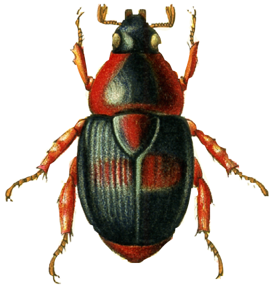

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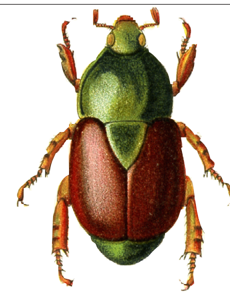

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The Musée des Confluences, Lyon (France) – Research and Repatriation of Specimens from the Soula Collection of Rutelini

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In two weeks of the scalding Kansas summer of 2013 I had the pleasure of visiting Wichita State University, with Mary Liz Jameson as my host. Our aim was a collaborative project on the molecular and taxonomic placement of a curious scarab, *Acrobolbia macrophylla* Ohaus. Using Natural History Museum (NHM) London specimens and the Jameson lab expertise, we endeavoured to resolve this long-standing problem – but that's another story! In the spirit of continued collaboration I was generously awarded a grant by the NHM to facilitate further research with Mary Liz Jameson and Matt Moore (PhD candidate, University of Florida) to produce a catalogue of Marc Soula's types for the purposes of clarifying Soula's taxonomic interpretation of the Rutelini. Most importantly for the NHM, at the time of Soula's untimely death he was in possession of many specimens (including types) belonging to many major research institutions worldwide. A condition of the grant award was to attempt to retrieve Natural History Museum (NHM/BMNH) specimens loaned to Soula and remaining in his collection.

Who Was Marc Soula?

Marc Soula (1945-2012) was a French amateur entomologist specialising in the scarab subfamily Rutelinae - the leaf chafers. His focus was largely species of New World distribution. A prolific fieldworker, he amassed a large collection of Neotropical specimens, many of which he used to describe new species. In the 13 years he was active within entomology, he described and published 535 new genera, species and subspecies (495 species). Given how famously slow traditional taxonomy can move, this is a remarkable feat but perhaps one to be considered with caution in some cases. His species descriptions and interpretation of the taxonomic placement of the subfamily were self-published in a series of books entitled '*Les Coléoptères du Monde*' (*The Beetles of the World*) in which he provided a synopsis of the pelidnotine scarabs and the many additional Ruteline scarabs. These ten publications were not peer-reviewed.

Soula's Collection in Lyon

It is a tale of fortune and tragedy that led to the Soula collection being deposited in the collections of the Musée des Confluences. In 2010, Cédric Audibert, then assistant curator at the Musée des Confluences, met Soula on a collecting trip to Massat in the Ariège region of southwestern France where collecting of beetles and snails (Cédric's expertise) led to discussion about the future of Soula's collection.

Cédric with some of Soula's beetles.

Soula's collection was spread over many floors in his home, and Cédric found it to be very impressive. Soula enjoyed showing off his *Pelidnota* specimens; favoured for their diverse colours and forms! He had decided not to deposit his collection in Paris, and so it was arranged that Soula would visit the Musée des Confluences collection to investigate that museum as a suitable repository. Following this meeting, Soula arranged for the deposit of his collection in Lyon in the event of his death. No one could have predicted that this would happen much sooner than anticipated. In February 2012, Marc Soula died in Peru whilst on a collecting trip. Much mystery surrounded his death.

Soula's collection comprised about 170 boxes containing around 2,000 species and subspecies exclusively of Rutelinae; total number of specimens was about 14,800, of which approximately 2,000 were "types". Once the collection had been quarantined it was necessary to catalogue the collection, accessioning it to the Lyon invertebrates collection. Soula had his own system of cataloguing his collection which comprised a card index detailing his own species but lacking other described species within the subfamily. So, as a tool for interpreting his collection, the card index was an additional resource (however, in the wider taxonomic sense, it was rather useless!).

Cédric set about imaging each store box in its original Soula classification developing a permanent digital record. Once imaged the specimens were transferred to standard French museum store boxes and catalogued accordingly. They now exist in 140 store boxes, (excluding Anomalini, and other Rutelinae tribes); total Rutelinae store boxes number 165.

Soula's Method

Soula described 21 new genera and subgenera and 516 species and subspecies of Rutelinae, and many types were deposited in his collection. Soula, when describing species, would more often than not designate holotype, allotype and paratype using large red labels. In fact Soula loved allotypes so much that he even created "néoallotypes". His species concept may not be agreeable to many scarab taxonomists. He determined to publish privately and also was motivated financially by receiving revenue from the sale of the publications as well as the sale of some of his paratypes. On account of publishing privately, he restricted the vital process of peer review and in many cases there was none. As a result there are many mistakes in his publications such as typographical errors, describing the same species more

Soula's original storage boxes.

Soula's collection recurated to Museum standard store boxes.

than once, failure to consult / cite relevant literature and a somewhat cavalier approach to interpreting the rules of nomenclature. More pertinently, he borrowed specimens from various institutions but failed to keep them separate or to label them with their collection of origin, thus making future repatriation difficult (and occasionally impossible). His collection was generally unavailable to the wider scientific community, being deposited in his own home and not distributed to relevant institutions. This is the first time that experts in the Rutelinae have had access to this material.

Three Go to France

In August 2014, following the successful Scarab conference held at the Natural History Museum London and the International Congress of Entomology conference at York, Mary Liz, Matt and I spent a week in Lyon at the Muséum d'Histoire Naturelle immersing ourselves in the Soula collection with Cédric's careful and helpful guidance. We soon came to realise that coffee and patisserie was essential for fortification against the taxonomic muddle that lay ahead of us each day and that a few glasses of Vin de Table was de rigueur to mull over the day's progress.

View over Lyon.

So how would we approach the daunting task of cataloguing Soula's types into a meaningful taxonomy? Well, we soon learned that one week in France was not long enough…

Division of labour was as follows:

Mary Liz: Cataloguing types with special attention to errors in description and notes on future synonymy. Cataloguing label data verbatim. Assisting Beulah in searching for the 'lost' NHM types.

Matt: Cataloguing types with special attention to errors in description and notes on future synonymy. Cataloguing label data verbatim.

Beulah: Searching for NHM type material. Imaging of Soula type specimens using Combine ZX stacking software. Assisting Mary Liz and Matt in transcription.

Cédric: Providing access to the collection, digitally and physically. Assisting in liaising with Museum National d' Histoire Natural (MNHN) Paris. Giving us some excellent collection tours including the spirit and mammal collections!

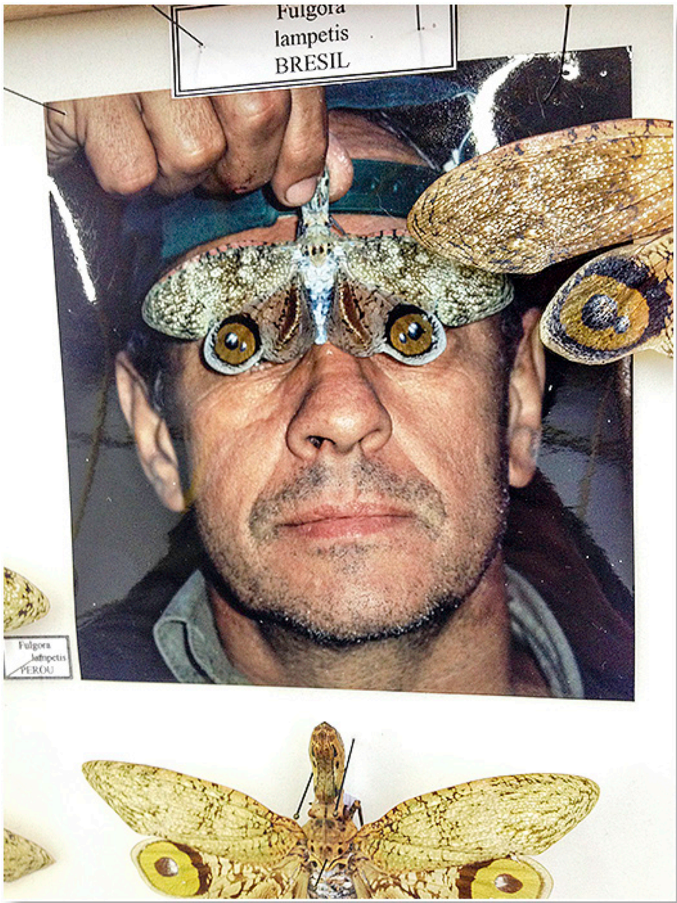
Retrieval of NHM types - a Cautionary Tale

If ever there was an example of the necessity of keeping one's house in order this is it! Museum curators and collection managers this is for you!

Soula's association with the NHM dates back to 1994 when he first received loans of *Macraspis* types. His final loan was in 2008. The loans were issued by Scarabaeidae curator Malcolm Kerley and later by temporary curator Conrad Gillett to Dr. Girard of the MNHN who acted as Soula's guarantor (NHM policy regarding private individuals operating out of private addresses stipulates the necessity for a relevant institutional guarantor). Over the years, 11 loans were issued to Soula and, indeed, some returned. But at the time of Soula's death, there were three outstanding loans totalling 17 type specimens of Bates, Ohaus, Gory, and Blanchard. Unfortunately for the museum, Dr Girard retired from MNHN during this time. So in legal terms, the outstanding loans were without a guarantor.

Armed with the relevant loan paperwork and some background knowledge on previous NHM practices of issuing loans from Max Barclay, I had the 'simple' mission of retrieving these specimens and returning them to the Natural History Museum. I might employ that wonderful French word 'naïveté' at this point! Upon initial inspection of the collection it soon became apparent that Soula did not label his loaned specimens (he may even have removed labels from certain specimens). After a morning spent searching for the types we were certain Soula had retained, we became increasingly worried. Some specimens were found relatively easily on account of obvious labelling, such as *Biologia Centrali America* material; others were more problematic, and some were apparently not to be found. Then Cédric offered a possible explanation. At the time of Soula's death when his estate was being dealt with by family, Patrick Arnaud, Soula's friend and colleague, offered to deal with his entomological specimens. Unfortunately, according to Patrick, the family had invited an antique dealer to pick over Soula's effects. Could it be possible that the ever-attractive *Chrysina* and some rare *Pelidnota* had been 'cherry picked' and sold on? We were put in touch with Patrick and, after a lengthy phone call,

Beulah, Mary Liz, Matt and Cédric at the entrance to the Centre de Conservation et d'Etude des Collections (CCEC).



Patrick Arnaud.

Juvisy.

were informed that Patrick was in possession of at least six BMNH types which he had retrieved for safe-keeping. Following our conversation in September 2014, he duly handed a small box with 11 NHM specimens to my colleague, Max Barclay, at the Juvisy International Insect Fair, of which he is the organiser.

In addition to the outstanding specimens known from the loan paperwork, we found 7 NHM beetles: four specimens of *Sorocha maylini* Soula (holotype, allotype, and 2 paratypes; ex Nevinson coll.) and three specimens of *Pelidnota* (ex BCA coll.) which we were not able to assign to any outstanding loan of named material.

Soula had visited the BMNH on more than one occasion, most recently in 2006, and had borrowed a number of 'undetermined specimens' which probably included these. It was not until 2010 that Max Barclay implemented a department-wide system of photographing all outgoing loans and uploading the photographs to our Ke-Emu Collections Management database, but if such a system had been in place earlier it would have made our task a lot easier.
In addition to the outstanding BMNH specimens, we also traced specimens from Paris, Brussels, Dresden, Canada, Berlin, and Copenhagen. The relevant collection managers were informed and put in contact with Cédric for future repatriation.

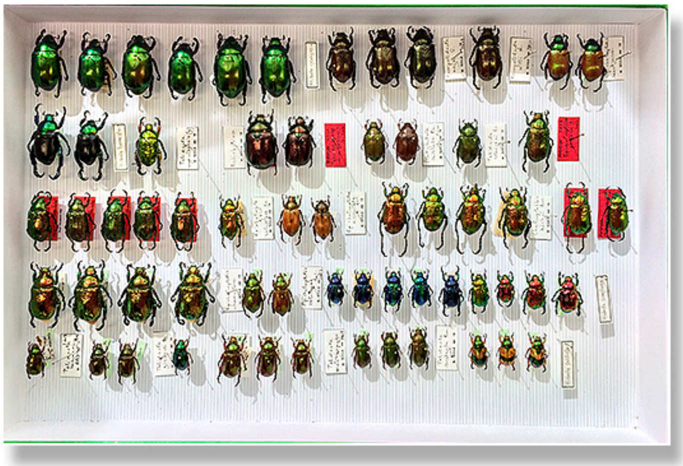
In conclusion, major institutions such as NHM are loaning and exchanging tens or hundreds of thousands of specimens a year. We have in place an alert system on our Ke-EMu loans database for when loans become outstanding. This experience couldn't be a better example of the benefits of keeping in regular touch with our borrowers to ensure that (1) the specimens are safe, (2) their research remains current and in progress, and (3) they are actually still alive!

Towards a Catalogue of Soula Types

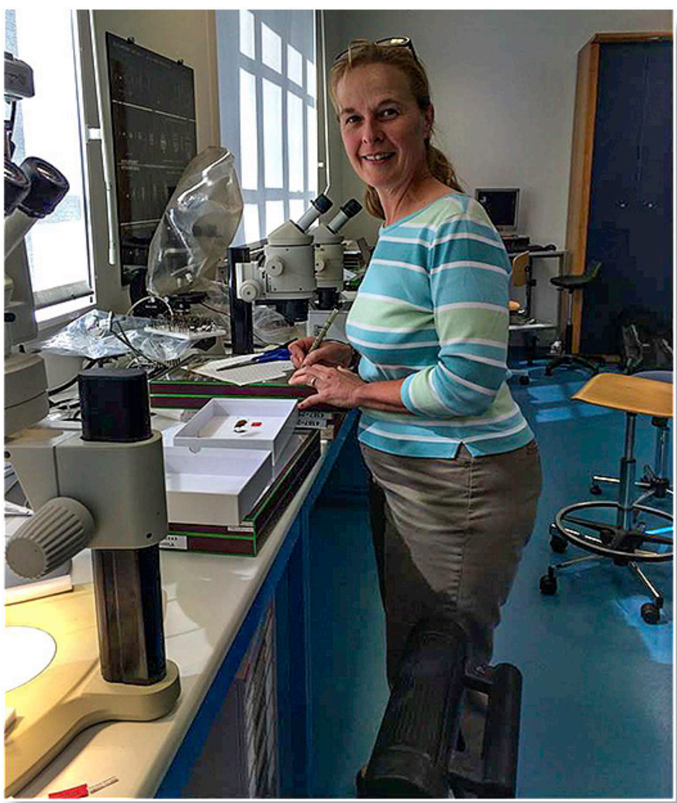
In order to place Ruteline species diversity in a broader context, it is essential that the peculiarities of Soula's work are clarified. It is likely that this will require an army of workers! For us to have first-hand access to his collection was in itself a privilege but also a daunting task, and the week we spent in Lyon was really just the beginning as familiarisation with the collection and understanding Soula's method took a few days. Soula often described from long series and nearly always included allotype. His label data was often inconsistent, and his hand writing not clear, so this also made the meticulous work of transcription rather slow.
We have currently transcribed approximately one third of his collection. It is estimated that one return visit should complete the catalogue. Not all types present will be imaged but we aim to complete the holotypes of full

Specimens retrieved from Arnaud.

***Pelidnota strigosa*. 'Type specimen of *Pelidnota strigosa alutacea* Bates, 1888; described by Henry Walter Bates in *Biologia Centrali Americana*. Originally in NHM (where it was labelled by Henry Howden in 1962. Designated as Lectotype (Hardy, 1975). Now in Soula / Lyon collection. Repatriated to NHM August 2014.**



***Pelidnota* from Soula's collection.**



Mary Liz Jameson deciphering Soula's work.

species, or at least the type species of his new genera and subgenera.

The Centre for the Conservation and Study of the Collections (CCEC)

The Centre for the Conservation and Study of the Collections (CCEC) of the Confluence Museum was inaugurated in November 2002 (previously the collections were stored in the Museum of Natural History of Lyon (MHNL), an old institution founded in 1772). The CCEC covers 3,300 square meters, equipped with storerooms which house compactors, laboratories, and consulting rooms to give access for researchers from around the world. Principal divisions are Palaeontology, Entomology, Malacology, Zoology, and Osteology.

The objectives of CCEC are conservation, inventory of specimens, and collaborations with scientific partners to enhance the collections through publications.

The Centre adheres to international curatorial standards (each storeroom has its own climatic parameters). The entomological collection is housed within one room with controls in place for stable humidity (rh50 %), stable temperature (19°c), and with a slightly pressurised environment to control dust accumulation. The boxes are stored in metal cabinets in open compactors. All boxes are quarantined before entering the collections using a 'double cold treatment' (-40° for 15 days, with 15 days between two treatments).

Unlike other disciplines (palaeontology, conchology and vertebrate zoology for example) which are rich in old and historical collections, a large proportion of the entomological collections were developed after the 1980s by Joël Clary, Life Sciences curator (retired in June 2014), who championed the development of scientific insect studies with a focus on utilising the data from the collections for regional studies of geographical distribution whilst also utilising data from other museums and individuals. The Musée d'Histoire Naturelle of Lyon is a highly respected institution both within France and Internationally. It is thereby favoured as a repository for entomological collections, especially on account of the high standards of environmental conditions.

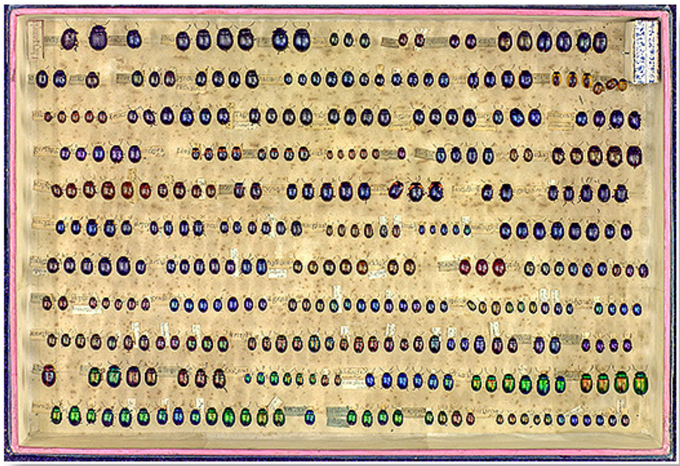
Insect Collections

The collection currently totals 14,000 standard boxes (39 x 26 cm) and 2,000 big boxes (40 x 50 cm). All boxes are numbered, given a locality, and scanned (by a Scanbook) into the Museum's database. Precise figures are not known, but the collection comprises approximately 500,000 Lepidoptera and more than a million Coleoptera. The other orders are numerically less significant.

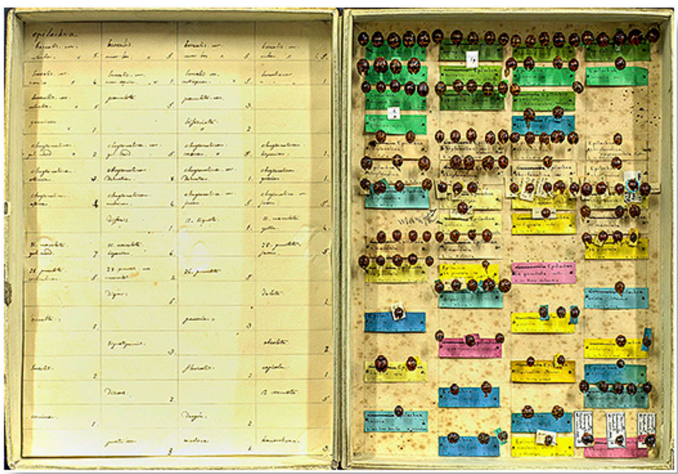
Rey (1817-1895): the collection includes 161 boxes with many types. Rey described alone or with his collaborator, Mulsant, 124 genera and 455 species, principally in Coleoptera.

Scarab life stages housed in the spirit collections Historical collections in Coleoptera.

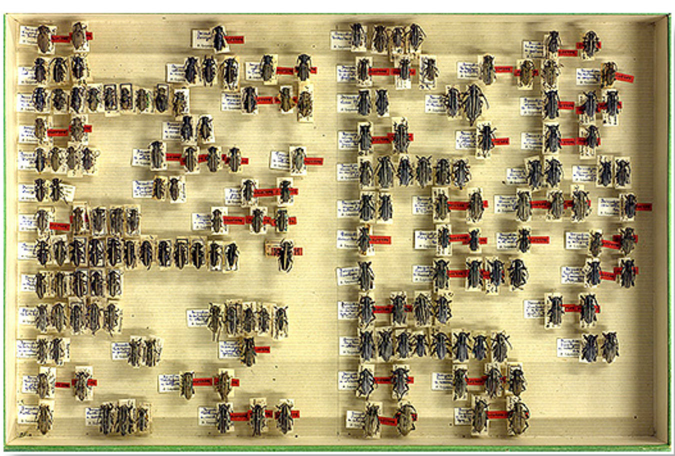
Rey's original store boxes.



'Entomo_Rey': Example of one of Rey's meticulously curated store boxes.



One Example of Dejean's original store boxes.



One Example from Lepesme's collection.

Guillebeau (1821-1897): another collaborator of Mulsant, with many types (the collection is a donation of the Muséum de Brou).

Dejean (1780-1845): 22 boxes of Hydrophilidae, Coccinellidae and Endomychidae.

Foudras (1821-1897): an old collection of insects; invented the method known as "à la Lyonnais" with elder pith, widely adopted by entomologists in France in the middle of the 19th Century.

Nicolas: Scarabaeidae (Africa + Palaearctic fauna) – 21,500 specimens.

Lepesme: Cerambycidae (Africa: the collection includes part of the worldwide Breuning collection) – 50,000 specimens.

Picka: Tenebrionidae (Palaearctic fauna) – 31,500 specimens.

Allemand: Byrrhidae (Palaearctic fauna) – 3,500 specimens.

Poulard: exotic Coleoptera: 25,000 specimens.

Audras: French Coleoptera fauna: 100,000 specimens.

Other important collections: Dufay (Chrysomelidae), Bonadona (Carabidae), Allemand (small families).

Scarabaeoids

The total of Scarabaeoids (incl. Lucanidae, Geotrupidae, Cetoniinae, Rutelinae, Melolonthinae and Dynastinae) probably exceeds 100,000 specimens, largely comprising French or European material.

About the Musée des Confluences

The invertebrate collections of the Musée des Confluences are the second largest in France after Paris. The natural history collections are stored in a specially equipped building, the Centre de Conservation et d'Etude des Collections (CCEC), in the 7th arrondissement of Lyon. The museum holds a number of important historical collections from the esteemed canon of French amateur entomologists as well as the world famous Rey collection. It continues to acquire collections both modern and historic.
The collection, as in Paris, is organised by collector and stored in modern museum boxes (with the exception of more notable historically important collections).

Joël Clary was the curator of Entomology but has recently retired, leaving Cédric Audibert with sole responsibility.

The new construction of the Musée des Confluences was completed as a remodelled science centre and anthropology museum at the end of 2014. It is now located in the 2nd arrondissement of Lyon, at the confluence of the Rhône and the Saône; the scientific collections remain at the CCEC.

http://www.museedesconfluences.fr/musee/

Acknowledgments

The authors thank Mary Liz Jameson and Maxwell Barclay for helpful editorial comments. We would also like to thank the Collections Enhancement Committee and Ms Theresa Howard (Head of Entomological Collections) of the NHM for granting funding to undertake this work.

Goliathus Then and Now: Last Piece of the Puzzle Found

by Jonathan Ting Lai

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The eighteenth century witnessed a rapid expansion of global knowledge as human inquisitiveness manifested in the form of flourishing intercontinental expeditions and exotic adventures, thanks to advancements in ship building and navigation. It was a fascinating period of discoveries, a time when excitement generated by peculiar creatures of extraordinary form and size swept across Europe. In 1766, the first Goliath beetle known to the West floated by a merchant ship that was cruising through the mouth of the River Gabon of the Gulf of Guinea. Naturally, the captain was not going to let the unprecedented "Goliath" simply drift by. The 95 mm giant was transported back to Europe, where "It became the centre of eighteenth-century arguments concerning ownership and engendered petty jealousies between collectors . . . The beetle is unique not only as the first to be found and the holotype for the name *G. goliatus*, but as an individual insect with a particularly broad social history" (Hancock and Douglas 2009).

The beetle (an example of the species now known as *Goliathus goliatus*) eventually came into the possession of William Hunter. Many collectors, including Dru Drury (1725-1804), became obsessed with the Goliath beetle and wanted one for their own collections. Unquenched desires fueled countless subsequent searches that turned out fruitless, as the native habitat of the Goliath beetle was then unknown. It would be another nine years before the second Goliath beetle was found, this time in Sierra Leone, by an expedition led by Henry Smeathman, who was sponsored by John Fothergill, Dru Drury, and Joseph Banks. Interestingly, the second Goliath beetle was a new species—today known as *Goliathus regius* (Klug 1835). At the time however, Drury had thought that it was only a color variant of the first Goliath beetle, and stopped short of describing and naming it. Thirty three years after Drury's death, entomologist John Westwood finally described it as *Goliathus druri* (Westwood 1837), with the intention of providing a tangible memorial to Drury (Hancock and Douglas 2009); unfortunately, Westwood's effort came two years too late. To give some idea of how rare the Goliath beetle was in collections of the time, according to Lasky (1813: 6), there were only three or four specimens in Europe, nearly half a century after the discovery of the first one in the mouth of the River Gabon in 1766.

Two and a half centuries later, people are still obsessed with the Goliath beetle. Some *Goliathus* are among the most sought-after, most expensive insect specimens of all time, with some large and minimally abraded examples fetching thousands of dollars. The reason for such high prices is simple: in comparison to many other scarab beetles, *Goliathus* would be considerably more problematic to captive rear on a commercial basis, due to the demanding requirements of its larval stage. In addition, no one has yet been able to rear a Goliath beetle to 100 mm, and captive-bred specimens of over 90 mm are extremely rare. Most captive-bred examples are in the 50-70 mm range. In contrast, over the past two decades, giant beetles from genera such as *Dynastes* and *Megasoma* have become easily propagated. Consequently, collecting pressure and prices for these beetles have dropped significantly. For example, the giant rhinoceros beetle *Dynastes hercules hercules* from Dominica and Guadeloupe has been well established in captivity in Asia. No known importation from either island has occurred since 2002. I estimate that there are at least tens of thousands of *D. h. hercules* in Asia, most of them in Japan. The Japanese raise them so systematically and scientifically that they even have pedigrees like cats and dogs. In fact, they are doing so well in captivity that Mr. Hirofumi Kawano of Japan produced a 171 mm *D. h. hercules* in early 2014. A friend and I flew to Japan to interview Mr. Kawano and see his record-breaking beetle in person. It has been officially documented as the largest ever captive-raised *D. h. hercules* in the Guinness Book of World Records for Beetles section of *BE-KUWA* magazine, Japan's most respected publication on beetle breeding. Incidentally, "be kuwa" means "let us be stag beetles" in Japanese. When a group of people fantasize about

171 mm *Dynastes hercules hercules* raised by Mr. Hirofumi Kawano.

Mr. Kawano and his beetle breeding room.

becoming stag beetles, it clearly reveals the great significance of these insects in their culture. The Japanese have long had "an inordinate fondness for beetles."

Why is it that the Goliath beetle has not yet been reared to at least 100 mm in captivity? One would expect that they would grow even larger on average than their wild counterparts, given that in captivity, nutritional and environmental conditions can be carefully maintained. The obvious conclusion to make, is that some important element must be missing. This "missing element" in the captive breeding of *Goliathus* has long puzzled entomologists. This article aims to change that.

Anyone familiar with raising rhinoceros and stag beetle larvae would find the larvae of *Goliathus* to be in a league of their own. Unlike the former, they do not develop in the disintegrating remains (logs, sawdust & compost) of dead wood alone. For almost a century, captive Goliath beetles would lay their eggs in substrates composed of compost, but the resulting larvae would mysteriously perish shortly after reaching the second instar. This phenomenon would not be explained until American entomologist Orin McMonigle made the discovery that *Goliathus* larvae require a high protein diet, and that kibbles of dog food could be used to raise them in the 1990s. With this finding, it finally became possible to complete the life cycle of the Goliath beetle in captivity.

However, the puzzle was not yet complete. Captive-reared adults were invariably rather small in comparison to their wild counterparts, not quite living up to the title of "Goliath." Optimal conditions for captive breeding are yet to be determined. Over the years, there have not been any major changes to the basic methods established by McMonigle, but through fine tuning of these techniques, along with dedication, *Goliathus* breeders have been able to sporadically grow individuals to at least 90 mm. Various breeding manuals have been written by several *Goliathus* breeders. All of them make reference to the "wandering phase" of the larvae, a peculiar behavior characterized by fully mature larvae wandering about on the surface of the substrate for weeks at a time, before finally settling down to make their cocoon (pupal cell) in the substrate. During this process, most larvae lose weight and vigor. A few even die. After the cocoon is constructed, further losses occur during metamorphosis to pupa or eclosion to adult, due to the depletion of energy reserve caused by the wandering phase. This puts the survival rate of captive Goliath beetles at 50-75%, far below that of rhinoceros and stag beetles, which is frequently 90-100%.

To be successful in rearing giant specimens of the Goliath beetle, the problem must be approached from two fronts. One of them would be to raise the larvae to as large a size as possible. The other would be to eliminate the "wandering phase." Wandering on the surface of the substrate for weeks cannot be a normal behavior. Doing this in the wild would almost certainly result in the larva being rapidly found by predators. A larva in the wandering phase will frequently attempt to climb up the walls of its rearing container, or forcefully push against the lid. It is obvious that the larva finds the environment no longer suitable, and wants to go elsewhere. The substrates typically used for the larvae to construct their cocoons are combinations of sand, compost, and peat moss of varying percentages.

What are the larvae looking for prior to cocoon construction? I first considered the physical factors. I made the substrate as deep as 60 cm. I used an 80 liter bucket to hold the substrate. I lowered the temperature from 25 to 20 degrees Celsius. I experimented with the humidity. I compressed the substrate to a high density. None of the above adjustments stopped the larvae from wandering. I then tried different kinds of substrates, such as ground coconut fiber, tree barks, whole chunks of decayed logs, decayed leaf litter, etc. The larvae ignored them all and continued to wander. I tried everything that would naturally occur in their forest habitat. I was drained of ideas. It was frustrating because enormous amounts of time and effort had been invested in the quest to demystify the biology of *Goliathus*.

A Goliath beetle larva in the "wandering phase."

Then, one fateful day, as I was examining some dried specimens of wild-collected Goliath beetles, I noticed that some of them had small traces of a fine, brown powder caught in the crevices of their pronotums. I carefully removed a sample with a fine needle. I thought to myself, "Is this what I think it is?" I mixed the material with a droplet of water. There it was, the last piece of the puzzle. All along, I had been thinking about what was in a forest. I had overlooked what was under a forest.

In hindsight, everything now makes sense. Goliath beetle larvae develop in the organic layer (composed of decaying leaves, wood, and other plant detritus) of the forest's substrate because this is where food is most abundant. However, this is not where *Goliathus* larvae prefer to construct their cocoons. Instead, they dig down into the inorganic layer below, where they remain for the next six to twelve months of their lives, most likely as a means of hiding from predators as well as avoiding seasonal fluctuations in moisture and temperature. In this layer, the soil (loam) is sticky, clay-like, and has a high density. It is considerably different from topsoil or compost, which are high in particles of organic matter that are non-sticky, flaky, loose, and light-weight. Since the Goliath beetle spends six to twelve months in its cocoon, one that is made of organic material is likely to disintegrate and expose the pupa or teneral adult to danger. A cocoon composed of surrounding particles is much easier to form in firm and sticky soil than in a loose, organic substrate such as compost. As a result, when *Goliathus* larvae are kept in substrates other than inorganic soil, they wander until they have absolutely no choice but to make a cocoon in the suboptimal substrate provided.

***Goliathus* larvae prefer inorganic soil for cocoon construction.**

Loam is sticky and easy to agglomerate.

In contrast, when larvae are placed in inorganic soil to pupate, they will dig down immediately to make their cocoons. Because time and energy are no longer spent wandering, the larvae do not lose weight. Prior to the discovery of inorganic soil as pupation substrate, a *Goliathus* larva with a maximum weight of 80 grams would only become an 80 mm beetle due to weight loss incurred during the wandering phase. With the use of inorganic soil, the same larva would become a 90-95 mm beetle.

Having discussed the optimal substrate for cocoon formation, we come to the other component involved in captive-rearing giant specimens of the Goliath beetle – how to raise their larvae to large size. Conventionally, *Goliathus* larvae are fed kibbles of dog food. Kibbled dog food is rather greasy, commonly having a fat content of 15-20%. After prolonged use, the grease in dog food tends to accumulate as a layer of waxy residue on the bodies of the larvae, especially around the mandibles, which in severe cases can hinder ingestion of food. On average, the protein content of dog food is approximately 20%. Are there better, less greasy, higher protein alternatives? I eventually settled on large pellets of koi food, which are at least 40% protein and at most 5% fat. Under optimal conditions, early stage third instar male larvae can achieve an impressive weight gain of 1-2 grams per day. Even the larvae of *Goliathus orientalis*, a species of somewhat smaller average size than *G. goliatus*, can attain a weight of 90 grams on koi food. Undoubtedly, with good care, the larvae of *G. goliatus* and *G. regius* can reach weights of over 110 grams. The koi food is soaked until it is saturated with water before it is offered to the larvae. The fact that *Goliathus* larvae prefer moist food to dry food was first documented by German beetle breeder Karl Meier some 15 years ago.

Although of critical importance, optimal nutrition is not the only factor involved in successfully rearing huge larvae. Of equal importance, is impeccable husbandry. *Goliathus* larvae must be kept very clean in order to grow large and well. If they are contaminated with mites or food residue (both of which occur as a result of poor substrate sanitation), they will not reach their full weight potential. In my practice, female Goliath beetles are placed in previously-frozen substrates to oviposit. All of the larvae are raised in previously-frozen substrates. A complete substrate change is carried out every ten days, at which time, each larva is thoroughly rinsed under

A bowl of koi pellets soaking in water.

This milestone *Goliathus goliatus* larva is being raised by Taiwanese beetle breeder Chen Chuin-bo. It is the largest known *Goliathus* larva to date. Because it is still white in color, it is expected to grow to over 100 grams.

A sibling of this 82 gram *G. orientalis usambarensis* larva reached 89 grams.

Raising a *Goliathus* larva to large size is very labor-intensive.

running tap water to remove any buildup of food residue. There really is no shortcut; because of the type of feeding regimen involved, this procedure is necessary to maintain hygiene in both the substrate and larvae. This persistence is maintained until the larvae are ready to construct their cocoons. The procedure is time consuming and laborious, but is the only known method of rearing truly major specimens of *Goliathus*.

We will now go into some details of the husbandry of Goliathus larvae. The larvae are kept individually in the round containers illustrated. Four different sizes are used. First instar larvae are kept in containers with a diameter of 6.1 cm and a height of 4.6 cm, second instar in containers with a diameter of 8.1 cm and a height of 5.7 cm, and third instar in containers with a diameter of 13 cm and a height of 20 cm (volume 2.5 liters). Large larvae weighing over 75 grams are transferred to containers with a diameter of 16 cm and a height of 21.5 cm (volume 6.5 liters) for cocoon construction. The substrate used for larvae still in the feeding stage is hardwood sawdust that has been composted for at least six months (dark brown in color). However, decayed leaves or decayed wood flakes could also be used, because the larvae are not particular about the feeding stage substrate, since the main constituent of their diet is the fish food. The water content of the substrate is approximately 50%, meaning for each 100 grams of dry substrate, 100 grams of water is mixed into it. The substrate is not compressed, and its depth should be three times the width of the larva. For example, if a larva is 2 cm wide, then it should be kept in substrate that is 6 cm deep. It is not necessary to keep larvae in excessively deep substrate; otherwise it may take them longer to find the fish food. Pellets of koi food are placed on the top of the substrate. Feeding frequency is every two days. If any food is uneaten after two days, remove it before adding new food. *Goliathus* larvae will not usually eat old food. Obviously, different brands of fish food come in different pellet sizes. The amount a larva eats changes over time as well. The rule is to feed an amount that the larva will consume within two days. If a first or second instar larva stops eating, this means that it is getting ready to molt. It will stop feeding for several days prior to molting. For *G. goliatus*, first instar lasts seven to fourteen days, and second instar twenty to thirty days. For *G. orientalis usambarensis*, first instar lasts fourteen to thirty days, and second instar thirty to fifty days. Generally, female larvae molt earlier than males. Males grow larger and therefore take longer to develop. The ideal temperature for the Goliath beetle appears to be 23-26 degrees Celsius.

The larval duration of Goliath beetles is highly unpredictable. Even from the same parent, some larvae begin cocoon construction as early as four months after hatching and weighing only 30 grams, while other larvae take as long as two years after hatching. Most larvae begin cocoon construction six to twelve months after hatching. Females generally have a shorter larval duration. The pre-pupal stage is also highly variable in length. While most larvae take two to three months, some take up to six months to transform into a pupa. These discrepancies in development time appear to be a natural mechanism to maximize the survival of a brood in the event that some natural disaster above ground wipes out the active adults, as well as perhaps a means of avoiding inbreeding.

When a third instar larva begins to wander on the surface and attempts to climb up the walls of the container for more than 24 hours in spite of fresh food in the container, it should be transferred to a container with inorganic soil for cocoon construction. It is important to note that a hungry larva with no food will also wander in search of food. Also, if old food is not discarded, or if the substrate has not been changed for more than ten days, leading to the accumulation of toxic compounds from spoiled food residue, a larva may also wander in search of a clean environment. Females tend to be less particular about the substrate when it comes to cocoon construction. For a female, I would fill the bottom 5 cm of the container with inorganic soil, place the larva on it, and then cover her with regular substrate, as illustrated. The total depth of the substrate should be

Containers of various sizes used to raise *Goliathus* larvae.

The actual setup of rearing containers for *Goliathus* larvae.

The setup for a female *Goliathus* larva to construct her cocoon. The bottom half is inorganic soil.

For a male *Goliathus* larva to construct a cocoon, it is best to fill the entire container with inorganic soil.

It is evident the larva does not like pure sand as a pupation substrate, as it wanders on the surface. Pure sand does not agglomerate.

at least 15 cm. The distinct smell of the inorganic soil will immediately induce the larva to stop wandering and begin constructing its cocoon, a process which takes seven to ten days to complete. For a male, I would fill the bottom 7 cm of the container with inorganic soil, place the larva on it, and then cover him with regular substrate. The total depth of the substrate should be at least 16 cm. For male larvae over 70 grams, I use only inorganic soil; no regular substrate is added on top of it. The depth should be at least 17 cm. Some mature third instar larvae may not wander immediately. They will only stop eating. If a third instar larva stops eating for more than ten days, it could be transferred to inorganic soil.

As a measure to conserve inorganic soil use, a cocoon can be carefully dug out two months after inactivity has been observed. If a larva is disturbed too early, it will break out of the cocoon and not make another one. The result is eventual death. Once the cocoon is removed, the remaining inorganic soil may be used for other larvae to construct cocoons. The removed cocoon can be half buried in moist regular substrate and covered with a lid to maintain moisture (of course, the lid would have ventilation holes). If you are curious, a small hole may be made in the cocoon five months after inactivity was first observed. By this time, most larvae will have become teneral adults. The teneral stage of *G. goliatus* is usually two to three months. That of *G. orien-*

A gigantic cocoon made of inorganic soil.

talis usambarensis takes approximately six months, after which the beetle becomes active and proceeds with mating and reproduction. In Asia, adult Goliath beetles are kept on specially formulated beetle jelly, which is commercially available in pet stores. Elsewhere, the beetles can be kept on slices of banana, apple, or diluted maple syrup. Goliath beetle adults can be long lived. If food is constantly provided, they can easily live four to six months, with some living up to twelve months. An adult female can produce over 100 eggs, although most females lay between 40-60 eggs, which can hatch in as little as ten days. In my experience, female larvae outnumber male larvae two to one.

Even when equipped with all of the necessary information and skill, it is very difficult to raise a Goliath beetle of giant size. I would estimate that only one out of ten male larvae becomes a truly large beetle, even if everything is done correctly to raise them. About 70% of the male larvae seem to be naturally "programmed" to pupate earlier, and are therefore destined to become smaller beetles. Of the remaining 30% that develop into large larvae, some die in their cocoons for no obvious reason. At least twenty male larvae need to be raised for any realistic chance of getting at least one beetle that measures over 90 mm. Keep in mind, that these are not larvae that can be left alone for two months at a time, like those of rhinoceros and stag beetles. *Goliathus* larvae need to be fed every two days for optimal growth. Neglected larvae quickly go into decline and either become small beetles or die. In my view, raising forty larvae at a time is about the limit for a breeder who wishes to still be able to have a relatively normal lifestyle. Anything beyond this number starts to become an unbearable, time consuming routine for most. It is understandable that a breeder would want to raise as many larvae as possible to maximize his or her chance of getting large beetles. However, it is better to keep fewer larvae and do well with each one, than a large number of larvae and do a poor job with all.

In my opinion, *G. regius* and *G. cacicus* have become highly vulnerable, as West Africa has some of the leading deforestation rates in the world. Ghana and Ivory Coast, where both species occur, have only 2-5% of their original primary forests remaining in highly fragmented patches (Insaidoo et al. 2012), which are

This captive-bred male *Goliathus goliatus* measured 95 mm with his head raised. This specimen was reared by Taiwanese beetle breeder Liao Kuo-kai and represents the largest captive-bred Goliath beetle to date.

"some of the most fragmented in the world having been converted to an archipelago of forest islands within a much larger agricultural mosaic or 'farmbush' where more open vegetation dominates" (Mudge et al. 2012). This can make it difficult for populations of species to maintain genetic diversity crucial to survival. Even worse, according to James Boafo, "Between 1990 and 2005, Ghana lost over a quarter of its total national forest cover. At the current rate of deforestation, the country's forests could completely disappear in less than 25 years" (2013). *G. regius* and *G. cacicus* could become extinct within the next few decades or sooner. It is hoped that the Goliath beetle can be better established in captivity as a last measure of conservation. In the event that it does vanish from the wild, at least it would not be reduced to mere dried specimens from the past. With dedicated efforts from beetle breeders around the world, we can make certain that what happened to the dodo does not also happen to the mighty Goliath.

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