



Exploratory Workshop Scheme

Scientific Review Group for Life, Earth  
and Environmental Sciences

ESF Exploratory Workshop on

# Tracking changes in plant diversity over the last 400 million years

Cardiff (United Kingdom), 11–12 November 2014

Convened by:

**Dr Christopher J. Cleal & Dr Heather S. Pardoe**

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## SCIENTIFIC REPORT

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## 1. Executive summary

The ESF Exploratory Workshop was held at Amgueddfa Cymru – National Museum Wales, Cardiff, UK (hereafter referred to as the Museum) over two days (11<sup>th</sup>–12<sup>th</sup> November 2014). The Museum's Oriol Suite meetings rooms were used for both the formal presentations and the discussions. Full IT facilities and technical support were provided by the Museum, including a PowerPoint projector and Wi-Fi access for delegates. The Suite is located adjacent to the Museum's restaurant and so both refreshments and lunches were also provided in the Oriol Suite, facilitating discussions during the breaks with minimum disruption. As the workshop started before the Museum was open to the public, delegates had to be escorted from the staff entrance to the Oriol Suite; also some of the facilities (e.g. rest rooms) were within part of the Museum not normally accessible by members of the public. Consequently, two members of the Museum staff (two of the Museum's botany curators) were always on hand for escort and other duties. One of the curators also provided a series of feeds through Twitter (using the hash-tag #ESFCardiff2014) providing a regular live update of events to people outside of the meeting.

All visiting delegates stayed at the same hotel, which was within 5 minutes' walk of the Museum. For all three evenings, meals were taken at restaurants, also within 5 minutes' walk of the hotel (delegates found the latter fact helpful given the very wet weather on the first two evenings). This included the Workshop Dinner, held on the last evening at the Park Plaza Hotel, which featured a special menu with a Welsh theme. Having the formal working sessions and social interactions in a very contained, closely-knit environment greatly facilitated the development of discussions throughout the meeting.

Visits to relevant parts of the Museum's collections were organised, in addition to the main sessions with presentations and discussions. On Tuesday delegates were shown the David Davies Collection of Carboniferous plant fossils that formed the basis of the presentation by Cleal. On Wednesday delegates were shown the Welsh National herbarium, together with palynological material from the Hyde Collection.

The workshop was attended by seventeen palaeobotanists and palynologists from ten countries (UK, Ireland, Spain, Belgium, Germany, Switzerland, Italy, Czech Republic, Romania and Bulgaria), plus the ESF Rapporteur. An additional three people should have attended but had to withdraw at the very last minute for personal or health reasons. One of those people was able to provide a poster for display during the meeting (there were two other posters provided for display by delegates); all three have asked to be kept informed of any future collaborative work that will develop out of the workshop.

The idea behind the workshop had evolved from discussions between the two convenors, who had both been involved in international collaborative projects dealing with aspects of plant diversity in deep time. Cleal had been senior co-ordinator of two International Geoscience Programme projects (IGCP 469 and 575) investigating late Carboniferous vegetation of Euramerica, whilst Pardoe is one of the senior coordinators of the Pollen Monitoring Programme (PMP) looking at patterns of pollen deposition during the Quaternary. Although many of the underlying aims of the two projects were comparable (determining temporal and spatial patterns of plant diversity change and the relationship between vegetation and the fossil record) it became clear that the approaches used in data collection and analysis were often different in the two fields. This was partly explicable in terms of the different plant groups being studied (fern / gymnosperm dominated vegetation in the IGCP projects, angiosperm dominated vegetation in the PMP) and the different temporal

resolutions that were achievable in the two time intervals being examined. However, there were also clearly differences that were the result of historical traditions that had developed in the two fields.

It seemed obvious to the convenors that a potentially productive way forward would be to bring together representatives of the IGCP and PMP research teams to exchange ideas and case studies. However, it also quickly became evident that the convenors were in a position to expand the remit of such a workshop beyond what had been covered by these two projects: not only did they have an extensive circle of colleagues in Europe who dealt with plant diversity studies of other ages, they were also co-editors of the biennial *European Bibliography of Palaeobotany and Palynology* and so were well aware of the most recent developments in the field. As a result, it proved possible to assemble a set of specialists for the workshop with both macropalaeobotanical and palynological expertise, and covering most periods from the Devonian to the present day – thus spanning almost the entire history of terrestrial plant life on Earth.

The aim of the workshop was to facilitate the cross-fertilisation of ideas between specialists in different aspects of plant diversity studies in deep time: to compare different analytical approaches that have been used, to consider the types of database used to collate the data, to compare the taphonomic filters that the different fossil-types and stratigraphical ages are subjected to, and to study the applications that the results of such studies have been used for (e.g. biodiversity studies, mass extinctions, palaeobiogeographical analyses). For example, could the types of metrics that are widely used in global mass extinction studies (e.g. boundary crosser metrics, polycohort analysis) have applicability in Quaternary palynology studies? What can we learn from studies on Holocene palynology to improve our understanding of Palaeozoic palynological studies? How can we relate the data from *in situ* ( $T_0$ ) assemblages and allochthonous assemblages? And ultimately, would there be any significant advantage in establishing a more structured network of specialists in these fields to encourage future collaboration?

Dr Peter Wakelin (Director of Collections and Research at the Museum) welcomed the delegates and opened the workshop. He explained that the Museum has a deep commitment to developing collaborative activities as part of its research programme. The meeting was structured broadly around four themes: (1) *Methodological approaches* – the different analytical techniques have been used and the effect that different taxonomic concepts / ranks can potentially have on results; (2) *What does the plant fossil record represent?* – how do *in situ* and allochthonous assemblages compare, and what are the significant taphonomic filters; (3) *Plant spatial distribution / biogeography* – the important role that geographical distribution of taxa can have on interpreting change in biodiversity; and (4) *Taxonomic diversity in time* – how can we interpret the changes in plant diversity through time?

It became clear during the meeting that there are a number of time intervals within the stratigraphical record, each in the region of 10 Ma duration, that have a good palaeobotanical record and could potentially be used as building blocks for developing a more continuous record of diversity dynamics through the history of vegetation. It was also evident that there was considerable unevenness in the techniques being used to measure and analyse that taxonomic diversity, and that, if any comparison was to be meaningful, effort was going to be needed to enhance collaboration and interaction between specialists in the field. It was agreed that potential funding for developing such a collaborative network would be investigated, including COST.

## 2. Scientific content of the event

The first session covered presentations dealing with techniques that can be used to measure taxonomic diversity in deep time. Cascales-Miñana described a range of metrics that had been developed by people like Mike Foote and John Alroy working on the palaeozoological record. In particular the use of boundary-crosser metrics was discussed as means of overcoming problems such as high diversity lagerstätte. These approaches have had only limited application in palaeobotany and (as far as delegates were aware) none in palynology. The Quaternary palynology delegates in particular expressed interested in trying to adapt these techniques. However, some reservation was expressed as to the effect of such metrics on determining “mass extinction” events because of the “smearing” effect that they can have.

Giesecke discussed techniques that had been developed to look at diversity in more modern environments using palynology. In particular he dealt with the problems associated with diversity metrics in palynology that reflect taxonomic dominance as well as richness. Although such metrics give a more meaningful indication of ecological structure in vegetation, the problem of variations in pollen production and dispersal between plant groups makes this problematic with palynology. However, Giesecke has shown that by combining Shannon Indices with rarefaction analyses, a meaningful indication of taxonomic balance is possible. The following discussion indicated that there might be problems with



**Figure 1. Prof. Barry Thomas delivering presentation on plant fossil diversity studies at Brymbo, north Wales.**

using such an approach with macrofloras, except where the best sampled assemblages are available. This approach is potentially useful in pre-Quaternary palynology.

Diez argued for some mechanism for stabilising palaeobotanical and palynological taxonomy, as otherwise diversity measures become extremely difficult to determine in an objective way. There is a tendency for taxa to be defined differently depending on the type of study being undertaken, be it biostratigraphical, palaeoecological or phylogenetic. These ideas generated an extensive discussion centred partly on the separation of taxonomic and nomenclatural issues. It is relatively straightforward to codify nomenclatural issues, but taxonomy has, by definition, to be partly subjective and so less easy to regulate. It was pointed out that there had been previous attempts in this direction, such as the Names in Common Usage project, but this had failed due to a combination of an inability to reach a consensus on taxonomic issues and the considerable time needed to collate the data.

Thomas presented preliminary results from a case study where palynology was being used to interpret lycopsid vegetation dynamics. This had involved an iterative revision of the taxonomy of the dispersed spores and the macrofossils. The results in Europe seemed to confirm the original model developed by Harold Smith, but Thomas was now introducing a more refined model involving some of the smaller taxa. However, it was also becoming clear that a simplistic application of this model to other areas, notably North America, could be misleading; the interaction between the lycopphyte groups appeared to be different here compared with Europe. The study emphasised the importance of examining the



**Figure 2. Dr Chris Cleal showing delegates the David Davies Collection of Carboniferous plant fossils.**

palaeogeographical as well as temporal dynamics of the taxa for a proper understanding of past plant dynamics

In the final presentation of this session, Cleal discussed his research on the Carboniferous floras of Euramerica, and in particular on the South Wales dataset. This coalfield had the merit of an extremely large dataset representing vegetation dynamics over a period of about 10 million years. The methods used to normalise the data set to give a more realistic indication of original plant diversity were discussed, as well as some of the analytical techniques used such as polycohort analysis. It was argued that species richness was a reliable means of indicating diversity dynamics. There was some discussion concerning the reliability of species richness compared to dominance metrics for interpreting palaeoecology, but again the problem with the latter became evident, at least with macrofloral studies. There was also some discussion as to what exactly the fossil macrofloras were sampling, and the differences between local, landscape and regional diversities.

Following this presentation, delegates were taken to see the Museum's David Davies Collection. This collection forms the basis of the dataset used in the South Wales studies.

The theme of the afternoon session was the representation of the original composition of the vegetation in the fossil record. Opluštil described work that had been done in the Czech Republic on an ash-fall deposit within the Carboniferous Radnice Coal, which had captured the coal swamp vegetation preserved *in situ*. Whilst other T<sub>0</sub> plant assemblages of this age are known from elsewhere, this is a very rare example of where both canopy (including lianas and/or epiphytes) and understory vegetation are preserved. Detailed mapping of several sites had allowed extensive data concerning the distribution and diversity of the original plants to be determined. During the following discussion it was pointed out that the observed diversity was in fact very similar to the diversity of the allochthonous roof shale floras but that the taxa present were different; the taphonomic explanation for this was not clear. It was argued that valuable insights would be obtained by analysing the data using dominance metrics.

Thomas, in his second presentation, discussed evidence from a more traditional type of T<sub>0</sub> assemblage from North Wales, where excellent specimens of lycopsid and sphenopsid stumps were preserved. It was clear that this assemblage was less complete, with only limited evidence of understory or lianas preserved. Nevertheless, it provided useful insights into the distribution of the major plants growing in this area of coal swamp. Thomas also demonstrated the database that had been developed to aid the analysis of this assemblage.

Ivanov discussed the rather different issues surrounding the study of Cenozoic assemblages, in particular leaf beds. It has been found that there can be discrepancies between the data revealed by such leaf beds and the palynology found in similar deposits, presumably reflecting different taphonomic filters. It is clear that both strands of data need to be taken into account to get a complete picture of the original vegetation.

At the end of the first day, the main discussion centred on producing a publication from the meeting. Further details of this debate is given in Section 3 of this report.

The second day commenced with a presentation on behalf of ESF by Prof. Wolfgang Weisser, outlining some of the potential routes for developing a collaborative network. There followed a series of presentations looking at the geographical / spatial context of



**Figure 3. Dr Heather Pardoe showing delegates the Welsh National Herbarium.**

diversity studies. Popa looked at the diversity of plant remains in the early Jurassic of SE Europe. There is a palaeobotanical record in this region spanning some 10 million years, with a number of particularly diverse assemblages such as at Anina (Romania). There remains much taxonomic work to be done on these floras but already it is possible to determine underlying patterns of change. Following discussion it was generally agreed that this area has the best potential for revealing diversity change in early Jurassic vegetation.

Stolle demonstrated the importance of biogeographical distribution when trying to determine diversity changes in the Palaeozoic palynological record. The underlying control on biostratigraphy and palaeobiogeography is the distribution of the original plant taxa, and if different plant taxa living in different habitats can produce similar spores this can produce misleading results if the empirical data are analysed uncritically. During discussion it was agreed that this is a particular problem with Palaeozoic palynology where the affinities of the spores is not always known.

The importance of databasing for resolving biogeographical as well as biostratigraphical distribution of taxa was dealt with by Davis. He discussed the historical development of such databases for Quaternary palynology. Initially databases were regionally developed but increasingly it became evident that progress could be significantly improved by making them compatible. Examples were shown of what is possible through the use of such databases for demonstrating geographical dynamics of vegetation in Quaternary times. However, it was also made clear that such databases require the support of financial resources as well as effort from palynologists who have to provide the data in standardised formats and

database managers who have the laborious task of promoting consistent standards of taxonomy and nomenclature within the database. A subsequent discussion agreed that such approaches were suitable for use with pre-Quaternary palynology and palaeobotany, but the resources to support such work remain a problem.

The final, extended session summarised a number of case studies on plant diversity in deep time. Kustatscher discussed the issue of taphonomy in determining patterns of diversity change in Triassic times. For instance, our understanding of the recovery of vegetation after the end-Permian extinction may be being distorted by the unfavourable taphonomic conditions in lower Triassic strata. However, the discussion suggested that this problem was most severe in the post end-Permian extinction, although must always be borne in mind when interpreting any apparent sudden extinction event.

Leroy reviewed palynological evidence of vegetation distribution in Europe during the Quaternary and what it tells us about vegetation diversity and dynamics in the region. She demonstrated the limitations of some of the widely used techniques for determining diversity patterns such as rarefaction analysis, but nevertheless argued that the underlying diversity patterns could be determined from the palynological record. She contended that many of the observed patterns could be related to Milankovitch-driven climate change and that a key factor was the location of the refugia during times of sub-optimal conditions. The data also provided crucial environmental evidence against which the appearance of hominids in Europe could be interpreted. The subsequent discussion emphasised the importance of such work as it provides a key link between observable diversity and dynamics in today's vegetation with the palaeontological evidence for vegetation history in deep time.

Before the lunch break, delegates were taken to visit the Welsh National Herbarium. They were introduced to the Hyde Collection of palynological samples and data. The latter were part of Hyde's pioneering palynological work undertaken in Cardiff, which in many ways laid the foundation of modern aeropalynological studies. Delegates were also given a guided tour of a major permanent palaeontology exhibition in the Museum entitled *Evolution of Wales*.

After lunch, Seyfullah discussed evidence that amber can provide for past vegetation diversity. She showed that there had been three bursts in amber production, in late Triassic, late Cretaceous and Eocene–Miocene times, and that these provide unique insights into biodiversity of those times. Although the taphonomic filter that amber imposes biases the record that it yields and so it cannot be used to interpret the overall biodiversity of the relevant time-window, amber can nevertheless reveal aspects of past diversity that are not found in other modes of preservation, especially of microscopic organisms. The amber record thus needs to be integrated with the more traditional palaeontological record to obtain a more complete understanding of past biotic diversity.

Filipova-Marinova reported the results of her team's studies using palynological evidence to identify significant vegetation changes that could be related to the development of human habitation in southeastern Europe. The work demonstrated the importance of integrating palynological data with sedimentological, palaeozoological and absolute dating evidence to get a proper understanding of the environmental changes that were taking place at Lake Varna, a biodiversity hotspot. Moreover this study emphasised the importance of collaborative effort in such research, bringing together the appropriate specialists to provide a holistic environmental picture. As was pointed out during the subsequent discussion, this



sort of work epitomises the sort of collaborative programme that the present workshop can hopefully initiate.

The final presentation by McElwain discussed recent work on analysing the vegetation changes occurring around the Triassic – Jurassic extinction event. The work is demonstrating the importance of determining climatic and atmospheric dynamics for understanding the drivers of observed changes of vegetation, and this in turn has been driving actualistic research to determine the responses of plants to high oxygen and carbon dioxide levels. The resulting discussion returned to the issue of trying to determine patterns of vegetation change during major ecological disruptions, including the problem of sampling.

The last day was brought to close with an extensive discussion on the potential way forward for developing a collaborative network to facilitate research in this field. The outcomes of this discussion are summarised in Section 3 of this report.

### **3. Assessment of the results, contribution to the future direction of the field, outcome**

There was a general consensus that the workshop had been worthwhile. Each of the schools of study represented at the meeting have tended to use different means of sampling, data collation and analysis and so it was valuable to facilitate the cross-fertilisation of ideas. Whilst the links established during the workshop will undoubtedly bear future fruit in directing new research, it was widely agreed that some more formal collaborative network would be of widespread benefit to the field. The need was not for the generation of new data (plenty of such data have already been and are still being generated) but more for the enhancement of collaboration and networking to improve the collation and analysis of those data.

A number of suggestions were made.

- It was agreed that the development of a formal network would be beneficial if it could facilitate the organisation of thematic workshops and exchanges. Although ESF was reported to be no longer a source of future funding, a number of other potential funding streams were suggested. The most likely potential source of support was suggested to be COST, which is specifically intended for such collaborative networks. It was pointed out that that would require the support of the individual national COST representatives. The workshop convenors undertook to draft an outline project proposal that would be circulated to delegates. When a consensus had been reached on such a proposal, this would be sent to the national COST representatives.
- An alternative way forward would be the development of a more informal collaborative network, around which individual project applications (e.g. through the Marie Curie Foundation) could be developed. It could also be used as a means of co-ordinating symposia at meetings such as the European Palaeobotany and Palynology Conferences. Such a network could be centred around a web site hub, either hosted at one or other of the represented institutions, another organisation (e.g. International Organisation of Palaeobotany, Research Gate) or even a stand-alone site such as operated through Google.
- It was agreed to produce a publication from the meeting. It was soon agreed that the preferable option would be to produce a single, multi-authored paper, reviewing the approaches that have been used in plant diversity studies in different parts of the stratigraphical column. It was agreed that there was little point in re-iterating

numerous case studies that had been published elsewhere. Instead, reference should be made to those published studies, but that the underlying themes behind them should be extracted for this paper. The meeting convenors agreed to draft out the structure of such a paper and to circulate it delegates by Christmas.

#### 4. Final programme

##### Tuesday 11 November 2014

- 09.30-09.40      **Welcome by Director of Collections & Research**  
**Dr Peter Wakelin** (National Museum Wales, Cardiff, UK)
- 09.40-12.30      Session One: Methodological approaches**  
**(Chair: Dr Heather Pardoe)**
- 09.40-10.10      **"Exploring the plant diversity through time: inference and bias"**  
**Dr Borja Cascales-Miñana** (Université de Liège, Belgium)
- 10.10-10.40      **"Estimating diversity, richness and evenness from late Quaternary pollen diagrams"**  
**Dr Thomas Giesecke** (University of Göttingen, Germany)
- 10.40-11.10      **"The relationship between taxonomy, biostratigraphy and phylogeny"**  
**Prof. Jose B. Diez** (Universidade de Vigo, Spain)
- 11.10-11.30      *Coffee / Tea Break*
- 11.30-12.00      **"Ecological interpretations of Palaeozoic lycophyte microspore floras with case studies from Europe and North America"**  
**Prof. Barry Thomas** (University of Aberystwyth / National Museum Wales, UK)
- 12.00-12.30      **"Determining taxonomic diversity trends from late Carboniferous coal-bearing sequences of Europe"**  
**Dr Christopher Cleal** (National Museum Wales, Cardiff, UK)
- 12.30-13.00      Visit to the Palaeontological Collections National Museum Wales (including David Davies Collection)**
- 13.00-14.00      *Lunch*
- 14.00-15.30      Session Two: What does the plant fossil record represent?**  
**(Chair: Prof. Barry Thomas)**
- 14.00-14.30      **"Diversity of middle Moscovian wetland floras; case study from the Radnice Member"**  
**Dr Stanislav Opluštil** (Charles University, Prague, Czech Republic)
- 14.30-15.00      **"Diversity of *in situ* lycophytes and sphenophytes at Brymbo, north Wales"**  
**Prof. Barry Thomas** (University of Aberystwyth / National Museum Wales, UK)
- 15.00-15.30      **"Cenozoic leaf beds and taxonomic diversity"**  
**Dr Dimiter Ivanov** (Institute of Biodiversity & Ecosystem Research, Sofia, Bulgaria)
- 15.30-15.50      *Coffee / tea break*
- 15.50-17.00      **Discussion**

## Wednesday 12 November 2014

- 09.15-9.30      **Presentation of the European Science Foundation (ESF)**  
**Prof. Wolfgang Weisser** (Scientific Review Group for the Earth and Environmental Sciences)
- 09.30-11.00      Session Three: Plant spatial distribution / biogeography**  
**(Chair Prof. M. Filipova-Marinova)**
- 09.30-10.00      **"Assessing plant diversity during Early Jurassic times in SE Europe"**  
**Dr Mihai Popa** (University of Bucharest, Romania)
- 10.00-10.30      **"It is always good to know the spatial distribution of palynological taxa – examples from the Late Palaeozoic"**  
**Dr Ellen Stolle** (Ernst-Moritz-Arndt-Universität, Greifswald, Germany)
- 10.30-11.00      **"Investigating plant diversity using Late Quaternary Pollen Databases "**  
**Dr Basil Davis** (Université de Lausanne, Switzerland)
- 11.00-11.20      *Coffee / Tea Break*
- 11.20-15.30      Session Four: Taxonomic diversity in time**  
**(Chair: Dr Christopher Cleal)**
- 11.20-11.50      **"Plant diversity in early Mesozoic times"**  
**Dr Evelyn Kustatscher** (Naturmuseum Südtirol, Bozen, Italy)
- 11.50-12.20      **"Change in plant diversity throughout the Quaternary in Europe"**  
**Dr Suzanne Leroy** (Brunel University, London, UK)
- 12.20-13.00      Visit to the Hyde Palynological Collection and the Welsh National Herbarium**
- 13.00-14.00      *Lunch*
- 14.00-14.30      **"What does the amber record tell us?"**  
**Dr Leyla Seyfullah** (Georg-August-Universität, Göttingen, Germany)
- 14.30-15.00      **"Non-pollen palynomorphs as promising additional indicators for human impact on the natural vegetation in submerged archaeological sites: case study from the Varna Lake, northeastern Bulgaria"**  
**Prof. Mariana Filipova-Marinova** (Varna Museum of Natural History, Bulgaria)
- 15.00-15.30      **"Plant extinction and recovery across the Triassic- Jurassic boundary. Insights from relative abundance distributions"**  
**Prof. Jennifer McElwain** (University College, Dublin, Ireland)
- 15.30-15.50      *Coffee / tea break*
- 15.50-17.20      **Discussion**



**Figure 4. Delegates to the ESF Exploratory Workshop “Tracking changes in plant diversity over the last 400 million years”.**

## **5. Final list of participants**

<b>Dr Christopher J. Cleal</b>	National Museum Wales, Cardiff, UK
<b>Dr Heather S. Pardoe</b>	National Museum Wales, Cardiff, UK
<b>Dr Christopher Berry</b>	University of Cardiff, UK
<b>Prof. Barry A. Thomas</b>	University of Aberystwyth, UK
<b>Dr Basil Davis</b>	Université de Lausanne, Switzerland
<b>Dr Borja Cascales-Miñana</b>	Université de Liège, Belgium
<b>Dr Mihai Popa</b>	Universitatea din București, Romania
<b>Dr Evelyn Kustatscher</b>	Naturmuseum Südtirol, Italy
<b>Prof. Jennifer McElwain</b>	University College Dublin, Ireland
<b>Dr Ellen Stolle</b>	Ernst-Moritz-Arndt-Universität, Germany
<b>Dr Thomas Giesecke</b>	Georg-August-Universität Göttingen, Germany
<b>Prof. Suzanne Leroy</b>	Brunel University, UK (Belgian National)
<b>Dr Stanislav Opluštil</b>	Univerzita Karlova, Czech Republic
<b>Prof. M. Filipova-Marinova</b>	Varna Museum of Natural History, Bulgaria
<b>Dr Dimiter Ivanov</b>	Inst. Biodiversity & Ecosystem Res., Bulgaria
<b>Dr Leyla Seyfullah</b>	Georg-August-Universität Göttingen, Germany
<b>Prof. Jose B. Diez</b>	Universidade de Vigo, Spain

## 6. Statistical information on participants

Age Bracket:	Early Career –	3
	Mid-Career –	10
	Senior / late-Career –	4
Countries of origin:	UK –	4
	Switzerland –	1
	Belgium –	2
	Romania –	1
	Italy –	1
	Ireland –	1
	Germany –	3
	Bulgaria –	2
	Czech Republic –	1
	Spain –	1
Male / Female repartition –		10 / 7