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CONTENTS

British Phycological Society Council	2
Announcement of BPS Studentships	3
Announcement of Scholarship Support for Field Courses	3
50th Anniversary of the BPS	4
BPS Winter Meeting 1999	5
Forthcoming Meetings	5
Freshwater Algal Course	7
Winter Meeting 1998 Abstracts	
Talks	8
Posters	32

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BPS Summer Research Studentships

In 1998, the BPS will again be offering up to two summer studentships (maximum value £500) to support undergraduate or prospective postgraduate students for four weeks (longer if you can make the award stretch that far) research 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 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 more than one side of A4) describing the project and the costs involved, and how it conforms to the objectives of the scheme. Proposals should be submitted no later than 30 April 1997. Supervisors will be notified by 14 May.

Address Proposals to: Dr Richard Geider
Secretary, British Phycological Society
Marine Biological Association of the United Kingdom
Citadel Hill
Plymouth PL1 2PB

Student Scholarships for Field Courses

The BPS will consider support of students who wish to attend field courses organised by bodies such as the Field Studies Council or summer schools at field stations of North American Universities, provided such courses are primarily directed at aspects of phycology. Applications should include information about the course, a brief c.v., a statement of support from a full member of the Society or the student's supervisor, and the student's budgetary plans for the course. A sum of up to £250 may be granted dependent on the nature of the course and the strength of the case.

Address Proposals to: Dr Richard Geider
Secretary, British Phycological Society
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BRITISH PHYCOLOGICAL SOCIETY 50TH ANNIVERSARY

The BPS was founded in 1952, following discussions in 1951 and followed by the acceptance of formal documentation in 1953. We celebrated the 25th anniversary in 1977 and it seems fitting that we should celebrate the 50th anniversary in 2002. This seems like quite a long way off, but, dependent on how we choose to celebrate the occasion, a relaxed planning horizon could avoid last-minute rushes.

The BPS Council has set up a small committee (myself as chair, Juliet Brody, Janet Kubler, Elliott Shubert, John Berges) to canvass opinion and make proposals on how the Society might proceed. The committee is anxious that consultation among the membership should be as wide as possible.

There were preliminary discussions at the 1998 AGM in London and I have written to a small sample of senior members to canvass their views. However, these constitute only a small proportion of the total membership so the purpose of this note is to ask the entire membership what it thinks the Society should do to celebrate its history and future.

This you can do by writing to me: Prof. Brian Moss, School of Biological Sciences, Derby Building, University of Liverpool, LIVERPOOL L69 3BX or sending me an e-mail: brmoss@liverpool.ac.uk All contributions will be considered by the committee.

We hope that there will be a substantial response - all ideas are very welcome - so that the committee can propose something that will please as many members as possible and do something very positive for phycology.

Thanks, Brian M

R Geider adds: The Jubilee celebration was considered briefly at the January 1988 Annual General Meeting. There were suggestions for activities that would be of particular interest to members of the society and also of activities that would appeal to the general public. It was suggested that the BPS explore the possibility of hosting the European Phycological Congress in 2003. It was generally acknowledged that the celebration should be forward and outward looking, promote greater awareness of algae, and include a venue for public and primary school children. Amongst the specific suggestions were (1) an exhibition to tour museums around the country, (2) a color poster for distribution to every biology laboratory in the country, (3) a slide show/video. Women have played key roles in the development of and promotion of phycology. Thus, it was also suggested that we record the role of women in the society and use this as a means to promote women in science.

BPS WINTER MEETING 1999

4-7 January 1999, University of Dundee, Scotland

The next BPS Winter Meeting will take place from 4-7 January 1999 at the University of Dundee. Professor John Raven is the local organiser. There will be an informal poster session and 2 1/2 days of papers. The topic of the Applied Day (5 January) will be "Threatened and Threatening Algae." This topic recognises man's damaging effect on algae and *vice versa* (namely that damage to man by algae is usually a product of man's intervention in the first place). There will be special sessions on "Uses and abuses of measurements of natural abundance of stable isotopes," "The species concept in algae," and "The carbon dioxide concentrating mechanisms in algae." The Manton prize will be awarded for best student presentation. A prize will be awarded for best student poster. Further details will be provided in the August issue of *The Phycologist*.

CHANGES IN THE MARINE FLORA OF THE NORTH SEA

July 13-15 1998, University College Scarborough, Scarborough, North Yorkshire, UK.

The conference, organised jointly with the Natural History Museum, will explore the patterns, monitoring, causes and consequences of recent changes in the marine flora of the North Sea. It will present a synthesis of current work in this area and, through field based workshops, investigate recent developments in biotope and biodiversity surveying. Sponsorship for the publication of a conference volume is currently being sought, and it is intended that prizes will be awarded for the best post-graduate talk and poster.

Contributions in the form of papers and posters are now invited. To offer a contribution or register your interest in attending the conference, please contact: Mary Barry, CERCI, University College Scarborough, Filey Road, Scarborough, North Yorkshire, YO11 3QG, UK Tel 01723 362392 Fax 01723 370815 Email maryb@ucscarb.ac.uk

CHEMISTRY AND ECOLOGY OF HIGHLY ACIDIC ENVIRONMENTS

University of Durham, England, from 16-19 August 1998.

The aim is to bring together researchers from various disciplines concerned with chemistry, microorganisms and general ecology of highly acidic environments. Aspects to be covered include mine drainages, thermal and non-thermal natural springs and fumaroles and the more severe effects of acidic atmospheric deposition on waters and terrestrial surfaces - basic science and practical problems of control. Algae are usually the most conspicuous organisms in such environments!

Anyone interested in this subject and who would like to participate, please contact Brian Whitton (email b.a.whitton@durham.ac.uk; Department of Biological Sciences, University of Durham, Durham DH1 3LE). Co-organizers are Dr Patrizia Albertano (Dipartimento di Biologia, Università degli Studi di Roma "Tor Vergata", Italy) and Dr Ken'ichi Satake (National Institute for Environmental Studies, Tsukuba, Japan).

The FLAGELLATES

An International Symposium

University of Birmingham, UK

September 7th – 10th, 1998

The purpose of this International Symposium is to examine flagellates from a multidisciplinary standpoint. Of primary concern will be the unifying structures, mechanisms and processes involved in flagellate biology. Other objectives will include exploration of the enormous diversity that occurs amongst flagellates generally, and of the latest information on flagellate phylogeny.

The meeting will include invited keynote addresses and contributed papers and posters. There will also be opportunities for informal discussions and workshops.

The keynote contributors include:

Common aspects of flagellates

Barry Leadbeater (UK) *Historical perspectives*
John Raven (UK) *The flagellate condition*
Mike Holwill (UK) *Flagellar propulsion*
Øyvind Moestrup (Denmark) *Cytoskeleton: ultrastructure*
Jeff Salisbury (USA) *Cytoskeleton: molecular aspects*
Burkhard Becker (Germany) *Flagellate surfaces*
Hiroshi Kawai (Japan) *Sensory mechanisms*

Diversity

Michael Sleight (UK) *Trophic strategies*
Guy Brugerolle (France) *Amitochondriate flagellates*
Keith Vickerman (UK) *Adaptations to parasitism*
Johanna Laybourn-Parry (UK) *The microbial loop*
Hartmut Arndt (Germany) *Functional diversity of flagellates in aquatic ecosystems*
David Patterson (Australia) *Biogeography*
Linda Medlin (Germany) *Flagellate populations*

Evolution

Mark Farmer & Marshall Darley (USA) *Organelles: evolutionary aspects*
Serguei Karpov (Russia) *Ultrastructural perspectives*
Tom Cavalier-Smith (Canada) *Flagellate megaevolution*

For further information, please contact the organisers:

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FRESHWATER ALGAL COURSE

A freshwater algal course will be conducted at the Kindrogan Field Centre (operated by the Scottish Field Studies Association) in the scenic Scottish highlands from the 25th of July to the 1st of August 1998 by Dr Eileen J Cox and Dr L Elliot Shubert (Department of Botany, The Natural History Museum, London). The area around Kindrogan has many different kinds of habitats (streams, rivers, ponds, lochs and bogs) supporting a diversity of freshwater and subaerial algal species. During last year's course, over 270 taxa representing ten divisions were identified. The course is designed for advanced undergraduate students, postgraduate students, biology teachers, those in a professional capacity who need to further their knowledge in algae, and others interested in freshwater ecosystems. Participants will receive both field and laboratory experience. The cost of the course is 335 GBP (approximately 536 USD), which includes accommodation, meals and tuition. Overseas participants can fly to Edinburgh or take the Eurostar and connect with a mainline train (originates at London Kings Cross via Edinburgh) to Pitlochry, where they will be met by a van from Kindrogan.

The course will be limited to 10 registrants on a "First Come, First Serve" basis. To ensure a place on the course you must complete the Kindrogan Booking Form and include a non-refundable deposit of 50 GBP (cheques only, in Sterling, payable to the Scottish Field Studies Association). Applications should be sent to the Kindrogan Field Centre. Two additional registrants will be selected from applications submitted by student members of the British Phycological Society.

Student members of the British Phycological Society are encouraged to apply for partial support of the course fees. Membership details can be obtained from Dr Laurence Carvalho (lcarvalh@geography.ucl.ac.uk). Two stipends of 250 GBP are available. Please send typewritten request on one page, including the following: 1. Name, address, telephone number, fax number and E-mail address. 2. Education (Institution, Degree, Date, include work in progress and expected completion date). 3. Briefly, explain how attending this course will contribute to your educational and professional development. 4. Name, address, telephone number, fax number and E-mail address of your research supervisor. 5. A letter of recommendation from your research supervisor sent under separate cover. 6. Send to Dr L E Shubert, Department of Botany, The Natural History Museum, Cromwell Road, London SW7 5BD, UK (overseas via airmail) 7. Deadline for receipt of application and letter of recommendation is 6 May 1998.

In addition, one outstanding applicant may be eligible for a British Ecological Society stipend. For more information and an application form contact: Ms Hazel Norman, BES, 26 Blades Court, Deodar Road, Putney, London, SW15 2NU, UK

FOR MORE INFORMATION AND APPLICATION FORMS

For a brochure describing Kindrogan Field Centre (location, facilities, courses and booking form) E-mail: Kindrogan@btinternet.com or write to: Kindrogan Field Centre, Enochdhu, Blairgowrie, Perthshire PH10 7PG, UK (telephone 0044 (0)1250 88 12 86; Fax 0044 (0)1250 88 14 33). For specific information about the course, please contact Dr L E Shubert (e.shubert@nhm.ac.uk)

For a student view of the course, see the Newsletter of the British Phycological Society (The Phycologist, Number 48, November 1997).

BRITISH PHYCOLOGICAL SOCIETY

Winter Meeting 1998

5-8 JANUARY 1998

Royal Holloway - University of London

ORAL PRESENTATIONS

ANDERSON¹ N. J. & I. Renberg² (¹Environmental History & Climate Department, Geological Survey of Denmark & Greenland Thoravej 8, Dk-2400 Copenhagen NV; ²Department of Environmental Health, University of Umeå, S-901 87 Umeå, Sweden). **Diatoms in annually-laminated lake sediments: the ultimate long-time series?**

Few biological time series are longer than 10-20 years although there are occasional records covering the last 50-years (e.g. English Lake District). For most lakes, of course, there is no information available at all. Lake sediments have been used extensively recently to provide complementary perspectives of cultural disturbance to those derived from contemporary monitoring programmes. Lake sediment records provide a longer-term temporal perspective and permit baselines for a number of biochemical indices to be determined. Annually-laminated sediments (or varves) are formed by the preservation of distinct seasonal inputs to the sediment from seasonal peaks in biological productivity or from the catchment. The best preserved varve sequences provide inter-annual temporal resolution records for hundreds of years. Examples will be given of annually-laminated time series from some Swedish boreal forest, dimictic lakes. Special emphasis is placed on the changes in the diatom communities in the lakes. Our recent attempts to use the long-term records to determine links between meteorological variability and diatom productivity will also be illustrated.

ANNING¹ T., H. MacIntyre², S. Pratt¹, P. Sammes¹, & R. Geider¹ (Marine Biological Association, Citadel Hill, Plymouth PL1 2PB, UK; e-mail: t.anning@wpo.nerc.ac.uk; ²Horn Point Environmental Laboratory, PO Box 775, Cambridge MD, 21613-0775, USA). **Mechanisms of photoacclimation in *Skeletonema costatum*.**

Regulation of photosynthesis in response to irradiance is hypothesised to be controlled at two levels. First by a group of molecules whose abundance does not vary, including the enzyme Rubisco and the ribosomes, and second by a group of molecules whose abundance changes including chlorophyll *a*, other photosynthetic pigments and components of the photosynthetic electron transfer chain. A light-shift experiment was undertaken to investigate the physiological and molecular regulation of photosynthesis in the marine diatom *Skeletonema costatum*. Fed- batch cultures were grown under nutrient-replete conditions at 50 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$ under a 12:12 light/dark cycle. Cultures were transferred to 1200 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$ until fully acclimated and then placed back to the original light level. Physiological responses suggest that the cells take 5 days to acclimate to an increase in light (as indicated by a 2-fold decrease in chlorophyll *a* cell^{-1}), and three days to adjust to a decrease in irradiance. This decrease in chlorophyll *a* cell^{-1} was paralleled by an increase in the chlorophyll *a* - specific maximum rate of photosynthesis. Additional physiological changes i.e. cell carbon, nitrogen and pigments will be discussed alongside changes in the levels of gene expression and protein abundance of Rubisco and the fucoxanthin light-harvesting complex protein.

BATTARBEE R.W. (Environmental Change Research Centre, University College London, 26 Bedford Way, London, WC1A 0HP; e-mail: rbattarb@geog.ucl.ac.uk). **Diatoms and long-term environmental change.**

Diatom analysis as a technique for reconstructing past environmental change came to major prominence in the 1980s during the so-called "acid rain debate". It was the diatom evidence for recent

lake acidification that helped to persuade the Thatcher government to throw in the towel and admit the causal link between sulphur emissions from power stations and environmental damage in the uplands of Britain and Scandinavia. Since those heady days diatomists have been busy developing similar methods for reconstructing and salinity history of lakes, and exploring how diatoms can be used as indicators of past climates. In this talk I will briefly introduce how modern diatom-chemistry training sets and transfer functions are derived, and then review how salinity, pH and total phosphorus transfer functions are being used in long-term climate change studies. Examples will be drawn from a wide range of lakes and time periods.

BERGES¹J. A., C. Gibson² & B. Stewart² (¹School of Biology and Biochemistry, Queen's University of Belfast, BT9 7BL, Northern Ireland, e-mail: j.berges@qub.ac.uk; ²Agriculture and Environmental Sciences Division, Department of Agriculture for Northern Ireland, Newforge Lane, Belfast). **Differing responses of phytoplankton communities in the Irish Sea to simulated upwelling.**

Models of marine production often treat phytoplankton as particles of chlorophyll responding uniformly to changes in irradiance and nutrients. Data collected while studying nitrogen uptake in the western Irish Sea, illustrates some limitations of this approach. In May and June 1996, phytoplankton from depth were sampled from nearly identical physical environments. 20 L samples were either left untreated (control) or enriched with 20 μM nitrate, and irradiance was increased to 50% of surface levels. Over 24 h, variable fluorescence (F_v/F_m), nitrate reductase activity (NR), nutrients, chlorophyll and particulate C and N were monitored. Initial chlorophyll *a* ($\sim 3 \mu\text{g L}^{-1}$), phosphate ($\sim 0.2 \mu\text{M}$), nitrate and silicate ($\sim 3 \mu\text{M}$) were similar in both months. In May, F_v/F_m stayed constant (0.5), and particulate C, N and chlorophyll did not change, although NR increased in all samples. In contrast, in June, F_v/F_m was near the theoretical maximum (0.7-0.8) initially, and remained constant in enrichments, but fell drastically in controls. Declines in controls were also seen for chlorophyll, particulate C and N, and NR activity. Thus, the addition of 20 μM nitrate had a significant effect even though ambient levels of nitrate ($>1 \mu\text{M}$) were not limiting. Microscopic examination revealed that while small flagellates predominated in the May samples, in June a variety of large chain-forming centric and pennate diatoms were found. We conclude that the response of a phytoplankton community is dependent on factors poorly represented by bulk measurements of chlorophyll and particulate elements.

BIRKETT D. A., M. J. Dring & G. Savidge. (QUB Marine Laboratory, The Strand, Portaferry, County Down, BT22 1PF, Northern Ireland; e-mail: D.Birkett@Queens-Belfast.ac.uk). **Primary production estimates for phytoplankton, macroalgae and microphytobenthos in a coastal ecosystem.**

Productivity estimates were made over a three year period for the coastal phytoplankton, the most abundant inter-tidal and sub-tidal macroalgal species and for the intertidal epipsammic microphytobenthos within the marine nature reserve of Strangford Lough, Northern Ireland. Several hundred phytoplankton samples were collected for chlorophyll *a* determination and 88 samples (collected approximately weekly) were incubated with ^{14}C to determine photosynthetic parameters (a , P_B^{max} , I_k). A total of 253 estimates of production were made with entire plants of *Ascophyllum nodosum*, *Fucus vesiculosus*, *F. serratus*, *Laminaria digitata*, *L. saccharina* and *L. hyperborea* using large (70 l) sealed perspex incubation chambers deployed *in situ*. Oxygen concentrations within the chamber were monitored continuously (YSI 6000 data logger & oxygen electrode) in order to estimate net production. A similar method was used to estimate oxygen production by the microphytobenthos for which additional estimates were made from a series of ^{14}C incubations. Phytoplankton production was estimated for the inter-tidal, shallow sub-tidal and sub-10 m depth areas of the Lough as 812, 5952 and 3394 tonnes C yr^{-1} respectively (total annual production 10,158 tonnes C). Net annual production by the inter-tidal macroalgae (standing stock of 276,281 tonnes wet

mass) was 24,098 tonnes C yr⁻¹; sub-tidal macroalgae (286,864 tonnes wet mass) contributing 68,582 tonnes C yr⁻¹ to the Lough. The inter-tidal area of the Lough has a mean shore width of 175 m; 43% of this area is rock, boulders and stable pebble, the remaining 57% of the area is composed of fine gravel, sand and mud. The productivity of these inter-tidal sediments was estimated as 1,895 tonnes C yr⁻¹.

BOWN¹ P., J. Plumb², J. Brodie² & P. K. Hayes¹ (¹University of Bristol, School of Biological Sciences, Woodland Road, Bristol BS8 1UG, UK; email: paul.hayes@bristol.ac.uk; ²Bath Spa University College, Newton Park, Newton St Loe, Bath BA2 9BN, UK; j.brodie@bathspa.ac.uk). **A molecular approach to species diversity of green and brown algal endophytes in the red alga *Chondrus crispus*.**

The red alga *Chondrus crispus* is host to a range of green and brown algae which are endophytic to a greater or lesser extent. On British shores, green and brown algal endophytes have been isolated from the cortex and medullary region of fronds of *C. crispus*. On the basis of their morphology the green algae have been identified as *Acrochaete operculata*, *A. repens*, *A. viridis*, *Enteromorpha* spp., *Phaeophila dendroides*, and *Pseudoendoclonium*, and the brown algae assigned to the genus *Streblonema*. The morphology of these algae can be highly variable and is influenced by environmental factors. Furthermore, the algae need to be isolated from the host and grown in culture before identification can be attempted. Preliminary results suggests that these algae can be distinguished using molecular techniques and that species diversity may be greater than currently realised.

BOYE M., A. Aldrich, G. Sarthou, & S. van den Berg (Oceanography Laboratories, Earth Science Department, Liverpool University, Liverpool, L69 3BX, UK). **Speciation of iron and zinc in cultures of *Emiliana huxleyi*.**

Cultures were set up in which the organism was grown in seawater with addition of nitrate and phosphate only, without addition of EDTA. The seawater was "cleaned" to bring the levels of trace metals down to oceanic conditions. The cell density of the cultures was low, growing from around 1,000 to 50,000 cells ml⁻¹, and the cultures grew very slowly with doubling rates of 0.3 d⁻¹ in the exponential phase. Some very interesting observations were made: 1. Organic iron and zinc binding ligands were released 2. Organic iron binding ligands were removed from solution at high ligand concentrations 3. The culture became iron-limiting at a total iron concentration of ~1.5 nM; however, it is likely that the free iron concentration (as Fe³⁺) was on the order of 10-20 pM due to organic complexation 4. The concentration of zinc binding ligands was about 5x greater than that of iron binding ligands indicating that they are different.

BUITENHUIS E., K. Timmermans, & H. de Baar. (Netherlands Institute for Sea Research, Texel, P.O. Box 59 1790, AB Den Burg, Texel, The Netherlands). **Zn-C co-limitation of *Emiliana huxleyi*.**

In analogy to the iron-hypothesis, Morel *et al.* (1994) have coined the Zn-hypothesis, which states that Zn may limit primary production and therefore influence the global carbon cycle. The proposed mechanism is that photosynthesis would be carbon limited due to a lack of the cofactor Zn in carbonic anhydrase. We have determined the K_m for growth of *Emiliana huxleyi* at 18 pM Zn²⁺ at ambient dissolved inorganic carbon concentrations, and a minimum requirement of 11 pM. The Zn²⁺ concentration in the North Pacific is 0.1 to 1 pM (Bruland 1989), showing that Zn-limitation may indeed occur. In the current model for inorganic carbon use by *E. huxleyi* (Nimer *et al.* 1995) carbonic anhydrase is present in the chloroplast to generate CO₂ from HCO₃⁻ at the site where it is fixed by Rubisco (Ribulose biphosphate carboxylase oxygenase). The H⁺ that is required in this reaction is produced in calcification (Buitenhuis & de Baar, submitted). From this it can be expected that carbonic anhydrase couples calcification to photosynthesis. We have tested this by growing *E.*

huxleyi under Zn^{2+} - HCO_3^- co-limitation. The results are inconsistent with the model. The experiment was conducted at a constant high concentration of CO_2 , but at low Zn^{2+} *E. huxleyi* was unable to use this CO_2 , showing that Zn^{2+} and possibly carbonic anhydrase activity are needed for CO_2 fixation also. It was also found that HCO_3^- can reduce the Zn^{2+} -requirement of *E. huxleyi*, but it was not determined whether this was due to a high calcification rate generating more H^+ , or due to an increase in the uncatalysed conversion of HCO_3^- into CO_2 in the chloroplast.

CALLOW M. E., J. A. Callow, J. D. Pickett-Heaps* & R. Wetherbee*. (School of Biological Sciences, The University of Birmingham, Birmingham, B15 2TT, UK; *Department of Botany, University of Melbourne, Parkville, Victoria 3052, Australia). **Primary adhesion of *Enteromorpha* zoospores.**

The importance of *Enteromorpha* as a ship fouling alga is widely recognised. Reproduction is through the production of large numbers of various types of reproductive propagules. High resolution video microscopy revealed novel features of the stages of zoospore and zygote settlement and adhesion, including; i) a possible role for the apical dome (not the flagella) in sensing the substratum involving top-like spinning behaviour, ii) a temporary adhesion phase, iii) a phase of commitment to permanent adhesion involving massive vesicular activity in the anterior region of the spore culminating in the release of adhesive, iv) gregarious settlement behavior and exploitation of the substratum via amoeboid-like movements. Standardised protocols have been employed to study the settlement and attachment of *Enteromorpha* spores. Zoospores and zygotes adhere rapidly but a proportion of any one population does not adhere within 48 hours and appeared incompetent at attaching to the substratum. Only a small percentage of gametes adhered within 48 h. Kinetic analyses of zoospore adhesion data were performed in order to provide insight into adhesion mechanisms. Scatchard plots indicated positive cooperativity at low spore densities and negative cooperativity at high spore densities. The possible mechanisms and significance of density-dependent spore adhesion will be discussed.

CHARRIER¹ S., A. Weeks¹, S. Lewey¹ & I. Robinson² (¹ Maritime Faculty, Southampton Institute, ²Department of Oceanography, University of Southampton). **Predicted underwater light in tidal waters and its possible effects on algal pigment content.**

The intertidal vertical zonation patterns of seaweed present a succession of different species, which result from many interacting factors. The amount of available light at a given site can be predicted using a model. An *in situ* experiment was carried out to study the response of intertidal algae to variations in the underwater light field caused by tidal levels. The amounts of photosynthetic pigments were measured in several common species (*Fucus* sp., *Ascophyllum nodosum*, *Ulva* sp., *Porphyra* sp.). These were attached to a pier at different levels above Chart Datum, in the intertidal zone of the Hamble Estuary (South England, UK). Observations were taken over two fortnightly periods in March and April 1997. The underwater light available to the algae during these experiments was estimated using a simple mathematical model which uses the vertical irradiance attenuation coefficient, K_d . During the study periods the vertical distribution of the predicted underwater light shows great variability with daily and lunar tidal cycles. These results reveal how phased tidal level fluctuations affect the underwater light available to intertidal seaweed, and how this may cause them to continuously optimise their pigment content in order to maintain the required level of energy acquisition.

COX E. J. (Department of Botany, The Natural History Museum, Cromwell Road, London, SW7 5BD; e-mail: e.j.cox@nhm.ac.uk). ***Stauronella* Mereschkowsky rediscovered: an intriguing benthic marine diatom genus with representatives worldwide.**

In 1903 Mereschowsky designated the genus *Stauronella* for a benthic marine diatom species originally described as *Amphiprora constricta* by W. Smith in 1853, but usually placed in *Stauroneis* because it possessed a transverse stauros. However, not only does *Stauronella* possess a different type of chloroplast and pore construction than *Stauroneis*, but the latter is now considered to be an exclusively freshwater genus, typified by *S.phoenicenteron*. *Stauronella* has not been recognised as a valid genus in recent reviews of the diatoms, even though its type species is distinctive and easily recognised. Specimens of *S.constricta* were first collected by the author over 20 years ago, but it has subsequently been found in a variety of localities and studied with both LM and EM. Other species of the same genus have also been examined. This paper will describe the important characteristics of the genus and discuss both its relationship to other naviculoid genera and the taxonomic significance of characters such as the stauros.

DAVEY M. S. & R.J. Geider (Marine Biological Association, The Laboratory, Citadel Hill, Plymouth PL1 2PB, United Kingdom). **Response of *Chaetoceros muellen* to iron-limited growth.**

Under conditions of iron-stress, the protein flavodoxin has been shown to replace the iron containing ferredoxin in a number of micro-organisms including several marine diatoms. It is suggested that the cellular abundance of flavodoxin, in relation to Rubisco and ferredoxin may be an indication of the extent of cellular iron-stress. In order to assess the use of flavodoxin as a molecular marker for iron-stress, it is important to establish the existence of a relationship between flavodoxin abundance/expressions and iron availability. Antibodies raised against flavodoxin from diatom *Phaeodactylum tricornutum* have been used to detect the presence of flavodoxin in *Chaetoceros* spp. grown under different iron regimes. The response of the coastal diatom *C. calcitrans* to decreasing iron concentrations in culture media was followed by a number of physiological measurements. In addition, the relative abundance of flavodoxin was examined by western blot analysis of protein extracts from cells grown under the range of iron regimes.

DE BAAR¹H. J. W., K. R. Timmermans¹, M. A. van Leeuwe¹, J.T. M. de Jong¹, R. F. Nolting¹, L. Gerringa¹ & C. Lancelot² (¹Netherlands Institute for Sea Research; ²Université Libre de Bruxelles). **Meteorology and Low Availability of Iron Control the Diatom Blooms in Atlantic and Pacific sections of the Southern Ocean.**

In austral spring (October-November, 1992) diatom blooms were found in the Polar Front (PF) but not at the Marginal Ice Zone (MIZ) of the Atlantic sector of the Southern Ocean. Simulation modeling of the plankton ecosystem has shown the diatom blooms depend on adequate Fe supply, as indeed observed at the Polar Front. However intense wind mixing prevented blooming at the MIZ. Indeed when the Wind Mixed Layer (WML) was very shallow blooms were eventually found at the MIZ, during a cruise in austral summer (January 1996). The very remote waters of the Pacific region of the Southern Ocean are the furthest away from any upstream and upwind continental Fe sources. In autumn (March-April 1995) the wind mixed layers were in the order of ~100m deep, thus mixing the algae down into the dimly lit part of the euphotic zone where photosynthesis is severely restricted. The dissolved iron was very low from 0.05 nM near the surface to 0.5 nM in deeper waters. Of this ultralow Fe some 80-99% is strongly bound to dissolved organic moieties, this affecting the availability for biological uptake. The unfavorable conditions were reflected in low phytoplankton biomass. Taxonomic identification with HPLC for pigments showed absence of diatoms in low silicate subAntarctic waters north of the Polar Front. On the other hand there were several lines of evidence of a preceding bloom situation at the Bellingshausen Sea region, in keeping with blooms observed in austral summer (1992) by the UK Sterna expedition.

DODGE J. D. (Biological Sciences, Royal Holloway, University of London, Egham, Surrey TW20 0EX; e-mail: J.Dodge@rhnc.ac.uk). **Founders Lecture: Planktonic dinoflagellates, tell-tales of the oceans.**

Planktonic dinoflagellates occur in all oceans and seas of the world in varying numbers of species, depending on the condition or type of the water and inevitably on the skill of the investigator! In addition, species association patterns vary according to a number of factors, such as nearness to land, but by far the most universally important appears to be water temperature. In this talk I will examine the related concepts of species diversity and species association in relation to work carried out on planktonic dinoflagellates in various oceans of the world, but especially my work over the past 25 years or so in the NE Atlantic and the seas around the British Isles. What tales might be told representing the past or present condition of the oceans, with the help of user-friendly computer analysis of these data, will be revealed. The use of planktonic dinoflagellates in studies of environmental change over time and space will be discussed.

DUDGEON S. R. & P. S. Petraitis (Department of Biology, University of Pennsylvania, Philadelphia, PA, USA; email: sdudgeon@sas.upenn.edu). **Post-disturbance recruitment of rockweeds varies with the scale of perturbation: A mechanism underlying the origin of alternative communities on rocky intertidal shores.**

Different communities of plants and animals often occur in seemingly similar environments. The idea that one environment can support, in turn, different communities is explained by the theory of alternative stable states. A central feature of this theory is that the switch between communities occurs at a threshold with a step-like transition in species composition, but the evidence supporting the theory is equivocal. On sheltered shores in New England, the intertidal zone is occupied by communities dominated either by *Ascophyllum nodosum* or barnacle and mussel beds. The two assemblages often occupy adjacent areas of the shore and may persist for long time periods (i.e., on the order of decades). We hypothesized that stands of *Ascophyllum* and mussel beds represent alternative states and the switch between them is made possible by large scale ice scouring during severe winters. We tested this hypothesis experimentally by making clearings of either 1, 2, 4 or 8 m in diameter in *Ascophyllum* stands, to mimic the effect of ice scour, and monitoring the subsequent recruitment of *Ascophyllum*, as well as invasion by mussels, barnacles, and *Fucus vesiculosus*. *Ascophyllum* recruited primarily to uncleared controls and 1 m clearings, but rarely to clearings >2 m in diameter. In contrast, recruitment of *Fucus*, barnacles and mussels on rock surfaces was greater in clearings ≥4 m in diameter. These results concur with the step-like transition at a threshold size of perturbation as predicted by theory, and implicate differential recruitment as a mechanism underlying the origin of alternative communities.

EDWARDS¹ G. O., J. A. Callow¹ & C. Brownlee² (¹School of Biological Sciences, The University of Birmingham, Edgbaston, Birmingham, B15 2TT, e-mail g.o.edwards@bham.ac.uk or e-mail j.a.callow@bham.ac.uk; ²Marine Biological Association, The Laboratory, Citadel Hill, Plymouth, Devon, PL1 2PB). **Interspecific Fertilisation In *Fucus*.**

Seaweed of the genus *Fucus* grows in large mixed-species populations along the coast of the British Isles. Species grow in distinct adjoining zones, and fertilisation periods tend to overlap. Theoretically this would lead to the existence of hybrid zones, where gene flow between species would occur. *Fucus* shows extreme levels of morphological variation which can hinder identification of distinct species, and the discovery of such morphologically indistinct forms has led to the publication of reports documenting the existence of putative hybrid plants. Are such plants true hybrids or merely type species examples displaying morphological variation? It has previously been demonstrated that species-specific barriers to fertilisation exist between gametes which appear to break down to some extent as material ages, resulting in low levels of apparent interspecific fertilisation. The existence of hybrids remains a contentious issue, and a fresh approach to this conundrum may be found via genetic fingerprinting. Using a combination of morphometric and molecular techniques (random amplified polymorphic DNA) we have addressed this question. Inter-specific zygotes formed during laboratory-based fertilisation experiments appear to be true hybrids as shown by RAPD analysis,

those influenced by mining operations and natural systems such as hot springs and volcanoes. In addition, there is much information available on algae in relation to lake acidification by acid rain. Some characteristics of these ecosystems are described and the mechanisms enabling algae to grow in such environments are considered. What characteristics do these algae have in common? What morphological, behavioral, physiological mechanisms enable these organisms to live in such environments? Why are biodiversity and primary productivity (usually) low?

GEIDER R. J. & T. Anning (Marine Biological Association of the United Kingdom, The Laboratory, Citadel Hill, Plymouth PL1 2PB; e-mail rdg@wpo.nerc.ac.uk). **Is there more than one photoacclimation strategy in phytoplankton?**

Light intensity is one of the environmental factors with the greatest impact on the growth rate and pigment content of microalgae. It is often assumed that photoacclimation serves to increase growth rate under suboptimal conditions over the value that would be achieved if cellular chemical composition were static. The assumption that biochemical composition is actively adjusted to yield maximum growth rate under prescribed environmental conditions has been applied in development of some phytoplankton growth models. However, acclimation may also serve to limit the damage that may be incurred as a consequence of exposure to adverse environmental conditions. Damage to the photosynthetic apparatus can occur when the excitation energy in absorbed photons exceeds the ability of cells to dissipate excess energy as heat. The excess of light absorption over photosynthesis will be more pronounced when nutrients are scarce or temperature lowered. Thus, acclimation may include a trade-off between maximizing growth at low irradiance versus minimizing the potential for photooxidative damage at high irradiance. Comparison of the light dependencies of growth rate and the chlorophyll *a*:carbon ratio under nutrient-replete conditions indicates that pigment content is not adjusted to maximize growth rate. Instead, a simple regulatory ratio based on the ratio of photosynthesis to light absorption describes the photoacclimation response in a number of microalgae.

GERRINGA¹ L. J. A., K. R. Timmermans² & H. J. W. de Baar². (¹ Netherlands Institute for Ecology, Center for Estuarine and Coastal Ecology, PO Box 140, 4400 AC Yerseke; ²The Netherlands Institute for Sea Research, PO Box 59, 1790 AB Den Burg, The Netherlands). **The reality of the ocean versus laboratory cultures of algae with respect to Fe availability research.**

Since the famous publication of Sunda and Guillard (1976), in which they concluded that growth rate inhibition and Cu content in the phytoplankton cells are related to the cupric ion activity and not to the total dissolved concentration, the importance of metal speciation for the life and productivity of phytoplankton is evident. Especially iron has become an important research topic recently, as limitation of phytoplankton growth by reduced iron availability has been observed. Most of the iron-phytoplankton research done was in cultures with either synthetic medium or filtered natural seawater. EDTA was added in order to detoxify high (other) metal concentrations, to minimize effects of iron contamination and in order to keep iron in solution and available. Another advantage of EDTA was the possibility to calculate the speciation and thus ionic metal concentrations. With EDTA (10^{-5} M) it was found that iron limitation was indeed *present*, and related to the Fe^{3+} activity. Moreover, uptake rates of iron by phytoplankton was related to the cell surface area and influenced by the light regime. Since knowledge of speciation is essential and since it can be measured, the use of EDTA to mimic natural conditions is questionable. In experiments without EDTA, however, there are restrictions in the choice of algae, ironically only the less relevant coastal algal species can be grown into Fe limitation. Open ocean species either have extremely low iron requirements, or simply cannot be grown in laboratory cultures.

GIBSON C. & Z. Qixing (Department of Agriculture for Northern Ireland and Queen's University Belfast). **Phytoplankton of Taihu Lake, one of China's large lakes.**

Lake Taihu is a very large (approximately 2500 km²) lake in the Yangtse Delta in south-east China which is virtually unknown in the West. The great extent of the water surface area and its shallow depth (averaging only 1.8 metre) make it of considerable interest. Following intensification of agriculture in the region, the lake has become rapidly enriched and is filling with inwashed sediment from the extensive paddy systems in the catchment. The phytoplankton is dominated by cyanobacteria and *Microcystis* blooms are a serious problem. The planktonic diatom *Aulacoseira granulata* also occurs, which is surprising in such a shallow lake. A model of sinking rate, filament width and growth rate is presented. The model suggests that the high water temperature in Taihu results in a growth rate high enough to offset sinking losses.

HAPPEY-WOOD C. M. (University of Wales, Bangor, Gwynedd, LL57 5UW). **Lakes in North Wales - recent, past and historical changes.**

Lakes in North Wales fall into two distinct categories: the soft water oligotrophic upland lakes of Snowdonia and mid-Wales, which contrast with the smaller nutrient-rich lakes of agricultural Ynys Mon. This paper will discuss historical, recent and current changes in the glacial upland lakes of Snowdonia, together with recent trends of eutrophication in selected Anglesey lakes.

HODGE¹, S. J. ., H. L. J Jones¹, & L. J. Rothschild² (¹NERC Centre for Population Biology, Imperial College at Silwood Park, Ascot, Berkshire, SL5 7PY; s.hodge@ic.ac.uk; ²NASA Ames Research Center, Moffet Field, California, 94035-1000. USA.). **Diurnal patterns in photosynthesis and feeding, in mixotrophic algae.**

Measurements of gross carbon production in the oceans relies on being able to correlate chlorophyll levels to primary production. However, this relationship is far less straight forward for mixotrophic algae than purely photosynthetic algae. This is because mixotrophic algae may supplement, or replace, photosynthetically-gained carbon with phagotrophically-gained carbon, while chlorophyll concentrations within the cells remain the same. In addition, rates of photosynthesis, and the balance between photosynthesis and phagotrophy, may vary diurnally. Experiments have been carried out over a 24 h period to determine photosynthetic rates, using ¹⁴C, and phagotrophic rates, measuring the uptake rate of DTAF-stained bacteria, in several mixotrophic algal species. These experiments have shown that mixotrophic algae, like purely photosynthetic algae, show diurnal patterns in photosynthesis. In addition, mixotrophic algae show diurnal patterns in feeding behaviour that may or may not be linked to patterns in photosynthesis. Remote sensing techniques, used to estimate CO₂ uptake and productivity in the oceans may, therefore, not be as accurate for mixotrophic algae as they are for purely photosynthetic algae. Understanding these fluctuations may help to interpret remote sensing data when applied to bloom-forming mixotrophic populations such as *Chrysochromulina polylepis*.

HOLLIGAN P. M. (Department of Oceanography, Southampton Oceanography Centre, European Way, Southampton SO14 3ZH; e-mail p.holligan@soc.soton.ac.uk). **Applications of Satellite Ocean Colour Sensors.**

Experience with the Coastal Zone Color Scanner (CZCS) between 1979 and 1986 has shown that satellite ocean colour scanners provide an effective means of detecting and monitoring large scale variability of phytoplankton biomass in the oceans. After a gap of 10 years, the launch of new improved sensors, including most recently the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), has opened the way for long term investigations to be undertaken. Examples of CZCS imagery illustrate the types of phenomena that might be investigated in the NE Atlantic Ocean. They include the effects of climatic conditions on the timing of the spring diatom bloom, of eutrophication on the growth of flagellates in coastal waters, of the introduction and spread of non-indigenous species (e.g. dinoflagellates), and of the interplay between biotic and abiotic factors on the seasonal appearance of

coccolithophores. New methods of data processing, interpolation and interpretation should now be developed to ensure that remote sensing is applied effectively to studies of marine phytoplankton distributions as potential indicators of environmental change.

HYENSTRAND P. (Institute of Limnology, Norbyvagen 20, S-752 36 Uppsala, Sweden. e-mail: Per.Hyenstrand@Limno.uu.se). **Cyanobacterial dominance of phytoplankton communities.**

Cyanobacteria are important constituents of virtually all aquatic systems on earth. Mass development (i.e. "blooms") of planktonic cyanobacteria frequently occurs in freshwater systems particularly under warm, stratified conditions. Traditionally, these blooms have been coupled to eutrophication of lakes. It may therefore seem anomalous that (i) cyanobacteria often become dominant during periods of nutrient stress and (ii) that cyanobacteria also can become dominant in oligotrophic lakes. Several studies indicate that the success of cyanobacteria must be explained by a complex of environmental factors, partly acting synergistically, rather than by one dominant factor. The objective of the presentation is to discuss a combination of factors leading to cyanobacterial dominance of the phytoplankton community. Special emphasis is placed on differences in nitrogen metabolism between cyanobacteria and eukaryotic phytoplankters which directly relate to a hypothesis concerning inorganic nitrogen species and cyanobacterial success. The aim is to lend support to the theory that cyanobacteria have a low competitive ability for nitrate compared with algae and a high ability to compete for ammonium, particularly under nitrogen-limiting conditions. It will be concluded that to understand cyanobacterial development and how high standing stocks in pelagic ecosystems are maintained, several single-factor hypotheses are required.

IGLESIAS-RODRÍQUEZ¹ M. D., P. K. Hayes¹, L. K. Medlin² & J. C. Green³ (¹School of Biological Sciences, University of Bristol, Woodland Road, Bristol, BS8 1UG; email: M.D.Iglesias-Rodriguez or Paul.Hayes@bristol.ac.uk; ²Alfred Wegener Institute, Am Handelshafen 12, D-27570 Bremerhaven, Germany; e-mail: lmedlin@AWI-Bremerhaven.DE; ³Plymouth Marine Laboratory, Citadel Hill, Plymouth, PL1 2PB; e-mail: JGR@wpo.nerc.ac.uk). **Using microsatellites to describe the genetic structure of *Emiliana huxleyi* populations.**

Large populations of the marine coccolithophorid *Emiliana huxleyi* occur in both neritic and oceanic waters world-wide. The scale of these populations coupled with the biology of *E. huxleyi* means that this cosmopolitan phytoplankter plays a significant role in the global carbon cycle and in the production of non-sea salt cloud condensation nuclei. Our previous studies have shown that *E. huxleyi* blooms are not clonal and others have shown that there are significant inter-clonal differences in physiology. We are developing molecular tools to allow us to determine the genetic structure of *E. huxleyi* populations. We are using length polymorphisms at simple repeat loci (VNTRs/microsatellites) within the *E. huxleyi* genome as markers of individual clonal lineages. As a first step we have sequenced a number microsatellite loci isolated from a genomic library enriched for DNA fragments carrying multiple repeats of simple dimeric motifs (GT, GC, GA, AT): the most common repeating motif is GT. Oligonucleotides that are complementary to the unique sequences flanking the repeats are being used to prime amplification reactions to ascertain which loci are polymorphic. Once this phase of the project is complete, pairs of primers for polymorphic loci will be used to explore the genetic structure of *E. huxleyi* populations.

KORB R. E. & V. A. Gerard (Marine Sciences Research Center, State University of New York, Stony Brook, NY 11794-5000 USA). **Nitrogen allocation in *Himantothallus grandifolius*, an Antarctic endemic seaweed, under saturating and limiting N-supply.**

Polar marine waters differ greatly in dissolved inorganic nitrogen (DIN) availability. Arctic regions are characterized by high winter and low summer DIN levels, while antarctic waters have year-round,

high concentrations. The present study compares N-allocation strategies of arctic and antarctic seaweeds growing at near-freezing temperature. After two weeks under limiting N-supply, sporophytes of the antarctic endemic, *Himantothallus grandifolius*, showed a drop in N, protein, and free amino acid content, but little or no difference in growth or photosynthesis relative to plants maintained at high N-supply. Although N and C-content declined only slightly, N-limited plants had lower rates of growth, photosynthesis and dark respiration after six weeks in comparison to N-replete plants, corresponding to reduced concentrations of photosystem II reaction centers (RCII) and chlorophyll *a*. Activity of Calvin cycle enzymes and nitrate reductase also declined, in conjunction with a drop in protein. Despite an initial reduction in Fv/Fm of N-limited plants, final Fv/Fm and Chl *a*:RCII ratios were similar or higher than in N-replete plants, suggesting that remaining PSII reaction centers were functioning efficiently in N-limited plants. In contrast to arctic and temperate kelps, which maintain large internal reserves of nitrogenous components, *H. grandifolius* showed no internal nitrate reserves and relatively small amounts of organic N-reserves, i.e., had no strategy for delaying or reducing impacts of N-limitation. Differences between antarctic and arctic or temperate species in lability of photosynthetic pigment and enzyme concentrations were particularly striking, suggesting that N-allocation in the former is primarily adapted to maintaining photosynthesis and growth under low light and temperature rather than low DIN conditions.

KÜBLER¹ J.E., S.R. Dudgeon², P. Petraitis² & R.L. Vadas³ (¹Department of Biological Sciences, University of Dundee, Dundee DD1 4HN email: jekubler@biolsci.dundee.ac.uk; ²University of Pennsylvania, Philadelphia, PA USA; ³University of Maine, Orono, ME USA). **Effects of hydrodynamics on the dispersal of *Ascophyllum nodosum* zygotes.**

Ascophyllum nodosum is a very long lived, common, dominant macroalga on relatively protected shores of the North Atlantic. In the Gulf of Maine, where these experiments were conducted, new recruits of *A. nodosum* are extremely rare. The high population density and large range of *A. nodosum* appears to be generated by episodic recruitment events. Because release of gametes is synchronous, sex ratios are close to even and populations are dense, zygotes rather than gametes are the primary dispersing agents. To determine the dispersal range of *A. nodosum*, we released fluorescently labelled, freshly fertilised zygotes within natural stands of adults and sampled settlement of both naturally and artificially released zygotes on a 12 m, radial array of ceramic tiles. Settlement density was site specific and inversely proportional to wave exposure. Settlement density was highest in the direction of the prevailing wind. The contributions of bulk directional transport (wind driven) and diffusive and/or turbulent transport to the dispersing cloud of released zygotes were estimated using a dynamic model based on sampling the density of zygotes in the water column after release.

LEAL F. & S. van den Berg. (Oceanography Laboratories, Earth Science Department, Liverpool University, Liverpool, L69 3BX, UK). **Speciation of copper in cultures of *Emiliana huxleyi*.**

Cultures were set up in such a way that they approached those in the natural system. The organism was grown in seawater with addition of nitrate and phosphate only, and without the usual addition of EDTA. *Emiliana huxleyi* appeared to grow well with additions of 180 μ M nitrate and 7 μ M phosphate (N and P equivalent to f/10 medium). The organism was found to release copper complexing ligands, raising the ligand concentration from a background level of 30 nM to ~100 nM at copper levels of 2-4 nM. The stability of the complexes was very high, with log-values for the conditional stability constant of 11.5-12.2. Copper uptake was monitored with and without added chelating agents (salicyl aldohime, thioacetamide, exudates from a previous culture). Compared to the control experiment (no ligands) the copper uptake was enhanced in the presence of SA and the thiol (thioacetamide) whereas it was lowered in the presence of the exudates. Copper toxicity to species of *Emiliana huxleyi* occurred at ~70 nM copper; this level of toxicity was moved to higher copper concentrations in the presence of SA, thioacetamide and exudates. Growth was stimulated at a low copper addition (20 nM) to the control, but no copper stimulation occurred in the presence of the added ligands. Simultaneous measurements of thiols by CSV showed that the thiols co-varied with

the ligands in the cultures. The thiol peak was masked when copper was added during titrations indicating that indeed the thiol compound was being titrated by the added copper. These data therefore indicate that the copper binding ligands released by *Emiliania huxleyi* are thiol compounds.

LI S., N. Bingham & L. Carvalho (Environmental Change Research Centre, University College London, 26 Bedford Way, London WC1H 0AP; email l.carvalho@ucl.ac.uk). **Spatial and Temporal Variability in Diatoms and Charophyte Oospores in the Fleet Lagoon, Dorset.**

Changes in salinity have been suggested as one of the greatest threats to lagoonal charophytes, which represent some of the UK's rarest plant species. Yet little detailed ecological information exists regarding their tolerance of salinity fluctuations. Oospore remains in lagoonal sediments, however, potentially offer a long-term record of the response of charophytes to changes in salinity. As no long-term records of salinity exist, diatom remains can be used as a proxy indicator of past salinities. This paper describes an analysis of sediments from The Fleet lagoon, Dorset one of the few remaining UK sites of the rare charophyte *Lamprothamnium papulosum*. It describes an initial study of spatial patterns in diatoms, oospores and charophytes along a strong salinity gradient and analysis of a short core examining temporal changes over a recent time-scale. Results suggest that transport and mixing result in a homogenous diatom assemblage along large distances of The Fleet, reflecting "average" salinity conditions. Oospores also get transported relatively large distances from the parent plant populations compared with other plant macrofossils. Analysis of the sediment core revealed that The Fleet has seen slight shifts in the balance of fresh and sea water in recent times, probably linked to slight modification of the sea outlet and oospore abundance is positively related to the fresher episodes.

MABERLY S. C., J. E. Parker & M. A. Hurley (Institute of Freshwater Ecology, Far Sawrey, Ambleside, Cumbria LA22 0LP). **Fifty years of surveillance: Variation in performance of *Asterionella formosa* in four basins of the Windermere catchment.**

Since 1945, the abundance and species composition of phytoplankton has been recorded, every week or fortnight, in four basins of the Windermere catchment. The four basins differ physically, e.g. in their mean depth and rate of hydraulic flushing, and chemically in nutrient availability, but are subject to the same year-to-year variation in weather. The average population dynamics of the major spring diatom, *Asterionella formosa*, in the four basins is defined and related to the characteristics of each basin. Conversely, the effect of *Asterionella* on the metabolism of the basins is described. Year-to-year variation in performance of *Asterionella* is compared across basins to try and separate changes caused by intrinsic factors within the basin and its sub-catchment, such as water chemistry, from changes caused by extrinsic factors such as meteorology. Long-term trends in the performance of *Asterionella* are analysed in relation to possible causative environmental factors.

MAGGS C. A. (School of Biology & Biochemistry, Queen's University Belfast BT9 7BL, N. Ireland). **Life-history variability in *Dasya ocellata* (Dasyaceae, Ceramiales).**

Four of the five members of the Dasyaceae found in the British Isles, *Dasya corymbifera*, *Dasya hutchinsiae*, *Dasya punicea* and *Heterosiphonia plumosa* appear to have Polysiphonia-type life histories on the evidence of field collections of tetrasporophytes and gametophytes, but none has been studied in culture. In the fifth species, *Dasya ocellata*, only tetrasporophytes have ever been observed in the British Isles, but there are two reports of gametophytes from further south in Europe. *D. ocellata* tetraspores were isolated into culture from populations in Strangford Lough, N. Ireland, and Agadir, Morocco, where one female thallus was collected amongst tetrasporophytes. *D. ocellata* from N. Ireland underwent a direct tetraspore-to-tetrasporophyte life history, which was followed through two complete cycles. Karyological studies showed that meiosis does not occur during tetrasporangial development, and tetrasporangia are mitotic, with c. 64 small chromosomes. Comparison with chromosome numbers in meiotic tetrasporangia of *D. hutchinsiae* showed that this

is the diploid chromosome complement. Tetraspores from the Moroccan isolate, by contrast, gave rise to gametophytes (although only the males became fertile) and tetrasporophyte recycling did not occur. This is therefore another example of life-history variability in the Ceramiales, and a sexual life history occurs only in southern populations.

MALIN G. (School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ; e-mail: g.malin@uea.ac.uk). **Algae and DMS - cells, blooms and climate.**

Sea-to-air transfer of the volatile compound dimethyl sulphide [(CH₃)₂S, DMS] is a key process in the global sulphur cycle. The major precursor of DMS is the tertiary sulphonium compound dimethylsulphoniopropionate (DMSP) which is found in some seaweeds and phytoplankton. DMSP has the characteristics of a compatible solute and may also act as a feeding deterrent. In the marine phytoplankton the highest DMSP levels are found in dinoflagellates and prymnesiophytes, but conversion of DMSP to DMS occurs via a network of production, transformation and utilisation processes which involve the whole microbial food web. Estimating the regional and global significance of DMS emissions necessitates calculations using DMS field concentration data and a transfer velocity model describing the physical sea-to-air exchange process. The amount of DMS entering the atmosphere is a small percentage of the water column pool. The impacts of volatile biogenic sulphur can also be assessed by analysis of aerosol methane sulphonic acid (MSA) or stable sulphur isotope ratios, and information about DMS emissions in the past has been obtained from ice core samples. DMS is rapidly oxidised in the air to form a range of compounds, including MSA, dimethylsulphoxide, dimethylsulphone, sulphur dioxide and sulphate. Sulphate aerosol particles directly absorb and scatter incoming radiation and provide the major source of cloud-condensation nuclei (CCN) in remote areas. Cloud albedo is strongly affected by CCN number density and the link between biogenic DMS, CCN and cloud albedo has been suggested as a climate regulating mechanism.

MARTIN¹ D., I. Ridge¹ & D. M. John² (¹Open University, Milton Keynes; e-mail D.Martin@open.ac.uk; ²Natural History Museum, London). **General features of the inhibition of algal and cyanobacterial growth by degraded plant litter.**

Plant litter has been shown to inhibit the growth of various species of algae and cyanobacteria when degraded aerobically. Barley straw in particular has been shown to inhibit nuisance algal growth in the field and the laboratory. The inhibitory substance is thought to be some form of oxidised polyphenol solubilised from lignin in the plant material as it is degraded. Tests with a number of different species suggest that there is no general taxonomic feature which confers resistance or sensitivity toward degraded plant litter. In the laboratory *Scenedesmus quadricauda* is shown to be inhibited by straw in the early stages of application. However, *S. quadricauda* appears to overcome this early inhibition and go on to grow and catch up, or even surpass the growth of the control. It also shows a decrease in chlorophyll a per cell even when the cell numbers show no inhibition of growth. *Pediastrum boryanum* and *Staurostrum pingue* have been shown to exhibit abnormal cell morphology when grown in the presence of decomposing barley straw and oak leaf litter. This appears to be non-specific since similar morphology is shown in the presence of inhibitory concentrations of copper sulphate. It is not clear whether this laboratory data can be extrapolated to the field where there are more variables.

METCALF J. S. & G. A. Codd (Department of Biological Sciences, University of Dundee, Dundee, DD1 4HN, UK). **Microwave extraction of hepatotoxins from cyanobacterial laboratory cultures and blooms.**

Cyanobacteria produce a wide range of secondary metabolites including several which present hazards to human and animal health. These include cyclic peptides (microcystins and nodularins) which are potent hepatotoxins, inhibitors of protein phosphatases *in vitro* and *in vivo*, and tumour-

promoters. Microcystins and nodularins are largely retained within the producer-cells until the latter breakdown, hence toxin extraction is necessary to permit quantitative analysis. We have developed a rapid, inexpensive and efficient procedure for cyanobacterial hepatotoxin extraction from aqueous samples of cells using a domestic microwave appliance. The procedure results in the release of a range of microcystins at yields virtually identical to those obtained by longer and conventional procedures, according to high-performance liquid chromatography with diode array detection and protein phosphatase inhibition assays. High molecular weight cyanobacterial proteins (phycobiliproteins) are denatured by microwave treatment, in contrast to the hepatotoxins. The procedure is appropriate for a range of laboratory cultures including *Microcystis*, *Oscillatoria* (*Planktothrix*) and *Nodularia* spp. and for environmental bloom samples, as evidenced by tests with blooms dominated by *Anabaena* and *Microcystis* spp.

NIMER¹ N. A., C. Brownlee² & M. J. Merrett¹ (¹School of Biological Sciences, University of Wales Swansea SA2 8PP; email:n.nimer@swansea.ac.uk; ²Marine Biological Association of the UK, The Laboratory, Citadel Hill, Plymouth PL1 2PB, UK). **Extracellular carbonic anhydrase (CAext) in relation to photosynthetic rate in the marine dinoflagellate *Prorocentrum micans*.**

In some marine phytoplankton species CAext is regulated by DIC availability whereas in others the enzyme is constitutive (Nimer et al. 1997, J.Phycol.33:625-31). CAext was detected in *P.micans* with cells under carbon replete conditions that is 2.0 mM total DIC, pH 8.3. The use of Dextarn Bound Sulphonamide (DBS), a potent membrane impermeable inhibitor of carbonic anhydrase, demonstrated the role of CAext in maintaining Vmax for photosynthesis under conditions of carbon limitation. Measurement of the internal inorganic carbon pool by the silicone oil centrifugation technique demonstrated that at pH 8.3 the internal DIC concentration was ten fold greater than the external. Events at the plasma membrane were investigated using the Confocal Laser Scanning Microscopy and fluorescence ratio imaging to measure intracellular pH.

OSBORNE¹ B., R. Geider² & S. Pratt² (¹Botany Department, University College Dublin, Belfield, Dublin 4, Ireland; ²Marine Biological Association of the United Kingdom, The Laboratory, Citadel Hill, Plymouth, PL1 2PB, UK). **Light absorption by the coccolithophorid *Emiliania huxleyi* (Lohmann) Hay & Mohler.**

The coccolithophorid *Emiliania huxleyi* (strain B 11, Plymouth Marine Laboratory) is an important component of many marine ecosystems. A characteristic feature of its cell morphology is an outer 'skeleton' of calcified scales, comprised largely of calcite and this results in a high degree of light scattering which complicates any assessment of light absorption using conventional spectrophotometers. We have measured light absorption in *E. huxleyi* using two spectrophotometers, one commercially-available (Hitachi, U-3000) and one custom built (Oriel/Labsphere products). Both employ integrating spheres to capture scattered light, although the collecting geometries differ. The Hitachi spectrophotometer only collects scattered light within a ~30 degree cone of the forward direction, whilst the custom-built instrument collects essentially all the scattered light. Possibly due to the restricted collecting angle of the Hitachi instrument we show, using the highly scattering suspensions of *E. huxleyi*, that appropriate corrections can not be applied to account for scattering losses. Rather surprisingly, comparison of cells with and without coccoliths indicates that the calcareous plates do not reduce light absorption. As there is no evidence of any wavelength-dependent differences in light absorption between cells with and without coccoliths we conclude that this is not due to an increased number of total internal reflections within the cell counteracting the increased scattering by the external plates. Estimates of the magnitude of the 'package effect' in cells disrupted using a Yeda press indicate that there is little effect of pigment packaging on light absorption in the red (675nm) region of the spectrum. In contrast, there was a significant reduction in *in vivo* absorption in the blue (~435nm). The significance of these results are discussed.

PEARSON¹ G. A. & S. H. Brawley (Department of Plant Biology and Pathology, University of Maine, Orono, ME 04469-5722, USA. ¹Current Address: U.C.T.R.A., University of Algarve, Campus de Gambelas, 8000 Faro, Portugal). **How do furoid algae know when to release gametes? Mechanisms for sensing periods of calm in a turbulent environment.**

High water motion inhibits gamete release in furoid algae. Gametes are released under calm conditions which is predicted to increase the chances of sperm-egg encounters, and thus fertilization success, in the periodically-turbulent intertidal zone. In laboratory experiments, high water motion inhibits gamete release in normal seawater, but not in inorganic carbon-free (IC-free) seawater; conversely, addition of IC under calm conditions inhibits release, suggesting that IC supply across the boundary layer provides a "water-motion sensor". In the intertidal furoid *Pelvetia compressa*, a rapid and massive release of gametes is triggered by a transfer of receptacles to darkness following a period of several hours under calm conditions in the light (potentiation). Experiments with DCMU (an inhibitor of electron transport from photosystem II) show that photosynthesis is required for potentiation in the light, while blocking photosynthesis (darkness, DCMU) triggers gamete release from potentiated receptacles. In addition, light signals appear to be transduced via a second, photosynthesis-independent, pathway. While potentiation in red or white light results in normal gamete release following a transfer to darkness, no gamete release occurs following potentiation in blue light. Furthermore, transfer of potentiated receptacles from white to blue light triggers gamete release. The mechanism of gamete release is associated with ion movements and turgor changes within receptacles: several inhibitors of anion channels cause gametes to be released in the light. Specific inhibitors of tyrosine kinases block potentiation, implicating phosphorylation events in the signal transduction pathway between potentiation and gamete release in furoid algae. Supported by National Science Foundation Grant OCE-9216981 to S.H.B.

PERKINS¹ R. G., G. J. C. Underwood¹ & P. Daldorff² (¹Dept. of Biological Sciences, University of Essex, Colchester, Essex, CO3 4SQ; ²Anglian Water Services Ltd., Compass House, Chivers Way, Histon, Cambridgeshire, CB4 4ZY, e-mail perkr@essex.ac.uk). **Long term changes in algal biomass in relation to ferric dosing and phosphorus concentrations in a pumped storage reservoir from 1981 to the present.**

Alton Water reservoir was constructed in 1981 since when a steady increase in average yearly chlorophyll *a* concentration was observed until 1992 when a nuisance bloom of *Coelosphaerium* sp. occurred (summer growth season chl. *a*, $69 \pm 7.2 \mu\text{g l}^{-1}$, peak value $121 \mu\text{g l}^{-1}$). Since 1993 summer average chl. *a* has decreased from 26 ± 2.5 to $4 \pm 1.4 \mu\text{g l}^{-1}$ in 1996. Reservoir input water has been dosed with ferric sulphate for phosphorus removal since 1981. Mass balance calculations indicate this to be 90 % efficient. As a result SRP is often below detection, ($< 0.005 \text{ mg P l}^{-1}$). Total phosphorus however occurs at higher concentrations due to algal biomass and particulates. Silica and nitrogen appear not to be limiting with concentrations rarely below 2 mg Si l^{-1} and 4 mg TON l^{-1} . Sediment slurry manipulations showed no detectable release of phosphorus in anaerobic or high pH conditions. Sediment phosphorus adsorption capacities were high with low equilibrium phosphorus concentrations (0.02 to 0.15 mg P l^{-1}). *In situ* nutrient manipulations indicated algal phosphorus limitation, with chl. *a* concentration increases in the order of 1000 % with phosphate addition. Alkaline Phosphatase activities were highest in treatments with no phosphate addition, $0.17 \pm 0.020 \mu\text{mol pNPP } \mu\text{g}^{-1} \text{ Chl } a \text{ h}^{-1}$. The effectiveness of ferric dosing is discussed using both Anglian Water data from 1981 to the present as well as a detailed survey of Alton Water from 1995 to 1997.

PETTERSSON K. (Erken Laboratory, Institute of Limnology, Uppsala University Norr Malma 4200, S-761 73 Norrtälje, Sweden). **Spatial distribution of *Gloeotrichia echinulata* during summer in Lake Erken (Sweden) as affected by buoyancy and wind.**

Gloeotrichia echinulata is a colony-forming, gas-vacuolated, migratory cyanobacteria of the order Nostocales and family Rivulariaceae appearing in intensive blooms during late summer in Lake

Erken (Sweden). It spends the winters as an akinete on the sediment and germinates during summer, migrating into the epilimnion. In laboratory experiments, the mean floating rate of the colonies was estimated to 43 m/day during the early part of the bloom and increased by a factor of two later on. This fact could be attributed to an increase in the colony-size. Colonies that were captured in inverted traps above the sediment in the lake showed a mean floating rate of 104 m/day. In Lake Erken, the vertical (0-10 meter) variation in number of colonies could reach over 40-fold during calm conditions. A wind-speed over 4.5 m/s reduced the vertical variation drastically. The horizontal distribution was very much affected by wind speed and direction. On a km scale, the variation maximized at 65-fold, matching the wind direction of the day of sampling or the day before. In near-shore areas the variation could be up to 17-fold (100 m scale) below a wind speed of 6 m/s, above which the variation was strongly reduced.

POOLE, L. J. & J. A. Raven (Department of Biological Sciences, University of Dundee, Dundee DD14HN). **Evidence for increased superoxide dismutase activity in *Enteromorpha* growing in a high oxygen environment**

Enteromorpha intestinalis grows successfully in both rockpools and on intertidal rock surfaces. Rockpool populations of *E. intestinalis* grow at oxygen concentrations higher than those tolerated by many other genera; this may aid *Enteromorpha* in maintaining dominance in these habitats. The detrimental effect of the greater oxygen radical production by plants living in environments with high oxygen concentrations may be minimised by increased scavenging activity. Assay of superoxide dismutase (a well documented oxygen radical scavenger) has shown that there is significantly greater activity ($P < 0.0001$) in *E. intestinalis* taken from rockpool populations naturally exposed to high oxygen concentrations. However in culture experiments where *E. intestinalis* was grown at 20, 40, 60 and 80 kPa of oxygen for a period of two weeks there was no significant difference in SOD activity between treatments for either rockpool or non-rockpool populations. The level of activity in samples from all the cultures was found to be similar to that of non-rockpool populations from nature.

RAVEN J. A. (Department of Biological Sciences, University of Dundee, Dundee DD1 4HN, UK; e-mail: j.a.raven@dundee.ac.uk). **Iron and Algae.**

Iron is abundant in the earth's crust, and was available as Fe^{2+} in the early anoxic ocean. Global oceanic anoxia was maintained long after the evolution of O_2 -producing photosynthesis in cyanobacteria some 3.5 Ga ago, since O_2 was scavenged by oxidation of Fe^{2+} to Fe^{3+} and of S^{2-} to SO_4^{2-} , although O_2 could have built up locally. Appropriate chemical properties, and availability, permitted Fe to play major roles in photosynthesis, respiration (which evolved in localized O_2 build-ups well before 2 Ga ago), N_2 fixation and NO_3^- assimilation. By 2 Ga ago, when eukaryotes evolved, global O_2 build up was established so the earliest eukaryotic algae (2.1-1.7 Ga ago) were in habitats with Fe as the relatively unavailable Fe^{3+} . Subsequent to this global O_2 build-up Fe has limited algal growth in some habitats, as is the case for the North-East Pacific, Eastern Equatorial Pacific and Southern Ocean today. Possibilities for economizing on Fe include a low photosystem I:photosystem II ratio, scavenging NH_4^+ rather than assimilating NO_3^- or, especially, fixing N_2 , substitution of Fe-free catalysts (flavodoxin, plastocyanin, Cu-Zn superoxide dismutase) for Fe-containing catalysts (ferredoxin, cytochrome c_6 and Fe superoxide dismutase), and minimizing the optical thickness of the tissue. Fe costs of growth predicted from the extent to which Fe-economical metabolism is used are often in general agreement with observations, but there are significant discrepancies on which further work is needed.

RENGEFORS K. (Institute of Limnology, Uppsala University, Norbyvägen 20, SE-752 36 Uppsala, SWEDEN. E-mail: Karin.Rengefors@limno.uu.se). **Environmental and endogenous regulation of cyst germination in two fresh-water dinoflagellates.**

The role of excystment in relation to seasonal succession was investigated in two fresh-water dinoflagellates, *Ceratium hirundinella* (O. F. Müller) Dujardin and *Peridinium aciculiferum* (Lemmermann). Field studies and laboratory experiments were performed to determine which factors regulate the timing of cyst germination. Environmental factors (temperature, light, nutrients, anoxia) and endogenous factors (maturation period, biological clock) were investigated. Our main results indicate that temperature and internal maturation period determine when germination can occur. *C. hirundinella* had a maturation period of 4.5 months, and germinated in the laboratory and the field at temperatures above 6 °C. *P. aciculiferum* had a maturation period of 2.5 months and germinated in the laboratory and in the field in temperatures below 7 °C. In addition, our results indicated that both species were regulated by a biological clock. Furthermore, anoxia prevented the germination of *C. hirundinella*, contrary to results in earlier studies. To conclude, we could explain the appearance in plankton of the two dinoflagellate species through two main factors regulating excystment, i. e. temperature and maturation period.

RICHARDSON¹ T. L., C. E. Gibson², & S. I. Heaney² (¹Dept. of Agricultural and Environmental Science, Queen's University of Belfast, Newforge Lane, Belfast BT9 5PX, ^{1,2}Agriculture and Environmental Sciences Division, Department of Agriculture for Northern Ireland, Newforge Lane, Belfast BT9 5PX). **Lake Baikal Phytoplankton: Effects of Temperature and Irradiance on Growth.**

Lake Baikal, Siberia is the oldest and deepest lake in the world and contains an extraordinary array of endemic plants and animals. We have isolated two taxa of phytoplankton from Lake Baikal, the diatom *Aulacoseira baicalensis* which often blooms under the ice of Lake Baikal in winter, and the dominant summertime cyanobacterium *Synechocystis limnetica*. Experiments are underway to determine the growth rates of these phytoplankton in response to variations in temperature and irradiance. Results so far show that at 3°C on a 12:12h light:dark cycle, *A. baicalensis* had a maximum chlorophyll-based growth rate of 0.14 d⁻¹. The growth rate vs. irradiance relationship has a broad plateau; maximum growth rates were comparable between irradiances of 50 and 120 µmol m⁻² s⁻¹ within the tested range of 5 to 450 µmol m⁻² s⁻¹. Growth rates estimated using particulate carbon and particulate nitrogen at 3°C were lower (0.1 d⁻¹ and 0.08 d⁻¹, respectively) but were maximum within the same broad range of irradiances. *Aulacoseira baicalensis* grew at rates of 0.06 to 0.08 d⁻¹ at 450 µmol m⁻² s⁻¹, an irradiance comparable to that found under clear ice of Lake Baikal on a cloudless day. Preliminary results from experiments conducted at 5°C show that *A. baicalensis* grew at rates comparable to those at 3°C. Completion of picoplankton counts and further experiments at 8°C and 11°C may show that the temperature windows for optimal growth of *A. baicalensis* and *S. limnetica* partly explain seasonal species succession in Lake Baikal.

ROTHSCHILD B. J.¹ & P. J. Haley² Jr. (¹CMAST, University of Massachusetts, North Dartmouth, MA 02747, USA; ²Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138, USA). **Influence of Physical Forcing on Carbon Microclouds in the Ocean.**

A statistical field theory on biological-physical processes in the ocean is developed using formalisms of stochastic geometry. The theory generates statistical length scales and volume fraction measures associated with plankton dynamics. As an example, the paper studies the theoretical basis for variability in the transformation of dissolved organic carbon (DOC) into heterotrophic biomass resulting from the aggregation of DOC microzones or "microclouds." Specific properties of the statistical field include the volume fraction occupied by the microclouds and length scales deduced from the covariance functions and spherical contact distributions. Volume fraction, covariance functions and spherical contact distributions for assemblages of Baltic Sea phytoplankton were computed using real data on phytoplankton cell density and size with conjectured microzone dimensions. By comparing microcloud length scales with molecular diffusion, turbulent diffusion and uncorrelated velocity length scales, we determined that variability in the turbulent kinetic energy (TKE) dissipation rate, which might be induced by global and basin-scale wind forcing (for example),

could influence the structure and functioning of the carbon microclouds. Basically, the data set suggested that microclouds, in contrast to microzones, are subject to the straining effects of turbulent diffusion, in addition to molecular diffusion. The microclouds themselves are often too small to be subject to uncorrelated velocities. However, the relative motion among microclouds is driven by the uncorrelated velocities of homogenous and isotropic turbulence. The concentrations of DOC suggest that the microclouds are temporary loci that enhance interaction among phytoplankton cells, bacteria and microzooplankton.

RUSSELL G., A. Ruuskanen & M. Kiirikki (Tvärminne Zoological Station, University of Helsinki, 10900 Hanko, Finland). **Sunlight, shade and tidal night: photoadaptation in *Fucus*.**

We have investigated two populations of *Fucus vesiculosus* in which the lower limits are determined by insufficient light rather than by the presence of a superior algal competitor. In the tidal reaches of the R. Mersey, water turbidity is so severe that *Fucus* experiences darkness when covered by an incoming tide. These plants therefore photosynthesise only when emergent and are hence exposed to full sunlight. Baltic *Fucus*, in contrast, is permanently submerged in an atidal environment and subject to shade conditions that increase with depth. Chlorophyll concentrations and ratios in these populations differ significantly and in a manner that suggests different photoadaptive strategies. Morphological differences are also present, with Baltic thalli showing greater distal expansion of the blade than Mersey plants. A transplant experiment involving Baltic plants alone failed to reveal any photoadaptive plasticity in thallus form.

SARTHOU G., C. M. G. van den Berg, & U. Riebesell¹ (Oceanography Laboratories, Earth Science Department, Liverpool University, Liverpool, L69 3BX, UK; ¹Alfred Wegener Institute für Polar und Meeresforschung, Bremerhaven, Germany). **Interaction of zinc with carbonic anhydrase in seawater.**

Carbonic anhydrase (CA) is inactive unless associated with zinc, with possible substitution by cobalt. It is possible that the CA activity is impaired in seawater when the zinc concentration is very low, or when it occurs complexed with competing organic ligands. The complexation of zinc by CA in seawater was determined by cathodic stripping voltammetry (CSV) with ligand competition. A value of 8.98 ± 0.27 was found for $\log K'_{ZnCA}$ where K'_{ZnCA} is the conditional stability constant for the complex of Zn^{2+} with CA in pH 8 seawater. This complex stability is similar to that of natural zinc-complexing ligands found in seawater or algal cultures. A value for the molecular weight of CA was calculated from its equivalent ligand concentration (in nM) obtained by titrations with zinc at various CA concentrations (1-4 mg/l). The value found ($34,740 \text{ g.mol}^{-1}$) for the molecular weight is consistent with values previously found by other methods ($29,000 - 31,000 \text{ g.mol}^{-1}$) confirming that the stoichiometry of the complex between Zn and CA is 1:1.

SERRÃO¹ E. A., L. A. Alice², & S. H. Brawley³ (¹Dept. Plant Biology, University of Maine, Orono ME, 04469, U.S.A.; ²Department of Biological Sciences, University of Maine, Orono ME 04469, U.S.A.; ³School of Marine Sciences, University of Maine, Orono ME 04469, U.S.A.). **Phylogeny of the Fucaceae based on nrDNA-ITS (Internal Transcribed Spacers).**

Sequences of the internal transcribed spacer region (ITS 1 - 5.8S -ITS 2; ITS) of nuclear ribosomal DNA were obtained from 16 species representing all genera of Fucaceae (*Ascophyllum*, *Fucus*, *Hesperophycus*, *Pelvetia*, *Pelvetiopsis*, *Xiphophora*). Parsimony analysis indicates that *Fucus* is monophyletic and is not ancestral in Fucaceae, contradicting the well established model for phylogenetic relationships proposed by Powell. ITS sequences reveal two main lineages within *Fucus*, one with *F. serratus* sister to the clade containing *F. gardneri*, *F. distichus*, and *F. evanescens*, and a second including *F. vesiculosus*, *F. spiralis*, and *F. ceranoides*. The genus *Pelvetia* does not appear to be monophyletic, because European

P. canaliculata is more closely related to *Fucus*, *Hesperophycus* and *Pelvetiopsis* than to other *Pelvetia* species. In general, the results indicate that in Fucaceae, the characters a) monoecious/dioecious and b) the number of eggs per oogonium, that form the basis of Powell's scheme, do not reflect the evolutionary history of the family. Supported by NSF: OCE-9216981 to S.H.B.

SIGEE¹ D. C., E. G. Bellinger & V. Krivtsov (1School of Biological Sciences, 1.800 Stopford Building, University of Manchester, Manchester M13 9PT; e-mail: David.Sigeeman.ac.uk).

Elemental composition of *Ceratium hirundinella* within mixed phytoplankton samples: an x-ray microanalytical study.

The elemental composition of cells of *Ceratium hirundinella* in mixed phytoplankton samples was determined by energy-dispersive X-ray microanalysis (XRMA). X-ray emission spectra routinely showed clear peaks of monovalent (Na, K) and divalent (Mg, Ca) cations plus Si, P, S and Cl. The technique provided information on: (1) Elemental concentrations within single cells. These varied considerably within the population. The ratio of detectable monovalent/divalent cations was relatively constant at 1.3, with significant correlations between anions and cations. (2) Intracellular correlations. Clear patterns of intracellular correlation between single elements occurred within individual samples, with significant positive correlations routinely present between particular pairs (e.g. Mg-P, K-Cl and K-P). (3) Cell/lakewater nutrient balance. Decrease in the level of available P in lakewater was associated with a sharp decrease in the intracellular concentrations of P and other correlated elements. The estimated C/P ratio markedly differed from the classical (Redfield) value at times of low P availability. The concentration of P in cells of *Ceratium* was approximately 10^4 times greater than in the surrounding water medium (total P), compared to values of 10^2 - 10^3 for K. The potential use of XRMA in characterising algal populations within mixed phytoplankton is discussed.

SHUBERT L. E. (Department of Botany, The Natural History Museum, London SW7 5BD, email: e.shubert@nhm.ac.uk). **Variations in the distribution and abundance of marine benthic and epilithic microalgae exposed to oil pollution.**

During February 1996, 200 km of Welsh coastline was contaminated with crude oil and heavy fuel when the Sea Empress tanker was grounded at Mill Haven, south west Wales. Collecting sites were established at Abereddy (not oiled = control), Newgale and Popton (lightly to medium oiled) and West Angle (heavily oiled) and replicate samples taken on 3-4 August and 27-29 September 1996. Sixty-five microscopic algal taxa were identified from sediments and rocks. Overall, the density of algae was greater in sediments compared to rocks. The sediments were dominated by diatoms, such as *Amphora coffeaeformis*, *Amphora exigua*, "*Berkeleya*" sp, *Luticola mutica* and *Nitzschia spathulata*. The highest density of algae were recorded from West Angle and decreased in a northerly direction. Alternately, algae attached to rocks were dominated by filamentous cyanobacteria, such as *Lyngbya aestuarii*, *Microcoleus lyngbyaceus*, and *Oscillatoria lutea*. The density of algae on rocks was greatest at Abereddy and decreased in a southerly direction to West Angle. Species "richness" on rocks was 50% less than species "richness" in sediments. In the absence of grazers, the diatoms in sediments flourished at the oil contaminated sites. Alternately, at the control site algae were reduced where grazers were present. This investigation demonstrated that marine benthic and epilithic microscopic algae survived a major oil pollution incident. The biofilm produced by algae may play a role in oil decontamination, provide a substratum for other benthic organisms and a source of food for heterotrophs during and after recovery.

SKIDMORE^{1,2} R. E., S. C. Maberly¹ & B. A. Whitton² (¹Institute of Freshwater Ecology, The Ferry House, Far Sawrey, Ambleside, Cumbria LA22 0LP; e-mail: R.Skidmore@IFE.ac.uk; ²Biological Sciences, University of Durham, South Road, Durham DH1 3LE). **Potamoplankton production, growth and biomass: interpretation of spatial and temporal changes in the River Trent.**

The effect of environmental factors upon phytoplankton performance in the River Trent was investigated between 1995 and 1997. At the tidal limit, phytoplankton biomass, measured as the concentration of chlorophyll *a*, showed a regular seasonal pattern of a winter minimum (1.4 to 1.7 $\mu\text{g l}^{-1}$) with a rapid increase to an annual maximum (120 to 160 $\mu\text{g l}^{-1}$) in April or May. This was followed by a rapid decline to a low biomass (6 to 18 $\mu\text{g l}^{-1}$) in summer. Daily measurements of chlorophyll *a* concentration showed rapid changes in biomass in response to changes in discharge during spring, emphasising the importance of hydraulic flushing in regulating potamoplankton populations. At the time of the annual maximum, phytoplankton biomass increased downstream. During late summer, however, the reverse occurred. Rates of change, estimated from changes in concentration of chlorophyll *a* downstream showed a consistent positive pattern of growth between April and June, reaching a maximum of 0.57 d^{-1} in June 1996, followed by a rapid decline during summer to a minimum of - 0.78 d^{-1} . The seasonal pattern of calculated column production was similar to that shown by biomass and growth with a switch to a heterotrophic system as water temperature increased from c. 12 to 20 °C and as species composition changed from populations dominated by centric diatoms to those dominated by green algae. Rates of growth estimated from productivity measurements could account for all but the highest estimates of biomass increase. Phytoplankton populations appear to be controlled primarily by physical factors in this river.

SMITH D. J. & G. J. C. Underwood (School of Biological & Chemical Sciences, John Tabor Laboratories, University of Essex, Wivenhoe Park, Colchester, Essex CO4 3SQ; e-mail: djsmitc@essex.ac.uk \ gunder@essex.ac.uk). **Rhythms of exopolymer production by epipellic diatoms.**

Epipellic diatoms are a major component of the microphytobenthos inhabiting fine cohesive sediments. Epipellic diatoms vertically migrate through the sediment in response to tidal and diurnal rhythms. The locomotive force required for migration has been attributed to the extrusion of carbohydrate-rich exopolymers (EPS). By binding adjacent sediment particles and producing a smooth surface layer, EPS has been implicated in increasing sediment stability and therefore production rates of EPS are of ecological significance. Rates and patterns of EPS production were investigated under laboratory conditions and *in situ*. In the absence of environmental stimuli, EPS production rates correlated with the migratory patterns of the epipellic diatoms, suggesting the existence of an inherent rhythm of EPS production. When epipellic diatom-dominated sediments were subjected to a constant light intensity, maximum EPS production rates occurred immediately prior to (174 $\mu\text{gC.m}^{-2}.\text{h}^{-1}$) and proceeding (81 $\mu\text{gC.m}^{-2}.\text{h}^{-1}$) periods of immersion and re-emersion respectively. Pulse experiments suggested that light intensity including dark treatment, had no effect on the reallocation of carbon into the EPS fraction, the greatest reallocation taking place immediately prior to immersion for laboratory and *in situ* studies. The production of EPS accounted for 0.1 - 1% of *in situ* primary production and 0.05 - 0.8 % of primary production determined in laboratory experiments. It is suggested that tidal induced circadian rhythms govern rates of EPS production and production is irrespective of light intensity. Results from this study also suggest that carbon in the EPS fraction may have been assimilated immediately prior to, and / or several hours before a specific sampling point. It is therefore proposed that the products of the catabolism of a photosynthetic storage product (a glucan) are utilised in the production of EPS which provides an hypothesis explaining how cells subjected to several hours of dark treatment (immersion) are able to migrate back up to the sediment surface.

SNELGROVE J. M. & M. Wilkinson (Heriot-Watt University, Edinburgh EH14 4AS; e-mail j.m.snelgrove@hw.ac.uk) **Inter-population variation in the results of in-situ bioassays with *Fucus vesiculosus*.**

An in-situ environmental bioassay has been devised using excised frond tips of *F. vesiculosus* explanted to field test sites. Ion leakage and photosynthetic and respiratory rates under standard

conditions after return to the laboratory were measured. A problem in using populations from a variety of field sites in exotoxicity assessment is the possible inter-population variation in response. A further problem in estuaries, where such testing may be most useful, is variation in salinity conditions possibly affecting response. To test the effect of estuarine salinity gradients and source population on test results reciprocal transplants were made between sites along the Forth estuary, between the Forth and Tees estuaries and from the mouth of the Tees to upstream Tees sites. Plants from mid and upper Forth populations showed no significant differences in all the parameters measured between each other and the full range of sites in the Forth. Plants from the mouth of the Forth showed increased ion leakage and respiration and decreased photosynthesis with distance up the estuary. Plants from the mouth of the Tees showed a similar gradient at sites along the Forth. The upper Tees transplant sites were the only ones used where *F. vesiculosus* did not occur naturally. Surprisingly plants from the mouth of the Forth showed significantly less adverse effect in the polluted upper Tees sites than did plants from the mouth of the Tees itself. Some populations appeared relatively insensitive to environmental variations whilst others did not. Further work is therefore needed.

STANLEY M. S., J. A. Callow & M. E. Callow (School of Biological Sciences, The University of Birmingham, Edgbaston, Birmingham, B15 2TT, U.K.). **Production of MAbs to Adhesive Glycoproteins Secreted By the Marine Biofouling Alga, *Enteromorpha*.**

Enteromorpha spp. are major contributors to marine biofouling in which a critical event is the primary adhesion of the zoospore to the surface. This involves the secretion of adhesive materials which appear to be glycoprotein in nature. This paper reports progress in attempting to identify these glycoproteins using antibody techniques. Monoclonal antibodies were raised to whole settled zoospores. Hybridomas were differentially screened by ELISA and indirect immunofluorescence microscopy (IIF) on fixed unsettled and settled zoospores, and by Western blotting. Antigens have been partially characterised with respect to molecular weight and glycosylation and the nature of the recognised epitopes has been determined by pronase digestion and periodate oxidation. The cellular location of the antigens has been studied by immunogold-EM.

SULLIVAN¹ M. B., R. Riosmena-Rodriguez² & M. S. Foster³ (¹Long Island University, Southampton College, 239 Montauk Hwy, Southampton NY 11968 USA; ²Moss Landing Marine Laboratories, P.O. Box 450, Moss Landing, CA 95039, U.S.A.; ³Universidad Autonoma de Baja California Sur, Dept. Biol. Mar., Ap. Postal 19-B, La Paz, B.C.S. Mexico). **How many species of *Calliarthron* (Corallinales; Rhodophyta) are distributed in the Northeast Pacific?**

Calliarthron is a geniculate coralline genus widely distributed in the Northeast Pacific from intertidal pools to kelp forest floors with a very important role in those assemblages. Based on incongruencies of the basic description of *Calliarthron cheilosporioides* Manza 1937 and *C. tuberosum* (Postels & Ruprecht) Dawson 1953, we have developed an extensive analysis of the taxonomic disposition of these species. Preliminary surveys suggested that morphotypes occurred under particular ecological conditions. Field collections and ecological experiments were then developed in the overlapping regions of the two species' distributions (Stillwater Cove, Monterey County, CA, U.S.A.) and an intensive review of representative specimens from several herbaria (UBC, UMich, LAM, UC) was conducted to estimate the number of valid species distributed in the Northeast Pacific. Traditional morphological characters (ie. height and width of intergenicula, height of the plant, angle of the wings to the main axis) and modern anatomical features (ie. number and size of intergenicular rows, the conceptacle anatomy and size, conceptacle pore structure and size) were examined. This study concludes that only one taxonomic unit is widely distributed all over the Northeast Pacific region and four taxa were subsumed under synonymy (*C. tuberosum*, *C. cheilosporioides*, *C. regenerans*, *C. setchelliae*). Experimental transplants showed after 12 months of monitoring that the basic morphological features used to discriminate species are unstable and unreliable as they are

environmental responses. The stability of the anatomical features also justifies the taxonomic conclusions derived in the study.

TAN I. H. & H. J. Sluiman (Royal Botanic Garden Edinburgh, 20A Inverleith Row, Edinburgh EH3 5LR; email i.tan@rbge.org.uk and h.sluiman@rbge.org.uk). **Molecular identification of *Enteromorpha* occurring in the Ythan estuary.**

For some years now, seasonal development of substantial mats of the green alga (*Enteromorpha* spp.) in the Ythan estuary have been causing concern. It is our objective to establish the species of *Enteromorpha* causing this green tide in the estuary; however, the identification of *Enteromorpha* species is problematic due to extreme phenotypic plasticity and wide ecological tolerance among the species. We present results of a molecular analysis carried out to identify the range of species of *Enteromorpha* occurring in the Ythan. Sequence analysis of complete ITS I & II sequence data revealed 4 well supported species complexes, morphologically identified as *E. intestinalis*, *E. compressa*, *E. prolifera* and *E. linza*. Further, the inferred phylogenies also suggested that the genera *Enteromorpha* and *Ulva* are not monophyletic. Molecular and morphological data will be presented to show the relationships among the *Enteromorpha* and *Ulva* species.

TAYLOR A. H. (Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth PL1 3DH). **Tracing a climatic connection between the Gulf Stream and plankton on the European shelf**

A time-series of the latitude of the north wall of the Gulf Stream at the US coast has been constructed from 1966 to 1996 (<http://www.npm.ac.uk/pml/labproj1/web2.htm>). The index of Gulf Stream position was derived from the north wall data by principal components analysis. The latitude of the Gulf Stream appears to depend on the wind patterns across the North Atlantic over several preceding years. The year-to-year changes in this series are strongly correlated with the abundances of plankton observed by the Continuous Plankton Recorder Survey around the British Isles, and also with the abundance of zooplankton in Lake Windermere. Non-parametric Multi-Dimensional Scaling is used to show the relationship is widespread across zooplankton and phytoplankton species. These connections reflect changing weather patterns across the North Atlantic and become manifest in the plankton via the annual cycle of stratification. It is shown that this process can be replicated by forcing simple models of the shelf-seas phytoplankton with three decades of meteorological data. These calculations reveal aspects of year-to-year differences in weather to which the planktonic ecosystem is sensitive. It seems that the timing of the onset of spring is correlated with the latitude of the Gulf Stream.

TAYLOR R. & J. A. Raven (Department of Biological Sciences, University of Dundee, Dundee DD1 4HN, UK). **"Green Tides" at the Ythan Estuary, Aberdeenshire - An Indication of Environmental Change?**

Eutrophication of marine ecosystems is particularly evident by the increased abundance of green algal taxa and the frequent occurrence of some species in dense blooms or "green tides". Over the last 20 years, mass blooms of fast-growing green algal species have been evident during the summer months at the Ythan Estuary, Aberdeenshire. In 1992 the Paris Commission recognised the site as being possibly eutrophic and requiring further study, hence funding has been made available by the Scottish Office for numerous projects investigating various aspects of the ecology of the site. This includes the current project, a 3 year study specifically investigating aspects of macroalgal ecophysiology. The study focuses on the ecophysiological characteristics of locally occurring *Enteromorpha* which are potentially important in permitting an *Enteromorpha* genotype to produce a "nuisance" in bodies of water such as the Ythan. Specifically, a series of laboratory studies are being conducted to evaluate the growth of *Enteromorpha* isolates under multifactorial treatments of light, temperature, salinity, inorganic N and inorganic P. In addition, growth, survival and decomposition of *Enteromorpha* spp. under both favourable and adverse conditions are under investigation. The

capacity to survive adverse circumstances, as well as the ability to grow under favourable conditions, is likely to be important in the specification of a "nuisance" alga, since the survival and over-wintering of material greatly affects the quantity of inoculum available for the next favourable growth period.

THORNTON D. C. O., L. F. Dong, G. J. C. Underwood, & D. B. Nedwell (Department of Biological Sciences, University of Essex, Colchester, CO4 3SQ; e-mail: dan@essex.ac.uk). **The effect of diatom dominated microalgal biofilms in estuaries on the exchange of nutrients across the sediment-water interface**

Microalgal biofilms dominated by diatoms are a characteristic feature of the cohesive sediments of East Anglian estuaries. The effect of the microphytobenthos on nutrient and oxygen budgets has largely been overlooked, though the photosynthetic activity of microalgae can effect the direction and magnitude of nutrient fluxes. The nutrient loads of most estuaries in Europe are subject to anthropogenic enrichment which may lead to the long term eutrophication of coastal seas. A greater understanding of nutrient fluxes through estuaries may be used to establish the nutrient status of an estuary and nutrient input to the coastal sea. Studies on two contrasting East Anglian estuaries (Colne and Great Ouse) have shown spatial and temporal patterns in biomass distribution and rates of processes. The effect of the microphytobenthos on nutrient and oxygen fluxes across the sediment-water interface was apparent from differences in both direction and magnitude of fluxes under conditions of light and dark. Changes in ammonium flux were most marked; uptake was observed in the light, whereas there was ammonium release from the sediment in the dark. Ammonium uptake in the light may have been due to assimilation by the biofilm. The photosynthetic and respiratory activity of the microphytobenthos effected the oxygen budget of the surface sediment layers, effecting the bacteria mediated processes of nitrogen oxidation and reduction. Denitrification, an anaerobic process, was inhibited during photosynthesis whereas there was a stimulation of nitrification.

TIMMERMANS¹ K. R., M. Davey², R. Geider², A. Aldrich³, M. Boye³, S. van den Berg³, J. de Jong¹, K. Bakker¹, H. Hillebrand¹ & H. de Baar¹. (¹Netherlands Institute for Sea Research, Texel, P.O. Box 59 1790 AB Den Burg, Texel, The Netherlands: klaas@nioz.nl; ²MBA, Plymouth U.K.; ³U. of Liverpool, U.K.). **Effects of iron on *Chaetoceros calcitrans* (Bacillariophyceae) grown in natural seawater without artificial chelators.**

The single cell diatom species *Chaetoceros calcitrans* was grown in MnO₂ cleaned seawater from the Gulf of Biscaye. Background total dissolved Fe concentrations were 5 - 10 nM. The only additions to the seawater (prior to cleaning) were nitrate, silicate (both 100 µM), phosphate (6.5 µM) (all final concentrations) and vitamins. During the experiments, organic Fe complexation, Fe redox speciation, as well as dissolved Fe were measured in addition to dissolved nutrients. The biological response of *C. calcitrans* on Fe availability was monitored by cell numbers, nutrient uptake, nitrate reductase activity and flavodoxin/ferredoxin measurements. In the course of the experiment, organic complexation of Fe increased and Fe²⁺ concentrations as well as total dissolved Fe decreased. Upon addition of a 100 nM Fe spike in subsamples of the cultures, growth rates, nitrate uptake and nitrate reductase activity increased within 48 h after the spike in the enriched bottles. The results of these experiments showed that *C. calcitrans* has signs of Fe-stress at total dissolved Fe concentrations of 5 - 10 nM. In response, organic complexes (siderophores) are produced. Fe²⁺ seems to be preferentially taken up. Fe-stress in *C. calcitrans* is further deduced from the stimulatory effect of Fe addition.

VOELKER C. & D. A. Wolf-Gladrow (Alfred Wegener Institute, Am Handelshafen 12, D-27570 Bremerhaven, Germany; email: cvoelker@AWI-Bremerhaven.DE). **Physical limits on iron uptake mediated by siderophores or surface reductases.**

YOUNG J. R. (Palaeontology Department, The Natural History Museum, Cromwell Road, London, SW7 5BD; e-mail: j.young@nhm.ac.uk). **Coccolithophorids and environmental change - achievements and ambitions.**

Coccolithophorids have the most extensive fossil record of any algal group and are the most intensively studied by geologists - there are still probably a couple of hundred professional micropalaeontologists around the world employed to study coccoliths and associated nannofossils. The prime value of coccoliths is as biostratigraphic, age dating, tools, particularly in deep-sea carbonate sediments where they are prime chronometers. Naturally there has also been much interest in the potential of coccoliths in palaeo-oceanographic and global change studies. Indeed at least three different major types of research can be identified in this field: 1. Use of coccoliths as proxies of environmental parameters and so as monitors of oceanographic change. 2. Modelling of the role of coccoliths on global change, especially their role in the carbonate cycle. 3. Study of the long term evolutionary history of coccolithophorids in relation to environmental change. Key achievements within these fields will be reviewed and the extent to which they have met ambitions discussed. In particular, attention will be paid to the problems due to inadequate understanding by palaeontologists of phycology, and a new interdisciplinary EC research network (CODENET) - Coccolithophorid Evolutionary Biodiversity and Ecology Network) with ambitions to address these problems will be introduced.

POSTERS

ABEL K. A. & J. A. Raven (Department of Biological Sciences University of Dundee). **The effects of external osmolality on intracellular osmolality and growth rate of *Chlamydomonas reinhardtii*.**

Work by Raven (82, 84 & 95), theorised that low intracellular osmolalities in freshwater algal cells could/should reduce energy costs of volume regulation. These energy costs are incurred by wall synthesis in walled cells and the cost of water efflux in wall-less cells. Experimental work, using axenic cultures of *Chlamydomonas reinhardtii*, has shown a correlation between cytoplasmic osmolality and the osmolality of the growth medium. This correlation is maintained over a range of extracellular osmolalities and subsequently allows a comparison of growth rates to extracellular/intracellular osmolalities. Recent work on the contractile vacuole cycle by Prof. Luykx, Department of Biology, University of Miami, has drawn a relationship between extracellular osmolalities and water efflux rates and should allow refining of experimental/theoretical cost-benefit analysis of growth of freshwater algae at low extracellular osmolalities.

BAPTISTA M.G. (School of Biological Sciences, University of Bristol BS8 1UG). ***Psammoparalia elliptica*, gen. and sp. nov., a epipsammic diatom from Porto Belo Peninsula, Santa Catarina, Brazil?**

A taxonomic survey of the psammic diatoms from Porto Belo Peninsula (27° 05' S, 48° 27' - 48° 37' W) in Santa Catarina state, Brazil has been conducted. Sand samples were taken from the backshore to the swash and a new centric epipsammic diatom was found. *Psammoparalia elliptica*, like *Paralia sulcata* (Ehrenb.) Cleve, is a colonial and heterovalvy diatom with a ring of rimoportulae around the edge and chambered mantle. The two species differ in valve shape outline, valve face undulation and habitat. The structure of their valves and frustules are compared using light microscopy, scanning and transmission electron microscopy observations.

BERRY L. & K.J. Flynn (Swansea Algal & Plankton Research Group, University of Wales Swansea, Swansea SA2 8PP; e-mail k.j.flynn@swansea.ac.uk). **Release of organic-N by phytoplankton.**

The release of organics by healthy phytoplankton has long been a subject of controversy. Recently the debate has included coverage of forms of organic-N (DON) as well as DOC. The problem is that while field workers may measure a significant release, laboratory studies invariably indicate that the release is minimal. In this study the release of dissolved free and dissolved combined amino acids (DFAA and DCAA) was measured during the growth of *Heterosigma carterae*, *Thalassiosira weissflogii* and *Mantoniella squamata* in low-P and hi-P nitrate-limited batch culture. Internal levels of free amino acids, total cell-N and external nitrate were also determined. Cells were filtered either gently (control), with high vacuum or with a high volume of wash in order to test the ability of the cells to resist rupture. No evidence was found for whole cell rupture. Amounts of DCAA exceeded DFAA by a factor of 3 or so with no evidence of a significant loss of cell-N through this route. In all the batch cultures run over many years, we have found no evidence of a significant loss of N (i.e. inorganic nutrient-N + cell-N has remained constant). The implication is that the reported high rates of DON release are in some way artifactual.

BOULCOTT M., C. A. Raines & G. J. C. Underwood (Department of Biological Sciences, University of Essex, Colchester. CO4 3SQ; Email mjboul@essex.ac.uk). **Patterns of carbohydrate (EPS & glucan) production in estuarine epipellic diatoms.**

Epipellic diatoms fix carbon through photosynthesis, a process which is frequently interrupted due to tidal immersion. Incoming tides also threaten epipellic diatoms with possible resuspension. In response to these environmental factors diatoms are able to migrate into the sediment through the secretion of Extracellular Polymeric Substances (EPS) resurfacing during daytime emersion periods. Studies in the laboratory have indicated that although cultures of epipellic diatoms produce EPS during light periods, an even greater quantity of EPS is produced during periods of darkness. This may be a physiological response as epipellic diatoms need to produce more EPS in order to migrate into the sediment. During these dark periods cell metabolism will be sustained through utilising a store of energy which will also provide the carbon for EPS production to facilitate an upward migration. Studies of the storage product in diatoms (glucan), have shown that during periods of darkness the increase in EPS coincides with depletion of glucan. Studies incorporating inhibitors of glucan synthesis combined with ^{14}C experiments are being used to determine whether EPS is synthesised only from carbon derived through the catabolism of glucan or also from carbon fixed directly through photosynthesis - thereby providing greater insight into EPS production pathways in epipellic diatoms.

CLARKSON N. & M.S. Davies (The Ecology Centre, The University of Sunderland, Sunderland, SR1 3SD; email: es0ncl@sunderland.ac.uk). **The response of diatoms to extremely low frequency electromagnetic fields.**

The marine diatom *Amphora coffeaeformis* has previously been shown to exhibit an increase in calcium-dependent motility when in specific combinations of electromagnetic fields (EMFs). However, independent research aimed at repeating the initial findings lead to mixed results and some controversy surrounding the theoretical models suggested to explain the effects. A new approach has been developed which offers real-time in vivo recordings of the response of the whole organism (*A. coffeaeformis* strains #2038, #2039 and an isolated wild strain) to exposure to a manipulated EMF environment. The diatom motility response to extremely low frequency (ELF) EMFs was determined using a microscope, the stage of which was at the centre of two pairs of *Helmholtz coils*, with an associated video link. Logarithmic phase cells were placed in a chamber on the microscope stage. The motility of diatoms in the chamber was measured on a monitor screen prior, during and post EMF exposure, for controls no power was applied to the coils. The EMFs used were those which gave positive results in previous studies, $B_V = 0 \text{ mT}$, $B_H = 20.9 \text{ mT}$, $B_{Hac} = 41.8 \text{ mT}$ peak-peak at 16 Hz. No significant increase in diatom motility was observed during exposure to EMFs. The results do not preclude the possibility of an EMF effect, but suggest that the diatom system does not constitute a reproducible bioelectromagnetic phenomenon.

DÍEZ I., A. Secilla, A. Santolaria & J. M. Gorostiaga (Departamento de Biología Vegetal y Ecología, Facultad de Ciencias, Universidad País Vasco, Apdo. 644 Bilbao 48080, Spain). **Marine benthic vegetation as ecological indicator of water quality. A case study.**

Subtidal benthic marine vegetation from the 'Abra de Bilbao' and proximal coast (Northern Spain) was monitored in 5 sites located along a pollution gradient in 1984, 1992 and 1996. The decrease of industrial activity, the closure of mineral washeries, and the establishment of wastewater-treatment plants have resulted in a water quality improvement. In response to this pollution decrease, vegetation experienced a general increase of species diversity, algal cover, proportion of morphologically complex species and vertical layering. The following steps could be pointed out, in this recovery process (from the most degraded stadium to a non-altered state): 1) Appearance of isolated specimens of filamentous (mainly ceramiaeceous: *Antithamnionella spirographidis*, *Anotrichium furcellatum*) and thin bladed (mainly delesseriaceous: *Hypoglossum hypoglossoides*, *Erytroglossum laciniatum*) forms on the empty substrata (often occupied by filter feeders). 2) Development of a basal layer composed mainly of caespitose forms such as *Pterosiphonia pennata*, *Chondria coerulescens* and other opportunistic algae such as *Acrosorium venulosum*, *Aglaothamnion cordatum*, *Rhodymenia holmesii* and *Dictyota dichotoma*. 3) Development of a crustose layer (Mesophyllum, Zanardinia) partially covered by ceramiaeceous algae. 4) Development of a continuous basal layer on the crustose layer with the progressive substitution of ceramiaeceous algae by caespitose forms (*P. pennata*, *C. coerulescens*, *Corallina officinalis*) and other perennials (*Pterosiphonia complanata*, etc.). 5) Development of an annual canopy (*Codium decorticatum*) and annual upper canopy of kelps (*Saccorhiza*). 6) Substitution of the annual canopy by a perennial one (*Gelidium sesquipedale*, *Cystoseira baccata*).

DRAKARE S. (Institute of Limnology, University of Uppsala, Norbyvägen 20, S-752 36 Uppsala, Sweden; e-mail:Stina.Drakare@limno.uu.se). **The role of picophytoplankton in a deep humic lake in northern Sweden.**

During the summers of 1996 and 1997 the abundance, biomass, and activity of picophytoplankton (less than 2 μm), heterotrophic bacteria and larger phytoplankton were analysed in a deep humic lake in northern Sweden. The comparison was made between two years with different DOC-levels in the lake, caused by extremely low spring meltwater inflow in 1996. Picophytoplankton and bacterioplankton abundance and biomass were analysed by epifluorescence microscopy. Activity was measured by size-fractionated ^{14}C -fixation for phytoplankton and by ^3H -leucine uptake for heterotrophic bacteria. Picophytoplankton importance relative to heterotrophic bacterioplankton and larger phytoplankton, as well as the probability of competition for nutrients and energy between these plankton groups, will be discussed.

FITZGERALD¹ O., D. B. Stengel & M. D. Guiry (¹Martin Ryan Marine Science Institute and Dept of Botany, University College Galway). **Irradiance and nutrient effects on pigmentation of intertidal fucoids from the Ireland west coast.**

Chlorophyll *a* levels in the marine intertidal brown alga *Ascophyllum nodosum* (L.) Le Jolis from the West coast of Ireland exhibited a strong seasonal pattern. This was thought to be due to variations in *in situ* photon irradiance and nutrient conditions. Laboratory studies of irradiance and nutrient effects demonstrated a positive relationship between chlorophyll *a* and enrichment (PES-Provasoli, 1968) for apical tips of *A. nodosum*. An inverse relationship was found between chlorophyll *a* and photon irradiance for *A. nodosum* and *Fucus serratus*. Enrichment by single constituents of PES medium did not result in the high chlorophyll *a* concentrations found in plants grown in full strength PES. Preliminary studies indicate the necessity for iron in macroalgal culture media and postulate a nitrogen - iron limitation, similar to that found for phytoplankton, in the nutrient-poor waters of the Irish west coast. Further experiments are presently being undertaken.

FRANKLIN¹ L. A., I. Yakovleva², U. Karsten³ & K. Lüning¹ (¹Biologische Anstalt Helgoland, Postfach 180, D-27483 Helgoland, Germany; email: 101377.3345@compuserve.com; ²Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences, Vladivostok 690041, Russia; ³Alfred-Wegener Institute of Polar and Marine Research, Am Handelshafen 12 D-27570 Bremerhaven, Germany). **How does *Chondrus crispus* deal with ultraviolet light?**

Intertidal macroalgae are exposed daily to ultraviolet radiation (UVR). The ability to protect or repair cellular components from damage by this highly energetic radiation, especially with respect to increasing global UVB levels and in combination with high photosynthetically active radiation (PAR), is critical to survival of intertidal populations. To further understand the impact of high UVB on macroalgae, the induction of protective pigments and repair of chloroplast protein damage caused by PAR and UVR was studied in intertidal and subtidal *Chondrus crispus* transferred to shallow water. Synthesis of 4 UVR-absorbing pigments (the mycosporine-like amino acids (MAA) palythine, shinorine, palythanol, and palythene) was induced in subtidal thalli by all irradiance treatments, including only natural PAR, PAR+UVA, or PAR+UVA+UVB. The presence of UVB slightly stimulated initial synthesis. Photosynthetic efficiency of transferred thalli gradually improved with increasing MAA concentration, but the accumulation of MAAs was not sufficient to prevent reduction in longterm growth by UVB. Neither did they prevent damage by UVR to chloroplast-encoded proteins in intertidal thalli which already contained high concentrations. Nevertheless, damage in plants from either depth could be repaired after a short period in dim light. It is likely that a gradual increase in UVB, when accompanied by the daily flux of high and low light in the field and the presence of UV absorbing pigments, will probably not seriously impact established populations of *C. crispus*. However, more information is needed on effects on recruitment and other species must be tested before community-wide conclusions on UVB effects can be reached.

FYSON^{1,2} A., D. Lessmann², B. Nixdorf², H. Krumbeck^{1,2} & C. E. W. Steinberg¹ (¹Institute of Freshwater Ecology and Inland Fisheries, Müggelseedamm 310, Berlin, D-12587, Germany; ²Lehrstuhl Gewässerschutz, Brandenburg Technical University Cottbus, Cottbus D-03013, Germany; e-mail: fyson@igb.fta-berlin.de). **Productive, Eutrophic yet Extremely Acidic Mining Lakes in Lusatia, Germany: What, Where and Why?**

Tagebausen are lakes formed through the infilling, of open cast lignite mining pits. The water chemistry of such lakes in the Lausitz region in eastern Germany (Saxony/Brandenburg) is characterised by high concentrations of Fe, H⁺ (pH 2.5-3.5), SO₄²⁻ and usually a low phosphate (DRP) and dissolved carbon concentrations. These lakes are very variable in size and are typically deep (20-45 m) and dimictic. Typically, Tagebausen have low productivity and biodiversity. However, a few lakes exhibit localized or episodic high productivity. In Lugteich, a small Tagebausee which received domestic wastewater for many years, water chemistry has high concentrations of DRP, NH₄-N, dissolved carbon (DIC and DOC) and high acidity (Fe²⁺/Fe³⁺ and H⁺). The phytoplankton biovolumes in this lake are extremely high (up to 60 mm³l⁻¹) but unlike typical, non-acidic, eutrophic lakes, species number is low (2-6 compared to more than 30). For much of the year, there is an intense chlorophyll a maximum near the metalimnion where dissolved O₂ concentration (<3 % saturation) and light (20-30 µE.m⁻².sec⁻¹) are low. The phytoplankton in this narrow zone is typically dominated by the Euglenophyte *Lepocinclis teres* (SCHMITZ) FRANCÉ which is found in many Tagebaurestseen. A Cryptophyte, *Cyathomonas* spp. may also be dominant in this lake and *Chlamydomonas* spp. (Chlorophyceae) are always present. The diurnal and seasonal variation in the extent and location of the chlorophyll maximum and its relation to both water chemistry and algal distribution are described.

GARGIULO G. M., G. Genovese & G. Tripodi (Institute of Botany, University of Messina, Italy). **A sexual stage in the life history of freshwater *Bangia atropurpurea* (Rhodophyta).**

Bangia atropurpurea (Roth) C. Ag. has marine and freshwater populations. The life cycle of the former is known as an alternation of multiseriate filaments bearing spermatia or carpogonia and uniseriate branched filaments, the conchocelis diploid phase, which differentiate usually haploid spores. This second step of the life history was not reported in individuals from freshwater populations, where only sterile gametophytic filaments were observed. Laboratory grown *Bangia* from Great Lakes of North America showed conchocelis filaments, interpreted as the result of germination of monospores, since carpogonia or spermatia were not observed. We present observations on the complete life history of this organism, studied in the river Alcantara, East Sicily, and in laboratory cultured individuals. *B. atropurpurea* thrives on basaltic rocks or epiphytic on filamentous green algae. The temperature of the water is between 9 C in winter and 21 C in the summer, pH 8.1. When cultured in laboratory, gametophytic filaments showed spermatangial cells with four spermatia, others differentiated carpogonia with a typical protrichogyne. Fertilized carpogonia with stages of the formation of carposporangia were also documented. During dry season short filaments have been observed showing the cell wall with an outer sheet, dissolved in the apical portion when the cellular growth starts. These presumably are resting stages of this organism. Endospores were observed in cultured gametophytic filaments.

HAN Y.-S. & T. Han (Department of Biology, University of Incheon, Incheon 402-749, Korea). **Effects of light on sporulation in a green alga, *Ulva pertusa*.**

Transformation of vegetative cells into reproductive ones in *Ulva pertusa* blades is strongly controlled by light. When *Ulva* discs cut from the marginal parts of thalli were grown for 12 days under different photon irradiances of 12:12 light-dark cycle, the sporulation process occurred at higher than $5 \mu\text{mol m}^{-2} \text{s}^{-1}$. The higher irradiances given except at $150 \mu\text{mol m}^{-2} \text{s}^{-1}$ where the sporulation seems to be inhibited the less time taken to complete the formation of swimmers. Both blue and red light at $20 \mu\text{mol m}^{-2} \text{s}^{-1}$ were similarly effective in inducing the generative activity. The sporulation was detected in green light only after 8 days since it had started in blue and red light. Different regions of thallus showed differences in sporulation percentage with time. Discs cut from the basal region had a slow but steady growth with no sporulation over 30 days while those from the mid region attained the largest sizes and sporulated up to 35% for 12 days. The growth of discs from the marginal region, though the fastest, stopped completely when production of swimmers reached more than 90% for the first 3 days.

HANLON A., K. Oxborough, G. J. C. Underwood & N. R. Baker (Department of Biological Sciences, University of Essex, Colchester, CO4 3SQ e-mail: armhan@essex.ac.uk). **The effect of sub-lethal concentrations of herbicides on *in situ* chlorophyll *a* fluorescence in salt marsh microphytobenthic communities.**

Estuarine saltmarshes have been subject to increasing levels of erosion over the past 30 years. The impact of sub-lethal concentrations of herbicides to saltmarshes may be an important factor leading to an increase in community instability thus compounding the problem of erosion. Microphytobenthic assemblages are important primary producers in saltmarshes and can enhance sediment stability through the production of cohesive extracellular polymeric substances (EPS). Sub-lethal concentrations of common herbicides were applied to axenic cultures of epipellic diatoms. The effect of sub-lethal concentrations of herbicides on epipellic diatoms can be quantified by measuring changes in *in vivo* chlorophyll *a* fluorescence parameters, growth and EPS production. Resultant changes in photosynthetic efficiency were measured using a Hansatech pulse modulated fluorimeter. Dose response curves indicated, for example, that simazine concentrations of $3.37 \mu\text{mol}$ significantly reduced dark adapted Fv/Fm over a 12 hour incubation period. Significant reductions in both dark adapted and steady state photosynthetic efficiencies were also noted at this concentration over a 7 day incubation period. Using a novel imaging system developed at the University of Essex, changes in chlorophyll *a* fluorescence parameters and photosynthetic performance can be measured *in situ* on

mixed microalgal mats. This technique has been used to detail species specific responses to the addition of herbicides at the level of individual microphytobenthic cell chloroplasts.

JOHN¹ D.M., B.A. Whitton², L.R. Johnson¹, A.J. Brook³ & P.V. York¹ (¹The Natural History Museum, London; ²University of Durham; ³University of Buckingham, UK). **Towards a modern freshwater algal flora of the British Isles.**

Many of the 26 collaborators have now made considerable progress with their contributions: preparing entries, writing keys, obtaining and preparing illustrative material, and providing information for a comprehensive list of all known species (ca. 5,000) for the United Kingdom and Ireland. A provisional checklist has been incorporated into a Determinand Dictionary that is now available. This forms part of the NERCs LOIS (Land-Ocean Interaction Study) programme. The first volume of the Flora will contain all groups except diatoms and the proposed publication date is Autumn 1999. Test keys have been produced for all chlorophyte, euglenophyte and xanthophyte genera known from the British Isles. Draft entries have been prepared for all chlorophyte species with the exception of the Chlorococcales, Oedogoniales and Volvocales. Desmids will be restricted to the more common and widespread species (about 300). Most desmid entries have been completed in draft form along with appropriate line drawings. In parallel with the hard copy versions of the 'Flora' there will be a photocatalogue comprising colour and monochrome photographs and line illustrations; this will be produced on CD-ROM from scanned images stored as JPEG or TIF files. Over 700 images are already available and digitised with almost as many awaiting to be scanned into the system.

KARLSSON I. (Blodstensvägen 1, 2tr., 75258 Uppsala, Sweden. E-mail: irene.karlsson@limno.uu.se). **A study of *Gloeotrichia echinulata* in Lake Erken (Sweden) during the summer of 1997.**

During the summer of 1997 I have been doing some preliminary studies of *Gloeotrichia echinulata* for my Ph.D. studies. I have tested the method of measuring the photosynthesis through the computer controlled illumination of algal colonies and the measuring of oxygen evolution through the Illuminova-system. The idea was to be able to determine the "fitness" of the colonies throughout the summer bloom. There are a few problems involved; first, the determination of the ideal light-exposure time for each level of light, and second, that the number of colonies needed to give a reliable response may vary according to colony size and chlorophyll content. The development of the bloom has also been monitored, with counting of colonies from a number of stations. A preliminary enclosure experiment was also made, to follow the growth and rate of division of a known number of colonies. My poster will be a summary and evaluation of the results and the methods used.

KING L., R. I. Jones & P. Barker (Department of Biological Sciences, IENS, Lancaster University, Lancaster LA1 4QW; Tel.: 01524-65201 ext. 93507, e-mail: cj.king@ukonline.co.uk). **Periphyton response to nutrient manipulation in lakes of different trophic state.**

Three approaches are being used to investigate the response of epilithic algal communities to nutrient availability: 1. Four surveys have been carried out of the epilithon of 20 lakes of various trophic state in the Lake District and the Yorkshire Dales. Sampling always includes the measurement of physical and chemical parameters of the surrounding water. 2. To explore seasonal variability, the epilithon of four lakes (Wastwater, Conistone Water, Esthwaite Water and Malham Tarn) is being sampled monthly over two years. 3. Nutrient manipulation experiments using clay flowerpots filled with nutrient-enriched agar and hanging from experimental rigs will be carried out after determination of the nutrient release rates in a laboratory experiment. These will be used to test the periphytic response to higher levels of nutrient availability. Using correlation analysis, the relationship between environmental parameters and periphytic communities will be investigated.

KONG J.-A. & T. Han (Department of Biology, University of Incheon, Incheon 402-749, Korea). **Rhythmic phenomena in a green alga *Ulva pertusa* exposed to different light qualities.**

Ulva pertusa exhibits a well-documented rhythm in cell division, chloroplast displacement and starch accumulation during a 12:12h light-dark period. Significant differences in those parameters were however found between the thalli grown in blue and red light. In blue light cell division occurred at the start of night, and cell expansion mostly during the day. On the other hand, red light-grown cells increased to their maximum in the mid-day, and then divided. Chloroplast displays the face position in light period and the profile position in the dark period irrespective of spectral qualities. The level of starch content quantified with a microscope using the potassium iodide-iodine reaction appeared to be coupled with rhythm in chloroplast movement in red light, but 6h out of phase with that in blue light.

KUHLENKAMP R. & K. Lüning (Biologische Anstalt Helgoland, PF 180, D 27483 Helgoland, Germany, e-mail: 101377.3345@compuserve.com). **Are natural surface radiation levels of PAR and UV-light detrimental to early germling stages of intertidal macroalgae?**

Macroalgae in the intertidal and high subtidal survive exposure to high levels of photosynthetically active (PAR) and ultra-violet (UVR) radiation, especially during low tide. It is not evident if this is also true for their propagules and subsequent germling stages if they do not find sun-protected settlement areas. Since survival at those stages directly influences recruitment of adult plants, effects of natural PAR and UVR were studied in *Fucus spiralis*, *Fucus serratus*, *Sargassum muticum*, *Dictyota dichotoma* and *Ulva lactuca* germlings. Experiments were conducted on Helgoland, North Sea, Germany, in September when all 5 algae were fertile in the field. Either 2 day old germlings obtained in laboratory culture or, in the case of *F. spiralis*, field-grown germlings of about 10mm length were transferred to an outdoor tank system and exposed in running sea water at a depth of 8 cm to 4 different light treatments: only PAR, PAR+UVA, full sun spectrum and full sun spectrum + artificial UVR. There were no differences in weight and length increase for any species among the 4 treatments. Germlings attained considerable size over several weeks in the experimental tank and it is conclusive that surface light levels during September did not effect their growth even with artificially elevated UVR. In future the same experiments will be conducted at periods with higher irradiances as in July when PAR and UVR are about 2-3 times higher than in September.

KÜSTER A. & R. M. Forster (University of Rostock, Fachbereich Biologie, Freiligrathstrasse 7/8, 18055 Rostock, Germany; e-mail: rod.forster@biologie.uni-rostock.de). **Does blue light control the lower depth limits of Charophytes?**

The distribution of Charophyte populations in brackish waters along the coast of the Baltic Sea has recently been surveyed. During this work the lower depth limit of *Chara* populations were assessed, together with underwater light measurements. It was found that the lower limit of *C. canescens* and *C. baltica* was well correlated to the depth at which blue light was diminished to 15% of the surface value. The relationship between lower depth limit and light quality was further tested by examining the vertical distribution of *Chara* species in 3 optically-distinct lakes of a national park in Mecklenburg-Vorpommern. Spectrally-resolved light measurements were made at each lake in July 1997. Lower limits of the main macrophyte populations were determined by diving or by dredging. Chemical (nutrients), biological (chlorophyll) and optical (Secchi depth) data have been monitored in these lakes for several years by local authorities so that the long term light history of the sites can be estimated and related to the observed distribution patterns. In addition, ecophysiological status of plants from both the upper and lower limits of the populations present at each site were characterised by measuring pigment composition with HPLC and photosynthesis-irradiance curves with an oxygen electrode. This work was supported by a British Phycological Society Summer Studentship.

LEE M.-S. & T. Han (Department of Biology, University of Incheon, Incheon 402-749, Korea).
Comparative sensitivity of UV-irradiated germlings and adult thalli of *Ulva pertusa* to light.

Exposure to UV-B radiation at 4.0 W m^{-2} for 1-2h resulted in substantial reductions in the surface area and number of cells of 8 day-old *Ulva pertusa* germlings. The surface area of germlings irradiated with UV for 1h was much larger at $100\text{ }\mu\text{mol m}^{-2}\text{ s}^{-1}$ than at $10\text{ }\mu\text{mol m}^{-2}\text{ s}^{-1}$ of white light under a 12:12h LD cycle although there was no significant difference in the number of cells. In adult thalli, however, UV irradiation did not cause any differential effect on the same parameters. Growth rate of UV-exposed germlings in both terms seems to be dependent on light qualities, judging from the fact that higher growth rate was observed in red light with blue being the next. The surface area of UV-treated adult thalli was almost the same among the light treatments, but the number of cells within a preselected area ($400\text{ }\mu\text{m}^2$) was greater in red light than in the other light conditions.

MARSHALL¹ H., K. J. Flynn¹ & R. J. Geider² (¹Swansea Algal & Plankton Research Group, University of Wales Swansea, Swansea SA2 8PP; e-mail: k.j.flynn@swansea.ac.uk; ²MBA, The Laboratory, Citadel Hill, Plymouth PL1 2PB; e-mail: rdg@wpo.nerc.ac.uk). **A Comparison Between Simulations Of Photoadaptation.**

An overview of two models of varying complexity describing responses of microalgae to N-status and irradiance will be presented. The more complex model enables greater control over the synthesis and degradation of photopigments and the interaction with the use of nitrate and/or ammonium as the N-source. The dynamics of this model will be compared to that of a simpler model to test if additional levels of complexity are warranted. The models use similar equations to describe the PI curve. In support of this theoretical study, experimental work is being conducted with 5 different phytoplankters (*Thalassiosira weissflogii*, *Emiliania huxleyi*, *Heterosigma carterae*, *Scrippsiella trochoidea* and *Isochrysis galbana*) to determine the net rate of pigment synthesis and degradation associated with changes in N-status and irradiance. These organisms are grown at either high or low irradiance and subsamples removed at different stages during the N-limited batch growth and exposed to the contrasting irradiance.

MARSHALL R. A., M. J. Dring & D. B. Harper (Department of Food Science & Marine Biology Station, The Queen's University of Belfast, Belfast BT7 1NN; e-mail: m.dring@qub.ac.uk).
***Falkenbergia hillebrandii* - a source of tri- and per- chloroethylene?**

Although volatile halocarbons are produced by many marine algae it has been generally assumed that the C_2 halocarbons, trichloroethylene (TCE) and perchloroethylene (PCE), originate solely from anthropogenic sources. However, recent reports suggest that there may be widespread release of both compounds by macroalgae, but there has been no unequivocal chemical identification of the compounds they produce. In this study, the production of TCE and PCE by the subtropical red alga, *Falkenbergia hillebrandii*, from which the highest rates of TCE release were reported, was examined using purge and trap instrumentation and gas chromatography/ mass spectrometry. A strain of *F. hillebrandii* from Florida showed no release of TCE or PCE in excess of the detection limit (0.4 ng/g fwt/h), after incubation for 24h under normal growth conditions. After longer incubations (40h), a compound was detected with a mass spectrum identical to that of dibromoethylene. Under high light stress, the alga released two additional halogenated compounds, dibromomethane and bromoform. Six other strains of *F. hillebrandii* were incubated in high irradiances and the release of these brominated compounds was quantified ($0.003\text{--}0.76\text{ }\mu\text{g/g fwt/h}$ for dibromomethane; $<0.0004\text{--}0.018\text{ }\mu\text{g/g fwt/h}$ for dibromoethylene; $<0.008\text{--}16.89\text{ }\mu\text{g/g fwt/h}$ for bromoform). At no time was TCE or PCE released by any strain of *F. hillebrandii*. In view of the close similarities between the gas chromatographic characteristics of dibromomethane and TCE, it is possible that earlier reports of TCE production were mistaken, or that the original algal sample examined was collected from an area contaminated with effluent containing TCE.

REUSS S. & M. J. Dring (University of Kiel, Germany and Queen's University Marine Laboratory, Portaferry, Co. Down BT22 1PF; e-mail: m.dring@qub.ac.uk). **Causes of afternoon depression of photosynthesis by macroalgae measured *in situ* in large chambers.**

Continuous measurements of oxygen-exchange of intact kelps or fucoid algae enclosed in 70-litre chambers and incubated for up to 3 days in the sea have shown that net photosynthesis declined soon after solar noon and remained depressed relative to irradiance until evening. The reasons for this afternoon depression of net photosynthesis were investigated in experiments under controlled lighting conditions. Changing the water in the chambers during the afternoon restored the photosynthetic rate to morning values, so that the depression appeared to be due to the changing conditions in the chamber during the incubation rather than to photoinhibition or to diel changes of photosynthetic capacity in the plants. However, pH did not increase significantly during incubation, so that the carbon supply did not appear to be depleted. The rate of dark respiration was often significantly higher after dusk than before dawn and, when 3 or 4 short dark periods were given during the day, respiration was found to increase from one dark period to the next. Reducing the oxygen-concentration in the chamber from 14 to 2 mg/l (by bubbling with helium) during one of these dark periods caused a fall in respiration rate, and other experiments demonstrated that, in general, net photosynthesis decreased and respiration increased as the concentration of oxygen in the chamber rose. However, smaller plants (with a higher proportion of younger tissue) showed a reduction in photosynthetic rate at lower oxygen concentrations than larger plants so that the increased rate of respiration may be related to anabolic activity.

PARK B.-J. & T. Han (Department of Biology, University of Incheon, Incheon 402-749, Korea). **Effect of UV-B radiation on gamete motility of *Ulva pertusa* (Chlorophyta).**

The motility of *Ulva pertusa* gametes was significantly impaired by UV-B radiation for 20 min at 2.4 Wm⁻² which simulated UV irradiance found in nature. UV-irradiated gametes showed differences in the motility depending on post-treatments. After UV exposure percentages of motile cells were much higher in light than in the dark. Of the four photon irradiances of white light the motility of UV-exposed cells highest at 100 $\mu\text{mol m}^{-2} \text{s}^{-1}$, and subsequently decreased at the following order of irradiance, 50-150-10 $\mu\text{mol m}^{-2} \text{s}^{-1}$. Both blue and red light of 8-10 $\mu\text{mol m}^{-2} \text{s}^{-1}$ appear to be similarly effective in sustaining motility of the gametes irradiated with UV while no such effect was detected in green light of the same irradiance.

POWTONGSOOK S. & D. J. Gilmour. (Department of Molecular Biology and Biotechnology, University of Sheffield, S10 2TN; e-mail: s.powtongsook@sheffield.ac.uk). **Investigation of glycerol leakage from the halotolerant green microalga *Dunaliella* spp.**

Dunaliella spp. accumulate glycerol as their compatible solute when growing in high salinity. Several studies have investigated the leakage of glycerol from *Dunaliella* immediately after being exposed to hypoosmotic shock. Most of the studies report that no glycerol was released from growing cells without hypoosmotic shock due to special properties of the cell membrane. However, observations carried out in our lab suggest that large amounts of glycerol are present in *Dunaliella* culture medium during exponential phase. In these experiments, *Dunaliella parva* CCAP 19/9 was grown in 1.5 M NaCl medium with HEPES buffer instead of Tris because the latter interfered with glycerol analysis by acetylacetone method. Algal cells were centrifuged and resuspended in fresh 1.5 M NaCl isoosmotic medium and glycerol concentration in the medium and in the cells was determined. The results showed that glycerol is constantly released from the algal cells. The leakage of glycerol could be clearly observed after 24 hours. After 4 days, up to 50% of total glycerol was found in the medium. Cellular growth, which was measured by chlorophyll concentration, and cell survival, which was determined by Evan's blue staining, indicated that glycerol leakage was not a result of cell death. Sodium vanadate did not have a strong effect on glycerol leakage while 25 mM CCCP, which could inhibit growth, slightly increased glycerol leakage. Experiments using ³H-

glycerol showed that no significant amount of glycerol was taken up by *Dunaliella*. Significant glycerol leakage was also found in *D. salina*. The role of glycerol leakage in *Dunaliella* cellular physiology will be discussed.

PRATT S. & R. J. Geider (Marine Biological Association, Citadel Hill, Plymouth PL1 2PB, UK; e-mail: s.pratt@wpo.nerc.ac.uk). **Light absorption and attenuation by marine phytoplankton.**

Phytoplankton are one of the primary factors accounting for variability in the depth of light penetration in continental shelf and oceanic waters. Phytoplankton affect the underwater light field by absorbing and scattering light. Light absorption is highly wavelength dependent, and largely reflects the intracellular pigment complement. Light scattering, on the other hand, is typically independent of wavelength except for the smallest phytoplankton cells. Light absorption and scattering are often expressed in terms of absorption and scattering efficiencies. The efficiency factor for absorption is the proportion of light incident on a unit cross-sectional area (perpendicular to a collimated light field) that is absorbed. Similarly, the efficiency factor for scattering is the proportion of incident light that is scattered. Efficiency factors for absorption and scattering depend on cell size, shape, organic matter content and pigment content. The relationship between absorption and scattering cross-sections and cell size, pigment and carbon contents are presented for several marine diatoms.

SAMMES^{1,2} P. J., H. L. MacIntyre³, R. J. Geider¹ & J. A. Raven² (¹Marine Biological Association, The Laboratory, Citadel Hill, Plymouth, PL1 2PB, e-mail: pip@wpo.nerc.ac.uk; ²University of Dundee, Scotland DD1 4HN; ³Horn Point Environmental Laboratory, PO Box 775, Cambridge MD, 21613-0775, USA). **Effect of prolonged darkness on some physiological and photosynthetic characteristics of *Skeletonema costatum* (Bacillariophyceae).**

The marine diatom *Skeletonema costatum* (Bacillariophyceae) can dominate algal blooms in turbid estuaries. In such an environment, the establishment of a strong pycnocline can create in effect two zones: a region overlying the pycnocline with relatively high light and low salinity, and a region underlying it with little or no light and high salinity. It can be very difficult for algal cells to move into or out of the upper photic zone if there is insufficient mixing in the water column, and it has been shown that cells can remain in relative darkness in the lower zone for several days. Most studies of phytoplankton growth are conducted under continuous light or in alternating periods of light and darkness designed to mimic diel variability of solar radiation. These studies do not yield information on several questions that pertain to how estuarine phytoplankton adjust their physiology to the prevailing conditions in the estuarine environment. Do cells adjust to prolonged periods of darkness? Does prolonged darkness lead to a reduction in photosynthetic performance once cells are reintroduced to the light? This experiment set out to quantify the physiology of *S. costatum* during both an extended period in the dark and in response to the reinstatement of low light conditions. Aliquots from a low-light adapted ($50 \mu\text{mol photons m}^{-2} \text{s}^{-1}$) batch culture were placed in complete darkness for six days, then reintroduced to low light. The "recovery characteristics" were qualified by daily sampling for the following parameters: photosynthesis-irradiance response curve, photosynthesis induction curve, chlorophyll *a*, light absorption, cellular protein, carbohydrate, carbon and nitrogen, dissolved inorganic nutrients.

SIMONS¹ J., J. Sinkeldam², A. van Beem¹ & H. van Dam³ (¹Vrije Universiteit, Dept. Plant Ecology, De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands; ²IBN-DLO, Dept Aquatic Ecology, PO Box 23, 6700 AA Wageningen, The Netherlands; ³AquaSense-TEC, Gen. Foulkesweg 72, 6703 BW Wageningen, The Netherlands). **Periphytic macro-and microalgae in a semi-artificial eutrophication gradient**

In 1989 an outdoor experimental system of 20 ditches was completed under the supervision of the DLO Staring Centre, Wageningen. Two series of 4 ditches were used for eutrophication studies. The eutrophication ditches were exposed to 4 different levels of external N and P input, varying from a zero input ("mesotrophic") via two steps to a poly-hypertrophic ditch with a high input of 25x the second moderately eutrophic ditch. The macrophyte development started with a charophyte phase (*Chara contraria* and *C. globularis*) in all ditches. During 1991 and 1992 the charophyte vegetation was replaced by fanerogamic species. In the low nutrient ditches charophytes decreased, but aintained up to present. From 1992 a rather stable stage was reached with in the two ditches with the highest nutrient load (hypertrophic) a closed layer of *Lemna minor*, while in the eutrophic ditches *Elodea nuttallii* reached domination. Filamentous macroalgae, often floating as "flab" were found in the meso- and eutrophic ditches, with *Cladophora fracta* as dominant species, mixed up with a lot of *Oedogoniales* and *Zygnematales*. Artificial substrates: non-diatoms: the chlorococcalean *Ectogeron elodeae* is a good indicator of poly(-eu)trophic situations. Good indicators for meso(-oligo)trophic situations are the greens *Aphanochaete magna*, *Chaetosphaeridium pringsheimii*, *Dicranochaete reniformis*, species of *Bulbochaete* and *Geminella*, the chrysophycean *Epipyxis* spp. and *Phaeoplacca thallosa*. Including an indifferent group of species (with among others *Pseudendoclonium prostratum* and *Chaetopeltis orbicularis*), the species could be arranged into 5 trophic categories, as in the diatoms. Diatoms: a computer ordination (CANOCO) yielded 5 species groups according the existing trophic categories.

TIEN C., D. C. Sigee¹ & K. White (¹School of Biological Sciences, 1.800 Stopford Building, University of Manchester, Manchester M13 9PT; e-mail: David.Sigee@man.ac.uk). **Cation adsorption by algal cells: analysis of copper uptake by laboratory cultures and phytoplankton samples using adsorption models.**

Algal surfaces (cell wall/mucilage) have the potential to bind cations due to the presence of large numbers of carboxyl, hydroxyl and other charged groups. Interspecific differences, however, in surface/cell mass ratios, cell wall chemistry and the amount and composition of surface mucilage may result in markedly different binding capacities. This study examines the copper adsorption by living and freeze-dried cultures of algae (*Anabaena spiroides*, *A.cylindrica*, *Eudorina elegans* and *Chlorella vulgaris*) plus mixed natural populations of phytoplankton from a local eutrophic lake. In each case, copper uptake obeyed the Freundlich model for single-layer adsorption. The adsorption capacity of living cells decreased in the order *A.cylindrica* > *A.spiroides* > *E.elegans* > *C.vulgaris*. Surface area/dry weight ratios decreased in the order *C.vulgaris* > *A.cylindrica* > *A.spiroides* > *E.elegans*, suggesting that *A.cylindrica* has the highest adsorption capacity due to its high surface/dry wt. ratio, while *C.vulgaris* has the lowest due to a small number of binding sites. No apparent relationship occurred between copper-binding ability and mucilage level. The copper-binding ability of mixed phytoplankton samples varied considerably with respect to the dominant species, and is considered in relation to the laboratory data.

WATSON A.G., R. I. Jones & J. D. Eccleston-Parry (Biological Sciences, Lancaster University; e-mail a.watson@lancaster.ac.uk). **Nutrient patchiness and phytoplankton competition.**

Coexistence of a variety of phytoplankton species in the water column has been explained in two ways. The equilibrium theory of competition states that species can coexist if limited by different resources. However, in non-steady state conditions it is thought that environmental variability allows the coexistence of different species competing for the same resource. One cause of environmental variability is nutrient patchiness. Areas of high concentrations of nutrients within a normally nutrient poor environment may allow the re-establishment of phytoplankton populations that require concentrations above ambient to maintain growth. Nutrient patchiness may also be advantageous to phytoplankton with a larger cell size. During a temporary pulse of a limiting nutrient these algae may be able to take up and store the nutrient in sufficient quantities to maintain a viable population between pulsing events. A heterogeneous nutrient environment may therefore contain a

greater diversity of species, including a greater proportion of larger phytoplankton, than a homogeneous nutrient environment. Semi-continuous cultures were used to investigate this hypothesis. Natural phytoplankton communities from Windermere South Basin were pulsed with phosphorus either every day, every eight days or every sixteen days. Changes in species numbers, biomass, bacterial numbers and dissolved phosphorus concentrations were monitored. This poster describes the results obtained.

WILKINSON M., J. B. Dawes, S. Jones & R. Wylie (Heriot-Watt University, Edinburgh EH14 4AS; e-mail m.wilkinson@hw.ac.uk). **Algal recovery over seventeen years of the tidal Billingham Beck from low pH, high metal pollution.**

The Billingham Beck is a small estuarine tributary of the Tees estuary in north-east England. At low tide and low river flow it is effectively an open effluent channel for factories manufacturing acrylics and fertilisers. It is strongly tidal and at high tide fills with saline water up to 25 ppt salinity. In the 1970's high levels of cyanide, copper and zinc and low pH were thought to result in the absence of macroscopic fauna and flora. With improved effluent treatment progressive amelioration of water quality has occurred since then. This has been accompanied by an increase in attached algal species from only 3 species in 1980 to 14 species in 1997. Even after this recovery the algal flora consists only of the mats of opportunistic species normally characteristic of the upper reaches of an estuary, although the high salinity might be expected to support the fucoid dominated communities of a lower estuary. In-situ bioassays with *Fucus vesiculosus* show it can survive, perhaps predicting future colonisation similar to that currently occurring in the lower Tees estuary after similar prediction based on bioassay results. However growth was poor and ion leakage measurements indicated stress. *Prasiola stipitata* has been the dominant alga throughout the 17 years and had a surprising ability to show positive net photosynthesis in undiluted fertiliser process effluent before mixing with the Beck water.

WOODRUFF¹ S. L., W. A. House², M. E. Callow¹ & B. S. C. Leadbeater¹. (¹School of Biological Sciences, The University of Birmingham, Birmingham B15 2TT; ²Institute of Freshwater Ecology, River Laboratory, Wareham, BH20 6BB). **The Effect of Biofilms on Chemical Fluxes at the Sediment Water Interface.**

Sediments play a crucial role in chemical cycling in rivers. The aim of this study was to investigate the effects of a mixed, natural, predominantly algal biofilm on the flux of chemicals across the sediment-water interface in a hard freshwater environment. Measurements were taken of the solution composition above a sediment sample placed in an artificial recirculating channel over a six week period during which a natural biofilm developed. Microelectrodes were employed to measure profiles of oxygen, calcium and pH in the bulk water and through the sediment. In addition, diurnal measurements of dissolved calcium, alkalinity and soluble reactive phosphorus (SRP) were made every 2 h over a 48 h period. Oxygen microprofiles showed depletion with increasing depth in the sediment. pH decreased markedly from the bulk water across the sediment interface and showed a further decrease with depth within the sediment. Calcium microelectrode measurements indicated a decrease in calcium ion activities just above the sediment surface due to calcium deposition as calcite. Mass balance calculations showed that calcite was precipitated during periods of photosynthesis, dissolution occurring during the night as the concentration of CO₂ at the sediment-water interface increased, leading to undersaturation with respect to calcite crystal formation. The importance of algae in calcite precipitation on sediments will be discussed.