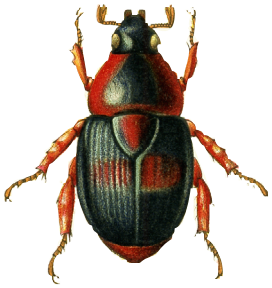
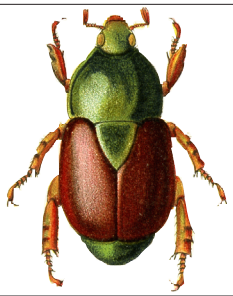


SCARABS



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Notes on *Chrysophora chrysochlora* (Coleoptera: Scarabaeidae: Rutelinae: Rutelini)

by Stéphane Le Tirant & René Limoges

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Introduction

The Rutelinae are among the most beautiful scarab beetles, but some species deserve special attention because of their ecological, historical or cultural importance. This is the case for *Chrysophora chrysochlora*. Its name literally means "gold bearing" "green-gold." This magnificent beetle is metallic green with gold reflections. Its legs are also metallic green, but with crimson reflections and blue tarsi. The elytra have a granulate texture.

In terms of its history, the species was described by French entomologist Pierre André Latreille (1762–1833) in 1811 under the name *Rutela chrysochlora*, but was collected during a Peruvian expedition by Humboldt (1769–1859) and Bonpland (1773–1858). Audinet-Serville (1775–1858) described the genus *Chrysophora* in 1825.

Biology and Taxonomy

To date, *Chrysophora chrysochlora* is the only species in this genus. The males are 28 to 40 mm long, while the females are often slightly smaller, from 27 to 29 mm. The males have hypertrophied legs and two outsized spurs, making them easy to distinguish from the females. This large beetle is diurnal and active mainly from September to November, during the rainy season. R. Haensch reported catching specimens between February and May. It lives in tropical rainforests mainly at an altitude of 500 to 1,000 m, and feeds primarily on *Chamaesennae reticulata*, *Gynerium saggitatum*, *Leucaena leucocephala* and *Buddleja* sp. foliage. The third

Male *Chrysophora chrysochlora* (Latreille, 1811).

Live specimen in Ecuador. Photo courtesy of the late Jacques de Tonnancour.

instar larva and the nymph were described by Morón and Pardo-Locarno. The complete laboratory breeding cycle was completed in one year. Genus *Chrysophora* is part of the Rutelini tribe, and is closely related to *Chrysina*.

Distribution

These splendid beetles are found in northwestern South America, in Colombia, Ecuador and Peru. They are fairly common at certain times. Early naturalists noted that they lived in communities. It is known that they are more numerous in certain years.

Use by Humans

In Ecuador, Sequoia and Shuar Indians use the beetle, which is sometimes abundant, to make headdresses, necklaces and other jewellery. Jivaros Indians also employ all or part of the insect. They use the elytra, often combined with other materials (seeds, bones, feathers, etc.), to fashion adornments that play an important symbolic role in ceremonies and everyday social life. Note that Ecuador issued a stamp featuring *Chrysophora chrysochlora*.

The authors wish to thank Dr. Miguel Angel Morón for providing a copy of his publication, and Denis Blaquière, Robert Beaudoin, Andrew Cockburn and the Musée des Confluences, for providing a number of photographs.

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Collective work. 2004. Des insectes et des hommes, *Ethnoentomologie*. 124 pages. EMCC.

Introduction

Les Rutelinae sont parmi les plus beaux scarabées, mais certaines espèces méritent une attention particulière, tant au niveau écologique que culturel ou historique. C'est le cas de *Chrysophora chrysochlora*. Son nom veut littéralement dire «qui porte de l'or», «vert-or». Ce magnifique coléoptère est vert métallique avec des reflets dorés. Les pattes sont aussi vert métallique, mais avec des reflets rouges et des tarses bleus. Les élytres sont granulés.

D'un point de vue historique, cette espèce a été décrite par l'entomologiste français Pierre André Latreille (1762-1833) en 1811 sous le nom de *Rutela* et *Melolontha chrysochlora*, mais elle a été ramenée lors d'une expédition de Humbolt (1769-1859) et Bonpland (1773-1858) au Pérou. En 1825, Audinet-Serville (1775-1858) décrira le genre *Chrysophora*.

Biologie & taxonomie

Chrysophora chrysochlora est à ce jour, l'unique espèce dans ce genre. Les mâles mesurent de 28 à 40 mm alors que pour les femelles, la taille varie de 27 à 29 mm. Elles sont donc très souvent un peu plus petites. Les mâles possèdent des pattes hypertrophiées et deux pointes importantes, ce qui les distingue aisément des femelles. Ce grand scarabée est diurne et surtout actif de septembre à novembre durant la saison des pluies. R. Haensch rapporte ses captures de février à mai. Il habite les forêts tropicales humides, principalement à une altitude de 500 à 1000 m . Il se nourrit essentiellement du feuillage de *Chamaesennae reticulata*,

Sequoia indians with Georges Brossard.

***Chrysophora* necklace with complete spécimens, Ecuador.**

Georges Brossard, founder of the Montréal Insectarium, with a large necklace, Ecuador.

Gynerium saggitatum, *Leucaena leucocephala* et *Buddleja* sp.
La larve au 3e stade ainsi que la nymphe ont été décrites par le Dr Moron et M. Pardo-Locarno. Le cycle complet de l'élevage en laboratoire s'est fait en une année. Le genre *Chrysophora* fait partie de la tribu des Rutelini et est proche des *Chrysina*.

Distribution

Ces magnifiques scarabées vivent au Nord-Ouest de l'Amérique du Sud en Colombie, en Équateur et au Pérou. Ils sont assez communs par période. Les premiers naturalistes mentionnaient qu'ils vivaient en communauté. On sait que certaines années, il y a des émergences plus importantes.

Utilisation par l'homme

En Équateur, les indiens Sequoia et Shuar utilisent ce coléoptère, parfois disponible en abondance, pour fabriquer des coiffes, des colliers et autres bijoux. Les indiens Jivaros utilisent aussi en partie ou en totalité cet insecte. Les élytres sont souvent intégrés avec d'autres matériaux comme des graines, des os, des plumes d'oiseaux, etc. Ces ornementations sont importantes et jouent un rôle symbolique dans les cérémonies et dans la vie sociale de tous les jours. Pour terminer, soulignons que l'Équateur a émis un timbre à l'effigie du *Chrysophora chrysochlora*.

Les auteurs tiennent à remercier le Dr Miguel Angel Morón pour une copie de sa publication ainsi que les personnes et institutions suivantes qui nous ont fourni quelques photographies: Denis Blaquière, Robert Beaudoin, Andrew Cockbrun et le Musée des Confluences.

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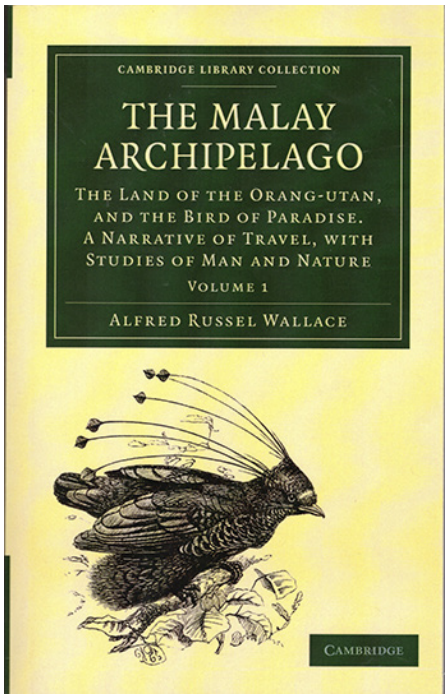
First Mention of a Portable Light Setup?

by Barney Streit

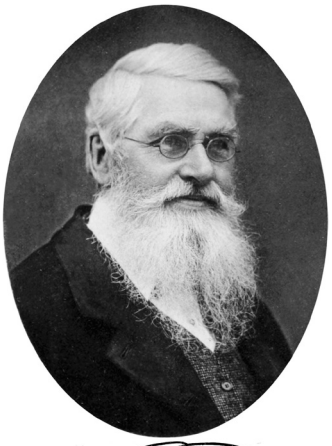
Shortly before I relocated to Singapore, it was recommended to me that I read *The Malay Archipelago*, by Alfred Russell Wallace. Wallace, known as the co-discoverer of natural selection, along with Charles Darwin, collected natural history specimens in the archipelago between 1854 and 1862. Of the insects, he was most interested in Coleoptera and Lepidoptera.

He was in Borneo from November 1855 to January, 1856. One of the places he stayed was in the valley of Saráwak, in a remote cottage on Peninjauh, a very steep mountain of crystalline basaltic rock, about a thousand feet high, and covered with luxuriant forest. What follows is an interesting account of his light collecting. The tables he mentions have been left out.



A few days afterwards I returned to the mountain with Charles and a Malay boy named Ali and stayed the three weeks for the purpose of making a collection of land-shells, butterflies and moths, ferns and orchids. On the hill itself ferns were tolerably plentiful, and I made a collection of about forty species. But what occupied me most was the great abundance of moths which on certain occasions I was able to capture. As during the whole of my eight years' wanderings in the East I never found another spot where these insects were at all plentiful, it will be interesting to state the exact conditions under which I found them.

On one side of the cottage there was a verandah, looking down the whole side of the mountain and to its summit on the right, all densely clothed with forest. The boarded sides of the cottage were whitewashed, and the roof of the verandah was low, and also boarded and whitewashed. As soon as it got dark I placed my lamp on a table next to the wall, and with pins, insect-forceps, net, and collecting boxes by my side, sat down with a book. Sometimes during the whole evening only one solitary moth would visit me, while on other nights they would pour in, in a continual stream, keeping me hard at work catching and pinning till past midnight. They came



Alfred Russell Wallace, 1823-1913.

literally by thousands. These good nights were very few. During the four weeks I spent altogether on the hill I only had four really good nights, and these were always rainy, and the best of them soaking wet. But wet nights were not always good, for a rainy moonlight night produced next to nothing. All the chief tribes of moths were represented, and the beauty and variety of the species was very great. On good nights I was able to capture from a hundred to two hundred and fifty moths, and these comprised on each occasion from half to two-thirds that number of distinct species. Some of them would settle on the wall, some on the table, while many would fly up to the roof and give me a chase all over the verandah before I could secure them. In order to show the curious connexion between the state of the weather and the degree in which moths were attracted to light, I add a list of my captures each night of my stay on the hill.

It thus appears that on twenty-six nights I collected 1,386 moths, but more than 800 of them were collected on four very wet and dark nights. My success here led me to hope that, by similar arrangements, I might in every island be able to obtain abundance of these insects; but, strange to say, during the six succeeding years I was never once able to make any collections at all approaching those at Saráwak. The reason of this I can pretty well understand to be owing to the abundance of some one or other essential condition that were here all combined. Sometimes the dry season was the hindrance; more frequently residence in a town or village not close to virgin forest, and surrounded by other houses whose lights were a counter-attraction; still more frequently residence in a dark palm-thatched house, with a lofty roof, in whose recesses every moth was lost the instant it entered. This last was the greatest drawback, and the real reason why I never again was able to make a collection of moths; for I never afterwards lived in a solitary jungle-house with a low boarded and whitewashed verandah, so constructed as to prevent insects at once escaping into the upper part of the house, quite out of reach. After my long experience, my numerous failures, and my one success, I feel sure that if any party of naturalists ever make a yaht-voyage to explore the Malayan Archipelago, or any other tropical region, making entomology one of their chief pursuits, it would well repay them to carry a small framed verandah, or a verandah-shaped tent of white canvas, to set up in every favourable situation, as a means of making a collection of nocturnal Lepidoptera, and also of obtaining rare specimens of Coleoptera and other insects. I make the suggestion here, because no one would suspect the enormous difference in results that such an apparatus would produce; and because I consider it one of the curiosities of a collector's experience to have found out that some such apparatus is required.

Scarab Beetles Fighting in Thailand (Coleoptera: Scarabaeidae: Dynastinae: Dynastini)

by Stéphane Le Tirant & René Limoges

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Introduction

The first author has been interested in ethnoentomology for many years now, and was lucky enough to attend beetle fights during several stays in northern Thailand.

Background

The beetles used for these fights are rhinoceros beetles (Dynastinae) and especially those of the Dynastini tribe. During our stays in Malaysia, we heard about fights between *Chalcosoma* beetles and other scarab beetles, but never had the opportunity to see them in person. In northern Thailand, more specifically in Sankampaeng and Doi Saket, although large Dynastinae like *Eupatorus* and *Chalcosoma* are sometimes used, the scarab beetles most often seen in fights are *Xylotrupes*. These rhinoceros beetles are called "khwaang" by locals. According to the latest revisions, *Xylotrupes mniszechi tonkinensis* is the most commonly found species in northern Thailand (Photo 1).

Beetle fights were very popular for many years, but fell into decline until recently. They were considered barely legal, and were often banned, but it seems that there has lately been a resurgence in these events, with organized fights and clubs and plans to breed the insects in captivity. For the past 12 years, in the Doi Lor district, one hour south of Chiang Mai, a "World Fighting Beetle Championship" has been held every year. Pairatth Disthabamrung, a 61-year-old well-known figure among fans, established the Hercules Beetle Club of Thailand in 1996, with over 1,000 members from seven regions in northern Thailand (Chiang Mai, Chiang Rai, Lamphun, Lampang,

Photo 1: *Xylotrupes* in the wild.

Photo 2: Scarab beetles for sale on the street.

Phayao, Phrae and Nan). The popularity of these beetles and their fights has grown constantly ever since.

The Fighters

Xylotrupes generally emerge in greater numbers in the rainy season in September and October. The owners look for vigorous specimens with well-developed horns (adult males). Tropical forests have shrunk over the years, though, and these beetles are not as abundant as they once were. It is currently unknown whether collecting specimens in the wild also affects local populations. Breeding the beetles in captivity would probably solve the problem, in any case. Specimens collected in the wild are also sold in local markets during this period (Photo 2). Prices range from 200 to 220 baht (US$5.00). They are often sold attached by the thoracic horn to a piece of sugar cane, their main food source (Photo 3). Owners frequently supplement their diet with ripe fruit. Champion fighters can occasionally fetch prices upwards of 1,000 baht (US$30.00), a considerable amount for their Thai owners.

Photo 3: Feeding and keeping the scarab beetle on sugar cane.

The Fight

Before the fight, the captive beetles are carefully prepared to do battle. Their owners keep them on logs and try to make them more aggressive with the goads that will later be used during the official fight. They choose the most active or aggressive beetles. Potential fighters are examined and only the most aggressive and those with high potential are kept for future fights (Photo 4).

On the evening of the event, the owners have their fighters rated according to different categories: not only size, but also colouring, although this actually has no influence on a specimen's "character." The "ring" is a piece of bamboo, with one or two females placed inside – females emit pheromones that make the males more aggressive. Another

technique is to make a hole in the bamboo and wedge a female in it, the top of her body even with the surface. A central line is drawn on the bamboo and one on either side of the fighters (Photo 5). An official referee presides and awards points to the combatants (Photo 6). The owners place their beetles in the centre of the log, and the battle begins! They may also carefully manipulate a small goad to urge on their fighters (Photo 7). If one beetle retreats or turns its back on the other, it loses points. Needless to say, if one of the beetles manages to lift its opponent up and knock it off the log, it is automatically declared the winner (Photo 8). If there is no "knockout," the winner is decided on points. Each 12-round fight lasts only a few minutes, and an enthusiastic crowd – mostly men – lays varying wagers on the outcome. Cheers and moans can be heard all evening long. The organization of these fights and all the preparation that goes into them is a testament to the close relationship between humans and these beetles. Photo 9 shows a larva.

Acknowledgments

The authors wish to thank Dr. Nicolas César for some of the photos used in this article and the late Jacques de Tonnancour, Michel Chantraine and Chamnong Phimphisarn.

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Photo 4: Keeping two aggressive males together.

Photo 5: Starting the fight.

Photo 6: The referee.

Introduction

Le premier auteur s'intéresse à l'ethnoentomologie depuis plusieurs années et lors de quelques séjours dans le Nord de la Thaïlande, il a eu la chance d'assister à des combats de scarabées (Photo 1).

Historique

Les scarabées utilisés pour les combats sont les scarabées rhinocéros (Dynastinae) et particulièrement ceux de la tribu des Dynastini. Lors de séjours en Malaisie, on nous a rapporté des combats de *Chalcosoma* ou d'autres scarabées mais nous n'avons jamais eu la chance d'y assister. Dans le Nord de la Thaïlande, plus particulièrement à Sankampaeng et Doi Saket et bien que la présence de grands Dynastinae comme *Eupatorus* et *Chalcosoma* soit possible, les scarabées les plus utilisés pour les combats sont les *Xylotrupes*. Localement, ces scarabées rhinocéros sont appelés «khwaang». Selon les dernières révisions, *Xylotrupes mniszechi tonkinensis* serait l'espèce que l'on retrouve le plus couramment dans le Nord de la Thaïlande.

Photo 7: The fight.

Les combats de scarabées ont été très populaires pendant longtemps, mais avaient un peu sombré dans l'oubli jusqu'à ces dernières années. Il semblerait que ces combats, plus ou moins légaux, ont fait l'objet d'interdiction. Récemment, ils sont réapparus plus importants que jamais en même temps que la mise en place de clubs et de projets de fermes d'élevage. Depuis une douzaine d'années maintenant, dans le district de Doi Lor, à une heure au sud de Chiang Mai, existe un championnat annuel: le «World Fighting Beetle Championship». Pairatth Disthabamrung, 61 ans, une figure connue dans ce domaine, a organisé le «Hercule Beetle Club of Thailand» en 1996 avec plus de 1 000 membres provenant de 7 régions du Nord de la Thaïlande (Chiang Mai, Chiang Rai, Lamphun, Lampang, Phayao, Phrae et Nan). L'engouement pour ces scarabées et leurs combats est de plus en plus important.

Les combattants

Les spécimens de *Xylotrupes* sortent généralement en plus grand nombre vers la saison des pluies en septembre et octobre. Les propriétaires cherchent tout particulièrement des spécimens aux cornes bien développées (mâles majeurs) et qui semblent aussi très vigoureux. La disparition de parcelles de forêts tropicales ne permet pas de trouver ces scarabées aussi abondamment qu'il y a plusieurs années. Est-ce que le prélèvement dans la nature de spécimens affecterait les populations locales? Nul ne le sait pour le moment. Des projets de fermes d'élevage régleraient probablement le problème. Les spécimens récoltés dans la nature sont en vente dans les marchés locaux durant cette période. (Photo 2) Les prix varient de 200 à 220 baht (US $ 5.00). Les spécimens achetés sont souvent gardés, attachés par la corne thoracique, sur un morceau de canne à sucre qui constitue leur nourriture principale (Photo 3). Les propriétaires complètent souvent la nourriture avec des fruits mûrs. Certains spécimens, des champions, peuvent parfois atteindre des prix importants pour les Thaïlandais, jusqu'à plus de 1000 baht (US$30.00).

Déroulement des combats

Avant les combats, les scarabées font l'objet d'une préparation en captivité. Ceux-ci sont donc «habitués» aux futurs combats. On les garde sur des rondins et on essaie de les rendre agressifs avec le stylet qui sera plus tard utilisé lors des combats officiels. L'examen des scarabées permet la sélection des spécimens les plus nerveux. Une présélection est faite parmi les combattants et seuls les plus agressifs et ceux présentant un bon potentiel sont gardés pour les futurs combats (Photo 4).

Photo 8: The end of the fight.

Photo 9: The larva of *Xylotrupes*.

Le soir venu, les propriétaires font évaluer leurs combattants et certaines catégories existent en fonction de la taille des individus mais aussi de leur coloration qui n'a pas vraiment d'influence sur le «caractère» des individus. L'arène de combat consiste en un morceau de bambou dans lequel on aura inséré une ou deux femelles émettant des phéromones qui rendront plus agressifs les mâles. Une variante est de creuser un trou dans le bambou et d'introduire une femelle dans cet espace jusqu'à ce que le dessus de son corps soit égal au-dessus du morceau de bambou. Une ligne centrale est tracée au milieu du bambou et une ligne de chaque côté des combattants (Photo 5). Un arbitre officiel juge le combat et attribue des points aux combattants (Photo 6). Les propriétaires mettent au centre les scarabées et le combat commence. Ils peuvent exciter leur combattant à l'aide d'un petit stylet qui est manipulé avec soin (Photo 7). Si un scarabée s'éloigne de l'autre combattant ou lui tourne le dos alors il perd des points. Évidemment, si un des scarabées réussit à soulever son opposant et le faire tomber du morceau de bois, il est alors déclaré automatiquement vainqueur (Photo 8). S'il n'y a pas de K.O, l'accumulation de points désigne alors le gagnant. Le combat dure quelques minutes et est constitué en 12 rounds. Bien sûr, une foule enthousiaste majoritairement masculine fait des paris plus ou moins importants sur les combattants. Les encouragements et les cris de joie ou de déception se font entendre tout au long de la soirée. L'organisation de ces combats et toute la préparation qui entoure ces derniers témoignent d'un rapport important entre l'homme et ces scarabées. La Photo 9 montre la larve.

Remerciements

Les auteurs tiennent à remercier le Dr Nicolas César pour certaines photographies de cet article ainsi que les regrettés Jacques de Tonnancour, Michel Chantraine et Chamnong Phimphisarn.

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The Siam Insect Zoo

by Barney Streit

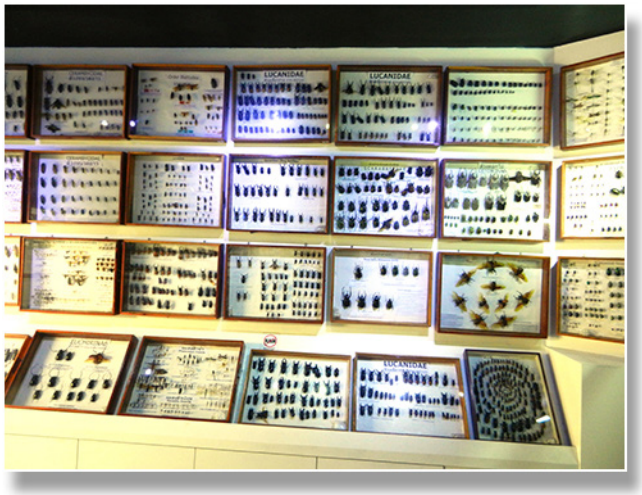
Since we are talking about Thailand, Chiang Mai is a popular tourist destination. Everybody visits the tiger exhibit, where you can go into cages with tigers ranging from babies to huge full-grown individuals. My wife Sandy is the cat on the right.

The elephant show is the other big attraction, and is amazing. This is a watercolor painting by Orgar, the baby elephant. Photo courtesy of my friend Ralph Hawkins, who purchased it after the show.

Along the same road is the Siam Insect Zoo. The proprietor, Pisuth Ek-Amnuay was in Bangkok when I dropped by. The family lives on the premises. Pisuth is primarily a lepidopterist, and raises many rare species in the butterfly house. That's our friend Diana, Alice, and my wife Sandy.

There are many displays featuring Coleoptera.

The displays are not limited to Asian species, as can be seen here.



Lots to look at!

A petting zoo for the children, here with a stick insect. The mandatory stingless black scorpions are also here.

Heliocopris exhibit.

The long-armed beetles.

Xylotrupes gideon exhibit. There is much more to the Siam Insect Zoo than can be shown here. It is well worth a visit.

Utilitarian Single-Image Macrophotography of Insects and Other Objects

by Jiri Zidek

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Introduction

"Single-image" refers to avoidance of composite imaging that requires stacking software for combining multiple exposures of an object into one final photo sharp throughout its depth, and incremental vertical- and/or horizontal-advance hardware necessary for the process. The software and hardware add cost and time, although in most instances the choice of proper equipment makes them unnecessary. For those new to macrophotography, the following paragraphs should help in acquiring the camera, lenses and accessories best suited for achieving good results with less effort and expense.

In the last decade analog cameras using film have become confined largely to art photography that often involves techniques requiring the silver process, whereas this article is primarily about documentation of small objects in which clarity and magnification are the overriding concerns. What is said below therefore pertains chiefly to digital cameras in which film is replaced by a sensor. It is not that film would fail to produce good results (see Fig. 1), but rather that the versatility of digital cameras and wide selection of their sensors better satisfy the objectives. Regardless of whether film or sensor, however, real macrophotography requires either a true macro lens or reversed wide-angle lenses attached by means of reversal rings to bellows. The latter method can produce up to 10x magnification, but is unwieldy and has the disadvantage of reducing the working distance to only about 50 to 35 mm from the subject, which makes adequate lighting

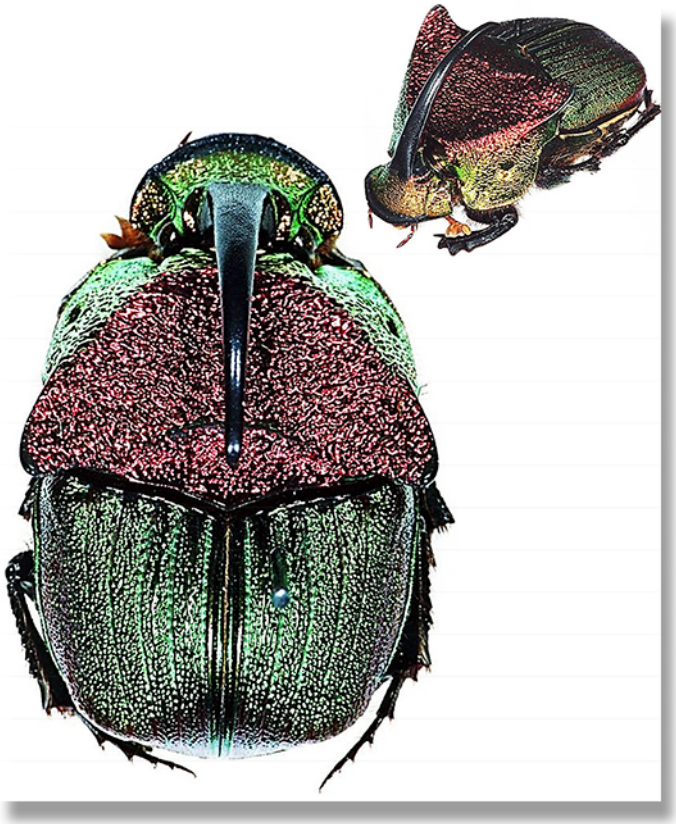

Fig. 1. Male scarab beetle *Phanaeus vindex*, length 18 mm, photographed with Nikon FM2n and a Nikkor 1:1 macrolens at aperture 22 on Fuji ISO 200 film. Dorsal view and a smaller anterodorsolateral view to show the height of the head horn and of pronotal crests. The size of the film frame corresponds to the full-size sensor of a digital camera that has a shallower depth of field than smaller sensors, yet virtually the entire image is in focus.

difficult to achieve and live, often weary and fast-moving organisms much harder to pursue. Hence a macro lens is preferable.

Some Basics

By definition, a true macro lens is one capable of achieving a life-size (1:1) reproduction. Anything imaged at a reproduction ratio less than 1:1 is considered merely a closeup (achievable with any telephoto lens), whereas anything magnified more is often called a supermacro. Macro lenses have fixed focal lengths, focus continuously to infinity, and can thus be used for general photography as well. Dozens of companies offer macro lenses with or without vibration control (VC), in focal lengths ranging from short (30 to 50 mm) through standard (60 to 105 mm) to long (150 to 200 mm), and with mounts available for two or more camera brands. The cost generally increases with the focal length and built-in VC. Most macro lenses are 1:1, as far as I am aware only Canon and Yasuhara Nanoha offer specialized 5:1 macro lenses that, however, cannot be used for reproduction ratio smaller than 1:1 (Canon MP-E 65 mm / f 2.8 1-5x Macro Photo), or in case of the Yasuhara Nanoha less that 4:1. A special case is the Photo-Optical Company's InfiniProbe TS-160 which focuses from infinity down to 18 mm from the object and is capable of up to 16x magnification, but costs more than twice as much (nearly $3,000) as the Canon 5:1 macro lens. It is therefore more feasible to stay with a 1:1 macro lens and use the size of the sensor, a teleconverter, and an accessory lens attachable to the front of the macro lens to increase magnification.

The choice of a macro lens depends on its intended use. Those photographing primarily live, fast-moving organisms wish not to frighten them and in order to stay at a reasonable distance therefore need lenses of greater focal lengths and built-in VC to maintain sharpness with a hand-held camera. In contrast, those photographing inanimate objects can get by with shorter focal-length lenses lacking VC, which in copy-stand photography with shutter delay should be turned off anyway. Both the working distance and magnification can be further doubled by placing a teleconverter or extension rings between the camera body and the macro lens. For work on a copy stand a greater than standard focal length can therefore become a hindrance, because in combination with the teleconverter the working distance may exceed the height of the stand.

Cameras are categorized as either SLR (Single-Lens Reflex) with mirrors or CSC (Compact-System Cameras) without mirrors. The SLRs are large and heavy because they have to accommodate a complex mirror and prism mechanism, whereas the CSCs are much smaller and lighter because the light passing through the lens reaches the sensor directly. All SLRs except Sony Alpha (see below) have optical viewfinders,

whereas in the CSC category viewfinders are present only on some models and are electronic. The CSCs are further subdivided into "point-and-shoot" with fixed lenses, nearly always zooms, and compacts with interchangeable lenses. The arrival of point-and-shoot CSCs closely followed the digitalization of SLRs, whereas CSCs with interchangeable lenses are a more recent development that has brought the system on par with the DSLRs and is of interest to macrophotographers namely because of the sizes of sensors used and advantages of the electronic viewfinders.

Having a viewfinder is important in macrophotography, because much of focusing is done manually, which cannot be accomplished as precisely on the rear monitor. Electronic viewfinders of CSCs provide a more accurate preview than the optical viewfinders of SLRs, because they show adjustments such as aperture, shutter speed or ISO in real time, whereas optical viewfinders of SLRs show them only after a photo is taken. However, since not all CSCs have viewfinders and for some models they are offered only as optional accessories at a substantial extra cost, it is important to choose a model that has a viewfinder built in.

A drawback of CSCs is that the battery does not last as long as that of SLRs, where it is bigger and draws power only when metering or recording picture data on the memory card. In CSCs the battery is necessarily smaller because of the small size of the camera body and in live view is engaged all the time, which causes it to last only 300 to 400 exposures. For longer field trips it is therefore wise to have a fully charged spare battery on hand.

Sensors come in a wide array of sizes, but only those in 35 mm cameras deserve closer attention because not too many people use the very expensive medium- and large-format cameras with oversized sensors, and cell-phone cameras (really downsized CSCs) with miniature sensors are not well suited for macrophotography. The term "35 mm" is derived from cameras that originally used 35 mm film and later were converted to digital. A full-size sensor therefore measures 36 x 24 mm, which corresponds to a frame of 35 mm film. It is the standard (crop factor 1.0) with which the crop of any smaller sensor view is compared. The full-size sensor is in SLRs such as the Nikon D810, Nikon D4, Canon EOS 5D Mark III, Sony A7R, Sony Alpha SLT-A99 (which has an electronic viewfinder), and also in the point-and-shoot Sony Cyber-Shot RX1. Other cameras use smaller sensors, for instance: Canon's ID Mark III and Mark IV have the APS-H sensor (28.7 x 19 mm) with crop factor 1.3; Canon's M and Rebel T5i, Nikon D3200, Pentax, Ricoh GR, Fuji and Sony NEX have APS-C sensors (22.2 x 14.8 mm to 23.7 x 15.7 mm) with crop factors 1.50 to 1.62; Sigma SLR and CSC cameras have the Foveon X3 sensor (20.7 x 13.8 mm) with crop factor 1.73; Olympus (OM-D E-M1, Pen E-PL5) and Panasonic

Lumix GH1, all of them CSCs, have the Four-Thirds MOS sensor (17.3 x 13 mm) with crop factor 2.0; and Nikon 1 and Sony's point-and-shoot Cyber-Shot DSC-RX10 and RX-100 have the Nikon CX sensor (13.2 x 8.8 mm) with crop factor 2.7, one of the smallest sensors available outside of the cell-phone camera market.

Like the choice of a lens, that of a sensor size has consequences that are positive or negative depending on the intended use. The smaller is a sensor the greater is the depth of field, the more affected is the angle of view of a lens not designed for the size of the sensor, and the less sensitive is the sensor to light because it has smaller pixels than a full-size sensor and therefore cannot collect as many photons (i.e. information) for the picture. For instance, a 50 mm lens mounted on a camera with Four-Thirds sensor (crop factor 2.0) changes the angle of view to behave as an equivalent of 100 mm lens, focuses farther away from the subject, provides a greater depth, and at high ISOs produces more "noise" (loss of detail). Lenses designed for smaller-sensor cameras cannot be used for larger-sensor cameras because they do not render images large enough for the larger sensors and therefore cause vignetting (softening and darkening of edges). Conversely, lenses designed for larger-sensor cameras can be used for smaller-sensor cameras, to which they are attached directly or in some cases by means of adapter rings that, depending on the cost, either do or do not furnish electronic communication between the camera body and the lens.

Magnification lowers the depth of field, which can be to some extent corrected by reducing the aperture (i.e. increasing the aperture number). The extent is limited by two interrelated phenomena, the circle of confusion and diffraction. The former is caused by a cone of light from a lens not coming to a perfect focus point but rather to a circle of blur, whose diameter increases as the aperture decreases. Diffraction refers to the distortion of light waves passing through an opening (aperture) and has a similar effect, the smaller is the opening the more distortion the light waves undergo and the result is a loss of detail. Calculation of the limiting effect is rather involved because a number of variables must be taken into account, some of them specific to the camera brand and model (e.g. exact shape of the aperture, type and size of the sensor, spacing, size and shape of the pixels), which makes it more practical to experiment with what is distinguishable to the human eye. A rule of thumb is to stay in the middle of the aperture scale, e.g. at 16 for a lens with maximum aperture number 32, but that may not be enough to achieve the desired depth. Some photographers try to circumvent this problem by using the highest aperture number available and re-sharpening the picture in the computer. It cannot restore detail that was not there in the first place, but it gets rid of blur and gives the impression of a sharp picture taken at a wider aperture.

Suggested Equipment

Since macrophotography is concerned with magnification and depth of field, the Nikon 1 system best satisfies those criteria. Of particular interest are its "V" models that have viewfinders and are sometimes called specialty cameras, although in all other aspects of still imagery and video they satisfy the needs of general photography as well. The Nikon 1 system has been criticized by some action and landscape photographers for an inadequate selection of dedicated lenses and inferior performance of the CX sensor in dim-light conditions requiring high ISOs, but these disadvantages are readily overcome by choosing from an abundance of non-dedicated lenses offered by Nikon and other manufacturers, and by keeping the ISO under 800 to avoid excessive noise. Non-dedicated lenses with the F bayonet mount are attached to the Nikon 1 body via the FT-1 adapter offered as an optional accessory, which provides electronic communication between the camera and the lens. To assure that the communication works properly, the firmware of the camera needs to be re-written for the V1 model to 1.40 and for the V2 model to 1.21, which can be done by the owner (instructions are on the internet) but is best left to a Nikon service. No re-write of the firmware is listed for the V3 model.

Each of the three so far produced Nikon 1 "V" models has its pluses and minuses. The V1 model has a 10.1 mpx (megapixel) sensor, virtually no grip (a sturdy grip is optional), no built-in flash (a hot-shoe flash is optional), and priority modes must be set in the menu. The V2 model has a 14.2 mpx sensor and all the features lacking in the V1, but its battery does not last as long and its price is about twice as high as that of V1. These two models are hard to find because they have been discontinued in favor of the V3, units still available are either second-hand or unsold remains of the old stock. The V3 has an 18.4 mpx sensor, an adequate grip, a built-in pop-out flash and a flip-out-and-turn monitor, but lacks a viewfinder which is offered only as an optional accessory and the camera costs four times as much as the V1. When the viewfinder, the FT-1 adapter and a macro lens are factored in, the V3 becomes an expensive camera not really worth the price. I have tested all three models and own the former two, but have become so accustomed to the V1 that the V2 rests still boxed in a closet. The good grip and built-in flash admittedly make the V2 better for field work, but I do little of that and find the 10 mpx sensor of the V1 perfectly adequate, as even full A4-page enlargements do not show any discernible grain.

The FT-1 adapter costs as much as the V1 camera, which is usually sold in set with the basic dedicated 10–30 mm Nikkor 1 zoom lens. A dedicated macro lens is not available for the Nikon 1 system. Reasonably priced (~$250–500) good-quality non-dedicated 1:1 macro lenses are Nikkor 40 mm f/2.8 Micro AF-S DX that costs

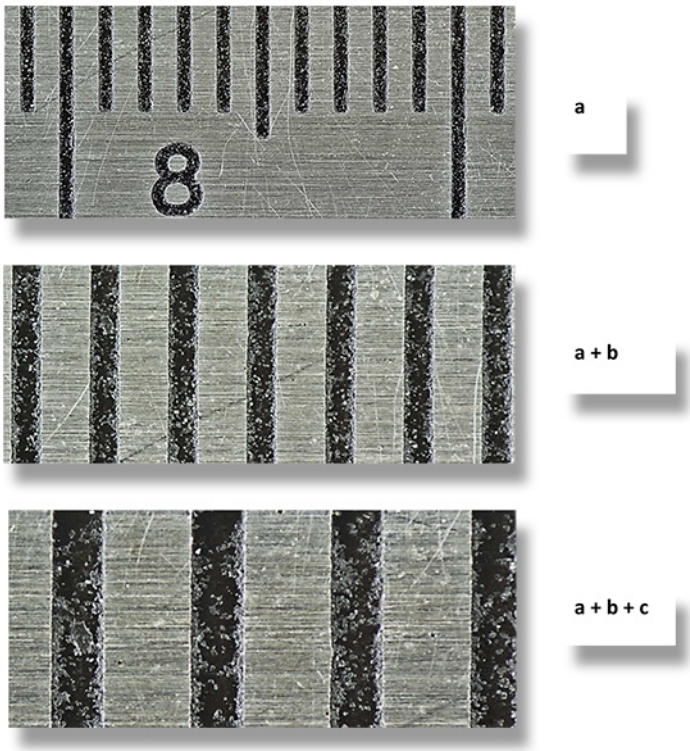

Fig. 2. Enlargements of millimeter scale across length of viewfinder using Nikon 1 CX-CMOS sensor (13.2 x 8.8 mm, crop factor 2.7). a) Tamron SP AF 90 mm f/2.8 Di macrolens; b) Kenko TCx2 Pro 300 N-AF DGX teleconverter; c) Raynox DCR-250 super macro lens.

slightly more than the V1 camera, Tamron SP AF 90 mm f/2.8 Di Macro that is about twice as expensive, and Tokina 100 mm f/2.8 AT-X D Macro that costs about as much as the Tamron lens. None of these lenses has VC, which is available only in a new version of the Tamron lens that, however, is much heavier and costs twice as much as the old version. I use the former two lenses and am satisfied with their performance.

As noted above, the magnification can be further increased by placing a teleconverter between the FT-1 adapter and the lens, and attaching an accessory supermacro lens to the front rim of the lens casing. The effect of this arrangement is shown in Fig. 2. The Kenko TCx2 Pro 300N-AF DGX teleconverter is used simply because it does exactly the same as the Nikon 2x teleconverter at less than half the cost. Kenko or any other extension rings were not tested because even as a full set (12/20/36 mm) they do not reach the 2x magnification of the teleconverter and, judging by the manufacturer's table, the loss of light is too great. The Raynox DCR-250 supermacro lens is used because of its quality and versatility. It can be snapped on any lens of 52–67 mm diameter by means of spring-loaded wings and used either separately or stacked up with other Raynox lenses of the same or different power. The DCR-250 has eight diopters which translates to 2x magnification, but MSN-202 has 25 diopters (6x) and MSN-505 has 32 diopters (8x). I have yet to test these stronger lenses. An interesting aspect of Fig. 2 is that according to the Kenko Company its teleconverter is not compatible with a number of Tamron lenses including the new 90 mm VC macro lens, but this limitation apparently does not apply to the older version of the 90 mm Tamron which lacks VC.

A tripod or at least a monopod to stabilize the camera is valuable in the field. Those who work mostly on a copy stand sometimes acquire and modify an old enlarger and soon regret it, because enlargers have the post slanted and focusing therefore requires constantly moving the object. To save time and nerves, it is recommended to invest in a real copy stand with a vertical post.

Light sources include flashes, gooseneck twin flashes, ring flashes and led rings or panels, some of which come with white removable plastic covers claimed to function as diffusers. In reality such covers are too close to the source to diffuse light and only reduce its intensity. An effective diffuser should be placed approximately half way between the light source and the object or closer to the latter, as is shown in Fig. 3. In the figure it is an open, flexible cylinder made of frosted drafting acetate, but a roll of white paper would suffice as well. Either material can be used in one or more layers, as needed. I no longer use a ring flash or ring light, because it attaches to the front of the lens which makes a diffuser hard to build, fasten and function properly, and re-focusing causes it to move up and down with the lens. Besides that, some ring flashes are designed specifically for lenses of shorter or longer focal lengths, and in case of a mismatch the result is an ugly ring of glare on the object; one should therefore inquire about specifications before purchase.

Since the shape of the sensor is a rectangle of 3:2 proportions, the illumination in Fig. 3 is four strong led lights mounted on posts in corners of a board of the same proportions (54 x 36 cm), with each light inclined at 45°. The object is thus evenly illuminated and, as long as is kept 2–3 cm above the background, any surrounding out-of-focus shadows are eliminated by the diffuser.

Fig. 3. Copy stand with optical equipment, diffuser, light table, and transformer (right) for operation of led lights. From top down Nikon 1-V1 camera, Nikon FT-1 adapter, Kenko TCx2 teleconverter, Tamron 90 mm macro lens (fully extended), Raynox DCR-250 super macro lens. Foreground: specimen manipulation tool.

Some shadows remain only when the object rests directly on the background (e.g. is glued to a card), in which case they can be deleted by a background-removal software (several freewares are available on the internet). Transparent / translucent objects that contain inset features, such as detached insect wings showing venation patterns, need to be photographed on a light table illuminated from both above and below, because they are never perfectly flat and on opaque background reflected light alone would create shadows paralleling the veins and resulting in a confusing mesh of twin lines. The transmitted light, although much weaker, eliminates the shadows. Other similar objects that may require transmitted light and sometimes also contrast enhancement by submergence in liquids are e.g. enclosures in amber

and preparations sealed in Canada balsam or industrial resins.

Conclusion

The larger the sensor is the smaller are the depth of field and achievable magnification, which often forces operators of cameras with large sensors to resort to stacking of multiple images to get an entire object into focus, and in some cases to use a stereo microscope to adequately magnify structures. The approach outlined above of course has its limits and the suggested items are not exactly cheap, yet the total cost comes to only about half of what macrophotographers commonly spend, not to mention institutions with elaborate photolabs and employees dedicated to the task. From the standpoint of both economy and performance the suggested setup is optimal or close to it, and its efficacy becomes apparent especially when faced with documentation of a large number of specimens.

Concrete prices of the above items are not given because they differ from country to country and dealer to dealer, and a list of literature is omitted because it would be virtually endless. One only needs to look at the macrophotography account in Wikipedia and pick from the numerous articles cited there, or spend weeks going over the scores of articles and discussions on web pages run by various groups devoted to the subject.

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