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Towards making Bornean biodiversity material and data available to all: The BORNEENSIS Collection of the Universiti Malaysia Sabah

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Abstract. The BORNEENSIS Collection, housed at the Institute for Tropical Biology and Conservation (ITBC), Universiti Malaysia Sabah, in northern Borneo, is one of the most important biological repositories in Southeast Asia. The collection, set up in 1996 and consisting of the Herbarium (BORH) and the Zoological Collections (BOR), was established with the goal of becoming a key reference collection for Bornean flora and fauna, especially those native to Sabah, that supports and assists biodiversity research and education. We provide a comprehensive account of the history of the collection, its current management status and holdings, and its roles in supporting local and international biodiversity and biosystematics research, undergraduate and postgraduate education and training, and in supporting non-formal educational outreach activities. Building on the experiences and challenges faced by BORNEENSIS thus far, we provide recommendations for the continued relevance of BORNEENSIS in terms of the continuity of collections care and management, promoting equitable specimen-based research and collections-based education and training, strengthening outreach efforts, and learning from our counterparts via improved networking.

Key words. natural history collection, university museum, herbarium, zoological, Malaysia, Southeast Asia

INTRODUCTION

Borneo, the third largest island in the world, is located within the Sundaland biogeographic region and is one of the most important hotspots of biodiversity evolution in Southeast Asia (de Bruyn et al., 2014). The Malaysian state of Sabah, in northern Borneo, with its diverse landscape ranging from ancient lowland rainforests to the sub-alpine regions on Mount Kinabalu (the highest in Sundaland), hosts an extensive diversity of flora (ca. 10,000 species). Among the fauna, the vertebrates are relatively well-studied, while most invertebrates remain largely undescribed (Natural Resources Office & SDBEC Secretariat, 2012). The rich biodiversity of Sabah has long attracted scientific interest, as shown by the colonial explorations carried out in the 19th and early 20th centuries (Burbidge, 1880; Whitehead, 1893; Smith, 1895; Chasen & Kloss, 1930; Kloss, 1931).

Despite the rich biodiversity in Borneo, natural history collections on the island were established relatively late compared to elsewhere in the region. The largest and oldest botanical and zoological collections in Southeast Asia are the Bogor Botanical Gardens (founded in 1817) and the Bogor Zoological Museum (founded in 1894), respectively, in Java, Indonesia (Larsen, 2000; Museum Zoologicum Bogoriense, 2018; Polgar et al., 2018). On Borneo, the Sarawak Museum was established in 1866 (Cranbrook & Leh, 1983; Maitland, 1998), but the herbarium was set up a century later in 1961 (Larsen, 2000). In Sabah, then British North Borneo, there were several short-lived attempts at setting up a general museum prior to 1866, culminating in the establishment of one by the British North Borneo Company in 1886, which included natural history material, and which was later taken over by the North Borneo Branch of the Royal Asiatic Society in 1895 until its closing in 1905 (Macaskie, 1961; Wong, 2000). The first dedicated natural history collection in Sabah was the Sandakan Herbarium, which was set up in 1916 by the Forestry Department of North Borneo. While its material was destroyed twice, once towards the end of World War II in 1945 and once by a fire in 1961, diligent efforts by staff rebuilt the collections to a respectable state (17,200 accessions) by 1964 (Sugau et al., 2016). Other natural history collections in Sabah were set up by various government agencies from the mid-1900s onwards—the Sabah Fisheries Department in the 1950s, entomological collections at the Forest Research Centre of Sandakan in 1966, zoological collections at the Sabah Museum in 1964, and the herbarium and zoological collections of Sabah Parks at Kinabalu Park in 1980 and 1994, respectively (Sabah National Parks Trustees, 1980; Chung & Chey, 2000; Stuebing & Wong, 2000; Lo, 2017; G. Gunsalam, pers. comm.). When Sabah, together with Malaya, Sarawak, and Singapore, formed the nation of Malaysia in 1963, the management of the few colonial-era

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collections were taken over by local government agencies, e.g., the Sabah Forestry Department manages the Sandakan Herbarium until today (Sugau et al., 2016).

Early collections in Sabah were established for various reasons, largely dependent on the priorities of the respective government agencies. The first research collections in a tertiary institution, which included a herbarium and the Museum of Zoology, were only established at the Universiti Kebangsaan Malaysia, Sabah campus (UKMS) in 1982, and played a significant role in biodiversity research until 1996 (Ng & Stuebing, 1989; Stuebing, 1991; Adam, 1995; Samat & Chin, 1996; Shukor, 1996; Sheldon, 2015; L. Kimsui, pers. comm.; R. Stuebing, pers. comm.). In 1996, the UKMS officially closed (Universiti Kebangsaan Malaysia, 2022) and most of the collections were brought back to the main campus in Peninsular Malaysia (Sheldon, 2015; L. Kimsui, pers. comm.; J. Gisil, pers. comm.; R. Stuebing, pers. comm.). One of the reasons for the closure of the UKMS was the establishment of the first full-fledged public university in Sabah—Universiti Malaysia Sabah (UMS)—in November 1994 (Universiti Malaysia Sabah (Incorporation) Order (P.U.(A)484/1994)). Public universities in Malaysia are regulated by the Ministry of Higher Education and are divided into 'Research' (research is prioritised), 'Comprehensive' (a variety of courses and majors are offered) and 'Focussed' universities (selected majors are prioritised) (Mohamad Sheriff & Abdullah, 2017). The UMS is categorised as a 'Comprehensive' university, offering more than 60 programmes across ten faculties (Ministry of Higher Education, 2024).

On 1 June 1995, in the first year of the founding of the UMS, the Tropical Biology and Conservation Unit (TBCU) was formed, comprising three Divisions, the Research and Development Division, the Reference Collection Centre (BORNEENSIS), and the Information Network Division (Sudin & Mohamed, 1999). In 2000, the TBCU was upgraded to become the Institute for Tropical Biology and Conservation (ITBC) and in 2001, the ITBC moved into its own building within the UMS main campus, which is situated about 10 km away from the city centre of Kota Kinabalu, the capital of Sabah (6°02′18.6″N 116°06′54.4″E).

Within the UMS, the ITBC is now one of four university-level centres of excellence for research, which are independent of the teaching-focussed faculties. Among the four, only the ITBC and the Borneo Marine Research Institute have reference collections, with the latter focussing on marine taxa. From its initial establishment as a unit, the core research areas of the ITBC have remained as 'Biodiversity and Biosystematics', 'Ecological Processes', 'Advancement of Biodiversity' (Natural Product Chemistry), and 'Nature Tourism'. Currently, the ITBC has 64 staff, 36 of whom are academic staff (faculty).

Funding for the core facilities and early research and capacity-building at the ITBC was obtained from the university and external sources including the Danish Cooperation for Environment and Development (DANCED) and the Japanese International Cooperation Agency (JICA) (see Collections and Research sections below). ITBC staff, students and affiliated researchers now have access to laboratories and other research facilities that complement the core research which include imaging and microscopy, molecular biology, botany and tissue culture, natural products, and ecological processes. Equipment available within those laboratories include research-grade stereomicroscopes with imaging and stacking functions, compound microscopes, scanning electron microscopes (SEM), PCR machines and associated equipment for DNA extraction and amplification processes, and laboratories equipped with facilities to support studies on mycology, endocrinology, tissue culture, and extraction of biochemical compounds (including liquid and gas mass spectrometers and chromatographs).

In addition to the laboratories, a core pillar of the ITBC is its reference collection, called BORNEENSIS, which serves as an important repository, particularly for staff and students who conduct research in the 'Biodiversity and Biosystematics' area. BORNEENSIS was established with the goal of becoming a reference collection for Borneo flora and fauna, that supports and assists research, teaching, and learning about biodiversity. The objectives of BORNEENSIS are: (1) to become the centre for the collection of Bornean flora and fauna especially those native to Sabah, (2) to serve as a reference centre, specifically for biosystematics research, (3) to provide facilities for biosystematics research to local and international scientists, and (4) to educate and increase awareness among Malaysians on the value of their natural heritage. The BORNEENSIS Collection consists of the Herbarium (BORH) and Zoological Collections (BOR), which will be referred to collectively in this article as BORNEENSIS.

In its early days, there was no separate structure for the management of the collections and most of the management for scientific work relied on research assistants, owing to the limited number of staff at the TBCU and later the ITBC (A. Sudin, pers. comm.). One of the research assistants (Ahmad Sudin), was delegated the task of managing the ITBC building, which included the collections. Early curatorial staff were hired as laboratory assistants or enumerators and some had prior collections-related training from their previous jobs (L. Kimsui, pers. comm.; J. Gisil, pers. comm.). In the first five years, there were only two laboratory assistants, Lucy Kimsui and Nordin Wahid. External funding enabled some staff to receive collections management training at Aarhus University in Denmark (J. Gisil, pers. comm.) and over the years, staff also received taxidermy training at the Sabah Museum (L. Kimsui, pers. comm.). A curator for the BORNEENSIS was first appointed in 2006 (Malaysian civil service grade S41). In that year, collection room managers were appointed among the ITBC academic staff to oversee the work of the curator and lab assistants. In 2009, four Museum Assistants (grade S17) were recruited on a contract basis to support the curator. To augment their expertise, a Specimen Collection and Preservation Course focusing on insects, vertebrates, and plants was held for the first time, with facilitation from Sabah Parks. The management of

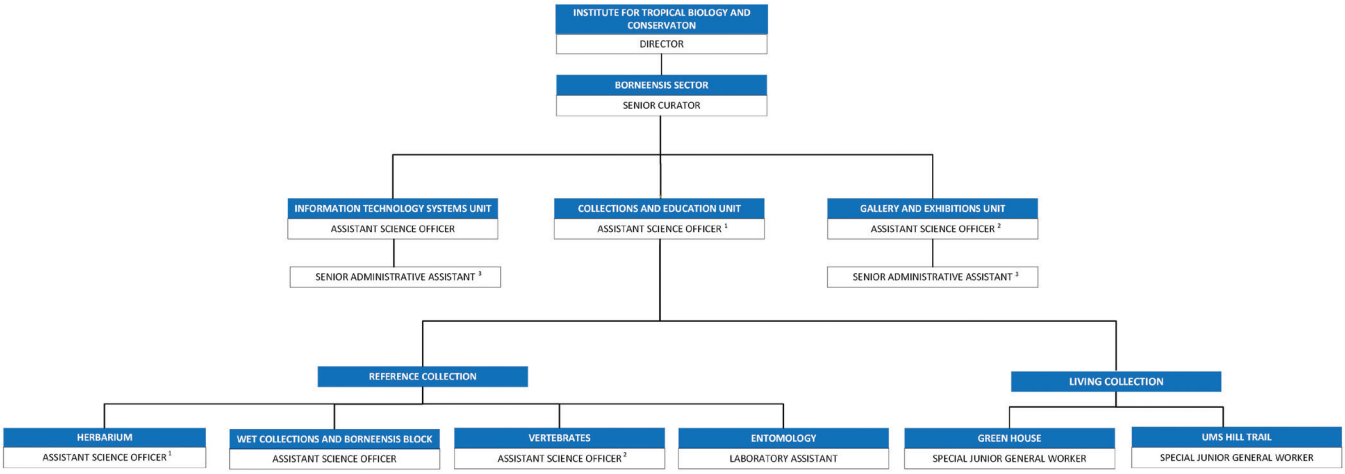

Fig. 1. Current organisational chart of the BORNEENSIS Sector, Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah. Numbers in superscript indicate the same individuals who have dual roles within the sector. Except for the role of 'Director', all other roles are indicated by the official job titles of the individuals.

BORNEENSIS was restructured in 2022, and the day-to-day management and care of the collection is now conducted by staff within the BORNEENSIS sector, led by the senior curator, who reports directly to the ITBC director. The senior curator manages eight staff within the sector, who are assigned to three units, 'Collections and Education', 'Information Technology Systems', and 'Gallery and Exhibitions', with some individuals holding dual roles (Fig. 1). Within the current team, seven are permanent employees and two are contract staff—all salaries are covered by the university.

BORNEENSIS received a huge boost from the early sources of funding to the ITBC mentioned above, in the form of installation of collections facilities and collections management training for the staff (see next section). Until 2024, the annual operational costs of BORNEENSIS were covered by the management budget of the ITBC, which was funded in turn by the university. The most recent allocations were on average RM10,000 (~USD2,100) per year for expendables. Additional funding is occasionally obtained from external sources based on specific digitisation or outreach projects, e.g., RM10,000 (~USD2,100) was obtained in 2023 for digitisation of selected specimens. Furthermore, academic staff who conduct specimen-based research would have to budget for the cost of preservatives and storage containers in research proposals (from national and international grants) to ensure that specimens from the projects will be well-preserved and suitable for deposition in BORNEENSIS. Funding for maintenance of the collection rooms is covered by the management budget of the ITBC (e.g., for replacement of large fixtures and appliances) and the development and maintenance office of the university (e.g., regular servicing of air conditioners, fungal-control and paintwork).

THE COLLECTION

History. Upon the closure of the UKMS in 1996, much of the material went back to the main UKM campus in Peninsular Malaysia (Thiers, 2024; J. Gisil, pers. comm.; L. Kimsui, pers. comm.; R. Stuebing, pers. comm.). Some material did remain in Sabah in the then-newly established UMS (Das & Haas, 2003), including botanical material that was part of the teaching collection (J. Gisil, pers. comm.). Most of the wet zoological collections and some entomological collections were also transferred into the BORNEENSIS Collection when it was set up in 1996. The collections that remained from the UKMS were stored in the 'Animal House' within one of the campus buildings for a short while after the closure of UKMS, only moving to the current campus grounds of the UMS when it was completed in 1999 (A. Sudin, pers. comm.).

BORNEENSIS was established to complement existing local collections at the time, e.g., the Sandakan Herbarium, and to establish its own niche (Sudin & Mohamed, 1999). Furthermore, the collection-building efforts largely depended on the expertise of ITBC staff and active collaborations during that period (see Research section). The initial focus of the herbarium was on "lower plants" (non-vascular), including medicinal and ornamental plants, and fungi from Borneo, while for the zoological material, the focus was largely on vertebrates (particularly small mammals) and insects (Sudin & Mohamed, 1999).

Within the first five years, there were extensive efforts to build up the collection including a survey of the flora and fauna of the site of the then-new UMS campus in 1995, several inventory surveys along the Crocker Range and Trus Madi in 1995–1998, a four-month inventory of flora and fauna of Mount Rara in 1996 and 1997, a long-term collection of amphibians beginning in 1996 to establish a reference collection of frogs and toads of Sabah, and a scientific expedition to the Maliau Basin in May 1996 (Mohamed et al., 1998). The TBCU at that time was located within the Faculty of Science and Technology (formerly known as the Faculty of Science and Natural Resources, and before that, the School of Science and Technology), and specimens were stored within the three laboratories that were assigned to the TBCU, i.e., the Botany, Mycology, and Zoology laboratories (A. Sudin, pers. comm.).

Table 1. Material deposited in the BORNEENSIS Zoological Collection (BOR) and Herbarium (BORH), Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, as of December 2024.

COLLECTION	NUMBER OF SPECIMENS	NUMBER OF TYPES	TAXON COVERAGE
HERBARIUM	**8,000**	**36**	**ALGAE, BRYOPHYTES, FUNGI/LICHEN, PTERIDOPHYTES, SEED PLANTS**
ENTOMOLOGY	**118,164**	**149**	**HYMENOPTERA, LEPIDOPTERA, COLEOPTERA, PHASMIDA, ORTHOPTERA, ODONATA**
VERTEBRATES	**5,180**	**–**	**MAMMALS, FISH, REPTILES, AMPHIBIANS**
MOLLUSCS	**134,577**	**96**	**GASTROPODA, BIVALVIA**

The development of the BORNEENSIS zoological and herbarium facilities only commenced in earnest in 2001, when the ITBC moved to its own building complex. During its initial stage, the UMS and the Sabah State Government embarked on a five-year technical cooperation named the Bornean Biodiversity and Ecosystems Conservation Programme in Sabah (BBEC), with the Japan International Cooperation Agency (JICA) in 2002−2007 (Mohamed & Kusano, 2002). As part of the research and education component of the programme, the ITBC received assistance in the development and maintenance of facilities in ITBC for taxonomy and biodiversity conservation research, including for BORNEENSIS. JICA funded the compactors in the herbarium and entomology collection rooms, while the dry and wet collection rooms were funded by the Malaysian government via the UMS Development Fund (Fig. 2). Japanese experts were also dispatched from three to 12 months to the UMS to assist the ITBC in setting up the collection rooms, as well as to build taxonomic capacity in the institute (JICA, 2008).

Herbarium. The BORNEENSIS Herbarium (BORH) is registered in the Index Herbariorum and is housed within a single 198.86 m^2 room, with specimen folders stored in acrylic drawers/boxes. The preserved plant specimens may be whole plants or plant parts, usually in dried form mounted on a sheet, but may also be kept in alcohol or other suitable preservatives, as in the case of some fruits and flower parts. Meanwhile, the dried fungi are kept in small boxes matching their size. As of December 2024, the BORH contains 8000 specimens of algae, bryophytes, fungi/lichen, pteridophytes, and seed plants, including 36 type specimens from various families (Table 1).

Zoological Collections. The BORNEENSIS Zoological Collection (BOR) comprises three rooms for the zoological collections, comprising one wet (225.94 m^2) and two dry collection rooms, one for Entomology (218.75 m^2) and one for Vertebrates and other Fauna (203.38 m^2) (Fig. 2). All specimens are kept on shelves of a compactor system. As of December 2024, the Entomology collection includes nearly 117,500 pinned specimens (Table 1). Among the major insect orders in the collection are Hymenoptera, Lepidoptera, Coleoptera, Phasmida, Orthoptera, and Odonata. The second dry collection includes vertebrates and other fauna. Specimens include preserved small mammal and bird skins and bones, and mollusc shells. As of December 2024, there are 467 specimens of dry-preserved vertebrates and more than 16,000 lots of molluscs. In the wet collection are whole animals, tissues and stomach contents preserved in fluid preservative, mostly ethanol. These include more than 4,713 specimens of vertebrates (small mammals, birds, freshwater fishes, reptiles, and amphibians), 665 samples of termites, and 106 samples of molluscs (Table 1). In total, the BOR holds 149 entomological types (including 54 holotypes) (Hymenoptera, Coleoptera, Homoptera, Orthoptera) and 96 molluscan types (including 38 holotypes) (Table 1). Efforts are ongoing to locate type specimens that were reported in publications as purportedly deposited in the BOR but have not been found in recent inventories of the collection.

Collections Management. As mentioned in the Introduction, the management and care of the BORNEENSIS collection is conducted by the BORNEENSIS sector, led by a senior curator with four staff members who are directly involved in the care of the collections and one staff assigned to manage the collections data. A committee consisting of ITBC academic staff, who are appointed by the ITBC director, plays an advisory role in the management and care of the collection. The committee serves to establish policies and strategies for the collection, and to conduct relevant events and training workshops to improve collections and specimen data management among ITBC staff and students. Protocols and policies related to 'Access and Use' and 'Specimen Acquisition and Accession' have recently been prepared by the committee and are currently being vetted at the university-level. Similar protocols and policies are being devised for data management and collections care.

The policies for BORNEENSIS comply with the Sabah Biodiversity Enactment 2000, which was amended in 2017 in accordance with the Nagoya Protocol, of which Malaysia is a signatory (Sabah Biodiversity Centre, 2024). Besides educational visits, all access and use of the Collection, including by ITBC staff and students, that involves material collected from Sabah, are deemed to fall under the definition of accessing "a biological resource or associated relevant knowledge…from…place where it is kept…for the purpose of research and development", and shall require an Access License (Sabah Biodiversity Enactment 2000 Part I, Section

Fig. 2. The BORNEENSIS collection rooms and public gallery, Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah. A, BORNEENSIS Herbarium; collection rooms for B, entomology; C, vertebrates and other fauna; D, wet collections; E, F, Galeri BORNEENSIS. Photographs by Azrie Alliamat.

2A, Subsection 1a; Sabah Biodiversity Centre, 2024). In addition, loans of material from institutions located outside Sabah will require a Transfer (export) License. Both licenses are issued by the Sabah Biodiversity Centre, which is the local authority responsible for regulating access and sharing of benefits arising from the use of biological resources or traditional knowledge associated with biological resources in Sabah (Sabah Biodiversity Centre, 2024). The policies have recently been formally accepted by the university higher management, and all new material deposited in

BORNEENSIS will now have to be declared as legally obtained, e.g., material collected from Sabah should have at minimum, an Access License and according to the requirements of the collection locality, relevant research permits (Universiti Malaysia Sabah, 2025). Furthermore, anyone who has obtained an Access License from the Sabah Biodiversity Centre to access material in BORNEENSIS will be able to apply to the Senior Curator to take out a material loan or to examine material on site (Universiti Malaysia Sabah, 2025).

The management of collection data has undergone some changes in the past three decades. The BBEC Programme also recognised the importance of collection management, thus JICA introduced a database system called MUSEBASE to manage the rapidly growing collections in BORNEENSIS (Kueh et al., 2006). The system was used from 2006 to around 2010 (Alliamat A, pers. comm.). Owing to issues with server maintenance for the previous database, a more accessible and streamlined process using Microsoft Access has been introduced and is currently being implemented. Separate databases are maintained for each taxon and managed by the 'Information Technology Systems' unit, which was newly set up in 2023. Usage of the standardised database remains uneven across collections but has been fully adopted for selected collections (molluscs, pteridophytes, bryophytes and angiosperms). Efforts are ongoing to digitise the specimens and associated collections data, following guidelines proposed by Ong et al. (2023), which are in line with FAIR Data Principles (Wilkinson et al., 2016). Recently published national-level guidelines for FAIR biodiversity data stewardship were developed based on the BORNEENSIS protocols (Liew et al., 2024). With funds from the Ministry of Natural Resources and Environmental Sustainability, some of the digitised material have been made available on the Malaysia Biodiversity Information System (https://mybis.gov.my/one/) online database (MyBIS, 2024).

SPECIMEN-BASED RESEARCH AND EDUCATION

Being part of a tertiary institution, the research conducted at the ITBC is closely linked to education. 'Biodiversity and Biosystematics', a core research area of the ITBC from its founding days, has contributed the most to specimen-based research and education. For the staff and students who focus on this research area and international researchers conducting research here, the BORNEENSIS collection has been a pivotal resource and repository for the advancement of specimen-based biodiversity research in Borneo.

Owing to the relatively young age of the collection, most of the published research citing BORNEENSIS material refer to specimens from the respective studies being deposited in BORNEENSIS, rather than specific use of the material for further studies (e.g., taxonomic revisions). BORNEENSIS houses priceless specimens from published research on a wide range of taxa from flora (e.g., Suleiman & Akiyama, 2007; Julius et al., 2007, 2010; Kulip et al., 2010; Repin et al., 2012; Majuakim & Anthony, 2016), fauna (e.g., Das & Austin, 2007; Bakhtiar & Chiang, 2011; Ng et al., 2017; Rahman et al., 2019) and fungi (e.g., Foo et al., 2018; Mh Subari et al., 2023) from around Southeast Asia, and especially Borneo and Sabah in particular. Besides contributions from studies in taxonomy and biodiversity (Matsui et al., 2007, 2013, 2017, 2020; Tsukaya et al., 2016; Suetsugu et al., 2018; Zieritz et al., 2021; Lam et al., 2022), BORNEENSIS specimens have featured in other studies including ecology (Yoh et al., 2020; Lok et al., 2021), biogeography (Liew et al., 2009; Zieritz et al., 2018), natural product chemistry (Ishii et al., 2010; Majuakim et al., 2014; Hoe et al., 2015; Phan & Vairappan, 2015), and even palaeontology (Ibrahim et al., 2013).

Capacity-building via collaborations. The foundations of specimen-based research at the ITBC began with collaborative efforts from the founding of the institute as a unit. In the previous Collections section, a few surveys and expeditions were mentioned as pivotal for early collection-building efforts. These were made possible by a number of collaborative efforts with local and international partners including Sabah government agencies (Sabah Forestry Department, Sabah Foundation, Sabah Wildlife Department, Sabah Parks), The Natural History Museum, London, University of London, Museum of Nature and Human Activities, Hyogo, Danish Cooperation for Environment and Development (DANCED) and the previously mentioned JICA. Programmes like the BBEC focussed on the capacity-building (of ITBC staff and students). The UMS also provided funding for postgraduate students, although the majority of funding was sourced externally (Mohamed, 1999). By the year 2000, multiple postgraduate scholarships and research funding amounting to nearly RM 8 million (approximately USD 2.1 million, based on exchange rates in 2000) had been obtained by the ITBC from international organisations, among others, DANCED, the Darwin Initiative, Gesellschaft fur Technische Zusammenarbeit, WWF and private companies (e.g., Kosinar) (Eggleton et al., 1999; Mohamed, 2000). Past and present research collaborations have relied on personal connections established and maintained by the ITBC academic staff, which in some cases have resulted in formalised agreements, e.g., memoranda of understanding (MOU) at university level with international and local partners.

These formal collaborations were instrumental in aiding the establishment of early research efforts at the ITBC. The DANCED project on 'Collaboration on Biodiversity between Universiti Malaysia Sabah and Danish Universities', spanning from 1997 to 2002, provided scholarships for the training of nearly 20 Malaysian postgraduate students (Abdul Kadir, 2002). During the period of the BBEC programme between 2002 and 2007, in addition to the abovementioned assistance provided for the establishment of collection facilities and data management, numerous advisors from Japan were stationed at the ITBC for up to one year to provide training on taxonomy and conservation biology, while 10 ITBC staff received training in Japan on topics regarding taxonomy and biology, collections management and biological conservation (JICA, 2008). Scientific expeditions that were conducted with Sabah agencies and via the DANCED project, which

included studies at Maliau Basin, Tabin Wildlife Sanctuary, and the Klias and Binsulok forest reserves, not only resulted in specimens for the collection but also numerous scientific publications (see Mohamed et al., 1998, 1999, 2000, 2003). These early efforts were intensified during the BBEC programme, which included expeditions to various protected areas within Sabah, such as Lower Kinabatangan, Crocker Range Park, Melalap, Lower Segama, and Kulamba (see JICA, 2008).

To aid in the teaching and training of taxonomy, collections management and other field methods, particularly during the period of the BBEC programme, 29 publications were jointly produced by the UMS and JICA partners (JICA, 2008). Among these publications were training manuals on collections data management, protocols for biodiversity inventory and collections (Hashimoto & Rahman, 2003; Hashimoto et al., 2006b) and guides on entomology, aquatic insects, mammals (see JICA, 2008 for full list of publications until 2006). In general, the publications served to provide standardised protocols for conducting taxonomy and biodiversity research, while emphasising the importance of proper management of data associated with the specimens. In 2005, the BBEC programme funded the establishment of the Journal of Tropical Biology and Conservation, the flagship journal of the ITBC, which aims to encourage scientific publishing among regional early career researchers and to publish reputable tropical biodiversity-related research (Universiti Malaysia Sabah, 2024). The Journal continues to be published today with support from the ITBC and the UMS.

Undergraduate education and postgraduate training. BORNEENSIS contributes to undergraduate education at the UMS primarily through the Bachelor of Science in Conservation Biology programme. A total of five core courses offered under the programme—Entomology, Animal Diversity, Plant Diversity, Systematics, and Preservation and Collection Management—utilise BORNEENSIS specimens. This programme and the courses have been offered since 1995, previously by the Faculty of Science and Technology, and currently, by the Faculty of Tropical Forestry.

Furthermore, based on a sample of theses deposited in the UMS library, at least 246 final-year theses produced between 1999–2023 by undergraduate students from the Conservation Biology programme either used the specimens from BORNEENSIS or deposited material in the collection while conducting their final-year projects. Out of those, 70.3% were on zoology, 24.8% on botany, and the remaining 4.9% on mycology (Fig. 3A). At the postgraduate level, 86 postgraduate theses produced between 1999–2023 relate to BORNEENSIS, with 62.3% on zoology, 23.3% on botany while the rest were on mycology (Fig. 3B), and these were part of research involving three academic programmes offered by the ITBC, namely 'Advancement of Biodiversity', 'Biodiversity and Biosystematics' and 'Ecological Processes' (Fig. 3C). The zoology theses were dominated by entomology, followed by herpetology, mammalogy, and ichthyology. Although the 'Ecological Processes' academic programme produced the greatest number of theses which relate to BORNEENSIS, the majority of research conducted included biodiversity surveys and were supervised by faculty members from the 'Biodiversity and Biosystematics' core research area.

Key taxa studied. While BORNEENSIS material has been linked to student projects across more than one research area, as mentioned at the start of this section, the collection is most closely linked to the research conducted by the staff and students of the 'Biodiversity and Biosystematics' core research area. Because of the close collaboration via the different collaborative programmes, unsurprisingly, many studies based at the ITBC was conducted in collaboration with, and often led by, researchers from the UK, Denmark, and Japan, some of whom were stationed in Sabah for up to a year or longer.

Flora-wise, much of the research focussed on bryophytes, with the BORNEENSIS Herbarium (BORH) holding the largest collection of Bornean mosses in the country. The earliest research was conducted on Mount Trus Madi (Suleiman & Edwards, 2002), with the material collected being among the first material deposited in the BORH. Later, documentation of bryophytes expanded to the rest of Sabah, with several new species and genera being described (e.g., Akiyama & Suleiman, 2015; Akiyama et al., 2021; Katagiri et al., 2012; Furuki & Suleiman, 2016; Zhu et al., 2017) and numerous new records for Borneo were reported (e.g., Suleiman & Akiyama, 2007; Ellis et al., 2015; Suleiman & Repin, 2016; Suleiman et al., 2017; Suleiman & Mustapeng, 2019; Mustapeng & Suleiman, 2020; Suleiman & Anwar, 2020).

Besides the bryophyte research, Japanese researchers via the BBEC programme also led the way for herpetofauna studies, where many new species of herpetofauna were described by Japanese-led research groups based on BORNEENSIS material (Matsui et al., 2010, 2013, 2014a, b, 2020; Shimada et al., 2011; Nishikawa et al., 2012; Eto et al., 2015; Dehling et al. 2016). Numerous new amphibian species, some endemic to Sabah, were described with the help of comparative material stored in the collection, such as *Feihyla inexpectata* (Matsui, Shimada & Sudin, 2014), *Ichthyophis lakimi* Nishikawa, Matsui & Yambun, 2012, *Leptobrachella sabahmontana* (Matsui, Nishikawa & Yambun, 2014), *Meristogenys stigmachilus* Shimada, Matsui, Yambun & Sudin, 2011 and *Philautus nephophilus* Dehling, Matsui & Imbun, 2016. One species, *Meristogenys maryatiae* Matsui, Shimada & Sudin, 2010, was named in honour of the first director of the ITBC, Maryati Mohamed (Matsui et al., 2010). The BOR collection is recognised in the fields of herpetology and ichthyology by the American Society of Ichthyologists and Herpetologists as a recognised institutional collection for specimen deposition (Sabaj, 2016). Today, the collection continues to represent an important repository of material used in current herpetological research in Sabah (Haas et al., 2018; Quah & Grismer, 2024a, b; Quah et al., 2024, 2025).

Entomology was one of the early focal points for specimen-based research, particularly on termites, via the Darwin Initiative (e.g., Eggleton et al., 1999) with research continuing until today (e.g., Rahman et al., 2018; Arumugam et al.,

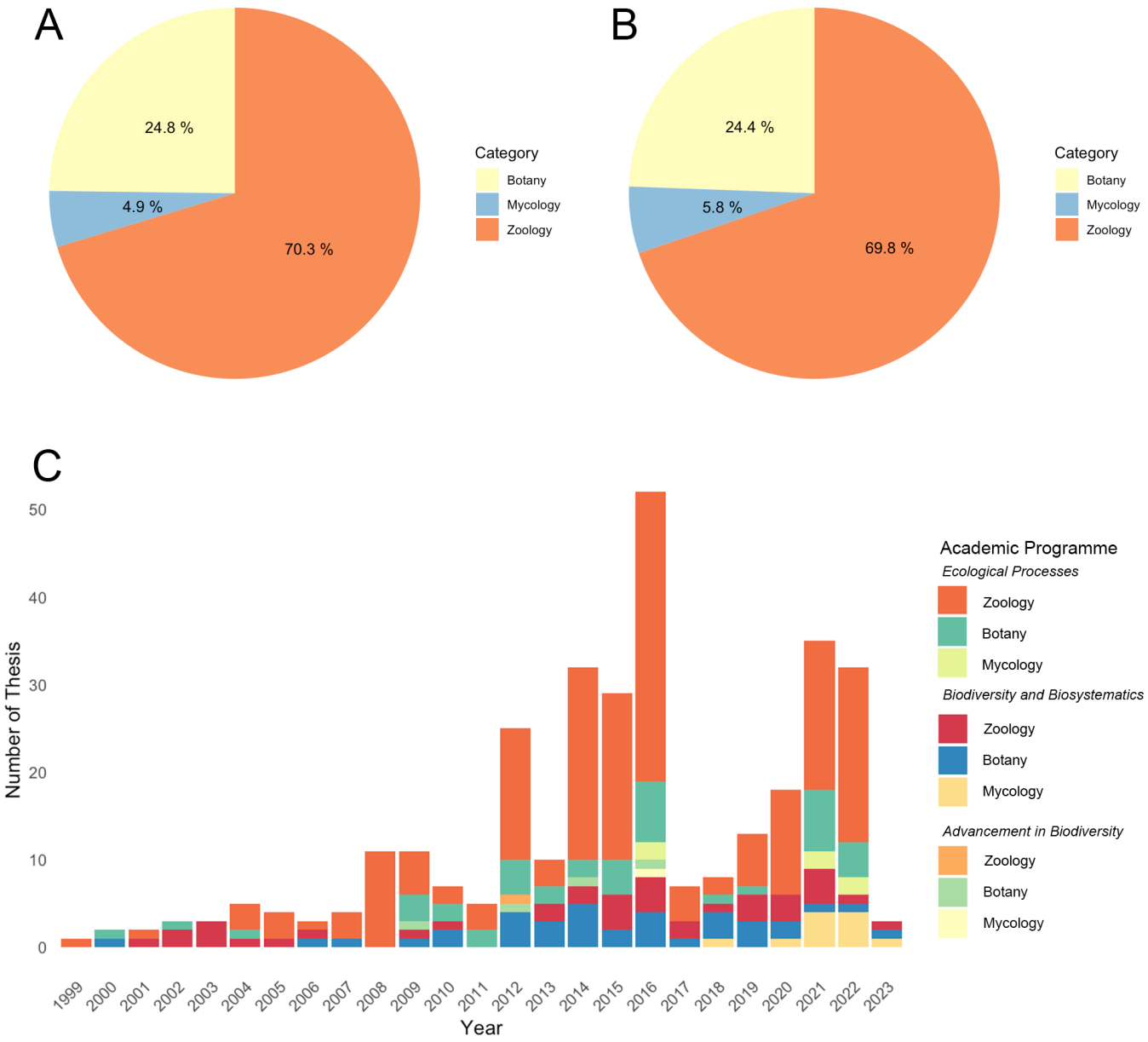

Fig. 3. Undergraduate and postgraduate theses on zoology, botany and fungi research since 1999 that utilised or deposited material in the BORNEENSIS Collection, Institute for Tropical Biology and Conservation (ITBC), Universiti Malaysia Sabah. A, undergraduate theses by category; B, postgraduate theses by category; C, postgraduate theses according to ITBC academic programmes.

2020). Ants are also another taxon that has received much attention, with research being conducted in collaboration with international colleagues (e.g., Brühl et al., 1999; Hashimoto et al., 2006a; Kohout & Mohamed, 2009; Pfeiffer et al., 2011).

Malacological research was established at the ITBC in the early 2000s (e.g., Schilthuizen et al. 2002; 2005; 2006). BORNEENSIS now houses the best collections for molluscs, primarily terrestrial species, in Malaysia and is the leader of malacological research in the country. Similar to the herpetofauna, numerous new species and even new genera of snails were described based on the collection's material (Liew et al., 2009, 2014a, 2020; Vermeulen et al., 2015; Foon & Liew, 2017; Liew & Clements, 2020; Vermeulen & Liew, 2022). Malacological research also extended to general diversity (Ng et al., 2017; Chang et al., 2019), ecology (Liew et al., 2008, 2014b; Phung et al., 2022; Woo et al., 2022) and biogeography (Liew et al., 2010; Foon et al., 2017).

Overall, material from recent and on-going studies continues to be deposited in BORNEENSIS, largely based on research done by ITBC staff and students. The use of the BORNEENSIS collection is expanding, e.g., to improve rapid assessment of species in the field—Ong & Hamid (2022) used the collection to evaluate the performance of deep learning models in classifying insects according to different taxonomic levels, and Ong et al. (2024) used the mosquito samples to develop a recognition system for mosquitoes from Sabah. Specimen-based research at the ITBC has evolved over time from being primarily led by international collaborators in the early days of its establishment, towards more local-led efforts, with new focal taxa, e.g., ferns (Anthony et al., 2025), gingers (Lam et al., 2022), fungi (Sathiya Seelan et al., 2020; Mh Subari et al., 2023), mantids (Norman & Mustaffa, 2019), mosquitos (Ng et al., 2016; Ebrahim & Dawood, 2018), myriapods (Ng et al., 2025) and small mammals (Bansa et al., 2020).

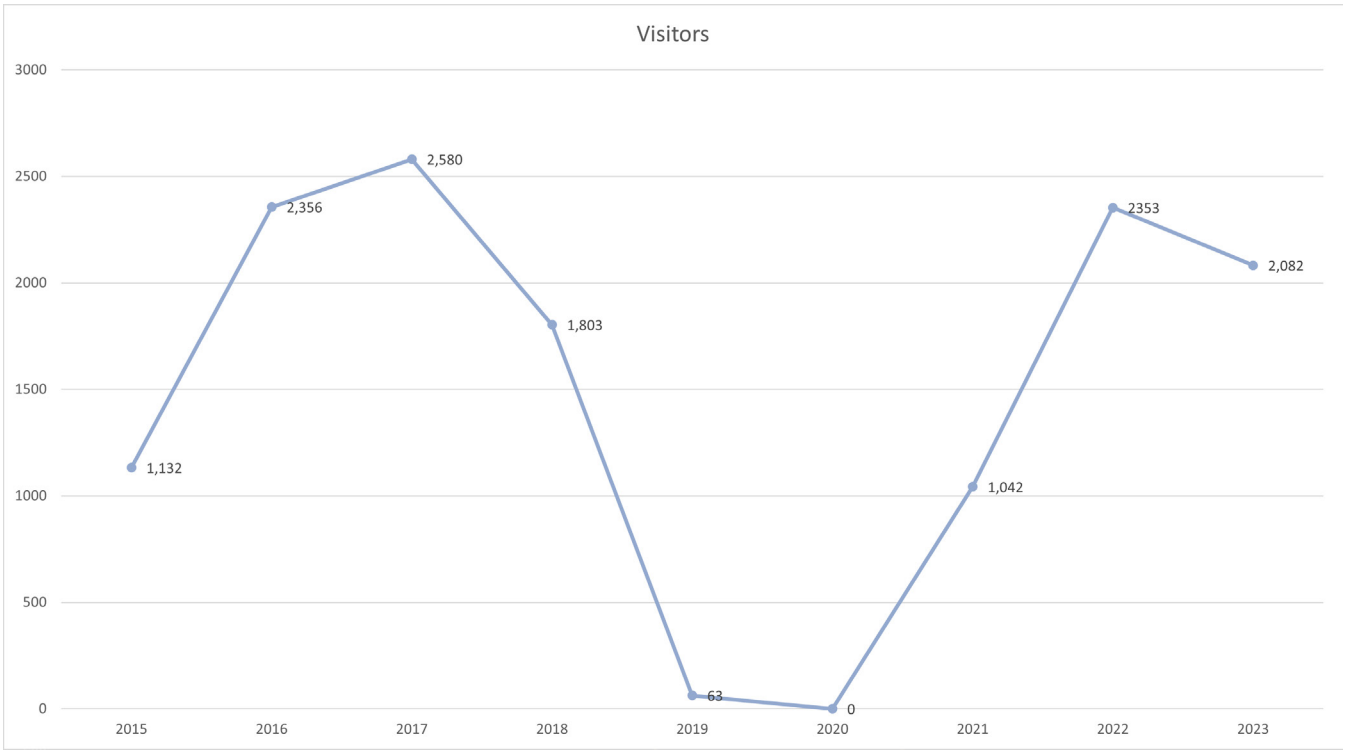

Fig. 4. Number of visitors to the Galeri BORNEENSIS, Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah from 2015 to 2024.

BORNEENSIS FOR OUTREACH

Outreach activities discussed in this section refers to efforts by the ITBC to introduce the BORNEENSIS Collection and other topics associated with biodiversity conservation and sustainable development in non-formal educational activities or settings. These activities are organised by BORNEENSIS through the 'Gallery and Exhibitions' and the 'Collections and Education' units.

Galeri BORNEENSIS. A key pillar of outreach for BORNEENSIS is the public gallery, Galeri BORNEENSIS. From the early days of the ITBC, an approximately 430-m^2, two-storey space had been allocated for a public gallery. Dioramas of local ecosystems and replicas of Bornean flora and fauna were the first to be opened for display while the rest of the gallery was being renovated. In 2003, a part of the allocated space, 96 m^2, was established as the 'ITBC Frog Museum' to showcase Bornean anuran amphibian research findings and specimens with the purpose of cultivating an appreciation for biodiversity and promote conservation efforts among stakeholders (Kueh & Mohamed, 2007). The Galeri BORNEENSIS was formally inaugurated on 13 March 2016 (Fig. 2), with the aim to promote biodiversity and better corroborate effective Education for Sustainable Development (ESD) through natural history collections primarily from Sabah and Borneo, and disseminate the knowledge through holistic advocacy, education and training. The implementation framework of the gallery is supported by three principles: (1) exhibitions focused on research findings, specimens, and materials gathered by experts in the field; (2) an effective interpretation model known as the 'Thematic, Organised, Relevant, Enjoyable' (TORE) model by Ham (1992); and (3) pragmatic utilisation axioms for sustainable development. Since 5 April 2023, the gallery now also encompasses the BORNEENSIS Living Laboratory for ESD that was launched as a living laboratory workstation, with special funding from the UMS, to initiate and implement diagnostic and prognostic sustainability solutions for the community and industry. Since opening to the public, Galeri BORNEENSIS has received an average of 200 visitors per month, primarily local students and international tourists. Visitorship fell to zero due to closures during the COVID-19 pandemic from April 2020 and throughout 2021, but the numbers have increased again since 2022 (Fig. 4). The majority of international visitors are East Asian tourists and educational groups, aligning with the aspiration of the gallery to match with international needs for sustainable and responsible tourism (Kueh et al., 2023).

Annual and ad hoc outreach events. Previous studies have lamented the lack of environmental knowledge in the Malaysian education system and of localised biodiversity topics in ESD or environmental education (Yean, 2014; Suzuki et al., 2019). BORNEENSIS, with the gallery and collections, serves as a knowledge hub emphasising the importance of the collections by providing both non-formal and informal educational opportunities to address the aforementioned gaps in education. The largest outreach event for BORNEENSIS is the annual Friends of BORNEENSIS Programme, which has been running since 2015 and has to date offered a unique experience for up to 300 local lower secondary school students to experience outdoor activities that promote understanding and respect of biodiversity. In addition, BORNEENSIS also conducts the yearly Sambutan Hari Biodiversiti Sedunia (World Biodiversity Day Celebration) to enhance public knowledge about

Table 2. Major outreach events conducted by BORNEENSIS, Institute for Tropical Biology and Conservation (ITBC), Universiti Malaysia Sabah (UMS) from 2022–2025.

Event	Year	Number of participants	Affiliations of participants
Fish Identification Course	2022	23	Sabah Fisheries Department, Sabah Parks, Sabah Museum, Sarawak Agricultural Department, Borneo Marine Research Institute (UMS)
Poisonous Fungi Course	2022	22	Sabah Foundation, University College Sabah Foundation, PACOS Trust, UMS
Friends of BORNEENSIS	2023	51	Students from 20 local secondary schools
Specimen Database Management Course	2024	5	ITBC staff and students
Workshop on Data Entry for the National Inventory of Biodiversity Specimen Collections	2024	8	ITBC staff
Basic Land Snail Identification Course	2024	11	Kuala Lumpur Agricultural Department, Sarawak Agricultural Department, Sabah Agricultural Department, Sabah Parks, Universiti Malaysia Sarawak
Workshop on Fish Preservation and Digitization	2025	17	K-Kaloi Foundation, Negeri Sembilan Fisheries Department, Sabah Parks, Universiti Malaysia Sabah, Sabah Fisheries Department, Borneo Marine Research Institute (UMS), Universiti Malaysia Sarawak (UNIMAS)

biodiversity, sustainability, and opportunities to collaborate with other organisations.

In addition to the visits to the gallery, BORNEENSIS provides packaged tours that include tours of the collections and additional educational activities such as the collecting and preserving of specimens (zoological and botanical), tree-identification along the on-campus UMS Hill trail (which is part of the Living Collections managed by BORNEENSIS) or other hiking activities. In the past two years, in collaboration with ITBC academic staff, BORNEENSIS has organised five workshops and short courses, most recently on species identification (fish, fungi, snails) and specimen database management, which are usually attended by staff and students from the ITBC, elsewhere in the UMS and other tertiary institutions and employees from government agencies (Table 2). On a more regular basis, every other month, BORNEENSIS sets up a mini exhibition of specimens during biodiversity- or science-related fairs and other educational events held throughout Sabah.

Resources for outreach efforts. Although the BORNEENSIS outreach activities have shown promising performance over the years, there are challenges in sustaining these initiatives. Besides the funding received for the Living Laboratory that is usually reserved for specific events, other outreach programmes rely on the limited operational budget of BORNEENSIS. Outreach activities are currently the only income-generating source for BORNEENSIS. Minimal entrance fees are collected from non-UMS visitors to the Galeri BORNEENSIS and a nominal fee is charged for participants of packaged tours and the workshops and short courses. While the total income generated was less than RM1,000 when the gallery first reopened post-pandemic and outreach events resumed, it increased ten-fold to more than RM13,000 in 2023 and has also exceeded RM10,000 for the period between January and July 2024. Close-knit collaborations with local communities, non-governmental organizations (NGOs), businesses, and international partners to augment the relevance of Galeri BORNEENSIS and its auxiliary living laboratory workstation, BORNEENSIS Living Laboratory for ESD, continue to be important in generating financial support and providing vocational exposure to the BORNEENSIS team. For instance, collaborative programmes on anurans and mushrooms carried out with Borneo Rainforest Lodge in 2023 generated in-kind and monetary funding amounting to about RM 60,000. The income generated was previously channelled into a general revenue account of the ITBC, which was then made available for any institute-level expenditure (not limited to BORNEENSIS). As of July 2024, a separate trust account was set up and any funds generated thence can be used specifically for BORNEENSIS purposes.

As mentioned at the start of this section, the units within BORNEENSIS that manage outreach activities are the 'Gallery and Exhibitions' and 'Collections and Education' units. As the collections staff in these units have other core duties, human resource constraints limit the number of outreach events that can be organised. Currently, only one member of staff is assigned to handle gallery visitors on a full-time basis, overseen by another staff member, who is primarily responsible for one of the collection rooms. Assistance from other ITBC staff and postgraduate students is usually required to run the larger-scale events. Similar to the collections advisory committee, another academic staff-led committee advises BORNEENSIS on outreach activities. It is via this advisory committee that BORNEENSIS accepts

invitations or requests from organisations that wish to collaborate with ITBC to conduct outreach activities outside the UMS campus. The ITBC provides various communication channels including the institute's social media accounts and annual newsletter, BORNEENSIS Bulletin, through which BORNEENSIS-related activities are often reported to stakeholders.

For the outreach programmes conducted to date, feedback is usually gathered from the participants using feedback forms (addressing programme objectives, content, delivery of the lecturers/coordinators, amenities, benefit to the participants). The responses received to date for almost all the programmes are generally positive, with participants commenting that they have benefited in one way or another. One of the outreach programmes under the BORNEENSIS Living Lab, the SEPLestari UMS Project, has benefitted approximately 150 Sabah youths and working adults in environmental care and green mindset growth pertaining to waste management in 2021–2024, e.g., an average of above 80% improvement of knowledge and skill adequacy, attitude change, and awareness among participants (Kueh, 2025).

RECOMMENDATIONS FOR THE FUTURE

The role of natural history collections has expanded beyond its roots as cabinets of curiosity and continues to remain relevant for interdisciplinary research and education (Bakker et al., 2020; Miller et al., 2020). For the BORNEENSIS to continue as a core pillar of the ITBC and remain relevant over time, we recommend that the following aspects be addressed: the continuity of collections care and management, promoting equitable specimen-based research, leading collections-based education and training, and strengthening outreach efforts.

Ensure continuity in collections care and management. One of the main strengths of BORNEENSIS currently is the team of staff members, who are managed by the Senior Curator, a benefit that is not enjoyed by most other institutional collections in Malaysia, and indeed globally (Miller et al., 2020). However, a number of staff within the BORNEENSIS team are approaching retirement in less than a decade and all staff are university employees with general job titles (except for the Senior Curator). Therefore, it is possible for any one of them to be transferred to a different department within the university. As mentioned in the Introduction, when the first group of Museum Assistants were recruited for BORNEENSIS in 2009, a Specimen Collection and Preservation Course for various taxa was organised as part of their training. There needs to be a clear induction and training programme that can be used for any new hires in the future. Furthermore, the policies and protocol for collections management and care must be continually kept updated by the BORNEENSIS team, with input from the advisory committee. As these policies and protocols would then go through institute- and university-level approval, the continuous processes would provide frequent opportunities to highlight the purpose and importance of the collections to decision-makers at different levels within the institution. Uncertainties do remain. For instance, the input from academic staff via the advisory committee relies on those who understand the value of, actively use, and are updated on issues regarding research collections. Furthermore, the cost of staffing and facility maintenance heavily relies on decision-making at the upper levels of the university, which creates uncertainty each time there are changes in management or budget cuts. In Sabah and in the rest of Malaysia, we know of anecdotal accounts of specimens being discarded when staff in charge retire or leave, or of collections that were rescued at the last minute from condemnation—situations that are familiar to many natural history collections globally (Donahue, 2022). Alongside carrying out the subsequent recommendations in this section, it would be necessary for academic staff and the BORNEENSIS team to regularly assess the status of the collection and create strategic plans, allowing for optimisation of limited resources and prioritisation of action. These in turn would generate information that can be used to update the management and other stakeholders for continued visibility and relevance (Huxley et al. 2021; Society for the Preservation of Natural History Collections, 2025).

Advocate for equitable specimen-based research. BORNEENSIS has another enviable opportunity of being located within a centre of biodiversity and should leverage that position to promote equitable research practices within the field of biodiversity and taxonomy. Like the rest of Borneo, the indigenous communities in Sabah have traditional knowledge and practices that utilise and conserve natural resources (Natural Resources Office & SDBEC Secretariat, 2012). For a more sustainable future, connecting with the indigenous community is the right way to collect more valuable data (Copote et al., 2023). Ongoing research done by ITBC staff utilise qualitative research methods such as interviews with local indigenous communities, particularly in ethnobotanical research (e.g., Kulip et al., 2010; Foo et al., 2018), which allow researchers to learn about traditional use of local flora and fauna. Although existing policies require all material to have been obtained legally, including complying with the Sabah Biodiversity Enactment, which includes prior informed consent to be obtained from communities, current BORNEENSIS databases and data management practices do not yet explicitly include indigenous knowledge, nor do clear internal guidelines yet exist for recording such knowledge. As we work towards crafting and implementing forward-looking policies for BORNEENSIS, it would be important to incorporate appropriate protocols to be followed and to ensure that the collections data goes beyond following the FAIR principles, to also incorporate CARE principles (Jennings et al., 2023).

BORNEENSIS has benefitted from international partnerships to varying degrees, most apparent in the contributions of the early collaborations in the provision of collections facilities and training in collections management best practices. As the discussions on the best practices of building meaningful collaborations and promoting equitable sharing of data and intellectual exchange continue to be raised in the scientific community (Ramírez-Castañeda et al., 2022; Rayadin &

Buřivalová, 2022), it appears unavoidable that the community at large will continue to move away from colonial mindsets of conducting science (Cisneros et al., 2022). Given the recency of state and national legislations linked to the Nagoya Protocol (Ministry of Natural Resources and Environmental Sustainability, 2021; Sabah Biodiversity Centre, 2024), despite earlier concerns voiced elsewhere regarding possible hindrances to biodiversity research (e.g., Grajal, 1999), it remains to be investigated if science has been stifled or if more formalised collaboration between local and international partners have been encouraged. As locals in a biodiverse region, we are in favour of forming working relationships that would allow our researchers and students to contribute intellectual labour and to develop their scientific expertise alongside international colleagues, e.g., being involved in writing the proposals for specific aspects of the project and in the decision-making for fieldwork. Ultimately, we are in support of science that is conducted legally and ethically.

Besides leveraging the sea of change in attitudes towards equitable collaborations for increasing the level of research conducted at the ITBC, it would be imperative that BORNEENSIS is equipped to build on the facilities set up and expertise gained from the early partnerships to establish a reputation as a trusted repository of material, including type specimens, especially for species described from Sabah. A conscious effort to build meaningful partnerships, which has ensured the majority of types of new species described being deposited locally can be seen in the example of terrestrial mollusc research conducted over the past two decades, in which the types of all 99 new species described from Sabah since 2007 are deposited within Malaysian Borneo, with the holotypes of 95 species and paratypes of four species being deposited in BORNEENSIS (Vermeulen & Liew, 2022). Current terms for permits to export biological material, which are issued together with Access Licenses by the Sabah Biodiversity Council, require all material to be returned to local collaborators.

Digitisation of BORNEENSIS collection data will also increase data availability to relevant stakeholders, alongside expanding the use of the collection (Miller et al., 2020; Huxley et al., 2021). Figure 5 shows the future direction of BORNEENSIS, with "Digitisation 1.0" still taking centre stage in the near future. According to Hedrick et al. (2020), Digitisation 1.0 is the creation and online mobilisation of digital content that originates from physical specimens. "Digitisation 2.0", on the other hand, builds on the digitised data, workflows and infrastructure created by Digitisation 1.0 to enable improved digitisation, curation and data connectivity to answer increasingly complex questions on a global scale. For example, Ong et al. (2023) listed the guidelines for the digitisation of physical samples in digitised form, although many improvements are still possible. At the same time, Digitisation 2.0 is being carried out using digitised data, such as the use of BORNEENSIS specimens to develop an automated system for classifying insects by taxonomic level (Ong & Hamid, 2022), annotation of some medically important flies for training machine learning (Ong & Ahmad, 2022), and development of an automated system to classify mosquitoes collected in Sabah (Ong et al., 2024). Furthermore, the digitised collection data can also be used to answer more challenging global questions, such as the impact of climate change on Borneo's species, food security, management of invasive species, and more (Fig. 5), feeding into global efforts such as the proposed digital extended specimen network (Hardisty et al., 2022). Ultimately, BORNEENSIS will continue to move forward in its digitisation efforts. It is imperative to recognise the transformative potential of digitised data. By utilising this resource to address critical environmental and socio-economic challenges, stakeholders in Borneo can make informed decisions for the conservation and sustainable management of their natural heritage.

Promote collections-focused education and training. As part of a tertiary institution, the ITBC, with its established collections facilities and expertise, is ideally placed to take the lead in expanding on the use of BORNEENSIS for education and training, particularly in producing the next generation of taxonomists and para-taxonomists in Malaysia. Recent training workshops and courses (see Table 2) have seen participants from a range of institutions including non-governmental organisations, other tertiary institutions and government bodies, including those beyond Sabah. The BORNEENSIS protocol for collections data management has also been adopted as national-level guidelines (Liew et al., 2024), demonstrating the ability for BORNEENSIS to further lead the community in efforts to promote education and training in collections management and care. Furthermore, the digitisation efforts mentioned in the previous section can also contribute to making specimen-based education more accessible to a wider student base (Sidlauskas et al., 2021), beyond students who are able to attend classes in person at the UMS. A concerted effort to develop educational programmes for specimen-based education and student-led research would ensure full integration of the collections into achieving the goals of the university (Hammerness et al., 2016; Hiller et al., 2017; Price et al., 2020).

Strengthen outreach efforts. It is imperative that the continuity and enhancement of the BORNEENSIS outreach programmes, based on its collection materials, be strengthened to encourage a collective belief among stakeholders in assuming responsibility for a sustainable future for Sabah's (and Borneo's) biodiversity. It might be useful to conduct a more formal analysis of the scope and impact of all outreach programmes to date, and to better align them to utilise and increase understanding of the collection. Additional marketing strategies should be implemented to increase public visibility on Galeri BORNEENSIS, including the possibility of collaboration with tour operators. The push to digitise the collections will also have the potential to extend outreach activities to a wider audience without necessitating one's physical presence in the gallery to view specimens (Butcher et al., 2021), which would be especially important in the context of Sabah, which faces challenges in ensuring equal access to education among the rural communities (Tan et al., 2016).

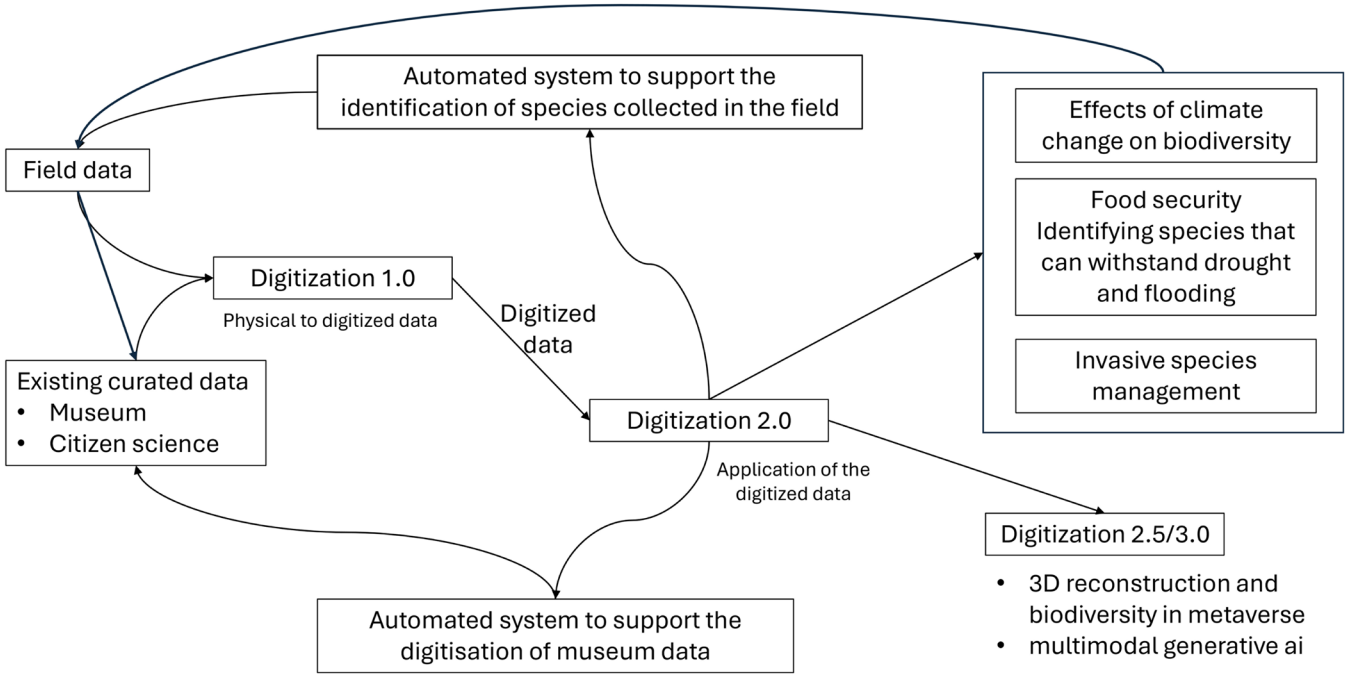

Fig. 5. The direction and potential applications of digitisation efforts of the BORNEENSIS Collection, Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah.

Outreach programmes have an important role to combat common misconceptions about collections, e.g., that collections are just dusty shelves of skeletons or old jars of pickled specimens, or that specimens in the gallery are merely for display purposes, and to advocate for the importance of natural history collections for humanity. The use of technology to enhance outreach initiatives can allow for a firmer connection to be made between the public-facing gallery and the back-of-house collections, which can incorporate artificial intelligence tools, or simply QR codes linking specimens on display to customised websites or published research (Carnall et al., 2013). Proper planning and structured activities, e.g., providing proper training to facilitators (Gupta et al., 2024) and establishing citizen science programmes (Ballard et al., 2017), alongside leveraging available technology, would allow the role of BORNEENSIS in society to be effectively conveyed to stakeholders. A taskforce could also be established to advocate for the importance of collections and represent BORNEENSIS in outreach events in not just in Sabah, but also throughout Malaysia and beyond.

Learn from others. While BORNEENSIS has come a long way since its inception, there are still many challenges ahead that are also plaguing other natural history collections around the world. On the other hand, there are numerous opportunities to learn from success cases from our counterparts elsewhere. A major challenge is funding for the continued maintenance of the collection in the face of inflation. One of the possible ways to overcome this is to look into the arrangement of long-term financial support through an endowment for BORNEENSIS through generous donors or patrons, e.g., the Lee Kong Chian Natural History Museum (LKCNHM) in Singapore was established through, and continues to be supported by, philanthropic donations (National University of Singapore, 2015; 2025).

Next, there is a lack of expertise for certain taxa, such as birds and many other invertebrate groups, that may cause potentially new species to be left undescribed in the shelves of the collection for years or even decades. As mentioned above, one of the ways to overcome this will be through the training of para-taxonomists or liaising with experts from other institutions such as Sabah Parks, Sabah Forestry Department, and international collaborators, who can aid with the identification and cataloguing of the collection. Such efforts would contribute towards the goal of more meaningful collaborations, in which external collaborators would be able to contribute their expertise towards local capacity-building.

In this aspect, the importance of networking to ensure the continued relevance of BORNEENSIS cannot be overemphasised (Donahue, 2022). It was through the strong networks that BORNEENSIS forged during the initial years with Danish universities and Japanese institutions when the collection first formed that it managed to build the infrastructure and collection to where it is today. Biodiversity research in Borneo has largely kept to colonial-era, and now national and state-level, boundaries, with the most prominent researchers—along with specimens collected— often being based abroad or in other national institutions outside of Borneo. Owing to where most type material are deposited and depending on the geographical scope of our taxa, it would be important to continue collaborating with various counterparts globally. However, with shrinking funding sources, opportunities with international partners would be highly dependent on personal connections and remain limited

in scope (selected taxa, small focal areas) and scale (projects with limited time periods, within individual career lifespans).

To expand the scope, increase the longevity, and maximise benefits of collaboration at the institutional level, BORNEENSIS should continue to seek wider research collaboration through research agreements and memoranda of understanding (MOU), and also conduct regular symposia to exchange ideas about our research and collections management by cooperating on a more 'local' level—with the natural history collections within Borneo, and elsewhere in Peninsular Malaysia and Southeast Asia, especially with those that hold historical reference material from Borneo (e.g., Chasen & Kloss, 1930; Kloss, 1931; Ng & Stuebing, 1989; Abdul Majid, 2000; Thiers, 2024). Efforts such as the Argentine Herbaria Network could serve as a model to be emulated (Yañez et al., 2025). In the absence of state- or national-level coordinating agencies that could support these efforts, it would be important for BORNEENSIS to maintain engagement with relevant government bodies and involve them in the research programmes and symposia. The recommendation in the previous section for a taskforce to advocate for the importance of collections could also be expanded to a larger group consisting of different Bornean and regional collections. It is important that it continues to maintain old collaborations (historically, mostly within Sabah and internationally), and form new ones for the future, particularly with leveraging national and ASEAN-level networks to collaborate more closely with Malaysian and other Southeast Asian counterparts in universities and natural history museums.

CONCLUSIONS

The BORNEENSIS, as an important natural history collection in Borneo, is an integral part of Malaysia's natural heritage that needs to be preserved and safeguarded. The services provided by the collection go beyond aiding research in systematics and biodiversity, and extends to education and outreach. Over the decades, the collection has evolved to stay relevant with measures including digitising of the collection, investing into expanding the public gallery to cater to more visitors, and conducting programs in line with sustainable development goals. Nevertheless, there are still challenges ahead that will require dedication from all stakeholders to allow BORNEENSIS to achieve the goal of making biodiversity material and data more accessible.

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LITERATURE CITED

Abdul Kadir K (2002) DANCED Corner. ITBC Newsletter, 1/2002: 5.

Abdul Majid HMB (2000) The Herbarium and Botanic Garden of University of Malaya. In: Matsuura K (ed.) Proceedings of the First and Second Symposia on Collection Building and Natural History Studies in Asia. National Science Museum Monographs, No. 18, Tokyo, pp. 69–75.

Akiyama H, Rimi R & Suleiman M (2021) Re-examination of the *Symphyodon perrottetii* (Symphyodontaceae) and related species in East and Southeast Asia. Hattoria, 12: 51–92.

Akiyama H & Suleiman M (2015) A new species, *Bryobrothera tambuyukonensis* (Daltoniaceae, Bryopsida), from Sabah, Borneo Island. Phytotaxa, 192(1): 13–23.

Akiyama H & Suleiman M (2015) A new species, *Bryobrothera tambuyukonensis* (Daltoniaceae, Bryopsida), from Sabah, Borneo Island. Phytotaxa, 192(1): 13–23.

Anthony F, Majuakim L & Gunsalam G (2025) Guide to the Ferns of Mount Alab. Universiti Malaysia Sabah Press, Kota Kinabalu, 125 pp.

Arumugam N, Appalasamy S, Mohamed Hassim AD & Rahman H (2020) Termite fauna of Sungai Kangkawat, Imbak Canyon Conservation Area (ICCA), Sabah. Journal of Tropical Biology & Conservation, 17: 19–26.

Bakhtiar EY & Chiang SL (2011) *Leptogenys* ants (Hymenoptera: Formicidae: Ponerinae) of Sabah. Serangga, 15: 37–54.

Bakker FT, Antonelli A, Clarke JA, Cook JA, Edwards SV, Ericson PGP, Faurby S, Ferrand N, Gelang M, Gillespie RG, Irestedt M, Lundin K, Larsson E, Matos-Maraví P, Müller J, von Proschwitz T, Roderick GK, Schliep A, Wahlberg N, Wiedenhoeft J & Källersjö M (2020) The Global Museum: natural history collections and the future of evolutionary science and public education. PeerJ, 8: e8225.

Ballard HL, Robinson LD, Young An, Pauly GB, Higgins LM, Johnson RF & Tweddle JC (2017) Contributions to conservation outcomes by natural history museum-led citizen science: examining evidence and next steps. Biological Conservation, 208: 87–97.

Bansa LA, Rosli QS, Daud US, Amat A, Morni MA, Dee JW, Jinggong ER, Rajasegaran P, Senawi J, Kumaran JV, Azhar I, Mahyudin A, Hasan NH & Khan FAA (2020) Survey on the small mammals in Sg. Kangkawat Research Station Imbak Canyon Conservation Areas. Journal of Tropical Biology & Conservation, 17: 149–163.

Brühl CA, Mohamed M & Linsenmair KE (1998) Altitudinal distribution of leaf litter ants along a transect in primary forests on Mount Kinabalu, Sabah, Malaysia. Journal of Tropical Ecology, 15(3): 265–277.

Butcher KR, Power MJ, Larson M, Orr MP, Velásquez-Franco S, Hudson MA & Bailey VJ (2021) Museum leadership for engaging, equitable education: the transformative potential of digitized collections for authentic learning experiences. Curator: The Museum Journal, 64(2): 383–402.

Burbidge FW (1880) The Gardens of the Sun. J. Murray, London, 364 pp.

Carnall M, Ashby J & Ross C (2013) Natural history museums as provocateurs for dialogue and debate. Museum Management and Curatorship, 28(1): 55–71.

Chasen FN & Kloss CB (1930) On a collection of birds from the lowlands and islands of North Borneo. Bulletin of the Raffles Museum, 4: 1–112.

Chang ZY, Phung CC, Goundilang E & Liew TS (2019) Land and freshwater snails of Imbak Canyon Conservation Area (ICCA), Sabah, Northern Borneo. Journal of Tropical Biology and Conservation, 16: 35–39.

Chung AYC & Chey VK (2000) The importance of the forest insect collection in Sabah. In: Yaacob Z, Moo-Tan S & Yorath S (eds.) Proceedings of the International Conference on In-situ and Ex-situ Biodiversity Conservation in the New Millennium. Sabah Museum, Kota Kinabalu, pp. 179–183.

Cisneros JC, Raja Nussaïbah B, Ghilardi AM, Dunne EM, Pinheiro FL, Regalado FOR, Sales MAF, Rodríguez-de la Rosa RA, Miranda-Martínez AY, González-Mora S, Bantim RAM, de Lima FJ & Pardo JD (2022) Digging deeper into colonial palaeontological practices in modern day Mexico and Brazil. Royal Society of Open Science, 9: 210898.

Copote JC, Kik A, Novotny V & Cámara-Leret R (2023) The importance of indigenous and local people for cataloging biodiversity. Trends in Ecology & Evolution, 38(12): 1112–1114.

Cranbrook EO & Leh C (1983) A history of zoology in Sarawak. Sarawak Museum Journal, 53: 15–34.

Das I & Austin CC (2007) New species of *Lipinia* (Squamata: Scincidae) from Borneo, revealed by molecular and morphological data. Journal of Herpetology, 41(1): 61–71.

Das I & Haas A (2003) A new species of *Kalophrynus* (Anura: Microhylidae) from the highlands of north-central Borneo. The Raffles Bulletin of Zoology, 51(1): 109–113.

de Bruyn M, Stelbrink B, Morley RJ, Hall R, Carvalho GR, Cannon CH, van den Bergh G, Meijaard E, Metcalfe I, Boitani L, Maiorano L, Shoup R & von Rintelen T (2014) Borneo and Indochina are major evolutionary hotspots for Southeast Asian biodiversity. Systematic Biology, 63(6): 879–901.

Dehling JM, Matsui M & Imbun PY (2016) A new small montane species of *Philautus* (Amphibia: Anura: Rhacophoridae) from Gunung Kinabalu, Sabah, Malaysia (Borneo). Salamandra, 52: 77–90.

Donahue MZ (2022) Addressing the uncertain fate of a lifetime's work. BioScience, 72(8): 718–724.

Ebrahim MI & Dawood MM (2018) Mosquito diversity between logged and unlogged forest areas in Kalabakan Forest Reserve, Sabah. Journal of Tropical Biology & Conservation, 15: 81–95.

Eggleton P, Homathevi R, Jones DT, MacDonald JA, Jeeva D, Bignell DE, Davies RG & Maryati M (1999) Termite assemblages, forest disturbance and greenhouse gas fluxes in Sabah, East Malaysia. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 354(1391): 1791–1802.

Ellis LT, Aleffi M, Bakalin VA, Bednarek-Ochyra H, Bergamini A, Beveridge P, Choi SS, Fedosov VE, Gabriel R, Gallego MT, Grdovic´ S, Gupta R, Nath V, Asthana AK, Jennings L, Kürschner H, Lebouvier M, Nair MC, Manjula KM, Rajesh KP, Nobis M, Nowak A, Park SJ, Sun B-Y, Plášek V, Číhal L, Poponessi S, Mariotti MG, Sabovljević A, Sabovljević MS, Sawicki J, Schnyder N, Schumacker R, Sim-Sim M, Singh DK, Singh D, Majumdar S, Singh Deo S, Stefănut S, Suleiman M**,** Chua MS, Váňa J, Venanzoni R, Bricchi E & Wigginton MJ (2015) New national and regional bryophytes records, 42. Journal of Bryology, 37(1): 68–85.

Eto K, Matsui M & Nishikawa K (2015) Description of a new species of the genus *Leptobrachella* (Amphibia, Anura, Megophryidae) from Borneo. Current Herpetology, 34(2): 128–139.

Foo SF, Saikim FH, Kulip J & Seelan JSS (2018) Distribution and ethnomycological knowledge of wild edible mushrooms in Sabah (Northern Borneo), Malaysia. Journal of Tropical Biology & Conservation, 15: 203–222.

Foon JK, Clements GR & Liew T-S (2017) Diversity and biogeography of land snails (Mollusca, Gastropoda) in the limestone hills of Perak, Peninsular Malaysia. ZooKeys, 682: 1–94.

Foon JK & Liew T-S (2017) A review of the land snail genus *Alycaeus* (Gastropoda, Alycaeidae) in Peninsular Malaysia. ZooKeys, 692: 1–81.

Furuki T & Suleiman M (2016) *Diplophylllum kinabaluense* (Scapaniaceae, Marchantiophyta), sp. nov. from Mt. Kinabalu, Malaysian Borneo. Journal of Japanese Botany, 91: 340–344.

Grajal A (1999) Biodiversity and the nation state: regulating access to genetic resources limits biodiversity research in developing countries. Conservation Biology, 13(1): 6–10.

Gupta P, Perez A, Martinez N, Knutson K, Crowley K & Chaffee R (2024) From "let me show you something cool" to "what do you notice?" Preparing college interns for floor facilitation in a natural history museum. Journal of Museum Education, 49: 398–408.

Haas A, Kueh BH, Joseph A, Asri Mb, Das I, Hagmann R, Schwander L & Hertwig ST (2018) An updated checklist of the amphibian diversity of Maliau Basin Conservation Area, Sabah, Malaysia. Evolutionary Systematics, 2: 89–114.

Ham SH (1992) Environmental Interpretation: A Practical Guide for People with Big Ideas and Small Budgets. Fulcrum Publishing, Golden, Colorado, USA, 456 pp.

Hammerness K, Macpherson A & Gupta P (2016) Developing a research agenda aimed at understanding the teaching and learning of science at a natural history museum. Curator: The Museum Journal, 59(4): 353–367.

Hardisty AR, Ellwood ER, Nelson G, Zimkus B, Buschbom J, Addink W, Rabeler RK, Bates J, Bentley A, Fortes JAB, Hansen S, Macklin JA, Mast AR, Miller JT, Monfils AK, Paul DL, Wallis E & Webster M (2022) Digital Extended Specimens: enabling an extensible network of biodiversity data records as integrated digital objects on the internet. BioScience, 72(10): 978–987.

Hashimoto Y & Rahman H (eds.) (2003) Inventory and Collection: Total Protocol for Understanding of Biodiversity. Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, and Japan International Cooperation Agency (JICA), Kota Kinabalu, 310 pp.

Hashimoto Y, Morimoto Y, Widodo ES & Mohamed M (2006a) Vertical distribution pattern of ants in a Bornean tropical rainforest (Hymenoptera: Formicidae). Sociobiology, 47 (3): 697–710.

Hashimoto Y, Rahman H & Mohamed M (eds.) (2006b) Inventory & Collection: Total Protocol for Understanding of Biodiversity, 2nd Edition. Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, and Japan International Cooperation Agency (JICA), Kota Kinabalu, 231 pp.

Hedrick BP, Heberling JM, Meineke EK, Turner KG, Grassa CJ, Park DS, Kennedy J, Clarke JA, Cook JA, Blackburn DC, Edwards SV & Davis CC (2020) Digitization and the future of natural history collections. BioScience, 70(3): 243–251.

Hiller AE, Cicero C, Albe MJ, Barclay TLW, Spencer CL, Koo MS, Bowie RCK & Lacey EA (2017) Mutualism in museums: A model for engaging undergraduates in biodiversity science. PLoS Biology, 15(11): e2003318.

Hoe ST, Padam BS, Vairappan CS, Abdullah MI & Fook YC (2015) Effect of preparation and extraction parameters of banana (*Musa balbisiana* cv. Saba) inflorescence on their antibacterial activities. Sains Malaysiana, 44: 1301–1307.

Huxley R, Quaisser C, Butler CR & Dekker RWRJ (2021) Managing Natural Science Collections: A Guide to Strategy, Planning and Resourcing. Routledge, Oxon, 231 pp.

Ibrahim YK, Tshen LT, Westaway KE, Cranbrook E, Humphrey L, Muhammad RF, Zhao J-x & Peng LC (2013) First discovery of Pleistocene orangutan (*Pongo* sp.) fossils in Peninsular Malaysia: Biogeographic and paleoenvironmental implications. Journal of Human Evolution, 65(6): 770–797.

Ishii T, Ueoka R, Matsunaga S & Vairappan CS (2010) Bioactive secondary metabolites from the Borneon soft corals of the genus *Nephthea*. Malaysian Journal of Science, 29(3): 262–268.

Jennings L, Anderson T, Martinez A, Sterling R, Chavez DD, Garba I, Hudson M, Garrison NA & Carroll SR (2023) Applying the 'CARE Principles for Indigenous Data Governance' to ecology and biodiversity research. Nature Ecology & Evolution, 7(10): 1547–1551.

JICA (2008) Programme Completion Report on Phase 1, Bornean Biodiversity and Ecosystem Conservation Programme in Sabah, Malaysia, February 2002–2008. Secretariat of BBEC, Kota Kinabalu, 320 pp.

Julius A, Suleiman M & Takano A (2007) Five new species of *Plagiostachys* (Zingiberaceae) from Borneo. Acta Phytotaxonomica et Geobotanica, 58(1): 1–17.

Julius A, Takano A, Suleiman M & Tukin WF (2010) Zingiberaceae of Maliau Basin, Sabah, Malaysia. Journal of Tropical Biology & Conservation, 6: 1–20.

Katagiri T, Suleiman M & Deguchi H (2012) Taxonomic studies of the Trichocoleaceae in Southeast Asia II. A new species of *Eotrichocolea* from Malaysia. The Bryologist, 115(4): 518–522.

Kloss CB (1931) Mount Kinabalu: a note. Bulletin of the Raffles Museum, 5: 1–2.

Kohout RJ & Mohamed M (2009) A preliminary list of the *Polyrhachis* ants of the Maliau Basin Conservation Area in Sabah, Borneo (Hymenoptera: Formicidae: Formicinae). Asian Myrmecology, 2: 63–70.

Kulip J, Lam NF, Manshoor N, Julius A, Said IM, Gisil J, Joseph JA & Tukin WF (2010) Medicinal Plants in Maliau Basin, Sabah, Malaysia. Journal of Tropical Biology and Conservation, 6*:* 21–33.

Kueh BH (2025) Diagnostic and prognostic sustainability action empowers local people in Sabah for resilient environmental care and green mindset growth. In: Mohd. Tahir H-A (ed.) Grounded Solutions: Community Resilience and Environmental Action in Malaysia. Society for the Promotion of Sustainable Development Goals, Petaling Jaya, pp. 438–451.

Kueh BH & Mohamed M (2007) Education for Sustainable Development (ESD) for environmental and biodiversity conservation: The case of 'ITBC Frog Museum'. In: Proceedings of the Environmental Education Towards A Sustainable Future – Partners for The Decade of Education for Sustainable Development: '4th International Conference on Environmental Education'. Centre for Environment Education, Ahmedabad, India, 12 pp.

Kueh BH, Nakada M, Hashimoto Y & Mohamed M (2006) MUSEBASE: Collection data management system for comprehensive and sustainable conservation of biodiversity and ecosystems. Research and Education Component, Bornean Biodiversity and Ecosystems Conservation (BBEC) Programme in Sabah, Malaysia, Kota Kinabalu, Malaysia, 62 pp.

Kueh BH, Saikim F-H & Miard P (2023) Sustainable and resilient tourism beyond frontiers: The Malaysian Borneo essence. In: Saikim F-H, Kueh BH & Miard P (eds.) A Handbook on Sustainable and Resilient Tourism Beyond Frontiers: The Malaysian Borneo Essence. Institute for Tropical Biology and Conservation, Kota Kinabalu, pp. 3–8.

Lam NF, Ibrahim H, Sam YY, Mohammad Zakaria R, Poulsen AD (2022) Two new species of *Boesenbergia* (Zingiberaceae), from Sabah, Malaysia. PhytoKeys, 211: 81–92.

Larsen K (2000) Botanical collections in the Malesian Region—what has been found, where is it and where to collect in the future. In: Yaacob Z, Moo-Tan S & Yorath S (eds.) Proceedings of the International Conference on In-situ and Ex-situ Biodiversity Conservation in the New Millennium. Sabah Museum, Kota Kinabalu, pp. 145–152.

Liew TS & Clements GR (2020) *Whittenia*, a new genus of land snails from Perak, Peninsular Malaysia (Gastropoda: Diplommatinidae). Raffles Bulletin of Zoology, Supplement, 35: 143–148.

Liew TS, Clements R & Schilthuizen M (2008) Sampling micromolluscs in tropical forests: one size does not fit all. Zoosymposia, 1: 271–280.

Liew T, Kok ACM, Schilthuizen M & Urdy S (2014a) On growth and form of irregular coiled-shell of a terrestrial snail: *Plectostoma concinnum* (Fulton, 1901) (Mollusca: Caenogastropoda: Diplommatinidae) PeerJ, 2: e383.

Liew TS, Marzuki ME, Schilthuizen M, Chen Y, Vermeulen JJ & Mohd-Azlan J (2020) Molecular phylogenetics and evolutionary history of the endemic land snail genus *Everettia* in northern Borneo. PeerJ, 8: e9416.

Liew TS, Ong SQ, Phon CK, Mat Jalaluddin NS, Azhar S & Sh Zulrushdi SMAS (2024) The Guidelines for FAIR Biodiversity Data Stewardship. Academy of Sciences Malaysia, Kuala Lumpur, 92 pp.

Liew TS, Schilthuizen M & bin Lakim M (2010) The determinants of land snail diversity along a tropical elevational gradient: insularity, geometry and niches. Journal of Biogeography, 37(6): 1071–1078.

Liew TS, Schilthuizen M & Vermeulen JJ (2009) Systematic revision of the genus *Everettia* Godwin-Austen, 1891 (Mollusca: Gastropoda: Dyakiidae) in Sabah, northern Borneo. Zoological Journal of the Linnean Society, 157(3): 515–550.

Liew T-S, Vermeulen JJ, bin Marzuki ME & Schilthuizen M (2014b) A cybertaxonomic revision of the microlandsnail genus *Plectostoma* Adam (Mollusca, Caenogastropoda, Diplommatinidae), from Peninsular Malaysia, Sumatra and Indochina. ZooKeys, 393: 1–107.

Lo A (2017) The natural history collection of the Sabah Museum. Sabah Museum Journal, 2: 53–60.

Lok YC, Siau VG, Mohd Kanapiah NAA, Lai TC, Haslan NNHH, Nukili NN, Daud US, Amat A, Gompoyo J, Tuh YYF & Hasan NH (2021) Bat species diversity trend along an elevation gradient: A study in Crocker Range Park, Sabah, Borneo. Biodiversity Data Journal, 9: e72651.

Macaskie CF (1961) North Borneo museums of the past. The Sarawak Museum Journal, 10 (17–18): 118–119.

Maitland G (1998) Sarawak Museum, the museum of Borneo. The Sarawak Museum Journal, 53(74, new series): 95–107.

Majuakim L & Anthony F (2016) Diversity and ecology of ferns on Mount Alab, Crocker Range Park, Sabah, Malaysia. Malayan Nature Journal, 68(1–2): 167–176.

Majuakim L, Ng SY, Abu Bakar MF & Suleiman M (2014) Effect of altitude on total phenolics and flavonoids in *Sphagnum junghuhnianum* in tropical montane forests of Borneo. Sepilok Bulletin, 19 & 20: 23–32.

Matsui M, Eto K, Nishikawa K, Hamidy A, Belabut D, Ahmad N, Panha S, Khonsue W & Grismer LL (2017) Mitochondrial phylogeny of *Leptolalax* from Malay Peninsula and *Leptobrachella* (Anura, Megophryidae). Current Herpetology, 36(1): 11–21.

Matsui M, Mohamed M, Shimada T & Sudin A (2007) Resurrection of *Staurois parvus* from *S. tuberilinguis* from Borneo (Amphibia, Ranidae). Zoological Science, 24(1): 101–106.

Matsui M, Nishikawa K, Eto K & Hossman MY (2020) Two New *Ansonia* from Mountains of Borneo (Anura, Bufonidae). Zoological Science, 37(1): 91–101.

Matsui M, Nishikawa K & Yambun P (2014a) A new *Leptolalax* from the mountains of Sabah, Borneo (Amphibia, Anura, Megophryidae). Zootaxa, 3753(3): 440–452.

Matsui M, Shimada T & Sudin A (2010) A new species of *Meristogenys* (Amphibia, Anura, Ranidae) from Sabah, Borneo. Zoological Science, 27(1): 61–66.

Matsui M, Shimada T & Sudin A (2013) A new gliding frog of the genus *Rhacophorus* from Borneo. Current Herpetology, 32(2): 112–124.

Matsui M, Shimada T & Sudin A (2014b) First record of the tree-frog genus *Chiromantis* from Borneo with the description of a new species (Amphibia: Rhacophoridae). Zoological Science, 31(1): 45–51.17

Mh Subari IAA, Tan YS & Seelan JSS (2023) New record of edible chicken of the wood mushroom, *Laetiporus versisporus* (Lloyd) Imazeki (Fomitopsidaceae, Polyporales) from Sabah (Northern Borneo), Malaysia. Borneo Journal of Resource Science and Technology, 13(2): 92–102.

Miller SE, Barrow LN, Ehlman SM, Goodheart JA, Greiman SE, Lutz HL, Misiewicz TM, Smith SM, Tan M, Thawley CJ, Cook JA & Light JE (2020) Building natural history collections for the twenty-first century and beyond. BioScience, 70(8): 674–687.

Ministry of Higher Education (2024) Universiti Malaysia Sabah. Ministry of Higher Education, Putrajaya. https://online.mohe.gov.my/epanduan/maklumatAgensi/UH (Accessed 31 July 2024).

Ministry of Natural Resources and Environmental Sustainability (2021) Access and Benefit-sharing Clearing-house. https://myabs.gov.my/login. (Accessed 28 July 2025).

Mohamed M (1999) Research flashes. ITBC Newsletter, 1/1999: 13.

Mohamed M (2000) From the Editor. ITBC Newsletter, 1/2000: 4.

Mohamed M, Andau M, Dalimin MN & Malim TP (eds.) (1999) Tabin Scientific Expedition. Universiti Malaysia Sabah, Kota Kinabalu, 168 pp.

Mohamed M & Kusano T (eds.) (2002) A Guide Book of Bornean Biodiversity and Ecosystems Conservation (BBEC) Programme in Sabah: Proceedings of the Official Launching Ceremony and Seminar, 25–26 March, 2000 at Universiti Malaysia Sabah, Kota Kinabalu, Sabah with the Cooperation Framework and Programme Documents. BBEC Secretariat, Kota Kinabalu, 189 pp.

Mohamed M, Schilthuizen M & Andau M (eds.) (2003) Tabin Limestone Scientific Expedition 2000. Universiti Malaysia Sabah, Kota Kinabalu, 180 pp.

Mohamed M, Sinun W, Anton A, Dalimin MN & Ahmad AH (eds.) (1998) Maliau Basin Scientific Expedition. Universiti Malaysia Sabah, Kota Kinabalu, 173 pp.

Mohamed M, Yusoff M & Unchi S (eds.) (2000) Klias-Binsulok Scientific Expedition. Universiti Malaysia Sabah, Kota Kinabalu, 107 pp.

Mohamad Sheriff N & Abdullah N (2017) Research universities in Malaysia: what beholds? Asian Journal of University Education, 3(2): 35–50.

Museum Zoologicum Bogoriense (2018) Museum Zoologicum Bogoriense: Bogor Zoological Museum. Indonesian Institute of Sciences (LIPI), Bogor, 16 pp.

Mustapeng MAM & Suleiman M (2020) New and noteworthy Hypnales (Bryophyta) records from the Nuluhon Trusmadi Forest Reserve in Borneo. Check List, 16(6): 1663–1671.

MyBIS (2024) Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Kota Kinabalu, Malaysia. https://www.mybis.gov.my/specimen/specimen.php (Accessed 17 September 2024).

National University of Singapore (2025) Lee Kong Chian Natural History Museum Endowment Fund. https://give.nus.edu.sg/LKCNHM-EF (Accessed 10 July 2025).

National University of Singapore (2015) Natural History Museum opens thanks to private gifts. https://www.science.nus.edu.sg/blog/2015/04/natural-history-museum-opens-thanks-to-private-gifts/ (Accessed 10 July 2025).

Natural Resources Office & SDBEC Secretariat (2012) The Sabah Biodiversity Strategy 2012–2022. Natural Resources Office, Kota Kinabalu, 200 pp.

Ng PKL & Stuebing R (1989) *Thelphusa dicerophilus* sp. nov., a new species of freshwater crab (Crustacea: Decapoda: Brachyura: Gecarcinucidae) found in mud wallows of the Sumatran rhinoceros from Sabah, Borneo. Indo-Malayan Zoology, 6: 45–51.

Ng SH, Rahman H & Chua TH (2016) Mosquitoes of Kudat: species composition and their medical importance (Diptera: Culicidae). Serangga, 21(2): 149–62.

Ng TH, Dulipat J, Foon JK, Lopes-Lima M, Zieritz A & Liew T-S (2017) A preliminary checklist of the freshwater snails of Sabah (Malaysian Borneo) deposited in the BORNEENSIS collection, Universiti Malaysia Sabah. ZooKeys, 673: 105–123.

Ng TH, Srisonchai R, Golovatch SI, Sutcharit C, Panha S, Latim M & Likhitrakarn N (2025) A taxonomic study of millipede genera, *Orangutana* Golovatch, 1996 and *Gigantomorpha* Jeekel, 1963 (Diplopoda, Polydesmida, Paradoxosomatidae), with description of four new species from Sabah, Borneo, East Malaysia. European Journal of Taxonomy, 987(1): 221–248.

Nishikawa K, Matsui M & Yambun P (2012) A new unstriped *Ichthyophis* (Amphibia: Gymnophiona: Ichthyophiidae) from Mt. Kinabalu, Sabah, Malaysia. Current Herpetology, 31(2): 67–77.

Norman EL & Mustaffa N (2019) Diversity of praying mantises (Insecta Mantodea) in Bukit Piton Forest Reserve, Lahad Datu, Sabah. Journal of Tropical Biology and Conservation, 16: 185–196.

Ong SQ, Ab Majid AH, Li WJ & Wang JG (2024) Application of computer vision and deep learning models to automatically classify medically important mosquitoes in North Borneo, Malaysia. Bulletin of Entomological Research, 114(2): 302–307.

Ong SQ & Ahmad H (2022) An annotated image dataset of medically and forensically important flies for deep learning model training. Scientific Data, 9(1): 510.

Ong SQ & Hamid SA (2022) Next generation insect taxonomic classification by comparing different deep learning algorithms. PloS One, 17(12): e0279094.

Ong SQ, Mat Jalaluddin NS, Yong KT, Ong SP, Lim KF & Azhar S (2023) Digitization of natural history collections: A guideline and nationwide capacity building workshop in Malaysia. Ecology and Evolution, 13(6): e10212.

Pfeiffer M, Mezger D, Hosoishi S, Yahya BE & Kohout RJ (2011) The Formicidae of Borneo (Insecta: Hymenoptera): a preliminary species list. Asian Myrmecology, 4: 9–58.

Phan CS & Vairappan CS (2015) Isopropyl (ene)-type cembrane diterpene an important chemotaxonomical marker in Bornean soft coral Genus *Sarcophyton*. Journal of Tropical Biology & Conservation, 12: 137–143.

Phung C, Choo M & Liew T (2022) Sexual dimorphism in shell size of the land snail *Leptopoma perlucidum* (Caenogastropoda: Cyclophoridae). PeerJ, 10: e13501.

Polgar G, Grafe TU, Pang HYK, Brahim A, Cicuzza D & Silk JWF (2018) The Universiti Brunei Darussalam biological collections: history, present assets, and future development. Raffles Bulletin of Zoology, 66: 320–336.

Price SA, Larouche O., Friedman ST, Corn KA, Wainwright PC & Martinez CM (2020) A CURE for a major challenge in phenomics: a practical guide to implementing a quantitative

specimen-based undergraduate research experience. Integrative Organismal Biology, 2(1): obaa004.

Quah ESH, Dukit A, Joseph A & Imbun PY (2025) Arrival of a new anuran invader in Borneo: first record of *Microhyla heymonsi* Vogt, 1911, from Sabah (Amphibia, Microhylidae). Check List, 21(5): 789–796.

Quah ESH & Grismer LL (2024a) Tail bifurcation in *Gehyra mutilata* (Wiegmann, 1834) (Squamata, Gekkonidae) and an updated compilation of tail abnormality records in Gekkota. Herpetology Notes, 17: 359–365.

Quah ESH & Grismer LL (2024b) One last meal before hitting the road: a Spotted House Gecko, *Gekko monarchus* (Schlegel, 1836), as prey of a road-killed Paradise Flying Snake, *Chrysopelea paradisi* Boie, 1827, with a review of prey reported for the species. Herpetology Notes, 17: 339–345.

Quah ESH, Imbun PY & Yek SH (2024) Enduring the earthquake: rediscovery of the Critically Endangered Mesilau stream toad, *Ansonia guibei* Inger, 1966 (Anura, Bufonidae) and its conservation implications. Zootaxa, 5447 (2): 253–262.

Rahman H, Fernandez K & Arumugam N (2018) Termites Infesting Malaysian Forests: Case Study from Bornean Forest, Sabah, Malaysia. In: Khan M & Ahmad W (eds.) Termites and Sustainable Management. Sustainability in Plant and Crop Protection. Springer, Cham, pp. 97–118.

Rahman H, Sidek A, Utu Satu H, Afendy A & Chua TH (2019) Fruit flies of Batu Timbang forest within Imbak Canyon Conservation Area, Sabah, Malaysia (Diptera: Tephritidae). Journal of Tropical Biology & Conservation, 16: 73–77.

Ramírez-Castañeda V, Westeen EP, Frederick J, Amini S, Wait DR, Achmadi AS, Andayani N, Arida E, Arifin U, Bernal MA, Bonaccorso E, Bonachita Sanguila M, Brown RM, Che J, Condori FP, Hartiningtias D, Hiller AE, Iskandar DT, Jiménez RA, Khelifa R, Márquez R, Martínez-Fonseca JG, Parra JL, Peñalba JV, Pinto-García L, Razafindratsima OH, Ron SR, Souza S, Supriatna J, Bowie RCK, Cicero C, McGuire JA & Tarvin RD (2022) A set of principles and practical suggestions for equitable fieldwork in biology. PNAS, 119(34): e2122667119.

Rayadin Y & Buřivalová Z (2022) What does it take to have a mutually beneficial research collaboration across countries? Conservation Science and Practice, 4: e528.

Repin R, Majuakim L, Suleiman M, Nilus R, Mujih H & Gunsalam G (2012) Checklist of trees in Crocker Range Park Permanent Research Plot, Sabah, Malaysia. Journal of Tropical Biology & Conservation, 9(1): 127–141.

Sabah Biodiversity Centre (2024) The Sabah Biodiversity Enactment 2000. Sabah Biodiversity Centre, Kota Kinabalu, Sabah. https://sabc.sabah.gov.my/content/sabah-biodiversity-enactment-2000 (Accessed 31 July 2024).

Sabah National Parks Trustees (1980) Annual Report of the Sabah National Parks Trustees for 1980. Kota Kinabalu, Sabah National Parks, p. 3.

Sabaj MH (2016) Standard symbolic codes for institutional resource collections in herpetology and ichthyology: an Online Reference. Version 6.5 (13 October 2020). American Society of Ichthyologists and Herpetologists, Washington, D.C. http://www.asih.org/ (Accessed 4 October 2024).

Samat A & Chin PK (1996) The balitorid fish of Sabah. The Sarawak Museum Journal, 50(71): 87–92.

Sathiya Seelan JS, Chong SY, Foo SF, Dawood M, Tan YS, Kim MJ, Park MS & Lim YW (2020) New species of *Termitomyces* (Lyophyllaceae, Basidiomycota) from Sabah (Northern Borneo), Malaysia. Mycobiology, 48(2), 95–103.

Schilthuizen M, Cabanban AS & Haase M (2005) Possible speciation with gene flow in tropical cave snails. Journal of Zoological Systematics and Evolutionary Research, 43(2): 133–138.

Schilthuizen M, Teravainen MIF, Tawith NFK, Ibrahim H, Chea SM, Chuan CP, Daim LJ, Jubaidi A, Madjapuni MJ, Sabeki M & Moktar A (2002) Microsnails at microscales in Borneo: distributions of Prosobranchia versus Pulmonata. Journal of Molluscan Studies, 68(3): 255–258.

Schilthuizen M, van Til A, Salverda M, Liew T-S, James SS, Elahan B & Vermeulen JJ (2006) Microgeographic evolution of snail shell shape and predator behaviour. Evolution, 60(9): 1851–1858.

Shimada T, Matsui M, Yambun P & Sudin A (2011) A taxonomic study of Whitehead's torrent frog, *Meristogenys whiteheadi*, with descriptions of two new species (Amphibia: Ranidae). Zoological Journal of the Linnean Society, 161(1): 157–183.

Sidlauskas BL, Burns MD, Buser TJ, Harper N & Kindred M (2021) Teaching ichthyology online with a virtual specimen collection. Ichthyology & Herpetology, 109(2): 407–423.

Sheldon FH (2015) Gazetteer and site-based history of the ornithology of Sabah, Malaysian Borneo. The Occasional Papers of the Museum of Natural Science Louisiana State University, 86: 1–91.

Shukor MN (1996) The mammalian fauna on the islands at the northern tip of Sabah, Borneo. Fieldiana: Zoology (ew series), 83: 1–51.

Smith EA (1895) On a collection of land-shells from Sarawak, British North Borneo, Palawan, and other neighbouring islands. Proceedings of the Zoological Society of London, 63(1): 97–127.

Society for the Preservation of Natural History Collections (2025) Threatened and Orphaned Collections. https://spnhc.org/threatened-and-orphaned-collections/#Museum_and_university_research_collections (Accessed 29 July 2025).

Stuebing RB (1991) A checklist of snakes of Borneo. Raffles Bulletin of Zoology, 39(2): 323–362.

Stuebing RB & Wong A (2000) The role of Sabah's zoological collections in the conservation of protected areas in Sabah. In: Yaacob Z, Moo-Tan S & Yorath S (eds.) Proceedings of the International Conference on In-situ and Ex-situ Biodiversity Conservation in the New Millennium. Sabah Museum, Kota Kinabalu, pp. 153–165.

Sudin A & Mohamed M (1999) BORNEENSIS Entomological Collection. In: Proceedings of the Third Entoma Seminar 1999. Kangar, Perlis, pp. 39–41.

Suetsugu K, Suleiman M & Tsukaya H (2018) A new species of *Gastrodia* (Gastrodieae, Epidendroideae, Orchidaceae) from the Maliau Basin Conservation Area, Sabah, Borneo. Phytotaxa, 367(1): 78–84.

Sugau JB, Pereira JT, Lee YF & Wong KM (2016) The Sandakan Herbarium turns a hundred. Sandakania, 21: 1–20.

Suleiman M & Akiyama H (2007) Checklist of mosses from southern part of Maliau Basin Conservation Area, Sabah, East Malaysia. Journal of Tropical Biology and Conservation, 3: 67–75.

Suleiman M & Anwar I (2020) The mosses of Kangkawat Research Station, Imbak Canyon Conservation Area, Sabah, Malaysia. Journal of Tropical Biology and Conservation, 17: 65–77.

Suleiman M & Edwards SR (2002) Mosses of Trus Madi, Sabah, Malaysia. Tropical Bryology, 21: 57–64.

Suleiman M, Masundang DP & Akiyama A (2017) The mosses of Crocker Range Park, Malaysian Borneo. PhytoKeys, 88: 71–107.

Suleiman M & Mustapeng AMA (2019) The discovery of a dung-loving moss *Tayloria octoblepharum* (Splachnaceae) on 'toilet pitchers' in Borneo. Malayan Nature Journal, 70(1): 17–20.

Suleiman M & Repin R (2016) The mosses of Gaya Island with two new records for Borneo. Sabah Parks Nature Journal, 10: 1–8.

Suzuki K, Tsuji N, Awangku Hassanal Bahar PB & Kueh BH (2019) Environmental Education for nature conservation: trends and challenges in international cooperation and aid assistance.

Japanese Journal of Environmental Education, Special Issue: Environmental Education in Asia, 48(4): 52–59.

Tan SC, Ho CM & Pang V (2016) Why has education inequality widened in Sabah, Malaysia? Economics Bulletin, 36(1): 569–575.

Thiers BM (2024) Universiti Kebangsaan Malaysia, Kampus Sabah. NYBG Steere Herbarium, Bronx, USA. https://sweetgum.nybg.org/science/ih/herbarium-details/?irn=126562 (Accessed 17 September 2024).

Tsukaya H, Suleiman M & Okada H (2016) A new species of *Epirixanthes* (Polygalaceaea) from Imbak Canyon, Sabah, Borneo. Phytotaxa, 266(2): 146–150.

Universiti Kebangsaan Malaysia (2022) History of the Establishment. Universiti Kebangsaan Malaysia, Bangi, Malaysia. https://www.ukm.my/portalukm/ukm-history/ (Accessed 17 September 2024).

Universiti Malaysia Sabah (2024) Journal of Tropical Biology and Conservation. Universiti Malaysia Sabah, Kota Kinabalu, Malaysia. https://jurcon.ums.edu.my/ojums/index.php/jtbc (Accessed 17 September 2024).

Universiti Malaysia Sabah (2025) Institute for Tropical Biology and Conservation: Collections and Research. https://ums.edu.my/ibtpv2/index.php/borneensis-page/collections-research (Accessed 10 July 2025).

Vermeulen JJ & Liew TS (2022) Land Snails and Slugs of Sabah and Labuan (Malaysia). Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, 432 pp.

Vermeulen JJ, Liew TS & Schilthuizen M (2015) Additions to the knowledge of the land snails of Sabah (Malaysia, Borneo), including 48 new species. ZooKeys, 531: 1–139.

Whitehead J (1893) Exploration of Mount Kina Balu, North Borneo. Gurney and Jackson, London, 317 pp.

Wilkinson MD, Dumontier M, Aalbersberg IJ, Appleton G, Axton M, Baak A, Blomberg N, Boiten J-W, da Silva Santos LB, Bourne PE, Bouwman J, Brookes AJ, Clark T, Crosas M, Dillo I, Dumon O, Edmunds S, Evelo CT, Finkers R, Gonzalez-Beltran A, Gray AJG, Groth P, Goble C, Grethe JS, Heringa J, Hoen PAC 't, Hooft R, Kuhn T, Kok R, Kok J, Lusher SJ, Martone ME, Mons A, Packer AL, Persson B, Rocca-Serra P, Roos M, van Schaik R, Sansone S-A, Schultes E, Sengstag T, Slater T, Strawn G, Swertz MA, Thompson M, van der Lei J, van Mulligen E, Velterop J, Waagmeester A, Wittenburg P, Wolstencroft K, Zhao J & Mons B (2016) The FAIR guiding principles for scientific data management and stewardship. Scientific Data, 3: 160018.

Woo S-Y, Foon JK & Liew T-S (2022) Exploring the predation of large land snails using preyed shell remains from rock anvil sites in a tropical limestone rainforest in Malaysia. Biodiversity Data Journal, 10: e90063

Wong TKD (2000) The British North Borneo Branch of the Royal Asiatic Society (1893–1897) and its museum. Journal of the Malaysian Branch of the Royal Asiatic Society, 73(1 (278)): 17–27.

Yañez A, Exner E, Mendez AL, Bringas A, Godoy I, Plos A, Calviño C, Aceñolaza PG, Alvarez MV, Bach HG, Barrientos E, Belgrano MJ, de los Ángeles Bertos M, Bonjour L, Campos G, Carbone LM, Carranza AV, Chamorro D, Pérez CHF, Deanna R, Demaio PH, di Pasquo M, Farina L, Fernández Pepi MG, Gandullo R, Gaviorno M, Gil ME, González CC, Goyenetche JM, Guerrero JM, Gutierrez DG, Honfi AI, Lamaro AA, Languasco MP, Lavornia JM, Lazcóz MV, Laphitz RML, Machado AS, Monsalvo MA, Muruaga NB, Parrado MF, Paye IA, Peichoto MC, Perera TC, Prado D, Rodriguez EE, Rodríguez J, Roger E, Rossi B, Salomón MES, Savoretti A, Sottile GD, Suárez PA, Tranchida MC, Valdés FE, Viera Barreto JN, Vignale MV, Villegas DO, Zapperi G, Zenón ÁE (2025) From Argentina to the world: building a network to enhance the capabilities of herbarium collections. Biological Journal of the Linnean Society, 145 (4): blaf049.

Yean AS (2014) Education for Sustainable Development in Malaysia's national curriculum reformation: A theoretical exploration. Journal of International and Comparative Education, 3(2): 199–212.

Yoh N, Azhar I, Fitzgerald KV, Yu R, Smith-Butler T, Mahyudin A & Kingston T (2020) Bat ensembles differ in response to use zones in a tropical biosphere reserve. Diversity, 12(2): 60.

Zhu R-L, Shu L, Mustapeng AMA & Suleiman M (2017) *Thiersianthus* (Marchantiophyta: Lejeuneaceae), a new genus from lowland rainforests in Borneo. The Bryologist, 120(4): 511–520.

Zieritz A, Bogan AE, Rahim KA, Sousa R, Jainih L, Harun S, Razak NFA, Gallardo B, McGowan S, Hassan R & Lopes-Lima M (2018) Changes and drivers of freshwater mussel diversity and distribution in northern Borneo. Biological Conservation, 219: 126– 137.

Zieritz A, Jainih L, Pfeiffer J, Rahim KAA, Prayogo H, Anwari MS, Fikri, AH, Diba F, Taha H, Sulaiman Z, Froufe E, & Lopes-Lima M (2021) A new genus and two new, rare freshwater mussel (Bivalvia: Unionidae) species endemic to Borneo are threatened by ongoing habitat destruction. Aquatic Conservation: Marine and Freshwater Ecosystems, 31(11): 3169–3183.