Implementation of fotogrametry techniques as body mass estimation of Indo-pacific bottle nose dolphin (Tursiops aduncus) in Bali dolphin lodge

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ABSTRACT

This study was aimed to estimate the body mass of Indo-Pacific bottlenose dolphins through photogrammetric techniques. Dolphins are animal listed in Appendix 2 according to Convention on International Trade in Endangered of Wild Fauna and Flora (CITES), which must be considered for its sustainability. Poor management of dolphins will causes stress. Morphometrics measurements need to be done to see the body condition of the dolphin. The data used are Indo-Pacific bottlenose dolphins that are captived in the Bali sea under professionally managed care. Dolphins are photographed with lateral and ventral position. Photographs result will be measured at a lateral position with lateral lengths, L1, L2, L3, and L4. Measurement at the ventral position are ventral lengths, D1, D2, D3, and D4. The measurement data obtained by reading with ImageJ then calibrated and analyzed with simple linear regression. From the results of regression analysis of dolphins weighted in the lateral position with L2 has a value (R^2 = 0.984) and lateral position with D2 (R^2 = 0.958).

Key words: *Fotogrametry techniques, Body mass estimation, Indo-pacific bottle, Tursiops aduncus*

Introduction

Indonesia is a country that has vast marine wealth. Indonesia's sea area according to the Ministry of Maritime Affairs and Fisherie is around 3.25 million km² and 2.5 million km² Exclusive Economic Zone (EEZ). Indonesian marine waters have a rich marine life of more than 2,200 species of reef fish and are crossed by a variety of species, including sea turtles and mammals (Estradivari, 2017). The ordo of marine mammals consists of three orders, i.e. Cetaceans, Carnivores and Sirenians. The Cetacean ordo is one of the marine mammals that crosses Indonesian marine waters. The Cetacean order has 33 species, and 17 species including family Delphinidae (Mustika, 2015; Mira, 2013). The waters of the Bali island in particular, there were 16 species of Cetacea ordos that crossed (Mustika, 2015).

The Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) according to the Convention on International Trade in Endangered of Wild Fauna and Flora (CITES) is included in the Appendix II category. Animals belonging to the category Appendix II are animals that are not threatened with extinction, but are threatened with extinction if traded without a clear rule. Cetacean conservation which aims to protect and maintain the stability of the cetacean population, especially the Indo-Pacific bottle nose dolphins (*Tursiops aduncus*), needs to be of more concern. Specifically in the body condition and stress level management of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) for their survival (Read, 1993).

Knowledge about the size and body condition of cetaceans can be used to determine nutritional status in individuals (Cornick, 2016). Body measurements and health monitoring in the overall Atlantic Nose Dolphins (*Tursiops truncates*) population as a reference for evaluating the health condition of the body in the wild (Hart, 2013). Opportunities to measure regularly from Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) are rare.

Predictive tools for estimating body size and growth patterns have been developed. Growth patterns and body size reference ranges for body conditions can be used to evaluate and compare entire populations (Read, 1993; McFee, 2012). Conducted morphometric measurements to estimate the weight of the Atlantic Bottlenose Dolphin (*Tursiops truncates*) (Lauderdale, 2019). Morphometric measurements were carried out on wild sea animals and captive animals. Wild sea animals are measured on the health assessment of capturing and releasing wild animals, while animals that are captive using a trainer handled, show results that can be used to predict body weight with R^2 = 0.937. This value has a meaning of 0.937 or 93.7% influenced by body length, and body circumference, while 7.3% is the result of a reduction of the total percentage of accuracy of the estimated weight of 100%. The value of 7.3% is explained by other causes.

Photogrammetry is a technique that involves measuring morphometry through photography techniques. This technique is appropriate to reduce any threat to animals because it does not require excessive handling of animals (Krause, 2017). Photogrammetry can be used to estimate the mass and volume of wildlife, such as pinnipeds (Beltran, 2018). The dorsalfin of Hector's dolphins (*Cephalorhynchus hectori*) by photogrammetric techniques (Webster, 2010). The dorsalfin length of the Hector dolphin (*Cephalorhynchus hectori*) is accurate enough to measure the surface area of dorsal fin when compared with the height of the dorsal fin Hector dolphin (*Cephalorhynchus hectori*). The prediction of the weight of the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) through photogrammetric techniques there is no research data. This is the reason for estimating the weight of Indo-Pacific bottle nose dolphin (*Tursiops aduncus*) using body measurements of the Indo-Pacific bottle nose dolphins (*Tursiops aduncus*) through photogrammetric techniques.

Materials and Methods

The research material used was seven Indo-Pacific bottlenose dolphins (*Tursiops aduncus*). The equipment used in this study includes measuring tape, remote shutter, stationery, monopod and Canon 50D camera with EF-S lens 10-18mm f / 4,5-5,6 IS STM.

Indo-Pacific animals are bottlenose dolphins (*Tursiops aduncus*), five males and two females. Animals are in a cage in the middle of the sea. Handling of animals is carried out by trainers who are on site, so it is easier to do the process of taking photos. Handling is done in seawater using a special whistle.

The process of taking pictures is done on a cage using a 50D canon camera, remote shutter and wide cannon lens EF-S lens 10-18 mm f / 4,5-5,6 IS STM along with a monopod. Shooting was done 50 times with a distance of 2.5 meters from animals and a 1.5 meter long monopod. Animals are fully photographed lateral and vental positions of the anterior and posterior parts. The picture is taken with an auto focus method that is centered on animals

This study was analyzed by the method of reading data from photos in the form of pixels with Image-J and then converted to cm based on the calibration results. Weight estimation was analyzed using paired sample t tests, multiple linear regression in SPSS version 25.

Results and Discussion

Measurement and callibration of the body circumference and length

The measurement of the body circumference is done with 8 positions, as shown in Figure 1 on the left side are L1, L2, L3, L4 in lateral position on the right side in ventral position are D1, D2, D3, D4. The measurement results in the pixels form which then calibrated with a measuring tape measured the number of pixels. Repetition was done in 10 times for each position. Figure 1 showed that there were different site of body circumference measurement by the number of the position. The lateral position resulting the letter marks such as A, B, D, E, F, G, H, I, J and T marks. The ventral position resulting the letter marks such as A, C, J, K, L, M, N, O, P, Q, R, S and T marks. Remarks A is end of rostrum, B is the point parallel to dorsal fin, C is pectoral fin sinister, D is cranial dorsal fin, E is ventral point perpendicular to D, F is apex dorsal fin, G is ventral point perpendicular to F, H is caudal dorsal fin, I is ventral point perpendicular to H, J is median notch, K is cranial pectoral fin sinister, L is cranial pectoral fin dexter, M is caudal pectoral fin sinister, N is caudal pectoral fin dexter, O is pectoral fin dexter, R is genital organs, P is cranial sinister point, Q is cranial dexter point, S is anus and T is flukes (tail).

The results of the calibration of the indo-pacific bottle nose dolphin thoracic circumference (*Tursiops aduncus*) are presented in Tables 1 and 2. The calibration results need to be multiplied 2 to fulfill the third table. The calibration results need to be multiplied twice to fulfill the third table. The multiplication results are presented in Table 3. Calibration results for indo-pacific bottle nose dolphins (Tursiops aduncus) are presented in Table 4.

Multiple linear regression equations

The equation of multiple regression lines results from multiple linear regression analysis. Beta coefficient shows the relationship between the independent variable and the dependent variable. Beta coefficients are used to make linear regression equations. Weight estimation can be done with a large R^2 value. The greater the value of R^2, the stronger the

Table 1. The result of callibration in lateral length data of indo-pacific bottle nose dolphin (*Torsiops aduncus*)

Name	Mean of Lateral Length Pixel	Lateral Length Calibration	Mean of Ventral Pixel Length	Ventral Length Calibration
Apollo	3810.61±173.35	277.13±13	3690.81±214.23	268.10±15.56
Ardhan	2880.22±191.12	209.22±13.88	3075.98±80.07	223.44±5.82
Jasmin	3026.00±77.56	219.81±5.63	2917.67±23.38	211.94±1.70
Marco	3171.87±88.70	230.40±6.44	3192.73±73.14	231.92±5.31
Rig	3220.79±121.44	233.96±8.82	2946.11±130.81	214.00±9.50
Rose	3270.45±55.32	237.59±4.02	3337.00±65.40	242.42±4.75
Triton	3436.76±115.12	249.64±8.36	3400.10±43.51	246.98±3.16

Table 2. The result of callibration in ventral circumference data of indo-pacific bottle nose dolphin (*Torsiops aduncus*)

Name	Pixel D1	Calibration D1	Pixel D2	Calibration D2	Pixel D3	Calibration D3	Pixel D4	Calibration D4
Apollo	377.60±32.45	27.43±2.36	443.74±31.75	32.23±2.81	393.67±27.50	28.60±2.00	946.87±59	68.78±6.45
Ardhan	337.60±22	24.52±1.83	380.93±20.47	27.67±1.49	322.53±14.40	23.43±1.05	908.07±29.35	65.96±2.13
Jasmin	370.92±20.86	26.94±1.52	433.00±13.35	31.45±0.97	339.83±6.50	24.69±0.47	902.87±33.10	65.58±2.40
Marco	339.73±14.33	24.68±1.04	405.03±17.09	29.42±1.24	354.13±7.30	25.72±0.53	880.67±18.53	63.97±1.35
Rig	309.61±16.29	22.49±1.18	383.86±19.48	27.88±1.42	317.75±13.69	23.08±0.99	633.47±31.83	46.01±2.31
Rose	332.23±3.52	24.13±0.26	4460.60±13.94	32.44±1.01	304.10±11.62	22.09±0.84	782.07±37.17	56.81±2.70
Triton	351.78±6.51	25.55±0.47	457.73±9.89	33.25±0.72	365.33±10.72	26.54±0.78	797.80±29.95	57.59±2.18

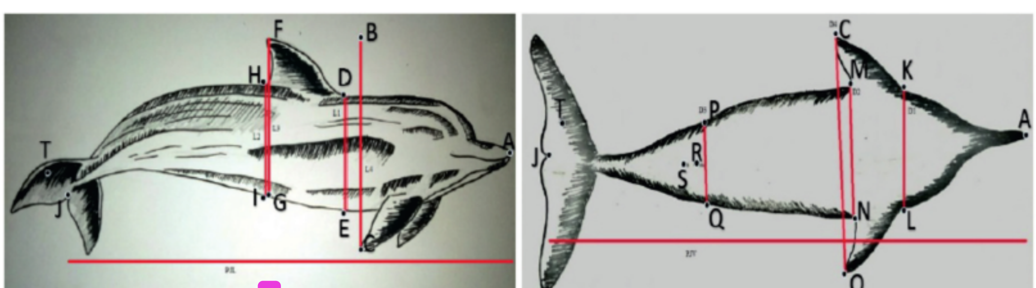

Fig. 1. Site of measurement of the indo-pacific bottle nose dolphin (*Tursiops aduncus*) in lateral view on the left side and in ventral view on the right side (Personal documentation, 2019)

regression model's ability is obtained or the stronger it is to estimate dolphin weight (*Tursiops aduncus*). The results of the regression analysis and the value of **R^2** are presented in Table 5.

The results of multiple linear regression analysis have a large R^2 value above 80%. Lateral length measurements with chest circumferences L1, L2, L3, L4, D1, D2, D3 and D4 have R^2 values of more than 90%. Measurement of ventral length with chest circumferences L1, L2, L3, L4, D1, D2, D3 and D4 have R^2 values of more than 80%. The value of R^2 is not much different from the value of R^2 measurements using a measuring tape, which is equal to 0.933 or 93% (Lauderdale, 2019).

The regression equation with the largest R^2 value is owned by PJLL2 (R^2 = 0.984) with the equation bb = 113,932 + 0.593PJL - 0.257L2 and PJLD2 (R^2 = 0.958) with the bb equation = 112.788 + 0.551 PJL -

Table 3. The result of callibration in ventral circumference data after multiplied twice of indo-pacific bottle nose dolphin (*Torsiops aduncus*)

Name	Pixel L1	Calibration L1	Pixel L2	Calibration L2	Pixel L3	Calibration L3	Pixel L4	Calibration L4
Apollo	720.93±46.82	52.37±3.40	700.80±47.84	50.91±3.47	1030.8±74.88	74.88±5.16	10383.6±169.29	100.5±12.30
Ardhan	528.63±51.49	28.40±3.74	520.67±45.60	37.82±3.31	790.67±90.49	57.43±6.57	1054.5±27.69	76.60±2.01
Jasmin	686.82±16.18	49.89±1.18	683.20±22.54	49.63±1.64	916.50±26.53	66.57±1.96	1048.8±59.40	76.18±4.31
Marco	632.60±22.98	45.95±1.67	601.43±22.05	43.69±1.60	931.73±36.82	67.68±2.67	1182.80±47.26	85.92±3.43
Rig	549.53±16.44	39.85±1.19	551.53±22.57	40.06±1.64	803.93±26.97	58.40±1.96	947.00±23.21	68.79±1.69
Rose	596.10±26.41	43.30±1.92	569.76±18.06	41.39±1.31	818.87±28.05	59.48±2.04	966.70±39.58	70.22±2.88
Triton	630.10±24.65	45.77±1.79	611.13±22.54	44.39±1.64	898.60±32.02	65.27±2.33	1146.8±20.57	83.30±1.49

Table 4. The result of double multiplication in body circumference measurements of indo-pacific bottle nose dolphin (*Torsiops aduncus*)

Name	L1(cm)	L2(cm)	L3(cm)	L4(cm)	D1(cm)	D2(cm)	D3(cm)	D4(cm)
Apollo	104.74	101.81	149.75	201.01	54.86	64.47	57.19	137.56
Ardhan	76.80	75.64	114.87	153.20	49.05	55.34	46.86	131.92
Jasmin	99.78	99.25	133.15	152.37	53.89	62.91	49.37	131.17
Marco	91.90	87.38	135.36	171.84	49.36	58.84	51.45	127.94
Rig	79.69	80.13	116.79	137.58	44.98	55.77	46.16	92.03
Rose	86.60	82.77	118.96	140.44	48.27	64.88	44.18	113.62
Triton	91.54	88.78	130.55	166.61	51.11	66.50	53.08	115.90

Table 5. The result of multiple linear regression analysis of indo-pacific bottle nose dolphin (Torsiops aduncus)

Information	Score R^2	Multiple Regression Equations
PJLL1	0.979	bb = 112.133 + 0.594PJL - 0.234L1
PJLL2	0.984	bb = 113.932 +0.593PJL - 0.257L2
PJLL3	0.965	bb = 111.414 + 0.582PJL - 0.136L3
PJLL4	0.955	bb = 107.007 + 0.519PJL + 0.011L4
PJLD1	0.964	bb = 120.009 + 0.551PJL - 0.375D1
PJLD2	0.958	bb = 112.788 + 0.551 PJL - 0.188D2
PJLD3	0.954	bb = 107.267 + 0.530PJL - 0.022D3
PJLD4	0.955	bb = 109.322 + 0.528PJL - 0.022D4
PJVL1	0.819	bb = 106.002 + 0.524PJV + 0.034L1
PJVL2	0.822	bb = 103.722 + 0.517PJV + 0.079L2
PJVL3	0.823	bb = 103.858 + 0.500PJV + 0.083L3
PJVL4	0.819	bb = 107.597 + 0.518PJV + 0.018L4
PJVD1	0.833	bb = 121.884 + 0.570PJV - 0.471D1
PJVD2	0.820	bb =110.86 + 0.549PJV - 0.113D2
PJVD3	0.835	bb = 100.335 + 0.466PJV + 0.445D3
PJVD4	0.904	bb = 120.472 + 0.598PJV _ 0.236D4

0.188D2. The average estimation results, if the values of PES, L2 and D2 are included in the equation are 231.01 and 231.73; while the average body weight is 231.71.

The body weight PJLL2 equation has a difference of 0.7. The results of paired analysis of the t test sample has 0.981 can be interpreted as not having a significant difference. The average PJLD2 equation with an average body weight has a difference of 0.2. The results of paired analysis of the t test sample has 0.982 can be interpreted as not having a significant difference. The results of equation analysis with paired sample t tests are presented in Table 6. The best statistical estimation formula that can be accepted with good results with the largest R^2 value for multiple regression analysis is PJLL2 with R^2 value 98.4%; this is in accordance with the position which is mostly done by bottlenose dolphins (*Tursiops sp.*) in the wild are mostly found in lateral measurement positions. Lateral position is the normal position of bottlenose dolphins (*Tursiops sp.*) (Kreb, 2005). The position of bottlenose dolphins (*Tursiops sp.*) Appears to be ventral only for animals that have done well in training (Lauderdale, 2019).

Conclusion

Photogrammetric photo techniques can be used as an alternative way to estimate the weight of the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) without having to come into direct contact with the dolphin. Weight estimation can be done using lateral length measurements with measurements of chest circumference L2 (PJLL2), BW = 113,932 + 0.593PJL-0.257L2 (R^2 = 0.984) and lateral length with measurement of chest circumference D2 (PJLD2), BW = 112.788 + 0.551PJL-0.188D2 (R^2 = 0.958).

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Table 6. The result of analysis on body weight estimation. conventional weight with paired sample t test of indo-pacific bottle nose dolphin (*Torsiops aduncus*)

Information	Estimated Weight (Kg)	Conventional Weight (Kg)	Paired sample t test Results
PJLL1	231.68±11.66	231.71± 11.79	0.959
PJLL2	231.73±11.69	231.71± 11.79	0.981
PJLL3	231.74±11.58	231.71± 11.79	0.974
PJLL4	231.66±11.51	231.71± 11.79	0.953
PJLD1	231.64±11.56	231.71± 11.79	0.930
PJLD2	231.73±11.53	231.71± 11.79	0.982
PJLD3	231.66±11.51	231.71± 11.79	0.956
PJLD4	231.66±11.51	231.71± 11.79	0.961
PJVL1	231.74±10.67	231.71± 11.79	0.988
PJVL2	231.71±10.69	231.71± 11.79	0.998
PJVL3	231.58±10.68	231.71± 11.79	0.945
PJVL4	231.76±10.67	231.71± 11.79	0.983
PJVD1	231.68±10.75	231.71± 11.79	0.984
PJVD2	232.47±10.67	231.71± 11.79	0.703
PJVD3	231.57±10.76	231.71± 11.79	0.940
PJVD4	231.81±11.22	231.71± 11.79	0.947

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