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February 1996

The Phycologist



The Newsletter of

The British Phycological Society

The Phycologist

Number 43 - February 1996

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The BPS is a registered charity No. 246707.

Editorial.

I would like to start by thanking Judith Taylor for her sterling efforts in getting the last issue of the Newsletter onto the streets. At years end there are so many things to do and taking on the Phycologist is not high in anyone's list. The last issue of the year is always quite tricky. This issue is mailed with the booking form for the winter meeting and the folks at the venue like to see a response well before Christmas. Judith must have done something right because more people attended the winter meeting at Lancaster than any previous BPS winter meeting.

In taking on the newsletter Judith allowed me to go to the Antarctic to do some sampling of the phytoplankton and the dissolved inorganic carbon. I was fortunate enough to be invited to join the Marion Dufrense, a brand new French research vessel. As a laboratory based cell physiologist with an increasing interest in the ecophysiology of marine phytoplankton it was a great opportunity to see how oceanographers and their like work at sea. I think the over riding impression was the size of the oceans (seems obvious), the lack of nutrients and the small snap shots taken when sampling. The way the Marion Dufrense worked was that it was only involved in research for four months in the year, the rest of the time it worked as a supply vessel for French bases in the Antarctic. So every piece of scientific equipment had to be freighted to Reunion, Indian Ocean months before. If anything was forgotten/broken that was it, end of work. Most of the time was spent sampling transects but on two occasions we were able to go ashore at Kerguelen, an island in sub-Antarctic. The wild life was of the order of a David Attenborough film. Generally it was not as cold as I feared. The food on the ship was as you would expect on a French ship and the number of OH groups consumed was impressive. I think I would go again if the chance comes.

You will be pleased to know that the society has a venue for the '97 Winter Meeting. It is to be held at the University of Sheffield, with Jim Gilmour as local secretary. This was quite a God send because as you know, the New Year falls in the middle of the week and most institutions start their Spring term in the following week. So this year the winter meeting will start on Thursday 2nd January and run till Sunday 5th January. The society has been considering for sometime whether to include the weekend during a meeting as this will allow our continental members to use the cheaper "Saturday night" flights.

In this issue there are the abstracts from the winter meeting. I tried to get each proof read by the authors at the meeting. This was very necessary this year as the efficiency of the scanner was very questionable. I hope not too many typos have slipped through.

Finally I would like to draw your attention to the article "Academic cleaning" in former Yugoslavia? written by Matt Dring. It describes the truly awful treatment of one of our colleagues, Dr Ivka Munda at the hands of the Slovene Academy of Science and Arts. I do encourage you to write a letter of protest to either the President of the Academy or the Director of the Research Centre.

Andrew M. Johnston

1996 Winter Meeting, Lancaster.

It seems each time I sit down and write a report on the winter meeting I start by describing some awful train journey. Well this year it was bad and then some. For some reason Edinburgh has decided to make a big thing out of New Year and something like 300,000 visitors descended on the city. My trip down from Dundee to Lancaster involved a change at Edinburgh. Arriving at Platform 13 I could see things were going to be difficult. Each door has at least 15 people waiting to get on. Some 15 minutes later I found a door with no one waiting, but no room to squeeze on. I stood and waited for 5 minutes while people were running up and down the platform looking for a space. Suddenly someone decided to get off the train at my door because he realised that the carriage was a non-smoker! I jumped on and stood all the way to Lancaster. Major delays meant rolling up to the Council meeting 90 minutes late, will not happen again, promise. Leaving Dundee at 6.20 in the morning I thought was bad enough but this year we had a large group of Swedish phycologists attending the winter meeting, and they had been travelling what seemed like days to get to Lancaster.

The Lancaster meeting, in my opinion, has to be one of the best Phyc Soc meetings I have been to. A record number of people attended the meeting, 163 registered and there were only a few no shows. I think this was down to the great work done by Roger Jones, Jackie Eccleston-Parry and Judith Taylor. We were very lucky that Colin Reynolds could give the Founders lecture, in the past Colin has been heavily involved in setting the rates for Kendal and has not been able to attend as many winter meeting as he would have liked. His lecture, entitled "Potamoplankton does it on the side.", was judged just right and, as I am a phytoplankton person, very interesting. The society was also pleased that Professor Fogg was able to attend the meeting and adjudicate the Irene Manton prize which this year was won by Anne Hartley. (Tip for future students, want to win this prize? Then do a PhD with Maureen Callow on calcification!). The society for the first time ran a prize for the best student poster, adjudicated by Professor Moss. It was won by P. Hyenstrand for his poster "The importance of inorganic nitrogen species as regulatory factors for cyanobacterial dominance". The "applied" day was based on "Nuisance Algae and their control". The special sessions covered "Photosynthesis and Growth" and "Resting stages".

The auction was moved from the night of the conference dinner to second night of the meeting and generated a great deal of money. Maureen Callow and Jennie Moore did wonders securing items for auction. Elliot Shubert, straw hat and all, did an incredible job selling the stuff. In all 906 pounds was raised, three times last years auction! Many thanks to all those that helped organise and run the auction. The disco was well attended and went on to the early hours, where "young at heart" Professors showed the young ones how to do their stuff. Yours truly was hauled onto the floor by a young lady from Scotland, via Sheffield, to dance (if that is the correct term) The Gay Gordon's, one of the few Scottish dances I know! The food in all the meals was the best yet and the wine fairly flowed at the conference dinner. All in all an excellent meeting.... roll on Sheffield.

Andrew M. Johnston

IMPORTANT DATE FOR YOUR DIARY.

The 1997 Winter Meeting of the British Phycological Society will be from Thursday 2nd January to Sunday 5th January 1997 and will be at the University of Sheffield. Dr Jim Gilmour will be the local organiser.

BPS Summer Studentships.

As announced in issue 41 of *The Phycologist* (August 1995), the British Phycological Society will offer up to 2 Summer Studentships in 1996 (max. value £500) to support undergraduate or prospective postgraduate students for a 4-week (or longer, if you can make the award stretch that far!) research project during the summer vacation. The scheme is designed to encourage interest in the algae among students by giving them direct experience of laboratory and/or field techniques related to algae, and a better awareness of the morphological or ecological range of the algae, and of their applications in pure and applied science. At the end of each project, a short report should be prepared for publication in *The Phycologist*.

Applications for these studentships are invited from prospective supervisors, who should submit a proposal (not exceeding 1 side of A4) describing the project and the costs involved, and how it conforms to the objectives of the scheme. Proposals should be submitted to the Past President of the Society (Dr M.J. Dring) at the address below before 31st March 1996, and all proposals received will be reviewed by a panel of referees appointed by him. Successful supervisors will be notified by 1st May, to allow time for the project to be advertised in the supervisor's institution and a student found to carry out the work during the summer.

Address proposals to: Dr M.J. Dring,
Marine Biology Station,
Queen's University of Belfast,
Portaferry,
Co. Down, BT22 1PF. Fax: 012477-28902

"Academic cleansing" in former Yugoslavia?

Ivka M. Munda, who has been a member of the British Phycological Society for many years, is well known in the phycological community for her work on the seaweed floras and the littoral ecology of the Adriatic and Iceland. She is based in the Biological Institute of the Scientific Research Centre in Ljubljana, which has been allied to the Slovene Academy of Science and Arts since Slovenia became an independent state.

In the summer of 1994, the Research Centre cancelled phycology from its research programme and gave permission for Dr Munda to continue her work in the Institute for only 1 year, after which all her literature, cultures and herbarium material would, apparently, be thrown out. Several phycologists from around the world, including Jan Rueness, Gunter Kirst and myself, wrote letters of protest at her treatment during the autumn of 1994.

In May 1995, Dr Munda was forbidden to enter the main premises of the Biological Institute (her office and laboratory are located in the attic) or to use the Institute's equipment (e.g. research microscopes or computers) or, even, the library. The Director of the Research Centre hadn't shown the letters of protest to the new leader of the Biological Institute or to the Administrative Board, which had voted to single out Dr Munda and deny her access without giving her an opportunity to make her case. The Director's response to a second round of protest letters (including Carolyn Bird and John Raven, this time) was to say that these letters from the international scientific community helped him to "support her special status at the Scientific Research Centre". "However", he went on to say, "Dr Munda has more space for her activity than any other researcher at Scientific Research Centre" and, as a retired scientist, "she is still working under the same conditions". These statements are hard to reconcile with the fact that what the Director called her "major office" is an attic room of 12 sq. m with no direct daylight, and her "separate small laboratory" is a converted bathroom of half this size. She was moved into these rooms in 1993 from a laboratory of 70 sq. m, which was then given to a retired entomologist.

According to the Director, "our concern for Dr Ivka Munda remains the same", and yet Dr Munda has now heard that her "special status" is not to be renewed and that she will be forced to leave the Research Centre entirely on 30 June 1996, and that all the books and journals on phycology in her rooms must be returned to the Institute's library where she will be unable to consult them because she is not permitted to enter this library. She will also then be unable to accept my invitation for her to contribute to the 1st European Phycological Congress, or to participate in an INTERREG project organised by the Polybios Institute (Trieste, Italy) on the exploitation of algal biomass in the Northern Adriatic. In early December, she was informed of a further restriction of her scientific activity. The editors of the Dissertations of the Slovenian Academy, in which she has published much of her work, have now refused to publish any papers from her, regardless of their quality or subject matter.

Slovenia was spared the infamous "racial cleansing" that has afflicted so many regions of the former Yugoslavia, because it separated early and relatively cleanly from Yugoslavia. However, this treatment of phycology, in the unfortunate person of Ivka Munda, sounds rather like the academic equivalent of racial cleansing. Please protest, if you feel like it, to the following addresses:

Dr Rado Bohinc
Ministry of Science and Technology,
Slovenska 50,
SLO-61000 Ljubljana,
Slovenia

Prof. Dr. Franc Bernik
President,
Slovene Academy of Science &
Arts,
Novi trg 3,
SLO-61000 Ljubljana
Slovenia.

M.J. Dring, Marine Biology Station, Portaferry, Co. Down BT22 1PF, N. Ireland.

CONSERVATION MATTERS

Plantlife Link UK Plant Conservation Strategy

Plantlife are currently preparing a 'Strategy' document intended to complement one entitled 'A UK Plant Conservation Strategy' prepared by Margaret Palmer for the JNCC and DoE Northern Ireland (see below). The principal objective of the 'Plantlife Strategy' is to inform decision-makers of the importance of plant conservation and the need to support conservation organisations through the provision of resources to fund projects, assist people to become involved in local plant conservation projects, and to reduce the impact of the activities of all organisations on plants and their habitats.

In 1994, the Conservation Committee provided the editor of the 'Plantlife Strategy' with general information on aquatic habitats and the diversity, distribution and conservation status of British freshwater and marine algae. A first draft was circulated to all contributors for comment prior to a meeting of Plantlife held in March 1995. The meeting felt there to be a need to restructure the document and make the 'Strategy' more action-orientated, bold, controversial and to cover areas not addressed by the statutory agencies. The editor (Miles King) hopes to have a final draft available for circulation early in 1996 with publication soon afterwards. The 'Strategy' should provide a useful synopsis of the current conservation status of all plant groups including stoneworts, seaweeds and freshwater algae.

Third Quinquennial Review of the Wildlife and Countryside Act, 1981

Plantlife Link and Wildlife Link have been coordinating the input of species lists from organisations like The British Phycological Society. No alga has been put forward as needing special legal protection under Schedules 5 and 8 of the Act. Long lists of lichens and bryophytes have been submitted which reflect the existence of considerably more knowledge of the distribution patterns and conservation status of these compared to the algae. Only two algae are afforded special protection in Great Britain under Schedule 8, the stoneworts *Lamprothamnium papulosum* and *Chara canescens*. A further 11 seaweeds are listed under Schedule 9 as plants that may not be 'planted' or otherwise caused to grow in the wild without a licence.

There is growing concern that the criteria for designating Schedule 8 plants is to change by having to demonstrate that species will 'benefit directly' by scheduling. If this happens then some currently recognised species might no longer qualify for statutory protection. The Statutory Agency Quinquennial Review Working Group has already agreed to add this criterion and there is pressure for a review of the whole Wildlife and Countryside Act. The newly formed Plant Conservation Working Group is looking into the operation and effectiveness of current species protection legislation within the Wildlife & Countryside Act. The Conservation Committee of BPS has a representative on the Plant Conservation Working Group.

EC Habitats and Species Directive

The Directive is one of the most important conservation instruments to have emerged at a European level and has great importance for the United Kingdom. A consultative draft was released in March and organisations were given very short notice to respond to it. An excellent response was prepared by Derek Ratcliff on behalf of Friends of the Earth and Plantlife, the BPS is affiliated to the latter. The Report expressed serious concern about the excessive secrecy surrounding the list of candidate Special Areas of Conservation (cSAC) prior to the Directives, a concern felt by the BPS Conservation Committee when first approached with a request to provide site information. The principal conclusion of the Report was that the cSAC proposed should be regarded as the absolute minimum in terms of representation since many important sites were omitted. Many of these omitted sites were aquatic and include rivers, lakes, rocky marine habitats and sea lochs. Some of the key aquatic systems recommended in the Report for automatic inclusion are the Rivers Tweed, Wye, Avon, Tywi, Usk, Loch Lomond, Bassenthwaite Lake, Lough Neagh and Loch Beg, Loch Leven, and various petrifying springs with tufa formations. One reason given for the omission of important aquatic sites was the decision to list only those sites which are on land and currently enjoy statutory protection as SSSIs or ASSIs. The draft 'Directive' states that 'Further areas for rivers, active raised bogs, blanket bogs, and the inter-tidal parts of some of the listed areas straddling the land-sea divide will be proposed when the necessary SSSI/ASSI procedures have been completed'. It is questionable whether the published list of cSACs meets the requirement for adequate extent of habitats and population size of species.

Biodiversity Challenge II

The second edition of 'Biodiversity Challenge: an Agenda for Conservation Action in the UK' was launched at a ceremony that took place in January 1995 at The Natural History Museum, London. It was compiled by six voluntary conservation bodies including Plantlife. The Society had endorsed 'Biodiversity Challenge II' only after corrections were made to an earlier draft, including the addition of 12 species of red algae to the list of 28 algal species requiring to be targeted for priority conservation action. Some of these algal species were also listed under appropriate target habitats that included coastal lagoons, maerl beds, rivers and streams, and chalk reefs and platforms.

Biodiversity: The UK Steering Group Report

The United Kingdom Government launched on 13 December 1995 its second 'Action Plan' document titled 'Biodiversity: The UK Steering Group Report'. It is published in two volumes: the first, 'Meeting the Rio Challenge', is a general introduction and the second, the 'Action Plan', consider species and habitat action plans only. The latter contains three lists of species requiring action plans: a long list of 1250 species, middle list of just under 300 species (plans to be prepared in next three years), and a short list of 116 species (action plans already produced). The short list contains one alga, the stonewort *Chara muscosa*. The middle list contains 10 stoneworts and the red alga *Anotrichium barbatum*. The long list includes 18 algae that includes those listed earlier, an additional 8 red algae and one brown alga (*Ascophyllum nodosum* var.

mackii). These species are the same as listed in 'Biodiversity Challenge II', many of which are supplied by members of the BPS Conservation Committee. A total of 13 stoneworts are given in the long list with 11 repeated from earlier lists. Also included are habitats at risk with costed action plans prepared for 14 and a further 24 listed for which action plans will be prepared in the next three years. Aquatic habitats for which costed plans have been prepared include chalk rivers, saline lagoons, seagrass bed and mesotrophic lakes. Others for which plans will be prepared in the next few years include eutrophic standing waters, aquifer fed naturally fluctuating water bodies, coastal saltmarsh, estuaries, *Ascophyllum nodosum* var. *mackii* beds, maerl beds (inlets, bays, open coast) and chalk coasts. Action statements are provided for some of these habitats as well as for inlets and enclosed bays, open coast, open sea water column, offshore seabed, canals, rivers and streams, and standing open water.

UK Plant Conservation Strategy

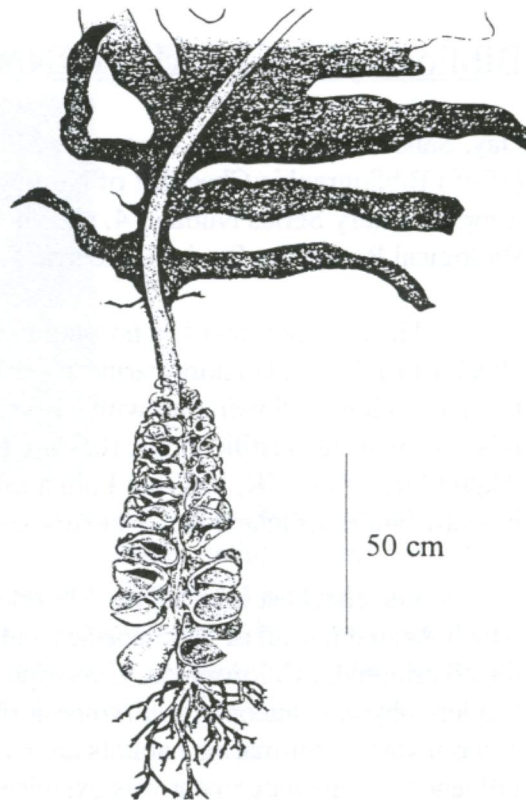
The full title of this document published in 1995 is 'A UK Plant Conservation Strategy: a Strategic framework for the Conservation of the Native Flora of Great Britain and Northern Ireland'. A second print has two attenda explaining The Conservation Regulation, 1994 (in relation to plants), and the new IUCN threat categories. It sets out a national strategy for the conservation of native plants and provides a framework for action by the statutory nature conservation agencies. Additionally, it draws attention to the enormous gaps in our knowledge of lower plants like algae and mentions the importance of lower plant assemblages in brackish lagoons and estuaries and marine communities; these latter include maerl beds, *Ascophyllum nodosum* var. *mackii* beds, communities for tide-swept narrows associated with sea lochs/loughs and communities of micro-algae on chalk cliffs. Some of the information published in the document was provided by BPS Conservation Committee who sent a three-page response to an early draft of the document.

Review of Non-native Marine Species in British Waters

The document is still in the draft stage and will be published this year. An early draft included 14 seaweed species prepared by members of the BPS Conservation Committee. Each non-native species is illustrated and various types of data provided: approximate year of introduction, its origin, reason for success, rate of spread and methods of spread. Since the earlier draft the algal list has been expanded to include 16 seaweed species and five diatoms. It includes the newest arrival to our shores, *Undaria pinnatifida*, first recorded in The Solent in June 1994 by Fletcher and Manfredi. The report is being prepared by Clare Eno on behalf of the INCC and will be used to formulate a policy on marine introductions in relation to nature conservation.

Dave John and Juliet Brodie

Illustration of *Undaria pinnatifida*
(Source: Marine Information Notes,
JNCC NO. 7, ed. 1, September 1995.)



SEAWEED HARVESTING.

Article from Scottish Environment News (SCENES), Issue 92, September 1995.
Published by Sue & Mike Scott.

The *West Highland Free Press* reported on a study commissioned by Scottish Natural Heritage and Comhairle nan Eilean into harvesting of seaweeds in the Western Isles. The report says that seaweed harvesting could be increased almost tenfold without detrimental effects to the amount of seaweed growing in the islands. However it recommends that further study should be carried out to ensure that an increased level of harvesting has no adverse effects on the marine environment.

Data from other countries suggests that, depending on the amount of stump left after cutting, harvested areas should recover in three to four years. However the report recommends further long-term studies to ensure that local effects are accounted for, and that removing the seaweed cover does not have an adverse effect on marine life.

The study, carried out as part of the Minch Project, estimated that there is around 110,000 tonnes of seaweed in the Western Isles, mainly knotted wrack (*Ascophyllum nodosum*), of which 88% is in the southern islands. It estimates that around 37,000 tonnes (described as "clearly a maximum") could be harvested annually. The present harvest is around 4,000 tonnes a year, worth around £300,000. The industry has declined from employing around 250 in the 1970's with three factories processing around 16,000 tonnes, to employing 60 people, less than 30 of these full time. The report says that the market is somewhat precarious because the only buyer is Kelco, with two factories on the mainland processing seaweed for alginate production, and advises that increased sales to Kelco and selling to other alginate producers should be investigated. It also recommends diversification into other market areas - food, fertiliser and cosmetics - where higher values can be achieved for low volumes of seaweed.

Bibliographic Checklist of Non-Marine Algae in Australia.

Day, Sandra A., Wickham, Rosemaree P., Entwisle Timothy J. and Tyler, Peter A. (1995) Bibliographic Checklist of Non-Marine Algae in Australia. Flora of Australian Supplementary Series Number 4. pp. vii + 276. ISBN 0 642 22788 8. Australian Biological Resources Study, Canberra. \$A 35.

The assertion that I, a non-taxonomist, was embarking on a review of a checklist of Australian non-marine algae for a British journal, caused one of my peers to mutter about following up with a review of a list of Venezuelan e-mail addresses. If this review needs justifications, they are that the B.P.S. is working on a Freshwater Algal Flora of the UK, and that I am a user of checklists, and that I have sought algae in many bodies of inland water in Australia.

The checklist is based on 399 references on non-marine habitats in Australia which yielded a total of 3043 species and 1839 species in 12 Divisions (Bacillariophyta, Chlorophyta, Chrysophyta, Cryptophyta, Cyanobacteria, Dinophyta, Euglenophyta, Glaucophyta, Prymnesiophyta, Raphidophyta, Rhodophyta and Tribophyta). Non-marine habitats are essentially all water not under marine tidal influence. Some judgement was exercised by the compilers in interpreting habitat descriptions. The taxa are classified by family and division, with Bourelly's classification scheme as the basis although with Divisional rank for his Chryophyta and his Pyrophyta and recognising his Isochrysiophycidies as the Prymnesiophyta. Craspedophyceae and colourless Chrysophyta are excluded. The procedures used in dealing with taxonomic and nomenclatural synonymy are clearly set out. The geographical resolution with Australia is to the level of the five states and two territories on the mainland, plus the state of Tasmania and 'other territory'.

The bulk of the value is taken up with 257 pages of checklist. A few percent of the area of these pages is taken up with 42 figures (mainly composite) illustrating over 200 taxa; alas, no scales are given. The listings are clearly and attractively printed. Immediately I received the book I looked up two taxa. One was *Psilosiphon scoparium* Entwisle (Lemaneaceae, Rhodophyta) which I had seen (courtesy of Dr Entwisle and Professor Gunning) *in situ* before Entwisle described it, and was interested to see that it has now been reported for Tasmania as well as New South Wales. The other was *Stigeoclonium*, which I thought I had seen in a ditch on the Australian National University campus in 1979. There are no listings for the Australian Capital Territory for *Stigeoclonium* or, indeed, for any of the Chaetophyceae. Is this a result of my inability to recognise *Stigeoclonium*, or the patchy occurrence of collectors of algae in Australia?

This is a very useful book for anyone interested in inland algae of Australia; it is to be hoped that it will be followed up by more detailed, floristic, treatments of these algae.

J.A. Raven. Dundee

Irene Manton Prize, 1996.



Professor G.E. Fogg, FRS, Chairman of the adjudicators for the 1996 prize at the University of Lancaster, described the talks as “a Chairman’s delight but an adjudicator’s nightmare”! The standard of the science was high, the time-keeping excellent, and the presentations were very good, so that choosing between them was not an easy task. However, Anne Hartley emerged as the winner, for her talk entitled “The precipitation of calcite in association with algal biofilms”, which showed considerable scientific innovation.

Anne studied ecology at the University of Lancaster (1990-1993), and is currently working for her PhD at the School of Biological Sciences, University of Birmingham, supervised by Drs Barry Leadbeater and Maureen Callow, together with Dr W.A. House at the Institute of Freshwater Ecology, Wareham. The subject of her research is microelectrode studies on calcification and gas exchange with hardwater algal biofilms, and the work is funded by a NERC CASE award.

We wish our third Manton prizewinner well in her scientific endeavours.

Professor L.V. Evans.

The British Freshwater Algal Flora Project.

A request for information

The purpose and aim of the British Freshwater Algal Flora Project is to produce a 2-volume handbook in the year 2000.!!!

The Freshwater Algal Flora Committee of the British Phycological Society has been actively seeking funding for the Flora Project, has set up a group of taxonomic experts to cover the major groups, and prepared detailed guidance notes on the format to be adopted. The planning stage of the Flora Project is now complete and its aim is to prepare a two-volume work and image database on CD-rom in the year 2000. Undoubtedly this is the first major algal Flora to make use of digital image technology

in order to produce an image database of line drawings and colour photographs of algae and their habitats. The intention is to make much of the text available in the form of an integrated database.

The Project is now gathering new initiative and this year should see considerable progress made. Several contributors have already been actively preparing material for the Flora Project, but this year sees its main thrust, that will culminate in a field collecting/workshop involving all contributors and to be held in July 1997 to review progress, examine material, and test keys.

The Flora will assemble all known data on British Freshwater Algae. Although we have access to much relevant data, there probably exists a wealth of unpublished material in the possession of retired professional phycologists or keen amateurs. Thus unpublished information would be welcome from readers of *The Phycologist*, or from friends or contacts, who would be willing to pass on any that may be of use to the flora Project, however small.

The type of information might include:

- * unpublished algal lists or inventories in the possession of individuals or groups including natural history societies
- * reports of ecological surveys that mention freshwater algae, but which have not received wide circulation
- * local knowledge of algae and their distributions
- * sites that possess any diverse populations of freshwater algae, or else possess unusual assemblages

The intention is to revisit this year many of the collecting sites of George and William West including Yorkshire, the home counties, N. Wales, the Lake District and the highlands of Scotland.

Please reply to the Coordinator:

Dr. L.R. Johnson,
Botany Department,
The Natural History Museum,
Cromwell Road,
London,
SW7 5BD.

Tel.: (+44) 0171-938-8758
Departmental Fax: (+44) 0171-938-9260
E-mail: lrj@nhm.ac.uk (internet)

Student Support for the First European Phycological Congress.

Grants will be available from the Society's Scientific Meetings Fund for students attending the Cologne Meeting in August 1996. To qualify students must be paid up members of the Society and must be giving either a poster or oral presentation at the meeting.

Applications for funding should be sent to:

Dr Lynne A. Terry
Hon. Treasurer
13 Harbour Street
Cruden Bay
Aberdeenshire
AB42 7NB

Before 1st June 1996

Applications should include:

1. details of estimated travel costs;
2. details of estimated accommodation costs and registration fees;
3. other sources of finance awarded or applied for;
4. a letter of support from the applicant's supervisor.

Council will consider the applications at the June meeting and applicants will be notified of the awards prior to the Congress. Applicants should make every effort to secure funding from other sources as the Society will not meet the full costs of attending the meeting.

SEASALTER SHELLFISH (WHITSTABLE) LTD.

Seasalter Shellfish (Whitstable) Ltd operate continuous monoalgal cultures and facilities for the cultivation of filter feeding invertebrates on a large scale at our two bivalve mollusc hatcheries, in Kent (Reculver, near Herne Bay) and Cumbria (Walney Island, near Barrow in Furness). We would be pleased to hear from potential users of cultured phytoplankton or breeders of marine invertebrates, alga researchers, hatchery operators, the pharmaceutical industry, biological monitoring laboratories, worm farmers or aquaria for example.

We maintain a dozen species of flagellates and diatoms in sterilised test tube culture continuously. These are transferred to 4 litre sterilised flasks as required, and the flasks used to inoculate 500 litre standing bags. Bags are supplied with pasteurised seawater, metered nutrients, carbon dioxide enriched air and supplementary

illumination when required, and take around a week to get up to strength and volume. There are usually 4-7 species in bag culture at any one time, with a total of 40 bags in a greenhouse with illumination. Individual bag cultures are kept running continuously, usually for several months, pipework being sterilised weekly using steam. Standing bags are supplied with water at a rate corresponding to 20-30% cropping per day and contain 100-200 mg/l of dry algal biomass. (Species not routinely cultured in bags, if suitable, can be expected to have rather lower growth and cropping rates). Flasks are about 2-4 times as strong. Cultures are of course monoalgal, but not axenic.

A further installation with 32 bags of 1500 litres each in a greenhouse and 20 bags of this size outdoors, without supplementary illumination and temperature control, allows algal production for much of the year at lower operating costs. Total output of single-celled algal culture is 4000-10,000 litres/day depending on the time of year.

Cultures can be concentrated using a continuous flow centrifuge. Quantities of a few litres are better left in their culture water, but larger amounts can be reduced to a slurry or paste and then supplied in a cool insulated box.

For the intensive rearing of the swimming or plankton filter-feeding stages of molluscs or other marine invertebrates there is an array of larval tanks with warmed continuous seawater supply, heat reclamation, interchangeable plankton-netting outlet screens, metered supply of the chosen combination of cultured algae and facility for chlorination of all pipework. (They have so far been used for some of the food organisms of interest to marine fish hatchery operators; rotifers, copepods and artemia, but their applicability is much wider). The use throughout of continuous flow allow very high culturing densities; routinely 1-2 orders of magnitude above those commonly used in batch-culture installations. Thus while the total larval facility volume adds up to around 2 cubic metres, individual 180 litre tanks can have a water throughput of up to 22 changes, or 2 cubic metres per day. In turn this has considerable advantages in ease of management and hygienic, energy efficiency, temperature control and avoidance of stress during filtration, grading and harvesting.

Indoor spat rearing facilities have a temperature-controlled water throughput of up to 2 litres per second (170 cubic meters per day). They offer the possibility of producing some tens of kilograms of sessile, weakly swimming or attached organisms which can be held on plankton-mesh trays or confined by gravity at high density in our range of upwelling vessels.

Tray-based outdoor nurseries are on an even larger scale with a total carrying capacity of around 25 tons. These are fed by various types of seawater ponds or lagoons; 1½ hectares of pumped seawater ponds at Reculver and 2 hectares of tidally-filled lagoon at Oare, near Faversham in Kent. There are 12 hectares of gravel ponds on Walney Island with a range of conditions and salinities; some ponds being tidally filled, others filling by seepage and being partly brackish in nature. A variety of algal blooms develop on these different sites, sometimes at high densities. Dinoflagellates in particular may be of interest to researchers since they are often not available in culture.

For further details please contact John Bayes or Rainier Pitt
Seasalter Shellfish (Whitstable) Ltd.

The Old Roman Oyster Beds

Reculver, near Herne Bay

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Abstracts of the 1996 Winter Meeting.

ANDREWS, M., E. BELLINGER, R.D. BUTLER and D.C. SIGEE (Department of Plants, Microbes & Environment, University of Manchester) **Biocontrol of cyanobacteria using protozoa.** In recent years, cyanobacterial blooms have increased in frequency and severity in freshwater bodies, resulting in the need for more diverse and effective methods of control. One such method may be the use of protozoa for predation of cyanobacteria.

Laboratory experiments tested the effectiveness of 2 species of protozoa, *Nuclearia delicatula* (amoeba) and *Nassula tumida* (ciliate), as potential biocontrol agents of 3 species of planktonic algae - *Microcystis aeruginosa*, *Anabaena flosaquae* and *Oscillatoria* sp.. The experiments were carried out over 5-day periods and the algal density and protozoan population assessed. *N. delicatula* was shown to be an effective predator of *A. flos-aquae* and *Oscillatoria* sp., and *N. tumida* predated upon *Oscillatoria* sp..

Small scale field experiments, using 350ml volumes of lakewater within suspended dialysis tubing, showed similar predation patterns in the lake environment to the laboratory experiments.

ANNING, T., M. WYMAN and D. PURDIE. (Plymouth Marine Laboratory, University of Southampton). **The expression of photosynthetic genes in natural populations of marine phytoplankton.**

Total RNA was extracted from natural populations of eukaryotic phytoplankton from Southampton waters in 1992 and 1993 prior to and throughout the course of the spring bloom. The relative abundance of *rbcL* mRNA was measured by northern hybridisation with a 1.4kb heterologous *rbcL* DNA probe, isolated from the cyanobacteria *Synechococcus* WH8103 (Wyman, unpublished). The temporal variation in *rbcL* mRNA abundance followed the same general trend as maximum rates of photosynthesis (P_m) and chlorophyll *a*, but was phase shifted such that the maximum *rbcL* mRNA abundance was observed 2-3 days prior to the maxima in P_m and chlorophyll *a*. This suggests that; (a) less close coupling exists between transcription, translation and activity of RuBisCO in natural populations of eukaryotic phytoplankton than was originally thought and (b) environmental conditions measured prior (2-3 days) to the observed increases in P_m and biomass in both years are more representative of the environmental trigger(s) that stimulate an increase in growth rate than would have been apparent from results based solely on measurements of primary production. Temporal variation of *rbcL* mRNA was not directly influenced by nutrient concentrations but an inverse relation between *k*, the attenuation coefficient and *rbcL* mRNA abundance was observed. This introduces the possibility of obtaining an accurate estimate of the the minimal depth of the euphotic zone required for bloom initiation.

BAILEY-WATTS, A.E. and L. MAY (Institute of Freshwater Ecology, Edinburgh Laboratory, Bush Estate, Penicuik, Scotland EH26 0QB). **Modelling phytoplankton development.**

This contribution to the session on 'Nuisance algae and their control' will firstly outline the major physical, chemical and biotic factors that appear to enhance the success of nuisance algae (primarily large, blue-green species); this will highlight why waters can vary considerably as regards the amounts of algae observed per unit of (limiting) nutrient input. Secondly, it will summarise models that have incorporated some of these features and proved reasonably successful over many decades in predicting annual mean levels of phytoplankton in lakes, or - by failing to predict them identifying other factors involved. Thirdly, the talk will illustrate modelling work that is progressively improving our ability to simulate and thus predict the dynamics of not just the the main phytoplankton nutrients, but the seasonal abundance of the dominant algal species - bearing in mind that algal biomass rather than nutrients *per se* are the main concern. Finally, some case studies which have used the models to predict the outcome of nutrient intervention (e.g. stripping of phosphorus from sewage effluent) will be discussed.

BALL, J.S. (Biology Division, I.E.B.S., Lancaster University, Lancaster, LA1 4YQ) **The role of picophytoplankton in lakes of different trophic state.**

The north and south basins of Windennere have been regarded as moderately oligotrophic and moderately eutrophic respectively. Theory suggests that picoplankton, although more numerous in eutrophic waters, should be relatively more important in oligotrophic waters due to enhanced nutrient uptake kinetics associated with their small size. The seasonal distribution of

picophytoplankton, bacterioplankton and autotrophic and heterotrophic nanoflagellates in both north and south basins of Windermere were recorded, using epifluorescence microscopy, throughout 1995. The picophytoplankton (0.2 - 2.0 μm) comprised orange and red fluorescing non-colonial cefis. Picophytoplankton densities ranged from 6.2×10^1 cells ml^{-1} in February to 1.6×10^1 cells ml^{-1} in July. Total chlorophyll *a* peaked in May at $8.6 \mu\text{g l}^{-1}$ while the minimum of $0.1 \mu\text{g l}^{-1}$ occurred in January. Picoplankton chlorophyll *a* also peaked in May at $1.4 \mu\text{g l}^{-1}$, while the minimum of $0.01 \mu\text{g l}^{-1}$ also occurred in January. The apparent picoplankton contribution to chlorophyll *a* ranged from 44 % in February to 5 % in April. The proportion of primary production attributable to picoplankton is being assessed by 14-carbon uptake, and an attempt is being made to estimate grazing rates and inherent growth rates by dilution experiments. Comparisons of the north and south basins of Windermere will be made, and conclusions about the relative importance of picoplankton drawn.

BELL, S.G., A.D. NEWLANDS, M.J. PEARSON¹ and G.A.CODD (Department of Biological Sciences, University of Dundee, Dundee DD1 4HN; ¹NRA Anglian Region, Kingfisher House, Peterborough PE2 OZR). **Effects of cyanobacterial toxins on fish and evidence for transmission through an aquatic food chain.**

Incidents of fish fatalities and illnesses have been attributable to the presence of blooms of toxic cyanobacteria in the water. Here we review reports of such incidents, presenting historical and geographical perspectives. Early evidence for the adverse effects of cyanobacterial toxins on fish was largely circumstantial, but recent incidents have produced stronger evidence. Reports of possible transmission of cyanobacterial toxins through food chains are also reviewed. Results of laboratory investigations into the acute and chronic effects of cyanobacterial hepatotoxins and neurotoxins on trout are presented. These include comparisons of lethal dose levels between the fish and mammals, histopathological findings and measurement of reduced growth rates upon chronic exposure. Uptake of a cyanobacterial hepatotoxin, microcystin-LR by food chain members was also investigated in the laboratory. Radioactivity was taken up by *Daphnia* when emersed in an aqueous solution of tritiated microcystin over 9 days. Subsequently, roach became radioactive when fed on the exposed *Daphnia*. Radioactivity was associated with flesh, liver and gut of the fish, but with no other tissues examined. These studies suggest that microcystin-LR can be taken up and transmitted through an aquatic food chain.

BIRKETT, D.A., G. SAVIDGE and M.J. DRING. (The Queen's University of Belfast, Marine Biology Station, Portaferry, BT22 1PF, County Down). **In situ measurements of macroalgal oxygen production in Strangford Lough, Northern Ireland.**

Oxygen production measurements were made for the intertidal macroalgae *Fucus vesiculosus*, *Ascophyllum nodosum*, *Fucus serratus*, *Ulva lactuca*, and the subtidal species *Laminaria saccharina*, *Laminaria digitata*, *Laminaria hyperborea* and *Saccorhiza polyschides*, during the summer of 1995. Entire, or large portions of plants were placed in perspex chambers holding 70 l of seawater. The chambers were suspended in the lough, with the chamber base at 2 m. below the surface. Using Yellow Springs Instruments 6000 series data-logging oxygen electrodes, oxygen concentrations in the seawater circulating within the chambers were measured at 15 min. intervals for periods of 6 to 90 h. Surface irradiance data were collected as 15 min. means, using a Li-COR 1000 data logger. Corrections were made for light attenuation at 2 m. based on K_d values obtained weekly. Data obtained during the summer months show that rates of oxygen production increased with irradiance (P.v.I.) with typical curve profiles during the first part of the day. However during the afternoons, reduced rates of oxygen production were recorded and the profiles of the P v.I. curves changed. Data obtained from a series of experiments to be undertaken during the late autumn/winter will be presented for comparison C. N.

BOLTON, J.J. and M.A.P. JOSKA. (Botany Department, University of Cape Town, South Africa). **Water quality and growth of *Cladophora glomerata* (L.) Kütz. in South African irrigation canals.**

Much of South Africa is semi-arid, and in many areas agriculture is dependant on irrigation schemes. Increasingly, a number of these systems are experiencing problems with large growths of *Cladophora* from spring to autumn. While there is great seasonal variation in temperature (9.5 to 22.5°C) and light (latitude is 29-30°S), measured parameters of water quality show aseasonal trends related to rainfall patterns, with gradual increases in conductivity, dissolved ions etc., and

periodic rapid drops over a few months. Control of problem growths in the short term is carried out by treatment with copper sulphate, including, in some systems, pre-treatment with sulphuric acid to reduce pH. We will report on work in progress to investigate the biology of the *Cladophora in situ* and in the laboratory, with the aim of increasing knowledge of factors triggering problem growths, and efficacy of control methods.

BRODIE, J., P.K. HAYES¹, G.L.A. BARKER¹ and L.M. IRVINE² (Applied Sciences, Bath College of Higher Education, Bath BA2 9BN, ¹School of Biological Sciences, University of Bristol BS8 1UG and ²Department of Botany, The Natural History Museum). ***Porphyra* (Rhodophyta): new insights using classical and contemporary techniques.**

There are substantial taxonomic and nomenclatural problems associated with the genus *Porphyra* in Britain and Ireland. Using a combination of molecular and morphological analysis to address these problems, our initial data suggest that the flora of this region is more diverse than previously reported. Sequence analysis of the *rbcL-rbcS* spacer places most British collections of *Porphyra* into distinct groupings. The power of our combined approach is now becoming apparent. For example, comparisons of sequence data have raised conceptual problems in relation to some critical species: plants of *P. purpurea* from British coasts are not con-specific with those from Helgoland identified by Kornmann. Also, the ability to obtain sequence data from herbarium material has opened a new dimension in the reexamination of some critical specimens: e.g. a specimen labelled *P. laciniata* by Drew in 1956, has a *rbcL-rbcS* spacer sequence that is identical to that obtained for newly collected British *P. purpurea*.

BROWNLEE, C. and T. ANNING. (Marine Biological Association, The Laboratory, Citadel Hill, Plymouth PL1 2PB) **Costs and benefits of calcification in coccolithophores.**

Coccolithophores, such as *Emiliania huxleyi* produce calcite structures (coccoliths) in intracellular compartments which are transported to the cell surface. The considerable ecological success of coccolithophores suggests that the ability to calcify may confer some competitive advantages under certain conditions. We have been investigating the energetics of the transport of the external substrates for calcification (Ca^{2+} and HCO_3^-) and removal of products (H^+ and CaCO_3) in order to gain some understanding of the cost of calcification. This has necessitated measurements of cytoplasmic and intracoccolith vesicle pH and membrane potentials. While the movement of HCO_3^- into the coccolith vesicle may not require energy input, uptake of Ca^{2+} into, and removal of protons from, this compartment are both energy-requiring processes. The costs of producing calcite are compared with the potential benefits of calcification in terms of raising the concentration of CO_2 at the site of Rubisco. The relevance of this in terms of the availability of nutrients during coccolithophore bloom formation is discussed.

CAMPBELL, C.N. and J.E. SIDGWICK. (Culture Collection of Algae and Protozoa, Dunstaffnage Marine Laboratory, Oban). **Chemotaxonomic studies on 3 "*Chlorella*" strains used in aquaculture.**

For many years several strains of "marine *Chlorella*" have been used in aquaculture for feeding to rotifers and then to larval fish. They have been found to be very useful due to their small size (3-5 μm), ease of culture and relatively high content of the polyunsaturated fatty acid eicosapentaenoic acid (EPA). A Japanese study has shown that a strain in use there in aquaculture, known as "marine *Chlorella*" was in fact indistinguishable from *Nannochloropsis oculata*, a member of the class Eustigmatophyceae.

Initially in this study 3 strains of "marine *Chlorella*" were examined microscopically, their diameter measured and the chlorophyll content assessed using high performance liquid chromatography. True chlorophytes, such as species of the genus *Chlorella*, contain chlorophyll *b*. The absence of chlorophyll *b* in the test samples indicated that they were more likely to be in the class Eustigmatophyceae.

Further studies were carried out employing gas chromatographic analyses on fatty acid methyl esters prepared from extracts of cultures of the test strains. These produced fatty acid profiles typical of *Nannochloropsis* with a relatively high EPA content. This is further evidence that the so-called "Chlorellas" are eustigmatophytes, probably *Nannochloropsis* sp..

CALLOW, M.E. (School of Biological Sciences, The University of Birmingham, Edgbaston, Birmingham, B15 2TT). **Fouling of ships' hulls and static structures**

The importance of algae in the fouling of ships' hulls and static structures has been recognized for several decades. Most attention has focussed on *Enteromorpha*, *Ectocarpus* and diatom slimes with respect to ship fouling and *Laminaria* with respect to the fouling of static structures. Aspects of the biology of ship-fouling algae which contribute to their success will be discussed.

Fouling of ships' hulls has been controlled traditionally by anti-fouling paints containing copper salts. During the last 25 years, control of all types of fouling, apart from the most resistant diatom slimes, has been possible with SPC (self polishing copolymer) paints containing tributyltin (TBT) and copper salts, sometimes in combination with other biocides. However, the effects of TBT on non-target organisms have resulted in restrictions on the use of TBT anti-fouling paints in most parts of the world. Alternative strategies to control fouling will be discussed.

CODD, G.A. (Department of Biological Sciences, University of Dundee, Dundee DD1 4HN) **Occurrence and significance of cyanobacterial toxins.**

Cyanobacteria produce a wide array of low molecular weight secondary metabolites. Several of these compounds present hazards to human health and are responsible for, or contribute to, the deaths of domestic and wild animals, birds, fish and invertebrates. We consequently term these metabolites toxins, a necessary concept in terms of the management of water quality and the protection of health. A broader view of cyanobacterial toxins as secondary metabolites is, however, of more value in investigating the genetic and biochemical basis of their production and in considering their possible biological functions. These points are illustrated by the hepatotoxic microcystins from e.g. *Microcystis*, *Nostoc*, *Oscillatoria* and *Anabaena* spp.

At least 50 toxins are recognised to be produced by cyanobacteria, with examples from freshwater lakes, reservoirs and rivers, estuaries, brackish lagoons, coastal and marine waters, and terrestrial environments. Perception of the occurrence of the toxins depends on: the nature of the investigation, ranging from reactive studies after animal deaths (e.g. cattle deaths in 1995) to proactive analytical programmes; and the choice of analytical procedures, which range in toxin detection limits from micrograms to picograms. Environmental and biological factors influencing the production, pool sizes and persistence of the microcystins are finally discussed.

DOUGLAS, G.E. (The Natural History Museum, London). **Taxonomic implications of ultrastructural studies of cellular development in photobionts from a specialised group of lichens.**

The identification of photobiont species in the lichenised state is usually difficult and in many cases impossible. Critical morphological characters are often lost or highly modified so that many lichenised algae are unidentifiable even to the generic level. As a result, the taxonomy of photobionts is poorly understood and they have rarely been considered in lichen taxonomy. Reliable identification of the majority of photobionts requires isolation and culture of the algae under controlled conditions where traditional morphological characters are expressed.

This work examines the cellular development of photobionts from a specialist lichen community growing on the metalliferous rocks of a disused copper mine in Anglesey. The developmental changes that occur during the progression from the lichenised to freeliving state are examined at the ultrastructural level and their implications for lichen algal taxonomy and the process of lichenisation are discussed.

DRING, M.J., V. MAKAROV¹, E. SCHOSCHINA¹ and K. LÜNING (Biologische Anstalt Helgoland, Germany; ¹Murmansk Biological Institute, Russia) **Growth and chlorophyll fluorescence as indicators of UV-damage in different life-history stages of three species of *Laminaria*.**

Gametophytes, young sporophytes and discs cut from mature sporophytes of *Laminaria digitata*, *L. hyperborea* and *L. saccharina* were exposed in the laboratory to UV-radiation, of similar spectral composition and irradiance to natural sunlight, for periods ranging from 15 min to 8 days, and were then returned to white light. Growth of gametophytes was reduced after exposures to UV longer than 1 h, whereas UV had little effect on growth of young or mature sporophytes unless exposure exceeded 48 h. Variable fluorescence ($F_v:F_m$) of all stages was strongly reduced immediately after short exposures to UV, but recovered almost completely within 24 h. However, exposure of gametophytes to UV for >4 h resulted in little or no recovery of $F_v:F_m$, whereas >16 h of UV were required to produce this result in young sporophytes, and >48 h in mature sporophytes. Thus, sensitivity to UV-radiation decreased from gametophytes to sporophytes, and with increasing

age of sporophytes but, in gametophytes, growth appeared to be a more sensitive indicator of UV damage than $F_v:F_m$ after 24 h recovery. The responses to UV of gametophytes of all three species were similar, but both growth and fluorescence measurements suggested that sporophytes of *L. saccharina* were more sensitive to UV than those of the other two species.

EILERTSEN, H.C. and C.H. VON QUILLFELDT. (Norwegian College of Fisheries Science, University of Tromsø, N-9037 Tromsø, Norway). **Entrainment and subsequent day-length regulated germination of diatom spores: A global mechanism?**

Results from laboratory experiments shows that the resting stages of diatoms belonging to the primary spring bloom in sub-Arctic areas germinate at a photo-period of 12 hours. Experiments where spores originally collected from bottom sediments were exposed to the appropriate "triggering" day-length, demonstrate that resting stages of all the "relevant" species, i.e. species that are quantitatively important during the bloom, can survive in dark at bottom temperatures for at least 2.5 years. The appearance of viable cells in our cultures followed a pattern comparable to what can often be observed during field investigations in northerly areas, and it is suggested that day-length regulated germination of spores may influence the succession of species. By using results from experiments performed on sediments from an African lagoon, and by reviewing data from descriptive inshore phytoplankton studies in the temperate region, we argue that this may be a global mechanism. Further it is stressed that, in order to understand phytoplankton bloom dynamics, it is important to focus upon the onset phase and to include the entire water column in sampling programmes.

ELLAWAY, J., G.E. DOUGLAS, D.M. JOHN, S.J. BROOKS, G.C. JONES and S.D. RUNDLE¹. (Natural History Museum, London and ¹Department of Biological Sciences, University of Plymouth). **A bloom of the water net (*Hydrodictyon reticulatum*) in a eutrophic lake: its seasonality, cause and impact.**

The uniquely structured water net has the potential to become a major nuisance in nutrient-enriched aquatic systems in the British Isles. It is with increasing frequency forming blooms in lakes and rivers including Loe Pool, Cornwall's largest freshwater lake. In Loe Pool its cylindrical, gas-filled colonies were very evident on the surface in early June 1995 and by the end of the month the alga had blanketed the lake bed, formed net-like curtains in the shallows and accumulated as dense floating mats along the shoreline. In early August the water net began to disappear from the lake surface but remained blanketing the bottom although confined to the marginal shallows. The lake switched to a plankton-dominated system during August as a bloom of *Microcystis aeruginosa* developed which persisted until October. Water temperature is implicated in the seasonal appearance of the water net but not in its August decline. Dense populations of cladocerans and copepod zooplankton and other invertebrates were associated with the water net mats, however grazing is not considered a 'top-down' mechanism accounting for the bloom's decline. Interactions between the water net and planktonic algae together with factors responsible for the sinking of its mats and their subsequent disappearance are discussed. Further study of the biology and ecology of the water net is urgently needed in order to develop the predictive models necessary to devise a strategy to prevent or manage its growth.

FLETCHER, R.L. (The Marine Laboratory, University of Portsmouth). **Epiphytism and fouling: a major problem in seaweed cultivation.**

Epiphytism and fouling are major, world-wide problems in seaweed cultivation, reducing the operational efficiency of a diverse range of open-water and on-shore farms; the problem is especially acute in tank cultivation systems. The present paper provides an overview of the literature on epiphytism and fouling in the seaweed mariculture industry. Topics considered include the identity of the main nuisance algae, aspects of their biology which contribute towards their success as epiphytes and fouling organisms, the detrimental effects which they exert on the host plants, and the range of physical, chemical and biological control methods which are practised. Recent changes in approach, with less emphasis on descriptive information and more emphasis on experimental studies of host/epiphyte interactions, are welcomed as these offer hope for the development of improved control measures.

FLETCHER, R.L. (The Marine Laboratory, University of Portsmouth). **The occurrence of *Undaria pinnatifida* (Harvey) Suringar (Laminariales, Phaeophyceae) on the south coast of England.**

An attached population of the large brown kelp *Undaria pinnatifida* (Harvey) Suringar, a native to the shores of Japan, has recently been discovered in the Solent region of the south coast of England. This represents the first report of this species for the British Isles. The plants are attached to floating pontoons of a marina and occur in dense stands at the water line region. Plants are also commonly epizoid on the fouling tunicate *Styela clava*. Some of the larger plants measure up to 1 m in length and are clearly fertile with mature zoospore releasing sporophylls. *Undaria* must now be considered as firmly established on our coasts and any attempts at its eradication would undoubtedly prove futile.

The introduction of *Undaria* into the British Isles was not unexpected given its adventive background. It was accidentally introduced into the Mediterranean from the Pacific in 1971 and, more recently, populations have been discovered in New Zealand, Tasmania and Brazil. Suggested vectors for these introductions include imported shellfish, hulls of boats and ballast waters. Boats are the most likely vector for the introduction of *Undaria* into the Solent, the plants originating from populations deliberately introduced from the Mediterranean into Brittany for commercial reasons.

The present paper examines the adventive background of *Undaria* which has led to its arrival into the British Isles, describes its current distribution and ecology in the Solent and discusses aspects of its likely spread and impact on the native flora in the North Atlantic.

FLYNN, K.J. (Swansea Algal Research Unit, School of Biological Sciences, University of Wales Swansea, Singleton Park, Swansea SA2 8PP) **Toxic Marine Phytoplankton; some aspects of nutrient ecophysiology.**

Most toxic events in marine waters are associated with dinoflagellates, and most of these are primarily phototrophic. As such one may suspect that factors affecting the physiology of the cells will affect their toxin content. Dinoflagellates growing in, or advected into, inshore waters may be expected to encounter various changes in their immediate environment. Such changes include light, salinity, temperature and nutrient availability.

An explanation for an increase in toxicity per cell is that toxin synthesis becomes decoupled from growth or cell division. This may explain changes associated with nutrient refeeding of starved cells. Phosphate-starved cells are larger and their toxin content may be higher or though the concentration (taking into account cell volume) remains unchanged. Decreased salinity, although it may free metabolites from the synthesis of osmoticums, does not appear to promote toxin content. Low temperature has been reported to enhance toxicity, the effects of light appear to be unclear. Problems in the interpretation of these results will be discussed.

FORSELL, L. (Institute of Limnology, Uppsala University, Uppsala, Sweden). **Phytoplankton migration - could the littoral zone be important?**

In recent years a number of studies have been made concerning the seasonal migration of phytoplankton in lakes. However, nearly all of these have been concerned with the migration from sediments at water depths of 2 m or more.

In order to determine whether the sediment areas above 2 m could be important for the migration of the cyanobacteria *Gloeotrichia echinulata*, the number of akinete-containing colonies in the sediments of a shallow bay in Lake Erken were quantified. In addition, the akinetes ability to survive possible draught and freezing during the winter were studied. The number of akinetes were higher in these shallow areas than in the deeper parts of the lake, but the incomparably highest numbers were found more or less on the shoreline. To check the viability of these akinetes after one winters exposition, the upper 0-2 cm layer of sediments from 0-0.5 m water depth were collected in the autumn and left in open boxes on dry ground until next spring. The sediment was then placed in bottles in the laboratory (20°C, 12:12 L:D) and the number of migrating colonies were counted during a period of three weeks. A control series was made simultaneously from freshly taken sediments in the same areas.

The results showed that even though the morphology of the akinete colonies on land had changed, they were still able to germinate. Although the number of migrating colonies were somewhat lower from the land-incubated sediment, it was not so much as to be significant. This indicates that the main part of the recruitment of new *Gloeotrichia echinulata* colonies originates from the littoral areas. Potentially this is also true for other species, suggesting that it will be important to include the littoral zone when studying migration.

GEIDER, R.J. and H.L. MACINTYRE (Marine Biological Association of the United Kingdom, The Laboratory, Citadel Hill, Plymouth PL1 2PB, College of Marine Studies, University of Delaware, Lewes, DE 19958 USA). **Photosynthesis in fluctuating light: control of light-saturated CO₂ Fixation by the concentration and activation state of the carboxylating enzyme ribulose biphosphate carboxylase/oxygenase.**

Light-saturated CO₂ fixation is often highly correlated with the abundance or activity of the enzyme ribulose biphosphate carboxylase (Rubisco). Previous work on microalgae was limited to investigations of the Rubisco activity under standard assay conditions. However, it is well known that Rubisco activity is regulated by irradiance in vascular plants. Observations of the regulation of Rubisco activity in marine diatoms will be presented and the implications of this regulation with regard to phytoplankton productivity in turbid waters will be discussed. Upon transfer from darkness to saturating irradiance, the photosynthesis rate of marine diatoms varies continuously over a range of time scales from seconds to days. The CO₂ fixation rate increases from zero to its maximum value within 5-10 minutes following the onset of illumination. This induction phase is most likely controlled by the build-up of Calvin cycle intermediates and changes in the activation state of Rubisco. Following the induction phase, a steady CO₂ fixation rate is maintained for tens of minutes. Thereafter, the rate of CO₂ fixation declines, probably due to limitation on the demand for Calvin cycle intermediates. This time dependence of CO₂ fixation is superimposed upon an irradiance dependence that is commonly described by a photosynthesis-irradiance response curve. Changes in the relative abundance of light harvesting pigments and Rubisco can further modify the photosynthetic response.

GLENN, R.F., H.A.S. EPTON, D.C. SIGEE (Department of Plants, Microbes & Environment, University of Manchester). **Biocontrol of blue-green algae using *Streptomyces*.**

Work at Manchester has resulted in the isolation of several potential biological control agents (bacteria, fungi & actinomycetes) of common bloom-forming blue-green algae. Certain *Streptomyces* soil isolates consistently produced large lysis zones when applied to lawns of *Anabaena* and *Microcystis* sp. In this study, lysis of the blue-green alga *Anabaena cylindrica* by a *Streptomyces* antagonist (designated Ss2B5) was examined in petri-dish agar culture and liquid batch-culture experiments.

The antagonism in liquid culture against *A. cylindrica* was characterised in terms of optical density, chlorophyll-a and filament length. Within 24 hrs the average filament length of *Anabaena* was halved in the presence of the antagonist. Filaments were broken into shorter lengths until no intact filaments remained and cell lysis occurred. Heterocysts, the specialised cells responsible for nitrogen fixation, have different cell wall structure and were apparently unaffected. The lytic agent is an extracellular, stable compound which is retained by dialysis tubing. Cell-free culture filtrates were shown to cause lysis of *A. cylindrica*.

Bloom samples brought back to the lab have been inhibited by the antagonist on lawns and in liquid culture experiments. *In situ* enclosed experiments have been carried out at a local lake using plastic bags and inhibition of *Microcystis aeruginosa* has been observed under these 'field conditions'.

HALLETT, R.I. and J. LEWIS (Applied Ecology Research Group, School of Biological and Health Sciences, University of Westminster, 115 New Cavendish Street, London, W1M 8JS.). **The effect of salinity on the morphology of the cyst of *Lingulodinium polyedrum* (Dinophyceae).**

This contribution describes the morphological variation exhibited by the dinoflagellate cyst *Lingulodinium polyedrum* (*Gonyaulax polyedra*) when grown in different salinities. Ten clonal strains have been cultured under equivalent conditions, in a range of salinities from 10 ppt to 40 ppt. The cultures produced hypnozygote resting cysts, which have a spherical body enclosing the cell and a variable number of radiating processes. The morphology of these processes are the cysts' major feature and have been measured in terms of length, basal width and outline. The principal results of the study provide evidence that cysts display shorter processes in lower salinities. *Lingulodinium* cysts occur in the fossil record and consequently fossil dinoflagellate cyst morphology may provide information concerning the salinity of ancient sedimentary environments. Cysts of this species illustrate significant morphological variation. Such variation in cysts from the fossil record would normally be considered to represent several species. Therefore these findings have important implications for fossil dinoflagellate cyst taxonomy.

HAN, T. (Department of Biology, University of Incheon, Korea). **Effect of UV-B radiation on the growth and pigmentation of *Ulva pertusa* (Chlorophyta).**

The intertidal alga, *Ulva pertusa* was exposed to artificial UV-B radiation within the irradiances simulated to the ambient levels measured on a clear day in September, 1995. The fresh weight and surface area were unaffected by the various durations of UV exposure whereas irradiation of 4.3 W m⁻² for 2 hrs caused a significant reduction in chlorophylls relative to the control. When a comparison was made on transmission of thalli after pigment extraction, UV-irradiated thallus showed remarkably higher transmission in the waveband range of 280-300 nm than the control, suggesting that some of the structural components of cells in the former might have been destroyed. This was somewhat confirmed by an observation of the transverse section of UV-irradiated thallus in which the death of cells was easily recognized by the irregular structure and change in colour.

HARTLEY, A.M., M.E. CALLOW, B.S.C. LEADBEATER and W.A. HOUSE¹. (School of Biological Sciences, University of Birmingham, B15 2TT, and ¹Institute of Freshwater Ecology, Wareham BH20 6BB). **The Precipitation of Calcite in Association with Algal Biofilms.**

The deposition of calcite is associated with algal biofilms in hardwater areas. Photosynthesis causes the removal of CO₂ which results in an increase in pH. The high pH results in a change in carbon speciation to favour CO₃²⁻ ions, so that there is a greater likelihood of combination of CO₃²⁻ with Ca²⁺ to form calcite. Thus, photosynthesis has a major effect on local water chemistry, since diffusive boundary layers in the solution above biofilms have pH values vastly different to the bulk water. Precipitation of calcite is therefore linked to local variations in the water chemistry close to the algal surface. Precipitation is also affected by non-biological factors, e.g. the adsorption of microcomponents such as phosphate onto nucleation sites, which results in an increased level of supersaturation with respect to calcite before precipitation is induced. The interaction between phosphate and calcite also has ecological significance, because the co-precipitation of phosphate with calcite can produce a "self-cleansing" effect, thereby influencing the trophic status of waters. Abiotic calcite nucleation and crystal growth have been followed in a standard solution of 2.5 mM calcium bicarbonate containing various concentrations of phosphate. The results will be compared with algal mediated precipitation in solutions of similar chemistry. Microelectrode studies are currently in progress in order to monitor the precipitation conditions within the microenvironment of algal biofilms.

HEAD, R.M.^{1,2}, R.I. JONES¹, and A.E. BAILEY-WATTS² (¹Biological Sciences, IEBS, Lancaster University and ²IFE, Edinburgh). **The distribution of *Anabaena solitaria* akinetes in the upper sediments of a small lake.**

The phytoplankton of temperate lakes exhibit periodic changes in the composition of the dominant species that relate to seasonally different environmental conditions. A number of planktonic species of cyanobacteria 'overwinter' unfavourable growth conditions as akinetes (spores) that survive in the sediments of lakes. These resting stages are potential inoculum for new populations when conditions improve and become conducive to growth. Although cyanobacteria in lakes have been widely studied, little research has been carried out on akinetes, especially *in vivo*. This paper reports the spatial and temporal distribution of *Anabaena solitaria* akinetes in the upper sediments of a small lake and the development of a pelagic population of *A. solitaria*.

HEANEY, S.I., R.H. FOY, R.V. SMITH, and S.D. LENNOX. (Department of Agriculture for Northern Ireland, Newforge Lane, Belfast BT9 5PX). **A catchment problem in controlling algae in Lough Neagh.**

Phosphorus (P) has been removed from the effluent of major sewage treatment works (STWS) in the Lough Neagh catchment since in 1981. Assessing the impact of this removal on river soluble reactive phosphorus (SRP) loadings is complex as river loadings are positively correlated with annual runoff and are quite variable on a year to year basis. After allowing for this variability, it was apparent that, after P reduction at STWs commenced, river SRP loadings declined in direct proportion to the amount of SRP removed at STWs only for a period of 3-4 years. Subsequently, loadings increased so that by 1990 there was little difference in SRP loadings compared to those measured prior to P reduction. Analysis of the complete data set of river loadings for the period 1974 to 1991 has revealed a steady increase in diffuse SRP loadings from agriculture in each of the six major rivers. The areal increase is equivalent to an increase of 4 tonnes P yr⁻¹ in the SRP loading to Lough Neagh. If allowed to continue unchecked this rate will remove the benefits

resulting from the decreased SRP loading from STWs of 65 tonnes P yr⁻¹. P use by agriculture within the Lough Neagh catchment has remained quite constant for a period of 40 years. However over that time P inputs to the land have consistently exceeded P outputs in crops leading to an accumulation of P in soils despite no increase in annual P inputs. Although the loss to water of P from agriculture is limnologically significant, it is agronomically insignificant compared to the P accumulation rate in the soil of 1000 kg P km⁻¹ yr⁻¹. In turn this P accumulation rate is quite modest in terms of rates for Northern European countries which can exceed 5000 kg P km⁻¹ yr⁻¹.

HEIN, M. (Freshwater Biological Laboratory, Helsingorsgade 51, DK-3400 Hillerod, Denmark). **Carbon limitation of freshwater phytoplankton photosynthesis.**

A study of carbon enhanced phytoplankton photosynthesis was performed in 6 Danish lakes in the summer of 1995. We know that carbon availability influence phytoplankton species composition of freshwater phytoplankton, especially in acidic or high alkaline lakes, but whether or not carbon availability influences overall community photosynthesis is still under debate. We surveyed the influence of total inorganic carbon (DIC) and free CO₂, on community photosynthesis and growth. The lakes were selected to ensure a wide range in chlorophyll a concentrations (1-190 µg l⁻¹), pH (5-10) and DIC content (0.01 to 2.6 mM). Experiments were accomplished by the ¹⁴C-technique in CO₂ manipulated water samples, either by changing pH or removing/adding CO₂. Results show that low-DIC lakes were dominated by chrysophytes and had a profound decrease in production rates at low CO₂ concentrations and a minor increase with increased CO₂ concentration. High-DIC lakes were dominated by green algae and blue green algae and showed no response to either increase or decrease in free CO₂ except for bloom-like situations.

HOEF-EMDEN, K. (Universität zu Köln, Botanisches Institut, Lehrstuhl 1, Gyrhofstr. 15, D-50931 Köln). **Towards a revision of the genus *Cryptomonas*.**

Over 70 freshwater strains assigned to the genera *Cryptomonas* and *Campylomonas* have been examined by light and electron microscopy. For light microscopy, the cells have been embedded live into a low-gelling agarose. To study the inner periplast component cells were treated with detergent and stained using whole mount techniques.

A proposal for a circumscription of the genus *Cryptomonas* is made. Due to a combination of several characters, the strains can be placed into at least 8 groups as an attempt towards a new species concept.

Sequence comparisons of the internal transcribed spacers (ITS 1 and 2) of the ribosomal DNA have been used to refine the structural information of the grouping of *Cryptomonas* strains.

JEWSON, D.H. (Freshwater Laboratory, University of Ulster, Traad Point, Ballyronan, Magherafelt, Co. L'Derry, BT45 5HE). **Resting stages in planktonic diatoms of Lake Baikal.**

Lake Baikal in Siberia is the world's oldest lake, with an estimated age of 30 million years. The lake is famous for the adaptive radiation that has occurred in many plant and animal groups but it is particularly unusual because the planktonic diatom community is dominated by endemic species. These endemics have become adapted to the unique environmental conditions that are found there. For example, although it is the deepest lake in the world (1680 m), it is oxygenated all the way to the bottom. A multidisciplinary Anglo-Russian project, co-ordinated through the Royal Society, is studying water column processes. One of the planktonic diatoms being studied closely resembles the description of a widely distributed species, *Aulacoseira islandica* subspecies *helvetica* (O. Müller) Simonsen, except that it has a morphologically distinct resting stage. Although similar resting stages are found in marine coastal diatoms they are rare in freshwater, so the factors controlling their production, settling and the mechanism for return to the water column in Lake Baikal will be described.

JOHNSTON, A.M. (Department of Biological Sciences, University of Dundee, Dundee. DD1 4HN, UK). **Photosynthesis and growth: the use of stable isotope analysis.**

Discrimination by photosynthetic aquatic organisms against ¹³C during the assimilation of inorganic carbon can be used as an indicator of the physiological status of the experimental organism. The relationship between the level of ¹³C discrimination and growth conditions, limited by light, temperature, CO₂ and nutrients, is discussed. In general the greater the growth rate the smaller the level of ¹³C discrimination. There are exceptions reported in the literature which will be used to consider the limitations of inorganic carbon stable isotope analysis. The link between

the affinity of marine phytoplankton (*Emiliania huxleyi*, *Phaeodactylum tricoratum* and *Thalassiosira angulata*) for inorganic carbon, the growth CO₂ concentration and the level of ¹³C discrimination will be described. In conclusion the ability to relate laboratory acquired data and models to data obtained from natural environment will be addressed.

JONES, H.L.J., C. COCKELL¹ and L.J. ROTHSCHILD¹. (NERC Centre for Population Biology, Imperial College at Silwood Park, Ascot, Berks, SL5 7PY, U.K.; ¹NASA/Ames Research Centre, Moffet Field, California 94035-1000, U.S.A.). **Intraspecies variation in *Poterioochromonas malhamensis* due to long-term culturing conditions.**

Poterioochromonas malhamensis (Chrysophyceae) is a well studied freshwater mixotrophic flagellate. Most recent investigations into its mixotrophic behaviour, however, have been carried out using strain L 1297 from the Starr collection, Texas. This strain was isolated in 1948 and has since been maintained in *Ochromonas* medium.

A second strain of *P. malhamensis*, from the Windermere collection, CCAP 933/1c, was isolated in 1951 and is maintained in Diatom medium, non-axenically but with no added bacteria or dissolved organic carbon compounds. The work presented shows a study of the behaviour of this strain. Results suggest that the strain 933/1c has developed behaviour which is more photoautotrophically biased than when it was first isolated. This contrasts with strain L 1297 which has been shown to be a mixotrophic alga with heterotrophy as the dominant mode of nutrition.

The evolution of a switch to more photoautotrophically biased behaviour within *P. malhamensis* strain 933/1c, due to the conditions under which it has been maintained, is discussed, as well as general strain variation within the *P. malhamensis* species.

JONES, L., W.F. FARNHAM and J.M. GOROSTIAGA¹ (The Marine Laboratory, University of Portsmouth, ¹Dep. Biología Vegetal y Ecología. Cinencias, Univ. Pais. Vasco, Apdo.644 Bilbao, 48080, Spain). ***Fucus chalonii* : attempts at elucidate its taxonomic position.**

Fucus chalonii was described by J. Feldmann from a very exposed shore at Hendaye on the French Basque coast but subsequently Powell (1963) regarded it as a variant of *Fucus vesiculosus* L. *linearis* (Huds.) Powell, caused by wave action. However, when a population of *F. chalonii* was discovered on only a moderately exposed shore near Ogeia Lekeitio (Vizcaya) this proposal was questioned.

During this investigation work has been carried out on a population of *F. chalonii* on the Spanish Basque coast (N. Spain) and on *Fucus vesiculosus* L. f. *linearis* at Southsea (S. England). Comparative morphometric studies have been performed on both populations and results have shown pronounced differences between aspects studied. Differences in wave action between sites have also been examined by measurement of the dissolution rate of plaster blocks.

Laboratory investigations have included comparative studies related to the growth of apical tips under varying conditions of light and temperature. Hybridization between individuals from both sites has also been investigated.

Preliminary techniques of DNA analysis have also been devised in an attempt to elucidate the true taxonomic position of *F. chalonii*.

JONES, R.I. and J.M. YOUNG (Biological Sciences, Lancaster University, Lancaster LA1 4YQ) **Autotrophic picoplankton in Loch Ness, Scotland.**

Loch Ness is a large, deep, oligotrophic lake in Scotland with poor light penetration. Conventional wisdom is that autotrophic picoplankton (APP) should be relatively more successful than larger phytoplankton under these conditions because of enhanced nutrient uptake and light capture ability. The growth of APP in Loch Ness has been studied as part of a larger programme on the loch. In the 0-30 m depth layer, the density of APP during 1992 and 1993 ranged from 0.4 to 5.7 x 10⁴ cells ml⁻¹. The maximum densities recorded are towards the lower end of the range reported from lakes. However, the integrated (areal) abundance of APP in Loch Ness appears to reach rather high levels. Growth of a clonal culture of a strain of APP isolated from Loch Ness was studied in a laboratory incubator. Under continuous irradiance, the maximum specific growth rate (SGR) achieved was only around 0.02 h⁻¹, but under a 15:9 light:dark cycle the maximum SGR approached 0.04 h⁻¹. An attempt was then made to simulate the fluctuating light climate in the mixed water column of Loch Ness, which led to both a lower SGR and poorer growth per unit daily light dose. The results from our field and laboratory studies lead us to suggest that growth of APP in Loch Ness is probably light limited through most of the year.

KAIRESALO, T. (Department of Environmental Sciences, University of Helsinki, FIN-15210 Lahti, Finland). **Control of cyanobacteria by biomanipulation.**

The disappearance of cyanobacteria is seldom continuous but has been found to occur in stepwise fashion with decreasing P concentration. For instance, in L. Vesijarvi (southern Finland) the collapse of cyanobacteria occurred with the decline of epilimnetic P concentration from 45 to 35 $\mu\text{g P l}^{-1}$. The seasonal dynamics of P during the stratification, however, may be largely steered by biotic processes and communities. In L. Vesijarvi, for instance, there existed regularly in early June a stepwise increase in the epilimnetic P during 1980's which could not be explained by traditional means, i.e. neither by external nor sediment derived P inputs. This P increase, however, coincided well with the massive early-summer migration of adult roach populations from the littoral areas to the pelagic zone. During 1989-93 these migrating fish populations, in particular, were the targets of trawling which led to a dramatic reduction in their biomass; from 172 kg ha^{-1} (i.e. about 100 mg P m^{-2}) in 1989 to less than 30 kg ha^{-1} (about 15 mg P m^{-2}) in 1993. This decrease in the fish-mediated P input provided an explanation for the observed decline in the epilimnetic P concentration and the displacement of cyanobacteria. The fish P compartment was so heavily exploited that it essentially influenced the pelagic P cycling and pooling in the algal biomass. In general, in eutrophic lakes even half of the limnetic P pool ('total-P' + 'fish-P') may be bound to, and transported with, the fish biomass. Temporal and spatial variation in the fish-P compartment may therefore be of crucial importance in lake P budget, and in the control of cyanobacteria.

KIRKWOOD, J.A., P. ROWELL and N.W. KERBY¹ (Department of Biological Sciences, University of Dundee, Dundee, DD1 4HN; ¹Mylnfield Research Services Ltd, Invergowrie, Dundee, DD2 5DA). **Sucrose phosphate synthase: a key enzyme in the osmotic response of *Synechococcus* PCC 6301.**

The freshwater unicellular cyanobacterium *Synechococcus* PCC 6301 accumulates K^+ and sucrose in response to hyperosmotic shock. Using a coupled assay involving lactate dehydrogenase and pyruvate kinase, sucrose phosphate synthase (SPS) activity, which had not previously been found in prokaryotes, was detected in cell-free extracts of both control (non-shocked) and hyperosmotically shocked *Synechococcus* PCC 6301. It was activated, *in vitro*, by NaCl and several other salts but no activation occurred when salt was absent from the assay mixture. Our data indicate that SPS is responsible for the synthesis of sucrose during hyperosmotic shock in *Synechococcus* PCC 6301. A 26-fold purification of SPS was achieved using anion exchange chromatography and the partially purified enzyme was shown to be extremely sensitive to the removal of salt. SPS activity was stimulated by Mg^{2+} and had a pH optimum of 8.0 - 8.5 and a temperature optimum of 30 - 35°C, above which the enzyme was labile.

KÖHLER, J. (Institute of Freshwater Ecology and Fisheries, POB 35, D-12563 Berlin, Germany) ***In situ* - measurements of growth of phytoplankton populations in a lowland river.**

Abundance of the dominant phytoplankton populations declined along the lower Spree (Germany) despite intensive photosynthesis. Respiration, exudation and grazing of zooplankton explained less than 20 % of carbon losses. The presumably most important loss processes (net sedimentation, grazing of benthic filter-feeders) are not measurable directly. A new diffusion chamber protected the incubated algae from settlement and grazing losses but kept their physical and chemical environment as close as possible to natural conditions. A lift moved the rotating chamber through the water column to simulate both vertical mixing and small-scale turbulence. The difference between rates of change of phytoplankton abundance along a river stretch and rates of algal growth in the diffusion chamber was used as measure of sedimentation and grazing losses. The influence of hydrophysical conditions and of morphological properties of the algae on these losses are discussed.

KUWATA, A. (Institut de Ciències del Mar, Passeig Joan de Borbó s/n, 08039 Barcelona Spain). **Survival mechanism of a marine planktonic diatom with resting stages under fluctuating nutrient environments**

Life-form responses as a survival mechanism of a planktonic algal population under fluctuating nutrient environments were examined using a coastal diatom, *Chaeroceros pseudocurvisetus*. Field (the regional coastal upwelling region in Japan) and culture experiments showed that a part of

the *C. pseudocurvisetus* population forms resting spores with heavily silicified frustules under nitrogen deficiency, a response requiring the absorption of a large amount of silica. The rest of the population forms vegetative-looking resting cells when confronted with shortage of silica.

Ecophysiological analysis of cultured resting spores and resting cells suggested that each life-form represented a different degree of adaptive dormant state. Respiratory and photosynthetic activities were depressed in both life-forms reducing nitrogen content. Net photosynthesis was slightly positive in resting spores and slightly negative in resting cells. Resting spores accumulated glucan and neutral lipids as storage energy sources, while resting cells stored neutral lipids only.

Demographic analysis using a cultured population revealed that resting spores have a greater capacity to survive under nitrogen depletion than resting cells, while resting cells exhibit more rapid growth response to nutrient supply than resting spores.

A population dynamics model predicted that resting spores mainly contributed to the maintenance of this algal population under nutrient fluctuations with long intervals, while resting cells maintain the population during short interval fluctuations. It also predicted that this dimorphic survival stage would be stable under conditions of nutrient fluctuations of random frequency as expected in natural coastal water.

MABERLY, S.C., M. SURIF¹ and J.E. PARKER (Institute of Freshwater Ecology, Ambleside, Cumbria LA22 0LP & ¹Universiti Sains Malaysia, Pulau Pinang, Malaysia). **The effect of CO₂ concentration on the photosynthesis, growth and distribution of *Dinobryon* and other Chrysophytes.**

Photosynthesis experiments have indicated that *Dinobryon sertularia* Ehrenberg (CCAP 917/2) is restricted to free CO₂ as a source of inorganic carbon. Rates of photosynthesis are dependent on the concentration of CO₂ and independent of the concentration of HCO₃⁻. The CO₂-compensation concentration varied between 2.5 and 4.5 mmol m⁻³ (approximately 64 to 115 μmol mol⁻¹ atmosphere) at alkalinities between 0.2 and 2.0 equiv m⁻³. Restriction to CO₂ is supported by growth experiments. No growth occurred when CO₂ was removed from solution by bubbling with CO₂-free air even when the concentration of HCO₃⁻ was high.

The ecological consequences of the restriction to CO₂ are examined in relation to long-term patterns of distribution for *Dinobryon* and other Chrysophytes in a number of Cumbrian lakes.

MAGGS, C.A. (School of Biology & Biochemistry, Queen's University, Belfast BT9 7BL) **Introduced marine macroalgae - are they a problem?**

Introduced species can be recognized by several characteristics, such as disjunct geographical distributions, sudden appearance in a new area and absence from similar habitats elsewhere, initial oscillations in abundance of populations, and low genetic variability. However, introduced species rarely present all of these features, and each presents problems. For example, an apparently disjunct distribution may actually consist of separate species with discrete distributions. A species that has suddenly colonized a new area may not be recognized as introduced due to taxonomic problems - species are often identified as new in each area where collected. Similarly, the degree of apparent genetic variability may depend on the methods used for investigation: whereas plastid DNA RFLPs are relatively invariant, RAPDs can provide a high level of resolution. Aquaculture, oyster culture in particular, is the chief source of alien algae, and is estimated to have been the vector for 25-50% of algal introductions into the Mediterranean. Deliberate introductions for seaweed cultivation have rarely been successful, but *Undaria pinnatifida* was brought from Mediterranean to Atlantic France where it has become established. There is little evidence of direct impacts of introduced species on native species and communities, mostly due to lack of research. Nuisance effects, such as competition with or damage to exploited species, interference with shipping and recreational boating, have been better studied. Beneficial effects of introduced algae include greater scientific interest in ecological interactions and taxonomy.

Biological diversity and biomass can increase, and the introduced alga can provide a food source for native marine animals, such as the endangered green turtle in Hawaii. Once an introduced species has arrived, control measures are largely ineffective, and legislation to prevent new introductions is the only potentially effective solution. Overall, the most serious problem is the rapidly escalating rate of new introductions, and the increasing likelihood that these will eventually include a seriously harmful species.

MILES, A.C. and D.M. PATERSON. (Gatty Marine Laboratory, St. Andrews University). **PRIMARY PRODUCTIVITY, LIGHT AND STRUCTURE OF INTERTIDAL DIATOM ASSEMBLAGES.**

Intertidal mudflats are now recognised as highly productive areas. The microphytobenthos that inhabit these sediments show high temporal and spatial variation, responding to the continuously fluctuating chemical and physical conditions of their environment. The complex patterns of migration of the pennate diatoms, coupled with the fact that calculations are often based on techniques that are increasingly being challenged, has meant that accurate carbon budgets for estuaries are difficult to obtain. The use of oxygen microelectrodes now allows for the accurate measurement of oxygen production on a microscale. However, such production values incorporated into carbon budgets are still primarily obtained from laboratory studies which can rarely match the extremely variable field conditions.

Data from the summer of 1995 represented an extended investigation of *in situ* primary productivity in the Eden Estuary, Scotland. The *in situ* algal production over daily and fortnightly tidal cycles was mapped and the use of microelectrodes in fieldwork evaluated. The fine cohesive sediments were dominated with the pennate diatom, *Navicula gregaria* and the cyanobacteria, *Oscillatoria sp.* LTSEM confirmed that the bulk of the algal assemblage was positioned within the top 100 μm of the sediment for the period of emersion. The use of fiber optic light sensors revealed that surface sediment radiation (P.A.R. $2000 \mu\text{E m}^{-2} \text{s}^{-1}$) decreased to less than 50 % within the top 200 μm . Oxygen concentration profiles showed an oxygen peak in the exposed sediments, at a depth of approximately 200 μm , ranging from 400 to 900 $\mu\text{mol O}_2 \text{l}^{-1}$. Despite an oxic layer of approximately 1500 μm , algal production was restricted to the top 400 μm of the sediments. Over the time period considered oxygen production ranged from 8 $\text{mmol O}_2 \text{l}^{-1} \text{hr}^{-1}$ to 67 $\text{mmol O}_2 \text{l}^{-1} \text{hr}^{-1}$.

NIMER, N.A., D. IGLESIAS-RODRIGUES and M.J. MERRETT (School of Biological Sciences, University of Wales Swansea. SA2 8PP UK). **Mechanisms of dissolved inorganic carbon utilization by marine phytoplankton species.**

Marine phytoplankton species acquire their inorganic carbon (Ci) for photosynthesis from the dissolved inorganic carbon (DIC) system in sea-water. The mechanism of DIC utilization is species dependent and some species can rapidly acclimate to changes in the concentration of dissolved CO_2 and/or HCO_3^- . Among the possible mechanisms for DIC utilization are "diffusive" uptake of CO_2 or the "active" transport of CO_2 . HCO_3^- may be utilized by "direct" uptake, when HCO_3^- is the form of inorganic carbon crossing the plasma membrane or "indirect" HCO_3^- utilization which requires carbonic anhydrase external to the plasma membrane to catalyse the interconversion of HCO_3^- and CO_2 . Recent results will be presented concerning the relative contribution of these mechanisms in DIC uptake by different phytoplankton species.

PHILLIPS, G. (National Rivers Authority, Ipswich UK.) **Algal control in the Norfolk Broads - What have we learnt in the last decade.**

Eutrophication has been a major concern in the Norfolk Broads since the late 1960s. It has resulted in a substantial loss in conservation value of the area and with the increased awareness of the potential hazards of cyanobacteria is now threatening the recreational use of the area. The NRA, working in partnership with the Broads Authority and other agencies have been developing a strategy to restore these lakes. The paper will describe the extent of the problem and the experimental work on which this strategy is based. It will demonstrate that a holistic view of lake ecology is required to achieve a sustainable improvement in these lakes.

PLUMB, J. and J. BRODIE (Applied Sciences, Bath College of Higher Education, Newton Park, Newton St. Loe, Bath, BA2 9BN). **A temporal investigation into the endophytic flora of the red alga *Chondrus crispus*.**

An investigation into the presence of endophytes in haploid and diploid phases of the red alga *Chondrus crispus* from a population on a shore in Somerset, indicates that levels of green and brown endophytic algae exhibit seasonal differences. Green algae belonging to the genus *Acrochaete* Pringsheim and brown algae assigned to the genus *Streblonema* Pringsheim were isolated from *C. crispus* in October 1994, January and July 1995. The highest level of infection was in October, where 95 % of both gametophytes and tetrasporophytes were infected. In January, 75 % of gametophytes and 65 % of tetrasporophytes were infected, whereas levels were 95 % and

85 % respectively in July. Infection by green algae remained relatively constant, with little variation between haploid and diploid phases of *C. crispus*. The presence of brown endophytes was more variable between both season and *C. crispus* ploidy. The results raise issues concerning the exact nature of the brown endophytic algae.

PYE, K.E., R.L. FLETCHER and D. FONTANA¹. (The Marine Laboratory, University of Portsmouth; ¹Department of Geography, University of Portsmouth). **"Green Tide" algae of Langstone Harbour, south coast of England - local and seasonal variations.**

Eutrophication of coastal waters, as the result of increased sewage discharge and agricultural run off, is now recognised as a major world wide problem. Probably the best documented effect of eutrophication on benthic organisms is an excessive growth of macroalgae, notably species of the green algal genera *Enteromorpha* and *Ulva*. Two sites within the UK, the Ythan Estuary, Aberdeenshire and Langstone Harbour, Hampshire are recognised by the Paris Commission (1992) as being possibly eutrophic. The present paper is concerned with an evaluation of the role of anthropogenic sources of nutrients on the occurrence, density and distribution of the green macroalgal mats present on the intertidal mudflats of Langstone Harbour. A field study is being undertaken, with particular attention being given to determining the environmental factors controlling this "Green Tide" phenomenon. The macroalgal flora of the Harbour is being surveyed and mapped using field sampling techniques and Infra Red False Colour aerial photography. Extensive field studies provide biotic information on macroalgal distribution, biomass and productivity. Macroalgal cover and biomass is determined at least monthly at a number of field sites and material collected is being analysed for chlorophyll and elemental composition (C, N and P). Using a network of sampling stations, seawater is regularly analysed for levels of nutrients, chlorophyll and SPM along with environmental parameters such as temperature, salinity, dissolved O₂, light and pH. Results obtained to date reveal marked local and seasonal variations in the occurrence, chemical composition and biomass of the main macroalgal components which appear to be related to selected environmental parameters. The present findings are discussed and compared with those obtained from previous studies.

RAGGETT, S.L., J.S. YUNES¹, L.F. NIENCHESKI¹ and G.A. CODD (Department of Biological Sciences, University of Dundee, Dundee DD1 4HN; ¹Unidade de Pesquisas em Cianobacteria and Laboratorio de Hydroquimica, Fundaçao Universidade do Rio Grande, Rio Grande RS, Brazil). **Effects of salinity on the growth and toxicity of *Microcystis aeruginosa* and ecotoxicological studies on *Microcystis* blooms in the Patos Lagoon, Brazil**

Blooms of the hepatotoxin-(microcystin-) producing cyanobacterium *Microcystis aeruginosa* are commonly encountered in eutrophic freshwaters, rather than brackish waters, although toxic blooms have been reported from parts of the Baltic Sea. We have investigated the effects of salinity on the growth and toxin levels in *Microcystis* PCC 7813, isolated from a Scottish freshwater loch. Growth rate, maximum biomass and microcystin levels per unit biomass were increased by the addition of low levels of sodium chloride (0.63 to 1.25 % of the sodium chloride content of seawater, % SW). Growth was inhibited by sodium chloride levels above 0.63 % SW. No ability of PCC 7813 to adapt to higher sodium chloride levels during repeated subculturing was apparent. Massive blooms and scums of *M. aeruginosa* occur in the largest lagoon system in South America, the Patos Lagoon in southern Brazil. Favourable bloom-forming conditions are provided annually in the northern and central (freshwater) regions of the Lagoon. We have investigated major flows of *Microcystis* blooms to the estuarine (southern) region of the Lagoon where cyanobacterial scum deposition has occurred on recreational beaches. Microcystin types and levels present in the blooms in the Lagoon and in the brackish waters of the estuarine region are under investigation.

RAVEN, J.A. (Department of Biological Sciences, University of Dundee, Dundee DD1 4HN). **Prediction of algal growth rates from short-term measurements of photosynthetic rates.**

The relationship between short-term measurements of photosynthetic rate and (necessarily) longer-term measurements of growth rate is of mechanistic interest and as a means of estimating growth rate from short-term photosynthetic measurements.

Under laboratory conditions measurements of net photosynthesis, organic C excretion and (if there is a scotophase) dark respiration can give good agreement with the measured growth rate provided the inorganic and organic C fluxes between algae and environment are measured over time periods

and at frequencies which are appropriate to environmentally induced (including cell division synchrony) variations in C fluxes.

In nature the fluctuations in the physicochemical environmental conditions are not under the investigator's control; furthermore, biotic influences (competition; grazing; parasitism) are involved. This greatly complicates the use of short-term photosynthetic rates in estimating growth rate.

RENGEFORS, K. and K. PETTERSSON (Institute of Limnology, Uppsala University, Norbyvagen 20, 752 36 Uppsala, Sweden). **Phosphorus uptake by resting cysts of the marine dinoflagellate *Scrippsiella trochoidea*.**

Lake sediments provide a phosphorus-rich environment which may serve as a potential nutrient pool for resting cysts. We studied whether or not dinoflagellates can incorporate phosphate during its resting stage despite the fact that this is a period of significantly reduced metabolism.

Cysts from a culture of the marine dinoflagellate *Scrippsiella trochoidea* were used for the experiment. They were incubated in darkness at 4°C and 20°C, in P-enriched and P-depleted medium. Phosphorus, carbon, and nitrogen content of cysts were analysed during a 28-day incubation period.

The results from the experiment show for the first time that dinoflagellate cysts accumulate phosphorus during their resting stage. The P-content of cysts incubated in P-rich medium was significantly higher than that of cysts in P-depleted medium. A trend of increasing P-content was seen until day 21 when the maximum content was measured. Meanwhile the P-concentration decreased in the medium without a corresponding increase in bacterial P. The ecological implications of these results are that accumulation of P during the benthic stage, would increase the survival of the newly excysted vegetative cell as it re-enters the water column, by providing it with a competitive advantage over other phytoplankton.

RIDGE, I. and J. PILLINGER¹ (Biology and ¹Earth Sciences Departments, The Open University, Milton Keynes, MK7 6AA). **Use of barley straw to control nuisance algae.**

When barley straw rots in water, inhibitors are released that suppress the growth of nuisance algae (including cyanobacteria). The method has been widely applied in the UK, mainly in small lakes, ponds and drainage ditches, and, provided that submerged straw remains aerobic, is generally successful. Some natural inputs to water bodies, notably certain kinds of deciduous leaf litter, also release algal inhibitors which appear to be of the same general type as those released from barley straw. Our evidence suggests that inhibitors are or derive from oxidised polyphenolics that are released from lignin or tannins: this view and alternative views will be discussed. We also discuss the selective nature of inhibitor action on different algal species and on other aquatic organisms, a point which is central to the environmental safety of the barley straw method and its long-term ecological impact.

SAVILLE, P.J. and A.M. JOHNSTON. (Department of Biological Sciences, University of Dundee, U.K. DD1 4HN). **Factors affecting isotopic discrimination of inorganic carbon during photosynthesis in marine phytoplankton**

A clear understanding of the factors controlling the ¹³C/¹²C isotopic composition, shown as δ¹³C, of marine phytoplankton is required if this information is to be used to make assumptions about environmental conditions at the time of growth. It may then be possible to reconstruct past variations in sea and atmospheric CO₂ from the sedimentary record.

Discrimination of carbon by *Skeletonema costatum*, an important coastal bloom forming diatom, has been grown in batch cultures with a range of environmental conditions. Discrimination (D) of inorganic carbon was calculated from the δ¹³C of organic matter, (-13 to -23 ‰) and took into account the isotopic composition of the substrate inorganic carbon in the growth media (-2 to +2 ‰). Data is presented for the effects on discrimination by variables including the concentration of inorganic carbon, and growth rate as influenced by the photon flux density, and these suggest that discrimination is high in slow growing cultures with a high inorganic carbon concentration. The effect of these variables on availability and composition of inorganic carbon at the site of photosynthesis is discussed, and how this influences the isotopic discrimination.

SHUBERT, L.E. (Department of Botany, The Natural History Museum, London SW7 5BD). **Factors affecting the abundance and productivity of periphyton.**

Kellys Slough, a saline wetland area surrounded by natural prairie and agricultural land, was studied during the 1994 growing season for the growth, distribution and productivity of periphytic algal communities attached to artificial substrates in relation to physical, chemical and climatic factors. The receiving water contained sewage effluent and runoff from a U. S. Airforce facility. Six study sites were sampled bi-weekly from May to September.

The maximum temperature occurred during July (25°C), which coincided with peak periphyton biomass production (mean 20.8 mg chl a cm⁻²) and productivity (mean 1.2 pg C fixed mg⁻¹ chl a hr⁻¹ or 0.9 pg C fixed cm⁻² hr⁻¹). Species composition, diversity and abundance differed markedly, both spatially and temporally. Cyanobacteria accounted for a major portion of the chlorophyll a biomass.

Using Canonical Correspondence Analysis (CCA), it was demonstrated that 25% of the variance in species was due to PAR light, 20% was due to salinity and 13% was due to pH in Kellys Slough, according to forward selection of variables with 99 permutations. *Nitzschia iriliformis* had the greatest tolerance to elevated levels of light, salinity and pH, and *Nitzschia amphibia* had the least tolerance. The data demonstrated that periphytic algae, attached to artificial substrates, can be used as indicators of environmental quality, at both the species and community levels.

SIGEE, D.C., E. BELLINGER and EL-BESTAWY (Department of Plants, Microbes & Environment, University of Manchester) **X-ray microanalytical studies on the algae *Spirulina* and *Cyclotella* in a polluted subtropical lake.**

Studies were carried out on the phytoplankton of a polluted sub-tropical lake (Lake Maryut, Egypt) over a 1 year sampling period. The elemental composition of two major algal constituents, *Spirulina platensis* and *Cyclotella meneghiniana*, was determined from mixed phytoplankton samples by electronprobe X-ray microanalysis.

X-ray emission spectra from cells of *Spirulina* revealed a wide range of detectable elements, with clear positive (e.g. K-P) and negative (Na-S, P-Cl) correlations - reflecting intracellular compartmentation. *Cyclotella* cells had a similar range, with the additional presence of Al, Fe and Cu. Comparison of correlation coefficients from separate sets of data revealed a clear pattern of elemental associations. Although heavy metal pollution in the lake was high, no significant uptake was detected in *Spirulina* and only limited uptake (of Fe & Cu) occurred in *Cyclotella*.

TAYLOR, R. and R.L. FLETCHER. (The Marine Laboratory, University of Portsmouth). **Nutrient uptake and removal by 'Green Tide' algae: Applications to waste water treatment.**

The phenomenon of eutrophication in the marine environment is increasing as greater quantities of sewage and waste waters are discharged into coastal areas world-wide. In Langstone Harbour, south coast of England, eutrophication is evident by the increased abundance of green algal taxa, *Enteromorpha* and *Ulva* sp. in particular.

Laboratory studies were performed on vegetative material of *Enteromorpha compressa* and *Ulva curvata* to determine uptake rates of PO₄, NH₄ and NO₃. Uptake rates were governed by the initial concentration of the media. For both algae, nitrogen uptake rates were always higher than those of phosphorus, and NO₃ uptake rates exceeded those of NH₄. NO₃ and PO₄ uptake was more rapid in *E. compressa* with NH₄ uptake more rapid in *U. curvata*.

Preliminary studies were also made of the effect of sewage effluent on the growth of the two species. Both algae were found to exhibit different growth rates when cultured in secondary treated effluent at concentrations ranging from 5 to 50%. Experiments also showed both species to be adept at removing nutrients (PO₄, NH₄ and NO₃) from sewage effluent. These results are discussed in relation to the potential use of 'green tide' algae as biofilters in reducing the nutrient load of eutrophicated waters.

WARD, C.J. and G.A. CODD. (Department of Biological Sciences, University of Dundee, Dundee, DD1 4HN). **Comparative toxicity of four microcystins from *Microcystis aeruginosa* to the protozoan *Tetrahymena pyriformis*.**

Microcystins are a family of cyclic heptapeptide toxins produced by members of a number of genera of aquatic and terrestrial cyanobacteria. To date, some 50 microcystins of differing structure have been identified. Little information on the comparative toxicities of microcystins is available. We have investigated the effects of four microcystins which differ in terms of amino acid composition and hydrophobicity on the growth and respiration of the protozoan *Tetrahymena pyriformis*. Microcystins MC-LR, -LY, -LW and -LF purified from *M. aeruginosa* PCC7813 were acutely toxic

to *T. pyriformis in vivo*: the LC₅₀ of MC-LR was 0.28 mg.ml⁻¹ with the other variants showing increased toxicity in the sequence MC-LF = -LW > -LY > -LR. Permeabilizing *T. pyriformis* with the detergent dimethylsulfoxide increased susceptibility to MC-LR but not to the other, more hydrophobic microcystins. Inhibition of whole cell respiration and growth rate occurred by all microcystins in the sequence of increasing toxicity MC-LR; -LY; -LW; -LF. *In vitro* toxicities of all variants, as determined by colorimetric protein phosphatase I inhibition assay, varied slightly, with MC-LR > -LY » -LW > -LF.

WHITTON, B.A. and D.M. JOHN. (Department of Biological Sciences, University of Durham; Department of Botany, The Natural History Museum, London). **Towards a modern Freshwater Algal Flora for the British Isles.**

The Flora is to be a synoptic account and practical guide to the freshwater and terrestrial (non-marine) algae to be found in the United Kingdom and Ireland. While planning the Flora project several Points became clear. The Flora needs to be based on a sound taxonomic understanding of all the major algal groups, but unevenness of treatment will be inevitable because knowledge of some taxa remains weak. Special problems are presented by the cyanobacteria with different approaches to their taxonomy and their nomenclature making it difficult to present a unified system that will satisfy all users. There are inevitably differences in the way various potential user groups would like to see the Flora presented: a classical floristic work, a more practically-orientated handbook, a set of standard identification keys, an interactive expert identification programme, and information accessed from a CD-ROM including an image database. Briefly summarised is current progress on this initiative of the British Phycological Society that currently involves the collaboration of 24 taxonomic specialists.

WILLIAMS, D.M. (Department of Botany, The Natural History Museum, Cromwell Rd. London SW7 5BD, UK). **New species in the diatom genus *Tetracyclus* and some implications for historical biogeography**

The diatom genus *Tetracyclus* Ralfs is composed largely of extinct, freshwater species many of which have been used as stratigraphic markers under the assumption that they are relatively widespread and confined to precise geological epochs. The taxonomy of the genus has to a greater extent relied almost exclusively on the shape and dimensions of the preserved siliceous valves; such features appear highly variable among specimens and warrant critical re-appraisal. In 1914 Hustedt presented a particularly detailed study of the species *T. ellipticus* and its relatives concluding that they were all very closely related among themselves, Hustedt's views have remained largely intact since their publication and the assumption that all 'elliptical' species are closely related has prevailed in discussions of their distribution both spatially and temporally. In this presentation I will discuss the morphology of the fossils from the 'ellipticus' species-group and discuss their possible monophyly in the context of the genus and the implications behind their global distribution.

POSTERS

ALABASTER, J.C. and G.B.J. DUSSART (Ecology Research Group, Science Department, Canterbury Christ Church College, North Holmes Road, Canterbury, Kent CT1 1QU.) ***Enteromorpha* control using barley straw; an experimental story.**

Enteromorpha intestinalis (L.) grows as a floating mat in brackish drainage ditches and can reach abundances which create a visual nuisance. The use of decomposing barley straw has wide application in algal control but not all species are susceptible. The aim of this study is to investigate the effect of barley straw on *Enteromorpha*.

A series of laboratory and cold frame experiments were carried out using different methods of straw application and growth conditions. The problems encountered and the difficulty of distinguishing non-action of straw from flawed method are discussed. The low success rate of laboratory experiments suggest efficacy in field control would be limited.

BETANCOURT, L., J. ABALDE¹, C. HERRERO¹ and C. J. BARWELL². (Institute of Oceanology, Ave. ra No 18406, 184-186, Habana, Cuba. ¹Faculty of Science, University of Coruna, Coruna, Spain. ²Department of Biological Sciences, University of Portsmouth, Portsmouth, UK). **Effect of**

culture conditions on phycocyanin production by the unicellular cyanobacterium, *Synechococcus* sp. (Cyanophyta).

There has been increasing interest, during the last decade, in culturing cyanobacteria. These contain photosynthetic accessory pigments which under certain physiological conditions accumulate within the cell reaching substantial quantities. One important pigment is the biliprotein phycocyanin, which has important applications in biomedical analysis and diagnosis together with potential as a natural blue colorant of foods, cosmetics and pharmaceuticals.

The biosynthesis of the biliprotein depends, amongst other factors, upon nutrients in culture media. In a project designed to evaluate Cuban marine cyanobacteria as sources of phycocyanin a species of *Synechococcus*, isolated from Cuban coastal water, was used to study phycocyanin production in culture. Primarily, the effect of nitrogen concentration and nitrogen to phosphorous ratio was investigated. A maximum, for the cellular content of the pigment, was obtained in cultures with 8 mM nitrogen and a N:P ratio of 10:1. There was an inverse relationship between growth rate and phycocyanin production.

BUTTERWICK, C. and J.G. DAY. (Culture Collection of Algae and Protozoa, Institute of Ecology, Windermere Laboratory, Far Sawrey, Ambleside, Cumbria LA22 0LP). The use of a commercially available UV system to control an algal bloom.

Due to the nature and management of ornamental garden ponds it is almost inevitable that environmental conditions will be eutrophic. This often leads to the formation of dense algal blooms. These may render conditions unsuitable for aquatic plants and ornamental fish, and in addition they are aesthetically unattractive.

The possibility of using UVC to "treat" an algal bloom was investigated. Experimental ponds (1500 l) were inoculated with laboratory grown cultures of *Chlorella vulgaris* CCAP 211/12 ($\sim 2.0 \times 10^5$ cells ml⁻¹). The ponds were treated by continuously circulating the algal suspension through a Hozelock Ultra Violet Purifier. Three flow-rates (6 - 32 l min⁻¹) were tested and the effects of treatment on pond appearance, algal density and algal physiology were monitored. A gradual decrease in algal density over time was observed in both treated and control ponds. After 4 days a visible difference in appearance could be seen, with treated ponds appearing less green. In addition, the UV treated *C. vulgaris* cells were incapable of further cell division on transfer to fresh medium. As some metabolic capabilities were retained by the treated cultures, the primary mode of action appeared to be damage to cell DNA.

The system tested effectively treated the algal bloom within 24 - 48 h, depending on the flow rate employed, with no viable planktonic algae isolated after 48 h treatment. However, benthic species colonized the sides of the pond and were apparently unaffected by the treatment.

CARTA, W., G. LOBINA and R. L. FLETCHER (The Marine Laboratory University of Portsmouth). Periodicity in the release of gametes and zoospores of *Enteromorpha compressa* (L.) Grev. and *Ulva rigida* C. Ag. in Langstone Harbour, south coast of England.

A "lunar" periodicity in reproductive spore formation is not an uncommon phenomenon in marine macroalgae and has been reported for a wide range of spore types distributed in the three main green, brown and red algal groups. Usually spore production coincides with the spring tide period; less commonly it coincides with the neap tide period. Such a periodic production (and subsequent release) of spores in an algal population offers a number of advantages. For example, it increases the chances of gametic union and can, in the case of spring tide release periods, result in a greater distribution of the reproductive bodies. For some algae occupying the upper eulittoral/littoral fringe, it is essential that spore release coincides with the spring tide period in order that they are dispersed. The present paper reports on the occurrence of a lunar periodicity, associated with the spring tide period, in the formation and release of motile spores of two green algae, *Enteromorpha compressa* (L.) Grev. and *Ulva rigida* C. Ag., which are commonly present in Langstone Harbour, south coast of England. The response was especially marked in the species of *Ulva*. Both zoospores and gametes displayed a periodicity in their release, although gametophyte plants greatly outnumbered sporophyte plants.

CHELLAPPA, N.T., (Dept. Oceanografia e Limnologia, UFRN, Natal/RN 59.014-100. Brazil). Studies on Microalgae of Rio Grande do Norte, Brazil. N₂ fixation by blue green alga *Gioeotrichia echinulata* Richter.

Nitrogen fixation by planktonic blue-green algae is a process extremely variable and provides a source of combined nitrogen to semi-arid freshwater ecosystems. In the present study, nitrogen fixation was estimated using acetylene reduction technique. A diurnal Nitrogen fixation by *Gloeotrichia echinulata* was studied during monsoon months (wet season) and summer months (dry season) and the rates of acetylene reduction were compared *in situ* which showed an interesting pattern for tropical waters of Lake Urubu in Northeast Brazil. The rates of acetylene reduction were expressed in relation to chlorophyll *a*. The rate of C₂H₄ production varied 0.085 nM in wet season and 0.068 nM per µg chl *a* min⁻¹ in dry season in *Gloeotrichia echinulata* colonies. During wet season, the rate of nitrogen fixation followed closely the diurnal curve of primary productivity. In the dry season, however, the photorespiratory oxygen loss at midday period did not inhibit the nitrogen fixation rate, instead showed an increase of 20% and presumably be contributed to the significant increase in nitrogenase activity. Correlation coefficient analysis between chlorophyll *a* and the acetylene reduction rate indicates that there is a significant correlation between these two variables, (N=24, df = 23 P>0.001).

CLOKIE, J.J.R. (The Sea Vegetable Co. Pitkerric, Balmuchy, Ross-shire, IV20 1TN). **Successional methods for controlling algal dominated facies in the marine littoral.**

The poster suggests the outline of a guide which should be assembled by those wishing to control the macroalgal associations on marine littoral substrata where the continued use of biocides or physical abrasion is not appropriate. Four examples from the author's experience are given together with their respective outcome.

These are 1) increasing *Porphyra* species abundance by restarting the succession at a specific time of year, 2) augmenting various edible algae by manipulations of the competitive environment, 3) cleaning by the enhancement of grazer populations of an expanse of soft shore which became covered with algae, 4) reducing the slipperiness of marine walkways and other walking surfaces by a series of measures to produce an overgrazed facies.

Successional gardening methods have long been in use in centres for the production of edible algae but are not described in the U.K. for our species (though see H. Powell's first field work) and are essential for continued production. The practical application of cleaning shores or jetties by steering the succession do not appear to be in use anywhere. Though many of the practicalities can be inferred and a successful outcome reached it seems quite extraordinary that more use is not made of the techniques and that more attention has not been paid to removing the uncertainties and increasing the general applicability.

DAY, J.G. (Culture Collection of Algae and Protozoa, Institute of Freshwater Ecology, Windermere Laboratory, Far Sawrey, Ambleside, Cumbria, LA22 0LP). **CCAP - A living resource.**

The primary remit of the Culture Collection of Algae and Protozoa (CCAP), is broadly similar to that of other collections of biological material, that is to act as a depository and to make the material accessible for end-users. For CCAP holdings are restricted to micro-algae (including cyanobacteria), small thalloid Rhodophytes and free-living non-pathogenic protozoa. The live cultures form the core of the collection. Their scientific value primarily lies in their current and past use in taxonomic and other research fields and the extensive literature published citing CCAP strain numbers. In terms of conservation of biodiversity, the collection arguably encompasses one of the largest degrees of biodiversity that can be found in any collection or genebank. This is particularly true for the algal collection which currently includes representatives of 50% of the algal species lodged in major culture collections worldwide. The algae are also widely employed in teaching science at both secondary and tertiary levels of education.

The poster discusses in greater detail the roles and services of the collection and its commercial and scientific value.

DE GREGORIO, S. and R.L. FLETCHER (The Marine Laboratory, University of Portsmouth). **Autecological studies of the Fucales (Phaeophyceae) in Langstone Harbour, south coast of England.**

Langstone Harbour is an almost landlocked tidal basin situated in the mid-south coast region of the British Isles. It is shallow, almost fully marine and, at low tide, comprises extensive mudflats and sandbanks. Although industrial pollution is light, it does receive a substantial input of sewage effluent in the upper part of the Harbour which is generally acknowledged to be responsible for the excessive, annual growths of green algae which occur on the soft sediments.

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As part of an EU sponsored study of this eutrophic Harbour, the present poster is concerned with an investigation of the macrophytobenthos colonising hard substrata, much of the latter being man-made and associated with coastal protection schemes, road bridges, harbour installations etc. Particular attention has been given to monitoring the populations of fucoid algae in the Harbour, represented by *Ascophyllum nodosum*, *Fucus serratus*, *F. vesiculosus*, *Halidrys siliquosa*, *Pelvetia canaliculata* and *Sargassum muticum*. Using permanent quadrats, clearance experiments, tagging experiments and transplantation experiments, information has been obtained on their local distribution patterns, biomass, growth rates throughout the year, periods of reproduction and epiphytic fauna and flora. Some laboratory culture studies have also been undertaken to determine the effect of sewage effluent on fucoid germling growth and development.

DIEZ, I. and J. M. GOROSTIAGA (Dep. Biología Vegetal y Ecología, Fac. Ciencias, Univ. País Vasco, Apdo. 644 Bilbao 48080, Spain). **Recuperating process in the intertidal algal communities in the polluted area of Abra de Bilbao and proximal Coast (Northern Spain).**

The intertidal macroalgae affected by severe pollution from the Abra de Bilbao and its surroundings were studied in 1984 and 1992. Changes in the community structures were assessed in terms of algal cover, species richness and species composition. Statistical cluster analysis applied to a network of 320 quadrats distributed in 8 sites and both years resulted in 2 main groups. The first group showed *Corallina elongata* as dominant species, and the second one *Gelidium pusillum* revealing 2 general degradation levels in the study area. The phytobenthic communities have undergone an improvement which consisted of an increase in algal cover on the lower littoral (due to the increase of species such as *C. elonjzata*, *Chondria coerulescens*, *Caulacanthus ustulatus* and *Codium decortcatum*), a decrease in algal cover on the midlittoral (due to the decrease of species such as *G. pusillum*, *Blidingia minima* and *Enteromorpha intestinalis*), an increase in species richness and changes in species composition which varied depending on the sites (*Chthamalus* sp. replaced *G. pusillum* and *B. minima*, *C. eloneata* replaced *Ceramium flaccidum*, *Chondria coerulescens* and *Caulacanthus ustulatus* replaced *G. pusillum*). These changes were related to the decrease in industrial activity and the closure of the mineral washeries, as well as the onset of urban wastewater treatment plants for various municipalities which have led to a decrease in water pollution. Sedimentation, turbidity and water toxicity were the main destabilizing factors among communities.

FLECK, R.A.^{1,2}, J.G. DAY¹ and E.E. BENSON². (¹Culture Collection of Algae and Protozoa, Institute of Freshwater Ecology, Windermere Laboratory, Far Sawrey, Ambleside, Cumbria, LA22 0LP. ²Dept. of Molecular and Life Sciences, University of Abertay Dundee, Bell St., Dundee, Scotland, DD1 1HG). **A comparative study of cryopreservation strategies on different life stages of *Haematococcus pluvialis*.**

Previous studies have indicated that specific features of cells may influence their ability to be successfully cryopreserved (eg. presence/absence of vacuoles, ability to withstand dehydration/osmotic stress). It could therefore be hypothesised that different life stages of an organism may also display distinct responses to cryopreservation protocols. The complex life history of the freshwater alga *Haematococcus pluvialis* offers the opportunity to compare the effectiveness of current cryopreservation strategies on different life history stages (motile single cells & the palmella, aplanospore stage). The success of two-step controlled cooling has been investigated, with different levels of post-thaw viability being observed (motile stage 85% \pm 21%; aplanospore stage 38% \pm 5.6%). In addition to the commonly used two-step cooling protocols more novel cryopreservation strategies were evaluated: Vitrification, using high molarity mixtures of cryoprotectants and Encapsulation/Dehydration in alginate beads. The concept of applying cryopreservation protocols to different stages in an organisms life history is also being applied to the freeze recalcitrant species *Vaucheria sessilis* (reproductive spore, mature filament) with the aim of developing effective cryopreservation strategies.

FROGLEY, A.J. and R-CHATTERJEE. (National Centre for Toxic and Persistent Substances, National Rivers Authority, Anglian Region, Kingfisher House, Orton Goldhay, Peterborough, PE2 5ZR). **Toxic algae and eutrophication control work at the NRA's national centre for toxic and persistent substances (TAPS).**

The TAPS Centre co-ordinates and supports the NRA's work on toxic and persistent substances in the aquatic environment. The four areas of work covered are the North Sea/PARCOM, pesticides, environmental toxicology, and toxic algae and eutrophication.

The toxic threat and aesthetic impact of blue-green algae and marine algae has wide implications for the NRA's roles, responsibilities and activities. The Toxic Algae Task Group was established in 1989 to assess the incidence of toxic algae and to make recommendations for monitoring and control measures to be taken in the future. The Task Group has published Toxic Blue-Green Algae, Water Quality Series Report No.2; information leaflets on blue-green algae and marine algae; and is currently producing a Water Quality Series Report on Marine Algae under contract.

Monitoring programmes have been implemented and the results are collated and reported by the TAPS Centre. Advice is given on all aspects of algal control. R&D programmes will aid the understanding, monitoring and control of algae. Blue-Green Algae Action Plans are being developed for individual waters. In the wider context TAPS is producing a National Eutrophication Control Strategy encompassing the findings from a number of projects including a manual of eutrophication control methods; cost-benefit analysis; review of legislation; development of environmental quality objectives and standards; and review of current eutrophication related R&D.

GOROSTIAGA, J.M., A. SANTOLARIA, A. SECILLA and I. DIEZ (Dep. Biología Vegetal y Ecología, Fac. Ciencias, Univ. País Vasco, Apdo. 644 Bilbao 48080, Spain) **A preliminary study of the sublittoral benthic vegetation of the Spanish Basque Coast. (Northern Spain).**

The sublittoral benthic vegetation of the Basque Coast was studied during the summer of 1991 following 39 transects along 120 km of coast. Information concerning the abundance of macrophytes and physical characteristics of the medium (type and slope of substratum, level of sedimentation, sediment nature and depth) were obtained in a network of 787 sampling-units. The most frequent habitat was bedrock of a moderate depth (4-9 m). The north-eastern coast was very exposed to the wave action and had moderate levels of silt-sand sedimentation. In the mid-western coast, the habitats were more variable, ranging from very exposed to semiexposed hydrodynamic conditions, with moderate-high levels of sedimentation, principally sand. A total of 100 species of macrophytes were recorded. *Mesophyllum lichenoides*, *Gelidium sesquipedale*, *Cystoseira baccata*, *Pterosiphonia complanata*, *Zanardinia prototypus* and *Codium decorticatum* were the most abundant. *Plocamium cartilagineum*, *Diclyota dichotoma*, *Corallina officinalis* and *Rhodymenia pseudopalmata* were frequent species. *G. sesquipedale* formed extensive beds in very exposed habitats with low sedimentation, while the beds of *C. baccata* occurred in exposed-semiexposed habitats with moderate-high sedimentation levels. *Pterosiphonia complanata* replaced *G. sesquipedale* and *C. baccata* in habitats with more sedimentation and in deeper waters. *Codium decorticatum* was abundant in very exposed and polluted habitats. The flora found, together with the scarcity of kelps reveal the meridional character of the vegetation with respect to other neighbouring Atlantic coasts.

HOWAT, J. and D. J. GILMOUR (Department of Molecular Biology and Biotechnology, University of Sheffield, Sheffield S10 2UH). **Physiological adaptation of two unicellular green algae to pH stress.**

We have selected two marine algae, *Dunaliella parva* and *Chlorococcum submarinum*, to study the effect of pH stress on single celled algae. *D. parva* has been well characterised physiologically, but not with regards to pH stress. *C. submarinum* has not been so extensively studied, but is known to grow over a wide pH range from 4.5 to 10.5.

Determinations of cell volume, internal pH and membrane potential have been carried out using both algae grown over a wide pH range. Cells are rapidly separated from the medium by centrifuging through a layer of silicone oil, which allows measurement of the distribution of a range of radiolabelled compounds between the cells and the medium.

Enzyme activities in crude extracts have also been measured to establish the effects of external pH changes on metabolic pathways.

HYENSTRAND, P., A. PETTERSSON & P. BLOMQUIST. (Institute of Limnology, Norbyvägen 20, S-752 36 Uppsala, Sweden). **The importance of inorganic nitrogen species as regulatory factors for cyanobacterial dominance.**

We propose that a high ability of cyanobacteria to utilize ammonium-nitrogen and a poor competitiveness for nitrate-nitrogen may be a missing link in understanding the success of

cyanobacteria. This hypothesis regarding inorganic nitrogen, has been evaluated in enclosure experiments in the mesotrophic, alkaline Lake Erken during 1993 and 1994. Additions of ammonium in combination with phosphate proved to stimulate the growth of non-nitrogen-fixing cyanobacteria whereas the outcome of nitrate additions combined with phosphate was repression of these species. In progress right now, are competition experiments with mixtures of cyanobacteria and green algae. The aim of these studies is to show that the source of inorganic nitrogen affect the outcome of competition between prokaryotic and eukaryotic phytoplankton. In order to clarify the underlying mechanism, future studies will include enzymatic activities involved in the inorganic nitrogen assimilation.

KELLY, M.C. and J.D. DODGE. (SOAFD Marine Laboratory, Victoria Road, Torry, Aberdeen, AB9 SDB; Royal Holloway, University of London, Egham, Surrey, TW20 0EX). **The use of scallop (*Pecten maximus* L.) digestive systems in monitoring toxic dinoflagellate outbreaks.**

The scallop (*Pecten maximus* L.) is a bottom-dwelling, suspension-feeding bivalve mollusc. In Scottish waters, scallops can accumulate paralytic shellfish toxins (PSP) through feeding on blooms of toxic dinoflagellates. PSP has been a serious problem during 1995 with East Coast fisheries closed for a period of some three months.

In this study the digestive system contents of scallops from the North East of Scotland were examined for the presence of dinoflagellates. Water samples taken from the areas in which the scallops were collected were also screened for dinoflagellates, *Alexandrium tamarense* and *Dinophysis* spp. were found in these samples. The scallops were taken from an area which was known to be positive for PSP. The animals were also tested for diarrhetic shellfish toxins (DSP), but to date no toxins have been found.

The digestive systems were found to contain recognisable remains of several dinoflagellates, particularly members of the genus *Dinophysis* which are known to be a source of DSP. Little evidence of the origin of PSP was discovered apart from a very small number of *Alexandrium* cysts. The value of this technique in surveys for potential dinoflagellate toxin occurrence will be assessed.

KRISDIANTO, N.J. MARTIN¹ and I.A.J. RATCHFORD¹. (Gang Petai No20b. RT 1 8, Simpang Empat Banjarbaru, South Kalimantan, Indonesia. ¹Biochemical Sciences Department, Scottish Agricultural College, Auchincruive, Ayr KA6 5HW.) **The effect of calcium ions on phosphate precipitation in high rate algal ponds (HRAP).**

Comparisons between HRAP's in Scotland and Southern France had shown marked differences in phosphate behaviour with considerable precipitation of inorganic phosphate in the French HRAP. It was considered that this might be linked to differences in water chemistry, in particular the very different calcium concentrations, at the two sites.

Investigations carried out in HRAP's at the Scottish Agricultural College, Auchincruive revealed that, compared to a control of 15 mg Ca l⁻¹, both medium (125mg Ca l⁻¹) and high calcium (750mg Ca l⁻¹) concentrations resulted in a decrease in dissolved phosphate. The dissolved phosphate concentration was inversely related to the level of calcium used in the treatment. The effects of calcium concentration were sufficient to mask any influence of algal productivity (measured as chlorophyll *a* concentration) on the phosphate removal.

High calcium ion concentrations increased the degree of flocculation and sedimentation rate of the microalgal biomass.

There were significant effects of calcium concentration on the relative efficiencies of chlorophyll extraction by the method of Humphrey and Jeffrey (1975) depending on whether biomass was isolated by centrifugation or filtration.

KÜBLER, J.E. and J.A. RAVEN. (Department of Biological Sciences, University of Dundee, Dundee DD1 4HN U.K.). **The average seaweed: do seaweeds simply integrate rapid variations in light supply?**

Net photosynthetic rates are subject to regulation by environmental variations such as light supply, inorganic carbon availability and temperature, on a number of temporal scales. To determine how closely rates of net gas exchange track variations in light supply representative of sunflecks through a wave-swept plant canopy, we measured time courses of gas exchange during and after exposure to either constant or dynamic light supplies of the same total photon dose. Temporal variation in light supply had significant effects on photoinduction kinetics, post-illumination dark respiration rates and photoinhibition. The results differed between species with different means of inorganic carbon

acquisition. Our results indicated that the operation of the bicarbonate use mechanism in *Palmaria palmata* was dependent, in a complex way, on light levels previously experienced at time scales from seconds to days. *P. palmata* did not simply integrate variations in light supply. This observation is consistent with previous evidence that temporal variation in light supply inhibited growth rate in this species. In contrast, *Lomentaria articulata* and *Phycodrus rubens*, which acquire dissolved CO₂ via diffusion, appeared to integrate variations of light supply occurring at 0.1 to 1.0 Hz. We conclude that active inorganic carbon acquisition by *P. palmata* has an absolute energy requirement and is sensitive to the timing of light supply.

LIUKKONEN, M., T. KAIRESAALO and E.Y. HAWORTH¹ (Department of Environmental Ecology, University of Helsinki, Niemenkatu 73, FIN-1 521 0 Lahti, Finland; ¹Institute of Freshwater Ecology, Ambleside, Cumbria LA22 0LP, UK). **Changes in the diatom community during the biomanipulation of Lake Vesijärvi; Paleolimnological analysis evidenced the initiation of a new species, *Actinocyclus normanii* fo. *subsalsus* into the lake's plankton.**

Lake Vesijärvi (110 km²) was known as one of the most eutrophic water courses in Finland during 1960's and 1970's. The diversion of effluent to the lake resulted in an initial recovery but, due to internal loading, heavy cyanophyte blooms degraded the water quality, especially in the Enonselkä basin (26 km²). Biomanipulation (i.e. mass removal of roach) during 1989-93 caused a drastic improvement in the water quality with a collapse of cyanophyte blooms and increased transparency (from 1-1.5 m to 3-3.5 m). We have sought the concomitant changes in the diatom community using paleolimnological analysis of the profundal sediment in the Enonselkä basin. The relative abundances of the small *Stephanodiscus* species, *S. parvus* Stoermer & Håkansson and *S. rugosus* Sieminska & Chudybova and *Aulacoseira islandica* (O.Müll.) Simonsen, have declined with concomitant increase of *Asterionella formosa* Hass., *Fragilaria crotonensis* Kitton, the large *Stephanodiscus* species, *S. alpinus* Hustedt and *S. heterostylus* Håkansson & Meyer, and *Tabellaria* species. The diatom community has thus become more diverse since the eutrophic period of the 1970's and 1980's. A new species, *Actinocyclus normanii* fo. *subsalsus* (Juhlin Dannfelt) Hustedt, has also appeared in the Enonselkä plankton subsequent to the dredging of the boat harbour in 1990. The rapid increase of this species may be one reason for a new equilibrium state in the phosphorus/chlorophyll *a* ration in the Enonselkä plankton.

MARTIN, N.J. and C.A. GLASBEY. (Biochemical Sciences Department, SC, Auchincruive, Ayr, KA6 7EW; Biomathematics and Statistics Scotland, JCMB, King's Buildings, Edinburgh EH9 3JZ). **Physiological applications of multimodal imaging.**

With cells that may often be large or highly refractile or both, the micro algae present a challenge to the microscopist trying to demonstrate their internal structure. The use of a number of different imaging techniques (imaging modalities) may be required to demonstrate different structures within the cell. Visualisation would often be simplified if the different images could be combined. With the exception of epifluorescence microscopy, conflicting optical requirements usually prevent the direct superimposition of images.

To retain the information content of the different modalities some degree of image processing is required prior to recombination. Before this can be attempted the images must be scaled to the same magnification and aligned since the different optical systems used may produce small image shifts or differ slightly in magnification. Using a variety of algal images this poster demonstrates the production of multimodal images. Scaling and alignment is by the application of a matching algorithm which maximises the cross correlation of outputs from an edge filter. Further information may be obtained by using principle components analysis to isolate aspects of the imaging information, such as the optical thickness of *Scenedesmus* cells, demonstrate in the poster.

POOLE, L.J. and J.A. RAVEN. (Department of Biological Sciences, University of Dundee, Dundee DD1 4HN, U.K.) **The success of the genus *Enteromorpha*.**

Life history and ecophysiological characteristics of the genus *Enteromorpha* which enable it to dominate nutrient rich estuaries have been sought from data and hypotheses (e.g. of ecological 'strategies') in the literature. The 10-20°C temperature optima for growth of common British species and their capacity for rapid uptake (and use in growth) of N and P sources over a range of external concentrations helps to account for its high productivity and biomass in the warmer months in high-nutrient estuaries. With no morphologically distinguishable resting stage the capacity of individuals to over winter under low light, frequently anoxic and sulphide rich, and sometime ice-encased

conditions help to provide inoculum for growth in the next favourable season. These characteristics do not necessarily distinguish *Enteromorpha* from the other Ulvophyceae macroalgae (e.g. species of *Chaetomorpha*, *Cladophora* and *Ulva*) which are usually common but less abundant in nutrient-rich estuaries, at least in North-Eastern Scotland, but may in combination help to explain why other macroalgae are less successful in these habitats.

POWTONGSOOK, S. and D.J. GILMOUR (Department of Molecular Biology and Biotechnology, University of Sheffield, Sheffield S10 2UH). **Production of glycerol by immobilised *Dunaliella parva*.**

Dunaliella accumulates intracellular glycerol as its osmoticum when exposed to high salinity. The leakage of glycerol from *Dunaliella* cells is studied as a potential commercial source of glycerol. In order to increase the efficiency of glycerol production, *Dunaliella parva* (CCAP 19/9) was immobilised using calcium alginate beads. Algal beads were prepared by mixing concentrated algae with 2.5% (w/v) sodium alginate and adding dropwise into 0.1 M calcium chloride solution. Beads were incubated in culture medium containing 1.5 M sodium chloride. The physiological study of algal beads was investigated by the determination of chlorophyll content, oxygen evolution and chlorophyll fluorescence. Glycerol production/leakage was determined by using an enzymatic method.

PROBERT, I.P., E. ERARD-LE DENN¹ and J. LEWIS (Applied Ecology Research Group, University of Westminster, 115 New Cavendish St, London WC1; ¹FREMER, Centre de Brest, BP70, 29280 Plouzané, France). **Sexuality and encystment as a contributory factor in bloom decline - A preliminary field survey of an *Alexandrium minutum* bloom in the Aber Wrac'h, Brittany.**

A largely monospecific bloom of the toxic dinoflagellate *Alexandrium minutum* Halim, with a maximum density of 55 million cells/liter, occurred in the Aber Wrac'h estuary in late July/August 1995, resulting in the prohibition of shellfish collection over a one month period. Surface water and surface sediment samples were taken daily at a fixed location and a fixed point in the tidal cycle. Cell numbers and size, and proportion of cells at different life stage (vegetative cells/planozygotes) were recorded. The cellular content of carbon, nitrogen and amino acids was analysed, together with external nutrient concentrations (ammonium, nitrate and phosphate). Cyst numbers were counted from sediment samples.

The bloom coincided with an extended period of unusually favourable environmental conditions (high temperature, low wind and rainfall, and low tidal amplitude). In the absence of significant environmental dispersion mechanisms, the population had the opportunity to utilize the available nutrient resource and hence develop to a very high density. Under these circumstances, the transition from vegetative to sexual reproduction, associated with intracellular nutrient status, may have been a significant factor in regulating bloom decline.

RATCHFORD, I.A.J. and H.J. FALLOWFIELD. (Biochemical Sciences Department, Scottish Agricultural College, Ayr, Scotland Author for correspondence; Environmental Health Unit, Dept Clinical Pharmacology, Flinders University of South Australia, Adelaide 5001 Australia).

The effect of light / dark cycles of medium frequency on the photosynthetic and respiration rates of *Chlorella vulgaris* 211/11c and *Synechococcus* 1479/5.

The effect of light / dark cycles on micro-algal productivity has been well examined, however, little attention has been paid to the effects of medium frequency light / dark cycles (associated with the photic zone of a water body) on photosynthetic and respiration rates. Short term incubations (24 hours) in an oxygen electrode chamber with light dark cycles (produced by a cyclic relay switch) were found to be extremely important in preventing photoinhibition. Exposure to light intensifies at photon flux densities associated with photoinhibition could be offset in both *Chlorella vulgaris* 211/11c and *Synechococcus* 1479/5 provided the cells received a specific amount of time in the dark. This dark incubation time prevented an overall reduction in the rate of oxygen evolution. Light dosage was not found to be an important factor in the studies.

RATCHFORD, I.A.J., R.C. NOBLE, L.T. WEAVER¹ and S. AMARRI¹. (Biochemical Sciences Department, Scottish Agricultural College, Ayr, Scotland; ¹Dept of Nutrition, YorkHill Sick Children's Hospital). **The production of ¹³C labelled docosahexaenoic acid from the marine microalga *Isochrysis* sp.**

^{13}C analysis represents a safe method of analysing the absorption, distribution, digestion and function of important fatty acids such as docosahexaenoic acid (DHA) in premature babies and infants. The production of specific ^{13}C labelled fatty acids is both expensive and difficult to carry out in the laboratory. A novel flat plate air lift photobioreactor has been designed and constructed to obtain high biomass concentrations from the marine alga *Isochrysis sp.* whilst providing the organism with ^{13}C labelled NaHCO_3 . ^{13}C labelled carbon is partitioned into DHA and other fatty acids by the growing cells. Increased levels of up to 80% of DHA and stearidonic acid were found in cells cultured at a temperature of 17°C compared to higher temperature cultured cells. Cultures allowed to enter stationary phase of growth displayed a lower phospholipid to triglyceride ratio at all growth temperatures. The results suggest that freshwater and marine microalgae represent an untapped method of producing ^{13}C intermediates when fed with appropriately labelled carbon dioxide or NaHCO_3 .

RAVEN, J.A.^{1,2}, J. BEARDALL¹, A.M. JOHNSTON², J.E. KÜBLER² and S. MCINROY² (¹Department of Ecology and Evolutionary Biology, Monash University, Clayton, VIC 3168, Australia, ²Department of Biological Sciences, University of Dundee, Dundee DD1 4HN, UK; ²permanent address of JAR). **Inorganic carbon acquisition by *Xiphophora chondrophylla* (Phaeophyta: Fucales).**

Measurements of parameters related to photosynthesis, with particular reference to the mechanism of inorganic C acquisition, were made on *Xiphophora chondrophylla* (R. Brown ex Turner), an Australian fucoid living in the upper subtidal and in low intertidal rock pools. Photosynthesis as a function of incident photon flux density and external inorganic C concentration, capacity to use HCO_3^- , diel changes in titratable acidity of cell contents ('CAM-like' behaviour), rates of dark inorganic ^{14}C fixation, and the d^{13}C values of plant organic C, were similar to values previously found for emersed and submersed specimens of the sympatric *Hormosira banksii* (Turner) Decaisne. This is consistent with the proposed close relationship of the general *Hormosira* and *Xiphophora*, and with earlier work showing the phyletic, as well as ecologically adaptive, importance of certain characteristics of inorganic C acquisition in the Fucales and related fucoids. The N content of *Xiphophora chondrophylla* was rather higher than that of sympatric *Hormosira banksii* (and its epiphyte *Notheia anomala* Harvey et Bailey: Fucales), so that the photosynthetic rate per unit tissue N was lower than that of these two algae and closer to that of some North Atlantic Fucales. Other things being equal, the photosynthetic characteristics of *Xiphophora chondrophylla* would make it more prone to overgrowth by the epiphyte *Notheia anomala* than is the alternative phorophyte, *Hormosira banksii*.

REID, G. and E.J. COX. (Department of Botany, The Natural History Museum, Cromwell Road, London, SW7 5BD). **The morphology of some sigmoid Naviculaceae (Bacillariophyta).**

The diatom genera *Gyrosigma* Hassall and *Pleurosigma* Wm. Smith are readily recognised taxa which include some very widespread marine intertidal species. However, not only have definitions varied at the generic level, but the specific limits are poorly understood and allocation to species is often very difficult. A detailed morphometric analysis was therefore initiated on taxa within these genera, including the type specimens of many taxa. The main morphological features of sigmoid naviculoid diatoms are reviewed and a protocol for specimen comparison is presented. The usefulness of the different characters in the identification and classification of *Gyrosigma* and *Pleurosigma* species is discussed.

RICHES, C.J., C.E. ROLPH and P.K. ROBINSON. (Dept. of Applied Biology, University of Central Lancashire, Preston, Lanes. PR1 2HE). **The effects of heavy metals on lipids from *Selenastrum capricornutum*.**

The effects of heavy metals (cadmium, copper and zinc) on lipids from *S. capricornutum* Printz (CCAP 278/4) have been investigated. Algal cells were grown at their metal EC-50 values of $5.7\ \mu\text{M}$, $124\ \mu\text{M}$ and $20\ \mu\text{M}$ for Cd, Cu and Zn respectively, as determined from growth inhibition toxicity tests. Total lipid, phospholipid, neutral lipid and sterols were separated by TLC. Fatty acids from these profiles and sterol fractions were analysed by capillary-GC. Results reveal that exposure of *S. capricornutum* to the three metals produced an accumulation of acyl-lipid (105-133% of control levels). Exposure to Cd, Cu and Zn resulted in cells with phospholipid/triacylglycerol ratios of 2.16, 1.37 and 4.27 respectively (control ratio, 3.75). Cd and Cu exposure elevated the amount of palmitate and oleate, whilst Zn exposure only significantly increased cellular oleate. The levels of

polyunsaturated fatty acids remained approximately constant. Greater levels of monounsaturated and saturated fatty acids may have arisen from inhibition of the enzymes D⁹-desaturase and acyl-ACP transacylases. Preliminary data from sterol analysis indicates that *S. capricornutum* contains the three sterols, stigmasta-7-en-3 β -ol, stigmasta-7,22-3 β -ol and ergosta-7-en-3 β -ol and that exposure to metal results in an increase in sterols desaturated within the B ring. These changes will hopefully enable identification and quantification of these pollutants in aquatic freshwater environments.

IGLESIAS RODRIGUEZ, D. and M.J. MERRETT. (School of Biological Sciences, University of Wales, Swansea SA2 8PP, U.K.). **Dissolved inorganic carbon utilization by a marine picoeukaryote, *Micromonas pusilla*.**

Photosynthetic picoeukaryotes comprise a major proportion of the marine phytoplankton, particularly in oligotrophic waters. *Micromonas pusilla* is a typical picoeukaryote in size, with a cell volume of only 1-3 μm^3 , and although not a major component of oceanic phytoplankton the species has a wide distribution. Unlike other picoeukaryotes investigated, the cells of *Micromonas pusilla* develop extracellular carbonic anhydrase when grown on modified f/2 medium. In marine diatoms, the relative concentration of HCO₃ and CO₂ regulate the development of extracellular carbonic anhydrase, whereas in *M. pusilla*, the development of extracellular carbonic anhydrase is determined solely by the concentration of dissolved CO₂ in the medium. At CO₂ concentrations below 4 μM , the development of extracellular carbonic anhydrase is rapid, maximum activity being reached in under 60 min. The development of carbonic anhydrase activity is light dependent but only partially inhibited by DCMU. The development of extracellular carbonic anhydrase will increase the availability of CO₂ at the cell surface, which together with an increased affinity of the cells for CO₂, will increase the CO₂ concentration around Rubisco under conditions of carbon limitation.

SAKER-SAMPAIO, S., M-H. YANG, C.J. BARWELL and D.J. ROGERS. (University of Portsmouth, Pharmacy and Biomedical Science, Park Building, King Henry I Street, Portsmouth, PO1 2DZ, UK.). **Seasonal content of Vitamin E and pro vitamin A carotenoids in *Palmaria palmata*.**

The European marine red alga, *Palmaria palmata*, has a traditional use as a human food. Chemical and biochemical analysis has shown that the alga contains relatively high amounts of pro vitamin A carotenoids and some reports indicate the occurrence of vitamin E. We are evaluating the nutritional composition of the alga with particular regard to its content of vitamin E and pro vitamin A carotenoids. To this end we have developed methods for their quantitative extraction and HPLC analysis. The methods have been applied to algal material collected during each month of the year, together with isolation and identification of compounds by ¹H nmr analysis.

Vitamin E was not detected in any of the monthly samples of fresh alga, under conditions where added vitamin E (a-tocopherol) was quantitatively recovered and the assay sensitivity was 1 μg per g fresh weight. Throughout the year the quantitatively major pro vitamin A carotenoids were: Lutein (1-4 μg per g fresh weight), a-carotene (5-24 μg per g fresh weight) and β -carotene (2-10 μg per g fresh weight). These values indicate that *Palmaria palmata* would be a useful source of dietary pro vitamin A carotenoids.

SCHMID, R. and J. MAIER. (Fachbereich Biologie/Botanik, Universität Marburg, Lahnberge, 35032 Marburg, Germany; Institut für Chemische Pflanzenphysiologie, Universität Tübingen, Corrensstr. 41, 72076, Germany). **Inhibition of pteridine biosynthesis eliminates stimulation of red-light saturated photosynthesis by blue light in *Laminaria saccharina*.**

Earlier investigations (Schmid and Dring, 1993, *Planta* 191, 489-495) had shown that stimulations of photosynthesis by blue light could be inhibited by flavin quenchers. However, these quenchers also act on pterins because of their similar structure and properties. Pterins have been suggested to co-act with flavins in blue-UV photoreception of plants and fungi (Galland and Senger, 1988, *Photochem. Photobiol.* 48, 811-820).

To investigate whether pteridines might participate in light sensing for the stimulations of photosynthesis by blue light in *Laminaria* we used 2,4-diamino-6-hydroxypyrimidine (DAHP). DAHP competitively inhibits GTP-cyclohydrolase II, which catalyses the initial step of the biosynthetic pathway of pteridines. Five days of treatment with 5 mM DAHP reduced the content of the pteridines as analysed by HPLC. The amount of pterin was about 14%, that of biopterin about 45% and that of a yet unidentified pteridin was about 27% in comparison with untreated controls. By contrast, the amount of neopterin appeared to be higher, but this might be an artifact.

Concentrations of flavins were slightly increased. Concomitantly with the reduction of the pteridines, the ability of photosynthesis to be stimulated by blue light was completely abolished. These results suggest that pteridines may be involved in this response to blue light, possibly by participating in photoreception.

SKIDMORE, R.E., S.C. MABERLY¹ and B.A. WHITTON². (Institute of Freshwater, Ecology, Monkwood, Abbots Ripton, Cambs PE17 2LS; ¹IFE Windermere, Ambleside, Cumbria LA22 0LP; ²University of Durham, Biological Sciences, Durham DH1 3LE). **Phytoplankton dynamics in the rivers Yorkshire Ouse and Trent, eastern England.**

Preliminary studies in 1993-94 have shown that the Yorkshire Ouse and Trent have supported large phytoplankton populations. The Yorkshire Ouse is fed by upland rivers while the Trent is characteristic of a lowland river. As part of the Natural Environment Research Council's LOIS programme, a detailed study has been started to quantify the influence of environmental factors on phytoplankton dynamics and productivity in these rivers. Data from 1995 have characterised the seasonal and spatial (downstream) changes in biomass. Chlorophyll a estimations showed a maximum of 190 $\mu\text{g l}^{-1}$ on the Trent in early May 1995 while the Ouse showed a later maximum of 187 $\mu\text{g l}^{-1}$.

Data will contribute to a model of flux of autochthonous carbon into the estuary under changing environmental conditions.

SWAIN, L.J., D.J. ROGERS, A.T. CRITCHLEY¹, E.G. PETRAKI and C.O. GEORGAKOPOULOS (School of Pharmacy and Biomedical Science, University of Portsmouth, U.K., ¹Botany Department, University of Witwatersrand, Johannesburg, R.S.A.). **Lectins from species of the genus *Codium*.**

Species of the genus *Codium* have proved to be reliable sources of lectins which may be used as tools in biochemistry and biomedicine. Of the lectins from *Codium* species which have been examined so far, the best characterised are those from *C. fragile* ssp. *tomentosoides* and *C. tomentosuni*. We have recently investigated extracts from five previously unexamined *Codium* species from the Republic of South Africa. Extracts of all five species contained lectins which produced agglutination of human erythrocytes which was independent of the presence of divalent cations. *C. spongiosum* and *C. prostratum* extracts contained lectins which bound N-acetyl-Dgalactosamine (GalNAc), but surprisingly, the lectin from *C. duthiae* appeared to bind to the glycoprotein, fetuin, but not GalNAc. Insufficient material was available from *C. papenfussii* or *C. megalophysum* to determine the carbohydrate specificity of the lectins from these two species.

Seventeen species or subspecies of *Codium* have now been examined for lectin presence. Twelve of these lectins bind GalNAc, three have not been tested for specificity and two (lectins from *C. taylori* or *C. duthiae*) do not appear to bind GalNAc, but bind fetuin. The lectins from these two *Codium* species warrant further investigation to confirm this apparent and unexpected discrepancy.

WEBB, K. and D.M. WILLIAMS (Department of Botany, The Natural History, Museum, Cromwell Rd, London SW7 SBD, UK). **The relationship between historical collections and the determination of biogeographic boundaries in *Fragilariforma virescens*.**

Fragilariforma virescens is usually considered to be a cosmopolitan species, a fact apparently confirmed by Museum as well as literature records. Examination of representative slides from the diatom collection at the Natural History Museum, London, and drawing on a wide range of global localities, shows this not to be the case. By and large, specimens called *F. virescens* that occur in the Southern Hemisphere turn out not to be either mis-identified or 'new', while "true" *F. virescens* seems to be limited to the colder parts of the Northern Hemisphere.

This presentation will illustrate the "true" *F. virescens* as well as a range of mis-identified species. Biogeographic implications will be briefly discussed.

YANG, H-M, F-L. HUANG, G. BLUNDEN and R. L. FLETCHER (School of Pharmacy & Biomedical Science and School of Biological Sciences, University of Portsmouth). **The growth and development of juvenile stages of *Codium* spp. in relation to temperature, irradiance and salinity.**

Recent studies of the marine algal flora of marinas on the south coast of England have revealed the occurrence of a juvenile growth form of *Codium fragile* subsp. *tomentosoides* (Goor) Silva. In habit it forms dark green, velvety, cushion-like thalli comprising erect, branched, closely packed, loosely

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WEBB, K. and D.M. WILLIAMS (Department of Botany, The Natural History Museum, Cromwell Rd, London SW7 SBD, UK). **The relationship between historical collections and the determination of biogeographic boundaries in *Fragilariforma virescens*.**

Fragilariforma virescens is usually considered to be a cosmopolitan species, a fact apparently confirmed by Museum as well as literature records. Examination of representative slides from the diatom collection at the Natural History Museum, London, and drawing on a wide range of global localities, shows this not to be the case. By and large, specimens called *F. virescens* that occur in the Southern Hemisphere turn out not to be either mis-identified or 'new', while "true" *F. virescens* seems to be limited to the colder parts of the Northern Hemisphere.

This presentation will illustrate the "true" *F. virescens* as well as a range of mis-identified species. Biogeographic implications will be briefly discussed.

YANG, H-M, F-L. HUANG, G. BLUNDEN and R. L. FLETCHER (School of Pharmacy & Biomedical Science and School of Biological Sciences, University of Portsmouth). **The growth and development of juvenile stages of *Codium* spp. in relation to temperature, irradiance and salinity.**

Recent studies of the marine algal flora of marinas on the south coast of England have revealed the occurrence of a juvenile growth form of *Codium fragile* subsp. *tomentosoides* (Goor) Silva. In habit it forms dark green, velvety, cushion-like thalli comprising erect, branched, closely packed, loosely

associated, coenocytic siphons very similar in appearance and structure to *Derbesia marina* (Lyngb.) Soler. It is from this growth form that the erect *Codium* plants arise; however, they frequently occur independently of the latter, appear more tolerant of environmental conditions and are likely to play an important role in vegetative reproduction via siphon fragmentation.

The present study was undertaken to determine if similar growth forms occur of other *Codium* species present around the British Isles and to investigate the effect of various environmental conditions on their growth and development. Species investigated to date include *C. fragile* subsp. *atlanticum* (Cotton) Silva and *C. tomentosoides*, *C. adhaerens* (Cabr.) C. Ag., *C. bursa* (L.) C. Ag., *C. tomentosum* Stackh. and *C. vermilara* (Olivi) Chiaje. Unialgal cultures were established for all taxa from isolated utricles and growth studies performed under different conditions of temperature (10-30°C), irradiance (0-175 $\mu\text{mol m}^{-2} \text{s}^{-1}$) and salinity (0-100% seawater growth medium). All cultures developed into juvenile growth forms similar to that described for field material of *C. fragile* subsp. *tomentosoides*. All growth forms grew rapidly in culture although the conditions for optimum growth did sometimes differ for individual species. For example, the optimum salinities for *C. adhaerens*, *C. vermilara*, *C. tomentosum* and *C. bursa* were 90%, 80%, 90% and 100% seawater respectively. The development of *Codium* plants, with utricles, similar to the parental material, occurred only occasionally in culture.