



## Collection of the sharks of the National Museum in Prague – Part 2. Skeletal preservations

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**Abstract.** In this paper the revision of all shark specimens preserved as skeletons in the National Museum in Prague is presented as a catalogue including 199 specimens of 28 species. The collection includes two large upper jaws of *Carcharodon carcharias*, both estimated to measure around 6 000 mm total length and the chondrocranium with jaws of *Prionace glauca* estimated to measure approximately 3 800 mm total length. The size of these three specimens is very close to the maximum size reported in the literature for these two species.

■ sharks, skeletons, size estimation, collection, National Museum in Prague

### INTRODUCTION

Almost all European museums own some shark skeletal parts, mainly jaws, in their collections, and some of these institutions hold remarkable specimens (Oliva 1958, Vanni 1992, Mizzan 1994, Kovačič 1998, Bruni et Würtz 2000, De Maddalena 2000). However, it is rare to find an actually extensive collection in a single institution. Most of these materials are historical pieces, acquired by the museums in the past, mainly during the 19<sup>th</sup> century and in the first half of the 20<sup>th</sup> century. Many of these skeletal materials are preserved in good conditions and include numerous interesting or rare species. Nevertheless, most of these materials have been poorly studied. Unfortunately, the catalogues are sometimes absent or, when present, often lack basic data. The species classification is very often incorrect or obsolete. However, although the references about shark teeth are numerous but incomplete, these collections are important as a source of study material for ichthyologists working in the field of shark taxonomy and palaeontology.

The National Museum in Prague has a rich and interesting collection of shark specimens, including numerous skeleton preparations. The 255 complete specimens, preserved taxidermied and in liquid, have been already revised (Šanda et De Maddalena 2003). A part of the collection of the shark skeletons was published in the list of skeleton preparations stored in liquid (Neumanová 1997). However, the list contains only the original names, mostly invalid, without any correction and revision of the identification.

As the preparation of skeleton of elasmobranch fishes is very difficult, the collection of skeletons in liquid is particularly interesting and important as documentation of craftsmanship of the old taxidermists.

The aim of the present work is to provide a complete and updated list of all sharks in the museum together with their basic data and to evaluate their scientific value.

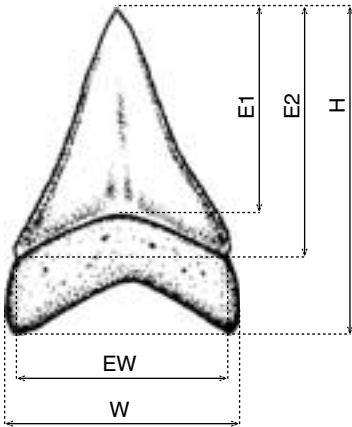


Fig. 1. Measurements of the shark tooth cited in this work: E1 = tooth enameloid height, E2 = tooth maximum enameloid height, H = tooth height, EW = tooth enameloid width, W = tooth width. Drawing by Alessandro De Maddalena.

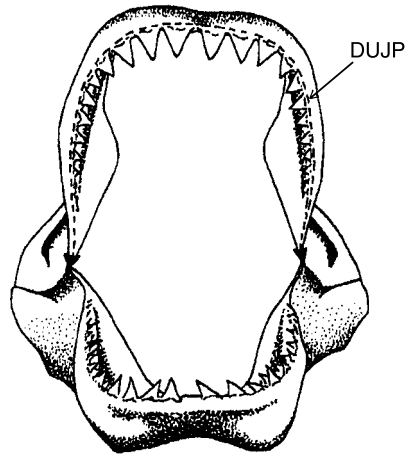


Fig. 2. Measurement of the shark jaw used in this work: DUJP = dried upper jaw perimeter. Drawing by Alessandro De Maddalena.

## MATERIAL AND METHODS

For each specimen the data are presented in the following order: species, catalogue number, type of material, sex, length in millimetres when appropriate, location and date of the capture, preservation type. The total length (TOT) was measured from the tip of the snout to the tip of the upper lobe of the caudal fin, with the caudal fin maximally tightened (Compagno 1984). When only complete skull with part of the spinal column and pectoral fins skeleton is preserved, the length in the catalogue is the length from the tip of the snout to the pectoral fin insertion (PP1) (Compagno 1984).

We estimated the total length of the selected large or rare specimens. The estimated size is included in the catalogue as estimated TOT. The estimations were based on measurements of teeth and jaws proposed in the latest literature (Mollet et al. 1996, De Maddalena 2000, Zuffa et al. 2002). We used DUJP = dried upper jaw perimeter, E1 = tooth enameloid height, EW = tooth enameloid width. The tooth position is indicated by U = upper, A = anterior, so for example: UA1E1 = first upper anterior tooth enameloid height. E1 is recommended by De Maddalena (2000) as the more precise and reliable measurement, because tooth root's margins cannot be often seen clearly in teeth implanted in the connective tissue of the jaw. Teeth size was measured using standard methods (Mollet et al. 1996), see Fig. 1. DUJP was measured with a string from one extreme corner of the mouth (where the upper and lower jaws join), along the curvature of the upper jaw just above the base of the teeth, to the other extreme corner (Fig. 2). The measurements of E1, EW and DUJP of specimens with estimated TOT are included in the catalogue.

For the estimation of the TOT of *Carcharodon carcharias*, we compared our measurements with available data in the literature (Hubbell 1996, Mollet et al. 1996, Cappo 1998, De Maddalena 1998, 2000, De Maddalena et al. 2001, 2003, Zuffa et al. 2002) and unpublished data (De Maddalena unpublished data).

Litvinov et al. (1983) quantified the relationship between the total length (TOT) of *Prionace glauca* and the third anterior tooth enameloid width:  $y = 0.035x + 2.227$ , where  $y =$

UA3EW in mm and  $x = \text{TOT}$  in cm. We used this relationship for the estimation of the TOT of *Prionace glauca*.

For estimation of the TOT of the other species, we used the data provided kindly by Jeremy Cliff from Natal Shark Board, South Africa (Cliff unpublished data).

Species identification was based on Bigelow et Schroeder (1948), Gilbert (1967), Johnson (1978), Cadenat et Blache (1981), Cigala Fulgosi et Gandolfi (1983), Compagno (1984), Randall (1986), Moreno (1995), Burdon et Heim (2002). The classification follows the nomenclature by Compagno (1984).

The collection includes dried material and material preserved in liquid preservatives, and consists of several different types of preparations which are listed below together with the abbreviations used in the catalogue: complete skeletons (SKE), complete skulls with part of the spinal column and pectoral fins' skeleton (SKU+), a chondrocranium and complete set of jaws (CH-CJ), right and left pectoral fin skeleton (RPEC and LPEC, respectively), complete sets of jaws (CJ), upper jaw (UJ) and lower jaw (LJ).

Further abbreviations used in the catalogue are: M = male, F = female, L = liquid, D = dried.

## RESULTS

The shark collection of the National Museum in Prague includes 199 specimens preserved as skeletons. They belong to 6 orders, 12 families, 24 genera and at least 28 species. The real number of species could be higher because some specimens were not possible to identify to lower than generic level due to the lack of determination criteria in the literature.

The specimens in liquid include 34 complete skeletons, 14 complete skulls with part of the spinal column and pectoral fins' skeleton, 2 chondrocrania with complete set of jaws, and 6 pectoral fin skeletons. Dried specimens include 74 chondrocrania with complete sets of jaws, 56 complete sets of jaws, 2 upper jaws and 11 lower jaws.

Order Hexanchiformes

Family Chlamydoselachidae

*Chlamydoselachus anguineus* GARMAN, 1884  
NMP6V 80530 – CH-CJ, F, PP1 190 mm, Japan, 1896, L

Family Hexanchidae

*Hepranchias perlo* (BONNATERRE, 1788)

Capture locality unknown:

NMP6V 47709 – SKE, F, TOT 720 mm, L  
NMP6V 47710 – SKU+, PP1 200 mm, L  
NMP6V 47711 – SKU+, PP1 210 mm, L  
NMP6V 47712 – SKE, F, TOT 860 mm, L

*Hexanchus griseus* (BONNATERRE, 1788)

NMP6V 80531 – CH-CJ, Mediterranean Sea, Nice, France, 1899, L

NMP6V 5266 – CH-CJ, Mediterranean Sea, D

Capture locality unknown:

NMP6V 47706 – SKE, F, TOT 780 mm, L  
NMP6V 47707 – SKE, M, TOT 850 mm, L  
NMP6V 47708 – SKE, M, TOT 650 mm, L

NMP6V 80532 – CH-CJ, D

NMP6V 80533 – CJ, D

Order Squaliformes

Family Squalidae

*Centrophorus* sp.

NMP6V 5265 – CH-CJ, Mediterranean Sea, Nice, France, D

Capture locality unknown:

NMP6V 47713 – SKE, F, TOT 700 mm, L  
NMP6V 47714 – SKE, F, TOT 630 mm, L  
NMP6V 23234, 23244–23246 – CH-CJ, D  
NMP6V 23236–23243 – CJ, D

*Dalatias licha* (BONNATERRE, 1788)

NMP6V 5262 – CH-CJ, Mediterranean Sea, D

Capture locality unknown:

NMP6V 80534 – SKE, M, TOT 470 mm, L  
NMP6V 47733 – SKU+, PP1 130 mm, L  
NMP6V 47734 – SKU+, PP1 170 mm, L  
NMP6V 23247–23256 – CH-CJ, D  
NMP6V 23506–23522 – CJ, D

***Somniosus microcephalus*** (BLOCH et SCHNEIDER, 1801)

NMP6V 5271 – CJ, capture locality unknown, D

***Somniosus rostratus*** (Risso, 1826)

NMP6V 23629–23635 – CH-CJ, capture locality unknown, D

***Squalus*** sp.

Capture locality unknown:

NMP6V 80535 – SKE, M, TOT 650 mm, L

NMP6V 47715 – SKU+, PP1 60 mm, L

NMP6V 47716 – SKU+, PP1 75 mm, L

NMP6V 47717 – SKU+, PP1 125 mm, L

NMP6V 47718, 47719, 47721 – RPEC, L

NMP6V 47720, 47722, 47723 – LPEC, L

NMP6V 47724 – SKU+, PP1 145 mm, L

NMP6V 47725 – SKU+, PP1 180 mm, L

NMP6V 47726 – SKE, F, TOT 370 mm, L

NMP6V 47727 – SKE, M, TOT 660 mm, L

NMP6V 47728 – SKE, F, TOT 660 mm, L

NMP6V 47729 – SKE, F, TOT 640 mm, L

NMP6V 47730 – SKU+, PP1 170 mm, L

NMP6V 47731 – SKE, M, TOT 720 mm, L

NMP6V 47732 – SKE, M, TOT 320 mm, L

Order Squatiniformes

Family Squatinidae

***Squatina*** sp.

Capture locality unknown:

NMP6V 5267, 23783–23788 – CH-CJ, D

NMP6V 5308 – SKE, F, TOT 500 mm, L

NMP6V 47754 – SKE, F, TOT 640 mm, L

NMP6V 80536 – CJ, D

Order Heterodontiformes

Family Heterodontidae

***Heterodontus*** sp.

Capture locality unknown:

NMP6V 47735 – SKE, M, TOT 350 mm, L

NMP6V 47736 – SKU+, PP1 170 mm, L

NMP6V 47737 – SKE, F, TOT 380 mm, L

NMP6V 5237, 23646–23655 – LJ, D

Order Lamniformes

Family Odontaspidae

***Carcharias taurus*** (RAFINESQUE, 1810)

NMP6V 5268 – CJ, capture locality unknown, D

Family Alopiidae

***Alopias vulpinus*** (BONNATERRE, 1788)

NMP6V 5264 – CH-CJ, Mediterranean Sea, Nice, France, 1901, D

Family Lamnidae

***Carcharodon carcharias*** (LINNAEUS, 1758)

NMP6V 5270 – UJ, capture locality unknown, estimated TOT app. 6 000 mm, UA1E1 = 39.05 mm, D

NMP6V 80544 – UJ, capture locality unknown, estimated TOT app. 6 000 mm, UA1E1 39.72 mm, D

***Isurus oxyrinchus*** (RAFINESQUE, 1809)

NMP6V 23488, 23489, 23497–23500 – CH-CJ, capture locality unknown, D

***Lamna nasus*** (BONNATERRE, 1788)

NMP6V 23235 – CH-CJ, capture locality unknown, D

NMP6V 80547 – CJ, capture locality unknown, D

Order Carcharhiniformes

Family Scyliorhinidae

***Galeus*** sp.

Capture locality unknown:

NMP6V 47738 – SKE, F, TOT 550 mm, L

NMP6V 47739 – SKE, F, TOT 560 mm, L

***Scyliorhinus*** sp.

Capture locality unknown:

NMP6V 47740 – SKE, M, TOT 460 mm, L

NMP6V 47741 – SKE, M, TOT 460 mm, L

NMP6V 47742 – SKE, M, TOT 530 mm, L

NMP6V 47743 – SKE, F, TOT 500 mm, L

NMP6V 47744 – SKU+, PP1 130 mm, L

NMP6V 47745 – SKU+, PP1 60 mm, L

NMP6V 47746 – SKE, M, TOT 500 mm, L

NMP6V 23257–23260 – CH-CJ, D

Family Triakidae

***Galeorhinus galeus*** (LINNAEUS, 1758)

Capture locality unknown:

NMP6V 23501–23505 – CH-CJ, D

NMP6V 23610–23618 – CJ, D

***Mustelus*** sp.

Capture locality unknown:

NMP6V 47747 – SKE, F, TOT 550 mm, L

NMP6V 47748 – SKE, F, TOT 580 mm, L

NMP6V 47749 – SKE, M, TOT 470 mm, L

NMP6V 47750 – SKU+, PP1 140 mm, L

NMP6V 23774–23782 – CJ, D

NMP6V 23232–23233 – CH-CJ, D

Family Carcharhinidae

***Carcharhinus amboinensis*** (MÜLLER et HENLE, 1839)

NMP6V 80540 – CJ, capture locality unknown,

estimated TOT app. 2 000 mm, DUJP 370 mm, UA2E1 10.55 mm, D

*Carcharhinus falciformis* (BIBRON, 1839)

NMP6V 5260 – capture locality unknown, CJ, D

*Carcharhinus leucas* (VALENCIENNES, 1839)

NMP6V 5261 – CJ, capture locality unknown, D

NMP6V 80537 – CJ, capture locality unknown, estimated TOT over 2 500 mm, DUJP 550 mm, UA2E1 13.85 mm, D

NMP6V 80546 – CH-CJ, capture locality unknown, D

*Carcharhinus limbatus* (VALENCIENNES, 1839)

NMP6V 80538 – CJ, capture locality unknown, D

*Galeocerdo cuvieri* MÜLLER et HENLE, 1837

NMP6V 5275 – CJ, capture locality unknown, estimated TOT app. 4 000 mm, DUJP 790 mm, UA2E1 18.00 mm, D

NMP6V 80541 – CJ, capture locality unknown, estimated TOT app. 3 500 mm, DUJP 730 mm, UA2E1 16.60 mm, D

*Negaprion brevirostris* (POEY, 1868)

NMP6V 5263, 80539 – CJ, capture locality unknown, D

*Prionace glauca* (LINNAEUS, 1758)

NMP6V 5276 – CH-CJ, Mediterranean Sea, Nice, France, 1899, estimated TOT app. 3 800 mm, UA2EW = 15.73 mm, D

Capture locality unknown:

NMP6V 47751 – SKE, M, TOT 570 mm, L

NMP6V 47752 – SKE, F, TOT 750 mm, L

NMP6V 6164 – SKE, F, TOT 820 mm, L

NMP6V 23477–23487, 80542 – CH-CJ, D

Family Sphyrnidae

*Eusphyra blochii* (CUVIER, 1817)

NMP6V 80543 – SKE, capture locality unknown, F, TOT 420 mm, L

*Sphyrna zygaena* (LINNAEUS, 1758)

NMP6V 5259 – CH-CJ, Mediterranean Sea, Nice, France, 1901, D

Capture locality unknown:

NMP6V 47753 – SKE, F, TOT 550 mm, L

NMP6V 23490–23496 – CH-CJ, D

## DISCUSSION

Teeth of some sharks have highly characteristic shape and the identity of the species can be determined even from a single tooth. Nevertheless, this is not the case of the most species. Moreover, tooth shape is often related to the shark's size. The shape of teeth of many shark species alters conspicuously because sharks can change type of preferred prey with the increasing size. Therefore, the species identification from teeth must be evaluated cautiously. We were able to identify most species following detailed examination of the teeth, but we were unable to identify to the species level the specimens belonging to genera *Centrophorus*, *Squalus*, *Squatina*, *Heterodontus*, *Galeus*, *Scyliorhinus* and *Mustelus*, because of the close resemblance in appearance of teeth among different species within these genera. Further studies are needed to establish peculiar morphological characteristics of teeth of all species belonging to these genera.

Skeletal parts of several large specimens of different species are deposited in the National Museum in Prague. The information concerning the size of these specimens is not included in the original documentation, therefore we estimated the total length of some of them from the size of their teeth and upper jaw diameter.

Although the methods for obtaining the length of *Carcharodon carcharias* from usually 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 2000, Zuffa et al. 2002), the comparative data for other species are almost completely lacking.

Mollet et al. (1996) and De Maddalena (2000) found out that the size of the largest teeth is sufficiently reliable index for estimation of the size of a young shark, however, it cannot reliably indicate the size of large individuals. Consequently the estimations presented in this work are necessarily approximate.



Fig. 3. The chondrocranium with jaws of large *Prionace glauca* (NMP6V 5276) from the Mediterranean Sea. The estimated size of this specimen should be around 380 cm total length.

The estimated size, around 6 000 mm, of the two specimens of *Carcharodon carcharias* (NMP6V 5270, NMP6V 80544) is very close to the maximum size reported in the literature for this species (De Maddalena et al. 2001).

The large chondrocranium with jaws of *Prionace glauca* (NMP6V 5276) is another interesting material (Fig. 3). We have not been able to measure UA3EW of the *Prionace glauca* preserved in the National Museum as proposed by Litvinov et al. (1983), because other teeth partially hide the third tooth base. Nevertheless, UA3EW is almost identical to UA2EW, therefore the latter was used. From UA2EW = 15.73 mm, we estimated TOT to be approximately 3 800 mm. If the estimation is correct, this *Prionace glauca* was very close to the reliable maximum size reported in the literature for this species (3830 mm according to Bigelow et Schroeder 1948). Moreover, this specimen may be the largest *Prionace glauca* ever caught in the Mediterranean Sea.

Other large specimens are two *Galeocerdo cuvieri*, NMP6V 5275 and NMP6V 80541, *Carcharhinus leucas* NMP6V 80537, and rare *Carcharhinus amboinensis* NMP6V 80540 (Fig. 4).

The collection includes skeletal remains of several uncommon species: the chondrocranium and jaws of *Chlamydoselachus anguineus* (NMP6V 80530), the jaws of *Somniosus microcephalus* (NMP6V 5271), the chondrocrania and jaws of seven specimens of *Somniosus rostratus* (NMP6V 23629, NMP6V 23630, NMP6V 23631, NMP6V 23632, NMP6V 23633, NMP6V 23634, NMP6V 23635).

In most cases it was impossible to find any data about the origin of the specimens in the collection. However, the collection consists of old material only, collected during the second half of 19<sup>th</sup> century and at the beginning of the 20<sup>th</sup> century. No specimens were collected more recently.

The collection of shark skeletal parts of the National Museum in Prague is one of the richest in Europe. Most specimens in the collection are well preserved. This material represents a precious instrument for worldwide researchers studying sharks anatomy, taxon-

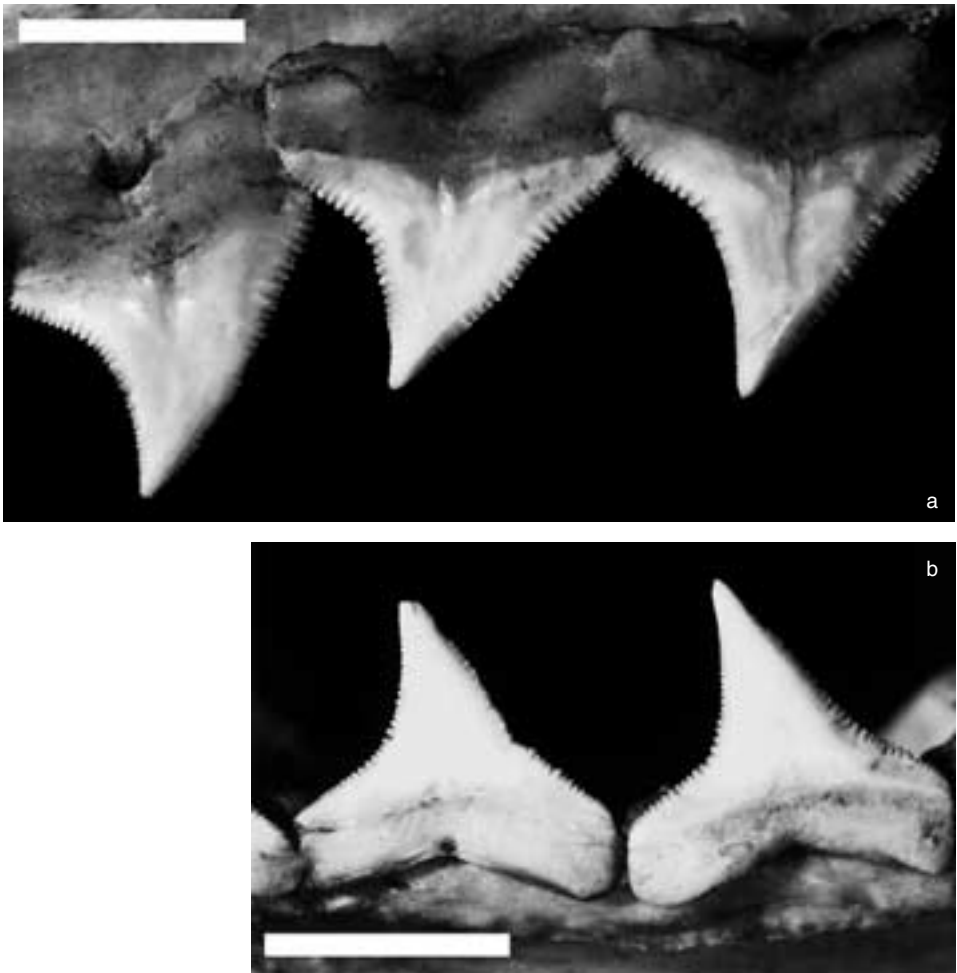


Fig. 4. Upper (a) and lower (b) teeth of pignose shark *Carcharhinus amboinensis* (NMP6V 80540); scale 10 mm.

omy, palaeontology, diet and growth. Therefore this collection will be of noticeable importance for future studies.

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