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NATIONAL CENTRE FOR
ECOTOXICOLOGY & HAZARDOUS SUBSTANCES

ALGAL MONITORING REPORT 2000

Report summarising freshwater (cyanobacterial) and marine microalgal monitoring during 2000

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Environment Agency, National Centre Ecotoxicology & Hazardous Substances, October 2001

CONTENTS

SUMMARY

- This report describes continuing work carried out by the Environment Agency of England and Wales, on monitoring and managing freshwater algal (primarily cyanobacterial) and marine microalgal (principally nuisance and harmful) incidents during 2000, and also discusses Regional differences and temporal trends during recent years. The National Centre for Ecotoxicology & Hazardous Substances collated data from the National Algal Contacts Group.

- Freshwater algal monitoring indicated similar frequency and distribution of affected sites to past years. The majority of sites were in central and southern England. Cyanobacteria were the dominant group examined, with 66% of water bodies sampled containing cyanobacteria. The warning threshold was exceeded in 77% of samples where cyanobacteria were present. In 2000 however, the total number of sites sampled was the lowest yet (242), primarily the result of fewer old sites being re-sampled (those sites containing cyanobacteria in past years), sites where known algal problems not being revisited or resampled. Staff resource was also being directed to the GQA quinquennial survey. The low number of sites sampled may also indicate that owners of affected sites and the public may be more aware of cyanobacterial problems and therefore not contacting the Agency.

- Toxicity analysis and assessment for cyanobacterial toxins continues by the University of Dundee for the Agency. In 2000, 6 samples were sent for toxicity analysis and assessment, much fewer in number compared to previous years. Testing appears to be concentrated on new sites or sites assessed as high risk to water users. Many sites with recurring problems are assumed to be toxic and risk assessments made thus.

- Marine algal monitoring indicated similar frequency and distribution of affected sites to past years. The majority of bathing waters, coastal waters and estuaries sampled, stretched between Environment Agency Wales' coast, along the SW coast towards Southern Region. The total number of sites monitored however has continued to decline annually, from 615 in 1992 to 137 during 2000. The percentage of monitored sites containing nuisance algae remains high, with 52% of sites containing nuisance species, with 12 incidences of potential toxin producing algae recorded during 2000, 10 of which were from the south west coast of England.

- There is an evident decline in the Agency's algal monitoring efforts indicated by a reduction in the freshwater routine monitoring programme, and by a reduction of the total number of sites sampled under the marine monitoring programme. The Agency's approach to marine algal monitoring is to be reviewed during 2001 and 2002 as part of a wider strategic review of tidal water activities. This will establish what monitoring programme is required in order to meet the needs of the Agency's frameworks for change, policies and drivers.

- Behaviour of different cyanobacterial taxa in occurrence is not homogeneous because their ecophysiological properties differ affecting where they are found, their frequency and distribution. The monitoring programmes are reactive nature, rather than a comprehensive coordinated monitoring programme. Marine monitoring programmes and frequencies also vary regionally, and consequently, sites that do not have visible algal blooms present are unlikely to be monitored. Owners and the public may also have increasing alertness and or awareness of algal blooms/scums; hence sites may be reported with varying frequencies. As a result, the use (in isolation) of these data as a robust indicator of the incidences of fresh and marine algae, and extent of eutrophication, must therefore be treated with caution.

- Eutrophication can result in visible cyanobacterial blooms, scums, algal and plant mats and benthic macrophyte proliferations. Decay may lead to deoxygenation of the water with secondary problems, for example fish mortalities and release of toxicants and nutrients bound to oxidised sediments. Toxins produced by cyanobacteria and marine algae give rise to acute and chronic implications for human and animal health, especially for those whose condition may already be compromised. The Agency has therefore identified nutrient enrichment as one of its key issues to be tackled in respect of water quality in England and Wales, and has published an aquatic eutrophication management strategy to address such problems. This comprises national action to reduce nutrient inputs to water, complemented by local, catchment level efforts centred on pilot eutrophication control action plans, to test and refine tools and techniques for assessing and managing eutrophication.

1. INTRODUCTION

A fundamental aspect of the Environment Agency's work is to monitor and assess the state of the environment. The monitoring programmes for freshwater and marine algae contribute to the data needed to assess the health of the freshwater and coastal environments and support the State of the Environment Reports (Environment Agency 2000a and 2000b).

The potential toxic threat of blue-green algae (cyanobacteria) and their toxins, and their aesthetic impact on freshwaters, has wide implications for the Agency's activities, roles, and responsibilities (NRA, 1990a). Similarly, nuisance marine algae and the potential toxic threat of certain marine algal species (mainly dinoflagellates) has similar implications for the Agency, which monitors coastal water quality for three nautical miles offshore, monitors bathing water quality and assesses the aesthetic quality of beaches. Past reports have discussed these issues in depth (Environment Agency, 1999b, 2000c, 2000d and 2000e).

The Agency, and its predecessor the National Rivers Authority, commenced an assessment of the incidence of potentially toxic and nuisance freshwater algae in 1989, and made recommendations for future monitoring and control measures (NRA, 1990b; NRA, 1991). Similarly, the Agency has routinely collated information since 1991 from all Regions regarding marine microalgal monitoring and management of incidents (Environment Agency, 2000d and 2000e).

All information from the monitoring programmes is collated by Regional Algal Contacts and sent to the National Centre for Ecotoxicology and Hazardous Substances (NCEHS) for reporting via completed annual questionnaires. Data have been summarised into reports available from NCEHS (Environment Agency, 1999b, 2000d, and 2000e). Details of the monitoring programmes are available from the Algal Scientist, NCEHS and Regional Algal Contacts. Blue-green and marine algal policy procedures are available on the Intranet site through 'solutions'. Nuisance marine algal procedures are also outlined in Lewis (1997).

1.2 Purpose of this report

Previous reports have reported separately on the annual freshwater and marine algal monitoring programmes and results (Environment Agency, 1999b, 2000d, and 2000e). This report summarises the results of the Agency's monitoring and management of freshwater and marine algal incidents during 2000, and discusses Regional differences and temporal trends in recent years.

2. FRESHWATER ALGAL AND CYANOBACTERIAL MONITORING

General Introduction

Cyanobacteria (also known as blue-green algae) occupy a taxonomic position between bacteria and plants. Like plants, cyanobacteria carry out photosynthesis, but their cellular makeup closely resembles that of bacteria. They are found almost everywhere: from the tropics to the poles, in lakes and oceans, on rocks and in soils. They have the distinction of being the oldest known fossils, more than 3.5 billion years old, in fact. They are one of the largest and most important groups of bacteria on earth.

Throughout their photosynthetic activity, they assimilate carbon dioxide (counteracting potential global warming) and replenish atmospheric oxygen. They contain photosynthetic pigments like phycocyanin or phycoerythrin, which are responsible for their blue, pink or other colouration.

Cyanobacterial toxins are naturally produced poisons stored in the cells of certain species. Some are known to attack the liver (hepatotoxins) or the nervous system (neurotoxins); others irritate the skin. Microcystin-LR is one of the most common microcystins found in water as well as being the one most often responsible for animal health problems, upon direct contact or ingestion of scum. The risk to animal and human health is very low when cyanobacteria are dispersed in a lake or reservoir. The hazard occurs when algal blooms and scums form, concentrating the toxins, hence potency. Blooms of this nature have been known to cause skin rashes in humans and animals and it is widely documented that the toxins can affect, in particular, the nervous system or cause liver damage in humans, fish, and plants. The Environment Agency and the World Health Organisation have developed warning threshold values to identify the hazard and enable the appropriate responses.

Research is continuing into cyanobacteria, internationally, namely into factors promoting their growth and factors influencing cell toxicity and survival rates of cyanobacterial spores in sediment. Research is also underway to gain further understanding of the human health significance of cyanobacteria and individual cyanotoxins and the practical means for assessing and controlling exposure to them.

The Agency carries out algal monitoring in response to external enquiries received (from owners, water users and the general public from all freshwater habitats), as part of a reactive monitoring programme. Reactive monitoring is divided into 'new sites' that have no records of cyanobacteria being present, and 'old sites' where historically cyanobacteria have found to be present (Environment Agency, 1999b). In addition to the reactive monitoring approach, certain sites are sampled routinely and others as part of a long-term monitoring programme.

2.1 Regional fluctuations between 1995-2000

Waterbodies sampled reactively for the first time (new site records of cyanobacteria), and those sampled reactively in the past which were subsequently re-sampled (old sites, previously sampled locations). Results are shown below in Figure 1 corresponding to 'new' sites, and Figure 2 corresponding to 'old sites'. The total number of waterbodies are divided into those which contained cyanobacteria as the dominant group, and those where cyanobacteria were absent.

No discernible trends are evident in the regional variations in the number of sites sampled reactively for the first time, and in the number of sites that were subsequently re-sampled. The highest number of sites sampled are evident in Midlands, Anglian, North West, South West, and Thames Region and lowest in North East and Southern Region. A complete list of the waterbodies sampled Regionally, with their details, is available from NCEHS on request.

2.2 Annual fluctuations

In 1989, initial monitoring resulted in 909 waterbodies sampled, although it was difficult to know precisely how often many waters were visited (ie. whether reactive or routine) or how many samples were taken. In 1990, a total of 1,724 waterbodies were sampled, which consisted of a mixture of reactive and routine monitoring, hence a direct comparison with subsequent years is difficult (Environment Agency, 1999b, 2000d).

Annual fluctuations between 1991-2000

Of 3,220 different water bodies sampled, 2,241 were sampled for the first time (new sites) and 979 resampled in past years (old sites). A lake inventory R&D project, Development of a geo-referenced based inventory of standing waters for England and Wales, together with a risk based prioritisation protocol - Phase 1 (P2-239/TR1), is currently being progressed. There are around 6,300 waterbodies >1 hectare in England and Wales, and from monitoring to date it is estimated that between a quarter to a half of these waterbodies have been affected by cyanobacterial blooms.

The annual fluctuations in the total number of waterbodies sampled by the Agency between 1991-2000, the total number of sites where cyanobacteria were present, and the total number where the warning threshold was exceeded is shown in Figure 3. The Agency warning thresholds are used as action levels above which there is risk of bloom formation, which indicate a likely risk to users of the waterbody.

Approximately two thirds of the total number of sites sampled in 2000 contained cyanobacteria, of which three-quarters exceeded the warning threshold.

Figure 1. Regional fluctuations in the total number of waterbody sites sampled reactively for the first time between 1995 - 2000

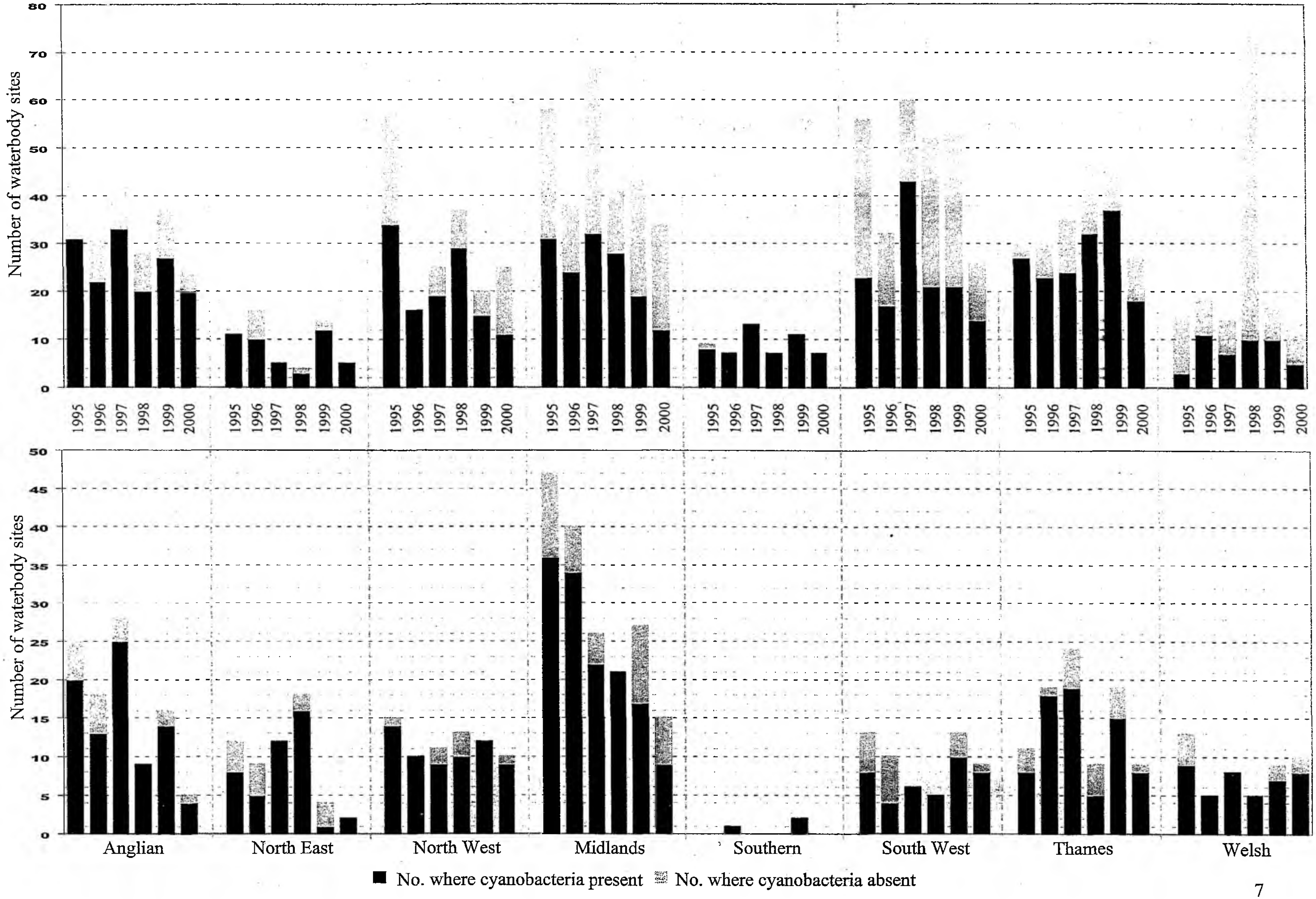

Figure 2. Regional fluctuations in the total number of waterbody sites sampled in the past that were subsequently resampled between 1995 - 2000

Figure 3. Total number of waterbody sites sampled in response to external enquiries as evident by visible algal problems between 1991-2000.

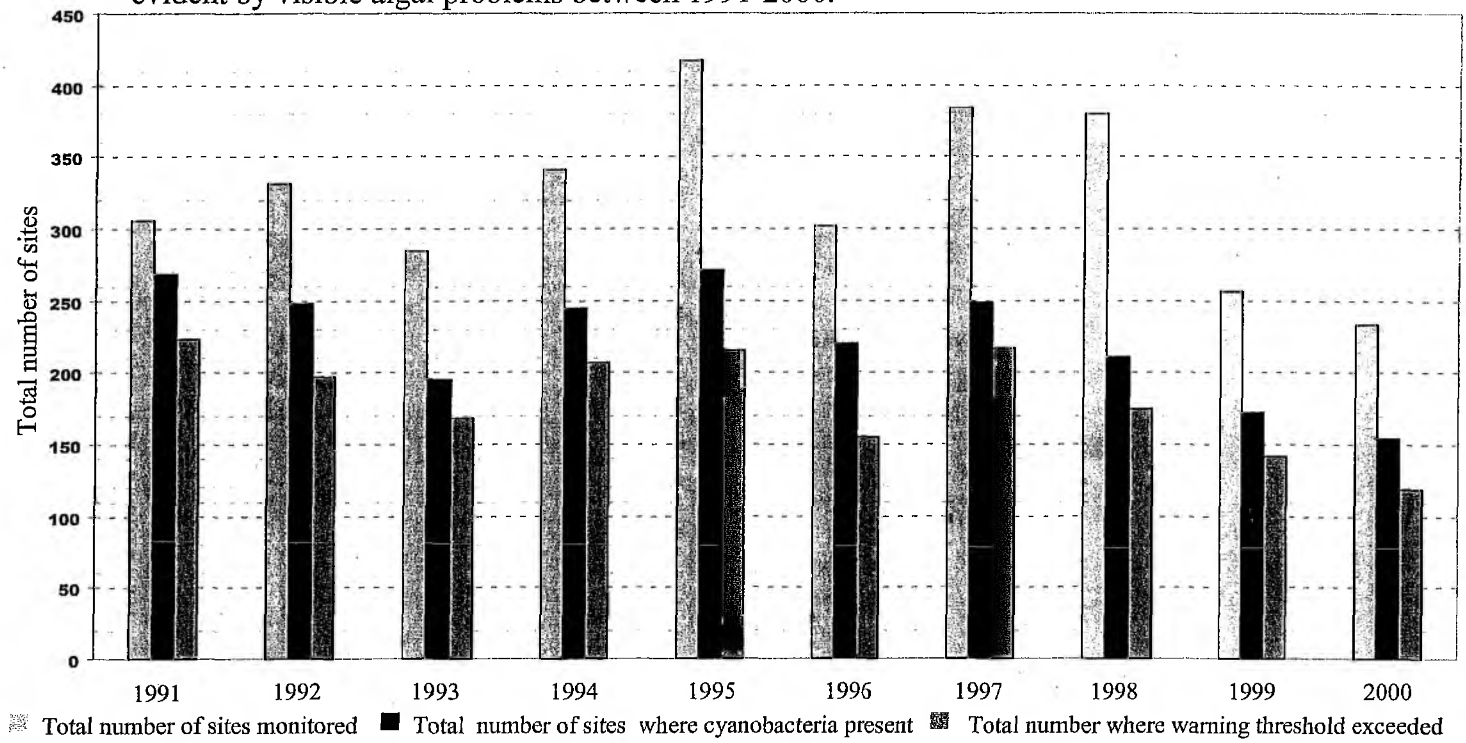

Table 1 below indicates split between the total number of sites sampled annually for the first time and those that were sampled before.

Table 1. Incidents of sites sampled reactively between 1991-2000.

Year	Total number of waterbodies sampled as part of the reactive monitoring programme	Number of waterbodies sampled for the first time: 'New sites'		Number of waterbodies sampled in past years and re-sampled during the year: 'Old sites'
		New sites	% of total	
1991	306	216	71	90
1992	331	218	66	113
1993	284	201	71	83
1994	341	217	64	124
1995	417	281	67	136
1996	302	190	63	112
1997	384	269	70	115
1998	380	300	79	80
1999	256	190	74	66
2000	219	159	73	60

The total number of sites sampled annually fluctuates between 219-417 sites per year, and those sampled for the first time represented the highest proportion. The lowest total number of sites sampled reactively (minus routine and long term monitoring), 219, was recorded in 2000.

2.3 Waterbodies sampled routinely

This includes waterbodies sampled as on-going investigations for specific regional and area requirements.

Similar trends are evident as recorded in the past, with continuing high incidences of cyanobacteria and a high proportion where warning thresholds were exceeded (Environment Agency, 1999b, 2000d). A significant decline in the number of sites sampled routinely from 137 in 1991 to 14 in 2000 is noted.

Table 2. Summary of the number waterbodies sampled routinely between 1991-2000.

Year	Number of waterbodies sampled	Number which contained cyanobacteria		Number where warning threshold exceeded		Number where bloom / scum was present	
		Cyano - bacteria	% Total Sampled	> Warning Threshold	% Sampled	Bloom / Scum Present	% Sampled
1991	137	101	74	71	70	44	44
1992	69	43	62	31	72	23	53
1993	80	61	76	60	98	40	66
1994	70	50	72	36	72	46	92
1995	44	35	80	22	63	16	46
1996	39	26	67	12	46	20	77
1997	33	27	82	19	70	21	78
1998	21	18	86	12	66	6	33
1999	15	8	53	4	50	5	62
2000	14	14	100	12	86	13	93

In Southern, Midlands and Thames Region no sites were routinely sampled and in Anglian the following sites within Norfolk Broads were monitored: Barton Broad, Ranworth Broad, Ormesby, Rollesby Broad, Whittlingham, Filby Broad, Hickling Broad and South Walsham.

In North East, Green Lee Lough is monitored monthly, and is also the region's long-term monitoring site. In North West, Preston Docks and Hollingworth Lake continues to be monitored at a monthly frequency. In South West, Poole Park Lake (sampled between June-October, weekly) and Upper Tamar Lake (sampled between July-November) continue to be monitored. Diatomaceous blooms were apparent in some rivers, particularly the deep, silty, slow flowing ones at the time, for example R. Stour, Dorset. In Thames fortnightly monitoring on the river Thames continues at 4 sites (Inglesham, Abingdon, Caversham and Windsor). In Environment Agency, Wales, Llyn Tegid was monitored fortnightly from June-August and monthly from August to October.

2.4 Long-term monitoring

Currently, each Region monitors one unmanaged site (defined as a site with no nutrient reduction or destratification measures) where cyanobacterial blooms have previously been recorded, in order to provide a minimal national picture of geographical and temporal change in terms of cyanobacterial populations. Long-term monitoring is monthly and continuous, whereas routine sampling is generally weekly or fortnightly (Environment Agency, 1999b, 2000d)

The long-term monitoring programme is associated with programmes agreed at National level by the Agency and implemented in all Regions. Monitoring has continued in Anglian (Filby Broad); Midlands (Upper, Lower and Millshrub Bittell reservoirs); North East (Greenlea Lough); North West (Pennington Flash - chemistry data only this year); Southern (Weir Wood reservoir); South West (Chilton Trinity Lake); Thames (Farmoor I reservoir); and Environment Agency Wales (Llyn Coron).

In addition, in South West, Combwich lakes, near Bridgwater have been monitored since 1999. A number of river sites (10) throughout England and Wales are monitored as part of the Environmental Change Network Programme (ECRC) involving long term, detail study of benthic diatoms (in addition to invertebrate, water chemistry and macrophyte surveys) using standard methodologies.

2.5 The extent of blooms and scums during 2000 compared to previous years

As past reports have indicated, this is very difficult to gauge with the available data.

Thames reported a similar number or slightly less incidents in 2000, with approximately the same number of sites sampled as in recent years. Fewer samples exceeded the warning threshold and this was thought to be associated with the heavy rainfall and a relatively short summer period. One of the most beautiful and interesting algae that we can find in the plankton of fresh water is the water net or *Hydrodictyon*. which was reported for the first time at Hampstead Heath Feeder Pond (not recorded prior to 2000). It has the form of a netlike hollow sack and in extreme cases it can grow to a length of several tens of centimetres. The mesh of the net is formed by five or six cylindrical cells lying against each other. *Hydrodictyon* likes clean, eutrophic water and can sometimes reproduce so very fast that it behaves like a pest, covering the surface of a lake like a spider's web.

South west reported similar or slightly fewer incidents. This was also thought to be due to very wet, mild climatic conditions with little sunshine A bloom of *Gomphosphaeria* spp. was recorded in Wimbleball reservoir at the end of 1999, which persisted into early 2000. High groundwater levels were noted.

North East and Midlands commented that 2000 was 'a quiet year' for cyanobacterial problems. Both experienced extreme wet weather conditions with a limited number of severe blooms occurring, with usual frequency of minor events. However, Midlands' long term monitoring programme recorded three new incidents around Loughborough.

Southern Region reported fewer incidents than usual, due they thought, to poor summer.

Anglian commented that 2000 was a long season (East Area) with blooms still occurring in November due to mild weather.

Environment Agency Wales commented that a *Gomphosphaeria* bloom is now a regular occurrence in Llys-y-Fran Reservoir and was also found to be present in the Afon Syfynwy downstream. Data from Lyn Tegid suggested that algal blooms/scums were less frequent. Only one cyanobacterial bloom was evident (1st January). Weather conditions were noted to be exceptionally calm for the time of the year. Reactive sites were surveyed in the south east area of Wales, blooms occurring in June and September. *Anabaena, Oscillatoria and Aphanizomenon* were recorded at Bute East dock, Cardiff Bay, and the event featured in the national press (*Microcystis* was evident in 1999). Similar blooms have been predicted to occur following the formation of the freshwater lake (Cardiff Bay Barrage). Particular concern and attention must be given to waterbodies like this that have a high level of recreational use and much public interest. One aspect of cyanobacterial research is currently focussing on recreational waters and health risk to users (Chorus, 1999). The World Health Organisation has published recreational guideline values and these will examined in 2002 with regard to potential use by Agency and waterbody owners.

2.6 Blooms in running waters

Planktonic cyanobacteria can and do occur in rivers under exceptional circumstances, during low flow regimes or where they are seeded from upstream standing waters, however, they are unlikely to persist in flowing environments. Benthic cyanobacteria, forming microbial mats, particularly in embayments of slow flowing and low flow rivers may be more common.

Environment Agency Wales reported presence of *Gomphosphaeria* in the Afon Syfynwy downstream Llys-y-Fran Reservoir. The algal scums were evident in the local fish farm. Several sites on Coventry Canal and a minor brook experienced algal blooms in Midlands Region.

Thames Region reported algal blooms on Lee Navigation between Cheshunt and Waltham Cross. Not reported on this stretch before 2000. Algal blooms regularly occur on the Grand Union Canal but were not apparent in 2000.

South West Region, Devon area, reported an *Anabaena* bloom on a stream associated with Kenwith Lake. Kenwith Lakes, Barnstaple, experienced algal blooms in September consisting of *Anabaena*, *Microcystis* and *Euglena*. Cyanobacteria were observed to be present for some weeks. Cornwall area described a bloom in the river Tamar below Tamar Lakes and in Porth stream below Porth Reservoir. Chocolate brown appearance of some of the deeper, silty, slow flowing rivers in Dorset was found to be caused by very high numbers of diatoms, dominated by centrics.

In North East Region, the river Coquet contained a short-lived *Aphanizomenon* scum, originating from Caistron gravel pits. Warning levels were not exceeded and environmental health was notified and warning signs were erected.

North West received samples from running waters and canals: Shropshire Union Canal, Mersey Estuary and a number of small streams.

Anglian observed a cyanobacterial bloom at Pebmarsh Brook, Evershot.

2.7 Cyanobacterial toxicity

The University of Dundee continues to carry out R&D work for the Agency, on the fate and behaviour of cyanobacterial toxins, as part of the Technical Service Agreement whereby regions send samples to Dundee as and when deemed necessary (Codd, 2000).

2.8 Incidents as a result of toxicity

Samples from various regional waterbodies containing cyanobacteria, which were warranted for toxicity analysis and assessment, are summarised overleaf (Table 3).

Table 3. List of waterbodies where samples were tested for toxicity.

Region and Name of Waterbody	Comments
Anglian	
Whitlingham Broad	*Gleotrichia* dominant. Anabaena present at low levels. Toxicity test negative for Microcystin toxins. *Gleotrichia* not known to produce microcystin or BG algal neurotoxins, however, some samples from other locations have shown toxicity which may be due to LPS (lipopolysaccharides)
South West	
Porthcurno beach pool	Negative. Tests carried out on inlet area in water on bottom of drained pool.
Environment Agency Wales	
Conservation Pond, Royal Welsh Showground	Bloom of a tiny species of desmid - *Cosmarium bioculatum* identified (not B/G as first thought). Immunoassay (ELISA) found no microcystins. Show organisers relieved.
Roath Park Lake, Cardiff	Bioassay of 370 mg dry wt did not indicate neurotoxicity but subacute liver damage apparent. No saxitoxins were detected. Analysis for microcystins was negative.
Bute East Dock, Cardiff Bay	Assays performed for microcystins - no toxicity. If neurotoxic would not be of a high or medium neurotoxicity.

2.9 Waters closed for recreational activities

Table 4 overleaf, summarises information received concerning waterbodies known where activities (recreational and others) were suspended, or the site closed during 2000.

Table 4. Waterbodies where recreational activities were suspended or the site closed.

Region and Name of Waterbody	Comments
South West	
Poole Park Lake , Dorset	Moderate/high risk water based activities were suspended for a short period (2 weeks) by notices erected informing users. Notices were placed for remainder of monitoring to inform of low risk. Recreational waters warning levels were used and risk assessment record kept by owner. Liaisons were good between EA and waterbody owner.
North West	
Hollingworth Lake	No details.
North East	
Nilston Rigg	Angling suspended dates unknown.
Anglian	
St Ives Sailing Lake	Sailing event for children postponed
Whitlingham Broad	Children's sailing event stopped for several weeks
Midlands	
Lodge Farm, Netherton	Sailing club and water ski club suspended activities for 3-4 weeks (i.e. until < warning level).
Environment Agency Wales	
Roath Park Lake	The lake was closed for boating activities for about a week.
Inland Sea, Four Mile Bridge, Anglesey	Warning notices were erected by Anglesey Council EH on 3rd July and removed when bloom dispersed
Thames	
Hampstead Heath	Activities not suspended but warning notices erected around lake.
Tykeswater	For about 7 days children not allowed on lake to sail
South Norwood Lake	Notified by Croydon Council of the suspension of angling and sailing activities on their lake. No further information received.
Serpentine	Activities not suspended but warning notices erected around lake.

3. MARINE MICROALGAL MONITORING

General Introduction

The Environment Agency has responsibility for territorial waters extending three nautical miles offshore. Within that responsibility is the requirement to maintain water quality, to monitor bathing water quality and to assess the aesthetic quality of beaches. All these factors may be influenced by the presence of excessive biomass of microalgae or phytoplankton.

There are thousands of living microalgal species, which are the base of the marine food web. Only a few dozen species are known to be toxic. Most are dinoflagellates, prymnesiophytes or chloromonads. Under ideal growth conditions microalgal growth is rapid. Microalgal blooms (transient, unsustainable growths, usually of a single species and often associated with a visible discolouration of the water) are a normal feature in the seasonal development of plankton. Some blooms may reach exceptional proportions or contain species (principally dinoflagellates) that can be toxic to humans and possibly have an important economic impact on mariculture, fisheries and tourism.

Certain blooms of algae, which are commonly termed red tides, are now known as harmful algal blooms. The tiny pigmented plants change the colour of the seawater to red, brown or even green. Spread over large areas the phenomenon can be both visually spectacular and catastrophic. One of the most serious impacts on human life occurs when clams, mussels, oysters or scallops ingest the algae as food and retain the toxins in their tissues. The shellfish themselves are only marginally affected but a single clam can sometimes accumulate enough toxin to kill a human being. These shellfish poisoning syndromes have been described as paralytic (PSP), diarrhetic (DSP), neurotoxic (NSP) and amnesic (ASP) shellfish poisoning (Anderson, 1994).

Phytoplankton can also kill marine animals directly, for example, as wild fish swim through blooms, the fragile alga rupture, releasing neurotoxins onto the gills of the fish, which die, ultimately from asphyxiation. Blooms can wipe out entire fish farms within hours. Some species produce polyunsaturated fatty acids and galactolipids which destroy blood cells. Other algal species produce other compounds or mixtures of compounds and neurotoxins. The diatom genus *Chaetocerus* (a non-toxic phytoplankton) can kill fish, yet no toxin has ever been identified. The ways in which algae kill fish are poorly understood.

The occurrence of nuisance or harmful algae is a natural phenomenon that has occurred throughout history, but there is an apparent trend of increasing frequency and distribution of marine microalgae worldwide (Anderson, 1989, 1994; Hallegraef, 1998). This is generally attributed to a number of factors, namely, an increased scientific awareness of toxic species, increased utilisation of coastal areas for shellfisheries/fisheries, increased transport of cells, cysts and shellfish stock, and an increase in human activities and climatic conditions, which further stimulate blooms (Hallegraeff, 1995). These influences are unlikely to be mutually exclusive.

3.1 Monitoring frequency

Increasing international concern over the effects of coastal eutrophication and the apparent rise in the incidence of nuisance and harmful algae around the UK coast prompted the Government to accept a review in 1991, presented by the Marine Pollution Monitoring Management Group. This proposed a minimum core programme of marine monitoring for UK coastal waters. A phased programme of monitoring was subsequently introduced and adopted by the Agency consisting of two levels; 'Minimum Effort' and 'Best Endeavours' (Lewis, 1997; Environment Agency 2000b). This is not a comprehensive monitoring programme.

Furthermore, the monitoring programmes and frequencies vary regionally, and as such, sites are rarely investigated which do not have a visible algal bloom present. In addition, many complex biological/chemical/physical factors also influence frequency and distribution of marine algae (Hallegraeff, 1998; Reigman, 1998), hence the use (in isolation) of these data as a robust indicator of the incidence of marine algae, and extent of eutrophication, must be treated with caution.

The monitoring strategies and frequencies adopted regionally between 1996-2000 are summarised below (Table 5). No data are available prior to 1996.

Table 5. Regional summary of monitoring strategy and frequency.

Region	Monitoring strategy	Monitoring frequency
Anglian		
1996	Minimum effort + sensitive areas	May-September
1997	Minimum effort + sensitive areas	May-September
1998	Minimum effort + sensitive areas	April-October
1999	Minimum effort + sensitive areas	April-October
2000	Minimum effort + reactive monitoring	May-September
North East		
1996	Minimum effort + reactive monitoring	May-October
1997	Minimum effort + reactive monitoring	May-September
1998	Minimum effort + reactive monitoring	May-September
1999	Minimum effort + reactive monitoring	May-September
2000	Minimum effort + reactive monitoring	May-October
North West		
1996	Minimum effort + reactive monitoring	April-September
1997	Minimum effort + reactive monitoring	May-September
1998	Minimum effort + reactive monitoring	February-November
1999	Minimum effort	June-September
2000	Minimum effort	April-September
Southern		
1996	Minimum effort	May-September
1997	Minimum effort	May-September
1998	Minimum effort	May-September
1999	Minimum effort	May-September
2000	Minimum effort + screening (microbiol)	May-October

South West		
1996	Minimum effort	April-November
1997	Minimum effort + reactive	May-September
1998	Minimum effort + reactive monitoring	March-October
1999	Minimum effort	March-October
2000	Minimum effort + reactive monitoring	March-October
Thames		
1996	No monitoring	
1997	Minimum effort	May-September
1998	Minimum effort	Sites sampled for microbiology only – algal investigations not required
1999	Minimum effort	May-July
2000	No monitoring	
Wales		
1996	Best endeavours Minimum effort	April-July August-September
1997	Best endeavours Minimum effort	April- June July-September
1998	Best endeavours Minimum effort	April- June July-September
1999	Best endeavours Minimum effort	May-September
2000	Best endeavours Minimum effort	May - July March - September

** Results from the Marine Biological and Chemical Consultants (MBCC, 1996; 1997; 1998).

A degree of quality and comparability in measuring phytoplankton biomass, as chlorophyll *a*, and phytoplankton assemblages is required. In order to achieve these aims across Europe, BEQUALM project (Biological effects quality assurance in monitoring programmes) was set up in late 1998 amongst 12 European countries, including England and Wales. Within BEQUALM, inter-calibration exercises were set up, in order to set standard protocols that will help gain good and comparable data from sampling sites all over Europe. Certain Agency laboratories have taken part in this exercise, the results of which will be reported. The project is scheduled to run until October 2001.

3.2 Regional fluctuations in monitoring between 1992-2000

No data are available prior to 1992. The total number of sites monitored in each Region between 1992-2000 and the number of sites with nuisance and potentially toxic algae are shown in Figure 4. Monitored sites included bathing and coastal waters, and estuaries.

Table 6. Notifiable toxic marine microalgal species

Class	Species	Toxic Effect	Action Levels
Bacillariophyceae	*Pseudo-nitzschia* spp.	ASP	>150,000 cells/litre
Dinophyceae	*Alexandrium* spp. *Gymnodinium catenatum* *Dinophysis acuminata* *D. acuta* *D. norvegica* *Prorocentrum lima*. *Amphidinium carterae* *Gyrodinium aureolum*	PSP PSP DSP DSP DSP DSP Kills fish Kills fish	Presence of species Presence of species >100 cells/litre >100 cells /litre >100 cells /litre >100 cells/litre Presence of species Presence of species
Haptophyceae	*Chrysochromulina polyepis* *Prymnesium parvum*	Kills fish Kills fish	Presence of species Presence of species
Raphidophyceae	*Fibrocapsa japonica* *Heterosigma akashiwo*	Kills fish Kills fish	Presence of species Presence of species
Cyanophyceae	*Nodularia spumigena*	Hepatotoxic	1,000 filaments/ml

Microalgal genera not known to be toxic, but which are a nuisance and are included under the term of Harmful Algal Blooms include *Phaeocystis*, *Noctiluca*, and diatoms (*Chaetocerus*, *Thalassiosira*, *Attheya* and *Asterionellpsis*).

The highest number of sites monitored and also the highest number of sites with nuisance algal blooms was indicated in Southern and South West Regions, and Environment Agency Wales. This may be attributed to a greater number of bathing waters and estuaries in these Regions than elsewhere, prolonged sampling periods and the use of the Best Endeavours monitoring programme. Without a comprehensive monitoring programme the extent of blooms is difficult to establish.

Evidently, the most common taxa recorded was *Phaeocystis*. Potentially toxic algae were recorded in South West Region, North East and Anglian during 2000.

Figure 4a. Regional summary of the total number of sites monitored and number of sites with marine algal blooms, as reported by the Agency between 1992-2000.

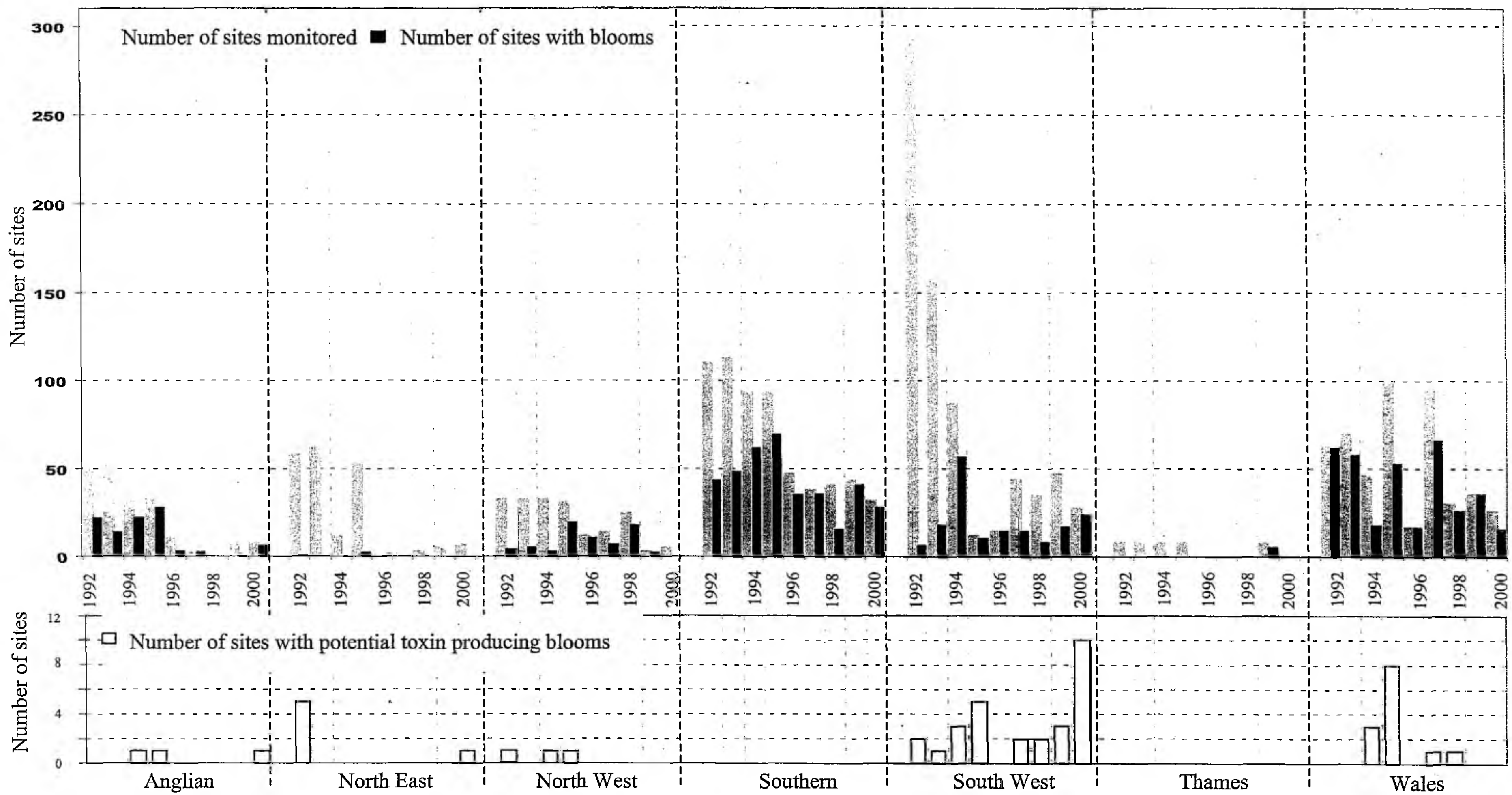

Figure 4b. The number of sites with potentially toxic algae, as reported by the Agency between 1992-2000.

3.3 Annual fluctuations between 1992-2000

The total number of sites monitored has continued to decline from a maximum of 615 in 1992 to 137 with 12 incidences of potential toxin producing algae reported during 2000 (Figure 5). Expressed as a percentage however, high proportions of monitored sites were found to contain nuisance algae, as indicated in Table 7.

Figure 5. Annual fluctuations in the total number of sites monitored the total number of sites with marine algal blooms and the total number of sites with potentially toxic algae, as reported by the Agency between 1992-2000.

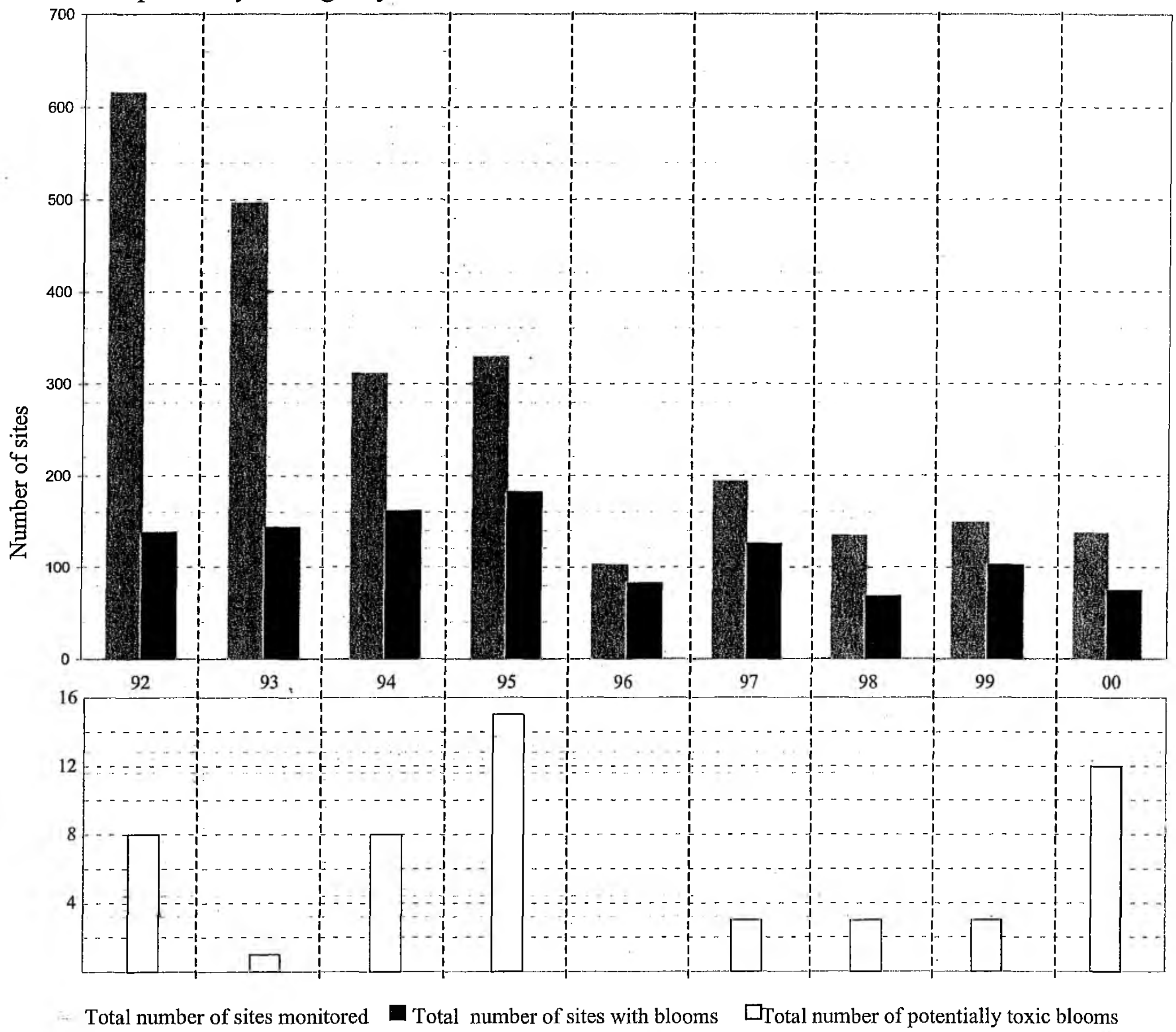

Table 7. Proportion of monitored sites containing nuisance algae.

Year	Percentage of sites monitored containing nuisance algae
1992	22
1993	29
1994	52
1995	80
1996	80
1997	65
1998	51
1999	68
2000	52

3.4 The extent of blooms compared to past years

As past reports have indicated, this is very difficult to gauge with the available data (Environment Agency, 2000b). The collation of such data, and hence of sites affected by coastal eutrophication should however continue, since this is the best available national information.

Marine algal blooms and incidents were not recorded from Thames in 2000, however, DSP toxins were reported from February onwards and led to the closure of fisheries in the Thames region (CEFAS, 2000).

North East reported media interest regarding general information on toxicity due to microalgae, very few incidents reported. Nationally consistent standard methodologies were for marine microalgal monitoring in the future.

In South West Region, Devon area, blooms of Phaeocystis were evident, particularly off the south Devon coast in spring. Also three incidents involving blooms of the nuisance diatom, *Attheya*.

Anglian region reported potential toxin producing algae at Mablethorpe, several nuisance blooms and phosphorescent algae at Hunstanton in August, causing public interest.

Table 8. In Cornwall area potential toxin producing species were observed at the following sites:

Location	Date	Taxa	Comment
Penryn River	11/05/01	*Dinophysis acuminata, Gyrodinium aureolum, Pseudonitzschia closterium*	Warning Letters sent
Penryn River	12/06/01	*Alexandrium sp.*	Warning Letters + Shellfishery closure
Summerleaze Beach	11/05/01	*Phaeocystis*	Warning Letter
Restronguet Creek	12/06/01	Alexandrium	Warning Letter + Shellfishery closure
St. Agnes Beach	01/08/01	*Gyrodinium aureolum*	Warning Letter
Chapel Porth Beach	01/08/01	*Gyrodinium aureolum*	Warning Letter

Alexandrium was recorded from three water sampling areas between June and August, namely Portland Harbour, Fal estuary and the Helford river. As in 1999, only in the Fal Estuary was the occurrence of Alexandrium coincident with PSP toxins being found in shellfish flesh (CEFAS, 2000).

Alexandrum tamarense was again observed in samples from Weymouth Inner Harbour and the Fleet Lagoon in July. Cysts of this species have been recorded from the sediment in winter months from the harbour (Environment Agency, 2000f)).

North West Region reported no change in pattern or frequency to 1999. Algae were routinely recorded along the Fylde coast but no action taken unless complaints received. One incident of algal mats (diatom/*Oscillatoria* dominant) recorded.

Environment Agency, Wales reported that *Phaeocystis* was at bloom levels in May at Saundersfoot, Pembrey and Rhossilli, this is much less than 1999 levels. Patterns were observed to be similar to 19998 results. *Asterionella* blooms were also reported to be at a much lower level of frequency and distribution than in 1999. A report of the marine algal monitoring programme, 1991, Welsh coast is available from NCEHS.

As in most of previous years' monitoring phytoplankton blooms have been more prevalent in the eastern half of Southern Region, in Sussex and Kent. Phaeocystis (April to June) dominated these blooms. *Noctiluca* was more widely distributed, at higher densities than in 1999, along the north Kent coastline. An exceptional bloom of flagellate algae (thought to be *Duriella*) was sampled at Weston Hard, Woolston in June, in response to foaming at the waters edge.

3.5 Results of shellfish flesh monitoring

Requirements under the European Shellfish Hygiene Directive are met through a monitoring and surveillance programme in England and Wales, whereby water samples and samples of bivalve mollusc and other shellfish are collected from shellfish production areas and sites with recent histories of toxic algae problems. Monitoring and analysis of phytoplankton is carried out by Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, whereas shellfish flesh analysis is carried out by Fisheries Research Services, Marine Laboratory, Aberdeen (CEFAS, 2000, Howard, 2000). This rolling monitoring programme was introduced in 1996 and currently covers all active shellfish harvesting sites and sites where toxic algal species were detected in recent years. Information exchange takes place between CEFAS and the Environment Agency.

The role of toxin production by some marine algae is not clear. Toxins may be produced as a protection against predation losses or as a survival strategy during periods of nutrient depletion. Resting spores of dinoflagellates for example may contain more toxin than the reproductive vegetative cells.

Marine biotoxin monitoring and surveillance results from the FRS MLA are presented in Howard (2000), and summarised overleaf (Table 9).

Table 9. Summary of the total number of sites sampled for presence of PSP and DSP toxins in shellfish and fisheries areas in England and Wales between 1996-2000. ASP analysis commenced in 1999.

Year	Number of shellfish/fishing sites examined	Number of samples analysed for PSP, with positive results of PSP detected in parentheses	Number of samples analysed for DSP, with positive results of DSP detected in parentheses	Number of samples analysed for ASP, with positive results of ASP detected in parentheses
1996	22	214 (11)	110 (0)	
1997	28	269 (31)	146 (3)	
1998	30	254 (17)	184 (8)	
1999	30	287 (5)	200 (5)	255 (23)
2000	34	302 (12)	397 (75)	243 (35)

DSP toxins were extremely persistent and widespread this year and an obvious concern to the shellfishery industry and associated organisations, with considerable disruption to harvesting. They occurred from February onwards and led to the closure of several fisheries along the south and west coast and in the Thames (some sites unaffected by the biotoxin until this year). During this year almost 30 sites recorded at least one sample of positive DSP toxins in shellfish flesh (CEFAS, 2000). The Agency and local councils have received notification from the shellfisheries regarding their concerns.
PSP toxins were detected at sites in the north east and in the south west of England, the action level was exceeded in the Fal Estuary.
ASP toxins were detected in samples from several locations, but all below the action level (Howard, 2000).

4. EXTERNAL LIAISON AND COMMUNICATION

Algal blooms attract public attention resulting in the Environment Agency receiving enquiries about them. The Agency is not the competent authority for matters dealing with public health, therefore, liaison takes place between Environmental Health, Centre for Environment, Fisheries and Aquaculture Sciences, and the Department for Environment, Food and Rural Affairs (DEFRA) when nuisance or potentially toxic algae are present. All queries were successfully dealt with, and there have been no complaints received concerning the Agency's approaches to dealing with algal incidents. Moreover, information on the Agency's approach to eutrophication and potentially toxic algae, and information detailing the responsibilities and actions of the organisations involved ensuring efficient implementation of duties, has been disseminated internally and to all relevant organisations. It has received positive feedback.

The publicity material used by the Agency consists of information leaflets ('Blue-green Algae', 'Marine Algae', and 'Algae or Sewage – helping you to tell the difference'), and posters for Blue-green algae and Algae or Sewage. Regions commented that feedback is rarely received on the publicity material used.

Moreover, the Environment Agency's internet web site (environment-agency.gov.uk) is used to provide information on freshwater and marine algal and eutrophication issues, with similar information internally on the intranet.

5. THE EUTROPHICATION STRATEGY

Excess nutrient concentrations may lead to increased frequency of potentially toxic and nuisance algae, together with other adverse effects on the ecology and uses of waters. This process is termed eutrophication. The need to control eutrophication was recognised by the Agency in its 1997 Environmental Strategy, is featured in the Environmental Vision, and has been highlighted in the recent European Environment Agency and Environment Agency state of the environment reports (European Environment Agency, 2000; Environment Agency 2000a, 2000b). In response the Environment Agency has produced an aquatic eutrophication management strategy (Environment Agency, 2000c). Further details are available from the Agency, and the eutrophication management strategy document is available on the Internet (environment-agency.gov.uk).

Existing Local Environment Agency Plans (LEAPS) have helped to identify eutrophication problems at local, catchment level, and building from this, the eutrophication strategy has selected a suite of pilot eutrophication control action plans (ECAPs), covering a variety of waterbody types, for managing local eutrophication issues at a catchment level. In addition, the eutrophication strategy will test and refine tools and techniques for assessing and managing eutrophication, which will be underpinned by national and international statutory drivers and commitments, namely the Urban Waste Water, Nitrates, and Habitat Directives, OSPAR, and the UK Biodiversity Action Plan (for mesotrophic and eutrophic standing waters). The Water Framework Directive will also, undoubtedly, influence the eutrophication strategy.

The eutrophication strategy consists of several key elements that form an overall framework. These include:

- The promotion of a partnership approach, at both local and national level, since solutions are generally beyond the remit of any one regulatory body or other party.
- A two-pronged approach:
    - (i) Across-the-board measures applied at the national level, to reduce nutrient inputs to the water environment. We will target action primarily in the industrial sectors that contribute the greatest loading of nutrients to the water environment, principally the water industry, phosphate and soap & detergent industries and the agricultural sector.
    - (ii) Comprehensive, catchment-based management action, within the context of a national framework, for waters most at risk from or affected by eutrophication.

- Achievement of environmental improvements through a case by case approach to determining the appropriate mix of control mechanisms. Such mechanisms could be regulatory, voluntary, collaborative, educational or economic.
- A review of the arrangements for measuring the extent and potential risks of eutrophication, to ensure we have robust monitoring programmes, consistent methodologies for assessing problems and reliable risk assessment procedures. This will include:
    - reviews of existing data and its presentation
    - reviews of sampling and analytical procedures
    - reviews of eutrophication monitoring
- The prioritisation of waters for management action on the basis of specified criteria: initial priorities will be waters where there are statutory requirements, or where water uses are adversely affected, or where special conservation interest is at risk, or where benefits can be delivered or deterioration prevented, with adequate confidence, at reasonable cost.
- The adoption of interim targets for eutrophication control in freshwaters and the continuing application of specific statutory and/or international commitments in relation to saline waters.
- Trials of the proposed tools, techniques and procedures through pilot catchment-based action plans, to inform any wider adoption of the approach.
- The promotion of a wider understanding of the nature and significance of aquatic eutrophication.
- A programme of research and development to improve understanding of the eutrophication process.

Annexed to the strategy is an initial implementation plan, summarising the actions, the main partners with whom the Agency intends to work and the time scales for initial tasks. Delivery of the plan will build upon and be strongly influenced by the main statutory drivers and international commitments, and over and above these initiatives, by the success of national and local collaboration.

Catchment-based management action for waters most at risk from or affected by eutrophication will be delivered on the ground primarily via local Eutrophication Control Action Plans (ECAPs). If introducing P removal at a single dominant STW source is the obvious solution to a local problem then an ECAP is inappropriate. However, in many cases, assessing the sources of nutrients and in-stream/lake ecological processes, and determining and implementing the best solutions to local problems is a far more complex matter, and may involve a range of internal and external interested parties. Such cases warrant the ECAP approach. An ECAP is seen as an extension of a LEAP, to pick up and address an issue identified therein, via a specific and more detailed action plan. To date 11 pilot 'A' list ECAPs have been identified. These include Llyn Tegid and Bittel reservoirs which are sampled as part of the routine and the long-term monitoring programmes. In addition, **a "B" list** of ECAP sites has been agreed, these are further waters where work has been undertaken which could inform the ECAP initiative.

6. DISCUSSION AND CONCLUSIONS

Nutrients (their loading and concentrations) are one of the main factors that influence algal growth, although there are many and complex biological/chemical/physical factors influencing algal development, as detailed in previous reports (Environment Agency, 1999b; 2000d and 2000e).

It is evident that eutrophication is regarded as a priority water quality issue requiring action, and that algal growth is exacerbated by nutrient enrichment (eutrophication). Typically, excessive growths (blooms) consist of nuisance or potentially toxic algae, which are one of the visible symptoms of eutrophication. Cyanobacterial blooms are dominant in fresh waters but also occur in marine waters, whereas dinoflagellate blooms are dominant in marine waters. The Royal Commission on Environmental Pollution in the UK has also inferred the increased incidence of algal blooms, in particular cyanobacteria, to be widespread as a result of increasing cultural eutrophication (Royal Commission on Environmental Pollution, 1992), and English Nature indicated that eutrophication is adversely affecting many stillwater sites of special scientific interest, SSSIs (Carvalho and Moss, 1995). Increased incidents of marine algae are also attributed to eutrophication (Riegman, 1998).

The interpretation of the incidences of algal blooms as carried out under the Environment Agency monitoring programmes, and hence extent of eutrophication is however difficult. Results from freshwater algal and cyanobacterial monitoring are based on a reactive, selective procedure whereby mainly only new sites affected with algal blooms and scums are analysed in response to external enquiries. Sites are rarely investigated which do not have a visible algal bloom/scum present or which have had historical cyanobacterial problems. Results from the marine algal monitoring are influenced by Regional variations in the monitoring programmes, the number of bathing sites, and also by the number of reports received from the public.

The use of Agency data as a robust indicator of the incidence of algal blooms and the extent of eutrophication in England and Wales must be treated with caution. This is because of the range of influences on the frequency of blooms and because the data are from a primarily reactive monitoring programme. The collation of such data, and hence of sites affected by eutrophication should however continue, since this is the best available national information on the incidence of algal blooms.

Results from Agency monitoring programmes indicate a continued reduction in sampling effort. This is evident by a decline in the number of 'old' sites resampled, a reduction in the number of sites sampled routinely, and a decline in the total number of sites sampled as part of the marine monitoring programme. The Agency's approach to algal monitoring is being reviewed during 2001 and 2002 as part of a wider review of eutrophication-related monitoring. This will include consideration of standardised monitoring procedures and new technologies, particularly for coastal waters, and how best to derive useful information from relatively limited data.

There continue to be high incidences of nuisance and potentially toxic algae, evident from the freshwater and marine monitoring programmes, hence the need to increase awareness of the health hazards presented by cyanobacterial and marine dinoflagellate toxins among water-users, associated organisations, water industry and public health professionals continues (Chorus and Bartram, 1999; Chorus, 2000; Vigo, 1997; Whitton and Potts, 2000).

There continue to be gaps in our knowledge base, that require further work, therefore, the Agency is continuing to sponsor R&D to achieve a better understanding of algal and eutrophication-related issues. This includes, with regards to coastal water quality, the use of new technology, novel monitoring techniques (including benthic diatom method studies in estuaries) and satellite imagery analysis (CASI and LIDAR). This national strategy will also drive further research to update monitoring programmes and management strategies for eutrophication control.

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