46 April 1997

The Phycologist

The Newsletter of

The British Phycological Society

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Contents

The British Phycological Society is a registered charity. No. 246707

Editorial

This will be my last issue as editor of *The Phycologist*. There have been a number of changes to the make up of the BPS council. After 6 plus years Eileen Cox has retired (not too strong a word) as the Hon. Secretary. Dr Richard Geider (MBA, Plymouth, rdg@wpo.nerc.ac.uk) has accepted the challenge to take the society into the next century. Not only has the society lost an Hon. Secretary Lynne Terry has retired as Hon. Treasurer and the society has been fortunate that Dr. John Berges (Queen's, Belfast, J.Berges@qub.ac.uk) has agreed to take over. To make a near clean sweep I have just completed three years as Hon. Editor of *The Phycologist*. Dr Nick Martin (SAC, Auchincruive, N.Martin@au.sac.ac.uk) has been good enough to take over this portfolio.

I would like to thank all those folk that have made my life as Hon. Editor much easier than it could have been. These include Eileen, Lynne and the folks in Dundee that have done so much for the mailing.

In this issue there are the abstracts of the winter meeting held at the University of Sheffield Jan 1997. I would like to acknowledge and thank Jim Gilmour for his great efforts in organising the meeting. The society had considerable difficulty finding a suitable venue as so many institutions started term in the second week of the year. In the end we were able to go to Sheffield at relatively short notice. To fit in it meant holding the meeting over a weekend. This was something the society had been considering for sometime, to see if it would make it easier for our European members to attend as they could take advantage of lower weekend fares. It is debatable whether this was a success but this may have been due to the time of year. Numbers were generally down on previous years. Again council has considered whether it would be better to have the annual meeting at some other time of the year. This debate is likely to be lengthy. Anyway next year the Winter Meeting is to be in London, **5th-8th January 1998** at Royal Holloway College, (see page 8).

Wishing you all the best in your endeavours, be they phycological or not.

Andrew Johnston

British Phycological Society Council.

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BPS Summer Studentships

In 1997, the British Phycological Society will again be offering up to 2 Summer Studentships (max. value £500) to support undergraduate or prospective postgraduate students for a 4-week (or longer, if you can make the award stretch that far!) research project during the summer vacation. The scheme is designed to encourage interest in the algae among students by giving them direct experience of laboratory and/or field techniques related to algae, and a better awareness of the morphological or ecological range of the algae, and of their applications in pure and applied science. At the end of each project, a short report should be prepared for publication in *The Phycologist* (a report on one of the 1996 Studentships appears in this issue).

Applications for these studentships are invited from prospective supervisors, who should submit a proposal (not exceeding 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 to Dr M.J. Dring at the address below before 30 April 1997, and all proposals received will be reviewed by a panel of referees appointed by him. Successful supervisors will be notified by 14 May, to allow time for the project to be advertised in the supervisor's institution and a student found to carry out the work during the summer.

Address proposals to:
Dr M.J. Dring,
Queen's University Marine Laboratory,
The Strand,
Portaferry,
Co. Down,
BT22 1PF.
Tel No. 012477 28230 Fax: 012477-28902

British Phycological Society Summer Studentship 1996

I was delighted to be chosen as one of the first BPS Summer Students. I have just finished the second year of my degree at the University of Ulster and the award provided a welcome bonus (both financial and intellectual) before starting my third year placement in Greece.

The aim of the studentship was to study the biodiversity of the benthic diatom populations in the largest freshwater lake in the British Isles, Lough Neagh. It is a relatively shallow lake with strong wave action but limited light penetration, so that there are few macrophytes and the main benthic primary producers are microscopic algae, particularly diatoms. The ecology of these benthic communities are relatively poorly understood compared to the plankton. One reason is the difficulty of sampling, which needs divers to scrape the samples off the rocks. I have only just started my SCUBA training, so one of the postgrads, Zoe Ruiz, offered to help. I then took the samples back to the main campus at Coleraine where Tanya Baxter and Dr. Steve Lowry taught me how to prepare the material and operate the scanning electron microscope.

The samples from the rocks were dominated by *Navicula* species but I also found a wide variety of other genera, including *Cocconeis, Cymbella, Stephanodiscus, Gomphonema, Rhoicosphenia, Achnanthes, Fragilaria, Amphora, Aulacoseira, Cyclotella, Cymbellonitzschia, Nitzschia, Epithemia, Synedra, Martyana, Gyrosigma* and *Surirella*. All depths sampled had a high diversity (at least 8 genera) but 2m had the highest, with 14 genera represented. This may be because there was still sufficient light for growth at this depth but it was below the worst of the wave action. The sandy shores had a lower diversity but two rare species were found. One of these had unusual siliceous stabilising bars and was identified as *Amphora calumetica* from a description sent by Mark Edlund (University of Michigan), who is preparing a paper on populations from the only other area where it has been recorded, the Great Lakes of America.

Another unusual but abundant species was *Cymbellonitzschia diluviana*. It has been recorded from only a few other lakes. One of these is the clear and deep Crater Lake in Oregon, which is almost the complete opposite to L. Neagh. It seems *C. diluviana* likes alkaline conditions but not too much calcium!

From studying these diatom communities, I realised that we need to know much more about the ecology of individual species. For example, around L. Neagh there are unusual diatomite deposits that are presently being investigated by a palaeocological research team looking at the link between past water levels and early man in Ireland. The benthic species are important in helping to reconstruct the environmental conditions that prevailed in the past. This involvement with research groups I found particularly enjoyable. It gave me a greater awareness of the morphological and ecological range of algae, while gaining experience in laboratory and field techniques. So, I would like to thank the BPS and all those at the Freshwater Laboratory who helped me, especially Tanya Baxter, Steve Lowry and David Jewson.

Lesley Brown
University of Ulster

BPS Winter Meeting 1998

The next BPS Winter Meeting will take place from 5th-8th January 1998 at Royal Holloway College, London.

There will be an informal poster and social meeting on the first evening, followed by 2 1/2 days of papers. The first full day will focus on "Tracing large-scale and long-term environmental change using algae", showing how algae can be used to answer a variety of global questions. In addition to special topics and the Manton prize presentations, there will also be a Founders' lecture, plus contributed papers as usual.

The local organising group comprises:
Eileen J. Cox (e.j.cox@nhm.ac.uk)
Harriet Jones (h.l.jones@ic.ac.uk)
Jane Lewis (lewisjm@westminster.ac.uk)
L. Elliot Shubert (e.shubert@nhm.ac.uk)

Any suggestions or queries can be directed to members of the group.

Eileen J. Cox Department of Botany, The Natural History Museum, Cromwell Road, London, SW7 5BD. Tel: 0171 938 9001 Fax: 0171 938 9260

The Second European Phycological Congress (EPC 2)

The Organising Committees of the Second European Phycological Congress (EPC 2) and the 8th International Conference on Applied Algology (8th ICAA) are pleased to announce that both meetings will be held in Montecatini Terme (Italy), the EPC 2 on 20-26 September and the 8th ICAA on 26 September - 1 October 1999. You are cordially invited to participate and take this unique opportunity for meeting a broad forum of scientists interested in basic and applied phycology.

The first circular will be mailed in May 1998.

EPC 2 Secretariat:
Prof. Francesco Cinelli
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BPS Auction needs you!

BPS holds an auction at each winter meeting. The wintery (snow and cold) meeting at the University of Sheffield was no exception. Over 1,000 GBP was raised through the auction of books, reprints, original works of art, and prints. My thanks to Maureen Callow for organising the donations, Jenny Moore for assisting at the auction, and the many generous members who spent their hard earned money on phycological memorabilia. All of the proceeds go for the support of students, the lifeline of our society.

The 1998 winter meeting will be held at Royal Holloway College near London. It is not too early to scan your bookshelves, desk, etc. for donations for the BPS auction. Your phycological 'white elephant' becomes someone else's phycological treasure. I am expecting the 1998 auction to be better than ever. Please help to make the BPS auction a continued success by donating items now. Contact Dr Maureen Callow or Elliot Shubert if you have items to donate. Thank you.

L. Elliot Shubert, BPS Auctioneer
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Freshwater algal course to be conducted in Scotland during July 1997.

A freshwater algal course will be conducted at the Kindrogan Field Centre in the Scottish highlands from 26th July to 2nd August 1997 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 120 taxa representing seven divisions were identified to genus/species. The course is designed for advanced undergraduate students, postgraduate students, biology teachers, and other interested in freshwater ecosystems. Participants will receive both field and laboratory experience. The cost of the course is 280 GBP (approximately 450 USD), which includes accommodation, meals and tuition. Overseas participants can fly to Glasgow or Edinburgh and take a mainline train to Pitlochry where they will be met by a van from Kindrogan.

STIPEND SUPPORT

Student members of the British Phycological Society are encouraged to apply for partial support of the course fees. Send written request on one page, including your name, mailing address, telephone, fax and email address, state the reasons you would like to attend the course, supporting letter from your supervisor, and the amount you

name, mailing address, telephone, fax and email address, state the reasons you would like to attend the course, supporting letter from your supervisor, and the amount you are requesting to: Dr. L. E. Shubert, Department of Botany, The Natural History Museum, Cromwell Road, London SW7 5BD, UK, no later than: 30 May 1997.

Applications will considered at the June meeting of the BPS Council and applicants will be notified by 30 June 1997.

Graduate students who are members of the Phycological Society of America are encouraged to submit an application for support from the 1997 Hannah T. Croasdale Fellowship fund, the purpose of which is "to broaden phycological training, not necessarily to further research goals." Application forms can be obtained from Dr. Harold J. Hoops (Hoops@uno.cc.geneseo.edu). The deadline for completed application form, transcripts, and a letter of recommendation is March 1, 1997.

In addition, one outstanding applicant will be selected by the Director of Kindrogan Field Centre as a recipient of a British Ecological Society stipend.

Non European students might consider combining attendance at the Freshwater Algal course with attendance at the 6th International Phycological Congress (IPS/PSA) to be held in Leiden, The Netherlands from 10-17 August 1997.

FOR MORE INFORMATION AND APPLICATION FORMS:

Please contact: Ms. Alison Gimingham, Director, Kindrogan Field Centre, Enochdhu, Blairgowrie, Perthshire PH10 7PG, UK or Dr. L. E. Shubert.

Algal nomenclature: a historical perspective

F.G. Hardy
Department of Marine Sciences and Coastal Management, University of Newcastle upon Tyne, Newcastle upon Tyne, NE1 7RU

As a systematic botanist one always experiences great pleasure when the classification of a particular species is resolved and, as a result, we have a clearer idea of how groups relate to each other. There have been many immensely important changes in our understanding of the marine algae in the twenty-one or so years that have elapsed since the publication of Parke and Dixon's check-list (Parke & Dixon, 1976). South and Tittley (1986) broadened the geographical spread by covering the whole of the North Atlantic (this check-list is now being revised by Tittley and Nielsen), and Guiry (1996) provides the latest names for the geographical area covered by the British Isles, the southern North Sea and the northern Atlantic coast of France. These works provide an invaluable resource, and enable one to keep up with changes that are occurring at a dramatic rate. However, one occasionally feels that names and relationships are changing so rapidly that the readily accessible literature

(such as flora volumes) is unable to keep up with the progress. As a result one can end up on the shore feeling that one does not know the name of the commonest of species!

If anyone should think that this is a modern phenomenon I would recommend the following passage from George Johnston's 1831 *A Flora of Berwick-upon-Tweed*:

146. AMPHICONIUM.

1. *Amphiconium aureum*, orange-coloured, caespitose, short; filaments branched, entangled, somewhat rigid; branches spreading; articulations longer than broad. - SPRENG. *Syst. Veg.* iv. 344. *Byssus aurea*, LIGHTF. *Scot.* 1002. *Conferva aurea*, DILLW. *Conf.* 54. t.35 and t. C *sup. Eng. Bot.* t.212. *Ceramium aureum*, HOOK. *Scot.* ii. 86. *Ectocarpus aureus*, GREV. *Fl. Edin.* 315.

Hab. On moist sandstone rocks, not rare. At the side of the footpath leading through the plantation above Ordmill. Ravine below Marshall Meadows.

DILLWYN says that *A. aureum* is generally to be found on calcareous rocks and in chalk-pits. In this neighbourhood it affects no rock but sandstone, which it covers in irregular tufts or patches, which bear a striking resemblance to a piece of orange-coloured velvet, and is a conspicuous and rather pretty object. When dried it retains its beautiful golden hue for some weeks, but ultimately changes to a dull ash-colour.

A little history of this alga, from one having authority in these matters, might afford a useful lesson; but our attempt will probably subject us to the charge of ignorance, or of wilful blindness to the merits of our superiors. The plant was placed by LINNAEUS in his genus Byssus, which, we will admit, was made up out of somewhat heterogeneous materials, and could not of course be permitted to remain unaltered, when the fashion came to have all the members of a genus as like to one another as was Sebastian to Viola. And firstly, then, the subject of our story became a *Conferva*, a change of nomenclature which, as the consequence of some little additional acquaintance with its structure, was perhaps not to be found fault with; but scarcely was the name familiarised to us, until another change was deemed necessary to fit it for its proper place in the natural system. Could anything be more natural than to arrange a terrestrial, slightly organised, filamentous production among plants which are natives of the sea, live constantly submerged, and possess a comparatively high and complex structure? Certainly not; and so our late *Conferva* was located among the *Ceramia*! Botany, however, has been said to be a progressive science; hence, in another year or so, a Ceramium this plant was not, and it figured next as an *Ectocarpus*. How many months or days it retained this appellation I do not know; it certainly in no long space of time was degraded to a synonym, and the very euphonical *Trentepohlia* usurped the higher station, too soon alas! to be displaced, or perhaps it ousted - for here my learning fails me - the little less euphonical *Amphiconium*. If the reader should ask a reason for my choice of this name in preference to the others, I might be puzzled for an answer; - a "sad choice led him perplexed;" and if I have erred, it may plead some palliation of the error to remember, that if a new name had been invented for the occasion, this little volume might have had a chance of being quoted in future by great botanists and in great books! But let not the reader suppose that *Amphiconium* is the latest *alias* for this plant; the name

things, physical, political, and moral, which has distinguished the intermediate years. And it is now discovered, what indeed was always too obvious, that all the above-mentioned mutations in its nomenclature, have not only not added one iota to our knowledge of the plant, either in structure or in its relations to other plants, but have led to error and confusion. For in the "natural system" most approved of at present, this alga finds no place of rest among the Algae, and is said to be a sort of mould, and figures away as an *Ozonium*, a genus which stands next to, and differs little from, the Linnaean genus *Byssus*! - The preceding sketch may appear, to the general reader, to be drawn up in the spirit of ridicule; but I am sorry to say that it is a true history, and only sins through defect, for at least one other synonym (*Dematium*) might have been added to the useless catalogue. HERSCHEL has asserted that "there is no science in which the evils resulting from a rage for nomenclature have been felt to such an extent as in mineralogy," but he would have divided the censure had he bestowed a passing thought on the labours of the cryptogamic botanists.

All very amusing - and, sadly, true! One wonders whether late twentieth century botanists expect their readers to be able to understand allusions to *Twelfth Night*!

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Manton Prize Winner, Sheffield 1997.

Dr. Tammi Richardson recently completed her PhD at Dalhousie University, Nova Scotia, Canada on the buoyancy of marine diatoms under the supervision of Professors John Cullen and Marlon Lewis. Her research included work on the fascinating floating diatom *Rhizosolenia* which forms massive mats in the upper layers of the ocean. The mechanism for buoyancy regulation in this diatom is not yet worked out, but Tammi's research described how its physiology is suited to its life mode of vertical migration between the nutrient rich thermocline and the nutrient depleted photic zone. During her work on the buoyancy of a smaller diatom, *Thalassiosira weissflogii*, Tammi worked with mesocosms built of pipe 2.1 m high by 0.3 m diameter which simulated the ocean environment. She is no stranger to student awards, in 1994 she won an Outstanding Student Paper Award for her mesocosm work at the American Geophysical Union Ocean Sciences Meeting in San Diego. Her new post is in Queen's University Belfast where she is a NERC post-doctoral fellow with Dr Ivan Heaney and Prof. Chris Gibson. She was switched from one algal puzzle to another - the under-ice diatoms from Lake Baikal, Siberia. She is studying the physiological ecology of *Aulacoseira baicalensis*, the winter dominant in Baikal and a picoplankter thought to be *Synechocystis limnetica* which is the most important summer phytoplankter. The mesocosm experience acquired in Dalhousie will be brought to bear in Belfast, where she is constructing another tank, this time to be run at 4°C! Tammi says she is really enjoying the challenge of working with low temperature phytoplankton.

Chris Gibson,
Agricultural and Environmental Division, Newforge Lane, Belfast.

BPS WINTER MEETING, SHEFFIELD 1997

ORAL PAPER ABSTRACTS

BALL, S.J. (Biology Division, I.E.B.S., Lancaster University, Lancaster, LA1 4YQ) **Are picophytoplankton relatively more important in nutrient poor lakes?**

Esthwaite Water, Windermere and Wastwater represent the full range of trophic states found in the English Lake District, being respectively eu-, meso-, and oligotrophic. Using epifluorescence microscopy, the seasonal abundance of picophytoplankton, bacterioplankton and nanoflagellates was recorded. The total chlorophyll concentration and the amount contributed by the pico (0.2 - 2.0 μm) size fraction were determined by fluorimetry. ^{14}Carbon uptake experiments were used to assess the contribution to primary production made by the picoplankton. While the absolute abundance of picophytoplankton showed no relationship with the trophic gradient, the relative importance of picophytoplankton was higher in lakes of lower trophic state.

BELL, S.G., A.V. HUMBLE and G.A. CODD. (Department of Biological Sciences, University of Dundee, Dundee, DD1 4HN, Scotland, UK). **Comparative effects of cyanobacterial toxins on rainbow trout *(Oncorhynchus mykiss)***

Although numerous fish kills have been associated with the occurrence of fresh-water cyanobacterial blooms, evidence is required to specifically link mortalities and deleterious effects with cyanobacterial toxins. These toxins are numerous and diverse, both in their structure and mode of action. We report on the effects of the cyanobacterial hepatotoxins and neurotoxins on yearling rainbow trout *(Oncorhynchus mykiss)* in both acute and subacute toxicity studies at environmentally-relevant concentrations. Intraperitoneal LD_{50} values were determined for microcystin-LR, microcystin-LF, anatoxin-a and neosaxitoxin and were compared with the corresponding values in mice. In subacute studies the chronic effects of the hepatotoxin microcystin-LR and its more hydrophobic variant, microcystin-LF, were assessed by measurement of hepatosomatic index and liver pathology of fish maintained in a flow-through system for a month. Exposure of rainbow trout to subacute levels of toxins radiolabelled with ^{14}C indicated that microcystin-LR was accumulated in fish flesh after 28 days exposure to free toxin in the surrounding water. Radioactivity measured in the flesh of fish after 28 days exposure to radiolabelled anatoxin-a, however, was no higher than background counts, indicating no accumulation of this toxin.

BERGES, J.A. (School of Biology and Biochemistry, Queen's University of Belfast, 97 Lisburn Road. Belfast BT9 7BL. email: j.berges@qub.ac.uk). **Death in the Sea? Involvement of proteases in mortality or survival of marine phytoplankton under environmental stress.**

The internal physiological processes associated with natural phytoplankton mortality (as opposed to mortality due to external factors such as sedimentation and predation) are very poorly understood. Cell survival was examined in batch cultures of a diatom *Thalassiosira weissflogii* (Gru.) Fryxell et Hasle, and a chlorophyte, *Dunaliella tertiolecta* Butcher, during extreme deprivation of nitrogen or light. Despite severe impairment of photosynthetic efficiencies, only minor declines in cultures of either species were observed under nitrogen deprivation over a two week period. In cells under nitrogen stress, levels of proteolytic enzymes increased up to two-fold, and there was gradual, selective loss of certain proteins, notable the large subunit of Rubisco. Cells apparently use protein degradation as a survival strategy. Effects were more severe in the diatom, suggesting an inherent sensitivity to nitrogen deprivation. In contrast, light-deprived diatom cultures were virtually unaffected

and showed no changes in protease activities. However, chlorophyte cultures underwent reproducible, catastrophic declines after approximately six days of darkness, coincident with order of magnitude increases in proteolytic activities. Casein zymograms demonstrated rapid induction of a specific protease at the point of culture decline. Although of uncertain adaptive significance, declines may represent a form of cell death analogous to apoptosis in metazoa. If present in other species, this novel phenomenon may have implications for species succession and cycling of organic matter in aquatic ecosystems.

BLOMSTER, J., C.A. MAGGS and M.J. STANHOPE. (School of Biology & Biochemistry, Queens University of Belfast, Belfast BT9 7BL, Northern Ireland). **Molecular approaches to the systematics of the green seaweed *Enteromorpha*.**

The very common green seaweed *Enteromorpha* is found in both clean and polluted habitats. Though *Enteromorpha* is an important fouling organism and it has commonly been used as an indicator of eutrophication, the taxonomy of the group is still unclear. The biggest problems arise from the difficulties of distinguishing between the effects of environment and the genetical makeup of the seaweeds.

In this study molecular data have been used alongside morphological characters to clarify the taxonomy of the group. *Enteromorpha* samples were taken from a wide range of clean and polluted habitats around NE Ireland and west Wales. Sequences of ITS1 and ITS2 spacers revealed several species or species complexes, provisionally identified by morphology as *E. intestinalis, E. compressa, E. prolifera, E. crinita, E. flexuosa* and several groups under species *E. linza.* Sequences for all the species showed more variable and less variable regions. Some samples of the genus *Ulva* grouped with *Enteromorpha,* so *Ulothrix* and *Monostroma* were also sequenced and used as outgroups. Organellar restriction fragment length polymorphisms (RFLPs), which were detected by probing Southern blots of total DNA digests of each sample, strongly supported the ITS l and ITS2 data.

BRODIE, J., P.K. HAYES[1], G.L.A. BARKER[1], and L.M. IRVINE[2]. (Applied Sciences, Bath College of Higher Education, Bath BA2 9BN; [1]School of Biological Sciences, University of Bristol BS8 lUG; [2]Department of Botany, The Natural History Museum, Cromwell Road, London SW7 5BD). ***Porphyra miniata* (Bangiales, Rhodophyta): a question of layers.**

Porphyra miniata (C. Ag.) C. Ag. is a monoecious species of red alga that is reported to occur in the shallow subtidal of northern British and Irish coasts. It has been considered a distinct species of *Porphyra* on the basis of the blade being two cell layers thick (distromatic) as opposed to one cell layer thick (monostromatic) which is the case for the other species in this region. Sequence analysis of the *rbcL-rbcS* spacer, reveals that specimens fitting the description of *P. miniata* in terms of colour and habitat, from several different localities have identical sequences, but can be mono- or distromatic. This brings into doubt the validity of the character of the number of cell layers in distinguishing between members of this genus. Amongst this material of *P. miniata* that we have tested are individuals that resemble isotype specimens of *P. elongata* Kylin which was described as monostromatic and we speculate that this may be the same species. Molecular and morphological data will be used to show the relationship of *P. miniata* with other members of the genus.

CHARRIER, S.[1] A. WEEKS,[1] S. LEWEY[1] and I. ROBINSON[2] ([1]Maritime Faculty, Southampton Institute, [2]Department of Oceanography, University of Southampton). **A preliminary study of the underwater light field in a turbid intertidal and estuarine environment, and its implication on the vertical zonation of macroalgae.**

The intensity and quality (colour) of light reaching submerged photosynthetic organisms play a key role in their growth and development. The attenuation of sunlight by the atmosphere, the air-water interface and the water column modulates the light available to

macroalgae, which is therefore determined by atmospheric conditions, the characteristics of the air-water interface, and the depth and optical properties of the water column.

This paper examines the intensity and spectral quality of underwater light measured in the Hamble estuary (Hampshire, UK) over daily and seasonal timescales. It also investigates the concentrations of photosynthetic pigments in macroalgae and considers these in relation to the incident light field.

In this highly turbid environment, the light is rapidly attenuated and spectrally shifted to give a green dim light. In mid-summer, at high tide and 3 m depth, the percentage of subsurface downwelling irradiance available to photosynthesis was less than 1% for blue wavelengths, only about 5% for green wavelengths, and 2% for red wavelengths. So far, the results suggest that tidal cycles strongly affect the optical properties of the water column, hence the underwater light field, over the course of a day. No significant variations due to the optical properties of the seawater have been found to occur within a month, but seasonal changes do exist. From the several species of macroalgae studied, no correlation between light and pigment content can be seen, although some common features of pigment content have been found.

CHESMAN, B.S. and M.T. BROWN. (Department of Biological Sciences and Plymouth Environmental Research Centre, University of Plymouth, Plymouth. PL4 8AA). **Arsenate tolerance in seaweeds: is the phosphate uptake system altered?**

The chemical similarity between arsenate and phosphate results in competition for the phosphate uptake system. If higher internal phosphate concentrations are accompanied by elevated arsenic levels then, since arsenate can inhibit growth of marine algae at relatively low concentrations, seaweeds growing in waters contaminated with this metalloid must somehow alleviate toxicity in order to survive. Such a situation arises in Restronguet Creek, part of the Fal estuary in South West England, where mining activity has resulted in elevated concentrations of arsenic and other trace metals in sediments and water.

The hypothesis was tested that tolerance of *Fucus vesiculosus* growing in an arsenic contaminated site is attributable to, at least in part, an altered phosphate uptake system thereby reducing arsenate accumulation. Phosphate uptake kinetics of individuals collected from a contaminated (Restronguet Creek) and 'clean' (Helford river) site were determined in the presence and absence of arsenate. Preliminary results will be presented which indicate modifications to the rate of phosphate uptake; the Restronguet population had lower uptake rates at all external concentrations. When media is spiked with 10 µM arsenate, both Restronguet and Helford material lose phosphate to the media initially, but positive uptake is regained earlier in material from Restronguet Creek.

COCKELL, C.S., B. SQUIRE, and L.J. ROTHSCHILD. (Ecosystems Science and Technology Branch, MS 239-20, NASA/Ames Research Center, Moffett Field, CA 94035-1000 USA). **DNA synthesis patterns in algal mats**

The objective of our research is to produce sophisticated models of Precambrian ecosystems and to study the effect of global change variables on algal ecosystems. We have assessed diurnal variations in DNA synthesis in taxonomically and ecologically diverse algal mats. Our results for cyanobacterial, red algal and green algal mats show clear diurnal patterns of DNA synthesis. Synthesis is minimal at night, rises in the morning, shows an early afternoon dip, rises again in the afternoon, and decreases at sunset. This result raises several ecologic, evolutionary and mechanistic questions, including "What causes the afternoon depressions" and "Why?". To test the possibility that UV affects this pattern, UV-transparent or UV-opaque screens were placed over red algal and green algal mats in the field for three days and also over cyanobacterial mats at our laboratory. DNA synthesis in these mats was then measured. DNA synthesis patterns were affected by UV radiation. DNA synthesis rates were higher in the presence of UV radiation than in its absence. We

believe that this result is explained by excision repair and would represent the first demonstration of excision repair in nature. It would concur with other results from our laboratory. This result has profound implications for modeling the Precambrian, a time when surficial UV fluxes were higher, and for present mats subjected to increasing fluxes of UV radiation as the result of stratospheric ozone depletion.

DE GREGORIO, S. and R. FLETCIHER. (The Marine Laboratory, University of Portsmouth). **Studies on the autecology of selected fucoid algae in Langstone Harbour, south coast of England.**

The present study is concerned with an investigation of the autecology of selected fucoid algae in Langstone Harbour, south coast of England. The distribution growth **rate,** reproduction and nutrient content have been studied with respect to *Ascophyllum nodosum* (L.) Le Jol., *Fucus spiralis* L. and *Pelvetia canaliculata* (L.) Dene et Thur. All three species show one seasonal reproductive period with receptacles initiated either at the beginning of the year, followed by maturation in late spring/summer *(F. spiralis, P. canaliculata),* or in the late autumn of the preceding year, followed by maturation in late winter and spring *(A. nodosum).* The growth rates also show a seasonal variation being lower during the period of maturation of the reproductive bodies. The nutrient contents exhibit a seasonal trend with the highest concentrations in winter and the lowest in spring.
In addition to field studies, some laboratory studies are being undertaken to determine the response of the algae to a range of the environmental parameters temperature, salinity and irradiance, using both zygotes and vegetative apical tips. Some additional studies are also being carried out to determine the effect of different percentages of sewage effluent on the above mentioned test material. Some preliminary results obtained from these studies will be presented and discussed.

DOHERTY, H.M., and D.G. ADAMS. (Department of Microbiology, University of Leeds, Leeds LS2 9JT). **Cell division and gene expression during the development of motile hormogonia in cyanobacteria.**

Vegetative filaments of heterocystous cyanobacteria differentiate to form hormogonia in response to a range of environmental stimuli. These may include transfer of cultures to fresh medium, growth under red light, or exposure to factors secreted by symbiotic partners.

We have identified some of the events taking place during hormogonia formation in the cyanobacterium *Fremyella diplosiphon* in response to a shift from white to red light. The first visible sign is a burst of cell division in filaments undergoing differentiation. The cells become smaller, the filaments fragment and at this stage the hormogonia become motile.

We have shown that this synchronous cell division is preceded by an increase in the abundance of transcripts hybridising to the cell division gene *ftsZ* from the related cyanobacterium *Anabaena* PCC 7120. We have cloned *ftsZ* from *Fremyella diplosiphon* and *Anabaena* PCC 7120, and comparison of the deduced amino acid sequences with known bacterial and chloroplast homologues suggests that cyanobacterial *ftsZ* contains unique features. Additional genes present in the ftsz gene cluster in *Anabaena* 7120 are also shown to be differentially expressed during hormogonia formation in *Fremyella diplosiphon.*

Expression of cell division genes is co-ordinated with expression of other genes involved in the formation of hormogonia. *pilT* codes for a protein involved in pilus function and may play a role in cyanobacterial motility. We have shown that *pilT* transcripts accumulate in parallel with the increase in *ftsZ* expression in *Fremyella diplosiphon.*

DRING, M.J., A. WAGNER & K. LÜNING (Queen's University of Belfast and Biologische Anstalt Helgoland, D-27483 Helgoland, Germany). **The UV-component of natural sunlight is less effective than the PAR-component in inhibiting photosynthesis of subtidal brown and red seaweeds.**

All 3 European species of *Laminaria* and 3 species of subtidal red algae *(Delesseria sanguinea, Plocamium cartilagineum, Phyllophora pseudoceranoides)* were exposed to natural summer sunlight on Helgoland (southern North Sea) for periods of 30 min to 4 h at a constant temperature (15°C), and dark-adapted variable fluorescence (Fv: Fm) was measured immediately after these treatments, and following up to 48 h of recovery in moderate irradiances of white light. The response of plants to the full spectrum of natural sunlight was compared with that to the PAR-component alone, UVA+PAR, UVA+UVB, or UVA alone. The variable fluorescence of all species was reduced to minimal values after 4 h in all wavebands, but the Fv:Fm-values of the more resistant species *(Laminaria* spp. and *P. pseudoceranoides)* were higher after 30-min exposures to UV-radiation alone than to PAR with or without UV. The recovery of Fv:Fm in all species was also more rapid in the 2 treatments that contained UV-radiation alone than in those that included PAR. There was no indication in any of the results that UVA+UVB was more damaging than UVA alone. These results indicate that it is the high irradiances of PAR which are responsible for the photoinhibition of photosynthesis of subtidal seaweeds in natural conditions, and that the current ambient irradiances of UV-radiation (either UVB or UVA) in northern temperate latitudes do not contribute significantly to this photoinhibition.

EMBLETON, K.V. and S.I. HEANEY. (Aquatic Systems Group, Department of Agriculture, Belfast, Northern Ireland). **The application of image analysis to natural populations of phytoplankton.**

The use of image analysis as a tool in algal recognition and quantification has developed markedly in recent years. This has been possible due to the rapid advances in computer power and software sophistication. Previous work has shown the feasibility of image analysis for classifying and measuring cultured populations of algae. The present study uses techniques to improve optical contrast of cells using a combination of staining and resin embedding. The higher contrast obtained improves segmentation, the process by which object and background are separated in image analysis. This has enabled recognition and quantification of major algal forms in natural populations from Lough Neagh. Macros developed allow the automatic separation and quantification of filamentous forms, without the requirement of manual editing. The application of image analysis to more complex natural populations will be discussed.

FARRELL, P. and R. FLETCHER. (The Marine Laboratory, University of Portsmouth). **Investigations into the distribution and biology of the recently introduced macroalga *Undaria pinnatifida* (Harvey) Suringar in the UK.**

Undaria pinnatifida was first discovered in the UK in June 1994 growing on the sides of marina floats in the Hamble Estuary in Southampton Water. With financial support from NERC, an initial study has begun on aspects of its biology and distribution. Particular attention is being given to determining its likely spread around the UK and the level of impact the alga will have on the native flora and fauna.

Firstly, a comprehensive survey is being carried out on the plants present in the Hamble, to determine their local distribution patterns, together with their growth rates, density, standing crop, reproductive development and associated fauna and flora. These records will then be compared with those obtained from later studies to show *Undaria's* rate of spread and population increase. The survey results are also being correlated with hydrographical records of salinity and temperature in order to determine the effects of these parameters on the distribution of *Undaria.* These results, together with those obtained from research into other limiting factors such as competition and predation will provide a more accurate prediction of the alga's likely further spread, establishment and impact on UK shores.

Secondly, attention is being given to determining if other areas have been colonised by *Undaria.* Initially, adjacent areas were surveyed, followed by all the main ports, harbours and marinas around the coast; more remote localities are being "investigated" by sending out a descriptive poster. The latter has achieved a good response, resulting in the discovery of two additional sites of introduction. The occurrence of *Undaria* at these three sites supports the hypothesis that small boats are the vector for its introduction and spread in the UK.

FEWER, D., C. MAGUIRE, M.J. DRING, G. SAVIDGE and C.A. MAGGS. (School of Biology & Biochemistry, Queen's University, Belfast BT9 7BL, Northern Ireland) **Two varieties of *Palmaria palmata* (Rhodophyta) from Strangford Lough (Northern Ireland): Morphology and Distribution.**

Samples of *Palmaria palmata* (Linnaeus) Kuntze were collected from stipes of *Laminaria hyperborea* (Gunnerus) Foslie at a number of sites in the narrows area of Strangford Lough and adjacent open coasts. The individuals collected displayed a high degree of morphological variation, the two extremes of which were consistent with the varieties *palmata* and *sarniensis* (Roth) Greville. The thalli of var. *sarniensis* were highly dissected in contrast to the broader thalli of var. *palmata.* The relative proportions of the two varieties at these sites were found to vary greatly over small spatial scales which may be related to local current regimes. An estimate of the genetic distinctness of these two varieties was determined by examining plastid DNA Restriction Fragment Length Polymorphisms (RFLPs). Total DNA was extracted from the two varieties, digested with various restriction endonucleases, Southern blotted, and detected using non-radioactively labelled *Antithamnion* organellar DNA as a probe. Analysis of these blots revealed that the RFLPs of the two varieties of *Palmaria palmata* are virtually identical, confirming their current taxonomic assignments. It is concluded that the two varieties belong to a single species.

FLECK, R.A.[1,2], J.G. DAY[1], E.E. BENSON[2] and K.J. RANA.[3] ([1]CCAP, Institute of Freshwater Ecology, Ambleside, Cumbria. LA22 0LP; [2]School of Molecular and Life Science, University of Abertay Dundee, Bell Street, Dundee. DD1 1HG, [3]Institute of Aquaculture, Stirling University, Stirling. FK9 4LA). **Lethal freeze-induced injury in the coenocytic xanthophyte *Vaucheria sessilis.***

The freshwater xanthophyte *Vaucheria sessilis* CCAP 745/1C, was cultured on basic mineral medium (JM) at 15°C under 12:12 h. light:dark regime (50 µmol m^{-2} s^{-1}). Filaments of the alga were sectioned into 12 mm lengths, followed by incubation under standard conditions for 48h. *V. sessilis* was then frozen using a two-step protocol with cooling rates of -0.3, -0.5 and -1°C min^{-1} to terminal temperatures of either -35 or -60°C. Cryoprotectant treatments comprised of 5-10% (w/v) Dimethylsulfoxide or Methanol. Survival at temperatures <0°C was not observed using the cryopreservation regimes employed.

The effects of controlled cooling, dehydration and freezing on *V. sessilis* were examined using a conductive cryo-microscope held at -60°C. When exposed to controlled cooling rates of -0.3, -0.5 and -1°C min^{-1} to 0°C the filaments were able to recover from dehydration, and partial plasmolysis. Ice nucleation in the extra-cellular solution was observed between 0 and -3°C, with further cryodehydration of the cell occurring at the holding temperature (-35, -60°C). Cryo-microscopic studies have highlighted several aspects of the protocol which have the potential to cause cryo-injury including: Intracellular ice formation, cell membrane rupture, mechanical damage and distortion of intracellular architecture by extra-cellular ice. Further investigations examining the physical and biochemical effects of freeze-induced injury in this alga are ongoing.

FORSTER, R.M. and H. SCHUBERT. (FB Biologie, Universität Rostock, Freiligrathstrasse 7/8, 18055 Rostock; rod.forster@biologie.uni-rostock.de). **Assessing the risk of ozone**

depletion on phytoplankton communities in eutrophic water bodies: the Darss-Zingst bodden chain as an example.

The effects of UV-B radiation on the autotrophic component of a shallow estuary on the southern Baltic Sea coastline were investigated between 1994-1996. Underwater measurements showed that the penetration of UV and visible irradiation was low, due to high concentrations of dissolved organic material and particulates respectively. Actual measurements of water column movements, together with wind speed measurements, were used to predict the rate and depth of vertical mixing. The water column was frequently fully mixed from surface to bottom. Residence time of phytoplankton in the UV-B exposed surface layer were inferred to be less than 5 min at wind speeds > 3 m s^{-1}. The relationship between exposure to light (e.g. fluence rate, duration, spectral composition) and photoinhibition of photosynthesis was examined. For short exposures, a linear relationship was obtained between biologically-weighted dose and extent of photoinhibition. Doses required for a significant decrease in photosynthetic efficiency were higher than those likely to be received by cells in a vertically-mixed water column. UV-B was of lesser importance than UV-A and PAR in causing photoinhibition under natural conditions. These findings were confirmed by field measurements of variable fluorescence from surface collected samples, in which midday depression in photosynthetic efficiency was only rarely observed, and by mesocosm experiments, in which UV-B doses were artificially enhanced. Further studies are planned to examine whether direct photochemical effects of UV radiation on DOM may alter its effectiveness as a "sunscreen" for the system.

FYSON[1], A., W-H. KUSBER[2], B. NIXDORF[1], U. MISCHKE[1] and C. STEINBERG[3] ([1]Brandenburg Technical University, Department of Water Protection, 15526 Bad Saarow; [2]Institute of Systematic Botany, Free University, Berlin; [3]Institute of Freshwater Ecology and Inland Fisheries, 12587 Berlin). **Euglenoid ecology in extremely acidic mining lakes in Lusatia (Germany).**

In the Lusatia region of eastern Germany, pits from open-caste lignite mining are infilling with groundwater. The water of these lakes (Tagebaurestseen) is characteristically highly acidic ($KB_{8.2}$ 2-20 mmol/L) with high concentrations of protons (pH 2.6-3.2) and dissolved iron (0-6 mmol/L) as well as high sulphate concentrations. Despite high concentrations of ammonium-N (typically around 0.1 mmol/L) productivity is generally low.

To survive in these acidic lakes, algae must be highly specialised and/or adaptable. A key limiting factor to primary productivity is the low concentration of dissolved carbon (DIC and DOC). Two niches where local carbon sources may support high local primary productivity are the water surface where CO_2 can be obtained from the atmosphere and the bottom waters where anaerobic decomposition of organic matter occurs providing substrates for photoheterotrophic growth.

Mesocosms 2.6 m x 0.1 m containing a 50 cm sediment layer and 15 L of Lake Koschen water (pH 3.1, Fe 15 mg/L) were set up to determine conditions favourable for high rates of primary production. Much of the water column was circulated through a peristaltic pump.

Where additional P was supplied, a distinct zone developed above the sediment characterized by O_2 supersaturation and abundant growth of a euglenoid, *Lepocinclis teres*. This organism can grow heterotrophically in the light using organic substrates as carbon and energy source. *L. teres* has been found in the field in Lake Koschen and other acid mining lakes in Lusatia. The ecological role of this euglenoid is being investigated.

GEIDER, R.J. (Marine Biological Association of the U.K., The Laboratory, Citadel Hill, Plymouth PL1 2PB, e-mail rdg@wpo.nerc.ac.uk). **Cybernetic phytoplankton: acclimation to light and nutrient limitation.**

A cybernetic system consists of three elements: these are (1) a closed-loop feedback system, (2) manipulation of the information which guides the system and (3) mechanisms for filtering out disturbances from the information channel. The description of phytoplankton growth and acclimation presented in this talk includes all three of these elements. As such, the term "cybernetic phytoplankton" can be used to describe the code that implements this new model of phytoplankton growth and acclamation. The model employs three indices of phytoplankton biomass: these are phytoplankton carbon (PC), phytoplankton nitrogen (PN) and chlorophyll (CHL). The model links the light-saturated photosynthesis rate to PN:PC, consistent with available observations. It also requires that chlorophyll a synthesis be coupled to nitrogen assimilation. We include several regulatory features including "feedback inhibition" of the nitrogen assimilation rate by increases in the PN:PC ratio, and regulation of chlorophyll a synthesis by the balance between light absorption and photosynthetic carbon fixation. Finally, the model treats respiration as the sum of a maintenance metabolic requirement plus the cost of biosynthesis. The model output compares favourably with data for cultures in balanced growth. In addition, the model accounts for accumulation and mobilization of carbohydrate energy reserve in response to variations of irradiance and nutrient availability.

GIBSON, C.E.[1,2] and C.BRADLEY[2] ([1]Department of Agriculture (N.I) Aquatics Group and [2]Queen's University, Belfast). **A Waterbloom in 3-D: synoptic survey of Lower Lough Erne, Co. Fermanagh.**

Lower Lough Erne is a large (109 km^2) eutrophic lake in Co. Fermanagh. Phytoplankton growth is light-limited in the deep central basin when the water is unstratified, because light penetration is controlled by the peat stain. In shallow areas around the margins, the light climate is more favourable for growth and water blooms are frequent in the harbours during the summer. It is not certain, however, whether these blooms are produced merely in the shallow regions or whether there is a contribution from the central basin. The ability of phytoplankton to grow hinges on the depth of mixing in relation to light penetration. In trying to model the light climate, assumptions have to be made about how the water mixes and what defines the central basin. In an effort to understand this, we carried out a synoptic survey of the central area using a combined temperature/conductivity/depth/fluorescence probe to take depth profiles over a grid of stations. The data enabled us to construct a clear picture of the spatial distribution of the phytoplankton, which revealed some surprising features. The surface layer of algae coincided with the temperature structure, but there was also a deep water fluorescence maximum representing algae sedimenting out. An anomalous region of low fluorescence and high conductivity was also seen and this has not yet been fully explained.

GIORDANO, M. and D.J. GILMOUR. (Facolta di Scienze, Universita di Ancona, 60131, Italy; Department of Molecular Biology and Biotechnology, University of Sheffield, UK).
Interactions between carbon and nitrogen metabolism in the unicellular alga *Dunaliella.*

Dunaliella is a genus of halotolerant unicellular wall-less green algae, which have the ability to grow in salinities ranging from 0.1 M NaCl to saturated salt (>5 M NaCl). In the present study we have examined the interaction between carbon and nitrogen metabolism in *Dunaliella parva* 19/9 by examining the activity of phosphoenolpyruvate carboxylase (PEPC) under a range of physiological conditions. PEPC is a key enzyme in the interaction between carbon and nitrogen metabolism because it catalyses the carboxylation of phosphoenolpyruvate (PEP) to oxaloacetate and by doing so replenishes TCA cycle intermediates. PEPC extracted from *D. parva* cells grown with NO_3 as the sole source of nitrogen exhibited maximum activity at pH 8 and the activity was saturated by 1 mM PEP. The effect of a range of key cell metabolites was determined on the V_{max} of PEPC. *D. parva* cells were also grown in continuous culture to investigate the effect of changing the source of

nitrogen in the medium from NO_3 to NH_4 over a period of 1-2 weeks. The activity of PEPC and Rubisco along with cell number and chlorophyll content were measured during the transition period from growth on NO_3 to growth on NH_4.

HAYES, P.K. and G.L.A. BARKER. (School of Biological Sciences, University of Bristol, Woodland Road, Bristol. BS8 1UG). **The genetic structure of Baltic Sea populations of *Nodularia.***

Surface blooms of cyanobacteria in the Baltic Sea are dominated by *Nodularia* and *Aphanizomenon.* An understanding of the changing structure of such populations is essential if we are to fully appreciate the influence of altered environmental conditions on primary productivity, nitrogen cycling and toxin production. Studies of phytoplankton population structure involve either the generation of many independent clonal cultures of the organisms before carrying out the genotypic analysis, or the cloning of specific gene loci amplified from DNA obtained from mixed populations prior to characterisation of the individual cloned sequences. We have adopted the first of these approaches in an attempt to describe the structure of *Nodularia* populations in the Baltic Sea. As in all such studies we have needed to assume that isolates that grow in laboratory culture are representative of the full range of diversity within the natural population, but is this a valid assumption? In order to find out we have used the PCR to amplify a specific gene locus, the PC-IGS (intergenic spacer region of the phycocyanin operon), from individual cyanobacterial filaments taken from clonal cultures and from natural blooms; sequencing of the PCR-products is being used to quantify and compare the diversity in these two situations. Furthermore, as a means of rapidly determining population structure we have used mixtures of PCR-primers to identify which PC-IGS allele is present in single filaments picked from natural cyanobacterial assemblages: we believe that this is the first such study of a bacterial population.

HUMBLE, A.H, G.M. GADD and G.A. CODD (Department of Biological Sciences, University of Dundee, Dundee, DD1 4HN, Scotland, UK). **Isolation and characterisation of bacterioferritins from freshwater cyanobacteria.**

Buffering and storage of iron is provided by ferritins, a class of high molecular weight proteins which specifically sequester iron in a non-toxic yet bioavailable form. Although widely distributed throughout plant and bacterial species, the only report to date of bacterioferritin isolation from a cyanobacterium has been presented by Laulhere *et al.* (1992), namely in *Synechocystis* 6803. The present study investigated the presence of bacterioferritin in the common bloom-forming cyanobacteria, *Anabaena* 27893, *Microcystis firma, Microcystis aeruginosa* 7813, *Anacystis nidulans* and *Synechocystis* 6803. FPLC-purified proteins from cyanobacterial extracts were characterised by PAGE, giving estimated molecular weights of 400 kDa for each of the native proteins. Two peptide subunits were identified having molecular weights of 20.5 and 17.0 kDa. Selective staining for iron-binding proteins and amino acid analysis confirmed the isolation of bacterioferritin. Amino acid analysis was also used to assess the degree of homology with bacterioferritin from *E. coli.* The apparent similarities in the amino acid profiles of the cyanobacterial and *E. coli* bacterioferritins initiated further investigations using antibodies to the two *E. coli* ferritins, BFR and FTN, in a series of immunodetection experiments designed to determine the presence of specific identity between these bacterioferritins.

IGLESIAS-RODR IGUEZ, M.D. and M.J. MERRETT. (School of Biological Sciences, University of Wales Swansea, Swansea SA2 8PP). **Inorganic carbon utilization in some marine photosynthetic picoeukaryotes.**

Photosynthetic picoeukaryotes are major contributors to the total marine phytoplankton community particularly in oligotrophic waters. A range of marine picoplankton species were investigated in relation to the presence of extracellular carbonic

anhydrase. Using batch cultures of *Micromonas pusilla, Nannochloropsis oculata, Stichococcus bacillaris, Pyramimonas sp., Pycnococcus* sp. and *Bathycoccus prasinos,* the development of extracellular carbonic anhydrase was only observed in *M. pusilla* at a nutrient-limiting state of the growth. A higher final biomass was observed in *M. pusilla* compared to the other species investigated although C/N ratios were found to be similar for *M pusilla, N. oculata* and *S. bacillaris. M pusilla* developed extracellular carbonic anhydrase when the concentration of CO_2 fell below 4 μM but the development was unaffected by the bicarbonate concentration. A pH drift experiment showed light-dependent alkalinization of the medium in a closed system. Development of extracellular carbonic anhydrase activity was found to be photosynthesis-dependent, maximum activity being detected within 60 minutes. A model is proposed for extracellular carbonic anhydrase development in marine picoplankton species.

JOHNSTON, A.M. (Department of Biological Sciences, University of Dundee, Dundee. DD1 4HN). **Direct and indirect abiotic effects on the level of ^{13}C discrimination by marine phytoplankton.**

The level of ^{13}C discrimination by photosynthetic organisms, dependent on CO_2 diffusion for their procurement of inorganic carbon, is determined by relative weight of diffusion and carboxylation fractionation. Using the Farquhar model of ^{13}C fractionation it is possible to demonstrate that when CO_2 is growth limiting then the level of ^{13}C discrimination will increase with increased [CO_2] as the growth rate increases. This relationship is considered to be a direct effect as [CO_2] directly influences the rate at which inorganic carbon is assimilated for photosynthesis and growth. When other abiotic factors, such as light intensity or nitrate concentrations, are considered for a constant [CO_2] then the level of ^{13}C discrimination will decrease as the availability of the limiting factor increases. These effects can thought of as indirect as they modulate the rate at which inorganic carbon is assimilated for a given [CO_2]. When the level ^{13}C discrimination is plotted against the growth rate/[CO_2] the same slope is obtained for each relationship.

Data is presented that shows there is considerable deviation between experimental data for light and CO_2 limited marine phytoplankton and the theoretical relationship. These findings will be discussed in relation to the use of bicarbonate ions as additional sources of photosynthetic inorganic carbon.

JONES, H. and R.I. HTCHMAN. (NERC Centre for Population Biology, Imperial College at Silwood Park, Ascot, Berks SL5 7PY; Environmental Sciences Division, Coventry University, Priory Street, Coventry, CV1 5FB). **The costs and benefits of mixotrophy**

Mixotrophic algae have two methods of obtaining carbon; they can either photosynthesise or ingest prey. While this would seem an ideal mode of nutrition, being able to exploit what ever resources are available, these mixotrophic algae do not dominate every aquatic system. There must, therefore, be a cost to being mixotrophic. Data presented will demonstrate the cost to a mixotrophic Chrysophyte, *Ochromonas* sp., isolated from a pond at Silwood park, of producing chlorophyll rather than using all heterotrophically gained carbon for growth. Many species of mixotroph not only employ two or more methods of obtaining carbon, but also divide their energy between vegetative growth and cyst formation. Data presented will show how natural populations of thecate and athecate mixotrophic dinoflagefiates form cysts at a time when they are able to dominate the microbial community in a small artificial pond. Some algae, therefore, not only ingest prey to enable them to survive immediate adverse conditions such as those experienced during winter months, but also form cysts to survive future potentially adverse conditions. It has been suggested that this type of behaviour may be indicative of the alga having evolved during a particularly unstable period.

JONES, L.A and W.F. FARNHAM. (The Marine Laboratory, University of Portsmouth)
What makes a common seaweed such as *Pelvetia canaliculata* (L.) Dcne et Thur. uncommon?

Pelvetia canaliculata (L.) Dcne et Thur. is one of the most common intertidal Fucales inhabiting the extreme upper littoral zone. It is a prominent feature of most zonation descriptions of the British shoreline. Its distribution around the Solent region is very patchy, with many apparently suitable sites being uncolonised. Laboratory and field investigations have been carried out in an attempt to understand the ecology of this species.

Culture of apical segments was carried out because of the difficulty in culturing whole plants in the laboratory. Apical tips were cultured under various temperature and light intensity regimes in order to determine optimum growth conditions. This experiment was repeated using culture media using water from two locations, Langstone Harbour, (where *Pelvetia* is present) and Bembridge, Isle of Wight, (where the species is absent). Laboratory culture was also carried out using zygotes in an attempt to ascertain the optimum light intensifies and temperature for growth.

Surface preference of released *Pelvetia canaliculata* zygotes on to different surfaces was also investigated. Field transplant experiments have also been undertaken at Bembridge, Isle of Wight. We consider that a medley of factors may be responsible for the apparent sporadic distribution of *Pelvetia canaliculata* around the Solent region.

LEWEY S.E.A. and E.C. NUMMELA (Maritime Faculty, Southampton Institute, East Park Terrace, Southampton S014 0YN) **Effects of s-triazines on the survival and growth of selected marine macroalgae.**

Triazines have been used as herbicides for many years, but more recently they are being employed as biocides in some antifouling paints. Concern has been expressed about the levels of s-triazines in marine and estuarine waters and the toxicity to marine species.

Laboratory toxicity tests were carried out on a number on intertidal algae, including *Ulva* sp., *Enteromorpha* sp., *Ceramium rubrum,* and *Fucus spirals.* LC_{50} values of between 16-25 ppm were recorded. Initial results indicated that species from the lower littoral zone were less tolerant to s-triazine than those from the upper and middle shore.

The effects of sub-lethal concentrations of s-triazine on the growth of *Fucus vesiculosus* were also investigated. Apical segments of the alga were grown in a range of s-triazine concentrations and temperatures, over a period of 21 days. Logistic curves were then fitted to the algal growth data, using a least squares technique. A small total error was confirmation that the logistic curve is a good model in this situation. The initial data suggest two areas for further investigation. Firstly the intrinsic growth rate remained nearly constant regardless of concentration. Secondly, the carrying capacity initially dropped as the triazine concentration was increased, but remained constant for concentrations greater than 25 ppm. This possibly indicates that growth is reduced by the toxin lowering the entire physiological system of the alga and not just one specific system.

MABERLY, S.C. and M. PETTITT. (Institute of Freshwater Ecology, Far Sawrey, Cumbria LA22 0LP). **The effect of ultraviolet radiation on *Asterionella formosa.***

The freshwater diatom, *Asterionella formosa,* was grown in culture at 20°C, and a photon irradiance (400-700 nm) of 50 or 100 µmol m^{-2} s^{-1} during a 16 hour photoperiod. The specific growth rate and cellular content of chlorophyll *a* was measured over five days in response to the flux and daily-dose of UV-B (280-320 nm) and UV-A (320-400 nm). At a PAR of 50 µmol m^{-2} s^{-1}, growth rate declined with the flux of UV-B radiation, administered for 14 hours per day, but was not sensitive to UV-A. Growth appeared to be linked more to daily-dose rather than flux: at an equivalent UV-B flux, growth rate was reduced more by exposures of 14 than 7 hours. In contrast, the cellular content of chlorophyll *a* was reduced by UV-A wavebands to less than 27% of the control without reducing growth rate. The

response appeared to be linked to both daily-dose and flux. A PAR of 100 μmol m^{-2} s^{-1} reduced the deleterious effects of high fluxes of UV-B radiation. No evidence was found for photoprotective substances. The results are discussed in the context of the ecology of this species.

MARTIN, D., I. RIDGE and D.M. JOHN[1]. (Biology Department, Open University, Milton Keynes, MK7 6AA; [1]Natural History Museum,, London). **The use of decomposing plant litter to control nuisance algae and its possible effects on natural algal assemblages.**

It is known that decomposing plant litter such as barley straw and oak leaves release inhibitors which suppress the growth of algae. Evidence suggests that these inhibitors are, or derive from, oxidised polyphenolics released from lignin or tannins. Laboratory experiments have been carried out to ascertain, (i) the relative sensitivity of different algal species to the inhibitors and (ii) possible taxonomic or functional similarities which may provide clues about the mode of action of the inhibitor(s). Field work in Cambridgeshire shows that suppression of filamentous algae with barley straw is followed by a return to a macrophyte-dominated flora. The relative sensitivity of species to the inhibitors may have important implications for the use of plant litter to control nuisance algae since its use may change natural algal assemblages. Long-term use of plant litter may favour those species which are resistant to the inhibitor(s) and to dominance by new species of nuisance algae which previously were only a minor component of algal biomass.

M^{c}IVOR, L., M. STANHOPE, C. MAGGS and V. WADDELL. (The Queen's University of Belfast, School of Biology and Biochemistry, 97 Lisburn Road, Belfast, BT9 7BL). **The search for a phylogenetically informative mitochondrial gene in the Ceramiales, Rhodophyta.**

Recently, two molecular phylogenies of the Rhodophyta have been produced, one using the *rbcL* chloroplast gene and the other using the 18S nuclear gene. These phylogenies are incongruent and have shown the largest order, the Ceramiales, to be paraphyletic. Mitochondrial gene sequences have often proved to be useful in animal phylogenetics. Therefore we are investigating the possibility that they could provide phylogenetic information which will resolve the incongruities between the nuclear and plastid phylogenies and clarify the phylogenetics of the Ceramiales. Three mitochondrial genes, *cox*3, *lrn* and *nad*1, have been sequenced from four species in the Ceramiales: *Hypoglossum hypoglossoides, Nitophyllum punctatum, Osmundea pinnatifida* and *Ceramium nodulosum.* The phylogenies produced from these sequences will be compared to those produced from *rbcL* and 18S for the same taxa. To date, it has been found that *cox*3 and *nad*1 it are unlikely to be of use at this taxonomic level since they do not show enough sequence divergence. However, a peculiar result was obtained from *cox*3, with *H. hypoglossoides* showing much more sequence divergence than the other taxa investigated. This anomaly is currently being investigated and the search for a phylogenetically useful gene is continuing.

NEWMAN, J.E. and M.T. BROWN. (Marine Biology and Ecotoxicology Group, Plymouth Environmental Research Centre, University of Plymouth, Plymouth, Devon, PL4 8AA, UK.) **Physiological responses of populations of *Gracilariopsis longissima* to copper exposure.**

Populations of *Gracilariopsis longissima* from sites differing in copper contamination have been characterised in laboratory based experiments. Growth rates, copper accumulation and photosynthetic parameters (measured by oxygen evolution and fluorescence) were measured after exposure to a range of environmentally realistic copper concentrations. While changes in growth rates and copper accumulation were observed in treatments as low as 12 ppb, photosynthetic parameters were unaltered at all levels of added copper. This apparent uncoupling of growth from photosynthesis has been investigated further. It was hypothesised that increased organic carbon exudate could account for this

uncoupling, but preliminary results suggest otherwise. Similarities and differences in the responses of populations to copper exposure will be highlighted.

NIMER, N.A. and M.J. MERRETT (School of Biological Sciences, University of Wales Swansea, SA2 8PP, U.K.). **Carbon dioxide availability, extracellular carbonic anhydrase (CA) activity and the regulation of photosynthetic rate in *Skeletonema costatum.***

In those marine phytoplankton species with extracellular carbonic anhydrase (CA_{ext}), inorganic carbon availability regulated activity. For *S. costatum* CA_{ext} activity was detected when the external free CO_2 concentration was less than 5 μM. Under such conditions CA_{ext}, which catalyses the interconversion of HCO_3^- CO_2 and H_2O external to the plasma-membrane, was essential to maintain V_{max} for photosynthesis. The presence of dextran-bound sulphonamide (DBS), a potent membrane impermeable inhibitor of CA_{ext} inhibits photosynthetic rate under conditions of carbon limitation. The photosynthetic rates were no greater in the presence of this inhibitor that might be expected from the diffusive entry of available CO_2. Results suggest that CA_{ext} maintains the steady state flux of CO_2 to RUBISCO, is activated when the flux of CO_2 into the chloroplast is insufficient to achieve V_{max} for photosynthesis at a given photon flux density. Measurement of trans-membrane electron transport at the plasma-membrane suggests the redox state of the cell determines CA_{ext} activity, which in turn regulates photosynthetic rate.

OLSEN, J.L. (Department of Marine Biology, The Biological Centre, University of Groningen, Postbox 14, 9750 AA Haren, The Netherlands). **From macromolecules to microsatellites in algal systematics and ecology - II: Applications**

This update lecture will use examples from our laboratory to illustrate problems in experimental design and data interpretation for both phylogenetic and population level studies. Over the past several years the focus of molecular studies on algae (excluding molecular genetics of model organisms like *Chlorella* and *Chlamydomonas)* has been on large-scale phylogenetic surveys*, especially higher-order relationships. The trend however, is going to be more and more towards species and subspecies levels. This raises a number of considerations that are generally only poorly accounted for. For example, biogeographic sampling will play a critical role and assumptions about hierarchical structure in the data may be questionable. Issues around paraphyly, cryptic species, taxon sampling, taxon age, and rates of evolution must to be even more carefully considered; and if taxonomic decisions are involved or if rooted trees are required, the stability of the tree will become even more important. In the case of population-level studies the problem of experimental design is entirely different as is the analysis. Statistical considerations in the sampling must include a larger sample size, replicate-nested sampling, and the scale over which the sampling is to be done. Questions must be sharply posed. To further complicate matters, the availability of new-generation, high resolution markers, that all come under the general name of "fingerprinting", make it hard to casually evaluate their relative utility.

*A survey (1988-1996) of applications fall roughly into the following categories: ca. 57% sequencing projects for phylogenetic purposes; ca. 25% in molecular evolution (chloroplast genomes and genes, mapping projects, regulation, etc.); ca. 8% in coevoluton, biogeography, population and life history studies; 7% oligonucleotide identification probes; and 2% methodological. A summary of 1995-1996 shows that molecular papers accounted for 15% of the articles in *Journal of Phycology,* 7% in *Phycologia,* 13% in *European Journal of Phycology* and <1 *% in Marine Biology.*

OSBORNE, B.A. (Botany Department, University College Dublin, Belfield, Dublin 4, Ireland. Email. BOsborne@Macollamh.UCD.IE). **Chipping at the foundations of a paradigm: re-evaluating the Z-scheme.**

Today, most people believe that the conversion of light energy into chemical energy during oxygenic photosynthesis is mediated by a process (Z-scheme), which involves the co-operation of two photosystems (PS1 and PS2). This is thought to produce all of the NADPH

which is required for the reduction of carbon dioxide in the Calvin cycle. Although generally-accepted, recent experimental results using green algal mutants devoid of PS1, or isolated PS2 reaction centres, suggest that NADPH synthesis can occur independently of PS1 activity. Even in plants containing PS1 and PS2 their spatial location and the restriction of intersystem electron flow due to macromolecular crowding, suggests some independence in the operation of the two photosystems. Also, many of the *in vivo* photosynthetic characteristics which are often cited in support of a functional agreement with the Z-scheme could have alternative and plausible explanations. *In vivo* photon yield measurements with microalgal cells or plant tissues also suggest, on the basis of the Z-scheme, that the light-energy transducing reactions can operate at near-maximal efficiency. Such an agreement between experiment and theory is difficult to reconcile with predicted inefficiencies and losses in a number of light harvesting, electron transport and energy transducing reactions, even if these losses in efficiencies are small. In this paper I will review the significance of these results with particular reference to measurements of the photon yield/photon requirement of a range of plant species. I will also provide evidence that photosynthetic structures can have a significant modulating effect on light energy transduction.

POOLE, L.J. and J.A. RAVEN. (Department of Biological Sciences, University of Dundee, Dundee DD 1 4HN, U.K). **The growth of *Enteromorpha intestinalis* in elevated oxygen concentrations.**

Data from seasonal and diel studies have shown that *Enteromorpha intestinalis* successfully inhabits water bodies supersaturated with oxygen. Seasonal oxygen concentrations, when corrected for temperature, have shown that there is a range from 231 to 903 mmol m^{-3} (i.e. 86 % to 378 % of air saturation) in a rock pool environment dominated by *E. intestinalis*. Diel studies have shown that high concentrations of oxygen, resulting from photosynthesis occurring throughout the day, with maximum concentrations (903 mmol m^{-3} O_2) at 12.00 GMT. In an aquatic system with excess oxygen, oxygen instead of $NADP^+$ is found at the reducing site of photosytem I, resulting in psuedocyclic electron flow, also known as the Mehler reaction. Toxic oxygen species produced as a result of the splitting of water may have an adverse effect on plant growth. Specific growth rate was not altered when *E. intestinalis* was grown in culture at oxygen concentrations of 20, 40, 60 and 80 kPa O_2. As no observable effects can be noted it is suggested that protective enzyme activity is responsible for the ability of *E. intestinalis* to tolerate potentially adverse oxygen concentrations. The role of enzyme quenchers and scavengers, such as superoxide dismutase and ascorbate peroxidase, are currently being examined.

POWTONGSOOK, S. and D.J. GILMOUR. (Department of Molecular Biology and Biotechnology, University of Sheffield, Sheffield S 10 2TN). **Immobilization of the green alga *Dunaliella* for the production of glycerol.**

Glycerol is produced by the green alga *Dunaliella* as its compatible solute for balancing osmotic pressure. Immobilization methods have been adopted in order to produce glycerol from this alga. This "green" technology may be a sustainable source of glycerol production in the future. Normally, *Dunaliella* retains glycerol inside the cell. However, it was found that the calcium alginate entrapped *Dunaliella* cells release large amounts of glycerol into the medium. Electron microscope studies suggest that glycerol may possibly be released from dead cells which had lysed inside the beads. The rate of glycerol leakage from immobilized cells was much higher than from free cells in liquid culture. Physiology of immobilized algal cells with respect to growth, photosynthesis and glycerol leakage has been studied. Several techniques have been tested for the improvement of glycerol production such as using osmotic shock and semi-continuous harvesting.

PROBERT[1], I., J.LEWIS[1] & E. ERARD-LE DENN[2]. ([1]University of Westminster, 115 New Cavendish St., London, W1M 8JS; [2]IFREMER, Centre de Brest, 29280 Plouzané, France)
Observations on vegetative reproduction and the sexual life cycle of the marine dinoflagellate *Alexandrium minutum* Halim

As part of a study into the possible factors inducing sexual reproduction in dinoflagellates, a morphological and nuclear study of the asexual and sexual reproductive cycles of the toxic dinoflagellate *Alexandrium minutum* Halim is described. Morphological studies were performed using both light and scanning electron microscopy; protargol silver staining and fluorescent stains were used to analyse nuclear changes. The processes of cell division and gamete mating and fusion are compared. Despite isolation and crossing of several strains, and manipulation of culture conditions, the planozygotes which form as a result of gamete fusion have not been observed to form the hypnozygote resting cyst stage in cultured populations. The present observations are compared to those of other dinoflagellate species in which sexual reproduction has been studied. The application of the findings of this study to research investigating potential triggers for the shift from asexual to sexual reproduction in natural and cultured populations of *A. minutum* is outlined.

RAVEN, J.A. (Department of Biological Sciences, University of Dundee, Dundee DD1 4HN). **Putting the C in Phycology.**

More than 95% of the organic C (45-50% of organic dry weight) of algae is fixed by RUBISCO, and the rest by other carboxylases operating in parallel to produce essential C skeletons not accessible from RUBISCO activity alone. Although all of the carboxylases are coded by single gene families the eukaryotic RUBISCO had at least three independent origins from prokaryotic RUBISCO's despite a (probable) single endosymbiotic origin of plastids from a cyanobacterium.

Most extant algae have the capacity to produce CO_2 concentrating mechanisms (CCMs), suggesting that inorganic C is a potentially limiting resource in nature, granted the properties of RUBISCO. Even with CCM's expressed some oxygenase activity of RUBISCO occurs, and algae have a variety of photorespiratory pathways which scavenge the resulting phosphoglycolate. Polyphyletic origins are likely for CCM's and the carbonic anhydrases associated with them (and with diffusive CO_2 entry), and for the glycolate-metabolising pathways (if not the individual enzymes). This is in agreement with a relatively late origin of both CCMs and photorespiration in relation to diversification of algae in the Proteozoic as O_2 levels increased and CO_2 levels fell. The present anthropogenic increase in atmospheric CO_2 will tend to decrease the selective advantage of CCM'S, although algae will continue to the major contributors to the global C cycle as they have been for at least the last 3.5 billion years.

RAVEN, J.A. (Department of Biological Sciences, University of Dundee, Dundee, DD1 4HN). **Can vacuoles replace carbonic anhydrase in carbon concentrating mechanisms?**

The most widely distributed carbon concentrating mechanism (CCM) in cyanobacteria and eukaryotic algae appears to involve energetized delivery of HCO_3^- to the compartment containing RUBISCO, followed by carbonic anhydrase (CA) activity supplying RUBISCO with CO_2 at a concentration in excess of that in the medium. Organisms with gas exchange characteristics suggesting a CCM but with no accumulation of inorganic C relative to the medium may involve HCO_3^- to CO_2 conversion in acidic compartments where the equilibrium CO_2:HCO_3^- allows a high [CO_2] out of equilibrium with the low [HCO_3^-] at the site of RUBISCO (provided CA is absent from the site). The acidic compartments include the lumen of the illuminated thylakoids (provided CA is present) and acid zones on the surface of characeans (catalysed by CA, or H^+). Another possibility for the acidic compartment is the vacuole. Supply of HCO_3^- by HCO_3^-:OH^- antiport at the plasmalemma and the HCO_3^- uniport (paralleling active H^+ influx) at the tonoplast could provide a high

enough steady-state [HCO_3^-] for the H^+-catalysed production of CO_2 at a rate and [CO_2] sufficient to satisfy photosynthetic requirements in (1) small-celled algae with very acid vacuoles (pH 1) and relatively low vacuole: cytoplasm ratio (e.g. *Desmarestia ligulata, D. viridis)* or (2) giant-celled algae with less acid vacuole and higher vacuole:cytoplasm ratios (e.g. *Chaetomorpha coliformis*). This 'vacuole' hypothesis is testable.

RICHARDSON, T.L.,[1] A.M. CIOTTI, and J.J. CULLEN (Dept. of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1, [1]Now at Dept. of Agricultural and Environmental Science, Queen's University of Belfast, Newforge Lane, Belfast BT9 5PX, Northern Ireland). **Physiology of the diatom *Rhizosolenia formosa* in the context of open-ocean vertical migration.**

Large buoyant diatoms of the genus *Rhizosolenia* are thought to migrate vertically in oligotrophic oceans (Villareal et al., 1993). We examined cultures of *Rhizosolenia formosa* to assess whether physiological and optical characteristics of this diatom were consistent with the vertical migration hypothesis, and to determine whether cells were adapted to life in an environment where light and nutrients are spatially separated. Nitrate (N) uptake measurements showed that both N-replete and N-depleted cells were capable of taking up nitrate in the dark. Uptake rates exceeded nitrogen-specific growth rates, indicating the capacity for luxury consumption of N which can be stored for later use in nutrient-depleted surface waters. Cells were able to survive relatively long periods of N depletion, as would be required during the migration cycle, and were able to resume uptake of N when it was re-introduced to culture medium. The percentage of positively buoyant *R. formosa* increased upon N re-addition indicating that cells may revert to a state of positive buoyancy upon sinking to N-rich deep water. Measurements of photosynthesis vs. irradiance, chlorophyll-specific absorption, and pigment composition showed that cells may be adapted for growth under a wide range of irradiances as would be experienced by a migrating diatom. We conclude that physiological and optical characteristics of *R. formosa* are consistent with the hypothesis of vertical migration in oligotrophic oceans, and that cells are well-adapted to life as a vertically-migrating phytoplankter. This may explain why these large diatoms are relatively successful in regions otherwise dominated by small plankton and food webs based on regenerated primary production.

RICHES, C.J., GREENWAY, D. and ROBINSON, P.K. (Department of Applied Biology. University of Central Lancashire, Preston, Lancs. PRI 2HE). **Lipid profiles from immobilised algae as indicators of heavy metal pollution.**

Applications of immobilised algal cell technology have increased in recent years, yet little attention has focused on the use of immobilised algae in biomonitoring. The use of lipids from immobilised algal cells to identify heavy metal pollutants in freshwater aquatic environments is described. Studies on the effects of heavy metals on *Selenastrum capricornutum* CCAP 278/4 have shown that long term metal exposure (in the μM concentration range) significantly inhibits algal growth and results in characteristic alterations in lipid profiles. Analysis of acyl-lipids by capillary-GC reveals greater levels of monounsaturated and saturated fatty acids, possibly resulting from inhibition of Δ9-desaturase activity. Sterol analysis reveals that sterol composition was also affected by metal treatment, with an increase in the 24-ethylcholest-7,22-dien-3β-ol to 24-ethylcholesta-7-en-3β-ol ratio. This alteration in sterol profile with metal exposure is significantly different to those changes associated with environmental factors such as illumination and temperature. The biochemical and physiological characteristics of *S. capricornutum* entrapped within gels (alginate, agarose and carrageenan) have also been investigated. Alterations in the growth rate and lipid metabolism of immobilised cells, resulting from exposure to copper will be described. Such changes in lipid profiles may enable identification and quantification of these pollutants in aquatic freshwater environments

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SHUBERT, L.E. and S. RUSSELL (Department of Botany, The Natural History Museum, Cromwell Road, London SW7 5BD). **Environmental aspects of stress protein production in a cyanobacterium induced by cadmium.**

Cyanobacteria respond to stressful environmental conditions, at the subcellular level, by a rapid and transient acceleration in the rate of expression of stress proteins. Stress factors, such as heavy metals, temperature and nutrient deficiency, play an important role in the distribution and abundance of cyanobacteria. The ability of cyanobacteria to adapt and survive fluctuating stressful environmental conditions can be studied by analysing changes in protein production. *Arthrospira platensis* (strain C-1) is a photosynthetic organism that is adapted to high temperature, high alkalinity, high salinity and hypertrophic aquatic habitats. Response to stress was tested in *A. platensis* by exposing it to a known cellular poison, cadmium (0 to 3000 ppb). Proteins were detected by SDS-PAGE and silver staining procedures. *A. platensis* has a protein profile comprising many different proteins of varying molecular weights. However, a stress protein (120 kDa) was expressed with increasing exposure time and concentration of cadmium up to 3000 ppb. Acute toxicity occurred at 3000 ppb. Using a cross light-temperature gradient plate, cadmium stressed cells were compared to other environmental stressors (temperature, light, nitrogen deficiency) that may induce or inhibit the expression of stress proteins. A combination of environmental factors affect the stress protein response. The dynamic nutritional quality of *A. platensis* may have important ecological implications for higher trophic levels.

SCHUBERT, H., H.C.P. MATTHIJSL[1] and R.M. FORSTER. (Universitat Rostock, D-18055 Rostock; [1]Universiteit van Amsterdam). **Occurrence of complementary chromatic adaptation in a eutrophic estuary.**

Several cyanobacteria are able to adapt their light harvesting apparatus to the spectral composition of the ambient light climate by varying the phycoerythrin/phycocyanin ratio of their phycobilisomes, in a process called complementary chromatic adaptation (CCA) . in eutrophic systems the absolute availability of light in the water column is reduced and the spectral range of underwater light becomes narrowed. Light harvesting ability may be increased by CCA under these conditions.

Kinetics and trigger-intensity dependence of CCA under orange and green light conditions, as well as under fluctuating light conditions (simulating wind-induced vertical mixing) , were tested in the laboratory. The equilibrium ratio of PE/PC was clearly dependent on the green/orange light ratio under changing light regimes but showed only slight intensity dependence, which can be explained by normal intensity adaptation. The time scale for full adaptation was approximately one week for all conditions.

However, during measurements in the Darss-zingst Bodden chain (Mecklenburg, Germany) evidence of CCA was not detected, despite high concentrations of phytoplankton and potentially light-limiting conditions. A reason was revealed by using underwater light measurements to model the light absorbed by cyanobacteria with different phycobilisome composition. The shift in spectral irradiance which occurs with increasing depth in phytoplankton blooms is to a wavelength range absorbed by PE and PC. CCA may only be important in increasing photosynthetic efficiency under relative stable light conditions such as present in stratified lakes or cyanobacterial mats.

SKIDMORE[1,2], R.E., S.C. MABERLY[1] and B.A. WHITTON[2]. ([1]Institute of Freshwater Ecology, Far Sawrey, Cumbria LA22 0LP; [2]Department of Biological Sciences, University of Durham). **Light as an ecological factor controlling the productivity of river phytoplankton.**

The effect of photosynthetically active radiation (PAR) on phytoplankton productivity in the Rivers Trent and Yorkshire Ouse is being studied as part of a project

sponsored by the Land Ocean Interaction Study: a NERC community programme. Approximately every two weeks, the response of rate of photosynthesis to PAR (P vs I) is measured in the laboratory, and characterised using a model. Seasonal changes in light-saturated rate of photosynthesis, initial slope of P vs I, I_K, respiration rate and extent of photoinhibition are related to species composition temperature, PAR attenuation and daily average radiation. Photoinhibition at high irradiance was apparent on some occasions. The data will be incorporated into a model to estimate rates of production within the river. The extent to which PAR limits production will be assessed and predictions will be compared to calculations using diel changes in oxygen concentration at the two sites.

STAM, W.T. (Department of Marine Biology, The Biological Centre, University of Groningen, Postbox 14, 9750 AA Haren, The Netherlands). **From macromolecules to microsatellites in algal systematics and ecology - 1: The toolbox**

This update lecture will review the standard techniques (DNA sequencing, PCR, RAPDs, RFLPs of various types and classic VNTR or multi-locus fingerprinting) and introduce two new methods (Amplified Fragment Length Polymorphisms [AFLPS] and PCR-based, single-locus microsatellite data [MSATs]). For all methods attention will be paid to how the procedure works, technical expertise required, practical difficulties/limitations, sampling effort required and cost aspects. In addition, a comparison of markers will be made in relation to their utility in answering particular categories of scientific questions. This is not always self-evident because the *species* level is itself problematic and because of non-equivalency of taxonomic ranks among groups.

WARD, C.J.,[1] W. PREISER,[2] G.K. POON[3], S. POURIA[4], G.H.NEILD[4] and G.A. CODD[1] ([1]Department of Biological Sciences, University of Dundee, Dundee, DD1 4HN. [2]University College London Medical School, Department of Virology, Division of Pathology, Windeyer Building, 46 Cleveland Street, London, W1P 6DB. [3]SmithKline Beecham, The Frythe, Welwyn, Herts. AL6 9AR . [4]Institute of Urology and Nephrology, Middlesex Hospital, Mortimer Street, London, W1N 8AA) **Analysis for cyanobacterial microcystins after multiple deaths at a haemodialysis clinic, Caruaru, Brazil.**

The possibility that cyanobacterial toxins can affect human health via the exposure route of haemodialysis was raised more than 20 years ago (Hindman, S.H., The Lancet 2, 732 [1975]). In 1996 a tragedy occurred at a haemodialysis clinic in Caruaru, Brazil, including the deaths of 55 patients from February to August inclusive. The water supply was the Tabocas reservoir, which produces blooms of toxigenic cyanobacteria.

Acute presentations were with neurotoxic symptoms (blindness, weakness, tinnitus, vertigo, and headaches). Surviving patients developed sub-acute liver failure of varying severity, leading to rapidly progressive hepatic failure and death. Examination of water filter materials from the clinic (granular activated carbon, GAC) revealed a range of microalgal cells and cell debris. Analysis of GAC eluates for cyanobacterial hepatotoxins yielded a peak by high-performance liquid chromatography which co-chromatographed with microcystin-LR standard but did not have the microcystin-LR molecular weight and was non-toxic by mouse bioassay. Evidence for low amounts of microcystins in GAC eluates was, however, provided by protein phosphatase inhibition assay and ELISA immunoassay.

One patient was given haemoperfusion therapy before eventual death. Analysis of prehaemoperfusion serum has indicated a microcystin level of 186 $ng.ml^{-1}$ according to protein phosphatase inhibition assay, with no microcystin detectable (<10 $ng.ml^{-1}$ serum), post haemoperfusion. ELISA assays with sera are in progress.

These findings confirm the need to formulate, implement and monitor procedures for the analysis and removal of cyanobacterial toxins from water sources which are prone to bloom development and destined for use in haemodialysis.

WILLIAMS, D.M. and K. WEBB. (Department of Botany, The Natural History Museum, Cromwell Rd, London SW7 5BD. UK) ***Fragilariforma virescens:*** **Ontogeny, species and biogeography.**

Fragilariforma virescens was described some 150 years ago by Ralfs as a species of *Fragilaria.* Since that time at least 40 + subspecific taxa have been attributed to it. Williams and Round used *Fragilaria virescens* as the type of the new genus *Fragilariforma.* Recent investigations have demonstrated that many of the so-called varieties of *F. virescens* are either completely unrelated to the nominate variety (e.g., "*Fragilaria" virescens* var. *exigua* is a different genus) or are parts of its life cycle. This paper will present a full description of *F. virescens,* via its life-cycle, to enable more meaningful comparisons with the remaining subspecific entities. We will present micrographs of auxospores -- or least cells that are probably initial cells occurring after the first one or two cell divisions -- vegetative valves and some of the smallest 'pre-auxospore' valves, the latter which have been named as separate entities. Additionally we will comment on the current understanding of the distribution of *F. virescens as* well as the redundancy of 'varietal' classifications.

POSTER ABSRACTS

BABIC, S. and D.G. ADAMS. (Department of Microbiology, The University of Leeds, Leeds, LS2 9JT). **Photoheterotrophy and nitrate metabolism in the symbiotic cyanobacterium *Nostoc* sp. strain LBG1 and mutant M22.**

Certain filamentous cyanobacteria, which are able to differentiate heterocysts (sites of dinitrogen fixation), are also able to form symbiotic relationships with bryophytes. In symbiosis the bryophyte host donates photosynthate to symbiotic colonies, which in return develop a high frequency of heterocysts and supply the host with fixed nitrogen as ammonium. It follows that uptake mechanisms are required by symbionts for host photosynthate.

In this study the symbiont *Nostoc* sp. strain LBG1 was isolated from symbiosis with the bryophyte *Phaeoceros*. The symbiont possesses a low affinity, high capacity glucose transport system which may function in symbiosis where a high dinitrogenase activity may result in a high demand for host photosynthate. In the free-living symbiont this transport system appeared to be regulated by availability of fixed nitrogen, since glucose uptake was enhanced in nitrate-grown cells compared with dinitrogen-fixing cells. In symbiosis the greater part of fixed nitrogen is not assimilated by the symbiont but is donated to the host. It thus appears that
photosynthate uptake mechanisms in symbiosis may not be dependent on fixed nitrogen availability.

Studies with strain M22, a mutant of *Nostoc* sp. strain LBG1 altered in glucose transport, imply that during photoheterotrophic growth with glucose and nitrate, the reduction of nitrate functions as an alternative electron acceptor to oxygen.

BARWELL, C.J.[1], G.C. WANG, B.C. ZHOU and C.K. TSENG. ([1]University of Portsmouth, School of Pharmacy & Biomedical Science, St Michael's Building, Portsmouth, PO1 2DT, UK; Institute of Oceanology, Chinese Academy of Science, Qingdao, 266071, China). **Evaluation of *Polysiphonia urceolata* as a source of R-phycoerythrin.**

With respect to their colour, alga biliproteins occur as two forms; red phycoerythrin and blue phycocyanin and allophycocyanin. These natural pigments have some current use and much potential for development as colourants. In order to be exploited as colourants an assured supply of algae and methods for economic large scale isolation of the biliproteins are required. Supply may be assured by mariculture and large scale isolation carried out by methods of protein purification which involve adsorption. The life cycle of *Polysiphonia* species and fragile nature of the thallus mean that the alga may be cultured to yield material from which biliproteins should be readily extracted. *P. urceolata,* which was collected in April at Qingdao, China, was evaluated as a source of R-phycoerythrin.

Extraction of alga material with either water or bicarbonate buffer, pH 10, yielded the same amount of R-phycoerythrin (2mg per g). However, the water-extract was viscous which caused slow loading onto columns of chromatography material. Column chromatography with Butyl Sepharose (hydrophobic interaction) followed by Q Sepharose (anion exchange) yielded R-phycoerythrin free from phycocyanin and allophycocyanin. Results demonstrated that *P. urceolata* would be a good source of R-phycoerythrin. The pigment may be readily released into an extract suitable for column chromatographic methods of protein isolation which may be used for large scale isolation of colourant.

BIRKETT, D.A., M.J. DRING and G. SAVIDGE. (The Queen's University of Belfast Marine Laboratory, Portaferry, County Down, BT22 1PF). **Estimations of microphytobenthic biomass and oxygen production from intertidal sediments in Strangford Lough, Northern Ireland.**

The contribution of sand and mud shores to oxygen production within Strangford Lough marine nature reserve has been estimated using laboratory and field based methods. Surface sediment samples were collected as a series of multiple shallow cores from 77 intertidal sites and were extracted for chlorophyll *a* as an estimate of biomass. Small scale (10 cm apart) surface distribution patterns of chlorophyll *a* were measured and found to vary widely within a 1 m^2 area. Suspensions of microphytobenthic organisms, obtained from core samples, were used in laboratory based ^{14}C incubations. Field measurements were obtained using perspex chambers fitted with Y.S.I. 6000 oxygen probes and data loggers.

Hydrostatically operated valves sealed the chambers after they had filled on a rising tide and allowed the chambers to empty as the tide fell. Water within the chambers was circulated by submersible pumps. Each chamber had an internal volume of 15 l and a footprint of 0.066 m^2. Chambers were deployed on mud or fine sand shores and remained *in situ* for between 4 and 8 days. Oxygen concentrations were recorded at 15 min intervals during periods of submergence. Biomass estimates ranged from a mean of 101.9 mg chl.*a* m^{-2} on mud shores to 140.0 mg chl.*a* m^{-2} on sand shores. Photosynthetic characteristics varied between sediment types, samples from mud shores having lower P^B_{max} values than samples from sand shores. Preliminary field results indicate that areas of sediment are net consumers of oxygen, despite the photosynthetic activity of the microphytobenthos.

DUGGAN, P.S., M.C. BEAN and D.G. ADAMS. (Department of Microbiology, University of Leeds, Leeds, LS2 9JT). **Cell wall structures associated with gliding motility in cyanobacteria.**

Many prokaryotes swim in liquids with the use of flagella. Others, including many filamentous cyanobacteria, are capable of gliding on surfaces. Cyanobacteria such as *Oscillatoria* spp. display permanent motility, while in other genera, for example *Nostoc,* gliding is restricted to transient morphological forms known as hormogonia. The mechanism of bacterial gliding is unknown, indeed, the structure or organelle responsible for this type of motility has not been identified.

We have employed electron microscopy to study cell wall structures in a number of cyanobacteria belonging to different genera. Using a variety of techniques we have demonstrated the presence of an ordered structure, sandwiched between the outer membrane and the peptidoglycan layer, and consisting of regular arrays of parallel fibrils covering the entire filament. Intact fibrils, free of cell wall material, have been isolated and found to be of the same size and shape as those observed *in situ.* Individual fibrils are between 20 and 30 nm in width and between 270 and 400 nm in length, depending on the organism from which they were isolated. The possibility that the fibrillar layer is involved in gliding motility is under investigation.

EDWARDS, G.O.[1], J.A. CALLOW[1] and C. BROWNLEE[2]. ([1]School of Biological Sciences, The University of Birmingham, Edgbaston, Birmingham, B15 2TT; [2]Marine Biological Association of the United Kingdom, The Laboratory, Citadel Hill, Plymouth, PL1 2PB).
Application of RAPDs to analyse hybridisation in *Fucus*.

The brown alga *Fucus* shows a great deal of morphological variation which may lead to difficulties in classifying an individual plant as either *Fucus serratus* L., *F. vesiculosus* L. or *F. spiralis* L. The appearance of such morphologically indistinct forms of *Fucus* has lent weight to the hypothesis that hybrids exist between the species of this genus, although this has yet to be conclusively proven. However it does seem certain that cross-fertilization may occur *in vitro* when eggs released from aged material are exposed to sperm of other species.

In order to determine whether cross-fertilization occurs in *Fucus* a random amplified polymorphic DNA (RAPD) protocol has been optimized. RAPD has been shown to be a useful tool for ecological and molecular research, having the advantage that no prior knowledge of the genome of the organism under investigation is required. It has been used

to demonstrate the existence of hybrids in other species. In this poster results will be reported demonstrating the value of differentiating between species of *Fucus*. Studies on the application of this technology to individual embryos will also be reported.

ELLAWAY, J.W., G.E. DOUGLAS, D.M. JOHN, S.J. BROOKS, and G.C. JONES. (The Natural History Museum, Cromwell Road, London). **A bloom of the water net *(Hydrodictyon reticulatum)* in a eutrophic lake: its seasonality, cause and impact.**

The water net is increasingly reaching bloom proportions in British lakes and rivers, including Loe Pool, Cornwall's largest freshwater lake. Here colonies of *Hydrodictyon* were evident from early summer leading eventually to a complete blanketing of areas of the lake surdace and floor by mats of this green alga. By late summer a switch to a plankton-dominated system occurred. Initial data analyses implicates water temperature in the seasonal appearance of the water net but not in its decline. Dense populations of zooplankton were associated with algal mats, however grazing is not considered a "top-down" mechanism accounting for the bloom's disappearance. Interactions between the water net and planktonic algae together with factors responsible for the departure of the bloom are discussed in relation to the development of a predictive model for use in water management.

FYSON[1], A., H. KRUMBECK[1], W-H. KUSBER[2] and B. NIXDORF[1]. ([1]Brandenburg Technical University, Department of Water Protection, 15526 Bad Saarow; [2]Institute of Systematic Botany and Plant Geography, Free University, Berlin). **Microscopy of Algae from Extremely Acidic Mining Lakes in Lusatia (Germany).**

In the Lusatia region of eastern Germany, pits from open-caste lignite mining are infilling with groundwater. The water of these lakes (Tagebaurestseen) is characteristically highly acidic ($KB_{8.2}$ 2-20 mmol/L) with high concentrations of protons (pH 2.6-3.2) and dissolved iron (0-6 mmol/L) as well as high sulphate concentrations. Although the pelagic primary productivity of these lakes is typically low, a diversity of algae from several taxonomic groups can generally be found. One Euglenophyte species (*Lepocinclis teres*) has also been examined by scanning electron microscopy and its characteristics related to the environment. The ecological and taxonomic implications of the morphology of this organism are discussed.

GREEN, J., and C.N. HUNTER (Robert Hill Institute of Photosynthesis, Krebs Institute of Biomolecular Research, Department of Molecular Biology and Biotechnology, University of Sheffield, Sheffield, S10 2UH, United Kingdom). **The isolation and characterization of the *ChlH* gene from the magnesium chelatase step of the chlorophyll biosynthesis pathway within the chlorophyte *Chlamydomonas reinhardtii.***

In chlorophyll biosynthesis magnesium chelatase catalyses the insertion of a magnesium ion into the protoporphyrin ring. Genes *bch H,I* and *D* encoding this step have been identified from the purple photosynthetic bacteria *Rhodobacter sphaeroides.* Homologues of these genes have also been found in higher plants, such as *Olive* from *Antirrhinum majus, CH-42* from *Arabidopsis thaliana* and *ChlD* from the cyanobacterium *Synechocytis* PCC6803 respectively.

Sequence alignments have been used to design polymerase chain reaction (PCR.) primers for the subsequent isolation of corresponding genes from *C. reinhardtii.* To date 120bp and 600bp fragments of the *ChlH* gene have been isolated using PCR. These fragments have been sequenced and alignments using DNA Star Megaline programs show 56.5% similarity to *A. majus, Olive* and a 58.6% similarity to *A. thaliana, ChlH.*

Southern analysis showed the H120 and H600 fragments had a strong and specific homology to fragments from cc-124 wild type *C. reinhardtii* genomic DNA and suggested that a unique part of the *ChlH* from *C. reinhardtii* had been isolated.

HARRIS, E., B. LEADBEATER and R. WOOD. (School of Biological Sciences, University of Birmingham, Birmingham, B15 2TT). **Virus infection of *Hincksia hincksiae* (Harvey) Silva: an ultrastructural and physiological study.**

Clonal cultures of *Hincksia hincksiae* were initiated from filament fragments bearing sporangia. The sporangia of some filaments displayed characteristic symptoms of virus infection. Plurilocular sporangia on filaments apparently uninfected by virus particles were conical, darkly pigmented and multilocular whereas sporangia on virus infected filaments were hyaline and lacked the 'uninfected' plurilocular appearance. Hyaline sporangia of infected filaments stained red/purple when treated with a mixture of acetocarmine and aniline blue stains. TEM observations of hyaline sporangia has confirmed the presence of many polyhedral virus-like particles (VLP's) and an absence of developing zoospores. This is in contrast to 'uninfected' plurilocular sporangia where each locule contains a developing zoospore and no VLP'S. VLP's are 130-170 nm diameter and consist of an inner electron dense core and an outer monolayered dense staining capsid.

Cultures of *Hincksia hincksiae*, initiated from spores of virus infected plants, were grown at 10°C, 15°C and 20°C in a 16h light/8h dark regime. After several passages of growth at these temperatures, filaments cultured at 15°C and below possessed considerably more infected sporangia than those at 20°C. In another experiment VLP's were used in an attempt to infect newly released spores from 'uninfected' material of *Hincksia* and other closely related taxa. Plants of *Ectocarpus siliculosus* and *Hincksia secunda* did not produce infected sporangia whereas ca. 30% of plants grown from spores of *Hincksia hincksiae* were classified as infected.

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

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

Determination of cell volume has been carried out using two different methods. The first method used $^{3}H_2O$ and ^{14}C-dextran to determine the volume of a pellet of cells which had been centrifuged through silicone oil. The $^{3}H_2O$ measures the overall volume of the pellet and the ^{14}C-dextran estimates the extracellular volume within the pellet since the large molecular weight of dextran used (70000) means that it cannot enter the algal cells. If the number of cells within the pellet is know then an average cell volume can be calculated. The second method involved direct microscopic measurements after calibration of the microscope with a micrometer. The results from both methods were compared.

The cell number, cell volume and chlorophyll content of both algae were determined over a wide range of pH values. This allowed conclusions to be drawn about the effect of pH stress on cell dimensions and the amount of chlorophyll per cell.

JOHN, D.M., L.R. JOHNSON, B.A. WHITTON[1], A.J. BROOK[2] and P.V. YORK. (Department of Botany, The Natural History Museum, London; [1]Department of Biological Sciences, University of Durham; [2]University of Buckingham). **Progress Towards a Modern Freshwater Algal Flora of the British Isles.**

The Flora is the first synthesis and user-friendly identification guide covering all British freshwater and terrestrial algae to be prepared since publication in 1927 of West and Fritsch's 'A Treatise on British Freshwater Algae'. During the course of the past year considerable progress has been made achieving the objectives of the Flora Project. A fifteen field relational database of taxonomic, ecological, distributional and bibliographic data has been prepared using Microsoft Access. A coded checklist of all known British freshwater

and terrestrial algae (c 5000 spp) has been prepared and is incorporated into a Determinand Dictionary prepared as part of NERC's LOIS (Land-Ocean Interaction Study) programme. Draft entries for the euglenophytes and several major chlorophyte orders have been completed (Chaetophorales, Cladophorales, Klebsormidiales). Good progress has been made with other chlorophyte orders including the Zygnemales and preparing a photocatalogue of digital images of algae and their habitats. The catalogue consists of colour transparencies, monochrome photographs and line illustrations scanned-in as computer image files stored in JPG and TIF format. After editing and addition of legends and scale bars are completed the images will be written to CD ROM.

JOHNSTON[1], N.A.J., R.J. MOLE[2] & D.G. ADAMS[1]. ([1]Department of Microbiology, University of Leeds, Leeds, LS2 9JT; [2]Department of Applied Biochemistry and Food Science, University of Nottingham, Sutton Bonington, Loughborough, Leicestershire, LE12 5RD). **Isolation of mutant cyanophages capable of lysing phage-resistant cyanobacterial strains.**

Cyanobacterial blooms characterise many nutrient-rich fresh and brackish waters. They cause problems in terms of human and animal health and water quality. A range of methods for controlling cyanobacterial populations has been tried with varying success. Potential biological control agents are the cyanophages (cyanobacterial viruses), which are known to contribute to the natural decline of cyanobacterial populations. Whilst the cyanophage AN-15 is capable of lysing wild-type *Anabaena* sp. PCC 7120, resistance to the phage arises at a very high rate of 10^{-4} -10^{-5}. We have isolated and studied some of the resistant strains (known as phage-resistant clones, PRC). At low MOI (multiplicity of infection) wild-type *Anabaena* sp. PCC 7120 is lysed by the phage, but the PRC strains are not. At higher MOI (1-20 cells/plaque forming unit) mutant viruses capable of lysing the PRC strains have been isolated.

JONES, J.L. and A. WHITTICK. (Department of Biology, Memorial University of Newfoundland, Canada Al B 3X9). **Season and substrate: morphological variation of intertidal *Pilayella littoralis* (Ectocarpales, Phaeophyceae) from insular Newfoundland.**

The morphological variation in *Pilayella littoralis* (L.) Kjellm. is well known. Some workers have attributed this variation to either seasonal changes or to ecological differences based on substrate or location. In Newfoundland the alga is a summer ephemeral in the intertidal. It usually appears in early April, develops throughout the summer reaching a maximum biomass in July-August, dying back in September and disappearing by late October or early November. Three populations of *P. littoralis* were studied, one from an estuary and two from full salinity waters, one an epiphyte on *Fucus vesiculosus,* the other an epilith. Samples were taken at approximately bi-weekly intervals over the growing season. Vegetative and reproductive characters were measured and subjected to various multivariate analyses. In explaining variation, substrate was shown to be unimportant and most variation was due to changes in season.

MAUGHAN, K., I. WATT, N.J. MARTIN and I.A.J. RATCHFORD. (Biochemical Sciences Department, SAC, Auchincruive, Ayr KA6 5HW). **Heterotrophic growth of algal and cyanobacterial species.**

In algal waste treatment systems, the role of algae is often assumed to be strictly autotrophic. However many species are capable of heterotrophic growth and an investigation was carried out to assess the heterotrophic growth potential of some algal and cyanobacterial isolates. Cultures of *Chlorella, Chlamydomonas, Ankistrodesmus, Scenedesmus* and *Synechococcus* were grown in ASM liquid medium to which the carbon sources were added. All the eukaryote cultures showed evidence of photoheterotrophic growth on glucose with the exception of *Chlamydomonas* which grew photoheterotrophically on acetate.

Synechococcus showed little evidence of heterotrophic growth. Only *Chlorella vulgaris* 211/11c and 211/8p showed clear evidence of heterotrophic growth in the dark. The heterotrophic growth of 211/8p was stimulated by light but growth of 211/11c on glucose was the same in the light and the dark.

MAY, S., S. LEWIS, D.N. PRICE, M.H. DEPLEDGE and M.E. DONKIN. (Plymouth Environmental Research Centre, University of Plymouth, Plymouth, Devon). **An assessment of the toxicity of the marine antifouling triazine Irgarol 1051 to *Enteromorpha intestinalis*.**

The triazine herbicide Irgarol 1051 (Ciba-Geigy) has been introduced for use in antifouling paints since 1989 and there are currently over 80 products containing this herbicide which are registered for use. Following on from previous work on levels of Irgarol 1051 in the Plymouth area we have investigated the effects on the adult thalli of *Enteromorpha* sp. Fluorescence induction ratios (F_v/F_m) were measured on thalli incubated in various concentrations of Irgarol 1051 for 0h, 18h, 42h, 90h and 7 days and dose response curves were presented. After 7 days incubation in Irgarol 1051 solutions the EC_{50} for the algae was found to be 10-20 µg/1. Growth of the thallus was also affected by treatment with Irgarol 1051.

The effects of Irgarol 1051 on pigments in the algae were also investigated using *in vivo* spectrophotometry to measure transmission and reflectance characteristics with an integrating sphere attachment to a Unicam Spectrophotometer. Treatment with Irgarol 1051 resulted in decreased reflection and increased transmission across the spectrum.

It was also observed that there was a dose response relationship between the Irgarol concentration and inhibition of sporulation in the thallus of the algae.

O'MAHONY, J., A. WEEKS and T. TAYLOR. (Maritime Faculty, Southampton Institute, East Park Terrace, Southampton, SO14 0YN). **Phytoplankton, tidal cycles and suspended articulate material dynamics in Southampton Water.**

There is evidence that phytoplankton growth is linked to tidal cycles in Southampton Water. This study investigates whether these cycles are controlled by the tidal regime or by light availability caused by variations in turbidity from suspended particulate material (SPM). Measurements of phytoplankton species composition and concentrations, SPM and chlorophyll concentrations, and the diffuse attenuation coefficient at 7-day intervals are being made over 12 months. The results will be linked to findings from the South Coast Nutrient Study (SONUS), which includes a time series of measurements of fluorescence and beam attenuation from moored sensors in Southampton Water.

PLUMB J, and J. BRODIE. (Applied Sciences, Bath College of Higher Education, Newton Park, Bath BA2 9BN). **Population dynamics of *Chondrus crispus* (Rhodophyta): A temporal study.**

A temporal study of a population of the red alga *Chondrus crispus* to determine patterns of recruitment, establishment and longevity, was conducted between January 1994 and September 1996, on a shore in Somerset that is subjected to high silt levels. This site is also influenced by drainage water which has a temperature range between 3.9°C and 29.5°C. Twenty eight permanent quadrats were established and all plants of *C. crispus* mapped. The presence or loss of plants and arrival of individuals, either by spores or regeneration from holdfasts was recorded in each quadrat once a month. The colonisation ability within the population was determined by periodic clearing of a further series of permanent quadrats. The population of *C. crispus* is composed of an array of differing age class individuals, perennial gametophyte and tetrasporophyte plants age in excess of 31 months. Juvenile recruitment and frond regeneration from old crustose discs both play important roles in maintaining the population structure. Juvenile ploidy, fertility, age and date of arrival and/or

loss, provide an insight into the population structure of this species. In view of the economic importance of *C. crispus as* a source of carrageenan, an understanding of the population structure of this species is of value in maintaining this natural resource.

PYE, K.E., R.L. FLETCHER and D. FONTANA[1]. (The Marine Laboratory, University of Portsmouth; [1]Department of Geography, University of Portsmouth). **Use of false colour aerial photography for the production of vegetation maps in Langstone Harbour, South coast of England.**

The eutrophication of coastal waters, as a result of increased sewage discharge and agricultural run-off is a well-documented, world-wide phenomenon. The increased input of nutrients sometimes results in the occurrence of excessive growths of macroalgae, known as "Green Tides", and these can cause major ecological imbalances. One recognised eutrophicated site in the UK which has been reported with these "Green Tides" is Langstone Harbour, on the south coast of England. The present study contributes to a current programme of ecological research on the Harbour and involves the use of infra-red false colour aerial photography and photogrammetry to provide both qualitative and quantitative assessments of the macroalgal mats which are present on the mud flats. All methods are comparable with previous work carried out in the 1970's and 1980's, to allow direct comparisons to be made. When the photographs are taken a simultaneous ground truth survey is carried out. One of the final products is a detailed map of vegetation cover on the mudflats. However, the most useful product is a complex computer database (including the vegetation map) from which large amounts of information can be obtained - e.g. species distributions, area covered by a species, percentage cover, increase/decrease of algae in the years studied. This system provides us with information over a relatively large area, most of which is inaccessible and inhospitable by foot. To carry out an equivalent detailed survey without employing these methods would be almost impossible. Preliminary results for Langstone Harbour indicate a change in species distribution over recent years and also suggest a marked increase in areas dominated by green macroalgae, particularly *Enteromorpha spp.*

RATCHFORD, I.A.J., FALLOWFIELD, H.J.[1] and MARTIN, N.J. (Biochemical Sciences Department, SAC, Auchincruive, Ayr KA6 5HW; [1]Environmental Health Unit Flinders University of South Australia, Adelaide, Australia) **The Effect of Reynolds Number on the cellular dimensions and biochemical composition of micro-algae.**

Novel photobioreactors designed for the growth of micro-algae often subject the cells to high shear forces. Little information exists concerning the impact of such forces on cell growth rates, physiology and intracellular biochemical composition. The effect of Reynolds number was examined on *Chlorella vulgaris* 211/11c and *Isochrysis sp.* when cultured in a multi-pass flat plate air lift reactor. At very high Reynolds numbers (fully turbulent >6000) cells of *C. vulgaris* had a volume of 59 μm^3 compared to 120 μm^3 at Reynolds number of 2500 (transition between laminar and turbulent flow regimes). Under identical conditions, *Isochrysis* sp. had a cell volume of 33.63 μm^3 at a Reynolds number of 6000 and 106.9 μm^3 at a Reynolds number of 3000. It was noted that a high percentage of *Isochrysis* sp. cells had lost their flagella at the higher Reynolds number. The growth rates of *Isochrysis* sp. were reduced by a factor of 3 when cultured at a Reynolds number of 6000 compared to those obtained at 3000. High Reynolds numbers also resulted in significantly reduced intracellular fatty acid levels.

SAMPAIO, A.H., D. J. ROGERS and C. J. BARWELL. (University of Portsmouth, School of Pharmacy & Biomedical Science, St Michael's Building, Portsmouth PO1 2DT, UK). **Improvement of lectin extractions from *Ulva* species.**

The occurrence and basic characteristics of lectins in extracts of species of the green marine algal genus *Ulva* were first described by Boyd *et al.* in 1966. Since this time, various workers have reported the presence of lectins in *Ulva* species, but none of them has achieved the isolation and characterisation of these lectins. One possible explanation could be the high levels of non-lectin proteins and carbohydrates extracted by aqueous buffers from *Ulva* species. The high level of carbohydrates, in particular, may interfere with the basic biochemical steps used in the purification of these lectins. Studies have shown that the level of soluble carbohydrates in extracts is time dependent being directly proportional to the exposure period to aqueous buffers. In order to minimise this problem and to facilitate the purification of these lectins, we have developed a methodology that drastically reduces the level of total carbohydrates in aqueous extracts of *Ulva lactuca* and *Ulva laetevirens.* This consists of pre-treatment of the alga with 70% ethanol in water, three times, before extraction with aqueous buffers. Results have shown that it is possible to reduce the amount of carbohydrate in extracts of *Ulva lactuca* 12 times and 10 times in *Ulva laetevirens* extracts. This new approach has provided extracts which are much more suitable for conventional biochemical preparative procedures for isolation and characterisation of these lectins.

STENGEL, D.B and M.D. GUIRY (Martin Ryan Marine Science Institute, Botany Dept., University College Galway, Ireland). **Environmental control of vegetative and reproductive growth of *Himanthalia elongata* (Phaeophyta) from the west of Ireland**

Himanthalia elongata (Fucales) grows in the lower intertidal on semi-exposed shores in the north-west Atlantic and is locally very common on the west coast of Ireland. Both vegetative growth and reproduction are seasonal, but a time overlap of growth and reproduction has been observed for individuals even within one single population. Gametes are released between June and February and the button-shaped vegetative plants appear about 8 months later. In most buttons reproductive growth starts in early autumn of the same year, but some buttons do not become fertile until the autumn of the following year, so that a wide range of reproductive stages is present within a population at any one time. In laboratory experiments effects of irradiance and photoperiod on the onset of reproductive growth were examined and the temperature tolerance of receptacles, zygotes, and young vegetative buttons produced at different times of the year was tested. Results will be discussed in relation to environmental conditions *in situ.*

TAYLOR, R. and R. FLETCHER (The Marine Laboratory, University of Portsmouth). **Decomposition of 'Green Tide' algae - its role in the nutrient budget of eutrophicated waters.**

'Green Tide' algae play an important role in the nutrient budget of Langstone Harbour, a eutrophicated tidal inlet on the south coast of England. At the end of their growing season, huge mats of *Ulva* and *Enteromorpha* spp. are washed up on the shoreline where they rapidly decompose. This decomposition process releases nutrients (primarily nitrogen and phosphorus compounds) back into the ecosystem where they can be used by the algae during the next growth season.

A series of laboratory experiments were undertaken in order to investigate both biomass changes and nutrient release during algal decomposition. *Enteromorpha compressa* and *Ulva curvata* were collected from the field and allowed to decompose at a range of temperatures under two different sets of conditions (i) dark, anoxic conditions and (ii) light, aerated conditions. Increased temperature caused an increased rate of decomposition in both algae under both sets of conditions. In both dark-anoxic and light-aerated conditions, ammonia (NH_4) was the nutrient released in greatest quantity. In light-aerated conditions, nitrate (NO_3) was released faster and in greater quantities than phosphate (PO_4). Under dark-anoxic conditions (where sediment samples had been added to the system), PO_4 release was greater than that of NO_3. Release of all three nutrients was greatest from both algae under

dark anoxic conditions. These results are discussed in relation to the role of 'Green Tide' algae in nutrient recycling in eutrophicated coastal waters.

WARD, S. and R. FLETCHER (The Marine Laboratory, University of Portsmouth). **Succession and seasonal progression in marine fouling communities in Langstone Harbour, south coast of England.**

A study is currently being made of the succession and seasonal progression of marine fouling communities colonising non-toxic test panels immersed from a raft in Langstone Harbour, south coast of England. Roughened acrylic panels, measuring 100 by 200mm are being attached to a steel frame and immersed at 3 depths (0m, 0.5m and lm) below the water-line. For each depth, 5 replicate panels are used. The immersion trials began on 1 April 1996 and the panels are being replaced at intervals of 1, 3, 6 and 12 months. The present poster reports on the results obtained during the first 6 months immersion period (one fouling season).

Panels which are submerged monthly are colonised mainly by a number of small, ephemeral, opportunistic macroalgae. The latter commonly included species of the green algal genera *Cladophora, Enteromorpha, Ulothrix, Ulva* and *Urospora,* the brown algal genera *Ectocarpus, Hecatonema, Hincksia* and *Pilayella,* and the red algal genera *Ceramium* and *Polysiphonia.* In general, ectocarpoid brown algae are the most dominant fouling group recorded on the panels, and very few differences are observed in the fouling community structure between different months and at the different depths. Animals make a minor contribution to the fouling community, although they increase in abundance with increased depth.

On panels immersed for the 3 month and 6 month periods, algal growths are less prominent, and the surface of the panels supports a greater abundance of animals, including barnacles, tube-forming amphipods, bryozoans and hydroids.

WATSON. A,G., R.I. JONES and J.D. ECCLESTON-PARRY (Biological Sciences, Lancaster University). **Cell size, nutrient pulsing and competition for phosphorus.**

Recent studies of phosphorus (P) cycling in lakes have shown that bacteria take up dissolved inorganic phosphorus (DIP) under P-limiting conditions more efficiently than phytoplankton. However, phytoplankton must be able to obtain DIP since they coexist with bacteria in P limited systems. Most studies which have investigated the kinetics of DIP uptake by bacteria and phytoplankton have supplied DIP continuously at low and constant levels. This is an unrealistic representation of the natural environment, where plankton experience nutrient patchiness. Phytoplankton are efficient at taking up DIP at high concentrations and, due to their large cell size, have greater ability to store nutrients than bacteria; which should be advantageous when DIP supply is heterogeneous. Therefore, nutrient pulses may provide a means for phytoplankton to obtain P and thus coexist with bacteria in aquatic systems.

Competition between bacteria and phytoplankton are being investigated using continuous culture. Pulses of DIP are delivered with increasing magnitude and decreasing frequency to determine how the competitive balance between the two types of plankton alters. This poster describes preliminary batch culture experiments undertaken prior to commencing the competition experiments. The physiological characteristics of the experimental organisms have been investigated, including their phosphorus kinetics and specific growth rates under the range of environmental conditions which will be used for the competition experiments.

YANG[1], M-H., G. BLUNDEN[1], E. TYIHÁK[2] and T. SÁRDI[3]. ([1]School of Pharmacy and [2]Biomedical Science, University of Portsmouth; [2]Department for the Biology and Biochemistry of Plant Resistance, Plant Protection Institute of the Hungarian Academy of

Sciences, Budapest, Hungary and [3]Department of Plant Genetics and Breeding, University of Horticulture and Food Industry, Budapest, Hungary). **Formaldehyde, as its dimedone adduct, from marine algae.**

Formaldehyde, as its dimedone adduct (formaldemethone), has been isolated from *Ascophyllum nodosum, Palmaria palmata, Ulva lactuca* and *Codium fragile* ssp. *tomentosoides* and characterised by thin-layer and overpressured layer chromatography, and from proton nuclear magnetic resonance spectroscopic and electron impact mass spectrometric data. Formaldemethone was also detected by thin-layer and overpressured layer chromatography in extracts of all the species tested in the Chlorophyceae, Phaeophyceae, Bangiophyceae and Florideophyceae. It is postulated that hydroxymethyl groups are formed during dynamic methylation and demethylation processes in the cells. Dependent on pH, the hydroxymethyl groups are in equilibrium with either free formaldehyde or ions such as oxonium, iminium and thionium; these species will react with dimedone to form formaldemethone.

All the algae tested contain either betaines or tertiary sulphonium analogues. These compounds probably play a major role in methylation and demethylation reactions in the plant and it is probable that these compounds, after enzymic hydroxylation, are those producing the active hydroxymethyl groups.

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All articles, reports, notes etc for THE PHYCOLOGIST, can be submitted on computer floppy disk and by electronic mail. Our publishing system is IBM compatible MS-DOS Wordperfect 5.1. Both 5.25 and 3.5 inch floppy disks can be handled and it is probable that most common word processing languages are acceptable, but please always include an ASCII file of your article on the disk as well. It would be best if the original is as simple as possible in layout (i.e. avoid justification etc). This reduces the amounts of editing. Electronic mail can be sent to the following address: AJ@BIOLSCI.DUNDEE.AC.UK

Copy deadlines:

January 31st
June 31st
September 30th

ISSN 0965-5301

THE PHYCOLOGIST (Previously the British Phycological Society Newsletter - ISSN 0267 - 1662) is published by the British Phycological Society, Honorary Editor: Dr. Andrew M. Johnston. The views expressed in THE PHYCOLOGIST are not necessarily those of the Society.