					0%			
Biological Class d					0%			
D Zn and FISH					3	0		
Fisheries Class 1					0%			
Fisheries Class 2					100%			
Fisheries Class 3					0%			
Fisheries Class 4					0%			
Fisheries Class 5					0%			
Fisheries Class 6					0%			
D Cu	4	354	4	354	1	357	307	51
D Cu and BMWP.EQI	1	160	1	160	0	161	139	22
Biological Class a	100%	86.88%	100%	86.88%		86.96%	89.21%	72.73%
Biological Class b	0%	8.13%	0%	8.13%		8.07%	7.19%	13.64%
Biological Class c	0%	5.00%	0%	5.00%		4.97%	3.60%	13.64%
Biological Class d	0%	0%	0%	0%		0%	0%	0%
D Cu and FISH	2	61	2	61	0	63	58	5
Fisheries Class 1	0%	55.74%	0%	55.74%		53.97%	55.17%	40.00%
Fisheries Class 2	100%	42.62%	100%	42.62%		44.44%	44.83%	40.00%
Fisheries Class 3	0%	0%	0%	0%		0%	0%	0%
Fisheries Class 4	0%	0%	0%	0%		0%	0%	0%
Fisheries Class 5	0%	1.64%	0%	1.64%		1.59%	0%	20.00%
Fisheries Class 6	0%	0%	0%	0%		0%	0%	0%

Table A15 Cont. Hardness Band A (0-50 mg/l $CaCO_3$) 393 Records

	Existing EQSs (Salmonid)		Existing EQSs (Cyprinid)		Proposed EQSs		Fisheries Directive (Salmonid)	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
D Cr	305	5	310	0	158	152		
D Cr and BMWP.EQI	147	1	148	0	67	81		
Biological Class a	87.76%	0%	87.16%		82.09%	91.36%		
Biological Class b	6.80%	100%	7.43%		7.46%	7.41%		
Biological Class c	5.44%	0%	5.41%		10.45%	1.23%		
Biological Class d	0%	0%	0%		0%	0%		
D Cr and FISH	40	2	42	0	9	33		
Fisheries Class 1	52.50%	0%	50.00%		55.56%	48.48%		
Fisheries Class 2	45.00%	100%	47.62%		33.33%	51.52%		
Fisheries Class 3	0%	0%	0%		0%	0%		
Fisheries Class 4	0%	0%	0%		0%	0%		
Fisheries Class 5	2.50%	0%	2.38%		11.11%	0%		
Fisheries Class 6	0%	0%	0%		0%	0%		
D Pb	252	58	310	0	252	58		
D Pb and BMWP.EQI	124	24	148	0	124	24		
Biological Class a	87.10%	87.50%	87.16%		87.10%	87.50%		
Biological Class b	6.45%	12.50%	7.43%		6.45%	12.50%		
Biological Class c	6.45%	0%	5.41%		6.45%	0%		
Biological Class d	0%	0%	0%		0%	0%		
D Pb and FISH	18	24	42	0	18	24		
Fisheries Class 1	33.33%	62.50%	50.00%		33.33%	62.50%		
Fisheries Class 2	66.67%	33.33%	47.62%		66.67%	33.33%		
Fisheries Class 3	0%	0%	0%		0%	0%		
Fisheries Class 4	0%	0%	0%		0%	0%		
Fisheries Class 5	0%	4.17%	2.38%		0%	4.17%		
Fisheries Class 6	0%	0%	0%		0%	0%		
D Ni	309	1	309	1	293	17		
D Ni and BMWP.EQI	147	1	147	1	139	9		
Biological Class a	87.07%	100%	87.07%	100%	87.05%	88.89%		
Biological Class b	7.48%	0%	7.48%	0%	7.19%	11.11%		
Biological Class c	5.44%	0%	5.44%	0%	5.76%	0%		
Biological Class d	0%	0%	0%	0%	0%	0%		
D Ni and FISH	41	1	41	1	39	3		
Fisheries Class 1	51.22%	0%	51.22%	0%	51.28%	33.33%		
Fisheries Class 2	46.34%	100%	46.34%	100%	46.15%	66.67%		
Fisheries Class 3	0%	0%	0%	0%	0%	0%		
Fisheries Class 4	0%	0%	0%	0%	0%	0%		
Fisheries Class 5	2.44%	0%	2.44%	0%	2.56%	0%		
Fisheries Class 6	0%	0%	0%	0%	0%	0%		

Table A16. Hardness Band B (51-100 mg/l $CaCO_3$) 470 Records

	Existing EQSs (Salmonid)		Existing EQSs (Cyprinid)		Proposed EQSs		Fisheries Directive (Salmonid)	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
T Zn	395	61	424	32	259	197	419	37
T Zn and BMWP.EQI	207	27	219	15	141	93	216	18
Biological Class a	84.54%	37.04%	81.28%	46.67%	92.20%	59.14%	81.94%	44.44%
Biological Class b	8.70%	29.63%	10.50%	20.00%	7.09%	17.20%	9.72%	27.78%
Biological Class c	4.83%	22.22%	5.94%	20.00%	0.71%	16.13%	6.02%	16.67%
Biological Class d	1.93%	11.11%	2.28%	13.33%	0%	7.53%	2.31%	11.11%
T Zn and FISH	83	3	86	0	58	28	86	0
Fisheries Class 1	36.14%	33.33%	36.05%		44.83%	17.86%	36.05%	
Fisheries Class 2	51.81%	0%	50.00%		51.72%	46.43%	50.00%	
Fisheries Class 3	0%	0%	0%		0%	0%	0%	
Fisheries Class 4	6.02%	66.67%	8.14%		0%	25.00%	8.14%	
Fisheries Class 5	6.02%	0%	5.81%		3.45%	10.71%	5.81%	
Fisheries Class 6	0%	0%	0%		0%	0%	0%	
D Zn					9	4		
D Zn and BMWP.EQI					6	2		
Biological Class a					66.67%	50.00%		
Biological Class b					16.67%	0%		
Biological Class c					16.67%	50.00%		
Biological Class d					0%	0%		
D Zn and FISH					9	2		
Fisheries Class 1					0%	0%		
Fisheries Class 2					100%	50.00%		
Fisheries Class 3					0%	0%		
Fisheries Class 4					0%	50.00%		
Fisheries Class 5					0%	0%		
Fisheries Class 6					0%	0%		
D Cu	329	120	329	120	173	276	396	53
D Cu and BMWP.EQI	180	49	180	49	104	125	208	21
Biological Class a	90.00%	42.86%	90.00%	42.86%	91.35%	70.40%	84.62%	33.33%
Biological Class b	7.22%	26.53%	7.22%	26.53%	6.73%	15.20%	10.58%	19.05%
Biological Class c	2.78%	22.45%	2.78%	22.45%	1.92%	11.20%	4.33%	33.33%
Biological Class d	0%	8.16%	0%	8.16%	0%	3.20%	0.48%	14.29%
D Cu and FISH	65	15	65	15	42	38	74	6
Fisheries Class 1	40.00%	26.67%	40.00%	26.67%	45.24%	28.95%	39.19%	16.67%
Fisheries Class 2	55.38%	40.00%	55.38%	40.00%	54.76%	50.00%	54.05%	33.33%
Fisheries Class 3	0%	0%	0%	0%	0%	0%	0%	0%
Fisheries Class 4	1.54%	26.67%	1.54%	26.67%	0%	13.16%	2.70%	50.00%
Fisheries Class 5	3.08%	6.67%	3.08%	6.67%	0%	7.89%	4.05%	0%
Fisheries Class 6	0%	0%	0%	0%	0%	0%	0%	0%

Table A16 Cont. Hardness Band B (51-100 mg/l $CaCO_3$) 470 Records

	Existing EQSs (Salmonid)		Existing EQSs (Cyprinid)		Proposed EQSs		Fisheries Directive (Salmonid)	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
D Cr	376	4	380	0	376	4		
D Cr and BMWP.EQI	198	1	199	0	198	1		
Biological Class a	80.30%	0%	79.90%		80.30%	0%		
Biological Class b	11.11%	0%	11.06%		11.11%	0%		
Biological Class c	6.57%	100%	7.04%		6.57%	100%		
Biological Class d	2.02%	0%	2.01%		2.02%	0%		
D Cr and FISH	30	2	32	0	30	2		
Fisheries Class 1	36.67%	0%	34.38%		36.67%	0%		
Fisheries Class 2	50.00%	0%	46.88%		50.00%	0%		
Fisheries Class 3	0%	0%	0%		0%	0%		
Fisheries Class 4	10.00%	50%	12.50%		10.00%	50%		
Fisheries Class 5	3.33%	50%	6.25%		3.33%	50%		
Fisheries Class 6	0%	0%	0%		0%	0%		
D Pb	361	14	372	3	361	14		
D Pb and BMWP.EQI	190	5	195	0	190	5		
Biological Class a	79.47%	100%	80.00%		79.47%	100%		
Biological Class b	11.58%	0%	11.28%		11.58%	0%		
Biological Class c	7.37%	0%	7.18%		7.37%	0%		
Biological Class d	1.58%	0%	1.54%		1.58%	0%		
D Pb and FISH	26	1	27	0	26	1		
Fisheries Class 1	42.31%	0%	40.74%		42.31%	0%		
Fisheries Class 2	42.31%	0%	40.74%		42.31%	0%		
Fisheries Class 3	0%	0%	0%		0%	0%		
Fisheries Class 4	11.54%	100%	14.81%		11.54%	100%		
Fisheries Class 5	3.85%	0%	3.70%		3.85%	0%		
Fisheries Class 6	0%	0%	0%		0%	0%		
D Ni	374	3	374	3	349	28		
D Ni and BMWP.EQI	196	0	196	0	183	13		
Biological Class a	80.10%		80.10%		81.97%	53.85%		
Biological Class b	11.22%		11.22%		10.38%	23.08%		
Biological Class c	7.14%		7.14%		7.10%	7.69%		
Biological Class d	1.53%		1.53%		0.55%	15.38%		
D Ni and FISH	30	0	30	0	26	4		
Fisheries Class 1	36.67%		36.67%		38.46%	25.00%		
Fisheries Class 2	46.67%		46.67%		42.31%	75.00%		
Fisheries Class 3	0%		0%		0%	0%		
Fisheries Class 4	13.33%		13.33%		15.38%	0%		
Fisheries Class 5	3.33%		3.33%		3.85%	0%		
Fisheries Class 6	0%		0%		0%	0%		

Table A17. Hardness Band C (101-150 mg/l $CaCO_3$) 229 Records

	Existing EQSs (Salmonid)		Existing EQSs (Cyprinid)		Proposed EQSs		Fisheries Directive (Salmonid)	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
T Zn	196	26	214	8	132	90	210	12
T Zn and BMWP.EQI	108	11	115	4	74	45	112	7
Biological Class a	77.78%	63.64%	77.39%	50.00%	87.84%	57.78%	77.68%	57.14%
Biological Class b	9.26%	27.27%	10.43%	25.00%	6.76%	17.78%	9.82%	28.57%
Biological Class c	6.48%	9.09%	6.09%	25.00%	5.41%	8.89%	6.25%	14.29%
Biological Class d	6.48%	0%	6.09%	0%	0%	15.56%	6.25%	0%
T Zn and FISH	67	7	71	3	32	42	71	3
Fisheries Class 1	11.94%	0%	11.27%	0%	18.75%	4.76%	11.27%	0%
Fisheries Class 2	41.79%	28.57%	40.85%	33.33%	65.63%	21.43%	40.85%	33.33%
Fisheries Class 3	22.39%	14.29%	22.54%	0%	3.13%	35.71%	22.54%	0%
Fisheries Class 4	4.48%	0%	4.23%	0%	6.25%	2.38%	4.23%	0%
Fisheries Class 5	13.43%	0%	12.68%	0%	3.13%	19.05%	12.68%	0%
Fisheries Class 6	5.97%	57.14%	8.45%	66.67%	3.13%	16.67%	8.45%	66.67%
D Zn					15	24		
D Zn and BMWP.EQI					12	11		
Biological Class a					58.33%	45.45%		
Biological Class b					8.33%	0%		
Biological Class c					25.00%	27.27%		
Biological Class d					8.33%	27.27%		
D Zn and FISH					13	19		
Fisheries Class 1					0%	0%		
Fisheries Class 2					46.15%	21.05%		
Fisheries Class 3					23.08%	31.58%		
Fisheries Class 4					15.38%	5.26%		
Fisheries Class 5					7.69%	26.32%		
Fisheries Class 6					7.69%	15.79%		
D Cu	181	21	181	21	80	122	198	4
D Cu and BMWP.EQI	94	12	94	12	50	56	103	3
Biological Class a	81.91%	41.67%	81.91%	41.67%	88.00%	67.86%	77.67%	66.67%
Biological Class b	10.64%	16.67%	10.64%	16.67%	10.00%	12.50%	10.68%	33.33%
Biological Class c	5.32%	25.00%	5.32%	25.00%	2.00%	12.50%	7.77%	0%
Biological Class d	2.13%	16.67%	2.13%	16.67%	0%	7.14%	3.88%	0%
D Cu and FISH	44	12	44	12	19	37	54	2
Fisheries Class 1	11.36%	16.67%	11.36%	16.67%	15.79%	10.81%	11.11%	50.00%
Fisheries Class 2	54.55%	8.33%	54.55%	8.33%	63.16%	35.14%	44.44%	50.00%
Fisheries Class 3	9.09%	16.67%	9.09%	16.67%	5.26%	13.51%	11.11%	0%
Fisheries Class 4	4.55%	8.33%	4.55%	8.33%	5.26%	5.41%	5.56%	0%
Fisheries Class 5	15.91%	16.67%	15.91%	16.67%	10.53%	18.92%	16.67%	0%
Fisheries Class 6	4.55%	33.33%	4.55%	33.33%	0%	16.22%	11.11%	0%

Table A17 Cont. Hardness Band C (101-150 mg/l $CaCO_3$) 229 Records

	Existing EQSs (Salmonid)		Existing EQSs (Cyprinid)		Proposed EQSs		Fisheries Directive (Salmonid)	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
D Cr	166	1	167	0	164	3		
D Cr and BMWP.EQI	89	1	90	0	88	2		
Biological Class a	79.78%	0%	78.89%		80.68%	0%		
Biological Class b	8.99%	100%	10.00%		9.09%	50.00%		
Biological Class c	6.74%	0%	6.67%		6.82%	0%		
Biological Class d	4.49%	0%	4.44%		3.41%	50.00%		
D Cr and FISH	33	0	33	0	31	2		
Fisheries Class 1	12.12%		12.12%		12.90%	0%		
Fisheries Class 2	27.27%		27.27%		29.03%	0%		
Fisheries Class 3	21.21%		21.21%		22.58%	0%		
Fisheries Class 4	6.06%		6.06%		6.45%	0%		
Fisheries Class 5	18.18%		18.18%		12.90%	100%		
Fisheries Class 6	15.15%		15.15%		16.13%	0%		
D Pb	160	12	172	0	160	12		
D Pb and BMWP.EQI	84	8	92	0	84	8		
Biological Class a	79.76%	62.50%	78.26%		79.76%	62.50%		
Biological Class b	8.33%	25.00%	9.78%		8.33%	25.00%		
Biological Class c	8.33%	0%	7.61%		8.33%	0%		
Biological Class d	3.57%	12.50%	4.35%		3.57%	12.50%		
D Pb and FISH	35	1	36	0	35	1		
Fisheries Class 1	11.43%	0%	11.11%		11.43%	0%		
Fisheries Class 2	22.86%	100%	25.00%		22.86%	100%		
Fisheries Class 3	28.57%	0%	27.78%		28.57%	0%		
Fisheries Class 4	5.71%	0%	5.56%		5.71%	0%		
Fisheries Class 5	17.14%	0%	16.67%		17.14%	0%		
Fisheries Class 6	14.29%	0%	13.89%		14.29%	0%		
D Ni	170	0	170	0	166	4		
D Ni and BMWP.EQI	91	0	91	0	89	2		
Biological Class a	78.02%		78.02%		77.53%	100%		
Biological Class b	9.89%		9.89%		10.11%	0%		
Biological Class c	7.69%		7.69%		7.87%	0%		
Biological Class d	4.40%		4.40%		4.49%	0%		
D Ni and FISH	36	0	36	0	36	0		
Fisheries Class 1	11.11%		11.11%		11.11%			
Fisheries Class 2	25.00%		25.00%		25.00%			
Fisheries Class 3	27.78%		27.78%		27.78%			
Fisheries Class 4	5.56%		5.56%		5.56%			
Fisheries Class 5	16.67%		16.67%		16.67%			
Fisheries Class 6	13.89%		13.89%		13.89%			

Table A18. Hardness Band D (151-200 mg/l $CaCO_3$) 117 Records

	Existing EQSs (Salmonid)		Existing EQSs (Cyprinid)		Proposed EQSs		Fisheries Directive (Salmonid)	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
T Zn	94	15	101	8	87	22	100	9
T Zn and BMWP.EQI	43	6	46	3	40	9	45	4
Biological Class a	62.79%	33.33%	63.04%	0%	65.00%	33.33%	62.22%	25.00%
Biological Class b	16.28%	16.67%	15.22%	33.33%	15.00%	22.22%	15.56%	25.00%
Biological Class c	9.30%	0%	8.70%	0%	10.00%	0%	8.89%	0%
Biological Class d	11.63%	50.00%	13.04%	66.67%	10.00%	44.44%	13.33%	50.00%
T Zn and FISH	46	4	50	0	43	7	49	1
Fisheries Class 1	2.17%	0%	2.00%		2.33%	0%	2.04%	0%
Fisheries Class 2	32.61%	0%	30.00%		34.88%	0%	30.61%	0%
Fisheries Class 3	10.87%	50.00%	14.00%		11.63%	28.57%	12.24%	100%
Fisheries Class 4	19.57%	0%	18.00%		20.93%	0%	18.37%	0%
Fisheries Class 5	21.74%	0%	20.00%		20.93%	14.29%	20.41%	0%
Fisheries Class 6	13.04%	50.00%	16.00%		9.30%	57.14%	16.33%	0%
D Zn					23	10		
D Zn and BMWP.EQI					14	6		
Biological Class a					57.14%	66.67%		
Biological Class b					14.29%	16.67%		
Biological Class c					7.14%	0%		
Biological Class d					21.43%	16.67%		
D Zn and FISH					23	4		
Fisheries Class 1					0%	0%		
Fisheries Class 2					26.09%	0%		
Fisheries Class 3					21.74%	50.00%		
Fisheries Class 4					17.39%	25.00%		
Fisheries Class 5					26.09%	0%		
Fisheries Class 6					8.70%	25.00%		
D Cu	96	8	96	8	36	68	101	3
D Cu and BMWP.EQI	45	2	45	2	16	31	46	1
Biological Class a	62.22%	0%	62.22%	0%	62.50%	58.06%	60.87%	0%
Biological Class b	20.00%	0%	20.00%	0%	31.25%	12.90%	19.57%	0%
Biological Class c	8.89%	0%	8.89%	0%	6.25%	9.68%	8.70%	0%
Biological Class d	8.89%	100%	8.89%	100%	0%	19.35%	10.87%	100%
D Cu and FISH	46	2	46	2	13	35	48	0
Fisheries Class 1	2.17%	0%	2.17%	0%	7.69%	0%	2.08%	
Fisheries Class 2	32.61%	50.00%	32.61%	50.00%	38.46%	31.43%	33.33%	
Fisheries Class 3	15.22%	0%	15.22%	0%	15.38%	14.29%	14.58%	
Fisheries Class 4	19.57%	0%	19.57%	0%	15.38%	20.00%	18.75%	
Fisheries Class 5	21.74%	0%	21.74%	0%	23.08%	20.00%	20.83%	
Fisheries Class 6	8.70%	50.00%	8.70%	50.00%	0%	14.29%	10.42%	

Table A18 Cont. Hardness Band D (151-200 mg/l $CaCO_3$) 117 Records

	Existing EQSs (Salmonid)		Existing EQSs (Cyprinid)		Proposed EQSs		Fisheries Directive (Salmonid)	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
D Cr	74	0	74	0	74	0		
D Cr and BMWP.EQI	34	0	34	0	34	0		
Biological Class a	55.88%		55.88%		55.88%			
Biological Class b	17.65%		17.65%		17.65%			
Biological Class c	8.82%		8.82%		8.82%			
Biological Class d	17.65%		17.65%		17.65%			
D Cr and FISH	32	0	32	0	32	0		
Fisheries Class 1	3.13%		3.13%		3.13%			
Fisheries Class 2	31.25%		31.25%		31.25%			
Fisheries Class 3	21.88%		21.88%		21.88%			
Fisheries Class 4	12.50%		12.50%		12.50%			
Fisheries Class 5	15.63%		15.63%		15.63%			
Fisheries Class 6	15.63%		15.63%		15.63%			
D Pb	71	5	76	0	71	5		
D Pb and BMWP.EQI	33	3	36	0	33	3		
Biological Class a	63.64%	0%	58.33%		63.64%	0%		
Biological Class b	15.15%	33.33%	16.67%		15.15%	33.33%		
Biological Class c	9.09%	0%	8.33%		9.09%	0%		
Biological Class d	12.12%	66.67%	16.67%		12.12%	66.67%		
D Pb and FISH	29	1	30	0	29	1		
Fisheries Class 1	3.45%	0%	3.33%		3.45%	0%		
Fisheries Class 2	20.69%	0%	20.00%		20.69%	0%		
Fisheries Class 3	24.14%	0%	23.33%		24.14%	0%		
Fisheries Class 4	17.24%	0%	16.67%		17.24%	0%		
Fisheries Class 5	20.69%	0%	20.00%		20.69%	0%		
Fisheries Class 6	13.79%	100%	16.67%		13.79%	100%		
D Ni	74	0	74	0	74	0		
D Ni and BMWP.EQI	35	0	35	0	35	0		
Biological Class a	60.00%		60.00%		60.00%			
Biological Class b	14.29%		14.29%		14.29%			
Biological Class c	8.57%		8.57%		8.57%			
Biological Class d	17.14%		17.14%		17.14%			
D Ni and FISH	32	0	32	0	32	0		
Fisheries Class 1	3.13%		3.13%		3.13%			
Fisheries Class 2	25.00%		25.00%		25.00%			
Fisheries Class 3	21.88%		21.88%		21.88%			
Fisheries Class 4	15.63%		15.63%		15.63%			
Fisheries Class 5	18.75%		18.75%		18.75%			
Fisheries Class 6	15.63%		15.63%		15.63%			

Table A19. Hardness Band E (201-250 mg/l $CaCO_3$) 102 Records

	Existing EQSs (Salmonid)		Existing EQSs (Cyprinid)		Proposed EQSs		Fisheries Directive (Salmonid)	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
T Zn	88	10	94	4	85	13	94	4
T Zn and BMWP.EQI	49	3	51	1	47	5	51	1
Biological Class a	55.10%	0%	52.94%	0%	57.45%	0%	52.94%	0%
Biological Class b	28.57%	33.33%	29.41%	0%	27.66%	40.00%	29.41%	0%
Biological Class c	12.24%	0%	11.76%	0%	10.64%	20.00%	11.76%	0%
Biological Class d	4.08%	66.67%	5.88%	100%	4.26%	40.00%	5.88%	100%
T Zn and FISH	45	3	47	1	44	4	47	1
Fisheries Class 1	4.44%	0%	4.26%	0%	4.55%	0%	4.26%	0%
Fisheries Class 2	35.56%	0%	34.04%	0%	36.36%	0%	34.04%	0%
Fisheries Class 3	24.44%	33.33%	23.40%	100%	25.00%	25.00%	23.40%	100%
Fisheries Class 4	13.33%	0%	12.77%	0%	11.36%	25.00%	12.77%	0%
Fisheries Class 5	22.22%	0%	21.28%	0%	22.73%	0%	21.28%	0%
Fisheries Class 6	0%	66.67%	4.26%	0%	0%	50.00%	4.26%	0%
D Zn					22	6		
D Zn and BMWP.EQI					13	3		
Biological Class a					46.15%	0%		
Biological Class b					30.77%	33.33%		
Biological Class c					7.69%	0%		
Biological Class d					15.38%	66.67%		
D Zn and FISH					21	2		
Fisheries Class 1					0%	0%		
Fisheries Class 2					33.33%	0%		
Fisheries Class 3					28.57%	0%		
Fisheries Class 4					28.57%	0%		
Fisheries Class 5					9.52%	0%		
Fisheries Class 6					0%	100%		
D Cu	86	7	86	7	84	9	92	1
D Cu and BMWP.EQI	47	2	47	2	46	3	49	0
Biological Class a	55.32%	0%	55.32%	0%	54.35%	33.33%	53.06%	
Biological Class b	27.66%	0%	27.66%	0%	28.26%	0%	26.53%	
Biological Class c	12.77%	0%	12.77%	0%	13.04%	0%	12.24%	
Biological Class d	4.26%	100%	4.26%	100%	4.35%	66.67%	8.16%	
D Cu and FISH	40	4	40	4	38	6	44	0
Fisheries Class 1	0%	0%	0%	0%	0%	0%	0%	
Fisheries Class 2	37.50%	25.00%	37.50%	25.00%	39.47%	16.67%	36.36%	
Fisheries Class 3	27.50%	25.00%	27.50%	25.00%	26.32%	33.33%	27.27%	
Fisheries Class 4	15.00%	0%	15.00%	0%	13.16%	16.67%	13.64%	
Fisheries Class 5	20.00%	0%	20.00%	0%	21.05%	0%	18.18%	
Fisheries Class 6	0%	50.00%	0%	50.00%	0%	33.33%	4.55%	

Table A19 Cont. Hardness Band E (201-250 mg/l $CaCO_3$) 102 Records

	Existing EQSs (Salmonid)		Existing EQSs (Cyprinid)		Proposed EQSs		Fisheries Directive (Salmonid)	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
D Cr	53	2	55	0	51	4		
D Cr and BMWP.EQI	31	1	32	0	30	2		
Biological Class a	41.94%	0%	40.63%		43.33%	0%		
Biological Class b	35.48%	0%	34.38%		36.67%	0%		
Biological Class c	12.90%	0%	12.50%		13.33%	0%		
Biological Class d	9.68%	100%	12.50%		6.67%	100%		
D Cr and FISH	22	0	22	0	20	2		
Fisheries Class 1	0%		0%		0%	0%		
Fisheries Class 2	31.82%		31.82%		35.00%	0%		
Fisheries Class 3	22.73%		22.73%		25.00%	0%		
Fisheries Class 4	27.27%		27.27%		30.00%	0%		
Fisheries Class 5	9.09%		9.09%		10.00%	0%		
Fisheries Class 6	9.09%		9.09%		0%	100%		
D Pb	54	0	54	0	54	0		
D Pb and BMWP.EQI	33	0	33	0	33	0		
Biological Class a	42.42%		42.42%		42.42%			
Biological Class b	33.33%		33.33%		33.33%			
Biological Class c	12.12%		12.12%		12.12%			
Biological Class d	12.12%		12.12%		12.12%			
D Pb and FISH	23	0	23	0	23	0		
Fisheries Class 1	0%		0%		0%			
Fisheries Class 2	30.43%		30.43%		30.43%			
Fisheries Class 3	26.09%		26.09%		26.09%			
Fisheries Class 4	26.09%		26.09%		26.09%			
Fisheries Class 5	8.70%		8.70%		8.70%			
Fisheries Class 6	8.70%		8.70%		8.70%			
D Ni	56	0	56	0	56	0		
D Ni and BMWP.EQI	33	0	33	0	33	0		
Biological Class a	42.42%		42.42%		42.42%			
Biological Class b	33.33%		33.33%		33.33%			
Biological Class c	12.12%		12.12%		12.12%			
Biological Class d	12.12%		12.12%		12.12%			
D Ni and FISH	23	0	23	0	23	0		
Fisheries Class 1	0%		0%		0%			
Fisheries Class 2	30.43%		30.43%		30.43%			
Fisheries Class 3	26.09%		26.09%		26.09%			
Fisheries Class 4	26.09%		26.09%		26.09%			
Fisheries Class 5	8.70%		8.70%		8.70%			
Fisheries Class 6	8.70%		8.70%		8.70%			

Table A20. Hardness Band F (>250 mg/l $CaCO_3$) 468 Records

	Existing EQSs (Salmonid)		Existing EQSs (Cyprinid)		Proposed EQSs		Fisheries Directive (Salmonid)	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
T Zn	418	29	437	10	381	66	426	21
T Zn and BMWP.EQI	222	10	227	5	207	25	223	9
Biological Class a	58.11%	10.00%	57.27%	0%	60.87%	16.00%	57.40%	22.22%
Biological Class b	22.07%	10.00%	22.03%	0%	21.26%	24.00%	21.52%	22.22%
Biological Class c	13.96%	10.00%	14.10%	0%	13.53%	16.00%	14.35%	0%
Biological Class d	5.86%	70.00%	6.61%	100%	4.35%	44.00%	6.73%	55.56%
T Zn and FISH	267	12	279	0	246	33	274	5
Fisheries Class 1	3.00%	0%	2.87%		3.25%	0%	2.92%	0%
Fisheries Class 2	17.23%	0%	16.49%		17.89%	6.06%	16.79%	0%
Fisheries Class 3	34.08%	8.33%	32.97%		35.77%	12.12%	33.58%	0%
Fisheries Class 4	17.60%	16.67%	17.56%		17.48%	18.18%	16.79%	60.00%
Fisheries Class 5	23.60%	66.67%	25.45%		21.95%	51.52%	25.55%	20.00%
Fisheries Class 6	4.49%	8.33%	4.66%		3.66%	12.12%	4.38%	20.00%
D Zn					131	20		
D Zn and BMWP.EQI					68	6		
Biological Class a					50.00%	0%		
Biological Class b					26.47%	16.67%		
Biological Class c					13.24%	50.00%		
Biological Class d					10.29%	33.33%		
D Zn and FISH					110	17		
Fisheries Class 1					1.82%	0%		
Fisheries Class 2					17.27%	0%		
Fisheries Class 3					27.27%	5.88%		
Fisheries Class 4					15.45%	23.53%		
Fisheries Class 5					32.73%	58.82%		
Fisheries Class 6					5.45%	11.76%		
D Cu	343	17	343	17	323	37	339	21
D Cu and BMWP.EQI	142	10	142	10	129	23	138	14
Biological Class a	63.38%	30.00%	63.38%	30.00%	64.34%	43.48%	62.32%	50.00%
Biological Class b	16.20%	40.00%	16.20%	40.00%	17.05%	21.74%	16.67%	28.57%
Biological Class c	12.68%	0%	12.68%	0%	12.40%	8.70%	13.04%	0%
Biological Class d	7.75%	30.00%	7.75%	30.00%	6.20%	26.09%	7.97%	21.43%
D Cu and FISH	215	3	215	3	205	13	215	3
Fisheries Class 1	3.72%	0%	3.72%	0%	3.90%	0%	3.72%	0%
Fisheries Class 2	20.47%	0%	20.47%	0%	21.46%	0%	20.47%	0%
Fisheries Class 3	28.37%	33.33%	28.37%	33.33%	29.27%	15.38%	28.37%	33.33%
Fisheries Class 4	14.42%	33.33%	14.42%	33.33%	13.66%	30.77%	14.42%	33.33%
Fisheries Class 5	29.77%	33.33%	29.77%	33.33%	28.29%	53.85%	29.77%	33.33%
Fisheries Class 6	3.26%	0%	3.26%	0%	3.41%	0%	3.26%	0%

Table A20 Cont. Hardness Band F (>250 mg/l $CaCO_3$) 468 Records

	Existing EQSs (Salmonid)		Existing EQSs (Cyprinid)		Proposed EQSs		Fisheries Directive (Salmonid)	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
D Cr	186	0	186	0	185	1		
D Cr and BMWP.EQI	78	0	78	0	78	0		
Biological Class a	39.74%		39.74%		39.74%			
Biological Class b	25.64%		25.64%		25.64%			
Biological Class c	16.67%		16.67%		16.67%			
Biological Class d	17.95%		17.95%		17.95%			
D Cr and FISH	129	0	129	0	129	0		
Fisheries Class 1	0%		0%		0%			
Fisheries Class 2	13.95%		13.95%		13.95%			
Fisheries Class 3	24.03%		24.03%		24.03%			
Fisheries Class 4	20.16%		20.16%		20.16%			
Fisheries Class 5	36.43%		36.43%		36.43%			
Fisheries Class 6	5.43%		5.43%		5.43%			
D Pb	176	4	178	2	176	4		
D Pb and BMWP.EQI	81	2	82	1	81	2		
Biological Class a	46.91%	0%	46.34%	0%	46.91%	0%		
Biological Class b	24.69%	0%	24.39%	0%	24.69%	0%		
Biological Class c	14.81%	0%	14.63%	0%	14.81%	0%		
Biological Class d	13.58%	100%	14.63%	100%	13.58%	100%		
D Pb and FISH	127	0	127	0	127	0		
Fisheries Class 1	0.79%		0.79%		0.79%			
Fisheries Class 2	14.96%		14.96%		14.96%			
Fisheries Class 3	25.20%		25.20%		25.20%			
Fisheries Class 4	16.54%		16.54%		16.54%			
Fisheries Class 5	36.22%		36.22%		36.22%			
Fisheries Class 6	6.30%		6.30%		6.30%			
D Ni	181	1	181	1	167	15		
D Ni and BMWP.EQI	81	0	81	0	77	4		
Biological Class a	44.44%		44.44%		46.75%	0%		
Biological Class b	24.69%		24.69%		25.97%	0%		
Biological Class c	14.81%		14.81%		12.99%	50.00%		
Biological Class d	16.05%		16.05%		14.29%	50.00%		
D Ni and FISH	127	0	127	0	117	10		
Fisheries Class 1	0%		0%		0%	0%		
Fisheries Class 2	14.17%		14.17%		15.38%	0%		
Fisheries Class 3	25.20%		25.20%		26.50%	10.00%		
Fisheries Class 4	17.32%		17.32%		17.09%	20.00%		
Fisheries Class 5	37.01%		37.01%		34.19%	70.00%		
Fisheries Class 6	6.30%		6.30%		6.84%	0%		

Table A21. Dissolved Arsenic

	Existing EQSs (Salmonid)		Existing EQSs (Cyprinid)		Proposed EQSs		Fisheries Directive (Salmonid)	
	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
D As	747	3	747	3	747	3		
D As and BMWP.EQI	353	1	353	1	353	1		
Biological Class a	70.54%	0%	70.54%	0%	70.54%	0%		
Biological Class b	13.88%	0%	13.88%	0%	13.88%	0%		
Biological Class c	9.07%	0%	9.07%	0%	9.07%	0%		
Biological Class d	6.52%	100%	6.52%	100%	6.52%	100%		
D As and FISH	145	1	145	1	145	1		
Fisheries Class 1	20.69%	0%	20.69%	0%	20.69%	0%		
Fisheries Class 2	25.52%	0%	25.52%	0%	25.52%	0%		
Fisheries Class 3	13.79%	0%	13.79%	0%	13.79%	0%		
Fisheries Class 4	17.93%	0%	17.93%	0%	17.93%	0%		
Fisheries Class 5	15.86%	0%	15.86%	0%	15.86%	0%		
Fisheries Class 6	6.21%	100%	6.21%	100%	6.21%	100%		

TABLES A22 TO A28

RESULTS OF PEARSON CORRELATIONS

Table A22. Hardness Band A (0-50 mg/l $CaCO_3$)

		ALL			FAILS		
		r	p	n	r	p	n
T Zn :	BMWP	-0.24	0.0007	178	-0.24	0.0109	90
	B.EQI	-0.24	0.0007	178	-0.21	0.021	90
	NO.TAXA	-0.24	0.0005	178	-0.27	0.0055	90
	TAX.EQI	-0.24	0.0005	178	-0.23	0.014	90
	FISH	0.21	0.038	76	0.26	0.027	57
Log D Zn :	BMWP	*	*	*	*	*	*
	B.EQI	*	*	*	*	*	*
	NO.TAXA	*	*	*	*	*	*
	TAX.EQI	*	*	*	*	*	*
	FISH	*	*	*	*	*	*
D Cu :	BMWP	-0.25	0.0006	161	-0.25	0.0006	161
	B.EQI	-0.24	0.0013	161	-0.24	0.0013	161
	NO.TAXA	-0.27	0.0003	161	-0.27	0.0003	161
	TAX.EQI	-0.24	0.001	161	-0.24	0.001	161
	FISH	0.21	0.045	63	0.21	0.045	63
Log D Cr :	BMWP	-0.05	0.26	148	-0.31	0.0027	81
	B.EQI	0.004	0.48	148	-0.38	0.0002	81
	NO.TAXA	-0.07	0.19	148	-0.24	0.017	81
	TAX.EQI	-0.005	0.48	148	-0.34	0.001	81
	FISH	-0.17	0.15	42	-0.11	0.26	33
D Pb :	BMWP	-0.06	0.25	148	-0.05	0.41	24
	B.EQI	-0.04	0.30	148	0.08	0.35	24
	NO.TAXA	-0.06	0.23	148	-0.08	0.36	24
	TAX.EQI	-0.04	0.33	148	0.10	0.32	24
	FISH	-0.17	0.14	42	-0.08	0.36	24
D Ni :	BMWP	-0.03	0.35	148	*	*	*
	B.EQI	-0.07	0.21	148	*	*	*
	NO.TAXA	-0.01	0.44	148	*	*	*
	TAX.EQI	-0.06	0.24	148	*	*	*
	FISH	0.05	0.38	42	*	*	*

Table A23. Hardness Band B (51-100 mg/l $CaCO_3$)

		ALL			FAILS		
		r	p	n	r	p	n
T Zn :	BMWP	-0.31	0.0000	234	-0.24	0.0095	93
	B.EQI	-0.30	0.0000	234	-0.23	0.015	93
	NO.TAXA	-0.33	0.0000	234	-0.27	0.0047	93
	TAX.EQI	-0.32	0.0000	234	-0.25	0.0085	93
	FISH	0.48	0.0000	86	0.32	0.048	28
Log D Zn :	BMWP	*	*	*	*	*	*
	B.EQI	*	*	*	*	*	*
	NO.TAXA	*	*	*	*	*	*
	TAX.EQI	*	*	*	*	*	*
	FISH	*	*	*	*	*	*
D Cu :	BMWP	-0.36	0.0000	229	-0.37	0.0000	125
	B.EQI	-0.38	0.0000	229	-0.39	0.0000	125
	NO.TAXA	-0.38	0.0000	229	-0.39	0.0000	125
	TAX.EQI	-0.40	0.0000	229	-0.41	0.0000	125
	FISH	0.44	0.0000	80	0.35	0.017	38
Log D Cr :	BMWP	0.03	0.34	199	*	*	*
	B.EQI	0.06	0.22	199	*	*	*
	NO.TAXA	0.03	0.31	199	*	*	*
	TAX.EQI	0.06	0.19	199	*	*	*
	FISH	0.53	0.0009	32	*	*	*
D Pb :	BMWP	-0.008	0.46	195	*	*	*
	B.EQI	-0.001	0.49	195	*	*	*
	NO.TAXA	-0.03	0.34	195	*	*	*
	TAX.EQI	-0.02	0.37	195	*	*	*
	FISH	0.31	0.058	27	*	*	*
D Ni :	BMWP	-0.16	0.014	196	0.24	0.22	13
	B.EQI	-0.12	0.053	196	0.38	0.098	13
	NO.TAXA	-0.16	0.014	196	0.30	0.16	13
	TAX.EQI	-0.11	0.055	196	0.45	0.064	13
	FISH	0.03	0.44	30	*	*	*

Table A24. Hardness Band C (101-150 mg/l $CaCO_3$)

	ALL			FAILS		
	r	p	n	r	p	n
T Zn : BMWP	-0.16	0.039	119	-0.02	0.45	45
B.EQI	-0.15	0.051	119	-0.04	0.40	45
NO.TAXA	-0.20	0.016	119	-0.08	0.29	45
TAX.EQI	-0.17	0.029	119	-0.07	0.33	45
FISH	0.36	0.0009	74	0.31	0.022	42
Log D Zn : BMWP	-0.22	0.16	23	-0.09	0.39	11
B.EQI	-0.21	0.16	23	-0.08	0.41	11
NO.TAXA	-0.37	0.039	23	-0.35	0.15	11
TAX.EQI	-0.28	0.10	23	-0.20	0.28	11
FISH	0.25	0.083	32	0.15	0.26	19
D Cu : BMWP	-0.22	0.012	106	-0.17	0.11	56
B.EQI	-0.23	0.008	106	-0.18	0.087	56
NO.TAXA	-0.21	0.014	106	-0.17	0.11	56
TAX.EQI	-0.24	0.0075	106	-0.18	0.094	56
FISH	0.22	0.054	56	0.07	0.34	37
Log D Cr : BMWP	-0.09	0.20	90	*	*	*
B.EQI	-0.07	0.25	90	*	*	*
NO.TAXA	-0.10	0.18	90	*	*	*
TAX.EQI	-0.08	0.23	90	*	*	*
FISH	0.40	0.0097	33	*	*	*
D Pb : BMWP	-0.04	0.35	92	*	*	*
B.EQI	-0.07	0.27	92	*	*	*
NO.TAXA	-0.08	0.23	92	*	*	*
TAX.EQI	-0.09	0.21	92	*	*	*
FISH	-0.20	0.12	36	*	*	*
D Ni : BMWP	-0.04	0.34	91	*	*	*
B.EQI	-0.03	0.39	91	*	*	*
NO.TAXA	-0.03	0.37	91	*	*	*
TAX.EQI	-0.03	0.40	91	*	*	*
FISH	0.28	0.047	36	*	*	*

Table A25. Hardness Band D (151-200 mg/l $CaCO_3$)

		ALL			FAILS		
		r	p	n	r	p	n
T Zn :	BMWP	-0.30	0.018	49	*	*	*
	B.EQI	-0.31	0.015	49	*	*	*
	NO.TAXA	-0.37	0.0042	49	*	*	*
	TAX.EQI	-0.36	0.0056	49	*	*	*
	FISH	0.39	0.0026	50	*	*	*
Log D Zn :	BMWP	-0.07	0.39	20	*	*	*
	B.EQI	-0.05	0.42	20	*	*	*
	NO.TAXA	-0.20	0.20	20	*	*	*
	TAX.EQI	-0.14	0.28	20	*	*	*
	FISH	0.42	0.015	27	*	*	*
D Cu :	BMWP	-0.24	0.050	47	-0.25	0.091	31
	B.EQI	-0.26	0.036	47	-0.27	0.069	31
	NO.TAXA	-0.29	0.026	47	-0.30	0.051	31
	TAX.EQI	-0.30	0.022	47	-0.30	0.048	31
	FISH	0.33	0.011	48	0.30	0.038	35
Log D Cr :	BMWP	0.036	0.42	34	*	*	*
	B.EQI	-0.08	0.32	34	*	*	*
	NO.TAXA	-0.09	0.32	34	*	*	*
	TAX.EQI	-0.15	0.20	34	*	*	*
	FISH	0.58	0.0003	32	*	*	*
D Pb :	BMWP	-0.30	0.037	36	*	*	*
	B.EQI	-0.34	0.022	36	*	*	*
	NO.TAXA	-0.40	0.0078	36	*	*	*
	TAX.EQI	-0.41	0.0068	36	*	*	*
	FISH	0.23	0.11	30	*	*	*
D Ni :	BMWP	-0.59	0.0001	35	*	*	*
	B.EQI	-0.59	0.0001	35	*	*	*
	NO.TAXA	-0.60	0.0001	35	*	*	*
	TAX.EQI	-0.60	0.0001	35	*	*	*
	FISH	0.27	0.069	32	*	*	*

Table A26. Hardness Band E (201-250 mg/l $CaCO_3$)

		ALL			FAILS		
		r	p	n	r	p	n
T Zn :	BMWP	-0.42	0.0009	52	*	*	*
	B.EQI	-0.42	0.001	52	*	*	*
	NO.TAXA	-0.47	0.0002	52	*	*	*
	TAX.EQI	-0.47	0.0002	52	*	*	*
	FISH	-0.30	0.020	48	*	*	*
Log D Zn :	BMWP	-0.63	0.0045	16	*	*	*
	B.EQI	-0.57	0.0099	16	*	*	*
	NO.TAXA	-0.62	0.0053	16	*	*	*
	TAX.EQI	-0.61	0.0061	16	*	*	*
	FISH	0.47	0.011	23	*	*	*
D Cu :	BMWP	-0.38	0.0039	49	*	*	*
	B.EQI	-0.36	0.0053	49	*	*	*
	NO.TAXA	-0.42	0.0015	49	*	*	*
	TAX.EQI	-0.41	0.0016	49	*	*	*
	FISH	0.29	0.029	44	*	*	*
Log D Cr :	BMWP	-0.20	0.13	32	*	*	*
	B.EQI	-0.25	0.083	32	*	*	*
	NO.TAXA	-0.27	0.067	32	*	*	*
	TAX.EQI	-0.28	0.058	32	*	*	*
	FISH	0.64	0.0007	22	*	*	*
D Pb :	BMWP	0.17	0.17	33	*	*	*
	B.EQI	0.16	0.18	33	*	*	*
	NO.TAXA	0.12	0.25	33	*	*	*
	TAX.EQI	0.16	0.19	33	*	*	*
	FISH	0.039	0.43	23	*	*	*
D Ni :	BMWP	0.12	0.26	33	*	*	*
	B.EQI	0.13	0.23	33	*	*	*
	NO.TAXA	0.13	0.24	33	*	*	*
	TAX.EQI	0.13	0.24	33	*	*	*
	FISH	0.21	0.17	23	*	*	*

Table A27. Hardness Band F (>250 mg/l $CaCO_3$)

		ALL			FAILS		
		r	p	n	r	p	n
T Zn :	BMWP	-0.22	0.0004	232	-0.37	0.035	25
	B.EQI	-0.23	0.0002	232	-0.36	0.039	25
	NO.TAXA	-0.27	0.0000	232	-0.45	0.012	25
	TAX.EQI	-0.28	0.0000	232	-0.44	0.013	25
	FISH	0.35	0.0000	279	0.029	0.44	33
Log D Zn :	BMWP	-0.54	0.0000	74	*	*	*
	B.EQI	-0.51	0.0000	74	*	*	*
	NO.TAXA	-0.52	0.0000	74	*	*	*
	TAX.EQI	-0.50	0.0000	74	*	*	*
	FISH	0.37	0.0000	127	-0.61	0.0048	17
D Cu :	BMWP	-0.27	0.0003	152	-0.38	0.038	23
	B.EQI	-0.27	0.0004	152	-0.36	0.046	23
	NO.TAXA	-0.32	0.0000	152	-0.45	0.015	23
	TAX.EQI	-0.31	0.0000	152	-0.44	0.018	23
	FISH	0.26	0.0001	218	-0.31	0.15	13
Log D Cr :	BMWP	-0.22	0.028	78	*	*	*
	B.EQI	-0.16	0.083	78	*	*	*
	NO.TAXA	-0.16	0.079	78	*	*	*
	TAX.EQI	-0.13	0.13	78	*	*	*
	FISH	0.30	0.0003	129	*	*	*
D Pb :	BMWP	-0.22	0.025	83	*	*	*
	B.EQI	-0.23	0.018	83	*	*	*
	NO.TAXA	-0.28	0.0056	83	*	*	*
	TAX.EQI	-0.29	0.0042	83	*	*	*
	FISH	0.0079	0.46	127	*	*	*
D Ni :	BMWP	-0.36	0.0004	81	*	*	*
	B.EQI	-0.39	0.0002	81	*	*	*
	NO.TAXA	-0.39	0.0001	81	*	*	*
	TAX.EQI	-0.41	0.0001	81	*	*	*
	FISH	0.18	0.021	127	*	*	*

Table A28. Dissolved Arsenic

	ALL		
	r	p	n
Log D As : BMWP	0.06	0.14	354
B.EQI	-0.052	0.16	354
NO.TAXA	-0.25	0.0000	354
TAX.EQI	-0.28	0.0000	354
FISH	0.16	0.026	146

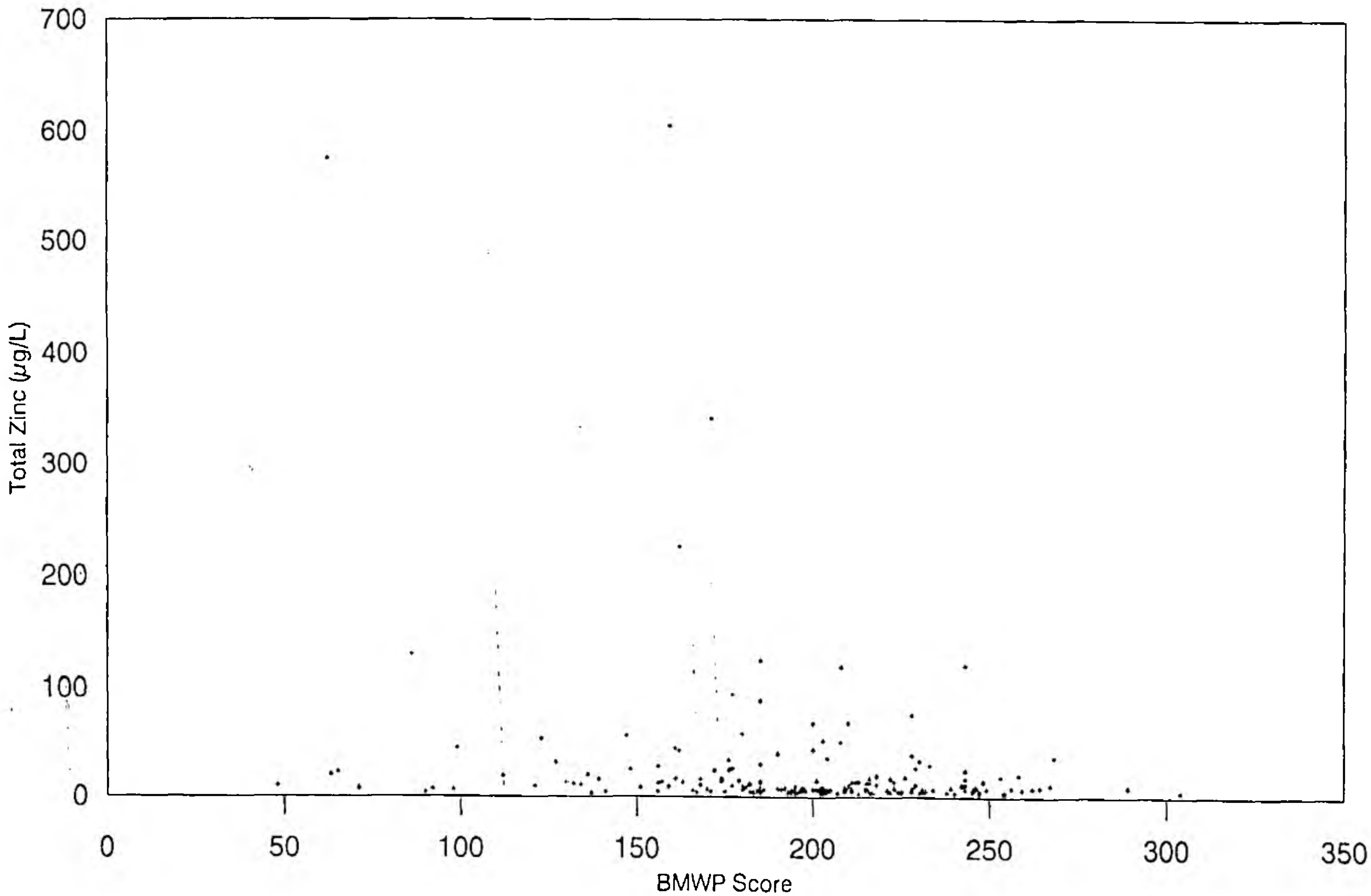
APPENDIX 2

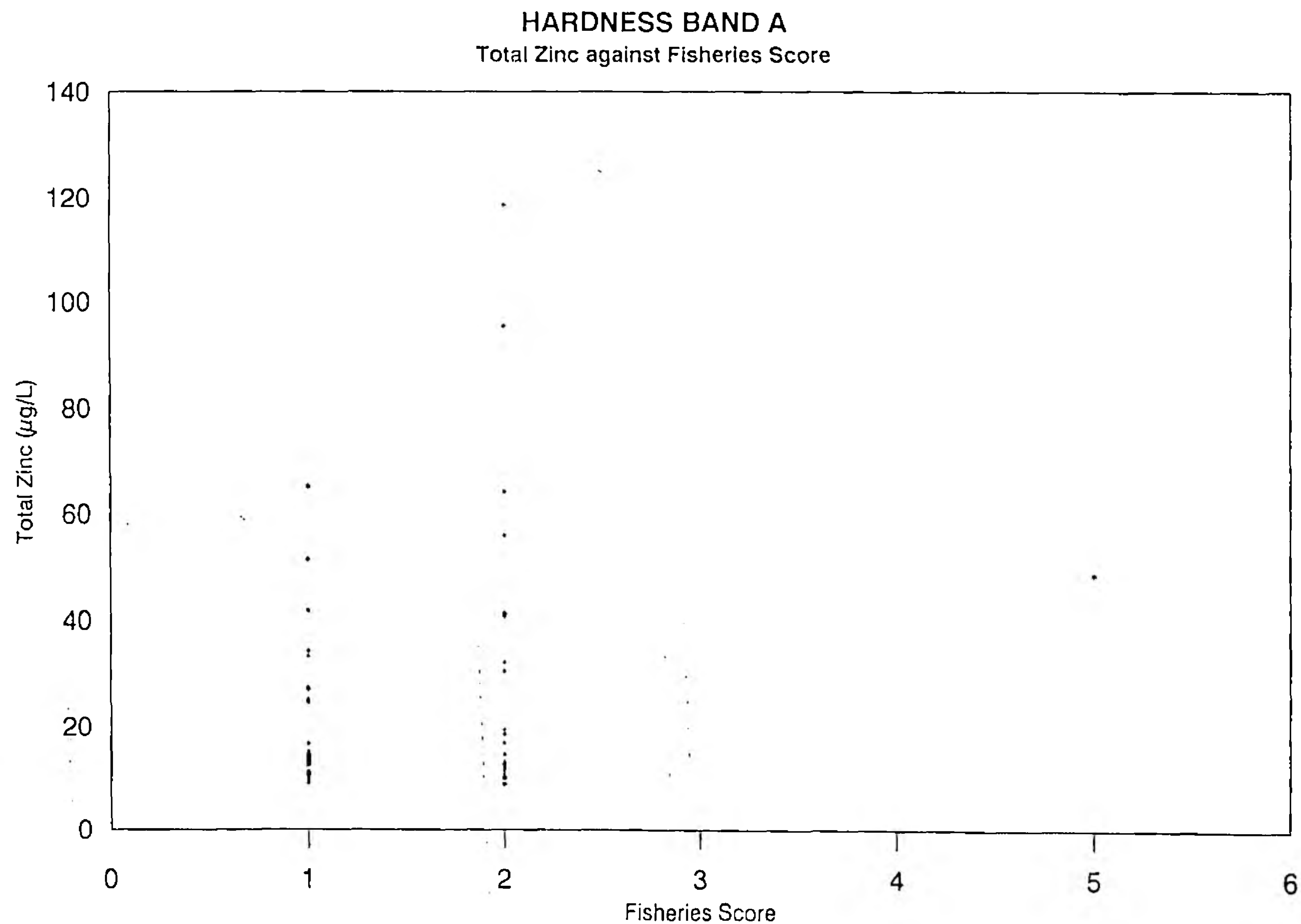
PLOTS

LIST OF PLOTS

HARDNESS BAND A

Total Zinc against BMWP Score

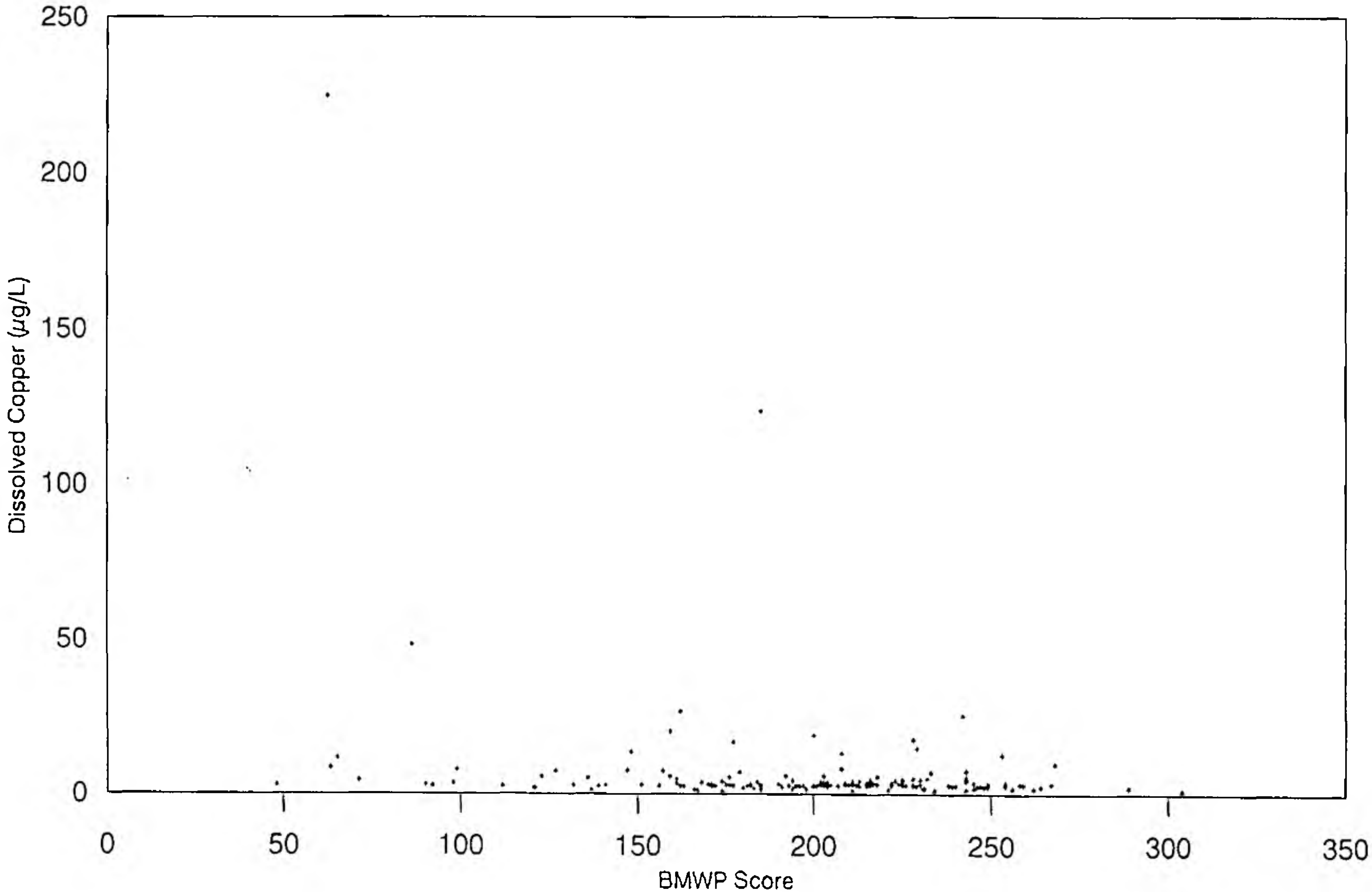


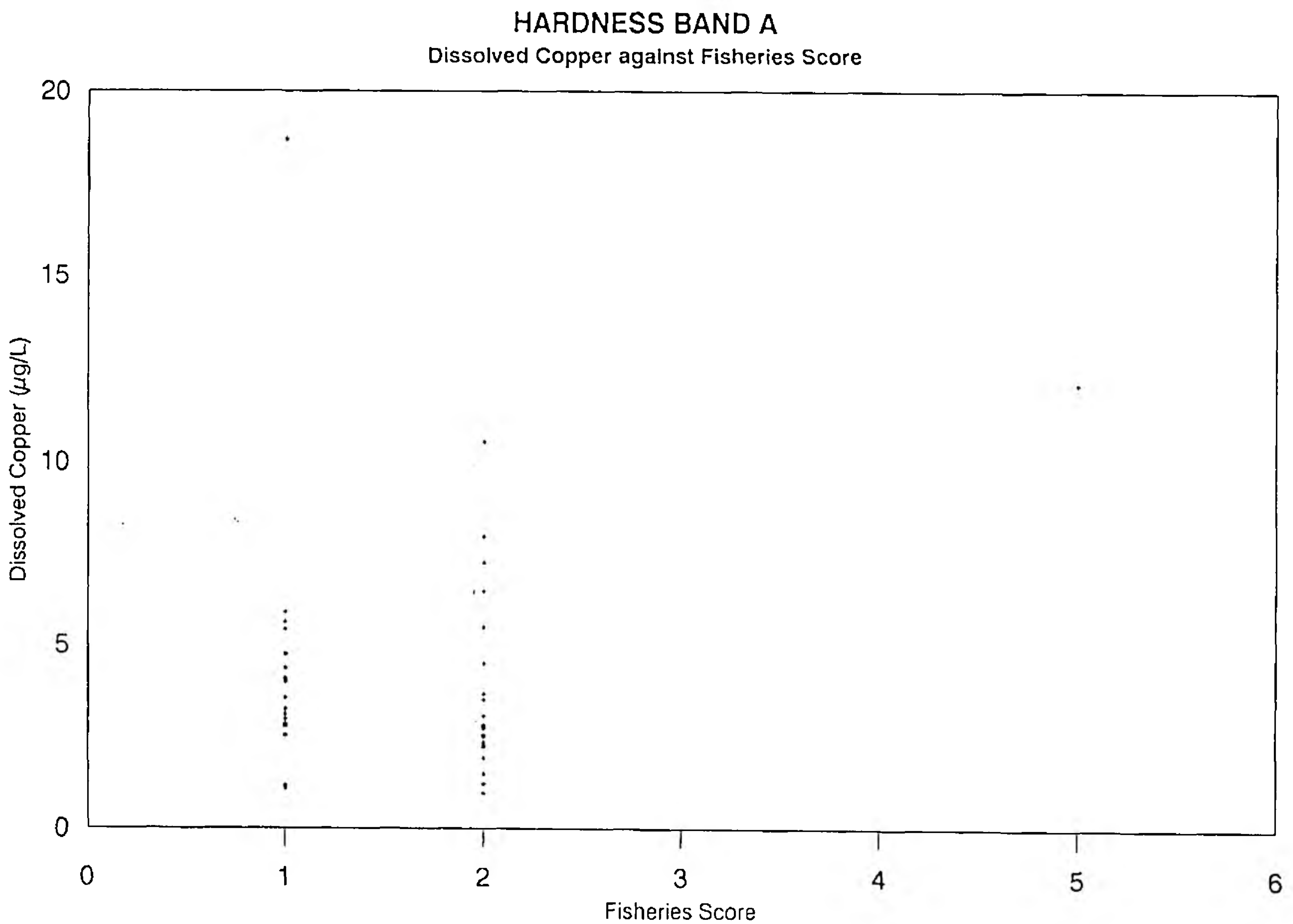


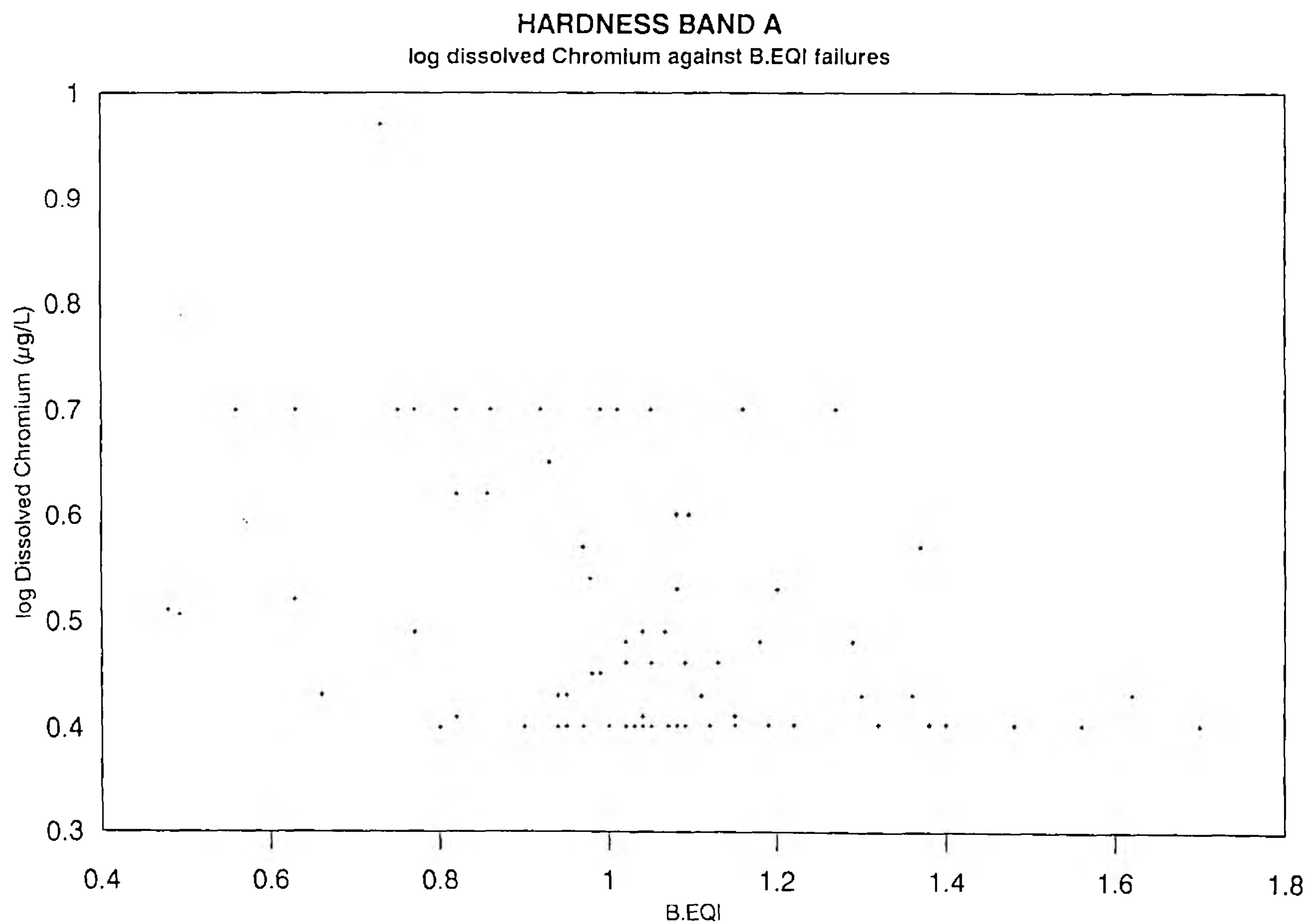
HARDNESS BAND A
Total Zinc against Fisheries Score
Total Zinc (µg/L)
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
Fisheries Score

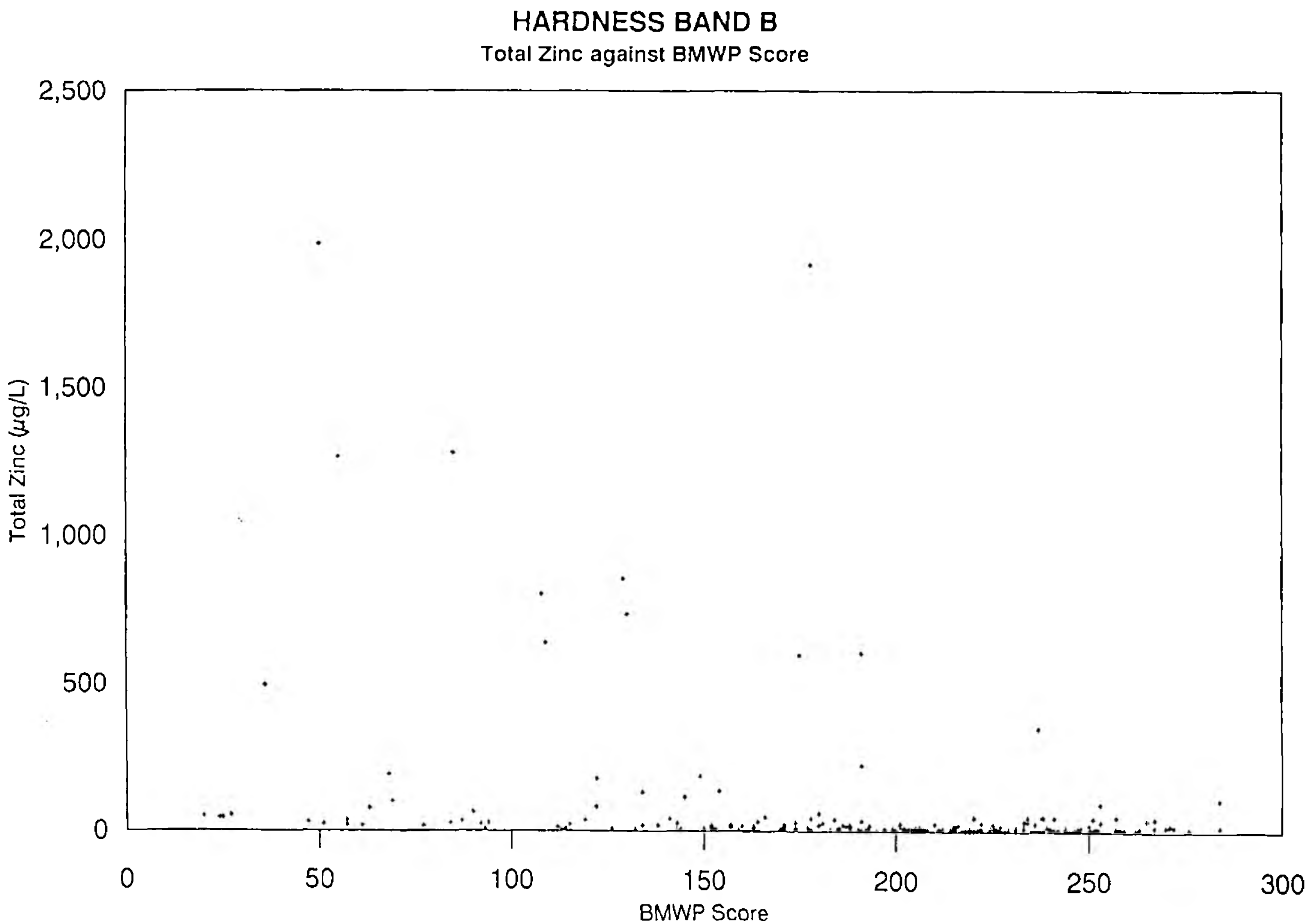
HARDNESS BAND A

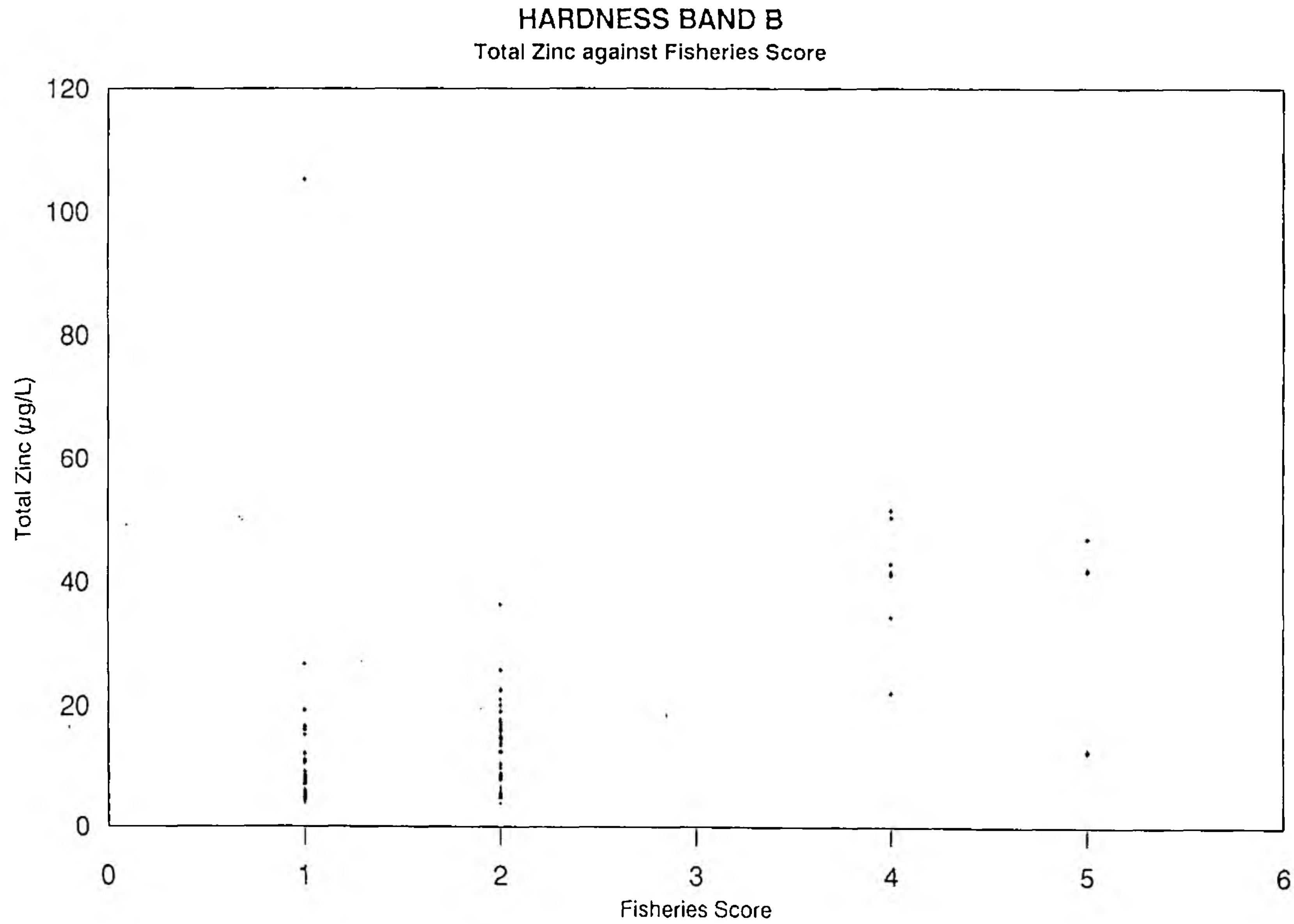
Dissolved Copper against BMWP Score




HARDNESS BAND A
Dissolved Copper against Fisheries Score
Dissolved Copper (μg/L)
0
5
10
15
20
0
1
2
3
4
5
6
Fisheries Score

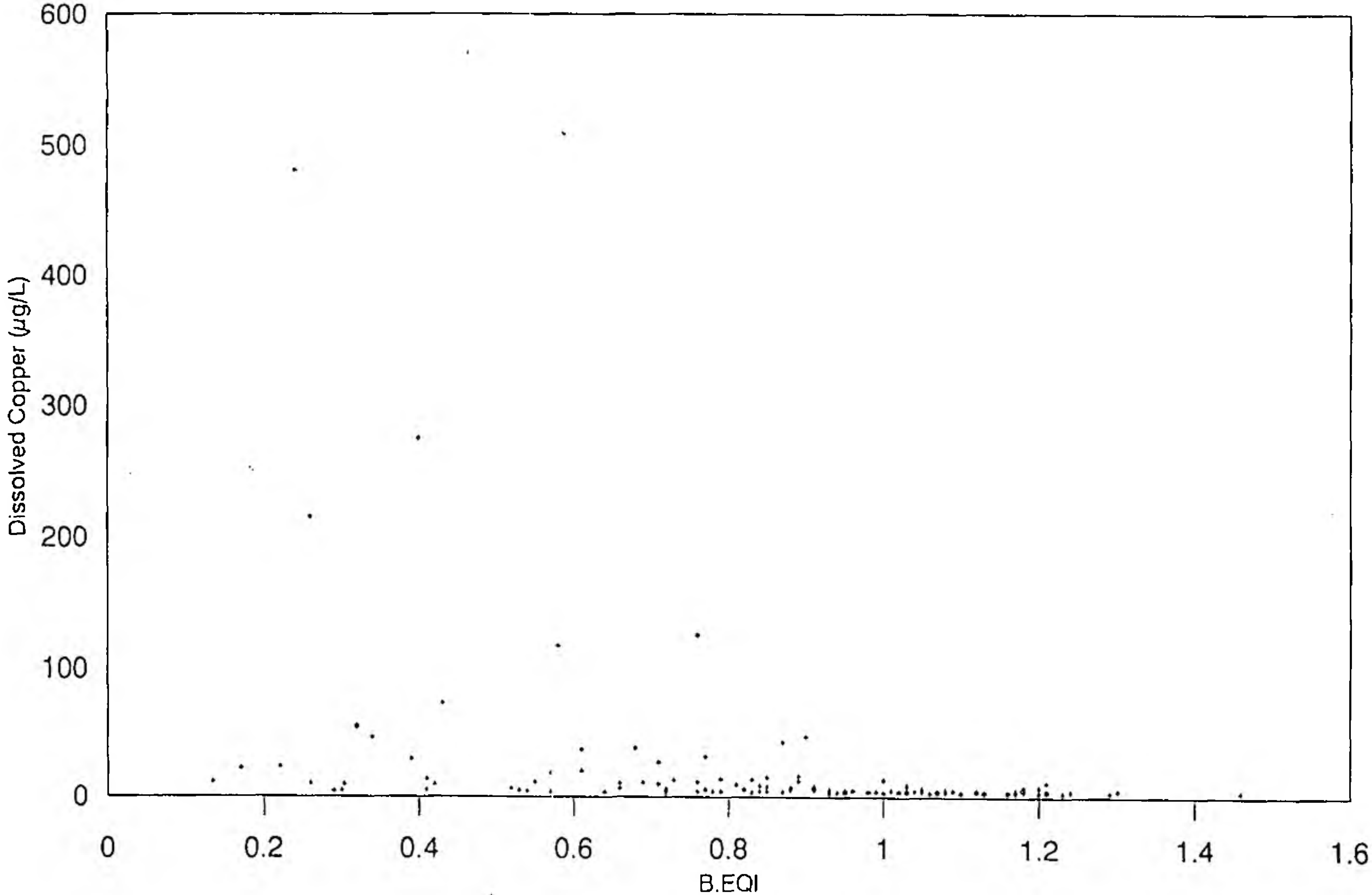

HARDNESS BAND A
log dissolved Chromium against B.EQI failures
log Dissolved Chromium (µg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
B.EQI


HARDNESS BAND B
Total Zinc against BMWP Score
Total Zinc (µg/L)
2,500
2,000
1,500
1,000
500
0
0
50
100
150
200
250
300
BMWP Score


HARDNESS BAND B
Total Zinc against Fisheries Score
Total Zinc (µg/L)
Fisheries Score
0
20
40
60
80
100
120
0
1
2
3
4
5
6

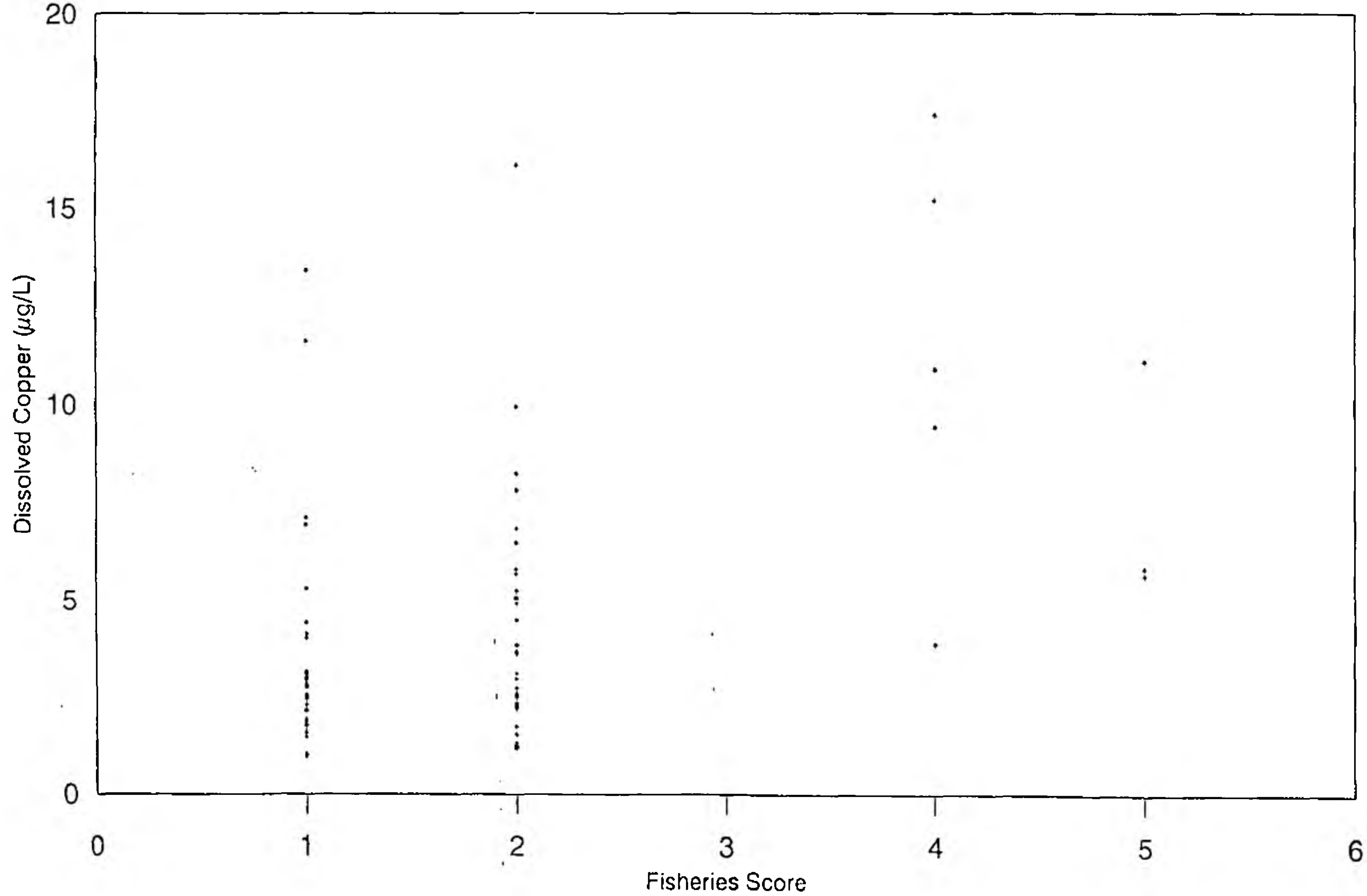
HARDNESS BAND B

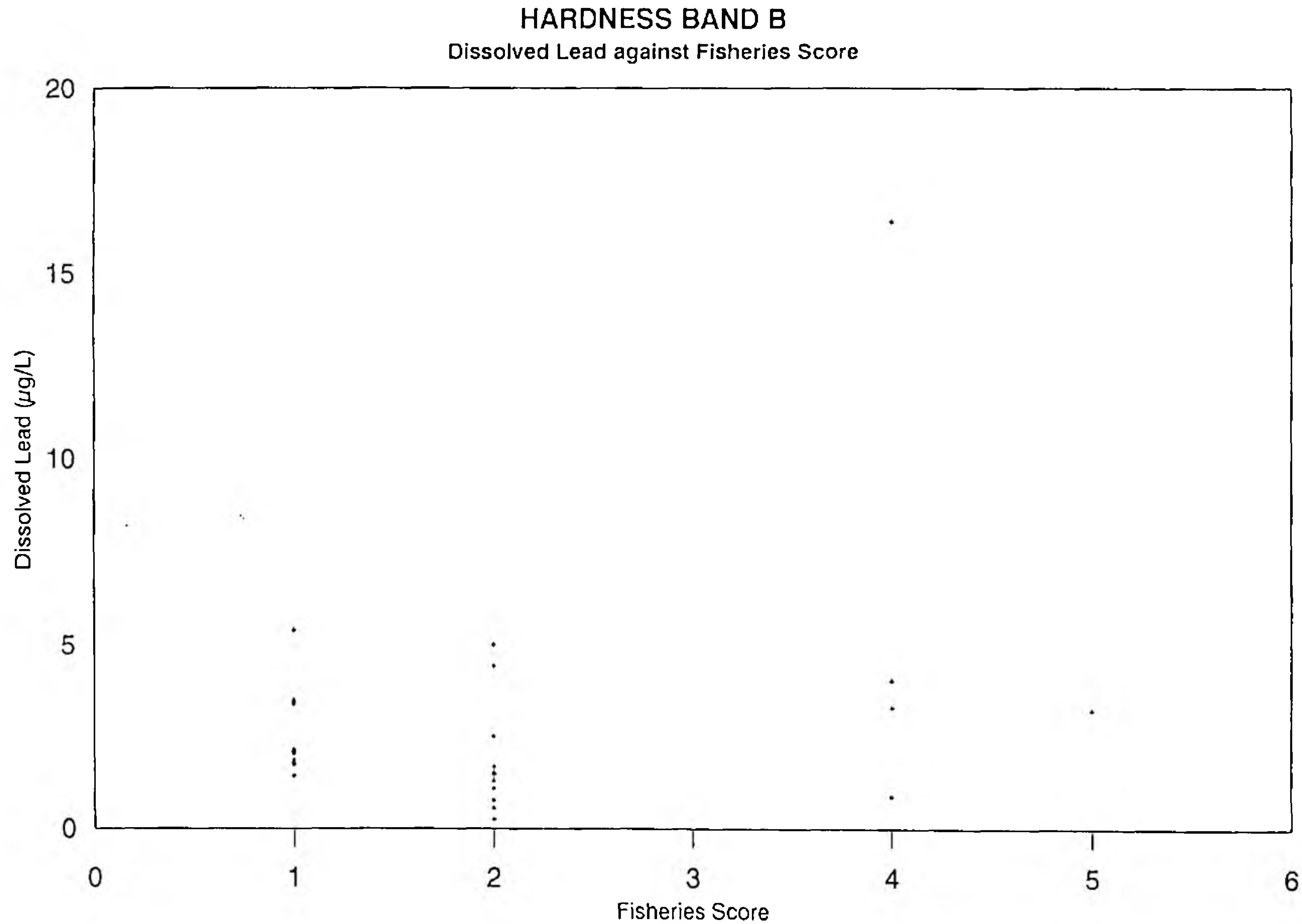
Dissolved Copper against B.EQI failures

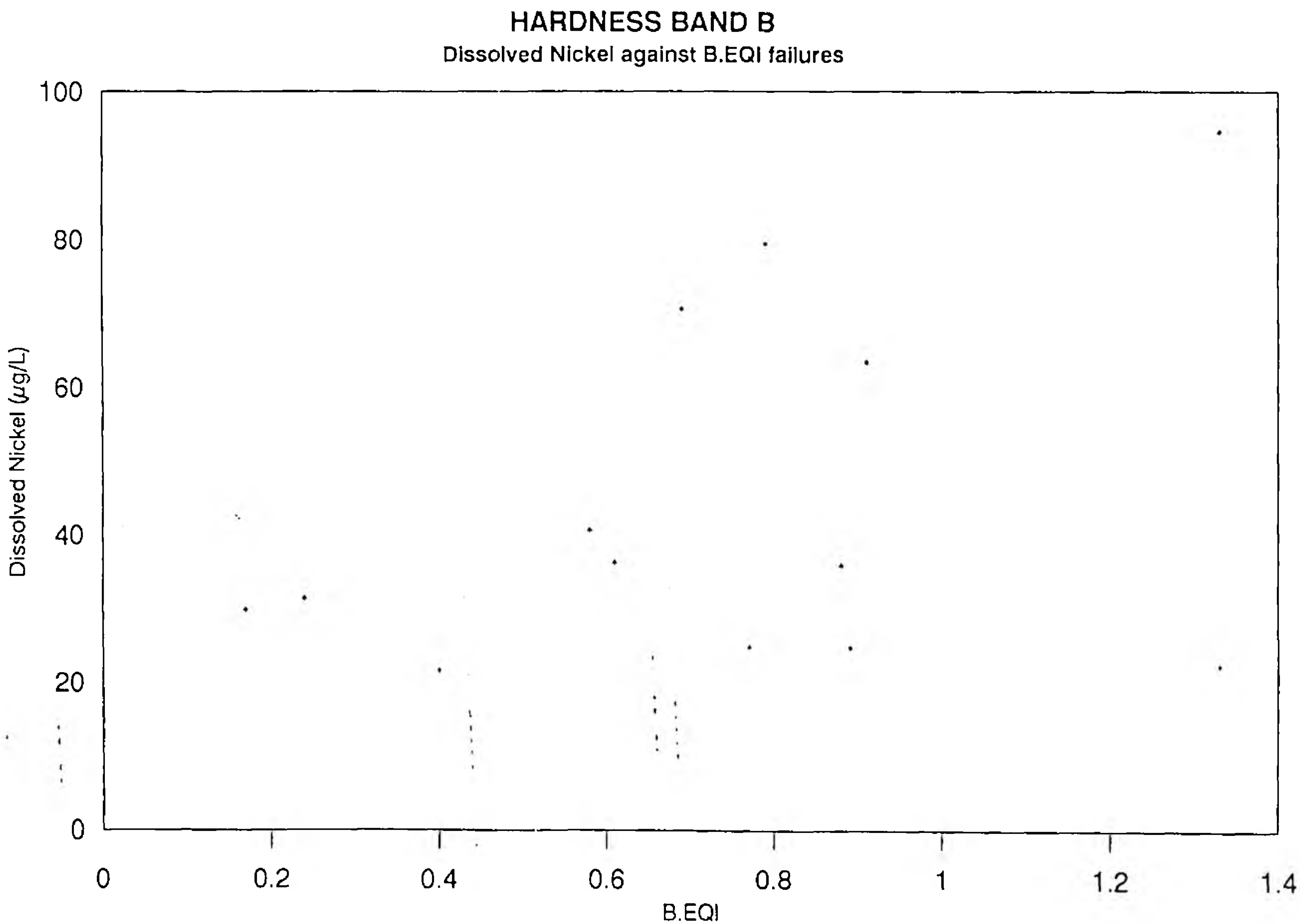


HARDNESS BAND B

Dissolved Copper against Fisheries Score



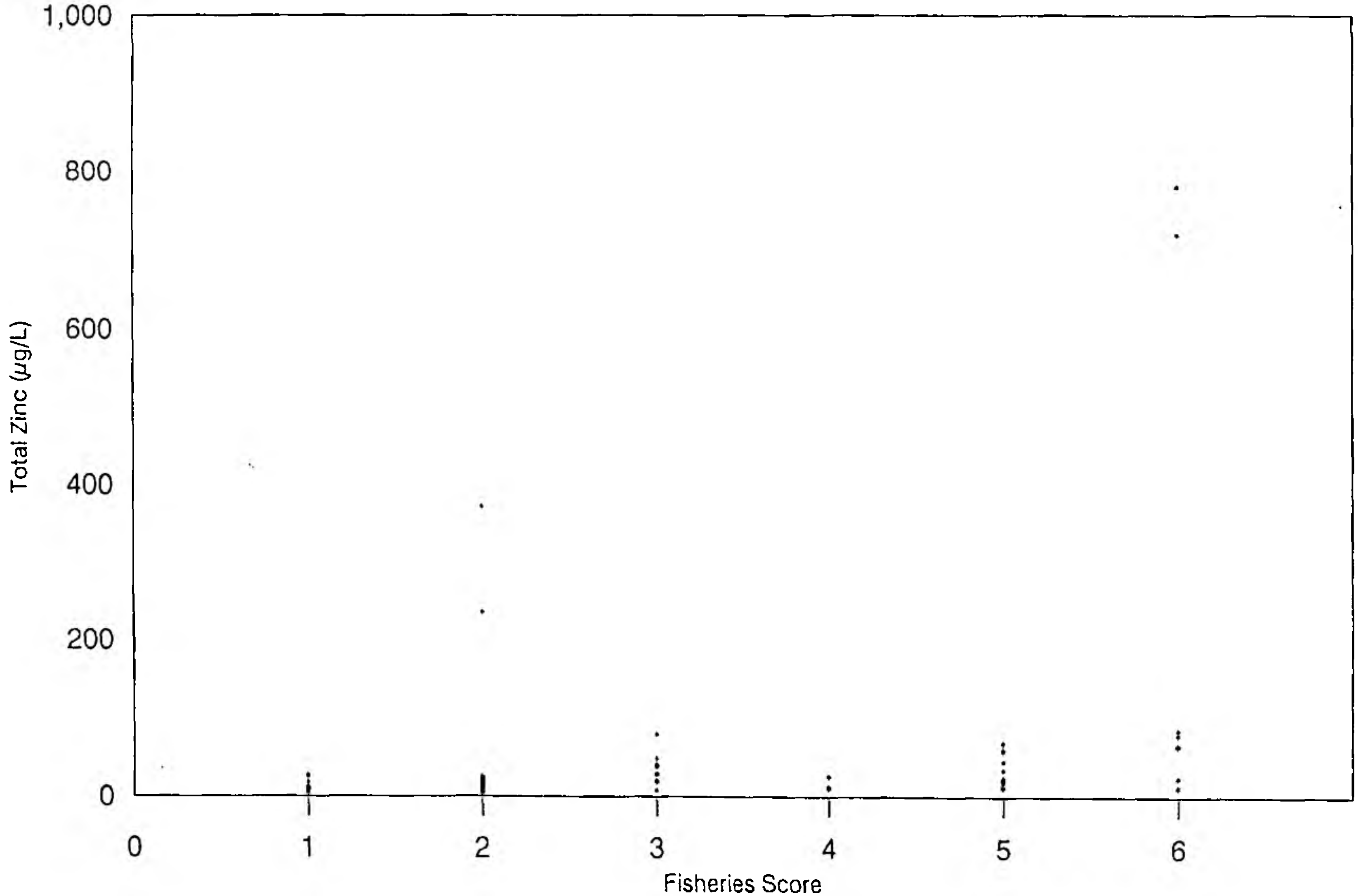

HARDNESS BAND B
Dissolved Lead against Fisheries Score
20
15
10
5
0
0
1
2
3
4
5
6
Dissolved Lead (µg/L)
Fisheries Score

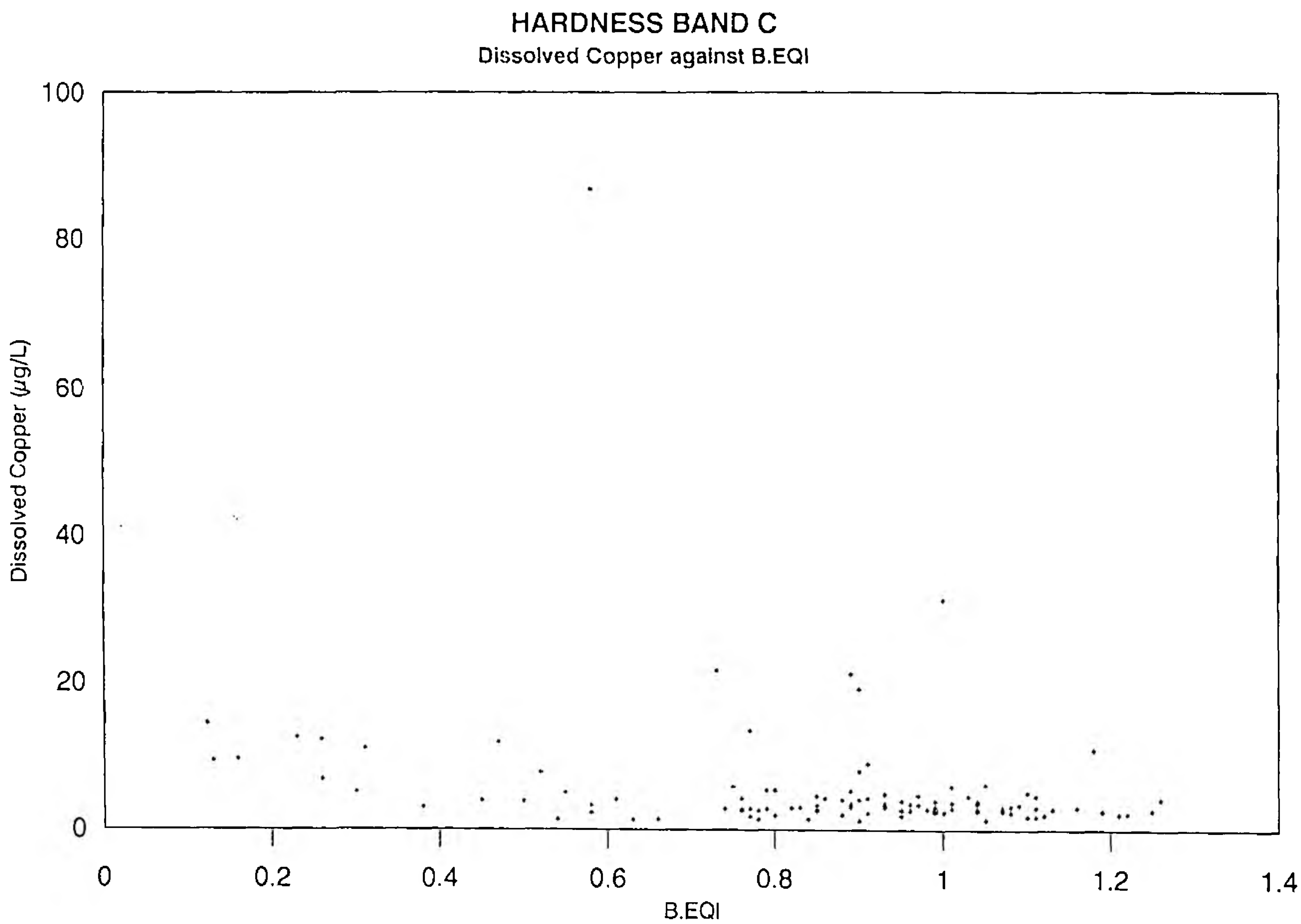


HARDNESS BAND B
Dissolved Nickel against B.EQI failures
Dissolved Nickel (µg/L)
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
B.EQI

HARDNESS BAND C

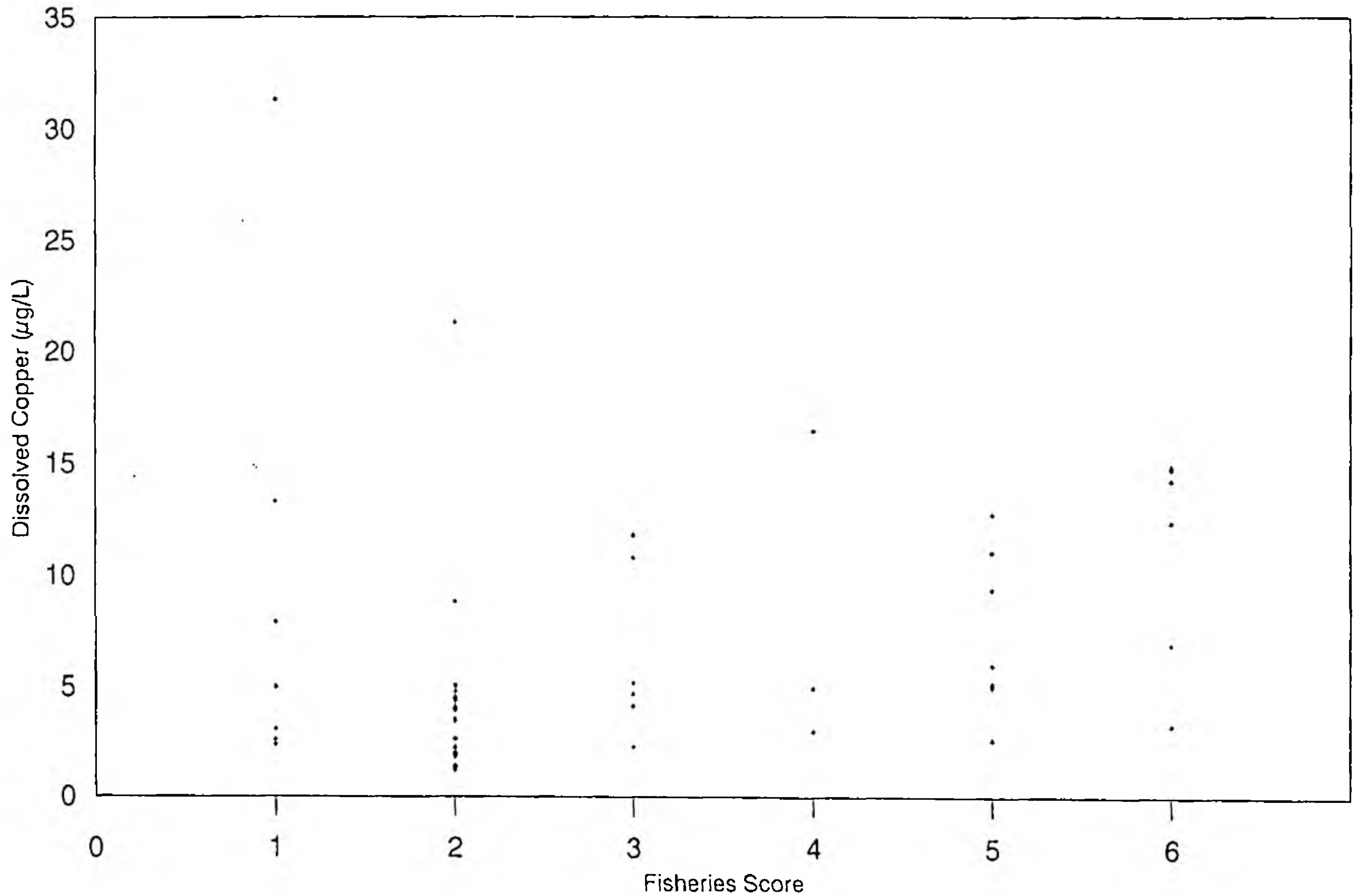
Total Zinc against Fisheries Score

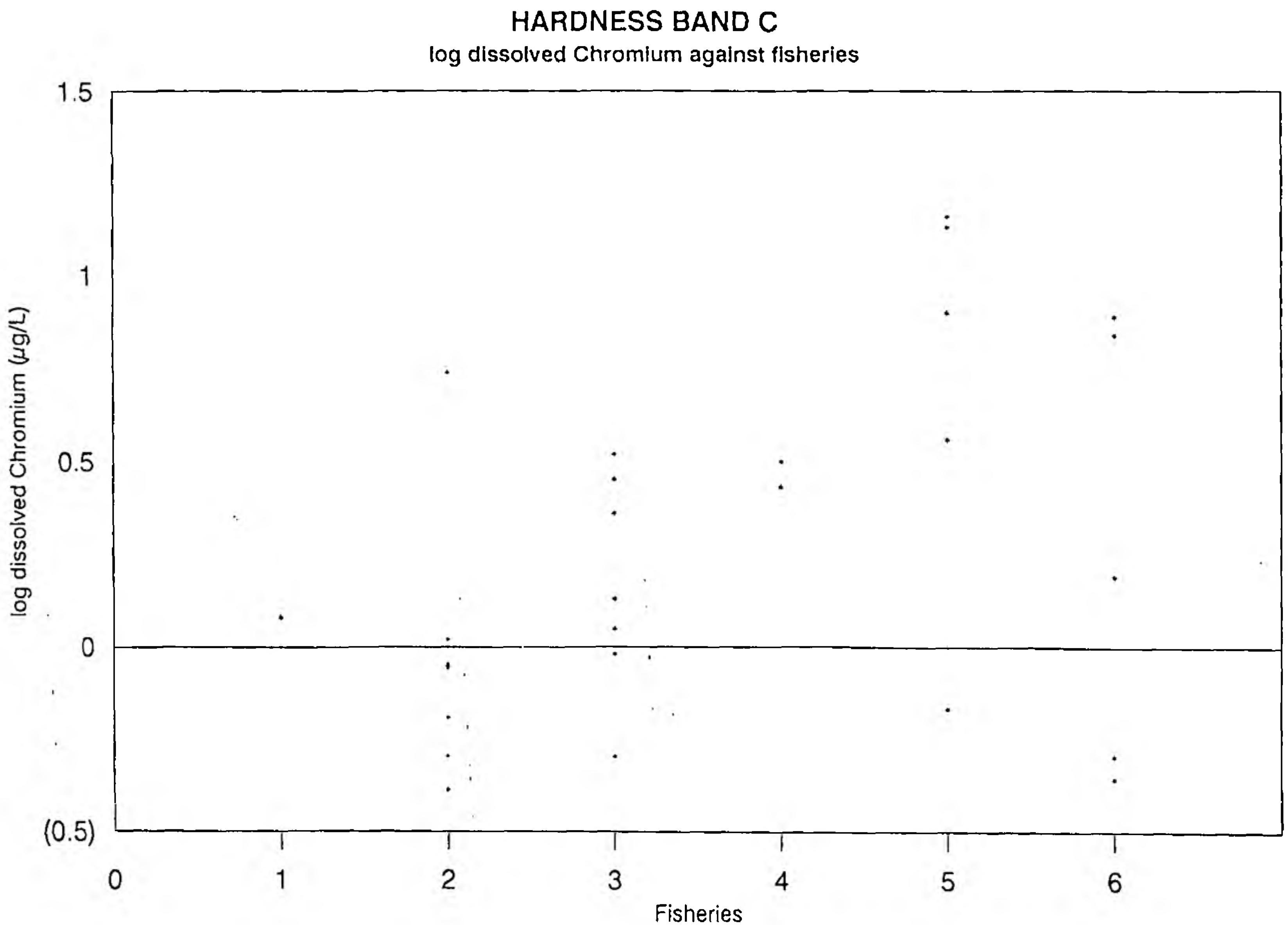



HARDNESS BAND C
Dissolved Copper against B.EQI
Dissolved Copper (µg/L)
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
B.EQI

HARDNESS BAND C

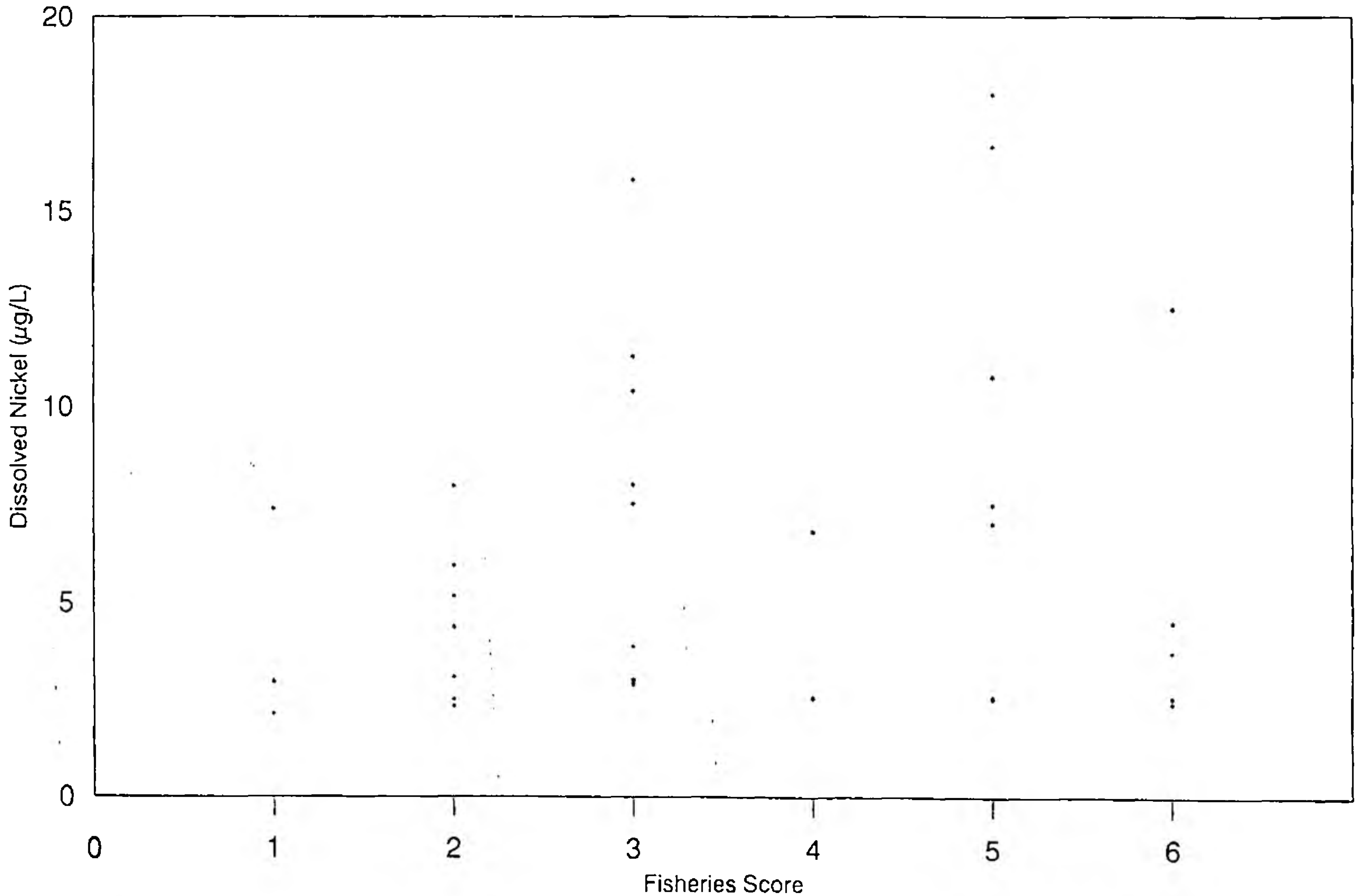
Dissolved Copper against Fisheries Score

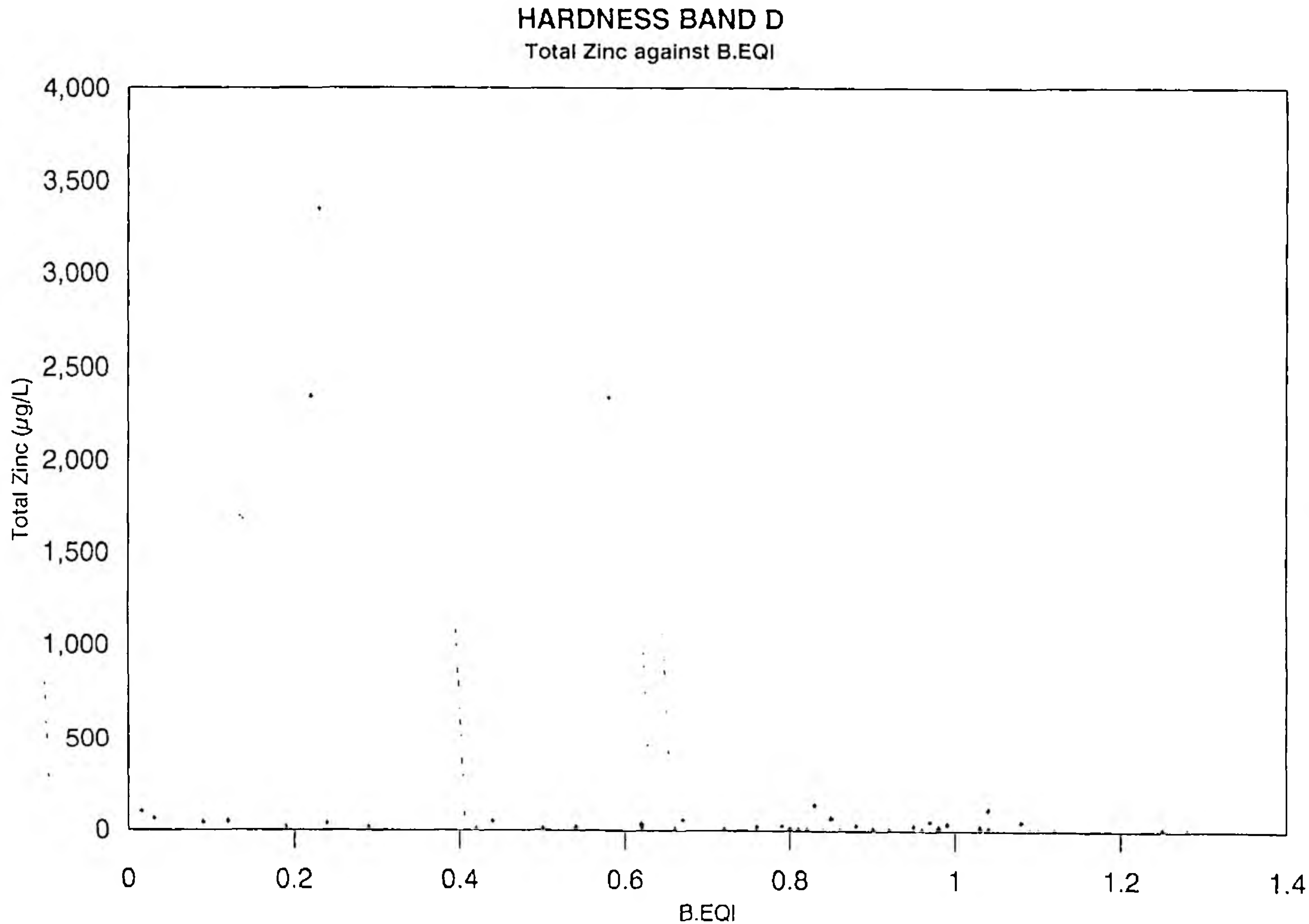



HARDNESS BAND C
log dissolved Chromium against fisheries
1.5
1
0.5
0
(0.5)
log dissolved Chromium (μg/L)
0
1
2
3
4
5
6
Fisheries

HARDNESS BAND C

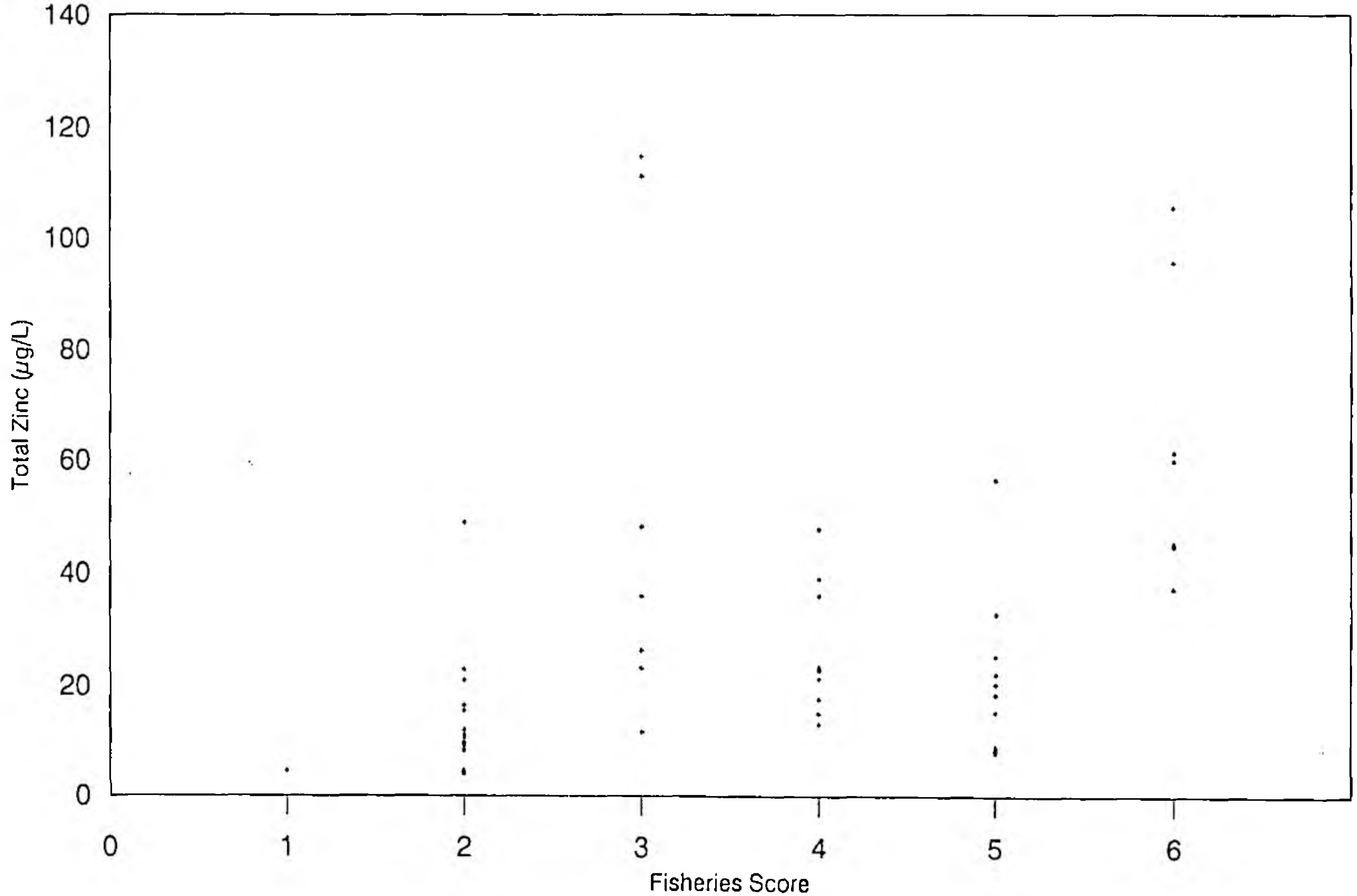
Dissolved Nickel against Fisheries Score

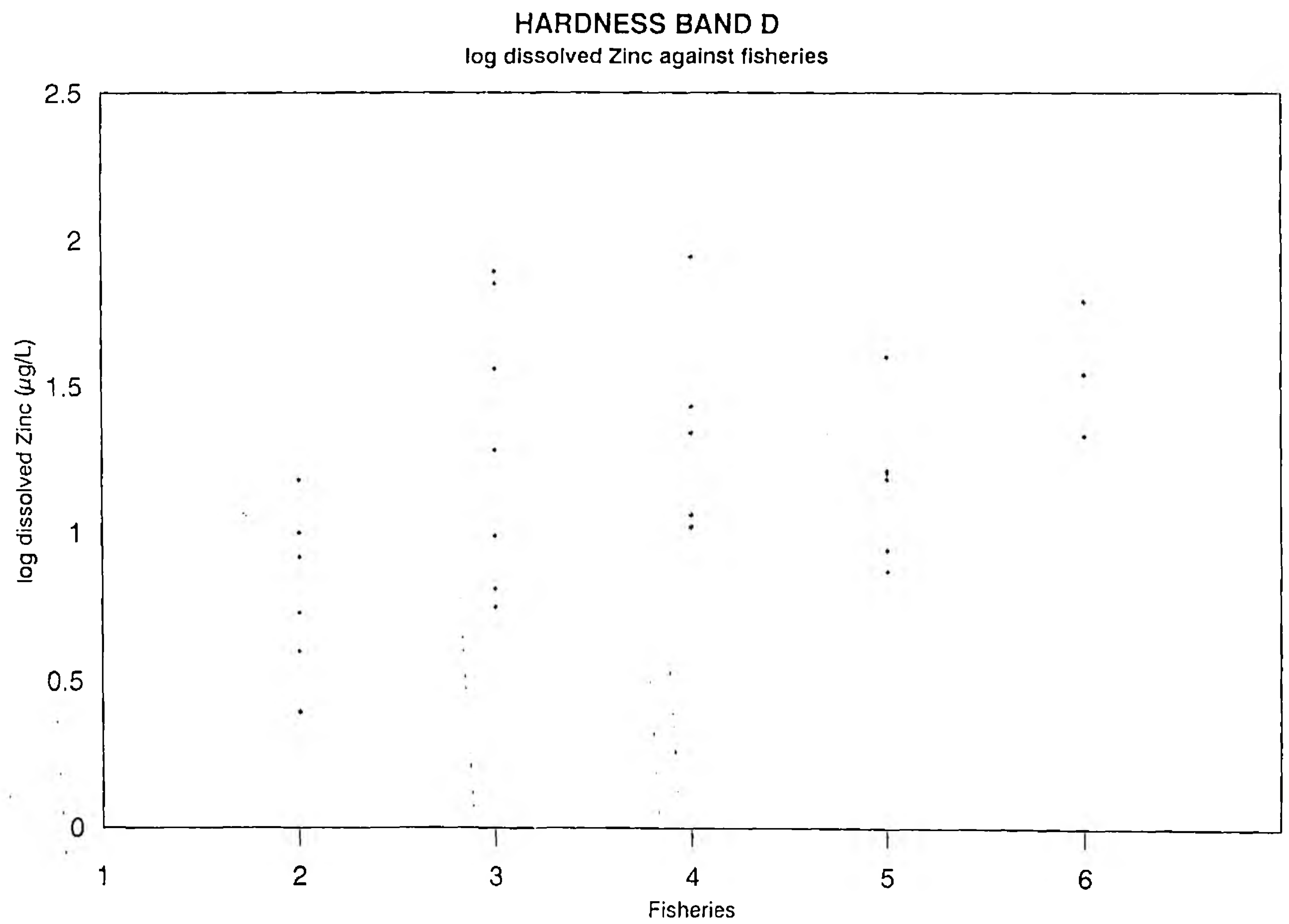


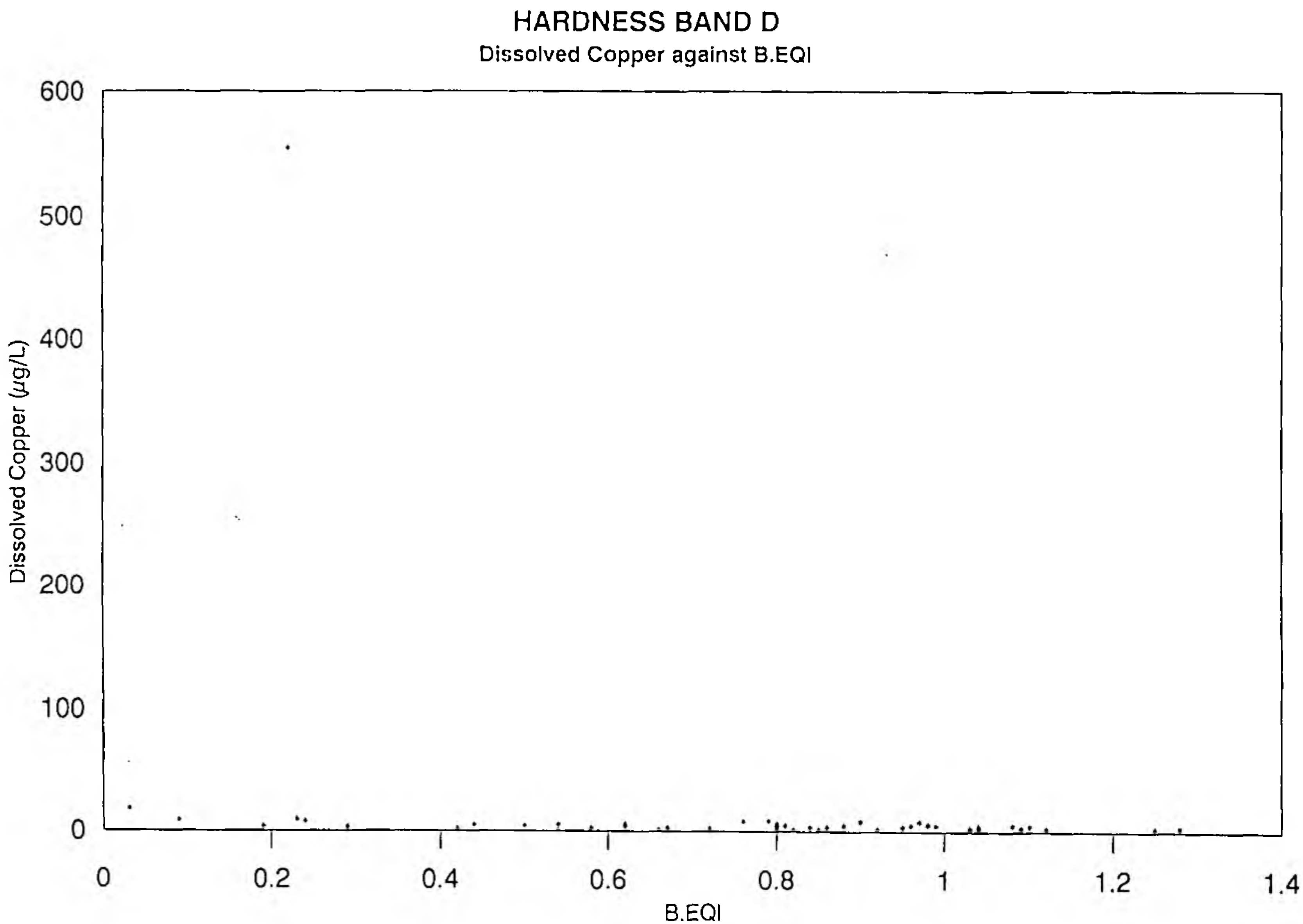

HARDNESS BAND D
Total Zinc against B.EQI
Total Zinc (µg/L)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
B.EQI

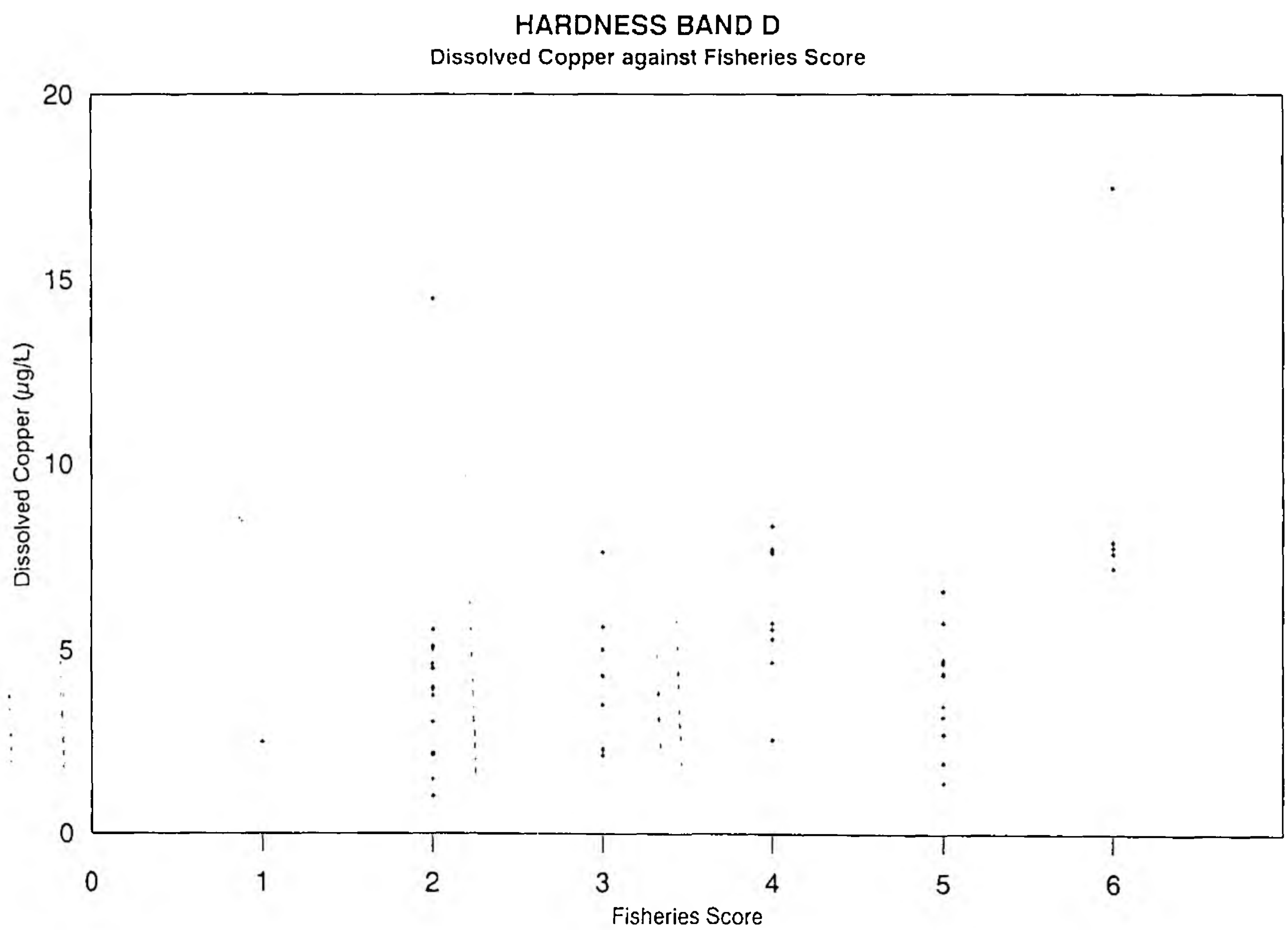
HARDNESS BAND D

Total Zinc against Fisheries Score

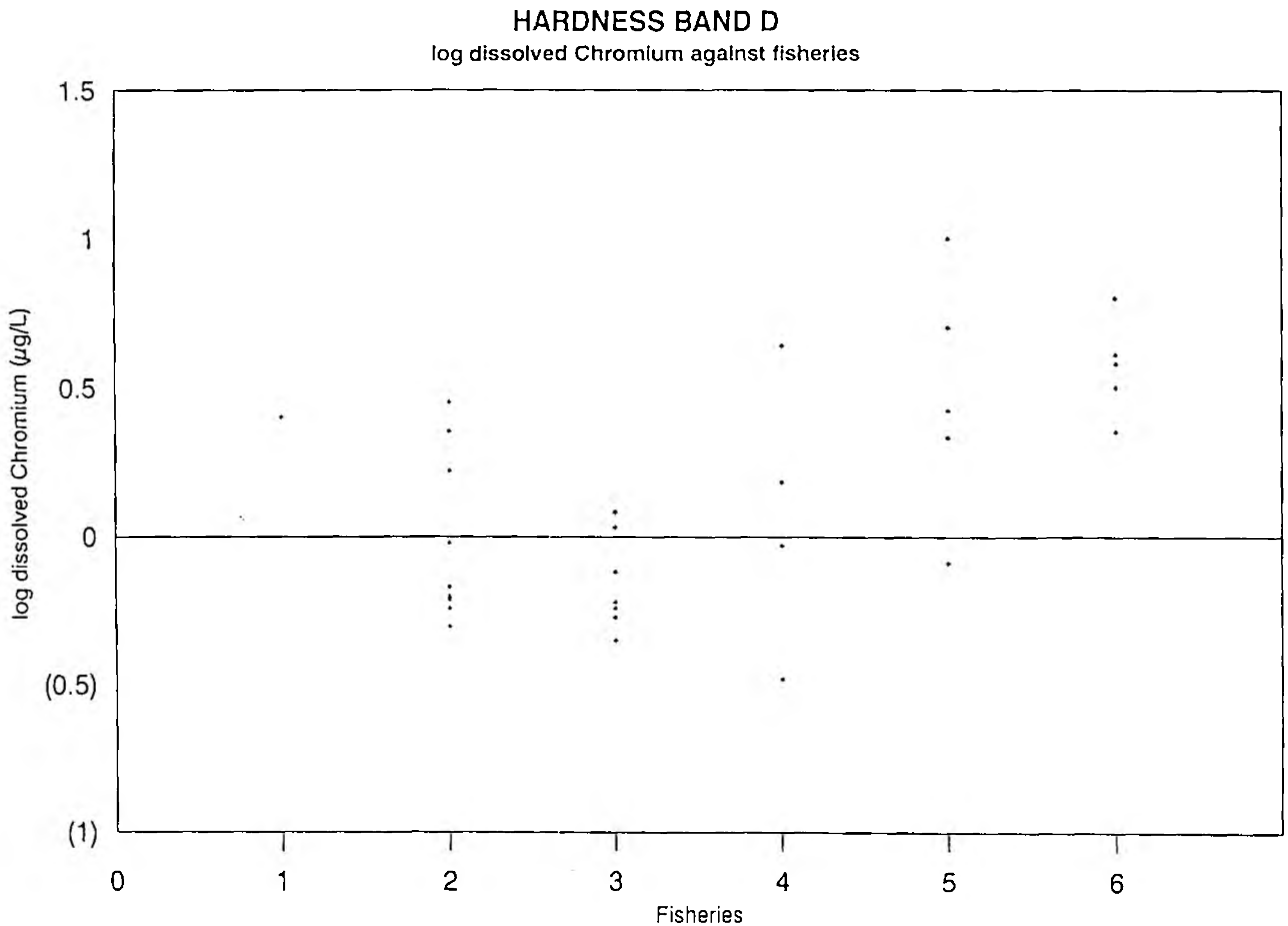


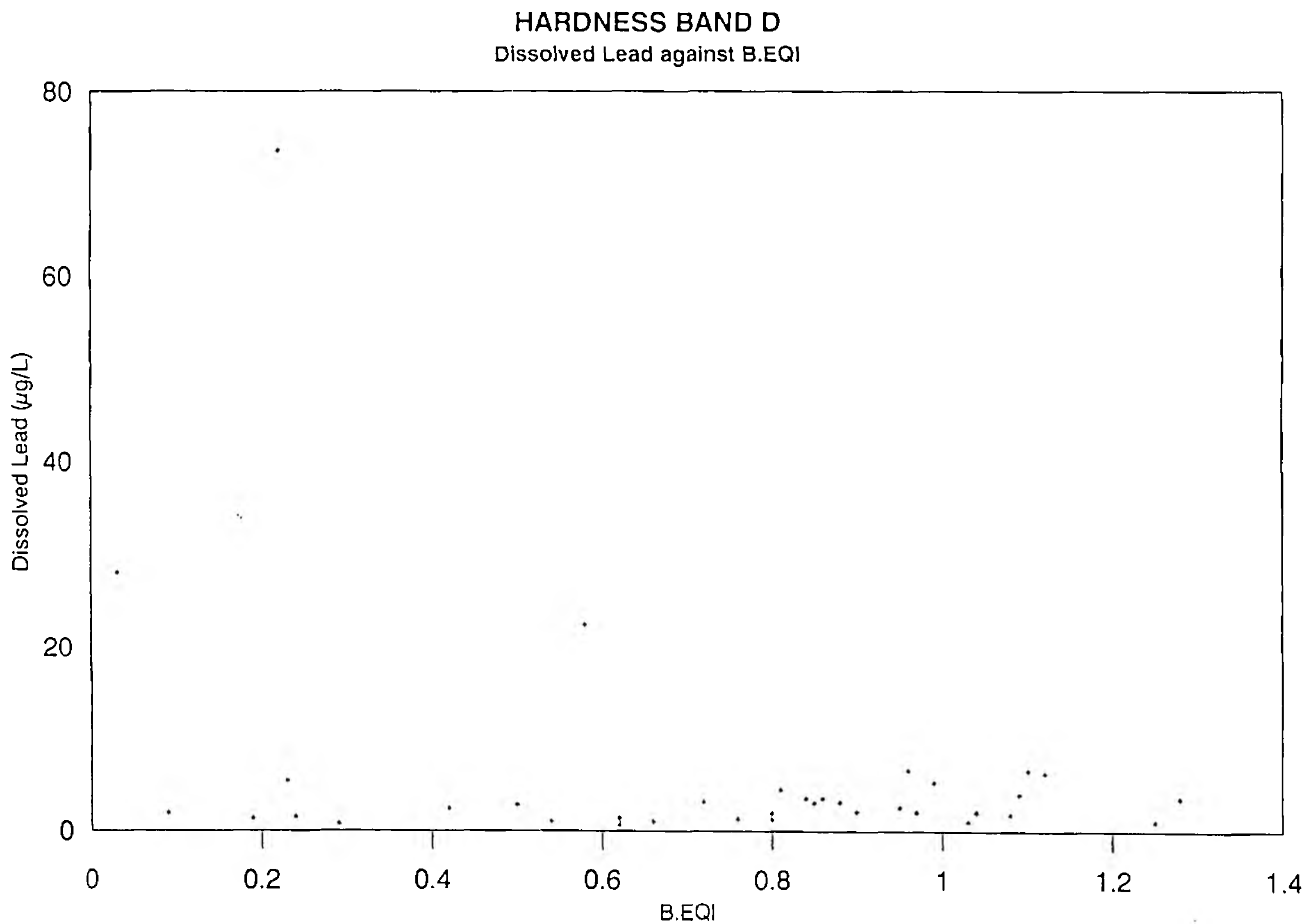

HARDNESS BAND D
log dissolved Zinc against fisheries
log dissolved Zinc (µg/L)
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
Fisheries

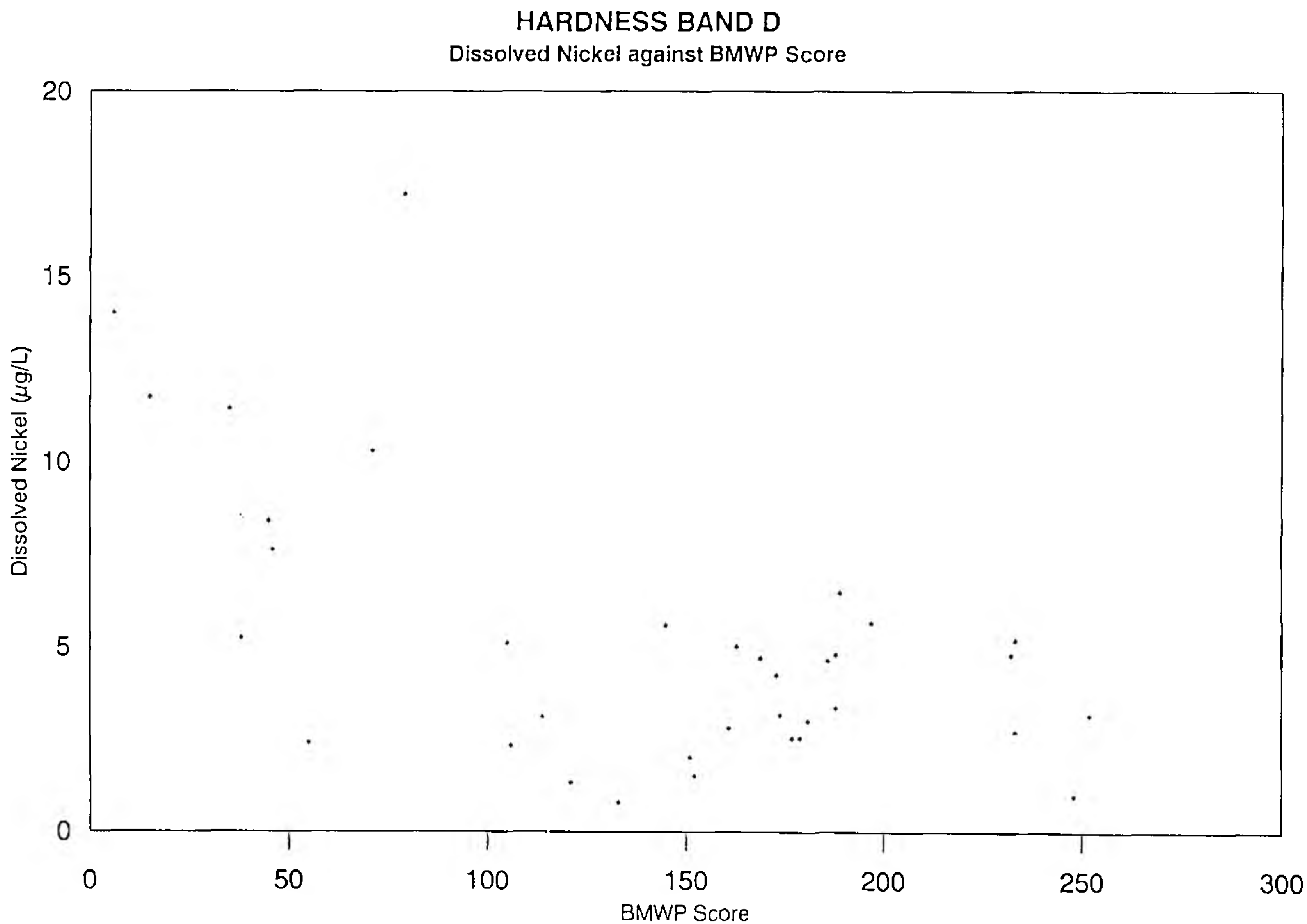

HARDNESS BAND D
Dissolved Copper against B.EQI
Dissolved Copper (μg/L)
600
500
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
B.EQI

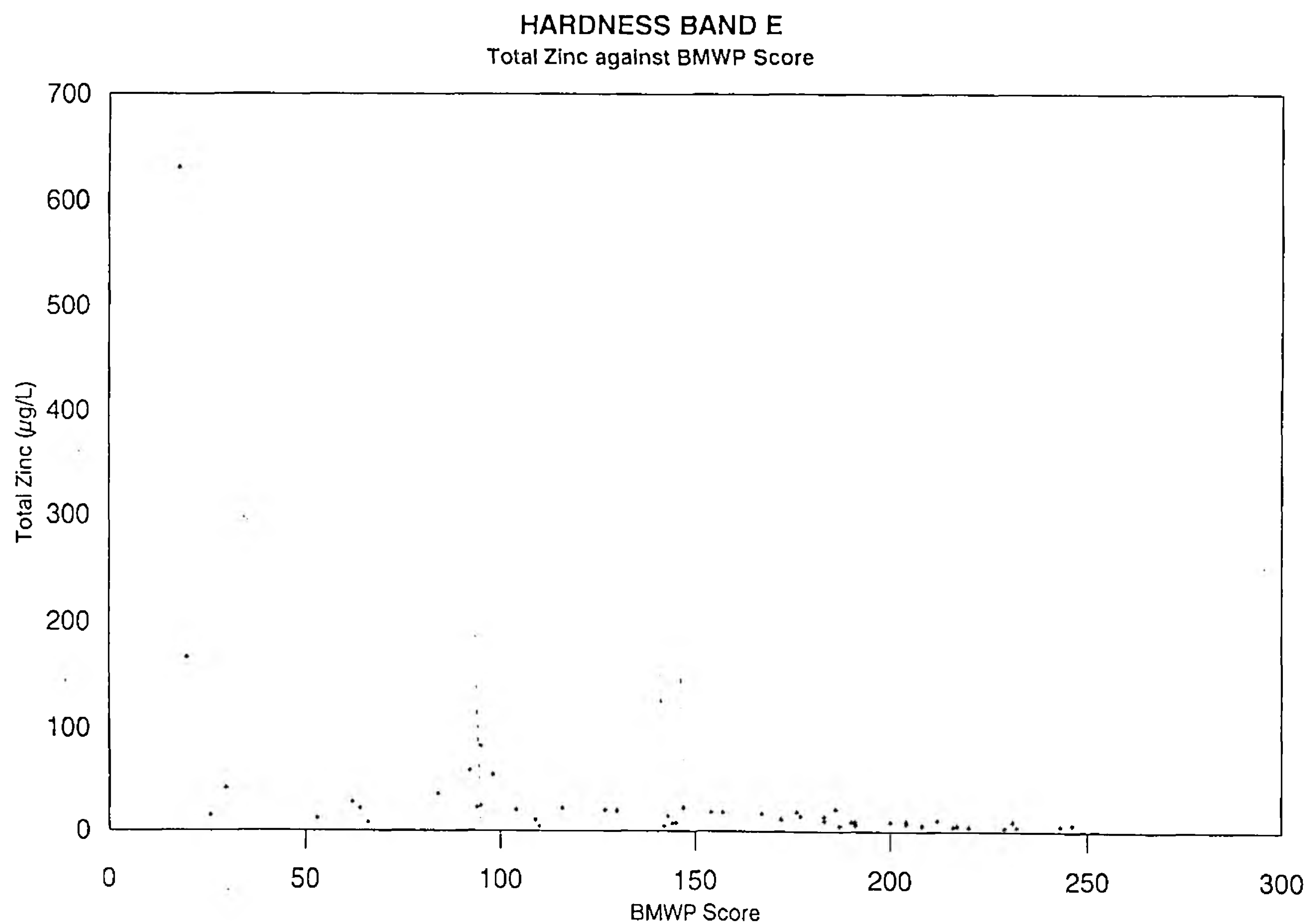


HARDNESS BAND D
Dissolved Copper against Fisheries Score
Dissolved Copper (µg/L)
Fisheries Score
0
5
10
15
20
0
1
2
3
4
5
6


HARDNESS BAND D
log dissolved Chromium against fisheries
1.5
1
0.5
0
(0.5)
(1)
log dissolved Chromium (µg/L)
0
1
2
3
4
5
6
Fisheries

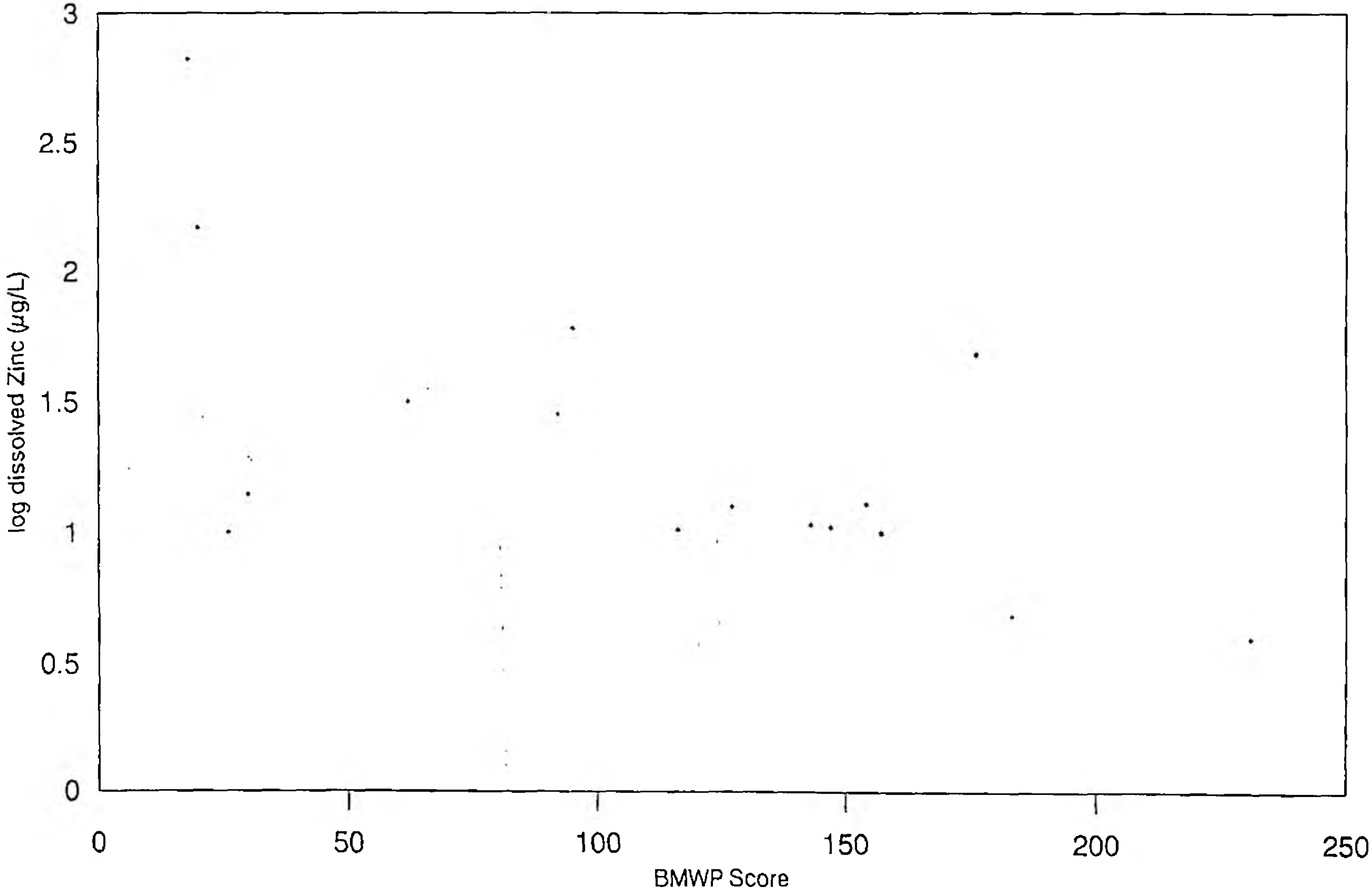

HARDNESS BAND D
Dissolved Lead against B.EQI
Dissolved Lead (μg/L)
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
B.EQI

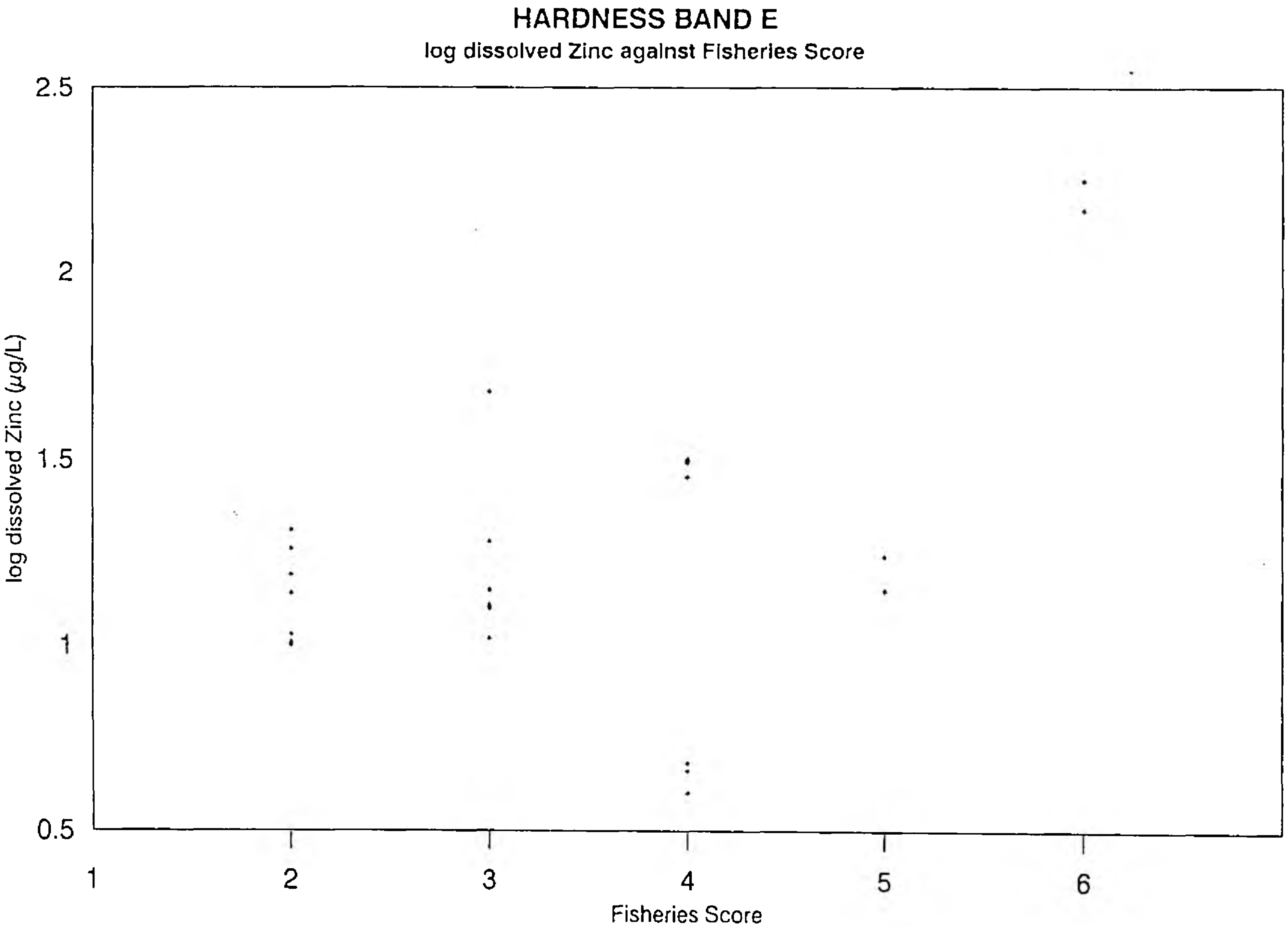

HARDNESS BAND D
Dissolved Nickel against BMWP Score
Dissolved Nickel (μg/L)
20
15
10
5
0
0
50
100
150
200
250
300
BMWP Score

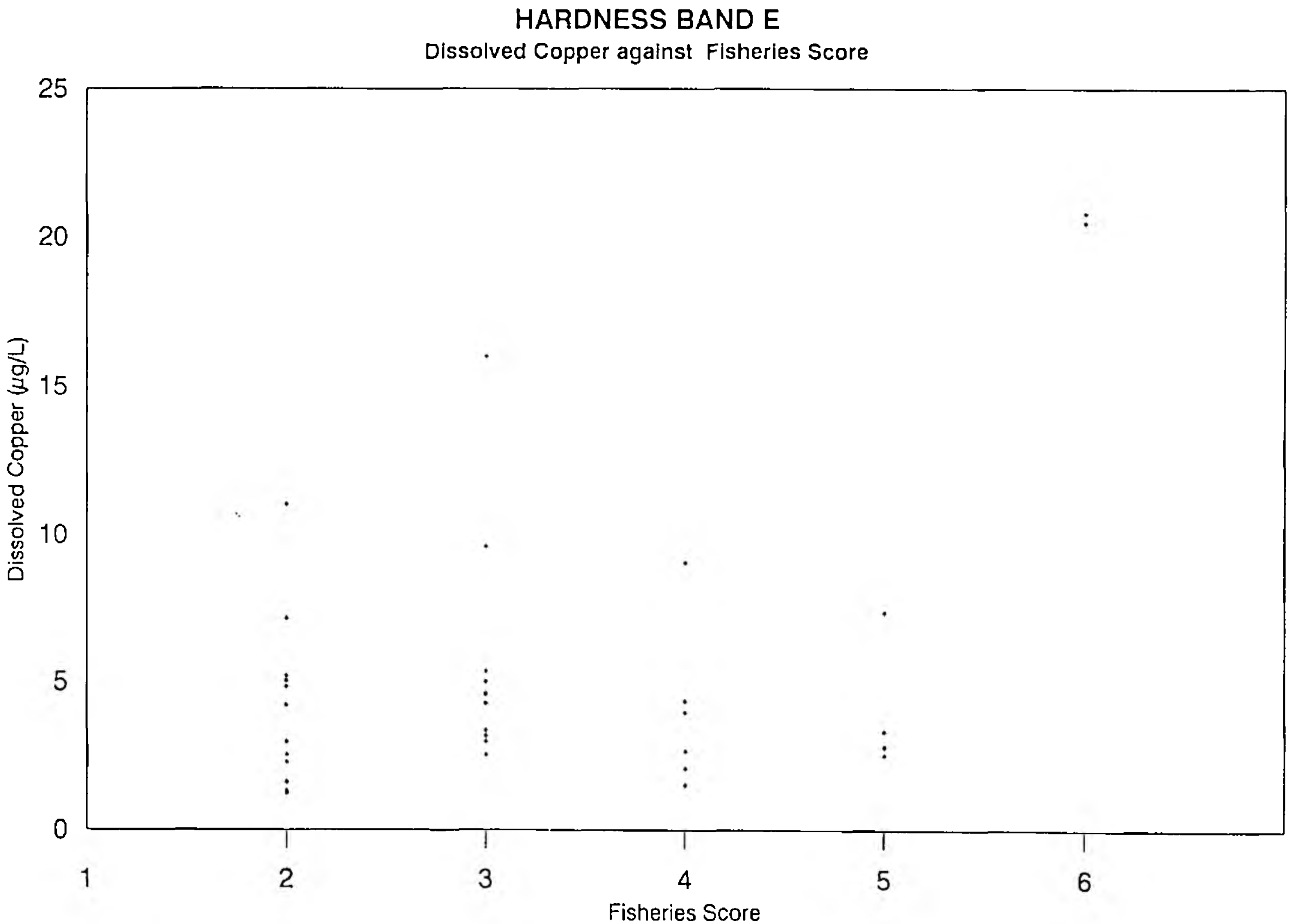

HARDNESS BAND E
Total Zinc against BMWP Score
Total Zinc (μg/L)
700
600
500
400
300
200
100
0
0
50
100
150
200
250
300
BMWP Score

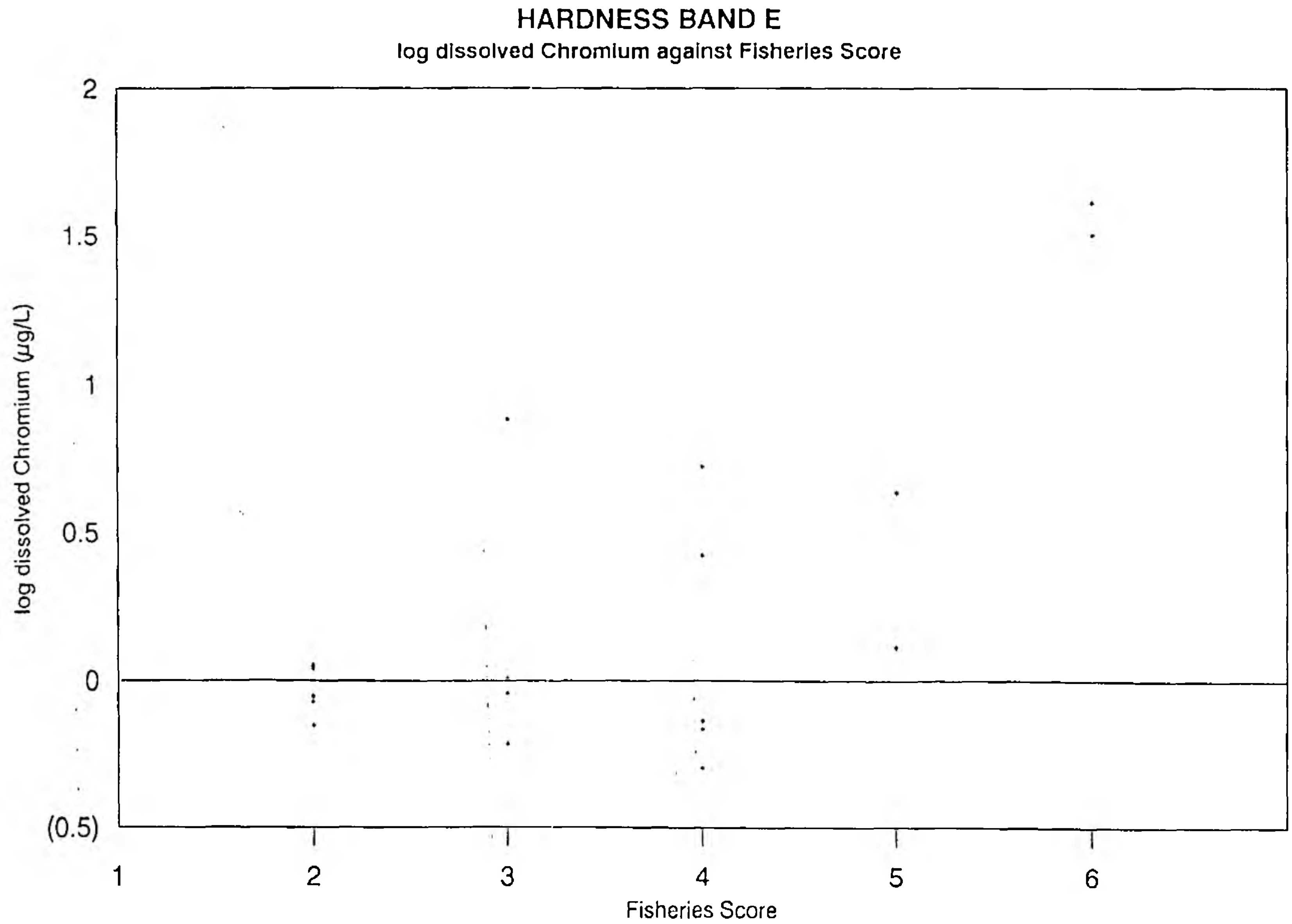
HARDNESS BAND E

log dissolved Zinc against BMWP Score



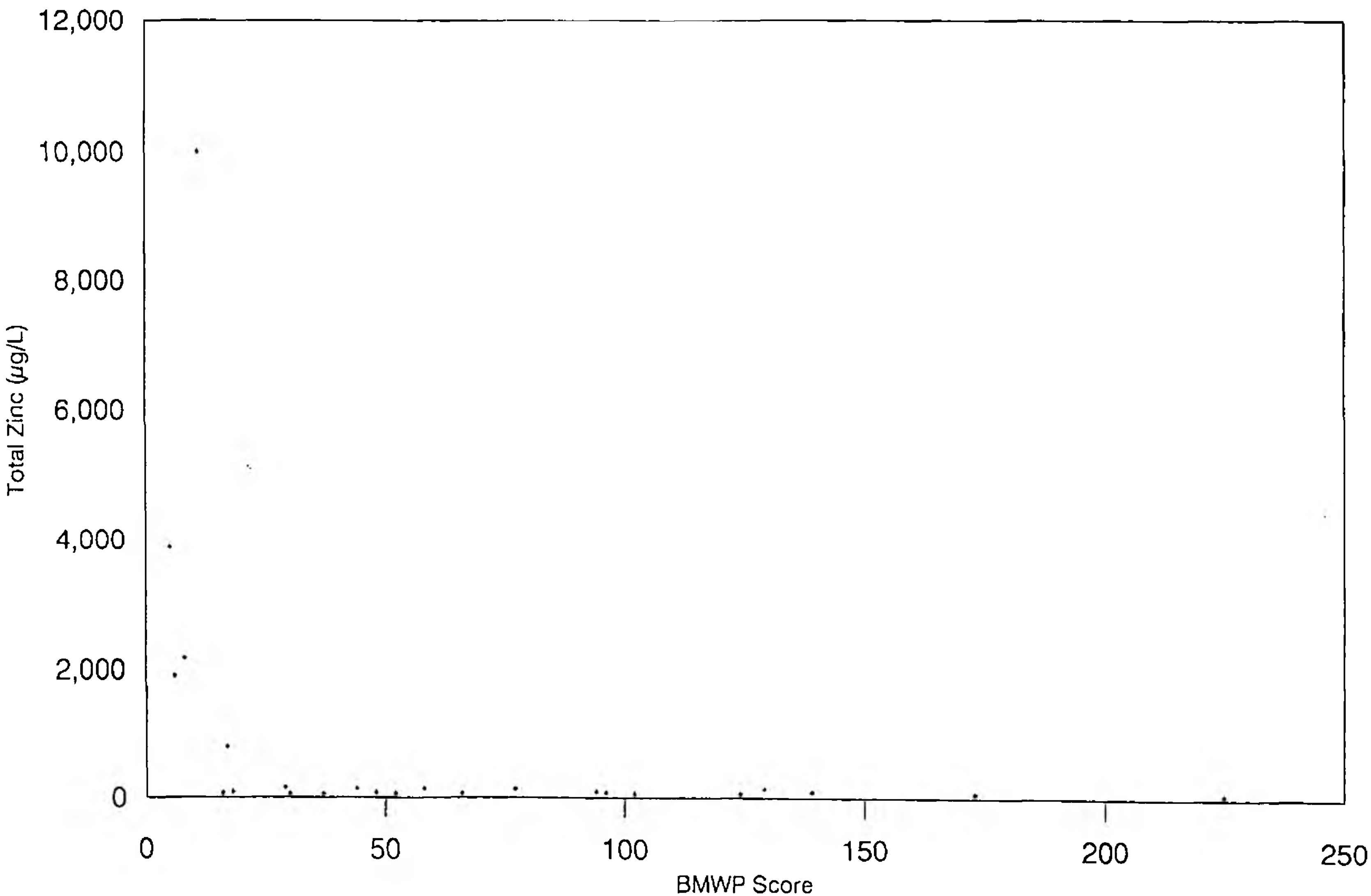

HARDNESS BAND E
log dissolved Zinc against Fisheries Score
2.5
2
1.5
1
0.5
log dissolved Zinc (µg/L)
1
2
3
4
5
6
Fisheries Score

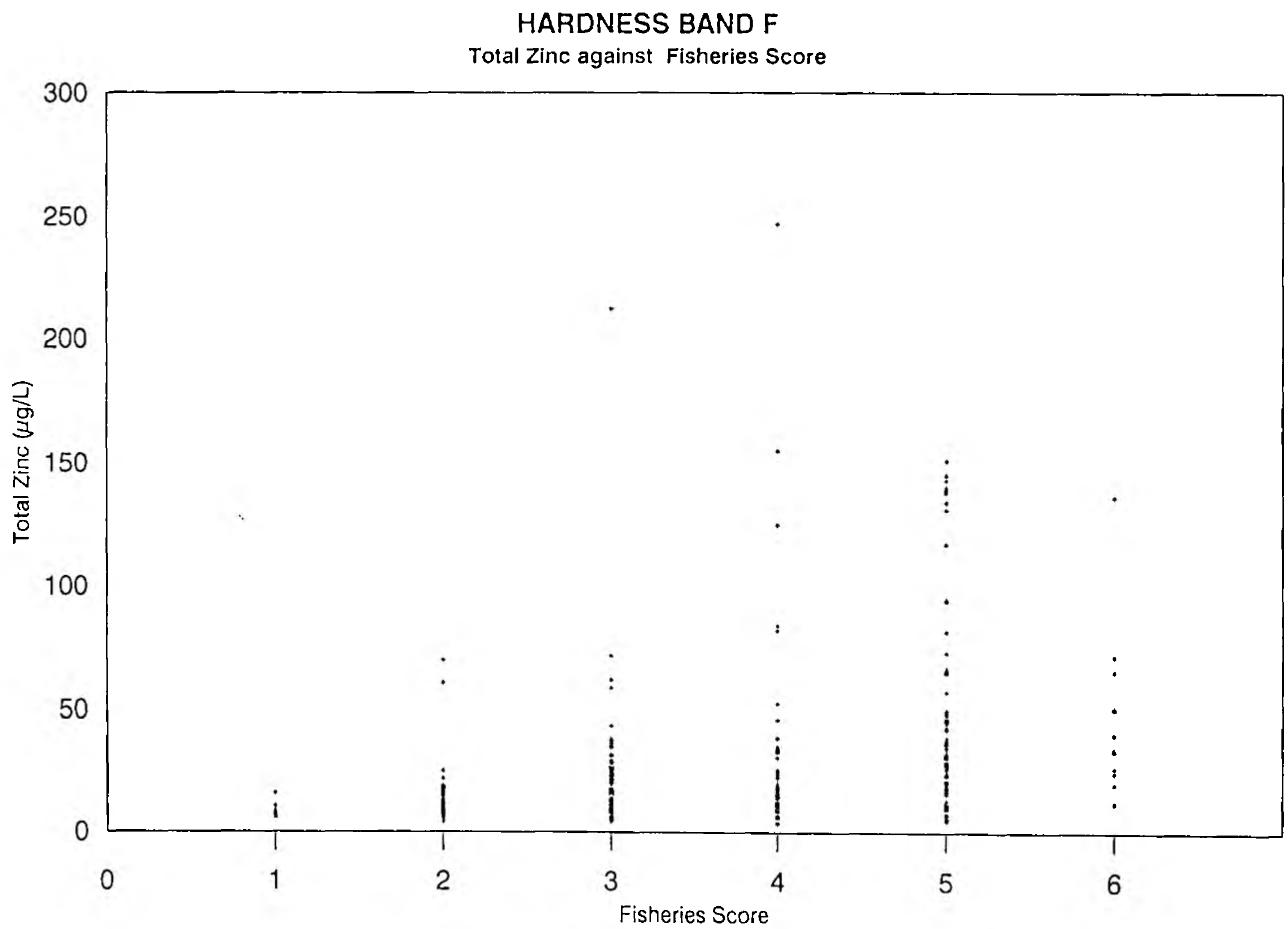

HARDNESS BAND E
Dissolved Copper against Fisheries Score
Dissolved Copper (µg/L)
25
20
15
10
5
0
1
2
3
4
5
6
Fisheries Score


HARDNESS BAND E
log dissolved Chromium against Fisheries Score
log dissolved Chromium (µg/L)
2
1.5
1
0.5
0
(0.5)
1
2
3
4
5
6
Fisheries Score

HARDNESS BAND F

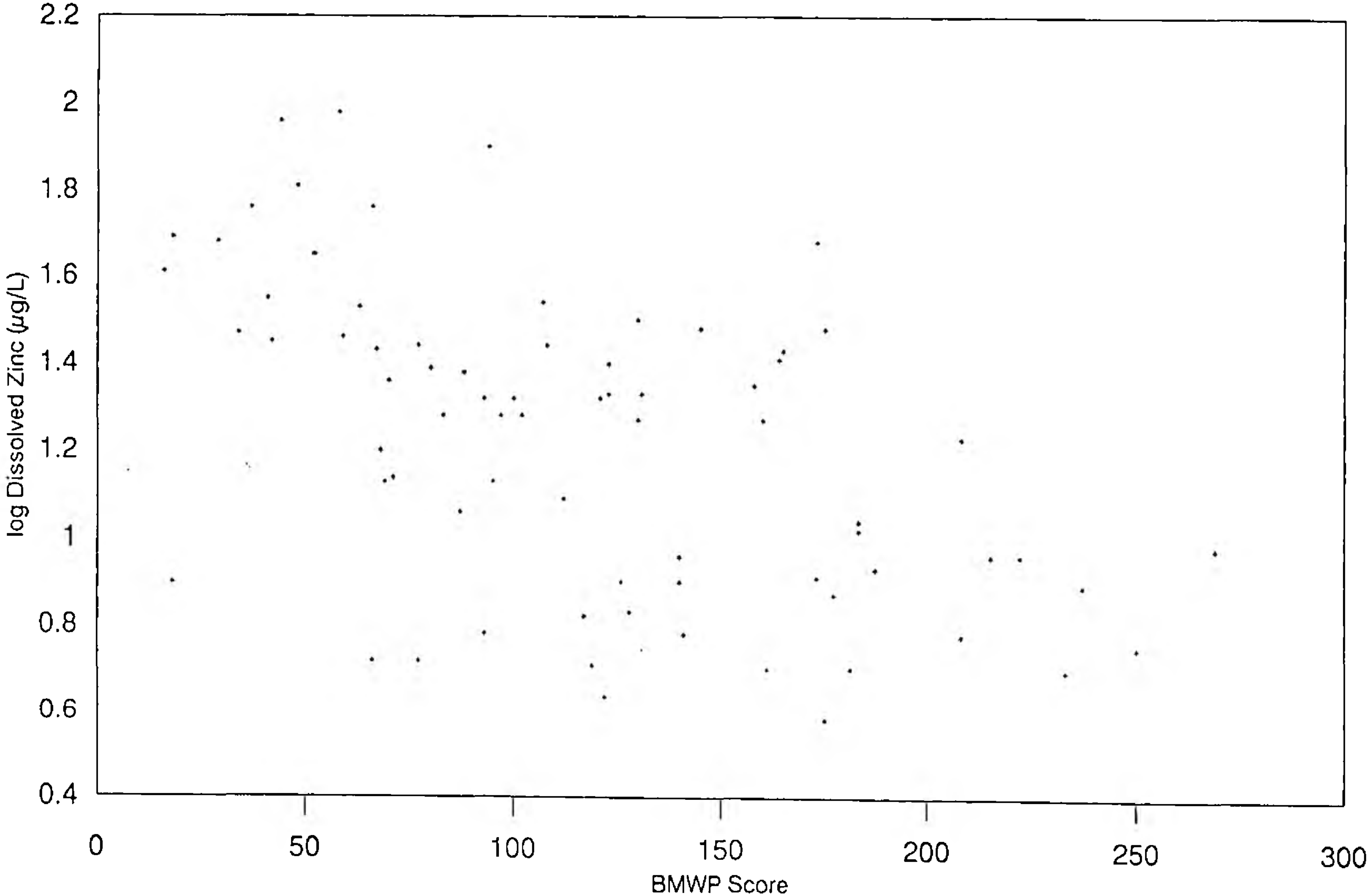
Total zinc against BMWP Score failures

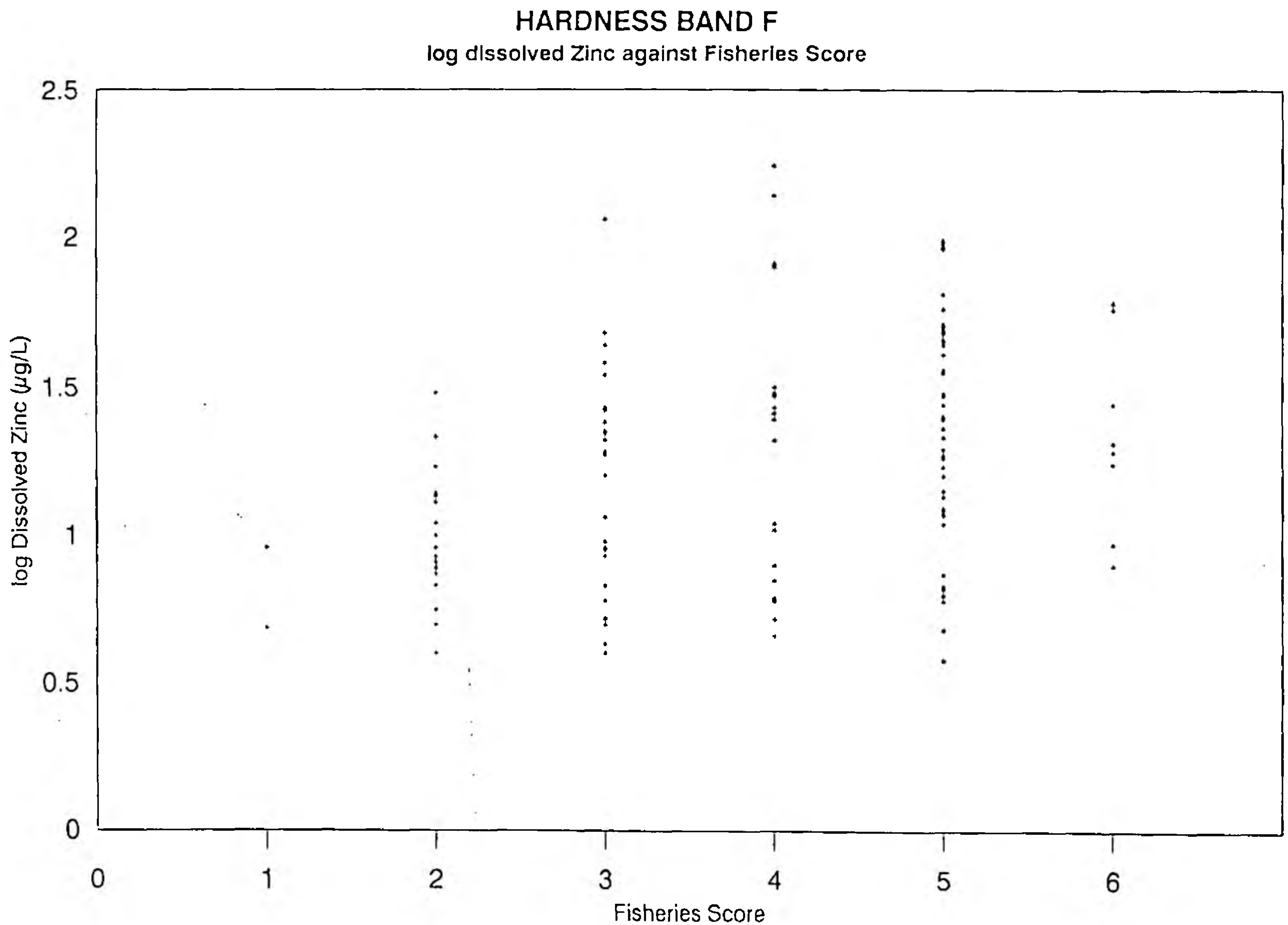


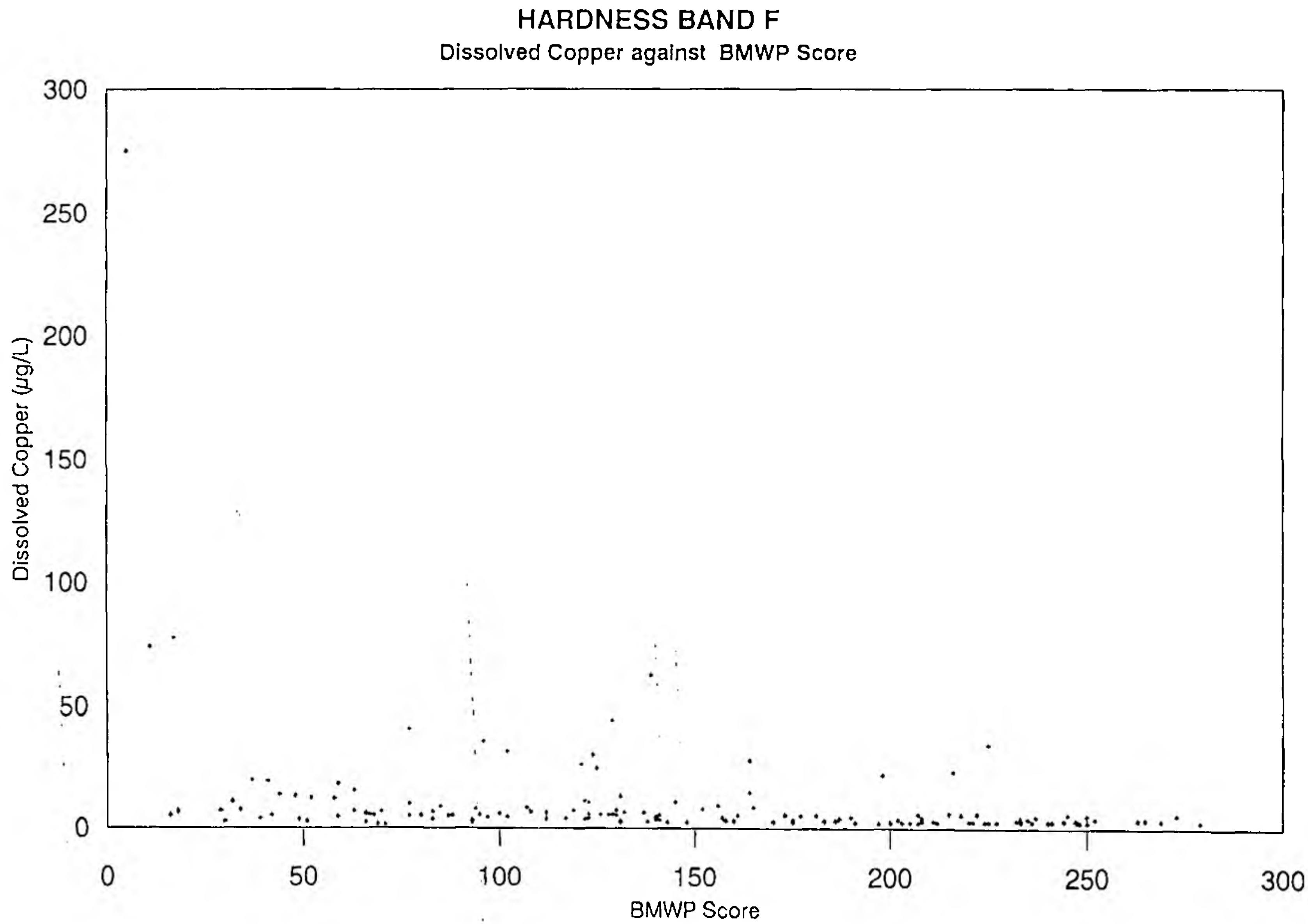

HARDNESS BAND F
Total Zinc against Fisheries Score
Total Zinc (μg/L)
300
250
200
150
100
50
0
0
1
2
3
4
5
6
Fisheries Score

HARDNESS BAND F

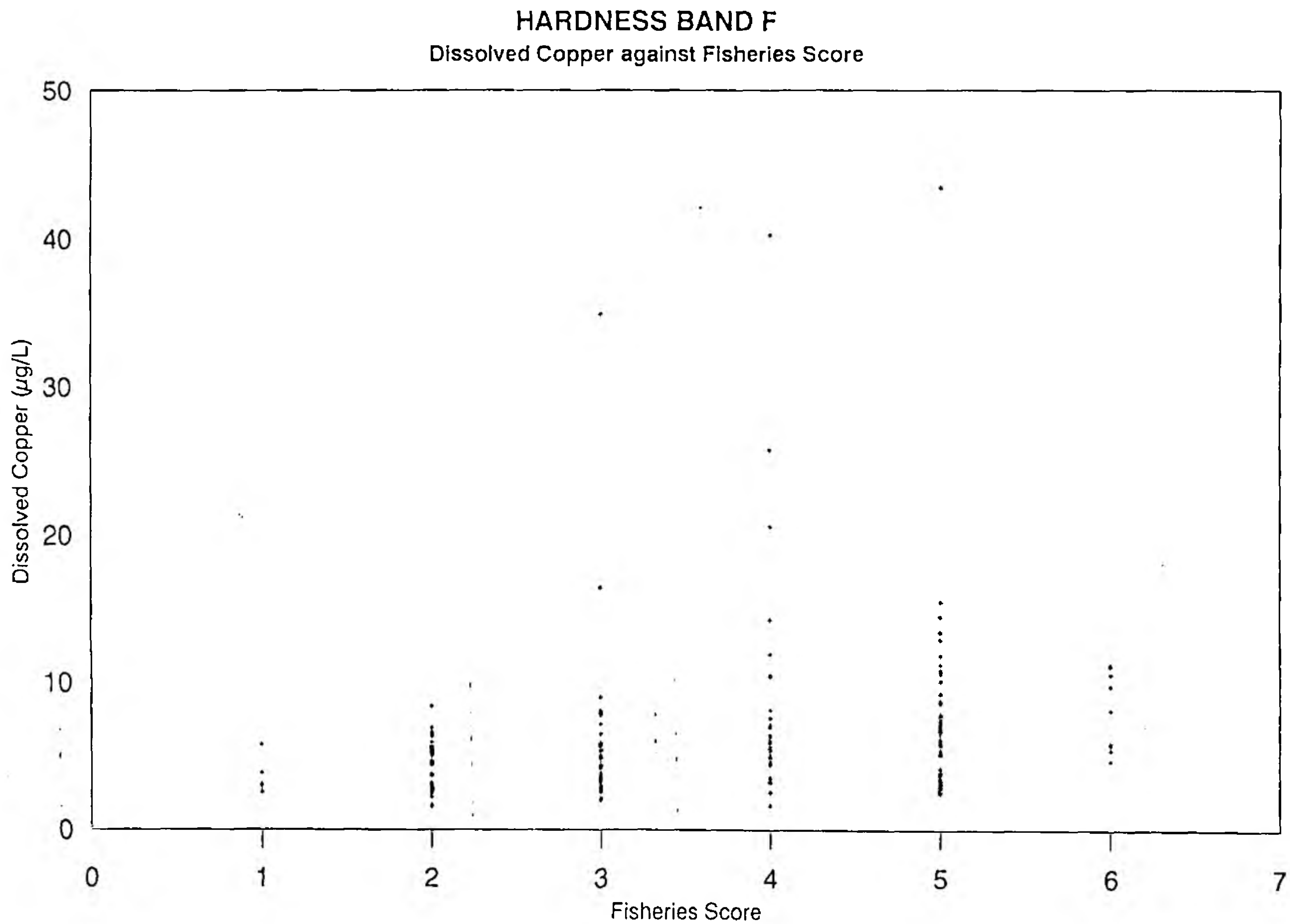
log dissolved Zinc against BMWP Score

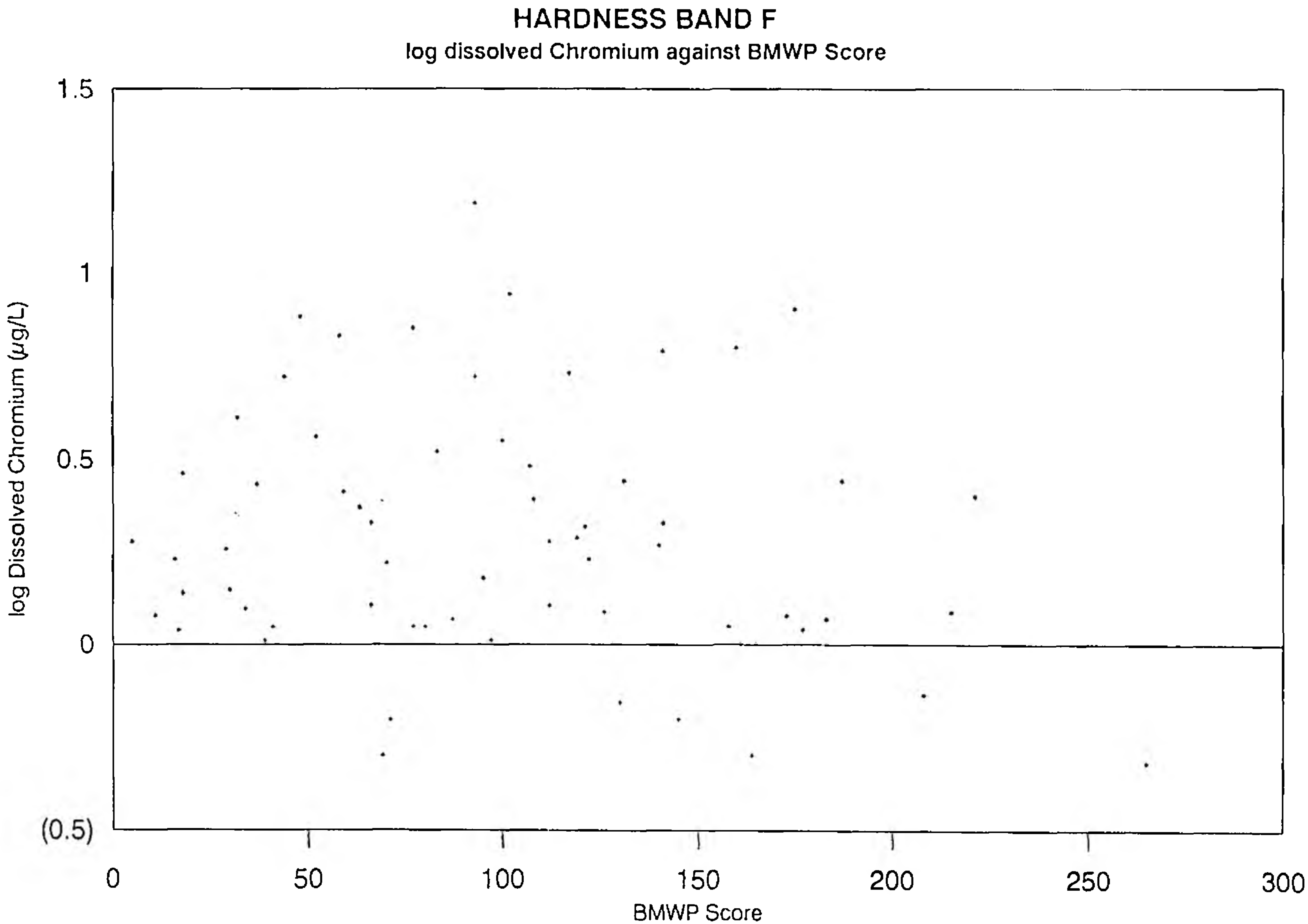


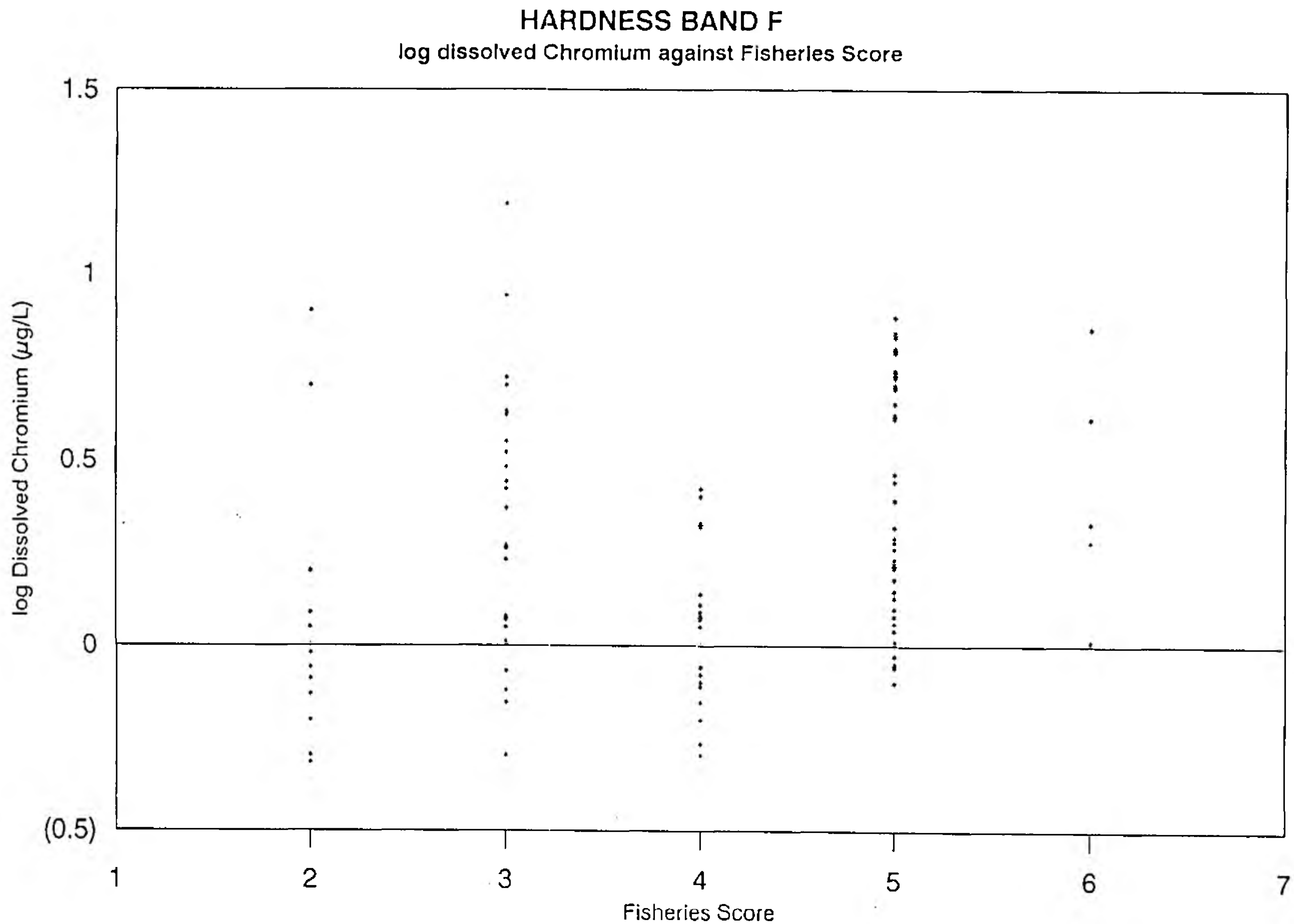

HARDNESS BAND F
log dissolved Zinc against Fisheries Score
log Dissolved Zinc (µg/L)
Fisheries Score
0
0.5
1
1.5
2
2.5
0
1
2
3
4
5
6

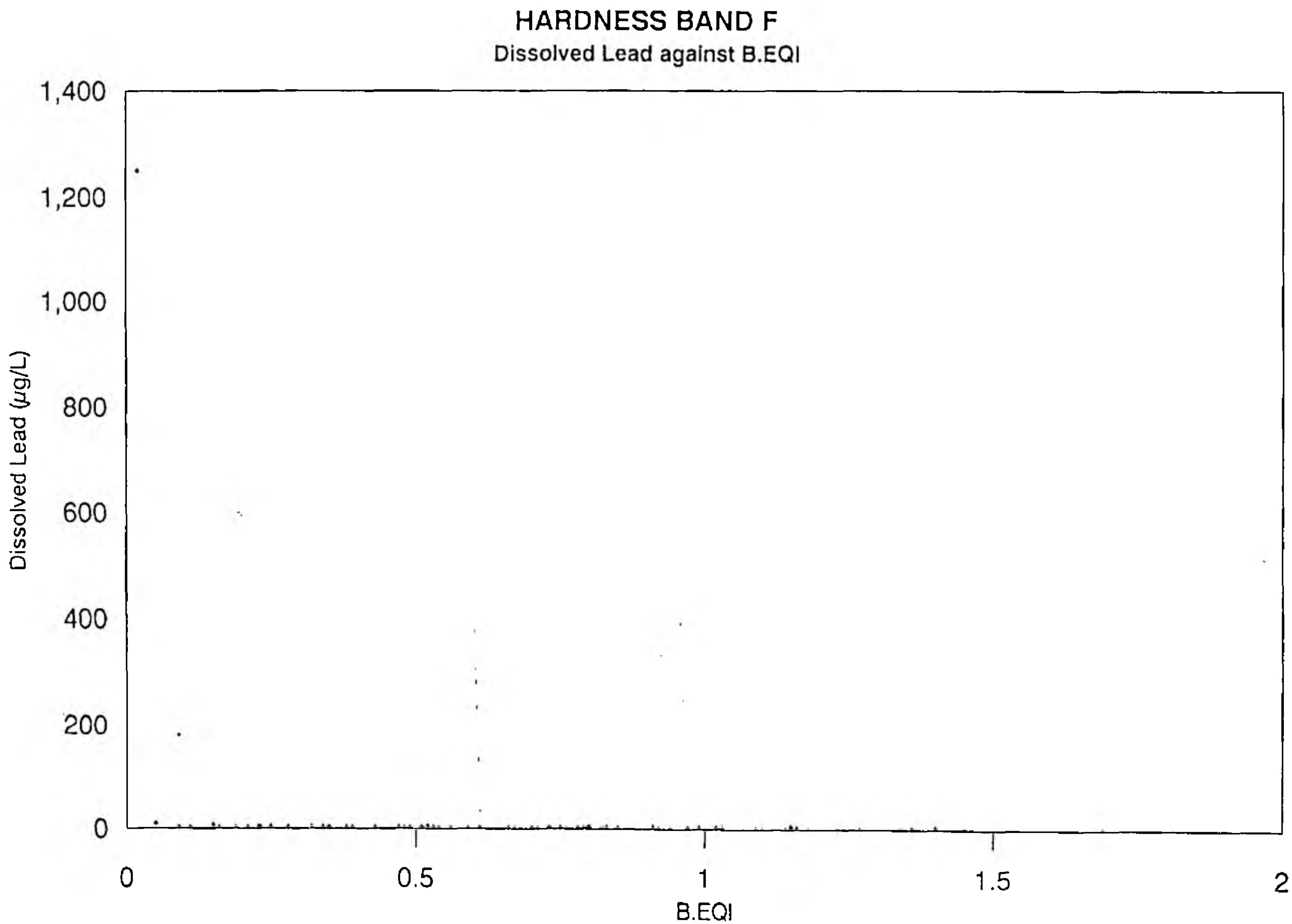


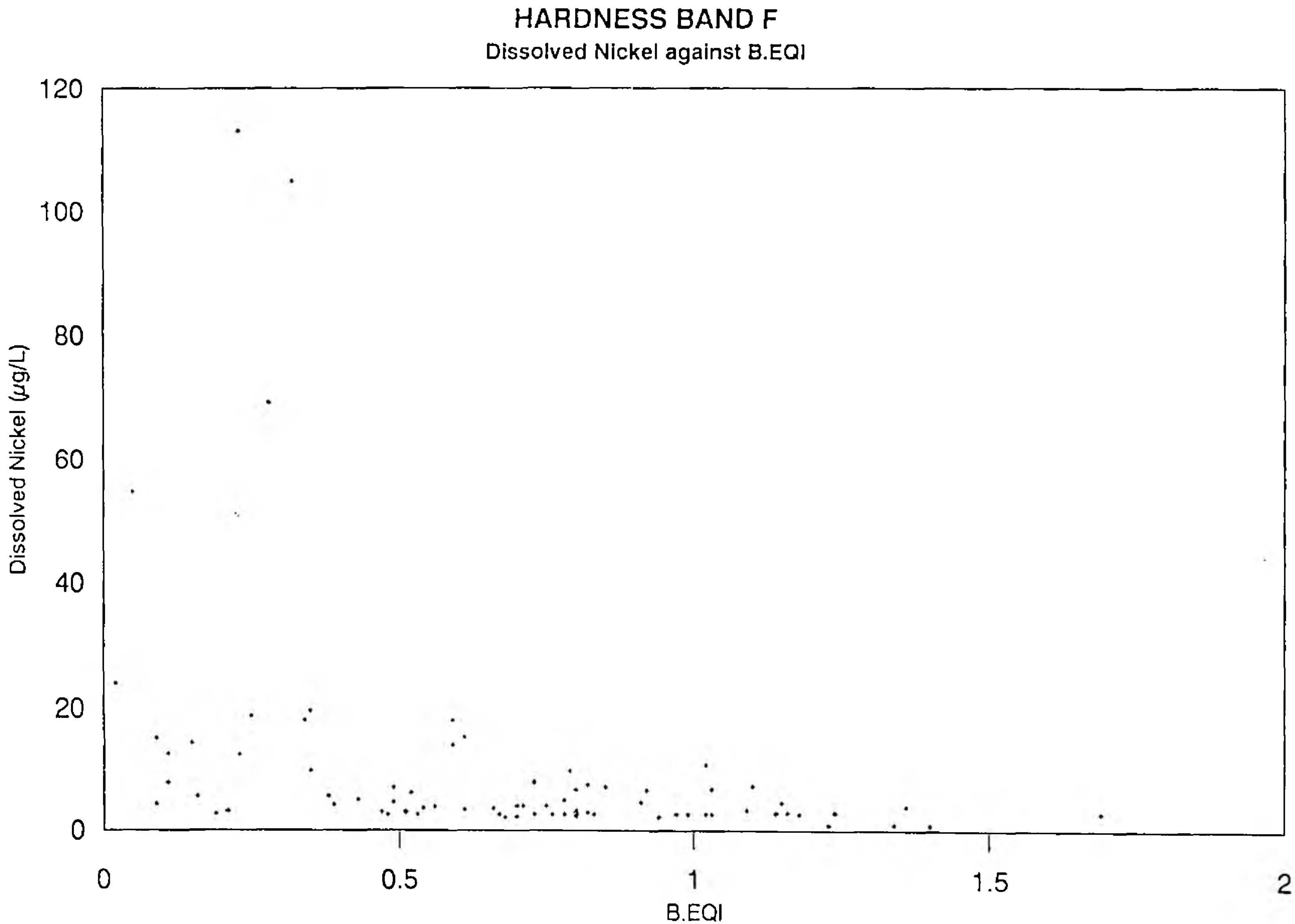
HARDNESS BAND F
Dissolved Copper against BMWP Score
Dissolved Copper (µg/L)
300
250
200
150
100
50
0
0
50
100
150
200
250
300
BMWP Score


HARDNESS BAND F
Dissolved Copper against Fisheries Score
Dissolved Copper (µg/L)
0
10
20
30
40
50
Fisheries Score
0
1
2
3
4
5
6
7


HARDNESS BAND F
log dissolved Chromium against BMWP Score
log Dissolved Chromium (µg/L)
1.5
1
0.5
0
(0.5)
0
50
100
150
200
250
300
BMWP Score


HARDNESS BAND F
log dissolved Chromium against Fisheries Score
log Dissolved Chromium (µg/L)
1.5
1
0.5
0
(0.5)
1
2
3
4
5
6
7
Fisheries Score


HARDNESS BAND F
Dissolved Lead against B.EQI
Dissolved Lead (µg/L)
1,400
1,200
1,000
800
600
400
200
0
0
0.5
1
1.5
2
B.EQI


HARDNESS BAND F
Dissolved Nickel against B.EQI
Dissolved Nickel (µg/L)
120
100
80
60
40
20
0
0
0.5
1
1.5
2
B.EQI

APPENDIX 3

DATABASE STRUCTURE

DATABASE STRUCTURE

The database was developed using dBASE III PLUS, a program that allows information to be managed and manipulated. The resulting database file (.DBF) may be imported and exported into a variety of data handling packages for further analysis.

Use of Database

Be sure that The Assistant Menu is on your screen and that your printer is ready to print.

- Open the Set Up menu and select **Database File.**
- Select the A drive (or the drive where you have stored the supplied files). A file submenu will appear.
- Select NRA.DBF. You will be asked if the database is indexed, press ENTER or N (no).

Although the database has now been selected and can be used in its current format, a screen has been developed to allow the data to be visualised and updated more easily (Figure A1). To view the data in this format it is necessary to follow these steps:

- Open the Set Up menu and select **Format for Screen.**
- Select the A drive and select NRA.FMT.

To view the data using the format screen, use either the **Edit** or **Append** options in the **Update** menu.

The disk supplied also contains a file called NRA.SCR. In the event that the existing format screen needs amendment, this file allows the format screen to be modified.

- Open the Modify menu and select **Format**.
- A submenu will appear with the Set Up menu open. To visualise the existing structure press **F10** and a screen called the *blackboard* will appear. To return to the menu press **F10** again.

Should you need to amend the structure and you are unfamiliar with dBASE III PLUS please contact Acer Environmental.

REFERENCE NO:	DESCRIPTION:
YEAR:	

Determinand:	n	MEAN	S.D.	95%ile	EQS	CEQS	PEQS	FISH DIR
ZINC (TOTAL)	•	•	•	•	x	x	x	x
ZINC (DIS.)	•	•	•	•			x	
COPPER (DIS.)	•	•	•	•	x	x	x	x
CHROMIUM (DIS.)	•	•	•	•	x	x	x	
LEAD (DIS.)	•	•	•	•	x	x	x	
NICKEL (DIS.)	•	•	•	•	x	x	x	
ARSENIC (DIS.)	•	•	•	•	x	x	x	
HARDNESS	•	•	•					

Biological:		EQI		
BMWP	•	•	FISHERIES:	x
ASPT	•	•		
NO. OF TAXA	•	•		

Legend

n	number of data points
MEAN	annual average
S.D.	standard deviation (σ_{n-1})
EQS	Pass/Fail/No data with respect to 'existing' EQSs for protection of sensitive aquatic life (e.g. salmonid fish)
CEQS	Pass/Fail/No data with respect to 'existing' EQSs for protection of other aquatic life (e.g. cyprinid fish)
PEQS	Pass/Fail/No data with respect to 'proposed' EQSs
FISH DIR	Pass/Fail/No data with respect to Fisheries Directive 95%iles.
DIS.	dissolved

All metal values as μg/l
Hardness as mg/l $CaCO_3$

Figure A1. Format Screen for Database

The database structure, as outlined below, is closely linked with the screen format files. Hence, care should be taken if it is necessary to modify the database structure.

Unless otherwise stated all metals are dissolved (filtered).

	Field	Field Name	Type	Width	Dec.	Description
1	REF_NO	Character	14	0		Chemical reference number
2	SITE_DESCR	Character	30	0		Chemical site description
3	YEAR	Character .	5	0		Year of survey/sampling
4	CHROM_CEQS	Character	1	0		Cyprinid EQS for chromium
5	COP_CESQ	Character	1	0		Cyprinid EQS for copper
6	ZINC_CEQS	Character	1	0		Cyprinid EQS for zinc
7	ZINC_T_CEQ	Character	1	0		Cyprinid EQS for total zinc
8	ARSEN_CEQS	Character	1	0		Cyprinid EQS for arsenic
9	NICK_CEQS	Character	1	0		Cyprinid EQS for nickel
10	LEAD_CEQS	Character	1	0		Cyprinid EQS for lead
11	ARSEN_FD	Character	1	0		Fish Directive for arsenic
12	NICK_FD	Character	1	0		Fish Directive for nickel
13	LEAD_FD	Character	1	0		Fish Directive for lead
14	CHROM_FD	Character	1	0		Fish Directive for chromium
15	COP_FD	Character	1	0		Fish Directive for copper
16	ZINC_FD	Character	1	0		Fish Directive for zinc
17	ZINC_T_FD	Character	1	0		Fish Directive for total zinc
18	ARSEN_PEQS	Character	1	0		Proposed EQS for arsenic
19	NICK_PEQS	Character	1	0		Proposed EQS for nickel
20	LEAD_PEQS	Character	1	0		Proposed EQS for lead
21	CHROM_PEQS	Character	1	0		Proposed EQS for chromium
22	COP_PEQS	Character	1	0		Proposed EQS for copper
23	ZINC_PEQS	Character	1	0		Proposed EQS for zinc
24	ZIN_T_PEQS	Character	1	0		Proposed EQS for total zinc
25	ARSEN_EQS	Character	1	0		Salmonid EQS for arsenic
26	NICK_EQS	Character	1	0		Salmonid EQS for nickel
27	LEAD_EQS	Character	1	0		Salmonid EQS for lead
28	CHROM_EQS	Character	1	0		Salmonid EQS for chromium
29	COP_EQS	Character	1	0		Salmonid EQS for copper
30	ZINC_EQS	Character	1	0		Salmonid EQS for zinc
31	ZINC_T_EQS	Character	1	0		Salmonid EQS for total zinc
32	HARD_N	Numeric	3	0		No. of hardness values
33	HARD_MN	Numeric	7	2		Mean hardness (mg/l $CaCO_3$)
34	HARD_SD	Numeric	7	2		Standard Deviation hardness
35	ZINC_T_N	Numeric	3	0		No. of total zinc values

36	ZINC_T_MN	Numeric	7	2	Mean total zinc (μg/l)
37	ZINC_T_SD	Numeric	7	2	Standard Deviation total zinc
38	ZINC_T_95	Numeric	6	2	95 %ile total zinc
39	ZINC_D_N	Numeric	3	0	No. of dissolved zinc values
40	ZINC_D_MN	Numeric	7	2	Mean dissolved zinc (μg/l)
41	ZINC_D_SD	Numeric	7	2	Standard Deviation dissolved zinc
42	ZINC_D_95	Numeric	6	2	95 %ile dissolved zinc
43	COP_D_N	Numeric	3	0	No. of dissolved copper values
44	COP_D_MN	Numeric	7	2	Mean dissolved copper (μg/l)
45	COP_D_SD	Numeric	7	2	Standard Deviation dissolved copper
46	COP_D_95	Numeric	6	2	95 %ile dissolved copper
47	CHROM_D_N	Numeric	3	0	No. of dissolved chromium values
48	CHROM_D_MN	Numeric	7	2	Mean dissolved chromium (μg/l)
49	CHROM_D_SD	Numeric	7	2	Standard Deviation dissolved chromium
50	CHROM_D_95	Numeric	6	2	95 %ile dissolved chromium
51	LEAD_D_N	Numeric	3	0	No. of dissolved lead values
52	LEAD_D_MN	Numeric	7	2	Mean dissolved lead (μg/l)
53	LEAD_D_SD	Numeric	7	2	Standard Deviation dissolved lead
54	LEAD_D_95	Numeric	6	2	95 %ile dissolved lead
55	NICK_D_N	Numeric	3	0	No. of dissolved nickel values
56	NICK_D_MN	Numeric	7	2	Mean dissolved nickel (μg/l)
57	NICK_D_SD	Numeric	7	2	Standard Deviation dissolved nickel
58	NICK_D_95	Numeric	6	2	95 %ile dissolved nickel
59	ARSEN_D_N	Numeric	3	0	No. of dissolved arsenic values
60	ARSEN_D_MN	Numeric	7	2	Mean dissolved arsenic (μg/l)
61	ARSEN_D_SD	Numeric	7	2	Standard Deviation dissolved arsenic
62	ARSEN_D_95	Numeric	6	2	95 %ile dissolved arsenic
63	BMWP	Numeric	6	0	Biological Monitoring Working Party Score
64	ASPT	Numeric	5	3	Average Score Per Taxon
65	NO_TAXA	Numeric	3	0	No. of taxa
66	EQI_BMWP	Numeric	6	3	Environmental Quality Index for BMWP
67	EQI_ASPT	Numeric	6	3	Environmental Quality Index for ASPT
68	EQI_NT	Numeric	6	3	Environmental Quality Index for number of taxa
69	FISHERIES	Numeric	2	0	Fisheries Score

Interrogation of Data

Having established the database structure and contents, it was necessary to interrogate the data. Several programs were designed by Mr Chris Valentine on behalf of Acer Environmental. They are each executed, in order, from the dBASE III Plus 'dot prompt' by typing DO followed by the filename. Ensure that the current DOS directory is the one containing both the program and .DBF files (e.g. C:\DBASE).

NRA2.PRG

For each record in NRA.DBF:

1. Calculates the 95 percentile for each metal variable.

2. Identifies the relevant hardness band for each record with respect to each set of standards.

3. Compares each metal value (mean or 95 percentile as relevant) with each standards' pass/fail value.

4. Records P, F or N in the relevant field signifying Pass, Fail or No Data (Arsenic treated as hardness band independent).

5. Displays the results on screen. Although the facility to display is included, the pause between each screen has been removed to allow faster processing. Should it be necessary to examine the individual records, the WAIT statements can be put back in.

   The rate of data processing may be increased by using a dBASE compiler such as Foxbase.

NRA3.PRG

1. Sorts the entire database by mean hardness, storing the sorted data in the file NRA_SORT.DBF.

2. Produces 6 new databases based on hardness bands. The new databases are stored in ascending mean hardness order.

3. For each of the 6 new databases, counts the number of passes and fails for each metal variable. The results are stored to the file, NRA_BNDS.DBF and displayed on screen.

New files produced:

BAND_A.DBF NRA_SORT.DBF
BAND_B.DBF NRA_BNDS.DBF
BAND_C.DBF
BAND_D.DBF
BAND_E.DBF
BAND_F.DBF

NRA5.PRG

1. For each record of the 6 new databases, pairs each metal concentration with five biological fields in turn to produce two field 'output' databases. The databases are coded DOS filenames (e.g. ATZNBMWP.DBF contains the data for hardness band A, total zinc paired with BMWP score).

   This program is demanding of the computer, therefore, please ensure your DOS 'Files' value (in CONFIG.SYS) is set high enough (at least 15) and that 'Buffers' is set to at least 25.

NRA6.PRG

1. Breaks down all sets of pass and fail data into four bands against BMWP.EQI (Field 66) and six bands against FISHERIES (Field 69), each expressed as a percentage of the biological pass/fail total.

2. Generates seven tables of percentage results, one each for the hardness bands and one for arsenic. In addition to the percentages, the tables also include total passes/fails for *all* records and for those records with only biological/fisheries and metal data.

   Seven files are used by the program to store the total passes and fails:

   TABLE_A.DBF
   TABLE_B.DBF
   TABLE_C.DBF
   TABLE_D.DBF
   TABLE_E.DBF
   TABLE_F.DBF
   TABLE_AR.DBF

   Their contents may be used for later analysis and are thus not blanked on completion of the program. The program will not run if these files are not present. For the results of this program to be accurate, the six files BAND_A.DBF to BAND_F.DBF produced by NRA3.PRG must be up-to-date.

As well as the above programs, there must also be present in the directory that contains the *working copy* of NRA.DBF:

CLEARBIT.PRG
BMWPBLNK.DBF
BEQIBLNK.DBF
FISHBLNK.DBF
BNDSBLNK.DBF

Please note that not only are field names but also field *positions* relevant to the NRA suite of programs. Although new fields can be safely added to the end of the NRA.DBF database, no earlier fields must be altered.

In order to reduce the amount of hard disk 'thrashing' during the operation of these programs, it is recommended that the target machine be installed with a large hard disk cache in memory. This can be achieved most easily using the MS-DOS utility SMARTDRIVE, for example with the AUTOEXEC.BAT line:

loadhigh c:\windows\smartdrv.exe 2048 c

where 'c' represents the hard drive containing both .DBF and .PRG files.

DISCLAIMER

Acer Environmental can accept no liability for loss of or damage to either data or equipment due to the use of this software.

ACER ENVIRONMENTAL
QUALITY ASSURANCE

Title	:	List II Metals: Evaluation of Standards using Field Data
Client	:	NATIONAL RIVERS AUTHORITY

ISSUE AND REVISION RECORD

Project No.	:	MIC4078/001A
Report No.	:	RT-EDA-0889
Revision No.	:	03
Date	:	October 4 1993
Originators	:	Stephen Hunt J.M. Hawkridge Stephen M Hunt Jane M Hawkridge Richard M Szydlo
Checked by	:	Alan Godfree Alan F Godfree (Technical Director)
Approved by	:	Alan Godfree Alan F Godfree (Technical Director)
Description	:	Final