

**CANADIAN OCEAN SCIENCE NEWSLETTER  
LE BULLETIN CANADIEN DES SCIENCES DE L'OCÉAN**

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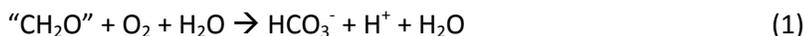
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## OCEAN SCIENCE PROGRAMS

### Acidification of the Lower St. Lawrence Estuary Bottom Waters<sup>1,2</sup>

Submitted by **Alfonso Mucci** - Department of Earth and Planetary Sciences, McGill University, 3450 University Street, Montréal, Québec H3A 2A7, Canada

The ocean is the largest sink of anthropogenic CO<sub>2</sub> released to the atmosphere (Sabine *et al.* 2004). Over the last century, uptake of CO<sub>2</sub> from the atmosphere has decreased the pH of the ocean surface by ~ 0.1, equivalent to a 30% increase in the proton concentration (Caldeira and Wickett, 2005). CO<sub>2</sub> is also added to the ocean by respiration of organic matter. In the open ocean, below the euphotic zone, dissolved inorganic carbon (DIC) and proton concentrations typically increase with depth as a result of respiration and reach maximum concentrations in the oxygen minimum zone. The respiration reaction, in one of its simplest form, can be written as:



Hence, if a water mass is isolated or poorly-ventilated to the atmosphere, metabolic CO<sub>2</sub> will accumulate, pH will decrease, and dissolved oxygen will become depleted.

Since the 1930s, the oxygen concentration in the bottom water ( $\geq 250$  m) of the permanently stratified Lower St. Lawrence Estuary (LSLE) has decreased from 130  $\mu\text{M}$  to 60 $\mu\text{M}$  (Gilbert *et al.* 2005). One half to two thirds of this decrease can be attributed to a change in ocean circulation in the Northwest Atlantic near the entrance to the Laurentian Channel. A steepening oxygen gradient along the channel from Cabot Strait to the LSLE over the past decades (Gilbert *et al.*, 2005), together with geochemical and micropaleontological evidence (Thibodeau *et al.*, 2006), suggest that increased oxygen demand within the bottom waters and the sediments of the Laurentian Channel (Lehmann *et al.*, 2009) may be responsible for the remainder of the

<sup>1</sup> A full account of this study can be found in Atmosphere-Ocean: Mucci A., Sundby B., Gilbert D. and Starr M. (2011) *Acidification of Lower St. Lawrence Estuary bottom waters. Atmosphere-Ocean* **49**: 206-213. doi:10.1080/07055900.2011.599265

<sup>2</sup> The A-O paper was selected by Québec Science magazine as one of the top ten discoveries of 2011 by Quebec researchers

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The Canadian National Committee of the Scientific Committee for Oceanic Research (CNC-SCOR) fosters and facilitates international cooperation. It is a non-governmental body that reflects the multi-disciplinary nature of ocean science and marine technology.

Le Comité national canadien du Comité scientifique de la recherche océanographique (SCOR) favorise et facilite la coopération internationale. Il reflète la nature multidisciplinaire de la science océanique et de la technologie marine.

oxygen decline. Being isolated from the atmosphere by a strong pycnocline, the bottom water loses oxygen gradually through respiration as it flows landward. At depths greater than 150 m, the oxygen lost cannot even be replenished by winter convection but only by weak diffusion from the overlying water or by tidal mixing at the head of the Laurentian Trough.

*Historical and recent pH measurements*

A historical record of pH measurements in the deep waters of the St. Lawrence Estuary exists since the early 1930's. Historical and recent pH measurements (on a common NBS scale) reveal that bottom water pH values have decreased by ~0.2-0.3 since the 1930's (Fig. 1). Our calculations show that, over the same period, the decrease in pH attributable to the uptake of anthropogenic CO<sub>2</sub> from the atmosphere alone ( $\Delta p\text{CO}_2 = +50 \mu\text{atm}$ ), is about 0.055. In other words, in response to the progressive oxygen depletion in the bottom waters of the LSLE, pH has decreased 4 to 6 times more than would otherwise have been anticipated, but similar to the change in surface ocean pH predicted over the next century (Orr *et al.*, 2005).

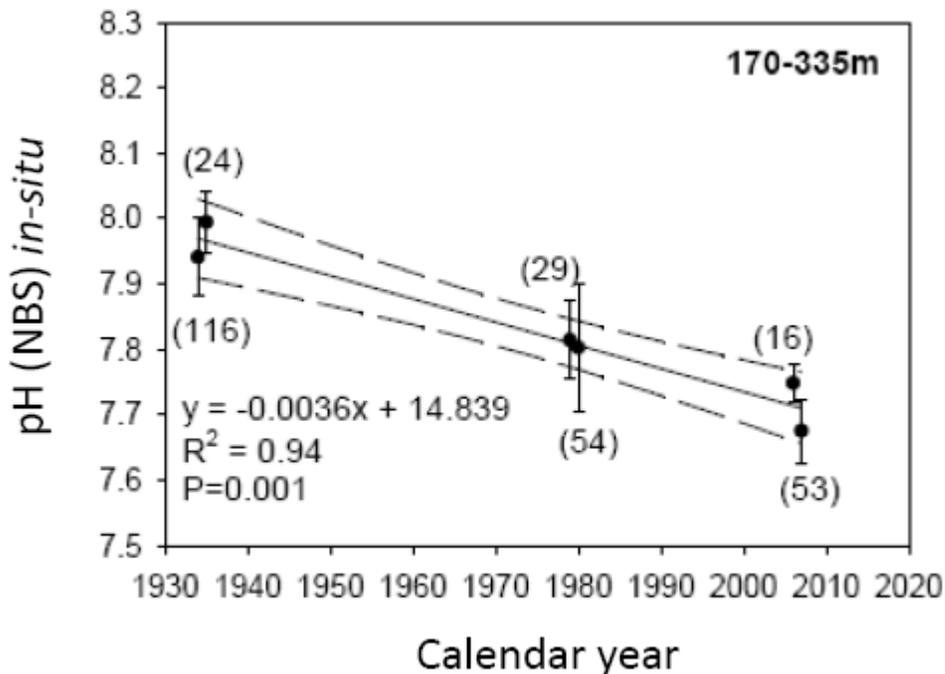


Figure 1 – Historical pH measurements (on the NBS scale) in the LSLE with 95% confidence intervals. Numbers in parentheses correspond to the number of data points for this depth interval (170-335m). Data are from May to September measurements, averaged for each year. From Mucci *et al.* (2011).

Recent, high resolution pH<sub>t</sub> measurements (on the total proton concentration scale), along with dissolved oxygen concentrations and calcite and aragonite saturation profiles are reported in Mucci *et al.* (2011) for a transect through the LSLE and into the western Gulf of St. Lawrence. The CaCO<sub>3</sub> mineral saturation states are given by:

$$\Omega_{c \text{ or } a} = [\text{Ca}^{2+}][\text{CO}_3^{2-}]/K_{c \text{ or } a}^* \quad (2)$$

where  $\Omega$  is the saturation state of the water with respect to either calcite ( $\Omega_c$ ) or aragonite ( $\Omega_a$ ),  $[\text{Ca}^{2+}]$  and  $[\text{CO}_3^{2-}]$  are the total calcium and carbonate ion concentrations, and  $K_c^*$  or  $K_a^*$  is the stoichiometric solubility constant of calcite or aragonite (Mucci, 1983) under *in-situ* conditions. A tongue of low  $\text{pH}_t$  waters near the bottom in the LSLE extends into the western Gulf of St. Lawrence at about 250 m depth (potential density =  $\sigma_\theta = 27.25 \text{ kg/m}^3$ ). This tongue corresponds to the oxygen minimum layer.

The saturation state of the water with respect to their skeleton mineralogy is critical to living organisms, particularly those that secrete carbonate shells. Whereas the bottom waters in the LSLE remain slightly supersaturated with respect to calcite ( $\Omega_c = 1.03$ ), they are now strongly undersaturated with respect to aragonite ( $\Omega_a = 0.65$ ). Hence, the driving force for calcium carbonate precipitation has been depressed and aragonite fossil shells that settle to the sediment-water interface are now subjected to more corrosive waters and are less likely to be preserved in the sediment.

In Mucci et al. (2011), we reconstruct temporal variations in the pH of the bottom waters of the LSLE using historical data as well as hydrographic and stoichiometric relationships between organic matter respiration, oxygen consumption, and carbonate chemistry. Our estimates of the preformed dissolved inorganic carbon concentrations of the source waters allowed us to constrain the mean ventilation age of the bottom waters of the LSLE to about 20 years.

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## 2012 Call for Working Group Proposals

The SCOR Secretariat is accepting proposals for new working groups until **15 April 2012**. Model proposals and information about the operation of working groups may be found on SCOR's website ([click](#)). Canadian scientists considering a proposal should discuss the idea as soon as possible with the CNC-SCOR chair ([click](#)) or by calling Rob Macdonald at 250.363.6409.

## MEETINGS

### Ocean Sciences Meeting, Salt Lake City, 20-24 February

This international meeting of more than 4,000 delegates is jointly sponsored by The Oceanographic Society, the American Society of Limnology and Oceanography and the American Geophysical Union. The program and daily schedules are available on the conference website ([click](#)) and registration is still open. Abstract submission is closed.

### Canadian Marine Science from Titanic to BIO, 5 March 2012

Eric Mills gives a free public lecture with this title at 7:30 PM at the Museum of Natural History, in Halifax. Canadian marine sciences developed most rapidly after the Second World War. These developments included increased research in the Arctic, initiation of graduate studies in oceanography, expanded study of marine geology & geophysics, and the founding of the Bedford Institute of Oceanography. The talk is part of a lecture series sponsored by the Nova Scotian Institute of Science.

### CMOS 2012 Congress, 29 May – 1 June 2012, Montreal

Abstract submissions close on **February 17<sup>th</sup>** for Canada's largest ocean sciences conference and trade show, this year at Montreal's Hyatt Regency Hotel. The conference theme is *The Changing Environment and its Impact on Climate, Ocean and Weather Services*. The program includes several oceanographic, climatological and interdisciplinary sessions ([click](#)). An abstract may be submitted by logging into the abstract portal on the CMOS site ([click](#)) and following the subsequent instructions.

The conference venue is located in the heart of Montreal. Discounted hotel rooms are available through block bookings at the Hyatt Regency and at UQAM's student housing centre. Discounted airfare and car rental codes are also available on the Congress website.

## JOBS & TRAINING

### President and CEO, Ocean Networks Canada, Victoria BC

Ocean Networks Canada (ONC) is searching for a new President and CEO ([click](#)). ONC, a University of Victoria initiative, has pioneered a world-class, internationally-renowned observatory supporting coastal and deep-water investigation. Through the VENUS coastal network and the NEPTUNE Canada ocean network, the ONC Observatory is transforming ocean research and associated technology development with an innovative subsea infrastructure and Internet-based access to data and instrumentation from anywhere in the world. This unique observatory is advancing our knowledge about the oceans –including subsea earthquakes and tsunamis, ocean

acidification and marine biodiversity, among others – and holds immense promise for the future. Through the federally funded Ocean Networks Canada Centre for Enterprise and Engagement (ONCCEE), the data, research results and technologies emerging from VENUS and NEPTUNE Canada are being disseminated to policy makers, industry and the general public. No application deadline is given.

### Scholarships Available in Ocean Sciences

Several scholarships awarded by CMOS and CNC-SCOR are available for graduate and undergraduate studies in 2012 at a Canadian university. Details are available on the CMOS website ([click](#)).

For undergraduates, the Daniel G Wright award of \$1000 is available to a student about to enter the final year of a BSc Honours program in mathematics and/or physics. Two \$500 CMOS awards are also available to students presently in their next-to-final year of study in a related field. The application deadline is **March 15**.

The CMOS - Weather Research House and CMOS - CNC-SCOR Post Graduate Scholarships, each of \$5000 a year and normally tenable for two years, are available to graduate students in receipt of an NSERC Post-Graduate Scholarship or a Canada Graduate Scholarship ([click](#)). The application deadline is **April 30**.

### Project Maury – Training for Schoolteachers

The American Meteorological Society, CNC-SCOR and CMOS will co-sponsor one elementary or high school teacher to attend this year's two-week summer workshop in oceanography at the US Naval Academy, Annapolis MD. The workshop takes place July 9-20 and is aimed at providing pre-university science teachers with oceanographic teaching tools and an expanded network of contacts. Some fieldwork is included. More information, an application form and a report from last year's participants can be found on the CMOS website ([click](#)). The application deadline is **March 8**. Please feel free to discuss this award with your child's favourite science teacher.

*Looking for work? Try the CMOS site ([click](#))*

## GENERAL

### Arctic Ice Cover Trends

Statistics Canada has released an analysis of summer sea ice coverage in the Arctic ([click](#)) based on the ice charts produced by the Canadian Ice Service between 1968 and 2010. The largest rates of decline in the Canadian Arctic have all been in the southern regions, with the southern Beaufort experiencing the greatest absolute loss.

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Previous newsletters may be found on the CNC/SCOR web site.  
Les bulletins antérieurs se retrouvent sur le site web du CNC/SCOR.

Newsletter #63 will be distributed on March 16, 2012. Please send contributions to Bob Wilson, [wilson@telus.net](mailto:wilson@telus.net)  
Bulletin #63 sera distribué le 16 mars 2012. Veuillez faire parvenir vos contributions à Bob Wilson, [wilson@telus.net](mailto:wilson@telus.net)

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