Considering Lag Times in Environmental Science and Management – An Essay to Engage Environmental Biologists

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1 This is an early draft on the topic. It has not yet been read by others or been peer-reviewed. Timely comments are welcomed.

This essay was stimulated by reflections on how long it can take for our respective societies across the globe to deal with important, often dire, environmental challenges such as pollution, habitat and biodiversity loss, and climate change. The reader familiar with environmental history[1] will know that this is not a new concern — some problems have been dealt with quickly, but many others known for ages, not so quickly. Given the range of problems faced against a backdrop of a still expanding human population and threatening climate change, there is considerable urgency to having, dare I say, a timely discussion on lag times.

Some key questions in this context emerge — what is the basis for the lag or delay in addressing key environmental problems? What role does time play in our fight against environmental pollution and a myriad of other stresses faced by our land, water, and the many species living there? Can we afford the time spent in recognizing and fully documenting the seriousness of a problem before acting upon it in a serious way?[2] How do we (society) reduce the time between recognizing and verifying a problem and ensuring that there is a meaningful policy and management response to it, along with proof that the response was effective?

Delving into the topic after many years of cogitation and notation, it is clear that this concern and some of the questions posed above are not new (see Owen et al. 2014; Varjopuro et al. 2014; Hering 2018; amongst others, and footnote 1), are multi-dimensional, and have been raised a number of times recently in the context of both environmental and human health (see the bibliography).

Given our combined knowledge of new and persistent environmental problems, the topic deserves the attention of environmental biologists such as members of the CSEB, and especially some follow-up action on problems with a Canadian context. We need to understand the different types of lag times, the history of delay (or not) addressing some of the critical Canadian problems, and how to overcome the barriers (from knowledge to policy and management) to ensure timely and effective responses to them.

For many decades, the topic or concept of lag times has been lurking behind the scenes in ecotoxicology (e.g., why do some chemically-induced effects on organisms show up long after exposures to non-lethal concentrations have ceased?), and more broadly in environmental biology (e.g., why did it take so long to recognize and accept the role of wolves as apex predators in our northern habitats?). It is important to our basic understanding of how anthropogenic chemicals, especially POPs or persistent organic chemicals (e.g., PCBs), act upon organisms and ecosystems, and to our ability to apply what we know and understand in a timely (sic) fashion to critical chemical and other environmental threats. In this context, lag time can be considered to be the time between the onset of a stimulus or event and the response of the receptor(s) to it. The concept is not trivial, nor just confined to ecotoxicology, but until quite recently (see the bibliography[3]), it has not been well considered in environmental science and management. The topic is much broader than originally conceived (by this author, at least!), as clearly shown by the recent literature.

As well, the current COVID 19 crisis or pandemic has highlighted the problem of lag times. It has been a true emergency but not entirely unexpected given the past history of pandemics. The fast response to this crisis in some countries (not all) shows that recognition of a true crisis, happening or pending, mobilizes and focuses both the science community and the policy and decision makers, and action is quickly taken. This rapid response has happened previously in major conflicts (e.g., WWII – atomic bomb development) and similar human health crises (e.g., Ebola in Africa, SARS in Canada, foot and mouth disease in the UK, algal toxin outbreaks in eastern Canada). The coronavirus response by agencies and governments clearly shows that science and the needs of the public health agencies are rapidly driving the political, policy and decision making activities, not the other way around. The time to significant action is short. It is a clear one-way flow of information, driven by the observations on the ground. It points to one principle — the urgency with which information is required for the "right" policy decisions, and in this case, health care action, reduces the time between understanding the problem (the virus) and acting on it (the vaccine).

In contrast to an urgent health crisis, a slow response to some key environmental threats (e.g., climate change, low level chemical contamination, habitat and biodiversity loss, reduction in aquifers in SW USA), with some marked exceptions where response was rapid (e.g., ozone depletion and CFCs, organotins, algal toxins, Hg in shellfish, acid rain), has put life on the planet into a perilous situation.

Climate change is clearly "the poster child" in this discussion about time. Despite the work of the IPCC (the Intergovernmental Panel on Climate Change) over the past three decades, there has been a delay in sufficient meaningful global response to the crisis, despite the efforts in some countries to reduce emissions and switch to alternative energy sources. This slow response has been recognized (note the American climate envoy, John Kerry's, recent talk — Kerry 2021) and now, hopefully, it will be addressed this year with the upcoming meeting in Glasgow, Scotland.

Another example much in the news is that of litter (plastics) in the ocean and the many risks posed to marine life. This issue was studied in the 1960s and early 1970s (Cundell 1974) and observed in the 1960s by the explorer Thor Heyerdahl in his various ocean voyages, as he observed huge quantities of litter caught in surface current windrows (Heyerdahl 1971). It has been described in many ocean assessment reports (see www.gesamp.org). Yet it

[1] Key readings on environmental history include Easterbrook 1995; Markam 1994; McNeill 2000; Merchant 2002; Ponting 2007; and Worster 1977. Reading even one of them gives some context to this essay and some pause for thought as to our collective progress or not in our fight to maintain a liveable planet.

[2] "Rome is burning" while we watch, as this literally is occurring this summer in numerous locations with huge forest fires in Ontario and western Canada, as well as elsewhere. Have we abandoned the precautionary principle and not acted in the absence of complete information for serious problems?

[3] See especially the reports (EEA 2001,2013) and the excellent book by Bowen et al. (2014).

took until the early part of this century, with the discovery of ocean gyres in the Pacific Ocean filled with floating plastics, for society at different levels (general public to the politicians and the United Nations) to wake up and respond.

Hence, a truly urgent situation can completely remove the barriers between knowledge about a problem (the flow of scientific information) and the needs of and actions by policy makers. As mentioned above, this happened in several environmental situations since the mid- 20th century (e.g., ozone depletion and CFCs; organotin, DDT and Hg pollution; algal toxins; long range transport of acid rain; right whales and ship collisions/ entanglement). It is clearly happening now, on a day to day basis, with the COVID 19 pandemic, climate change, and plastics in the oceans. Policy and management response to a crisis can be very fast and even effective, if it is deemed serious enough by the decision makers in government.

Unfortunately, this is not always the case, as not all problems are deemed urgent, especially if humans are not being affected. The reasons why are worth evaluating. First, what are the different sorts of time lags or delays? Clearly, lag or delay times exist at several points in the management cycle, as one moves from detection of a problem through to its management and resolution. A framework (**Figure 1**) for addressing the scope and implications of time lags or delays has been developed, with references to relevant examples.

Clearly, time is a major factor at every stage of understanding, addressing and resolving environmental problems. The environmental implications of time lags for addressing serious problems are many and often severe in terms of impact on ecosystem and/or human health. Climate change is probably the top example; it was recognized as occurring due to human influences back in the 1960s, yet it took until the 1990s under the IPCC for assessments and some action to take place. Action to this day globally is considered insufficient and too slow, despite some progress in several countries (e.g. Germany, UK). Reactions to other issues, such as deteriorating water quality, the health effects of some contaminants (e.g. herbicides such as glyphosates), and the needs for biodiversity conservation, have also been slow, with examples in Canada. In contrast, if human welfare has been at stake (CFCs and ozone depletion, algal toxins, mercury poisoning, lead in gasoline, release of radionuclides), responses have generally been very fast and generally effective.

If action is slow, why? Where are the barriers? The framework gives some ideas of where they occur and of the wide scope of the problem. This needs to be more widely recognized, outside of scientific and academic literature/circles. Only widespread discussion and cooperation will reduce critical time lags on problems yet unresolved. Especially on climate change and biodiversity conservation, across the planet, time is of the essence!

To conclude, I initially approached this topic as an aquatic toxicologist, realizing that exposure of organisms to toxicants often led to delayed effects, depending upon the chemical, its concentration, the species and life stage, and the length of time of its exposure. Clearly, the literature shows that the topic is much broader and more complex, covering many aspects of environmental science, information, policy and management,

Figure 1. Types of lag (delay) times, with links to key references found to date, 8-21.

1. Scientific:
- a. Detecting and recognizing problems (Grandjean 2018, Hellou 2011, Wood and Foot 1981).
- b. Acquiring sufficient information and knowledge about a problem or a process (DeSombre 2005, FWW 2019, Mulhern 2020, Pahl et al. 2014, Rudnick 1989).
- c. In pollution studies, considering multiple organism responses in toxicity tests, lethal or sub-lethal (Cairns and Niederlehner 1994).
- d. Acquiring sufficient expertise and equipment to address problems.
- e. Monitoring ecosystem response and recovery, post-management., post-control (EPA 2008, Ghidoni 2017, Hastings 2016, Hamilton 2011, Mueller, Hamilton and Doole 2015, Samset et al. 2020, Vero et al. 2017).

2. Information and communication
- a. Analysing the data and publishing the results (Cairns and Niederlehner 1994).
- b. Writing for the right audience.
- c. Policy and decision making.
- d. Accepting the scientific evidence and advice.
- e. Making a decision in the light of various options and considerations, including economic and political (Bretschger and Smulders 2018) .

3. Managerial and institutional action.
- a. Regulatory acceptance of the science and its techniques (Cairns and Niederlehner 1994).
- b. Interaction with industry, agriculture, etc. to address the problem.
- c. Establishing new programs to address and resolve the problem, including adaptive management (Anon. 2019, Baird 2009, Hastings 2016).
- d. Managing, using the precautionary approach (Baird 2009, EEA 2001, 2013, Owen et al. 2014).
- e. Establishing monitoring to verify problem resolution (Angor et al. 2018, Anon. 2020, Bristow and Brumbelow 2006, Hastings 2016, Kim et al. 2020, Varjopuro et al. 2014).
- f. Recognizing societal time scales (Goldberg 1977).

4. Legal and Ethical
- a. Establishing new laws, regulations, guidelines, etc. within national jurisdictions.
- b. Establishing a legal framework to address problems of global significance (DeSombre 2005, Karlsson and Gilek 2019).
- c. Considering and accepting the ethical dimensions of the issues (Brown 2001).

and deserves a more in-depth analysis. As well, my perspective has greatly benefited from being part of an inter-disciplinary research team at Dalhousie University, studying the enablers and barriers to the use and influence of information to resolve marine environmental problems (www.eiui.ca). Time lags deserve scrutiny from many angles and by many players.

To conclude, this essay's role is to initiate a discussion within the CSEB. A concerted effort to reduce lag times for effective action is needed on many critical problems discussed recently in the pages of the CSEB Bulletin. **So CSEB members — take up the banner and add your voice to this discussion from your perspective. Time is short, especially with climate change upon us!**

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