was twice as high in Canada. Despite these climatic differences, we found that sites with similar soil drainage had similar C stocks and post-burn C recovery. Additionally, at both study areas, as soil drainage became progressively drier we saw lower burn severities, slower C recovery over time, and lower overall C stocks.

B33C CC: 524 A Wednesday 1330h

Dissolved Organic Carbon in the Biogeochemical Functioning of Systems III *(joint with H, GC)*

Presiding: **T Moore,** McGill University**; K Bishop,** Swedish University of Agricultural Sciences

B33C-01 1330h INVITED

DOC Lability Across Aquatic Ecosystems and its Link to in Situ Bacterial Carbon Metabolism

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The biological reactivity or lability of organic matter is a key aspect of the carbon cycling in all aquatic ecosystems. Dissolved organic carbon (DOC) lability is an operational term that defines the proportion of the dissolved C pool that can be utilized by aquatic microbes within a given period of time. Lability is generally determined using bioassays that follow the changes in DOC concentration with time, typically days to weeks, in the absence of light and of any new sources of DOC or nutrients. This in vitro DOC consumption thus represents the minimum level of microbial metabolism that can be supported by the ambient DOC pool. In the past, comparisons of DOC lability reported by different studies have been hampered by differences in approaches, so it is unclear how the amount of labile DOC varies among aquatic ecosystems. Here we compare DOC lability measurements from estuaries and salt marshes, rivers and lakes, determined with similar protocols, and we compare these data with the actual in situ bacterial carbon metabolism. We show that in most freshwater systems surveyed, the in vitro rates of DOC consumption rates are low and fall within a relatively narrow range, in spite of large variations in total DOC, chlorophyll, and nutrient concentrations among systems. In most freshwater ecosystems, the proportion of labile DOC is below 3%, and this labile pool generally represents a small fraction of the measured in situ rate of bacterial respiration, suggesting that these freshwater lability bioassays only capture a remnant pool of organic matter and not the pool that fuels most of the heterotrophic microbial metabolism. The proportion of labile DOC is on average much higher in estuarine and marsh ecosystems, and also represents a larger proportion of the total in situ microbial metabolism. These results point to fundamental differences in the patterns of DOC sources and cycling between brackish and estuarine systems on the one hand, and lakes and rivers on the other. Although the metabolism supported by the remnant DOC pool is small in most freshwaters, it can nevertheless play an important role in determining the baseline microbial respiration, particularly in the more unproductive aquatic systems. This baseline respiration may in turn determine the role of freshwaters as sources or sinks of CO2.

B33C-02 1350h

Seasonal Variation of CO_2 in the Gulf of Bothnia: Indications for Net Heterotrophy

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Marine systems have been considered to be in carbon balance with the atmosphere, which means that primary production equals total respiration within the system. However, recent studies indicate that large parts of the ocean, especially oligotrophic marine systems, are net heterotrophic and, thus, a source of CO_2 to the atmosphere. Net heterotrophy implies that organic carbon is transported to low-productive areas, either by redistribution of organic carbon (OC) from more productive marine zones or by input of terrestrial OC via rivers. This study was conducted in the Gulf of Bothnia, which is situated between Sweden and Finland in northern Europe. It is a brackish water body with two major basins (Bothnian Bay and Bothnian Sea). The Gulf receives a high input of OC from Swedish and Finnish rivers, but also from the adjacent more productive water body of the Baltic Proper. Previous studies on carbon balance in the Gulf of Bothnia have indicated that the system is net heterotrophic. We therefore employed, for the first time, direct estimates of CO_2 saturation to assess the net ecosystem exchange in the two major basins of the Gulf of Bothnia during one year. Primary and bacterial production (PP and BP) was also measured in order to calculate the respiration-production balance in the Gulf of Bothnia. On an annual basis the surface water was supersaturated with CO_2, indicating net heterotrophy. The Gulf of Bothnia oscillated between being a sink and a source of CO_2 over the studied period, largely decided by the temporal variation in bacterial respiration (BR) and primary production in the water column above the pycnocline. Calculated annual respiration-production balance (BR-PP) was very similar to the estimated CO_2 emission from the Gulf of Bothnia, indicating that these processes were the major determinants of the exchange of CO_2 between water and atmosphere. The southern basin (Bothnian Sea) had a lower net release of CO_2 to the atmosphere than the northern Bothnian Bay (7.1 and 9.7 mmol C m^{-2} d^{-1}), due to higher primary production, which to a larger extent balanced the respiration in this basin. In conclusion, net flux of CO_2 is very sensitive to changes in climatic conditions such as freshwater inflow, currents from the Baltic Proper, or changes in primary production within the system. Even moderate changes in the catchment, or within the Gulf of Bothnia can have considerable effects on the carbon balance, and on the role of the system as a source or a sink of atmospheric CO_2.

B33C-03 1405h

Hot Stuff: Lability of Forest Floor DOM to Aerobic Degradation

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The hypothesis that the lability of DOM to aerobic microbial degradation to CO_2 is related to its age and character is tested in an incubation study conducted using an assemblage of soil bacteria in their natural state. Extracts (WF) of leaf and forest floor material characterized by different degrees of degradation: green leaves, fresh fallen leaves, litter (one year weathering), fibric matter, hemic matter and peat were used in this study. The working hypothesis is that these extracts represent a chronosequence of degradation and DOM extracted from them might also represent a similar lability sequence. As well aliquots of the WF extracts were processed to remove DOM fractions. Thus a fulvic acid (FA) fraction was made by precipitating and removing humic acid, and a hydrophilic fraction (HPI) by removing hydrophobics from the FA using XAD-8 resin. Incubations were carried out on all three DOM solutions from each extract to determine if there were differences in lability among the fractions. When comparing the WF solutions for CO_2 production, the green leaves, litter, fibric and hemic extracts showed approximately the same CO_2 yield, on an equal C basis, and the fresh fallen leaves and peat produced less. For five of the six extracts the respective WF and HPI solutions yielded nearly the same quantity of CO_2 per mg C suggesting that the HPI component contributes almost all the lability. Furthermore the magnitudes of the C-normalized CO_2 yield for these solutions are similar to that for glucose, which fractionates as HPI. For the same five extracts the FA solution yielded lower quantities of CO_2, on an equal C basis, than WF and HPI suggesting that the hydrophobic content of the extracts may inhibit aerobic degradation. The peat extract solutions yielded a different CO_2 production distribution with the HPI only slightly higher than the FA which in turn was much greater than WF. The material from which this extract was made is much older and contains significant HA, suggesting that the hydrophobics in peat do not inhibit aerobic degradation, but the humic acid does. These preliminary results suggest that lability to aerobic degradation of DOM extracted from forest floor organic matter differs somewhat with age but more with DOM character. These results indicate that the humic and hydrophobic fractions of DOM are more refractory to aerobic microbial activity, degrading more slowly than hydrophilic DOM. As well preliminary results suggest that refractory DOM may have an inhibitory effect on the degradation rate of the labile DOM.

B33C-04 1420h

Identifying Sources and Controls of Dissolved Organic Carbon Losses in Northern Hardwood Forest Ecosystems Under Elevated Nitrogen Deposition

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Anthropogenic nitrogen (N) deposition in northern hardwood forest ecosystems has modified soil carbon cycling, resulting in the substantial leaching of dissolved organic carbon (DOC). Despite the significance of this finding, the exact source of this DOC has not been found and a mechanistic explanation has been lacking. In order to identify sources of and mechanisms for this apparent N stimulation of DOC leaching, we conducted a controlled laboratory leaching experiment using soil and fresh litterfall from a previously-studied northern hardwood forest stand in northern Lower Michigan. This stand has received 10 years of both ambient and experimental (3 times ambient) atmospheric NO3- deposition. Three replicate soil and litter samples were collected from 3 plots receiving ambient and 3 plots receiving experimental NO_3- deposition. Our laboratory experiment used soil and litter collected from each plot to understand if fresh leaf litter was the source of increased DOC leaching in plots receiving experimental NO3- deposition. In laboratory incubations, we investigated microbial respiration and DOC production from: 1) soil from each plot, 2) litter and soil from each plot, and 3) litter from each plot placed over sterile sand. This combination of treatments enabled us to determine the contribution of soil organic matter, fresh leaf litter, and both to DOC production. Results showed that N deposition had no significant effect on microbial respiration, but that treatment differences were significant. Most of the DOC production (75%) was associated with leaching from fresh litter. Soil was a significant sink for litter-derived DOC across the treatments, but less so in the fertilized plots where 30% more DOC was leached on average compared to un-fertilized plots. These results suggest that N deposition might not influence the production of DOC in soil and litter, but the ability of the soil to physically adsorb or the microbial population to sequester DOC inputs. Therefore, changes in soil physical characteristics and/or soil microbial communities may explain the patterns of DOC export seen in past studies and represent an unexpected ecosystem consequence of increased anthropogenic N deposition.

B33C-05 1435h

Risk Analysis of UVB Exposure in Canadian Inland Waters

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Exposure to UVB (290-320 nm) harms some aquatic taxa and processes. With the restoration of pre-industrial ozone levels still some years away and the possibility that climate change might lower dissolved organic matter (DOM) concentrations and thus lead to increased exposure, evaluating the extent to which freshwater environments in Canada are at risk is warranted. First, the distribution of a UVB-sensitive zooplankton genus, *Daphnia*, was examined as a function of DOM and maximum depth (Z_{max}) in 258 lakes and ponds in Ontario and the eastern U.S. to determine whether UVB exposure restricts its distribution. Our results indicate that the distribution of *Daphnia* is not restricted by exposure to UVB with the possible exception of very clear, shallow systems underrepresented in the surveys. Secondly, the maximum depth of UVB transmission (the depth at which 1% of surface irradiance at 320 nm occurs, $Z_{320,1\%}$) was compared to Z_{max} in over 900 aquatic systems in different Canadian ecozones to determine the proportion of optically clear systems ($Z_{max} < Z_{320,1\%}$) and the extent to which systems that are not clear may become so (at risk') should they lose 50% of their DOM. The proportion of systems deemed optically clear is low (<6%) across Canada with the exception of three ecozones between 13% and 20%. The proportion of systems deemed at risk is 0% in most regions with 5–9% in five regions from four ecozones. These results suggest that DOM levels are adequate to prevent large-scale loss of sensitive species from direct exposure to elevated UVB in most regions of Canada.

B34A CC: 524 A Wednesday 1530h

Interpreting Stable Isotope Measurements in Ocean Biogeochemistry: What Are We Learning?

Presiding: **K Denman,** Canadian Centre for Climate Modelling and Analysis**; R W Macdonald,** Institute of Ocean Sciences

B34A-01 1530h INVITED

Oceanic Nitrogen Isotope Biogeochemistry - A Status Report

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Nitrogen occupies redox states spanning -3 to +5 and is correspondingly subjected to a relatively large number of biogeochemical transformations with substantial potential for isotopic discrimination. In most settings, terrestrial or marine, many nitrogen cycle pathways are operating simultaneously. A reasonable a priori assumption could be that variations in N isotopic ratio would be difficult to interpret due to multiple influences. Several decades of study of oceanic patterns in 15N/14N (d15N), however, show that several aspects of marine N biogeochemistry result in the dominance of only several processes on present and past variations in d15N. This simplification results from 1) N in chemically combined form being a biologically limiting nutrient in much of the near-surface ocean and 2) physical separation of major transformation processes either as a function of depth or oceanographic region. Much of the large scale variation in d15N in the ocean is associated with processes directly influencing the d15N of dissolved nitrate (0 to 20 per mil range; 5 per mil average), the major form of combined N in the ocean. Denitrification of nitrate to N2 in suboxic intermediate waters has a large isotope fractionation factor (20 to 30 per mil) such that these regions have typically high d15N values. N2 fixation in oligotrophic gyres contributes combined N with d15N 1 to 2 per mil less than atmospheric N2 and results in decreased d15N for subsurface nitrate. Since nitrate is typically the predominant form of new nitrogen to oceanic phytoplankton, these large-scale variations in d15N are imprinted on organisms, the organic matter they produce, and ultimately the sediments. Sediment d15N has been shown to provide, for example, important records of past variations in water column denitrification. In HNLC regions where near-surface ocean nitrate is not completely consumed by phytoplankton, isotopic fractionation (5 to 8 per mil) during uptake is expressed as low d15N for plankton and increased d15N for nitrate as function of its degree of utilization. Trophic transfer and organic matter diagenesis can also alter d15N values but do not produce regional variations.

B34A-02 1550h

Sedimentary N Isotopes Dominated by Glacial-Interglacial Modulation of the Marine N Cycle

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Sedimentary nitrogen isotopes (δ^{15}N) have been most often interpreted as recorders of local biological parameters. However, numerous sedimentary δ^{15}N records compiled from widely distributed marine environments can be parsimoniously explained as reflecting, instead, the isotopic impact of broadly synchronous global changes in water column denitrification on glacial-interglacial cycles. Furthermore, other records display tantalizing evidence of synchronous response by N-fixation communities. We suggest that the spatial and temporal averaging achieved by sedimentation processes effectively eliminates any imprint of local ecosystem variability in most sedimentary environments, producing records that tend to integrate the isotopic signatures of regional fixed-N pools. A potential mechanism to explain the global coherence of the denitrification records involves a simple physical control on the flux of dissolved oxygen to suboxic zones, and the coupling to fixation via the supply of phosphorus to diazotrophs in suitable environments. Accordingly, lower glacial-stage sea surface temperature and greater sea-ice coverage in high-latitude regions increased oxygen solubility and probably enhanced the rate of intermediate-water formation, respectively. The resultant colder, rapidly circulating intermediate waters diminished the extent of denitrification and, consequently, N fixation. During warm periods, sluggish circulation of warmer, less oxygen-rich intermediate waters caused expansion of denitrification zones and a concomitant increase in N fixation. Local fluctuations in productivity due to variable atmospheric circulation patterns would have modulated this low frequency global signal.

B34A-03 1605h

Stable Isotopes in Sinking Particles: Answering two Questions at once

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The stable isotopic composition of organic matter in sinking particles reflects the source of the particles and the processes involved in their production. Both del C-13 and del N-15 are affected by the balance between terrigenous and marine organic matter. Del C-13 is also affected by productivity, while del N-15 varies with the length of the local aquatic food chain and with the availability of nutrients. Individually, the two isotopes do not necessarily provide a unique interpretation. However, by plotting del C-13 against del N-15 it is possible to understand that seasonal and spatial variations in sediment trap data collected over three years in the Strait of Georgia are due to changes in the composition of local phytoplankton and the relative proportion of marine- vs. terrigenous organic matter. The sinking organic matter can therefore be described as a mixture of three end-members - terrigenous, marine summer and marine winter. The techniques and observations described here are likely to be generally applicable to coastal waters with high local productivity and significant terrestrial run-off.

B34A-04 1620h

Oceanographic Controls on the Stable Carbon Isotopic Composition of Sinking particles and Surface Sediments in the Cariaco Basin.

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Stable carbon isotopic compositions of organic matter ($\delta^{13}C_{org}$) are used as a paleoproxy for aqueous CO_2 concentration and productivity, yet there are many variables which can influence the integrity of the signal created in the surface ocean. As part of the CARIACO Project we analyzed the $\delta^{13}C_{org}$ of sinking particles over the period extending from 1996-1999 in order to investigate the oceanographic and environmental variables which can affect the $\delta^{13}C_{org}$ as it sinks through the water column and is preserved in the sediments. The $\delta^{13}C_{org}$ of sediment trap samples ranged from -17.6 $^o/_{oo}$ to -22.6 $^o/_{oo}$ over the three year period. Three multi-cores were also analyzed for the $\delta^{13}C_{org}$ of sedimentary organic matter. The values $\delta^{13}C_{org}$ in core MC-2A, taken at 192 m water depth, ranged from -20.4 $^o/_{oo}$ to -18.2 $^o/_{oo}$, core MC-3A, taken at 354 m water depth, ranged from -19.7 $^o/_{oo}$ to 18.8 $^o/_{oo}$ and core MC-4A, taken at 432m water depth, ranged from -20.4 $^o/_{oo}$ to 19.1 $^o/_{oo}$. The $\delta^{13}C_{org}$ of sinking particles was positively correlated with CO_2 which is contrary to models constructed based on passive diffusion. Temperature and the $\delta^{13}C_{org}$ of sinking particles are highly correlated (r^2 = 0.64). The lowest integrated water column temperature (used as a proxy for intensity of upwelling) is inversely proportional to yearly integrated $\delta^{13}C_{org}$ values with highest (most enriched) $\delta^{13}C_{org}$ being associated with the years of the lowest temperature (strongest upwelling). Examination of the sediments show that there is an inverse relationship between alkenone derived temperature and the $\delta^{13}C_{org}$ values for the two deeper cores which are below the oxycline. We suggest that the $\delta^{13}C_{org}$ may be a proxy for strength of upwelling, although the mechanism for $\delta^{13}C_{org}$ enrichment during upwelling is not known.

B34A-05 1635h

Stable Carbon Isotopes Reveal Food Web Shifts due to Arctic Sea Ice Decline

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