

A New World of Moths Explored across Three Continents

Stephen Sutton¹ and Lim Kooi Fong²

¹ *Institute of Tropical Biology and Conservation,
Universiti Malaysia Sabah,
88400 Kota Kinabalu, Sabah, Malaysia.
stephensutton7@gmail.com; www.stephensutton.info*

² *Biovis Informatics Sdn. Bhd.,
No. 45B, Jalan SS24/8,
47301 Petaling Jaya, Selangor, Malaysia.
kooifong.lim@gmail.com; www.eol.my*

ABSTRACT

A preliminary survey of the diversity and abundance of moths of the Superfamily Pyraloidea at tropical latitudes was made as part of a study of the abundance of flying insects at different levels between floor and canopy in rainforests across the world over a period of 20 years. Since the most extensive pyraloid material collected was from the island of Borneo, in 1994 this became the focus for ecological and evolutionary research. However, research of this type proved impractical because the taxonomy of the group was so undeveloped. Funding to establish a taxonomy at the species level became available in 2003. Cataloguing is taking place of all the known pyraloids of Borneo, with images of all the species, named and unnamed, which are held in museums and private collections. This is at the level of a preliminary guide rather than a taxonomic monograph, to stimulate production of the latter.

The work has progressed to the publication of a major website with images and a very large amount of text for 25 per cent of the known Bornean species, with completion of an estimated 2200 species expected in late 2017. In addition, a printed guide to some of the species has been published, with two more in preparation, to print the images we have available of all the species or unnamed morphotypes at or near the species level. The main functions of the printed volumes are to aid pyralid identification in the field at research sites beyond broadband reach and to act as portals to the website species via QR codes.

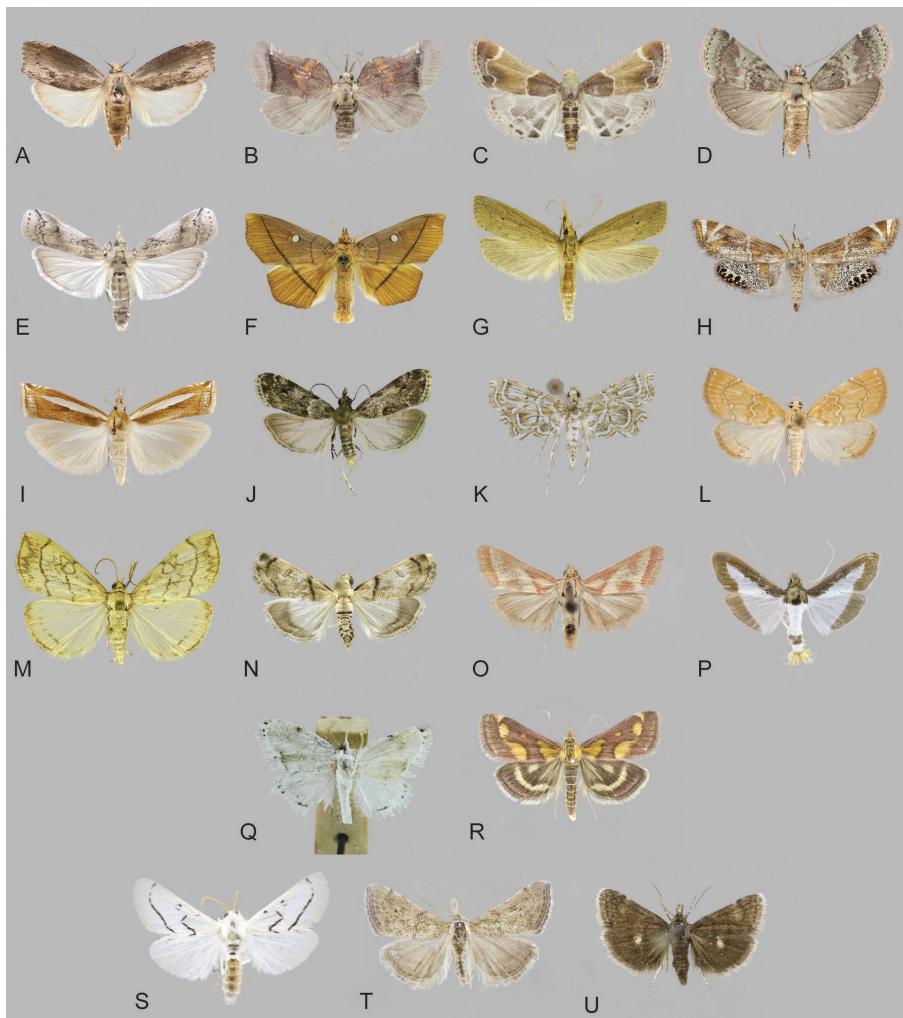


Fig. 1. Typical species of the subfamilies of the Superfamily Pyraloidea; A–E: Subfamilies of the Family Pyralidae; F–R: Subfamilies of the Family Crambidae; S–U: Subfamilies not yet assigned to a family. Not shown: Subfamily Lathroterinae (Crambidae), only recently described (Minet, 2015). Image courtesy of Alma Solis, published in Regier *et al.* (2012).

INTRODUCTION

Moths of the Superfamily Pyraloidea ('pyraloids', 'pyralids', 'pyrales') are extremely speciose¹ in tropical and sub-tropical regions around the world, particularly in tropical

1 (Biology/taxonomy) Species-rich, such as when many species are members of a single genus.

forests. There are over 16,000 described species and perhaps as many undescribed. Most, but not all, are small and brightly coloured. With the advent of smartphones with remarkable macro-photography capability it is much easier to illustrate and study these small moths. Some of the most notorious pests of rice, fruits, vegetables and stored products are found in this moth group and there are also a number of potential bio-control agents. The sheer size of the superfamily raises questions about the origin and maintenance of mega-diversity in tropical forests. Borneo is the ideal arena to study this, being large in area but circumscribed by the sea. For Borneo, 60 per cent of the material is unnamed and disentangling good species from local varieties is a slow task, so the total number of species in collections is still not known; it is likely to be in excess of 2200, with many more species still to be discovered. This compares with 936 butterfly species and 4563 macro-moths in Borneo (Holloway, 2011). As discussed in Whitaker (2015), Holloway and others estimate close to 13,000 Lepidoptera species in Borneo, including over 6300 micro-moths of which 3000–4500 are likely to be pyraloids. The abundance of individuals of pyraloids in the forests of Borneo (and in other tropical forests worldwide) can be truly staggering. This implies a major set of ecological roles for the superfamily.

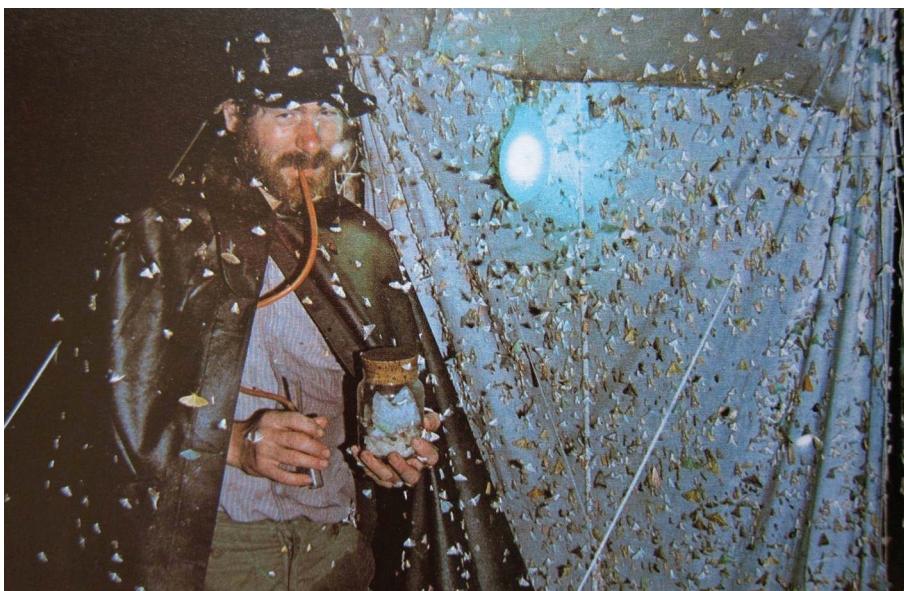


Fig. 2. Martin Brendell ‘and friends’ after evening rain in Morowali National Park in Sulawesi. Martin has a ‘pooter’ in hand for sucking up very small moths. 70% of the moths are pyraloids, recognisable because of their ‘swept wing’ appearance.

Such a large number of pyraloid individuals and species suggests they may be important in maintaining ecosystem services. Moreover, insect biodiversity has importance as natural heritage value to the sovereign states on the island of Borneo

which is much underestimated. Added to that is the long catalogue of pest species amongst the pyrales which are poorly understood taxonomically. Without knowing which species you are dealing with, it is possible to waste a great deal of money on poorly designed control measures. So it is important to determine and publish the true extent of pyraloid biodiversity in Borneo to provide a knowledge base for further scientific study.

This research falls naturally into three phases: exploration, compilation and publication. The exploration phase for this project, which is now largely over, preceded the other phases by some 30 years because of funding constraints.

EXPLORATION PHASE

The survey was started by Stephen Sutton (SLS) on the Zaire River Expedition in the Democratic Republic of the Congo (officially named as Zaire during the late (but hardly lamented) President Mobutu's dictatorship) in 1974/5; in Brunei (Henry Barlow (HSB)/SLS 1978/82); Panama (1980); Genting Highlands, West Malaysia



Fig. 3 (above left). Unknown pyrale (Mahua waterfall, Crocker Range, Sabah). **Fig. 4** (above right). *Microthyris* sp. (Spilomelinae) from Nicaragua. **Fig. 5** (below left). *Vitessa pyraliata* (SE Asia). **Fig. 6** (below right). *Nevrina procopia* (Kinabalu Mountain Lodge, 1600 m. Widespread in SE Asia). Note all four have long legs with spines and 'swept-back' wings characteristic of pyraloids.

(HSB 1980–present); Papua New Guinea (Angela Wilkins/SLS 1982); Sulawesi (SLS 1982); Costa Rica (SLS 1984); Borneo Kalimantan (SLS 1992), Belum, Perak, West Malaysia 1993 HSB); Danum Valley, east Sabah (SLS/HSB/Andrew Davis 1992/1999) and Danum and western China (Roger Kitching & Terry Whitaker (TMW) (2006–2012). The work in the Congo was carried out as part of the Zaire River Expedition, that in Brunei in the Temburong salient with the support of the 10th Gurkha Rifles and the Brunei Museum, in Panama, Papua New Guinea and Sulawesi as part of the Operation Drake round-the-world expedition, in Costa Rica on Operation Raleigh (now Raleigh International), in Danum Valley 1992–1999 as part of the SE Asia Rainforest Research Programme (SEARRP) and in Danum Valley 2006–2012 on grants from the National Geographic Society to Roger Kitching.

The material collected on the expeditions was very variable in quality. On the earlier expeditions much of it was by-catch from forest canopy studies using UV light traps, which produced battered material unsuitable for museum collections, although useful for ecological analysis (Sutton, 1983). However, in Sulawesi and Borneo good material was collected. Details of where it is kept can be found in Sutton, Barlow & Whitaker (2015) and the website ‘*Pyralid Moths of Borneo*’ (PoB) ‘www.pyralidsofborneo.org’.

COMPIILATION PHASE

The focus of this study is now on cataloguing the pyraloids of Borneo island, since the bulk of good material for taxonomy was collected here and funding became available in 2003. Compilation of data and images is done by a team of three. Henry Barlow (HSB) is the pioneer of modern Borneo Lepidoptera studies, starting with his expedition to Mount Kinabalu in 1965 with Jeremy Holloway and Jonathon Banks. This led to Holloway’s *Moths of Borneo with Special Reference to Mount Kinabalu* (1976) and later indirectly to HSB’s *An Introduction to the Moths of South East Asia* (1982). These works were largely concerned with macrolepidoptera (‘macros’), but larger pyraloids were collected (they are easily mistaken in the field for macros).

HSB has the leading private collection of West Malaysian material, a major reference library and is the sponsor of the project. Terry Whitaker (TMW) is the collector and compiler of images and notes from the various collections. He is also the curator of the Sutton/Whitaker collection, another of the main sources for the databases. Stephen Sutton (SLS) compiles the data and images for publication, and acts as editor and coordinator. This study is based entirely on set specimens in collections, not on live material. Images of live specimens cannot provide data on wing venation, minute sculpturing of the basal sections of the antennae, genitalia structure or DNA profiles. Thus it is, for effective conservation of insects, that a tiny percentage of individuals have to be killed and preserved in museums in order to build up the taxonomic foundation on which conservation of all the rest depends.

Apart from the HSB and SLS/TMW collections, other main sources of images and data were the Natural History Museum (NHM) in London and the Schulze collection at the University of Vienna. The NHM has the largest collection of pyraloids, while Vienna has the most recent collection (therefore the specimens with the freshest colours for photography). This fine collection was made by Christian Schulze in 1997 in the Kinabalu National Park (Schulze, 2000; Schulze & Fiedler, 2003).

Visits were also made to the Museum für Naturkunde der Humboldt-Universität in Berlin and collections in the Forest Research Centre, Sepilok and the Agricultural Research Centre, Tuaran (both in Sabah). These visits were all made by TMW for collection of images and notes, and discussions with curators.

Of particular Borneo interest, a large number of type specimens collected by Alfred Russel Wallace in Sarawak as the guest of James Brooke, first White Rajah of Sarawak, are in the Hope Entomological Collections of the University Museum in Oxford. Images of these are available online for our use. The sheer diversity of the moths Wallace caught set him wondering why there were so many. This was one of the puzzles that set him on the trail of the theory of evolution through natural selection, which he worked out independently of Charles Darwin. Their original outline of this theory was published jointly.

The core resources of the project are the photo taxonomic database, with 17,000 images (mostly duplicates of the same species from different collections) and Paradox, an advanced relational database with one page (screen) for each species or unnamed morphotypes at or near the species level. Each page brings together all the data collected for that species and has an image. Where males and females have different *facies* (appearance, structures visible without dissection or preparation) they have separate pages. There is also much duplication with variable material from different regions of Borneo. There are currently 4,000+ records on Paradox, but it is expected this will fine down to about 2,200 named and unnamed taxa when all the data and images has been thoroughly assessed. Each page has an image and extensive data on literature, morphology and distribution. Ecological data are absent for 95 per cent of species. This is because previously there was no means of field identification, which has severely limited ecological and evolutionary studies at the species level. Only species which are serious pests have extensive data.

TMW produces batches of Paradox species pages in the UK which are then uploaded in Kuala Lumpur by Biovis Informatics onto the PoB website, using advanced PHP software developed in Berlin by Oliver Georgi. We use this because it is fast, versatile and stable. This software was originally developed for Biovis to execute a contract for a fashion house for Society ladies in Kuala Lumpur. The remit was to sell ‘evening dresses’. These were divided into long dresses & short dresses, and then the long dresses were divided into ball gowns and less formal long dresses, while the short dresses were divided into formal (including, no doubt, the classic ‘little black cocktail

number'!) and informal wear, thus constructing a hierarchy. It took rather little change to adapt this to create a website for identifying pyraloid moths. In fact, this kind of hierarchical structure is the basis of all animal and plant classification (and can be used to classify beads, coins, medical ailments — stars in the universe, for that matter). Classification is an activity fundamental to human knowledge development.

The process of uploading species using this software is supervised by Lim Kooi Fong (owner of Biovis) and SLS.

A new phase of the compilation process is collaboration with the Institute of Tropical Biology and Conservation at the Universiti Malaysia Sabah (IBTP-UMS) which is setting up, in its museum facility Borneensis, a reference collection of Bornean and SE Asian Pyraloidea for the use of regional scientists developing pest control methods and studying evolutionary relationships and ecological impacts. Much work is being done on pyraloids in China, and Borneensis will provide an opportunity to link research in China with that in SE Asia.



Fig. 7. Unsorted pyrales for the UMS Borneensis collection, from 1600 m in lower montane forest on Mount Kinabalu. (Note: pen for scale.)

PUBLICATION PHASE

Initially, in 2003 we planned to have printed volumes only, but by 2009 the rapid development of website technology allowing easy and cheap retrieval of data meant that it made far more sense to put online the huge amount of material TMW had collected. We have therefore developed a website as the main publication output. There are currently rapid developments in knowledge of evolutionary relationships in the Pyraloidea of SE Asia. New subfamilies and genera are being created and many species descriptions are being published, so the flexibility of a website vis-à-vis printed volumes is a great advantage.

The *Pyralids of Borneo* (PoB) website has been online since 2014 and is fully functional, but only one quarter of our pyraloid species have been uploaded as yet. (More correctly, the title of the site should be ‘Pyraloids of Borneo’ because it refers to the Superfamily Pyraloidea, but the old name ‘Pyralid’ is still in popular use.)

The full complement of species should be online by the end of 2017 (it is slow work adding unnamed species to the PoB website because of the amount of study needed to decide whether they are really separate species or just local varieties).

As a side issue, we have uploaded to the website 295 species of the Superfamily Thyridoidea. Until 1990 these were regarded as a family within the Pyraloidea, but a thorough study of their morphology, using criteria developed in recent decades, shows that they could hardly be more distantly related from the pyraloids and still be classified within the Lepidoptera! Such is the degree of change in systematics with modern methods of study. But although the thyridoids are only distantly related, we have included them in the website because in the older literature (before 1980) they are ‘embedded’ in the pyraloids. They make a small but interesting superfamily, well worthy of study, with a number of pests of fruit trees but most of them mysteriously rare.

Due to new funding we have now begun to exploit development in barcode technology to publish printed volumes of images with ‘matrix’ or Quick Response (QR) codes. (Fig. 8.) The evolution of bar codes to the current compact matrix format promises to be a blessing for PoB (and for a host of other situations where linkages are needed to large amounts of information), as it allows the printed volumes to be no more than plates of images, each with a facing page of QR codes and an index. Each QR code is species specific and goes directly to the *species entry* on the website, using a smartphone and one of the readily available QR apps. The only limitation is the need for broadband coverage — it is not necessary to be browsing the website. With moderate broadband the linkage is very fast.

We can therefore use these printed volumes as *portals* (gateways) to access species pages on the website. This helps us to address the pressing need to put the biodiversity of Bornean pyraloids into the public domain as soon as possible to encourage awareness of, and research on, this enormously diverse and interesting group.

The second major benefit of the print medium is that it can be used as a laboratory manual for provisional sorting and identifying moths at field sites where there is no broadband (broadband coverage in Borneo is mostly restricted to cities, towns and highways).



Fig. 8. A QR code.

We aim to have all three printed volumes covering the Pyraloidea published by early 2017. *A Preliminary Guide to the Pyralid Moths of Borneo Part 1* was published in September 2015 (Sutton, Barlow & Whitaker, 2015) and work on Parts 2 and 3 is well advanced. Not least of our aims in doing this is to make government agencies aware of the importance of pyraloids to forest ecology and natural heritage to enhance prospects for forest conservation in Sabah and the rest of Borneo.

Publication: Part 1 of the planned printed volumes

Part 1 (Fig. 9) has images and legends for 286 named and 379 unnamed Pyraloidea (total 665) and 168 named and 127 unnamed Thyridoidea (total 295). With duplicates (males and females), the total number of images in this volume is 1077. There is currently no other printed source for the identification of South East Asian Pyraloidea and Thyridoidea. In the past, the *Field Guide to the Smaller Moths of South-east Asia*, published by the Malaysian Nature Society (Robinson, Tuck & Shaffer, 1994) was a useful starter, with 259 pyraloids and thyridoids illustrated, but it is long out of print and difficult to find.

Part 1 was printed before the first 665 pyraloids included in it were loaded onto the website, so they have no QR codes. Only the 295 species of Thyridoidea have these codes.

Acting (as noted above) as ‘portals’ to the large amounts of data held on the PoB website, these volumes are very simple. The core feature is a set of high quality colour plates with 35 images on each, of standard size regardless of specimen size. For example, Fig. 10 shows Plate 1 of Thyridoidea (for the full set of 10 plates showing 295 species of thyridoids, see Fig. 17 below).

Facing each plate is a page of boxes matching the positions of the images. For the thyridoids, these boxes contain the QR codes, with species’ names to check the link to the image (Fig. 11). For the pyraloid plates in Part 1, as noted above, there were no QR codes available at the time of printing. Instead, each box on the page facing a plate of images contains the name of the species (also given under the image), wing length, whether recorded in Borneo or only adjacent to it (and therefore likely to be found in Borneo at some stage), and the file name of the image (Fig. 12). Since the file

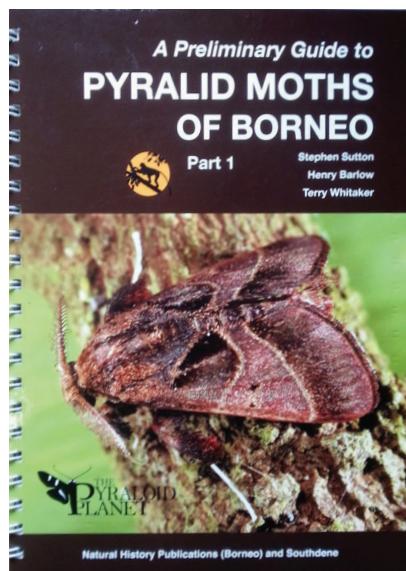


Fig. 9. Part 1 of the projected series of 3 printed volumes.

name is from TMW's image database where it is linked to the collection from which the image was taken, the image in the book can be traced back to the locality from which it was originally collected.



Fig. 10. Plate 1 of 35 plates (Thyridoidea) in Part 1 of the printed volume series.

website NRB		see website RB		
Canaea tessellatula Pagenstecher 1892 NRB	Mathoris sp. 1 RB	Monodecus sp. 1 NRB	Striglina cinnamomea Rothschild 1915 NRB	Striglina duplicitifimbria Warren 1896 RB
Canaea sp. 2 RB	Mathoris sp. 3 RB	Sonagara sp. 1 RB	Striglina crassisquama	Striglina irresecta Whalley 1976

Fig. 11 (above). Part of a facing page for a Thyridoidea plate page (e.g., Fig. 10); QR codes are included in the text boxes. **Fig. 12** (below). Part of a pyraloid facing page; in early editions of volume 1 of the series, the text boxes for pyraloids do not include QR codes.

10 mm; RB; 2503; Orthaga sp. 14 1_2. psd	9 mm; RB; 620; Orthaga sp. 15 Vienna_POB_391- 680.JPG	8 mm; RB; 621; Orthaga sp. 15a Vienna_POB_523- 681.JPG	nr; RB; 2501; Orthaga query sp. 15 1_1.psd	9 mm; RB; 619; Orthaga sp. 16 Vienna_POB_390- 679.JPG
13 mm; RB; Orthaga sp. 17 1_2.jpg	15 mm; RB; 653; Orthaga sp. 18 query Vienna_ POB_421-717.JPG	6 mm; RB; 14 mm; Orthaga sp. 19 1_1 Dscn3875.jpg	14 mm; RB; Orthaga sp. 20 female 1_2. jpg	nr; RB; Orthaga sp. 2_1.jpg (Orthaga sp. 21)
nr; RB; Orthaga sp. 3_1.jpg (Orthaga sp. 22)	nr; RB; Orthaga sp. 23 Vienna POB 1045 1_1.jpg	12 mm; NRB; Orthaga sp. 25 1_2. jpg	6 mm; RB; Orthaga sp. 7 1_1.jpg (Orthaga sp. 26)	nr; RB; 676; Orthaga sp. 27 Vienna_ POB_366A-742.JPG

In future editions of Part 1, and for species loaded onto the website by the time of print publication of parts 2 and 3, where possible there will be QR codes. However, as we feel it is a priority to print Parts 2 and 3 by early 2017, and as the processing of the databases to determine the number of unnamed morphotypes to be included cannot be finished by then, not all taxa in Parts 2 and 3 will have QR codes.

Such is the rapid advance of digital technology that QR codes, in this application, may prove to be only a temporary necessity, as they may be merely a stepping stone to the

use of pattern analysis of wing shape and colour pattern. Pattern analysis capability is being driven by demand for ‘augmented reality’ and still has a long way to go before it can be reliably used for our purpose, but we will be trying it out experimentally, as an alternative to QR codes. It could eliminate the need for any text at all and halve the number of book pages.

‘Augmented Reality’: Its application to animal and plant taxonomy

‘Augmented Reality’ (AR), is a live, direct or indirect view of a physical real-world environment, whose elements are augmented by computer-generated sensory input such as images, sound, video or GPS data. It is related to a more general concept called ‘mediated reality’ in which a view of reality is modified by computer. By contrast, ‘Virtual Reality (VR)’ replaces the real world with simulated ones.

With this technology, information about the real world of the user becomes interactive and capable of digital manipulation. As a result, AR enhances one’s perception of reality.

AR is the process of adding layers of information onto the world we see, viewable only through technology. For instance, an AR App (such as Layar) installed in a smartphone or tablet, when pointed to an image, launches a web page containing information about that image. The information is hosted online, but viewing is triggered only when the image is scanned and recognised by the AR App.

The advent of AR technologies opens up many opportunities for animal and plant taxonomy. It is particularly useful for species identification. Where once the use of QR codes was the norm, AR now offers huge promises to change the way taxonomists see and interact with the natural world.

AR means we can use an App such as *Layar* to point a smartphone/tablet at one or other of the c. 2500 moth images in the printed portals and it will take us straight through to the species’ page on the website, without the need for a QR code. But a good deal of refinement of this software is needed before this can happen. For example, the spectrum of the lighting on the printed image will vary with the type of lamp being used. The spectrum of ‘daylight’ lamps as opposed (say) to ‘warm white’ may result in errors of recognition and the software must be developed to take account of this.

Publication: the Website ‘www.pyralidsofborneo.org’

At the time of writing (April 2016), the public part of the website is confined to the 295 species of thyridoids. There are 500 named species and unnamed morphospecies of pyraloids on the site, but they are currently ‘private’. Infrastructure software for putting these in the public domain is still ‘work in progress’ (there are more than

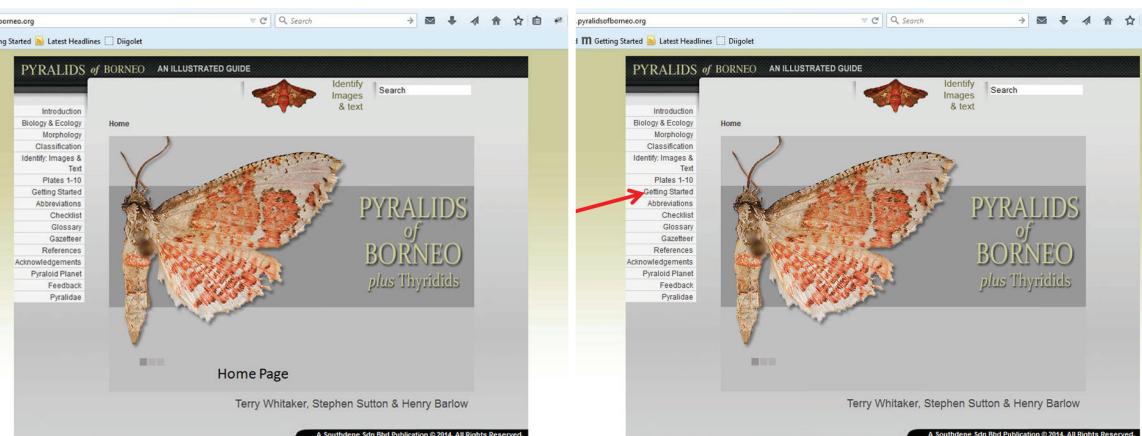
150 genera). We estimate that there are at least 1500 more species/morphospecies of pyraloids to be added after further study.

The purpose of this site is to give information on all aspects of pyraloid and thyridoid ecology and taxonomy and to identify specimens to species.

The Identification Function

A key feature is the choice of pathways and shortcuts to navigate the site, depending on the user's familiarity with it.

1. 'Getting started', and the 'red moth' shortcut. The Home Page has a menu bar on the left side giving access to the 16 sections of the site (Fig. 13). For first-timers, the 'Getting Started' menu entry route is recommended (Fig. 14). The 'Getting Started' section contains advice and gives information on using the 'Identify: Images & Text' section', which is where the species listed on the site can be identified.



Figs. 13 (left). Screenshot of the Home (1st) Page of the website. **Fig. 14 (right).** Home Page (detail): 'first timers' can click on 'Getting started' (red arrow) on the Menu Bar for advice on identification.

Alternatively, there is a shortcut for those practised at using the site. A red moth (circled in red in Fig. 15), which occurs on the top of every screen, is actually a 'hot link': clicking on the red moth takes you directly to representative species of each of the 28 genera of the Thyridoidea (Fig. 18, below).

2. Pathways for identifying a species and accessing the images. Fig. 16 shows three different ways of identifying a species. These three methods are referred to according to the number shown in the yellow circle.

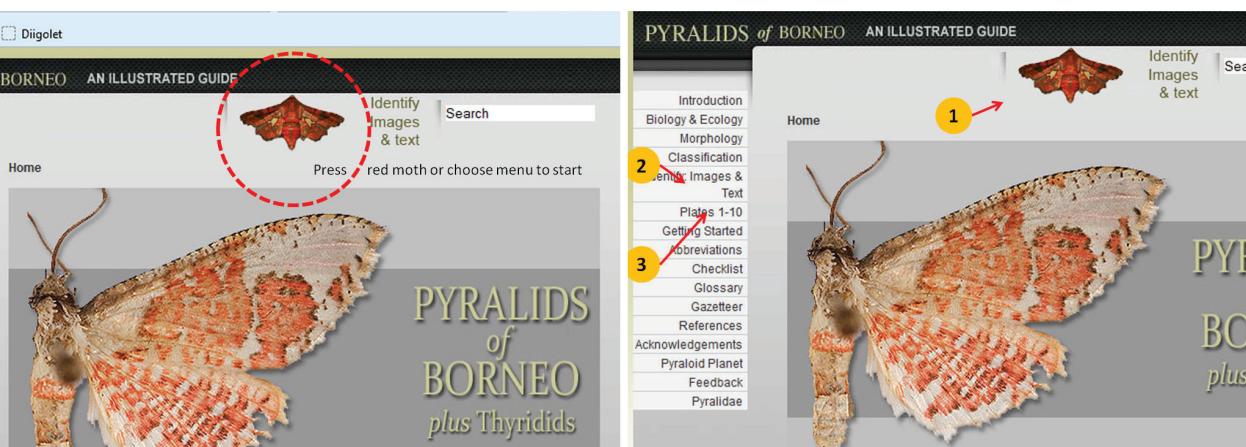


Fig. 15 (left). Home Page (detail): the red circle marks the shortcut which takes you to the ‘Identify: Images and Text’ section. **Fig. 16** (right). Three identification routes.

- Method 1: as already explained, clicking on the red moth is a shortcut to the ‘Identify: Images & Text’ section, which shows a representative species for each genus.
- Method 2: the ‘Identify: Images & Text’ section can also be accessed by clicking on ‘Identify: Images & Text’ in the menu bar (see, e.g., Fig. 20, below). With both these methods, clicking on a genus representative takes you through to images of all the members of that genus.
- Method 3: click on ‘Plates 1–10’ in the menu bar; altogether, these plates show all 295 of the species of thyridoids (Fig. 17).

Once you have opened the page showing all the plates (Fig. 17), clicking the image of a particular plate (e.g., Plate 1) will take you to a full-screen image of that plate. Most plates contain 35 species images. Each species image is ‘hot-linked’, so that when you click on an image it takes you directly to the main page for that species.

If you are trying to locate a particular genus or species, another method is to type its name into the ‘Search’ box at the top right of the screen. You will be told which plate has images of that genus/species.

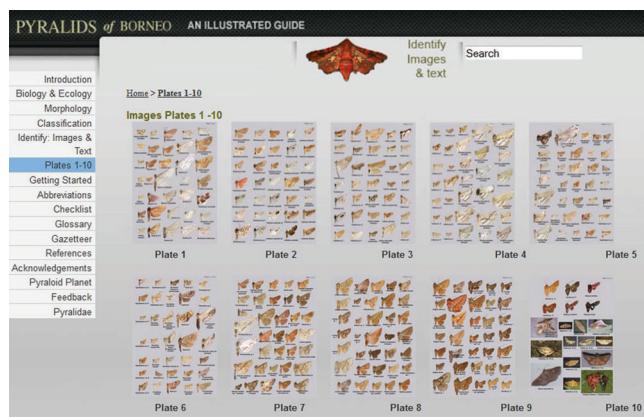


Fig. 17. The 10 plates displaying the 295 species of thyridoids.

Methods 1 and 2 discussed above enable you to access the image of a representative species for each genera; then, clicking on the image of a representative species for a genus takes you through to the images of all the species in that genus. As usual, however, the site provides you with a choice of pathways for accessing information. Three ways of accessing the images of all the species in a genus are shown in Fig. 18 by the arrows and the numbers in the yellow circles (yc); for example, to access images of all the species in the genus *Novobelura*, you can scroll, select and click on the genus *Novobelura* either in the menu which lists genera according to taxonomic order (yc 1) or according to alphabetical order (yc 2), or you can simply click on the image of the representative species of genus *Novobelura* (yc 3).

Another way, as explained above in relation to Fig. 17, is to type the name of the genus or species into the ‘Search’ box at the top right of the screen. This will direct you to the number of the plate to look at for images of all the species in a genus. Clicking a particular species image will take you to its main page.

3. The main pages. As we have seen, clicking the representative image for a genus takes you through to the images of all the species in that genus. You can then click on one of the species images: all the images are ‘hot-linked’, so clicking on a species image takes you through to the main ‘page’ for that species.

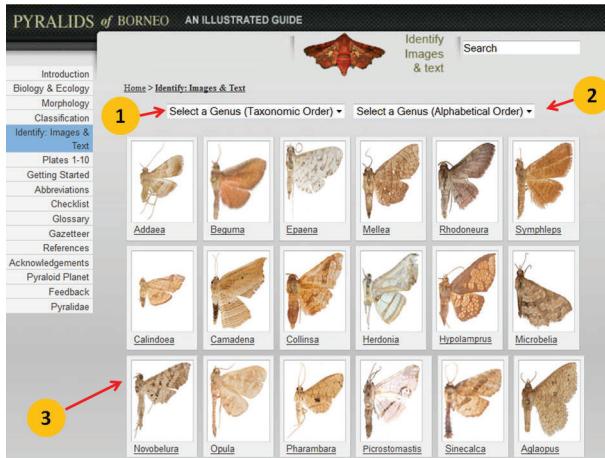


Fig. 18. Genera of Thyridoidea. Note that only 18 of the 28 genera are visible in this screenshot; to see the remaining 10, scroll down using the black bar on the right. (This ‘scroll down bar’ is used throughout the PoB site where the initial screen does not show all the information available.) The arrows show the three different ways of accessing the images of all the species in the particular genus chosen.

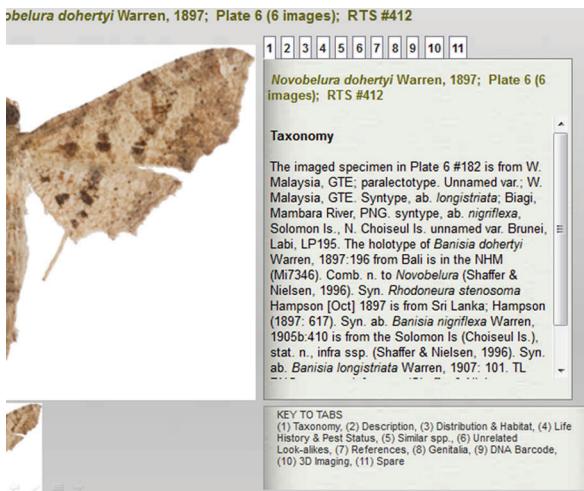


Fig. 19. The Main Page for the species *Novobelura dohertyi*. On the screen above the text box there are Tabs (numbered 1–11); each Tab opens up pages containing particular information on the selected species. Below the text box is the Key to Tabs.

Like a Chinese paper scroll, one can use the mouse to scroll through the Tabs from the initial screen view (e.g., Fig. 19 shows the initial screen view of the text for Tab 1, i.e., ‘Taxonomy’, for the species *Novobelura dohertyi*). Moreover, you can choose (click) different tabs and scroll down each one, e.g., ‘Life History & Pest Status’. A key to the tabs is given bottom right.

4. The tabs. Tabs are the heart of the species page. Each opens a screen on a different aspect: 1) Taxonomy; 2) Description; 3) Distribution & Habitat; 4) Life History & Pest Status; 5) Similar-looking related species; 6) Unrelated look-alikes; 7) References to the literature; 8) Genitalia structure; 9) DNA characteristics; 10) 3D imaging; 11) Spare.

At present we have good content for tabs 1–3 and 7, but *Life History and Pest Status* data (tab 4) is, for the most part, available only for known pest species. One of the aims of the website is to stimulate enquiry into the biology and ecology of this superfamily. Much of this work (e.g., breeding larvae through to adults and cataloguing food-plants) can be done perfectly well by non-professionals.

Tabs 5 and 6 indicate other species with which confusion is likely because of similar facies.

Tab 7: *References*. The number of references on the website is in excess of 750 and with every newly included species it increases. The publication of new papers is monitored via ‘Globiz Pyraloidea’ <http://globiz.pyraloidea.org>’ (Nuss et al., 2003–2010). In this Menu Section the reference to the original description of each named species is given, plus any others referring to ecology, biology, taxonomy or systematics.

Tab 8: *Genitalia*. These are the copulatory organs of the male and female which work to hold the male and female together during mating. In most moth groups the design of the genitalia is extremely complex and species specific, helping to ensure genetic isolation between species.

Tab 9: *DNA barcoding* is a remarkable development dating from 2003. BOLD (Barcode of Life Datasystems) <http://www.ibol.org/about-us/what-is-dna-barcoding/> (University of Guelph in Canada) is of enormous significance to the taxonomy of animals. A leg of a moth sent for analysis there is sufficient to produce enough of a DNA profile to allow most species to be separated. We intend to incorporate a DNA barcode on each species page of the website.

Tab 10: *3D imaging*. Although the technology is not miniaturized enough yet, it is likely that the 3D structure of the genitalia can, in the future, be scanned in the same way that a vase or human hand can be scanned now (a starting point for 3D printing).

The highly complex 3D structure of insect genitalia can be preserved by mounting it in a transparent block of paraffin wax. By 3D scanning of this one should be able to quantify, using existing software, the differences between species. This would add another criterion alongside the facies and DNA barcode of a moth specimen to determine what species it belongs to, and where that species belongs in the taxonomic hierarchy.

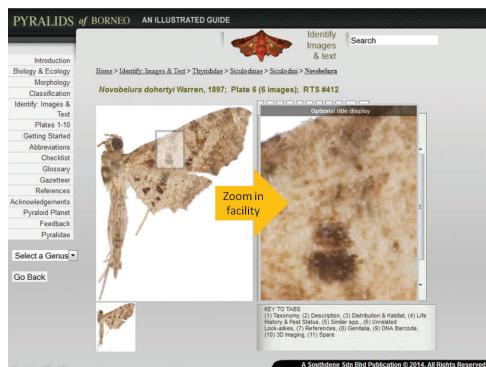


Fig. 20. Zoom facility.

5. The zoom. The main image on the species main page has a zoom facility for examining fine detail (Fig. 20).

Website functions other than identification

Apart from providing a means of identification, the website has a number of other functions, such as providing a Checklist, References, a Gazetteer to place names across SE Asia and access to the publication 'Pyraloid Planet'. They are listed in the Menu on the left in Fig. 21. Pyraloid Planet is a yearly digital newsletter which goes out to the 100 or so subscribers, all people actively involved in research into the Pyraloidea. These are a mix of professional entomologists and dedicated individuals who make a living by less esoteric means.

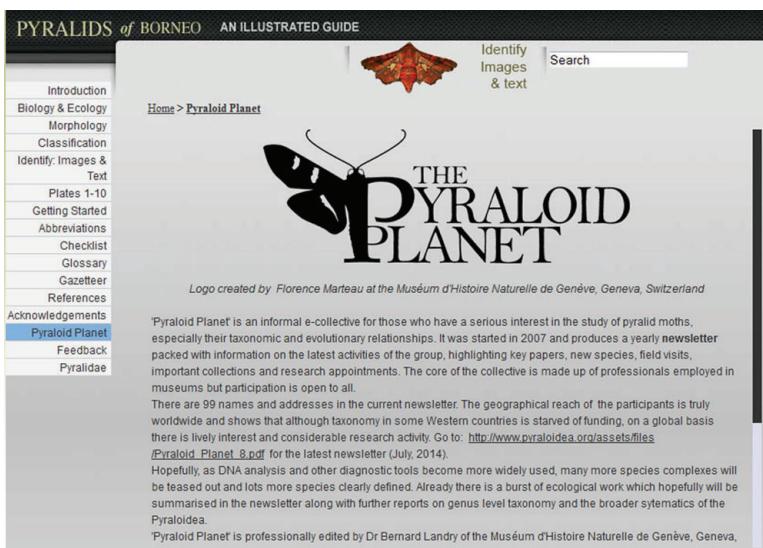


Fig. 21. The list of sections in the Menu, with that for 'Pyraloid Planet' highlighted.

Publication: the AppBooks

The ‘AppBook’ (as defined in Wikipedia and as we use the term) is a hybrid book and multi-media offering. It has digital text, supported by audio and video clips and an abundance of still images. The AppBooks ‘Pyraloid Moths of Borneo’ are still in preparation, but a good accessible example of the genre is ‘Birds of Mt Kinabalu’ published in the Tropical Gems series (currently available in Apple IOS — <https://itunes.apple.com/us/app/tropical-gems-series/id809373884?ls=1&mt=8>). This lists 165 species by altitudinal zone, with high quality images in a picture gallery, diagrams and audio of songs. The approach is that of a detailed introduction. It is restricted in size to be downloadable from the internet onto a tablet.

We see the Pyralids of Borneo AppBooks as filling a gap. The website is not available in most of the forest sites where pyralids are most diverse and unstudied. The printed volumes do not have the text of the species pages (to limit the cost of printing and to allow updating). The AppBooks will be large enough to include the introductory sections of the website and the text of the species pages. The images will be in the printed volumes. By producing a version of Paradox with lower resolution of the images it should be possible to include that software in the AppBooks, too. There will have to be more than one AppBook due to the large number of pyraloid species. The AppBooks will be detailed enough to identify species, but brief enough to serve as introductions to different subfamilies within the Pyraloidea.

The end result will be a *triangle* of publications (an example of the developing trend of ‘hybrid publication’), with each medium supporting the other two and the website providing the external links to other sources of information such as the digitised reference books in the Natural History Museum of London’s library, the global catalogue of pyraloids <http://globiz.praloidea.org> and Lepindex www.nhm.ac.uk/our-science/data/lepinde/. The website will be at the apex of this triangle, and information from it and the external sources to which it is linked will flow into the printed volumes and the AppBooks, which will be updated from time to time.

The AppBooks can be downloaded and accessed via smartphones or mobile tablets. However, this will not make the printed medium redundant, as most taxonomists working at the lab bench in a field site will tell you that a large (A4) *print* format is the best aid to identification.

Declaration re Publications

The publication of an image and description of an unnamed species in the printed volumes, the AppBooks and the website do not constitute a formal published description of a species. No name is given and the images are copyright and can be traced.

Our approach goes against the policy of only publishing species descriptions in tandem with the revision of the relevant genera. *Available* funding for taxonomy is far, far too small to do this. Our publications are designed to stimulate such taxonomic work, encourage *more* funding and to make public the full extent of one substantial element of the biodiversity of Borneo.

REFERENCES

- Barlow, H.S. (1982). *An Introduction to the Moths of South East Asia*. Malayan Nature Society, Kuala Lumpur. pp. 305, 50 plates, 727 text figs.
- Holloway, J.D. (1976). *Moths of Borneo with Special Reference to Mount Kinabalu*. Malayan Nature Society, Kuala Lumpur. pp. 264; 50 plates.
- Holloway, J.D. (2011). The Moths of Borneo Part 2: Families Phaudidae, Himantopteridae and Zygaenidae: revised and annotated checklist. *Malayan Nature Journal* 63(1/2), pp. 1–548.
- Minet, J. (2015). Lathrotelidae Clarke, 1971: a rehabilitated name deserving subfamily rank (Lepidoptera, Crambidae). *Bulletin de la Société entomologique de France* 120(I): 109–112.
- Nuss, M., Segerer, A. & Kunert, G. (2003–2010). Globiz.Pyraloidea: <http://globiz.pyraloidea.org>
- Regier, J.C., Mitter, C., Solis, M.A., Hayden, J.E., Landry, B., Nuss, M., Simonsen, T.J., Yen, S-H., Zwick, A. & Cummings, M.P. (2012). A molecular phylogeny for the pyraloid moths (Lepidoptera: Pyraloidea) and its implications for higher-level classification. *Systematic Entomology, London* 37(4): 635–656.
- Robinson, G.S., Tuck, K.R. & Shaffer, M. (1994). *A Field Guide to the Smaller Moths of South-East Asia*. Malaysian Nature Society, Kuala Lumpur & Natural History Museum, London. pp. 308, 51 text figs, 32 plates.
- Schulze, C.H. (2000). Auswirkungen anthropogener Störungen auf die Diversität von Herbivoren. (Analys von Nachtfalterzönosen entlang von Habitatgradienten in Ost-Malaysia). Unpubl. PhD thesis, University of Bayreuth, Germany, pp. 350.
- Schulze, C.H. & Fiedler, K. (2003). Vertical and temporal diversity of a species-rich moth taxon in Borneo. In Basset, Y., Novotny, V., Miller, S.E. & Kitching, R (eds), *Arthropods of Tropical Forests*. Cambridge University Press, Cambridge, pp. 69–85.

- Sutton, S.L. (1983). The spatial distribution of flying insects in tropical rain forests. In Sutton, S.L., Whitmore, T.C. & Chadwick, A.C. (eds.), *Tropical Rain Forest: Ecology & Management*. Blackwell Scientific Publications, Oxford, pp. 77–91.
- Sutton, S.L., Barlow, H.S. & Whitaker, T.M. (2015). *A Preliminary Guide to Pyraloid Moths of Borneo. Part 1*. Natural History Publications (Borneo) & Southdene. pp. 89.
- Whitaker, T.M. (2015). From Yorkshire to China via Borneo: a biological excursion through tropical moth ecology. *Naturalist* 140(1089): 81–96.

ACKNOWLEDGEMENTS

These are generally the same as those on the website ‘www.pyralidsofborneo.org’, except that we would like to pay tribute to our co-workers Dato’ Henry Sackville Barlow OBE and Dr Terry Whitaker, Past President of the Yorkshire Naturalists’ Union, UK, for their expert inputs and unfailing support over more than a decade. Special thanks to Ahmad Basir Omar for image management and to Banu Priya Kaliana Sundram for her accurate work in uploading species entries to the website. We thank Prof. Charles Vairappan, Director of the Institute of Terrestrial Biology and Conservation, Universiti Malaysia Sabah, for supporting the initiative to create a South East Asian Reference collection of Pyraloidea in the Institute’s Borneensis Museum.

SOURCES (LINKS)

To view the website: <http://www.pyralidsofborneo.org>.

To purchase books: ‘**A Preliminary Guide to the Pyralid Moths of Borneo**’. Visit the website <https://www.nhpborneo.com/book/a-preliminary-guide-to-pyralid-moths-of-borneo/>. Part 1 only is now available. RM120.00 + postage (weight 900 g). ISBN 978-983-812-162-0. It has 89 pages with 35 colour plates, 1077 images. Facing pages to the colour plates have names and data in text boxes for each image. There is an index to genera and species.

A few copies of Robinson, Tuck & Shaffer (1994) may still be available via stephensutton7@gmail.com.

To purchase AppBooks: These will not be assembled until the website is complete and all three Parts of the Preliminary Guide published, unless separate funding becomes available.