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Diversity and Distribution of Orchidaceae in Myanmar

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Diversity and Distribution of Orchidaceae in Myanmar

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Abstract

Myanmar is situated in the Southeast Asia and lies in the Indo–Burma Biodiversity Hotspot. Myanmar possesses many types of vegetation, including tropical rainforest, tropical savannah, coastal mangrove forest and subtropical montane forest. Myanmar forest possesses rich biodiversity resources areas with high species richness and diversity. Approximately 273 families, 2371 genera, and over 11800 species of vascular plants have been recorded in Myanmar in 2003. Out of which, 800 species are orchid. Myanmar orchid flora is highly diverse but very poorly known mainly due to few botanical explorations. Botanical surveys were very few in Myanmar after 1950, leading to large gap of knowledge on flora of Myanmar. Various Orchidaceae species have been over–collected and becoming endangered because of their great economic importance, to floral and pharmaceutical industries, many species have been over–collected and are becoming endangered. Understanding how geographical and environmental gradients influence species richness is essential for the conservation of orchids. Myanmar biodiversity resources urgently needed conservation attempts for species survival and sustainability. From conservation point of view, how geographical and environmental gradients influence species richness is essential and it would increase our knowledge about the potential effects of global change on orchids. However, the variability in this diversity along those gradients is rarely examined, especially on a large scale. Environmental conditions associated with elevations exert a strong influence on orchid species composition and distribution. We amassed 3423 distribution records for 923 species from 142 genera of Orchidaceae. Herbarium specimens (PE) and online herbarium specimens were also examined. The species richness was firstly tried to test the correlation with the environmental factors by Pearson's method. Total orchid species richness shows a hump–shaped relationship along a temperature–elevational gradient with a maximum at about 800 m a.s.l. (=18°C). This study has showed that the diversity of orchid species in Myanmar decreases significantly with altitude.

Keywords: altitude, biodiversity of Orchidaceae, biogeography, conservation, Myanmar, precipitation, temperature.

မြန်မာ့သစ်ခွမျိုးစိတ်အမျိုးအစားများ ပျံ့နှံ့ပေါက်ရောက်မှု

ဒေါက်တာအေးသင်းမူ၊ ဒုတိယညွှန်ကြားရေးမှူး
အပူပိုင်းဒေသစိမ်းလန်းစိုပြည်ရေးဦးစီးဌာန

စာတမ်းအကျဉ်း

မြန်မာနိုင်ငံသည်အရှေ့တောင်အာရှတွင်တည်ရှိ၍ အင်ဒို-ဘားမား ဇီဝမျိုးစုံမျိုးကွဲများပေါကြွယ်စွာတည်ရှိသည့်နိုင်ငံတစ်ခုဖြစ်ပါသည်။ အပူပိုင်းမိုးသစ်တော၊ အပူပိုင်းဆာဗာနား၊ ကမ်းရိုးတန်းဒီရေတောများနှင့် သမပိုင်းသစ်တောများအပါအဝင် သစ်ပင်များပေါများစွာပေါက်ရောက်လျက်ရှိပါသည်။ မြန်မာ့သစ်တောများအတွင်းသစ်ပင်မျိုးရင်းပေါင်း (၂၇၃) ခု၊ မျိုးစုပေါင်း (၂၃၇၁) နှင့် မျိုးစိတ်ပေါင်း (၁၁၈၀၀) ခန့်ရှင်သန်ပေါက်ရောက်လျက်ရှိပြီး ၂၀၀၃ ခုနှစ် မှတ်တမ်းများအရသိရှိရပါသည်။ ၎င်းတို့အနက် မျိုးစိတ်ပေါင်း (၈၀၀) ခန့်သည်သစ်ခွမျိုးစိတ်များဖြစ်ပါသည်။မြန်မာ့သစ်ခွမျိုးစိတ်များစွာရှင်သန်ပေါက်ရောက်လျက်ရှိသော်လည်း ရာကျွဇေဒဆိုင်ရာလေ့လာဆန်းစစ်မှုများနည်းပါးသည့်အတွက် သစ်ခွမျိုးစိတ်များနှင့် ပတ်သက်၍လေ့လာရန်လိုအပ်လျက်ရှိပါသည်။ အမျိုးမျိုးသော သစ်ခွမျိုးစိတ်များကိုအလွန်အကျွံစုဆောင်းခြင်း၊ ဆေးဝါးဖော်စပ်ခြင်းတွင်အသုံးပြုရခြင်းနှင့် စီးပွားရေးအကျိုးဋာအလွန်အမင်း စုဆောင်းရောင်းချခြင်းတို့ကြောင့် သစ်ခွများသည် တဖြည်းဖြည်းပို၍ ပို၍ ရှားပါးလာပြီး မျိုးသုဉ်းမည့် ဘေးအန္တရာယ်သို့ ကျရောက်လာပါသည်။ အပင်များကို ထိန်းသိမ်းစောင့်ရှောက်နိုင်ရေးအတွက် ၎င်းတို့ပေါက်ရောက်လျက်ရှိ သည့် မြေမျက်နှာသွင်ပြင်အနေအထားများနှင့် ပတ်ဝန်းကျင်ဆိုင်ရာ အခြေအနေများကို သိရှိနားလည်ထားရန်အလွန်အရေးကြီးပါသည်။ မြန်မာ့ဇီဝမျိုးစုံမျိုးကွဲ အရင်းအမြစ်များ ရှင်သန်စေရေးနှင့် ရေရှည်စဉ်ဆက်မပြတ် တည်ရှိရေးအတွက် ထိန်းသိမ်းစောင့်ရှောက်ရန် အရေး တကြီးလိုအပ်လျက်ရှိပါသည်။ ထိန်းသိမ်းစောင့်ရှောက်ရေး ရှုထောင့်မှ ကြည့်ရှုပါက အပင်များသည် မြေမျက်နှာသွင်ပြင်အနေအထားများနှင့် ပတ်ဝန်းကျင်ဆိုင်ရာ အခြေအနေများအလိုက် တည်ရှိနေမှုကိုသိရှိရန်အရေးကြီးပါသည်။ ထိုကဲ့သို့ သိရှိလေ့လာခြင်းသည် ကမ္ဘာပေါ်တွင် သဘာဝအလျောက် ဖြစ်ပျက်ပြောင်းလဲမှုများကြောင့် အပင်များပေါ်တွင် အကျိုးသက်ရောက် မှုအလားအလာကို သိရှိနိုင်ပါသည်။ မျိုးစုပေါင်း (၁၄၂) အနက်မှ မျိုးစိတ်ပေါင်း (၉၂၃)ခု၏ မျိုးစိတ်မှတ်တမ်း (၃၄၂၃) ခု (Herbarium specimens (PE) and online herbarium specimens) အား လေ့လာဆန်းစစ်ခဲ့ပါသည်။ မျိုးစိတ်ပေါ ကြွယ်ဝမှုနှင့် ပတ်ဝန်းကျင်ဆိုင်ရာ အချက်အလက်များ၏ ဆက်စပ်မှုကို Pearson’s method အား အသုံးပြု၍လေ့လာခဲ့ပါသည်။လေ့လာတွေ့ရှိချက်များအရ temperature – elevational

gradient နှင့် သစ်ခွ အများဆုံးတည်ရှိနိုင်သည့် ပုံစံဆက်စပ်ချက်သည် အခုံး ပုံ (Harmed Shape) ဖြစ်ပါသည်။ ပင်လယ်ရေမျက်နှာပြင် အမြင့်ပေမြင့်တက်လာသည် နှင့်အမျှ သစ်ခွ မျိုးစိတ်များ ပို၍တိုးမြင့် တွေ့ရှိရပြီး အများဆုံးတွေ့ရှိနိုင်သည့် နေရာသည် ပင်လယ် ရေမျက်နှာပြင်အထက် (၈၀၀) မီတာ(18°C) ဖြစ်ကြောင်း၊ ၎င်းအမြင့်ပေထက် ပိုမိုမြင့် တက်လာပါက သစ်ခွမျိုးစိတ်များ တွေ့ရှိရမှု တဖြည်းဖြည်းလျော့ကျလာကြောင်း လေ့လာ တွေ့ရှိရပါသည်။

Diversity and Distribution of Orchidaceae in Myanmar

1. Introduction

Tropical Asia which includes Myanmar still possesses forests rich in biodiversity. Almost all of Myanmar lies within the Indo-Burma Biodiversity Hotspot, one of 35 global hotspots that support high levels of biodiversity and endemism (Mittermeier et al., 2004; Mittermeier et al., 2011; Sodhi et al., 2004; Myers et al., 2000). The Indo-Burma hotspot ranks in the top 10 hotspots globally for irreplaceability and in the top five for threats (MCRB, 2008). Myanmar possesses rich biodiversity resources, with high species richness and diversity. There are 273 families, 2371 genera, and over 11800 species of vascular plant recorded in Myanmar according to the checklist of Myanmar flora (Kress et al., 2003). Myanmar biodiversity resources urgently needed conservation attempts for species survival and sustainability (Mittermeier et al., 2011; Sodhi et al., 2004; Myers et al., 2000).

The relationship between species richness and elevation is a central topic in biodiversity research and many studies have documented this relationship with a variety of taxa and geographical regions (Terborgh 1977; Bhattarai et al. 2004; Jacquemyn et al. 2005; McCain 2005, 2007; Oommen & Shankar 2005; Rahbek 2005; Grytnes et al. 2006; Grau et al. 2007) because of the short geographical distance but large climatic differences found as elevation changes (Korner 2007; Acharya et al. 2011).

In Myanmar, due to its broad latitudinal range (tropical to subtropical) and topographical (usually mountainous) and climatic (monsoonal) factors, there are various types of ecosystems, from southern tropical evergreen rainforest and coastal mangrove forest ecosystem to northern subtropical montane forest ecosystem through central dry deciduous forests. Myanmar is renowned with its rich biodiversity resources. However, biodiversity research is very limited and many species of fauna and flora still remain unexplored and unknown. Few botanical surveys in Myanmar was conducted after 1950 (Kress et al., 2003), and since then, large gap of knowledge on flora of Myanmar is recognized.

The botanical collections that do exist suffer from spatial bias. By itself then, the collection record is insufficient to describe the phytogeography of Myanmar comprehensively. Therefore, understanding how its species richness varies along geographical and environmental gradients is essential for conservation efforts. However, there is still limited in research record about the diversity and distribution of orchids in Myanmar, especially on a large scale.

Large-scale ecological inventories on orchidaceae are lacking from the Myanmar tropics. Hence, the present study was undertaken aiming at a large-scale detailed analysis of Orchidaceae in a tropical evergreen forest. Here, we use the largest available dataset of orchid collection records, together with abiotic spatial data, to arrive at objective conclusions about patterns of species richness in a transparent, quantitative way.

Therefore, this study will investigate the species richness and diversity of Myanmar orchid flora along the elevational and climatic gradients. It is expected to bridge the gap of knowledge on orchid species richness and diversity of Myanmar. In addition, it will contribute to biodiversity conservation in Myanmar where species diversity is very high but still poorly known.

2. Research Objectives

The main aims of our study are:

1. to describe the orchid species richness patterns with respect to total, endemic, epiphytic, saprophytic and terrestrial and relate these richness variables to temperature and precipitation after area has been counted for;
2. to test the prediction that maximum endemic richness occurs at a higher elevation than total orchid richness; and
3. to compare and assess climatic factors together with area as casual explanations for the observed patterns.

3. Methodology

3.1 Study area

The study area covered the whole country of Myanmar (92°10'-101°11' E, 9°32'-28°31'N) with approximately 676,577 km2 (**Error! Reference source not found.**). It is bounded by People Republic of China in the North and North East, Lao in the East, Thailand in the South East, Bangladesh and India in the West. Mountain ranges of Myanmar strengths from north to south. Elevational ranges from 0-5881 m above sea level (Kharaborazi Mountain) and includes tropical to temperate climatic zone. Myanmar composed of 7 states and 8 regions of administrative section. Myanmar can be separated into five topographic regions mountainous area in the north (1830 to 6100 m a.s.l.); the western ranges (1830 to 6100 m a.s.l.); the Eastern Shan Highlands (910 m a.s.l.); the central Myanmar; and the fertile delta and the southern lower valley regions of the Irrawady and Sittaung rivers. Myanmar has a tropical monsoon climate with three seasons: the monsoon or rainy season, from May to October, the cool season, from November to February; and the hot season, from March to April.

In order to investigate species richness of Myanmar orchid flora, a series of fieldwork had been conducted in various ecosystems across Myanmar. Seven protected areas across Myanmar, namely Hponkanrazi Wildlife Sanctuary and Hkakaborazi National Park of Kachin State, Popa Mountain Park of Mandalay Region, Nat Ma Taung National Park of Chin State, Alaungdaw Kathapa National Park of Sagaing Region, Taunggyi Bird Sanctuary and its adjacent areas of Shan State and Tanintharyi Nature Reserve of Tanintharyi Region, had been investigated two to five times respectively, during 2016-2018.

3.2 Specimen collections and identification

In total, approximately 1000 specimens of orchids were collected for vouchers (kept in PE and RAF). More than 75 % of total specimens were collected from Hponkanrazi Wildlife Sanctuary and Hkakaborazi National Park, Putao District, Kachin State, Northern Myanmar. Putao is the northernmost district of Myanmar where there are vast areas of primary forest with high species richness and diversity. The remaining proportions were collected from other study areas. In the collections, most species are species of Dendrobium, Bulbophyllum and Coelogyne. The remaining proportions are species of some common genera Eria, Liparis and Oberonia.

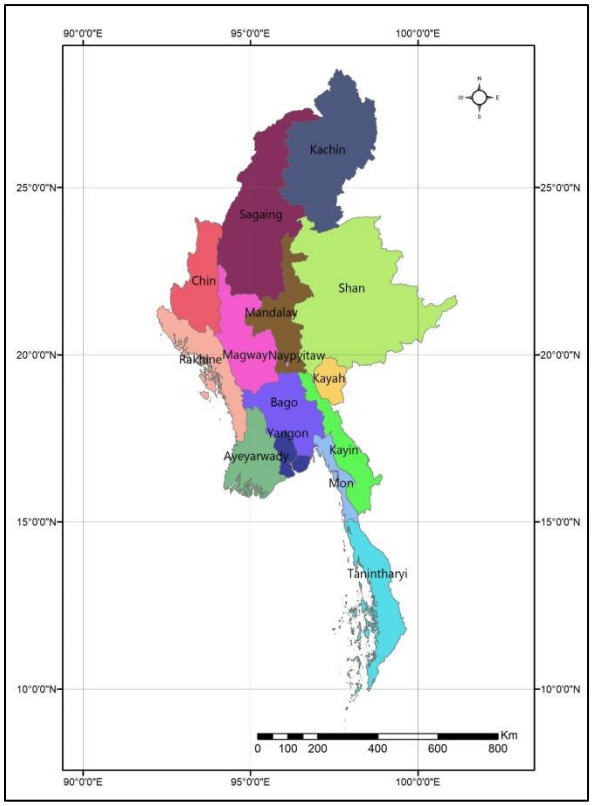


Fig. 1. Myanmar with Administrative Boundaries

All collected specimens were taxonomically identified based on relevant literature, field notes, photographs taken during fieldwork, herbarium specimens (PE) and online herbarium specimens such as Kew Herbarium Catalogue and Chinese Virtual Herbarium (Chase et al., 2015; Kurzweil and Lwin, 2014; Pedersen et al., 2011 & 2014; Pridgeon et al., 2005 & 2014; Chen et al., 2009; Dressler, 1993; Kress et al., 2003; Seidenfaden, 1992). For verification of taxonomic status of all species, all relevant literature and online databases such as WCSP are reviewed to confirm its respective taxonomic status (WCSP, 2019; Ng et al., 2018; Raskoti et al., 2017; Raskoti et al., 2016; Chase et al., 2015; Jin et al., 2014; Pridgeon et al., 2005 & 2014; Vermeulen et al., 2014; Gardiner et al., 2013; Gardiner, 2012; Chen et al., 2009).

In total, there are ca. 3000 herbarium specimens examined, including specimens of my own collections and previous collections (PE), Kew herbarium specimens (K) and specimens from online herbaria: AMES, BM, E, GH, K, L, NY, P, US and W (herbarium codes from Index Herbariorum at http://sweetgum.nybg. org/ih/). In addition to my own collections and previous collections at PE (ca. 1000 specimens), Kew herbarium specimens (ca. 700 specimen photographs) were examined by having access to specimen photographs taken by my supervisor Dr. Xiaohua Jin during his research cooperation at Kew Herbarium, Royal Botanic Gardens Kew, UK.

In addition, all available datasets of herbarium specimens (ca. 1500 specimens) and specimen photographs were downloaded from online herbaria and examined to enumerate the number of species and to investigate the species occurrences in Myanmar. The followings are specimen records downloaded from each online herbarium, AMES (12 records), BM (420 records), E (496 records), GH (3 records), K (324 records), L (39 records), NY (116 records), P (87 records), US (81records) and W (11 records). During my field trips in Myanmar, some old herbarium specimens at RAF (ca. 200 specimens) were also examined at herbarium (RAF) of Forest Research Institute in Yezin, Nay Pyi Taw.

As for species occurrences, the herbarium specimens (BM, E, K) provide the information on past record of species occurrences in Myanmar, for example; old collections (past 100 years) by some well-known plant collectors such as Charles Parish, George Forrest, J. H. Lace, Frank Kingdon-Ward, W. A. Robertson, F. G. Dickason, C. W. D. Kermode during last half of 19th century and first half of 20th century (Figure 2.4). The herbarium specimens (PE) provide information on current status of species occurrences across Myanmar. In addition, some literature provide information on specimens collected from Myanmar so that it can be cited as specimen-based species occurrences in Myanmar (Aung and Jin, 2018; Aung et al., 2018; Kurzweil and Ormerod, 2018; Liu et al., 2018; Tanaka et al., 2018; Zhou et al., 2018; Aung et al., 2017; Jin and Kyaw, 2017; Liu et al., 2017; Yang et al., 2017; Kurzweil and Lwin, 2015; Tanaka et al., 2015; Watthana et al., 2015).

3.3 Verification of specimens

The number of species in the updated checklist is a result of taxonomic attempts, mainly based on my own collections, all available herbarium specimens, checklist of Kress et al. (2003) and all relevant literature (Aung and Jin, 2018; Aung et al., 2018; Govaerts, 2018; Jin and Kyaw, 2018; Kurzweil and Ormerod, 2018; Liu et al., 2018; Tanaka et al., 2018; Zhou et al., 2018; Aung et al., 2017; Liu et al., 2017; Yang et al., 2017; Chase et al., 2015; Tanaka et al., 2015; Kurzweil and Lwin, 2014; Kurzweil, 2013; Kurzweil and Lwin, 2012; Pedersen et al., 2011 & 2014; Ormerod, 2012; Tanaka et al., 2010; Chen et al., 2009; Roberts et al., 2008; Kress et al., 2003). Both the number of species and its taxonomic status were verified with the reliable online databases of World Checklist of Selected Plant Families (WCSP), International Plant Names Index (IPNI) and the Plant List (TPL).

As for species occurrences, Global Biodiversity Information Facility (GBIF) and relevant online herbaria (AMES, BM, E, GH, K, L, NY, P, US and W) were also consulted to check the species occurrences of Orchidaceae in Myanmar.

3.4 Data sources

This study was conducted at country level in Myanmar. Due to limited researches and documentations related to orchid in Myanmar, records from field survey and available secondary records were collected as much as possible. We compiled data on the elevational distribution of native orchid species from various sources to determine species richness patterns along elevational gradients. We have comprised all available orchid species reported so far. Field survey on orchid species in Myanmar were surveyed under the project. The recorded data were applied in this study. Also, available secondary data were compiled from Herbarium [Kew Herbarium (England), Forest Research Institute (Myanmar), Yangon University (Myanmar) and Mandalay University (Myanmar)], Botanical Garden [Pyin Oo Lwin Botanical Garden], Theses and Books [Theses from Myitkyina University, Mandalay University and Yangon University, A Checklist of the Trees, Shrubs, Herbs, and Climbers of Myanmar, and A Guide to Orchids of Myanmar], and global database [the Global Biodiversity Information Facility (GBIF)]. On the Update checklist of Orchid of Myanmar in 2003, Jhon Kress has documented 897 species in 152 genera. Duplicate specimens and specimens that are indefinite were removed from the database. Non-native species were not included in our analysis. Some species that are roughly reported or did not provide elevational range are excluded from the analysis. All orchid species were classified into three groups: epiphytes, saprophytes and terrestrials. All data were confirmed with online databases of World Checklist of Selected Plant Families (WCSP), International Plant Name Index (IPNI) and the Plant List (TPL). The number of endemic species to Myanmar with elevation data is 15. A digital elevation model (DEM) was obtained from the United States

Geological Survey with a resolution of 30 m (**Error! Reference source not found.**) (Source: http://reverb.echo.nasa.gov/ reverb/redirect/wist).

3.5 Data compilation and analysis

We compiled the data from different above-mentioned sources into a set of data for assessing the geographical and elevational distribution and diversity. Available data from various sources could be overlapped, and therefore we excluded the duplicate specimens as well as indefinite specimens from the database. Also, non-native species were not included in our analysis. All data were confirmed with online databases of World Checklist of Selected Plant Families (WCSP), International Plant Name Index (IPNI) and the Plant List (TPL). All orchid species were classified into three groups: epiphytes, saprophytes and terrestrials as well as endemic species. Some specimens are provided with incomplete information, and therefore based on available information, this analysis was performed.

As for the geographical distribution and diversity, the administrative boundary of the Republic of the Union of Myanmar was applied. In Myanmar, there are 15 States and Regions, including new-established Nay Pyi Taw Union Territory. In these 15 States and Regions, we simply summarized the number of specimens and species from the interpolated database. In addition, we grouped the species by life forms in each State and Region.

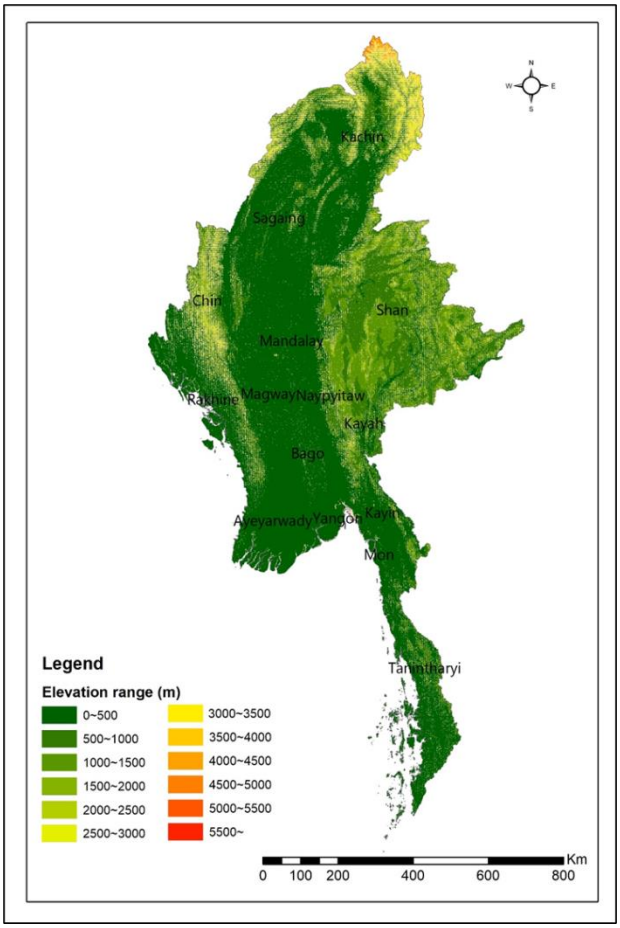


Figure. 1. Elevational Gradients in Myanmar

To assess the elevational patterns of the species richness and distribution, we applied the actual frequency of species presence from the dataset we compiled from various sources rather than an interpolation to analyze the elevational pattern of richness because the latter method may produce an artificial pattern [34]. The elevational distribution of the orchids in

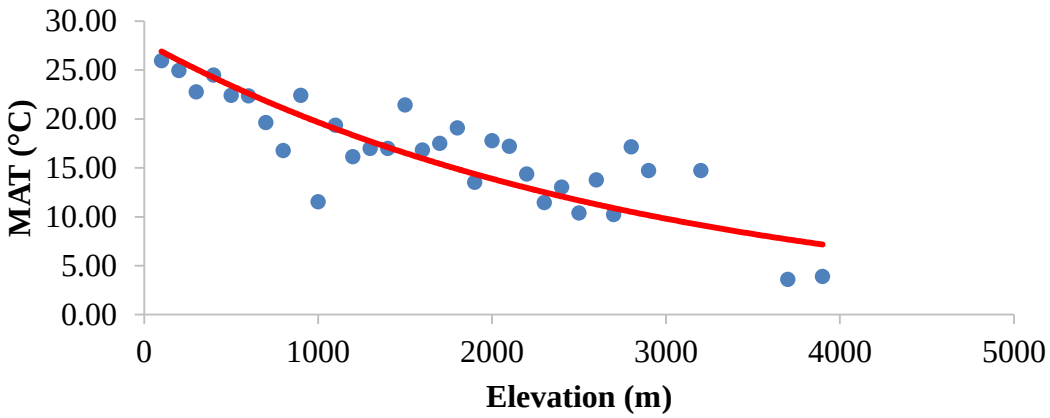
our dataset ranged from 2 m to 4700 m. We interpolated them into 100-m step (0-100, 101-200, …, 4601-4700 m), even though there were no available data in some elevational steps. Species richness along the elevational gradients was analyzed by total species, by different life forms and by endemism.

In addition, we tried to elaborate the relation between the species richness of total orchid species as well as by life forms and various environmental factors such as mean annual temperature (MAT, ºC), average annual precipitation (MAP, mm) and proxy area (m2) along the elevational gradients. We extracted the MAT and MAP from the climatic data from Meteorological data sharing service system (https://climatecharts.net) for each latitude and longitude of the specimens we complied. We also checked the MAT and MAP data with the station-based meteorological data of Myanmar recorded between 1986 and 2016. The climatic gradients along the 100-m elevational steps are shown in **Error! Reference source not found.**.

For all the analysis in this study, we applied the Microsoft Excel 2016 and SPSS 20.0 for the descriptive and inferential statistics. The species richness along the elevational gradients was described in additive generalized linear models to simply assess the trend of total orchid species as well as by life forms. In addition, the species richness was firstly tried to test the correlation with the environmental factors by Pearson's method, and then the association between the species richness as dependent variable and the environmental factors as explanatory variables was analyzed for total orchid species and by life form as well endemic orchids. Besides, we used the ArcGIS 10.2 to map the species distribution and diversity in terms of the number of records and species, as well as according to life forms in States and Regions of Myanmar.

3.6 Data interpolation

We were divided elevation gradients between 100 m to 4700 m into 47 elevational zones (100 m). A species is defined as being present in each 100 m elevational interval between the upper and lower elevational band by interpolation (Vetaas & Grytnes 2002; Bhattarai et al. 2004). The term of species richness used is the total number of species present in each 100 m elevational band i.e. gamma diversity sensu Lomolino (2001). We recorded the number of species in each elevational band. The area bands were calculated using ArcGIS 10.2 and compiled comparable to the climate and orchid data.



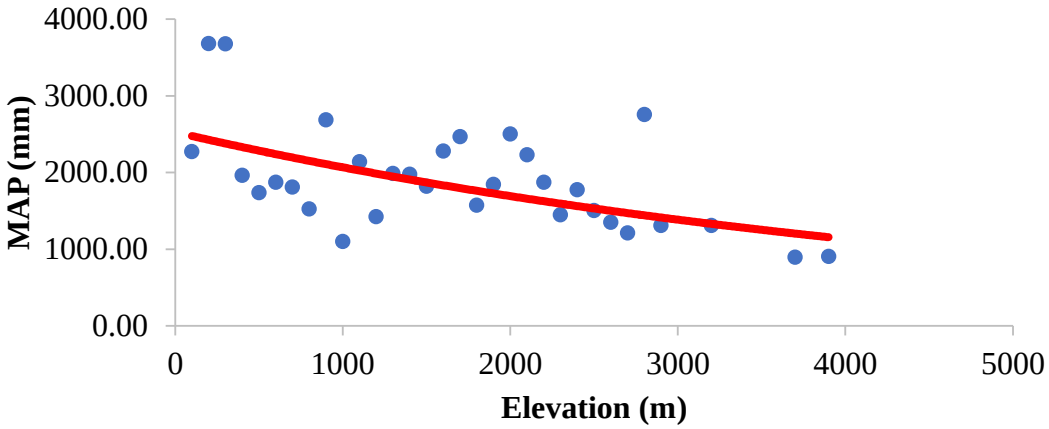


Fig. 3.Climatic Gradients along 100-m elevational steps in Myanmar

3.7 Climatic variables

We used climate as possible determinants of large-scale patterns of orchid richness in Myanmar. We used the following climatic variables to explore the influence of climate on the orchid richness in Myanmar: mean annual temperature (MAT, .C) and mean annual precipitation (MAP, mm). The general trend temperature and precipitation was calculated from the climatic data from Meteorological data sharing service system (https://climatecharts.net). Mean annual temperature and mean annual precipitation were calculated from regression models derived from the meteorological data of Myanmar recorded between 1986 and 2016. We regressed mean annual temperature by generalized additive models (GAMs). Then we used generalized linear models to estimate mean annual precipitation for each 100-m elevation zone. These estimates were later used as explanatory variables of orchid species richness in generalized linear models.

4. RESULTS

4.1 Botanical investigations

As a result of botanical investigations in Myanmar, five new species and 30 new records were discovered from Myanmar (Plate 1 & 2). The discoveries contribute to the increased number of species (about 200 species) in the updated checklist (1032 species). Most species of the common genera *Bulbophyllum* and *Dendrobium* were also observed during fieldwork in Myanmar (Figure 3.4).

Botanical collections still remain under-represented the whole diversity of Myanmar orchid flora. Although there are 1032 species currently known from Myanmar, it is estimated that there will be some other species remain unexplored and are expected to be discovered in future studies on Myanmar orchid flora.

The present study results in an updated checklist of Myanmar orchid flora which includes 1032 species and 150 genera currently known from Myanmar (Appendix 1). The number of species is increased by about 200 species more than the checklist of Kress et al. (2003). The increase in number of species is mainly due to the recent discoveries of new species to science as well as new species records for Myanmar. There are 74 endemic species of Orchidaceae in Myanmar which need high conservation attentions.

The updated checklist provides the accepted species names, their respective distribution in Myanmar, voucher specimen citations and conservation status. Species

distribution ranges (usually provincial level) in Myanmar are provided for almost all species. Specific locality information is also provided if known for some species.

4.2 Orchid species richness and distribution

4.2.1 Orchids by administrative boundaries

Based on this study, we observed 3423 records and 942 identified species in Myanmar Table 1. In Kachin State, the largest number of orchid species and specimen records was found (475 identified species and 1021 records), representing about 50% of total number of identified species and about 30% of total specimen records (Figure 2). Shan State shows the second highest in number of identified species and specimen records, which are 272 species (29% of total identified species) and 525 records (15% of total records). Other parts of Myanmar

Table 1: Orchid Species Records by Administrative Boundaries in Myanmar

State/Region	# of species	# of records
Ayeyarwaddy	3	3
Bago	26	30
Chin	252	403
Kachin	475	1021
Kayah	1	1
Magway	14	14
Mandalay	195	360
Mon	76	107
Nay Pyi Taw	17	28
Rakhine	2	2
Sagaing	62	85

Shan	272	525
Tanintharyi	140	217
Yangon	35	47
No specific state/region	313	580
Total		3423

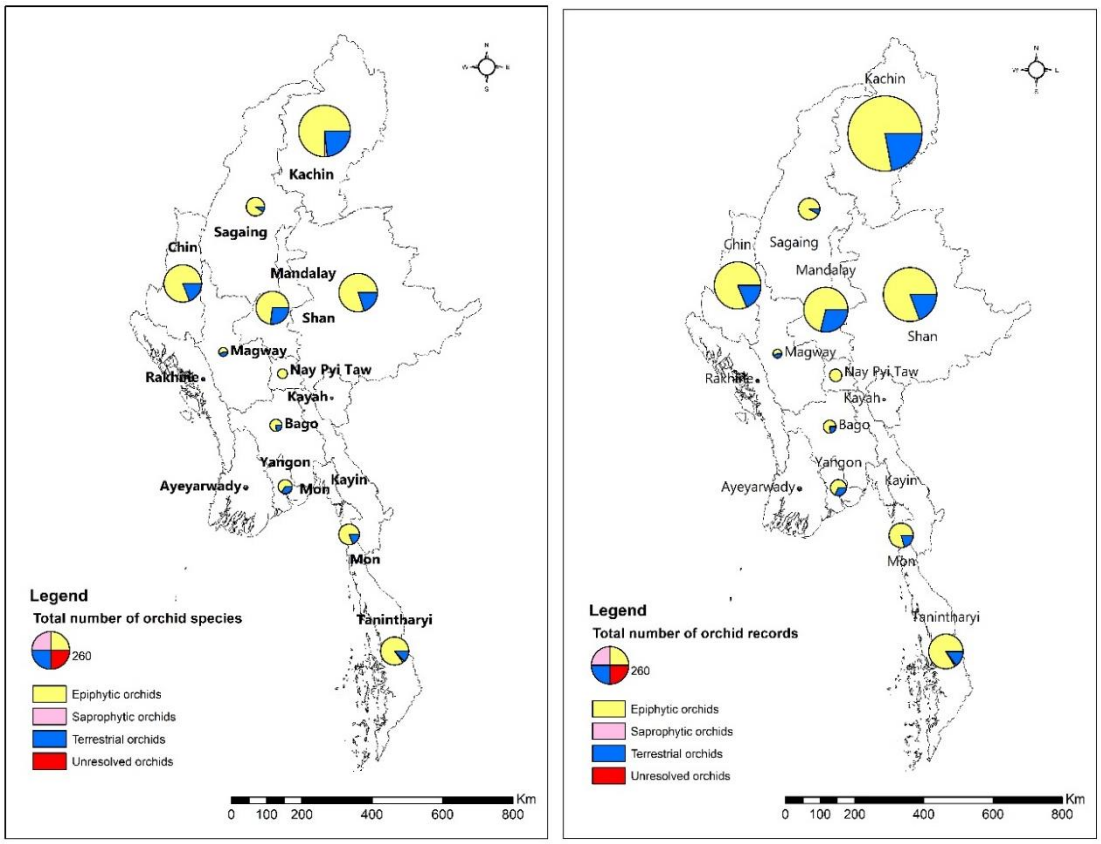
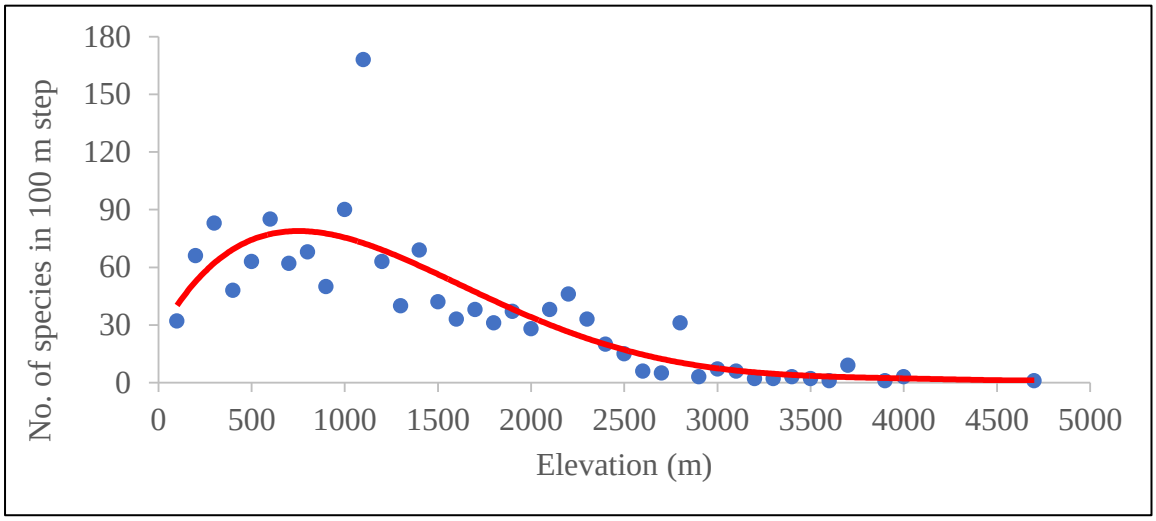


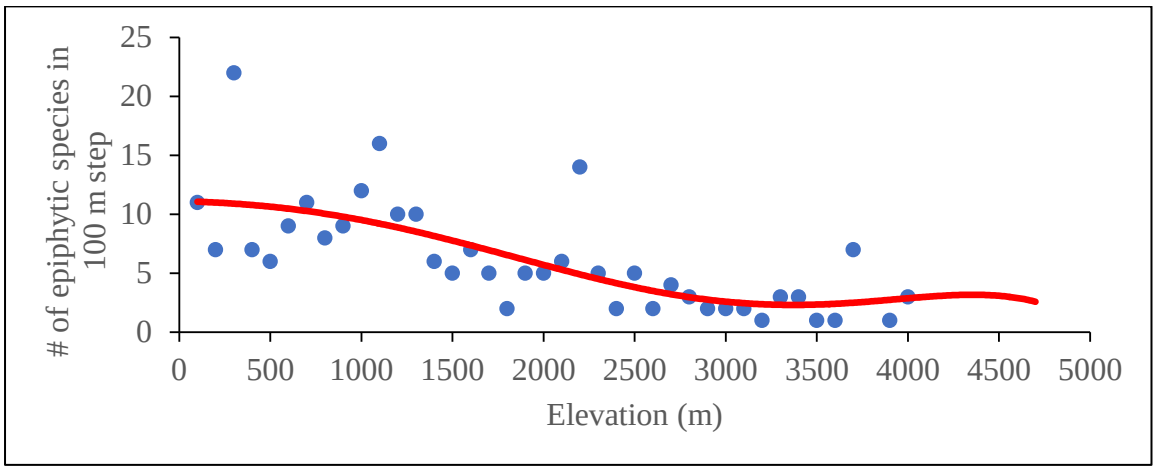
Figure 2:Distribution of Orchid Species and Specimen Records by Administrative Boundaries in Myanmar

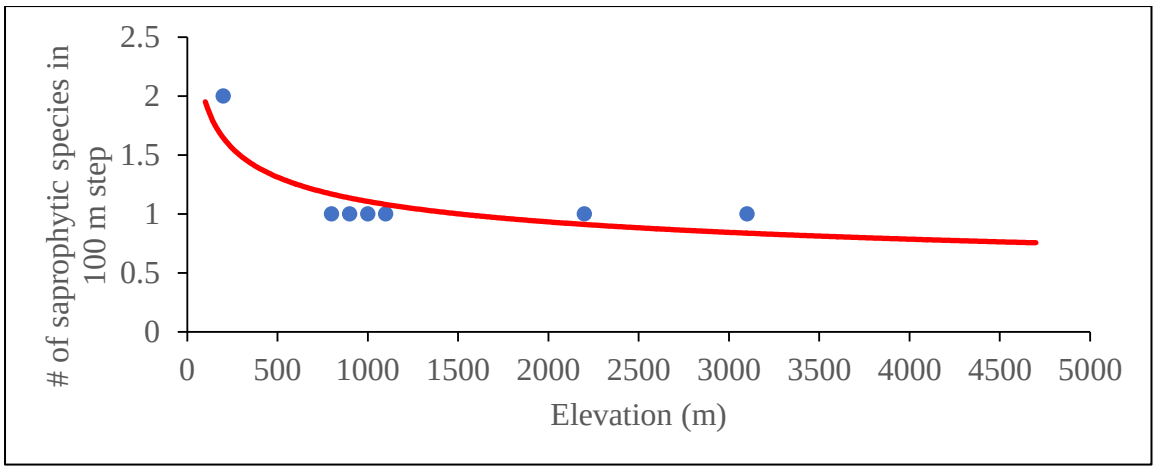
4.2.2 Orchids along the elevational gradients

Total orchid species richness shows a hump-shaped (monotonically decreased) relationship along a temperature-elevational gradient with a maximum at about 800 m a.s.l. (=18°C) (Fig.3a, Table -1). This study has showed that the diversity of orchid species in Myanmar decreases significantly with altitude. The peak of endemic species is dominated by epiphytic species (Fig. 3b). The data for epiphytic orchid life form showed a hump-shaped relationship with the temperature–elevational gradient (Table 1), with a peak around 900 m a.s.l. (=20° C) (Fig.4b). Terrestrial and saprophytic orchids show a decreasing pattern with

low elevation relationship with a peak at 100 m a.s.l. (=37° C) respectively. (Fig. 4c, 4d, Table 1).







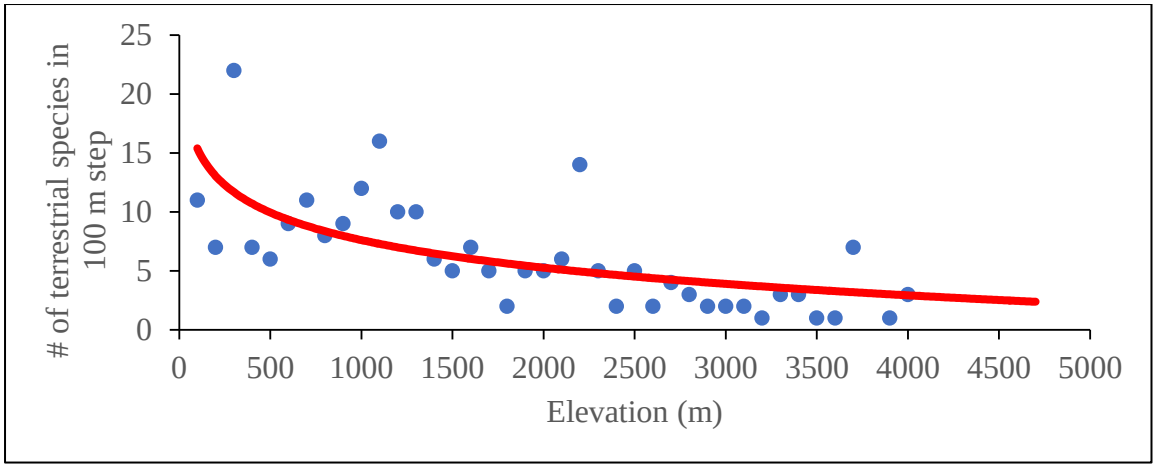


Figure 3: Orchid Species Distribution Along 100-m Elevational Steps by Different Life Forms (a) total orchid species richness; (b) epiphytic orchid species richness; (c) terrestrial orchid species richness; (d) saprophytic orchid species richness

4.2.3 Orchids by the climatic variations

The GLM analyses show that area is a significant factor for all life forms except for terrestrial orchids. Second-order polynomial of MAP and MAT were highly significant for all orchid species and epiphytic life form except for terrestrial and saprophytic orchids.

Lifeforms	MAP (mm)	MAT (°C)	Area (km^2)
All orchid species	0.354^{*}	0.469^{**}	0.370^{*}
Epiphytic orchids	0.324^{*}	0.471^{**}	0.338^{*}
Epiphytic or lithophytic orchids	0.449^{**}	0.496^{**}	0.344^{*}
Epiphytic or terrestrial orchids	0.108^{ns}	0.297^{*}	0.055^{ns}
Lithophytic orchids	0.442^{**}	0.411^{*}	0.428^{**}
Lithophytic or terrestrial orchids	0.109^{ns}	0.159^{*}	0.338^{*}
Saprophytic orchids	0.330^{*}	0.261^{ns}	0.300^{*}
Terrestrial orchids	0.369^{*}	0.376^{*}	0.404^{*}
Endemic orchids	0.206^{ns}	0.189^{ns}	-0.118^{ns}

Pearson's Correlation of Orchids along Elevational Gradeints

	Intercept	MAP (mm)	MAT (°C)	Area (km^2)	R^2	SE
All species	-1.249	0.002	2.339	0.000109	0.229	31.312
Epiphytic	-5.056	-0.000429	1.898	0.000035	0.223	21.322
Epiphytic or lithophytic	-3.330	0.002	0.386	-0.000000	0.267	5.282
Epiphytic or terrestrial	-0.229	0	0.140	-0.000010	0.137	1.319
Lithophytic	-0.278	0	0.012	0.0000078	0.248	0.917
Lithophytic or terrestrial	0.934	0	-0.016	0.0000157	0.124	1.111
Saprophytic	-0.117	0	-0.005	0.0000037	0.131	0.581
Terrestrial	3.708	0.001	0.084	0.0000418	0.199	4.766
Endemic	-0.103	0	0.094	-0.0000128	0.157	0.995

4.2.4 Endemic orchid species

Endemic orchid species show hump-shaped pattern with flat crown between 700 to 1300 m a.s.l., with peaks for endemic epiphytic and terrestrial orchids at about 1100 m a.s.l. (20°C) (Fig.3b, Table). There are no records of endemic orchids above 3300 m in the region.

5. Discussion

5.1 Human impacts and habitat loss

As for orchid conservation in Myanmar, all recorded species of Orchidaceae have been legally protected by national legislation and CITES management authority of Myanmar Forest Department. But there are some major challenges on the pathway of orchid conservation in Myanmar such as few taxonomists, few financial supports and illegal wildlife trade.

A large number of orchids facing high risk of threat because of regular and rapid destruction of natural habitat by deforestation, agricultural land expansion and local ornamental orchid collection. Many species are threatened, endangered and critically endangered in the region. In addition, deforestation, a major threat to species survival,

becomes a major issue to be urgently addressed in Myanmar (FAO 2015). The extension of agricultural lands, rapid deforestation and various developmental projects directly harm the natural population of Orchids in Myanmar. So it is needs to work out the suitable conservation strategies and also to protect their survival in natural habitats.

Educational activities focused on orchid conservation (promotes their conservation) include lectures to middle school and college students, training courses and discussion meetings with NR staff and local people, an orchid photography competition, and an orchid show in Myanmar. Therefore, conservation of natural habitat is urgently necessary by means of conduction village level awareness programs by government departments and NGOs with constant affiliation with department of forest and wildlife in the regions is the only solution to save our praiseworthy Orchid diversity resources of Myanmar is vanish forever from nature.

5.2 Orchid conservation awareness

In Myanmar, orchids are usually used for ornamental purpose but rarely used for food or medicinal purpose. Historically, one orchid species (Bulbophyllum auricomum Lindl.) had been recognized as a royal flower in Myanmar during the period of Konbaung dynasty (1752-1885). Nowadays it has been recognized as one of the national flowers of Myanmar, indicating the special attention of Myanmar society on orchid (Hinsley et al., 2018). In the perception of Myanmar society, orchids are regarded as special plants and charismatic flowers for special ceremonies. As for biodiversity conservation motivations for government sectors and public sectors, orchids should be considered as flagship species for biodiversity conservation due to the high vulnerability of orchids to various threats, the contributions of orchids to human society, the global conservation concern on orchids and the special role of orchids in the perception of Myanmar society.

5.3 Contributions to biodiversity conservation

The present study contributes to biodiversity conservation in Myanmar by providing the orchid species of Myanmar orchid flora which includes the number of species and its respective distribution range in Myanmar. The result will be the backbone data for further studies on orchid flora of Myanmar.

For effective biodiversity conservation, there are two fundamental questions of species occurrence and distribution;
How does the species richness of different life forms for orchids vary with elevation?
Which factors most likely explain that elevational pattern of richness?

The present study is the attempts to answer such basic questions in order to realize effective biodiversity conservation in Myanmar. The present study results in discoveries of five new species and 30 new records for Myanmar. These discoveries also contribute to the updated checklist of Myanmar orchid flora 923 species. In the updated checklist, the number of species has increased sharply by about 110 species more than those recorded before. It is the progress in orchid studies in Myanmar and will be vital to biodiversity conservation action plans of Myanmar. In sum, the present study contributes to biodiversity conservation in Myanmar to some extent.

We amassed 3423 distribution records for 923 species from 142 genera of Orchidaceae. The collected specimens studied in this study comprised 475 species in Kachin State, 272 species in Shan state, 252 species in Chin State, 195 species in Mandalay Region, 140 species in Tanintharyi Region, 76 species in Mon State, 62 species in Sagaing Region, 8 species in Yangon Region, 26 species in Bago Region, 10 species in Naypyitaw Region, 14 species in Magway Region, 3 species in Ayeyarwady Region, 2 species in Rakhine State and 1 species in Kayah State. Of these, (364) species were epiphytes, (305) were terrestrials, and

(22) were saprophytes. We observed (1611) species (130 genera) of the family Orchidaceae with elevation record in this study. The orchid found in the lowest elevation is Acriopsis indica, at 48 m a.s.l., whereas the highest recorded is Vanda ampulacea, reported at 4700m a.s.l..

Twenty-nine orchid species are endemic to our study area (Fig. 1), fourteen of them are without elevational data and are therefore were excluded from our analysis. The majority of endemic orchids are epiphytic (nine species) followed by six terrestrial species.

5.4 Challenges for biodiversity conservation

Myanmar is making a lot of efforts at implementation of biodiversity conservation plans which cover all ecosystems of the whole country. But there are some challenges on biodiversity conservation pathway in Myanmar. It is very obvious that there are three major challenges, lack of sufficient biodiversity database, habitat loss and weakness of law enforcement.

As for biodiversity database, there is no enough well-documented database of biodiversity in Myanmar. Botanical surveys are basically needed for better understanding on Myanmar flora. Faunal surveys such as bird surveys or mammal surveys are also needed to well document the species richness and diversity across Myanmar. As there is long coastline in southern Myanmar, the coastal and marine ecosystem conservation is also needed to save coral reels, mangrove forest and its dwellers including local people. Fish resources are vital to livelihoods of local communities in riverine areas, contributing food security in those areas. To sum up, the well-documented database on biodiversity richness is essential for effective conservation in Myanmar. Thus, lack of sufficient database is recognized as a major challenge for biodiversity conservation in Myanmar.

As for habitat loss, the deforestation rate is high in Myanmar, ranked on the list of top ten countries with high deforestation rate (FAO, 2015). Under the circumstances of weak economic infrastructure, the national revenues mainly depend on its natural resources such as forest resources and mineral resources. Overlogging in past decades drives the natural forests into degraded forests and consequently leads to habitat loss for most native species. In addition, the plantation forest areas increase for compensation of degraded forests. Initially, it is promising signal of increasing plantation forest areas in Myanmar. But the substitution of existing natural forests (perhaps economically less desirable species) with commercial plantation forests becomes a major threat for habitat conservation in Myanmar. For example, such substitution leads to habitat loss for wild elephants in Bago Yoma area where there were once rich in teak trees but now depleted in natural teak trees. Expansion of crop land areas is also major threat for habitat conservation in Myanmar. Substitution of natural forests with rubber or oil palm plantations is a major threat for habitat conservation in southern Myanmar. Human settlements in natural forestland become a major issue to be addressed for habitat conservation. In Myanmar, there are many underlying, even interlinked, root causes of habitat loss to be addressed in appropriate way.

As for law enforcement, the national peace-making process plays a key role in rule of law across Myanmar. Despite legislation of wildlife conservation law and its related civil laws, the law enforcement is still in question across Myanmar, especially in borderline and remote areas. It is obvious that illegal logging or black markets for timber are the common breach of forest law across Myanmar. Undocumented or invisible wildlife trade might remain alive along the borderline areas. The weak rule of law is still a big challenge for law enforcement in Myanmar.

Despite these three major challenges to confront for biodiversity conservation, lots of effort has been making for biodiversity conservation programs in Myanmar, in cooperation with international biodiversity conservation and research institutions. To address these three issues, there are some promising signals in Myanmar.

6. Conclusion

The present study is the preliminary step into future orchid studies in Myanmar, with contributions to both floristic studies of Myanmar and biodiversity conservation of Myanmar. The present study provides the updated checklist of Myanmar orchid flora which provides the number of species, its local distribution ranges and respective conservation status. The present study is mainly based on my own collections of specimens, herbarium specimen sheets available, relevant literature and online databases.

The present study will contribute to Flora of Myanmar Project recently launched by Myanmar Forest Department, jointly with international research institutions. It will also provide the updated data on Myanmar orchid flora so as to guide conservation actions in future. The followings are recommendations to better understand the orchid biodiversity of Myanmar;

1. Much more botanical collections and explorations are needed to better understand the orchid biodiversity of Myanmar.
2. Capacity building of human resources, especially plant taxonomists, should be accelerated in cooperation with international research institutions such as Southeast Asia Biodiversity Research Institute, Chinese Academy of Sciences (CAS-SEABRI).
3. Herbaria in Myanmar, especially herbarium (RAF) in Forest Research Institute, should be paid special attentions and should be upgraded with proper funding and efficient human resources such as skillful curators (Figure 5.1).
4. International cooperation of biodiversity research and conservation should be accelerated so as to better understand the biodiversity of Myanmar.
5. National budgetary allocations should be paid more attentions on biodiversity research and conservation.

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