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The Past and Future of the University of Bordeaux's Bird Skeleton Reference Collection

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ABSTRACT— The PACEA laboratory at the University of Bordeaux houses a collection of a little over a thousand of bird skeletons, including specimens from Europe and the French West Indies. The collection started in the 1950s to support the lab's various research projects. In recent years, the rhythm of acquisitions has accelerated due to the development of new research topics and a collective investment in managing the collection. Since its creation, the priorities of collection have shifted from a pure focus on osteology to the recording of detailed biological and contextual information for each specimen. This evolution reflects the succession of various research topics carried out in the lab: determining the paleoenvironmental context of fossil specimens, avian zooarchaeozoology, and more recently, changes in Caribbean bird communities through time. over the next few years, our aim is to publish the collection in biodiversity databases, such as VertNet and gBIF, include virtual specimens (digital models based on high-resolution X-Ray tomography) in the collection, and expand inter-institutional exchanges.

Key words: Archaeozoology, Birds, Osteology, Palaeoecology, Taphonomy.

RESUME— Une collection de squelettes d'oiseaux au laboratoire PACEA de l'université de Bordeaux, pour quoi faire ? Le laboratoire PACEA de l'Université de Bordeaux possède une collection d'un peu plus d'un millier de squelettes d'oiseaux, documentant des taxons européens et antillais. Cette collection a été initiée dans les années 50 en soutien de l'activité de recherche des membres du laboratoire. Le rythme d'acquisition des spécimens s'est accru ces dernières années, en relation avec l'apparition de nouveaux sujets de recherche et d'une gestion collective de la collection. De sa création à aujourd'hui, la collection est passée du concept de spécimen ostéologique à celui de spécimen biologique et les informations contextuelles des individus collectés sont renseignées. Cette évolution reflète la succession de différentes thématiques de recherche : détermination des spécimens fossiles dans une perspective paléoenvironnementale, archéozoologie aviaire et, plus récemment, étude des modifications dans le temps des communautés aviaires caribéennes. Les objectifs d'évolution future de la collection sont le reversement du catalogue et des données d'occurrence dans les inventaires internationaux des collections muséales (Vertnet et GBIF), le développement des échanges inter-institutions et l'archivage en collection des spécimens virtuels issus d'une modélisation par tomographie RX de spécimens muséaux.

Mots-clés : Archéozoologie, Oiseaux, Ostéologie, Paléoécologie, Taphonomie.

The European Bird Curator Congress in Paris provided a unique opportunity to present the PACEA reference collection of bird skeletons to researchers working on paleo-ornithology. This collection comprises over a thousand osteological specimens and documents avifauna from France and its overseas territories (i.e. Guadeloupe, Martinique, etc.). Here we present an assessment of the collection designed to identify the motives that led the PACEA research laboratory to devote what were sometimes relatively considerable resources to maintain and develop an osteological collection of birds.

Considering the age-old separation between regional museums and universities in France, it should come of no surprise that the collection lacks any specific mission statement concerning its accessibility to the public or heritage preservation. In this respect, the objectives of this collection differ from those typical of museum collections, meaning that the most appropriate way to present our laboratory's unique approach to this substantial avian reference collection is to trace its evolution over time.

The inception of the collection parallels the development of French universities following the Second World War. Built over a period of about sixty years, which is a relatively short span of time compared to most museum collections, the collection represents a significant investment for a research laboratory. The emergence of new research objectives over this period inevitably enlarged the scope of the collection. The development of the PACEA avian collection can be divided into three distinct stages:

- an initial focus on palaeontology and paleoenvironments,
- followed by the investigation of processes influencing the preservation of avifauna accumulations in archaeological sites and the role of birds in the prehistoric diet,
- and current work devoted to West Indian avian communities and their evolution.

This distinction is somewhat artificial in the sense that, while rapid changes in the way the collection was built or managed certainly existed, new research objectives nevertheless drew upon previous results. With that said, a clear link is evident between the development of new research objectives, policies concerning the acquisition of new specimens, and the overall management of the collection. In fact, each of the three periods in the development of the collection arrived at a different solution to this equation.

Here we investigate the influence of rainfall regime and differing forested habitats on the demographic patterns of this invasive rodent on Guadeloupe during the wet and dry seasons based on data collected from trapped black rats. We hypothesize that forested habitats with marked hydric seasonality should support more variable black rat populations whose size varies seasonally compared with the climatically more stable forested habitats.

The 1950s to 1980s: Creation of the osteological collection

The avifauna collection of the Bordeaux University is rooted in the teaching of prehistory, which began with the creation of a university degree in Prehistory and Anthropology by G. Malvesin-Favre in 1951, followed by the founding of the Laboratory of Anthropology and Prehistory a few years later in 1954. Malvesin-Favre, a lecturer in botany, was also a passionate archaeologist and a member of the Bordeaux Archaeological Society since 1918. The laboratory he established was successively known as the Prehistory Laboratory (1956), the Laboratory of Prehistory and Quaternary Geology (1959), the Quaternary Institute (1968), the Institute of Prehistory and Quaternary Geology (1993) before becoming the PACEA (*de la Préhistoire à l'Actuel, Culture, Environnements, Anthropologie*) laboratory in 2003.

The beginning of the collection coincided with the founding of the laboratory, and initially comprised specimens purchased from French *naturalia* shops (Boubée et cie, Auzoux, Deyrolle, Schluter) with the aim of supporting teaching. Details of the original collection resembled a Prévert-

style inventory - eagle (*Aquila* sp.) and hawk (*Accipiter* sp.) leg bones and skulls are recorded alongside a series of prehistoric human skulls and two fossil Orangutan teeth.

As members of the laboratory began to undertake numerous excavations at sites in southwestern France, particularly in the Les Eyzies region, the priorities of the collection changed direction. These field projects, particularly the famous work of F. Bordes from the 1950s to the 1970s, in no small part helped forge the laboratory's reputation. This work also helped establish the Palaeolithic cultural succession in south-western France over the past 100,000 years (Delpech & Jaubert, 2011).

These excavations produced rich assemblages of flint artefacts as well as abundant faunal remains, highlighting the necessity of developing an osteological reference collection for faunal analyses. This collection included the skeletons of large and small mammals, a few amphibians and reptiles, and birds.

Moreover, since its creation and due to it being part of the Faculty of Sciences, the laboratory developed a multidisciplinary research project combining prehistory, geology, palaeobotany and palaeontology in order to trace the trajectory of human evolution and its environmental backdrop. The reconstruction of ancient fauna and their evolution was itself a major research topic for the laboratory (e.g. Prat, 1966a, b, c), with osteology playing an essential role in this research (e.g. Prat, 1957). Thus, from the 1950s to about the 1990s, faunal analysis carried out at the laboratory primarily concerned regional prehistoric sites and focused on aspects of paleontology and the reconstruction of paleoenvironments. This research focused on documenting the biological evolution of animals, reconstructing past animal communities, establishing a relative chronology of sites, and determining the environmental conditions in which prehistoric hunter-gatherers lived.

From this point onwards, birds regularly figured on published fauna lists, such as for the Late Glacial fauna from the site of Gare de Couze in the Dordogne, where F. Prat (1962) initially identified Snowy Owl *Bubo scandiacus* and Willow Ptarmigan *Lagopus lagopus*, and F. Delpech (1967) added a curlew (*Numenius* sp.), Blackbird *Turdus merula*, Redwing *Turdus iliacus* and Eurasian Nuthatch *Sitta europaea*. The identifications of these species aided in reconstructing palaeoenvironmental conditions that prevailed during the formation of the site. For example, the predominance of Snowy Owls in the bird assemblage indicated the occupation of the site to have coincided with cold climatic conditions (Arctic tundra). This example equally illustrates the necessity of determining as many species as possible, from passerines to large raptors, when reconstructing paleoenvironments.

During this period, the first evidence for human modification of bird bones also emerged in the form of the intentionally sawn-off ends of a tibiotarsus from the large Pleistocene Crane *Grus primigenia* at the site of Duruthy in the Les Landes department (Delpech, 1968). However, traces of human modifications on bird bones were not systematically investigated, as it will become the case with the development of zooarchaeology.

In addition to the purchase of specimens, the growth of the collection was largely due to accidental discoveries by members of the laboratory, mainly F. Prat and F. Delpech, as well as the donations of old collections, such as the one from the Bordeaux Zoological Institute (Armand et al., 2015). The re-use of stuffed specimens and the recycling of waste from taxidermists were also largely responsible for increasing the taxonomic diversity of the collection. Consequently, a significant portion of the collection from this period consists of incomplete skeletons (Fig. 1). By the mid-1990s, the osteological collection comprised nearly 400 complete and incomplete individuals, the large majority of which remained European specimens (Fig. 2).



Figure 1. Partial specimens recovered from taxidermists. Left: partial skeleton (wings and skull) of Short-toed Snake-Eagle, *Circaetus gallicus* (PACEA-O-46) obtained by recycling a stuffed specimen. Right: postcranial axial skeleton of an individual of the same species (PACEA-O-246) obtained by recovering naturalization by-products.

Caractère partiel des spécimens issus de la taxidermie. Gauche : squelette partiel de Circaète Jean-le-Blanc, *Circaetus gallicus* (PACEA-O-46) obtenu par recyclage d'un spécimen naturalisé et documentant les membres et le crâne de l'oiseau. Droite : squelette partiel d'un individu de la même espèce (PACEA-O-246), obtenu par récupération des sous-produits de naturalisation et documentant le squelette axial post-crânien.

It is important to note that the constitution of this “initial” collection essentially took place prior to the development of legislation targeting wildlife conservation. As a result, no specific procedures were followed to trace the origin of skeletons and, although a typewritten inventory exists for the purpose of managing the collection, it does not establish the legal origin of the specimens. Moreover, information concerning the geographical origin and biological characteristics (maturity, sex) of the specimens are not provided. The overall lack of archival information accompanying the acquisitions means that very little documentation is available for this older collection.

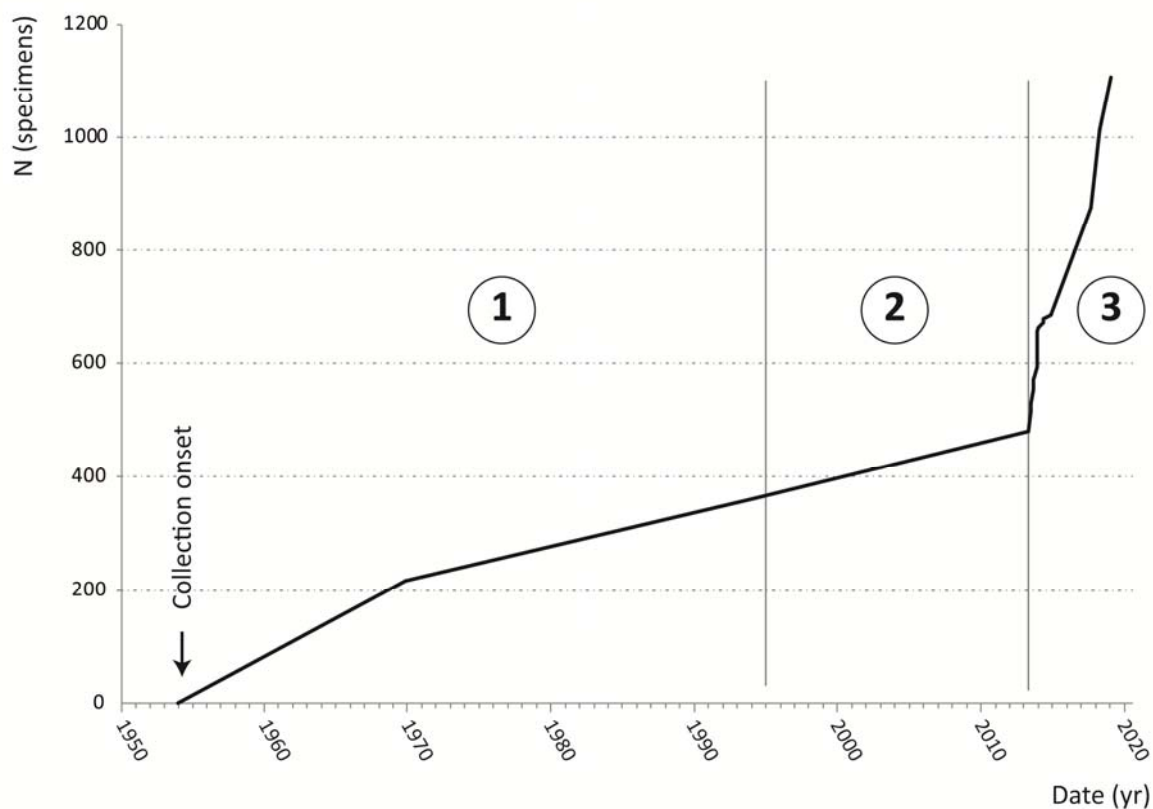


Figure 2. Growth of the bird skeleton collection since the founding of the PACEA laboratory in 1954. The three periods of the collection constitution are shown on the graph: 1 = 1950s to 1980s; 2 = 1990s to 2010s; 3 = 2010s to present.

Accroissement de la collection d'ostéologie aviaire au cours du temps, depuis la constitution du laboratoire PACEA (1954) jusqu'à aujourd'hui. Les trois périodes de constitution de la collection sont identifiées sur la figure : 1 = années 50 à 80, 2 = années 90 à 2010, 3 = années 2010 à aujourd'hui.

1990s to 2010s: Zooarchaeology and Taphonomy

In the 1990s, the development of zooarchaeological (e.g. Chaix & Ménéral, 1996; Kenneth, 1996) and taphonomic approaches (e.g. Behrensmeyer & Hill, 1988; Lyman, 1994) underlay the emergence of new research themes. During this period, several of the laboratory's projects focused explicitly on avian remains, with the related goals of investigating site formation processes (i.e. distinguishing the role of humans and natural processes in the accumulation of faunal assemblages) and documenting the relationship between humans and birds. This latter aspect concerned both determining the species exploited by prehistoric groups and for what ends (food, the creation of tools or personal ornaments).

This new period is equally reflected in the completion of university dissertations focusing on avian remains (Laroulandie, 2000) and the subsequent recruitment of an ornitho-zooarchaeologist who supervises master's theses on the taphonomy and archaeozoology of bird remains (e.g. Le Bail, 2005; Bouchard, 2007). This work primarily concerns the Palaeolithic of southern France.

Western palearctic avifauna, particularly boreal taxa well represented in prehistoric sites, remained poorly documented in the bird skeleton collection of this period. This period prioritized the acquisition of complete skeletons, which are particularly important, as zooarchaeological and taphonomic studies require the largest possible sample of bones collected during excavations to be identified (Peres, 2010; Lefebvre & Sharpe, 2018). A recent study of Snowy Owl bones (*B. scandiacus*)



Figure 3. Human and non-human modifications on bird humerus; a) fracturation and bilateral beak impacts on a pigeon humerus observed in modern *Bubo bubo* pellets, b) beak impact on a pigeon humerus in modern food remains of *Falco peregrinus*; c) experimental crushing, notching and tearing on *Perdrix perdix* produced during the disarticulation of the elbow; d) archaeological crushing, notching and tearing on *Lagopus* sp. from the Magdalenian site of La Vache (France).

Modifications humaines et naturelles d'humérus d'oiseau ; a) impact bilatéral de bec et fracturation d'humérus de pigeon issu de pelotes de régurgitation de *Bubo bubo*, b) impact de bec sur humérus de pigeon dans des restes alimentaires actuels de *Falco peregrinus* ; c) écrasement expérimental, arrachement et encoches obtenus expérimentalement par désarticulation d'aile de *Perdrix perdix* ; d) écrasement, arrachement et encoches observés sur des restes archéologiques de *Lagopus* sp. du site magdalénien de La Vache (France).

from the Gare de Couze is an instructive example. The anatomical representation of the skeletal elements of this taxon reveals an over-representation of the terminal and penultimate phalanx. This data, combined with the presence of cut-marks referable to disarticulation, not only supports a human origin for the accumulation but also makes it possible to explore why and how Late Glacial hunter-gatherers used these elements (Le Bail, 2005; Laroulandie, 2009).

The general improvement of the osteological collection was not the only motivation for acquiring new bird specimens. There was equally the need to (a) build taphonomic reference collections documenting bone damage produced by different agents involved in the formation of fossil assemblages (*e.g.* Laroulandie, 2002) and (b) carry out butchery and disarticulation experiments designed to aid zooarchaeological interpretations (Fig. 3, see also Laroulandie, 2005).

This period also saw the development of legislation to protect and preserve wild species (CITES and French laws for the protection of wildlife). The acquisition of several specimens missing from the collection required authorizations that involved a substantial time investment and legal expertise. As it stands, obtaining these authorizations somewhat hindered the ambitious goals for growing the avifauna collections. However, a ministerial authorization obtained in 1998 allowed the transport and possession of protected wild specimens from animal welfare centres to the laboratory.

Despite these issues, about a hundred new specimens were added to the collection (Anatidae, Columbids, Tytonids, Passerines), mainly species recovered from France. However, species that may have been present during glacial periods remained poorly represented, meaning that the analysis of avifaunal assemblages from Palaeolithic sites in Western Europe could only be carried out by consulting comparative material housed at the French National Museum in Paris.

The 2010s: Palaecological issues

New research topics have been addressed at PACEA over the past decade, including the evolution and structure of bird communities in relation to natural or human-induced environmental changes, temporal variations in the distribution of taxa, and morphological modifications of these species. The emergence of a more ecology-based approach is highlighted by the Bivaag (2013-2015: *Biodiversité insulaire vertébrée ancienne de l'archipel de Guadeloupe*) and ECSIT (2016-2020: *Écosystèmes insulaires tropicaux, réponse de la biocénose vertébrée terrestre à 6 000 ans d'anthropisation du milieu*) projects that focus on the French West Indies.

These projects have produced evidence for a high number of extinct reptile (Bailon *et al.*, 2015), mammal (Stoetzel *et al.*, 2016) and bird species from several contexts in the West Indies. A preliminary analysis of the bird bones collected from palaeontological and archaeological sites on the Guadeloupe islands documented two extinct species, the Macaw (*Ara cf. guadeloupensis*) and a Barn Owl (*Tyto* sp.), and 11 species extirpated from one or more islands: the Black-capped Petrel *Pterodroma hasitata*, three Rallidae (*Porphyrio martinica*; *Porzana flaviventer*, *Laterallus cf. jamaicensis*), the Burrowing Owl *Athene cunicularia*, the Swainson's Hawk *Buteo swainsoni*, a nighthawk of the genus *Anthrostromus*, two Turdidae (*Turdus lherminieri* and *Turdus cf. nudigensis*), and two mimids (*Cinlocerthia ruficauda*, *Mimus gundlachii*). Moreover, these now-extinct taxa suggest a significant turnover of island birds over the past 15,000 years. The presence of several fossil-bearing caves on Marie-Galante currently makes it the best documented context. On this island, nearly 30% of the avian taxa represented in fossil or archaeological sites are extirpated or extinct species (Gala *et al.*, 2016).

The determination of bird bones is thus at the core of a doctoral research currently being carried out at the laboratory by one of the co-authors of this paper (M.G.). However, this research requires a comprehensive comparative collection of West Indian birds, as illustrated by a previous study that demonstrated the presence of an indigenous macaw on the Guadeloupe archipelago. This was based on an ungual claw bone recovered from a Pleistocene layer preserved in one of the caves of Marie-Galante (Gala & Lenoble, 2015). The association of this extinct taxon with *Ara guadeloupensis* Clark 1905 is consistent with Clark's original description based on accounts from the European colonial

period. This demonstration required substantial comparative work based on the fossil specimen itself and *Ara* and *Amazona* skeletons from the Paris Museum and the PACEA collection. For this study, about fifteen additional psittacids specimens were added to the PACEA bird skeleton collection, all of which were donated by breeders and taxidermists.

Caribbean bird specimens are currently poorly or very partially represented in European museum collections, which meant that research in this area required the development of a dedicated osteological collection. This was made possible through financial support from associated research projects, with the improved reference collection continuing to benefit all of the laboratory's projects. The development of the reference collection first involved drawing up a list of desired taxa and contacting appropriate organisations (*i.e.* animal welfare centres, wildlife management structures, zoos or museums) susceptible to furnish the specimens. The procedures for acquiring, processing and best exploiting the new osteological material was reorganised, and laboratory staff were trained in the legal requirements for obtaining the necessary acquisition/transport/possession permits for protected specimens. To date, approximately thirty permits have been obtained for the acquisition of new specimens. In addition, the preparation of the specimens has been improved; a more rapid enzymatic maceration process has been introduced (Simonsen *et al.*, 2011), and the preparation area has been standardized and certified by the relevant health authorities.

Contextual information has also been improved and now systematically includes the geographical origin and biology of the specimens, supplemented, if necessary, by photographic evidence to document the bird's plumage. This progress emerged in parallel with the development of zooarchaeology and taphonomic analysis and reinforces the shift from an emphasis on osteological or paleontological specimens, which prevailed during the early years of the collection, to a focus on a biological specimen concept. The recording of biological information has also been enhanced; necropsies are commonly carried out, and, in the case of wild specimens and when interested research institutions have been identified, tissue samples are taken. Since 2014, some two hundred tissue samples from Caribbean birds, as well as those from the European Atlantic coast, have been sent to the Paris Museum. Finally, the collection catalog has been made entirely accessible to lab members via the laboratory's server, which allows interested researchers to contribute to the management of the catalog. A simplified version is also available to the international research community via the laboratory's website (<http://www.pacea.u-bordeaux.fr/Collection-d-anatomie-comparee.html>).

This new organization significantly increased the avifauna collection (Fig. 2). Currently, the collection consists of a little over 1,100 specimens from 25 orders dominated by passerines and Charadriiformes, followed by Columbiformes, Anseriformes and Accipitriformes, with approximately four hundred specimens, or 35% of the total collection, comprising Caribbean avifauna. As West Indian specimens are also poorly represented in Caribbean osteological collections, a portion of the collection, around a hundred bird skeletons, has been donated to the Guadeloupe Departmental Museum of Archaeology to help develop zooarchaeological and palaeobiological research.

The acquisition of West Indian specimens has thus been an important focus of the PACEA laboratory in recent years, and has resulted in a substantial collection of bird skeletons. This is particularly true for Guadeloupe, where the majority of the studied palaeontological and archaeological sites are located. Thanks to the support of governmental or public structures in the French West Indies, it has been possible to collect specimens that were poorly represented in museum collections. Of the 248 species on the list of birds from the islands of Guadeloupe, excluding introduced species, 118 are mentioned as "uncommon", "common" or "very common" in the list (Levesque & Delcroix, 2015). Three-quarters of these 118 species were acquired by the PACEA laboratory (Fig. 4).

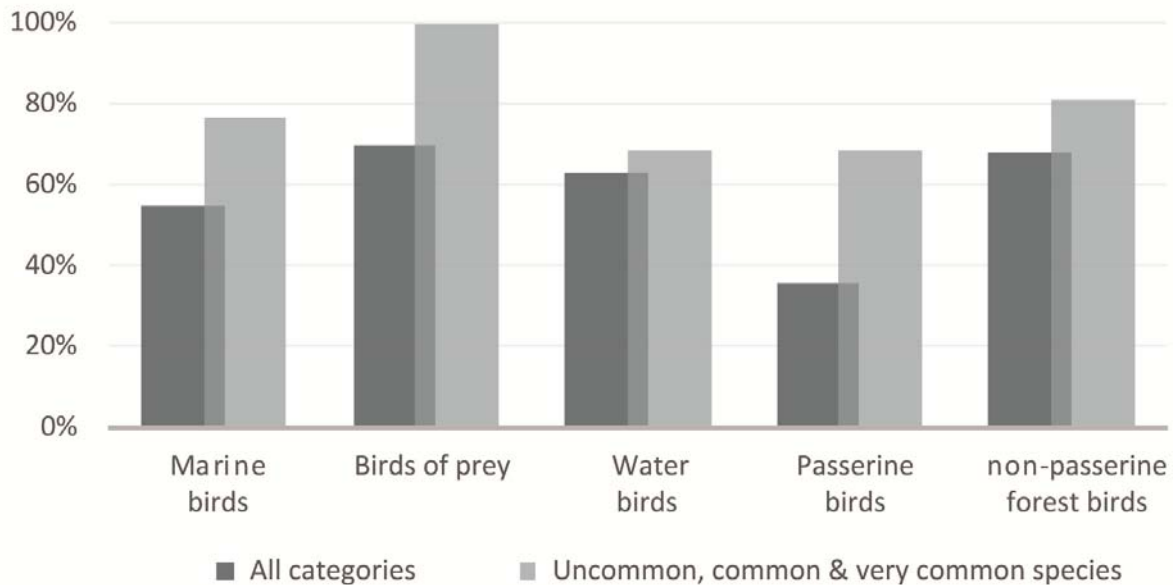


Figure 4. Representation of the Guadeloupe bird fauna in the skeleton collection of the Bordeaux University.
 Représentation de l'avifaune de Guadeloupe dans la collection ostéologique d'oiseaux de l'Université de Bordeaux.

Moreover, the Guadeloupe avifauna includes sixteen so-called “patrimonial species” that group together the endemic species of Guadeloupe with endemic species of the Eastern Caribbean. These taxa are occasionally represented in osteological collections, mainly in North America (e.g. the Smithsonian Institute, the Florida Museum or the Royal Ontario Museum). Fourteen of these sixteen species are represented in the PACEA reference collection, and, according to VertNet, skeletons of three species exists only in this collection: The Guadeloupe Woodpecker *Melanerpes herminieri*, the Forest Thrush *Turdus lherminieri*, and the Plumbeous Warbler *Setophaga plumbea*. Several species are, however, still missing from the collection, including both rare species and species currently absent from Guadeloupe but which may have been in the past, such as the Lesser Antilles Owl *Tyto insularis*, which is currently present only in Dominica and Saint Vincent, or the White-breasted Thrasher *Ramphocinclus brachyurus*, an endangered species represented by small populations on the islands of Saint Lucia and Martinique.

As the identification of extinct species involves comparing fossil remains with all specimens from a given family, or at least its Caribbean representatives, the list of essential specimens was expanded to include birds from other Caribbean islands. Overcoming this limitation required innovative solutions, for example inter-museum loans of specimens or 3D models rendered from CT-scans of specimens preserved in other establishments. This allowed the morphologies of loaned specimens to be recorded or obtain 3D models of bones from specimens that are too rare to be loaned or represented only by specimens preserved in alcohol. To date, 50 specimens from the Caribbean avifauna have been microscanned. The continuation and development of these two approaches, however, implies that the PACEA collection and studies carried out at the lab are made available to the broader community of avian collection curators

The future of the collection

The future objectives of the collection can succinctly be summed up as “accessibility, donation, and exchange”. While a web-accessible catalog, tissue donations, and the lending or exchange of

specimens with other research institutions is, of course, a promising start, much remains to be done. Improving the accessibility of the collection remains at the forefront of future objectives and includes plans for a web-based research engine as well as integrating our database in international databases, such as Vertnet or GBIF. In addition, obtaining permanent permits for the possession of protected species should entitle PACEA to a CITES exemption procedure and facilitate the loan or exchange of specimens.

A more long-term objective is the integration of the PACEA CT-scanned specimens within a national, European or international network of virtual specimens. The PACEA laboratory currently has a large sample of 'virtual' specimens that can be made available to other institutions; with the inclusion of 3D models of numerous specimens missing from our collection would be of great help to the research conducted in the laboratory. However, such an exchange network or structure is yet to be developed.

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