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Landmark based morphometric variation in Common dolphin (*Delphinus delphis* L.,1758)

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Abstract — In this study we compare Mediterranean stocks of *Delphinus delphis* (L., 1758) with other populations of the same species coming from different seas using a geometric morphometrics method. The aim is to define the patterns of geographical variation of *Delphinus delphis* through a geometric morphometrics analysis of the skulls of 124 individuals from seven marine areas (West and East Pacific Ocean; North-east and South-East Atlantic Ocean, West and East Indian Ocean, Mediterranenan Sea).

Index Terms — common dolphin, geometric morphometrics, skulls.

1 Introduction

The Mediterranean sea has experienced significant changes in the last decades in terms of biodiversity, due to a combination of environmental and anthropogenic influences. In this project we focus the attention on the common dolphin, *Delphinus delphis*, whose Mediterranean population was drastically reduced starting from the Sixties and is considered as “Endangered” from 2003 “[3], [4]”. Analyses where devoted to clarify the pattern of geographic variation of the species through a geometric morphometric approach, and to evaluate any specific differentiation/adaptation of the Mediterranean stock with respect to other populations across the range of the species. Due to the difficulties related to data collection and records in the field, the museum collections represented the primary source of information, as in many other Cetacea“[6]”.

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2 Materials and Methods

A total 124 skulls of adult specimens from seven marine areas across the distribution range of the species (Tab. 1) were photographed on dorsal, ventral and lateral projections with a digital camera using a standard procedure to avoid the effects of distortion. Previous analyses on the absence of sexual dimorphism in the shape of the skull “[9]” allowed to pool males and females.

The analysis of 24 two-dimensional cartesian coordinates (landmarks) have been recorded on the various projections using the software tpsDig “[10], [11]” (Fig. 1). Data have been translated, rotated and superimposed through a General Procrustes Analysis, GPA “[11]” using the tpsRelw software “[10]”. Centroid sizes were stored for allometric and size variation evaluations. Multivariate ordination of specimens was performed through Relative Warp Analysis on the weight matrix of aligned specimens.

SEAS	*REGION*	*LOCATION*	*SAMPLES*	*SYMBOL*
Mediterranean	-	-	14	○
Atlantic	*North East*	Portugal	26	●
		Danmark, Netherlands	7	
		Ireland	5	
	South East	East Africa	31	
		South Africa	1	
Indian	*West*	Oman	3	○
		Persian Gulf	1	
	East	Australia	3	
Pacific	*South West*	New Zealand	26	●
	South East	Perù	7	
TOT			**124**	

Tab. 1 – Number of specimens and their geographical location: 14 from the Mediterranean sea (Italians Naturalistic and Zoological Museums), 70 from the Atlantic Ocean (Lisbon Natural History Museum, 26; Zoological Museum of Amsterdam, 25; Zoological Museum of Copenhagen, 19), 33 from the Pacific Ocean (Zoological Museum of Amsterdam, 31; Zoological Museum of Copenhagen, 2), 7 from the Indian Ocean (Zoological Museum of Amsterdam, 3; Zoological Museum of Copenhagen, 4.

3 Results

Fig.2 shows the results of ordination analysis of the residual from GPA for the dorsal view of the skulls, while Fig.3 shows the results of classification analysis run on the Mediterranean, Atlantic, Indian, and Pacific stocks. The first two PC (retaining 37,7% and 10,5% of cumulative variation respectively) do not allow a clear identification of different stocks except for the Indian ocean sample. Nevertheless Mahalanobis distances among groups derived from CVA scores are highly significant (Tab. 2). Procrustes distances among populations confirm the Indian stock as the most divergent from all other samples, while the Mediterranean is the most different with respect the Atlantic and the Pacific dolphins.

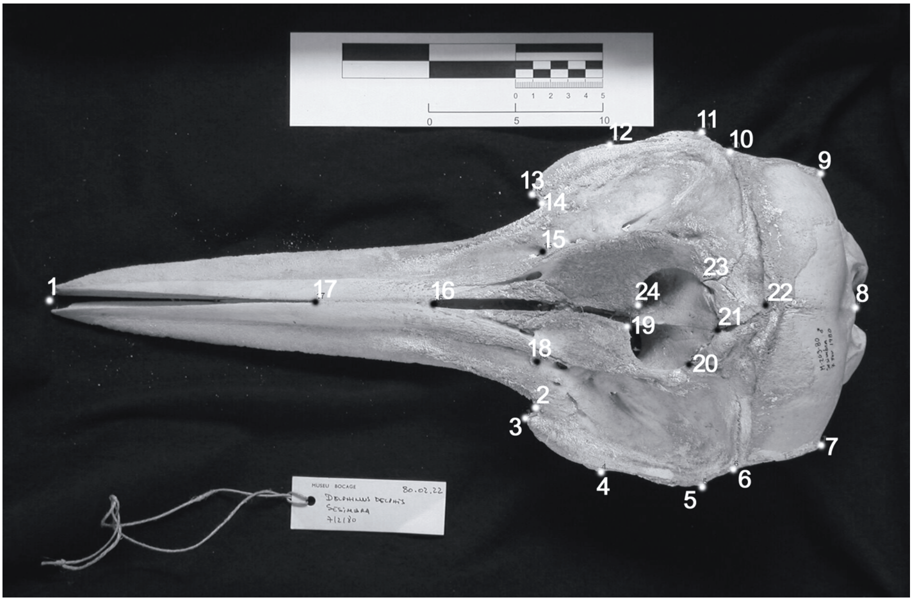

Fig.1 – Landmark recorded on the dorsal projection of the skull.

	Atlantic	Indian	Mediterranean	Pacific
Atlantic	-	0,0552	0,0211	0,0220
Indian	5,0605***	-	0,0521	0,0440
Mediterranean	2,7085***	5,2529***	-	0,0247
Pacific	3,0821***	5,6897***	3,2302***	-

Tab. 2 – Above diagonal: Procrustes distances among populations; below diagonal: Mahalanobis distances among groups derived from CVA scores. *** P < 0.0001.

The deformation grid on the left in the graph (Fig.2) is referred to the shape changes characterizing the Indian Ocean dolphins. The skulls of these specimens shown an elongation of intermaxilla bones and infraorbita foramina aligned to the antorbital notch respect the mean.

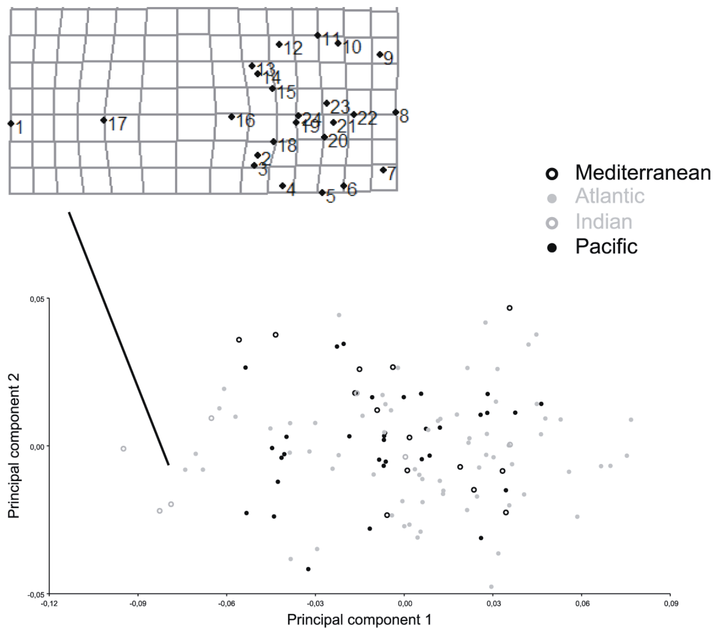

Fig. 2 – Results from PCA run on the residuals from GPA for the dorsal view of the skull: the deformation grid on the left is referred to the Indian population.

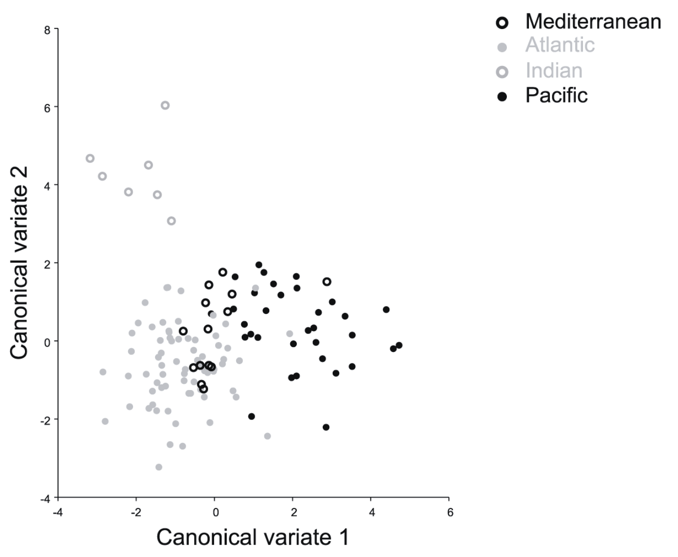

Fig. 3 – Results from the first two canonical axes extracted from residual from GPA. Symbols refer to the groups are the same for PCA and CVA.

4 Conclusion

Geometric morphometrics has shown significant differences in the shape of the skulls of *Delphinus delphis* populations from different geographical areas. Differences are particularly evident in the dolphins from the Indian ocean which appear the most divergent among all.

Other authors used the morphometric approach to identify shape differences between populations in the same dolphin species living in different geographical area "[7], [12], [13]" and also for phylogenetic and evolutionary studies "[2]". Many papers also underline the importance of morphometric analysis to support the genetic, ecological and ethological results as a powerful tool to describe and understand the mechanism of morphological differentiation "[1], [5], [8]".

These preliminary results show the need to include the other projections of the skulls to better elucidate the degree and the pattern of geographic variation, as well as adaptive traight involved in this pattern and to analyse in depth the degree and pattern of asimmetry in the region involved in the acousticmotor complex.

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References

[1] D. C. Adams, F. J. Rohlf and D.E. Slice, "Geometric morphometrics: 10 years of progress following the 'revolution'", *Ital. J. Zool.*, vol. 71, pp. 5-16, 2004.

[2] A. R. Amaral, M. M. Coelho, J. Marugàn-Lobon and F. J. Rohlf, "Cranial Shape Differentiation in Three Closely Related Delphined Cetacean Species: insights into Evolutionary History", *Zoology*, vol. 112, pp. 38-47, 2009.

[3] G. Bearzi, "*Delphinus delphis (Mediterranean subpopulation)",* IUCN Red List of Threatened Species, http://www.iucnredlist.org, 2009.

[4] G. Bearzi, R. R. Reeves, G. Notarbartolo di Sciara, E. Politi, A. Cañadas, A. Fratzis and B. Mussi, "Ecology, Status and Conservation of Short-beaked Common Dolphins (*Delphinus delphis*) in the Mediterranean Sea", *Mammal Review*, vol. 33(34), pp. 224-252, 2003.

[5] A. Cardini, D. Nagorsen, P. O'Higgins, P. D. Polly, R. W. Thorington and P. Tongiorgi, "Detecting biological uniqueness using geometric morphometrics: an example case from the Vancouver Island marmot", *Ecology, Ethology and Evolution*, DOI 10.1111/j.1439-0469.2008.00503, 2009.

[6] A. Loy, "Morphometrics and Theriology Homage to Marco Corti", *Hystrix It. J. Mamm.*, vol. 18 (2), pp. 115-136, 2007.

[7] A. Loy, A. Tamburelli, R. Carlini and D. E. Slice, "Craniometric Variation of some Mediterranean and Atlantic Populations of *Stenella caeruleoalba* (Mammalia, Delphinidae): a 3D Geometric Morphometrics Analysis", *Marine Mammal Science*, submitted for publication. (pending publication)

[8] A. Natoli, A. Cañadas, C. Vaquero, E. Politi, P. Fernandez-Navarro and A. R. Hoelzel, "Conservation Genetics of Short-beaked Common Dolphin (*Delphinus delphis*) in the

Mediterranean Sea and in the Eastern North Atlantic Ocean", *Conserv. Genet.* DOI 10.1007/s10592-007-9481-1, 2008.
[9] P. Nicolosi, A. Loy, "Morphometric Variation of Mediterranean vs Atlantic Stocks of Common Dolphin (*Delphinus delphis* Linnaeus, 1758)", *Paleontologia I Evolució, memòria especial,* vol. 3, pp. 97-99, 2009.
[10] F. J. Rohlf, *TpsDig, TpsRelw*, Department of Ecology and Evolution. State University of New York at Stony Brook. http://life.bio.sunysb.edu/morph/, 2008.
[11] F. J. Rohlf, D. E. Slice, "Extensions of the Procrustes Method for the Optimal Superimposition of Landmarks", *Systematic Zool.*, vol. 39, pp. 40-59, 1990.
[12] A. J. Westagate, "Geographic Variation in Cranial Morphology of Short-beaked Common Dolphins (*Delphinus delphis*) from the North Atlantic", *Journal of Mammology*, vol. 88(3), pp. 678-688, 2007.
[13] K. A. Viaud-Martinez, L. R.Jr. Brownell, A. Komnenou and A. J. Bohonak, "Genetic Isolation and Morphological Divergence of Black Sea Bottlenose Dolphins", *Biological Conservation,* vol. 141, pp. 1600–1611, 2008.