Turk. J. Fish.& Aquat. Sci. 20(3), 221-228
http://doi.org/10.4194/1303-2712-v20_3_06

PROOF
RESEARCH PAPER

Turkish Journal of FISHERIES and AQUATIC SCIENCES

External Morphology and Weight - Length Relationships (WLRs) of Harbour Porpoise, *Phocoena phocoena* (Cetacea: Phocoenidae) in the Black Sea

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Article History
Received 10 January 2018
Accepted 08 April 2019
First Online 10 April 2019

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Keywords
Harbour Porpoise
Phocoena phocoena
Cetacea
Morphometric
Black Sea

Abstract

The present study summarized information on the morphometric characteristics and weight-length relationships (WLRs) of pregnant females, non-pregnant females and males of harbour porpoise, *Phocoena phocoena* (Linnaeus, 1758) along the Rize coast in the Black Sea, Turkey. A total of 68 harbour porpoises (31 males, 22 non-pregnant females and 15 pregnant females) were obtained as bycatch in the turbot gill net fisheries from April 2010 to July 2011. A total of 16 external morphological characteristics of the harbour porpoises were examined by Principal Component Analysis (PCA). The PCA results clearly showed that there is sexual dimorphism mainly in the general size between non-pregnant females and males and also pregnant females and males. The greatest body length in the sample was 142.0 cm for females and 128.0 cm for males. Weight - length relationships (WLRs) of harbour porpoise showed negative allometric growth characteristics (Pauly' t test, P<0.05). The slopes of the regression lines for males, non-pregnant females and pregnant females were significantly different from the isometric growth curve slope of 3 (Pauly' t test, P<0.001). Correlation coefficient (*r*) was significant for both sexes (P<0.05). These results will enable researchers, fishermen and fisheries management authorities to enhance the knowledge of harbour porpoises life history and ecology.

Introduction

The Black Sea is inhabited by three cetacean species, that is the harbour porpoise *Phocoena phocoena* (Linnaeus, 1758), the common bottlenose dolphin *Tursiops truncatus* (Montagu, 1821) and the short beaked common dolphin *Delphinus delphis* (Linnaeus, 1758) (Zaitsev & Mamaev, 1997; Öztürk *et al.*, 2004) and in the past they had been exploited by dolphin fisheries (prior to 1966 in USSR, Romania and Bulgaria, and 1983 in Turkey). It is clear that other anthropogenic impacts such as habitat degradation, pollution, disturbance and especially incidental catch in fishing gear have still influenced and reduced Black Sea cetaceans' populations (Birkun, 2002). Almost all of the cetaceans, especially *P. phocoena* are caught in bottom set gillnets such as turbot (*Psetta maxima*), spiny dogfish (*Squalus acanthias* Linnaeus, 1758) and sturgeon (*Acipenser* spp.) in the Black Sea and the peak occurs from April to June during the turbot season, in territorial waters of all six riparian countries (Birkun, 2002; Öztürk, Öztürk & Dede, 1999; Reeves & Notarbartolo di Sciara, 2006). Turbot gill net fishing is the most dangerous for incidental mortality of Black Sea cetaceans mainly for harbour porpoises (Radu, Nicolaev, Anton, Maximov & Radu, 2003; Birkun, 2002).

The harbour porpoise exhibit sexual dimorphism otherwise unusual among odontocetes: females grow to

Published by Central Fisheries Research Institute (SUMAE) Trabzon, Turkey in cooperation with Japan International Cooperation Agency (JICA), Japan

larger size than males and have an extended period of growth (Galatius, 2005). It was reported that females grow to lengths of 161 cm, whereas males only grow to 148 cm in the inner Danish and adjacent Swedish and German waters, including the German north coast from Schleswig to Rügen and the Swedish west coasts from Skåne to Bohus (Galatius, 2005). In the Black Sea the maximum length of males was 120 cm and that of females was 130 cm (Tonay, Dede & Öztürk, 2017).

Knowledge on biological features such as weight-length relationships (WLRs) of cetacean species are important tools for marine biologist and fisheries managers. The WLRs have many applications in stock assessments and ecological studies. Furthermore, one of the basic parameters for fisheries biologists is body weight. Because weighing on board fishing vessel can be impossible if there is no weighing machine or if the sea is rough, a method of calculating the body weight from morphological measurements is needed (Kastelein & van Battum, 1990). Morphometric features of cetaceans are also important parameters for fisheries researcher because these parameters can be used for determining the sex of a specimen and these parameters can show geographical variation. The WLRs of harbour porpoise for combined sex were studied by Karaçam, Düzgüneş & Durukanoğlu (1990) in the Black Sea, by Lockyer (1995) in the British waters.

Studies on the harbour porpoise with respect to sexual variation in morphometric characteristics and weight-length relationships are scarce in the Black Sea. The present study summarizes information on the external morphology and the WLRs of pregnant and non-pregnant females and males of harbour porpoise; *Phocoena phocoena* obtained as bycatch in the turbot gill net fisheries along the Rize coast in the Black Sea.

Materials and Methods

Sample Collection

Turbot gill net fishing operations were conducted by commercial turbot gill nets fishermen on the Rize coasts from 10 to 50 m water depth in the southeastern Black Sea (Figure 1). A total of 68 harbour porpoise were collected as bycatch from the turbot gill net during April 2010-July 2011. The sample was split in males (n=31), pregnant females (n=15) and non-pregnant females (n=22).

Morphometric Characteristics

A total of 16 external morphological measurements of harbour porpoises were collected following the guidelines suggested by Gol'din (2005) (Figure 2).

The measurements were analyzed by Principal Component Analysis (PCA) using the software package PAST version 1.8 (Hammer, Harper & Ryan, 2001).

Weight - Length Relationships (WLRs)

The total body length (L) of 68 harbour porpoise (31 males, 22 non-pregnant females and 15 pregnant females) was measured from the notch of flukes to the tip of the rostrum. Total body weight of the animals was weighed using rechargeable electronic balance. Least squares regression analysis with MS Excel software was used to calculate the weight length relationship parameters of all specimens.

The weight length relationship was estimated as:

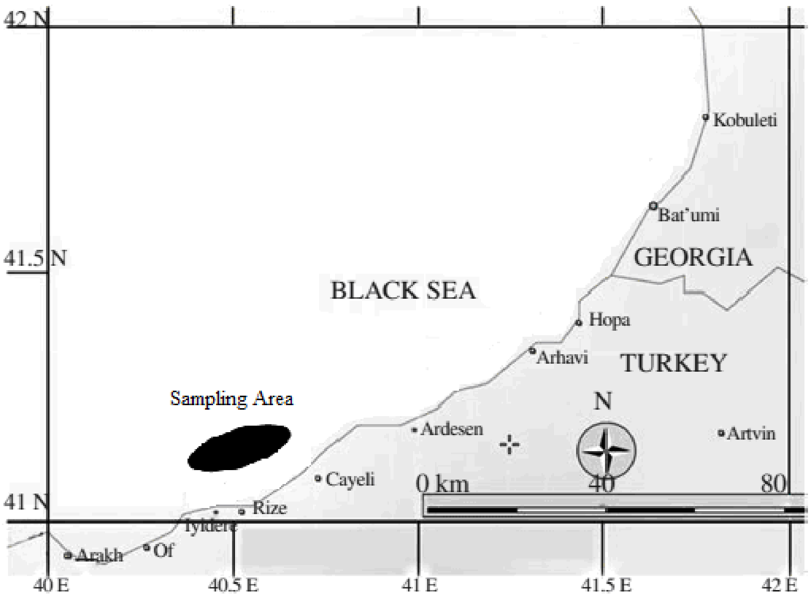

Figure 1. Turbot gill net fishing operations sampling area on the Rize coasts in the southeastern Black Sea.

$$W = aL^b;$$

The length-weight relationship was also estimated using log transformed length and weight data as: Log (*W*)=a + b x log (*L*),

where *W* is the body weight (kg), *L* is the total length (cm), *a* is the intercept, and *b* is the slope of the regression line.

To compare the slope from *b*=3 (isometric growth) for all species, Pauly's *t*-test was performed (Pauly, 1984). Pauly's *t*-test statistic was calculated as:

$$t = \frac{Sd_{\log TL}}{Sd_{\log W}} \frac{|b-3|}{\sqrt{1-r^2}} \sqrt{n-2}$$

where Sd_{logL} is the standard deviation of the log *L* values, Sd_{logW} is the standard deviation of the log *W* values, n is the number of specimens used in the computation. The value of *b* is different from *b*=3 if calculated *t* value is greater than the tabled *t* values for n-2 degrees of freedom (Pauly, 1984). Correlation coefficient (*r*) was tested by zero *t*-test (Snedecor & Cochran, 1989).

Results

Length and Weight Structure

Length – frequency distribution of harbour porpoise is showed in Figure 3. The length of non-

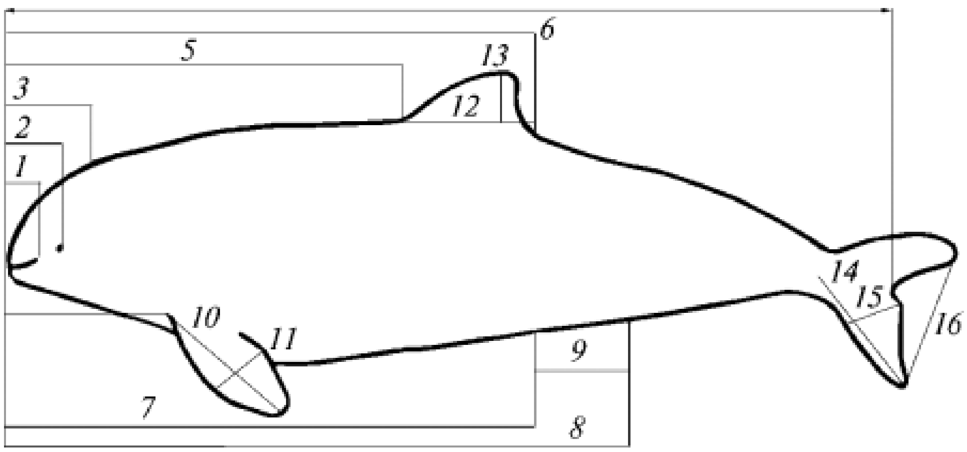

Figure 2. Morphometric measurements of the harbour porpoise, 1: rostrum to tip of mouth, 2: rostrum to eye, 3: rostrum to blowhole, 4: rostrum to maxilla, 5: rostrum to front edge of base of dorsal fin, 6: rostrum to back edge of base of dorsal fin, 7: rostrum to centre of genital slit, 8: rostrum to centre of anus, 9: centre of genital slit to centre of anus, 10:length of flipper, 11: width of flipper, 12: base of dorsal fin, 13: height of dorsal fin, 14: length of outer edge of tail fluke, 15: maximum width of tail fluke and 16: maximum fluke span. (From Gol'din, 2005).

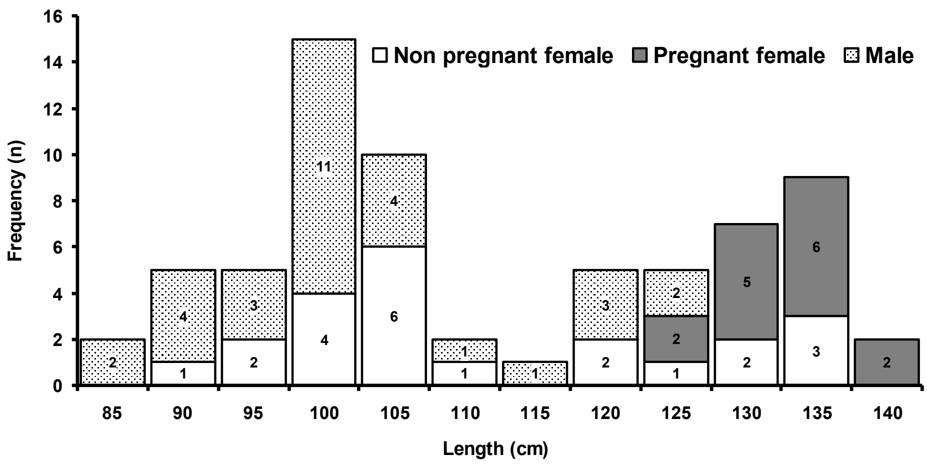

Figure 3. Body length (*L*) frequency distribution of harbour porpoise.

pregnant females ranged from 94.5 to 139.6 cm (mean: 113.7±3.11 cm, n=22), the length of pregnant females ranged from 128.3 to 142.0 cm (mean: 135.4±1.09 cm, n=15) and the length of males ranged from 85.6 and 128.0 cm (mean: 104.0±1.96 cm, n=31). The mean length of pregnant females was statistically greater than the mean length of non-pregnant females and males (One-way ANOVA, P<0.05). Mean length of non-pregnant females was calculated statistically greater than the mean length of males (t-test, P<0.05) (Figure 3) Size frequency distributions were significantly different between pregnant females and males (Kolmogorov-Smirnov two-sample test; d=0.9677, P<0.05) and between pregnant females and non-pregnant females (Kolmogorov-Smirnov two-sample test; d=0.9546, P<0.05). Size frequency distributions were not significantly different (Kolmogorov-Smirnov two-sample test; d=0.2625, *p*=0.2909) between non-pregnant females and males.

Non-pregnant females weight was determined from 13.3 to 40.5 kg (mean: 21.2±1.43 kg), pregnant females weight was determined from 31.8 to 43.05 kg (mean: 37.6±0.96 kg) and males weight was determined from 11.3 to 33.5 kg (mean: 17.9±0.85 kg). The mean weight of pregnant females was statistically greater than the mean weight of non-pregnant females and males (One-way ANOVA, P<0.05). Mean weight of non-pregnant females was calculated statistically greater than the mean weight of males (t-test, P<0.05). A total of 15 pregnant females obtained as bycatch in May 2010 (1), in February (1), April (7) and May (6) 2011. Fetus harbour porpoise weight was determined between 1.09 kg obtained on 22 February 2011 and 4.34 kg obtained on 18 May 2010 (mean: 3.2±0.27 kg, n=15). Unfortunately, the length measurements of fetus were not done.

Morphometric Characteristic

The measurements 16 morphometric characteristics were analyzed by Principal Component Analysis (PCA). Scatter plots of the first two principal components (PC I and PC II) of 16 morphometric characters are shown in Figure 4 and the variables loading on the first metric PC I–II are given in Table 1. The PCA separated males from pregnant males and non-pregnant females. Also, there was marginal overlap between non-pregnant females and pregnant females. These results clearly showed that there are sexual dimorphism between non-pregnant females and males and also pregnant females and males.

Weight - Length Relationships (WLRs)

Weight - length relationships (WLRs) of *P. phocoena* obtained as bycatch in 2010 and 2011 from

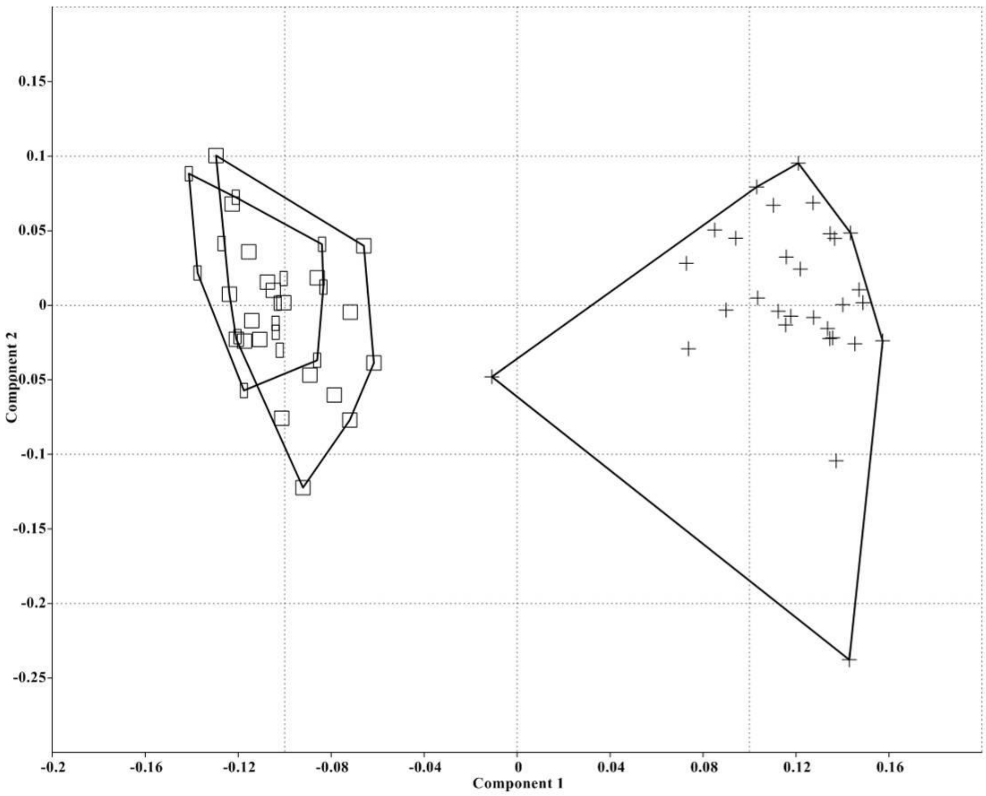

Figure 4. Scores of the PC I vs. PC II of 18 external morphometric measures of *Phocoena phocoena* specimens: □ non- pregnant females, ▯ pregnant females, +: males.

the Rize coast in the Black Sea showed negative allometric growth characteristics (Pauly' t test, P<0.05). The slope of the weight - length relationship was significantly different between sexes (Pauly' t test, P<0.001). Therefore, this relationship was investigated separately for each sex.

The slopes of the regression lines for males, non-pregnant females and pregnant females were significantly different from the isometric growth curve slope of 3 (Pauly' t test, P<0.001). The WLRs results and statistics of *P. phocoena* between sexes showed below and in Figures 5 and 6.

Table 1. Character loading on principal components I–II for 16 measurements taken on 68 specimens of *Phocoena phocoena*

Morphometric features (in percent of length, L %)	PC I	PC II
1. Rostrum to tip of mouth	0.02756	0.03966
2. Rostrum to eye	0.04321	0.04411
3. Rostrum to blowhole	-0.006497	0.0369
4. Rostrum to maxilla	0.03771	-0.004137
5. Rostrum to front edge of base of dorsal fin	-0.118	0.7161
6. Rostrum to back edge of base of dorsal fin	-0.03049	0.2476
7. Rostrum to centre of genital slit	-0.6596	0.07218
8. Rostrum to centre of anus	0.06958	0.2266
9. Centre of genital slit to centre of anus	0.7327	0.1554
10. Length of flipper	0.02951	0.01335
11. Width of flipper	0.01307	0.004188
12. Base of dorsal fin	0.01152	0.04727
13. Height of dorsal fin	0.02336	0.02465
14. Length of outer edge of tail fluke	0.01444	-0.0157
15. Maximum width of tail fluke	0.01817	0.002442
16. Maximum fluke span	0.04242	0.003594

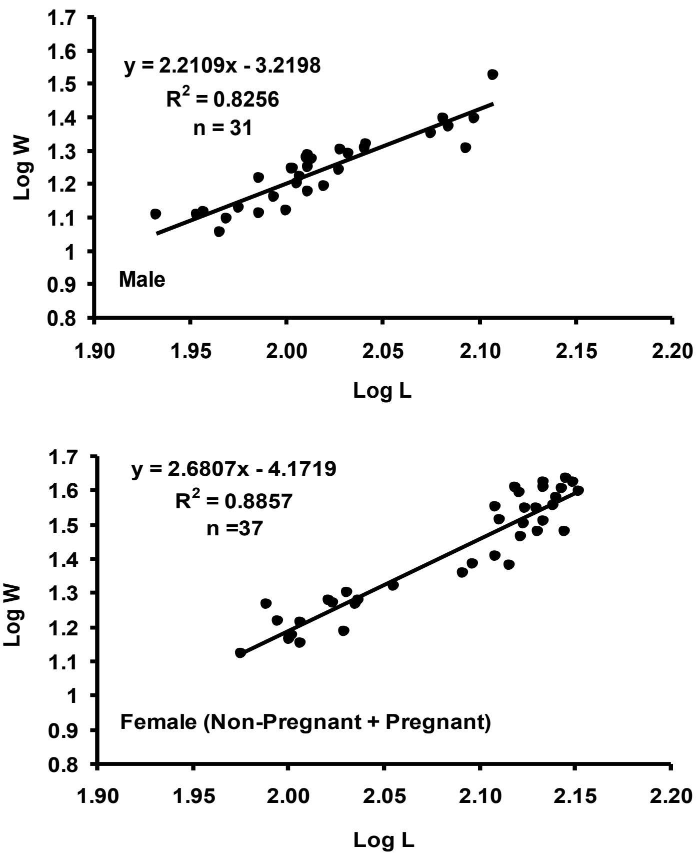

Figure 5. Weight – length relationships of the harbour porpoise male and female (non-pregnant female + pregnant female).

$W=0{,}0006L^{2.2109}$, $r^2=0.8256$, ($LogW=2.2109L-3.2198$), Sd_{logL} = 0.019413, Sd_{logW} =0.007979, n=31, Pauly' t test=2475733.849, P<0.001, negative allometric growth (Male).

$W=7E\text{-}05L^{2.6807}$, $r^2=0.8857$, ($LogW=2.6807L–4.1719$), Sd_{logL} =0.009539, Sd_{logW} =0.027172, n=37, Pauly' t test=196152.5623, P<0.001, negative allometric growth (Non-pregnant female + pregnant female).

$W=0.0009L^{2.1305}$, r^2 =0.8593, ($LogW=2.1305L–3.0641$), Sd_{logL} =0.032428, Sd_{logW} =0.01411, n=22, Pauly' t test=238253.2081, P<0.001, negative allometric growth (Non-pregnant female).

$W=0.0103L^{1.6707}$, r^2 =0.2685, ($LogW$ =$1.6707L–1.9881$), Sd_{logL} =0.003503, Sd_{logW} =0.011293, n=15, Pauly' t test=17379633.38, P<0.001, negative allometric growth (Pregnant female).

Comparison of the difference of correlation coefficient (*r*) from zero *t*-test (Snedecor and Cochran, 1989) was applied and the values of (*r*) for males (*r*=0.9086, *t*=11.7165), non-pregnant females + pregnant females (*r*=0.9411, *t*=16.4685), non-pregnant females (*r*=0.9269, *t*=11.0511) and pregnant females (*r*=0.5181, *t*=2.1840) are different from zero (P<0.05), indicated that the harbour porpoises has high correlation between body length and weight. In addition to this, to compare the estimations calculated from the present study with other studies, log (a) values were plotted against values of b (Figure 7), proved to be consistent with previous studies data for *P. phocoena* except for pregnant and non pregnant + pregnant females.

Discussion

Sexual dimorphism in the harbour porpoise is well known and females are larger than males as reported in the populations such as from the Sea of Azov and the Black Sea (Gol'din, 2004; Gol'din, 2005), from the British Isles (Lockyer, 1995) and from the North Sea (Van Utrecht, 1978; Kastelein & van Battum, 1990). There is geographical variation in the body size of porpoises. Namely, Gol'din (2004) reported that animals from the Sea of Azov are longer than animals of the same age from the Black Sea. The differences in body size between animals from different seas can be explained from the ecological perspective such as differences of fish

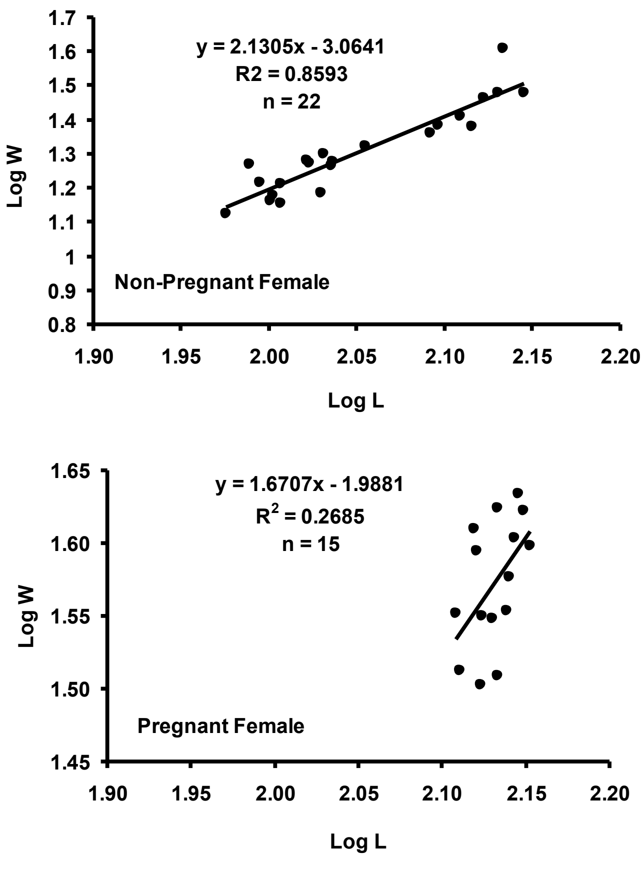

Figure 6. Weight – length relationships of the harbour porpoise non-pregnant female and pregnant female.

productivity and variety of prey species for harbour porpoise (Gol'din 2004). The results of this study showed that harbour porpoise, females tend to attain larger size than males. Similar results have been reported for harbour porpoises from different geographical areas (Lockyer, 1995; Van Utrecht, 1978; Gol'din, 2004; Gol'din 2005).

The weight-length relationships parameters of harbour porpoise from different regions are shown in Table 2. The WLRs of harbour porpoise was studied from the Baltic Sea by Møhl-Hansen (1954), from the North Sea by Van Utrecht (1978) and Kastelein & van Battum (1990). Bryden (1986) calculated WLRs for harbour porpoise from the Baltic Sea using the data of Møhl-Hansen (1954) and found these relations as log *W*=2.8011 log *L* - 4.3473 n=208 in males, log *W*=3.0395 log *L* - 4.8814 n=164 in females. We calculated WLRs for harbour porpoise from the North Sea using the data of Kastelein & van Battum (1990) as log *W*=0.2732 log *L* +1.6863 n=7 in males, log *W*=0.3933 log *L* + 1.5395 n=18 in females. Van Utrecht (1978) calculated WLRs from the North Sea as log *W*=2.8902 log *L* - 4.6445 n=41 in males,

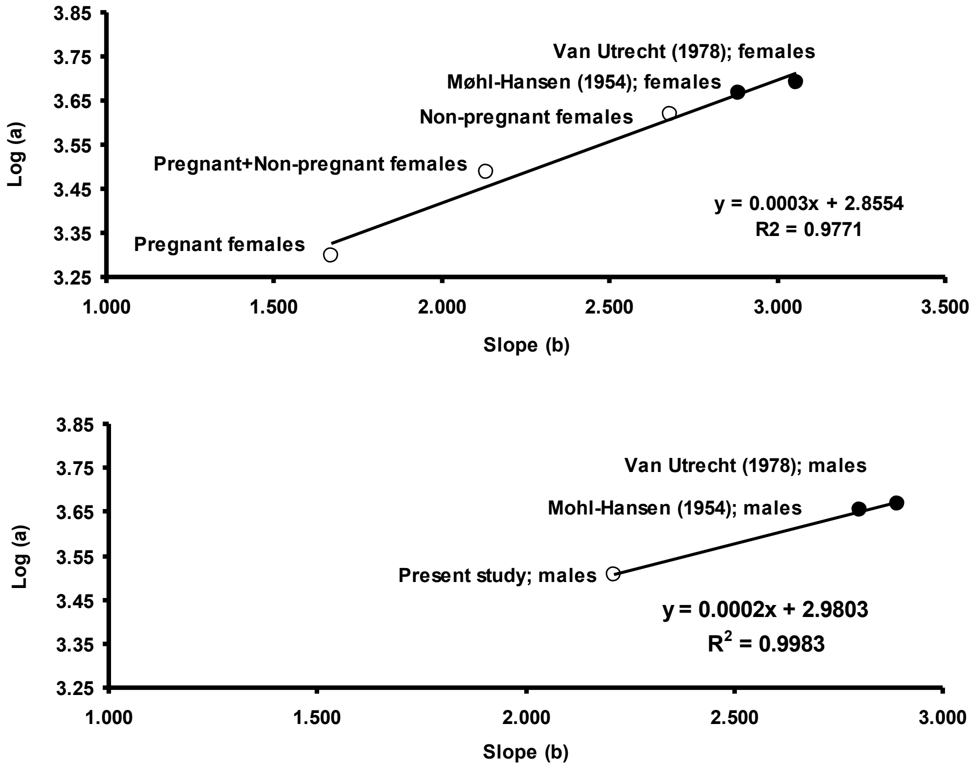

Figure 7. Test plot of *log (a)* against *b* for the WLRs of *Phocoena phocoena*. Black dot = estimated parameters of two other studies, white dot = present study parameters.

Table 2. The weight-length relationships parameters of harbour porpoise (*Phocoena phocoena*) from different regions.

Sex	Equation	Region	References
Male	LogL=1.552+0.357LogW (n=208)	Baltic Sea	Bryden (1986)
Male	LogL=1.607+0.346LogW (n=41)	North Sea	Van Utrecht (1978)
Male	LogL=1.546+0.389LogW (n=18) R^2 = 0.97)	North Sea	Kastelein and van Battum (1990)
Male	LogL=1.554+0.373LogW (n=31) R^2 = 0.83)	Black Sea	Present study
Female	LogL=1.606+0.329LogW (n=164)	Baltic Sea	Bryden (1986)
Female	LogL=1.609+0.347LogW (n=58)	North Sea	Van Utrecht (1978)
Female	LogL=1.686+0.273LogW (n=7) R^2 = 0.88)	North Sea	Kastelein and van Battum (1990)
Female	LogL=1.525+0.403LogW (n=22) R^2 = 0.86)	Black Sea	Present study
Pregnant female	LogL=1.879+0.161LogW (n=15) R^2 = 0.27)	Black Sea	Present study
Female +Prg.Female	LogL=1.617+0.330LogW (n=37) R^2 = 0.89)	Black Sea	Present study

log *W*=2.8818 log *L* - 4.6369 n=58 in females. These WLRs results were similar to our results. In addition to this, the values for the exponent (*b*) remain mostly out of the expected range of 2.5 - 3.5; these results may be due to the small number of specimens and also narrow length ranges.

The present study reports the data on external morphology of the harbour porpoises from the southeastern Black Sea, a poorly known, endangered population. The present study can also contribute to researchers, fishermen and fisheries management authorities' knowledge of harbour porpoises life history and ecology

Acknowledgements

The authors thank fishermen Sami Akmermer, Kazım Akmermer Uğur Akmermer and Ahmet Kalkavan for their help during the field studies. This study was supported by the Recep Tayyip Erdogan University, Scientific Research Project (BAP 2010.103.03.2).

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