VERTEBRATE ZOOLOGY

66 (2): 169 – 177

20.10.2016

SENCKENBERG

Tracking a syntype of the Australian skink *Anomalopus leuckartii* (Weinland, 1862): 'lost' treasures in the Senckenberg Natural History Collections Dresden highlight the importance of reassessing and safeguarding natural history collections

Sven Mecke [1] *, Felix Mader [2], Max Kieckbusch [1], Hinrich Kaiser [3], Wolfgang Böhme [4] & Raffael Ernst [5]

[1] AG Evolution und Systematik der Tiere und Zoologische Sammlung Marburg, Fachbereich Biologie, Philipps-Universität Marburg, Karl-von-Frisch-Straße 8, 35032 Marburg, Germany — [2] Janusstraße 5, 93051 Regensburg, Germany — [3] Department of Biology, Victor Valley College, 18422 Bear Valley Road, Victorville, California 92395, USA; and Department of Vertebrate Zoology, National Museum of Natural History, Smithsonian Institution, Washington, DC 20013, USA — [4] Sektion Herpetologie, Zoologisches Forschungsmuseum Alexander Koenig, Adenauerallee 160, 53113 Bonn, Germany — [5] Sektion Herpetologie, Museum für Tierkunde, Senckenberg Naturhistorische Sammlungen Dresden, Königsbrücker Landstraße 159, 01109 Dresden, Germany — *Corresponding author; meckes(at)staff.uni-marburg.de

Accepted 15.vii.2016.
Published online at www.senckenberg.de / vertebrate-zoology on 28.ix.2016.

Abstract

We here report the rediscovery of a type specimen of the Australian skink *Anomalopus leuckartii* (Weinland, 1862) in the Museum of Zoology (Museum für Tierkunde), Senckenberg Natural History Collections Dresden (accession number MTKD 10205), heretofore presumed lost during World War II. Eidonomic data for the specimen conform to the original species description, and combined with the specimen's history, we are able to unequivocally identify it as part of the original syntype series. Weinland's description was based on two specimens, one of which does indeed appear to be lost. Consequently, MTKD 10205 is designated as lectotype of *A. leuckartii*. This find invalidates the subsequent designation of AM R 44677 (Australian Museum, Sydney) as neotype for the species. The rediscovery highlights the importance of maintaining natural history collections, not merely as static archives but rather as dynamic and lively databases. This in combination with optimal taxonomic expertise as bedrock guarantees an environment, in which new discoveries are not impeded but actively promoted, thereby inevitably advancing modern biodiversity research.

Kurzfassung

Wir berichten über die Wiederentdeckung eines Typusexemplars des australischen Skinks *Anomalopus leuckartii* (Weinland, 1862) im Museum für Tierkunde, Senckenberg Naturhistorische Sammlungen Dresden (Sammlungs-Nr. MTKD 10205), das bisher als im Zweiten Weltkrieg verloren galt. Eidonomische Daten für das Exemplar entsprechen denen in der Originalbeschreibung. Anhand dieser Daten und der Geschichte des Exemplars ist es uns möglich, es unzweifelhaft als einen Teil der originalen Syntypen-Serie zu identifizieren. Weinlands Artbeschreibung basierte auf zwei Exemplaren, von denen eines tatsächlich als verschollen betrachtet werden muss. Daraus folgend designieren wir MTKD 10205 als Lektotypus für *A. leuckartii*. Der Fund macht den inzwischen festgelegten Neotypus für diese Art (Australian Museum, Sydney, Sammlungs-Nr. R 44677) ungültig. Die Wiederentdeckung unterstreicht die Wichtigkeit der Instandhaltung naturgeschichtlicher Sammlungen, die als dynamische Datenbanken und nicht als statische Archive fungieren sollten. Dies, kombiniert mit einer soliden taxonomischen Expertise als Fundament, schafft ein Umfeld, in dem neue Entdeckungen gefördert anstatt erschwert werden und trägt somit zur Weiterentwicklung einer modernen Biodiversitätsforschung bei.

Key words

Scincidae, Lygosominae, *Anomalopus leuckartii*, Australia, taxonomy, syntype, lectotype, morphology, natural history collections, museums.

Introduction

The holdings of the Museum of Zoology (Museum für Tierkunde) now housed in the just recently (2009) formed Senckenberg Natural History Collections Dresden, Germany (formerly the Staatliche Naturhistorische Sammlungen Dresden), are an excellent and poignant example of a collection that has seen dramatic changes and periods of turmoil (reviewed by Fritz, 2002): Dating back to the 16th century, and therefore one of the oldest natural history collections in the world, the institution was struck by disaster several times throughout its history. Consequently, it suffered from dramatic losses of valuable material. During the 1849 May Uprising in Dresden (struggles towards the end of the revolutionary upheaval that began in 1848, also known as the Spring of Nations), the collection fell victim to a fire, in which the majority of the zoological specimens was destroyed. After a period of growth and the addition of unique and valuable specimens, the collection was again almost entirely destroyed near the end of World War II, during the allied bombing of Dresden in the night from 13–14 February 1945. The alcohol-preserved collections, including the herpetological holdings, were severely hit, and the latter was reduced from 6,704 to only 98 specimens. In an effort to re-establish the collection in subsequent years, the museum received material from various sources, including former university collections. Among the specimens received, those from the collection of the former Zoological Museum at the University of Leipzig (herein abbreviated MUL) were probably one of the most diverse additions. This addition contained holdings collected and catalogued by Eduard Friedrich Poeppig (*1798 †1868), and was later revised by Willi Hennig (*1913 †1976), with a detailed treatment (Obst, 1977a, b) received from the former director of the Staatliche Naturhistorische Sammlungen Dresden, Fritz Jürgen Obst (*1939). Other, nonetheless interesting and significant parts of the collection have received less attention, partially because the provenance of these appeared much less traceable. As a consequence, some valuable specimens remained unrecognized in the drawers and on collection shelves for decades.

One such specimen is a syntype of the Australian lygosomine skink *Anomalopus leuckartii* (Weinland, 1862) that was assumed to have been lost (see Greer & Cogger, 1985). It was recently rediscovered in the herpetological section of the Senckenberg Natural History Collections Dresden. We here present an account of how this rediscovery was made and provide eidonomical data for the type, which we compare with those given in the original species description.

The rediscovery serves as an important example of a valuable, 'lost or forgotten treasure' hiding in a museum archive. Although as taxonomists we are well aware of the fact that discoveries of historical material, including new species, continue to be made in collections, we feel that the importance of natural history collections is not generally understood by the public and at present only insufficiently acknowledged by administrators. Hence, we discuss their value and call for safeguarding collections with highly elevated conscientiousness and under consideration of optimal expertise in taxonomy and natural history. Only then can natural history collections survive into the future as the powerful tool they have traditionally been for research in the life-sciences.

Material and Methods

The specimen in question is housed in the Museum of Zoology (Museum für Tierkunde), Senckenberg Natural History Collections Dresden (now MTD, formerly MTKD) under accession number MTKD 10205. The following measurements (in mm) and counts were made to allow both a comparison with the original description of the type material by Weinland (1862–63) as well as the data presented by Greer & Cogger (1985) for the species: snout-vent length (SVL), measured from tip of snout to vent; tail length (TailL), from vent to tip of tail; arm length (ArmL), from axilla to longest finger; leg length (LegL), from groin to tip of styliform appendix; head length (HeadL), measured from tip of snout to retroarticular process of lower jar; number of supralabials (SupraLab); number of infralabials (InfraLab); number of supraciliaries (SupraCil); number of supraocular scales (SupraOc); number of paravertebral scales, beginning with the scale bordering the parietal posteriorly to (1) level of cloaca (PVS1) and (2) to posterior edge of thigh (PVS2); number of scale rows around midbody (MBSR); number of supracaudals (SupraC), including all scales from cloaca to tail tip. Measurements and counts of characters occurring bilaterally were taken on the left side of the specimen. Note that in his count for paravertebral scales, Weinland included a parietal scale, which conforms to our PVS1 + one additional scale. Supracaudals are not normally counted in modern squamate taxonomy but this count allows further comparison with Weinland's data. We do not provide a full description of the type specimen, since as, the only member of *Anomalopus* Duméril & Duméril, 1851 with didactyl forelimbs, the species is easily diagnosed. We also present a photograph of the rediscovered type to readily allow comparison with Weinland's illustration.

Results

During a practical part of the 'Senckenberg Course in Taxonomy'(www.senckenberg.de/taxonomy_school), the first author discovered in the herpetological collection of the MTD several valuable scincid specimens. The most important finding was the discovery of an Australian ly-

Fig. 1. *Anomalopus leuckartii*. (**A**) Photograph of MTKD 10205 in its current condition. (**B**) Illustration of MTKD 10205 as figured in the original description by Weinland (1862–63). Scale bar = 2 cm.

gosomine skink (MTKD 10205; Fig. 1 A) in a jar containing a label with the inscription "*Rhodona*" . *Rhodona* Gray, 1839 is a junior synonym of *Lerista* Bell, 1833 (see Greer 1967)[1], a diverse (> 90 species) Australian skink genus containing various morphotypes, ranging from short-bodied forms with well-developed limbs bearing five digits, to elongate and limbless forms (Wilson & Swan, 2013). In species of *Lerista* with reduced limbs, hindlimbs are always longer than forelimbs, and the opposite morphology (i.e., forelimbs longer than hindlimbs) is a rare trend in Australian lizards, known to occur in a single scincid genus only: *Anomalopus* (Wilson, 2012). Since the forelimbs of the MTD "*Rhodona*" specimen are longer than the styliform hindlimbs, we were able to identify the specimen as a member of the genus *Anomalopus*. Using the identification key for the genus in Cogger (2014) we diagnosed the specimen as *A. leuckartii* (Weinland, 1862).

Beyond the issue of misidentification, closer inspection of the label inside the jar focused our attention on the donor of the specimen, Karl Georg Friedrich Rudolf Leuckart (*1822 †1898), in whose honor David Friedrich Weinland (*1829 †1915) named *A. leuckartii*. The original species description appeared under the genus name *Brachymeles* Duméril & Bibron, 1839 and was based on specimens originating in "Neuholland" (= Australia). Weinland (1862–63) clearly indicated that only two specimens of his new taxon were available, and both formed the basis for the description; they must therefore be considered syntypes. The specimens were housed in the Giessen Zoological Museum (herein abbreviated GZM), Giessen, Germany, at the time of Weinland's description. The Zoological Institute Giessen, which included the collections, burned and was destroyed completely during World War II (Ankel, 1957). Hence, the two specimens of *A. leuckartii* were believed to have been lost in the disaster (Greer & Cogger, 1985).

Leuckart was professor for zoology in Giessen from 1850–69, and subsequently became chair of zoology and zootomy at the University of Leipzig as well as director of the MUL (Wunderlich, 1978; Daintith *et al.*, 1994). On the first page of the historical accession catalogue of the MUL (Accessions Catalog 1869), which is now kept at the MTD, some reptile specimens donated by Leuckart are listed, including a single "*Brachymeles Leuckarti*" from "Neuholland" (acquisition number 19). There is little doubt that this specimen, along with many others, was originally part of the GZM or of Leuckart's private collection (see Discussion). In 1933, Willi Hennig, then a student at Leipzig University, revised the herpetological collection. In one of his hand-written catalogues for the squamate reptiles (Hennig, 1933; part Sauria), a specimen of "*Lygosoma verreauxii*" (= *Anomalopus verreauxii* Duméril & Duméril, 1851) is listed with a direct reference to the original designation and catalogue entry as follows: "*Brachymeles Leuckartii* Weinl., Nova Hollandia, Leuckart d.dt. [= dono dedit], Acc. Cat. [= Accession Catalogue] 1869/70: Nr. 19." Hennig (1933) gave the specimen the catalogue/collection number RVa316. The MUL was dissolved in 1968 and partly acquired by the MTD in 1970/71. Based on a handwritten entry on the first page of Hennig's catalogue by Obst in 1974, 248 jars with lizards were received and the specimens integrated into the herpetological collection of MTD. In a more recent collection catalogue (Nr. 2) of the herpetological section of MTD (1972–79) the new number MTKD 10205 was assigned to RVa316. Curiously, the name "*Rhodona*" was used in the catalogue to refer to this particular specimen. The recent catalogue entry

[1] Smith (1937) also treated *Glaphyromorphus pumilus* (Boulenger, 1887) and the three species of the genus *Isopachys* Lönnberg, 1916 known at that time as members of the genus *Rhodona*.

Table 1. Metric data (in mm), body proportions, and scale counts of MTKD 10205 (*Anomalopus leuckartii*), along with data from, or calculated from, the original description (WEINLAND 1862–63) and data presented by GREER & COGGER (1985). *n* = sample size.

Character	MTKD 10205	Weinland (1862–63)	Greer & Cogger (1985)
SVL	113	110	39–137 (*n* = 120)
TailL	121	124	—
HeadL	9.0	9.0	—
ArmL	3.6	4.0	—
LegL	1.5	1.5	—
TailL/SVL	0.93	1.13	0.69–1.24 (*n* = 43)
ArmL/SVL	0.03	0.04	0.03–0.04 (*n* = 18)
LegL/SVL	0.01	0.01	≤ 0.01 (*n* = 2)
SupraLab	6	6	6
InfraLab	6	6	6
SupraCil	6	—	5–7 (*n* = 96)
SupraOc	3	—	2–4 (*n* = 62)
PVS1	126	127[a]	—
PVS2	122	—	108–128 (*n* =19)
MBSR	20	20	18–22 (*n* = 56)
SupraC	139	139[b]	—

[a] WEINLAND (1862–63) counted paravertebral scales from the interparietal to a point above the cloaca, and hence his count (127) is higher than the value obtained by application of the commonly used counting method, beginning with the first scale bordering the parietal posteriorly.

[b] In addition to providing paravertebral scales (from interparietal to cloaca), WEINLAND (1862–63) stated that he counted scales from the cloaca to the tip of the snout ("… und von da [Kloake] bis zur Schnauzenspitze 139" [and from there (cloaca) to the tip of the snout] WEINLAND, 1862–63: 142). However, this would imply that WEINLAND counted dorsal scales back and forth, and included head scales in one of his counts. While this appears odd, the number of head scales does also does not equal 12 (the difference between 127 and 139 dorsals). It is more likely that the German term for snout tip [Schnauzenspitze] was confused with the one for tail tip [Schwanzspitze]. Both words look fairly similar if written in old-German handwriting, and it was common practice during WEINLAND's time to submit handwritten manuscripts to a journal. Hence, we assume that "Schnauzenspitze" is a transfer error for "Schwanzspitze" that occurred during type-setting. Moreover our count for SupraC yielded 139 scales, conforming to the number of scales WEINLAND obtained.

and species label in the collection jar alone provide little evidence and no unambiguous clues that would allow for the identification of a presumably lost type specimen.

Data of the relevant *Anomalopus leuckartii* specimen (MTKD 10205; Fig. 1A) are presented in Table 1, along with measurements, selected proportions, and scale counts given for the species by WEINLAND (1862–63) in the original species description and by GREER & COGGER (1985). Our eidonomical data (e.g., PVS1, MBSR) for MTKD 10205 agree very well with those reported by WEINLAND (1862–63), and since some of these characters are known to be quite variable interspecifically, this concordance in eidonomy supports the concept that WEINLAND described the taxon based on the individual now registered as MTKD 10205. WEINLAND (1862–63: Plate 4, Fig. 3) also illustrated a specimen that is identical to MTKD 10205 (see Discussion), based on the presence of an original tail (curled downwards under the body), and we present this figure herein for comparison (cf. Fig. 1A & B). Eidonomic data and the history of the specimen therefore corroborate that MTKD 10205 is indeed one of the syntypes that had been presumed lost. In the absence of the second syntype, we herein designate MTKD 10205 as lectotype of *A. leuckartii*. The neotype designation of Australian Museum specimen AM R 44677 by GREER & COGGER (1985) is thus invalid, since it is superseded by the original type rediscovered (see ICZN, 1999: article 75.8). MTKD 10205 thus becomes the oldest known herpetological type specimen in the MTD collection.

Discussion

WEINLAND's description of *Anomalopus leuckartii*. For his description of *Anomalopus leuckartii* (original name: *Brachymeles Leuckartii*), WEINLAND (1862–63) had two specimens available. However, his measurements are evidently based on a single specimen with an intact tail (see "Proportionen und Dimensionen des vollständig erhaltenen Exemplars" [proportions and dimensions of the complete specimen]; WEINLAND, 1862–63: 142), whereas the second specimen had a mutilated, partly regenerated tail ("… es liegen deren [= *A. leuckartii*] zwei zur Beschreibung vor, wovon Eines mit verstümmeltem aber theilweise wieder ersetztem Schwanz…" [there are two specimens available for the description, of which one has a mutilated but partly regenerated tail]; WEINLAND, 1862–63: 142) and was probably only used to describe coloration (see below). A second line of evidence showing that WEINLAND used only one of the available specimens comes from the listing of scale characters (PVS, MBSR, SupraC), which he obtained from a single specimen only. This can be inferred from the lack of mention of any variation in the descriptive data. Since both metric and meristic data in Weinland's description are essentially identical to those of MTKD 10205, we assume that scale counts were based only on the 'intact specimen' as well. Minor discrepancies in measurements or counts may be attributed to different ways of recording data, or perhaps on slight errors. The specimen with original tail was also the one illustrated in Weinland (1862–63: Plate 4, Fig. 3; Fig. 1B herein) and is considered to be identical with MTKD 10205.

The 'Leuckart Collection': origin and whereabouts. The historical accession catalogue of the MUL (Accessions Catalog 1869) at MTD clearly indicates that most specimens received during that period were donated by Leuckart. About two thirds of the app. 1,200 specimens listed in the catalogue are marked as e.g., "Ex. don. Lt." [= specimen donated by Leuckart], and these include mainly parasitic and marine invertebrates; additional anatomical specimens are listed in a separate catalogue. However, it is not clear whether respective specimens were part of the GZM or Leuckart's private collection, and specimens (especially duplicates) were likely exchanged informally and bidirectionally between the two collections when Leuckart was professor at the University of Giessen. According to Spengel (1902) and Schmidt (1938), Leuckart increased the collection of the GZM by adding specimens in spirits from all groups of the animal kingdom. There is evidence that Leuckart donated to the GZM parts of his own collection (Bischoff, 1852: invertebrates), and that duplicates received were, at least in some cases, deposited in the GZM and Leuckart's private cabinet (von Kölliker, 1872: *Kophobelemnon leuckartii*). Weinland (1862–63) noted that the only specimens of *Brachymeles Leuckartii* (the two syntypes) known to him were housed in the GZM. However, it is not unlikely that one of these specimens (MTKD 10205), as a duplicate, was already part of Leuckart's private collection at the time of Weinland's description, which would indicate a possible error by Weinland (1862–63) or that the specimen came into Leuckart's private cabinet later on.

While the exchange of specimens between the GZM and Leuckart's private collection are difficult to trace in detail, it is evident that the MTD houses a large number of specimens donated by this famous zoologist, who was the founder of modern parasitology (e.g., Kreis, 1937; Krämer, 2006) and an advocate of comparative morphology (Krämer, 2006), corresponding with Charles Darwin (*1809 †1882), and lecturing about Darwinian theories (Wunderlich, 1978; Ellis & Kirchberger, 2014). During his time in Giessen, Leuckart had become one of zoology's leading scientists (Wunderlich, 1978), who was in contact with many renowned naturalists (e.g., Carl Bergmann, Antoine René-Edouard Claparède, Henry James Clark, Justus Liebig, Karl Lindemann, Ilja Iljitsch Metschnikow, Japetus Steenstrup, Jean Baptiste Vérany, Rudolf Wagner, David Friedrich Weinland, and Friedrich Albert von Zenker) and received specimens from a variety of sources (e.g., Leuckart, 1863: parasites; Lütken, 1892: a fish; Grimpe, 1933: a cephalopod). He also made specimens from the GZM and/or his own collection available for examination by others (e.g., Claus in von Siebold & von Kölliker, 1860: siphonophores; Claus in von Siebold & von Kölliker, 1863: copepods; Weinland, 1862–63: skinks; von Kölliker, 1872: sea pens). According to Wunderlich (1978), Leuckart also described almost 100 invertebrate species (many during his time in Giessen), and 27 taxa have been named in his honor (Hess, 1906).

Leuckart's lively scientific exchange highlights the importance of the 'Leuckart Collection' received by the MUL, now part of the MTD, which likely includes many type specimens. In a historical overview and annotated type list of the MTD's ichthyological collection, Zarske (2003) already reported the rediscovery of another type from the 'Leuckart Collection': the holotype of the siluriform fish *Acanthopoma annectens* Lütken, 1892, which Leuckart received from the German botanist Gustav Wallis (*1830 †1878), and which is also listed in the accession catalogue of the MUL (Accessions Catalog 1869).

The importance of the 'Leuckart Collection' is, however, only now becoming more fully appreciated, and the rediscovery of the *Anomalopus leuckartii* type specimen prompted a systematic search for Leuckart material housed in various collections of different MTD sections.

A search for Leuckart material in the collection for lower invertebrates yielded about 60 specimens that he had donated to the MUL, including many parasites (Andreas Weck-Heimann, pers. comm.). In the malacological collection (which includes additional invertebrate taxa) André Reimann (pers. comm.) found a specimen of the pennatulacean (a group of Octocorallia) *Kophobelemnon leuckartii* from Nice, France, which is also listed in the accession catalogue (Accessions Catalog 1869) and likely was used by von Kölliker (1872) to describe the taxon; this potentially represents another 'lost' type specimen.

The accession catalogue of the MUL (Accessions Catalog 1869) is a powerful tool that can be used to trace more of Leuckart's specimens. Entries in the catalogue referring to Leuckart might vary, since they were likely being written by different employees and/or at different times. The collection locality data "Gießen," where Leuckart was professor before he took up his position in Leipzig, as noted in the catalogue (in the column titled "Herkunftsland" [country of origin]) and on specimen labels, also provides evidence for a donation by Leuckart, even if a direct reference to the donor is lacking. Scientific publications on particular taxa, providing information on Leuckart specimens, including collection numbers of the Leipzig museum, are available as well. For example, Grimpe (1933), in his overview on arctic cephalopods, notes under the name *Sepietta scandica* (Steenstrup, 1887) that Leuckart received a giant, "original" (= type) specimen of that taxon from the describer (Steenstrup) and provided the MUL collection number "Nr. 69/71." Based on our preliminary observations, we are confident that a more detailed reconstruction of the 'Leuckart Collection' is feasible. This will likely yield additional types that have been presumed be lost.

The importance of reassessing and safeguarding natural history collections: a herpetological perspective. From their origin as private 'cabinets of curiosities' or 'cabinets of wonders' in the 16th and 17th centuries to the modern-day tools of scientific research and public education, natural history collections have undergone substantial changes in the course of history (Alexander & Alexander, 2007). Present day collections are more than just physical backups of the extinct and recent organismic diversity, but rather represent all-encompassing databases that contain a wealth of information that can be used to track the past, document the present, and even predict the future of the biosphere (Nudds & Pettitt, 1997; Shaffer *et al*., 1998; Lister, 2011; Kemp, 2015). Moreover, these 'repositories of knowledge' are the basis for higher and formal education programs and therefore rank as irreplaceable, high-value assets (Lane, 1996; Nudds & Pettitt, 1997; Bradley *et al*., 2014). Unfortunately, the importance of collections and their multiple functions is not always recognized and acknowledged. Collections throughout the world are currently more directly than ever before confronted with shortsighted development plans that emerge from a harsh climate of economic decision-making (see Dalton, 2003; Bradley *et al*., 2014). This situation is particularly lamentable given that we have entered a century that has been called the "Age of Biology" (Glover, 2012), in which the life sciences have already made unprecedented progress. This appears like an almost euphoric atmosphere for research, and both the scientific community and political representatives are sometimes heard to proclaim that the study of organismic biology must now be redefined to meet future challenges and develop a next-century road map that aims at serving both science and society. Natural history collections should certainly remain particularly important in this respect, thereby heightening the prospects for the road map.

The use and appreciation of natural history collections has, however, always been unsteady and fluctuating throughout the centuries. As a result, collections historically underwent dramatic changes. Holdings were variously destroyed, sold off, relocated and dispersed, dissolved (completely or in parts), or simply left unattended due to a lack of interest or a cut in the economic resources required to maintain such facilities.

This fluctuation for herpetological collections is perhaps best exemplified by the natural history cabinet of the Dutch-German natural history collector Albertus Seba (*1665 †1736), whose first collection was sold to Peter the Great (*1672 †1725) (Engel, 1937; Boeseman, 1970), with a second, rebuilt and even larger collection auctioned and dispersed following Seba's death (e.g., Engel, 1937; Boeseman, 1970; Juriev, 1981; Daszkiewicz & Bauer, 2006; Bauer & Günther, 2013). Fortunately, some dispersed specimens were subsequently rediscovered, such as in the Museum für Naturkunde, Berlin, Germany (ZMB) (Bauer & Günther, 2013). Other examples include the cabinet of the German naturalist and explorer Prince Maximilian zu Wied-Neuwied (*1782 †1867), whose collection was purchased for the American Museum of Natural History (AMNH) in 1869 and only recently received full attention, including the identification of many type specimens (Vanzolini & Myers, 2015). Some of Wied's specimens may also have survived in the Zoologische Sammlung der Universität Marburg, Germany (ZSUM; Mecke pers. obs.), a university collection dating back to 1818/19 that contains a large number of important (but largely neglected) specimens; the unsteady history of this collection was summarized by Bohle (2015). The private collection of Alexander Macleay (*1767 †1848), now at the University of Sydney and rich in type specimens, may serve as another example for a collection that went through many periods of neglect. In 1969, the type specimens that could be located were sent to the Australian Museum on permanent loan (Cogger, 1979). However, since then other types have been found in the collection (Glenn Shea, in litt.; for a list of herpetological types see Goldman *et al*., 1969; Cogger, 1979; Cogger *et al*., 1983; Shea & Sadlier, 1999).

The rediscovery of the type of *A. leuckartii*, together with other recent (re)discoveries of valuable herpetological specimens, including new species and presumably lost types (e.g., Nowak-Kemp & Fritz, 2010; Bauer & Wagner, 2012; Bucklitsch *et al*., 2012; Bauer & Günther, 2013; Borczyk, 2013; Böhme, 2014; Kathriner *et al*., 2014; Böhme *et al*., 2015; Hartmann *et al*., 2016; Kieckbusch & Mecke *et al*., 2016) in natural history collections, highlights their outstanding importance for clarifying many of the most fundamental questions in organismic biology. However, this requires that unique knowledge about the history of particular collections (including knowledge about the naturalists that were associated with them) is preserved. Moreover, sound taxonomic expertise, and an extensive organismic background are necessary to detect potentially interesting specimens in the first place. In the case reported herein, the rediscovery of a single specimen (the type of *Anomalopus leuckartii*) that was long presumed lost, led to the discovery of many other valuable specimens, yet to be reported on. These finds might be regarded as a case example of how discoveries, in combination with the relevant expertise, can change our knowledge about whole collections.

We also believe that collections house a vast number of undescribed amphibians and reptiles, a phenomenon well documented for other groups (Green, 1998: insects; Bebber *et al*., 2010: plants). Authors of this study, for example, have discovered many new reptile species based on museum material alone, with shelf lives (the gap between the collection and formal description date of a new species) of three recent discoveries, *Varanus nesterovi* Böhme *et al*., 2015, *Cyrtodactylus klakahensis* Hartmann *et al*., 2016, and *Cylindrophis subocularis* Kieckbusch *et al*., 2016 being 102, 87 and 79 years, respectively (see also Green, 1998; Fontaine, 2012).This highlights the need for describing an appreciable amount of already catalogued but still undescribed biodiversity. Natural history collections also house treasures that are important witnesses of past human influences on the biosphere (e.g., specimens of already extinct taxa, first or historic distribution records) and thus allow predicting future impacts of human activities on global biota.

Such discoveries, however, can only continue to be made, when the importance of natural history collections is more sufficiently acknowledged, and this is only possible by maintaining these facilities and by funding researchers, who are engaged in collection-based science. Without museum-based taxonomic research the proper identification of species is impossible, and this affects other disciplines, such as ecology and conservation (e.g., Wägele *et al*., 2011; Bradley *et al*., 2014). Many collections struggle for survival and the traditional taxonomist is already on the edge of extinction, due to limited support by funding agencies and universities that almost entirely focus on molecular rather than organismic disciplines (e.g., Kemp, 2015). Hence, some of the world's largest collections are maintained by the lowest possible number of staff only, which allows specimen conservation but does not allow collection-based research carried out by qualified museum employees. Collections thus run the risk of becoming static archives rather than active and lively databases essential for any meaningful scientific research. This is particularly unfortunate considering that we are in the midst of a biodiversity crisis (Ceballos *et al*., 2015), and a 'simple' quantification what is there and what is lost is of paramount importance. Yet about half of the specimens kept in collections may be labeled with wrong names (see Goodwin *et al*., 2015: tropical plants), thus hampering a sound assessment. Molecular methods applied to museum specimens and digitization of collections to make them more accessible are advantageous but are insufficient in the absence of specific expertise in taxonomy. We need to work toward overcoming the current 'taxonomic impediment,' because only then can collections survive, and remain valuable and powerful tools for research.

Acknowledgments

Sven Mecke and Felix Mader are indebted to the organizers and lecturers of the 'Senckenberg Course in Taxonomy,' who offered an inspiring scientific course on all relevant aspects of taxonomy and systematics through both conceptual and applied approaches. We thank Markus Auer (MTD) for technical support and facilitating work in the collection at the MTD, and an anonymous reviewer for helpful comments on an earlier version of the manuscript.

References

Accessions Catalog (1869): Accessions Catalog für die Jahre 1869, 1870, 1871, u. 1872. Zoologische Sammlung – Leipzig, Germany, 1–53.

Alexander, E.P & Alexander, M. (2007): Museums in Motion. An Introduction to the History and Functions of Museums, 2nd edition. − AltaMira Press, Lanham, USA, 366 pp.

Ankel, W.E. (1957): Zur Geschichte der wissenschaftlichen Biologie in Gießen. In: Gießen: Ludwigs-Universität, Justus-Liebig-Hochschule: 1607–1957. Festschrift zur 350-Jahrfeier, 308−340.

Bauer, A.M. & Wagner, P. (2012): Previously unrecognized types from the Baudin Expedition (1800–1804) in the Naturhistorisches Museum Wien. − Herpetozoa, **24**(3/4): 135−147.

Bauer, A.M. & Günther, R. (2013): Origin and identity of the von Borcke collection of amphibians and reptiles in the Museum für Naturkunde in Berlin: a cache of Seba specimens? − Zoosystematics and Evolution, **89**(1): 167−185.

Bebber, D.P., Carine, M.A., Wood, J.R.I., Wortley, A.H., Harris, D.J., Prance, G.T., Davidse, G., Paige, J., Pennington, T.D., Robson, N.K.B. & Scotland, R.W. (2010): Herbaria are a major frontier for species discovery. − Proceedings of the National Academy of Sciences, **107**(51), 22169−22171.

Bell, T. (1833): Descriptions of two reptiles and the types of two genera hitherto undescribed. Characters of two new genera of reptiles. − Proceedings of the Zoological Society of London, **1833**: 98−99.

Bischoff, T.L.W. (1852): Das neue Anatomiegebäude zu Giessen. − Universitäts-Buchdruckerei von G.D. Brühl I., Gießen, Germany, 20 pp.

Boeseman, M. (1970): The vicissitudes and dispersal of Albertus Seba's zoological specimens. − Zoolologische Mededelingen, **44**(13): 177 − 206.

Bohle, H.W. (2015) Von der Naturgeschichte zur Zoologie. Blasius Merrem und die Entwicklung der Zoologie an der Universität Marburg im 19. Jahrhundert (1807 bis 1928), Band 12 der Reihe Academia Marburgensis. − Waxmann Verlag GmbH, Münster, Germany, 302 pp.

Böhme, W. (2014): Herpetology in Bonn. – Mertensiella, **21**: 1–256.

Böhme, W., Ehrlich, K., Milto, K., Orlov, N. & Scholz, S. (2015): A new species of desert monitor lizard (Varanidae: *Varanus*: *Psammosaurus*) from the western Zagros region (Iraq, Iran). − Russian Journal of Herpetology, **22**(1): 41−52.

Borczyk, B. (2013): Rediscovery and redescription of the holotype of *Liolaemus lemniscatus* Gravenhorst, 1838 (Reptilia, Squamata, Liolaemidae). − Zookeys, **320**: 97−101.

Boulenger, G.A. (1887): Catalogue of the Lizards in the British Museum (Natural History). Second Edition. Volume III. Lacertidae, Gerrhosauridae, Scincidae, Anelytropsidae, Dibamidae, Chamaeleontidae. Printed by order of the Trustees, London, United Kingdom, 575 pp.

Bradley, R.D., Bradley, L.C., Garner, H.J. & Baker, R.J. (2014): Assessing the value of natural history collections and addressing issues regarding long-term growth and care. − BioScience, **64**(12): 1150−1158.

Bucklitsch, Y., Geissler, P., Hartmann, T., Doria, G. & Koch, A. (2012): Rediscovery and redescription of the holotype of *Lygo-*

soma vittigerum (= *Lipinia vittigera*) Boulenger, 1894. − Acta Herpetologica, **7**(2): 325 − 329.

Ceballos, G., Ehrlich, P.R., Barnosky, A.D., García, A., Pringle, R.M. & Palmer, T.M. (2015): Accelerated modern human-induced species losses: Entering the sixth mass extinction. – Science Advances, **1**(5): 1 – 5.

Claus, C. (1860) Ueber *Physophora hydrostatica* nebst Bemerkungen über andere Siphonophoren, pp. 295 − 329, in: von Siebold, C.T. & von Kölliker, R.A. (eds.). − Zeitschrift für Wissenschaftliche Zoologie, Verlag von Wilhelm Engelmann, Leipzig, Germany, **10**(3): 504 pp.

Claus, C. (1863): Die frei lebenden Copepoden mit besonderer Berücksichtigung der Fauna Deutschlands, der Nordsee und des Mittelmeeres. − Zeitschrift für Wissenschaftliche Zoologie, Verlag von Wilhelm Engelmann, Leipzig, Germany, 230 pp.

Cogger, H.G. (1979): Type specimens of reptiles and amphibians in the Australian Museum. − Records of the Australian Museum: **32**(4): 163 − 210.

Cogger, H.G. (2014): The Amphibians and Reptiles of Australia. − CSIRO Publishing, Collingwood, Australia, 1064 pp.

Cogger, H.G., Cameron, E.E. & Cogger, H.M. (1983): Zoological Catalogue of Australia. Volume 1. Amphibia and Reptilia. − Australian Government Publishing Service, Canberra, Australia, 313 pp.

Daintith, J., Mitchell, S., Tootill, E. & Gjersten, D. (1994): Biographical Encyclopedia of Scientists. Second Edition – 2 Volume Set. − Tayor & Francis, London, UK, 1581 pp.

Dalton, R. (2003): Natural history collections in crisis as funding is slashed. − Nature, **423**(6940): 575.

Daszkiewicz, P. & Bauer, A.M. (2006): Specimens from the second collection of Albertus Seba in Poland: the Natural History Cabinet of Anna Jablonowska (1728 − 1800). − Bibliotheca Herpetologica, **6**(2): 16 − 20.

Duméril, A.M.C. & Bibron, G. (1839): Erpétologie Générale ou Histoire Naturelle Complète des Reptiles. Volume 5. − Roret, Paris, France, 854 pp.

Duméril, A.M.C. & Duméril, A.H.A. (1851): Catalogue Méthodique de la Collection des Reptiles du Muséum d'Histoire Naturelle de Paris. − Gide et Baudry, Paris, France, 224 pp.

Ellis, H. & Kirchberger, U. (2014): Anglo-German Scholarly Networks in the Long Nineteenth Century. − Brill, Leiden, Netherlands, 238 pp.

Engel, H. (1937): The life of Albertus Seba. − Svenska Linné-Sällskapets Årsskrift, **20**: 75 − 100.

Fontaine, B., Perrard, A. & Bouchet, P. (2012): 21 years of shelf life between discovery and description of new species. − Current Biology, **22**(22): 943 − 944.

Fritz, U. (2002): Herpetology and herpetological type specimens at the Museum für Tierkunde Dresden with a bibliography of herpetological contributions by Fritz Jürgen Obst (Amphibia, Reptilia). − Faunistische Abhandlungen, Staatliches Museum für Tierkunde Dresden, **23**: 3 − 34.

Glover, A. (2012): The 21st Century: the Age of Biology. − OECD Forum on Global Biotechnology, Paris, France.

Goldman, J., Hill, L. & Stanbury, P.J. (1969): Type specimens in the Macleay Museum, University of Sydney. II. Amphibians and reptiles. − Proceedings of the Linnean Society of New South Wales, **93**(3): 427 − 438.

Goodwin, Z.A., Harris, D.J., Filer, D., Wood, J.R.I. & Scotland, R.W. (2015) Widespread mistaken identity in tropical plant collections. − Current Biology, **25**(22): 1066 − 1067.

Gray, J.E. (1839): Catalogue of the slender-tongued saurians, with descriptions of many new genera and species. − The Annals and Magazine of Natural History, **1**(2): 331 − 337.

Green, S.V. (1998): The taxonomic impediment in orthopteran research and conservation. − Journal of Insect Conservation, **2**: 151 − 159.

Greer, A.E. (1967): A new generic arrangement for some Australian scincid lizards. − Breviora, **267**: 1 − 19.

Greer, A.E. & Cogger, H.G. (1985) Systematics of the reduce-limbed and limbless skinks currently assigned to the genus *Anomalopus* (Lacertilia: Scincidae). − Records of the Australian Museum, **37**(1): 11 − 54.

Grimpe, G. (1933): Die Cephalopoden des Arktischen Gebietes. Fauna Arctica, Bd. 6. – Gustav Fischer Verlag, Jena, Germany, 25 pp.

Hartmann, L., Mecke, S., Kieckbusch, M., Mader, F. & Kaiser, H. (2016): A new species of bent-toed gecko, genus *Cyrtodactylus* Gray, 1827 (Reptilia: Squamata: Gekkonidae), from Jawa Timur Province, Java, Indonesia, with taxonomic remarks on *C. fumosus* (Müller, 1895). − Zootaxa, **4067**(5): 552 − 568.

Hennig, W. (1933): Katalog der Reptiliensammlung des Zoologischen Museums der Universität Leipzig, Germany. – 3 Hefte.

Hess, W. (1906): Leuckart, Karl Georg Friedrich Rudolf, pp. 672 – 675, in: Allgemeine Deutsche Biographie. − Historische Kommission bei der Bayerischen Akademie der Wissenschaften, München, Germany, **51**.

ICZN (1999) International Code of Zoological Nomenclature. Fourth Edition. International Trust for Zoological Nomenclature, London, United Kingdom.

Juriev, K.P. (1981): Albert Seba and his contribution to the development of herpetology, pp. 109 – 120, in: Ananjeva, N.B. & Borkin, L.J. (eds.). – Trudy Zoologicheskogo Instituta. Akademiia nauk SSSR [in Russian], **101**.

Kathriner, A., Bauer, A.M., O'Shea, M., Sanchez, C. & Kaiser, H. (2014): Hiding in plain sight: a new species of bent-toed gecko (Squamata: Gekkonidae: *Cyrtodactylus*) from West Timor, collected by Malcolm Smith in 1924. − Zootaxa, **3900**(4): 555 − 568.

Kemp, C. (2015): Museums: the endangered dead. − Nature, **518** (7539): 292 − 294.

Kieckbusch, M., Mecke, S., Hartmann, L., Ehrmantraut, L., O'Shea, M. & Kaiser, H. (2016): An inconspicuous, conspicuous new species of *Cylindrophis* from the south coast of Jawa Tengah, Java (Reptilia: Squamata: Cylindrophiidae), and an overview of the tangled taxonomic history of *C. ruffus* (Laurenti, 1768). – Zootaxa, **4093**(1): 1 – 25.

Krämer, E. (2006): Leben und Werk von Prof. Dr. phil. Günther Enderlein: (1872 – 1968). − Hans Tolzin Verlag, Echterdingen, Germany, 290 pp.

Kreis, H.A. (1937): Rudolf Leuckart, der Begründer der modernen Parasitologie. − Ciba-Zeitschrift, **5**: 1755 − 1757.

Leuckart, G.F.R. (1863): Die Menschlichen Parasiten und die von Ihnen Herrührenden Krankheiten. Ein Hand- und Lehrbuch für Naturforscher und Aerzte. Erster Band. C. F. Winter'sche Verlagshandlung, Leipzig, Germany, 766 pp.

Lönnberg, E. (1916): Zoological results of the Swedish Zoological Expedition to Siam 1911–1912 and 1914. 2. Lizards. – Kungliga Svenska Vetenskapsakademiens Handlingar, **55**(4): 1 – 12.

Lister, A.M. & Climate Change Research Group (2011): Natural history collections as sources of long-term datasets. – Trends in Ecology and Evolution, **26**(4): 153–154.

Lütken, C.F. (1892) Om en med Stegophiler og Trichomycterer beslaegtet sydamerikansk Mallefisk (*Acanthopoma annectens* Ltk. n.g. & sp.?). – Videnskabelige Meddelelser fra den naturhistoriske Forening i Kjøbenhavn, For **1891**: 53–60.

Nowak-Kemp, M. & Fritz, U. (2010): Chelonian type specimens at the Oxford University Museum. Zootaxa, **2604**: 1–19.

Nudds, J.R. & Pettitt, C.W. (1997): The Value and Valuation of Natural Science Collections. – The Geological Society Publishing House, Bath, UK, 276 pp.

Obst, F.J. (1977a): Herpetologische Taxa von Eduard Poeppig (1798–1868). – Zoologische Abhandlungen, **34**(12):167–170.

Obst, F.J. (1977b): Die herpetologische Sammlung des Staatlichen Museums für Tierkunde Dresden und ihre Typusexemplare. – Zoologische Abhandlungen, **34**(13): 171–186.

Schmidt, W.J. (1938): Einiges aus der Geschichte der Zoologie in Gießen. – Verhandlungen der Deutschen Zoologischen Gesellschaft, **1938**: 18–33.

Shaffer, H.B., Fisher, R.N. & Davidson, C. (1998): The role of natural history collections in documenting species declines. – Trends in Ecology and Evolution, **13**(1): 27–30.

Shea, G. & Sadlier, R. (1999): A catalogue of the non-fossil amphibian and reptile type specimens in the collection of the Australian Museum; types currently, previously and purportedly present. – Technical Reports of the Australian Museum, **15**: 1–91.

Smith, M.A. (1937): A review of the genus *Lygosoma* (Scincidae: Reptilia) and its allies. – Records of the Indian Museum, **39**(3): 213–234.

Spengel, J.W. (1902): Vorgeschichte und Geschichte des Zoologischen Instituts der Universität Gießen und über dessen gegenwärtige Einrichtungen. – Verhandlungen der Deutschen Zoologischen Gesellschaft, **1902**: 10 – 17.

Steenstrup, J. (1887): Notæ Teuthologicæ. 6. Species generis *Sepiolæ* Maris Mediterranei. – Oversigt over det Kongelige Danske Videnskabernes Selskabs Forhandlinger, **1887**: 47–66.

Vanzolini, P.E. & Myers, C.W. (2015): The herpetological collection of Maximilian, Prince of Wied (1782–1867), with special reference to Brazilian materials. – Bulletin of the American Museum of Natural History, **395**: 1–155.

von Kölliker, R.A. (1872): Anatomisch-Systematische Beschreibung der Alcyonarien. Erste Abtheilung. Die Pennatuliden. – Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft, **7/8**: 85–275.

Wägele, H., Klussmann-Kolb, A., Kuhlmann, M., Haszprunar, G., Lindberg, D., Koch, A. & Wägele, J.W. (2011): The taxonomist – an endangered race. A practical proposal for its survival. – Frontiers in Zoology, **8**(25): 1–7.

Weinland, D.F. (1862–1863): Beschreibung und Abbildung von drei neuen Sauriern. (*Embryopus Habichii* und *Amphisbaena innocens* von Haiti, und *Brachymeles Leuckartii* von Neuholland.) Tafel V. – Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft, **4**: 131–143.

Wilson, S. (2012): Australian Lizards: a Natural History. – CSIRO Publishing, Collingwood, Australia, 208 pp.

Wilson, S. & Swan, G. (2013): A Complete Guide to Reptiles of Australia, fourth Edition. – New Holland Publishers, London, United Kingdom, 592 pp.

Wunderlich, K. (1978): Rudolf Leuckart: Werk und Weg. – Gustav Fischer Verlag, Jena, Germany, 152 pp.

Zarske, A. (2003): Geschichtliche Entwicklung und vorläufige, kritisch kommentierte Typusliste der ichthyologischen Sammlung der Staatlichen Naturhistorischen Sammlung Dresden, Museum für Naturkunde. – Zoologische Abhandlungen, **53**: 5–36.