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RADIOLOGICAL OBSERVATIONS ON THE SKELETAL DEVELOPMENT IN FETAL AND NEWBORN SPECIMENS OF *DELPHINUS DELPHIS* L. AND *STENELLA COERULEOALBA* (MEYEN)

(*Mammalia Cetacea*)

Abstract. — Twentytwo fetuses and a newborn belonging to *Delphinidae* (9 *Delphinus delphis*, 4 *Stenella coeruleoalba*, 1 *Globicephala melaena* and 9 unidentified individuals belonging to either the genus *Delphinus* or *Stenella*) were examined radiographically to describe the patterns of their skeletal development. Special attention has been given to the differentiation of the spine in various stages of uterine life; the development of the skull, the thoracic limbs and the pelvic bones were also considered. On the whole, the present investigation shows the tendency — starting from early fetal life — toward a precocious development of structures of functional importance for the swimming habits of the adult. The thoracic and lumbar sections of the vertebral column, as well as the first part of the caudal section, appear earlier and develop quicker than the cervical portion and the last part of caudal vertebrae. Pelvic bones appear later than the thoracic limbs; the skull telescopes only at the 4th-5th month of uterine life; the cervical fusion takes place just before birth.

Riassunto. — *Rilievi radiologici sullo sviluppo dello scheletro in feti e neonati di* Delphinus delphis *L.* e Stenella coeruleoalba (*Meyen*) (Mammalia Cetacea).

Sono stati esaminati 22 feti ed un neonato appartenenti alla famiglia *Delphinidae*. Di essi 9 erano *Delphinus delphis*, 4 *Stenella coeruleoalba*, 1 *Globicephala melaena* e 9 di incerta attribuzione tra i generi *Delphinus* e *Stenella*. Gli esemplari esaminati sono stati suddivisi secondo classi di età in rapporto alla lunghezza e sottoposti ad indagine radiologica. Particolare attenzione è stata posta nel valutare il differen-

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ziamento della colonna vertebrale nei vari stadi di sviluppo; sono stati osservati anche lo sviluppo del cranio e dei cinti appendicolari. Complessivamente i risultati ottenuti consentono di affermare che nel corso dell'ontogenesi fetale di questi Delfinidi si sviluppano più precocemente strutture di interesse funzionale per la dinamica natatoria dell'adulto; a questo proposito è interessante notare che all'interno della colonna vertebrale i settori toracico, lombare e la parte iniziale di quello caudale si sviluppano assai precocemente, a differenza di quello cervicale e delle ultime vertebre caudali, la cui importanza funzionale nell'adulto è minore. Nel cranio dei feti nei primi stadi di sviluppo (fin verso il 4°-5° mese di vita intrauterina) non si nota ancora nessun accenno al processo di telescopia che porterà all'allungamento del massiccio facciale. Le ossa dell'arto toracico si sviluppano con notevole anticipo rispetto ai residui pelvici, che compaiono solamente intorno al 6° mese di vita fetale. La fusione delle prime vertebre cervicali inizia nell'ultima fase della gravidanza e si completa dopo la nascita.

Abbreviations.

v.c. - vertebral column;
v.b./v.bb. - vertebral body/ies;
o.c./o.cc. - ossification center/s.

Introduction.

The Cetacean vertebral column (v.c.) has undergone a number of fundamental morphological and functional changes in the course of the evolution, demonstrating a series of marked adaptations to the marine environment. In fact Cetacea are the most differentiated mammals in relation to the primitive terrestrial quadruped ancestors. Cetacea possess no sacral vertebrae, due to the absence of developed pelvic limbs; the caudal region of the v.c. becomes highly developed in relation to vertebral number and size, as well as for the thickness of intervertebral disks and the presence of chevron bones. These transformations are a result of the new functional role acquired by the caudal part of the body in Cetacea with the caudal part of the trunk and the tail becoming propulsory organs in water. The neck, functionally insignificant, is not evident, and in many species cervical vertebrae are fused to various degrees. Many Authors have studied the Cetacean v.c. by an osteometric approach (Van Beneden & Gervais, 1868; Omura, 1971a, 1975; Omura & coll., 1962, 1970, 1971b; Cagnolaro, 1977; Cagnolaro & Notarbartolo di Sciara, 1979). Slijper (1946), Grassé (1958), Omura (1971a) and Cozzi (1981) have investigated the Cetacean spine from a morphodynamic point of view. According to De Smet (1977) it is even possible to reclassify the various regions of the Cetacean v.c. based it on the morphology of the Cetacean spine alone, without comparison with ter-

restrial mammals. ARVY (1976, 1979) argues that the Cetacean girdles (and specifically the pelvic one) are not homologous to the other mammalian girdles.

The development of the Cetacean spine has been scarcely studied. DE SMET (1977) used X-rays to corroborate his statements; FELTS & SPURRELL (1965, 1966) investigated radiographically the structure and development of the humerus, radius and ulna. HUI (1977) and later OGDEN & COLL. (1981a) tried to define standards for the determination of bone development in Cetacea by radiologic analysis.

FRAZER & HUGGETT (1959), BRYDEN (1972) and PIRLOT & KAMIYA (1982) studied different aspects of Cetacean development. Nevertheless only OGDEN & COLL. (1981b) investigated the development of the v.c. (the cervical portion of the spine in *Globicephala macrorhyncha*) in fetuses, by histologic methods; they too commented on the lack of published reference data available.

With this in mind we investigated the development of the spine in some *Delphinidae* by radiographing various dolphin fetuses of increasing length as well as one newborn specimen. Special care was taken to ascertain the various ontogenetic steps in the development of this structure and to analyse the data obtained in light of their functional significance in terms of the animal biology. We related — when possible — our results with what is currently known of the behaviour of the examined species, and in particular the connections between the v.c. and their swimming habits.

In our investigations we also followed the development and ossification of the skull and the girdles, the development of the chevron bones, as well as their relationship with the lower part of the vertebral bodies in the caudal region of the v.c. .

Materials & methods.

We examined 22 fetuses and one newborn Cetacean belonging to the Family *Delphinidae* (see Table I). Nine of these specimens were positively identified as *Delphinus delphis* L., 1758, five of which belonging to the subspecies *Delphinus delphis ponticus* (Barabash-Nikiforov, 1938), from the Black Sea; four fetuses were *Stenella coeruleoalba* (Meyen, 1833); one was *Gobicephala melaena* (Traill, 1809). The taxonomic standing of the remaining 9 fetuses, which were presumably less than five months old could not be determined. These specimens, labelled at the time of cataloguing *Delphinus sp.*, being still in an early developmental stage, did not show any features clearly characteristic of any given species. These specimens then can correspond to either *Delphinus*

TABLE 1. — Fetal Length and Age Groups (TOMILIN, 1957, page 491).

Age	Ref. N.	Species	Museum	Cat. N.	Length (cm)
Under 3 months	1	*Delphinus delphis* or *Stenella coeruleoalba*	MNHGE	CE 46875	6.2
	2	*Delphinus delphis* or *Stenella coeruleoalba*	MNHGE	CE 46872	8.2
	3	*Delphinus delphis* or *Stenella coeruleoalba*	MNHGE	CE 46873	9.0
	4	*Delphinus delphis* or *Stenella coeruleoalba*	MNHGE	CE 46871	11.9
	5	*Delphinus delphis ponticus*	MNHGE	CE 46874b	2.3
	6	*Delphinus delphis ponticus*	MNHGE	CE 46874a	6.3
	7	*Delphinus delphis ponticus*	MNHGE	CE 46870	6.9
	8	*Delphinus delphis ponticus*	MNHGE	CE 31608	9.7
About 3 months	9	*Delphinus delphis* or *Stenella coeruleoalba*	MNHGE	CE 46877	20.0
	10	*Delphinus delphis* or *Stenella coeruleoalba*	DAHBR	no number	25.0
	11	*Delphinus delphis* or *Stenella coeruleoalba* (or *Tursiops truncatus*)	MNHGE	CE 41777	33.0
About 4-5 months	12	*Delphinus delphis* or *Stenella coeruleoalba*	MNHGE	CE 36930b	42.0
	13	*Delphinus delphis* or *Stenella coeruleoalba*	MNHGE	CE 36930a	46.5
	14	*Delphinus delphis*	MNHMI	4745	42.0
	15	*Delphinus delphis*	MNHGE	CE 46876	46.2
About 6 months	16	*Delphinus delphis ponticus*	MNHGE	CE 38832	50.5
	17	*Stenella coeruleoalba*	MNHGE	CE 4525	54.5
	18	*Stenella coeruleoalba*	MNHGE	CE 36931	57.5
	19	*Stenella coeruleoalba*	MNHGE	CE 36932	59.0
About 7-8 months	20	*Delphinus delphis*	MNHGE	CE 36933	67.0
End of pregnancy	21	*Delphinus delphis*	MNHGE	CE 36934	87.0
Birth	22	*Stenella coeruleoalba* (*)	MNHMI	4744	87.0
(About 4 months)	23	*Globicephala melaena*	MNHMI	4743	41.5

(*) newborn stranded; skeleton preserved.

Abbreviations: MNHGE - Museum of Natural History of Genoa.
MNHMI - Museum of Natural History of Milan.
DAHBR - Dept. of Animal and Human Biology of the University of Rome (formerly Institute for Comparative Anatomy « G. B. Grassi »).

delphis or *Stenella coeruleoalba*. Specimen n. 11 (see Table I) could be a *Tursiops truncatus* (Montagu, 1821). Nineteen of the specimens came from the alcohol or formalin collections of the Museum of Natural History of Genoa (MNHGE), while three fetuses came from the Museum of Natural History of Milan (MNHMI) and one from the Institute for Comparative Anatomy « G. B. Grassi » of the University of Rome (now Dept. of Animal and Human Biology - DAHBR). The MNHGE material is listed in a catalogue containing informations on date and location of recovery (ARBOCCO, 1969), recently revised (POGGI, 1982). The examined animals are quite similar to each other (with the exception of *Globicephala melaena*). In fact the adult *Delphinus delphis* and *Stenella coeruleoalba* are close in terms of morphology, biology, feeding habits, swimming patterns and habitat. We believe that these fetuses (with the exception of *G. melaena*) can be considered as a significant biological type even if they belong to two separate genera.

The fetuses were distributed according to their presumed age and subdivided in age-groups, which were in turn defined on the basis of the total body length. This, in accordance with TOMILIN (1957, pag. 491) and FRAZER & HUGGETT, (1959). In addition we have reported the exact total length of each specimen studied.

The v.c. has been subdivided with the same criteria adopted in terrestrial mammals, even if the suggestions expressed by DE SMET (1977) have been held in consideration.

The number of thoracic vertebrae was determined based on the number of ribs, while the number of caudal vertebrae has been correlated with the number of lumbar vertebrae present in the adult; this since the chevron bones characteristic of the fully-developed caudal region of the adult are not present in the early developmental stages of the fetus. References to the adult v.c. come from the works of TOMILIN (1957), NISHIWAKI (1972), CAGNOLARO & COLL. (1983) and LEATHERWOOD & COLL. (1983).

Radiographs have been taken utilizing standard orthogonal projections: straight lateral (l-r and r-l) and sagittal projections (dorso-ventral or ventro-dorsal), with the addition of a few oblique views.

Some specimens required a greater number of radiographs because of their distortion due to long-term preservation in tight containers.

Results.

The first age group contained eight fetuses (probably all under the 3rd month of development); in these specimens it is possible to recognize different ossification centers (o.cc.) of the skeleton, which are

destined to become bones or parts of bones. In the following list these centers are presented in chronological order of appearance.

— bony orbits;
— premaxillary, aboral part of the maxillary, occipital (multicentric asynchronous ossification), ribs (14 pairs);
— aboral portion of lower jaws;
— frontal, sphenoid, humerus;
— v.bb. of the thoracic, lumbar and initial part of the caudal regions; hemiarches of cervical and thoracic vertebrae (the latter are slightly radiopaque).

In the above-mentioned list more than one o.c. appears simultaneously in the same stage of development. It is possible that the limited number of specimens examined did not allow determination of the appearance of different o.cc. in their true chronological sequence; two or more o.cc. may « suddenly » appear together, while they are in fact separated by a lapse of time. It was impossible to further subdivide this first group of eight fetuses in more detailed age classes. An additional problem was due to the fact that techniques used to preserve these specimens, had tended to mechanically deform several of the subjects. The use of preservation fluids and their storage in small containers had in fact distorted some of the specimens, making them difficult to study.

It is possible that during the early periods of intrauterine life a sudden, tumultuous sequence of o.cc. appears in a very short lapse of time; in this case it would be virtually impossibile to isolate any single primitive stage of ossification. In fact histologic examination usually allows detection of an o.c. before its presence can be demonstrated radiographically.

It is likely that the first o.cc. of the v.bb. appear in the last part of the thoracic region and in the first part of the lumbar region. This is suggested by the size and the radiographic density of these o.cc. Other o.cc. appear later both caudally and cranially to these ones, while the cranial vertebrae are the last to exhibit o.cc. . Thus it seems that the process of ossification proceeds at a slower rate in the cranial region. Each vertebra, ossifies through three separate centers; ventro-medial (for the v.b.) and dorso-lateral (l and r) for the arch and the processes. The ribs are evident as slender, straight rods standing somewhat apart from the median vertebral centers and from the lower outline of the fetal body.

Other o.cc. appear towards the 3rd month of uterine life (specimens n. 9, 10 and 11); in the meantime the o.cc. already visible become still

more opaque to X-rays, because of their higher degree of development and calcification.

The o.cc. are located in the following bones:

— nasal, tympanic bulla, v.bb. of the axis, and the following cervical vertebrae, dens of the axis, hemiarches of the lumbar and caudal regions, radius, ulna;

— basihyoid, scapula, II, III and IV metacarpals; four phalanges of the II finger and three phalanges of the III;

— v.bb. of the last caudal vertebrae: no hemiarches are evident in the last 14-15 vertebrae (see Figs. 1 and 2).

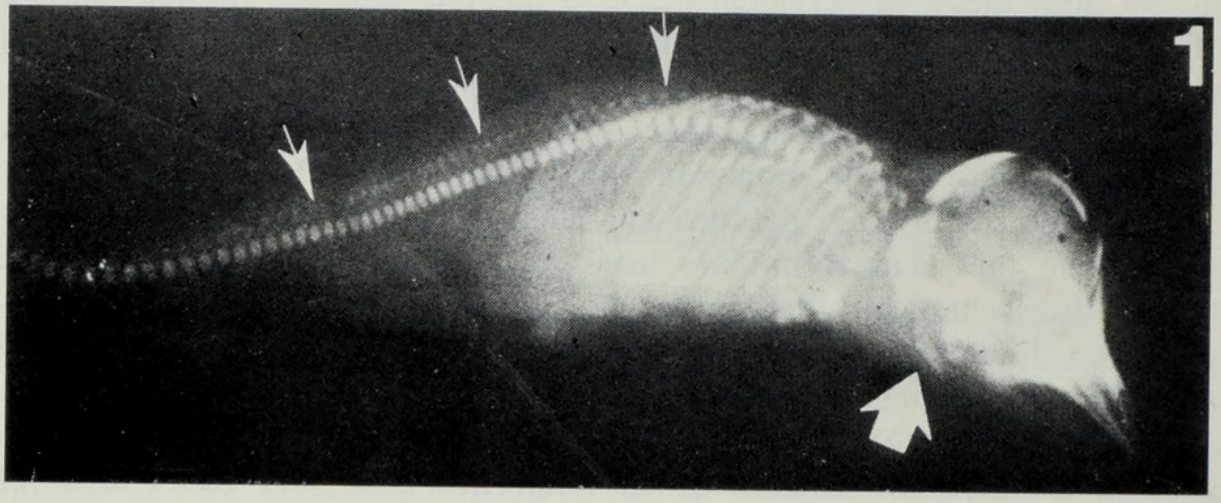

Fig. 1. — Specimen n. 9. Lateral view. Large arrow: o.c. for the basihyoid; slender arrows: o.cc. for the vertebral hemiarches.

The visible hemiarches appear in lateral radiographs as small rods located dorsally to the median center of the v.b., inclined posteriorly for the first 33 vertebrae, and anteriorly or perpendicularly for the remaining ones. Their lower end is separated from the outline of a v.b. by a radiotransparent band. The v.bb. of C_3, C_4, C_5, C_6 and C_7 are extremely reduced in size and resemble slender disks in a regular succession.

The v.bb. of the thoracic, lumbar and caudal vertebrae never show an homogeneous radiopacity; it is possible to recognize a thickening in correspondence of their anterior and posterior margins while at the center a bony framework with radially oriented lamellae is present.

The head of the fetus is on the whole nearly spherical, with the exception the upper and lower jaws.

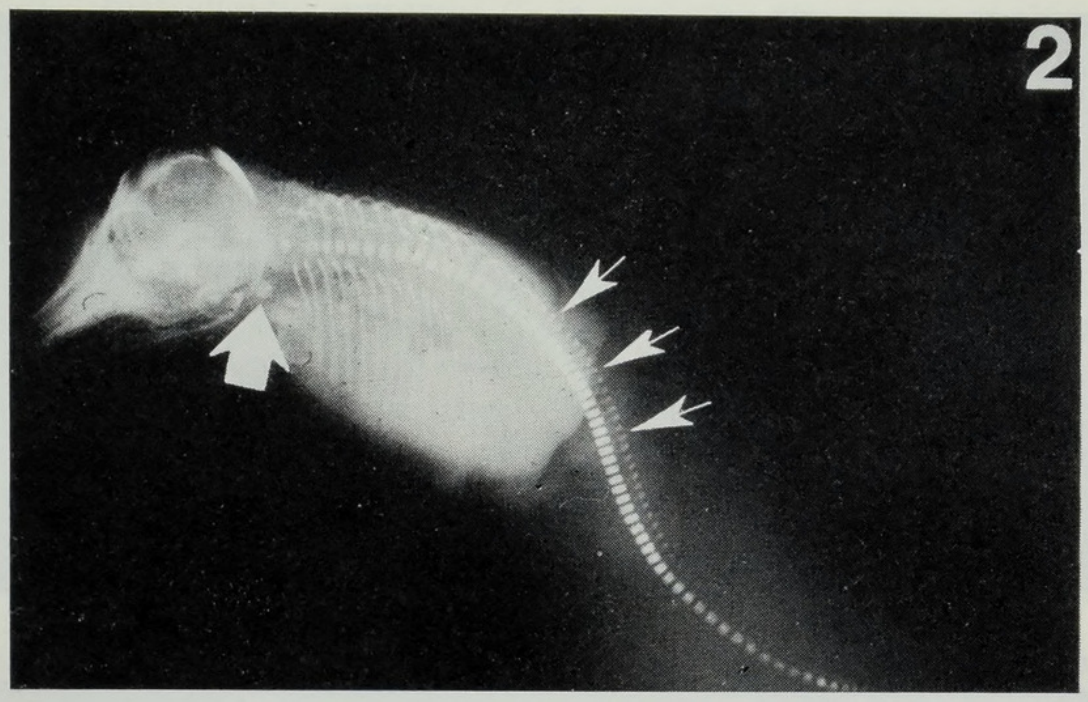

Fig. 2. — Specimen n. 11. Lateral view. Large arrow: o.c. for the dens of the axis; slender arrows: o.cc. for the vertebral hemiarches.

In fetuses of the 4th - 5th month (n. 12, 13, 14 and 15) there is the appearance of the o.cc. of the stylohyoid, of some chevron bones and of three sternebrae. In these specimens the dental buds of the upper and lower jaws are evident, displaying various degrees of calcification; the zygomatic arches are manifest; the os petrosum (petrous part of the temporal bone) is quite radiopaque (with dim and uncertain borders); the occipital condyles are more convex caudally. The general shape of the skull changes considerably, and the dorso-ventral axis of the cranial cavity expands dorso-ventrally. At this stage the telescopy of the skull is just beginning, the bones of the face increasing in length.

Another o.c. appears in the hypochordal connective tissue, ventral to the o.c. of the arch of the atlas. This will give rise to the dens of the axis. Sometimes this can be seen even in less developed specimens (see n. 11 in Fig. 2). Therefore the development of the axis takes place through four o.cc.: two for the arches, one for the v.b. and the last for the dens.

Some prominences start to develop in the lateral o.cc. of the thoracic vertebrae. These prominences are destined to form the cranial and caudal articular processes, the transverse and spinous processes. The spinous processes develop also in the lumbar region and at the beginning of the caudal region. The costal cartilages of the 3rd, 4th and 5th ribs are partially calcified. The rib cage begins to show signs of the torsion of the adult rib cage.

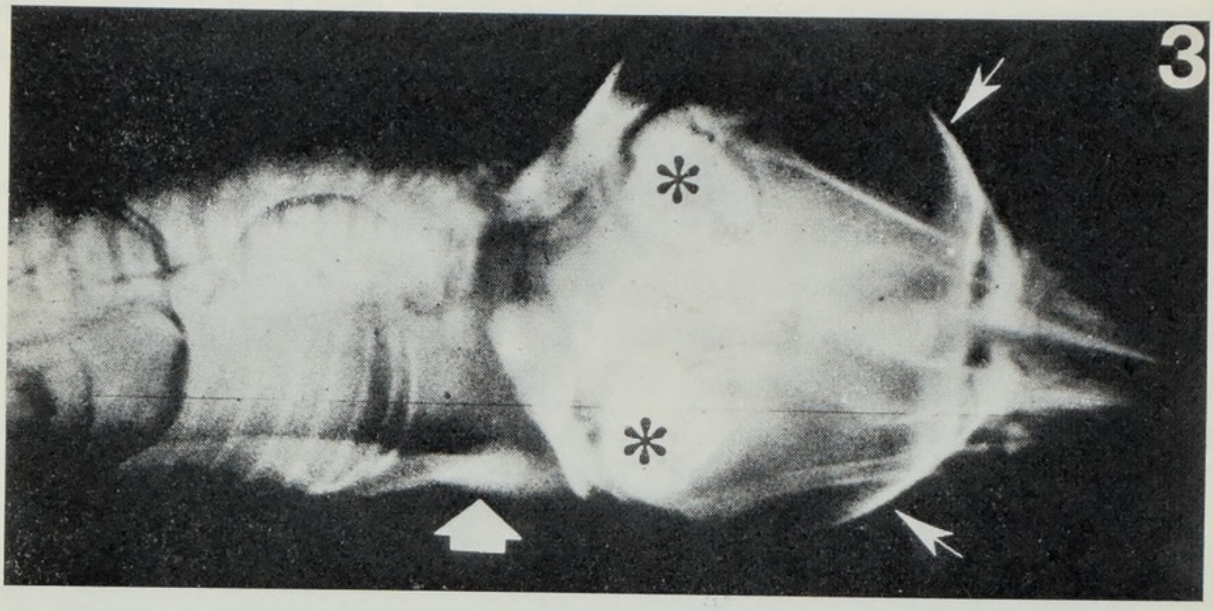

Fig. 3. — Specimen n. 16. Dorso-ventral view. Large arrow: scapula; slender arrows: zygomatic arches; asterisks: tympanic bullae.

The dimensions of the v.bb. (well evident in specimen n. 12), change according to the region of the spine under consideration. The body of the axis is quite voluminous; those of C_3, C_4, C_5 and C_6 are the smallest, while that of C_7 is somewhat larger than those that precede it. Starting

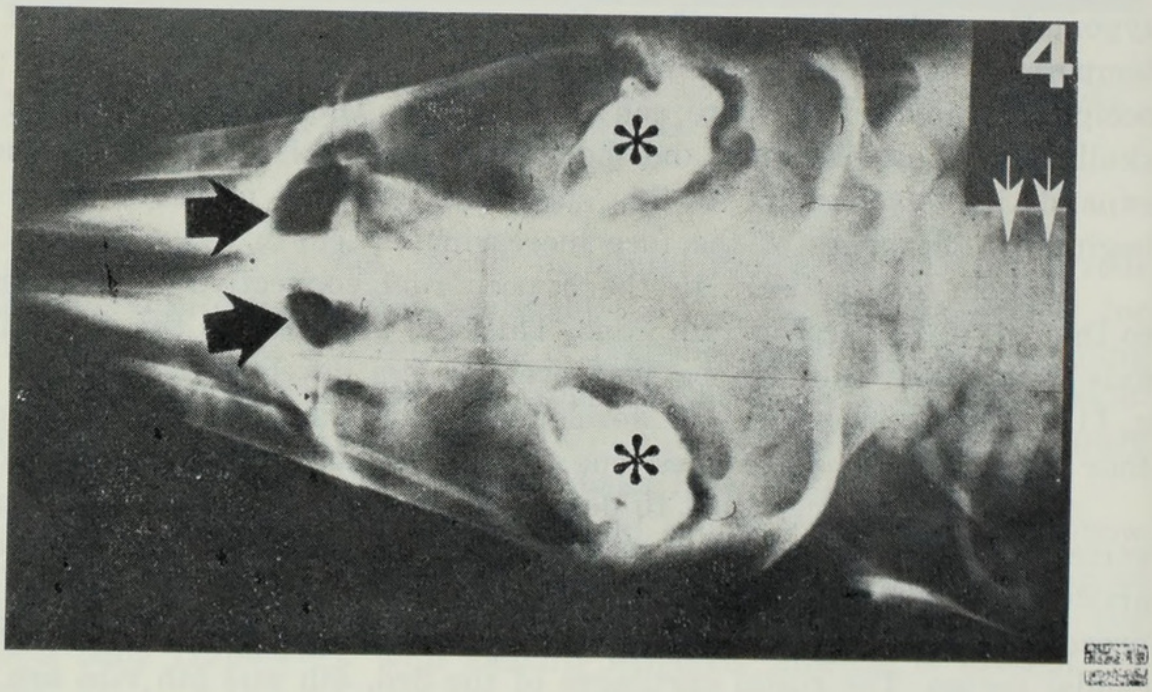

Fig. 4. — Specimen n. 17. Dorso-ventral view. Large arrows: nasal passage; slender arrows: v.bb. of cervical vertebrae; asterisks: tympanic bullae.

from T_1 (that slightly surpasses C_7 in size), the dimensions of the v.bb. slowly increase reaching a maximum at T_5, remaining unmodified to the level of L_2; from this point the vertebrae grow increasingly taller and larger, yet more compressed cranio-caudally up to the 6th-7th caudal vertebra. From here to the end of the spine the volume of the vertebrae decreases. The general conformation of the v.c. in the fetal *Globicephala melaena* (n. 23, probably a four-months-old fetus) is different from that of the other dolphins examined; here, one finds fewer vertebrae, while the radiotransparent spaces between adjoining vertebrae (which correspond to the vertebral disks) are wider. Beginning from T_4 and up to the caudal extremity of the column, the v.bb. acquire a quadrangular shape with uniform dimensions.

At about 6 months of fetal life (specimens n. 16, 17, 18 and 19, Figs. 3, 4, 5), new elements appear especially in the v.c.. In the last 13

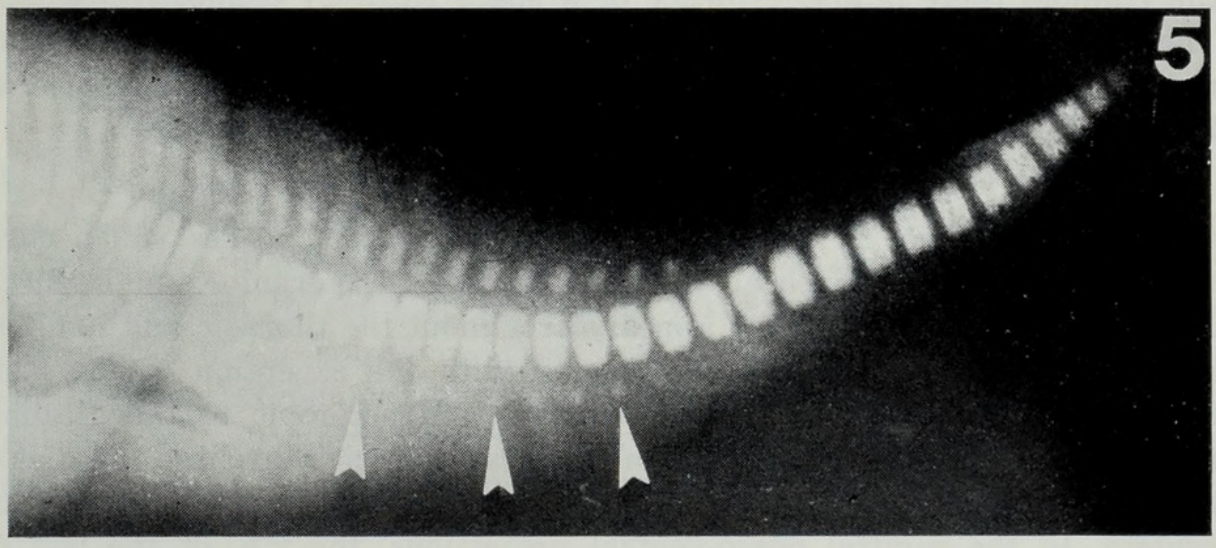

Fig. 5. — Specimen n. 17. Lateral view. Arrows: chevron bones.

to 14 caudal vertebrae a small notch becomes visible at the center of the dorsal and ventral faces of the median vertebral o.cc.. In the first vertebrae of this caudal sector there is evidence of an epiphyseal o.c., developing from the cranial and caudal faces of the v.b., destined to give rise to the epiphysary disks. These nuclei are found simultaneously in the last four thoracic and in the first four lumbar vertebrae, even if they appear less developed. The number of chevron bones increases in comparison with the former stages of development. The cartilagineous extensions of the 1st, 2nd and 5th ribs are calcified. The rudimentary pelvic bones appear ventrally to the last lumbar and the first caudal vertebrae; their shape resembles the radiopaque image of an inverted « 7 ».

The only fetus 7-8 months old (n. 20) that underwent radiological examinations shows no assessable changes in the process of skeletal ossification.

It had not been possible to acquire any information from specimen n. 21 (a fully developed fetus, or perhaps even a newborn specimen), due to the intense de-calcification of the skeleton. The epiphysary nuclei of the v.bb. are evident in the thoracic and lumbar regions as well as in the greater part of the caudal region.

On the contrary in the stranded newborn *Stenella coeruleoalba* (n. 22) the skeleton is in a more favorable state of preservation and calcification. The following is a list of the radiological observations made, organized according to the various regions considered.

Skull - The cranial bones are well developed. Among them there are still fontanels filled by fibrous connective tissue. The most evident are placed between the parietals and the occipital; between the sphenoid and the ethmoid there is also evidence of a space filled by connective tissue. The tympanic bullae are hypotransparent. The most dorsal parts of the nasal cavities show up as two roundish hypertransparent images at the base of the upper jaw.

Vertebral column - The v.c. has, on the whole, a straight course; there is an increase in width of the radiotransparent spaces which correspond to the intervertebral disks, proceeding in a cranio-caudal sense. Epiphyseal nuclei of the v.bb. appear throughout the thoracic and lumbar regions, as well as in the caudal region with the exception of the last 8 vertebrae. Such nuclei are well evident and adherent to the cranial and caudal faces of each v.b., yet in the first thoracic vertebrae the disks are still scarcely evolved and stand somewhat apart from the median centers. In the sagittal dorso-ventral projections, the v.b. of the last 6 caudal vertebrae (except the very last one) display a cleft placed laterally and open to the outside. These vertebrae therefore are spindle-shaped if seen from above (Fig. 6). The cleft closes laterally, forming two radiotransparent images in those caudal vertebrae preceding this last group of six if viewed in a lateral sense. Such images seems at first very extended and included in the mass of the v.b.; later they become roundish and peripherical, and then find themselves included between the lateral border of the median center and the base of the future transverse processes.

In the latero-lateral radiographs the last 18 caudal vertebrae (except the very last) show a radiotransparent stripe in the middle, extending from the dorsal to the ventral border (see Fig. 7).

Ventrally to the caudal intervertebral spaces (except the last 8) it is possible to note up to 26 chevron bones.

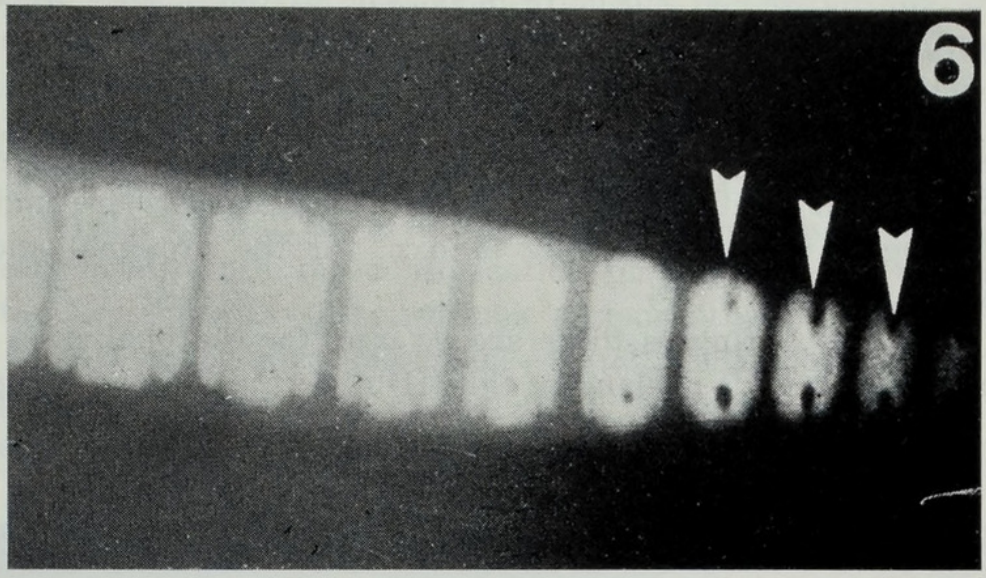

Fig. 6. — Specimen n. 22. Dorso-ventral view. Arrows: « spindle-shaped » vertebrae.

The main ventro-medial and dorso-lateral o.cc. are not yet fused; it is impossible to detect if there has been a median fusion of the hemi-arches. The lateral o.cc. are absent in the last 14 caudal vertebrae. The apophysis of the thoracic and lumbar vertebrae are already formed for the most part. In the last 11 lumbar vertebrae there are o.cc. for the extremities of the transverse processes; from C_3 to C_7 there are o.cc. for the apex of the spinous processes. The o.cc. of the atlas seem to be fused with those belonging to the arches of the axis. The o.c. of the dens of the axis is not yet fused with the median center of C_2.

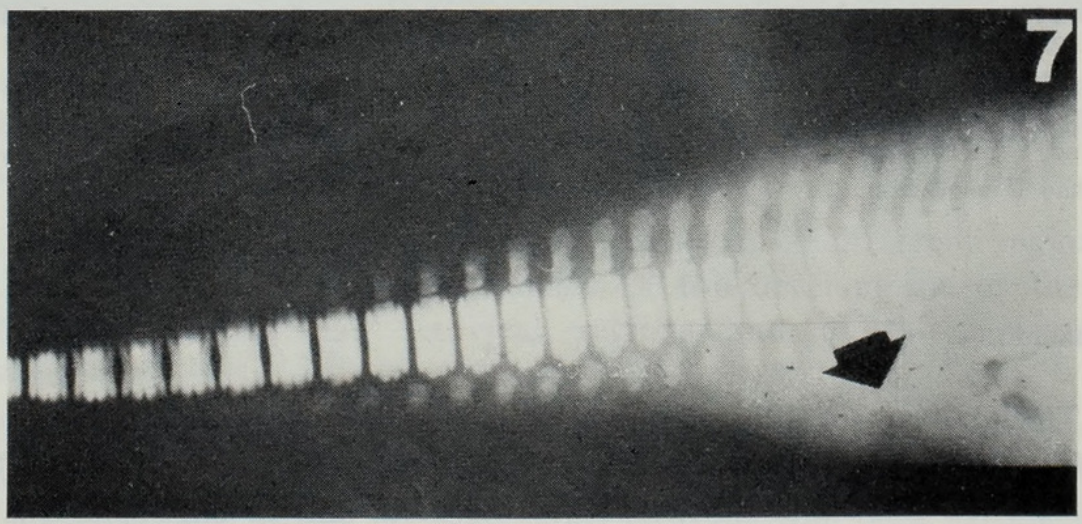

Fig. 7. — Specimen n .22. Lateral view. Arrow: pelvic bones.

The total number of rib pairs is 14. The cartilagineous processes of the first 7 pairs are calcified. The sternum is made up of 3 sternebrae and is connected with the first 4 pairs of ribs.

Carpus, Metacarpus and Fingers - The carpus is composed of 5 coarsely roundish small bones. The I and V metacarpals are underdeveloped. In the II there is evidence of o.cc. for the proximal and distal epiphyses.

In the I and V fingers there are no o.cc. for the phalanges. The II finger is made up by 7 phalanges; the III by 5; the IV by 2 (Fig. 8).

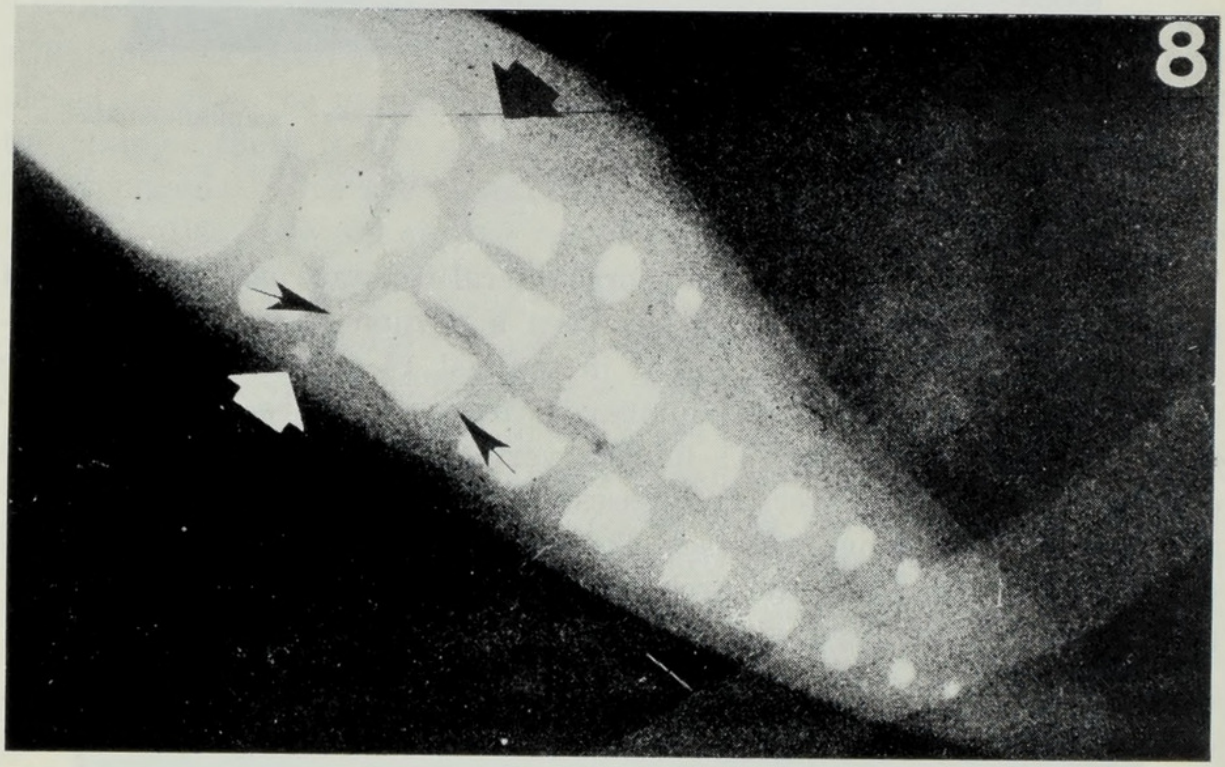

Fig. 8. — Specimen n. 22. Dorso-ventral view of the left hand. Large arrows: I and V metacarpals. Slender arrows: o.cc. for the proximal and distal epiphysis of the II metacarpal.

Discussion.

The analysis of the radiographs allows us to propose a few considerations concerning the general ontogenetic development of the skeleton in *Delphinus delphis* and *Stenella coeruleoalba*, and in particular in relation to their v.c. .

In the early stages of development, i.e. in fetuses under 3 months of age, the skull and the v.c. begin to differentiate and slowly take shape.

At first the bones of the face are not yet elongated as in the adult, and the general profile of the head closely resembles that of other mammalian orders. In the v.c. the early appearance of the o.cc. in the thoracolumbar regions, as well as in the first caudal vertebrae, has probably some relationship with the conformation of the spine in the adult, in which the vertebrae of these various regions attain a discrete size as well as acquire a functional importance (COZZI, 1981). The lack of functional importance of the cervical region in the adult swimming pattern may well explain the « delay » in the ossification of this segment.

In the following stage there is an obvious overall increase of the process of ossification. In the cervical spine the bodies of each vertebra appear well separated, resembling slender rods in series, except for the atlas, which has two distinct o.cc. . The inclination of the developing hemiarches along the spine indicate an arrangement useful for mechanic reasons. The skull has yet to begin its telescopic process. It should be noted that for the development of the thoracic limbs, the humerus is the first element to appear.

In fetuses of 4-5 months the most striking modifications occur in the skull, where the facial bones lengthen, and the neurocranium shortens and increases in height. Teeth appear in both jaws.

At 6 months there is a further morphological development of the v.bb. of the last caudal vertebrae. At the same time the pelvic bones start at last to differentiate radiographically, quite later than the bones of the thoracic limb.

For the following months of development, the imperfect preservation of some specimens and the de-calcification of some others, has made it impossible to collect precise and significant data. The examination of the stranded newborn specimen has been far more satisfactory, because it was in a better state of preservation. On the whole the results obtained repeat some general characteristics of the development in these *Delphinidae*. These are:

— the simultaneous appearance of different o.cc. in different regions of the spine, with a significant delay in the development of the less functionally important cervical regions and of the last caudal vertebrae;

— the initial independence of each cervical vertebra, so that they never appear to fuse until birth; according to OGDEN & COLL. (1981b) there is no cervical fusion of the spine even in the fetal *Globicephala macrorhyncha*;

— the delay in the ossification of the scapula in relation to the bones of the arm and the late radiological appearance of the pelvic bones: both data can be explained as an early onset of the ossification of those parts of the limbs that have a functional meaning in the locomotion of the adult;

— the process of telescopy starts in the skull only at about the 4th-5th month of pregnancy.

It is highly probable that an histologic screening would allow a more precise and detailed understanding of the developmental phenomena in these species, sometimes difficult to detect radiographically because of the low calcification state of the subjects. This, however, is not always possible, since these museum specimens could not be sectioned or damaged, thus precluding any attempt of microscopic observations.

At any rate it is possible, on the basis of radiological investigations, that in the ontogenesis of these species the locomotory necessities of the adult play an important role in differentiation, « rewarding » the development of those parts of dynamic importance.

It may thus be said that some of the evolutionary changes undergone by the Cetacean spine may be observed in an early period of fetal life; for other phenomena, on the other hand, the complete development can be observed only at birth, as for the cervical vertebrae, in which fusion takes place more or less at the end of uterine life.

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