A catalogue of great white sharks *Carcharodon carcharias* (Linnaeus, 1758) preserved in European museums

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ABSTRACT. A catalogue of white sharks preserved in European museums is presented, representing 101 specimens from 42 institutions. Most specimens with known capture locations come from the Mediterranean. The jaws belonging to BAM, Milano, dated from at least 1640-1660, are the oldest white shark material preserved in Europe. The largest specimens of which parts are preserved in any museum may be those of which skeletal parts are preserved in MACR, Roma, and MZF, Firenze: for both these specimens an approximate length of 600 cm is indicated in the literature. The cast of a 565 cm long female, preserved in the MCZL, Lausanne, is the world’s largest that has been reconstructed directly from a whole specimen. The largest taxidermied specimen is a 522 cm long female preserved in the MCSNT, Trieste. The 150 cm long female preserved in SFN, Frankfurt/Main is the smallest taxidermied white shark. The data collected reconfirms that the size of teeth and jaws is not a reliable index for estimating the size of large or medium-sized white sharks.

- Key words: great white shark, *Carcharodon carcharias*, museums, Europe

INTRODUCTION

Since 1996 the Italian Great White Shark Data Bank (*Banca Dati Italiana Squalo Bianco*) has collected a substantial amount of information regarding historical and recent records of the white shark, *Carcharodon carcharias* (Linnaeus, 1758), from the Mediterranean Sea. This data includes information on size, distribution, habitat, behaviour, reproduction, diet, fishery and attacks on humans (De Maddalena 1998, 1999, 2000a,b, 2002, Celona et al. 2001, De Maddalena et al. 2001, 2003, Galaz & De Maddalena 2004). To date, 478 records of white sharks from the Mediterranean have been recorded. This data was obtained by bibliographical research, location and study of material preserved in natural history museums, examination of fish caught in the area and transported to fish markets, collaborations with other researchers, coast guards, and private citizens, especially commercial fishermen, sport fishermen and scuba divers.

The location and the study of white sharks preserved in natural history museum is a fundamental part of this research program. Almost all European museums own at least some sharks in their collections, and some of these institutions hold remarkable specimens (Vanni 1992, Mizzan 1994, Kovačić 1998, Bruni & Würtz 2000, De Maddalena 2000a, Šanda & De Maddalena 2003, 2004). As a first step, a detailed study of 28 white shark specimens preserved in Italian museums has been presented by De Maddalena (2000a). Further studies collected substantial information on many white shark specimens preserved in European museums. Most of the specimens belong to old collections but have never been the object of previous study. Available data and measurements of this material is presented herein.
MATERIAL AND METHODS

A total of 239 museums have been contacted, including museums and institutes of natural history, zoology, biology, anatomy and ichthyology across all of Europe. Material held by private citizens has not been considered; that means that some especially interesting pieces, such as the large jaws of a female white shark captured in Filfla, Malta, on 17 April 1987 and estimated to be 6.68-6.81 m TOT (De Maddalena et al. 2001), are not included in this paper. I preferred to restrict the focus of the catalogue to the material that has been preserved in museums and scientific institutes and is available for research.

The material found includes complete specimens (mounted skins), jaws, teeth, crania, vertebrae, heads, brains, eyes, hearts, and olfactory capsules. Specimens and anatomical parts were preserved by taxidermy, dried, in liquid or as casts. The material has been examined in part directly by the author and in part by the staff of the contacted museums (in the latter case the author has usually checked the proper species identification by examination of photographs).

Fig. 1. Measurements used in this work, following the methods of Mollet et al. (1996). a) Measurement of the white shark length: TLn = total length with the caudal fin in a 'natural' position. b) Measurement of the white shark upper jaw: DUJP = dried upper jaw perimeter. c) Measurements of the white shark largest upper anterior tooth: UAE1 = enamel height. Drawing by Alessandro De Maddalena.
In each case, when possible, the following data was reported: name of the museum or institute where the material is preserved, catalogue number, kind of material, preservation method, capture date, capture location, sex, enamel height (UAE1) of the largest upper tooth, dried upper jaw perimeter (DUJP), total length with the caudal fin in a ‘natural’ position (TLn). Morphometric measurements were made following the methods of Mollet et al. (1996). Mollet et al. (1996) reported a mean shrinkage of 4% for white shark DUJP. As some set of jaws in this work are several centuries old it is possible that the shrinkage has been significantly greater but that is impossible to determine. Photographs of the specimens have also been collected when possible.

Methods for estimating the length of *C. carcharias* specimens from commonly preserved skeletal parts (teeth, jaws, vertebrae) have been investigated and applied by various authors (Randall 1973, 1987, Gottfried et al. 1996, Mollet et al. 1996, De Maddalena 2000a, Zuffa et al. 2002). However, while Mollet et al. (1996) and De Maddalena (2000a) found out that the size of the largest teeth is a sufficiently reliable index for estimation of the size of a young shark, it cannot reliably indicate the size of large individuals. Consequently these methods have not been used in this work.

Much of this material is preserved in good condition and includes numerous interesting specimens. Unfortunately, the catalogues are sometimes absent or, when present, often lack basic data. The information concerning the size of these specimens is usually not included in the original documentation. The species classification of the white shark specimens found was very often incorrect or obsolete. On the other hand, several other specimens that were identified as *C. carcharias* were actually different species, such as the bull shark *Carcharhinus leucas* (Valenciennes, 1839) and the pigeye shark *Carcharhinus amboinensis* (Müller & Henle, 1839).

**MUSEUM ACRONYMS:**

- BAM - Biblioteca Ambrosiana, Milano
- BMAG - Bristol Museum & Art Gallery
- BMNH - British Museum of Natural History, London
- BZL - Biologiezentrum Linz, Austria
- DTRG - Dipartimento del Territorio e delle sue Risorse, Genova
- GLAHM - Hunterian Museum, Glasgow
- HNS - Haus der Natur, Salzburg
- IEND - Inatura–Erlebnis Naturschau Dornbirn, Austria
- IIG - Istituto di Idrobiologia, Ganzirri
- KBIN - Koninklijk Belgisch Instituut voor Natuurwetenschappen, Brussels
- MACB - Museo di Anatomia Comparata, Bologna
- MACR - Museo di Anatomia Comparata, Roma
- MCRE - Musei Civici, Reggio Emilia
- MCSN - Museo Civico di Storia Naturale, Ferrara
- MCSNG - Museo Civico di Storia Naturale "G. Doria", Genova
- MCSNT - Museo Regionale di Scienze Naturali, Trieste
- MCSNV - Museo Civico di Storia Naturale, Venezia
- MCZL - Musée cantonal de Zoologie, Lausanne
- MHNG - Muséum d’histoire naturelle de Grenoble
- MHNN - Muséum d’histoire naturelle de Nîmes
- MHNP - Muséum National d’Histoire Naturelle, Paris
- MNIN - Muzeul National de Istorie Naturala “G. Antipa”, Bucureşti
- MNKB - Museum für Naturkunde, Berlin, Germany
- MNSNT - Museo Regionale di Scienze Naturali, Torino
- MOM - Musée Océanographique, Monaco
- MSNL - Museo di Storia Naturale, Livorno
RESULTS

Material belonging to a total of 101 great white sharks from 42 institutions of 15 countries has been catalogued. Full available data and measurements of the great white sharks preserved in the European museums are reported in Tab. 1.

DISCUSSION

Most material is represented by taxidermied specimens (22 specimens, or 21.8%) and jaws (55 specimens or 54.5%), in a few cases accompanied by chondrocranium and vertebrae, while internal organs (olfactory capsules, eyes, brain, heart) have rarely been preserved.

Most white shark material is preserved in Italy that hosts 41 specimens or 40.6% of the total 101 specimens preserved in Europe. 36 specimens (35.6% of the total 101 white sharks) come from the Mediterranean Sea, while 4 specimens were captured in the Atlantic Ocean (4.0%), 14 in the Indian Ocean (13.9%), 2 in the Pacific Ocean (2.0%) and 44 are from unknown location (43.6%).

The large majority of specimens preserved in European museums are very old, only 12 specimens (11.9%), having been captured after 1950. The jaws of a great white shark belonging to BAM in Milano, Italy, temporarily held at the MCSNM in Milano, dated from at least 1640-1660, have been identified as the oldest white shark material preserved in any European museum. The set of jaws was originally preserved in the Museo Settala in Milano (17th century). Capture date and location are unknown (De Maddalena 2005).

European museums hold some specimens that are among the largest white sharks preserved world-wide. The largest specimens of which parts are preserved in any European museum may be those of which skeletal parts are preserved in MACR in Roma, Italy, and MZF in Firenze, Italy. For both these specimens, a probable female caught off Civitanova, Italy, in early February 1839 (Bonaparte 1839, Metaxà 1839, Vinciguerra 1890, Condorelli et al. 1909, De Maddalena 1999, 2000a,b), and a female caught off Monterosso, Italy, on 10 December 1891 (Tortonese 1956, Vanni 1992, De Maddalena 2000a), an approximate length of 600 cm is indicated in the literature. For the specimen of MACR a confirmation of its huge size has been presented by De Maddalena (1999), where a 602 cm total length has been estimated from the size of its largest vertebra.

The cast of a 565 cm TLn (589 cm TOT = total length with caudal fin in depressed position) female great white shark preserved in MCZL in Lausanne, Switzerland, is the largest
Table 1. Data and measurements (terminology and parameters follow Mollet et al. 1996) of the great white sharks *Carcharodon carcharias* preserved in the European museums. All measurements are given in millimetres.

<table>
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<th>City / Country</th>
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<th>Capture dateᶜ</th>
<th>Capture location</th>
<th>Sex</th>
<th>UAEI</th>
<th>DUJP</th>
<th>TLn</th>
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**Germany**

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a See museum acronyms.
b T = taxidermied, D = dried, F-D = freeze-dried, L = liquid, C = cast.
c Format: dd.mm.yyyy
world-wide that has been reconstructed directly from a whole specimen. The model features the original fins and teeth. This specimen, captured off Sète, France, on 13 October 1956, is one of the three largest white sharks ever measured accurately (De Maddalena et al. 2003).

The largest taxidermied specimen is the 522 cm female preserved in MCSNT in Trieste, Italy, captured on 29 May 1906 in the Kvarner Gulf, Croatia (De Maddalena 2000a,b). This specimen may be the second largest world-wide taxidermied white shark, exceeded only by the 530 cm female preserved in the Victor Sadowsky Museum of Cananéia, Brazil.

Fig. 2. 460 cm long, taxidermied female white shark preserved in the Zemaljski muzej Bosne i Hercegovine, in Sarajevo, Bosnia and Herzegovina (without cat. no.). Photo courtesy of the Zemaljski muzej Bosne i Hercegovine.

Fig. 3. 522 cm long, taxidermied female white shark preserved in the Museo Civico di Storia Naturale of Trieste, Italy (without cat. no.). Photo by Alessandro De Maddalena.
(Arfelli & Amorim 1993). Other two huge taxidermied specimens preserved in Europe reach a 5 m total length: the 500 cm female preserved in MNHN in Paris, France, without capture date and location (B. Séret, pers. comm.), and the 500 cm male preserved in HNS in Salzburg, Austria, captured off Malindi, Kenya, in summer 1989 (Zuffa et al. 2002). The latter is also one of the largest male white sharks ever recorded world-wide.

The 150 cm long taxidermied female preserved in SFN in Frankfurt am Main, Germany, caught in 1822 off Napoli, Italy (Müller & Henle 1838, F. Krupp, pers. comm.), has been identified as the smallest white shark preserved in any European museum. Other very young specimens are a 198 cm taxidermied female preserved in BMNH in London, United Kingdom, caught off the Cape, South Africa, before 1849 (Compagno 2001, O. Crimmen, pers. comm.), and a similar-sized specimen caught before 20th century in an unknown location, of which the chondrocranium and the jaws are preserved in MSNT in Calci, Italy (De Maddalena 2000a).

The measurements of white shark teeth and jaws collected in this work reconfirmed what emerged from the data presented by Mollet et al. (1996) and De Maddalena (2000a), that the size of teeth and jaws is not a reliable index for estimation of the size of large or medium-sized white sharks. That can be clearly seen taking into consideration for

Fig. 4. Recently restored 375 cm, taxidermied male white shark preserved in the Museo Civico di Storia Naturale of Venice, Italy (cat. no. 2039). Photo courtesy of the Museo Civico di Storia Naturale of Venezia.
example the 565 cm female preserved in MCZL in Lausanne, Switzerland, and the 470 cm female preserved in PMR in Rijeka, Croatia, both having a 4.0 cm UAE1 despite their notable difference in total length.

CONCLUSIONS

Populations of great white sharks are decreasing in all oceans because of human activities. Therefore the numerous white sharks preserved in European museums represent precious material for researchers studying sharks worldwide, and may be of noticeable importance for future studies. It is hoped that the material now in an inadequate preservation state will be properly restored. It is also important that the material is very attentively stored, in order to avoid cases of theft, such as those occurred in the museums of Firenze, Venezia and Lausanne, where in the past teeth have been stolen with the consequence of great damage to the specimens. The danger is that these kinds of episodes may increase as *C. carcharias* becomes more and more rare and its jaws and teeth reach higher prices on the market.

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