ENVIRONMENT AGENCY

Investigation into the Effect of Sewage Disinfection on the Bioaccumulation of Chloroform, Bromoform, Dibromochloromethane and Dichlorobromomethane by Fucoid Seaweeds.

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CONTENTS

1. ABSTRACT

Spatial and temporal patterns in the bioaccumulation of trihalomethanes (THMs) were investigated in relation to the disinfection of four sewage effluents along the North Wessex coast (Minehead, Burnham-on-Sea, Weston-Super-Mare and Kingston Seymour).

Seaweeds (*Fucus vesiculosus* or *Fucus serratus*) were collected four times during 1994 in April, June, September and November (before, during and after the disinfection period). Tissues were analysed for chloroform, bromoform, dibromochloromethane and dichlorobromomethane.

Increases in levels of chloroform and bromoform during June and September at Burnham Slip and sites adjacent to the West Huntspill outfall were believed to be related to the disinfection process. The highest levels of chloroform were recorded from Burnham Slip. The possible combined impact of disinfected effluent from West Huntspill and Chiltern Trinity S.T.W.s is discussed.

The discharge from Minehead appeared to have only a limited impact on local beaches. High levels of bromoform at Porlock are discussed in relation to the disinfection scheme.

No clear relationship was seen at Weston-Super-Mare in 1994, but previous studies did suggest a connection between the disinfection at Black Rock and the distribution of THMs within seaweeds collected from Weston Bay. Past data is discussed.

No relationship could be demonstrated between the levels of THMs accumulated in seaweeds and the disinfection process at Kingston Seymour.

There appeared to be no clear relationship between the disinfection process and the levels of dibromochloromethane recorded from seaweed tissues during this study. Detectable levels of dichlorobromomethane were not observed.

Seaweed from a number of sites were found to contain THMs outside the disinfection period. Possible reasons for this are discussed.

2. INTRODUCTION

2.1 Background

Sewage disinfection has been adopted at a number of outfalls on the North Wessex coast to reduce levels of faecal bacteria and comply with the E.C. Bathing Water Directive (Council Directive 76/160/EC). Disinfection is achieved by dosing the effluent with chlorine based compounds (eg. sodium hypochlorite). However, the resulting discharge can be deleterious to aquatic organisms. The toxicity of chlorinated wastes and waters has been demonstrated on a number of marine fish and invertebrates (Davis & Middaugh, 1977). Effects ranged from avoidance, inhibition of motility and fertilization to 100% mortality.

List I of the Dangerous Substances Directive (76/464/EEC) contains substances selected on the basis of their toxicity, persistence and bioaccumulation. This includes substances belonging to the organohalogen group. Chloroform is already controlled by a daughter directive (88/347/EEC) and has an Environmental Quality Standard of 12µg/l. Halogenated organic compounds (including trihalomethanes such as chloroform) are known by-products of the disinfection process.

The discharge of disinfected sewage from several outfalls along a relatively short stretch of coast could be potentially harmful to the local aquatic environment.

2.1 Study Aims

The aim of this study was to investigate spatial and temporal patterns in the bioaccumulation of trihalomethanes (THMs) in relation to the discharge of disinfected effluents along the North Wessex coast. High levels of THMs accumulated during the bathing season would suggest an impact from sewage disinfection. Similarly high levels recorded from sites closest to, or most likely to receive effluent from, the outfall would suggest that the probable source of these compounds was the disinfected discharge.

A bioaccumulation programme was undertaken during 1994 using fucoid seaweeds (*Fucus vesiculosus* or *F. serratus* depending on availability), to investigate effluent disinfection at Minehead, Burnham-on-Sea, Weston-Super-Mare and Kingston Seymour. This was an extension of the bioaccumulation work undertaken at Weston-Super-Mare in 1991, 1992 and 1993 (N.R.A. South Western Region, 1993).

2.2 Outfall Details

Of the four outfalls studied only Minehead discharges directly into the Severn Estuary. The others all discharge into the estuary via rivers or creeks which have a reduced capacity for dilution at low tide (West Huntspill and Bridgwater via the River Parrett, Black Rock via the channel of the River Axe and Kingston Seymour via Kingston Pill).

During the summer bathing season, the outfalls undergo disinfection to ensure that local beaches satisfy the requirements of the E.C. Bathing Water Directive (Council Directive 76/160/EC). The summer bathing season is defined as beginning on the first Monday in May, which falls a fortnight before the Spring Bank Holiday and ending on the Sunday which falls in the second full weekend of September (D.O.E. COPA/1288). In reality the discharge period is usually longer than this due to pre-season trials and post-season run down (Table 1).

Table 1 Period of Disinfection

Outfall	Start	End
Black Rock - Weston-Super-Mare	23.04.94	01.10.94
Minehead	27.04.94	03.10.94
Kingston Seymour	23.04.94	05.10.94
West Huntspill - Burnham-on-Sea	27.04.94	02.10.94
Chilton Trinity - Bridgwater*	27.04.94	30.09.94

3. METHODS

3.1 Site Selection

Samples of fucoid seaweeds (*Fucus vesiculosus* or *F. serratus* depending on availability) were collected from a total of 23 sites along the Severn Estuary between Clevedon (Avon) and Porlock (Somerset) on the North Wessex coast (Figure 1).

Nine of the sites already existed as part of the Weston-Super-Mare bioaccumulation programme. Additional sites were selected on the following criteria;

a) Distance from outfall
b) Presence of hard substrata and fucoid seaweeds
c) Access to foreshore

Due to the proximity of the Kingston Seymour, West-Huntspill and Black Rock outfalls some of the sites overlapped.

3.2 Sampling Regime

Samples of fucoid seaweeds were collected before, during and after the disinfection period (Table 2). *Fucus vesiculosus* was collected from all sites with the exception of Ladye Bay (one of the reference stations), where only *F. serratus* was available. Approximately 15-20 plants were collected from each site and transported to the N.R.A's Blandford Laboratory under cool and dark conditions.

* The effluent from Chilton Trinity could not be directly monitored due to the lack of fucoid seaweeds in the area. Details of the discharge have still been considered due to the potential combined effects of this effluent and the West Huntspill discharge.

FIGURE 1 LOCATION OF SAMPLING SITES - Disinfection Bioaccumulation Study 1994

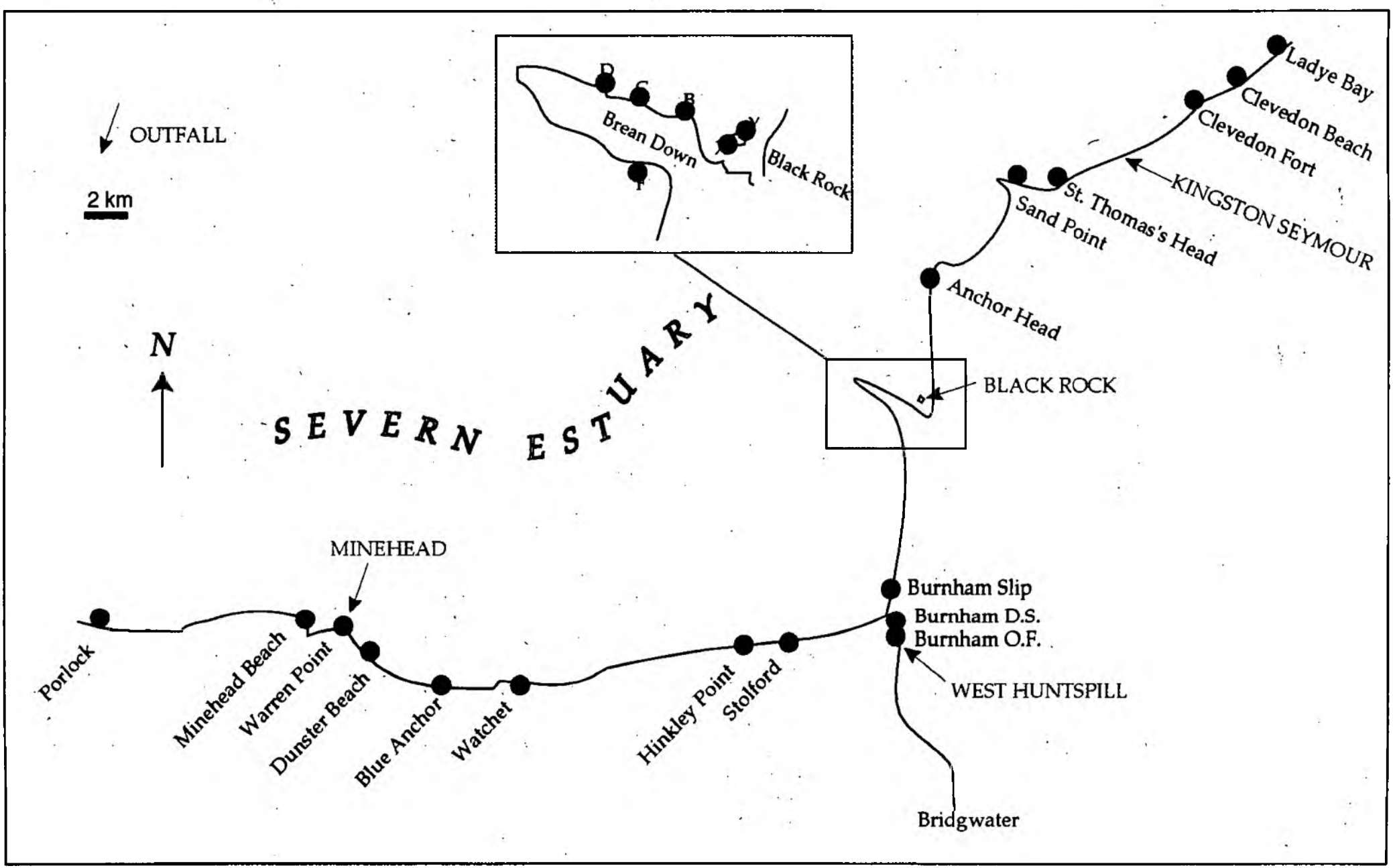


Table 2 Seaweed Collection Dates

Outfall	Pre Disinfection	During Disinfection Period		Post Disinfection
Black Rock	7th April	6-7th June	19th, 21st Sept.	2nd Nov.
Minehead	18th April	9th June	22nd Sept.	7th Nov.
Kingston Seymour	21st April	6-7th June	21st, 28th Sept.	3rd Nov.
West Huntspill	19th April	13th June	16th, 28th Sept.	8th Nov.

3.3 Seaweed Analysis

Seaweeds were washed in distilled water to remove surface debris and the excess water shaken off prior to dissection. Fruiting bodies, bladders and seaweed tips (which have the potential to form reproductive tissue) were removed. The amount of growth in any one year is not clear, but it is thought to include two dichotomous divisions (Barrett and Yonge, 1958). Using this rule of thumb, light green (ie: newest growth) tissue was removed and chopped into thin strips using stainless steel scissors. Approximately 60-70g of material was chopped into glass jars and frozen until the analysis could be undertaken at the N.R.A.'s laboratory at Exeter.

Seaweeds were either chopped the same day or refrigerated overnight and chopped the following day.

4. RESULTS

All results are presented in Appendix I and illustrated in Figures 2-4. Dichlorobromomethane was not recorded above the limit of detection (3µg/kg) at any of the sites examined. Chloroform, dibromochloromethane and bromoform were recovered from seaweed tissues throughout the survey period.

4.1 West Huntspill

4.12 Chloroform

Chloroform was recorded from sites in the vicinity of the West Huntspill outfall throughout the sampling period, the highest levels occurring at Burnham Slip and site B downstream of the outfall. During June and September, Burnham Slip exhibited the highest levels recorded from any of the 23 sites sampled (17.6µg/kg and 19.6µg/kg respectively).

The most westerly site to have accumulated chloroform was Stolford during April (6.44µg/kg). It should be noted that this was close to the detection limit of 6µg/kg.

During April all sites sampled between Stolford and Brean (site D) exhibited determinable levels of chloroform before the 1994 disinfection season was underway.

4.13 Dibromochloromethane

Dibromochloromethane was recorded at three separate sites on three separate occasions during this study; Burnham Slip in June (6.78µg/kg), Stolford in September (6.33µg/kg) and Hinkley in November (6.5µg/kg). It should be noted that these values were not notably higher than the limit of detection (6µg/kg).

4.14 Bromoform

Burnham Slip was the only site in the vicinity of the West Huntspill discharge to exhibit detectable levels of bromoform. This occurred during September (25.8µg/kg) at the end of the disinfection period, all other months were below the detection limit.

4.2 Minehead

4.21 Chloroform

Chloroform was recorded from three different sites on three separate occasions; Blue Anchor (April 6.33µg/kg) and Dunster (September 10.34µg/kg) to the east of the outfall and Porlock (November 9.09µg/kg) to the west.

4.22 Dibromochloromethane

This compound was only recorded during April (ie: pre-disinfection) at Blue Anchor (8.76µg/kg)) and Porlock (7.58µg/kg).

4.23 Bromoform

The highest levels of bromoform of all the 23 sites sampled were recorded from Porlock. Concentrations of 71.44µg/kg were recorded during September, but had decreased to 43.62µg/kg by November. These levels were up to 4 times higher than the detection limit (<15µg/kg). The only other site to exhibit any levels of bromoform during the survey was Burnham Slip in September.

4.3 Kingston Seymour

4.31 Chloroform

Chloroform was only recorded to the east of the outfall at Clevedon Fort in September (7.68µg/kg) and Clevedon Beach in November (8.64µg/kg).

4.32 Dibromochloromethane

Dibromochloromethane was detected from three sites in the vicinity of the Kingston Seymour outfall during April and June. Of these, the highest levels were detected from St. Thomas's Head (April 10.4µg/kg) before the 1994 disinfection period began.

Dibromochloromethane was the only compound to be recorded from the reference site at Ladye Bay (November-9.20µg/kg).

4.33 Bromoform

Bromoform was not found at levels above the detection limit.

4.4 Black Rock

4.43 Chloroform

Chloroform was only recorded from sites in the vicinity of the Black Rock outfall during April, before disinfection had begun. These were restricted to Black Rock itself and Brean Down (both north and south sides). Site D, the furthest site on the north side of Brean Down, exhibited the highest levels (11.16µg/kg).

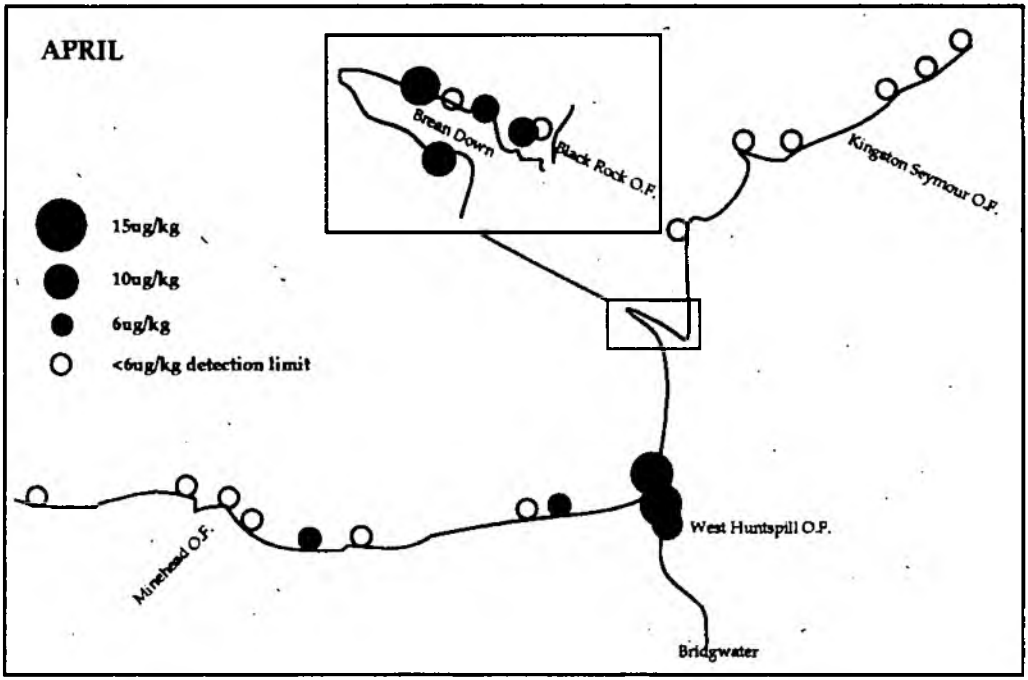
4.44 Dibromochloromethane

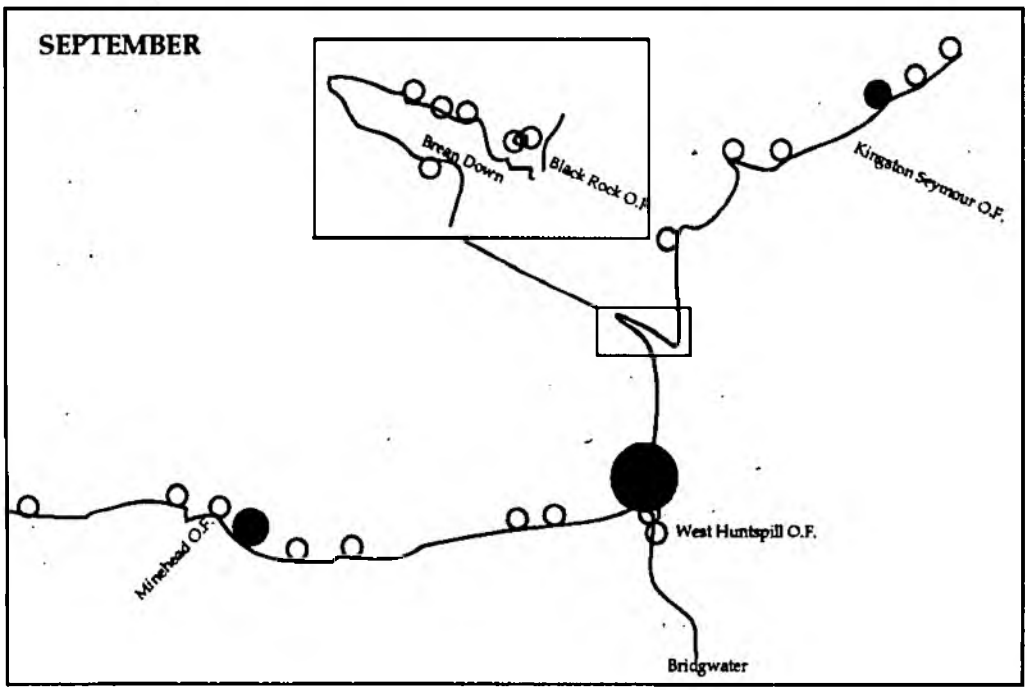
Apart from a single record at site C during June (7.66µg/kg) the largest accumulation of dibromochloromethane occurred during November after the disinfection period had ceased. Site D exhibited the highest levels (13.8µg/kg) of all 23 sites surveyed.

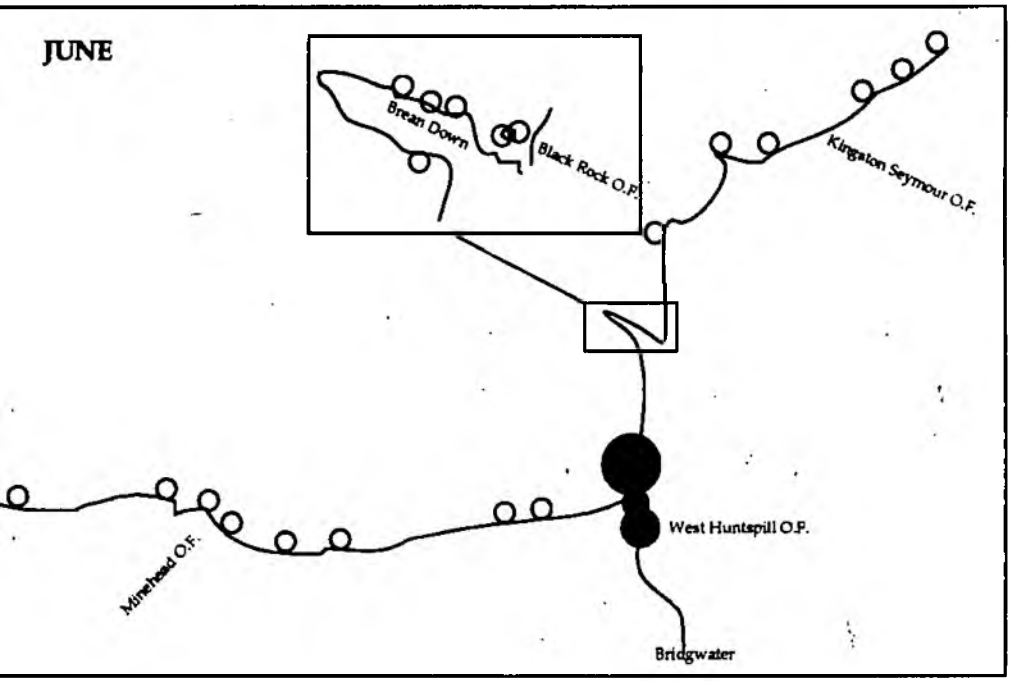
4.45 Bromoform

Bromoform was not found at levels above the detection limit.

FIGURE 2 CHLOROFORM LEVELS IN FUCOID SEAWEEDS - 1994



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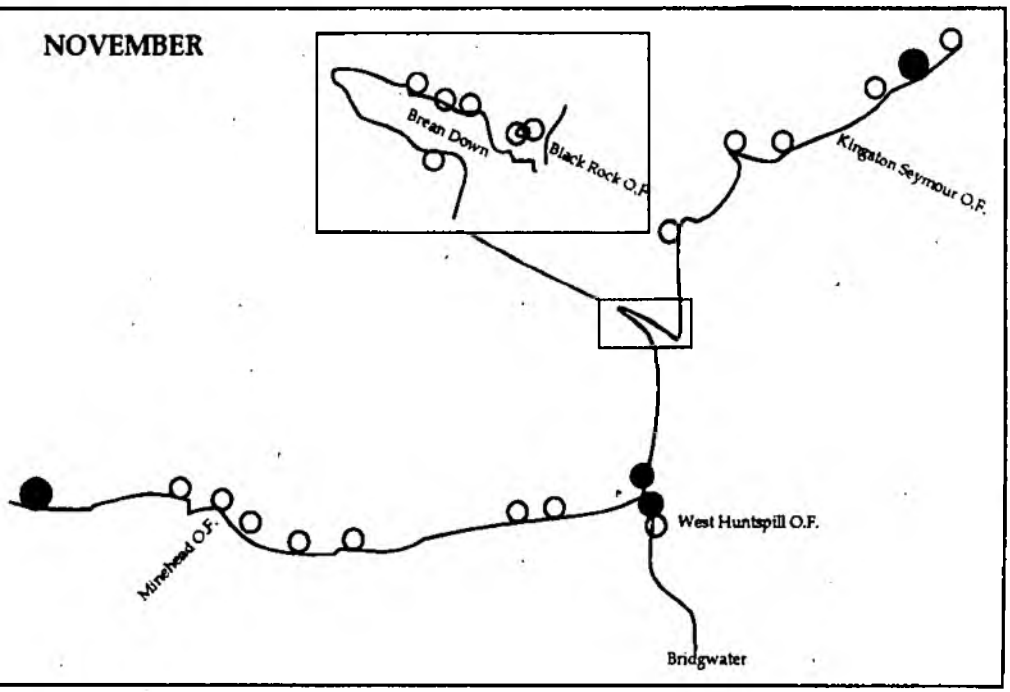
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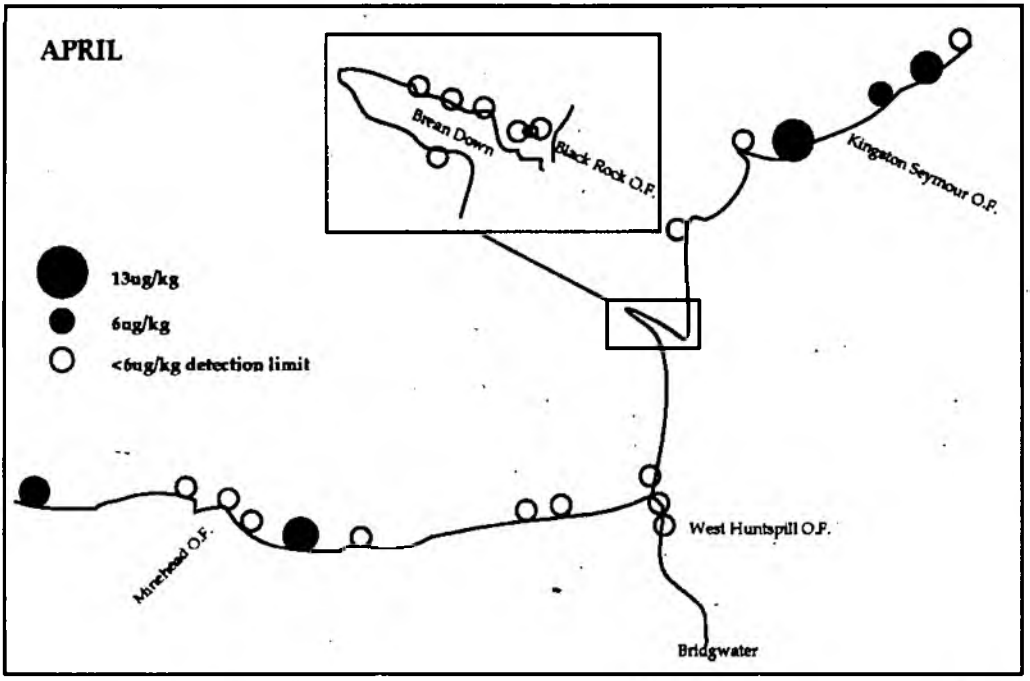
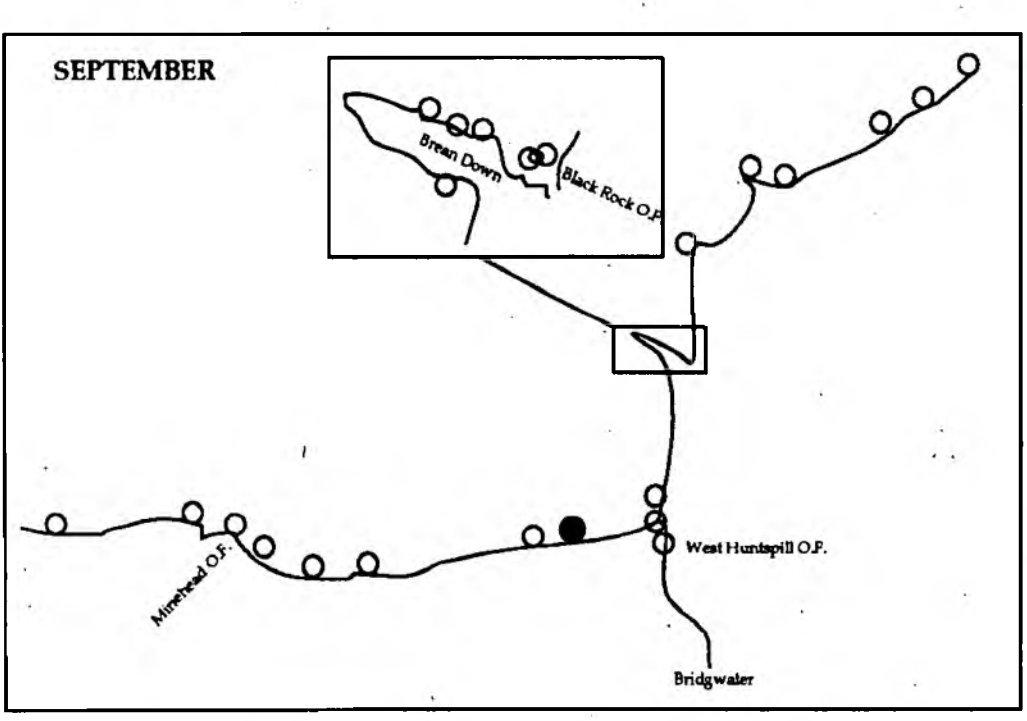
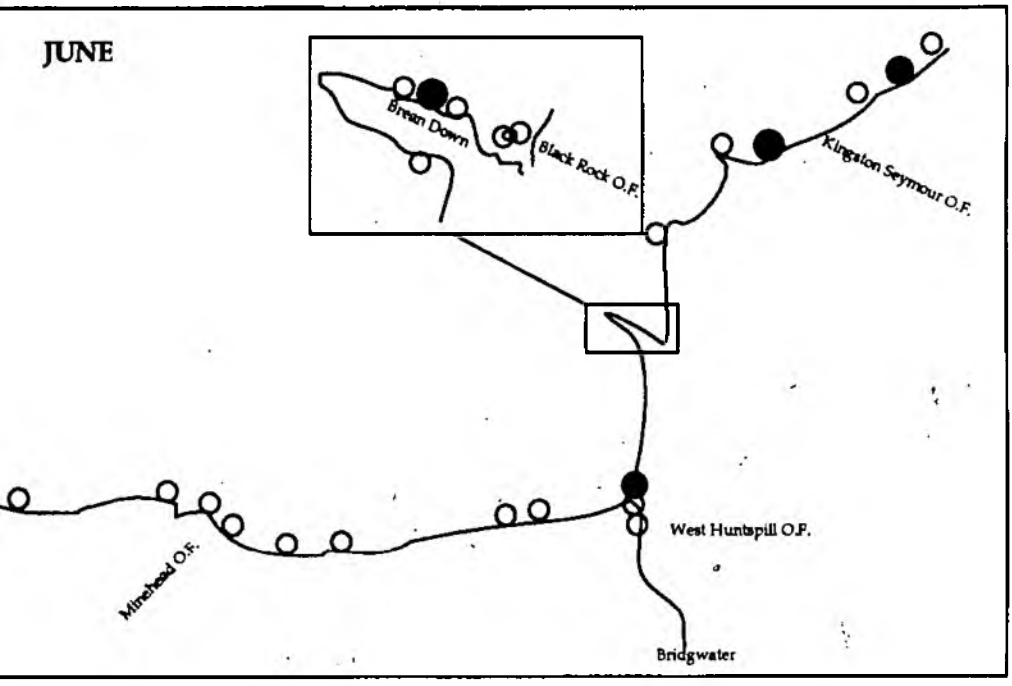
FIGURE 3 DIBROMOCHLOROMETHANE LEVELS IN FUCOID SEAWEEDS -



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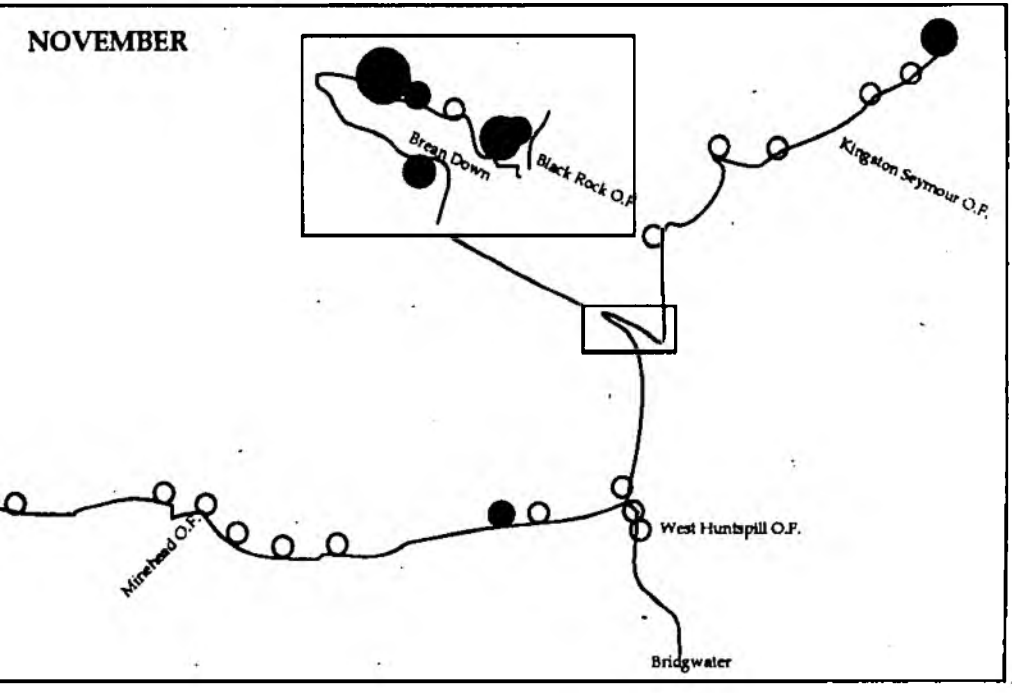
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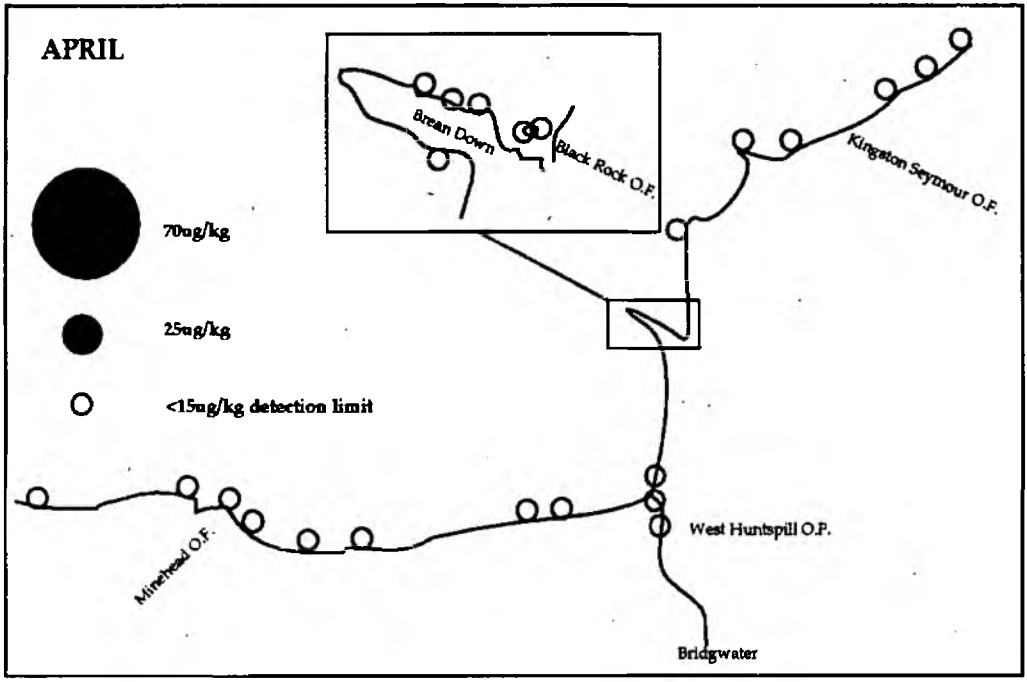
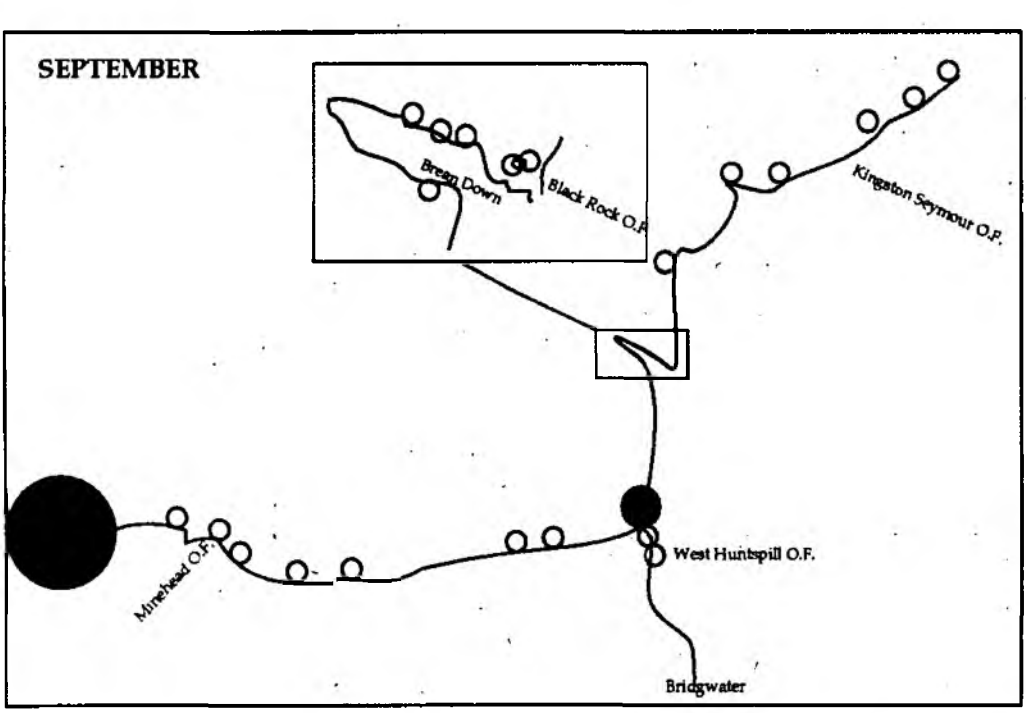
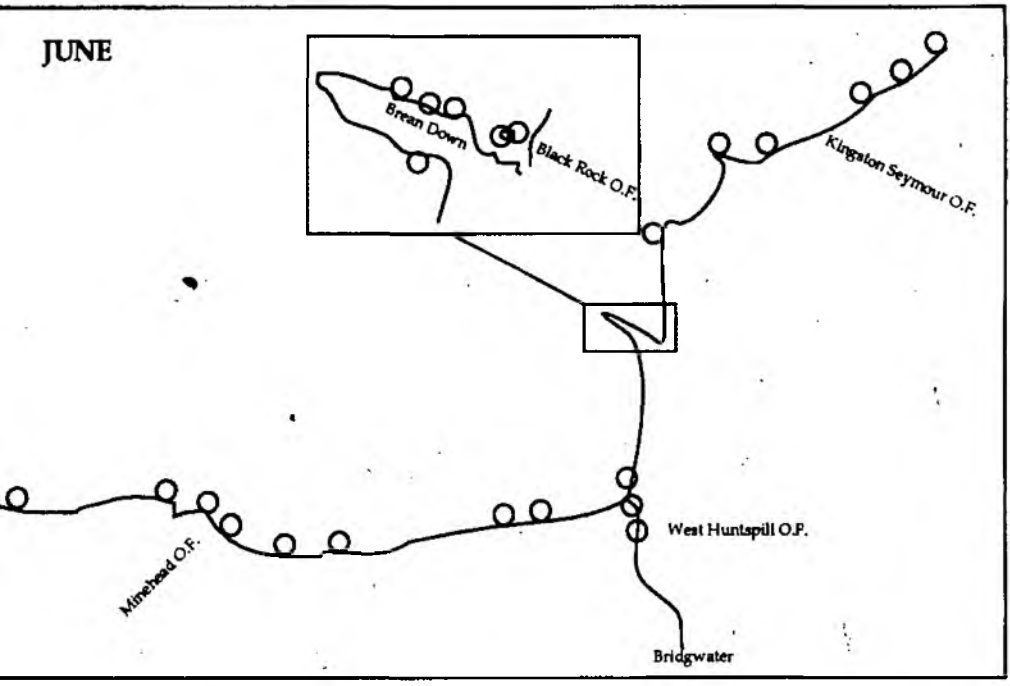
FIGURE 4 BROMOFORM LEVELS IN FUCOID SEAWEEDS - 1994



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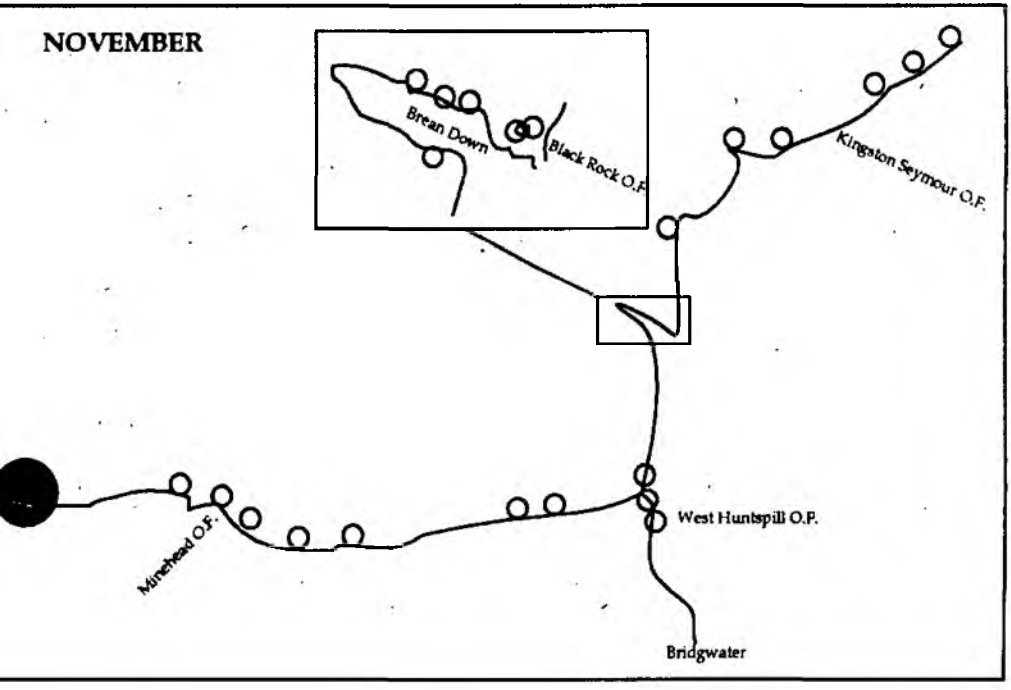
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5. DISCUSSION

5.1 West Huntspill

Clear spatial and temporal trends in the bioaccumulation of THMs, which could be attributed to the disinfection process, were observed at West Huntspill.

During the bathing season, an increase in the levels of chloroform and bromoform was recorded in seaweed tissues collected from sites adjacent to the West Huntspill outfall, with Burnham Slip exhibiting the highest levels. Disinfected effluent from both West Huntspill and Chiltern Trinity (Bridgwater) S.T.W.s. discharge into the River Parrett, which then flows into Bridgwater Bay. The Bay therefore receives a large volume of disinfected sewage and consequently a potential source of various halogenated organic compounds[1,2]. Previous bacteriological studies have indicated that sewage can hit Burnham beach on a returning flood tide (N.R.A. National Centre 1989/90). Disinfected sewage following the same dispersion pattern would explain the presence of chloroform and bromoform at Burnham Slip.

Levels of chloroform recorded from Burnham Slip and sites adjacent to the outfall were relatively high in April, eight days prior to the start of disinfection at West Huntspill. Chloroform was also present at reduced levels in tissues collected during November, one month after the end of disinfection. Possible reasons for the occurrence of THMs outside the disinfection period are discussed in section 5.5.

During the survey period small amounts dibromochloromethane were recovered from Stolford and Hinkley. Hinkley Point power station uses hypochlorite as an antifoulant in its cooling water pipes. This is not done on a regular basis however, and its last recorded use was 5 years ago (personal communication: Consents - E.A. North Wessex). The nearest source would therefore appear to be West Huntspill. However, the distribution of dibromochloromethane at other sites during the survey period, was found to be variable. No clear relationship could be found between the levels recorded and the timing of disinfection (Figure 3). Therefore, the presence of this compound at Stolford and Hinkley cannot be confidently attributed to the West Huntspill discharge.

Based on the accumulation of THMs during the bathing season, it appears that the impact of the disinfected effluent within the intertidal area studied is quite localised with Burnham Slip exhibiting the worst contamination.

5.2 Minehead

The only site east of the Warren outfall to exhibit detectable levels of THMs during the disinfection period was Dunster Beach in September. THMs were also recovered from Blue Anchor during April, but this was ten days prior to the start of disinfection (see section 5.5). Disinfection of effluent discharged from the Warren outfall during 1994 would therefore appear to have only a limited impact on local beaches.

In contrast, the levels of bromoform recorded at Porlock were surprisingly high. This site is more than 12km west of the Minehead discharge. Enquiries regarding nearer outfalls at Bossington and Porlock, revealed that these are not disinfected and neither received major industrial inputs (personal communication: Water Quality - E.A. North Wessex). Similarly there are no major industrial or disinfected outfalls to the west of Porlock along the North Devon coast (Personal Communication - Devon Area E.A.). The nearest potential source of trihalomethanes would appear to be the disinfection scheme at Minehead, where levels of THMs in the post-chlorinated effluent were found to be at higher levels than at other disinfected discharges in the area (North Wessex N.R.A. 1994b). Due to the topography and distribution of seaweeds, no other sites could be surveyed between Minehead and Porlock. Consequently there is no additional data to the west of the outfall to confirm that the source of these high concentrations is the discharge of disinfected sewage from Warren Point.

Recent studies have revealed that *Fucus serratus* is able to naturally produce bromoform (Nightingale et al, 1995). It may be possible that other fucoid weeds also possess this ability and that the large concentration of bromoform at

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[1] Studies of the trihalomethane content of the final effluents at these works during August and September (N.R.A. 1994b) revealed levels of chloroform averaging 8.91 and 16.229 µg/l at West Huntspill and Chiltern Trinity respectively.

[2] Residual chlorine in the discharge can react with natural organic matter in the estuary (eg; adsorbed to suspended sediment) to produce more THMs (Uhler & Means, 1985).

Porlock is a natural phenomenon. However, if this was the case high concentrations would also have been observed at other sites (no detectable levels were recorded in the sample of *F. serratus* taken from Ladye Bay). The elevated levels recorded from Porlock cannot therefore be readily explained.

5.3 Kingston Seymour

The Kingston Seymour outfall discharges into a stretch of coast which is predominantly mud flats and saltmarsh, the nearest rocky outcrops are situated approximately 2km to the west and 4km to the east. Consequently the sites surveyed for this outfall were some distance from the point of discharge. Levels of chloroform around Kingston Seymour were generally lower than recorded from other sites during this survey, suggesting that the stations sampled were not as affected. Dibromochloromethane was accumulated at a larger proportion of these sites, but the highest levels were recorded during April before disinfection had begun. St. Thomas's Head was the most westerly site to exhibit bioaccumulation, suggesting there was no overlap between the Kingston Seymour and Black Rock discharges.

No clear relationship could be made between the disinfection process and the levels of THMs recovered.

5.4 Black Rock

Spatial patterns in the data suggested that the impact of disinfection at Weston-Super-Mare was limited to Black Rock and Brean Down. However, these patterns were observed during April and November when the disinfection process had ceased. Possible reasons for the occurrence of these substances outside the period of disinfection are discussed in section 5.5.

The absence of detectable levels of chloroform and bromoform during the 1994 bathing season, suggest that disinfection was not affecting local seaweeds. This contrasts with data obtained from previous years (Section 6).

5.5 April and November Levels of THMs

As mentioned in previous sections, temporal patterns of bioaccumulation in relation to the timing of disinfection were not always clear. Peaks of chloroform outside the disinfection period and the occurrence of THMs throughout the survey period do not lend themselves to simple interpretation.

In a similar study undertaken in South Wales at Pwll S.T.W. (Wharfe et al 1981), it was suggested that disinfection by-products were only temporarily accumulated, the highest levels being from tissues sampled towards the end of the disinfection period. The Pwll work also showed that levels of halogenated compounds remained high two months after disinfection had ceased, but after five months had returned to pre-disinfection levels. The decrease in chloroform and bromoform observed between September and November at Burnham and Porlock would appear to agree with the observation that the compounds are only temporarily accumulated.

Conversely, levels of dibromochloromethane at Weston-Super-Mare were highest during November. Although it may be possible for seaweed tissues to hold on to these compounds one month after the end of the process, it is strange that detectable levels were not recorded during September. The November data suggests that the seaweeds were actively accumulating dibromochloromethane outside the disinfection period, this could not be proven within the scope of this study. It should also be noted that levels of this compound at the reference sites of Ladye Bay and South Brean were also relatively high, thus no direct link to the Black Rock discharge could be confidently made.

There are a number of possible reasons why chloroform and dibromochloromethane were recorded during April, before the start of disinfection;

- It may be possible that high levels of compounds were accumulated during the 1993 survey and that some was still present in the tissues when they were sampled in April.

As already mentioned, in the Pwll study levels of halogenated compounds had returned to pre-disinfection levels after 5 months. Effluents from North Wessex contained higher levels of residual chlorine[1] (North Wessex N.R.A. 1994a, b) and had longer disinfection periods (6 compared to 3 months) than Pwll. Higher concentrations and longer exposure time may lead to a longer 'recovery' time, consequently the October to April period in which there is no disinfection may not be long enough for all seaweed levels to return to normal.

- The release of sediment bound THMs (Irving & Solbé 1980) or secondary formation of THMs outside the disinfection period.

It may be possible for halogenated organics to accumulate in the sediments during the bathing season and subsequently become a source of these compounds outside the disinfection period. Studies of drinking water chlorination have shown that residual chlorine can react with humic material to produce a chlorinated organic intermediate, which can slowly produce chloroform over a period of days (personal communication - Mike Fielding WRc). Whether this process could continue to occur several months after disinfection had ceased is difficult to establish.

- Seaweed physiology.

There may be some physiological reason for the occurrence of compounds outside the disinfection period. For example, seaweeds may be capable of regulating and excreting certain compounds during the warmer, summer months.

- Data represented background levels of THMs.

If the levels observed during April were simply background, there would not have been a difference between sites close to the outfall and those selected as reference stations. For example levels recorded at Burnham Slip were twice as high as reference material from Ladye Bay[2] and Sand Point.

- Disinfection may have started earlier than stated.

6. COMPARISON OF 1994 WESTON-SUPER-MARE DATA WITH PREVIOUS RESULTS (1991-1993)

Patterns in the distribution of dichlorobromomethane are not discussed as detectable levels were only recorded in September 1993. Results from November 1991 to 1994 are presented in Figures 5 to 8 and recorded in Appendix II.

Levels of THMs recorded in seaweed tissues varied between years, with the highest concentrations being observed in 1993. Although dosing of hypochlorite is controlled to achieve a residual chlorine level of 35mg/l in the contact chamber, the actual levels recorded in the effluent prior to discharge during 1994 varied between 4 and 50mg/l (North Wessex N.R.A. 1994a). The differing levels of THMs recorded in seaweeds over the past 3 years, may be partly due to the variable concentrations of residual chlorine in the discharge.

Despite the variation in actual levels, the general pattern of bioaccumulation was similar between years, with seaweeds collected from sites on Black Rock and Brean Down containing the highest levels of THMs. It would appear from the 1993 data that all sites along the Weston side of Brean Down can be impacted by the disinfection process. The 1992 data illustrates the potential for Anchor Head to also be affected, although this was not repeated in later studies. During the disinfection period, levels at the selected reference sites (Sand Point, Ladye Bay and South Brean) were lower than observed within Weston Bay, which demonstrates that the observed increase in THMs were related to the Black Rock outfall.

During 1992 and 1993 increases in bromoform and dibromochloromethane were observed after the start of disinfection. For example levels of dibromochloromethane increased between April and June 1993, while bromoform was shown to increase between November 1991 to June 1992, and April 1993 to June 1993. Levels at corresponding reference sites remained low suggesting that the change was related to the disinfection process at Black Rock. This was not observed in 1994.

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[1] Black Rock 4-50mg/l (North Wessex E.A. 1994a), Minehead 0.8-3.6mg/l, West Huntspill 3-6.4mg/l and Kingston Seymour 0.3-4.88mg/l (North Wessex E.A. 1994b), Pwll S.T.W. 0.5-1.0mg/l (Wharfe et al 1981).

[2] It should be noted that *Fucus serratus* was collected from Ladye Bay due to the absence of *F. vesiculosus* at this site.

Levels of chloroform in seaweed tissues were interesting. Throughout this study the highest levels were found during November (with the exception of 1994 when they occurred in April). Levels at the reference sites remained low suggesting a spatial distribution which appears to be related to the outfall at Black Rock. Possible reasons for this have already been discussed (Section 5.5).

7. CONCLUSIONS

Bioaccumulation of trihalomethanes by fucoid seaweeds could be related to the discharge of disinfected sewage effluent from outfalls at West Huntspill and Minehead. No clear relationship was seen at Weston-Super-Mare in 1994, but previous studies did suggest a connection between the disinfection at Black Rock and the distribution of THMs within seaweeds collected from Weston Bay. No such relationship could be demonstrated at Kingston Seymour.

From this work, it would appear that the area affected by these outfalls (with the possible exception of Minehead) was quite localised, although the Black Rock study suggested that the actual area impacted may vary from year to year. The area affected by a disinfected effluent is likely to be greater than observed from this study, which by its nature, was restricted to hard substrates within the intertidal zone. The potential effects of disinfection on subtidal and pelagic organisms should be considered. Halogenated compounds are known to have detrimental effects on the physiology, reproduction and recruitment of many aquatic organisms, and sewage disinfection has been shown in a number of studies (eg. WRc, 1995) to be a source of these compounds. Ecotoxicological studies using oyster embryos showed that the toxicity of the West Huntspill discharge was significantly greater when undergoing disinfection [EC50 of 7.2 pre-disinfection compared to 0.98 post-disinfection] (Personal communication- Jon Ponting E.A. Southwest). The presence of chloroform, a List I substance (76/464/EEC) in tissues from Burnham Slip during the summer of 1994 should be a cause for concern.

The bioaccumulation process was found to be potentially complex with the confounding issue of accumulation outside the period of disinfection. Further work into the bioaccumulation rates and biomagnification of these compounds is necessary.

FIGURE 5 Key to Figures 6-8 (Distribution of THMs in Fucoid Seaweeds at Weston-Super-Mare 1991-1994)

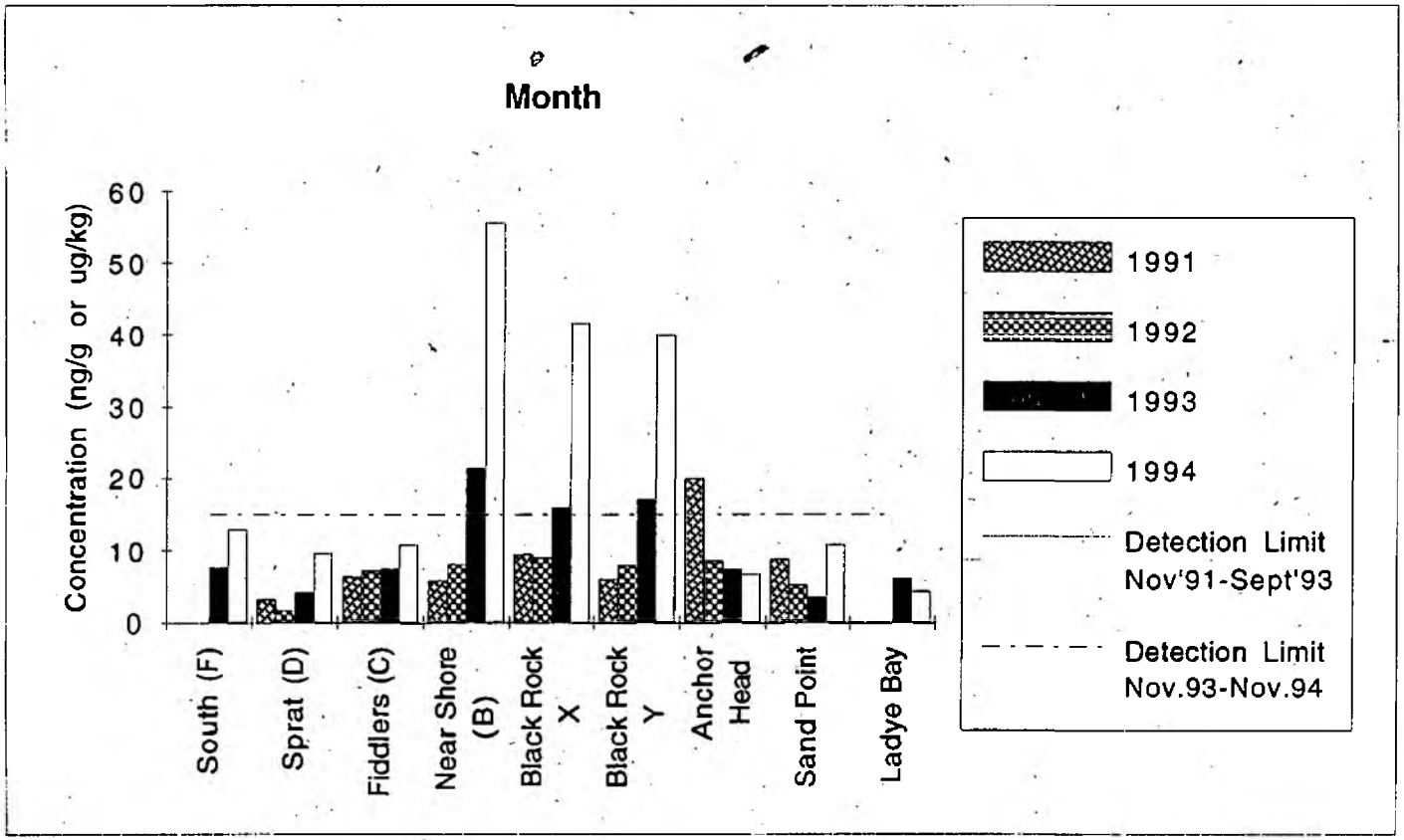


FIGURE 6 Distribution of Chloroform in Fucoid Seaweeds at Weston-Super-Mare 1991-1994

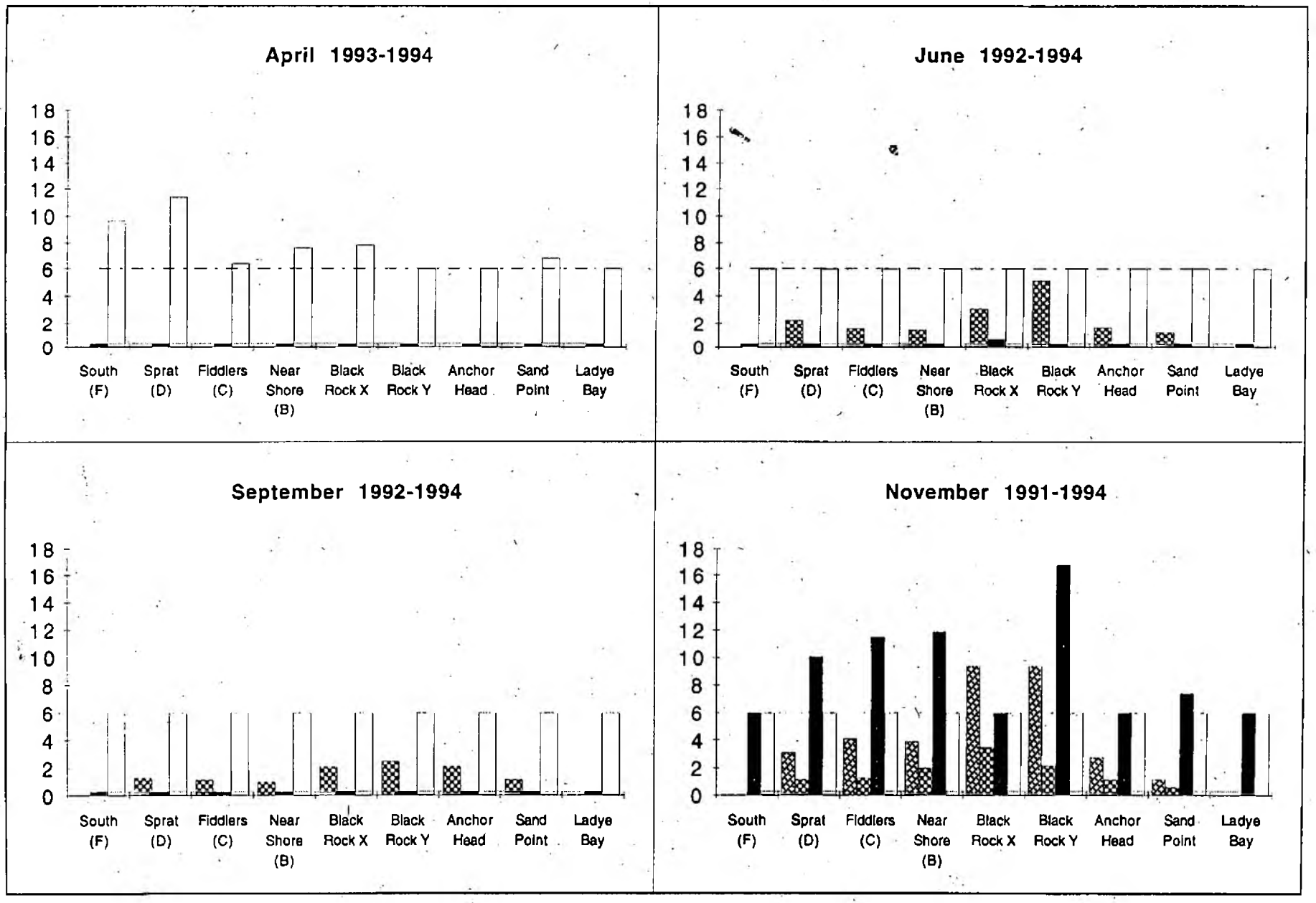


FIGURE 7 Distribution of Bromoform in Fucoid Seaweeds at Weston-Super-Mare 1991-1994

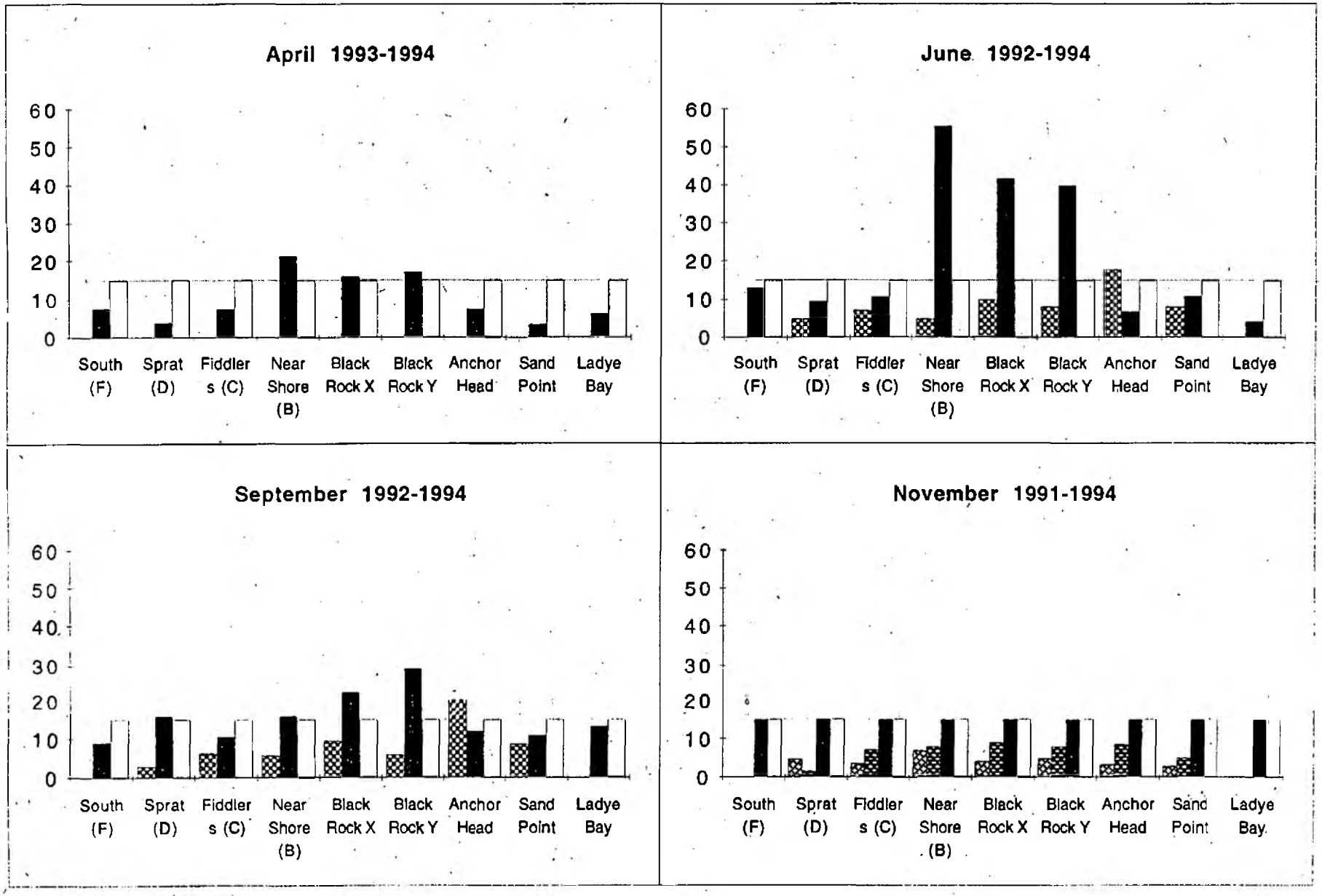
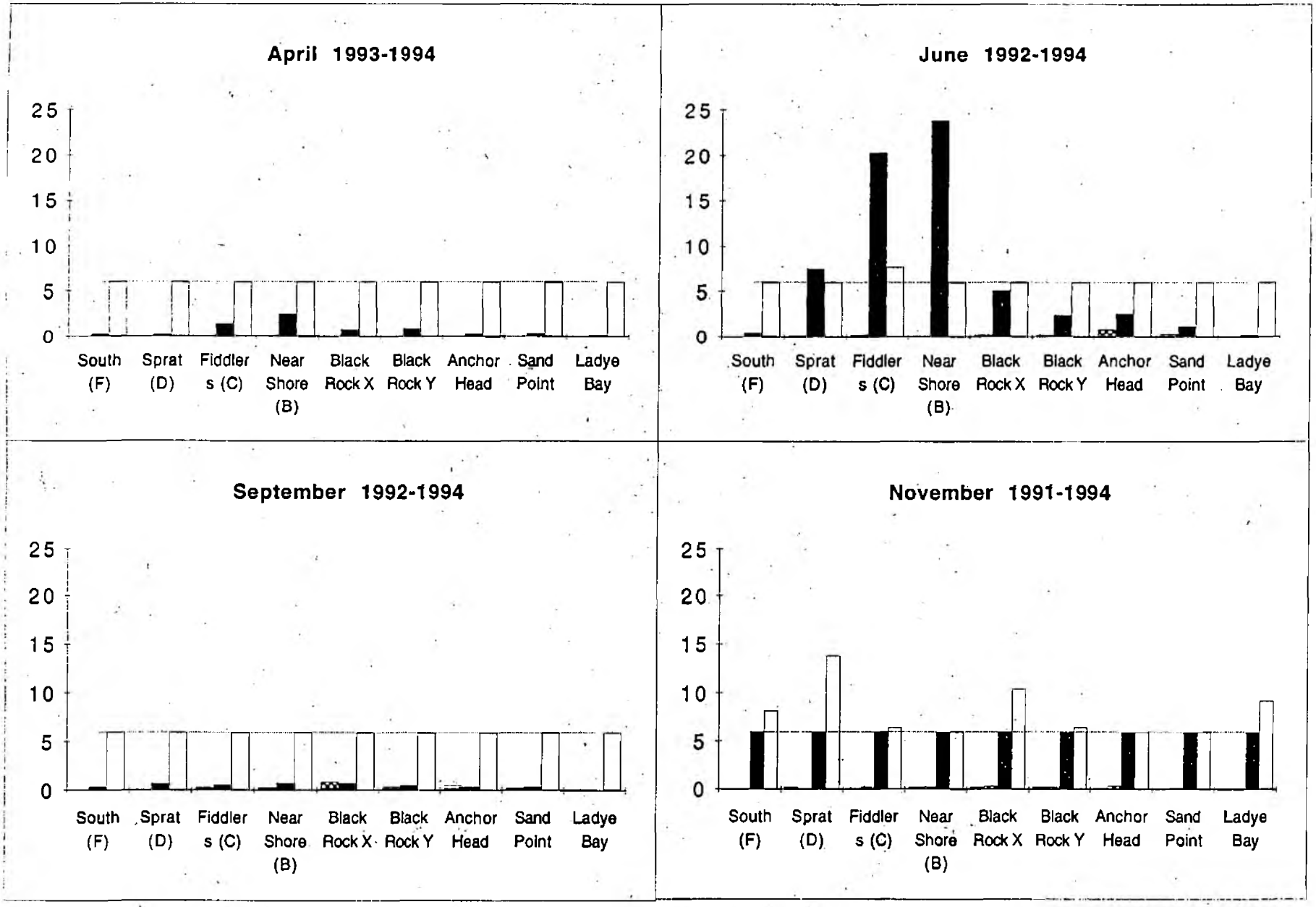


FIGURE 8 Distribution of Dibromochloromethane in Fucoid Seaweeds at Weston-Super-Mare 1991-1994



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APPENDIX I - Levels of Trihalomethanes in Fucoid Seaweeds along the North Wessex Coast 1994.

	CHLOROFORM				BROMOFORM				DIBROMOCHLOROMETHANE				DICHLOROBROMOMETHANE			
	APRIL	JUNE	SEPT	NOV	APRIL	JUNE	SEPT	NOV	APRIL	JUNE	SEPT	NOV	APRIL	JUNE	SEPT	NOV
Porlock	<6	<6	<6	9.09	<15	<15	71.44	43.62	7.58	<6	<6	<6	<3	<3	<3	<3
Minehead Beach	<6	<6	<6	<6	<15	<15	<15	<15	<6	<6	<6	<6	<3	<3	<3	<3
Warren Point	<6	<6	<6	<6	<15	<15	<15	<15	<6	<6	<6	<6	<3	<3	<3	<3
Dunster Beach	<6	<6	10.34	<6	<15	<15	<15	<15	<6	<6	<6	<6	<3	<3	<3	<3
Blue Anchor	6.33	<6	<6	<6	<15	<15	<15	<15	8.76	<6	<6	<6	<3	<3	<3	<3
Watchet	<6	<6	<6	<6	<15	<15	<15	<15	<6	<6	<6	<6	<3	<3	<3	<3
Hinkley Point	<6	<6	<6	<6	<15	<15	<15	<15	<6	<6	<6	6.5	<3	<3	<3	<3
Stolford	6.44	<6	<6	<6	<15	<15	<15	<15	<6	<6	6.33	<6	<3	<3	<3	<3
Burnham O.F.	8.63	11.5	<6	<6	<15	<15	<15	<15	<6	<6	<6	<6	<3	<3	<3	<3
Burnham D.S.	12.1	7.73	<6	6.93	<15	<15	<15	<15	<6	<6	<6	<6	<3	<3	<3	<3
Burnham Slip	12.2	17.6	19.6	6.54	<15	<15	25.8	<15	<6	6.78	<6	<6	<3	<3	<3	<3
South (F)	9.67	<6	<6	<6	<15	<15	<15	<15	<6	<6	<6	8.25	<3	<3	<3	<3
Sprat (D)	11.4	<6	<6	<6	<15	<15	<15	<15	<6	<6	<6	13.8	<3	<3	<3	<3
Fiddlers (C)	<6.4	<6	<6	<6	<15	<15	<15	<15	<6	7.66	<6	6.48	<3	<3	<3	<3
Near Shore (B)	7.62	<6	<6	<6	<15	<15	<15	<15	<6	<6	<6	<6	<3	<3	<3	<3
Black Rock X	7.86	<6	<6	<6	<15	<15	<15	<15	<6	<6	<6	10.4	<3	<3	<3	<3
Black Rock Y	<6	<6	<6	<6	<15	<15	<15	<15	<6	<6	<6	6.44	<3	<3	<3	<3
Anchor Head	<6	<6	<6	<6	<15	<15	<15	<15	<6	<6	<6	<6	<3	<3	<3	<3
Sand Point	6.8	<6	<6	<6	<15	<15	<15	<15	<6	<6	<6	<6	<3	<3	<3	<3
St. Thomas' Head	<6	<6	<6	<6	<15	<15	<15	<15	10.4	7.58	<6	<6	<3	<3	<3	<3
Clevedon Fort	<6		7.68	<6	<15	<15	<15	<15	7.7	<6	<6	<6	<3	<3	<3	<3
Clevedon Beach	<6	<6	<6.3	8.64	<15	<15	<15	<15	7.94	6.74	<6	<6	<3	<3	<3	<3
Ladye Bay	<6	<6	<6	<6	<15	<15	<15	<15	<6	<6	<6	<6	<3	<3	<3	<3

Data expressed as ug/kg

APPENDIX II - Levels of Chloroform, Bromoform and Dibromochloromethane in Fucoid Seaweeds. Black Rock 1991-1994

	91/11	92/06	92/09	92/11	93/04	93/06	93/09	93/11	94/04	94/06	94/09	94/11
CHLOROFORM												
South (F)	NO DATA	NO DATA	NO DATA	NO DATA	<0.3	0.3	<0.3	<6	9.67	<6	<6	<6
Sprat (D)	3.1	2.3	1.3	1.2	<0.3	<0.3	<0.3	10.06	11.4	<6	<6	<6
Fiddlers (C)	4.1	1.6	1.2	1.3	<0.3	<0.3	<0.3	11.52	<6.4	<6	<6	<6
Near Shore (B)	3.9	1.5	1	2	<0.3	0.3	<0.3	11.9	7.62	<6	<6	<6
Black Rock X	9.4	3.1	2.1	3.5	0.3	0.7	<0.3	<6	7.86	<6	<6	<6
Black Rock Y	9.4	5.1	2.5	2.2	<0.3	<0.3	<0.3	16.8	<6	<6	<6	<6
Anchor Head	2.8	1.7	2.1	1.2	<0.3	<0.3	<0.3	<6	<6	<6	<6	<6
Sand Point	1.2	1.3	1.2	0.6	<0.3	<0.3	<0.3	7.4	<6.8	<6	<6	<6
Ladye Bay	NO DATA	NO DATA	NO DATA	NO DATA	<0.3	<0.3	<0.3	<6	<6	<6	<6	<6
DIBROMOCHLOROMETHANE												
South (F)	NO DATA	NO DATA	NO DATA	NO DATA	0.3	0.5	0.4	<6	<6	<6	<6	8.25
Sprat (D)	0.3	0.2	0.1	0.1	0.3	7.5	0.7	<6	<6	<6	<6	13.8
Fiddlers (C)	0.2	0.3	0.3	0.3	1.6	20.4	0.6	<6	<6	7.66	<6	6.48
Near Shore (B)	0.3	0.2	0.3	0.3	2.7	23.9	0.8	<6	<6	<6	<6	<6
Black Rock X	0.3	0.3	0.9	0.4	0.9	5.1	0.8	<6	<6	<6	<6	10.4
Black Rock Y	0.3	0.3	0.4	0.3	1	2.6	0.6	<6	<6	<6	<6	6.44
Anchor Head	0.2	0.9	0.6	0.4	0.4	2.8	0.4	<6	<6	<6	<6	<6
Sand Point	0.1	0.4	0.3	0.2	0.4	1.3	0.4	<6	<6	<6	<6	<6
Ladye Bay	NO DATA	NO DATA	NO DATA	NO DATA	0.2	0.3	1.5	<6	<6	<6	<6	9.2
BROMOFORM												
South (F)	NO DATA	NO DATA	NO DATA	NO DATA	7.7	13	9.1	<15	<15	<15	<15	<15
Sprat (D)	4.8	4.9	3.1	1.7	4.1	9.6	16	<15	<15	<15	<15	<15
Fiddlers (C)	3.6	7.2	6.4	7.2	7.5	10.8	10.5	<15	<15	<15	<15	<15
Near Shore (B)	6.9	4.9	5.8	8.1	21.4	55.6	16	<15	<15	<15	<15	<15
Black Rock X	4.2	10.1	9.5	9	16	41.7	22.4	<15	<15	<15	<15	<15
Black Rock Y	4.9	8.2	6	8	17.1	40	29.3	<15	<15	<15	<15	<15
Anchor Head	3.3	17.8	20	8.7	7.5	6.8	12	<15	<15	<15	<15	<15
Sand Point	2.9	8.2	8.8	5.2	3.6	10.9	10.9	<15	<15	<15	<15	<15
Ladye Bay	NO DATA	NO DATA	NO DATA	NO DATA	6.3	4.3	13.2	<15	<15	<15	<15	<15

Data expressed as ug/kg - 1994; ng/g - 1991/1993. ie: parts per 1,000,000,000.