SKELETON ANALYSIS OF *Tursiops truncatus* REGIO COSTAE AND SCAPULA STRANDED ON SENGGIGI BEACH, WEST LOMBOK

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Abstract

The dolphin (*Tursiops truncatus*) is the most studied and most common species of *cetacean* in captivity. In this study, the size results obtained were the *ribs* and *scapula*. The first measure is a difference from the proximal to the distal end between the literature and this study. the second and third sizes have long, short, and longer proximal to distal differences. The fourth, fifth and sixth sizes show that the bones of *T.truncatus* are smaller than those of the *Numataphocoena yamashitai* species and the seventh size shows that the differences between *T.truncatus* and the *Numataphocoena yamashitai* species are several short and long costae. For the *scapula*, the dimensions of the first and second bones are larger than the present study species *T.truncatus* and *Numataphocoena yamashitai*. The sizes of the three results from this study are almost the same as the species *Numataphocoena yamashitai* except for the species Prosqualodon marplesi, which is larger than this study and research in California. The fourth size, which is 49.0 mm from head to tuberculum, is larger than the species *T.truncatus* and *Numataphocoena yamashitai* studied. The fifth size, the diameter of the *rib* head of this research species is smaller than the species *Numataphocoena yamashitai* and *Prosqualodon marplesi*, both of which are smaller than *T.truncatus*, and some of these differences are caused by food, habitat and environmental conditions.

***Keywords**: Tursiops truncatus, Senggigi, Morphometrics, Costae, Scapula*

Abstrak

Lumba-lumba (*Tursiops truncatus*) adalah spesies *cetacea* yang paling banyak dipelajari dan yang paling umum di penangkaran. Dalam penelitian ini, hasil ukuran yang didapatkan *os costae* dan *os scapula*. ukuran pertama terdapat perbedaan dari ujung proksimal ke distal antara literatur dan penelitian ini. ukuran kedua dan ketiga memiliki perbedaan proksimal ke distal yang panjang, pendek, dan lebih panjang. Ukuran keempat, kelima dan keenam menunjukkan bahwa tulang *T.truncatus* lebih kecil dari spesies *Numataphocoena yamashitai* dan ukuran ketujuh menunjukkan bahwa perbedaan antara *T.truncatus* dan spesies *Numataphocoena yamashitai* beberapa costae pendek dan panjang. Untuk bagian scapula, ukuran pertama dan kedua tulang ini lebih besar dari spesies penelitian ini *T.truncatus* dan *Numataphocoena yamashitai*. Ukuran ketiga hasil penelitian ini hampir sama dengan spesies

Numataphocoena yamashitai kecuali untuk spesies *Prosqualodon marplesi*, yang ukurannya lebih besar dari penelitian ini dan penelitian di California. Ukuran keempat, yang berjarak 49,0 mm dari kepala ke *tuberculum*, lebih besar dari spesies *T.truncatus* dan *Numataphocoena yamashitai* yang diteliti. Ukuran kelima, diameter kepala *costae* spesies penelitian ini lebih kecil dari spesies *Numataphocoena yamashitai* dan *Prosqualodon marplesi*, keduanya lebih kecil dari *T.truncatus*, dan dari beberapa perbedaan ini disebabkan oleh faktor makanan, habitat, dan kondisi lingkungan.

Kata Kunci*: Tursiops truncatus, Senggigi, Morfometri, Costae, Scapula*

1. INTRODUCTION

Dolphins belong to a group of marine animals known as *cetacea* that have evolved completely to live in water. In Indonesian waters, almost all cetacean species have been classified as protected biota. Bottlenose dolphins (*Tursiops truncatus*) are the most studied *cetacean* species and the most common in captivity (Clegg et al., 2017). *T.truncatus* is a marine mammal distributed throughout the world. For decades, scientists have noticed some populations because they are easy to find on coasts. The common bottlenose dolphin *T. truncatus* is a clever species for understanding the health of marine ecosystems as well as *cetacean* life (Barratclough et al., 2019).

The thoracic vertebrae have two functions, namely as longitudinal support for the body and support for the respiratory muscles. *Os costae* and *os sternum* are two parts of the thoracic vertebrae. The *scapula*, *humerus*, *radius ulna*, *manus* and *clavicle* form the fins. Cetaceans have fins that play a role in maintaining body balance, offering alternative support, and turning slowly. When cetaceans migrate, their large flippers are used to create lift. Cetacean fins change shape into concave and convex arcs when swimming and move in an alternating dorsal-ventral movement pattern compared to other types of cetacea (Reynolds III & Rommel, 2018).

Research on the size of the thoracic skeleton and thoracic extremities of the bottlenose dolphin *T.truncatus* species is rarely carried out, especially in Indonesia. With so little research on this species, it is difficult for veterinarians and researchers to determine the characteristics of stranded dolphins. One of the obstacles for rescuers of cetaceans stranded in the field is the difficulty of species identification (Yusmalinda et al., 2017). Some of the bones are actually encrusted in soil, fragile and difficult to identify (Buckley et al., 2014). Based on data on the size of the dolphin's thoracic *skeleton* and thoracic extremities from various countries. Most data is only from other species and there is a lack of skeleton size data from the species *T.truncatus*, especially in Indonesia. So it is necessary to analyze the skeleton of *T.truncatus* to determine the characteristics of this species. Therefore, the purpose of this study was to analyze the skeleton so as to make it easier to determine the character and age of the species *T.truncatus*, a bottlenose dolphin that washed up on Kila Beach, Senggigi, West Lombok.

2. MATERIALS AND METHODS

2.1 Second-Level Heading

The tools used in this research were dolphin skeletons (T. toothbrush, and a small knife (Domínguez-Rodrigo et al., 2010).The materials used are paper, references/literature studies, cloth, thread, gloves, masks, gasoline, 10% formalin, and 30% hydrogen peroxide (Tefera, 2011).

2.2 Sample Observation

The carcass of a T. truncatus dolphin was found washed up on Ampenan beach, Mataram City. To avoid the smell of carcasses, the carcasses were transported to Senggigi beach in West Lombok for burial. The appointment took place four months after the burial. To avoid pathogenic microorganisms in bone or meat carcasses, collection is done manually using a hoe or shovel and latex gloves. After almost all the flesh rots, only small remains remain attached to the bones. The smell of carcasses still pierced people's noses. The remaining bones were cleaned using a spatula and brush (Avila et al., 2015).

2.3 Sample Preparation

The carcass that has been removed is cleaned, measured and reconstructed to its original shape. A solution of 3% H2O2 (hydrogen peroxide), 70% alcohol and water is used to clean the meat. Bones that have been cleaned are soaked for three days using 5 liters of gasoline and 10% formalin. After soaking, the bones are dried and the meat is dried in the sun until dry. A layer of clear flash polish was used to finish this sample (Tefera, 2011).

2.4 Measurement and Analysis of Costae and Scapula Samples

Bone samples were measured using a small meter from proximal to distal and based on the literature we obtained. A measuring tape is the main tool needed in the field to obtain length and thickness measurements. The scapula consists of two pairs in the supraspinous fossa, which is located between the cranial border and the spine of the scapula, is dorsal to the acromion and is slightly wider between the acromion and infraspinous fossa. In lateral view the wide acromion is adjacent to the coracoid process. The infraspinous fossa dominates the undulating lateral surface of the scapula which lies behind the spine. in ventral view, the glenoid cavity is oval in shape. the coracoid process is intact, small in size and somewhat adjacent to the acromion (Zhang et al., 2023).

3. RESULTS AND DISCUSSION

Results of observations of the skeleton of a dolphin (T.truncatus) cosate and scapula region at the West Nusa Tenggara Museum. Based on observations and measurements, there are different changes in bone size between the skeletons on Senggigi beach and other literature studies.

Table 1. Measurement results of *T.truncatus costae* in mm

NO.	Species Name	Distance/diameter and side length	*Costae*													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	*T.truncatus*	The distance between the proximal and distal ends	7,3	123	145	164	189	189	184	186	185	193	180	170	146	161
		Arc length	111	158	205	224	234	233	220	211	211	223	195	185	151	171
		Anteroposterior diameter of the heads of the ribs	8	7	6	6	5	5	7	8	9	9	6	5	6	6
		Distance from head to tubercle	20	22	22	21	21	22								
		Distance between the lateral border of the tubercle and the distal limb	7,9	128	155	174	195	192								
		The length of the articular tubercle	10	5	5	7	5	5								
		Distance from the tubercle to the costal angle	23	20	22	29	37	36								

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Table 2. Results of measurements of the *scapula* of *T.truncatus* in mm

NO.	Species Name	*Scapula*		
		Distance/diameter and side length		Size
2.	*T. truncatus*	1	The greatest length of the scapula	109
		2	Distance between the lateral border of the tubercle and the distal extremity	80
		3	Arc length	21
		4	Distance from the head to the tubercle	18
		5	anteroposterior diameter of the heads of the ribs	17

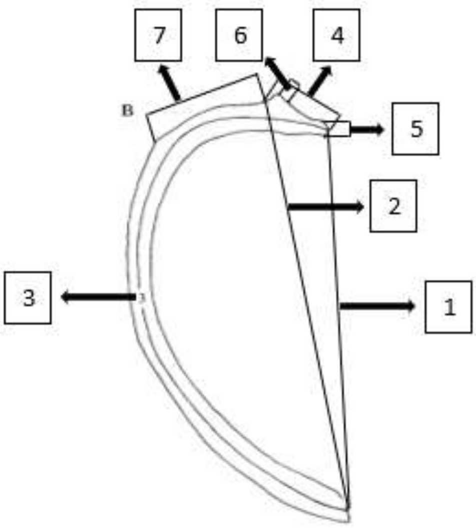

Figure 1. Species *Numataphocoena yamashitai* 1 distance between proximal and distal ends, 2 distance between lateral border of tubercle and distal limb, 3 arc length, 4 distance from head to tuberculum, 5 anther posterior diameter of head of rib, 6 length of side of articular tubercle, 7 Distance from the tubercle to the costal angle (Ichishima & Kimura, 2000)

The mammalian *os costae* articulate with the thoracic vertebrae via a head and tubercle, via a direct or indirect connection to the *sternum*. Usually one or two pairs of caudal *ribs* have no direct or indirect connection to the *sternum* (S. A. Rommel and Reynolds, 2018). The *ribs* attach to the *vertebral column* and attach to the *sternum*. Floating *ribs* are those that do not touch each other's transverse processes. There are twelve to fourteen *os costae* in bottlenose dolphins. The vertebral *ribs* attach to the vertebral column by synovial joints in the anterior *thorax* and by imple fibrous connections in the caudal *thorax*. The most anterior four to five *ribs* are two-headed, they each have a proximal capitulum and a distal tubercle (Rommel, 1990).

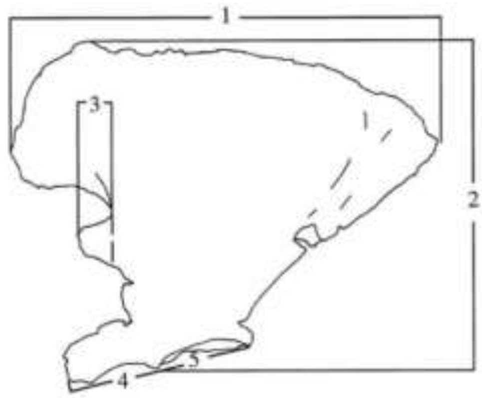

Figure 2. Species *Numataphocoena yamashitai* 1 Length of greatest scapula, 2 distance between lateral margin of tubercle and distal extremity, 3 Length of bow, 4 distance from head to tuberculum, 5 anterposterior diameter of head of rib (Ichishima & Kimura, 2000)

The scapula is attached to the axial skeleton only by muscles; there is no functional *clavicle* in marine mammals. The scapula consists of a flattened blade slightly concave

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medially with an elongated scapular spine extending laterally. The distal end of the spine is the acromion; in most mammals the spine of the scapula is approximately in the middle of the blade of the scapula. However, in cetaceans and manatees, the spine is close to the cranial edge of the blade of the scapula, and its acromion process extends beyond the anterior edge of the blade (S. A. Rommel and Reynolds, 2018).

3.1 Natural Conditions Habitat of T. truncatus dolphins

Bottlenose dolphins are hierarchically structured. The strongest levels of genetic differentiation were found between coastal and pelagic dolphins with microsatellite and mtDNA markers. The haplotype network shows two separate mitochondrial lineages without complete lineage segregation between coastal and pelagic dolphins. Shared haplotypes indicate possible migration, incomplete lineage sorting. Genetic diversity is higher in pelagic populations than in coastal populations. Many pelagic populations were discovered by aerial surveys during winter where many bottlenose dolphins were detected. This cannot be used as a reference because the method used is still incomplete. However, this event suggests that the evolutionary history of bottlenose dolphins may differ between regions. Genetically identified coastal bottlenose dolphins were only biopsy sampled in shallow water, whereas genetically identified pelagic individuals were sampled in deep water. This supports a habitat-driven population structure in bottlenose dolphins. Although sex biased distribution methods are known to have low power and thus caution should be exercised when interpreting the results. This suggests that both males and females are philopatric as found in several other bottlenose dolphin populations (Louis et al., 2014).

Dolphins' large body size, high mobility, and wide distribution might lead us to expect them to have high levels of genetic exchange among their populations. However, genetic studies have revealed the existence of genetic subdivisions or differences among these populations. for example, Northern right whale dolphins and spinner dolphins in the North Pacific and Eastern tropical Pacific, respectively, show a lack of subdivision despite being separated by considerable distances. However, populations of humpback whales and harbor porpoises show limited evidence of genetic exchange despite breeding in the same localities. In addition, studies also found high genetic differentiation between killer whale populations that are close to each other (Rosel et al., 2009).

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Table 3. Measurement results of *Costae Numataphocoena yamashitai* in mm (Ichishima & Kimura, 2000).

NO.	Species Name	Distance/diameter and side length	*Costae*
1.	*T.truncatus*	The distance between the proximal and distal ends	150
		Arc length	177
		Anteroposterior diameter of the heads of the ribs	240
		Distance from head to tubercle	43
		Distance between the lateral border of the tubercle and the distal limb	13
		The length of the articular tubercle	16
		Distance from the tubercle to the costal angle	29

Table 4. *Numataphocoena yamashitai scapular* measurement results in mm (Ichishima & Kimura, 2000

NO.	Species Name	*Scapula*		
		Distance/diameter and side length		size
2.	*T. truncatus*	1	The greatest length of the scapula	190
		2	Distance between the lateral border of the tubercle and the distal extremity	145
		3	Arc length	22
		4	Distance from the head to the tubercle	36
		5	anteroposterior diameter of the heads of the ribs	43

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The results of the several measurements above show that the results of the *T.truncatus* bone measurements on the *os costae* and *os scapula* are different from the results of bone measurements from other literature. In the literature written about bones of the *Numataphocoena yamashitai* species from Japan, only one costal bone size has been described. First, a distance of 150 mm between the proximal and distal ends (Ichishima & Kimura, 2000). However, the measurement results from this study are very different. The first, second, third, and thirteenth *os costae* have a carry size of 150 mm. Because the heads of the ribs are adjacent to the distal ends of the ribs, they are short in size. For sizes above 150 mm, there are on the fourth, twelfth, and fourteenth *os costae*. Because the rib tubercle is higher than the distal *os costae*. The results of this measure indicate that the literature and this study differ in the long and short bone lengths. In addition, the study was also carried out on the species *Prosqualodon marplesi*, which was 170 mm long from the proximal to distal end, which is the same size as the 12th *os costae* in this study (Tanaka & Fordyce, 2014).

In the second measure, the distance between the lateral margin of the tubercle and the distal extremity is 177 mm (Ichishima & Kimura, 2000). However, in this study, the measurements of the first, second, and third ribs were under 177 mm. The size below 177 mm is due to the short distance between the side of the tubercle and the distal ribs. on the four ribs the distance from the lateral tubercle to the distal costae is roughly the same size as that of the *Numataphocoena yamashitai* species. At the fifth and sixth ribs, the distance between the tubercle and the distal extremity was farther than the results of this study. This difference has almost the same length, longer, and shorter. The length of the third arc reaches 240 mm (Ichishima & Kimura, 2000), but from this study, the bone size of the first, second, eleventh, thirteenth, and fourteenth ribs is below 240 mm. On the third to tenth *os costae,* the arcs are about the same length and shorter than that of the *Numataphocoena yamashitai* species. This study on *os costae* first to sixth, bones measuring 43 mm or shorter than those of the *Numataphocoena yamashitai* species, indicating that the bones of T. truncatus are smaller at size four than those of the *Numataphocoena yamashitai* species. whereas in the fourth size, the distance between the head and the tubercle is 43 mm (Ichishima & Kimura, 2000).

In the present study, the bone size from the first to the fourteenth rib was under 13 mm. whereas the fifth antero-posterior diameter of the rib heads was 13 mm (Ichishima & Kimura, 2000). This difference indicates that the bones of this study were smaller than those of the *Numataphocoena yamashitai* species. The sixth size of the costal articular tubercle was 16 mm (Ichishima & Kimura, 2000), but the results of this study indicate that the first to sixth ribs are sized by the size of the species *Numataphocoena yamashitai*, indicating that the bones of *T.truncatus* are smaller than those of this species. However, the measurement results from this study showed that the first to third ribs were less than 29 mm, had a rather short angle. the fourth rib has the same size and the fifth and sixth ribs are more than 29 mm, have a rather long rib angle from tubercle to tubercle. The difference between *T.truncatus* and *Numataphocoena yamashitai* is that there are several *os costae* that are longer, shorter and the same length. While the seventh measure the distance from the costal angle to the tubercle is 29 mm (Ichishima & Kimura, 2000).

There are differences in the *os scapula* section of the *Numataphocoena Yamashitai* literature with the findings of this study. The first size of *Numataphocoena Yamashitai's os scapula* has the largest length of 190 mm (Ichishima & Kimura, 2000), but the results of this study are less than 190

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mm, which means the length of the largest *os scapula* is larger than the *os scapula* of this study. Apart from this literature, research was also conducted on the species *Prosqualodon marplesi* from New Zealand, which has the largest bone length of more than 233.0 mm (Tanaka & Fordyce, 2014), which is larger than the *T.truncatus* and *Numataphocoena yamashitai* that we studied. The results of this study are smaller than the literature because the tuberculum and extremity boundaries are only 145 mm. In the New Zealand species *Prosqualodon marplesi*, the lateral margin of the distal tubercle and limb was 169.0 mm more, more than that found in our study and the California study. While the size of the second *Numataphocoena yamashitai* is 145 mm the distance between the distal extremity and the lateral tubercle border (Ichishima & Kimura, 2000).

The size of the three *os scapula* species *Numataphocoena yamashitai* has an arc length of 22 mm (Ichishima & Kimura, 2000). The results of this study indicate that the arc length of the two species is almost the same. The bows of the *Prosqualodon marplesi* species from New Zealand were up to 97.5 mm longer than those found in California and in this study. In size four, the species *Numataphocoena yamashitai* had a head-to-tubercle distance of 36 mm (Ichishima & Kimura, 2000), but in our study, the *Prosqualodon marplesi* species from New Zealand had a head-to-tubercle distance of 49.0 mm, which is larger than species *T.truncatus* and *Numataphocoena yamashitai*. The sizes of the five *Numataphocoena yamashitai* species have an anteposterior diameter of the rib heads of 43 mm, which is very different from the results of the present study. Therefore, the diameter of the rib head of this species is smaller than that of other *Numataphocoena yamashitai* species. However, in a study conducted in New Zealand, the species *Prosqualodon marplesi* measured 35.0 mm, the bones were smaller than this study and in California (Tanaka & Fordyce, 2014).

The reason for the difference in bone size could be food and habitat. A study of stable isotope analysis of marine mammals off the coast of Northwest Africa and unique trophic niches says mammal bones reflect not only differences in trophic level but also shifts in where to find food. In marine ecosystems, coastal marine mammals are thought to have lower nitrogen values than their oceanic counterparts or those in the oceanic seas because macrophytes show lower nitrogen values. Nitrogen and carbon values were higher in the East Atlantic sub-tropics as a consequence of coexistence in the area of the Short and Long-Beaked Dolphin Mortotypes, individuals from the Northeast Atlantic displayed lower nitrogen values reflecting the disimilarity in diet and variation in local isotope baselines. The traffic behavior of common dolphin populations around the world was well analyzed and revealed substantial differences, most likely reflecting the adaptive strategies of the genus and differences in ecosystem structure. Apart from that, bone is the tissue of choice with a low turnover rate reflecting the animal's diet for several years (Morais, 2015).

Apart from food and habitat differences in bones can also be caused by heavy metals. A study on kidney and bone tissue toxicity of heavy metals in adult South Australian bottlenose dolphins stated that several dolphins showed evidence of toxicity and explained the cause of the abnormality. Increased metallothionein (MT) causes kidney damage and loss of bone density and complexity. MT induced by metal toxins forms large metal-MT complexes which cause structural damage to the kidney. This causes leakage of calcium, phosphate, and protein from the kidney, inhibits bone remodeling and causes loss of bone density (bone mineral density) and complexity (bone

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histomorphometry) (Lavery et al., 2009).

Apart from the causes of food, habitat and heavy metals, differences in bones can also be caused by environmental factors during burial in the sand or the position of the bones in the sand. all bones are generally similar in color to the white shells that make up the beach, making detection of small bones more difficult. Some of the smaller skeletal elements may also be buried more quickly. In addition, smaller skeletal elements can be destroyed more quickly by physical processes such as abrasion by wind-driven sand grains and/or exfoliation due to drying and intense UV radiation in this sunny, hot and sunny region. Bone with a lower surface area to volume ratio or higher density can survive for a longer time, biasing the bone mass toward larger, denser bones (Liebig et al., 2003).

4. CONCLUSIONS

The results of this study explain the size of the *ribs* and *scapula* of the dolphin bones. Comparing the bone sizes of *T.truncatus*, *Numataphocoena yamashitai* and *Prosqualodon marplesi* dolphins. The differences between these species in the first size costae are differences in the length of the bones, some are the same and some are short between the literature and this study. the second and third sizes have almost the same length difference, the short one, and the longer one. The fourth, fifth and sixth measurements indicated that the bones of *T.truncatus* were smaller than those of the *Numataphocoena yamashitai* species and the seventh size indicated that the differences between *T.truncatus* and the *Numataphocoena yamashitai* species were that some *costae* were short, the same and longer. For the *scapula*, the dimensions of the first and second bones are larger than the present study species *T.truncatus* and *Numataphocoena yamashitai*. The size of the three results of this study was almost the same as the species *Numataphocoena yamashitai* except for the species *Prosqualodon marplesi*, which was larger in size than this study and studies in California. The fourth size, which is 49.0 mm from head to tuberculum, is larger than the studied *T.truncatus* and *Numataphocoena yamashitai* species. The fifth size, the diameter of the head of the *rib* of this research species is smaller than the species *Numataphocoena yamashitai* and *Prosqualodon marplesi*, both of which are smaller than *T.truncatus*, and some of these differences are caused by factors of food, habitat and environmental conditions.

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