

Photo-identification and its application to gregarious delphinids: Common dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand

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ABSTRACT

Common dolphins (*Delphinus* sp.) remain one of the most poorly understood delphinids within New Zealand waters. Baseline data on their abundance, site fidelity, movement patterns, and social structure remain unknown. This thesis applies photo-identification (photo-id) methods to fill in this data gap and provide the first comprehensive assessment of abundance, site fidelity, movement patterns, and social structure of *Delphinus* within New Zealand waters.

Traditional cetacean photo-id relies on identification of dorsal fin nicks and notches. Photo-id is, therefore, rarely applied to common dolphins due to the lack of distinctive markings for individual identification and their gregarious nature. This study, however, applied this technique to identify unique individuals by examining dorsal fin nicks and notches in combination with dorsal fin pigmentation patterns in an effort to provide an additional stable feature for individual identification. Of all individuals examined, 95.3% exhibited dorsal fin pigmentation, with 92.7% manually identified using pigmentation as the only identifying feature. Novel computer vision and machine learning techniques were applied to examine pigmentation patterns. The correct individual was identified via pigmentation patterns alone 52.5%, 70.8%, and 78.7% of the time within the top-1, top-5, and top-10 matches, respectively. Furthermore, 79.9% of individuals were able to be classified as adult or immature based on pigmentation patterns alone. Overall, results suggested that pigmentation patterns are stable over time (for up to 11 years), although it is not known what proportion of the population exhibits such stability. Pigmentation patterns proved to be a reliable means of identification and can be used as a primary feature for identifying individual common dolphins in the Hauraki Gulf (HG). Future studies should trial this technique for this species in other worldwide populations.

To estimate population parameters, mark-recapture (MRC) analysis can be conducted. This thesis examined the challenge of using this technique to estimate population parameters for common dolphins in the HG. The main challenges identified included the: high portion of unmarked animals; low levels of distinctiveness, and; the gregarious transient nature of *Delphinus*. Despite such challenges, reliable photo-id protocols were developed to increase the accuracy of individual identification and produce estimates of population parameters. These protocols included: combining the use of nicks and notches with pigmentation patterns as a primary feature for identification; classifying

individuals as highly distinctive (D1), distinctive (D2), or non-distinctive (D3); the development of a distinctiveness threshold to catalogue individuals, and; for population analysis, stratifying data by the level of individual distinctiveness (by examining differences between D1 individuals only compared to D1&D2 individuals combined). The use of these protocols enabled the identification of 2,083 unique individual common dolphins in the HG between 2010 and 2013. Sighting records from these 2,083 individuals were used in a POPAN framework to estimate population parameters. The total population abundance was then calculated using a mark ratio (for D1 only and D1&D2 individuals) to account for the proportion of unmarked dolphins in the population. The best model selected for D1 individuals included constant survival and probability of entry and time dependant capture probability ($\phi_{(t)}$, $p_{(t)}$, $\beta_{(t)}$), whereas for D1 and D2 individuals combined, probability of entry varied by time ($\phi_{(t)}$, $p_{(t)}$, $\beta_{(t)}$). Apparent survival was constant for both D1 (0.767) and D1 and D2 (0.796) individuals. The low apparent survival estimates are likely caused by emigration of transient dolphins. Capture probability varied over time for both D1 (range=0.021-0.283) and D1 and D2 (range=0.006-0.199) individuals. Probability of entry remained constant for D1 individuals (0.062) but varied over time for D1 and D2 individuals (range=0.000-0.413). The total population was estimated at 7,795 dolphins (CI=7,230-8,404) when only D1 individuals were included, but increased to 10,578 individuals (CI=9,720-11,512), with the addition of D2 individuals. The photo-id protocols used here allowed maximised use of the photo-id data and provided a useful approach to estimate population parameters of poorly marked gregarious delphinids. The techniques applied here could be used for MRC studies of other *Delphinus* populations, or for other similar low marked gregarious species.

Considering the large number of individuals found to use the HG, the level of site fidelity for common dolphins within this region was assessed. Likewise, an assessment was conducted to determine if individuals move between regions, primarily to the Bay of Plenty (BOP), and additionally to the Bay of Islands (BOI) and the Marlborough Sounds (MS). Common dolphins displayed long-term site fidelity to the HG, with 2,399 marked individuals identified within this region between 2002 and 2013. These individuals were classified as occasional visitors (95.1%), moderate users (4.8%), and frequent users (0.1%). Individuals were also found to move between neighbouring regions including the Bay of Plenty (2.2%) and Bay of Islands (0.2%). In addition, a number of individuals were

defined as travellers moving between multiple regions. Travellers exhibited opposite seasonal peaks in re-sightings between the HG and the BOP, which may represent an influx of individuals from these neighbouring regions. A total of six travellers were observed to move between the HG and the BOP in stable pairs. Knowledge of common dolphin site fidelity to the HG and movement patterns to other regions is vital for identifying management units and, therefore, providing effective conservation of this species in New Zealand waters.

The definition of management units requires knowledge of a species social structure. Findings presented here provided the first analysis of *Delphinus* social structure in the Hauraki Gulf. Considering common dolphin associations may be difficult to study due to their gregarious nature, an assessment of which sighting thresholds were best for conducting social structure analysis was conducted. Sighting thresholds were assessed to determine which is best for: maintaining reliability without the loss of data; association indices, and; representation of the true social structure. Precision of the data increased when the sighting threshold decreased. Levels of association were reported to decrease when restricting the number of times an individual was observed. Notwithstanding, maximum association indices were similar regardless of the sighting threshold used. Social structure analysis was considered to be a 'somewhat representative' pattern of the true social organisation of common dolphins in the HG. For these reasons, a threshold of four or more sightings was considered the best representation of social structure for this population. Common dolphins in the HG displayed fluid associations at the population level (Coefficient of Association; COA=0.02), although some individuals were found to associate with particular companions (maximum COA=0.46). The population was also classified as a well-differentiated society ($S=1.230$). Individuals did not form short-term companionships but instead preferred long-term associations. Structured relationships existed, some of which lasted for periods of up to 70 days. The examination of the sociality of gregarious species is therefore possible using photo-id techniques and provides information on association patterns for common dolphins within New Zealand waters. Such information is important to collect over the long-term to be able to determine relationships between individuals which can be used to develop effective management this population.

To efficiently manage common dolphins in the HG and New Zealand waters, it is important to be able to identify the natural and anthropogenic pressures faced by

populations. To examine this, photo-id was also applied to assess the prevalence of lesions and deformities. The majority (78.0%) of individuals photo-identified exhibited lesions, whereas only 0.5% had deformities. Of all body segments examined, the anterior peduncle exhibited the highest percentage of lesions or deformities (91.1%). A significant difference in the prevalence of lesions between the leading and trailing edges of dorsal fins was also evident. A number of possible causes of lesions and deformities were highlighted including intra- or inter-specific interactions, congenital malformations, environmental conditions, infectious origins, fisheries and vessel interactions, and/or human-induced environmental stressors. Considering the number of pressures faced by this population it is important to monitor lesion and deformity prevalence over time to highlight natural or human induced impacts within the environment.

As common dolphins remain part of an open super-population, which inhabits the north-eastern coastline of New Zealand's North Island, they are therefore, subject to cumulative pressures. Considering a baseline abundance estimate is available, further monitoring and meaningful re-evaluations of this population is required. Proactive as opposed to reactive conservation is, therefore, recommended to ensure effective management of this species in New Zealand waters.

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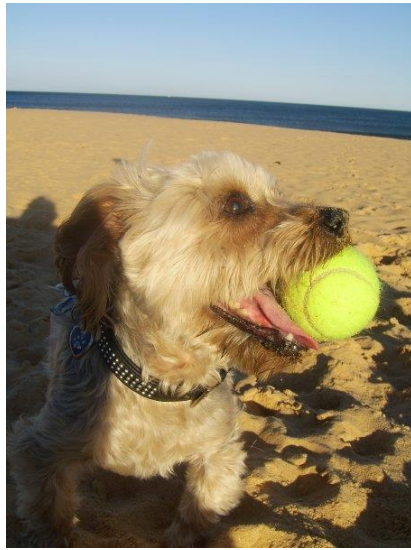
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LIST OF ABBREVIATIONS

Abundance	N
Admiralty Bay	AB
Akaike's Information Criterion	AIC
All captured	AC
Apparent survival/survival probability	ϕ
Association indices	AI
Bay of Islands	BOI
Bay of Islands Common Dolphin Catalogue	BOICDC
Bay of Plenty	BOP
Bay Of Plenty Common Dolphin Catalogue	BOPCDC
Beaufort Sea State	BSS
Canonical Analysis of Principal Co-ordinates Procedure	CAP
Capture probability	p
Centimetre	cm
C-hat	\hat{c}
Chi-square	χ^2
Coefficients of association	COA
Coefficient of variation	CV
Confidence interval	CI
Constant	.
Cophenetic correlation coefficient	CCC
Correlation coefficient	r
Cormack-Jolly-Seber	CJS
Distinctive individual	D2
Distinctively marked individual	DMI
East Auckland Current	EAUC
Exempli gratia, for example	e.g.

Encounter rate	ER
Et alii, and others	et al.
Goodness of fit	GOF
Global positioning system	GPS
Half-weight index	HWI
Hauraki Gulf	HG
Hauraki Gulf Common Dolphin Catalogue	HGDC
Highly distinctive individual	D1
Horse-power	hp
Inner Hauraki Gulf	IHG
International Union for Conservation of Nature	IUCN
International Whaling Commission	IWC
Interquartile range	IQR
Iterative closest point	ICP
Jolly-Seber	JS
Kilometres	km
Kilometres squared	km ²
Knots	kts
Lagged Association Rate	LAR
Leave-one-out cross-validation	LOOCV
Linear discriminant analysis	LDA
Marked population	\hat{N}_m
Marked and unmarked population	\hat{N}_{total}
Mark ratio 1	MR1
Mark ratio 2	MR2
Mark-recapture	MRC
Marlborough Sounds	MS
Marlborough Sounds Common Dolphin Catalogue	MSCDC

Metres	m
Monthly sighting rates	MSR
Non-metric dimensional scaling	MDS
Multivariate	MV
Nick/notch distinctiveness	ND
Non-distinctive individual	D3
Not all captured	NAC
Null Lagged Association Rates	NLAR
Outer Hauraki Gulf	OHG
Photo-identification	photo-id
Photographic quality	PQ
Polychlorinated biphenyls	PCBs
Population size	N
Probability of entry	β
Practical salinity unit	psu
Quasi-like Akaike Information Criterion	QAICc
Queen Charlotte Sound	QCS
Sea surface temperature	SST
Seasonal sighting rate	SSR
Shrinkage discriminant analysis	SDA
Simple Ratio Index	SRI
Super-population	\hat{N}_{Super}
Standard errors	SE
Standard deviation	SD
Standardised Lagged Association Rates	SLAR
Standardised Null Lagged Association Rates	SNLAR
United States of America	U.S.A.
Unpublished	Unpub.

Variance inflation factor c-hat	\hat{c}
Varying by time	t
Yearly sighting rates	YSR