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The relevance of Italian museum collections for research and conservation: the case of mammals

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Abstract The twentieth century saw the decline of interest toward museum collections and an increased support to 'experimental' and 'evolutionary' biology, implicitly recognising the opposite nature of the 'old' museum-based taxonomy. With few exceptions, such as those of Florence and Verona, Italian museums after World War II were pushed at the border of scientific activity by the academic world and had to fight for their survival. Examples from the USA and elsewhere show the increased relevance of modern mammal collections to several fields of research. Despite an increased and welcomed attention to the value of historical collections, there is still scarce awareness of the need and relevance of maintaining and implementing mammal collections in museums as a valuable, long-term, source of data in the field of conservation biology, faunistic, taxonomy, molecular biology and health monitoring. In the present paper we suggest to create a network between mammalogists and a number of mammal collections, with one museum serving as focal point for a national mammal collection.

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> "noi invece non solo non aumentiamo le nostre collezioni, ma perdiamo sovente per mancanza di cura quelle che radunarono i nostri antecessori e ciò spesso in modo brutale sì che stringe il cuore".
>
> Giacomo Doria 1887
>
> "… nel quale mi parto dal concetto che 'ogni soggetto' dei nostri musei debba essere 'messo in valore' per il difficile compito della sistematica mammalogica".
>
> Oscar de Beaux 1917

1 Introduction

In 2011, the discovery that a neglected 'jackal' taxon of North-East Africa was in fact a wolf-like canid with a wider distribution (Rueness et al. 2011) provoked huge interest in the world's media and evidenced one more time how much remains to be discovered of our unique biological planetary heritage, even in the field of large mammals systematics. Incidentally, the more complete series of specimens belonging to the African wolf *Canis lupaster* Hemprich et Ehrenberg, 1833, is probably housed in the Museum of Natural History of Genoa. In fact, several specimens were collected in 1927 by Carlo Confalonieri during the Scientific Expedition to the Oasi of Giarabub, Libya (de Beaux 1929). As pointed out elsewhere, the taxonomic history of *lupaster* is quite illustrative of how mammalian systematic has been approached for most of

the twentieth century (Gippoliti and Groves 2012; Cotterill et al. 2014).

2 Research and mammal collections

Nowadays, the scientific importance of museum collections in biodiversity research, outside the traditional discipline of taxonomy, is widely recognised (Suarez and Tsutsui 2004; Winker 2004). Museum data represent, with some limitations, the main tool to adequately map species' distribution range and understand their response to environmental changes (Newbold 2010). For some little-known taxa, museum specimens offer unique data for understanding the ecological preferences of a species, as has been done with African forest genets *Genetta* spp. (Gaubert et al. 2006).

Moreover, information from museum collections is becoming increasingly available over the Internet. These data, when integrated with spatial environmental data, can be used to study a broad range of topics, from ecology and evolution, to issues concerning applied conservation, agriculture and human health (Graham et al. 2004). One of the foremost databases is provided by the global biodiversity information facility (GBIF) which allows free access to digitized biological data from different sources. A particular strength of GBIF is its easy combination with species distribution modelling (SDM), where potential ranges of species are predicted from climate-based correlations (Beck et al. 2013).

Notwithstanding the possible shortcomings, such as the taxonomic inaccuracies (Graham et al. 2004), deriving from using museum collections for SDM, this approach has a great potential even for those species whose biology and distribution are not completely known (Papes and Gaubert 2007). Moreover, it permits to estimate the extinction risk from species-occurrence data by means of the population viability analysis (PVA) that estimates the population growth terms and the quasi-extinction risk (Skarpaas and Stabbetorp 2011).

The advancement of taxonomy and the discovery of new species often make voucher specimens the only source of accurate distribution data. In Italy, this is the case for the members of the genus *Sorex* and *Crocidura* and many others (Reutter et al. 2003). Without museum collections, the efficacy of biodiversity inventories and mapping, as requested by the Convention on Biodiversity, is ill-founded (Latella 2007). The validity of Atlas projects is also enhanced by the vouchers preserved in natural history collections (Battisti et al. 2012) and the historical data allow a better understanding of the trends in the abundance and decline of certain species (Pergams and Nyberg 2001). Furthermore, historical series are unique resources to asses microevolutionary processes (Pergams and Lawler 2009; Tomassini et al. 2014).

Historical museum specimens proved to be extremely useful in several other instances, for example in demonstrating the species status of *Canis rufus* in south eastern North America (Nowak 1992). Osteological museum material was instrumental to assess the health status of an endangered small population of *Puma concolor* living in Florida before restocking (Duckler and Van Valkenburgh 1998). Another strong evidence of the unique properties and value of museum historical specimens came from a study of a particular retrovirus (KoRV) through the study of koala specimens dating back some 120 years (Ávila-Arcos et al. 2012).

Finally, apart from the vast amount of morphological data stored in museum specimens, molecular studies offer an opportunity to uncover much of the geographical and temporal genetic variation hold in them (Bi et al. 2013). The study of the Sunda colugo *Galeopterus variegatus* (Mason et al. 2011) is representative of this point. However, genetic studies of historical museum specimens typically rely on extracting highly degraded and chemically modified DNA samples from skins, skulls or other dried samples. Up to the present time, it was possible to obtain only short fragments of DNA sequences using traditional PCR amplification. Recently, approaches using high-throughput next-generation sequencing to obtain reliable genome-scale sequence data have been proposed (e.g., Rowe et al. 2011). Such technique allows to obtain data of single-nucleotide polymorphisms (SNPs) or the complete mitochondrial genome sequences even from difficult source materials. The biological material used for the DNA extraction has been reduced to as little as 10 mg with high success rate. This is particularly important for museum scientists, as it removes the need for destructive tooth or bone sampling (Guschanski et al. 2013; Wandeler et al. 2007).

3 Mammal taxonomy today

The increased number of mammalian species discovered and accepted in the past two decades (Reeder et al. 2007) calls into question the amount of knowledge we hold to effectively manage even the most visible part of global biodiversity. To overthrow the 'taxonomic bias', molecular methods became widely use in mammal taxonomy, especially in those groups, such as rodents and bats, that supposedly have a large number of morphological cryptic species. Some researchers relied upon DNA barcoding (Hebert et al. 2003) to verify taxonomic assignments and to discover cryptic diversity in morphologically uniform and taxonomically understudied mammal groups (Borisenko et al. 2008). However, in some cases the identification of recently diverged species using

DNA barcodes has been reported to be problematic due to the lack of the "barcoding gap" as a result of the overlapping of intra- and inter-specific genetic distances (van Velzen et al. 2012). Other authors, mainly to address the limitation of the biological species concept (BSC) and to overcome the difficulties of an operative use of the BSC, adopted either a genetic or a phylogenetic species concept (Baker and Bradley 2006; Cotterill et al. 2014). However, the use of inadequate markers may lead researcher to erroneous taxonomic conclusion. The case of brown bear *Ursus arctos* is emblematic. On the basis of the mitochondrial DNA (mtDNA) analysis, such taxon resulted paraphyletic (Talbot and Shields 1996) due to the fact that polar bears root within brown bear. A more recent analysis based on a larger number of multilocus genomic markers (Hailer et al. 2012) shed a new light on the taxonomic status of *U. arctos* supporting its monophyletic status. Thus, despite DNA data are becoming increasingly important in mammalian taxonomy, they are not a panacea for species delimitation. The DNA analysis maximum potential is more likely to emerge when combined with other types of data in an integrative approach to taxonomy (McDonough et al. 2008). New and powerful morphometric tools are provided by the noteworthy discipline called geometric morphometrics, which is showing a fast growing interest among mammal experts. In Italy it was spread thanks to Dr. Marco Corti's pioneering studies on small mammals (Loy 2007). Museum collections are thus essential tools to understand the true taxonomic meaning of genetic discontinuity, often identified by phylogeographic studies (Amori et al. 2009) but hardly translated, especially in Western Europe, in formal taxonomic decisions.

4 Relevance of taxonomy for conservation strategies

From the publication of the classic paper on *Sphenodon* taxonomy and its conservation consequences (Daugherty et al. 1990), the importance of taxonomy for conservation policies and legislation has always been clear (McNeely 2002). Species names are the currency for conservation policy (Dubois 2003), and there have been several instances of biologists asked to furnish information on the taxonomy of protected taxa in judicial courts, especially in the USA (Geist 1992; O'Brien and Mayr 1991).

However, the scientific and conservation communities were unprepared to tackle the alpha diversity explosion in vertebrate species that is now occurring and coined the term 'taxonomic inflation' for the (apparently) unjustified raising of 'subspecies' to species status (Isaac et al. 2004; Meiri and Mace 2007; Zachos et al. 2013). While it is obvious that the adoption of different species' concepts (among researchers, regions, taxonomic groups, etc.) has a series of consequences for comparative biology and conservation sciences (Agapow et al. 2004), it is equally obvious that a single concept cannot be imposed on taxonomists and the only solution is to consider their expertise and opinions from the beginning of the entire conservation assessment. Furthermore, as stressed by Gippoliti et al. (2013), intraspecific variability was already a goal of conservation biology, so theoretically, nothing should change if the Sumatran tiger would be considered a separate ESU (evolutionary significant unit) or a full species as *Panthera sumatrae* (but see Gippoliti and Amori 2007). On the contrary, the consequences of failures in species recognition for identifying biodiversity hotspots and ecological modelling exercises seem to have been scarcely investigated. The differences in ecology, physiology and range size of such cryptic species led to underestimate species extinction rate and undermines much of current research modelling concerning the effects of global warming on biodiversity (Bernardo 2011).

Should Palacios (1996) have had no access to the nineteenth century hare specimens collected in Italy and stored in a few Italian—mainly Florence, where the "Italian Vertebrate Collection" was assembled by Enrico Giglioli (1845–1909)—and foreign museums, he would have missed the opportunity to re-evaluate the taxonomic status of *Lepus corsicanus* De Winton 1898, an Italian endemic species. This species, as others, fell victims to the 'new systematic' (Huxley 1940; Mayr 1942), typified by the synthesis proposed by Ellerman and Morrison-Scott (1951) for Palearctic and Indian mammals who "set the tone" of mammal taxonomy for the next 50 years (Gippoliti and Groves 2012). Restocking of game species utilising stocks from a wide geographic range, encouraged by this new taxonomic approach emphasizing the polytypic species concept, led to the introduction of non-native genepools of game species all over Europe, thus making historical collections particularly valuable to understand the original phylogenetic structure of the native species.

In the last decades phylogeographic studies, which primary focus is not taxonomy, raised a new attention on the taxonomic re-evaluation of divergent lineages. In some cases mtDNA research evidenced cryptic diversity as a first step in the recognition—or better, revaluation—of new species in the Old Continent, as in the case of *Microtus levernedii* (Paupério et al. 2012) a species, previously included in *M. agrestis*, also occurring in Italy. It should be pointed out that the efficacy of such studies for taxonomy is greatly enhanced by the preservation of voucher specimens in public collections (Puillandre et al. 2012).

In other cases, however, the information gathered from the study of museum specimens concerning the evolutionary status of a particular population is not always concordant with molecular data. A study of Apennine brown bear skulls using a geometric morphometric

approach evidenced a large phenotypic gap between the relict population of central Italy and other brown bear populations (from northern Italy, Croatia and Bulgaria) belonging to the same mitochondrial lineage (Colangelo et al. 2012), and greatly enhanced the conservation relevance of this relict population.

5 Italian mammal collections

In Italy, museum collections had apparently a difficult history from the beginning (Doria 1887). However, thanks mainly to the museums of Genoa and Turin, between the end of the nineteenth century and the beginning of twentieth century, a valuable activity of collecting and research was undertaken especially in Eastern Africa, South America, South-East Asia and New Guinea. In the same period, following the beginning of the Italian colonial policy, some Italian natural history museums showed an increased interest in biological collecting. Mammalogical materials were studied by Italian researchers such as Giacomo Doria, Enrico Festa and Lorenzo Camerano and famous foreign mammalogists such as Peters, Dobson, Andersen and Oldfield Thomas. But at the beginning of the twentieth century experimental biologists saw natural history collections as a waste of space and resources, and Italian university museums, in particular, heavily suffered this state of affairs. Nowhere was this as evident as in Rome. Here the Zoological Museum of Rome University, after the retirement of Antonio Carruccio in 1914, practically ceased to exist and was partially recovered in 1932 to become the Rome Civic Zoological Museum (Capanna 1989). However, also in other Universities (Bologna, Naples, Padua, Pavia, Pisa, Turin to cite the most important), zoological museums lost their original importance, to become, at most, historical heritage, cramped in inadequate quarters (Corti 1931), sometimes accessible to a few, 'out fashioned', taxonomists. After the rise of fascism in 1922, a renewed emphasis on territorial expansionism led to a new wave of biological exploration, closely connected to military operations, that requested the collaboration of some Italian museums. In those years the valuable Libyan and North-Eastern African mammal materials, assembled mainly in the Genoa and Milan museums, were studied by the director of the Genoa museum, Oscar de Beaux (Gippoliti 2006). Regional collections of Italian mammals were assembled by enthusiastic researchers (such as Enrico Festa, Giuseppe Altobello, Guido Castelli, Giambattista Dal Piaz), who worked independently from any institutional programme. After the fall of fascism and the end of Second World War, only the Zoological Museum of the Florence University and the Natural History Civic Museum in Verona maintained an institutional interest in mammal collection (mainly from North East Africa and Italy) and taxonomic studies (Simonetta 1968; Krapp 1975). It is easy to say that mammal research, with its emphasis on genetics, ecology and behaviour, was, for the main part, separated from museums, with a few exceptions (i.e. Lanza 1960). As a result, the basic taxonomic research concerning Italian mammals in general involved foreign researchers and institutions, in particular the "Alexander Koenig" Zoological Museum in Bonn, where several types of new mammal species and subspecies from Italy are now stored (Hutterer and Peters 2010). The situation was worsened by the lack of a National Natural History Museum and by the general scarce attention toward science, typical of several Mediterranean countries (Pinna 2012). As a consequence, and despite a growing interest in biodiversity assessment and evaluation, there are actually no national collections and not a single professional mammalogist in charge of cumulating and updating specimen-based database on species occurrence and distribution at a national level. Therefore, it is not surprising that most taxonomic changes to the Italian mammal fauna originated from foreign researches (Brünner et al. 2002; Graf et al. 1979; Kiefer and Veith 2001; Palacios 1996). In the past decades there has been some promising collecting activities (Aloise et al. 1993; Lapini et al. 1995; Paolucci 1984) but again only as individual initiative outside the institutional programmes. Despite this, Italian museums often preserve valuable materials, such as one of the two known skulls of the cetacean *Indopacetus pacificus* (Azzaroli 1968) and one of the three existing specimens of the rodent *Uromys rex* from the Salomon Islands (Helgen et al. 2008). The historical importance of preserved specimens is considerable (Giuseppini and Capanna 2012), as also shown by the recent confirmation of holotype status for an old *Elephas maximus* skeleton of the Florence Natural History Museum (Cappellini et al. 2013).

It has been suggested that these old collections would be usefully employed in current research and conservation programmes regarding the world biodiversity hotspots (Gippoliti 2005; Gippoliti and Agnelli 2014). In fact, some Italian museums have collections of international relevance for particular foreign regions. Regrettably, the potentialities of Italian collections for the knowledge of North-eastern Africa mammals seem far from being fully explored (Gippoliti 2010). In recent years, however, such collections were instrumental in the discovery of a new Rodent species (Gippoliti and Amori 2011): in the re-evaluation of an endemic Somali subspecies of Primate (Gippoliti 2006) and in revising the historical distribution range of a large ungulate species in southern Somalia (Gippoliti and Fagotto 2012) and in the evaluation of the skull morphological variability of *Nanger soemmeringii* (Chiozzi et al. 2014). Even foreign scientist benefitted of

Italian collections, as in the case of the revaluation of the specific status of the desert warthog *Phacocoerus aethiopicus* (d'Huart and Grubb 2001) or the study of other mammals endemic of the Horn of Africa (Capellini 2006; Groves 1981). A wider use of mammal collections is often prevented by the scarce knowledge existing abroad about the available "Italian" material, a by-product of the lack of mammalogists in museum's staff and of the scanty financial resources which make cataloguing and taxonomic revisions difficult to undertake (but see Bruner and Gippoliti 2006; Cagnolaro 1976; De Marinis and Lapini 1994; Helgen et al. 2008). This lack of expertise and overlooking of the unsolved taxonomic questions concerning mammals possibly reduce the acquisition of old collections (of ungulate trophies, for example) which might represent the last vestige of now extinct or greatly threatened taxa. Scarce interest has been also directed to the inventory and study of type specimens stored in Italian museums (but see Cagnolaro 1976; Lanza and Harrison 1963). A notable exception regards the collecting activities of stranded cetacean specimens. An intense collaboration between museums, universities and NGO's has resulted in an increased number of specimens conserved in several Italian museums (Cagnolaro et al. 2012), in new faunistic data (Podestà et al. 2005) and in high-quality researches (i.e. Loy et al. 2010). Furthermore, the Padua University maintains a tissue bank of stranded Mediterranean cetaceans for future researches (Ballarin et al. 2005), a technique that should become a standard method of conservation in museums.

6 Conclusions: from census to strategy

As pointed out in the present paper, professionally maintained collections of mammal specimens in public institutions are of fundamental importance for basic and applied research. Regrettably, in Italy there is often a chasm between the research world and the country's Natural History Museums. However, some attempts to fix the mammalogical material stored in the Italian museums, under the auspices of the Associazione Teriologica Italiana (ATIt), do exist (De Marinis et al. 2007). Considering the current financial crisis, a stronger cooperation among museums and between these institutions and the ATIt, as already done by Cetacean researchers under the aegis of the Centro Studi Cetacei, might offer new research opportunities while maintaining an updated and enriched catalogue of the national mammal diversity. The lack of a National Museum of Natural History clearly yields negative consequences for Italy (Minelli 2013). However, it should be possible to overcome some of them by identifying a unique repository for a major national mammal collection in one of the existing museums, where type specimens and a sample of local populations, including exotic introduced species, should be deposited by professional mammalogists. A network including other major mammal collections should be created with a focus on covering specific regions in a detailed way (Deflorian and Pedrini 2013). Considering the extent and national coverage of its current collections (partly an heritage of Enrico Giglioli's Italian Vertebrate Collection), at the moment the Natural History Museum of Florence University appears as the most appropriate choice for a National Mammal Collection. However, this proposal should be thoroughly discussed inside the Italian community of mammal experts. This initiative may not completely fill the gap between Italy and other European countries. However, in our opinion, it was of the utmost importance to raise the scientific community's concern over such a relevant issue.

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