The Ecology of the Past

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Inaugural lecture: Professor of Palaeoecology & Biogeography

“The Ecology of the Past”

William D. Gosling

22 December 2022 (16:30)

The Aula, University of Amsterdam

Slide 1:
Mister Rector Magnificus, Mister Dean, esteemed Professors, colleagues, friends and family. It is a great pleasure for me that you are all able to be here today to mark the inauguration of my chair in Palaeoecology & Biogeography here at the University of Amsterdam.

I wanted to start today with this photo that I took 20 years ago on Laguna Caceares on the Bolivian Pantanal. This photo was taken as we returned to shore after a particularly long and hazardous day of sediment coring. During that day there was a moment when I did wonder if we would make it safely back to shore. In the end we did but I like to keep this image around and I have recounted the story many times since. I like to think I have learnt something about conducting field work – more specifically, don’t jump off your boat into snake and caiman infested waters swim through various water plants to reach the open water where you have waves above your head only to turn round and not be able to see the boat that you just got off – and also gained a perspective on other problems from this experience. So this story is important to me…

Slide 2:
And stories of all sorts have been important throughout my life. When I was growing up I used to “loose” my mother at home because she had a new book and had gone off to a quiet spot to read it. I now have children who love reading.

Slide 3:
And I have a wife who writes novels – so if you still need Christmas presents, out now in paper back and ebook!

Slide 4:
So stories are important to me. But stories are also important for you and for our societies . They tell us about who we are - cultural heritage. They tell us about our power – how we can change environments. They provide a framework for guiding our lives, and our actions. And given that we are living on a changing planet understanding the story of how the current situation came about, and what sort of changes the Earth system can tolerate becomes ever more important. And I think one of the greatest mystery stories that we are still reading is the story of our past.

Slide 5:
So I want to tell you some stories about “the ecology of the past”, but what is ecology and when was the past?

Ecology is about how living organisms interact with each other, and their physical surroundings – such as the soils, climate or fires.

The past is stuff that has happened, which is quite a lot… but what past is important to ecology? I would argue that the most critical timescale to study for providing a context for living on a changing planet is the timescale of those organisms. So hundreds of years to understand change related to the lifespan of a tree. Or thousands of years to think about the successional processes involved in the building of ecosystems.

Slide 6:
So with the rest of the time I have today I would like to take you through three stories related to the ecology of the past. The first of which was work I did with Thiago Rangel, Neil Edwards, Phil Holden and Rob Colwell among others. This work linked computer models of past climate change with models of evolution to explore biodiversity patterns in South America.

Slide 7 (video):
Here we have a simulation of precipitation change and temperature change across South America over the last 800,000 years. I remember very well the first time I saw an early version of this model. Rob Colwell was visiting IBED as part of a PhD training event I was running and he showed me this model. I remember thinking "wow". This parameterization of climatic change at spatial and temporal scales relevant to ecosystem change allows us to test fundamental ideas about the Earth system works. We used this in our 2018 paper to think about biodiversity pattens across the continent. By plugging Thiago and Rob's model of speciation into the Neil and Phil's climate model we could start to make predictions about diversity across the continent.

Slide 8 (video):
So here we place an theoretical species into the Andes and run the climate model. The species behaviors is governed by set of rules that allow it to occupy different climate space on the continent. The rules also allow that species to evolve. So if two populations are separated for a given amount of time speciation occurs and a new species is formed. This coupling of past climate and biogeographic models allowed us to predict where – in space and time – speciation was likely to occur, where – in space and time – species were likely to go extinct, and what the overall pattern of diversity would look like at the end of this process.

Slide 9:
What was remarkable was that the simulated pattern of biodiversity was comparable with the modern observed pattern of biodiversity. Suggesting that through the understanding of the ecology of the past – how the physical environments change and how organisms interacted – we could understand better the modern environment. But, these are models, how can we verify these models and provide empirical evidence on the story of the Earths system? It takes a long time for us to wait 100,000 years to see if these models are actually right.

Slide 10:
And this is where my real expertise comes in… It is not practical to try to try and monitor change through time over the 100s or 1000s of years that are relevant to tree life cycles, and ecosystem assembly. We therefore need to turn to the sedimentary record to extract the story of the ecology of the past. So how can this be done?

Lake are a good place to look for sediments that have continuously accumulated over 100s, 1000s and even 100,000s of years. To extract these sediments you usually need some sort of boat and platform, and a coring device. These can range from the inflatable dinghies and hand operated Livingstone corer shown here, up to drilling rigs that come in multiple lorries such as those operated by the International Continental Drilling Program. But regardless of the coring method the aim is the same to raise undisturbed sediments from which evidence of past ecological change can be extracted.

Slide 11:
So what sort of things can we extract from the record. We can look at chemicals, physical properties – such as colour – as well as many microfossils. These can tell us about the processes going on in the landscape around the lake and how this change through time. For example, here are examples of two pollen grains. The top one from a pine tree, and the lower one from a daisy. By measuring the abundance of the various types of pollen we find in the sediments we can track through time the change in the vegetation around the lake.

Slide 12:
So given that we have this powerful tool for understanding the ecology of the past, what are the key questions we should be addressing. In 2019 “unprecedented” fires were widely reported in the press as sweeping across the Amazon, as a result of human ignition and dry conditions. But what did unprecedented mean in this context? It meant since the start of the gathering of fire data from across the Amazon using satellites around 20 years ago. While unprecedented in the scale of two decades is quite shocking, this is just the fraction of the lifespan of a tropical tree. So the question for the record of past ecological change was “How has fire varied across the continent and through time on timescales relevant to those tree lifecycles and the assembly of the ecosystems?” Along with a large group of researchers we have been pushing forward on our understanding of fire in tropical ecosystems.

Slide 13:
However, not all fires are the same. To understand the fires of the past, and what their ecological impact was, we need to understand the different components of the fires.

Broadly speaking fire properties can be broken down into three components. Severity, frequency and intensity. Severity refers to the ecological impact of the fire and is often parameterized at the amount of biomass consumed. Frequency refers to how often fires occur per unit time. While intensity relates to the amount of energy released by a fire. Even in modern situation the energy release of a fire is hard to parameterize and this aspect of fires is often characterized through temperature.

Slide 14:
Can we parameterize these different aspects of fire in the record of past ecological change? Fire severity is the most straight forward to characterize through the measurement of the abundance of charcoal contained within the sediments. Based on the principle that the larger the amount of biomass consumed the larger the amount of charcoal that will be produced and preserved. To characterize past fire frequency a clear measure of time is required along side the ability to identify the fire event itself. The characterization of past fire intensity – or temperature – is more challenging and the development of a method to characterize this has been at the forefront of research efforts in Amsterdam. I must give special credit here to Henk Cornelissen who was a BSc researcher working with us a few years ago now. Henk carried out the first experiments into the use of Fourier Transformed Infrared Spectroscopy to characterize the chemical properties of charcoal from which the temperature at which they were formed could be inferred.

Slide 15:

Now we have a set of methods through which we can characterize past fires we can now look again at the history of fire across the Amazon basin and try and place those “unprecedented” fires of 2019 into a temporal context relevant to the generation time of tropical trees.

Here we have map of Amazonia. The colours show the length of the dry season. With the brown colours indicating a long dry season, and the dark green indicating no dry season. The black dots indicate the places from across the Amazon basin from which fire histories have been developed spanning a significant part of the last 10,000 years. The time since the end of the last ice age.
For simplicity and time we will focus on two groups of these lakes today – the wet north and north-western, and the dry eastern.

Slide 16:
In this figure we show a compilation of the fire histories from the eastern region. Time runs from left to right, with 10,000 years ago on the left and modern on the right. The data from all the records have been combined into 500 year time windows and the variance of the amount of charcoal within those records is shown by the size of the box and whisker plots. So the higher the amount of charcoal found in the samples for that period the higher the box will go up the scale. Fire is found to be present through the last 10,000 years and the highest prevalence of fire across the eastern region is found to occur in the time period from 3500 to 1000 years ago.

Slide 17:
Now to compare this with the wetter north and north-western region. We can clearly see that the abundance of charcoal present in the sediments, and consequently the past fire severity, in the north and north-western region is significantly lower than that of the eastern region.

Slide 18:
Indicating that while the vegetation of the eastern region may have some inherent resilience to fire due to a long fire history, the wetter – and more biodiverse region in the west does not. The increased penetration of fires westwards across the Amazon basin seen in recent years is therefore of increasing concern.

Slide 20:
This fire history of the Amazon is based on the abundance of the charcoal in the sediments – reflecting the fire severity – or amount of biomass burned. However, as I mentioned earlier, other properties of fires are also important. In particular fire intensity – or temperature. This is because the ecological impact of a fire is often related to its temperature, for example – a sub-canopy fire used for slash and burn agriculture would typically have a temperature of less than 500 oC, while a canopy fire used in land clearance would easily exceed 500 oC. We are currently working on developing a record of past fire temperature change from a lake in western Amazonia. This is Lake Condores – which is also known as the lake of the mummies.

Slide 21:
Lake Condores sits on the eastern Andean flank, today it has an a-seasonal climate. The lake is today surrounded by evergreen rainforest and it is famous for the mummies that are preserved in rock niches along its shoreline.

Slide 22:
In 2004 a sediment core was raised from the lake – shown by the blue cross – by a team lead by Mark Bush of Florida Institute of Technology. The record from Laguna Condores was dated to around 2000 years ago, and was investigated for the past vegetation and environmental

change by his team. We are now using this record as a test site for applying our new method for extracting past fire temperature data. I will now talk you through our preliminary data from the site.

Slide 23:
Here we have two curves. At the bottom – in black – is the abundance of charcoal particles found in the record from previous work by Mark Bush's team. From these data insights into the amount of biomass burned – severity – and the frequency of fires through time can be gained. Based on the changing abundance of charcoal in the record it can be seen that around 800 years ago there was a decrease in the amount of biomass burnt around the lake.

In the upper panel we have the new past fire temperature data. The different colours represent changes in the proportion of charcoal fragments that were formed in three distinct temperature categories. With the hottest fires shown in red and the coolest fires shown in blue. We can see that, generally speaking, in the later portion of the record charcoals are produced by lower temperature fires.

Slide 24:
The switch towards more lower temperature fires is roughly coincident with the start of the use of the lake as a mortuary site.

Slide 25:
Furthermore, the oldest part of the record – which contains the highest abundance of charcoals produced by the hottest fires – is coincident with the lowest abundance of forest vegetation in the pollen record. Suggesting that these hot fires were being used for forest clearance to keep the landscape open for cultivation. Our new approach is thus giving us a chance to see previously unobservable aspects of how people were modifying landscapes in the past.

Slide 26:
So far I have spoken mainly about how we can reconstruct elements of past ecosystems through the examination of evidence from the sedimentary record. However, I started out by explaining that ecology was about the interaction between living organisms and their physical environment. One of the biggest challenges ahead of us is in thinking about past ecological change is characterizing and integrating records in such as way that we can determine these relationships and how they have changed through time.

Slide 27:
To look at this further we are going to jump continents to Africa and look at an exceptional record of past ecological change from Lake Bosumtwi in Ghana. Lake Bosumtwi was created around 1 million years ago by a meteorite impact and has been filling up with sediments ever since. In 2004 around 300 vertical meters of sediment are raised from the bottom of this 80 m deep lake by the International Continental Drilling Program and the Lake Bosumtwi Crater Drilling Project team. I started working on Lake Bosumtwi just after 2007 and our latest work – published this year – integrates our findings from this lake with external information about past changes in the Earths system.

This work is a combined effort with Lottie Miller, Tim Shanahan, Phil Holden, Jonathan Overpeck and Frank van Langevelde playing significant roles in generating data sets, developing numerical approaches and refining ecological interpretation.

Slide 28:

Lake Bosumtwi is ideally placed for the study of past ecological change because it is located in western Africa – about 6 oN – on the southern edge of a vegetation gradient with forests in the south and grasslands and desert to the north.

Slide 29:
The vegetation gradient is broadly matched by a south to north gradient in precipitation.
Slide 30:
Which is in turn related to a seasonal gradient in fire. And thus the changes recorded in the sediments of Lake Bosumtwi over the last 1 million years should track changes in ecosystems, climate and fire.

Slide 31:
This figure shows variance in a number of factors for the last 500,000 years. Again the oldest material is shown on the left, moving towards the modern on the right.

The first four data sets – woody cover, fire, herbivores and moisture availability – are all directly derived from the Lake Bosumtwi sedimentary record. The next two data sets – temperature and seasonality – are derived from model outputs specific for the latitudinal band in which Lake Bosumtwi falls. The final curve – carbon dioxide – is the atmospheric CO2 concentrations as recorded in polar ice cores. For all the curves up indicates more – so more woody cover, more sever fires, more animals in the landscape, more moisture availability, higher temperatures, greater seasonality, and higher atmospheric CO2.

Slide 32:
To explore the relationships between these different variables we created a model based on our current understanding of system dynamics. So we anticipated that there would be a relationship between seasonality and fire – a longer dry season the more fire, and we anticipated that fire would have an impact on the amount of woody cover. We expected that atmospheric CO2 would have a strong influence on vegetation cover. In growth chamber experiments and modern field observations elevated atmospheric CO2 has been shown to have a fertilizing effect on plants and vegetation. Because of the strong relationship between CO2 and vegetation many of our Earth system model include a CO2 fertilization effect, and the capacity of tropical forests to soak up some of the CO2 humans are releasing has been put forward as a mitigating factor in projected global climate change.

Slide 33:
Taking into account temporal uncertainty we loaded all our data into our model. The output is given as the strength of the relationship found within the data. So the bigger the arrow the stronger the relationship. The colour of the arrow indicates if the relationship is positive – green – or negative – pink. Strikingly the strongest factor controlling woody vegetation cover around Lake Bosumtwi over the last 500,000 years is moisture, closely followed by fire. The influence of CO2 on the woody vegetation cover is found to be trivial.

Slide 34:
Thus the incorporation of CO2 as a key driving factor of tropical vegetation cover change in Earth system models is brought into question. Highlighting the need for the generation of empirical data on the ecology of the past to test modelling assumptions. However, further work is required to test this at fire time resolution and at other locations.

Slide 35:

So far I have presented three stories related to the Ecology of the Past. The first showing how modern pattens of biodiversity can be predicted through the mechanistic modelling of past climate and species relationships across space and through time.

Slide 36:
The second one demonstrating how we can parameterize different aspects of the Earth system from material extracted from the sedimentary record, with specific focus on disentangling different aspects of past fires.

Slide 37:
And finally bringing together different data steams in a way that we can assess how ecosystems have functioned on timescales relevant to the assembly of ecosystems.

Slide 38:
For the final part of this lecture I will focus how improving our understanding of past ecological change can help societies develop and manage the planet we live on. In this section I draw - in part - on ideas that were developed along side Crystal McMichael, Janu-Carlos Jimenze Munoz, and Mark Bush over the last couple of years.

Earth's ecological systems are under threat directly from land-use change, and indirectly from climate change. In this image, the forest on the left we cannot save, however, the forest on the right we might be able to. But to achieve this we have to be able to understand how these systems function, their resilience to change, and the role of people within them in the past, as well as now.

Billions of euros and dollars are invested in conservation actions designed to avert desertification, or to sequester atmospheric carbon. We know that shifts between desert and forests have occurred in the past, and we know that changes in atmospheric composition have been shaped by biological systems. What we need to do now is work out the mechanisms by which this occurred, and harness this power to inspire and guide environmental policy.

To achieve this we need to continue to develop a systems approach to understanding the ecology of the past. We need to generate and integrate these complex datasets over timescales relevant to ecosystem function and climate change, and across spatial scales relevant to societies and ecological communities. We need to make sure that Earth system models are grounded in empirical evidence of Earth system function, and that the mechanisms and approaches identified are successfully communicated to policy makers.

END:

I would like to take a moment to formally thank the executive board of the University of Amsterdam for the trust placed in me for this appointment, and the Dean of the Faculty of Science for nominating me for this honor.

I would also like to thank my friends and colleagues for their support throughout my career and especially during my time at the University of Amsterdam.

I would like to thank my family. I really appreciate the efforts of all of you to be here today. I especially want to thank my wife - Clari - and children - Freddie and Margaret - for their unwavering support.

Ik heb gezegd