Skull morphometry of the common dolphin, *Delphinus* sp., from New Zealand waters

A thesis presented in partial fulfilment of the requirements for the degree of

Master of Science in Conservation Biology

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Abstract

The short-beaked, *Delphinus delphis*, and long-beaked, *D. capensis*, common dolphin, two morphotypes of the *Delphinus* genus, are recognized as different species. However, to date, species status of the New Zealand common dolphin, among other geographic populations, remains unclear, owing to morphometric and genetic uncertainty. This lack of taxonomic knowledge is one of the reasons preventing adequate threat status assessment. The main objective of the current skull morphometric study, the first to solely focus on New Zealand *Delphinus* sp., was therefore, to obtain further information regarding taxonomy and life history for conservation purposes. In particular, the study aimed (1) to determine age at cranial maturity through the computation of a suture index; and (2) to assess the validity of several cranial parameters as cranial maturity indicators through the determination of a misclassification index. Furthermore, (3) presence of cranial sexual dimorphism was investigated in (i) metric characters through ANOVA and ANCOVA analyses and in (ii) non-metric characters through Chi-Square tests. (4) The taxonomic status was assessed based on the rostrum length to zygomatic width (RL/ZW) ratio, tooth counts, and the Kalya Index. Moreover, (5) Potential regional differences between Hauraki Gulf (HG) and non-HG specimens were investigated through MANOVA analyses (metric characters), Chi-Square tests, and the computation of the mean measure of divergence (non-metric characters). In addition, (6) measurement error of two metric data acquisition methods (callipers *versus* microscribe) was compared through the computation of three precision estimates (variance, mean absolute difference (MAD), and relative error magnitude (REM)). A total of 67 common dolphin skulls from stranded and by-caught individuals were available for analyses. The majority of skeletal material (73.1%, n = 49), had been archived frozen as intact heads following necropsies at Massey University. Those heads were prepared as part of the present study via applying the manure decomposition method. The remaining 26.9% (n = 18) of

skulls were cleaned specimens housed at the Museum of New Zealand Te Papa Tongarewa. Sex was known for 88.1% (n = 59) of specimens (males: 40.7%, n= 24; females: 59.3%, n = 35). Based on age data and the suture index, 46.3% (n = 31) and 53.7% (n = 36) of specimens were regarded as cranially immature and mature, respectively. Sex ratio of immatures was approximately 1:1 (males: n = 16, females: n = 13), while that of mature specimens was almost 1:3 (males: n = 8, females: n = 22). The suture index suggested that New Zealand *Delphinus* sp. obtain cranial maturity at approximately 11 years. Specimens with ≤ 6.8 % of partly worn teeth were between 1 to 3 years and cranially immature, while specimens with any number of rostral teeth worn down to the gum line were physically mature. Sexual size dimorphism, with larger sizes recorded for males, were detected in total body length (TBL) and in 22.7% (n = 15) of cranial characters analyzed, of which 86.7% (n = 13) were width measurements. In total 70.0% (n = 7) of size dimorphic characters that could be allocated to a cranial functional complex were related to the feeding apparatus. RL/ZW ratio (mean: 1.49 ± 0.06 (SD); range: 1.39 - 1.61) and upper tooth counts (45 - 56) of cranially mature New Zealand specimens assessed (pooled for both sexes) overlapped with values published for both the short-beaked and long-beaked form. Values of TBL, condylobasal length (CBL), rostrum length (RL), and zygomatic width (ZW) were also of intermediate status in both sexes. Findings reported herein suggest that New Zealand *Delphinus* sp. should be regarded as a large form of *D. delphis* until further morphometric and genetic data becomes available. No evidence of regional differences between HG and non-HG specimens was detected in either metric or non-metric characters, however, sample sizes were small. Variance of repeated measures was lower in the calliper (range: 0.1 to 0.7%) than in the microscribe (range: 1.1 to 10.7%) data set for all characters assessed (n = 33). High precision between both data sets was detected for 69.7% (n = 23) of characters (MAD below the 1 mm threshold) and REM of 93.9% (n = 31) of character was deemed excellent or good, indicating high compliance between both methods for the majority of characters assessed.

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This project would not have been possible without the engagement, commitment, and help of many people. I would especially like to thank both of my supervisors, Dr. Karen Stockin and Dr. Sinéad Murphy, for providing continued support, advice, help, feedback, and words of encouragement throughout the length of this Masters project, as well as for passing on invaluable skills and knowledge. In addition, thank you, Karen, for giving me the opportunity to conduct this research, and thank you, Sinéad, for your engagement, for bringing the microscribe component into this project, and for the road trip to the Museum of New Zealand Te Papa Tongarewa.

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THANK YOU!

'Was mich nicht umbringt, macht mich stärker.'

Friedrich Nietzsche

Therefore, I now know that I am able to tackle the next challenge! ☺

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List of Abbreviations

95% CI	=	95% Confidence Interval
ANCOVA	=	Analysis of Covariance
ANOC(R)	=	Length from the right antorbital notch to the right occipital condyle
ANOVA	=	Analysis of Variance
APM	=	Age at physical maturity
ASM	=	Age at sexual maturity
CBL	=	Condylobasal length
cm	=	Centimetres
COH	=	Configuration of the optical hiatus
CPN	=	Contact between premaxilla and nasal bone
CV	=	Coefficient of Variation
DoC	=	Department of Conservation
fr-fr	=	Frontal-frontal suture
fr-in	=	Frontal-interparietal suture
fr-or	=	Frontal-orbitospenoid suture
g	=	Gram
GLG	=	Growth layer groups
GLLPTF	=	Greatest length of the left post-temporal fossa
GWEN	=	Greatest width external nares
GWIN	=	Greatest width internal nares
GWM	=	Greatest width across both maxillae
GWPA	=	Greatest width of the parietal bone
GWPR	=	Greatest width of the premaxillae
GWRM	=	Greatest width of the right maxilla bone
HG	=	Hauraki Gulf
HLM	=	Height left mandible
HMF	=	Height foramen magnum
I.Q.R.	=	Interquartile range
IAS	=	Interalveolar septa
ID	=	Identification
Im	=	Cranially immature
km	=	Kilometres

la-fr	=	Lacrimal-maxilla-frontal suture
LLLAC	=	Length of the left lacrimal bone
LLM	=	Length left mandible
LLSQ	=	Length of the left squamosal bone
LMF	=	Length of the mandibular fossa
LOL	=	Left orbit length
LRM	=	Length right mandible
LWPA	=	Least width of the parietal bone
MAD	=	Mean absolute difference
MANCOVA	=	Multivariate Analysis of Covariance
MANOVA	=	Multivariate Analysis of Variance
Mat	=	Cranially mature
MaxDLTF	=	Maximum diameter of the left temporal fossa
MaxDRTF	=	Maximum diameter of the right temporal fossa
max-fr	=	Maxilla-frontal suture
ME	=	Measurement error
Mio	=	Million
mm	=	Millimetres
MMD	=	Mean measure of divergence
MNC	=	Extension of the maxillae relative to the nuchal crest
mtDNA	=	Mitochondrial DNA
na-fr	=	Nasal-frontal suture
non-HG	=	Non-Hauraki Gulf
NZCDP	=	New Zealand Common Dolphin Project
pa-ex	=	Parietal-exoccipital suture
pa-fr	=	Parietal-frontal suture
pal-max	=	Palatine-maxilla suture
pal-pal	=	Palatine-palatine suture
pa-so	=	Parietal-supraoccipital suture
pers. comm.	=	Personal communication
POOW	=	Postorbital width
premax-max	=	Premaxilla-maxilla suture
PROW	=	Preorbital width
pt-ba	=	Pterygoid-basioccipital suture

pt-pal	=	Pterygoid-palatine suture
REM	=	Relative error magnitude
REXN	=	Distance from tip of rostrum to external nares
RL	=	Rostrum length
RL/ZW ratio	=	Rostrum length to zygomatic width ratio
SD	=	Standard deviation
so-ex	=	Supraoccipital-exoccipital suture
SSD	=	Sexual size dimorphism
SST	=	Sea surface temperature
SW	=	Skull weight
SW/CBL^3	=	Skull weight to condylobasal length ratio
SW/ZW^3	=	Skull weight to zygomatic width ratio
TBL	=	Total body length
TRIN	=	Distance from tip of rostrum to internal nares
unpubl.	=	Unpublished
WBOCS	=	Width between the basioccipital crest at the basioccipital-sphenoid suture
WFM	=	Width foramen magnum
WMF	=	Width of the maxillae relative to the frontal bones
WPT	=	Width of the pterygoid bones
WR1/2	=	Width of rostrum at midlength
WR3/4	=	Width of rostrum at 3/4 length from base
WR60	=	Width of rostrum at 60 mm from base
WRB	=	Width of rostrum at base
ZW	=	Zygomatic width
zy-pa-ex	=	Zygomatic-parietal-exoccipital suture