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Biological collections are a vital resource of information to guide conservation and research.

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Keywords – Belgian natural history collections, biodiversity, birds, conservation, Africa.

Summary – Belgian federal museums contain very important zoological collections, many of tropical origin. Their type specimens have a permanently important status for taxonomic research. Less well known is that aspects of the biology of certain rare species (often never studied in nature) can be deduced from the study of the "old" specimens (including the non-types). Those series must therefore be retained. This is shown on the basis of African birds from the Royal Museum for Central Africa. Classical methods are used: morphology, moult study and historical range and altitudinal analysis. The importance of such information when defining protected areas and designating new research zones is demonstrated, with the African Albertine Rift as example.

Trefwoorden – Belgische natuurhistorische verzamelingen, biodiversiteit, vogels, natuurbehoud, Afrika.

Samenvatting – Informatie over de biologie, afgeleid uit museum-specimens.

Belgische federale musea herbergen zeer belangrijke zoölogische verzamelingen, vaak van tropische herkomst. Hun type-exemplaren hebben een permanente belangrijke status voor taxonomisch onderzoek. Minder bekend is dat aspecten van de biologie van bepaalde zeldzame soorten (vaak nooit in de vrije natuur bestudeerd) kunnen worden afgeleid uit studie van "oude" specimens (inbegrepen de niet-types). Die reeksen moeten daarom behouden blijven. Dit wordt aangetoond aan de hand van Afrikaanse vogels uit het Koninklijk Museum voor Midden-Afrika. Er wordt gebruik gemaakt van klassieke methodes: morfologie, ruistudie en historische areaal-analyse (inbegrepen hoogte). Het belang voor afbakening van beschermde zones en aanduiding van nieuwe onderzoekzones wordt aangetoond voor de Afrikaanse Albertine Rift.

Résumé – Information sur la biologie, obtenue de spécimens dans les musées.

Mots-Clés – Collections d'histoire naturelle belges, biodiversité, oiseaux, conservation, Afrique.

De très importantes collections zoologiques, souvent d'origine tropicale, sont conservées dans les musées fédéraux en Belgique. Leurs spécimens-types ont un statut important permanent pour la recherche taxonomique. Il est moins connu que des aspects de la biologie de certaines espèces rares (souvent jamais étudiés dans le milieu naturel) peuvent être dérivés de l'étude de spécimens « anciens » (y compris les non-types). Ces séries doivent donc être maintenues. Nous démontrons ceci par des exemples parmi les oiseaux africains au Musée Royal de l'Afrique Centrale en utilisant des méthodes classiques : analyse de la morphologie, de la mue et de distribution géographique et altitudinale historique. L'importance pour la délimitation de zones protégées et l'indication de nouvelles zones de recherche est démontrée pour le Rift Albertin en Afrique.

Introduction

Zoological specimens, historically at first treated as curiosa, became later incorporated in Natural History Collections (NHC). These are important for their holdings of types. In biology, a type is a particular specimen (or a group of specimens) to which the scientific name of that organism is formally attached. According to a precise set of rules laid down in the International Code of Zoological Nomenclature and the International Code of Nomenclature for algae, fungi, and plants, the scientific name of every taxon is almost always based on one particular specimen, or in some cases specimens. Types are of great significance to biologists, especially to taxonomists. Types are usually physical specimens that are kept in a museum or herbarium research collection, but failing that, an image of an individual of that taxon has sometimes been designated as a type. Describing species and appointing type specimens is part of scientific nomenclature and alpha taxonomy. Before the word "biodiversity" became fashionable, perhaps until twenty years ago (see Rappé and Robbrecht 1999, 2000), it was unusual to publicise the discovery of new animal species; the description of the type was made in a scientific journal, types were deposited as required by the taxonomic rules, and the event was hardly known to the general public.

Of course, the NHC also contain many "non-types". There is a long-established traditional use of collections whereby both types and non-types are also used for non-taxonomic purposes, such as identification, education, and material for illustrations; furthermore NHC specimens are much used to prepare revisions, monographs, fauna's and flora's. The NHC worldwide allow us to make verifiable identifications of animals and plants. My purpose in this paper is to demonstrate the less well-known potential use of zoological collections. Biological information as yet unobserved in the wild and potential applications (e.g. for conservation), resulting from the metadata, are the topics explored.

Belgian zoological collections and their ornithological component

There are two major Federal Scientific Institutions (FSI) containing zoological material in Belgium; the botanical collections, for which the Botanical Garden in Meise is the leading institution, will not be discussed here. The oldest FSI is the Royal Belgian Institute of Natural Sciences) in Brussels (RBINS); its origins date back to the Brussels City Museum. According to the website https://www.naturalsciences.be/en/science/home , it houses 38 million scientific specimens (all disciplines included), with a worldwide scope. Bird specimens from about 1800 are present, and many collected in the National Parks in DR Congo and Rwanda during the colonial period. In 1898, the 'Belgian Congo Museum' was founded, later called the Royal Museum for Central Africa (RMCA), at Tervuren, which has an exclusively African collection. According to the website http://www.africamuseum.be/en/research/collections_libraries/biology/collections , the RMCA holds 10 million zoological specimens (among which 153,343 birds: Louette et al. 2010). They represent circa 125,000 African animal species and include the type material for 26,615 insects, 543 fishes, 104 reptiles, 81 amphibians, 227 birds and 36 mammals.

Because of the colonial history (and later on, active surveys in several tropical countries), the Belgian NHC hold many African specimens; e.g. the ornithological collections of RBINS and RMCA combined contain 155,000 specimens from the DR Congo (Sonet et al. 2011). As mentioned, some of this material was taken in National Parks and biological hotspots, but a great many of the birds in the RMCA were obtained outside those areas, in a haphazard way, which, in retrospect, was fortunate because the general distribution of animals can be deduced from such data.

The bird collection of the two Belgian FSI combined places them in second position – according to numbers of bird specimens – among European NHC, and in sixth place in a worldwide census

(Roselaar 2003). Most of the bird specimens are study skins (in a study skin almost all of the body inside the skin is removed and replaced with cotton so that the final result resembles a bird lying on its back with its wings folded); some material is preserved in alcohol and the odd specimen is dried formalin preserved. The number of mounted specimens is insignificant (a few of the older skins were at first mounted for public exhibition and later dismounted). Recently, these "old" FSI specimens became the source of tissue for molecular phylogenetic study, to complement traditional taxonomy in taxa that are morphologically difficult to delimit. Indeed, feathers still can yield some DNA after > 50 years, but toepads (skin scraping from the specimen's foot) give the best results. Some remarkable taxonomical conclusions have been based on molecular data from the FSI bird collections (see e.g. Sonet et al. 2011, Breman et al. 2013). It is very likely that other techniques exploiting preserved specimens will be developed over time.

Biological information and taxonomy

The RMCA holds type material for 227 nominal bird taxa; at least 124 of these are still in use as valid names (Louette et al. 2010). Amongst them are some singleton type specimens that may well represent valid biological species. Can we learn something about the biology of these birds merely by studying these study skins?

The biology of a fair number of African bird species is known thanks to observations in the field (birds in general are among the best known animals in nature), but some of the RMCA types are of species not known in life. A case in point is Prigogine's Nightjar *Caprimulgus prigoginei*, known from only 1 (female) specimen collected in 1955 in the Itombwe mountain range in South Kivu (DR Congo) (Louette 1990). The bird was never seen in the flesh again; some sounds were recorded that may or may not be of this species. Dowsett-Lemaire & Dowsett (2000) thought they heard it near the type locality in 1996 and supposedly in Congo-Brazzaville in 1997. But what we do know, is that, because of the long rictal bristles, it must be not closely related to the subfamily Chordeilinae and was indeed placed in the Caprimulginae by Cleere (1999). Jackson (2009) studied primary emargination (a characteristic in the wing) in all Afrotropical nightjars; his study confirms the placement of *prigoginei* in the genus *Caprimulgus*, and its biology can be supposed to be comparable to other nightjars in the genus that are generally ground-dwelling; it certainly does not belong in the more arboreal African (subgenus) *Veles*.

Biological information from functional morphology study

Moult study (the pattern of feather replacement) can yield information on the acquisition of adult (= sexual) plumage, timing and duration of breeding episodes, but also on the physical condition of the individual (Pyle 2005). In temperate Accipitriform raptors, these aspects have been studied directly; the sequence, duration and timing of their flight and tail feather moult process are also known. It is tempting to start from there and to speculate on the biological meaning of moult patterns in the tropical congeners, as deduced from specimens. In the small species with an annual moult, one may assume that this comparison is plausible. This would not be the case for large species, with more complex patterns, e.g. flight feathers that are being retained for more than one year. Two cases of raptor biology, based on moult study of museum specimens will be discussed here.

1. Double-brooding in the Black Sparrowhawk *Accipiter melanoleucus*

In an adult raptor, moult stage is closely related to the timing of reproduction. The annual moult of the primary remiges (long feathers on the hand; generally 10), starts at about the beginning of the annual breeding cycle. Because moult proceeds descendantly (= outwards) from the innermost primary (P1) in Accipitriformes, the position of the moult wave indicates the phase in the breeding cycle. Usually (with one breeding episode per year), this moult wave is completed in about five-six months in small species of raptors, including the whole genus *Accipiter*. Very few raptor species are known to breed twice in one year (e.g. Black-shouldered Kite *Elanus caeruleus*, an opportunistic breeder during rodent outbreaks with the strategy of successive polyandry does so: Mendelsohn 1989) and almost none in tropical regions. However, occasional double-brooding was demonstrated in *Accipiter melanoleucus* in the temperate climate of South Africa: Curtis et al. 2005). This rapid sequence of breeding events results in serial moult, which means that another wave of primary replacement is beginning at P1, while the previous wave is not yet finished (Herremans 2000). The serial descendant moult patterns found in *Accipiter melanoleucus* specimens from DR Congo (Louette 2006 a, 2010, see Figure 1) indicates also occasional double brooding in tropical Central Africa.

Figure 1

However, one should pay attention to the symmetry of this moult pattern. Of course, an asymmetrical pattern could be due to accidental replacement of feathers (which is sometimes obvious in the museum specimens). Some of the patterns found in particular specimens are so complicated that it is unlikely that these would relate to multiple breeding attempts in rapid succession, and an accidental loss of primary remiges should be considered (Louette & Herroelen 2007).

2. Condition in the Long-tailed Hawk *Urotriorchis macrourus*

Few references are made to the occurrence of asymmetrical moult. The standard general work on raptor moult (Stresemann & Stresemann 1960) says "symmetry in remiges is the rule"; these authors found much more asymmetry in the rectrices (large tail feathers, usually 12). Possibly asymmetry in this feather tract is less crucial for the flying performance of the bird than it is in the remiges. However, in *Urotriorchis macrourus* tail moult is striking: the (brown) juvenile central rectrix pair is replaced by the piebald new generation (= first generation adult) even before body feather and primary remex moult start, but in an asymmetrical way. In the later moult episodes, i.e. when fully adult, tail feather replacement is a permanent ongoing process, largely asymmetrical, particularly in the central two pairs. This means that one feather of a pair always a fresh contrasting appearance, which may help in signalling status and/or sexual attraction (Louette 2009, 2010). This is interpreted as being most likely a signal of the individual's status as a high ranking individual in intraspecific competition and as a potential high-quality breeder.

<u>Biological information from range and altitudinal mapping: importance for conservation</u>

1. The geographical distribution of the Lufira Masked Weaver *Ploceus ruweti*

For many years the status of *Ploceus ruweti*, described from the unique male type specimen, obtained in 1960 at Lake Tshangalele (an artificial impoundment on the Lufira River) in Katanga, DR Congo, remained obscure. In this case, the type locality being situated in man-made habitat, the question of the bird's requirements needed study. Was it present at this locality before the lake was created? In 2009, the type locality was revisited and weavers breeding there photographed (including females and young birds), and their song recorded; nests and eggs were described for the first time (Louette & Hasson 2009) and tissue was collected for taxonomical study. In subsequent years, the species was found also about 60 km downstream along the Lufira River, proving that the geographical region and not the micro-habitat of an artificial lake was the determinant factor for its presence. Its restricted distribution is matched by three allospecies of this weaver in the valleys of other river-systems in Katanga (Katanga Masked Weaver *Ploceus katangae*, Upemba Masked Weaver *Ploceus upembae* and Reichard's Weaver *Ploceus reichardi*), which are separated from one another by unsuitable habitat (Craig et al. 2011). The molecular phylogeny of this large genus is still incomplete but *ruweti* was found to be very similar to its allospecies.

2. The altitudinal distribution of Albertine Rift bird endemics

The Albertine Rift in DR Congo is a prime area of endemicity in Africa with two World Heritage Sites (Virunga & Kahuzi-Biega) and a potential third one (Itombwe); it is home to 41 endemic bird species and is considered data-deficient (Birdlife International 2018). Among the different massifs of the chain, Itombwe supports the highest number of endemic bird species, but it is unprotected and conservation initiatives are needed urgently (Bober et al. 2001).

In colonial times, 43,000 birds were collected in the Albertine Rift for the RMCA (Louette 2006 b), including 2,372 specimens of endemic bird taxa. When these data are analysed, they indicate (historical) geographical distribution ranges. Naturally the altitudinal distribution of the endemic birds needs to be taken into account for determination of the importance of each site, and thus for the answer to the question: "what parts of the Albertine Rift hosted most endemics, and should be included in a newly designed park (if the habitat persists)?" The specimens are the main (sometimes the only) source for that purpose. Modelling distribution ranges can be done combining:

- abiotic factors derived from geographical profiles (topography, climate, soil, hydrology ...)

- biotic factors derived from ecological species profiles (vegetation, habitat preference, correlations between presence/absence of other species, specific food or reproductive requirements, movements ...)

A conservation status assessment could be made in the future, by comparisons between historical range or modelled range and present-day distribution (when recent field data become available) or habitat availability from satellite images.

Figures 2 and 3

The results of such an analysis are illustrated here for just one of those bird species, Yellow-crested Helmetshrike *Prionops alberti*, an endemic bird of the Albertine Rift (see account in Herremans et al. 2004, 2006, and see Figures 2 and 3). This bird is most common at rather high altitudes (especially 1700-2100m a.s.l.), but sometimes descends below the montane limit of 1500 m a.s.l and is thus apparently somewhat eurytopic, This may reflect seasonal movements (altitudinal migration). The type was obtained at very high altitude (4.467 m a.s.l.) in apparently unsuitable habitat, showing that information from the type alone may sometimes be misleading!

A general conclusion (full results in Plumptre et al. 2007): contrary to expectations for a montane region, 14 of the 19 Albertine Rift endemics with small ranges are restricted to, or have strongholds in lower-altitude forests (see Figure 4). Particularly the forests at intermediate altitude (800-2,000 m a.s.l.) to the West of the Albertine Rift are of utmost importance to the survival of endemics, but these are the most accessible and most affected by deforestation. The analyses show a trend for endemic birds with smaller ranges to occupy a smaller altitudinal belt in the transitional and lower montane forests, rather low on the mountains.

Figure 4

Conclusion and future prospects

The NHC in the Belgian FSI contain much irreplaceable biodiversity information. The value of types in general has long been accepted and the need for continued taxonomical research is emphasized in a number of important papers; see for a compilation, 19 papers in Godfray & Knapp (2004). The additional value of zoological specimens for specific scientific enquiries is demonstrated here, with a few examples concerning the biology of some bird species. Furthermore, I indicate the potential importance of these existing collections for biodiversity conservation. It is clear that NHC are sources of data that can strongly complement ongoing research. Whereas very few field surveys have operated for more than a few decades, NHC contain samples extending over many years, spanning the period of accelerated anthropogenic habitat destruction, and thus reflecting baseline conditions before its major impact (Lister et al. 2011). Worldwide information from all NHC is becoming increasingly available over the Internet. This should extend the utility of NHC data by further developing methods and statistics related to biogeography, ecology and evolution. We can expect novel insights into how historical environmental, geographical and ecological factors have influenced the distribution of biodiversity and how best to conserve it (Graham et al. 2004).

At this point, I would like to direct the reader, who would be tempted to ask the question "why do birds matter?" to a recent overview by Sekercioglu et al. (2016), who showed that birds are important components of the world's ecosystems, and they contribute both ecological and cultural services. Birds are also have inherent biological and methodological advantages for biodiversity study; they can be bioindicators (Temple & Wiens 1989). But Beale (2018) has demonstrated that there are still notable gaps in taxonomic, geographic and thematic coverage in African ornithological research. So inevitably, we have to answer the question: "is there need for more collecting?" In spite of 250 years of taxonomic classification and over 1.2 million species (of many organisms) already catalogued in a central database maintained by the National Center for Biotechnology Information, results suggest that some 86% of existing species on earth and 91% of species in the ocean still await description (Mora et al. 2011). Even for birds, supposedly well-known, the inventory is not complete; each year a number of new valid species are described, in total no less than 288 new species since 1960 (Brewer 2018). Nowadays, DNA can be collected (e.g. from droplets of blood), without damaging the individual bird, which can be released, and must not be killed. However, the correct identification needs to be made (photographs and measurements may not in every case be reliable), and therefore a restricted number of specimens should still be taken. This reasoning is prone to much debate, following the publication of arguments pro collecting by Remsen (1995); see for a long list of scientists in favour: Rocha et al. (2014).

What about the future for the Belgian NHC? Although there can be no doubt that they have to be cared for in an appropriate way, this future is not guaranteed; several reasons for vigilance can be enumerated:

- Budget cuts in FSI, resulting especially in non-replacement of retiring scientists. Formerly, the scientists working on these NHC were assigned "to maintain the collection, to expand and to publish scientific articles based on it", but there is nowadays a tendency to split these tasks diminishing significantly the number of zoologists and to employ instead a few "collection managers".
- Series of non-types in the NHC are sometimes regarded by non-specialists as less important, asking "is it useful to conserve those in numbers?" As I demonstrated above, these specimens equally need great care (some of them - we do not yet know which ones - could become types in the future!): they certainly cannot be considered as 'duplicates'. A whole series of zoological specimens is necessary to demonstrate age variation, sex variation, geographical variation, and, for birds in particular, moult stage and other inter-annual variation, and finally migration.
- Collection-based research is perhaps not "sexy" at the moment in Belgium, contra some other countries, such as the USA; see a recent overview for mammals by McLean et al. (2016).

A final point: should the historical collections be returned to their country of origin? This question has been asked for some time and the present RMCA director has made the position clear (Gryseels 2004). It is fair to say that until recently, many countries in the tropics did not have the infrastructure, finances and the know-how to care for zoological specimens in an appropriate way. Since a few years, however, in the DR Congo, the “Centre de Surveillance de la Biodiversité” at Kisangani University has developed capacity in collection care (see https://centresurveillancebiodiversite.org/), and future collections from that country could be deposited there.

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Figure 1.

Wing and tail moult diagram of adult Black Sparrowhawk *Accipiter melanoleucus*, specimen RMCA 74.44.A 139 (Kivu, DR Congo, October 1945), showing serial descendant primary remiges moult, dorsal view. One moult wave has arrived at P8 (near tip), another wave has started (P1, P2 growing left side, P1 growing right side). Primary remiges are counted outwards from the marker. Dotted feather = old feather; blank = new feather. Growing feathers are drawn according to their real size. Wing span approximately 105 cm.

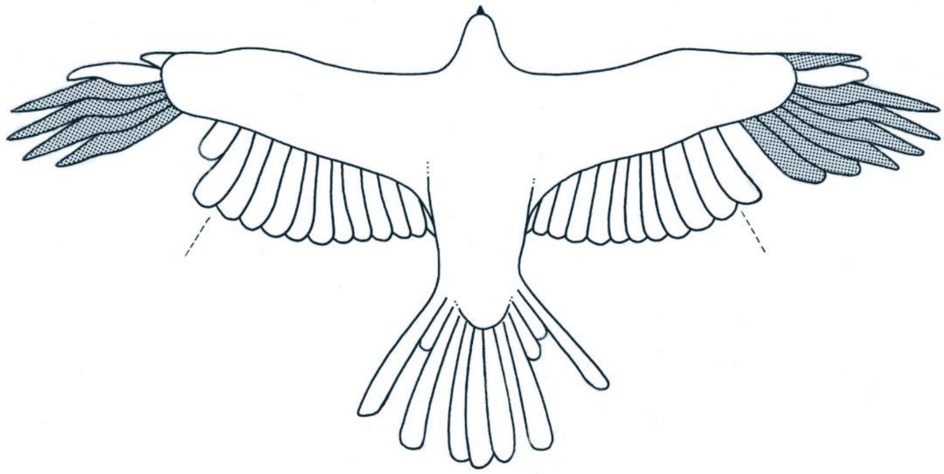

Figure 2.

World distribution of Yellow-crested Helmetshrike *Prionops alberti*, indicating localities for RMCA specimens (Great Lakes region) and photograph of type in RMCA.


Prionops alberti
Loc. Nyawaronga
Dat. 26-2-1959
Coll. Prigogine
No
♀

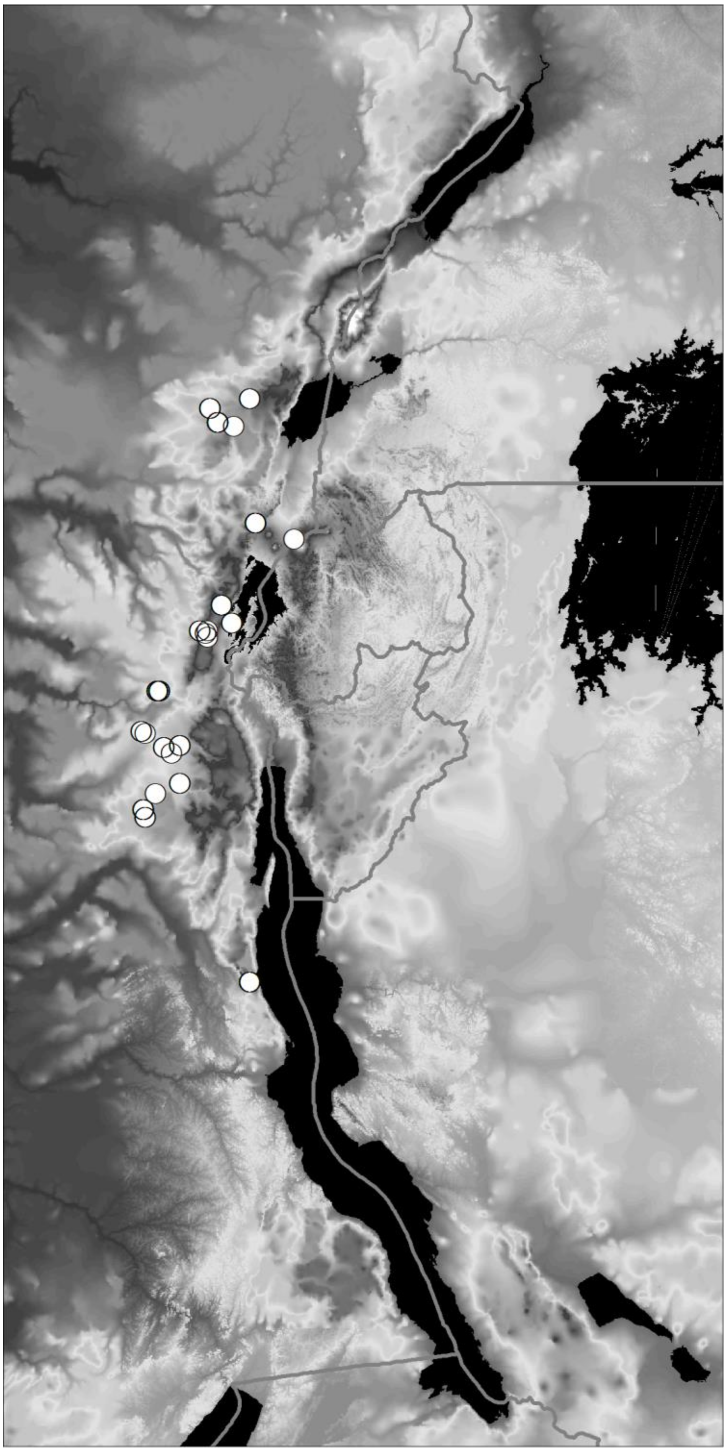

Figure 3.

Altitudinal profile of Yellow-crested Helmetshrike *Prionops alberti* specimen localities in relation to land surface size and total specimen sampling.

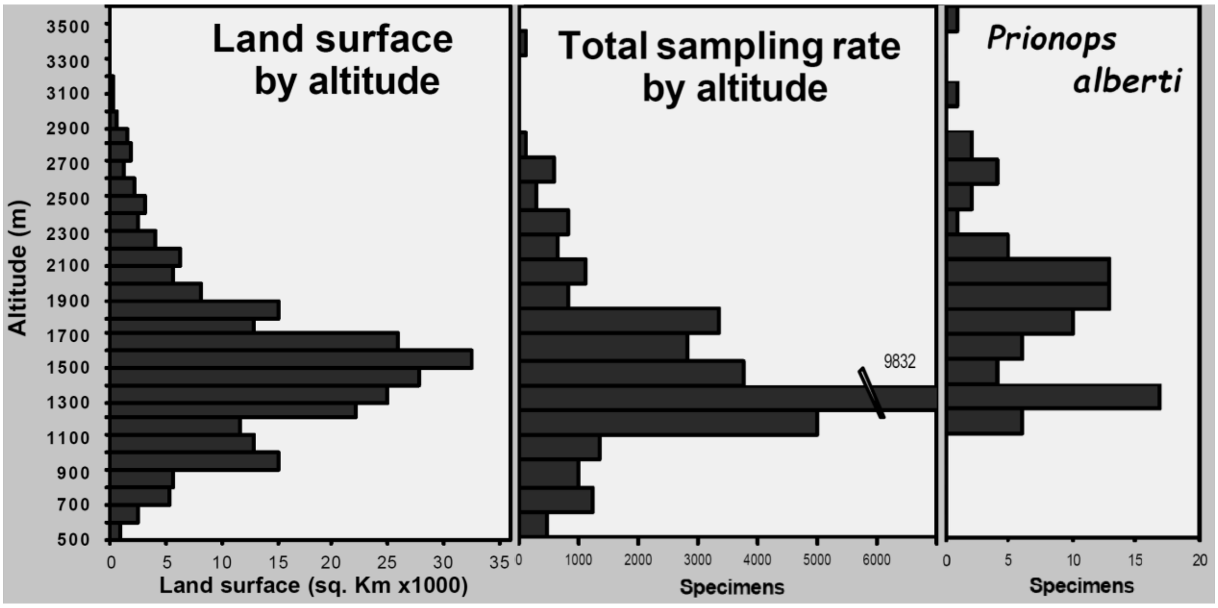

Figure 4.

Albertine rift endemic bird species (each dot represents one species): analyses show a trend for endemic species with smaller ranges to occupy a smaller altitudinal belt in the transitional and lower montane forests, and significantly low down on the mountains (full details and list of bird species concerned in Plumptre et al. 2007).