WHAT CAN WE LEARN FROM ISLANDS?

THE PERSPECTIVES OF EIGHT RESEARCHERS

Marta Daniela Santos

Foto: © Paulo Borges

cE3c
centre for ecology, evolution and environmental changes

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1st EDITION - JANUARY 2017

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SCIENTIFIC REVISION: Paulo Borges (Azorean Biodiversity Group, cE3c), Maria João Cruz (cE3c).

PREFACE: Paulo Borges (Azorean Biodiversity Group, cE3c).

INTRODUCTION: Marta Daniela Santos (cE3c).

ISBN: 978-989-99697-7-3

ACKNOWLEDGEMENTS: Paulo Borges (Azorean Biodiversity Group, cE3c), Maria João Cruz (cE3c), Margarida Santos-Reis (cE3c). To all the interviewees, for their generosity and trust not only to talk about their research but also about what drove them to choose their research areas. To the conference organizers, for trusting in me for this work. To all of those who made this publication possible.

ON THE COVER: Pico Island from Faial with the Pico mountain covered with snow. Photo by Paulo Borges.

This work was funded by national funds through FCT - Fundação para a Ciência e a Tecnologia in the frame of the project UID/BIA/00329/2013 (2015-2017).

PREFACE

Islands host extraordinary levels of biodiversity. However, global changes are impacting island ecosystems and promoting the erosion of their unique biota. Even though scientists are fully aware of the value of island biodiversity and the ongoing anthropogenic impacts on it, the implementation of adequate conservation strategies constitutes a daunting task.

The recent "Declarations for Islands" (Réunion 2008 and Guadaloupe 2014) highlight the need to inform the public and environmental managers about the importance for islands of the impact of invasive species, land-use changes and habitat deterioration, resource extraction (including hunting of endangered species) as well as the impacts of global climate change. Consequently, Island Biology research needs to include a holistic approach in order to contribute to find solutions for the adaptation to the global change impacts.

In the summer 2016 the Azorean Biodiversity Group (cE3c) organized the second ISLAND BIOLOGY congress in Angra do Heroísmo (Terceira, Azores). It was a highly participated event, with more than 400 attendees, and eight scientists were invited to give plenary talks: Daniel Simberloff (Univ. Tennessee, USA), George Roderick (Univ. Berkeley, California, USA), Isabel Sanmartín (Real Jardim Botanico de Madrid, Spain), Jens Olesen (Univ. Aarhus, Denmark), Pedro Cardoso (Finnish Museum of Natural History, University of Helsinki, Finland), Robert Whittaker (Univ. of Oxford, UK), Susan Clayton (The College of Wooster, USA), and myself (Paulo A. V. Borges, University of Azores, Azorean Biodiversity Group). The criteria for the selection of these speakers were their complementary skills and the high international impact of their current research.

In this work, Marta Daniela Santos, responsible for the Science Communication and Outreach Office of cE3c, interviews these eight scientists aiming to learn more about their research and their visions for the current and future of island biology research. This unique opportunity to listen to the voices of experts will be an inspiration for a new generation of biologists, appreciating the unique natural heritage of islands.

Paulo A. V. Borges
Chair of the ISLAND BIOLOGY 2016
University of Azores (Azorean Biodiversity Group, cE3c)

INTRODUCTION

Between July 18th and 22nd, 2016, over four hundred researchers met on Terceira Island (Azores) with a purpose: to participate in the international conference Island Biology 2016 - II International Conference on Island Evolution, Ecology and Conservation.

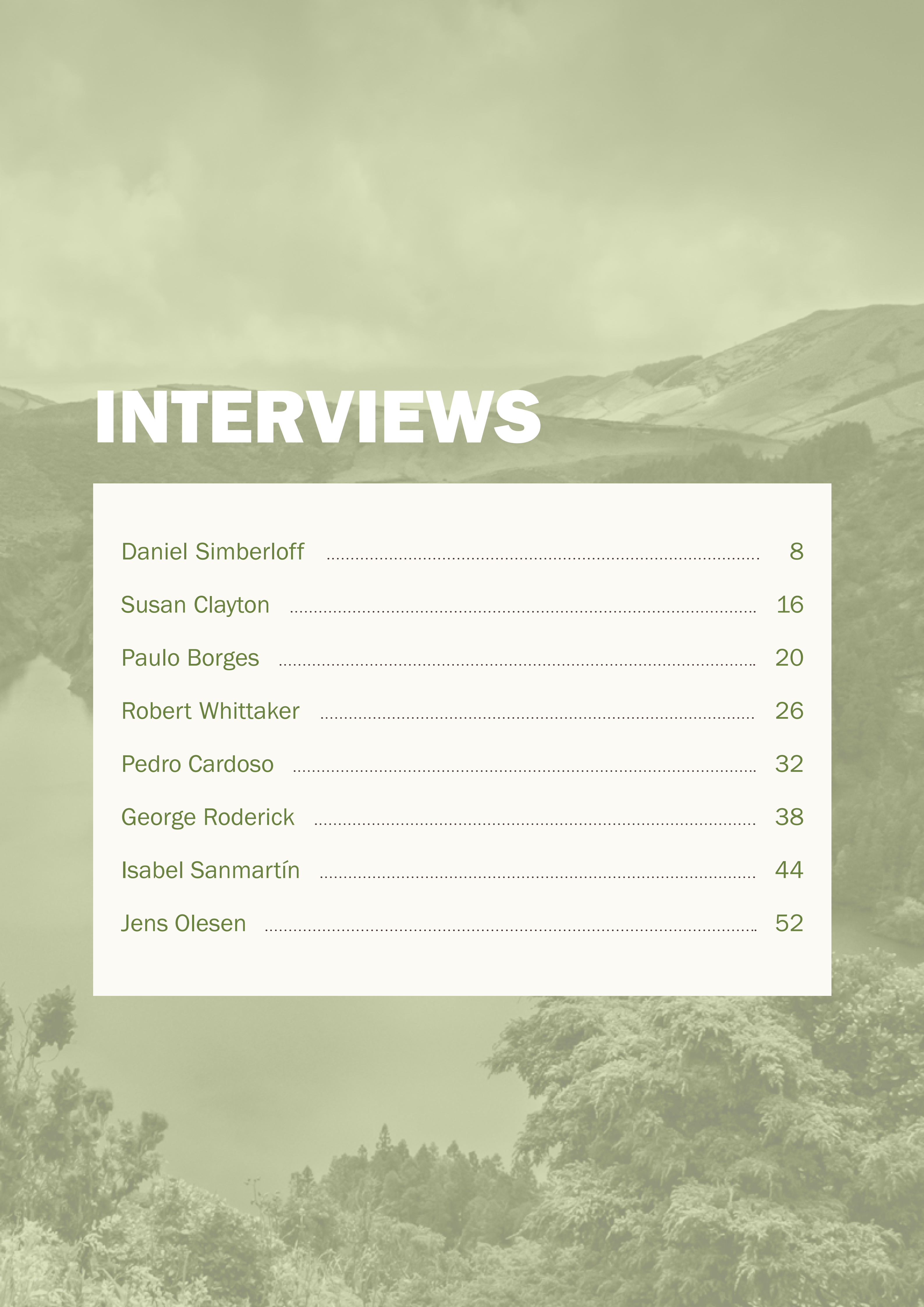
Islands represent just a small proportion of the Earth's surface - yet, at the same time, they hold a very high proportion of biodiversity. How are islands formed and how do they evolve, from the point of view of geology? How does its geological evolution, over thousands of years, affects the evolution of the species that inhabit it? What can happen when new species are introduced into a system with these reduced dimensions? Throughout the five days of the conference, these were just a few of the many issues on which researchers have debated and presented the latest advances in their work.

My challenge was ambitious: to interview the eight plenary speakers, for the conference's future memory. What started as just another task framed in the communication strategy of the conference, rapidly grew into a memorable experience. I learned a lot about island biology and science communication while working on these interviews. And this was only possible because the conference organizers trusted me for this work, and the interviewees trusted me not only to talk about their research but also about what drove them to choose their research areas. Thank you all for your trust and sharing.

In these interviews I always tried to keep the public in mind. I have tried to conduct the conversations in such a way that anyone, even without training in these areas, can follow and be curious about these topics. I might have not always been successful: the art of interviewing is complex and is learned with time and practice. But I hope that the conversations here reproduced spark your curiosity about these areas and about the fascination for islands.

Marta Daniela Santos

Science Communication & Outreach Office of cE3c
- Centre for Ecology, Evolution and Environmental Changes



INTERVIEWS

WHAT HAPPENS WHEN A SPECIES IS INTRODUCED IN AN AREA OUTSIDE ITS GEOGRAPHIC RANGE?

Daniel Simberloff

What happens when a species is introduced in an area outside its geographic range? What are the impacts on the existing community? How can these invasions be managed? These are a few of the several questions in which Daniel Simberloff currently works and which characterize the recent research field of Invasion Biology.

Currently Gore Professor of Environmental Science at the University of Tennessee (USA), Daniel Simberloff's research spans areas such as Ecology, Evolution, Conservation Biology and Biogeography, to mention just a few.

In this interview, Daniel Simberloff talks about his research fields and his scientific passions: not only Biology, which fascinates him since he was a little boy collecting insects in cigar boxes, but also Mathematics – an area in which he considered graduating, before taking a Biology course for non-majors that made him change his mind.

Invasion biology is one of your current main research interests. What really defines an invasive species?

First of all, it's not just any non-native species. It has to be a non-native species that persists without human help and spreads into a more or less natural environment. It doesn't have to cause damage. Probably it does, because it's hard to imagine how it will get in that new environment and not affect some other species, but the damage isn't part of the definition. The definition is non-native, survives on its own without further help from humans in more or less natural environments.

And how did the ever faster and longer range means of transportation in the last few centuries - sailing ships, then trains and then air travel - affect biological invasions and the way they are studied?

Biological invasions were dramatically affected. In the era of sailing ships, if we're talking about terrestrial species like terrestrial plants or animals, it had to be something that could live on boats somehow, for thirty days or even longer. For example, in North America almost all of the earliest introduced species that eventually became invasive were plants and soil insects that live in the vicinity of Land's End, England. It's called Land's End because it's the last piece of land in Southwest England. Boats would stop there before they would start to cross the Atlantic to pick up soil for ballast, because they were going to the Americas to bring back timber. And the soil had plants and insects that could survive the thirty or so days.

Then in the 19th century finally there were steam ships, much faster, that brought a whole flood of other species. For example people were transporting ornamental plants - some of which became invasive - and the insects that lived on those plants. And they could get there much more quickly than one month on a ship.

Air travel, of course, is almost not a problem for anything. There's another issue, though: if you move a species from the northern to the southern hemisphere very quickly, you're taking it from its own winter, for example, into the austral summer. It may not be adapted. But it certainly has greatly facilitated the movement of species all over the globe. ►

Now, as for the study of invasions...there was no study of invasions until the 20th century, and actually very little until the mid-20th century. For example, the first scientific record of invasive species was by a Swedish Finn named Pehr Kalm, who was sent by [Carl] Linnaeus to the New World just to see what was there. And he recognized hundreds of things: for example, he saw fifteen plants that he knew to be European, and he gathered that they were introduced. He didn't talk about impact, he just noted they were there. And then in the 19th century there was the age of exploration; they would often send natural explorers, especially the British, called Victorian naturalists. They were the ones that sort of established the biogeography of the Earth, which species are where, beginning in the early 19th century. Among them was for example a man named Hewett Watson, who produced one of the earliest category classifications of species as native or introduced.

But...it's interesting. Of all these really remarkable scientists, many of them noted introduced species, but only two suggested that there was an impact: Charles Darwin and Alfred Russel Wallace. Darwin talks in several places about introduced species and how they have a huge impact. And Wallace noticed tremendous impacts of introduced species on islands. But they were the only ones, and that was before there was even a science of Ecology. The term Ecology was invented by a German in the 19th century, but there wasn't substantial ecological research on plants until the very early 20th century, and of animals until the late 1920s.

So even though those two, and only those two, noticed the impact, it didn't lead to the study of biological invasions. Even in the 20th century people occasionaly wouldn't notice it. Probably the greatest, most comprehensive treatment was by a man named [George M.] Thomson, who in the 1920s wrote a whole book on introduced plants and animals in New Zealand [The Naturalisation of Animals and Plants in New Zealand, 1922], where he talked about which species were where, about impact... But it was too early! [laughs]

It's often said that the field was founded in 1958, in a classic book by Charles Elton entitled The Ecology of Invasions by Animals and Plants. But it wasn't! It's a great book, he raised almost all the problems we study nowadays, but it didn't lead to sustained study. People did study introduced species that were highly problematic, for example some pest insects of agriculture, but those were one-offs; it wasn't part of a science of invasion. That didn't happen until the 1980s, through an international organization called SCOPE - Scientific Committee on Problems of the Environment - whose *raison d'être* was to bring together scientists to study environmental problems.

In 1980 SCOPE convened a working group on problems of mediterranean-type ecosystems, which took place in Stellenbosch, South Africa. The people at that meeting noticed automatically that each speaker talking about his or her place was talking about introduced species being a big problem. Also, on the conference field trip they went to a hotspot of plant diversity which didn't have trees, and they could see the invasions by planted trees, especially pines and acacias. All of this led them to think about the possibility of having a SCOPE working group just on invasions in mediterranean areas, and presented this proposal to the following meeting of the SCOPE Governing Board, which was in Ottawa in 1982. The Governing Board not only agreed with the idea, but felt that invasions should be studied globally, not only in mediterranean-type areas - and this working group lasted from 1982 to 1988. It got a lot of people interested. Most of the scientists that attended the meetings that were held during that period had not worked on invasions before but in related areas, like population biology or ecology. And so by the end of 1980s, early 1990s, there was a well-established, although young, field of invasion biology.

And...how did your interest in this specific area of invasive biology began?

Well...I did my doctoral work on the theory of island biogeography. What I did was, I fumigated a bunch of small islands (I did a census first, to see what was there) and then I watched the recolonization for a year, and then one year after that [Daniel Simberloff's doctoral work was on the mangrove islands in the Florida Keys archipelago]. And as I was watching colonization, I was thinking how I was ostensibly testing the equilibrium theory. I had read Elton's book, and even though there was no science of invasion biology then, I thought invasions should be a test of the theory. I was thinking somewhat about invasions as almost a natural extension of my own research on the ecology of colonization by natives.

And what really got me interested, what really changed my research life, was... The biggest conservation NGO was the Nature Conservancy, which is now global. It's a very wealthy organization. Originally it just bought huge amounts of lands and managed this land for conservation, or bought it before it could be ruined and eventually passed it on to government entities. I was invited to join the National Board of Governors of the Nature Conservancy, and... most of the governors were not scientists, they were people interested in conservation. They might be hunters, many of them were investment bankers, lawyers, government people... and of the whole board of about thirty people only four were scientists. So I went to these board meetings, where they would bring in some land steward from one of the hundreds of areas that Nature Conservancy managed, to tell us what they were doing and what the problems were. It struck me that for most of them the big problem was introduced species - introduced plants, insects, sometimes mammals. All of this made me think that this was not only an academically interesting question - how does one new species in the area affect the existing community? - but it's a question of great conservation significance. That's when I began to move my research increasingly towards looking at impacts of introduced species, and I encouraged ►

my grad students to study this kind of problem. So, it wasn't really two separate areas; there was one that sort of naturally led to the other. Of course lots of invasion biology research is on islands, the biggest impacts [of invasive species] on general are on islands.

The impact is greater because it is a restricted area?

Well, that's a subtle question. It is a restricted area, so there are fewer places where native species can exist that the invader hasn't gotten to. But there's another issue, which is evolutionary. Oceanic islands especially just lack certain kinds of species. In most of them the only native mammals are bats, and they certainly don't have predatory mammals like various species of cats, or dogs, or mongooses, for example. Oceanic islands do not have native ungulates, like deer, for example. So, the plants have not evolved adaptation to grazing or trampling, and when you introduce goats or pigs...

...the effect is much greater and much faster!

It's devastating. That's why islands' biotas are much more damaged and fragile with respect to invasions.

I had not thought from that perspective. I would like to go back a bit now. Is it true that you started by not being sure which scientific area you wanted to pursue, and you were very interested in pursuing...mathematics?

Yeah, you know...I really love mathematics for the aesthetics. It's extremely elegant. And the aspects of physics that I like are basically mathematics. I don't know what book you use for calculus, but...I was in a class at Harvard where we used the two-volume set by [Richard] Courant. Courant was a very good mathematician who was very keen to find a physics analogue to all the proofs - and I liked that.

I was always interested in biology. Even when I was a little boy, I collected insects, I remember I kept them in cigar boxes with pins. I didn't live too far from New York, and my earliest memory of going to the American Museum of Natural History was when I was 6 years old - although my parents probably took me there before then. Nowadays natural history museums have dioramas and films, but 50 years ago museums would have cases where they would have all the specimens. The American Museum [of Natural History] has one of the great insect collections in the world, and I remember I'd stare at these cases. Each case would be all about one species of beetle, for example, and you could even see the variations within ▸

species: some individuals are bigger, some are smaller, some are wider... And my little brother wanted to go see the dinosaurs, and I remember my parents having to drag me. [laughs]

So, I was always interested. I was seduced by the elegance of math as a college major, but I was very lucky: American universities and education are much less rigid than in Europe. Usually now in Europe you're channeled automatically into what you're going to do for your whole life beginning in your first year in college. I took a course in biology for non-majors that was really fascinating. It was taught by George Wald, the Nobel Laureate, and a bunch of people he would invite. And I thought: "This is really what I would like to go to grad school to study", but I had no biology except for this one course for non-majors. But in the US that might not matter, if they believed you could learn stuff in a hurry. I went to talk to Ed[ward] Wilson, who was my advisor, and he made a deal with me. He had never learned much math, he was beginning to collaborate with [Robert] MacArthur and he was convinced that math was very important. So he said that if I helped him to learn elementary calculus and some algebra, he would teach me all the biology I had missed.

That is amazing!

And he did! So he accepted me as a student and that's how I entered that area. I still use math in some of my work.

You were able to more or less merge these two passions.

Certainly through my career I have employed advanced math less and less. But early in my career I did quite a bit. Even in my doctoral work I developed a model for colonization that expanded on the MacArthur and Wilson model, it was pure math.

So, you earned your PhD in 1969, with Edward Wilson as your advisor. It is said that shortly after you published a few articles [here and there] in which you contradicted your own theory...but, is "contradicted" really the right word?

Oh, I see. I was satisfied that my work with Ed largely fit the equilibrium model. But it was very obvious to me, by the time I wrote that review in 1974, that most of the literature purporting to support the model didn't really test it. It was all just about the relationship of the number of species to the area of island, which could be explained by the model but could be explained by other things also. And so I felt it was being widely viewed as a model for nature without much evidence. ▶

The other thing that really distressed me pretty early was that it very quickly became applied to conservation, with these rigid rules and references, none of which had anything to do with the model. If you look closely they were empirical matters, they did not spring logically from the math of the model. So, I didn't say that those were bad ideas, but they didn't spring from the model. Another thing I was criticising was the widespread acceptance of the model without real tests of the underlying key idea, which is ongoing extinction and immigration without the islands's otherwise changing - we call it equilibrium turnover. Except for my PhD work with the mangrove islands there was almost nothing. Very little.

So, it was more like...you were alerting people to interpret the theory with care, to not over-interpret it.

Exactly. That's exactly what it was.

So, first island biogeography, then biological invasions - one research interest naturally led to the other, both of them being connected with conservation. To summarize, do you have any message or advice you would like to give in terms of reserve design and management?

No! That's the wrong question, so my answer will be to explain why it is the wrong question. I think that has been a huge problem with conservation biology in general and to some extent with ecology in general. Ecology isn't like physics. Physics has a rather limited number of particles - they're ever more, but even if they're a couple hundred, in ecology we're dealing not only with hundreds or thousands of species but, within each species, with many different genotypes, and...that's vastly more complicated. So a sort of statistical mechanical approach, like Boyle's Law or something, doesn't work. The systems are very idiosyncratic so the best one can hope to do, in my opinion, for both ecology and for invasions, is a sort of set of approximate patterns or expectations to begin to look at. But each system is different. There are no laws of ecology as there are laws of thermodynamics, for example. There are always many outliers, there are clouds of points...one can draw a regression line through it and there's enough points that it is significant, but it doesn't explain much of the variance at all. And what's important is to study why each point is where it is. ■

“WE OFTEN THINK ABOUT NATURE AS SEPARATE FROM HUMANS. THAT THE BEST WAY TO SAVE NATURE IS TO KEEP HUMANS AWAY. I THINK THAT IS NOT A GOOD WAY TO THINK ABOUT IT”

Susan Clayton

Most people go to the zoo to see the animals. But some people go to the zoo to watch the people see the animals. Meet Susan Clayton (College of Wooster, Ohio, USA) a specialist in the new and emerging field of conservation psychology.

As part of some of her research projects, Susan Clayton spends a significant amount of time observing people at zoos, not only to study their response to the animals but also to understand how people interact with one another in the presence of the animals - how they turn the visit into a social experience. Through this, Susan Clayton aims to examine how people connect with the environment, and how it can lead them to the conservation of Nature.

In your research you merge psychology and conservation of biodiversity, areas which we are not used to see together. How did you first become interested in conservation psychology?

Well, it's nothing in my training, I wasn't trained in this at all. I started as a psychologist, and in my psychological training we didn't talk about environmental issues. But I like nature, I like spending time in the natural environment. A friend of mine who is also a psychologist and I, we thought that psychology is relevant to environmental problems and so we decided to start organizing symposia, and more and more people got involved. We weren't the first by any means, but we didn't know about the work of other people - I had to discover that work.

So that's part of the reason I saw that psychology was relevant to the environmental issues I cared about. The other part of the reason was talking to other people who cared about the environment and getting to know their motivations. I thought "This is really psychological! There are really some interesting psychological processes involved in the way people think about the environment!".

As part of your research, you spend a significant amount of time observing people at zoos. What can these observations tell us about human behavior and our relationship with nature?

The way I started this research was generally just as field biologists might start their observations. I saw what was happening, and then I came up with a tipology of behaviors and started to develop categories. What you learn from the behavior depends on what you're looking for. I was interested in how people were responding to the animals: Were they happy?, Were they sad?, Were they interested? I was particularly interested in whether they tried to imitate the animal or get the animal's attention. Another thing in which I was interested is how people were relating to each other in the presence of the animal. I wanted to understand how did the zoo become a social experience, in what ways did people try to create interactions with each other while they were looking at the animal.

And you did this research in zoos all over the world?

The main research I did has been in the US. I've been in other zoos since then, but these observational studies were mostly in the US. ►

As a curiosity: are the visitants of the zoo curious themselves when they see you observing them?

Yes [laughs]. It's interesting, actually. We have to be very ethical, and not make people uncomfortable. Many times people just didn't notice me and I tried to be nonintrusive. But if they did notice me and ask what was I doing, I would say I was observing visitor behavior. And they thought it was funny. They said "Oh, you're watching us watching the animals!".

It's like...second level observing! [Laughs]

Exactly! [Laughs]

If I recall correctly, you have also worked in a few zoos in China and France as well. Do you notice cultural differences in their design?

There clearly are cultural differences, but I don't know enough to really talk about it. I've only seen one zoo in China and a few zoos in France, so to talk about general things... Certainly some zoos are more old fashioned in the way they put the animal on display, and the cage is very bare and depressing and there is no concern for the animal's well-being, while there are others much richer and more natural-looking.

And how can your research in zoos help us tackle one of the most severe challenges we are currently facing, climate change?

I think one reason is that people actually learn about climate change when they're in the zoo. A lot of zoos have messages about climate change and how it is threatening animals. So while people are at the zoo, in contact with the animals, they're feeling the emotional response and they're kind of receptive to a message about climate change. So there's really two things: one is that they're ready to hear about climate change, and another is that seeing makes them think about how animals are affected and care about them. At least ideally.

And then the message can become more effective.

Yes.

And taking into account your perspective on conservation psychology, what is your view on the Paris Agreement that followed COP21?

Well, I try to be optimistic, because otherwise you just have to give up! [smiles] I think it was further than we had gone before. It wasn't as far as we could have gone as a global ►

community, but I felt positive about the fact that climate change has just reached that level of international attention and that there was some type of agreement, even though it doesn't have inforcement mechanisms. So, I would say cautiously optimistic.

In 2005 you published a paper entitled "Can psychology help save the world?". To summarize, 11 years after I would like to ask you again: can psychology help save the world? How do you compare this research field 11 years ago to now?

I think there's been a lot more interest, more psychological work. The trend is positive. I know of more projects that have interdisciplinary collaborations with psychologists. Has there been much behavior change? It's very slow. My own hope is that we'll reach a positive inflection point when change will start to happen a lot more quickly. And in terms of public awareness of climate change...at least in the US very few people were talking about it even 10 or 15 years ago in the public media. Scientists were talking about it, but the public was ignoring it and that certainly has changed a lot. I don't think psychologists can take the credit for that, but I think it indicates that there's been a trend towards more concern and more action.

We often think about Nature as separate from humans, that humans have to sacrifice in order to save nature. That the best way to save nature is to keep humans away. I think that is not a good way to think about it. Obviously there need to be some protected areas, but to really create more general concern we need to recognize that humans are part of nature. They should save it for their own sakes.

FROM BIRDS TO INSECTS

Paulo Borges

Paulo Borges (Azorean Biodiversity Group - cE3c) began by studying birds, but nowadays he dedicates himself to the study of arthropods - animals like flies, grasshoppers, spiders or beetles, among others. His projects span from basic to applied research - such as the insect pests that affect the Azores and have serious economic and social implications.

Recently, Paulo Borges also coordinated the large team that organized the international congress Island Biology 2016, which on last July brought to the city of Angra do Heroísmo more than 400 researchers, from 46 countries.

The portuguese version of this interview is available here.

How did the opportunity arise to organize Island Biology 2016?

This conference comes as a result of an application of our group [the Biodiversity Group of the Azores - cE3c] to its organization during the first edition of Island Biology, held in Hawaii in 2014. After presenting a business plan, fortunately we were selected as the entity having the necessary logistics and capacities, not only scientific but also finantial, for the organization of an event of this dimension. It was a vote of confidence in the work that the group has been developing on islands, particularly in the Azores.

You had an enormous engagement from the public - more than 400 participants, is that right?

Yes. After Hawaii, in which there were about 430 participants, being able to attract 409 participants from about 40 countries just two years after was extraordinary.

It lived up to your expectations, then.

Initially our expectations were lower: we thought that the Azores would have a lower mobilization, being a lesser-known archipelago, less attractive than Hawaii. However it was on the contrary, which was extraordinary. We had over 50 people from the United States, for example. A quarter of the conference participants was Portuguese, also showing that Portugal is working on high level research on islands. We counted with the presence of leading research groups in Portugal working on these issues, namely cE3c, CIBIO and MARE, which shows that islands remain a very attractive research topic, both nationally and internationally.

And the work didn't end with the end of the conference: you are now working to identify the 50 fundamental questions in Island Biology, right?

Yes. This idea comes from a group of researchers who have worked together in recent years, including Professor Brent Emerson, who is now working in the Canaries in the IPNA-CSIC, his postdoc Jairo Patiño, Professor Robert Whittaker from the

University of Oxford [United Kingdom], myself and Professor José Fernández-Palacios from the University of La Laguna in the Canary Islands. This idea was inspired by the idea of William Sutherland of the 100 fundamental questions in Ecology, and taking advantage of the fact that in 2017 we celebrate the 50th anniversary of the book The Theory of Island Biogeography by Robert MacArthur and Edward Wilson. We hope that the identification of the 50 fundamental questions in Island Biology can also serve as a springboard for further research on ecological and evolutionary theory on islands.

Turning now to your scientific research work. One of your passions are arthropods - flies, grasshoppers, spiders, beetles, etc. Why these animals?

Originally my interest was for birds. One of my first works, still as a teenager, was a study in which I compiled the most scientific names I could find of bird species in the Azores and the world. It was also around that time that I began to watch birds. The idea of studying arthropods comes from the realization that in the Azores the diversity of birds was very low. Then there was the suggestion of some biologists and naturalists, such as Dalberto Teixeira Pombo of the Centre of Young Naturalists, who inspired me to start looking at arthropods and in particular at the Coleoptera of the Azores. I started as a collector, and then gradually I was learning the taxonomy with the support of Professor Artur Serrano from the Faculty of Sciences of Lisbon, Portugal, with whom during my degree I learned to work with this group of organisms.

What have we learned so far with research on arthropods of the Azores?

Arthropods have served as a very interesting model at various levels. Not only in terms of new species discovered - which proves that there is still much to learn about the biodiversity of the Azores - but mainly as an ecological model to test various theories. An example is the work I developed in my PhD, which evaluated the importance of the geological age of islands to the knowledge of their diversity, which adds a new variable to the MacArthur and Wilson's theory key variables, area and the distance to the mainland. This work also inspired the theory of GDM [General Dynamics Model] of Professor Robert Whittaker and colleagues, which incorporates the geological age in a dynamic model explaining the species diversity on islands.

So, arthropods eventually emerge as a model to inspire ecological studies and evolution on islands. In addition, I also used arthropods to study the process of how diversity varies on islands in natural areas with different characteristics. In particular, for the first time it was carried out a standardized study on islands in different protected areas with standard methodologies, with the BALA project ▸

[Biology of Arthropods of Laurissilva of the Azores, 1998-2005] and, nowadays, these methods are starting to be applied to other archipelagos.

One of the problems to which you have also devoted yourself recently is that of infestations by termites in the Azores. What is the current situation?

Research with termites is my most applied work. It is not, let's say, my scientific passion, but a need there is of working with a serious problem in terms of economic impact in the Azores. Being one of the few enthomologists here in the region, I ended up involving myself in this issue, which dates back to 2004 - for more than 12 years. We have had a lot of work, involving several researchers not only from the University of Azores but also from north-american universities and LNEC [Portuguese National Civil Engineering Laboratory]. In particular Professor Rudolf Scheffrahn, Professor Timothy Myles and Professor Lina Nunes from LNEC, who have collaborated with me in order to better understand this problem and propose new techniques adapted to the situation of the Azores for pest control of termites.

The situation at this time is variable. In the case of subterranean termites we are able to control the situation and may possibly be able to eradicate them locally. In the case of the dry-wood termite, one that initially inspired all the work, the situation is more serious. In the case of Angra do Heroísmo, Ponta Delgada and Horta their control seems rather difficult, but we are working so that at least people can control the pest in their homes and we can reduce the population of termites in the coming years.

How many islands are already affected?

That we know of, only three islands are not affected: Flores, Corvo and Graciosa. But there is no guarantee that the problem does not already exist in these islands: it can be so local and small that it has not yet been detected.

The social and economic consequences are quite significant, right?

Yes, yes. The economic impact is already at the level of a few million euros and there are estimates that indicate that in the coming years could reach several million euros, taking into account the reconstruction of houses and roofs. Some houses have been completely rebuilt in Angra do Heroísmo and Ponta Delgada, with values between 100 and 200 thousand euros per household. If we multiply this by several thousand homes, quickly we come to very large figures for the economic impact of this pest. ▶

It is therefore a problem that will extend over years or even decades.

Yes. Our team has been monitoring and testing different techniques along the years, and we have students working on this problem. We have had a PhD in this area, we are finishing another doctorate, and there are several high-impact research projects running in terms of application of science to reality.

Thinking of students who may be considering working in this area, what are the biggest challenges you see for the near future?

The major challenge will be to enter the area of chemistry, of communication between termites, in order to be able to find ways of control by attraction - sexual pheromones or the like. It is something that one of our PhD students is already exploring, but it requires a considerable investment in the coming years so that we can devise an attractive trap for adult termites at the time of swarming. This would be the great innovation and applied discovery that we would like to achieve in the coming years, and to which we will try to find appropriate financing.

"THE BIGGEST CHALLENGE IS WORKING OUT HOW TO CONSERVE ISLAND BIODIVERSITY AND TO DO SO ALONGSIDE THE NEEDS OF HUMAN SOCIETIES LIVING ON ISLANDS"

Robert Whittaker

Robert Whittaker's interest in ecology emerged early; probably since when he first learned about Darwin's finches in the Galapagos Islands. From there, it was a brief step until he started working on island biology, on the opposite side of the world, and on biogeography – understanding which species are where, a knowledge that can bring new insights to questions in ecology, evolution and conservation.

Currently Professor of Biogeography at the University of Oxford, one of his major contributions has been to incorporate in this field the notion that islands are not static, geologically speaking: they are born, evolve, and then die, which leads to new predictions about island species richness.

Island biogeography: in a very simple way, can we say that this research area corresponds more or less to the study of which species are where, in this case in an island? Please correct me if I am wrong.

You can define it that way, yes. Another way to define it is to say that islands are model systems, so we can use the fact that there are many islands and they vary in their properties, such as area, isolation, the age of the island, human interference...all these are key variables that we know influence diversity and distribution of species. By selecting the right islands, for a particular purpose, we can use them to answer lots of different questions in ecology, evolution and conservation. And biogeography encompasses that space, really.

And when did this research area began?

I think you can probably say that Alfred Russel Wallace really defined the subject of island biology, when he wrote a book called Island Life [published in 1880], in which he drew together the observations as they were accumulated over the course of the 18th to 19th century, and he distilled the sort of main messages, rules, patterns that pertain to islands.

Another landmark on this research area dates from the middle of the 20th century: the theory of island biogeography, by Robert MacArthur and Edward Wilson. Since it is a key element in the work you have later on developed, can you please explain in general terms the main elements of this model?

Yes. Their model proposes that the distance of an island from a source of species regulates the frequency of arrival of new species to the island. The isolation thus controls the immigration rate: near islands have a high immigration rate, distant islands have a low immigration rate. And then there's the loss of species. The species don't stay put just because they arrive in a place, they don't stay there forever. The idea was that, if you imagine an empty island filling up with species by this immigration process, it comes a point where the amount of resources available to each new species that arrives becomes less and less. So some species have to start going extinct. Not necessarily late arrivals, maybe early ones. But there's going to be an increase in extinction as the island fills up. ▶

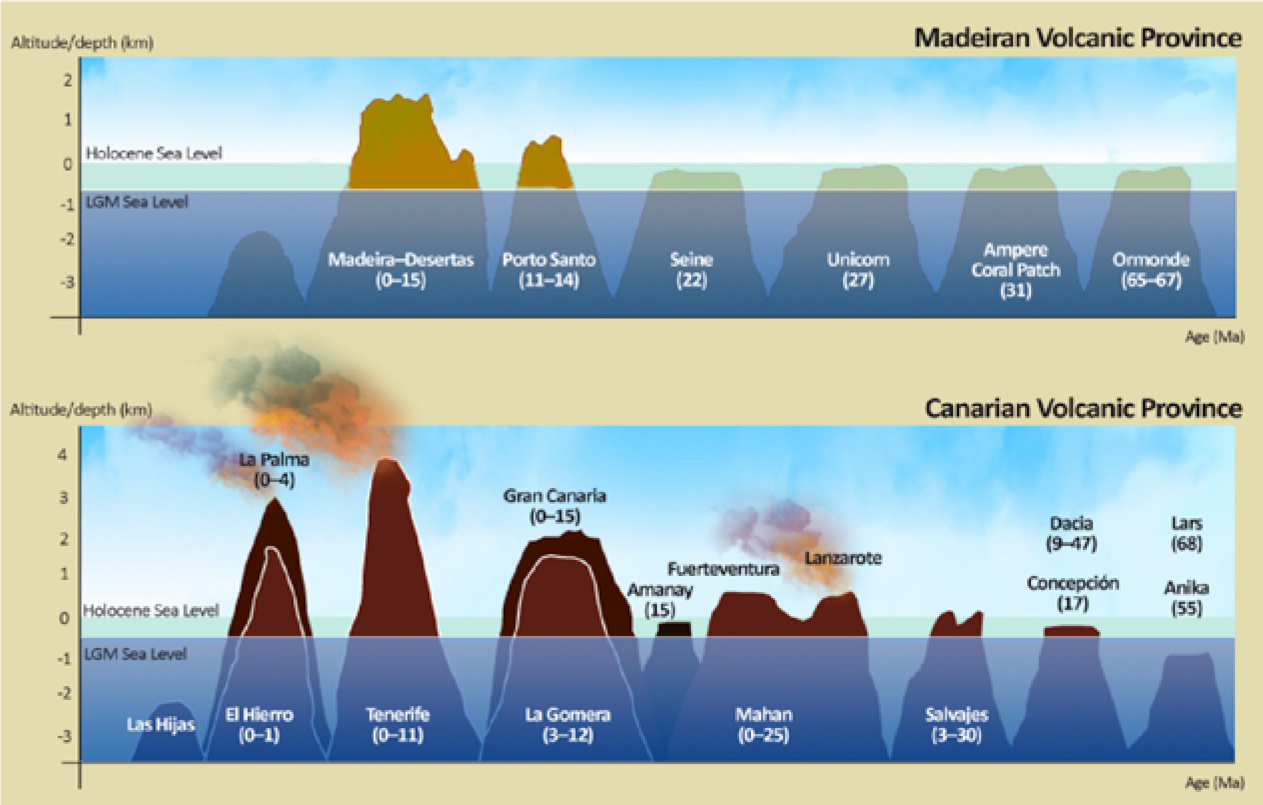
In the MacArthur and Wilson model, they say that the smaller the island the quicker it fills-up, and the higher the rate of extinction. And the larger the island, the lower the rate of extinction. So they propose that you get a balance: species over time arrive and other species go extinct. There's a lot more behind it, but their model had this very simple form and they expressed it in a very simple, graphical model, which is very easy to communicate. It has a tremendous value in teaching, because people can see why the system should be dynamic and why it should produce a predictable pattern of richness across a set of islands.

That idea has turned out to be very productive. It allows you to generate lots of different predictions about how island life should behave, and it made people think in a more quantitative way. Prior to that, people had tended to look at island systems and how they behave in sort of historical terms, but not really thinking about this idea that they should be continually changing in their make-up.

That was the idea that was really new and generated lot of research. It allowed scientists to predict patterns people didn't know about before, and could be tested comparatively easily. Meanwhile other biologists were studying lots of other things going on on islands, such as how a bird species arrives somewhere remote like the Galapagos Islands and develops over time into an array of different species. The adaptive radiation of Darwin's finches, for example, which is certainly taught in my country in highschool as a classical example.

But...the MacArthur and Wilson model didn't work so well for really remote islands, right?

Yes, because those islands have lots of unique species that have evolved there. Their model didn't say very much about speciation, and that's where our model [General Dynamic Model - GDM] comes in. Again, lots of people have worked on speciation, but what our model did was draw together three things. The MacArthur and Wilson dynamic model, of species arriving and natural processes of extinction, was the first bit. Then the second was the understanding that you get lots of speciation happening in very remote islands. And the third thing was a knowledge that has come from geology. Since the plate tectonics revolution we have begun to understand that continents haven't stayed all in the same place; they moved about in these plates. It also began to become apparent that islands have a very dynamic behavior. Not all islands, but particularly islands like the Canaries, Madeira, the Azores (although it's a little more complicated), Hawaii, Galapagos... ▶



An example of the representation of the various stages of island cycle, in this case for the Madeiran and Canarian volcanic provinces. Color version of the image from the paper "A reconstruction of Palaeo-Macaronesia, with particular reference to the long-term biogeography of the Atlantic island laurel forests", J. Biogeogr. (2011), 38, 226-246. Special thanks to José María Fernández-Palacios, and Robert Whittaker, for the authorization to use this image.

The simplest way of describing this is as a conveyor belt: the plate moves over a hotspot in the mantle, the hotspot is producing magma plumes which build up and create an island poking above the ocean surface - and don't forget the oceans are really deep when you get to the middle of the Atlantic! [laughs] Then, over time, the plate continues to move and takes the island away from the magma plume. The island eventually begins to erode and it also sinks because of the weight of the mass on the crust, and then another island is forming behind it over the magma hotspot. So you've got a sequence of islands forming, moving away, eroding and subsiding. They go through a life span, to which we've given the label ontogeny: it's a technical word, but it just means that they go through birth, maturation, and then senescence - they disappear.

Our model simply put those three things together and generates some new predictions. And I think what is proved interesting about it is that it has pulled together people who are doing research in both ecology and evolution. Because we're making predictions that you can test through looking at distributions of species on islands but also by looking at the evolutionary lineages. ▶

Can you explain your model, the General Dynamic Model [GDM], in more detail?

Well, the model says this: when an island comes out of the sea, to begin with it's a bare volcanic cone, so it takes time for species to build up an ecosystem. Initially the rate of immigration from an older island nearby will be quite high, and it declines through time because there aren't many species in that area nearby, on land. Processes of speciation start taking place to fill the vacuum, and diversity increases.

But islands can only support so many species. There's a limited amount of area, of diversity of habitats and nutrients, so you can only have so many individuals and they have to be distributed accross all the different species that have arrived and evolved. So there comes a point at which the island starts to decline and come back into the ocean, and the extinction rate - which we already know is largely linked to how big the island is - is going to go up. At some point the diversity must reach a peak and start to decline again, and as it declines the space for new species to be created through speciation becomes more and more limited. So, it's really predicting in its simplest that species and diversity of the endemic forms follow a very simple pattern. And lots of other things we can test follow from that.

Can you give an example of a particular case that has already been studied in the perspective of the GDM?

Yes, the GDM predicts that the proportion of species that are endemic to a single island should show a hump-shaped pattern over time. And tests for the Canary islands and for other archipelagos like Galapagos and Hawaii show that this model predicts the data very well. We also expect that, on the whole, species that arrive earlier in an archipelago will diversify and move down the island chain. Each time they reach a new island there's an opportunity to speciate, and on older islands speciation rates should slow down. And this has been looked at in a number of studies of evolutionary biology.

While I was researching for your interview I read in a biographical sketch of yours that you have "a thing for islands". Were you always interested in this research area? What interests you more on islands?

Well, I was always interested in ecology. But I guess my starting interest was the Galapagos' finch example in highschool: something that really grabbed my attention that was island specific. Then, while I was at the university, I had the opportunity to join part of an expedition to go to the Krakatau islands in Indonesia. They're very famous because in 1883 they had a huge eruption there, which displaced about two thirds of the land area into the sea and unfortunately caused a large tsunami wave. About 35 000 people were killed. ▶

This huge natural disaster attracted a lot of scientific attention. Within that, biologists started surveying the recovery of the ecosystem and it became a test system for MacArthur and Wilson's island biogeography theory. So I went as an undergraduate on an expedition to re-survey the plant diversity, to see if it fitted the prediction of what should happen over time. And that really spanned my interest in islands. Afterwards, after I had graduated and done my PhD (which was on arctic alpine succession) and got my first academic position, I and some of my colleagues from my undergraduate expedition decided that we needed to go back and finish the job, do some more research there. So I worked on Krakatau for many years: from 1979 through to 2002. Then, around that time, I felt I needed to be doing something that was less hard on the knees [laughs] and branching out into a broader view.

In fact, I wanted to know how did my system fit into island biogeography theory. I ended writing a book about island biogeography [Island Biogeography: Ecology, Evolution and Conservation, 1st edition dates of 1998], and when you do that you realize there's always unanswered questions. At some point, I got to know particularly José María Fernández-Palacios, who's in La Laguna University in Tenerife, and Paulo Borges, from the University of Azores, and we began to work together. Paulo Borges has this wonderful research line based on studying invertebrates of the Azores and I began to collaborate on that, and with José Maria Fernández-Palacios I began to work on the Canary Islands. In time, all this led to a number of research interests, and amongst them was the General Dynamic Model, which we stumbled upon as an idea.

You mentioned that in the process of writing one of your books you stumbled upon several unanswered questions. To wrap up, I was wondering: what do you see as the next challenges on this area, some of the most challenging unanswered questions?

There are lots of hugely interesting questions in island biology. But really the most pressing questions are how to look out after the island biodiversity we've got. Island species and ecosystems face many threats and pressures due to habitat change, land use transformation and interactions with species from other parts of the world that have been introduced to the island. Now, over the next decades, climate change and all of these factors are driving species populations down and endangering many island endemic species.

So, the biggest challenge is working out how to conserve island biodiversity and, to do so alongside the needs of human societies living on islands. They need to have a sustainable economy, good living standards and so on. They need to use their limited resources for other purposes than just creating nature reserves. There's a lot of challenges there, and I think those challenges are the most important ones that island biologists need to keep in mind. It's great to work on pure science questions, which I do most of the time, but it's really important that we also think about how to work with politicians, how to encourange island people to learn about their biodiversity and to understand why it matters to them. ■

FROM SPIDERS TO ARTIFICIAL INTELLIGENCE

Pedro Cardoso

Most people are afraid of spiders, or at least don't mind not having a close encounter with them. But this is not the case of Pedro Cardoso (Finnish National Museum of Natural History; cE3c), who works for several years on arachnids – or, on his own words, "spiders and something else".

Recently, Pedro Cardoso also began to develop a new and surprising research area: the application of Artificial Intelligence to Ecology. As for his motivation, it has always been the same: to work on something different, in which no one else was working.

Why spiders as object of study?

It was...almost by chance. During my university degree I didn't know which group I wanted to study, but I knew I didn't want to do the same as everyone else. To study birds, for example, would be to follow the herd, or to study mammals and do the normal work on the diet of the otter: at that time there were at least 3 or 4 projects each year about the diet of the otter.

I knew I wanted to do something different from everyone else. And spiders were not studied in Portugal since the 1940s - by Professor [António de] Barros Machado, the last Portuguese arachnologist. Eventually he was asked to leave the country by the regime of the time, being anti-regime he was basically deported to Angola. So, for more than 50 years no one did anything with spiders in Portugal. I ended up going that way, I saw there was much to do and I thought I was going to do something nobody was doing in Portugal.

And then you continued.

And then I continued, yes. Then I discovered that spiders are an excellent object of study, they have many advantages over other organisms...

Advantages in what sense?

They are relatively easy to identify compared to other diverse taxa such as Coleoptera and Diptera. They are also relatively easy to collect in the field. Being predators they have many unique adaptations, the best example being their webs. They are quite fascinating and allow us to address some issues that cannot be dealt with using any other organisms. So it turned out to be the ideal object of study, and it still is. ►

Currently your interest in spiders is part of a more general work that you have been developing on the conservation of invertebrates. What are the obstacles to their conservation?

To start with, we have the political impediment: politicians may even know what a bird or a mammal is, but an invertebrate, an insect, is...something to kill. As for the public, unfortunately it is commonly a purely cultural obstacle: people are afraid of spiders, or think that insects are pests, just useless. They do not realize how much diversity exists and its importance.

Then we have the scientific impediment. After all, it is scientists who decide where the money goes [for research] and they decide that the money should all go to vertebrates. There is a significant lack of culture in the scientific community; oddly enough, it is one of the biggest obstacles.

And then there are, of course, all those [impediments] that are inherent to the lack of knowledge. We don't even have an idea of how many species exist globally. Even in Portugal: we don't have the slightest idea of how many invertebrate species are there. Globally, it is said that is anything between 3 and 30 million. [laughs] It's an order of magnitude, isn't it?

Exactly! [laughs] I read an estimate that invertebrates represent about 97% of animals; for me that was a surprise.

Yes, yes. In Portugal, for example, we do not have any idea of how many species of insects there are. We have a vague idea of what was already seen, but the truth is that even in Portugal we can manage to find a new species of spider, which are the ones I know best, in one hour. Not a new species for Portugal, but a new species for science!

Really?

In one hour, yes. Someone knowing how to do it can find a new species for science in one hour. So, when we talk about species conservation policy, we are in fact talking in a void.

It is a whole world to explore...

We have no data. This is the first obstacle, we don't even know which species we have. The second obstacle is that even those that are already known...we don't ►

know where they exist. For several species there is a single record and it hasn't been seen again - but it was not searched for again, also [laughs]. Then, we don't know what their sensitivity to changes in their habitats is. For some species that have already been studied we do have a pretty good idea. One example is for the Azores, which in Portugal is the best studied region by far, and thanks to the efforts of Paulo Borges. But globally we do not know which species are sensitive to habitat change or whatever. Also, we don't know how the populations fluctuate in time and space. If we don't even know where they exist, we can't know how the natural fluctuations of populations are.

As part of your research work you propose changes to the criteria adopted for the preparation of the IUCN Red List [International Union for Conservation of Nature], so that they can be applied to invertebrates. Since there is much still to be explored on invertebrates...what changes can be proposed?

Four of the five IUCN criteria are based on the number of individuals of a species, of populations. And we never have this data for invertebrates. So many of the changes we are proposing intend to use the distribution areas and with that try to create alternative criteria that correspond more or less the same in terms of effective population, so that we can classify our species with the data we do have.

Can you give an example?

For example, one of the criteria states that a species is classified as critically endangered if its effective population has decreased by 80% or 90% (it then depends on other factors) over the past 10 years or 3 generations. But we never have this data. So the idea is to use data on habitat decrease instead. The decrease in habitat area will never be these 80% or 90%, theory says that in fact, to lose 80% or 90% of the effective population we just have to lose...I'll make up numbers because we don't know yet, but for example we might need to lose only 50% to 60% of the habitat area. It is these numbers that we are trying to find out.

First spiders. Then invertebrates. Now, more recently, Artificial Intelligence. How did you become interested in this area, and how can Artificial Intelligence and Ecology be combined?

Again, the interest arose because no one was working on it. [laughs] ►

...it's a good reason to start! [laughs]

Ecological systems are extremely complex. Physical systems are already complex; even so we manage to deduce laws that allow us to make predictions for the future. Of course, then there are chaotic systems, such as weather, but in any case we already have ways to predict the future. For ecological systems we can't do that yet, we are far from it. There are too many variables and interactions to be taken into account. Usually we are talking about hundreds or thousands of species interacting, exchanging energy in different ways... It is a complex system par excellence, taken to the extreme. That is why we often can't understand these systems. On the other hand, we cannot predict the future: we can't predict how the species will behave if we destroy a given patch of forest, for example. Not only we have few data, we also don't have the necessary tools to analyze it.

Artificial Intelligence comes precisely to automate this process. The area in which I am working intends to take data and make sense of it without us having to give any particular input. That is: usually what we do is to pick up certain data, sometimes we have an idea of which are the most important variables and we forget all others, and we make some linear regressions, very simple things. Yet nature is not linear or anything like that. What this aspect of Artificial Intelligence - genetic programming - does is to try to find out what kind of relationship exists between the different variables, evolving the shape of functions with the data. Genetic programming allows to find out what are the shape and parameters of the relationship that best fits the data. Our task is to check if this result makes sense.

That should require great computational power...

Yes, ideally one should always use a cluster. This is a very recent area, I was the first one to propose the use of such methods in Ecology, so I am still developing it. To top it off, because this is very new, it is not well accepted by ecologists, so I am basically doing this without funding.

And finally: in your opinion what may be the consequences, good and...not so good, of introducing Artificial Intelligence not only in Ecology but in all kinds of tasks in any area?

That's a good question, not answered in any area. Everything indicates that in 15 to 20 years we will have computers with a capacity equal to that of a human being, including for things we think as unique to us, such as intuition. There's even a case already of a computer that creates and tests hypothesis by itself in some biochemistry experiments. From here to start writing projects and articles...we are talking about 10 to 20 years. ►

There are already people - including Stephen Hawking and Elon Musk, for example - that are beginning to warn of the dangers and saying that we need to create regulations for what can be done with Artificial Intelligence. Google has one of the most advanced neural networks, which for example deals with the automatic recognition of photographs among many other functions we do not have access to. The efficiency of this network is already very close to a human in this particular task, and Google is creating a sort of switch, an emergency button to stop the neuronal network if something goes wrong.

In fact, in this past year there have been many publications on the dangers of Artificial Intelligence. For now the strongest fear is that it will replace 50% to 70% of existing jobs. But I don't think it will be so soon, I would say it will still take 20 to 30 years until the most advanced systems are able to overcome a human. ■

"WE CAN LEARN FROM ISLANDS THAT IT IS NOT A LOST CAUSE TO THINK ABOUT CLIMATE CHANGE AND ADDRESSING WORLD PROBLEMS"

George Roderick

Do you think it is impossible to create a detailed digital replica of an island's entire ecosystem? Well, think again. The Island Digital Ecosystem Avatars (IDEA) Project is assembling an international group of researchers to recreate the entire ecosystem of Moorea, an island of volcanic origin in French Polynesia and one of the most studied ecosystems in the world.

George Roderick (UC Berkeley, USA) is currently working on the IDEA Project, which allows him to pursue his research interests in biological invasions, the history and structure of populations and sustainability and global change. But this is only one among his several research projects, which take advantage of the opportunities associated with the geography of Pacific Basin, Pacific Islands and Pacific Rim, including California.

You're currently working on an ambitious research project, that at a first impression can almost seem like science fiction: the idea of being able to recreate in a virtual way the whole ecosystem of an island. Can you please explain what is an island avatar and how did this idea first come up?

As you know on Earth we're faced with many challenges, especially having to do with global change and globalization. Some of these are related to positive developments related to human well-being. But, associated with that, changes are happening: in temperature, sea level rise, ocean acidification, land use, CO_2 in the atmosphere...all kinds of things. And it's hard to get a handle on how these are connected, what factors contribute to these changes and what can we do about them.

Islands are well-defined ecosystems, and typically there's a lot of work on them by researchers with a very place-based focus, who are approaching different problems. Moorea is one of these places, where people work in coral reefs, anthropology, agriculture, medical health-related things... Because islands are well-defined, it's a small group of people who run into each other all the time, and it's a perfect place to think about connections between disciplines.

The idea is also to understand how what's happening in these different ecosystems is affecting other ecosystems. For example: how does what happens in the coral reef ecosystem affect how people live? How do climate change and changes in land use affect the people? And how does that affect the run-off that eventually ends up in the ocean and affect the coral reef? On islands, like any microcosm, you have the chance to model these interactions and figure out how they are connected. I agree it sounds ambitious. The name [of the project, IDEA] is somewhat catchy, I suppose, but it does convey this idea that it is a representation of the connections between these different disciplines. We can't do everything, but we're trying at least to understand how what happens in the terrestrial ecosystem affects the marine ecosystem and vice-versa, how what happens in nature affects the society, and so on.

And what makes islands the best models for this is their confinement, right?

Yes. Well...in fact at this meeting we had a big argument with physicists about whether islands are closed or open systems. For example, you think of Earth as open with ▸

respect to energy, because the [energy from the] Sun comes in and heat goes out, and pretty much closed with respect to matter, because except for satellites and meteors there's not a lot of movement in matter. So, similarly, we finally decided that yes, islands are open in the sense that they are connected to the real world, but they are somewhat confined and certainly their flow of materials is limited.

Another thing is that islands tend to collect in the same location people who are approaching different questions and doing different kinds of work. All these people, whether they are astrophysicists, climate change biologists or anthropologists, they are all interested in what happens on that island. And Moorea isn't unique in that regard. Hawaii, the Canaries, the Azores, and so on, in any of these locations there is a lot of focus-based work going on.

Another cool thing about islands is that they're small, which means that you can describe all the species. And there is a limited number of people, so the economists involved think they can actually make a model where they incorporate the activities of every single person. On Moorea they're 17 000 people, and many islands are even smaller.

When we go to the project's website, at a first glance the Moorea avatar almost seems like a Google Earth representation. But it has another dimension - time. So, how does the website work, what can we find?

To start with, it allows you to fly over Moorea. They took images from a couple of satellites so they could recreate the three-dimensional idea, and they sort of modelled all the houses and even some of the trees, things like that. As for the coral reefs, they flew over with drones and used other kinds of sensing to try to get some understanding of the ocean depth.

So, part of that is just to have a platform where you can connect observations spatially. And then you can look at that over time. But the real point of the website is to bring together people who are studying different things in different ways. We haven't realized that yet, it's not complete, but at least it's a start to get people who otherwise wouldn't talk to each other, in science or social sciences, to interact.

So it's an ongoing project, with a lot of work ahead.

Yes. And we're still looking for really large funding. The idea and the things we have done so far are based on grants that people had for their own research, or smaller contributions. The project really isn't funded yet and that's something we are working on. ►

I should say we're not the only ones to do this kind of thing. There are a lot of places, like the Azores and Hawaii, where there are sets of researchers that are working together with similar purposes. I think that in terms of our research and student career and opportunities there is a lot to be said for understanding the connections between different disciplines, and especially between science and the humanities. These are disciplines that have very different cultures, and they go about finding the truth in different ways. We don't even have the same language to communicate what we do. So I think there is a real chance here: when different kinds of people are focused on one place and they care about it, it makes it easier for them to communicate. That's a big challenge.

The other big challenge is communicating with the public. I think that we as researchers are really the ones with knowledge to provide solutions, and to do that we need to communicate with people that don't have our training and speak a different language.

You also work with the local people. Do you notice that the project has an impact on them? Do they become more concerned about biodiversity conservation, for example?

Yes… I know mostly about the people of Polynesia, but this is probably true for people who live on islands everywhere. Their livelihoods are very dependent on what happens on the terrestrial and marine ecosystems. Everyday they're fishing, or farming or dealing with tourism, so they're very connected to what's happening in the real world and they have a very strong interest in this.

Also, I think that science has gone one direction and the cultural understanding of the environment has gone in another, and only recently there have been attempts for scientists to do outreach and to really listen to the people who have generations of understanding of these organisms and environments.

For example, we had a school project on Moorea called the EthnoCode, in which the school kids identified plants that were important for their environment and had to do a report on it. They came to the research station and talked about it, and DNA was gathered from the plants and put into an already existing database, with all the other organisms from Moorea.

There are also projects where the local people come and talk about their observations and how they view these organisms with the scientists. We had a big outbreak of *Acanthaster planci*, which is a big seastar that was eating up the corals. There was a lot of concern, but it turns out that these outbreaks happen every 25 or 30 years. People get very worried about it, but eventually it goes away. The ▸

local people and the community had some experience with this in the past, in fact they could even identify when an outbreak last occurred, so they were not as concerned. And that's just one example.

On many islands there is a set of marine protected areas where people can't fish, and creating those takes a lot of interaction with the local people, because they're giving us immediate resources for potentially better resources in the future. So understanding that, and making that work, takes a lot of interaction.

I read that in Moorea there are more alien or introduced plant species than native species. Is this always the case, in other islands and groups of islands?

It's not always the case: a lot of it has to do with the extent to which there are urban areas and agriculture. Another big factor is the extent to which islands were colonized by people. At the lower elevations, on most of the islands in the Pacific (including Hawaii) all the vegetation is largely introduced. Before the Europeans came there were lots of people on most of these islands, and they had a big impact on the vegetation and the ecosystem in the lower elevations; not so much in the upper elevations, which were harder to get to - but also, you couldn't easily farm them.

In fact, they had these *tapus* - *tapu* is a Polynesian word [the English word taboo derives from it] - for not going into the mountains, especially at night.

Anyway, at the lower elevations the vegetation on all these islands looks the same: very pretty, but exotic (introduced) - it comes from elsewhere. Some things, like coconut, have probably been there naturally, but many of the plants have been introduced. We don't really have a good handle on what the low land vegetation biota was before people came to the islands, although there are some projects where anthropologists are digging in the ground to find deposits of seeds and animal parts below the level where humans first came. When humans came there is a signature of carbon: there's a lot of burning, and they see organisms like rats and chicken - that were introduced by humans - and different kinds of fish, because people were throwing fish bones around after they ate them. But below that, you can find seeds and native organisms. And then in some caves there are bird parts, so for some of these groups we have a pretty good idea of the organisms that were there before humans.

On this point, there was a study done by Dov Sax, looking at many islands in the world, that found that for plant species there were more exotic introductions of plants than there had been naturally. And for bird species it was about equal. Many of these islands have a biota that is largely introduced as well as native. And in the marine system there are far fewer endemic marine organisms proportionally, compared to ►

the terrestrial system – the level of endemism (species found nowhere else) is much lower in marine systems. But even in marine systems there are a lot of introduced species, like different kinds of algae. So introduced species are a big deal.

And I imagine that on islands the impact of these introduced species is greater.

Yes, people debate that. Daniel Simberloff has written papers about whether the impact is, in fact, greater or not. Certainly I think we see the impact more easily, because there are lots of people who are observing these things and there are fewer species on islands. But he and others have argued that the impact could be just as great elsewhere. In any case there is definitely a great impact of invasive species on islands, and it's easy to observe and measure.

To summarize: which lessons can we draw from islands to live more sustainably?

I think the first is that everything is connected. And we see this on islands very plainly. It may be that in continental systems the ecological, social and cultural connections are more complex, but...everything is connected, in ways that we are really just beginning to understand. So when there is more or less fishing...that affects the economy. And when people get sick, that affects how much they are fishing...all these things are connected. When we are flying in airplanes, when we are choosing to eat certain kinds of food, whether you are choosing to eat meat, or vegetables, all these decisions have an impact on Earth.

The second thing is that we can learn from islands that it is not a lost cause to think about climate change and addressing world problems. We can see on islands that when we create marine protected areas, for example, the fisheries come back. When people set up reserves and keep ungulates and pigs out of areas, the ecosystems recover. So, I think we can take from this research a message of hope, that we can have an impact. Maybe on islands we see it more easily, maybe it happens in weeks and months, not a lifetime, but I think it does provide these lessons to the public that it is possible to change the trajectory of what we're doing.

And I think the third thing is that islands are permanently under stress. There's sea level rise, climate change, the way of people's livelihoods is being impacted, effects of globalization, invasive species...and so on.

Everything's connected, islands give us hope for being able to change things in the future, and islands are in serious trouble. They are systems that need more efforts on conservation. ■

"I THINK IT IS A GOOD TIME TO BE A BIOGEOGRAPHER"

Isabel Sanmartín

What is more determinant for the geographical distribution of a species: its dispersal, or the geographical barriers it encounters? The answer is far from straightforward and represents an ongoing debate in historical biogeography, to which Isabel Sanmartín (Real Jardín Botánico de Madrid, Spain) dedicates her research.

An enthomologist that started working on botanics along the way, in this interview Isabel Sanmartín talks about her work of reconstructing the past by using data about the present distribution of species, and reflects about the main trends and challenges she sees for this research field in the near future.

In your research, you use data about the present to try to reconstruct the past. Is it fairly correct to say that you are, in a certain sense, a historian of Nature?

That is a nice definition. That's the main difference with the other side of biogeography, ecological biogeography, which deals with the present and what we see now. They are more interested on explaining current distributions and maybe predicting where they may be in the future, whereas we look into the past.

That must be a challenging task, because you deal with very large time scales. What are the tools you can use to get that knowledge about the past?

Basically we use phylogenetic information. We have the present distributions and the phylogenies - the evolutionary relationships among taxa. In the past we use morphology-based trees like cladograms, and now we are using DNA to try to reconstruct those evolutionary trees. Those are the basic datasets we use. Recently we have also added new sources of information, as fossils or geology, and even paleoclimate.

So, historical biogeography joins together many different research areas. It does require a lot of communication between scientists of these different areas, right?

Yes, that would be the idea. But I will say that that has only come to be realized recently. In the past, for example, we didn't have much contact with paleontologists, so there was not a good link between the two sides, even though they also try to understand the past. But right now I think there is starting to be a good bridge between the two disciplines. And as you mentioned before, we, historical biogeographers, deal with long time scales; and as we go deep into the past, we have less and less data, so we are more reliant on paleontology.

What can be considered more important to determine the geographical distribution of species, if we can say it that way: is it the dispersal of a given species, or the geographical barriers that it encounters?

That is a big question in biogeography! [laughs] That's the basis of the heated debate between dispersalists and vicariancists [supporters of the formation of the geographical barriers as the main factor to determine the geographical distribution of species], and the focus has changed over the last few decades. In my view both are equally important: it depends on the group you are studying, on the time-frame, and the type of question you want to answer. For example: if you are dealing with an ancient group that evolved over periods of millions of years, you need to consider the effect of geology and plate tectonics on geographic distributions, such as plate collision or the opening of new ocean barriers. In other words, the geographic template you observe now is not what it was in the past: the continents were not where we find them today. But if you are dealing with more recent temporal scales, then you need to consider dispersal over ocean barriers as a possible explanation. And in my case, that I work with plants, dispersal is a very important process and shouldn't be dismissed.

Why have you chosen plants in particular as your object of study?

That's a long story! I actually started as an entomologist [laughs]

Oh, it's a long way! [laughs]

Yes, is a long way! I did my PhD thesis on a group of beetles that were feeding on plants, on olive trees. This group was Mediterranean, so while studying its spatio-temporal evolution I became interested in biogeography: that was the starting point. Later on, when I moved to Sweden I began working with botanists: because I was coming from the animal background, and dealing with ancient groups, I found it really interesting to go to the other side and work with more recent plant lineages. Plants, in general, are better dispersalists because of the seeds that can be moved around by winds or ocean currents, so I found that dispersal was more prevalent in plant patterns than in animals. It was kind of a challenge for me to address this, and later on, because of family and work-related logistics I ended up working on plants at the Real Jardín Botánico in Madrid. But I am not a botanist by training.

From the biogeographical perspective, do plants and animals behave differently in dispersal and in entering a new habitat?

Yes. I mean, it is probably a bit of a generalization, but it's something that I found interesting when I started working on biogeography. In 2001, I wrote a paper [Sanmartín et al. 2001] on the biogeographic history of the Northern Hemisphere, which was based mainly on insect distributions, and the patterns I found were very congruent, they matched very well the geological history of the Holarctic continents. Then the study was later repeated in plants by some American botanists ▶

[Donoghue & Smith, 2004] and they found somewhat different patterns, which could be explained by more recent dispersal.

That was the starting point of the idea. A few years later I repeated my study with the Southern Hemisphere [Sanmartín & Ronquist, 2004]. I compared animals and plant phylogenies, and I found again that animal patterns showed a good match to plate tectonics. But in plants dispersal was more prevalent: many of the patterns could be explained by later dispersal crossing ocean barriers. So the idea came: Do animals move less often but once they are in place they change and evolve [giving rise to new species]? Plants, on the other hand, are more easily moving around, so they tend to reflect more recent patterns because the signal of plate tectonics on their distribution has been obscured by long-distance dispersal. On the other hand, plants are more dependent on the environmental conditions, once it arrives the seed needs to germinate in the rigth soil and temperature. That's a generalization that needs to be tested properly, and one of the ideas behind my current work.

One of the questions to which you have dedicated your research is why is there an increase in overall species richness as we more from the poles towards the equator. What are the conclusions you have reached concerning this question?

Yes, that pattern is called the Latitudinal Diversity Gradient [LDG]. It is not my idea, it has been discussed and studied for many centuries. The LDG pattern has mainly been addressed from an ecological viewpoint, but more recently it has been studied by historical biogeographers like me.

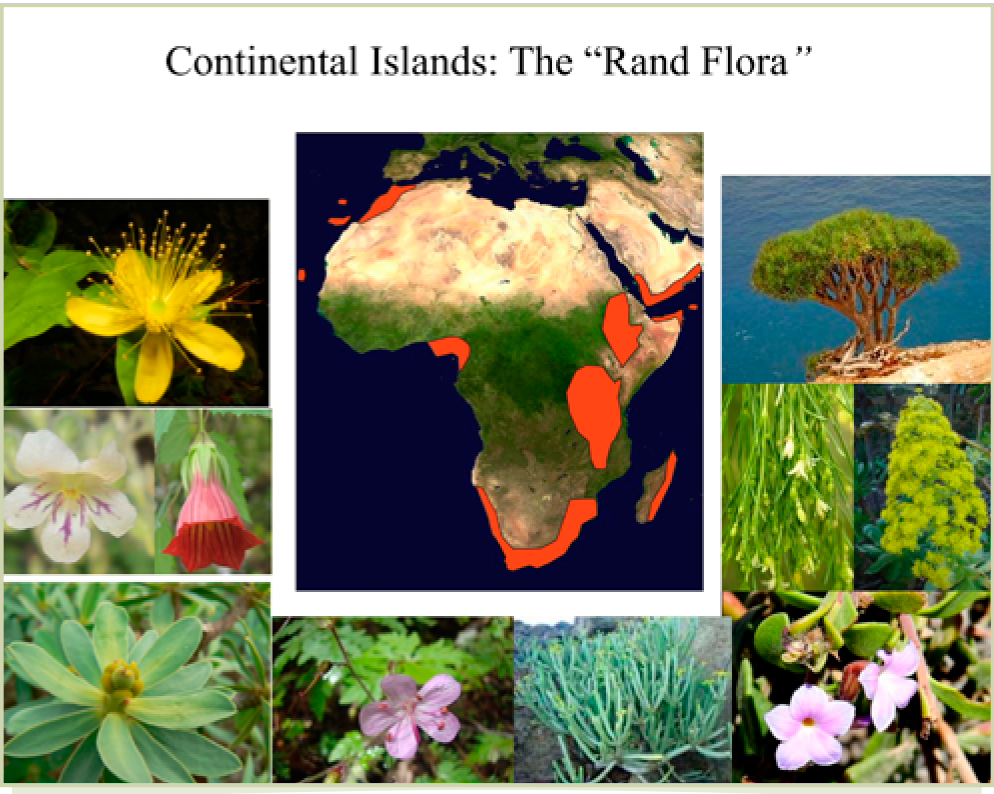
The main conclusion is that there is no conclusion. There are many different underlying explanations. One of them is of course ecological: there are more species in the tropics because of higher environmental stability close to the equator, higher precipitation and temperatures favoring larger ecosystem productivity. But other explanations are historical or evolutionary because, as I said before, the position of the continents in the past was not as we observe them today, so maybe they have not been always climatically stable. One evolutionary explanation is that many groups showing this pattern originated in the tropics and only recently moved into the temperate regions; so, because of the time-to-speciation effect, you expect to have a lower number of species in the temperate regions than closer to the Equator. But even this explanation has been challenged: there is conflicting evidence just showing the opposite pattern, some groups are actually more diverse in the temperate regions than in the tropics and they are also ancient. ►

So it is still an open question.

Yes. I think it must be addressed both from the ecological and the phylogenetic or evolutionary viewpoint. Climate and environment are important but, as I mention, we live in a dynamic Earth, in which geography and climate have changed over time, and you need to take into account those dynamics when you're trying to make inferences about what you see today.

Another evolutionary puzzle to which you have dedicated your research is centered on a continent: the Rand Flora in Africa. It consists of plant species that are related but distributed only in the rim of the continent, right?

Yes. We call it the "Ring Flora", because the pattern resembles a ring, with species distributed in the margins of Africa, leaving the center of the continent "hollow". The name actually comes from the German word "rim" or "edge". As you just said, it is a pattern relating different families of plants, angiosperms or "flowering plants" -, and that's what is exciting about it: these families are not closely related (for example, geraniums, bellflowers, and so on) and yet all of them show a similar pattern of distribution in which a species is present, for example, in the Canary Islands and the sister-species lives in the Island of Socotra, on the other side of the continent. Other species are endemics to the Ethiopian Highlands, in the distant Eastern African mountains, and some to South Africa.



Courtesy of Mario Mairal & Isabel Sanmartín.

And is there already an explanation for the origin of this pattern?

As always in biogeography and biology, there is not a single explanation [laughs]. The traditional theory is that the pattern was formed by climatic extinction. There was an ancient flora living in Africa around 50 million years ago; then, as Africa broke up from the rest of Gondwana and moved towards the Equator, the continent underwent an aridification process that probably led some plant taxa to extinction. So what we observe today as the Rand Flora pattern is the remains of that ancient flora, relictual groups that live in the margins of the continent because those areas are climatically more stable for these plant lineages.

But that is the traditional hypothesis, and what I want to test. Another hypothesis is that the pattern was formed by more recent long-distance dispersal among those regions. One of the aspects that attracted me on the Rand Flora pattern was the idea of large-scale extinction, that is, extinction that takes place at a large spatial (continental) and long temporal scale, because the aridification process in Africa is still going on.

It is still necessary to compare and investigate the two explanations.

Yes. Going back to the Latitudinal Diversity Gradient: one explanation that hasn't been considered in enough detail is extinction. Extinction is generally a process that hasn't been given the importance it deserves in biogeography, basically because it is so difficult to study: there is no evidence of extinction in the phylogeny [the species that goes extinct leaves no trace]. So, one aspect I am addressing with the Rand Flora project is whether we can find the phylogenetic signature of extinction in those groups, and develop analytical tools to infer climate-driven, large-scale extinction. In this case, extinction does not affect only one species or family, but a whole biota formed by families with different ages, origins, and morphological adaptations. It is challenging; we don't know yet how we will do it, but it is something we aim to.

I see that you are very enthusiastic about your work, and you are also actively involved in communicating it to the public. Do you find obstacles when you communicate your research to the public?

I will say that I am not really very good in communicating, because I struggle to find ways of making my field attractive. I think that we, as scientists, are not really well-trained on communicating our research, on what we call educational outreach. That's something I try to do, but I won't say that I am really very active. I have written over the years several general-scope papers to introduce my field, and that was because I felt that there was not a good review paper summarizing its main achievements and challenges. Biogeography is a synthetic discipline, which has grown very fast in the last decade, and you need to be very active to catch up.

To summarize: what do you see as the major trends for historical biogeography for the near future?

What I see as the most exciting avenue for the discipline is the integration of different sources of information in biogeographic reconstructions. As I mentioned, in the past, we could only count with the phylogeny, the evolutionary relationships, and the geographic distribution of taxa. But all recent developments aim at integrating other data, such as paleontology, the fossil record, paleoclimate reconstructions, geology and plate tectonics, and that is because in order to understand the present you need to consider the past. We have been generally quite narrow in our view of biogeography. But this is slowly changing...

So, greater and greater integration of knowledge.

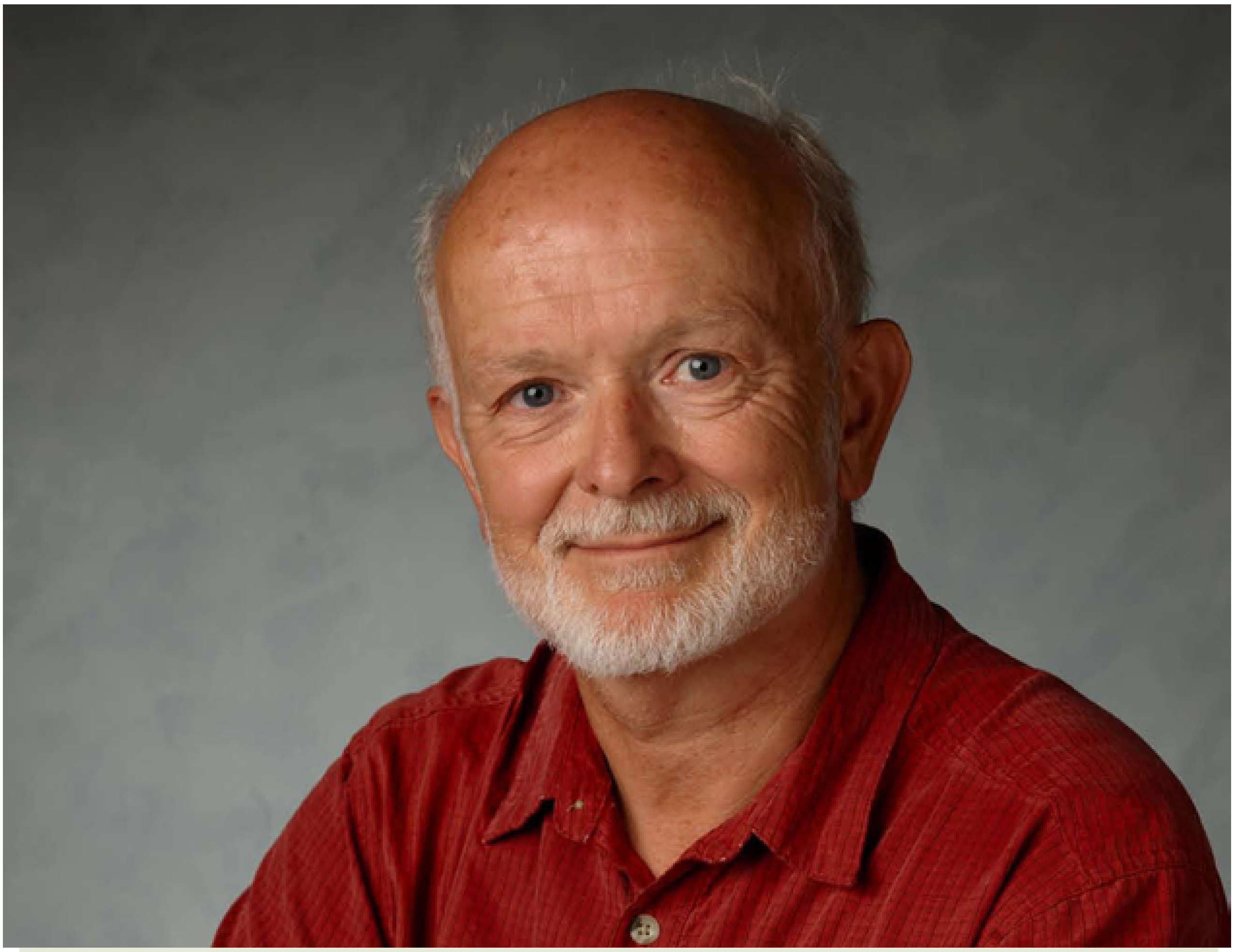
Yes, greater and greater integration. And for that, we need more sophisticated analytical tools: it was only with the advent of probabilistic models in biogeography that we have been able to do this integration in a more analytical way. This has been actually very important for moving forward, but it has not been available until recently. You know, the birth of probabilistic biogeography has been in the last 10 years, so it is a very recent discipline.

I would like to leave an invitation to biogeographers for a better integration among disciplines, especially between ecological and historical biogeography, but also between the latter and paleontology. There is a late trend towards more integration, but maybe we need even more and it must go in all directions. For example, we [phylogenetic biogeographers] have typically focused on the spatial (migration) aspect, dispersal versus vicariance, but have been quite ignorant about the importance of considering the ecological side, such as as adaptation to the environment by evolving new biotic traits. On the other hand, I think for ecological biogeographers there has been too much focus on predicting the outcomes of climate change using only extant distributions and current environmental conditions. Since climate and geography have changed so dramatically over geological history, we should consider that maybe the group has undergone climate change in the past and developed some kind of evolutionary resilience, which might help them to cope with current climate change. And genomics is another aspect that I would like better integration in biogeography; it provides the link between adaptation and evolution, how genes function and evolve.

So, exciting future ahead!

Yes! [laughs] I think it is a good time to be a biogeographer. ■

HOW CAN NETWORKS HELP US TO BETTER UNDERSTAND ISLANDS?



Jens Olesen

Networks surround us in every aspect of our lives. Social networks, transportation networks, power grids...there are innumerous examples. And of course, networks are also an invaluable tool in Biology.

Jens Olesen (Aarhus University, Denmark) is interested in looking at islands in their entire complexity by studying the networks of interactions between the species that live on them. What can we learn with this approach, that we cannot learn by studying individual species? Which predictions can be made?

In this interview Jens Olesen talks not only about this interdisciplinary research area, but also about interesting patterns he found while studying species interactions in the Galapagos Islands, and the (exhausting) experience of organizing an International Biology Olympiad.

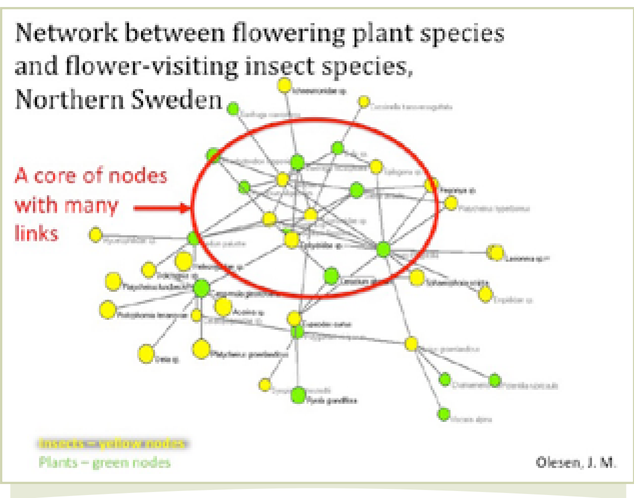
Right now we are using a network to have this interview - the Internet [the interview was conducted via Skype]. But networks are everywhere, right? Can you give us a more concrete idea of the different kinds of networks that are present in our lives?

I think social networks were the first kind of networks to be studied. When I give public lectures I often use them as a reference, because that makes it much easier to understand others that might be more abstract. On social networks you have interactions of all kinds - friendship, family, colleagues, political parties, and so on - and you can identify the links in many different ways.

In the 1950s and 1960s sociologists were already studying social networks, but only small ones. Now we have big data, for example mobile phone networks and Facebook, and many scientists are now using huge social networks. I take these concepts and software and bring it into Ecology.

There is that popular saying that any two randomly chosen people are connected on average by 6 degrees of separation. Does it really work that way?

Yes...more or less. [laughs] It's the average. Of course there are longer and shorter paths between people, and it's an old expression too. In the 1960s there was an American sociologist, Stanley Milgram, who was asking that question - "how close are we to each other?". He did an experiment with a chain letter, and it turned out that the answer was 5.5 in US at that time. But now many people would say that the 6 degrees of separation is global.



Let's imagine, for example, my distance to another random person in the world. I know somebody who knows more people than I know, and that person knows more people than that person...you go to the core of the social network, where you have people with a lot of connections, and then you go to the periphery again. That's the way it is always organized: many people with few links, and a few people with many links. It's the heterogeneity in it that makes the distance so short. ►

Nowadays we are more and more connected, so maybe the 6 degrees of separation figure is shrinking?

It is difficult to know, but I think it will be shrinking. For example: you see kids playing on the computer and they don't care if they are playing with somebody in Coimbra or in New York, because for them geographic distance does not exist anymore. We are on a transition: of course we know our neighbors and our friends and they live close to us, but we also know somebody far away. It's a transition from an old and maybe medieval situation, when you only knew somebody in your close neighborhood, and the future in which you will completely ignore geography.

Since we are increasingly more connected online, do you think that will affect our abilities to socialize with people? Will that have consequences, of us being less able to empathize?

Sure, of course. That's a debate in this country, that kids are losing their social emphathy. But it's difficult to know, because you can also expect that people become more flexible and more able to cope with many kinds of links, for example. But I don't know the sociology literature, I don't know if that is the trend.

So it is an open question.

Yes, to me at least. Maybe there is somebody out there in the network that knows more. [laughs]

So, we have networks everywhere...including islands. Your research focuses on the networks of interactions between species on islands. What can we learn more about an island from this abstract perspective?

When I do a network study on an island, I am interested in the entire complexity of the island. Traditionally on islands, and also on mainland, people have been studying single species or a couple of related species and how they behave. Then, of course, the more data and software you get the more you're able to study more and more complex systems. And I think that one first step is to study islands. Because they are simpler systems - of course, compared to mainland -, they have fewer species, and it's possible to collect the data in the field. That means you can study the complete entity - island ecosystem or island network. You look at the big animals, plants, insects and so forth, and you can also include various kinds of links, such as predation, mutualistic links between species and so on. ▶

By using the appropriate software you can also start to look at emergent properties, properties you could not anticipate the character of if you just studied species A, B and C. Because there is a kind of self-organization in the system: you start having hundreds and hundreds of species and you cannot take a single species approach, you have to pull lots of data together and use network software. Then you can study if the network is more or less stable, if it is resistant against invasion, or how fast will it recover if a hurricane strikes the island or something like that. You can start looking at it as an entity, and I think that is what is really fascinating.

So species extinction, or the emergence of new species, creates new links. Will those links generate cascades or something on that network?

Yes, it does.

And this approach allows you to study it in a more global way.

Yes. Of course you can do computer simulations. You can have this interplay between adding more and more data, from more and more islands, and then you can start killing species - on the computer! [laughs] - or adding species, and see what happens to the properties of the entire network. All the time we have to make a reference to the real work, of course, but still, we can make the models more and more realistic.

But it's true when you say that we see these cascades, and it is very difficult sometimes to predict what is going to happen. For example: many islands have lost top predators, maybe instead they got human introduced predators. That affects some small animals, and that affects smaller and smaller animals and finally the plants - this is called a trophic cascade. It is really fascinating, but extremely difficult to anticipate what the outcome is.

That's very interesting. Also, with some of your colleagues you have invested a lot of time in studying species interactions in the Galapagos Islands. Did you find any interesting pattern? Do you want to share any interesting story about this emblematic archipelago?

Of course! First and foremost, it is true that they are very famous, and many scientists want to do work there. But to some extent they are, more or less, like other islands. One of the reasons to do the study there is that most of the islands are more or less outside, or have not had very much human influence. You have therefore islands that are inhabited by humans, and then there are the other islands which have either never been inhabited or are now restoring the damage caused ►

by humans. This makes it possible to look at islands in a much more pristine state, and from that point of view it is really interesting.

What we see there is that most species live on an edge of starvation. The species there are able to survive because they are very flexible in their ecology, they are very plastic. You can take an insect-eating bird that may suffer from lack of food and then, during some months in the year, they start eating seeds or visit flowers for nectar, or they even go along the beach and take small marine animals. So these animals survive because they are extremely flexible in their ecology, and that's surprising!

Scientists or ecologists, we think we know what we are going to see, and then we are only looking for that. And it becomes more difficult the older you get, because you think "I've seen it before". But when you go there and you try to be completely open-minded, then you suddenly see these surprising things.

There is always more work to be done there.

Oh, yes. That is for science in general, it is an expanding universe. One answer gives three new questions, and you get new tools...it is never-ending.

In the case of islands, it is difficult today to find pristine islands around the world. And by using network analysis you can look at the robustness and you can also see where are the weak points in the network where an invader could get into.

It is also important to study these networks from a restoration point of view, because that is also what is going on on the Galapagos. For example, last time I was there they had eradicated rats on a small island, and then of course you have to see what is happening afterwards. It's not always beneficial, even in the first decades, maybe because some other native species have benefited from invadors. It could be that rats were eaten by native Galapagos hawks, and when you remove the rats the hawks have to find other food items. You get a reshuffling of the native networks after you remove the alien elements, and that again makes it very difficult to predict the outcome.

You also said [on the plenary talk at the Island Biology 2016 congress] that you want to bring the sea back to island biology. What does this mean?

Well, it's been a kind of common wisdom that islands in the big oceans are isolated. And of course they are for land animals and land plants. But islands are not isolated, not in the sense that they are connected to the surrounding sea, and if the sea is very productive on the plankton and the fish and so on, it makes it ►

possible for sea birds to have huge colonies on these islands. And sea birds bring organic matter from the sea all the time. That input of nutrients is extremely important on many islands. So, it is this interplay between the land and the sea that has to be included in island biology models.

It will probably lead to new predictions.

Yes, I'm sure it will. For example: in the Galapagos you have these El Niño years in which the sea temperature increases and the sea becomes more or less dead, and then the mammals or birds that live on Galapagos and get the food from the sea stop reproducing, and many die. But in the same years you have lots of rain, and the land flora and fauna flourish.

Then, in between the El Niño years, it's the marine life that is flourishing, and the finches and all the other birds at the Galapagos stop reproducing at all. So it switches between years, it goes back and forth all the time. And this fluctuation between states is also found for many other islands around the world.

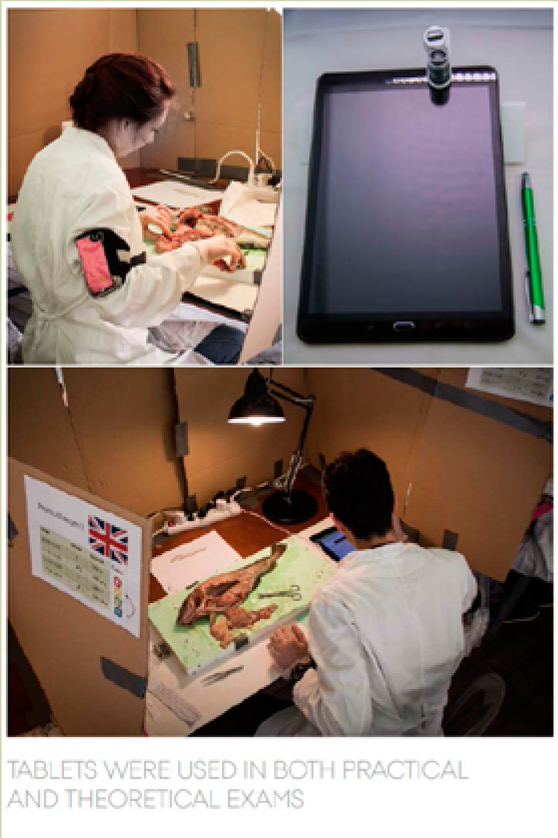
That's really interesting.

Now I would like to focus on some other recent projects of yours as well. You were involved in the organization of the 26th International Biology Olympiad: how was this experience? Which challenges did you find?

Oh, it was exhausting! [laughs] It took us several years to prepare. We went to three Olympiads the years before to see how it was organized. But let's start with the beginning.

The Biology Olympiad is for highschool biology students, so they are in between 17 and 19 years old. In Denmark last year we had 61 countries; from each country come four students and their teachers. So we have around 250 students, and probably 500 to 700 teachers. My job was to make the questions: they have two theoretical exams and four practical ones in different fields - animal physiology, plant physiology, microbiology, biotechnology, and so on.

In the theoretical exams I made one hundred questions. There's an introduction and then they have multiple true-false statements, and this has to be based on recent scientific research. I find a paper, make some short introduction, four statements, and the students will have to say if they are true or false. Then, when the guests come and the Olympiad begins, we place all the teachers in a big room in the day before the exam and they have to translate my English questions to their ►



The International Biology Olympiad 2015 in Aarhus, Denmark.
The practical exam in animal physiology.

own language. They are not allowed to communicate with the students: they [the students] stay in another hotel, and we confiscate all their phones. Very secret! [laughs] Then they upload the questions in their own language, and we begin the exams.

It was a lot of work!

Yeah. It takes a long time, and it's difficult to agree about the questions and the answers. There is a lot of negotiation in the teacher's room, with all these countries, because of course, they think differently when you have 61 countries. But it is a wonderful experience. You get a lot of nice friends from all countries, and you start seeing how different humans from different cultures look at Biology. That is really interesting.

You were saying you had to confiscate the students' phones...The kids at this age are increasingly more online: how do you see the challenges of communicating science, and your work in particular, for this new generation?

When we asked the students why they were interested in Biology, for example, we got lots of different reasons. I think that basically from European countries students are very much motivated by their personal interests, and they get this interest from very different sources. It could be the school, it could be parents, friends...

But if you go to other continents, like for example Asia - there were a lot of Asian countries present - they also have the motivation that if they score very high at the Olympiads, they get free university studies. They have this social mobility carrot in front of them. And that is not the case, I think, for any European student. Maybe in Europe we would take a competition like this a little bit relaxed, but for the Asian students it is extremely serious. It's all about their entire future. So we get complaints from these countries if they feel that they have been scored incorrectly, which we have to take care of. ▶

And there's also the fact that many countries are suspicious that other countries are cheating. Because you can imagine, it's very difficult for us to control all the translations, and there have been cases of cheating over the years. We check it out, of course, but for a small sample, as we don't master all these languages.

Overall there can be very different reasons for the students motivation to study Biology; I think it is difficult to generalize.

I hadn't thought about that perspective. The backstage of organizing such an event can have different details that we don't know about.

To summarize our interview: what are the challenges you see for the future of your own research field?

For me, I continue working with islands. Again because they are simple systems, and they could be models for continental systems. I am also interested in islands because they constitute this small portion of land area in the world and at the same time they have such a high proportion of the biodiversity. And they are the systems in most danger, of course.

Also, I want to understand the dynamic of the complexity on islands. For example: I was talking about how you can move quickly from one state to another, from El Niño years to La Niña years [La Niña and El Niño are natural phenomena of rich marine life/poor land life and poor marine life/rich land life, respectively], and how you can have a native predator suddenly disappears that causes these cascades into the system. This is part of a new theory that came out 15 to 20 years ago: critical transition theory, where you approach tipping points and then suddenly go into another state. I want to incorporate that theory in my work with island biology, because only very recently I understood that these things are more connected than I previously thought. ■

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