Specimen management of the genus *Lygodium* (Pteridophytes) in the biota collection room, Universitas Indonesia (ruang koleksi biota UI/RKB UI), Depok

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Abstract. Herbarium specimens play an extra role nowadays. Aside from its traditional taxonomic function, they are also an important data source for ecology, ethnobotany, mapping, and biogeography studies. In modern herbarium management, the specimens have been made more accessible to society through the digitizing process so that all specimens act as learning media. The University of Indonesia collection room or Ruang Koleksi Biota Universitas Indonesia (RKB UI) harbor spirit collections, carpology, and dried herbarium specimens collected from various student activities in botanical studies. In this study, *Lygodium* collection in RKB UI is revitalized. This study aims to revitalize all specimens with three steps of workflows, (1) Re-examining all taxonomical properties (taxonomic validation), (2) repairing herbarium sheets, and (3) digitizing all specimens (documentation and databasing). All 86 specimens recorded as *Lygodium flexuosum*, *Lygodium scandens*, *Lygodium circinnatum*, *Lygodium microphyllum*, *Lygodium sp.*, and unidentified specimens were successfully re-identified into 3 species *Lygodium flexuosum* (L) Sw., *Lygodium microphyllum* (Cav.) R.Br., *Lygodium circinnatum* (Burm. F) Sw. Validation resulted in the moving of 80 specimens formerly placed in Schizaeaceae into Lygodiaceae, while 6 remaining specimens did not receive any validation treatment. All but one specimen has been improved into a representative specimen (one specimen already in good condition). Digitizing was done by documenting each photographed specimen, recording all taxonomical data in a worksheet, and storing both documents as a database on the RKB UI website.

1. Introduction

Herbarium can have several meanings in the botanical field. The herbarium as an institution is a building that housed dried plant specimens, carpology collections, and herbarium spirit collections [1] [2]. Herbarium also means an object, a specimen of preserved plants, either as dried or wet collections. The development of science has made herbarium specimens a source of information on the morphological characteristics of a plant, its ecological preference, and a reference in identification, taxonomic revision, anatomical characters, species molecular data such as a variation on interspecific, chemical analysis, and reference of soil science [3]. With the help of information and technology, plants' information exploration was made possible without being limited by space and time. Specimen information in digital...
format can support large-scale details such as mapping the distribution of species, the biodiversity of a species, invasive plant species, and an ecosystem's environmental conditions [4].

A valid and reliable specimen collection is crucial for a collection institution such as Herbarium. Herbarium management is needed in maintaining valid, complete, and accurate specimen information, especially if it will be stored in digital form. Digital herbarium will have a broader impact in research in various botanical studies [5]. Management consists of several stages, starting from specimen observation, validation to improve both label information and specimen condition [6].

Herbarium Depokensis (DEP) is a part of the University of Indonesia Biota Collection Room (RKBUI) and is a growing small university herbarium. Herbarium DEP harbors a total of 2,225 herbarium sheets, mostly specimens collected from the University's area and surrounding and students' botanical excursion. These specimens will be introduced globally through digital media. It is intended that the information from the specimens in RKBUI can be accessed by any level of society, as a learning media or as complementary information. One fern genus kept as collections are Lygodium, a member of the family Lygodiaceae, Pteridophyte. Members of Lygodium have characteristic features: rhizome creeping, surface densely covered with multisepalate hairs; primary rachis branches dormant, short, on apices are covered with hairs; secondary rachis branches appear opposite (twining rachis) [7]. Lygodium is pantropic in nature, which is distributed from Southeast Asia to Central America. Indonesia is one of the areas where Lygodium is found, including Lygodium circinatum, Lygodium flexuosum, Lygodium japonicum, Lygodium longifolium, and lygodium microphyllum [8-9].

The condition of Lygodium specimens in herbarium DEP has not received proper handling. Based on the preliminary observations, 86 copies of Lygodium specimens were recorded, showing 1 Lygodium circinatum specimen, 3 Lygodium microphyllum specimens, 17 Lygodium sp. specimens, 6 Lygodium scandens specimens, 58 Lygodium flexuosum specimens, and one unidentified specimen with characters resembling the Lygodium genus. The specimens' observed condition included unrepresentative appearance and damage to the specimens, either only in a few parts or as a whole.

Management work for all Lygodium specimens is needed to build a reliable and reachable collection. A work in nomenclature validation, specimen revitalization, and digitalization of all specimens will be made herbarium DEP moving into a modern herbarium. Digitalized specimens can be accessed publicly. Thus, it will have a broader impact on society. This study aims to revitalize all Lygodium specimens and construct a database for all Lygodium taxonomical data as an initial step to develop a modern herbarium.

2. Material and methods

2.1. Taxonomic validation

All 86 specimens labeled as Lygodium spp. consisted of 1 sheet of Lygodium circinatum, 3 sheets of Lygodium microphyllum, 17 sheets of Lygodium sp., 6 sheets of Lygodium scandens, 58 sheets of Lygodium flexuosum; we also included 1 sheet unidentified with close appearance to Lygodium flexuosum. Morphological observation on all specimens conducted to group specimens based on their morphological similarities and dissimilarities. Characters used in the observation were rhizome (surface ornament), stipe (surface ornament), frond (times branching), rachis branch (ornaments), and leaflets (shape, apex, margin, base, sorophore) following Holtum [10]. We add secondary branches ornament as seen in specimens.

Specimens in the group were identified into genus and species level by comparing morphological characteristics using references from Holtum [10] and plant databases websites such as Tropicos, Plant Of The World (POWO), Kew Herbarium Catalogue, and International Plant Name Index (IPNI). Nomenclature validation regarding the valid and accepted name and synonyms will follow IPNI, POWO, and Smith [7]. The identification results were used to update taxonomical information included in all herbarium sheets labels.

2.2. Herbarium restoration

Herbarium restoration was carried out through 3 stages, (1) label's information editing, (2) specimen's physical reparation, and (3) specimen's digitalization based on [11-12]. Digitalization started with
digitalizing all specimen sheets using a DSLR camera Canon EOS500D, Copy stand, Dino-Lite Edge Digital Microscope AM4115ZT, and lighting. All taxonomical and support information stated in the label were transferred into an excel worksheet. All digitized herbarium specimens and taxonomical data were uploaded to construct a database of Ruang Koleksi Biota/RKB UI's website http://ruangkoleksibiotaui.id/.

3. Results and discussion

3.1. Taxonomic validation

Based on our extensive examination, all specimens are confirmed to belong to Lygodium. All specimens exhibit main characters for Lygodium: rhizome short, creeping beneath the soil surface, surface covered with stiff multisepate hairs; young fronds are rigid, branches dichotomy one to two times; mature frond consists of primary rachis branches and secondary rachis branches; primary rachis branches dormant, at the apices, are covered with hairs; secondary rachis branches appear opposite (twinning rachis), bear leaflets on each branch; the margins of leaflets are flat (integer) or serrated (serrate), and fertile leaflets have narrow lamina due to sorophores’ presence. These characters were confirmed to belong to Lygodium.

We made 3 groups of Lygodium after a thorough examination of all specimens. Group 1 consists of 81 specimens with characters referred to as L. flexuosum. Group 2 consisted of 3 specimens with characters that resembled L. microphyllum, and group 3 only consisted of 1 specimen showing the character of L. circinnatum. One unidentified specimen was included in group 1 as it resembles the character of L. flexuosum: secondary rachis branch ornament with hair; leaflets palmate, edge serrate to bisserate, apex generally acute to acuminate, and base auriculate. Observation resulted in a matrix of diagnostic characters for each species and here presented in Table 1.

Diagnostic characters differentiating the three species are primary rachis branches ornament color, secondary rachis branches ornament, leaflets size, shape, and margin of leaflets. Primary rachis branches hair in L. flexuosum are cinnamon, terracotta in L. microphyllum, and beige in L. circinnatum. Secondary rachis branches ornament was only found in L. flexuosum in short hairs < 2 mm. Leaflets in L. circinnatum and L. flexuosum are palmate, L. microphyllum has leaflets ovate. Leaflets margin in L. flexuosum is serrate to bisserate, serrate in L. microphyllum, and integer in L. circinnatum. The leaflets’ length from the longest to the shortest of the three species was shown, leaflets of L. microphyllum with a range of 0.2-2.6 cm, leaflets of L. flexuosum with a variety of 0.3-13.8 cm, and leaflets of L. circinnatum 8-19 cm long. Based on these characters, there are 2 different characters from the book Flora of China, including the color of the primary rachis branches and secondary rachis branches surface ornament. We found character variation in primary rachis branches surface ornament different from Xianchun’s study [13]: the hair of L. flexuosum is pale brown, L. microphyllum is golden to reddish, L. circinnatum is pale. Meanwhile, we found L. flexuosum with primary rachis branches cinnamon, terracotta in L. microphyllum, and beige in L. circinnatum. Another character found in our collections is hairs in the secondary rachis branch, in L. flexuosum < 2mm (Figure 4a).

Short descriptions of Lygodium species:

Lygodium flexuosum
Rhizome creeping, thick, covered with black hairs < 2mm; Stipe smooth surface; young fronds dichotomy two to three-time, branch bear one leaflet; apical dormant primary rachis branches covered with hairs < 2 mm cinnamon; secondary rachis branches appear opposite, surface covered with hairs < 2mm, each branch carries 3-7 leaflets; sterile leaflet consists of 3-5 lobes, palmatisect,0.3-13.8 cm long, 0.2-2.2 cm wide; the apex of the leaflets vary from acute, acuminate, obtuse, and are sometimes to be emarginate, retuse, and bilobed; the margins of sterile and fertile leaflets serrate to biserrate.

Lygodium microphyllum
Rhizome creeping, short, covered by hairs < 1 mm; stipe grows on the surface of the rhizome with a glabrous surface; The frond is dichotomized two times; the apical of the primary rachis branches dormant, covered with terracotta (brownish) hairs < 2 mm; secondary rachis branches appear opposite,
bear leaflets; leaflets ovate, 0.2-2.6 cm long and 0.2-1 cm wide, margin crenate, base truncate to auriculate, apex variation from acute, obtuse, and sometimes retuse.

*Lygodium circinnatum*
Rhizome surface covered with black hairs <1 mm, the surface of the stipe hairless; frond dichotomized two times; primary rachis branches surface covered by beige hairs ~<2mm; secondary rachis branches appear opposite and glabrous surface, each branch bear leaflets palmatisect with 4-5 lobes, base cuneate and sometimes asymmetrical, margins integer and thickened, 8-19 cm long and 0.5-3 cm wide, base obtuse and acute.

### 3.2. Nomenclature validation

The validation process has mainly resulted in 2 parts. First, the alteration of all written as *Lygodium* in 80 specimens as members of Schizaeaceae to *Lygodiaceae* (Table 2). These shifts were based on the work of Smith [7]. In his work, *lygodium* was excluded from forming separate families based on morphological and molecular data. Second, specimens under *Lygodium scandens* were changed to *L. flexuosum*, as the former name is a synonym Xianchun [13].

The entire *Lygodium* herbarium only consisted of 3 groups identified as *L. circinnatum*, *L. microphyllum*, and *L. flexuosum*. The initial identification results of *L. circinnatum* and *L. microphyllum* were correct, so the nomenclature did not change for the two species. Other specimens named *Lygodium* sp., *L. scandens*, and unidentified specimens were initially identified as *L. flexuosum*. *Lygodium scandens* are no longer an accepted name and synonym to *L. flexuosum* [13]. We checked all the specimens' characters and confirmed to place formerly named *L. scandens* to *L. flexuosum* group.

Specimen marked as *Lygodium* were identified as *L. flexuosum* because we observed characters belong to *L. flexuosum*: leaflets palmate, margin bisserate, with variation in the apex (acuminate, emarginate, retuses, bilobed). Holtum's [10] put *Lygodium* as a genus of the Schizaeaceae family. In his work, Smith [7], *Lygodium* was excluded from schizaeaceae and made a new family Lygodiaceae based on morphological characters and molecular data.

### 3.3. Herbarium restoration

Physical observation on all specimens showed that 59% was in poor condition (physical damage), 40% in a good physical condition (but poor label quality), and only 1% was in representative condition (good physical condition and good label quality) (Figure 1).

The most problem founded on specimens is physical damage. Most of the specimens were damage in terms of having fragile parts, lots of holes, and specimens decolouring. Factors causing damage to come from the herbarium collection process. We only cut the part of the leave with holes. Specimens with loose parts and brittle repaired by gluing using acid-free glue, tape and tightened the thick part into the sheets [14]. Changes in colors and white spots of all parts are due to mold and cleaned using a soft brush dipped in given 95% ethanol [15].
| Group/Spesies | Surface ornament | Frond Branching | Stipe Rachis | Leaflet | Size | Sorophore (present/not present) | Length (cm) | Width (cm) |
|--------------|------------------|----------------|--------------|---------|------|-----------------------------|-------------|-----------|
| Group 1      |                  |                |              |         |      |                             |             |           |
| *Lygodium flexuosum* | black hair < 1 mm | -              | dichotomy 2-3 times | Cinnamon (yellowish brown) hairs < 2 mm | short hairs < 2 mm | palmatisect serrate to bisserate | generally acute, acuminate and obtuse. Sometimes emerginate, retuse and bilobed | generally auriculate, sometimes oblique and asymmetric | present | 0.3-13.8 | 0.2-2.2 |
| Group 2      |                  |                |              |         |      |                             |             |           |
| *Lygodium microphyllum* | black hair < 1 mm | -              | dichotomy 2 times | terracotta (brownish) hairs < 2 mm | - | ovate crenate | generally acute and obtuse, sometimes retuse | truncate to auriculate | present | 0.2-2.6 | 0.2-1 |
| Group 3      |                  |                |              |         |      |                             |             |           |
| *Lygodium circinatum* | black hair < 1 mm | -              | dichotomy 2 times | beige (very pale creamy brown) hairs < 2 mm | - | palmatisect entire | obtuse, acute | Cuneate asymmetrical | not observed | 8.0 - 19 | 0.5-3 |
Table 2. Changes in taxa's position during validation process revision

| No. | Species                                   | Number of specimens | data before validation | After data validation results |
|-----|-------------------------------------------|---------------------|------------------------|-----------------------------|
|     |                                           |                     | Schizaeaceae | Lygodiaceae | Schizaeaceae | Lygodiaceae |
| 1   | Lygodium circinnatum (Burm.f.) Sw.        | 1                   | -           | 1           | -            | 1           |
| 2   | Lygodium microphyllum (Cav.) R. Br.       | 3                   | -           | 3           | -            | 3           |
| 3   | Lygodium flexuosum (L.) Sw.               | 82                  | 80          | 2           | -            | 82          |
| 4   | Unidentified                              | 1                   | -           | -           | -            | 1           |

Poor label quality was the second most problem found in specimens. We detected labels' appearance, incomplete species information, invalid species name, and old label. Old labels were replaced with a new one and rewrite all taxonomic data. Labels with incomplete species information are corrected with a new label, rewrite all information, and add species information. Invalid species name on the label, we changed information based on nomenclature validation and revision performed earlier than written on the revision label (figure 1). We also made changes in the way we attach the label. Only the right side of the label was glued to keep all characters visible and easy to examine. (Figure 2).

3.4. Digitalization of specimens
The digitalization process resulted in a database of taxonomy data and photographed herbarium (Figure 3). All taxonomy and nomenclature validation were transferred into an excel format database. The information included in the excel database was aligned with the data needed for the database in the website: family, genera, species, collector, number collection, year, date, determination, vernacular name, island, location, habitat, notes, and condition.
On the website added some photos diagnostic characters such as the sorophore’s, rhizome surface ornament, primary rachis branches surface ornament, and secondary rachis branches surface ornament were documented using Dino-lite microscope (Figure 4).

All data were then uploaded to the RKB UI website page. Successfully uploaded data were then confirmed by typing one taxa name in the search engine feature (Figure 5a). Searching will provide a result page containing all uploaded data consisting of specimen ID, collection number, collector, family, genus, species, local name, location, specimen photo, and taxonomic information (Figure 5b). To view all photos provided, we can choose the ‘camera’ icon (Figure 5c). To see nomenclature validation, we can choose and ‘taxonomic information’ (Figure 5d).

**Figure 3.** Photos of Lygodium spp. specimens. (a) Lygodium flexuosum, (b) Lygodium microphyllum, (c) Lygodium circinnatum

**Figure 4.** Results of the Dino-Lite microscope documentations: (a) secondary rachis branch surface ornament Lygodium flexuosum, (b) Lygodium rhizome surface ornament, (c) the appearance of the sorophore Lygodium microphyllum, (d) Lygodium primary rachis branch surface ornament

**Figure 5.** Features in RKB UI database website: (a) search engine display, (b) search results display, (c) digital photo, (d) specimen label information
4. Conclusion

All specimen sheets named under *Lygodium* and other specimens that resembled *Lygodium* were confirmed to belong to one genus *Lygodium* (Lygodiaceae). There were 3 groups of species identified as *Lygodium flexuosum* (L) Sw., *Lygodium microphyllum* (Cav.) R.Br., *Lygodium circinnatum* (Burm. F) Sw. Diagnostic characters differentiated the three species are: primary rachis branches ornament color, secondary rachis branches ornament, leaflets (shape, margin, and length). Nomenclature validation and specimen documentation resulted in a piece of confirmed and valid information for all specimens. Digitalization of all specimens was uploaded as the main input resource to construct a comprehensive database herbarium in an herbarium website.

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