

How to Survive as a Taxonomic Institute: The amalgamation of the large Dutch herbaria and their collections

Peter C. van Welzen and Christel Schollaardt

Abstract

In the late nineties of the last century, the Dutch herbaria of Leiden (L), Utrecht (U), and Wageningen (WAG) were merged to form the National Herbarium of the Netherlands (NHN). The merger was followed by an even larger unification, that with the other natural history collection institutes of the Netherlands to form Naturalis Biodiversity Center in Leiden. Naturalis is now by far the largest natural history museum of the Netherlands and ranks among the world's top 10 largest natural history institutes. While the research programme of Naturalis is still being developed, the digitisation of all herbarium collections and wood and slide collections, together with state-of-the-art facilities for molecular, computational, and (ultra)microscopic imaging put the institute in an ideal position for innovative collection-based biodiversity research and teaching.

Key Words: Leiden, National Herbarium of the Netherlands, Naturalis Biodiversity Center, Rijksherbarium, Utrecht Herbarium, Wageningen Herbarium, Zoological Museum of Amsterdam

Peter C. van Welzen, Naturalis Biodiversity Center, P.O. Box 9517, 2300 RA Leiden, and Leiden Institute of Biology, Leiden University, P.O. Box 9505, 2300 RA Leiden, The Netherlands. Email: peter.vanwelzen@naturalis.nl

Christel Schollaardt, Naturalis Biodiversity Center, P.O. Box 9517, 2300 RA Leiden, The Netherlands. Email: christel.schollaardt@naturalis.nl

Most of the Dutch herbaria originated during colonial times in the nineteenth century (see Table 1 for sizes and foundation dates of the botanical collections in the Netherlands, and Fig. 1 for a map of where they were initially located). Three of the old herbaria were by far the largest, those of Leiden, Utrecht and Wageningen. The herbarium of Utrecht, in the centre of the Netherlands, is the oldest Dutch herbarium (Erkens & Baas 2008). The Leiden herbarium, second in row, officially started as the 'Rijksherbarium' (= National Herbarium) and was founded on March 31, 1829 by the Dutch King Willem I, probably on the

instigation of its first director, Carl Ludwig Blume (Smit 1979), to study his vast Indonesian collections. In those days the Netherlands also included Belgium and - because Leiden already contained a Natural History Museum - the National Herbarium started in Brussels in order to keep a political (and perhaps scientific) balance between the southern and the northern Netherlands (Smit 1979). The Wageningen herbarium was founded later, officially in 1896, though substantial collections were already present before that year (Aleva *et al.* 1996).

Two other university herbaria, those of Amster-



Fig. 1. Localities of (former) Dutch herbaria, presently all merged and in Leiden.

Table 1. Codes, founding years and estimated sizes of the five largest herbaria in the Netherlands.

Herbarium	Code	Founding year	Size of collections
Utrecht	U	1816	800,000
Leiden	L	1829	4,200,000
Amsterdam	AMD	?	200,000
Groningen	GRO	1890	50,000
Wageningen	WAG	1896	1,000,000



Fig. 2. Portraits of Philipp Franz von Siebold (1796–1866). (A) A watercolour-coloured pencil drawing of von Siebold by Kawahara Keiga (1786–1860?), a late Edo period Japanese painter who produced paintings of natural history for von Siebold. The portrait was painted in the 1820s and is now in the Saga Prefectural Museum of Art near Nagasaki, Japan. (B) Von Siebold in a colonel's uniform of the Dutch East-Indian Army. Portrait made in 1859, reproduced as a lithograph by E. Chiossone in 1875, now in Rijksmuseum voor Volkenkunde, Leiden. Both images are in the public domain and reproduced from Wikimedia Commons.

dam (University of Amsterdam) and Groningen, were much smaller. Both were abolished before the large merger of herbaria started. Amsterdam was incorporated with the herbarium in Leiden (though still kept separate), and the collections of the Groningen herbarium were divided between Wageningen (the African vascular plants) and Leiden (the remainder, merged with the Leiden collections).

As mentioned above, the National Herbarium of the Netherlands started in Brussels. To understand why it moved to Leiden, we first have to look to the other side of the globe. In the early 19th century the Netherlands was the only country allowed to trade with Japan. The Dutch had to live on Deshima, a small

fan-shaped artificial island, which had been constructed in the bay of Nagasaki in 1634. Among the Dutch on Deshima was a German physician, Philipp Franz von Siebold (Fig. 2). Von Siebold, with the aid of Japanese patients, friends, and students, gathered a vast collection of preserved and living plants, animals and ethnographical objects. After his return to the Netherlands he settled in the vicinity of Leiden, where he had most of his Japanese collections housed at various institutions (the Ethnological Museum, the Natural History Museum – now Naturalis Biodiversity Center, and the Hortus botanicus). In 1830, he went to Brussels to donate his collections of dried plant specimens to the National Herbarium. In those very days in 1830,

the Belgian uproar started, resulting in the independence of Belgium. The director of the National Herbarium, Blume, was absent, and von Siebold, who realised the gravity of the situation, consulted with Blume's assistant and the government in The Hague (at that time, Brussels and Amsterdam alternated as capital of the Netherlands every second year, while the government remained in The Hague). With official approval, von Siebold had the collections in Brussels packed and moved to Leiden. Word has it, that when the collections were transferred to a barge in Ghent (Belgium), they were almost destroyed by a mob, but von Siebold could convince the mobsters of his neutrality based on his German identity and was allowed to ship off the plants. In Leiden the collections were gradually incorporated and united with collections already present at the Leiden University, though this was not an easy process. Blume had, to honour him, a personal title of professor, but he had no teaching obligations. Teaching was done by the professor of botany, in those days Caspar Georg Carl Reinwardt, who hardly had access to the specimens. The complete inclusion of the herbarium in Leiden University succeeded under the third director, Willem Frederik Reinier Suringar, who also occupied the chair of botany at the university (Smit 1979; Kalkman 1979).

The three major herbaria in the Netherlands (L, U, WAG) divided their labour and specialised in different areas, thus facilitating independent workflows. The staff at L worked on the Dutch and other European floras, on the south-eastern Asian (Malesian) flora, and had established a strong cryptogamic botany group. The staff at herbarium L gradually incorporated the *Flora Malesiana* botanists, when they returned to the Netherlands, which happened after Indonesia became independent in December 1949. Cornelis Gijsbert Gerrit Jan van Steenis, later one of the directors of herbarium L, was the founder of the *Flora Malesiana* project, covering an area ranging from the Malay Peninsula to New Guinea. As a result herbarium L focussed a large part of its research on the *Flora Malesiana* project. Herbarium U focussed on southern and central America, especially on the former Dutch colony Suriname and the Dutch Antilles, and coordinated

the *Flora of the Guianas*, which covered Guyana, Suriname and French Guiana. Finally, WAG concentrated on Africa, particularly parts of central and western Africa, with flora projects like the *Flora of Benin*, *Flore du Gabon*, *Flora of Togo*, etc. Besides these taxonomic and geographical foci, there were wood anatomical, palynological and cytological research teams, either with or closely associated with the three main herbaria.

The herbaria house some of the oldest book herbaria in the world, like the En Tibi herbarium, perhaps the oldest surviving book herbarium worldwide, presumably dating from 1542 and made in Italy; part of the Clifford Herbarium (<http://www.george-clifford.nl/>); the Petrus Cadé Herbarium (dating from 1566; <http://www.nationaalherbarium.nl/Cade/index.htm>); but also the herbaria of of Leonhart Rauwolff (1535–1596), part of the Paul Hermann herbarium (1646–1695; <http://www.hermann-herbarium.nl/>), the herbarium of Paolo Boccone (1633–1704), etc. The Van Royen herbarium and some other old herbaria have their specimens mounted on loose sheets, not in books, with cut-out paper vases and banners (Fig. 3a) to hide the cut branch ends. The wood collection contains some historical treasures such as Junghuhn's collection of woods from Java, shaped as books (Fig. 3b), and the world-famous collections of woods from Hokkaido, with paintings of the leaves and branches by Mogami Tokunai, a Japanese samurai, scholar, geographer and explorer, who donated this collection to von Siebold, who in turn sent them to the Rijksherbarium (for an excellent overview of the history of the Leiden collections, see Steenis-Kruseman 1979).

The worldwide economic recession in the early 1980s resulted in heavy budget cuts. The herbaria of U and WAG were seriously affected by this, with a serious loss of staff. U even reduced its research mainly to the New World Annonaceae. The herbarium L lost some staff, but could prevent catastrophic damage by re-organising itself together with the Leiden Botanical Garden into a research institute, a new form of academic organisation introduced by the Ministry of Education, Culture and Science for excellent university departments, which had a greater than usual research task relative to their teaching duties. The



Fig. 3. Some notable old specimens in the botanical collections at Leiden. (A) Sheet with crocuses from the Adriaan van Royen herbarium, a friend of Linnaeus, note the printed vase (bottom) and the printed banner (top) glued over the specimens; from <https://science.naturalis.nl/media/cache/a1/3d/a13d868341732481b2481b6c03917beb.jpg>. (B) Junghuhn's wood specimens disguised as books; from <https://science.naturalis.nl/media/cache/d8/4d/d84de71fe33c7b4c10ec7b-c785c5df9a.jpg>. Both images available from the home page of Naturalis.

new research institute, officially combined the Rijks-herbarium and the botanical garden (Hortus botanicus) into one organisation: RHHB (RijksHerbarium/Hortus botanicus) – a masterstroke by its then director Prof. Cees Kalkman.

Unfortunately, in 1993 the Leiden Science Faculty decided that maintaining large collections did not belong to its core business. It proposed such draconian budget cuts that the future of the herbarium L was in

imminent danger – an ironic fate, one year following the global Convention on Biological Diversity (CBD) agreed at the Rio summit, with the Netherlands as an enthusiastic signatory. Not only the herbarium L was under threat, also in the course of time many of the Dutch botanical gardens attached to universities encountered financial problems. A committee of the Royal Netherlands Academy of Arts and Sciences (KNAW) analysed the problem, and in 1995 the Acad-

Table 2. Chronological order of events after the National Herbarium of the Netherlands (NHN) was established.

1999	National Herbarium of the Netherlands (Leiden, Utrecht Wageningen) established
2004	University of Utrecht withdraws from NHN
2005	Negotiations to start Naturalis Biodiversity Center
2008	Utrecht leaves negotiations
2010	Merger of NHN and Natural History Museums of Leiden and Amsterdam to form Naturalis
2016	Start of new exhibition wing and restructuring old exhibition space for collection
2020	Expected union of all groups under one roof

emy advised that the herbaria should be united into one decentralised institute (meaning central management, but with the work done at the different universities). In 1996, after much pressure, the responsible minister agreed to provide funds for this plan and asked the Academy to organise the decentralised herbarium. He announced it during the official opening of the new Van Steenis building in Leiden (by Her Majesty Queen Beatrix), controversially adding that all research should concentrate on south-eastern Asia. This gave a somewhat false start of the National Herbarium of the Netherlands (NHN); Africa and Neotropical taxonomists from herbarium WAG and U were understandably not amused – neither was the Leiden Director Prof. Pieter Baas (Baas 2000). The merger was officially completed on the first of January 1999 (see Table 2 for a chronological order of events to follow).

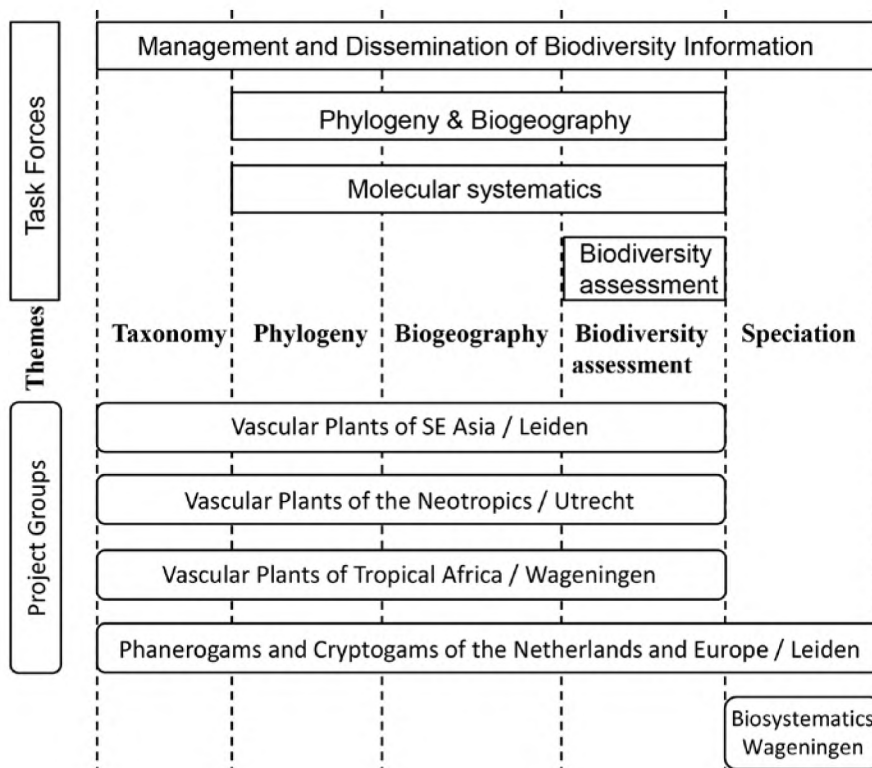
National Herbarium of the Netherlands

The Dutch Government supported the NHN with, in addition to what came through the university budgets, a directly granted annual sum of 2 million guilders (c. € 0.9 million). This was granted in order to largely compensate for the budget cuts received by the universities. Prof. Pieter Baas, director of L, became the director of the NHN and had the task to

create synergies between the three institutes, which used to be independent institutions with different curatorial methods, which prevented a physical integration. For instance, the three institutes used different sizes of herbarium sheets and different classification systems for their collection management. The herbarium L followed the oldest system (mainly the Dalla Torre's evolutionary classification) and the herbarium U followed the most modern system (then APG II). Families were arranged either alphabetically (U, WAG) or evolutionarily (L), geographically first (U) or taxonomically first (L, WAG). Each institute had one or several research groups, each with their own topics and geographic area of interest. In order to create a synergistic link between the three institutes, the planning of research was intensively discussed by a complete group consisting of permanent and adjunct scientific staff and PhD students. This bottom-up approach resulted in long-term support for the restructuring of research groups and the establishment of thematic cross-linking task forces (Fig. 4).

It was felt a nice idea to concentrate on fewer *plant families* for taxonomic research. Normally, a single researcher would work on one family for one of the flora projects. This had to change to teamwork for species-rich plant families, whereby an integrative approach was envisaged, and alpha taxonomy should be combined with molecular, phylogenetic and histori-

Fig. 4. Distribution of themes over Project Groups (active per herbarium) and Task Forces (inter-herbarial) (Adjusted from the Progress Report 1999 of the Nationaal Herbarium Nederland).



cal biogeographic approaches. Examples were studies of the Orchidaceae and the Annonaceae (Fig. 5). The latter was selected as a model taxon for phanerogam systematics, and was the only family for which a pan-tropical coverage was possible as all three institutes had staff working on this family. Unfortunately, this approach was later eroded due to understaffing. Synergy between the three former herbaria was also created by regular meetings, like those of the task forces, which rotated among the institutes.

One of the in-house published journals, *Blumea*, had to change its policy; before the merger it was (mainly) devoted to south-east Asian taxonomy, after the union of the herbaria it changed to a worldwide coverage.

During the establishment of the NHN, the Netherlands Science Foundation (NWO) helped by providing funds for digitisation of the type collections and their presentation on the internet. A specially appointed database manager, Luc Willemse, selected the Botanical Research and Herbarium Management

System (BRAHMS) for this purpose (<http://herbaria.plants.ox.ac.uk/bol/brahms/>). BRAHMS was and is still being developed by Denis Filer at the University of Oxford, and the NHN became the largest and most complex user and tester of the software, which, over time, quickly expanded and changed to become one of the most versatile and most used packages for herbarium collections worldwide. The type project resulted in the digitisation of ca. 50,000 type specimens. High definition scans were made of the specimens and the label information was entered in BRAHMS. The Expert centre for Taxonomic Identification (ETI, then part of the University of Amsterdam, now incorporated in Naturalis Biodiversity Center in Leiden) created the software to search and view the specimens on the internet. The result was second to none in the world.

Maintaining quality and managing a decentralised herbarium was not easy. All botanical and zoological systematics at Dutch universities had been judged as poor by a broad peer review of the whole of Dutch



Fig. 5. The National Herbarium of the Netherlands has focussed on the pantropical Annonaceae, for example *Guatteria pudica* N. Zamora & Maas. Photo by P.J.M. Maas; front page of *Blumea* 60 (2015), reproduced with permission.

Biology in 1993 by a non-systematist committee, but subsequent reviews were much more positive with – as a peek – the unanimous qualification of excellent for the herbarium L on all scores in 1999. The peers had very high expectations of the NHN-*in statu nascendi*.

Further Threats and a Leap Forward

In 2004 the Faculty of Biology at the University of Utrecht had to realise severe budget cuts and decided to withdraw from the NHN and to discontinue their financial support for the Utrecht branch (Erkens & Baas 2008). This could result in the end of the NHN as a recipient of earmarked money from the ministry, as the NHN was intended to keep all three institutes

(L, U, WAG) united. Long before, heavy clouds had also gathered above the Zoological Museum of Amsterdam University (ZMA; founded 1838), and a merger of ZMA and Naturalis (the natural history museum in Leiden) *sensu stricto* was on its way. The NHN Board therefore embraced the plan to safeguard all important biological collections by uniting NHN, ZMA and Naturalis. The former director of Naturalis, Ronald van Hengstum, had a strong interest in such a merger in order to safeguard the research capacity of his Museum and create an ‘Academic Work Place’ (an exception among Dutch museums, where normally only a few curators would be employed). The merged Naturalis should be co-funded by the Science and Education department of the Min-

istry, rather than only by the less research-friendly Culture department of the same ministry, responsible for the Dutch museums. On behalf of NHN, the negotiations were mainly conducted by its new director, Prof. Erik Smets.

Naturalis, founded in August 1820, was for a long time a museum without exhibition space. It had just moved to a new location in Leiden, close to the herbarium L, where a large exhibition space became available. Naturalis was already combined with the former National Museum for Geology and Mineralogy and was, by far, the biggest institute of all merging parties involved. The ideas of unification were received with enthusiasm by the Ministry of Education, Culture and Science and also by the University of Utrecht. However, the negotiations took longer than expected, also because the director of Naturalis, van Hengstum, suddenly died (he was succeeded by Bert Geerken in 2008, and in turn in 2011 succeeded by Edwin van Huis). Finally, the University of Utrecht decided to withdraw from the negotiations. It closed down the herbarium, and even considered to sell the collections to Brazil. The ministry prevented the latter, because they decided that the collections were Dutch cultural heritage and thus became owner of the collections. After this move, Naturalis was asked to manage the collections, and they were then transferred to Leiden.

Naturalis Biodiversity Center (starting under the name Netherlands Biodiversity Center Naturalis) was officially founded on 28 January 2010. It was a joined project by Naturalis, and the universities of Amsterdam (ZMA zoological collections), Leiden (herbarium L) and Wageningen (herbarium WAG), which are all represented on the Board of Trustees. The combined collections mounted to an estimated total of 37 million objects, and with this number of specimens the Naturalis Biodiversity Center is among the ten largest natural history collections in the world. The combined wood collections in Naturalis represent the largest collections of wood samples in the world.

It was also decided that there would be a unified location for the collections, no more decentralised ‘institutes’. In fact, all collections were moved to Leiden, but at present they are still spread all over town until

the construction of a new exhibition building (the old one being already too small), and the renovation of the old exhibition space into collection space is completed. Then, probably in 2020, Naturalis Biodiversity Center will be renewed with all personnel and all collections finally together. During the move of the botanical collections the opportunity will be seized to move all collections to the APG IV classification, which in itself will be a major operation.

Naturalis Biodiversity Center is not only a popular museum for family-visits (top 10 in the Netherlands), but it is also a research institute with more than a 100 researchers, housing one of the largest biodiversity collections in the world. The government helped the initiative by providing 30 million €, which were partly for a new building, but also for equipment, for digitising large parts of the collection and for DNA barcoding (the latter in cooperation with the KNAW Fungal Biodiversity Centre in Utrecht). Already, Naturalis offers excellent opportunities for state-of-the-art research: modern microscopy, scanning (SEM, TEM, Micro-CT), mineral and gem laboratories, plant-anatomical labs, next generation sequencing, DNA barcoding facilities, a large division for information and communication technology, ample computer facilities, and vast digitised collections. The general director is presently Edwin van Huis, and Erik Smets (education) and Koos Biesmeijer (research) are the two scientific directors.

Digitisation

Before Naturalis Biodiversity Center started with large scale collection digitisation, the NHN and the combination now forming Naturalis had several times received funds by the Dutch Research Foundation (NWO) to digitise collections. In the NHN the ‘special collections’, kept separate, including the wood collection, the collection of material in spirit and the carpological collections (collections of dried seeds and fruits), were then to be digitised. However, once Naturalis started digitisation, all dried plants mounted on herbarium sheets were selected as one of the flagship projects. All plants had to be photographed



Fig. 6. One of the three assembly lines for photographing specimens. Shown is the beginning of the belt, where specimens and their folders are placed in two rows, halfway the QR codes are added (man with the black pistol-grip) and at the end, in the black box, the camera, which will only photograph the specimen row. The specimens are surrounded by buttons for colour calibration. Photo by the firm Picturae, reproduced with permission.

and a minimum number of label data had to be recorded. As the only exception within Naturalis, this job was to be done by an external company, Picturae (<https://picturae.com/uk/>). Following the example of herbarium P in Paris and with the aid of Luc Willemse and other staff at Naturalis, three almost fully automated assembly lines were created to photograph the specimens (Figs. 6, 7). At the start of every assembly line, boxes had the free mercury removed (the free mercury was condensed from evaporating sublimate, formerly in general use to safeguard the specimens against insect attacks), and staff then placed the sheets on the belt (Fig. 6). In this process, the specimens were provided with a QR barcode, and, while passing along the assembly band, photographed and assembled again in the same sequence as in which they started and were finally returned to their proper box (Fig. 7). Each photograph was automatically checked for various variables like presence of the QR code, focus, etc. (Fig. 7). If a photograph was found to be incor-

rect, then the belt would move back automatically and re-photograph the faulty specimen. Collections that occupied more than one sheet were marked with colour tabs at the side, so they could later be linked together in the database. At the peak of the work, more than 30,000 specimens were photographed and moved to and from the herbarium! – a total of ca. 600 boxes per day.

The files with the digital images of the specimens, with the QR codes functioning as identifiers, were sent online to Suriname, where a team of 50 trained data typists recorded the names of the collectors, collector numbers and dates, identifications, and collecting localities (and, if present, coordinates of the place of collecting). The names on the major folders were also photographed and formed a test of the identification of the specimens stored in the folder (Fig. 7). The digitised data were returned to Leiden, where another team of ca. 10 (mainly part-time) persons checked the data files before they were added to the Brahm database.



Fig. 7. End of the belt where the specimens are gathered again, put in their folders and the folders in their box. To the right the large greyish-black box with the camera, from where the photographed specimens come out on the band. In the front (near the panic-button) a specimen box and a major folder for specimens. The major folder is photographed before the specimens in order to record the scientific name of the following specimens (this is used in Suriname data input), then follows photographs of the plant specimens themselves. In parallel with the specimens follow the opened specimen folders. In the middle a computer screen showing the photographed specimens (folder, first specimen, etc.). On this screen the checking process is displayed automatically, correct items light up in green above the photos. Photo by the firm Picturae, reproduced with permission.

All herbarium sheets, 3.5 million, are digitised now and their label data is available via the internet version of BRAHMS, BRAHMS Online (BOL; <http://vstbol.leidenuniv.nl/>). The digital images are also available, but unfortunately still only in low resolution (100 DPI). High resolution images (300 DPI) are available on demand.

The completed Naturalis database has tested the limits of what BRAHMS 7 can handle. Problems have to do with the FoxPro software, the database management software, which does not allow for much more data. Another problem is that the FoxPro software is

no longer maintained by Microsoft. Presently, BRAHMS 8 is being developed based on Microsoft NET Framework. As default, V8 will use SQLite software [SQL = Structure Query Language], completely portable and requiring no special installation, but larger institutions may opt for systems like Microsoft SQL Server (MSSQL) or PostgreSQL. For a description of BRAHMS 8, see <http://herbaria.plants.ox.ac.uk/bol/brahms/Software/v8>. This new version of BRAHMS has the possibility to link the database to other data via Application Programming Interfaces (API's). For example, if one visits e-Flora Malesiana

(<http://portal.cybertaxonomy.org/flora-malesiana/>), it becomes possible to create distribution maps on the fly by loading the coordinates of collecting localities from BRAHMS via an API. The major weak spot of BRAHMS remains the dependency on its few designers, mainly Denis Filer at Oxford. Naturalis Biodiversity Center is trying to create a consortium, which can provide support during development of BRAHMS and safeguard the continuation of BRAHMS once the present staff retires. Interested parties are welcome to join consortium.

Naturalis Biodiversity Center is more than just a museum with vast collections. It offers excellent opportunities for researchers not only to consult the specimens, but also to do this with the most modern equipment. Botanical visitors are very welcome and can announce their intended stay via botanicollectie@naturalis.nl.

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