



# Linnaeus Lecture Series



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Biodiversity and Climate Change



Convention on  
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## Preface

On 23 May 2007, the world celebrated the 300th anniversary of the birth of Carl Linnaeus, the Swedish scientist who created the science and system used to uniquely classify all living things. To mark this tricentennial anniversary, the Secretariat of the Convention on Biological Diversity, in collaboration with the Kingdom of Sweden and the United Nations Educational, Scientific and Cultural Organization (UNESCO), has launched the Linnaeus Lecture series. In doing so, the Secretariat pays tribute to an historic citizen of Sweden for his unique contribution in promoting taxonomy and



advancing the knowledge of nature and at the same time honors Sweden for hosting the United Nations Conference on the Human Environment in June 1972 that led to creation of the United Nations Environment Programme (UNEP), the host organization of the Convention on Biological Diversity (CBD) and 18 other multilateral environmental agreements. The inaugural Linnaeus lecture took place on Wednesday, 23 May 2007, at the CBD Secretariat in Montreal, Canada. Mr. Yvo de Boer, the Executive Secretary of the United Nations Framework Convention on Climate Change (UNFCCC), Mr. Peter Bridgewater, the Secretary-General of the Ramsar Convention on Wetlands, and Mr. Frederik Alfer, the Second Secretary at the Embassy of Sweden in Ottawa were the guest speakers. In line with the theme for the 2007 International Day for Biological Diversity, the first lecture, on “What Linnaeus would have thought of climate change”, focused on the links between climate change and biodiversity.

The CBD Linnaeus Lectures will be organized on a regular basis at the margins of major meetings of the Convention and in particular during the meetings of the Conference of the Parties. Eminent personalities will be invited to share their perspectives and visions on the challenges to biodiversity and opportunities it provides within the context of achieving sustainable development. It is expected that the next CBD Linnaeus Lecture will take place at the margins of the ninth meeting of the Conference of the Parties to be held in Bonn, Germany from 19 to 30 May 2008. I also sincerely hope that, in the future, the CBD and Sweden can jointly establish a Linnaeus award to honour scientists who bridge science and policy.

Ahmed Djoghlaoui

*Executive Secretary  
United Nations Convention on Biological Diversity*

## Linnaeus: The Father of Sustainable Development

Students are the best harbinger of the future. When Carl Linnaeus, the father of taxonomy, presented his bid for a professor's chair at Uppsala University, students did not look kindly to his competitor. In a riotous gesture, they ripped the competitor's dissertation into pieces during his defence. Like his students, Linnaeus tore through previous systems of naming organisms and bequeathed to the world the most enduring tool for remembering life on earth.

As the father of taxonomy, Linnaeus was inspired by the desire to find plants and other organisms of practical utility to Sweden. He strongly believed in “botanical innovation” as substitute for military conquest as a way to secure the resources needed for the welfare of the Swedish people. By focusing on botanical innovation, Linnaeus helped to lay the foundation for what we today call “sustainable development”. But more importantly, Linnaeus' most enduring contribution is bringing the best scientific and technological knowledge to address sustainability challenges.

Linnaeus proclaimed that “each country produces something especially useful”. But it is only “by the help of reason man tames the fiercest animals, pursues and catches the swiftest, nay he is able to reach even those, which lie hidden in the bottom of the sea.” But drawing our attention to the role of species in human welfare and focusing on self-sufficiency, Linnaeus also provided initial ideas that have come to shape our thinking about sustainable development.

The 300th anniversary of the birth of Linnaeus coincides with the 20th anniversary of the release of *Our Common Future*, the report of the World Commission on Environment and Development (chaired by Norwegian Prime Minister Gro Brundtland). There can be no better moment than now to reflect on 300 years of conservation practice and to map a new vision for the future that brings scientific and technological knowledge to bear on conservation. It is the dawn of the age of conservation innovation.

Calestous Juma PhD, FRS

*Professor of the Practice of International Development  
Belfer Center for Science and International Affairs  
Kennedy School of Government, Harvard University  
Former Executive Secretary  
United Nations Convention on Biological Diversity*



# The Biography of Carl Linnaeus (1707-1778)

- Born 23 May 1707 in the southern Swedish province, of Småland.
- Studied medicine in Sweden at Lund University, transferring after a year to Uppsala University. He finished his medical degree at the University of Harderwijk in the Netherlands in 1735, and then enrolled in the University of Leiden.
- During his studies at Uppsala, Linnaeus organized botanical and ethnographical expeditions to the largely unexplored Lapland region and to central Sweden. Linnaeus traveled extensively, undertaking many research trips to England, France and Germany but spent most of his time in Holland, where he was extremely productive in publishing many important works.
- Although he published over 180 works, one of his most famous is *Systema Naturae* (1735-70), which began as an 11-page pamphlet but expanded into a multi-volume work encompassing some 15,000 species. Another famous work is *Species Plantarum* (1753), where every known species of plant at the time was identified and documented.
- Linnaeus returned to Sweden in 1738 where he practiced medicine in Stockholm, specializing in the treatment of syphilis.
- Married Sara Elizabeth Moraea in 1739 and had two sons and four daughters.
- Appointed chair of medicine at Uppsala University in 1741. In 1742, he exchanged his chairmanship to botany and made three more expeditions to various parts of Sweden.
- His lectures attracted students from all over the world and he arranged to send many of them on expeditions abroad.
- Linnaeus became chief royal physician in 1747.
- In 1761 he was ennobled by the King of Sweden and became Carl von Linné.
- He retired in 1776 and was permitted to appoint as his successor his son Carl the Younger at the University.
- Linnaeus died on 10 January 1778 in Uppsala, after a lengthy period of deteriorating health. He is buried in Uppsala Cathedral.

# The Legacy of Linnaeus

Carl Linnaeus was a renowned botanist, physician and zoologist and one of the most influential scientists in history. He attempted to describe the natural world in its entirety and explore the relationships between groups of organisms and individual species. He is known as “the father of modern taxonomy,” “the father of botany” and has also been called the first ecologist. He was the first to define the human being as an animal among other animals, naming us *Homo sapiens*.

*Linnaeus’ most famous contributions to science:*

## Popularization of Binomial Nomenclature

Binomial nomenclature is the Latin scientific name of a species that is formed by the combination of the genus and species name (e.g. *Homo sapiens*). Although Linnaeus was not the first to use binomial nomenclature, he was the first to use it consistently, and it is now the scientific standard internationally.

## Taxonomic Classification System

Linnaeus sought a universal classification of all creation within a hierarchy based on morphological characteristics. At the top were three Kingdoms: Animalia for animals, Vegetabilia for plants and Mineralia for minerals. Kingdoms were divided into Classes, Classes into Orders, Orders into Genera, which were in turn divided into Species. Although, the classification system used today is based on Linnaean taxonomy, much has been re-classified due to new discoveries and scientific progress, especially with the advent of phylogenetic systematics and genomics.



*Linnaeus borealis*: Linnaeus’ favorite plant and personal symbol when he was ennobled. This plant is also the emblem of Linnaeus’ home province.

Statue of Linnaeus at Woodward Park in Tulsa, Oklahoma



## Summary of presentations from the inaugural Linnaeus Lecture

### Remarks by Mr. Fredrik Alfer, Second Secretary, Embassy of Sweden in Ottawa



Noting that Linnaeus developed the binary system of nomenclature for classifying animals and plants, and was also a medical doctor, zoologist and writer, Mr. Alfer said that when reading what Linnaeus wrote in the 1750s, “it becomes apparent that he was very concerned about the human impact of nature and that today he would surely be called an environmentalist.” Mr. Alfer emphasized that the aim of the tricentennial celebrations is to “increase interest in science, particularly among young people, to create and inspire curiosity and innovation in the spirit of Linnaeus.” He also added that Linnaeus is central to our current understanding of how species relate to one another, and was the first to define humans as animals, naming us *Homo sapiens*.

Mr. Alfer said that one of Linnaeus’ most successful apprentices, Peter Kalm was also, in many ways, before his time. Kalm took due note of everything that he saw, including the length of the skirts of Canadian women and of differences in the emancipation of women in town and country. Some 250 years ago Kalm wrote in his diary of the export of Canadian Ginseng to France, describing the insatiable French appetite for ginseng. Kalm writes that the Natives traveled across Canada to collect the roots, and worried about the future of the Ginseng root when he saw the ruthless harvesting of Ginseng.

From Kalm’s writings we see that not much has changed, human activity continues to impact negatively on biodiversity. Many varieties have been affected by direct human interference, like heavy forestry or high use of pesticides. In addition to these direct factors, climate change will also impact biodiversity.

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### Presentation by Mr. Yvo de Boer, Executive Secretary of the United Nations Framework Convention on Climate Change:

#### *Climate Change Challenges*

The CBD and the UNFCCC have a long tradition of collaboration. Many linkages between climate change and biodiversity exist, and experts have been exploring ways to address these linkages and identify synergies. Mr. de Boer focused on elements of the climate change process that are of interest to the CBD, as well as their directions in the future.



New scientific findings and increase in interest in climate change have contributed to putting climate change at the center of high-level political debates within and outside the UN process, including the UN Security Council, the G8 and G8+ 5. The UN Secretary General, Ban Ki-moon has made climate change one of his top priorities and has appointed three special envoys on climate change to solicit the views of world leaders and to facilitate negotiations. Policy makers will be expected to find a political solution to findings of the IPCC in Bali at the 13th meeting of the Conference of the Parties to the UNFCCC, in December 2008.

Mr. de Boer emphasized that a long-term global response is necessary to reduce impacts of climate change on the environment as well as on economic and social development.

This global response includes:

- Major emissions cuts from industrialized Parties.
- Incentives for developing countries to limit emissions and assistance to adapt to the impacts of climate change while safeguarding socio-economic growth.
- Reducing emissions from deforestation in developing countries.
- An enhanced carbon market providing cost-effective implementation and incentives for developing countries.

Mr. de Boer stressed that enhancing cooperation among countries and organizations is necessary to build partnerships and synergies to urgently and effectively address the climate change problem.

## Presentation by Mr. Peter Bridgewater, Secretary General of the Ramsar Convention on Wetlands:

### *What Would Linnaeus Have Thought About Climate Change?*

Linnaeus would, from his medical background been concerned about the effects of climate change on human life. And on all the variety of life he was discovering and describing – and by describing, communicating about! While the science of genetics, ecology and evolution had yet to emerge in their full force, I am sure that Linnaeus would have instinctively understood, and appreciated, the hierarchical nature of the biodiversity concept.



He would also have appreciated that understanding the reactions of biodiversity to climate change require a multi-functional approach, from the most obvious level of species-climate interactions, to the effect on the genome, and the very 2-way interactions of ecological systems. Linnaeus also would have understood that promoting ecological resilience is an excellent way to combat climate change. He may not have understood, however, that promoting natural disturbances to enhance resilience – vital for adaptation – works against ecosystems which sequester carbon, which tend to be non-disturbance types of systems. This question of balancing between ecosystem types which can help in adapting to climate change, and those which can help mitigate climate change, is possibly the biggest challenge for biodiversity in an era of rapid and unpredictable climate change.

Science is telling us more and more about actual changes we are seeing, usually in species range extensions or contractions, or in their behaviour related to climatic variables such as earlier reproductive behaviour. However, we have not yet really understood what will happen to ecosystems which are isolated more and more from each other, under the impact of climatic change. It seems most likely however that existing ecosystems will persist until a tipping point is reached – and then the consequences will be unpredictable, but will range from complete system breakdown, to a sorting of ecosystem components, including the incorporation into ecosystems of invasive species, and loss of species from their natural range.

We know there is an element of redundancy in ecosystems, what we don't know or understand imperfectly is how much redundancy there is. And if that redundancy is needed for

other factors, such as providing the genetic basis for a more rapid evolution of new species, something which will certainly occur. Management of biodiversity at all levels must therefore be conducted to take these factors into account – simply providing for conservation is unrealistic, and will in the end result in even greater biodiversity loss.

A key issue that needs more focus in this debate is the linkage between cultural diversity, especially cultural land and water management practices, and their ability to help adapt to and mitigate against climate change – or else make the processes more complex. But better understanding of the complex linkages between cultural diversity and biological diversity is vital in confronting the challenges of climate change – something Linnaeus with his wide experience of the links between people and organisms would surely have understood.

One fact is clear, given these areas of unpredictability and uncertainty we need to closely monitor biodiversity and its changes. Understanding also how climate change will compound and increase the loss of biodiversity generally means monitoring of change; especially loss will be a key measure of actions involving biodiversity and climate change.

So we need a global response to this global issue, yet this is complicated as the response is effective only at local levels, yet we have a global focus on it. Here a key issue is the International Environmental Governance architecture is incapable of swift response, and has difficulties with locally-based responses. Yet somehow we need a global set of responses, tailored and applied locally.

Perhaps we should adopt the view that the world is a “garden” and that we are the “gardeners”. With this view in mind, our future may then become one of global “gardening” (landscape management) in the most effective way.

This gardening would mean:

- Improving carbon sequestration
- Promoting ecological resilience
- Maximising delivery of ecosystem services
- Managing at system level not species
- Using a robust assessment process, with dependable and definable indicators.

And all this within a more flexible and responsive global governance framework that sets the key parameters and priorities. If we can achieve this, Linnaeus would be duly proud that his legacy has helped us cope with the greatest environmental challenge we have created for all life on this planet.



### Understanding Adaptations of Biodiversity to Climate Change using Taxonomy

Global distributions of species and their community composition are expected to shift as a consequence of climate change. When taxonomists collect a specimen, they note the specific latitudinal and longitudinal coordinates and habitat where it was found. For many ecologically important but lesser known taxa, spatial distribution data is insufficient for analysis, which is a major taxonomic constraint when assessing effects of climate change on biodiversity. The following case studies demonstrate the need for increased taxonomic research in this area.

#### Climate Change, Human Impacts, and the Resilience of Coral Reefs

*Hughes, T. P. et al. 2003. Science 301 (5635): 929-933*

Reefs are now globally threatened due to human impacts and are among the most sensitive ecosystems to climate change. Increases in water temperature and changes in water chemistry produces thermal stress in corals called thermal bleaching. This causes them to expel their zooanthellae, symbiotic algae that provide most of the coral's nutrients. If the colony survives, it may take months for recolonization by new zooanthellae.

Not all coral and zooanthellae species respond identically to thermal stress and coral species at various locations and times may have different bleaching thresholds. Some species have already demonstrated far greater tolerance to climate change and coral bleaching than others. This implies varying capacities for adaptation depending on the coral species in response to climate change. More taxonomic research is needed to address gaps in knowledge in temporal, regional and global patterns of coral species, genetic responses to environmental change as well as population structure and modeling.

Photo courtesy of Sonpanich/UNEP/Alpha Presse

### Butterfly Species Richness Patterns in Canada: Energy, Heterogeneity, and the Potential Consequences of Climate Change

*Kerr, J.T. 2001. Conservation Ecology 5(1):10*

Pollinator species provide important ecosystem services, including pollinating a large percentage of our food crops. As is the case with most invertebrates, their spatial patterns have been poorly documented and many are threatened by human activities including climate change. Regional changes of species distributions have already been documented in Europe and North America for a variety of species and groups of organisms, with northward expansions. In Canada, butterflies are the only relatively complete pollinator taxon where enough data exists for analysis of spatial distribution based on climate history.

The analysis was conducted using butterfly and skipper specimens from the Canadian National Collection Database collected throughout the 1900s in Canada. It was found that butterfly diversity increases with high climatic energy and land cover variation, and that these factors explain 50-80% of butterfly species richness. Therefore, climate change is likely to have significant effects on species distributions on a regional scale, through heat-related and habitat diversity changes. It was found that butterfly spatial patterns were extremely similar to other organisms such as birds and mammals, suggesting that the same factors control the distribution of many different organisms.



*Papilio glaucus* - Eastern Tiger Swallowtail Butterfly & *Danaus plexippus* - Monarch Butterfly on thistle

Photo courtesy of Doug Sutherland/www.flickr.com



# Case Studies

## Impacts of Climate Change on Range Expansion by the Mountain Pine Beetle

Carrol, A.L., et al. 2006. *Mountain Pine Beetle Initiative Working Paper*. Canadian Forest Service

Insect life-cycles are extremely dependant on temperature and are expected to respond rapidly to climate change by shifting their geographic distributions to take advantage of new niches that become available. Since the mid-1990's, mountain pine beetle (MPB) (*Dendroctonus ponderosae* (Hopkins)) populations have erupted in British Columbia (BC) into the largest outbreak ever recorded, causing massive damage to lodgepole pine forests, although other pine species can be attacked. Hot summers have facilitated beetle reproduction and mild winters have allowed greater survival of offspring in recent decades.

Under normal conditions, native bark beetles, such as MPB, attack dead or dying wood and provide vital ecosystem services such as nesting habitat for birds, food sources for predators and nutrient cycling. Under global warming, many habitats that were uninhabitable to MPB due to climate are now hospitable. MPB is most common in south-central BC and the north-western US but has recently expanded its range to breach the Rocky Mountain geo-climatic barrier and is now established in north-eastern BC and Alberta. The number of infestations since 1970 in formerly inhospitable environments shows expansion of populations into new areas at an increasing rate. It is predicted that most of the boreal forest will be available for infestation by MPB and a continued eastern expansion is probable. Taxonomic research has been essential for identifying, mapping and predicting the impacts of the MPB and linking its expansion to climate change.



Photo courtesy of Kenneth Erfurth

## Taxonomy Today

By the end of the 18th century, the estimated number of species on Earth was about one million. Today's more accurate estimates place the number of species between five and 30 million. In the 250 years of taxonomic research since Linnaeus, we have discovered and identified approximately 1.8 million species but no central inventory exists as of yet.

At this rate, to identify 20 million more species would require 2500 years of taxonomic work. Linnaeus provided a solution to the first bioinformatics crisis and now we find ourselves at another turning point where our world's changing biodiversity due to human impacts is increasing the demand for taxonomic information and expertise. No taxonomist can deny that the power of the Internet for the progress and popularization of taxonomy, as well as free and easy access to taxonomic and biodiversity information that professionals and amateurs can contribute to worldwide. To understand anything in science, things need to be named in a way that is understood universally and important steps must now be taken to further Linnaeus' legacy and to adapt to today's challenges.

### Linnaeus Quotes:

*"Nature does not proceed by leaps and bounds"*

*"If a tree dies, plant another in its place"*

*"The study of nature guards against prejudice"*

Carl Linnaeus, 1707-1778