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POPULATION PARAMETERS, MORALITY AND EXPLOITATION RATES OF EUROPEAN HAKE, *Merluccius merluccius* (LINNAEUS, 1758) IN ISKENDERUN BAY (OFF KARATAS COASTS, ADANA)

ABSTRACT
This study was carried out from September 2002 to April 2003 in Karataş Coasts (Iskenderun Bay). A total of 212 specimens were trawled by monthly sampling in 2002-2003 fishing season. The age of *Merluccius merluccius* varied from I to IV age classes. The mean total length and total weight values was calculated as 12.87±2.67 cm and 22.93±12.86 g respectively and the calculated length-weight relationship was $W=0.0267L^{2.5309}$. The von Bertalanffy growth parameters were L_∞= 42.61 cm, K= 0.123 year^{-1} and t_o= -1.906 year. Total mortality was 2.41, the natural mortality was 0.29 and the fishing mortality was estimated to be 2.12. The exploitation rate calculated as 0.88 using value of M and F. Therefore, the population of *M. merluccius* off the Karatas coast exploited over the optimum level because of overfishing pressure.
Keywords: *Merluccius merluccius*, Iskenderun Bay, Population Parameters, Mortality Rate, Exploitation Rate

İSKENDERUN KÖRFEZİ'NDE (KARATAŞ KIYILARI, ADANA) BERLAM, *Merluccius merluccius* (LINNAEUS, 1758)'UN BAZI POPULASYON PARAMETRELERİ, ÖLÜM ORANLARI VE STOKTAN YARARLANMA DÜZEYİ

ÖZET
Bu çalışma, Eylül 2002-Nisan 2003 tarihleri arasında, Karataş Kıyıları'nda gerçekleştirilmiştir. 2002-2003 balıkçılık sezonu boyunca aylık trol çekimleri ile yapılan örnekleme sonucunda 212 bireyi elde edilmiştir. İncelenen bireylerin I-IV yaş grupları arasında değişim gösterdiği belirlenmiştir. Ortalama total boy ve ağırlık değerleri sırasıyla 12.87±2.67 cm ve 22.93±12.86 g olarak hesaplanmış olup; boy-ağırlık ilişkisi $W=0.0267L^{2.5309}$ olarak bulunmuştur. von Bertalanffy boyca büyüme sabitleri ise L_∞=42.61 cm, K=0.123 yıl^{-1} ve t_o=-1.906 yıl olarak tahmin edilmiştir. Ayrıca toplam ölüm Z= 2.41, doğal nedenlerle olan ölüm M=0.29, balıkçılık nedeniyle olan ölüm ise F=2.12 ve stoktan yararlanma düzeyi E=0.88 olarak hesaplanmıştır. Buna göre söz konusu stokunun optimum seviyenin üzerinde sömürüldüğü ve aşırı balıkçılık baskısı altında olduğuna karar verilmiştir.
Anahtar Kelimeler: *Merluccius merluccius*, İskenderun Körfezi, Populasyon Parametreleri, Ölüm Oranı, Stoktan Yararlanma Düzeyi

1. INTRODUCTION (GİRİŞ)

European hake, *Merluccius merluccius* (Merlucciidae) inhabit the north-eastern Atlantic from Norway to Mauritania and the entire Mediterranean; in the Black Sea the species lives only along the southern coasts [1]. The species is a benthic species found usually between 70 and 370 m depth. However, bathymetric distribution of the species in the Adriatic is from only several meters in the coastal area to 800 m in the South Adriatic Pit [2]. Adults live close to the bottom during day-time, but move off-bottom at night. Adults feed mainly on fish (small hakes, anchovies, pilchard, herrings, cod fishes, sardines and gadoid species) and squids [3]. The young feed on crustaceans (especially euphausiids and amphipods) [4].

European hake can grow to 130 cm of total length. However, its usual length in trawl catches is from 10 to 60 cm. This is a long-lived species it can live more than 20 years. In the Adriatic, however, the exploited stock is mainly composed in number of 0+, 1+ and 2+ year-old individuals [1]. In the spring months, there are local movements of sexually immature adolescent hakes into the shallower waters. Adult European hake are mainly caught at depths of 100 to 150 m. In the spring, adult hakes migrate to more shallow coastal waters for spawning. After spawning, adult fish migrate towards the deeper water, wintering with the juveniles [5]. In the southern Adriatic the largest individuals are caught in waters deeper than 200 m, whereas medium-sized fish appear in the stratum not deeper than 100 m [6].

Distribution, feeding habits, reproduction, age, growth, mortality, exploitation and selectivity parameters were studied for *M. merluccius* in the Mediterranean previously [1, 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 and 18]. Knowledge of the demographic parameters for a given species can be assist in developing management models for the sustainable exploitation of fish stock. The objectives of this study were to determine the age, growth, mortality and exploitation of *M. merluccius* off the Karatas coast of Iskenderun Bay.

2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

In this study, age growth, mortality and exploitation rate of the *M. merluccius* determined off Karatas coast. Results of this study can be assisting in developing management models for the sustainable exploitation of fish stock for other researcher, governmental organization. On the other hand, the estimated parameters may vary as a function of a variety of factors such as region, sampling methods, year and methodology. This represents demographic parameters of the *M. merluccius* inhabiting off Karatas coast. As a result, this study showed the sock of *M. merluccius* off the Karatas coast exploited over the optimum level because of overfishing pressure.

3. MATERIAL AND METHOD (MATERYAL VE YÖNTEM)

This study was carried out between September 2002 and April 2003 off Karatas Coasts of Iskenderun Bay during the 2002-2003 fishing season. The materials were obtained by monthly sampling using commercial bottom trawl vessel (Coskun Reis, 22m length and 285HP) in depths from 0 to 100 m from the stations represented in Figure 1. Trawl operations were done day time with 1 hour haul duration using Mediterranean Type Bottom Trawl 22mm mesh size (knot-to-knot).

All of the catch were transferred from field to the laboratory in the ice and stored in -18°C in the refrigerator. Then the samples were defrost and sorted by species and weighted for the determination of Catch Per Unit Effort (CPUE) in the laboratory for each depths ranges. In order to determine population parameters, the sub sampling procedure was applied as recommended by Holden and Raitt [19]. The

total length and the total weight were measured and weighted to the nearest 1 mm and 0.01 g respectively. The sagittal otoliths were examined under the stereo binocular microscope for the age determination.

The length-weight relationships were determined according to the allometric equation given by Sparre and Venema [20] as $W=a*L^b$. In this equation, *W* is total weight, *a* and *b* are regression constants and *L* is total length. Growth in length and weight were expressed in terms of von Bertalanffy equation $L_t=L_\infty[1-e^{-K(t-to)}]$. The growth parameters *K*, L_∞ and t_o were estimated using the Least Squares Method recommended by Sparre and Venema [20].
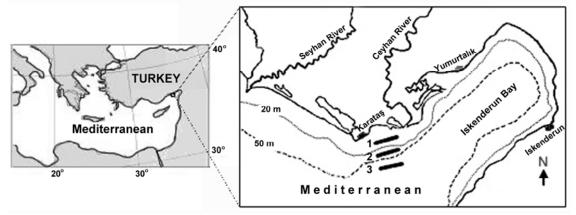

Figure 1. Study area and sampling stations
(Şekil 1. Çalışma sahası ve örnekleme istasyonları)

Correspondence between empirical data and an expected distribution was tested by Khi^2 test. The *b* value was tested by t-test to verify that it was significantly different from the isometric growth (*b*: 3).

Total mortality rate (*Z*) was estimated based on the length at first capture methods evaluated by Beverton and Holt [21]. $Z=K*(L_\infty-L_m)/(L_m-L_c)$. Where; L_m is the average total length of the entire catch, while L_c is the length at which 50% of the fish entering the gear are retained [20]. Instantaneous natural mortality rates (*M*) was estimated using the equation derived by Ursin [22] based on the mean total length, where $M=W^{-(1/b)}$ (*W*: mean total length; *b*: constant of length-weight relationship). Fishing mortality rates (F) was calculated as the difference between *Z* and *M* (Z=F+M). The value of the average annual exploitation rate (*E*) was obtained by E=F/Z [20].
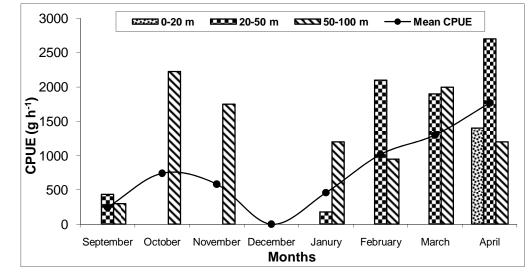
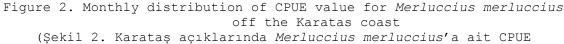## 4. RESULTS (BULGULAR)
4.1. Monthly Time Series of Trawl Catch
(Aylık Trol Ürün-Zaman Serisi)

Monthly distribution of CPUE value of *M. merluccius* for each depth range and whole study period was given in Figure 2. As can be seen the figure, opening of the fishing season (September) and following months CPUE were low level. The CPUE has been increasing starting to January and the highest CPUE was obtained in April 1.8 kg h^{-1} and 28.9% of total catch was observed in same months. Overall mean CPUE estimated 0.8±0.6 kg h^{-1} during the study period.

To take CPUE distribution in each depth range into considering, over half of the catch (52.5%) was obtained in depths of 50-100 m and 39.9% was obtained in depths of 20-50 m and only 7.6% was obtained in depths of 0-20 m. The CPUE increased from coastal area to deeper waters.

Figure 2. Monthly distribution of CPUE value for *Merluccius merluccius*
off the Karatas coast
(Şekil 2. Karataş açıklarında *Merluccius merluccius*'a ait CPUE
değerinin aylık değişimi)

4.2. Age and Growth Parameters (Yaş ve Büyüme Parametreleri)

A total of 212 individual were sampled, ranging in size from 8.80 to 21.80 cm TL and in weight from 7.12 g to 77.12 g. Overall mean total length and weight were calculated as 12.87±2.67 cm and 22.93±12.86 g, respectively. Length-frequency distribution of *M. merluccius* was given in Figure 3. As can be seen the figure, dominant length groups were 13cm and 12cm length classes with the values of 13.80% and 13.13%, respectively. 82.76% of the total examined individuals consisted of the length classes between 10 and 16 cm.

Length-frequency distribution, minimum, maximum and mean length and weight values of *M. merluccius* for each age class were listed in Table 1. As can be seen the table, the age of *M. merluccius* ranged from I to IV age classes and the most dominant age class was I with the value of 67.0% and followed age class II with the value of 21.2%.
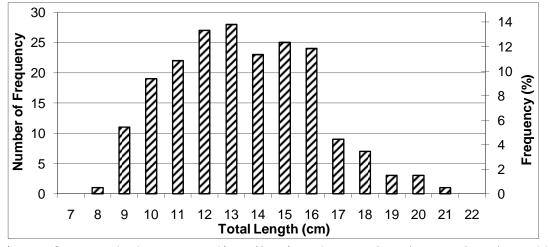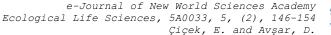

Figure 3. Length-frequency distribution for *Merluccius merluccius* off
the Karatas coast (10 mm length classes)
Şekil 3. Karataş açıklarında *Merluccius merluccius*'a ait ait boy-
frekans dağılımı (10 mm boy aralığı)

Table 1. Length-frequency distribution, minimum, maximum and mean length and weight values for each age class for *Merluccius merluccius* off the Karatas coast
(Tablo 1. Karataş açıklarında *Merluccius merluccius*'a ait yaş-frekans dağılımı ile her yaş grubu için minimum, maksimum ve ortalama boy ve ağırlık değerleri)

Age	n (frequency)	Total Length (cm)		Total Weight (g)	
		Min-Max	Mean	Min-Max	Mean
I	136 (% 67.0)	8.80-15.70	12.40±1.69	7.12-51.38	16.85±7.76
II	43 (% 21.2)	14.40-18.30	16.10±0.84	17.89-45.24	29.93±6.94
III	23 (% 11.3)	16.30-20.80	18.13±1.34	27.64-78.02	43.42±11.65
IV	1 (% 0.5)	21.80	21.80	77.12	77.12
Total	203	8.80-21.80	13.87±2.67	7.12-77.12	22.93±12.86

The relationship between *TW* and *TL* is presented in Figure 4. As can be seen the figure, length-weight relationships was expressed $W=0.0267L^{2.5309}$. The calculated von Bertalanffy growth parameters were L_∞: 42.61 cm, K: 0.123 $year^{-1}$ and t_o: -1.906 year.
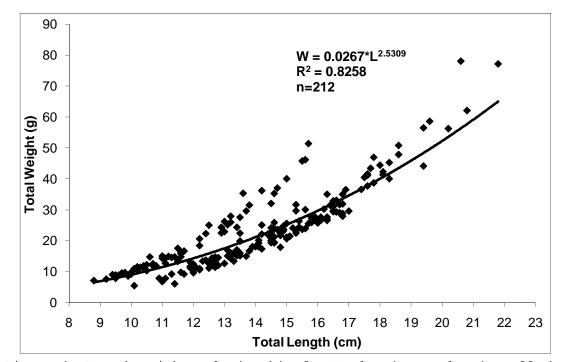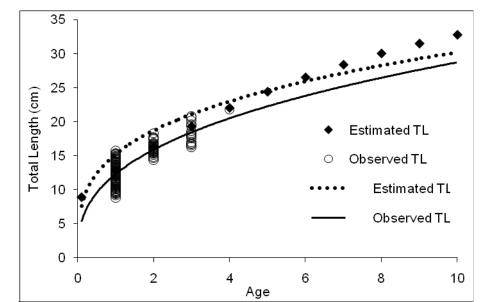

Figure 4. Length-weight relationship for *Merluccius merluccius* off the Karatas coast
(Şekil 4. Karataş açıklarında *Merluccius merluccius*'a ait boy-ağırlık ilişkisi)

The back-calculated lengths were determined using von Bertalanffy growth parameters and the observed and calculated growths in total length were listed in Table 2. The growth curves were not significantly different between observed and calculated length (p>0.05). The von Bertalanffy growth curve was fitted to lengths-at-age for *M. merluccius* (Fig. 5). Growth is fast until the II age classes and with growth in length slightly reduced beyond the age class II.

Table 2. Observed and calculated total length of *Merluccius merluccius* using von Bertalanffy growth equations off the Karatas coast
(Tablo 2. Karataş açıklarında *Merluccius merluccius*'a ait her yaş için ölçülen ve von Bertalanffy büyüme eşitliği kullanılarak hesaplanan ortalama boy değerleri)

Age	Total Length (cm)		Total Weight (g)	
	Observed	Calculated	Observed	Calculated
I	12.40	12.83	16.85	17.05
II	16.10	16.29	29.93	31.17
III	18.13	19.34	43.42	48.14
IV	21.8	22.04	77.12	67.01

Figure 5. von Bertalanffy length-at-age growth curve for *Merluccius merluccius* off the Karatas coast
(Şekil 5. Karataş açıklarında *Merluccius merluccius*'a ait von Bertalanffy büyüme eğrisi)

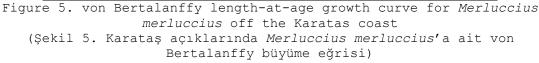### 4.3. Mortality and Exploitation
(Ölüm Oranları ve Stoktan Yararlanma Düzeyi)

The annual instantaneous rate of natural mortality (M) was estimated at 0.29 yr^{-1} and instantaneous total mortality rate was estimated at 2.41 for *M. merluccius*. Using the estimate of Z from the mean total length and the estimate of M obtained using the based on the length at first capture methods, an estimate of fishing mortality was obtained at 2.12 The exploitation rate was estimated at 0.88 using the value of Z and the estimated F.

5. DISCUSSION (TARTIŞMA)

Dramatic decrease from opening of the fishing season to end of the season was observed for the most of trawlable species during the study period. Different from the other trawlable species, monthly distribution of CPUE of *M. merluccius* did not show dramatic changing during the fishing season [16]. In deed while the coefficient of variation of CPUE was 175.4% for *M. barbatus* and the value was calculated 33.28% for *M. merluccius*.

To take CPUE distribution in each depth range into considering, *M. merluccius* distributed to range over a wide depth range, it prefers deeper than the depth of 50 m and the value of CPUE increased from coastal area to deeper waters. Indeed usual distribution was reported

70-370 m by Froese and Pauly [4]. On the other hand, because of the competition with *Saurida undosquamis* is a lesssepsian immigrant fish species, *M. merluccius* withdrawn into deeper water [7].

LW relationships parameters and the von Bertalanffy growth parameters were listed in Table 3 in the previous studies in Turkey. As can be seen the table, *b* value ranged from 2.942 to 3.196 in these studies. According to Froese and Pauly [4] *b* value was reported between 3.0 and 3.408 for different region of the Mediterranean. All these result indicates type of growth showed isometric or positive allometric growth for both in Turkish coasts and Mediterranean. The lowest *b* value was estimated at 2.538 in this study. The growth type was founded as negative allometric growth (SE: 0.082; 95% confidence intervals of *b*: 2.377-2.699).

Table 3. Length-weight relationship and von Bertalanffy growth
parameters of *Merluccius merluccius* from Turkish coasts
(Tablo 3. Türkiye kıyılarında yapılmış çalışmalarda *Merluccius
merluccius* için belirlenmiş olan boy-ağırlık ilişkisi ve von
Bertalanffy büyüme sabitleri)

n	*a*	*b*	R^2	L_∞ (cm)	*K* (yıl^{-1})	t_0 (yıl)	Author/s
336	0.0045	3.194	0.98	81.70	0.085	-1.155	[11]
165	0.0091	2.942	0.98	-	-	-	[10]
614	0.0000043	3.090	0.99	-	-	-	[8]
1114	0.000037	3.117	0.99	-	-	-	[8]
567	0.0046	3.152	0.98				[17]
220	0.0267	2.530	0.83	42.61	0.123	-1.906	This study

The value of L_∞ reported as 81.66 cm by Uçkun et al. [11] in Aegean Sea. The value of L_∞ is ranging from 19.7 to 117.0 cm with the median value of 63.8 cm from different parts of the World [4]. The estimated L_∞ value was lower than both in the coast of Turkey and a lots of studies in Mediterranean. Differences of the estimated value between this study and previous studies could be explained differences in total length range of sample. Indeed some of these studies maximum length of sampled individual reached 92 cm [4]. The maximum total length was observed 21.80 cm in this study. On the other hand, the species is a long lived fish respectively and maximum age reported 20 years by Muus and Nielsen [23]. However, the most of the sampled individual consisted of under II age classes (88.2%). Indeed Gonçalves et al., [24] informed that, the estimated parameters may vary as a function of a variety of factors such as region, sampling methods, year, methodology etc.

The *K* observed in this study is lower than previous 0.3 imply growth of *M. merluccius* population inhabiting off Karatas coasts was slow [4]. Therefore, estimated low *b* value and negative allometric growth are not surprise in this study.

The estimated fishing mortality rates and exploitation rates were very high in the study area. Also the estimated L_∞ value was relatively lower than previous studies. These results indicated that this species was under an extensive fishing pressure on the fish populations in the studied area. Taking into account the size of first maturity for females (35.1 cm TL), the highest fishing pressure was exerted on the stock by the trawl fishery, which exploited basically juveniles of the first two age-classes [18]. In this case, it can be claimed growth overfishing in Iskenderun Bay. Indeed overfishing on stocks of *M. merluccius* was reported by Muus and Nielsen [23] in Adriatic and Merino et al. [25] in Aegean Sea.

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