The historic greenhouses of the Greifswald Botanic Garden (Mecklenburg-Western Pomerania, Germany) – rescued in the nick of time

Peter König[1]

Abstract

The historic greenhouses of the University of Greifswald, built between 1884 and 1886 and covering an area of almost 300 m^2, are characterised by their riveted frame construction typical of the era. After almost 130 years of uninterrupted use, they were briefly on the brink of collapse in 2014 because damage caused by corrosion had reached a critical level. The State Monument Preservation Office campaigned strongly for the greenhouses, so that the university, with the support of the State of Mecklenburg-Western Pomerania and other sponsors, was ultimately able to successfully carry out the restoration. The costs are expected to amount to around €4.3 million. The construction work undertaken on the tropical, palm and cycad houses guarantees that valuable plant collections will be preserved and that more extensive growth phenomena and ecological relationships can be demonstrated in the future.

Introduction

History of Greifswald Botanic Garden

The botanic garden of the University of Greifswald looks back on a long tradition, with its foundation dating back to 1763. At that time, it was laid out between the main university building and the city wall. The first garden director, Samuel Gustav Wilcke, quickly built up a collection of 1,438 species and varieties of plants (Wilcke, 1765). He had previously studied natural history in Uppsala under Linnaeus.

Christian Ehrenfried von Weigel, the eponym for the genus *Weigela*, was director of the garden from 1773 to 1781. Carl Friedrich Ledebour worked from 1805 to 1811 as a demonstrator of botany (Ledebour, 1806–1810) and listed 1,600 plant species for Greifswald before he became director of the botanic garden and professor in Tartu, Estonia, and wrote his *Flora Rossica*. Michael Succow, who became known nationwide and was honoured for his international commitment to nature conservation in 1997 with the Right Livelihood Award, was director of the garden from 1992 to 2002.

The garden was relocated due to building activity at the original site in the second half of the 19th century. Julius Münter, director from 1851 until his death in 1885, was instrumental in driving the construction of a new greenhouse facility. In 1886 a new garden with a complex of three large greenhouses was completed on 2 ha of land on the western outskirts of the city (Fig. 1): these

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contained a warm house, now referred to as the tropical house, a central palm house and a cold house, today called the cycad house. Many of the plants came from the existing old stock. The accession book shows a particularly large number of additions for the period 1883–1888, which came as whole plants, most of them exchanged, some purchased. Donor institutions included Botanischer Garten Berlin and the large nursery business Haage & Schmidt, Erfurt. This greenhouse ensemble has been in continuous use for over 130 years and has survived more than one war; it is one of the very few comparable facilities in Germany with such a long history of uninterrupted use. The three houses form the core of the complex of fourteen greenhouses currently in use, with an expanded glass area of 1,333 m^2, two-thirds of which is accessible to visitors. The garden also includes an arboretum covering 6 ha. The two parts of the garden, the greenhouse complex and the outdoor collection of woody plants, are situated about 4 km apart.

The garden is run by the University of Greifswald, meaning that teaching and research are the main activities. Greifswald has 60,000 residents, including 10,000 students. In particular, students in the fields of biology, landscape ecology and nature conservation, geography and pharmacy receive training in or with plants from the botanic garden. A botany school is dedicated to the education of pupils from all years. Run in cooperation with the local school authorities, it has a state-funded biology teacher, with the garden providing equipment and plants.

Layout and content of Greifswald Botanic Garden

A mid-sized institution in the context of German botanic gardens, Greifswald is an all-round garden with a wide range of plant

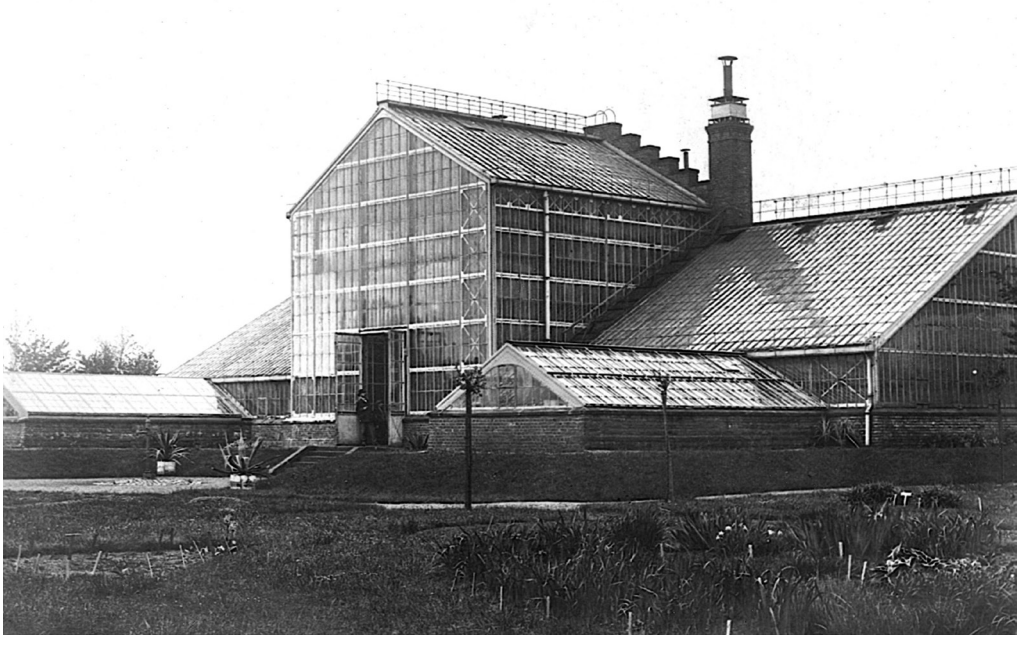

Fig. 1 The greenhouse complex, c. 1895 (from left to right with their original names: warm house, palm house, cold house and two nursery/propagation houses at right angles to the main complex). Photo: F. Schütt.

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families and forms. The focal points are trees and shrubs of the northern hemisphere, subtropical woody plants, aquatic plants, tropical orchids and succulents, and medicinal and other useful plants.

In July 2021 the plant collection included 6,566 acquisitions representing 5,223 taxa, fully recorded in a Microsoft Access database.[2] A seed exchange has been established with nearly 400 partner institutions all over the world. The garden is part of the network of botanic gardens in the Baltic Sea region (Rosén & Jonsell, 2011).

Numerous posters and information sheets make the collections accessible to visitors, together with the usual plant labels. A comprehensive garden guide is available in German (König, 2017).

The garden sections are open to the general public, and during the summer months tourists from the nearby seaside resorts on Usedom and Rügen islands also take time to explore the site. Visitor numbers are estimated at around 20,000 per year, and admission is free except for special events.

Tropical ecosystems and representative plants are displayed in the greenhouse collections as follows:

- tropical house representing the tropical rainforest, with numerous arum species, bromeliads and orchids, heated to 22–24 °C and with a relative humidity (RH) of 85–90%
- succulent house representing deserts, with species highly specialised for arid conditions, heated to 8–12 °C (but with no RH management)
- palm house for large tropical plants such as palm trees, bamboo and wild banana, heated to 18–20 °C and with RH of 75–85%
- cycad house to display primitive seed plants and ferns, heated to 16–18 °C and with RH of 65–75%

It is almost impossible to imagine a botanic garden without such highlights, and thanks only to these collections can the diversity of the equatorial flora be understood. For many of these tropical plants, the height and size of the historic greenhouses in Greifswald has proven essential, because large species, and palm trees in particular, require ample space to develop fully. Phenomena such as the importance of epiphytic lifestyles (Fig. 2) can only be presented and made understandable with a certain amount of space. Within the greenhouse complex, the interplay of important ecological relationships, special adaptations of the plants to tropical habitats, as well as their uniqueness and thus vulnerability in terms of global changes can be explained and experienced in a unique way for students and visitors.

The garden has faced two challenges to the preservation of its living collections in recent years: the greenhouse complex was threatened by decay and the university was restructured in 2005, the horticultural sector losing staff positions as a result. The coronavirus pandemic did not make the situation any easier. The greenhouses had to remain completely closed and the outdoor area was only accessible at certain times, in accordance with the university regulations. Education and public relations activities were also interrupted by the pandemic.

Construction status and challenges

The first extensive reconstruction measures were carried out from 2010

[2] µHortus, version Greifswald 2.6. Software developed by D. Meuthen.

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Fig. 2 The tropical house illustrates a tropical rainforest scenario with its common epiphytic growth forms. Photo: P. König.

to 2012, with considerable support from the German government's future-investments programme at the time (the 'Konjunkturpaket II', which was launched after the bankruptcy of Lehman Brothers on 15 September 2008 and the subsequent global financial crisis). The increasing dilapidation, including rotted wooden rafters, affected the succulent house, orchid house, propagation house and the passageway between the glasshouses.

The more representative iron-and-glass greenhouses had already undergone thorough restoration in the late 1980s and were not assessed as a restoration priority. The situation changed fundamentally in 2012, when severe corrosion was discovered during a routine structural inspection. The corrosion had advanced to the extent that stability could no longer be guaranteed; closure seemed imminent and urgent action was required. This was shocking news – and a challenge for the garden's management.

The following sections briefly describe the greenhouse complex and what happened to avert disaster, ultimately leading to the successful reconstruction of the greenhouses.

Description of the greenhouses and justification for historic monument status

In 1884, construction work began in the southern part of the garden on the oldest section of the greenhouse complex that exists today. The design is attributed to Paul Emil Hofmann, who was appointed university master builder in 1878 and worked alongside engineer Louis Burau. Burau was employed by the Greifswalder Maschinenbauanstalt und Schiffswerft, the company commissioned to build the greenhouse. On the university's side, construction work was supervised by

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the horticultural inspector Edmund Goeze. Prof. Julius Münter also consulted the Berlin garden director August Wilhelm Eichler. Münter himself fell seriously ill during the building project and died before the inauguration (Rütz & Weiß, 2014).

The steel came from the Burbach/ Saarbrücken ironworks, the bricks from the Devin brickworks near Stralsund and the sandstone covers from Silesia. Delays in 1885 due to a shortage of construction materials meant that the building was not completed on time and was not inaugurated until 1886.

The one-storey, 12 m high building stands out because of its imposing height and the position of the gable. To the north and south, parts of the building used as warm and cold houses adjoin symmetrically the central palm house. The roof shape is gabled. In some areas, the frames stand on masonry brick bases. The rear of the greenhouse faces west and is closed off by a massive extension forming the service building. Two chimneys and the stepped-wall gable were originally also characteristic of the overall appearance. The railings of the catwalks on the ridges and those of the accessible gutters are also part of the architectural design, as are the bracing St Andrew's crosses in the facades (Fig. 1). Inside, the palm house is reinforced by thin struts in the roof (Fig. 3) and has two surrounding galleries (Fig. 4).

The original greenhouse complex was expanded with the addition of 13 more greenhouses throughout the 1950s and 1960s. At the same time, the appearance of the existing greenhouses was simplified by straightening the rear stepped gable

Fig. 3 Reinforcement bracing developed by two engineers, Wiegmann and Polonceau, in the palm house, the largest greenhouse in the complex with a ridge height of 12 m, before restoration. Photo: P. König.

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Fig. 4 Palm house, two U-shaped maintenance galleries with access ladder, after restoration and the addition of a safety cage. Photo: P. König.

(which improved rainwater drainage) and deconstructing the chimneys so that their tops were in line with the top edge of the roof. They were no longer necessary given the more modern connection to central municipal heating. The northernmost of the two small greenhouses attached on the east side of the building (Figs 1 & 5) was demolished in 1989 because it was dilapidated.

Essentially, the three large greenhouses, as the core of construction from 1884 to 1886, have been preserved in their original substance and today represent a technical monument from the period of important iron constructions made of puddled steel. This material superseded cast steel, which made the steel malleable and enabled holes to be drilled for rivets. Riveting was the most modern technology at the time and made large steel structures possible. Puddled steel was reheated on an open pan-like surface to remove carbon and make it less brittle. The historical value derives especially from this riveted steel construction (Fig. 6), a technique that was used, for example, in London's Crystal Palace (1851) and is epitomised by the Eiffel Tower in Paris (1889).

The entire greenhouse ensemble was listed as a historic monument in the 1990s by the relevant Greifswald municipal authority,

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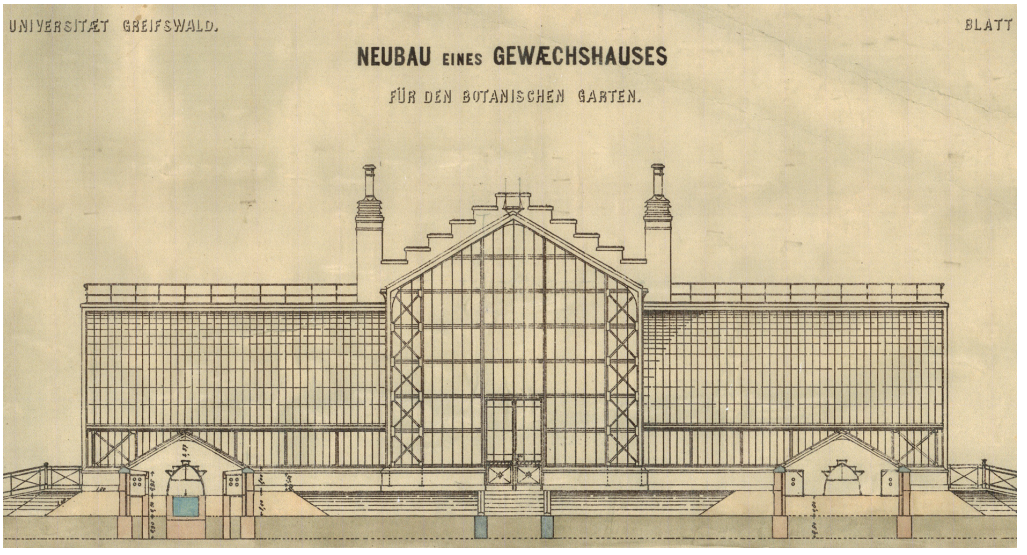

Fig. 5 Architectural drawing from 17 April 1884 for the construction of a new greenhouse for the Botanic Garden of the University of Greifswald. The renovation plan, which was drawn up in 2014 with the participation of the State Office for Culture and Monument Preservation Mecklenburg-Western Pomerania, envisages the restoration of the stepped gable and chimney ensemble.

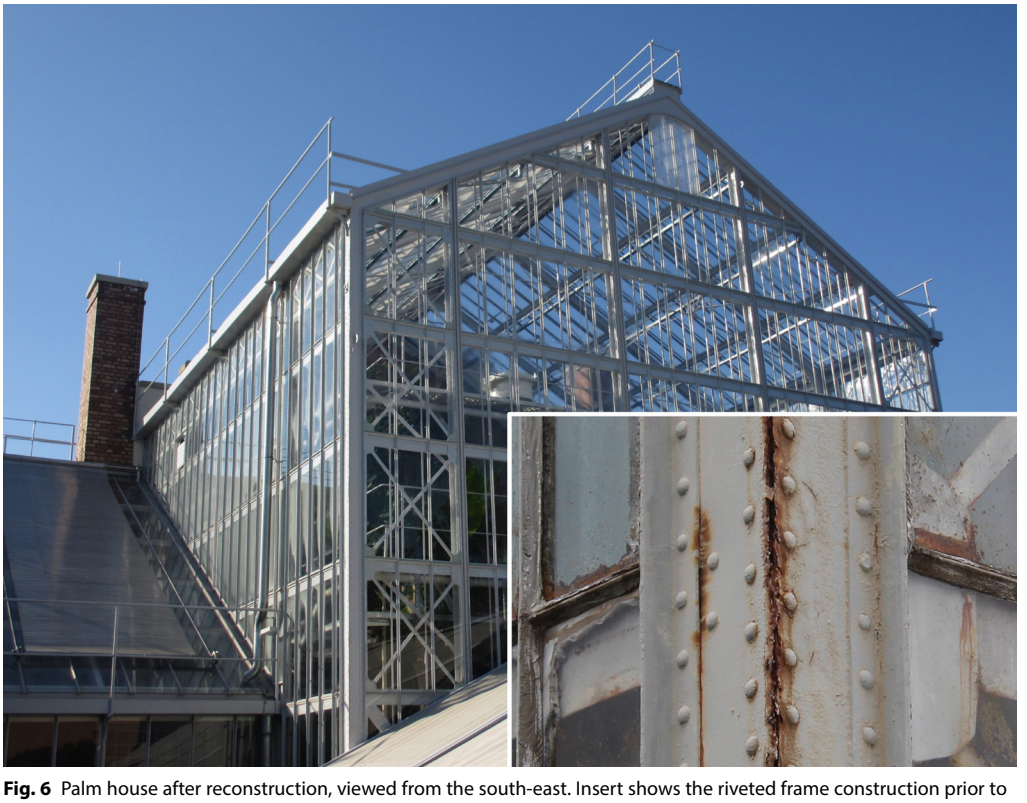

Fig. 6 Palm house after reconstruction, viewed from the south-east. Insert shows the riveted frame construction prior to renovation. Photos: P. König.

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and no changes have been made to the cubage of the facility since then. However, the historic core of the facility required fundamental repairs for the operator's wishes to conform to historic monument requirements.

An evaluation of the historic greenhouse complex by the State Office for Culture and Monument Preservation Mecklenburg-Western Pomerania led to the following decision on 14 August 2014:

> 'The object "palm greenhouse with warm and cold house" of the Botanic Garden of the Ernst Moritz Arndt University of Greifswald is a historic monument according to Article 2 Paragraph 1 of the Historic Monument Protection Act. The object has been established as suitable and worthy of historic monument status, so that the building complex has been included in the list of historic monuments of the Hanseatic City of Greifswald. The ensemble is an important individual monument due to the proven historic monument quality, its original substance is largely preserved in essential areas, to demonstrate its heritage worth. Its rarity also endows it with national importance.'

The Greifswald greenhouse is the only one of its kind to survive in Mecklenburg-Western Pomerania; furthermore, there are only a few large greenhouses in Germany that have been preserved in their original form. Other examples are Pillnitz (completed in 1859), Karlsruhe (1863 – only the steel framework remains) and Frankfurt am Main (1869).

Presentation of the structural damage

As a result of decades-long use and the warm and humid atmosphere in the greenhouses, the structurally important elements of the glazing and the bases of the entire steel support structure had rusted severely. During a thorough overhaul and expansion of the greenhouse complex from 1950 onwards (the buildings had been neglected during WWII and the immediate post-war years), the double glazing was replaced by single glazing, because algal growth in the 15 cm gaps was persistent. The comprehensive maintenance measures carried out in the years 1986 to 1990 were able to stop corrosion temporarily, but could not prevent it in the long run. Deglazing, derusting, partially replacing the steel, painting with corrosion protection and finally reglazing were all mainly carried out by the gardeners themselves in addition to their horticultural duties, and the locksmith work with after-hours brigades. Some measures could not be implemented properly. This approach, taken in GDR times, would be unimaginable today. Individual elements were now so severely corroded that their load-bearing capacity was compromised (Fig. 7).

An expert inspection, especially of static safety with respect to the stability of the structure, was carried out in 2012 by an engineering and architectural company for structural planning. The results were presented on 5 November 2012.

The inspectors' report was worrying: the palm house no longer met the required technical safety level. The stability of individual components, especially that of the frame supports, could no longer be guaranteed. During the inspection, no deformations, cracked glass panels or other damage were found that would indicate an immediate collapse of the construction. The frames of the glass panels in the walls and roof and the inertia of the dead weight of the steel construction provided the residual

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Fig. 7 Corrosion and rust damage at the base of the frame construction. Photo: P. König.

rigidity that had previously prevented the construction from failing. Structural measures were urgently needed to ensure the stability of the main axes and to reduce deformation in the frame corners. In terms of structural fitness, the steel components showed signs of corrosion damage, which made urgent anti-corrosion measures necessary. Individual components, especially in the area around the base of the column, also showed corrosion damage and thus weakened cross-sections. These were to be replaced. Without renovation the palm house would face imminent closure.

The main components of the cycad and tropical houses still met the required level of technical safety. Stability requirements and load-bearing capacities were essentially fulfilled. However, stability in the transverse direction of the buildings was provided by the palm house and was therefore at risk. Some of the frames for the roof glass act as horizontal bracing at roof level, and thus improve the transverse strength of the frame. Rusting of the steel components, which was also progressing in these houses, required short-term measures to prevent further corrosion. As the load-bearing cross-sections suffered partial losses due to corrosion, these had to be replaced.

The gable of the service building is of crucial importance to the transverse bracing of the palm house. An insertion of two double T-beams at the support points of the roof was required, as were rust removal and anchor sealing. These were implemented in 2013 as an immediate measure.

Preserving the greenhouses

As early as 2012, it was confirmed that after almost 130 years of operation, the corrosion-related wear limit of the steel construction had been reached. The static assessment, updated on 6 June 2013 after an extensive

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material test, showed that the structurally critical condition would allow use without substantial structural improvement measures for a maximum of one more year. After that, no one would be allowed to enter the historic greenhouses, given the danger posed by walking or standing under the glass constructions, especially when the storms frequent in this region battered the facade.

The state building authority of Mecklenburg-Western Pomerania then ordered the building to be closed on 6 June 2014. From that point on, neither visitors, students nor employees were allowed to enter the palm, cycad and tropical houses. In these houses 417 plant species – around 14 per cent of the entire garden stock – grew on a total area of 285 m^2. These were disastrous prospects, because not only was a valued collection for teaching and research in danger of destruction, but also special specimens, such as a wild banana (*Musa acuminata*) that was still developing seeds, were threatened. Others, such as a ridge-to-ceiling specimen of the Buddha tree (*Ficus religiosa*) and bamboo (*Bambusa vulgaris*) could not be moved, as they were too mature to be transplanted and rehoused. Rare cycads (Fig. 8), which came to Greifswald more than 90 years ago, are also considered particularly valuable. This phylogenetically ancient and slow-growing group of plants already existed when dinosaurs ruled the earth and is a valuable part of the displays. The opportunity to show the seed production of a decades-old plant would be lost if the plant died.

The garden's horticulture staff conducted a kind of botanical triage to assess what could be saved in the short term. They checked which plants could realistically be moved to other greenhouses and which areas were already very crowded. Yellow plastic tags

Fig. 8 The replanted cycad house is home to a 100-year-old female *Cycas circinalis*, weakened since the construction period. The *Sansevieria* collection is located in the right-hand part of the plant bed. The pillar construction typical of the construction period can be seen, as can the old radiators in the background. Photo: P. König.

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were placed on those plants that were to be moved. Red tags showed which plants would have to be abandoned. It was also necessary to check whether other botanic gardens, for example in nearby Rostock, were interested in any of them. A plant auction was considered.

In view of these unsatisfactory alternatives, however, the complex was given a reprieve. An expert once again inspected the critical supporting pillars of the greenhouses, which had since been exposed, to determine whether staff could enter the greenhouses at least for a transitional period, or whether the greenhouses could be temporarily upgraded. As a result, in 2014 support elements were installed under the roof girders in the tropical and cycad houses to relieve the footings of the supporting pillars, and the palm house was reinforced with scaffolding and bolting (Fig. 9). The operating permit (up to Beaufort wind force 6) was initially extended by one year and later annually. Horticultural activities could therefore be continued, but visitor traffic had to be stopped. This temporary static safeguarding bought us important time for construction planning and fundraising to carry out all the renovations required.

Fig. 9 The advanced corrosion of the footings in the palm house made bracing with scaffolding elements necessary. Fortunately, garden staff could continue to look after the plants, albeit under difficult conditions and with a few 'gymnastics'. Photo: P. König.

Financing

At first, contradictory signals were received from the university administration. In 2011, the minimum funds deemed necessary for a thorough renovation of the greenhouses were estimated at just under €1.73 million. Including renovation of the service building, the total costs were set at €2.5 million. These funds had not been included in the university budget in 2014, and were thus simply not available. Accordingly, the university stated, 'with the funds available until 2020, we can only finance the most urgent measures such as the construction of a new data centre'. Although the historic greenhouses can be used for teaching and also attract external visitors, their use for research is limited. Hence, the university did not prioritise them.

At the beginning of the planning stage, demolition of the old buildings and construction of a significantly smaller new facility was considered and possible locations were discussed. A modern greenhouse could be erected quickly with funds from the university's corporate budget. Initially, there was talk of around €500,000, but thanks to positive feedback from the public, the funding commitment was temporarily increased to €1 million. But that would have been just enough for a tropical glasshouse covering a grand total of only 100 m^2. This option of a very much reduced display area

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was a sobering and frustrating thought for botany, horticulture and all garden enthusiasts.

A number of articles were published around this time in German-language gardening magazines about the precarious situation in Greifswald and the efforts to preserve the historic greenhouses (König, 2014; Weiß, 2014).

In this difficult situation, the State Monument Preservation Office issued a groundbreaking statement on 29 August 2014. Since the present static calculation for the frame of the side wings showed sufficient dimensions, and the statics were proven for the central palm house and the requisite additional horizontal brackets, the technical authority did not see sufficient reason for complete demolition of the historic greenhouses. Rather, after examining the damage patterns and causes, as well as considering possible reconstruction measures, a concept was to be developed that would preserve as much of the original substance as possible.

In the meantime, the historic iron construction was secured by supports to such an extent that entering the greenhouse was not completely forbidden. The remaining plants, which occupied the entire height of the space and therefore could not be moved to other greenhouses, could still be cared for by garden staff. This safety measure was limited to two years, acknowledging the need to carry out the necessary detailed investigations as quickly as possible, not only to develop but also to implement a renovation plan compatible with the preservation of the monument.

The corresponding results would have to be worked out step by step over the subsequent weeks and months. As a result, specific information had to be provided on the extent to which the original structure could be preserved, including replacement of the steel cross-sections and the horizontal bracing structures.

In the course of the examination, the impression prevailed that large parts of the historical substance could be preserved, if financial support from public and private funds was possible. Against this background, the State Monument Preservation Office could not offer to provide a replacement building in the grounds of the botanic garden. Rather, it was pointed out that the greenhouse from 1884 to 1886, which, like the entire botanic garden, is listed as a historic monument, should be preserved in accordance with § 6.1 of the Monument Protection Act, treated with care and, if necessary, repaired in accordance with its historic monument status. In addition, according to § 6.4, long-term use had to be secured.

Public relations

With the closure of the greenhouses ordered in mid-2014, a wave of regional and national sympathy swept towards Greifswald. Within three months, more than 7,000 people had signed a petition calling for the 'preservation of the listed greenhouses from 1886 and the plant collection of the Botanic Garden in Greifswald'.

Radio, television and newspapers reported on the precarious situation and unleashed a storm of indignation at the prospect of closure. Headlines (translated into English) included the following:

- 'Greenhouses threatened with closure' (*Ostseezeitung*, 12 May 2014)
- 'University gives up on historic greenhouses' (*Ostseezeitung*, 19 May 2014)

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Fig. 10 Demonstration in 2014 for the preservation of the historic greenhouses. The banner reads 'No future for palm trees?'. Photo: P. König.

- 'Greifswald fears for historic greenhouses' (*Norddeutscher Rundfunk*, 29 May 2014)
- 'Why isn't anyone interested in this natural beauty?' (*Nordkurier*, 5 June 2014)
- 'Will the state save the greenhouses?' (*Ostseezeitung*, 28 July 2014)

Fundraising activities

Numerous campaigns by individuals and businesses who had a particular fondness for the garden helped to publicise the emergency and attract morale-boosting donations with special activities and slogans.

- Bike-seat covers with the slogan 'Protect your bike seat when it rains and support the historic greenhouses with a donation' were sold.
- The Trekkinghaus Greifswald outdoor store produced a shopping bag with the slogan 'The bag for the greenhouse'.
- University students set up a crowdfunding campaign and organised parties ('Dancing for the greenhouse'), donating a portion of the ticket proceeds to the fund.
- The Friends of the Botanic Garden organised benefit concerts.
- The clothing store Jesske gave a donation every time the company was 'liked' on social media, with the accompanying slogan 'Do good with a "like"'.
- Greifswald Botanical Origami Club regulars made origami blossoms and sold 'Blossoms for cash' (Fig. 11).

In September 2014 an application was made to the Monument Protection Special Program V of the Federal Commissioner for Culture and the Media to fund the renovations required to keep the glasshouses open as a research and education facility. It was approved, and €1.36

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Fig. 11 Origami blossoms. Photo: M. Eick.

million was promised. In return, the garden received supra-regional political support.

Various foundations active in the field of preservation and care of historical-cultural assets were asked by the university and the garden administration for support, with a 'Report on the need for renovation' provided to all those who were approached. Many donors responded generously, the most significant of which contributed a substantial grant towards the renovations.

Finally, the state of Mecklenburg-Western Pomerania joined in to cover the funding gap. Table 1 shows the funding plan in 2017, shortly before the start of reconstruction in 2018. This amount was calculated for the greenhouse complex of 285 m^2 plus the service building sector of 186 m^2. By the end of 2022, the total renovation costs are expected to near €4.3 million due to unforeseeable increases. The additional costs of €400,000 have been borne by the state of Mecklenburg-Western Pomerania.

Table 1 The 2017 funding plan

Cost estimate	**– €3,900,000**
University resources	€350,000
Grant, Federal Commissioner for Culture and Media	€1,360,000
Private donors (students, citizens, foundations)	€120,000
Other funding according to the target agreement between the state of Mecklenburg-Western Pomerania and the university	€2,070,000

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New start versus abandonment

Planned restoration measures

The design, drawn up by two planning companies specialising in the renovation of historical steel constructions and greenhouse planning, provided for a reconstruction that was largely true to the original. The unique characteristics of the building would remain visible. Wherever possible, the original steel beams would be restored and, if necessary, re-riveted. Accordingly, the extremely corroded parts that rest directly on the walls were to be replaced. The facade with the two chimneys originally used for heating and the sandstone gable were to be largely restored (Fig. 5).

Cooperation with the State Office for Culture and Monument Preservation Mecklenburg-Western Pomerania turned out to be very constructive. Significant structural changes in order to comply with historic monument status are as follows:

- upgrading the historically significant rivet construction and restoring the original appearance of the facade (Fig. 6)
- replacing the previous 3–4 mm thick, energy-inefficient single glazing with highly efficient and UV-permeable thermal glazing (energy saving), if possible
- using safety glass for the roofs of the three greenhouses in accordance with overhead glazing regulations
- preparing the existing catwalks with handrails along the ridge lines of all three greenhouses and along the rain gutters of the palm house in accordance with accident prevention regulations and fitting these with additional railings and safety cages. Their present condition no longer meets the current requirements.
- to a limited extent, designing ridge-, roof- and standing-wall ventilation flaps with automated shaft drives and toothed racks with modern technology. The existing drives for operating the ventilation windows with a hand crank and cable pull were retained (Fig. 12), allowing an intervention away from the installed temperature- and humidity-controlled computer technology.
- modern heating control
- redesigning the planting areas and routing for efficient use and modern presentation. Cultivation on benches has been abandoned, with horticulturists switching to cultivation in beds. The existing set of plants having proven suitable for the garden's conditions and activities, the plant stock was modified only slightly to meet the educational requirements for a varied collection of plants displaying the diversity of the plant world.
- changing the soil substrate (about 65 m^3). Instead of the previously used compost with additives, a mineral substrate with artificial fertiliser will be used in the future, mainly because it is expected to have greater structural stability.
- relocating the main entrance for easier access from the outdoor area and thermally more favourable transitions (Fig. 13)
- provision of mobile seating in the cycad house (about 20 seats) to enable lessons and lectures close to the object, with demonstration microscopes and projection options

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Fig. 12 The existing lever on a ventilation flap was retained and is fully functional. Photo: P. König.

Construction measures and their implementation

Initially three to four construction phases were planned, with options for the temporary storage of plants. However, this was abandoned in favour of an all-in-one approach that required less coordination.

Due to the very limited storage space, the stock of plants had to be pared down, and all accessions that were not absolutely necessary were transferred to a non-profit garden centre in Waren and to Rostock Botanic Garden, approximately 80 km away. The large palms *Roystonea regia* and *Washingtonia robusta* had reached the limit of available space as they were already touching the greenhouse roof, and so they had to be felled. The outsourcing and overwintering of unproblematic potted plants was organised via a commercial provider in Rostock. In summer the plants were returned to the garden and used for display and demonstration outside.

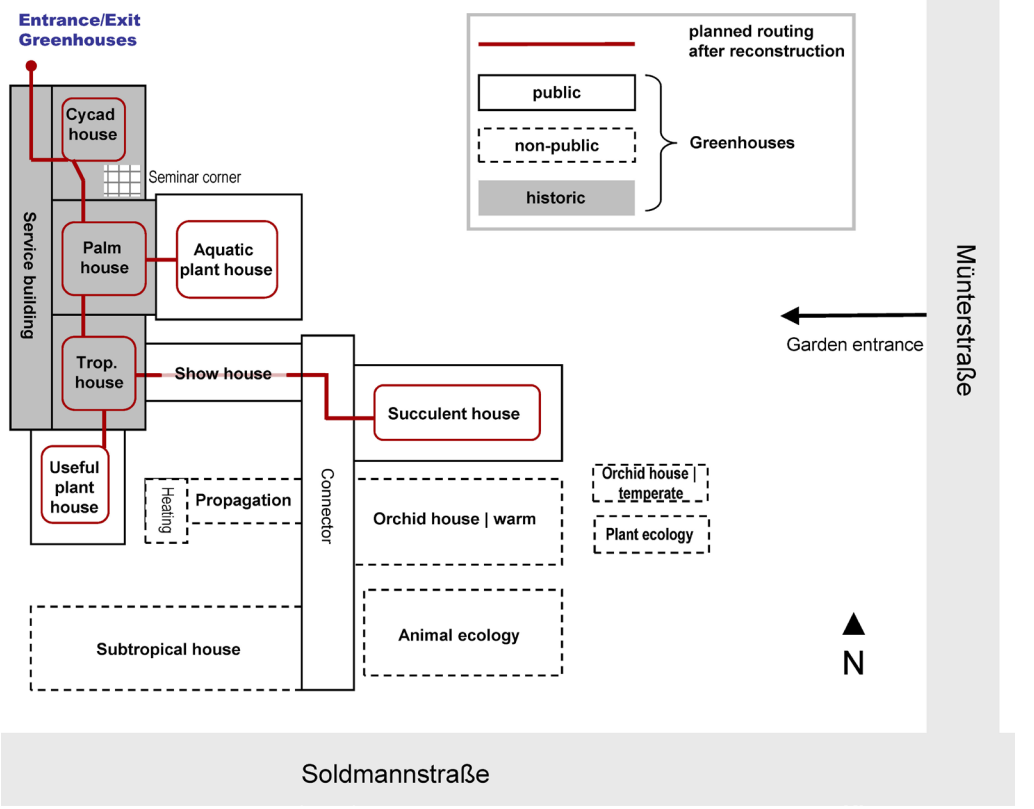

Fig. 13 Layout of the greenhouses and routing after the reconstruction of the historic buildings. Drawing: P. König.

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Most of the plants were split into smaller ones by propagation from cuttings and housed in both the aquatic plant house and an on-site research greenhouse. Since the plants were cleared out well before construction actually began, many plants had to be multiplied by cuttings, repeatedly potted, moved back and forth between different locations and kept under the gardener's watchful eye.

With the exception of seven plants that could not be removed due to their age or special features, the greenhouses were completely cleared (Fig. 14). These plants had to be protected against mechanical damage to the trunk and root area as well as against cold and inadequate light.

The remaining species were *Bambusa vulgaris* (probably from the 1880s), *Coccoloba pubescens* (from Halle Botanic Garden, 1955), *Cycas circinalis* (from Saigon Botanic Garden, 1931), *Ficus cyathistipula* with aerial roots (planted in 1988/1989 at a height of 2–3 m), *Ficus religiosa* (from Thailand, 1984, planted out in 1986), *Gnetum gnemon* (from Dresden Botanic Garden, 1982, planted out in 1988) and *Musa acuminata* (from before 1963). The original location names were given in the accession books from the time. They were housed separately during the reconstruction work and provided with lighting and temperature control (Fig. 15).

It was an ambitious undertaking and a challenge to keep the plants alive during the reconstruction period. *Gnetum gnemon* and *Musa acuminata* in particular suffered from the limited lighting within the enclosure, and for a while it was uncertain whether they

Fig. 14 Almost-empty tropical house: (centre) the two cast-iron supports; (right) the temporary static reinforcement with scaffolding elements. Photo: P. König.

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Fig. 15 *Bambusa vulgaris*, one of seven plants remaining in the greenhouses during the reconstruction work, protected by heated and illuminated polyethylene enclosures. The massive bamboo probably dates back to the early days of the greenhouses. Photo: P. König.

would survive. But happily, in the end, they did.

The system was then completely deglazed and encased in order to sandblast the steel structure. Immediately afterwards, the bare material was coated with an anti-corrosion agent, and successive steel sections that had been destroyed by rust were replaced. Ultimately, more than 90 per cent of the existing historical steel structure was preserved.

The interior of the service building was very much in need of renovation. The massive building extends west over 35 m, the entire length of the three historic greenhouses, but is only 2.8 m wide (Fig. 17). When houses were still heated with coal, this was where the stoker lived and worked. The original boilers no longer exist, but the associated radiators of this hot-water system are, after a comprehensive review and overhaul, still in operation today. With the transition to district heating, this space was converted to the gardeners' storage and recreation rooms. Also present are the plant room for heating, power connection, fuse boxes and control cabinets. A temporary relocation of staff welfare areas such as the common room and WC to the inspector's villa in the garden area offered the opportunity for a comprehensive renovation. The external extensions from a later period (such as visitors' WCs) were removed and housed elsewhere, and the original appearance of the ensemble was restored.

Energy assessment

Early plans to replace the glazing with thermal glass in keeping with the campaign to run a CO_2-neutral university could not be implemented for a number of reasons. In addition to the structural requirements requested, we were concerned that the new buildings erected in 2010–2012 and equipped with thermal glass did not meet the energy-saving expectations of the time. Rather, some of the light-hungry succulents in particular showed growth anomalies manifesting as unusual elongation due to lower UV transmittance of thermal glass, and this necessitated the addition of energy-intensive lighting. Thermal glass is also less permeable in terms of radiant heat (reducing the literal greenhouse effect). Plant growth, energy and illumination requirements had to be considered in the multifactorial analysis.

As a result, special 8.76 mm thick laminated safety glass in the roof area with a high ultraviolet transmittance of $T_{UV} = 0.68$ and a light transmittance of $T_V = 0.90$ was selected, and for the standing walls, a 4 mm

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Fig. 16 View from the tropical house towards the palm house after renovation, with planting not yet complete: (right) trunk which would be used to display epiphytes; (bottom right) the old radiators. Photo: P. König.

Fig. 17 West view of the service building after the reconstruction. The hatches, which are now glazed, were formerly used as coal chutes. The gable of the palm house can be seen in the upper part of the photo. Photo: P. König.

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Fig. 18 A 2022 view of the greenhouse complex with the renewed historical section (two rebuilt chimneys). The aquatic plant house (erected in 1960, overhauled in 1997) is in the foreground, with the show house, succulent house and other greenhouses (1950s to 1962, demolished and rebuilt in 2010–2012) on the left. Photo: P. König.

thick single-pane safety glass with $T_{UV} = 0.72$ and a $T_V = 0.91$ was used.

All's well that ends well

In the final analysis, the restoration turned out well. Sincere thanks go to everyone involved for making this project a success. There were sometimes difficult circumstances and conflicting interests to contend with. The historic greenhouses were not available for educational work or recreation from mid-2014 until the ceremonial reopening in mid-2022. The replanting of the beds, epiphyte trunks and climbing aids took six months, and it will still take some time for the plants to grow back to their full beauty.

The restored facade is not only a distinctive feature of the garden, but also represents the historic heritage of both the University of Greifswald and the Hanseatic City of Greifswald, which is known and appreciated nationwide. A metal plaque placed at the reopening event honours the historic achievement of Julius Münter, 1815–1885, as the initiator of the greenhouse complex. The six gardeners and garden workers responsible for the greenhouse area intend to create stimulating displays of tropical plants for a long time to come.

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