Lakes in the Anthropocene: Reflections on Tracking Ecosystem Change in the Arctic
John P. Smol
Excellence in Ecology 30.
International Ecology Institute, Oldendorf/Luhe, Germany, 2023
ISBN 978-3-946729-30-3
Pages: 438; € 50

John P. Smol
Department of Biology
Queen's University
Kingston
Ontario K7L 3N6
Canada

This book - requested by S.J. Hawkins, the Editor of Excellence in Ecology, when John Smol was recognized with the International Ecology Institute Prize - is certainly one of the most modern and complete texts on the Canadian Arctic. The polar area like many other extreme environments that I studied during my scientific activity (*e.g.*, Greenland, Antarctica, Svalbard archipelago, Finland Lapland and mountain ecosystems), has for years been subject to great alterations due to climate changes ("the big threat multiplier"), mine effluents, local and long-distance pollution. The book provides an excellent overview of how the arctic environment has developed during the last ca. 200 years and even before.

The Arctic environment is transforming rapidly. The accelerated melt of glaciers, ice caps, and the Greenland and Canadian ice sheets together with the increased glacial runoff, diminishing sea-ice extent and volume, coastal erosion and permafrost have all profoundly affected the Artic coastal environments.

As this book shows, the arctic is also subject to a surplus of contaminants from the industrialized southern regions, via long-range transport through air masses, fishes and birds. Polar regions are highly vulnerable to climate changes and human impact. They play a key role in global change as they have an important effect in a number of positive feedback cycles. Responses to global warming are predicted to be greatest in these environments and to occur there first. Accordingly, the book reports on the ecological changes in many aquatic ecosystems, which often dominate the northern landscapes and are sentinels of environmental changes.

John's ecological approach is proposed again in this new book, which represents an updating on the situation of the Arctic Circle, thus providing an important reference not only for researchers but also for politicians, economists and local population, which are increasingly interested in the environment.

Greenland ice cores, the best known paleoclimatic archives from the Arctic, show only little variability for the Holocene. As John presents, this is different from lake sediment records that show major environmental changes throughout the Holocene and especially over the last ca. 150 years.

Using a rather innovative and clear writing style (narrative, including anecdotes and memoirs), the author presents some basic examples of limnology and paleolimnology in many lakes (*e.g.*, Meretta Lake, Cape Vera Ponds, Char Lake), streams, riparian ecosystems, and ponds of the Canadian Arctic islands, or rather of the Arctic Cycle with particular reference to the historical period that ecologists and geologists call the Anthropocene (the last ca. 200 years). Nowadays, with further appreciation of warming by greenhouse gases, most media attention has moved to retreating ice caps and decreasing sea ice.

The conclusions are very worrying. The conditions of arctic lakes and ponds are today remarkably different from those of the 1800s and often quite changed from those of just a decade or so ago. Declining ice covers, development of new aquatic habitats, changes in thermal stratification, and other climate-related changes have had profound effects on the limnological properties and the biota of these lakes.

The various chapters (13 in number) are well written. They read like a novel especially when John talks about the fieldwork, often in difficult, extreme conditions in the company of polar bears, the aggressive arctic tern or under a katabatic wind. The work of colleagues and their experience in the paleolimnological field is properly acknowledged and cited.

I liked the story about the workshop in Boulder (Colorado) and how John appreciated the talk of Bruce Finney on the salmon nursery and the data on $\delta^{15}N$ as an isotopic signature preserved in the sediments. From that time, a long and productive friendship and research collaboration started between John and Bruce.

A characteristic feature of the circumpolar Arctic is the incredible number and diversity of waterbodies that dot the landscape. It was estimated that about ¼ of our planet's lakes are in the northern high latitudes, with almost 6% of

Received: 7 November 2023.
Accepted: 7 November 2023.

J. Limnol., 2023; 82:2170
DOI: 10.4081/jlimnol.2023.2170

the arctic land surface occupied by lakes. The vast majority of these water bodies are shallow ponds, which are sensitive bellwethers of environmental change (unfortunately, many ponds are now disappearing). In addition, the Hudson Bay region that has long been considered one of the last arctic refugia from global warming is now changing since researchers have started to report dramatic declines on sea ice extent and increased air temperatures.

As a paleolimnologist, I believe that this book, due to the compactness and detail with which it deals with the topics, can represent a point of reference on the environmental situation, often worrisome and negative, determined in many arctic lakes by man activities. For example, it is shown that diamond mining has some environmental impacts, as the release of nutrients, such as phosphate, nitrate and ammonia, to nearby surface waters. In addition, calcium effluents from the mine alter zooplankton assemblages and other organisms of the food web. These ecological shifts started in the 1990s together with the change in the thermal structure of the water bodies.

The book also considers and well describes the seasonal freeze and thaw cycle and their implications for the aquatic ecosystems and their role in shaping and re-shaping the lake geomorphology. Permafrost not only shapes the landscape but also affects the amount of water accumulating and draining off the land. With accelerated warming, these processes are changing so that a better understanding of permafrost characteristics and dynamics has considerable relevance for water quality, ecosystems, and carbon cycling. For example, with warming and permafrost thaw, microorganisms can break down organic matter, releasing greenhouse gases, such as methane, which were previously locked in the frozen soils. These, as well as many other aspects about the permafrost processes are described in the chapter "when the permafrost moves, everything moves" documented with many impressive photographs.

John, in collaboration with archaeologists, also provides historical notes on the human populations living in the Arctic and whether these had an impact on the lake ecosystem. This chapter is very fascinating, and I learned a lot about the occupation of the high arctic Canada from 2500 and 3000 BCE to present days.

This kind of collaboration involves the challenge of linking two different scientific communities. Although data exchange between paleoenvironmental and archeological research groups is increasing, true interdisciplinary studies are still rare, probably because of the difficulty to find a common language accepted by both communities. Here, instead, the collaboration of ecologists and archaeologists demonstrate that it is possible to find a common style of expressing results without obscuring the particular individual style of each scientific community.

For most of the time since the first appearance of modern man, sometime around the last interglacial, the climate–man relation worked in only one direction with shifts of climatic conditions influencing human societies and their cultural development.

Even before carrying out chemical and biological analyses of the water of some ponds abandoned by the Dorset and Thule populations, a simple look into the water clearly indicated that there were biological effects of fertilization (dense algal growth). Laboratory analyses showed high nutrients and chlorophyll *a*, and high concentration of dissolved organic carbon. This process is due to the slowly degrading whalebones and the other refuse left in the catchments when the Thule people abandoned those sites centuries ago.

Very curious is the study on Alaskan sockeye salmons (*Oncorhynchus nerka* Walbaum) as carriers of fertilizing substance, which are also possible contaminants. These fishes bioaccumulated POPs (Persistent Organic Pollutants) and PCBs (Polychlorinated biphenyls) in the ocean and, upon return to the nursery lake, their carcasses decompose acting as major biovectors of marine-derived contaminants in Alaskan lakes. This 6-fold increase in PCBs above atmospheric loading represents a kind of "biological pump". However, sediment studies show that, over the last 3 centuries, sockeye salmon numbers were declining due to human interference but that some striking changes pre-dated anthropogenic stressors. These results were obtained by the analyses of isotopes, *i.e.*, $\delta^{15}N$, diatoms, chironomids, chrysophycean stomatocysts and Cladocera in sediment cores from several lakes. A decline of salmon in early periods, 1910 and 1935 and in early-1700s was attributed to climate (cooler Gulf of Alaska Sea Surface Temperature). Thus, paleolimnological data suggested that past climate-driven regime changes had affected salmon population long before the advent of intensive anthropogenic disturbances.

Seabirds, given their impressive numbers (about 110 million seabirds and several million waterfowl in the Canadian Arctic alone), especially fulmars (*Fulmarus glacialis* L.), are another major biovector conveyor playing, as the salmons, an important role in transporting both marine-derived nutrients and contaminants. Ponds near the nesting cliffs had total phosphorus concentrations exceeding 200 $\mu g\ L^{-1}$ (hypereutrophic conditions), whilst reference ponds were as low as 4 $\mu g\ L^{-1}$ (ultra-oligotrophic conditions).

The birds affected chlorophyll *a*, pH, and carried several other elements, including trace metals (*e.g.*, Hg) and POPs (the insecticide DDT and the fungicide and other industrial uses, HCB). Concentrations of these compounds increased many folds over the gradient of bird impact indicating that the northern fulmars were biovectors not only of marine-derived nutrients but also of contaminants. Birds are also responsible of strong development

of filamentous algae in some ponds near Cape Vera cliffs: do you remember, John? Here, John tells a terrible (fun for the colleagues) experience about his fall into the putrid, completely green water of a pond and the amused reaction (hysterical laughing) of his colleagues and the helicopter's pilot: poor John! Another memorable aspect of the field expedition was to see how the terns (*Sterna paradisaea* Pontoppidan) aggressively protected their nests by dive-bombing you: "In order to protect ourselves we had no other choice than to cover our heads with a sampling hilarious bucket".

In some ponds, the seabirds were able to affect the pH at the limit value of 10.75 (!!) while reference ponds had values of 6.9.

Other researches focus instead on the decline of some bird species, for example the common eider duck (*Somateria mollissima* L.), the largest duck in the Northern hemisphere and a food source for the indigenous people. Using fecal steroids in sediment cores as a reliable proxy for tracking eider presence and abundance over time, a clear decline of the eider population in the early 20th century in the Hudson Strait was demonstrated. This decline has been largely explained by local anthropogenic stressors (*i.e.*, harvest pressure and the widespread use of shotguns). The meeting with Mark Mallory, a seabird biologist, was fruitful and marked the start of a strong collaboration during which ornithology met paleolimnology giving birth to a new discipline called "paleo-ornithology".

Another chapter ("You are what you eat") discussed data on two colonies of seabirds, the arctic tern, famous for its migratory behavior, traveling from Arctic to Antarctica coast, ca. 90,000 km, the longest round-trip migration route of any animal, and again the common eider duck. These two birds' colonies fortuitously drained into two separate ponds and this optimal situation allowed a quasi-laboratory approach to paleolimnology. The hypothesis was that the different trophic position of terns and eiders on the marine food web should result in differences in concentrations of tissue biomagnifying metals and waste products between these seabirds. Therefore, we should be able to track these differences by measuring metal concentrations in sediment cores from the tern, and eider, affected ponds.

Data on sediment cores (fossil diatoms) and water chemistry from the two ponds (only ca. 1 km apart) showed clear limnological responses to bird-delivered nutrients registering elevated nutrient and pH levels and eutrophic diatom assemblages. The tern pond sediments contained the highest concentrations of metals such as Hg and Cd and the highest sedimentary level of $\delta^{15}N$, a proxy to track marine-derived nutrients and to characterize trophic structure, reflecting the tern's trophic position as a piscivore feeding predominantly on nearshore fish. The data of the eider pond were very different with Pb, Al and Mn concentrations more closely associated with the molluscivorous eider-affected site. In short, this study showed that seabirds feeding on different preys and at different trophic levels varied with respect to the quantity and type of contaminants that were biotransported and deposited. This study also showed that lake sediments can help "fingerprinting" which species were affecting the lakes in the past.

One technical feature of the book, which I appreciated very much, is the incorporation of numerous and informative images and figures, as signposts throughout the text. They constitute a series of sub-headings highlighting the structure of the text and showing the fieldwork and the numerous colleagues that worked under extreme conditions for many years. Rightly, the important contributions of John R. Glew (1942-2019) and Weston Blake Jr (1930-2021) are remembered.

John also underlined how this experience on the arctic was positive even when he and the colleagues were under continuous criticism. Accordingly, you remember our unforgettable friend Rob Peters (1946-1996) who said: "we hone our theories and research until they are as keen and sharp as they may be. The whetstone against which we sharpen our tools is criticism". Rob also said: "in art, criticism has a grim finality because a work is fixed forever. In science, criticism is not such a hopeless exercise. It is simply the first step to improvement".

John wrote numerous paleolimnology papers and books. The rapid and highly appreciated development of this discipline in the academic field and beyond is certainly due to John and his colleagues, students, technicians. They strongly contributed to transform a science, that in the 70s was considered almost esoteric, into a branch of ecology particularly valid, as it allows to reconstruct the history of an aquatic environment over time, with long-term information that is often missing in classical limnological studies (with the exception of those performed by the Long Term Ecological Research Network, LTER).

There is increasing realization and concern that human modification of the Earth system runs the risk of inducing abrupt transition in climate, ocean circulation, the cryosphere, ecosystems, and society. Our ability to predict when and where such sharp transition, the so called "tipping point", might happen is limited. Some years ago, a multi-model assessment revealed abrupt events in state-of-the art models, suggesting the possibility of predicting the likelihood of such events (Drijfhout *et al*., 2015). Science does crucially depend on such investigations, synthesized results, and increment the proliferation of scientific knowledge; therefore, provide a base to apply our scientific knowledge to issues such as the probability of abrupt changes in the future and predicting the associated risks.

The last chapter of the book can be shortly synthesized in these three statements: understand the past, confront

the present, and prepare the future. What future? The concluding remarks are quite dramatic and alarming. The findings show that we are crossing the final ecological threshold and that several ecosystems are disappearing. "The arctic warns us of the tremendous environmental pressure we have put on our planet". It is no coincidence that John quotes Martin Luther King's famous phrase: "we are confronted with the fierce urgency of now". John concludes his book with personal thoughts and the hope of communicating the urgency of these results to an audience of policymakers, and the public at large, including scientists within and external to climate science community, activists, philosophers, musicians, artists…

"Although the self-destructive tendency of our species is undeniable, I cannot help but think that there is hope. And it is for them that I decided to write this book. For those who don't give a damn". This book gives a final answer to those people (some are certain politicians) that reading these pages, foolishly ask: "who cares? So what? No one lives there…"

For sure, this book will not suffer of the "dinosaurs syndrome" (cf. Eugene P. Odum), *i.e.*, "sometimes the new books become so enlarged in successive editions that the brevity and simplicity that made them successful in the early editions is lost. One of his concerns in writing new books is that they tend to become larger, more encyclopedic, and less useful to students, especially beginners. Besides, like those prehistoric monsters, they quickly become extinct". I believe this is not the case here!

As John said, "this is not a textbook, this book is very much a re-telling of my 35+ yrs of limnological and paleolimnological research in the circumpolar Arctic, summarizing the fruitful and enjoyable interactions my lab has had with my talented colleagues".

Well done, John!

References

Drijfhout S, Bathiany S, Beaulieu C, Brovkin V, Claussen M, Huntingford C, Scheffer M, Sgubin G, Swingedouw D, 2015. Catalogue of abrupt shifts in Intergovernmental Panel on Climate Change climate models. P. Natl. Acad. Sci. USA 112:E5777-86.

Piero Guilizzoni
Senior Associate Researcher
National Research Council, Water Research Institute (CNR-IRSA), Verbania-Pallanza, Italy